2011 Nutrients and Suspended Sediment in the Susquehanna River Basin

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SUSQUEHANNA RIVER BASIN COMMISSION

The Susquehanna River Basin Commission was created as an independent agency by a federal-interstate compact* among the states of Maryland and New York, the Commonwealth of Pennsylvania, and the federal government. In creating the Commission, the Congress and state legislatures formally recognized the water resources of the Susquehanna River Basin as a regional asset vested with local, state, and national interests for which all the parties share responsibility. As the single federal-interstate water resources agency with basinwide authority, the Commission's goal is to coordinate the planning, conservation, management, utilization, development, and control of basin water resources among the public and private sectors.

**Statutory Citations: Federal - Pub. L. 91-575, 84 Stat. 1509 (December 1970); Maryland - Natural Resources Sec. 8-301 (Michie 1974); New York - ECL Sec. 21-1301 (McKinney 1973); and Pennsylvania - 32 P.S. 820.1 (Supp. 1976).*

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ABSTRACT

In 1985, the Susquehanna River Basin Commission (SRBC) along with the United States Geological Survey (USGS), the Pennsylvania Department of Environmental Protection (PADEP), and United States Environmental Protection Agency (USEPA) began an intensive study of nutrient and sediment transport in the Susquehanna River Basin. Funding for the program was provided by grants from the PADEP and the USEPA's Chesapeake Bay Program Office. The long-term focus of the project was to quantify the amount of nutrients and suspended sediment (SS) transported in the basin and determine changes in flow-adjusted concentration trends at 12 sites. Several modifications were made to the network including reducing the original 12 sites to six long-term sites then adding 13 sites in 2004, four sites in 2005, and four sites in 2012. The current network consists of 27 sites throughout the Susquehanna River Basin varying in watershed size and land use.

Samples were collected monthly with eight additional samples collected during four storm events throughout the year. An extra sample was collected each month at the six long-term sites including Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga. Sample collection was conducted using approved USGS methods including vertical and horizontal integration across the water column to insure collection of a representative sample. Samples were analyzed for various nitrogen and phosphorus species, total organic carbon (TOC), total suspended solids (TSS), and SS. Data were used to calculate nutrient and sediment loads and trends using the USGS estimator model. Results for annual, seasonal, and monthly loads were compared to long-term means (LTM) and to baseline data. Trends for all parameters and flow were calculated over the entire time period for each dataset and compared to previous years' results to identify changes.

2011 precipitation was above LTM and fairly well distributed throughout all seasons including a very wet spring and historic flows in September due to Tropical Storm Lee (T.S. Lee). Flows ranged from 165 to 186 percent of the LTM. During the highest flow months, March, April, and September, between 45-54 percent of the annual total nitrogen (TN) load, 63-82 percent of the annual total phosphorus (TP) load, and 70-94 percent of the annual SS load were transported. The majority of the loads for TP and SS were transported during September alone. The TP load during September at Marietta was greater than the annual load at Danville while the September Marietta SS load was 98 percent of the annual Danville load.

Baseline comparisons showed patterns of response between stations. Towanda and Danville annual baselines were higher than predictions for SS, while seasonal predictions were above baseline predictions for both TP and SS during summer. Marietta and Conestoga summer yields were also above baseline predictions for TP and SS due to loads during September that were high enough to bring annual yield for both parameters above baseline predictions. Smaller influence of T.S. Lee led to only seasonal SS yields at Lewisburg and Newport being above the baseline predictions while all annual yields were below baseline predictions. Trend directions for all sites for TN, TP, and SS remained downward and unchanged from 2010 while the magnitude of all trends increased. The only exception was TP at Towanda, which had no trend for both 2010 and 2011. No flow trends were found at any site.

BACKGROUND

Nutrients and SS entering the Chesapeake Bay (Bay) from the Susquehanna River Basin contribute to nutrient enrichment problems in the Bay (USEPA, 1982). Several studies in the late 1970s and early 1980s showed high nutrient concentration in both stream water and groundwater and high SS yields within the Lower Susquehanna River Basin (Ott et al., 1991). Subsequently, much of the excessive nutrients and SS that entered the Bay were thought to originate from the Lower Susquehanna Basin. Results from these studies concluded that the sources and quantities of the loads warranted determination. In 1985, the PADEP Bureau of Laboratories, USEPA, USGS, and SRBC conducted a five-year study to quantify nutrients and SS transported to the Bay from the Susquehanna River Basin.

The initial network consisted of two mainstem sites on the Susquehanna and 10 tributary sites with the goal of developing baseline nutrient loading data. After 1989, several modifications to the network occurred, including reduction of the number of stations to five in 1990, and additions of one station in 1994, 13 stations in 2004, four stations in 2005, and four stations in 2012. The current network consists of six sites on the mainstem of the Susquehanna River and 21 tributary sites. The 27 site network contains six sites in New York, 20 in Pennsylvania, and one in Maryland. Table 1 lists the individual sites grouped as long-term sites (Group A) and enhanced sites (Group B) along with subbasin, drainage area, USGS gage number, and land use. Actual locations of current sites are shown in Figure 1.

All site additions from 2004 onward were added as part of the Chesapeake Bay Program's Non-tidal Water Quality Monitoring Workgroup's effort to develop a non-tidal monitoring network uniform in site selection criteria, parameters analyzed, and collection and analysis methodology. Objectives for the network included the following: to measure and assess the actual nutrient and sediment concentration and load reductions in the tributary strategy basins across the watershed; to improve calibration and verification of the partners' watershed models; and to help assess the factors affecting nutrient and sediment distributions and trends. Specific site selection criteria included location at outlets of major streams draining the tributary strategy basins, location in areas within the tributary strategy basins that have the highest nutrient delivery to the Bay, and to insure the various conditions in the Bay watershed among land use type, physiographic/geologic setting, and watershed size were adequately represented. This project involves monitoring efforts conducted by all six Bay state jurisdictions, USEPA, USGS, and SRBC. The purpose of this report is to present basic information on annual and seasonal loads and yields of nutrients and SS measured during calendar year 2011 at the six SRBC-monitored long-term sites, and summary statistics for the additional 17 sites, and to determine if changes in water quality have occurred.

DESCRIPTION OF THE SUSQUEHANNA RIVER BASIN

The Susquehanna River drains an area of 27,510 square miles (Susquehanna River Basin Study Coordination Committee, 1970), and is the largest tributary to the Chesapeake Bay. The Susquehanna River originates in the Appalachian Plateau of southcentral New York, flows into the Valley and Ridge and Piedmont Provinces of Pennsylvania and Maryland, and joins the Bay at Havre de Grace, Md. The climate in the Susquehanna River Basin varies considerably from the low lands adjacent to the Bay in Maryland to the high elevations, above 2,000 feet, of the northern headwaters in central New York State. The annual mean temperature ranges from 53^{o} F (degrees Fahrenheit) near the Pennsylvania-Maryland border to 45^{o} F in the northern part of the basin. Annual precipitation in the basin averages 40 inches and is fairly well distributed throughout the year.

Land use in the Susquehanna River Basin, shown in Table 1, is predominantly rural with woodland accounting for 69 percent; agriculture, 21 percent; and urban, 7 percent. Woodland occupies the higher elevations of the northern and western parts of the basin and much of the mountain and ridge land in the Juniata and Lower Susquehanna Subbasins. Woods and grasslands occupy areas in the lower part of the basin that are unsuitable for cultivation because the slopes are too steep, the soils are too stony, or the soils are poorly drained. The Lower Susquehanna Subbasin contains the highest density of agriculture operations within the watershed. However, extensive areas are cultivated along the river valleys in southern New York and along the West Branch Susquehanna River from Northumberland, Pa., to Lock Haven, Pa., including the Bald Eagle Creek Valley.

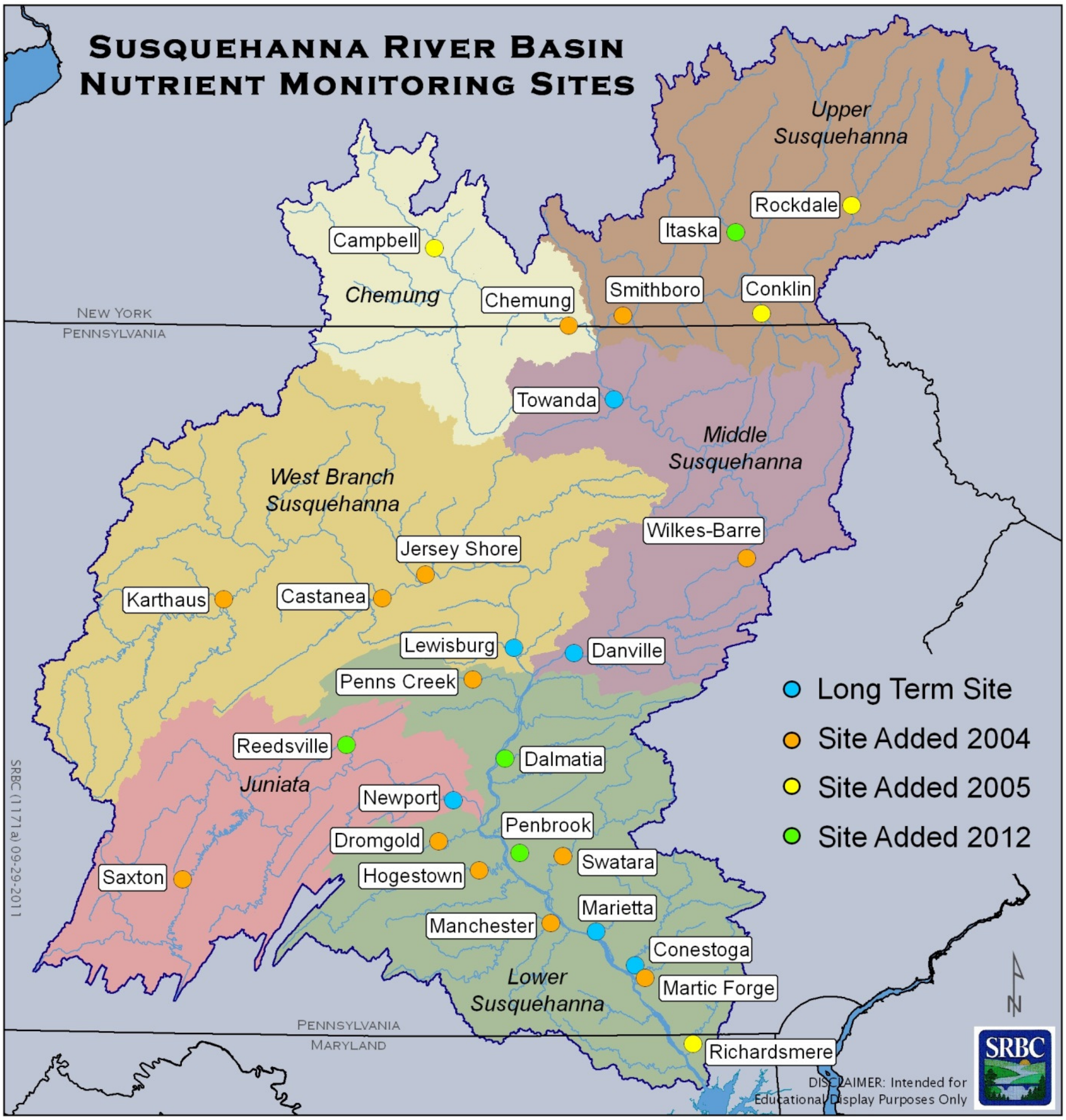

Figure 1. Locations of Sampling Sites Within the Susquehanna River Basin

Table 1. Data Collection Sites and Their Drainage Areas and 2000 Land Use Percentages

Site Location	USGS Site ID	Subbasin	Waterbody	Drainage Area (Sq. Mi.)	Water/ Wetland	Urban	Agricultural			Forest	Other
							Row Crops	Pasture Hay	Total		
Group A: Long-term Sites											
Towanda	01531500	Middle Susquehanna	Susquehanna	7,797	2	5	17	5	22	71	0
Danville	01540500	Middle Susquehanna	Susquehanna	11,220	2	6	16	5	21	70	1
Lewisburg	01553500	W Branch Susquehanna	W Branch Susquehanna	6,847	1	5	8	2	10	84	0
Newport	01567000	Juniata	Juniata	3,354	1	6	14	4	18	74	1
Marietta	01576000	Lower Susquehanna	Susquehanna	25,990	2	7	14	5	19	72	0
Conestoga	01576754	Lower Susquehanna	Conestoga	470	1	24	12	36	48	26	1
Group B: Enhanced Sites											
Rockdale	01502500	Upper Susquehanna	Unadilla	520	3	2	22	6	28	66	1
Conklin	01503000	Upper Susquehanna	Susquehanna	2,232	3	3	18	4	22	71	1
Itaska	01511500	Upper Susquehanna	Tioughnioga	730	2	4	22	5	27	66	1
Smithboro	01515000	Upper Susquehanna	Susquehanna	4,631	3	5	17	5	22	70	0
Campbell	01529500	Chemung	Cohocton	470	3	4	13	6	19	74	0
Chemung	01531000	Chemung	Chemung	2,506	2	5	15	5	20	73	0
Wilkes-Barre	01536500	Middle Susquehanna	Susquehanna	9,960	2	6	16	5	21	71	0
Karthaus	01542500	W Branch Susquehanna	W Branch Susquehanna	1,462	1	6	11	1	12	80	1
Castanea	01548085	W Branch Susquehanna	Bald Eagle	420	1	8	11	3	14	76	1
Jersey Shore	01549760	W Branch Susquehanna	W Branch Susquehanna	5,225	1	4	6	1	7	87	1
Saxton	01562000	Juniata	Raystown Branch Juniata	756	< 0.5	6	18	5	23	71	0
Reedsville	01565000	Juniata	Kishacoquillas	164	<0.5	5	20	6	26	67	2
Dalmatia	01555500	Lower Susquehanna	East Mahantango	162	1	6	20	6	26	66	1
Penbrook	01571000	Lower Susquehanna	Paxton	11	<0.5	50	9	11	20	29	1
Penns Creek	01555000	Lower Susquehanna	Penns	301	1	3	16	4	20	75	1
Dromgold	01568000	Lower Susquehanna	Shermans	200	1	4	15	6	21	74	0
Hogestown	01570000	Lower Susquehanna	Conodoguinet	470	1	11	38	6	44	43	1
Hershey	01573560	Lower Susquehanna	Swatara	483	2	14	18	10	28	56	0
Manchester	01574000	Lower Susquehanna	West Conewago	510	2	13	12	36	48	36	1
Martic Forge	01576787	Lower Susquehanna	Pequea	155	1	12	12	48	60	25	2
Richardsmere	01578475	Lower Susquehanna	Octoraro	177	1	10	16	47	63	24	2
			Entire Susquehanna River Basin	27,510	2	7	14	7	21	69	1

Major urban areas in the basin, many of which are located along river valleys, include: Binghamton, N.Y. in the Upper Susquehanna Subbasin; Corning and Elmira, N.Y., in the Chemung Subbasin; Scranton and Wilkes-Barre, Pa., in the Middle Susquehanna Subbasin; Clearfield, Lock Haven, and Williamsport, Pa., in the West Branch Subbasin; Altoona and Lewisburg, Pa., in the Juniata Subbasin; and Harrisburg, Lancaster, Sunbury, and York, Pa., in the Lower Susquehanna Subbasin.

SAMPLE COLLECTION

2011 sampling efforts at the six long-term (Group A) sites included sampling during monthly base flow conditions, monthly flow-independent conditions, and seasonal storm conditions. This resulted in two samples collected per month: one with a set date near the twelfth of each month independent of flow and one based on targeting monthly base flow conditions. The mid-monthly samples were intended to be flow independent with the intention that the data would help to quantify long-term trends. Additionally, due to the linkage of high flow and nutrient and sediment loads, it was necessary to target storm events for additional sampling to adequately quantify loads. Long-term site sampling goals included targeting one storm per season with a second storm collected during the spring season. Spring storms were planned to collect samples before and after agricultural crops had been planted.

All storm samples were collected during the rising and falling limbs of the hydrograph with goals of three samples on each side and one sample as close to the peak as possible. The enhanced sites (Group B) targeted a mid-monthly flow independent sample and two storm samples per season. Storm samples were planned to have one sample on the rising limb and one on the falling limb of the hydrograph with the goal that one of the two be as close to the peak as possible. Due to the quick nature of the hydrograph on several of the smaller streams, sometimes the two storm samples per season were taken from two different storms with the goal of having samples as close to the peak of each storm as possible.

The goal of actual sample collection was to collect a sample representative of the entire water column. Due to variations in stream width and depth and subsequent lack of natural mixture of the stream, it was necessary to composite several individual samples across the water column into one representative sample. The number of individual verticals at each site varied from three to ten dependent upon the stream width. Based on USGS depth integrated sampling methodology at each vertical location, the sampler was lowered at a consistent rate from the top of the water surface to the stream bottom and back to insure water from the entire vertical column was represented (Myers, 2006). Instream water quality readings were taken at each vertical to insure accurate dissolved oxygen and temperature values.

All samples were processed onsite and included whole water samples analyzed for nitrogen and phosphorus species, TOC, TSS, and SS. For Group B sites, SS samples were only collected during storm events. Additionally, filtered samples were processed onsite to analyze for dissolved nitrogen (DN) and DP species. Several sites included additional parameters pertinent to the natural gas industry.

SAMPLE ANALYSIS

Samples were either hand-delivered or shipped directly to the appropriate laboratory for analysis on the day following collection. When storm events occurred over the weekend, samples collected were analyzed on the following Monday. Samples collected in Pennsylvania and at the Octoraro Creek site near Richardsmere, Md., were delivered to PADEP's Bureau of Laboratories in Harrisburg, Pa. Samples collected at New York sites were shipped to Columbia Analytical Services in Rochester, N.Y. Parameters for all samples at all sites included various nitrogen and phosphorus species, TOC, and TSS. Specific parameters, methodology, and detection limits are listed in Table 2.

Due to the high influence of stormflow on sediment concentrations, SS samples were collected during storm events at all sites with the goal of two samples for each event and one event per quarter. Of the two samples per storm, the more sediment laden sample was analyzed for both sediment concentration and sand/fine particle percentage. The additional sample was submitted for sediment concentration only. Sediment samples were shipped to the USGS sediment laboratory in Louisville, Ky., for analysis. Additional SS samples also were collected at all Group A sites as part of each sampling round. These samples were analyzed at the SRBC laboratory for sediment concentration alone.

Table 2. Water Quality Parameters, Laboratory Methods, and Detection Limits

Parameter	Storet	Laboratory	Methodology	Detection Limit (mg/l)	References
Total Ammonia (TNH_3)	610	PADEP	Colorimetry	0.020	USEPA 350.1
		CAS*	Colorimetry	0.010	USEPA 350.1R
Dissolved Ammonia (DNH_3)	608	PADEP	Block Digest, Colorimetry	0.020	USEPA 350.1
		CAS*	Block Digest, Colorimetry	0.010	USEPA 350.1R
Total Nitrogen (TN)	600	PADEP	Persulfate Digestion for TN	0.040	Standard Methods #4500-N_{org}-D
Dissolved Nitrogen (DN)	602	PADEP	Persulfate Digestion	0.040	Standard Methods #4500-N_{org}-D
Total Organic Nitrogen (TON)	605	N/A	TN minus TNH_3 and TNOx	N/A	N/A
Dissolved Organic Nitrogen (DON)	607	N/A	DN minus DNH_3 and DNOx	N/A	N/A
Total Kjeldahl Nitrogen (TKN)	625	CAS*	Block Digest, Flow Injection	0.050	USEPA 351.2
Dissolved Kjeldahl Nitrogen (DKN)	623	CAS*	Block Digest, Flow Injection	0.050	USEPA 351.2
Total Nitrite plus Nitrate (TNOx)	630	PADEP	Cd-reduction, Colorimetry	0.010	USEPA 353.2
		CAS*	Colorimetric by LACHAT	0.002	USEPA 353.2
Dissolved Nitrite plus Nitrate (DNOx)	631	PADEP	Cd-reduction, Colorimetry	0.010	USEPA 353.2
		CAS*	Colorimetric by LACHAT	0.002	USEPA 353.2
Dissolved Orthophosphate (DOP)	671	PADEP	Colorimetry	0.010	USEPA 365.1
		CAS*	Colorimetric Determination	0.002	USEPA 365.1
Dissolved Phosphorus (DP)	666	PADEP	Block Digest, Colorimetry	0.010	USEPA 365.1
		CAS*	Colorimetric Determination	0.002	USEPA 365.1
Total Phosphorus (TP)	665	PADEP	Persulfate Digest, Colorimetry	0.010	USEPA 365.1
		CAS*	Colorimetric Determination	0.002	USEPA 365.1
Total Organic Carbon (TOC)	680	PADEP	Combustion/Oxidation	0.50	SM 5310D
		CAS*	Chemical Oxidation	0.05	GEN 415.1/9060
Total Suspended Solids (TSS)	530	PADEP	Gravimetric	5.0	USGS I-3765
		CAS*	Residue, non-filterable	1.1	SM2540D
Suspended Sediment Fines	70331	USGS	**		
Suspended Sediment (SS)	80154	SRBC	**		
		USGS	**		

* Columbia Analytical Services, Rochester, N.Y. (New York sites only)
** TWRI Book 3, Chapter C2 and Book 5, Chapter C1, Laboratory Theory and Methods for Sediment Analysis (Guy and others, 1969)

PRECIPITATION AND DISCHARGE

Precipitation data were obtained from long-term monitoring stations operated by the U.S. Department of Commerce. The data are published as Climatological Data–Pennsylvania, and as Climatological Data–New York by the National Oceanic and Atmospheric Administration at the National Climatic Data Center in Asheville, N.C. Monthly data from these online sources were compiled across the subbasins of the Susquehanna River Basin. Discharge values were obtained from the USGS gaging network system. All sites were collocated with USGS gages so that discharge amounts could be matched with each sample. Average daily discharge values for each site were used as input to the estimator model used to estimate nutrient and sediment loads and trends. Average monthly flow values were used to check for trends in discharge.

DATA ANALYSIS

Sample results were compiled into an existing database including all years of the program. These data were then listed on SRBC's web site as well as submitted to various partners for use with models and individual analyses. Specific analyses at SRBC include load and yield estimation, LTM comparisons, baseline comparisons, and trend estimation.

Loads and Yields

Loads and yields represent two methods for describing nutrient and SS amounts within a basin. Loads refer to the actual amount of the constituent being transported in the water column past a given point over a specific duration of time and are expressed in pounds. Yields compare the transported load with the acreage of the watershed and are expressed in lbs/acre. This allows for easy watershed comparisons. This project reports loads and yields for the constituents listed in Table 2 as computed by the Minimum Variance Unbiased Estimator (ESTIMATOR) described by Cohn and others (1989). This estimator relates the constituent concentration to water discharge, seasonal effects, and long-term trends, and computes the best-fit regression equation. Daily loads of the constituents were then calculated from the daily mean water discharge records. The loads were reported along with the estimates of accuracy. Average concentrations were calculated by taking the total load and dividing by the total amount of flow during the time period and were reported in mg/L.

Load and trend analyses were not completed at Group B sites. Summary statistics have been calculated for these sites, as well as the long-term sites for comparison. Summary statistics are listed in Appendix B and include minimum, maximum, median, mean, and standard deviation values taken from the 2011 dataset.

Long-term Mean Ratios

Due to the relationship between stream discharge and nutrient and SS loading, it can be difficult to determine whether the changes observed were related to land use, nutrient availability, or simply fluctuations in water discharge. Although the relationship is not always linear at higher flows than lower flows, in general, increases in flows coincide with increases in constituent loads (Ott and others, 1991; Takita, 1996, 1998). In an attempt to determine annual changes from previous years, 2011 nutrient and SS loads, yields and concentrations were compared to LTMs. LTM load and discharge ratios were calculated for a variety of time frames, including annual, seasonal, and monthly, by dividing the 2011 value by the LTM for the same time frame and reported as a percentage or ratio. It was thought that identifying sites where the percentage of LTM for a constituent, termed the load ratio, was different than the corresponding percentage of LTM for discharge, termed the water-discharge ratio or discharge ratio, would suggest areas where improvements or degradations may have occurred for that particular constituent. At odds with this conclusion is that individual high flow events tend to produce higher loads, especially for TP and SS, than would be predicted by a simple comparison with the LTM. Thus, the presence or absence of significant storm events during a time period tends to be the major contributing factor towards the resultant loads.

Baseline Comparisons

As a means to determine whether the annual fluctuations of nutrient and SS loads were due to water discharge, Ott and others (1991) used the relationship between annual loads and annual water discharge. This was accomplished by plotting the annual yields against the water-discharge ratio for a given year to calculate a baseline regression line. Data from the initial five-year study (1985-89) were used to provide a best-fit linear regression trend line to be used as the baseline relationship between annual yields and water discharge. It was hypothesized that as future yields and water-discharge ratios were plotted against the baseline, any significant deviation from the baseline would indicate that some change in the annual yield had occurred, and that further evaluations to determine the reason for the change were warranted.

Due to the size of the current dataset, the opportunity exists for there to be non-linear changes in the yield versus water discharge plot as more years are added. Therefore, this report included comparisons to baselines created from different time frames including the initial five-year period of the dataset for each station, the first half of the entire dataset, the second half of the entire dataset, and the entire dataset. Although the tendency was for increasing loads to be associated with increasing flows, this relationship was not strictly linear, especially when dealing with TP and SS.

All comparisons include an associated R^2 value representing the strength of the correlation between the two parameters in the regression. The closer the R^2 is to a value of one, the better the regression line is for accurately using one variable (flow) to predict the other with an R^2 of one meaning that there is perfect correlation between the two variables. For example, R^2 values for TN tend to be close to one as the relationship between TN and flow is very consistent through various ranges of flows. R^2 values for TP and SS tend to vary more, especially towards higher flows. Thus, when regression graphs include high flow events, the resulting correlation tends to be less perfect indicated by a low R^2 value. This is an indication that single high flow events, and not necessarily a high flow year, are the highest contributors to loads in TP and SS and that these contributions do not necessarily follow a strictly linear increase. As has been evident in the last few years, the high loads that have occurred at Towanda and Danville can be linked directly to high flow events, specifically Hurricane Ivan in 2004, Tropical Storm Ernesto in 2006, and by the combination of a synoptic type storm event and Tropical Storm Nicole in 2010 (Maddox et al., 1979). Several significant high flow events occurred in 2011 including a very wet spring and high summer flows resulting from Hurricane Irene and Tropical Storm Lee. Seasonal baselines also were calculated for the initial five years of data at each site.

Figure 2 shows the baseline regression line developed for TN at Marietta using the first half of the dataset where each hollow circle represents an individual year during the first half of the dataset. Each hollow circle was plotted using an individual year's yield and the same year's discharge ratio. The discharge ratio was calculated by dividing the year's annual flow by the 12-year average flow for the baseline years used. A regression line was drawn through these data points and the equation of the trend line was used to calculate a baseline prediction for the 2011 yield given the 2011 discharge ratio. The baseline prediction for 2011 TN yield is shown as a black diamond on the graph at 15.44 lbs/ac. The actual 2011 yield at the same discharge ratio, 11.72 lbs/ac, is shown as the black circle. Since the actual 2011 yield was lower than the prediction made by the first 12 years of data, the comparison implies that improvements may have occurred.

Figure 3 shows the baseline regression lines that were developed using the initial five years at Marietta, the first 12 years at Marietta, and the most recent 12 years at Marietta. Using multiple regression lines developed from different time periods within that dataset also can show whether changes occurred. The larger vertical oval in the graph shows the relevant comparisons to be made; at a discharge ratio of 2.20, the initial five-year baseline predicts the 2011 yield to be 20.73 lbs/ac, while the actual 2011 yield was 11.72 lbs/ac (shown in the bottom of the oval). This suggests a more dramatic reduction than the comparison to the regression from the most recent 12 years, which predicted the 2011 TN yield to be 13.94 lbs/ac shown within the smaller oval. Additional support for improvements can be seen when comparing the entire baseline regression lines to each other. As more recent years were added to the baseline, the entire regression line lowered. This implied that the more recent 12-year dataset included lower yield values as compared to the initial 12-year dataset. Thus, a regression line that predicts lower yields for the same water discharge ratio directly implies improved water quality between the two timeframes.

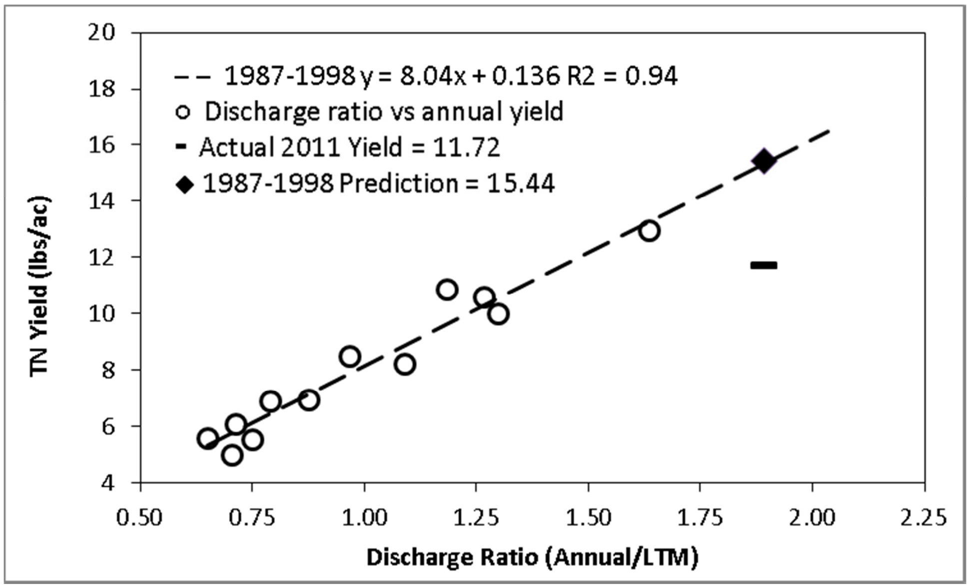

Figure 2. First Half Baseline Regression Line, 2011 TN Yield Prediction, and Actual 2011 Yield for TN at Marietta

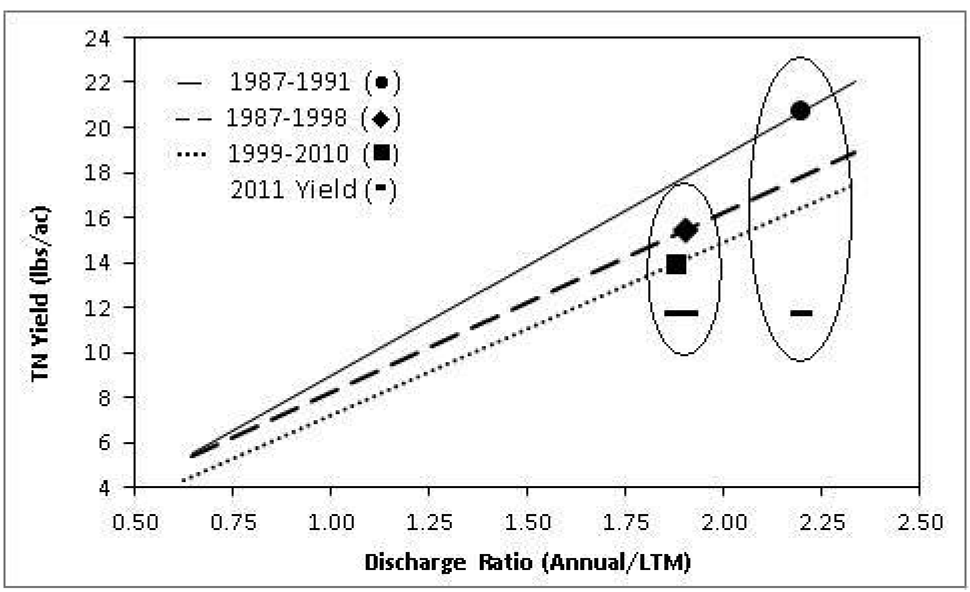

Figure 3. Initial, First Half, and Second Half Baseline Regression Lines, Yield Predictions, and Actual 2011 Yields for TN at Marietta

Flow-Adjusted Trends

Flow-Adjusted Concentration (FAC) trend analyses of water quality and flow data collected at Danville, Lewisburg, Newport, and Conestoga were completed for the period January 1984 through December 2011. Both Marietta and Towanda began later and their respective trend periods are 1986-2011 and 1988-2011. Trends were estimated based on the USGS water year, October 1 to September 30, using the USGS 7-parameter, log-linear regression model (ESTIMATOR) developed by Cohn and others (1989) and described in Langland and others (1999). ESTIMATOR relates the constituent concentration to water discharge, seasonal effects, and long-term trends, and computes the best-fit regression equation. These tests were used to estimate the direction and magnitude of trends for discharge, SS, TOC, and several forms of nitrogen and phosphorus. Slope, p-value, and sigma (error) values are taken directly from ESTIMATOR output. These values are then used to calculate flow-adjusted trends using the following equations:

Trend =
100*(exp(Slope *(end yr – begin yr)) – 1)

Trend minimum =
100*(exp((Slope – (1.96*sigma)) *(end yr – begin yr)) – 1)

Trend maximum =
100*(exp((Slope + (1.96*sigma)) *(end yr – begin yr)) – 1)

The computer program S-Plus with the USGS ESTREND library addition was used to conduct Seasonal Kendall trend analysis on flows (Schertz and others, 1991). Trend results were reported for monthly mean discharge (FLOW) and individual parameter FACs. Trends in FLOW indicate any natural changes in hydrology. Changes in flow and the cumulative sources of flow (base flow and overland runoff) affect the observed concentrations and the estimated loads of nutrients and SS. The FAC is the concentration after the effects of flow are removed from the concentration time series. Trends in FAC indicate that changes have occurred in the processes that deliver constituents to the stream system. After the effects of flow are removed, this is the concentration that relates to the effects of nutrient-reduction activities and other actions taking place in the watershed. A description of the methodology is included in Langland and others (1999).

INDIVIDUAL SITES

Towanda

2011 precipitation and discharge values at Towanda are listed in Table A1. 2011 had above average flows during all months except for January, February, and July. Although two of three winter months were below their respective LTMs, the total flow for the season was 126 percent of LTM due to an early wet spring. Highest seasonal flow during 2011 occurred during summer, which is normally the lowest flow time period. This was due to the two historical storm events that occurred during August and September resulting in summer flows that were 301 percent of the LTM. Annual flows at Towanda were 166 percent of the LTM. Highest flows occurred during March, April, and September.

2011 loads for TP, SS, TON, and TOC were above the flow LTM of 166 percent at Towanda including 412 percent of LTM for SS. TNO_{23}, DNO_{23}, and DP were lower than the flow LTM with DP at 100 percent of LTM. Tables A3 and A4 look at closer time periods showing that the majority of the SS load was moved during September. As a percentage of annual load, September accounted for 14 percent of the TN load, 40 percent of the TP load, and 73 percent of the SS load. The three highest flow months, including March, April, and September, amounted for 54 percent of the annual flow, 57 percent of TN, 77 percent of TP, and 94 percent of the SS load.

2011 TN yields at Towanda were below the predictions of all four baseline comparisons while both TP and SS yields were above all baseline predictions. The 2011 seasonal yields were lower than the initial five-year baseline predictions for winter, spring, and fall except for SS during winter. Table A6 shows that the R^2

value for the SS baseline was 0.02 and thus unreliable at predicting the 2011 value. Closer inspection of the baseline data for this period shows that there was one outlier that led to the low R^2 value. The spring of 1993 contained a very large snow melt that resulted in high SS levels. This snow melt had a large effect on March SS concentrations but a small effect on the average flow for the time period, thus creating the outlier. 2011 yield for summer, which contained both Hurricane Irene and Tropical Storm Lee, were dramatically higher than the predicted values for TP and SS. Summer discharge was 478 percent of the LTM resulting in 2011 SS yields of 2,027 pounds/acre (lbs/ac) while the baseline prediction was 73 lbs/ac.

Trend directions remained unchanged from 2010 except for DP, which changed from no trend to an improving trend. Trend magnitudes in other parameters fluctuated while not altering the actual trend direction. Notable magnitude changes included TOC and DOP with the magnitude of the TOC improving trend increasing and the magnitude of the DOP degrading trend decreasing.

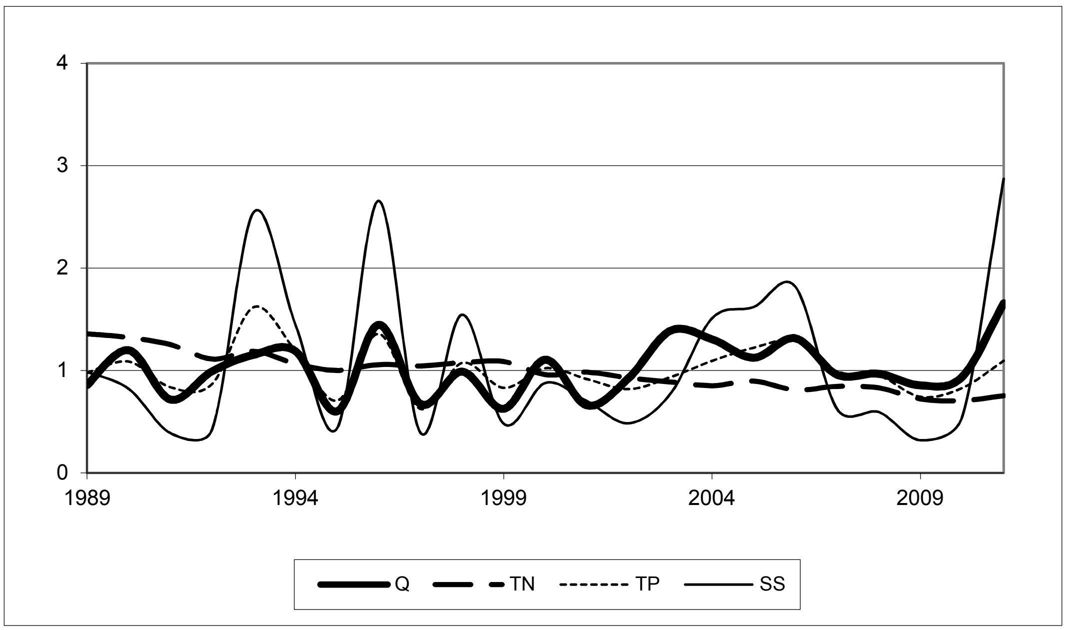

Figure 4. Annual Discharge and Calculated Annual TN, TP, and SS Concentrations Expressed as LTM Ratio

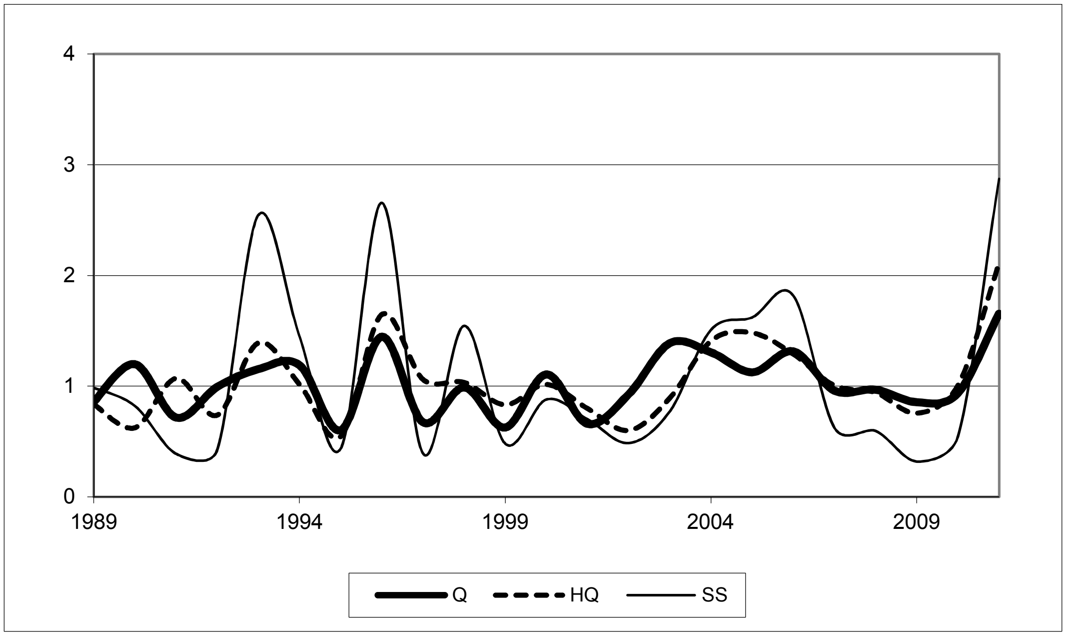

Figure 5. Annual Discharge and Annual Daily Mean High Discharge and Calculated Annual SS Concentration Expressed as LTM Ratio

Danville

2011 annual rainfall above Danville was 11.68 inches above the LTM resulting in flows that were 186 percent of the LTM. Largest departures for precipitation occurred during the spring and summer seasons. Flow values exceeded LTM during all seasons with 133 percent during winter and 363 percent during the summer. Although highest flows and subsequent highest loads of all constituents occurred during T.S. Lee in September, nine months recorded flow above the LTM with highest departures during September, October, and May, respectively.

2011 seasonal loads for TN, TNOx, and TNH_3 were higher during winter and spring than summer. The high flow months within these seasons were similar with 69,235, 64,007, and 64,923 cfs occurring for March, April, and September, respectively. Although these flows were similar, TN was highest during March and April and lowest during September, while TP and SS were the opposite. The difference within the months was high sustained flows with a lower peak during March and April and a very high peak event during September, which accounted for 13 percent, 39 percent, and 72 percent of the annual load of TN, TP, and SS, respectively.

Baseline comparisons for TN and TP show that 2011 yields were below all predictions except for the baseline using the second half of the dataset for TN. 2011 SS yields were substantially above all baseline predictions. The 2011 SS yield was 170 percent of the baseline prediction using the five-year baseline and 243 percent of the baseline when using the second half dataset baseline.

The seasonal baseline comparisons show that much of the annual baseline deviation from predictions was due to the summer, specifically T.S. Lee. Seasonal comparison to baselines showed 2011 TN yields below predictions for all seasons, while both TP and SS yields were above including the 2011 SS yield being 2,121 percent higher than the baseline prediction. Consideration of the value should include that of T.S. Lee's anomalous effects. The baseline created for the summer at Danville included years with discharge ratios ranging from 0.66 to 1.39, whereas the discharge ratio for 2011 was 4.94. Considering that SS loads may not increase linearly with increased flow, using a linear regression line likely makes the prediction and actual value seem further apart.

There were no changes in trend directions from 2010 to 2011 although there were a few notable magnitude changes. The larger changes in magnitude included a decrease for TNH_3 and an increase for TP and TOC. There were no trends for flow.

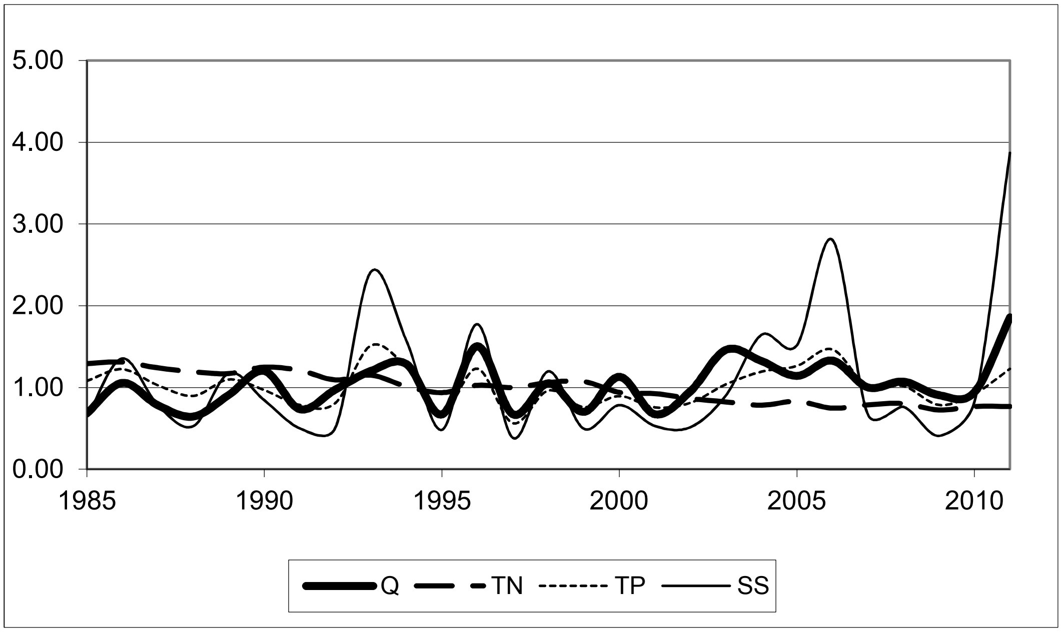

Figure 6. Annual Discharge and Calculated Annual TN, TP, and SS Concentrations Expressed as LTM Ratio

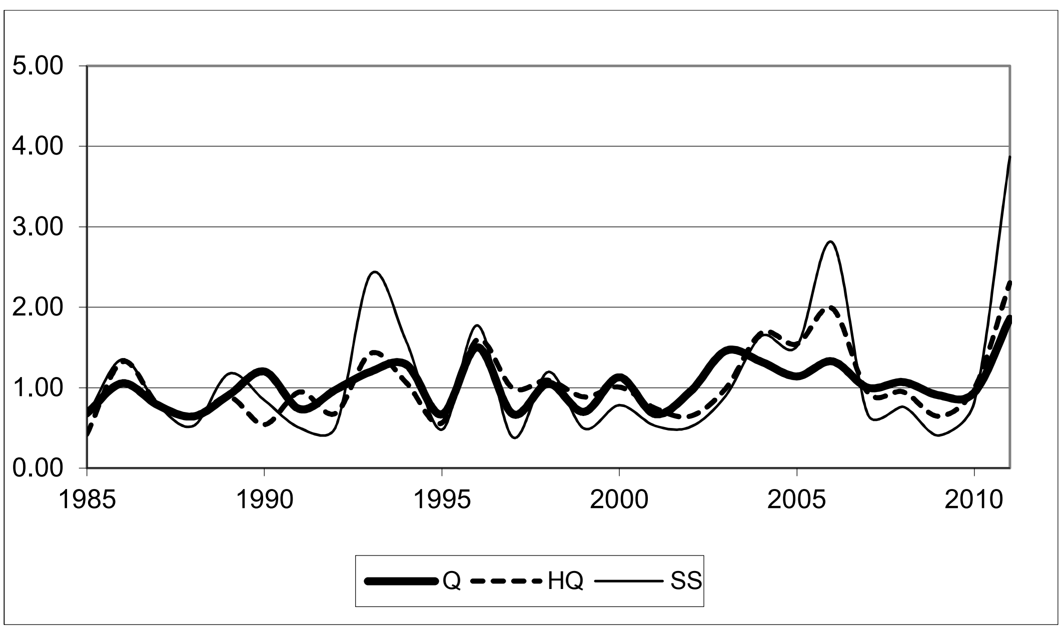

Figure 7. Annual Discharge and Annual Daily Mean High Discharge and Calculated Annual SS Concentration Expressed as LTM Ratio

Marietta

2011 annual rainfall in the basin above Marietta was 18.87 inches above the LTM with the majority of the departure during spring and summer. Annual discharge was 183 percent of the LTM ranging from 130 percent during winter to 294 percent during summer.

2011 annual loads expressed as a percentage of LTMs were below the 183 percent discharge value for all parameters except TP, SS, TON, and TOC. Calculated average annual concentration values for these parameters were 113 percent of the LTM for TOC and TON and 145 percent and 269 percent of LTM for TP and SS, respectively. All other parameters had annual concentration values below the LTM by at least 15 percentage points.

2011 monthly flow was highest for March, April, and September, respectively, with September being the lowest average but highest departure from the LTM. Similar to Danville, nine of 12 months were above LTM flow values. While April and September flows were comparable with 148,010 and 137,867 cfs, respectively, TN load for September was 100 percent of April's load. TP and SS loads were 303 percent and 508 percent, respectively, for the same monthly comparison.

2011 annual and seasonal yields were below all baseline predictions for TN while annual yields for TP and SS were above all baseline predictions. Seasonal yields for both parameters were above baseline predictions for winter and summer.

2011 trend directions remained unchanged from 2010 for all parameters; however, many trend magnitudes increased. Increases in trend magnitude included DON, TNOx, DNOx, TP, DP, TOC, and SS. There were no flow trends.

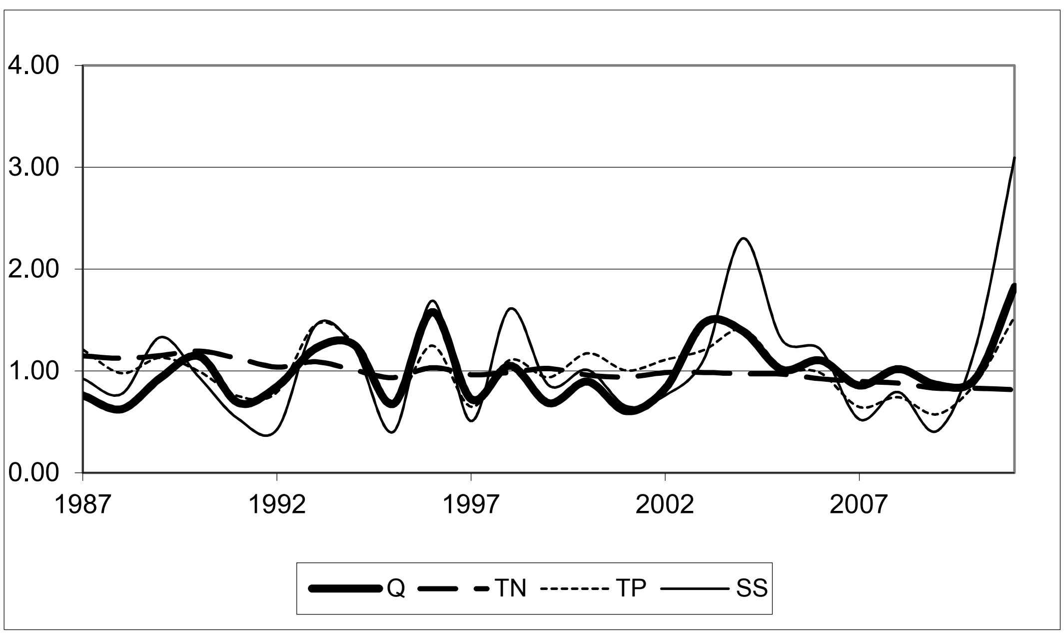

Figure 8. Annual Discharge and Calculated Annual TN, TP, and SS Concentrations Expressed as LTM Ratio

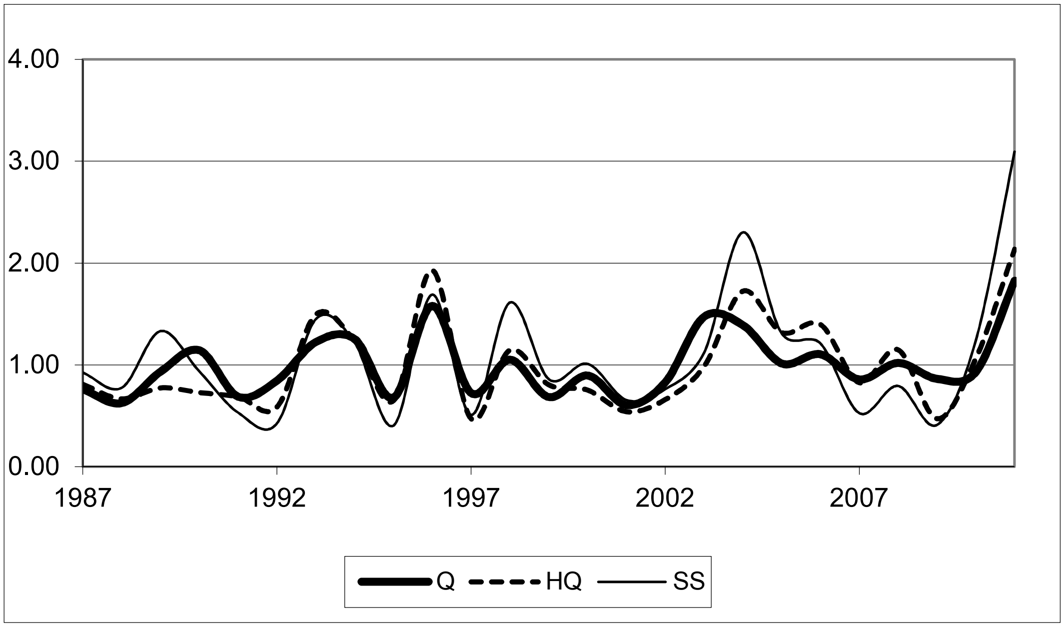

Figure 9. Annual Discharge and Annual Daily Mean High Discharge and Calculated Annual SS Concentration Expressed as LTM Ratio

Lewisburg

2011 seasonal and annual precipitation and discharge were above LTMs at Lewisburg. Precipitation ranged from 3.34 inches above the LTM for winter to 9.67 inches above LTM for summer. Although rainfall and departure from the LTM were larger for summer, the discharge percent of LTM was greatest for spring which had sustained high flow through April and May.

Annual loads were above LTMs for all parameters except DP and DOP, which were 59 and 70 percent of the LTM, respectively. Annual average concentrations were below the LTM for all parameters except TOC. Although the annual peak flow occurred in September, the monthly averages were half the monthly averages of April and May. This resulted in loads for TN and TP for both March and April being higher than September loads. Only September SS load was higher than March and April loads but only by 11 and 2 percent, respectively. September at Lewisburg accounted for 26 percent of the annual sediment load as compared to 72 percent at Danville.

2011 TN, TP, and SS yields were below both annual and seasonal baselines predictions. The exception was SS during summer as compared to the initial five-year baseline. This baseline has a low R^2 value due to a tropical storm that occurred in 1988 which dumped a heavy and isolated amount of rainfall over the West Branch of the Susquehanna. This resulted in a pulse of sediment while not overly influencing the average seasonal flow used to calculate the baseline. With the outlier removed, the prediction changed to 23 lbs/acre which remained substantially lower than the actual 2011 yield. Thus, the low R^2 was not the driving factor in the comparison.

Trends remained relatively unchanged from 2010 with the only exceptions being increased magnitude of the downward trend for TP and SS. There were no flow trends.

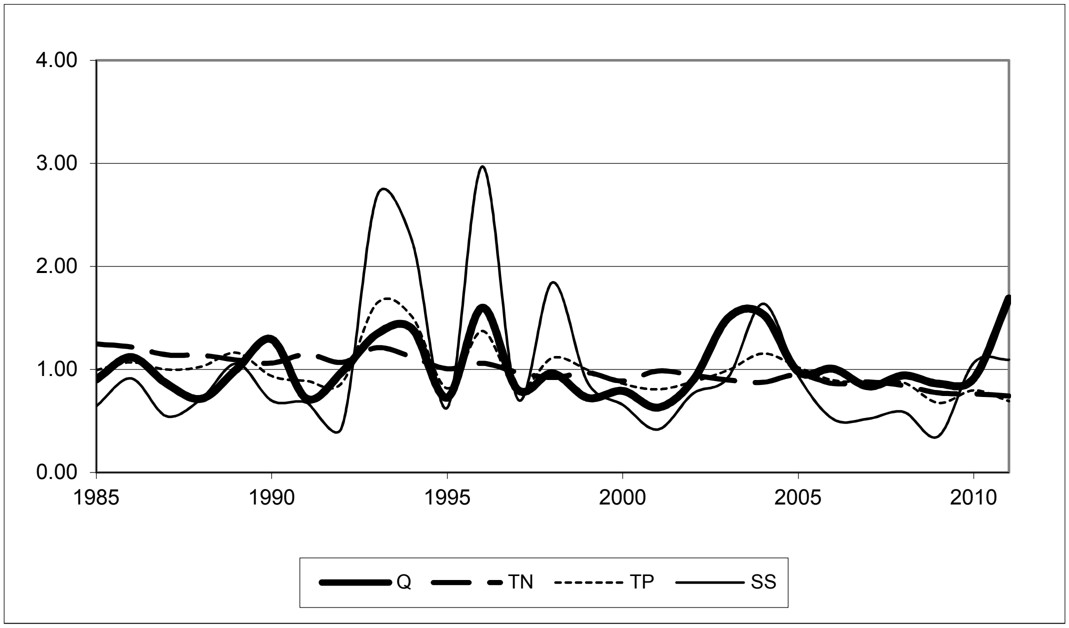

Figure 10. Annual Discharge and Calculated Annual TN, TP, and SS Concentrations Expressed as LTM Ratio

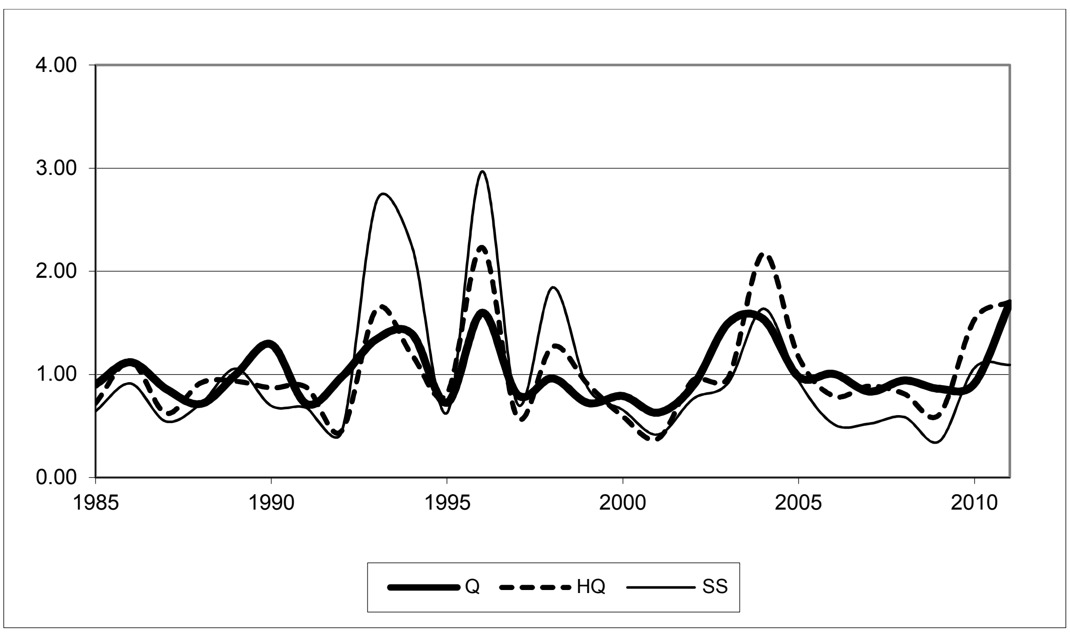

Figure 11. Annual Discharge and Annual Daily Mean High Discharge and Calculated Annual SS Concentration Expressed as LTM Ratio

Newport

2011 precipitation and discharge at Newport were unique as compared to the other five sites. Although the highest amount of rainfall occurred in summer, the highest average flow and highest peak flow occurred during spring. Summer had the second highest peak flow and the lowest average discharge of all four seasons. September had the fourth highest average monthly discharge. Annual discharge at Newport was 175 percent of the LTM.

2011 annual SS load was 200 percent of the LTM while all other parameters were below 175 percent of their respective LTMs. DP loads were the only parameter below the LTM at 91 percent and had an annual average concentration that was 52 percent of the LTM.

Monthly average discharge during March and April was greater than September and resulted in higher TN loads during these months. TP and SS loads were highest during September due to the effects of T.S. Lee even though March contained a higher peak event.

Baseline comparisons show 2011 yields to be lower than all predictions for TN, TP, and SS. All 2011 seasonal yields were below baseline predictions with SS being the only exception during summer. The predicted baseline yield was 151 lbs/ac compared to the actual 2011 yield of 159 lbs/ac.

2011 trends directions remained unchanged from 2010 although all existing trends improved in magnitude. This included a reduction in the upward trend for DOP. All other parameters with downard trends increased in magnitude. TNO_{23} and DNO_{23} continue to show no trends while being the highest contributor to the TN load. Largest reductions for TN and DN occurred for TON and DON. There were no flow trends.

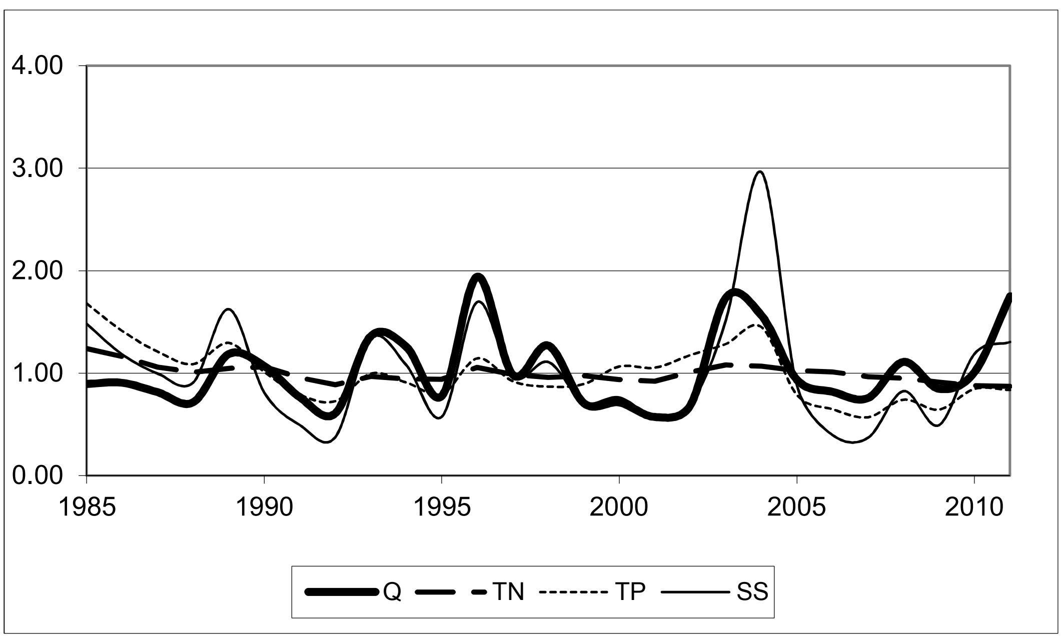

Figure 12. Annual Discharge and Calculated Annual TN, TP, and SS Concentrations Expressed as LTM Ratio

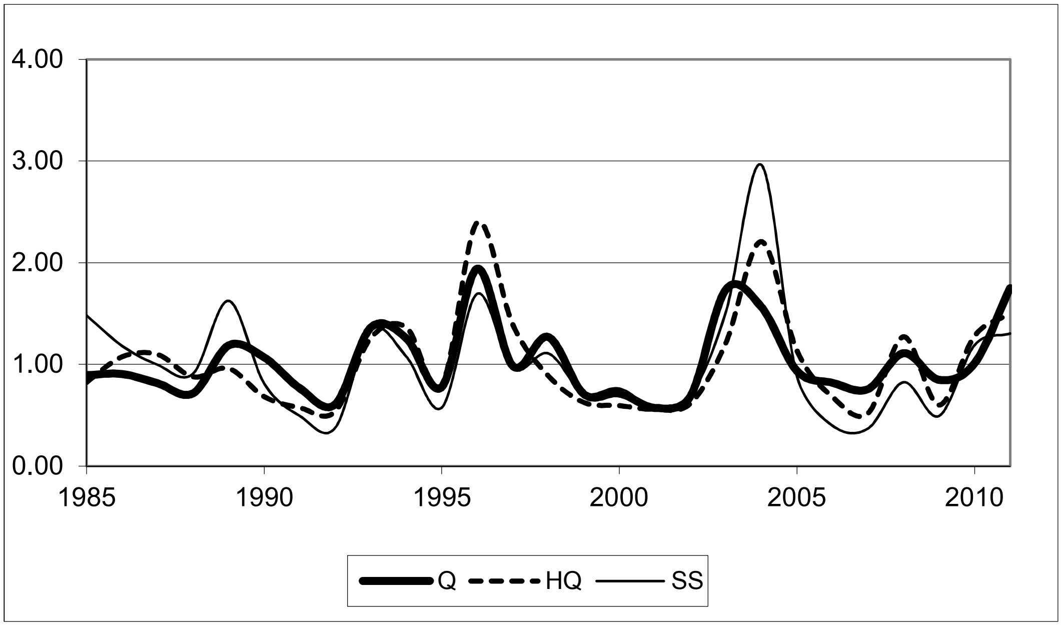

Figure 13. Annual Discharge and Annual Daily Mean High Discharge and Calculated Annual SS Concentration Expressed as LTM Ratio

Conestoga

T.S. Lee had a dramatic effect on Conestoga during 2011. Annual precipitation was 16.28 inches above the LTM with 10.08 inches falling during the summer months that contained T.S. Lee. Annual discharge was 165 percent of the LTM with summer having the highest deviation from the LTM at 275 percent. Peak flow for T.S. Lee surpassed 25,000 cubic feet per second (cfs) while the second highest peak flow for 2011 was near 7,500 cfs.

Annual loads were all above the respective LTMs except for DON. Greatest departure from LTMs occurred for TP and SS with 274 percent and 425 percent, respectively. While TN loads were evenly distributed throughout the four seasons, TP and SS were greatest during summer. Although TN was evenly distributed among seasons, the summer load was concentrated in September as were TP and SS with 75 percent of the annual TP load and 89 percent of the annual SS load being delivered during the month.

2011 annual and seasonal TN yields were below all baseline predictions. Both TP and SS annual yields were above all annual predictions, which were dominated by the summer event. Only summer had yield values above the seasonal baseline predictions with 2011 TP at 392 percent of the prediction and SS at 355 percent of the prediction.

2011 trends for all parameters remained unchanged from 2010. Increases in the magnitude of the trends did increase for TON, DON, TP, DOP, TOC, and SS. TNO_{23} and DNO_{23}, the largest load contributors to TN and DN, continue to have no significant trends. TNH_3 and DNH_3 had the highest magnitude trends but the lowest overall effect as they were the smallest portion of the TN and DN load.

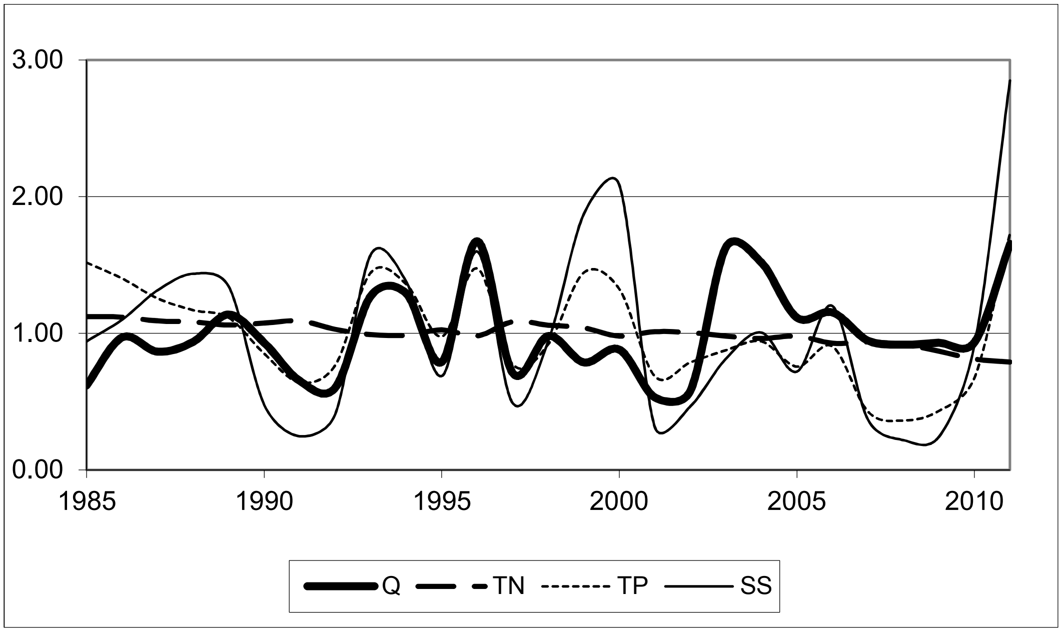

Figure 14. Annual Discharge and Calculated Annual TN, TP, and SS Concentrations Expressed as LTM Ratio

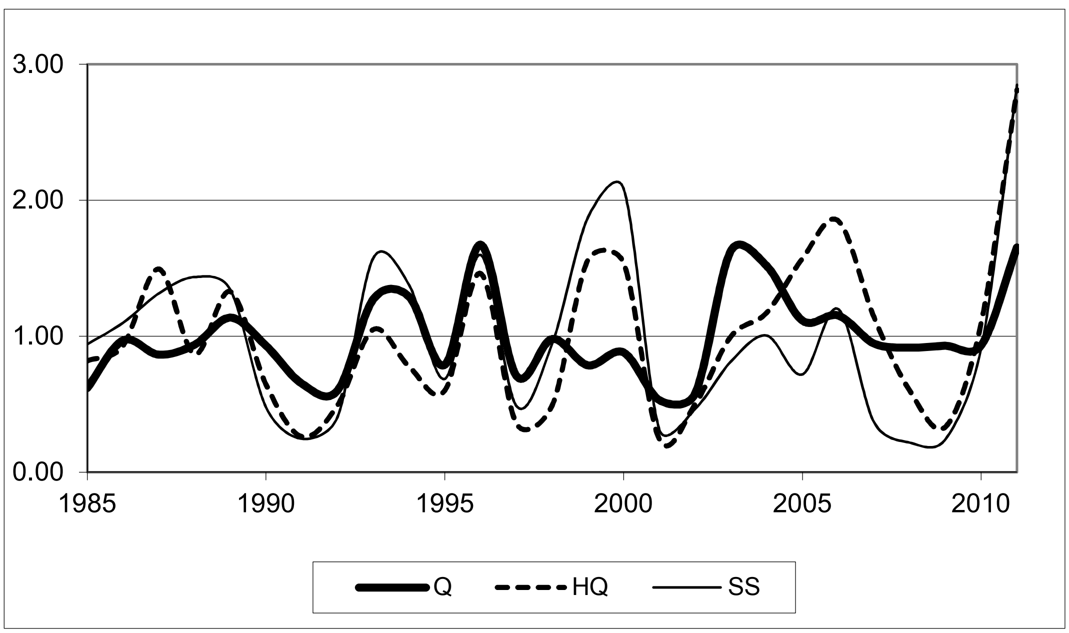

Figure 15. Annual Discharge and Annual Daily Mean High Discharge and Calculated Annual SS Concentration Expressed as LTM Ratio

2011 KEY FINDINGS

2011 brought several high flow events spread throughout the year with the largest occurring in August and September. Hurricane Irene and T.S. Lee brought intense rainfall and extreme nutrient and suspended sediment loads. Whereas Hurricane Irene affected the eastern portion of the basin, T.S. Lee affected the entire basin. However, each subbasin within the watershed was affected differently. The Conestoga Watershed was dramatically affected by both Irene and Lee resulting in a September high daily average discharge that was 330 percent of the closest daily high that occurred in March. In comparison, high daily average discharge at Lewisburg was 140 percent of the March high and the average daily high flow for September at Newport was 91 percent of the March high.

Annual rainfall ranged from 11 inches above the LTM at Towanda to 22.33 inches above the LTM at Lewisburg. Although the two major events brought the most significant amounts of precipitation, the spring events collectively produced 1.5 inches less. The rainfall was spread through a few months during the spring and concentrated during a short period of time during August and September.

T.S. Lee peak flow at Conestoga occurred on September 8 reaching 6.3 feet over major flood stage, second only to Hurricane Agnes in 1972. Peak flows at Towanda and Danville were historically second highest as well. September peak flow at Marietta was historically fourth, 11th at Lewisburg, and outside the top 15 at Newport.

Although T.S. Lee affected the entire basin, lower peak flows at Lewisburg and Newport led to dramatically lower yields of TP and SS as compared to the other four sites. This led to less impact, including lower SS yields at Marietta, as compared to Danville and Towanda. However, TP yields were higher at Marietta than at Danville and Towanda. Comparison of loads from Lewisburg, Danville, and Newport, to Marietta suggests that 49 percent, 61 percent, and 23 percent of the TN, TP, and SS loads at Marietta, respectively, was transported by the lower basin above Marietta. Within the lower basin, Swatara recorded peak flows over 10 feet above the closest historical peak flow and 12.8 feet over major flood stage.

September at Conestoga had the highest yield values for TN, TP, and SS. Due to the size of the Conestoga Watershed and the loads delivered, this occurred most previous years. September 2011 was unique in that not only was the September TP load at Conestoga larger than the September loads at Lewisburg and Newport, it was larger than the entire annual loads at Lewisburg and Newport. The SS load at Conestoga was above the annual load at Newport and was 78 percent of the annual load at Lewisburg. For comparison, September average flow was 22,459 cfs at Lewisburg, 11,873 cfs at Newport, and 3,034 cfs at Conestoga. September TN load at Conestoga was 8 and 9 percent of Lewisburg and Newport's annual load, respectively.

Summary statistics for all sites showed all four West Branch sites having the lowest mean TP concentrations and the Lower Susquehanna Subbasin having the top five when all sites were compared. Three of the top five were below Marietta and did not affect the load there while Swatara and the West Conewago were above it. Comparing the summary statistics based on location, West Branch Susquehanna Sites had lower mean TN and TP values, Juniata sites had higher mean TN and lower TP values, mainstem Susquehanna sites had lower mean TN and higher mean TP values, and lower Susquehanna sites had higher mean TN and TP values. The Chemung site had values similar to the mainstem while Unadilla, Cohocton, Penns, and Bald Eagle had lower mean TN and TP values.

When the TN, TP, and SS load was broken down into tributary contribution, Danville accounted for 38, 39, and 64 percent, respectively, of the Marietta load. Lewisburg and Newport combined accounted for 28, 12, and 8 percent of the respective loads. Subtracting this from the Marietta loads suggests that the Lower Susquehanna above Marietta accounted for 34, 50, and 28 percent of the TN, TP, and SS load, respectively. Discharge contributions were 43, 36, and 21 percent of Marietta's annual flow from Danville, Lewisburg plus Newport, and the lower subbasin tributaries, respectively.

Comparison of 2011 trends between Marietta and Danville, Lewisburg, and Newport suggest that the Lower Susquehanna's tributaries may be reducing the downward trends. Although all nitrogen species had downward trends at Danville and Marietta, the magnitude of these trends was less at Marietta. This included TON, TNH_3, and TNO_{23}. Six of the eight monitored tributaries to the Lower Susquehanna had the highest TNO_{23} average concentrations over all other sites. TNO_{23} trend magnitudes were lower for Lewisburg and there was no trend for Newport, playing an additional role in lowering the magnitude of the Marietta TNO_{23} trend as compared to Danville. The same was found for DNO_{23} while TNO_{23} and DNO_{23} constituted the majority of the TN load. Whereas Danville and Towanda showed larger magnitudes of improving nitrogen trends, both showed less improvement in phosphorus species. This included no trend for TP, an upward trend for DOP at Towanda, and no trend for DP at Danville. There were large magnitude trends for TP at all three tributary sites as well as large downward trends in DP at Newport and Conestoga.

SS trends were similar to TN trends in that Marietta had a much lower magnitude trend than Danville. Both Lewisburg and Newport trend magnitudes were similar to Marietta's.

Conestoga, the highest yield watershed in the basin for TN, TP, and SS, showed some of the highest magnitude reductions in trends. This included 73–81 percent reduction in TNH_3 and DNH_3, 70–80 percent SS, 54–64 percent TP, and the only downward trend for DOP of all six sites. Conestoga and Newport continue to have no trends for TNO_{23} and DNO_{23}, which constitutes the majority of TN and DN loads.

The data in Table 3 show that the high flow events drove the loads for many constituents including TP and SS during 2011. The three highest flow months of 2011 accounted for between 60–82 percent and 73–94 percent of the TP and SS load while TN loads accounted for 40–57 percent of that annual load. September alone accounted for 75 and 89 percent of the annual TP and SS load, respectively, at Conestoga. Considering the total flow and load of TN, TP, and SS transported from Marietta between 1987 and 2011, March, April, and September accounted for 3.7 percent of the flow, 3.03 percent of the TN, 7.92 percent of the TP, and 17.2 percent of the SS. September alone accounted for 1.12, 0.94, 4.71, and 12.36 percent of the total 24 year flow and load of TN, TP, and SS, respectively. The SS load that was transported past Marietta during September was equivalent to the entire load transported through Danville for 2011. This volume would be enough dry sand to reproduce the largest pyramid in Egypt two and a half times.

2011 showed that TN, TP, and SS react differently to individual high flow events. TN follows downward tendencies regardless of flow, whereas TP and SS show variable tendencies depending on presence of high flow events. A possible reason for this is management action that has occurred in the watershed. With increases in impervious surfaces and channeling of water into rivers, it is possible that storm flows are reaching their peaks faster and higher and subsequently having greater ability to erode streambanks and scour streambeds.

Another potential reason for the large increase in TP and SS load during a major event could be related to the watershed Best Management Practice (BMPs) design capacities. Since many BMPs are designed for 10 to 25-year storms, they cannot function properly during the extreme events that have hit the basin over the recent past including the major events of 2011 (Baldwin, 2007). Thus, while we find continued reductions in loads when we experience flows within their design capacity, massive transport of TP and SS occurred when flows surpassed the BMPs' functional design capacity.

Table 3. March, April, and September Total Precipitation, Flow, and Nutrient Loads as Percentage of Annual Totals and the Percent of LTM for Flow

Site	Time Period	Mean Q	High Daily Mean Q	Flow	TN	TP	SS
Towanda	March	47,732	106,000	20	23	18	8
	April	45,037	110,000	19	20	19	12
	September	36,785	220,000	15	14	40	73
	3-mo Total			54	57	77	94
Danville	March	69,235	167,000	18	22	17	9
	April	64,007	164,000	17	18	17	11
	September	64,923	301,000	17	15	39	72
	3-mo Total			52	55	73	91
Lewisburg	March	45,226	109,000	20	22	23	23
	April	44,343	99,500	20	19	25	25
	September	22,459	153,000	10	9	16	26
	3-mo Total			50	49	63	75
Newport	March	17,765	59,000	19	19	19	21
	April	15,755	40,600	17	16	15	16
	September	11,873	53,900	13	13	26	32
	3-mo Total			48	47	60	70
Marietta	March	162,713	423,000	18	19	16	12
	April	148,010	363,000	17	16	15	12
	September	137,867	616,000	16	16	44	63
	3-mo Total			51	51	75	88
Conestoga	March	1,651	7,960	12	13	4	3
	April	1,480	3,860	11	11	3	2
	September	3,034	25,400	22	17	75	89
	3-mo Total			45	40	82	93

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APPENDIX A

Individual Site Data

INDIVIDUAL SITES: TOWANDA

Table A1. 2011 Annual and Seasonal Precipitation and Discharge at Towanda

Season	Precipitation (inches)			Discharge (cfs)		
	2011	LTM	LTM Departure	2011	LTM	% LTM
January-March (Winter)	9.10	7.64	1.46	21,058	16,712	126%
April-June (Spring)	16.04	10.80	5.24	27,652	15,720	176%
July-September (Summer)	15.48	11.34	4.14	14,963	4,973	301%
October-December (Fall)	9.50	9.28	0.22	16,454	11,056	149%
Annual Total	50.11	39.07	11.04	20,005	12,083	166%

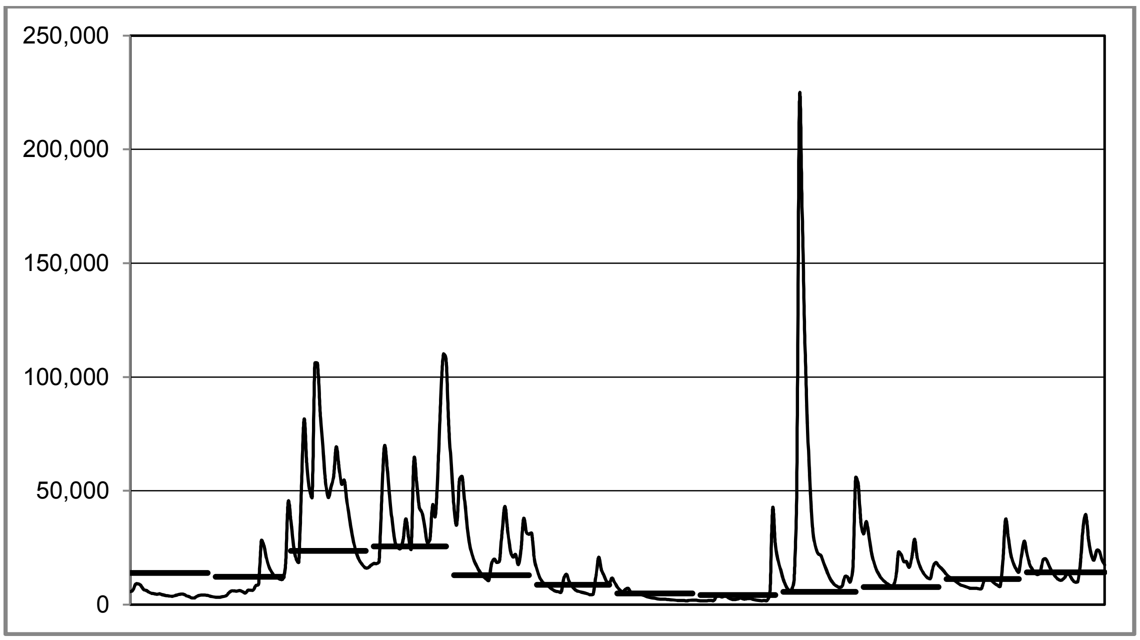

Figure A1. 2011 Daily Average Flow and Monthly LTM at Towanda

Table A2. 2011 Annual Loads (1000's lbs), Yields (lbs/acre), and Concentrations (mg/L) at Towanda

Parameter	Load	Load % of LTM	Error %	Yield	LTM Yield	Ave. Conc.	Conc. % of LTM
TN	34,683	127%	4%	6.95	5.49	0.88	76%
TON	17,793	174%	8%	3.57	2.05	0.45	105%
TNH_3	1,639	122%	13%	0.33	0.27	0.04	74%
TNO_{23}	17,444	108%	4%	3.50	3.24	0.44	65%
DN	30,302	126%	4%	6.07	4.80	0.77	76%
DON	11,364	159%	9%	2.28	1.43	0.29	96%
DNH_3	1,557	146%	11%	0.31	0.21	0.04	88%
DNO_{23}	17,515	109%	5%	3.51	3.21	0.44	66%
TP	4,135	174%	10%	0.829	0.475	0.105	105%
DP	796	100%	9%	0.160	0.160	0.020	60%
DOP	584	129%	11%	0.117	0.091	0.015	78%
TOC	142,028	169%	3%	28.46	16.83	3.61	102%
SS	13,697,320	412%	21%	2,745	666	348	249%

Table A3. 2011 Seasonal Loads (1000's lbs) and Yields (lbs/acre) at Towanda

Parameter	Winter		Spring		Summer		Fall	
	Load	Yield	Load	Yield	Load	Yield	Load	Yield
TN	10,146	2.03	12,122	2.43	5,755	1.15	6,660	1.33
TON	3,707	0.74	6,051	1.21	5,846	1.17	2,189	0.44
TNH_3	432	0.09	519	0.10	407	0.08	281	0.06
TNO_{23}	5,722	1.15	5,711	1.14	2,022	0.41	3,989	0.80
DN	9,117	1.83	10,343	2.07	4,281	0.86	6,561	1.31
DON	2,641	0.53	4,041	0.81	2,735	0.55	1,947	0.39
DNH_3	428	0.09	525	0.11	347	0.07	257	0.05
DNO_{23}	5,747	1.15	5,728	1.15	1,995	0.40	4,045	0.81
TP	802	0.161	1,258	0.252	1,724	0.345	351	0.070
DP	193	0.039	288	0.058	188	0.038	127	0.026
DOP	146	0.029	209	0.042	132	0.027	97	0.020
TOC	28,652	5.74	45,312	9.08	43,043	8.63	25,021	5.01
SS	1,177,770	236	2,152,025	431	10,115,399	2,027	252,126	51

Table A4. 2011 Monthly Flow (cfs), Loads (1000's lbs), and Yields (lbs/acre) at Towanda

Month	Flow		TN			TP			SS		
	2011	% LTM	Load	Yield	% LTM	Load	Yield	% LTM	Load	Yield	% LTM
January	4,860	35%	731	0.15	24%	21	0.004	9%	3,386	0.7	1%
February	9,460	77%	1,348	0.27	55%	47	0.009	35%	18,114	3.6	19%
March	47,732	202%	8,067	1.62	166%	734	0.147	189%	1,156,270	232	251%
April	45,037	176%	6,894	1.38	137%	799	0.160	170%	1,637,954	328	222%
May	28,406	219%	4,075	0.82	170%	380	0.076	215%	470,622	94	215%
June	9,488	109%	1,153	0.23	83%	79	0.016	53%	43,449	8.7	17%
July	3,697	74%	431	0.09	57%	29	0.006	36%	8,448	1.7	10%
August	5,112	120%	603	0.12	95%	62	0.012	88%	65,610	13	106%
September	36,785	647%	4,721	0.95	580%	1,633	0.327	1,058%	10,041,341	2,012	1,697%
October	18,220	235%	2,314	0.46	179%	168	0.034	127%	141,943	28	114%
November	12,918	114%	1,694	0.34	83%	78	0.016	45%	45,206	9	28%
December	18,109	128%	2,652	0.53	96%	105	0.021	52%	64,977	13	39%
Annual[#]	20,005	166%	34,683	6.95	127%	4,135	0.343	174%	13,697,318	2,745	412%

Table A5. 2011 Annual Comparison to Baselines at Towanda

Parameter	2011	Period	Y'	Q ratio	R^2
TN	6.95	89-93	11.62	1.73	0.86
		89-99	11.24	1.80	0.89
		00-10	7.66	1.63	0.85
		89-10	8.98	1.71	0.62
TP	0.828	89-93	1.173	1.73	0.70
		89-99	1.154	1.80	0.89
		00-10	0.838	1.63	0.82
		89-10	0.976	1.71	0.83
SS	2,745	89-93	1,094	1.73	0.38
		89-99	2,215	1.80	0.71
		00-10	1,266	1.63	0.60
		89-10	1,536	1.71	0.60

Q = discharge ratio
R^2 = correlation coefficient
* indicates a R^2 that is low and thus is less accurate at predicting

Table A6. 2011 Annual and Seasonal Comparison to Initial Five-Year Baselines at Towanda

Time Period	Flow Ratio	TN			TP			SS		
		R^2	Y'	Y11	R^2	Y'	Y11	R^2	Y'	Y11
Winter	1.50	0.95	3.33	2.03	0.61	0.188	0.161	0.02*	138	236
Spring	1.55	0.97	4.02	2.43	0.93	0.442	0.252	0.89	895	431
Summer	4.78	0.99	1.64	1.15	0.99	0.126	0.345	0.94	73	2,027
Fall	1.46	0.98	2.40	1.33	0.96	0.207	0.070	0.85	311	51
Annual	1.73	0.86	11.62	6.95	0.70	1.173	0.828	0.38	1,094	2,745

* indicates a R^2 that is low and thus is less accurate at predicting

Table A7. Trend Statistics for the Susquehanna River at Towanda, Pa., October 1988 Through September 2011

Parameter	STORET Code	Time Series/Test	Slope	P-Value	Slope Magnitude (%)			Trend % Change	Trend Direction
					Min	Trend	Max		
FLOW	60	SK	-	0.198	-	-	-	-	NS
TN	600	FAC	-0.025	<0.001	-47	-44	-41	41-47	Down
TON	605	FAC	-0.027	<0.001	-53	-47	-40	40-53	Down
TNH_3	610	FAC	-0.027	<0.001	-55	-47	-37	37-55	Down
TKN	625	FAC	-0.028	<0.001	-54	-48	-42	42-54	Down
TNOx	630	FAC	-0.024	<0.001	-46	-42	-38	38-46	Down
DN	602	FAC	-0.022	<0.001	-44	-40	-37	37-44	Down
DON	607	FAC	-0.021	<0.001	-46	-39	-31	31-46	Down
DNH_3	608	FAC	-0.017	<0.001	-43	-33	-20	N/A	BMDL
DKN	623	FAC	-0.020	<0.001	-44	-37	-29	29-44	Down
DNOx	631	FAC	-0.023	<0.001	-46	-41	-37	37-46	Down
TP	665	FAC	-0.005	0.067	-23	-12	1	N/A	NS
DP	666	FAC	-0.008	0.008	-29	-18	-5	5-29	Down
DOP	671	FAC	0.081	<0.001	373	496	650	373-650	Up
TOC	680	FAC	-0.006	<0.001	-17	-13	-8	8-17	Down
SS	80154	FAC	-0.017	<0.001	-46	-33	-16	16-46	Down

Down = downward/improving trend
Up = Upward/degrading trend
BMDL = Greater than 20% of values were Below Method Detection Limit
NS = No significant trend

INDIVIDUAL SITES: DANVILLE

Table A8. 2011 Annual and Seasonal Precipitation and Discharge at Danville

Season	Precipitation (inches)			Discharge (cfs)		
	2011	LTM	LTM Departure	2011	LTM	% LTM
January-March (Winter)	9.27	7.80	1.47	30,765	23,113	133%
April-June (Spring)	16.05	10.92	5.13	41,646	21,673	192%
July-September (Summer)	16.49	11.57	4.92	26,793	7,374	363%
October-December (Fall)	9.54	9.38	0.16	27,361	16,081	170%
Annual Total	51.35	39.67	11.68	31,619	17,018	186%

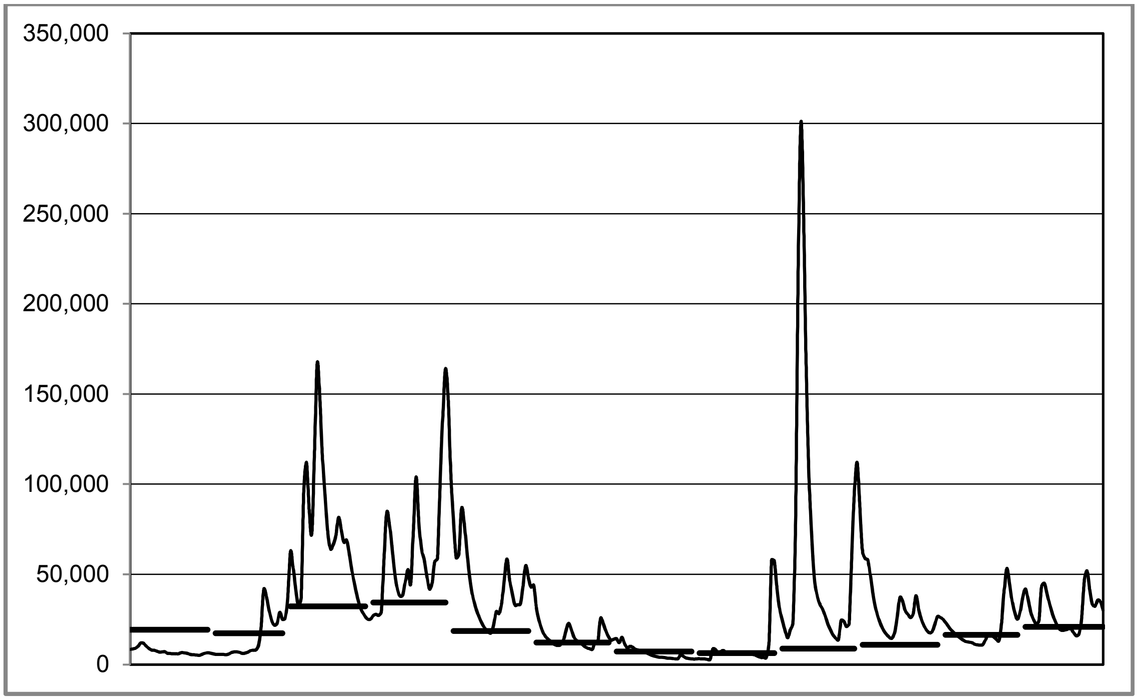

Figure A2. 2011 Daily Average Flow and Monthly LTM at Danville

Table A9. 2011 Annual Loads (1000's lbs), Yields (lbs/acre), and Concentrations (mg/L) at Danville

Parameter	Load	Load % of LTM	Error %	Yield lbs	LTM Yield	Ave. Conc.	Conc. % of LTM
TN	63,147	145%	4%	8.79	6.05	1.01	78%
TON	28,397	175%	8%	3.95	2.25	0.46	94%
TNH_3	3,438	159%	14%	0.48	0.30	0.06	85%
TNO_{23}	32,252	127%	5%	4.49	3.54	0.52	68%
DN	53,035	143%	4%	7.39	5.15	0.85	77%
DON	15,642	156%	8%	2.18	1.40	0.25	84%
DNH_3	3,268	171%	14%	0.46	0.27	0.05	92%
DNO_{23}	32,270	128%	5%	4.49	3.51	0.52	69%
TP	8,186	218%	11%	1.140	0.522	0.132	117%
DP	1,505	140%	12%	0.210	0.150	0.024	75%
DOP	955	156%	16%	0.133	0.085	0.015	84%
TOC	238,667	201%	4%	33.24	16.50	3.83	108%
SS	24,497,398	606%	23%	3,412	563	394	326%

Table A10. 2011 Seasonal Loads (1000's lbs) and Yields (lbs/acre) at Danville

Parameter	Winter		Spring		Summer		Fall	
	Load	Yield	Load	Yield	Load	Yield	Load	Yield
TN	17,266	3.95	20,765	2.89	11,884	1.65	13,232	1.84
TON	5,916	0.82	9,606	1.34	9,123	1.27	3,752	0.52
TNH_3	922	0.13	1,057	0.15	724	0.10	735	0.10
TNO_{23}	9,610	1.34	9,728	1.35	4,615	0.64	8,299	1.16
DN	14,966	2.08	16,966	2.36	8,500	1.18	12,603	1.76
DON	3,630	0.51	5,269	0.73	3,847	0.54	2,896	0.40
DNH_3	902	0.13	989	0.14	673	0.09	704	0.10
DNO_{23}	9,633	1.34	9,700	1.35	4,567	0.64	8,370	1.17
TP	1,523	0.212	2,383	0.332	3,401	0.474	879	0.122
DP	331	0.046	518	0.072	384	0.053	272	0.038
DOP	209	0.029	320	0.045	244	0.034	182	0.025
TOC	43,903	6.11	71,196	9.91	79,516	11.07	44,052	6.13
SS	2,157,626	300	3,689,698	514	17,755,145	2,473	894,929	125

Table A11. 2011 Flow (cfs), Loads (1000's lbs), and Yields (lbs/acre) at Danville

MONTH	Flow		TN			TP			SS		
	2011	% LTM	Load	Yield	% LTM	Load	Yield	% LTM	Load	Yield	% LTM
January	7,232	37%	1,243	0.17	26%	36	0.005	10%	6,641	0.9	2%
February	14,227	82%	2,356	0.33	62%	97	0.013	46%	43,224	6.0	37%
March	69,235	215%	13,667	1.90	181%	1,390	0.194	228%	2,107,761	294	353%
April	64,007	186%	11,245	1.57	150%	1,412	0.197	204%	2,592,732	361	316%
May	44,452	239%	7,288	1.01	197%	797	0.111	277%	990,685	138	381%
June	16,387	135%	2,232	0.31	109%	174	0.024	72%	106,281	15	28%
July	6,610	92%	843	0.12	72%	56	0.008	45%	19,566	2.7	19%
August	10,076	162%	1,338	0.19	131%	148	0.021	139%	181,059	25	280%
September	64,923	742%	9,703	1.35	675%	3,197	0.445	1,232%	17,554,520	2,445	2,083%
October	31,281	287%	4,700	0.65	224%	449	0.063	226%	575,853	80	412%
November	20,577	125%	3,215	0.45	91%	172	0.024	58%	123,071	17	67%
December	30,006	144%	5,317	0.74	111%	258	0.036	71%	196,005	27	88%
Annual[#]	31,619	186%	74,247	10.34	145%	8,186	0.343	218%	24,497,398	3,412	606%

Table A12. 2011 Annual Comparison to Baselines at Danville

Parameter	2011	Period	Y'	Q ratio	R^2
TN	8.79	85-89	18.65	2.36	0.95
		85-97	13.31	2.03	0.88
		98-10	8.483	1.83	0.71
		85-10	10.26	1.92	0.55
TP	1.14	85-89	4.25	2.36	0.97
		85-97	1.345	2.03	0.87
		98-10	1.15	1.83	0.84
		85-10	1.225	1.92	0.75
SS	3,412	85-89	2015	2.36	0.99
		85-97	1699	2.03	0.77
		98-10	1405	1.83	0.52
		85-10	1511	1.92	0.62

Q = discharge ratio
R^2 = correlation coefficient
* indicates a R^2 that is low and thus is less accurate at predicting

Table A13. 2011 Annual and Seasonal Comparison to Initial Five-Year Baselines at Danville

Time Period	Flow Ratio	TN			TP			SS		
		R^2	Y'	Y11	R^2	Y'	Y11	R^2	Y'	Y11
Winter	1.85	1.00	4.00	2.40	0.97	0.299	0.212	0.90	401	301
Spring	2.24	1.00	4.52	2.89	1.00	0.398	0.332	0.98	494	514
Summer	4.94	0.99	2.73	1.65	0.93	0.233	0.474	0.79	117	2,473
Fall	2.08	1.00	3.59	1.84	0.98	0.265	0.122	0.95	181	125
Annual	2.36	0.95	18.65	8.79	0.97	4.25	1.14	0.99	2,015	3,412

* indicates a R^2 that is low and thus is less accurate at predicting

Table A14. Trend Statistics for the Susquehanna River at Danville, Pa., October 1984 Through September 2011

Parameter	STORET Code	Time Series/Test	Slope	P-Value	Slope Magnitude (%)			Trend % Change	Trend Direction
					Min	Trend	Max		
FLOW	60	SK	-	0.101	-	-	-	-	NS
TN	600	FAC	-0.023	<0.001	-50	-47	-44	44-50	Down
TON	605	FAC	-0.031	<0.001	-62	-57	-51	51-62	Down
TNH_3	610	FAC	-0.026	<0.001	-58	-50	-41	41-58	Down
TKN	625	FAC	-0.030	<0.001	-61	-56	-51	51-61	Down
TNOx	630	FAC	-0.020	<0.001	-45	-41	-37	37-45	Down
DN	602	FAC	-0.019	<0.001	-44	-41	-37	37-44	Down
DON	607	FAC	-0.022	<0.001	-52	-46	-39	39-52	Down
DNH_3	608	FAC	-0.020	<0.001	-52	-42	-31	31-52	BMDL
DKN	623	FAC	-0.020	<0.001	-49	-43	-36	36-49	Down
DNOx	631	FAC	-0.019	<0.001	-45	-41	-36	36-45	Down
TP	665	FAC	-0.012	<0.001	-37	-28	-17	17-37	Down
DP	666	FAC	-0.003	0.376	-21	-7	10	N/A	NS
DOP	671	FAC	0.081	<0.001	524	713	959	N/A	BMDL
TOC	680	FAC	-0.009	<0.001	-26	-21	-17	17-26	Down
SS	80154	FAC	-0.028	<0.001	-61	-53	-43	43-61	Down

Down = downward/improving trend
Up = Upward/degrading trend
BMDL = Greater than 20% of values were Below Method Detection Limit
NS = No significant trend

INDIVIDUAL SITES: MARIETTA

Table A15. 2011 Annual and Seasonal Precipitation and Discharge at Marietta

Season	Precipitation (inches)			Discharge (cfs)		
	2011	LTM	LTM Departure	2011	LTM	% LTM
January-March (Winter)	10.3	8.21	2.09	71,997	55,412	130%
April-June (Spring)	17.05	10.99	6.06	97,148	50,703	192%
July-September (Summer)	20.75	11.88	8.87	55,042	18,716	294%
October-December (Fall)	11.5	9.65	1.85	70,047	36,598	191%
Annual Total	59.6	40.73	18.87	73,502	40,256	183%

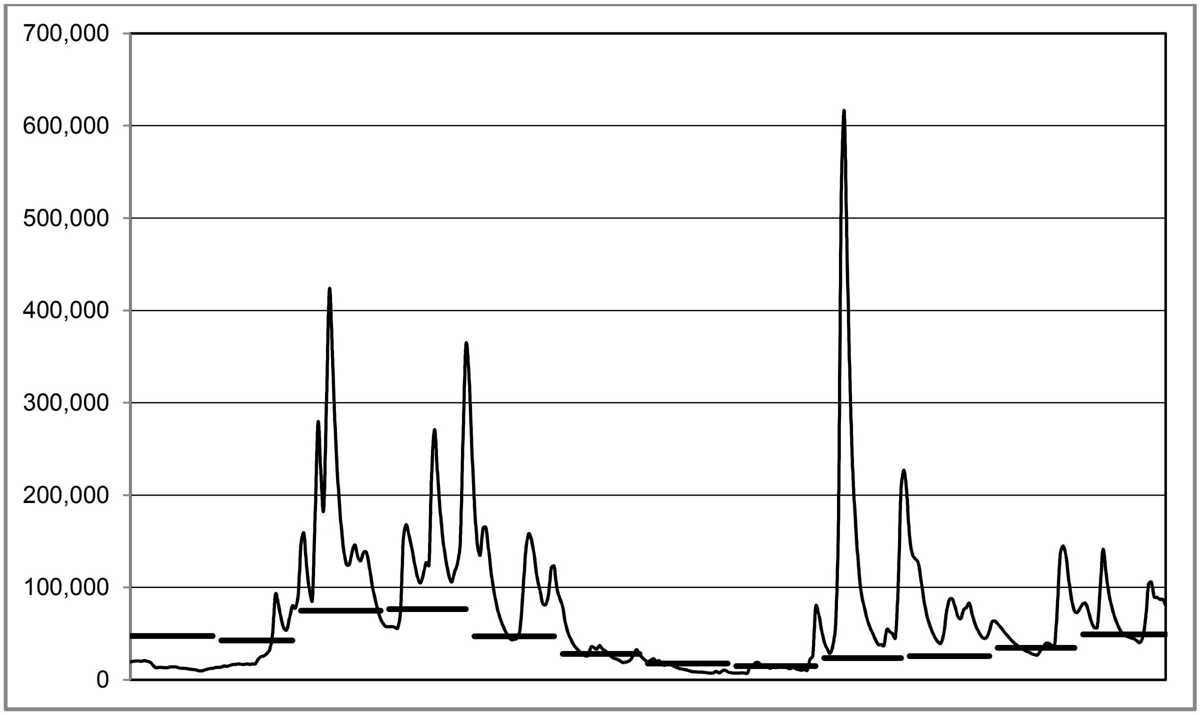

Figure A3. 2011 Daily Average Flow and Monthly LTM at Marietta

Table A16. 2011 Annual Loads (1000's lbs), Yields (lbs/acre), and Concentrations (mg/L) at Marietta

Parameter	Load	Load % of LTM	Error %	Yield	LTM Yield	Ave. Conc.	Conc. % of LTM
TN	194,879	150%	4%	11.72	7.83	1.35	82%
TON	72,584	206%	10%	4.36	2.12	0.50	113%
TNH_3	6,582	144%	12%	0.40	0.28	0.05	79%
TNO_{23}	124,135	135%	5%	7.46	5.52	0.86	74%
DN	157,333	139%	4%	9.46	6.81	1.09	76%
DON	24,975	130%	11%	1.50	1.16	0.17	71%
DNH_3	5,384	136%	12%	0.32	0.24	0.04	75%
DNO_{23}	124,184	136%	5%	7.47	5.49	0.86	75%
TP	21,202	265%	9%	1.275	0.481	0.147	145%
DP	2,843	126%	9%	0.171	0.135	0.020	69%
DOP	1,951	156%	10%	0.117	0.075	0.013	85%
TOC	506,677	206%	4%	30.46	14.80	3.50	113%
SS	38,143,676	491%	16%	2,293	468	264	269%

Table A17. 2011 Seasonal Loads (1000's lbs) and Yields (lbs/acre) at Marietta

Parameter	Winter		Spring		Summer		Fall	
	Load	Yield	Load	Yield	Load	Yield	Load	Yield
TN	48,284	2.90	58,900	3.54	36,019	2.17	51,676	3.11
TON	15,109	0.91	23,189	1.39	21,927	1.32	12,359	0.74
TNH_3	1,688	0.10	1,871	0.11	1,418	0.09	1,605	0.10
TNO_{23}	31,912	1.92	36,128	2.17	19,757	1.19	36,338	2.18
DN	39,740	2.39	45,897	2.76	26,561	1.60	45,135	2.71
DON	5,685	0.34	7,548	0.45	5,604	0.34	6,138	0.37
DNH_3	1,395	0.08	1,536	0.09	1,104	0.07	1,349	0.08
DNO_{23}	31,927	1.92	36,092	2.17	19,656	1.18	36,509	2.19
TP	3,536	0.213	5,246	0.315	9,666	0.581	2,754	0.166
DP	491	0.030	694	0.042	899	0.054	759	0.046
DOP	317	0.019	447	0.027	634	0.038	553	0.033
TOC	98,095	5.90	154,036	9.26	146,160	8.79	108,386	6.52
SS	4,792,423	288	7,064,468	425	24,138,561	1,451	2,148,224	129

Table A18. 2011 Monthly Flow (cfs), Loads (1000's lbs), and Yields (lbs/acre) at Marietta

Month	Flow		TN			TP			SS		
	2011	% LTM	Load	Yield	% LTM	Load	Yield	% LTM	Load	Yield	% LTM
January	14,455	30%	3,248	0.20	22%	49	0.003	6%	10,174	0.6	1%
February	35,268	83%	7,329	0.44	64%	187	0.011	44%	96,771	5.8	36%
March	162,713	217%	37,707	2.27	184%	3,300	0.198	268%	4,685,478	282	397%
April	148,010	193%	30,568	1.84	154%	3,108	0.187	229%	4,726,378	284	359%
May	108,923	230%	22,144	1.33	191%	1,860	0.112	264%	2,176,598	131	333%
June	34,120	121%	6,188	0.37	99%	278	0.017	63%	161,492	9.7	38%
July	12,731	71%	2,205	0.13	55%	78	0.005	32%	23,183	1.4	15%
August	17,199	116%	3,331	0.20	97%	164	0.010	74%	87,006	5.2	62%
September	137,867	584%	30,483	1.83	530%	9,424	0.567	1,092%	24,028,372	1,445	1,446%
October	78,894	308%	19,025	1.14	262%	1,404	0.084	323%	1,269,306	76	389%
November	57,323	165%	13,885	0.83	137%	627	0.038	118%	421,439	25	121%
December	73,513	149%	18,766	1.13	123%	723	0.043	93%	457,479	28	79%
Annual	73,502	183%	194,879	11.72	150%	21,202	0.343	265%	38,143,676	2,293	491%

Table A19. 2011 Annual Comparison to Baselines at Marietta

Parameter	2011	Period	Y'	Q ratio	R^2
TN	11.72	87-91	20.73	2.20	1.00
		85-98	15.44	1.90	0.94
		99-10	13.94	1.88	0.96
		87-10	14.67	1.89	0.90
TP	1.274	87-91	1.041	2.20	0.79
		85-98	1.119	1.90	0.90
		99-10	1.045	1.88	0.79
		87-10	1.082	1.89	0.85
SS	2,293	87-91	1,004	2.20	0.70
		85-98	1,170	1.90	0.88
		99-10	1,191	1.88	0.67
		87-10	1,178	1.89	0.77

Q = discharge ratio
R^2 = correlation coefficient
* indicates a R^2 that is low and thus is less accurate at predicting

Table A20. 2011 Annual and Seasonal Comparison to Initial Five-Year Baselines at Marietta

Time Period	Flow Ratio	TN			TP			SS		
		R^2	Y'	Y11	R^2	Y'	Y11	R^2	Y'	Y11
Winter	1.65	1.00	4.33	2.90	0.87	0.163	0.213	0.97	115	288
Spring	2.09	1.00	5.75	3.54	0.91	0.388	0.315	0.92	488	425
Summer	3.76	1.00	2.92	2.17	0.89	0.174	0.581	0.88	111	1451
Fall	2.40	1.00	4.63	3.11	1.00	0.252	0.166	0.98	240	129
Annual	2.20	1.00	20.73	11.72	0.79	1.041	1.274	0.70	1,004	2,293

* indicates a R^2 that is low and thus is less accurate at predicting

Table A21. Trend Statistics for the Susquehanna River at Marietta, Pa., October 1986 Through September 2011

Parameter	STORET Code	Time Series/Test	Slope	P-Value	Slope Magnitude (%)			Trend % Change	Trend Direction
					Min	Trend	Max		
FLOW	60	SK	-	0.431	-	-	-	-	NS
TN	600	FAC	-0.015	<0.001	-35	-31	-27	27-35	Down
TON	605	FAC	-0.027	<0.001	-56	-49	-42	42-56	Down
TNH_3	610	FAC	-0.016	<0.001	-43	-33	-21	21-43	Down
TKN	625	FAC	-0.025	<0.001	-54	-48	-41	41-54	Down
TNO_{23}	630	FAC	-0.009	<0.001	-25	-20	-14	14-25	Down
DN	602	FAC	-0.022	<0.001	-47	-43	-39	39-47	Down
DON	607	FAC	-0.027	<0.001	-56	-49	-41	41-56	Down
DNH_3	608	FAC	-0.014	<0.001	-40	-30	-18	N/A	BMDL
DKN	623	FAC	-0.023	<0.001	-52	-44	-36	36-52	Down
DNO_{23}	631	FAC	-0.009	<0.001	-25	-20	-14	14-25	Down
TP	665	FAC	-0.015	<0.001	-40	-32	-23	23-40	Down
DP	666	FAC	-0.024	<0.001	-52	-45	-37	37-52	Down
DOP	671	FAC	0.073	<0.001	360	487	650	N/A	BMDL
TOC	680	FAC	-0.007	<0.001	-20	-16	-11	11-20	Down
SS	80154	FAC	-0.020	<0.001	-50	-39	-27	27-50	Down

Down = downward/improving trend
Up = Upward/degrading trend
BMDL = Greater than 20% of values were Below Method Detection Limit
NS = No significant trend

INDIVIDUAL SITES: LEWISBURG

Table A22. 2011 Annual and Seasonal Precipitation and Discharge at Lewisburg

Season	Precipitation (inches)			Discharge (cfs)		
	2011	LTM	LTM Departure	2011	LTM	% LTM
January-March (Winter)	11.76	8.42	3.34	20,148	15,442	130%
April-June (Spring)	17.9	11.23	6.67	26,424	13,228	200%
July-September (Summer)	22.44	12.77	9.67	9,070	5,146	176%
October-December (Fall)	12.57	9.92	2.65	19,029	10,458	182%
Annual Total	64.67	42.34	22.33	18,638	11,041	169%

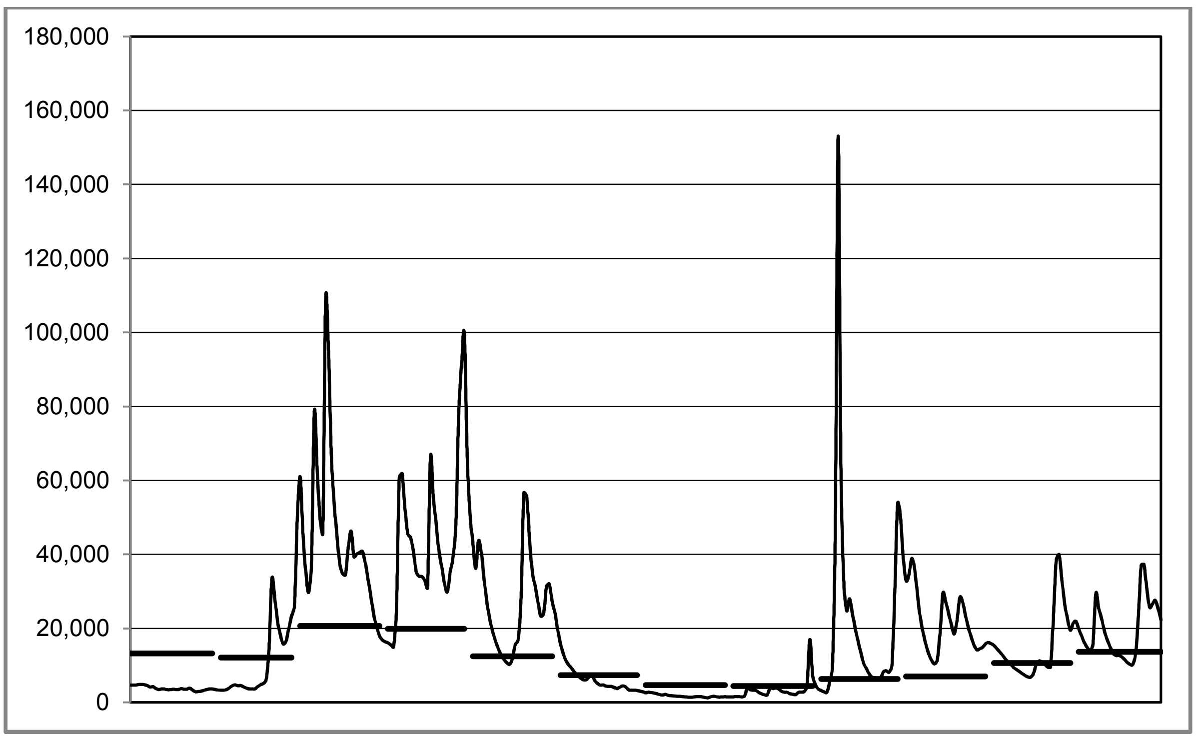

Figure A4. 2011 Daily Average Flow and Monthly LTM at Lewisburg

Table A23. 2011 Annual Loads (1000's lbs), Yields (lbs/acre), and Concentrations (mg/L) at Lewisburg

Parameter	Load	Load % of LTM	Error %	Yield	LTM Yield	Ave. Conc.	Conc. % of LTM
TN	29,066	125%	5%	6.63	5.29	0.79	74%
TON	8,819	121%	13%	2.01	1.66	0.24	72%
TNH_3	1,279	123%	12%	0.29	0.24	0.03	73%
TNO_{23}	19,416	129%	4%	4.43	3.43	0.53	76%
DN	26,121	127%	4%	5.96	4.69	0.71	75%
DON	5,620	114%	11%	1.28	1.12	0.15	68%
DNH_3	1,217	134%	11%	0.28	0.21	0.03	80%
DNO_{23}	19,327	129%	4%	4.41	3.41	0.53	77%
TP	1,399	113%	11%	0.319	0.282	0.038	67%
DP	273	59%	17%	0.062	0.106	0.007	35%
DOP	158	70%	24%	0.036	0.051	0.004	42%
TOC	82,456	178%	5%	18.82	10.56	2.25	106%
SS	1,921,672	164%	17%	439	267	52	97%

Table A24. 2011 Seasonal Loads (1000's lbs) and Yields (lbs/acres) at Lewisburg

Parameter	Winter		Spring		Summer		Fall	
	Load	Yield	Load	Yield	Load	Yield	Load	Yield
TN	8,451	1.93	9,611	2.19	3,259	0.74	7,745	1.77
TON	2,440	0.56	3,369	0.77	1,308	0.30	1,702	0.39
TNH_3	366	0.08	402	0.09	141	0.03	370	0.08
TNO_{23}	5,670	1.29	5,961	1.36	2,044	0.47	5,741	1.31
DN	7,615	1.74	8,369	1.91	2,815	0.64	7,322	1.67
DON	1,579	0.36	2,032	0.46	702	0.16	1,307	0.30
DNH_3	369	0.08	388	0.09	121	0.03	339	0.08
DNO_{23}	5,660	1.29	5,915	1.35	2,028	0.46	5,724	1.31
TP	361	0.082	570	0.130	236	0.054	232	0.053
DP	68	0.016	113	0.026	37	0.009	55	0.012
DOP	42	0.010	67	0.015	19	0.004	30	0.007
TOC	18,999	4.34	28,478	6.50	14,825	3.38	20,154	4.60
SS	475,976	109	698,866	159	503,500	115	243,330	56

Table A25. 2011 Monthly Flow (cfs), Loads (1000's lbs), and Yields (lbs/acre) at Lewisburg

Monthly	Flow		TN			TP			SS		
	2011	% LTM	Load	Yield	% LTM	Load	Yield	% LTM	Load	Yield	% LTM
January	3,798	29%	673	0.15	25%	8	0.002	6%	2,175	0.5	1%
February	10,484	86%	1,457	0.33	67%	35	0.008	39%	24,135	5.5	40%
March	45,226	219%	6,321	1.44	166%	318	0.073	154%	449,666	102.6	209%
April	44,343	223%	5,468	1.25	158%	348	0.079	168%	488,055	111.4	205%
May	28,294	228%	3,362	0.77	171%	196	0.045	189%	199,611	45.6	232%
June	6,573	89%	781	0.18	71%	26	0.006	45%	11,200	2.6	37%
July	1,803	38%	256	0.06	35%	6	0.001	14%	1,036	0.2	6%
August	3,379	76%	441	0.10	64%	12	0.003	29%	4,763	1.1	16%
September	22,459	356%	2,562	0.58	276%	218	0.050	326%	497,701	113.6	529%
October	22,052	313%	2,777	0.63	236%	114	0.026	183%	121,844	27.8	272%
November	15,161	142%	2,066	0.47	107%	53	0.012	54%	53,279	12.2	66%
December	19,748	144%	2,902	0.66	113%	65	0.015	54%	68,207	15.6	75%
Annual#	18,638	169%	29,066	6.63	125%	1,399	0.343	113%	1,921,672	438.5	164%

Table A26. 2011 Annual Comparison to Baselines at Lewisburg

Parameter	2011	Period	Y'	Q ratio	R^2
TN	6.63	85-89	11.95	1.89	0.91
		85-97	9.78	1.68	0.94
		98-10	8.18	1.80	0.94
		85-10	9.29	1.73	0.81
TP	0.319	85-89	0.591	1.89	0.92
		85-97	0.651	1.68	0.87
		98-10	0.534	1.80	0.91
		85-10	0.603	1.73	0.83
SS	439	85-89	522	1.89	0.71
		85-97	962	1.68	0.76
		98-10	575	1.80	0.63
		85-10	823	1.73	0.65

Q = discharge ratio
R^2 = correlation coefficient
* indicates a R^2 that is low and thus is less accurate at predicting

Table A27. 2011 Annual and Seasonal Comparison to Initial Five-Year Baselines at Lewisburg

Time Period	Flow Ratio	TN			TP			SS		
		R^2	Y'	Y11	R^2	Y'	Y11	R^2	Y'	Y11
Winter	1.58	0.99	3.21	1.93	0.98	0.133	0.082	0.89	139	109
Spring	1.96	1.00	3.46	2.19	0.99	0.226	0.130	0.96	228	160
Summer	2.19	0.99	1.12	0.74	0.97	0.066	0.054	0.41*	20	115
Fall	2.06	1.00	2.94	1.77	0.99	0.129	0.053	0.95	92	56
Annual	1.89	0.91	11.95	6.63	0.92	0.591	0.319	0.71	522	439

* indicates a R^2 that is low and thus is less accurate at predicting

Table A28. Trend Statistics for the West Branch Susquehanna River at Lewisburg, Pa., October 1984 Through September 2011

Parameter	STORET Code	Time Series/Test	Slope	P-Value	Slope Magnitude (%)			Trend % Change	Trend Direction
					Min	Trend	Max		
FLOW	60	SK	-	1.0	-	-	-	-	NS
TN	600	FAC	-0.017	<0.001	-41	-36	-32	32-41	Down
TON	605	FAC	-0.037	<0.001	-70	-64	-58	58-70	Down
TNH_3	610	FAC	-0.017	<0.001	-47	-37	-24	N/A	BMDL
TKN	625	FAC	-0.031	<0.001	-63	-57	-51	51-63	Down
TNO_{23}	630	FAC	-0.007	<0.001	-23	-18	-12	12-23	Down
DN	602	FAC	-0.014	<0.001	-36	-32	-27	27-36	Down
DON	607	FAC	-0.030	<0.001	-63	-57	-50	50-63	Down
DNH_3	608	FAC	-0.011	<0.001	-38	-26	-12	N/A	BMDL
DKN	623	FAC	-0.023	<0.001	-53	-46	-39	39-53	Down
DNO_{23}	631	FAC	-0.007	<0.001	-23	-18	-12	12-23	Down
TP	665	FAC	-0.020	<0.001	-51	-41	-30	30-51	Down
DP	666	FAC	-0.031	<0.001	-65	-58	-48	N/A	BMDL
DOP	671	FAC	0.055	<0.001	211	325	481	N/A	BMDL
TOC	680	FAC	0.001	0.511	-5	3	11	N/A	NS
SS	80154	FAC	-0.018	<0.001	-51	-38	-22	22-51	Down

Down = downward/improving trend
Up = Upward/degrading trend
BMDL = Greater than 20% of values were Below Method Detection Limit
NS = No significant trend

INDIVIDUAL SITES: NEWPORT

Table A29. 2011 Annual and Seasonal Precipitation and Discharge at Newport

Season	Precipitation (inches)			Discharge (cfs)		
	2011	LTM	LTM Departure	2011	LTM	% LTM
January-March (Winter)	8.12	7.69	0.43	7,977	6,547	122%
April-June (Spring)	16.75	10.09	6.66	10,513	5,604	188%
July-September (Summer)	18.97	10.36	8.61	4,695	2,054	229%
October-December (Fall)	11.72	9.26	2.46	8,362	3,865	216%
Annual Total	55.56	37.4	18.16	7,879	4,504	175%

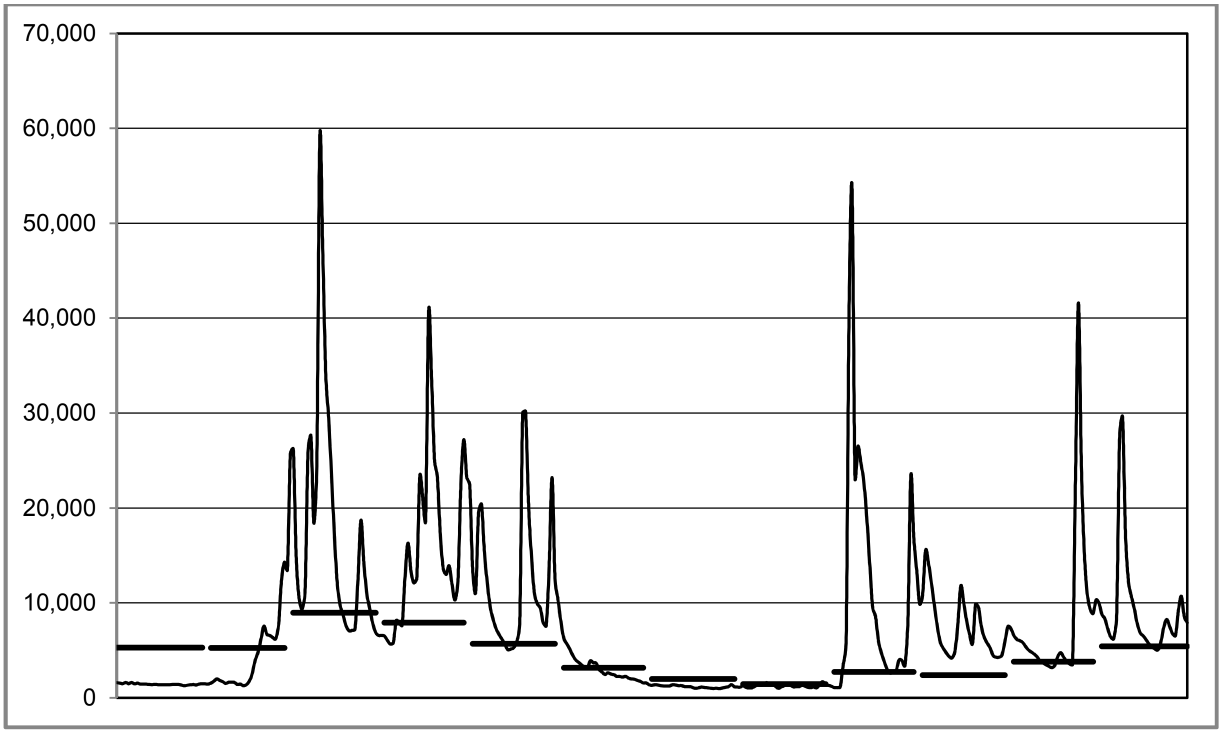

Figure A5. 2011 Daily Average Flow and Monthly LTM at Newport

Table A30. 2011 Annual Loads (1000's lbs), Yields (lbs/acre), and Concentrations (mg/L) at Newport

Parameter	Load	Load % of LTM	Error %	Yield	LTM Yield	Ave. Conc.	Conc. % of LTM
TN	24,834	151%	3%	11.57	7.64	1.60	87%
TON	5,996	151%	12%	2.79	1.85	0.39	86%
TNH_3	512	135%	12%	0.24	0.18	0.03	77%
TNO_{23}	18,841	154%	3%	8.78	5.69	1.21	88%
DN	22,116	149%	3%	10.30	6.90	1.43	85%
DON	2,965	119%	10%	1.38	1.16	0.19	68%
DNH_3	440	135%	12%	0.20	0.15	0.03	77%
DNO_{23}	18,921	156%	3%	8.81	5.65	1.22	89%
TP	1,110	143%	10%	0.517	0.362	0.072	82%
DP	327	91%	9%	0.152	0.167	0.021	52%
DOP	251	118%	10%	0.117	0.099	0.016	67%
TOC	48,466	170%	5%	22.58	13.32	3.12	97%
SS	1,056,106	200%	17%	492	245	68	115%

Table A31. 2011 Seasonal Loads (1000's lbs) and Yields (lbs/acre) at Newport

Parameter	Winter		Spring		Summer		Fall	
	Load	Yield	Load	Yield	Load	Yield	Load	Yield
TN	6,126	2.85	7,668	3.57	3,647	1.70	7,393	3.44
TON	1,556	0.72	2,062	0.96	1,138	0.53	1,240	0.58
TNH_3	113	0.05	173	0.08	109	0.05	117	0.05
TNO_{23}	4,597	2.14	5,633	2.62	2,592	1.21	6,019	2.80
DN	5,391	2.51	6,732	3.14	3,171	1.48	6,822	3.18
DON	704	0.33	974	0.45	526	0.24	761	0.35
DNH_3	92	0.04	146	0.07	97	0.05	105	0.05
DNO_{23}	4,610	2.15	5,663	2.64	2,597	1.21	6,051	2.82
TP	232	0.108	335	0.156	300	0.140	243	0.113
DP	60	0.028	93	0.043	83	0.039	91	0.042
DOP	43	0.020	67	0.031	68	0.032	73	0.034
TOC	10,747	5.01	15,435	7.19	9,728	4.53	12,556	5.85
SS	235,250	110	312,548	146	341,688	159	166,620	78

Table A32. 2011 Monthly Flow (cfs), Loads (1000's lbs), and Yields (lbs/acre) at Newport

Month	Flow		TN			TP			SS		
	2011	% LTM	Load	Yield	% LTM	Load	Yield	% LTM	Load	Yield	% LTM
January	1,435	27%	338	0.16	19%	5	0.002	7%	668	0.3	2%
February	4,381	83%	1,068	0.50	70%	20	0.009	38%	9,585	4.5	40%
March	17,765	198%	4,720	2.20	174%	207	0.096	173%	224,997	104.8	252%
April	15,755	199%	3,864	1.80	172%	171	0.079	160%	170,664	79.5	228%
May	12,520	220%	3,104	1.45	194%	144	0.067	176%	134,378	62.6	259%
June	3,197	101%	700	0.33	85%	20	0.009	41%	7,506	3.5	27%
July	1,182	59%	224	0.10	42%	7	0.003	22%	1,243	0.6	6%
August	1,262	87%	256	0.12	68%	8	0.004	39%	1,459	0.7	24%
September	11,873	433%	3,167	1.48	389%	285	0.133	375%	338,986	157.9	354%
October	7,558	317%	2,234	1.04	290%	78	0.036	209%	42,725	19.9	216%
November	8,177	215%	2,349	1.09	180%	90	0.042	149%	73,635	34.3	204%
December	9,345	173%	2,810	1.31	147%	75	0.035	101%	50,260	23.4	120%
Annual	7,879	175%	24,834	11.57	151%	1,110	0.343	143%	1,056,106	492.0	200%

Table A33. 2011 Annual Comparison to Baselines at Newport

Parameter	2011	Period	Y'	Flow ratio	R^2
TN	11.57	85-89	16.04	2.00	0.84
		85-97	13.59	1.76	0.95
		98-10	14.38	1.84	0.98
		85-10	13.98	1.80	0.96
TP	0.517	85-89	1.004	2.00	0.68
		85-97	0.686	1.76	0.75
		98-10	0.789	1.84	0.83
		85-10	0.736	1.80	0.78
SS	492	85-89	867	2.00	0.94
		85-97	580	1.76	0.90
		98-10	766	1.84	0.73
		85-10	667	1.80	0.77

Q = discharge ratio
R^2 = correlation coefficient
* indicates a R^2 that is low and thus is less accurate at predicting

Table A34. 2011 Annual and Seasonal Comparison to Initial Five-Year Baselines at Newport

Time Period	Flow Ratio	TN			TP			SS		
		R^2	Y'	Y11	R^2	Y'	Y11	R^2	Y'	Y11
Winter	1.54	0.96	4.03	2.85	0.84	0.238	0.108	0.91	163	110
Spring	1.87	0.98	4.562	3.57	0.89	0.284	0.156	0.98	249	146
Summer	2.35	1.00	2.19	1.70	1.00	0.162	0.140	1.00	151	159
Fall	2.76	1.00	5.47	3.44	0.96	0.34	0.113	0.87	204	78
Annual	2.00	0.84	16.04	11.57	0.68	1.004	0.517	0.94	867	492

* indicates a R^2 that is low and thus is less accurate at predicting

Table A35. Trend Statistics for the Juniata River at Newport, Pa., October 1984 Through September 2011

Parameter	STORET Code	Time Series/Test	Slope	P-Value	Slope Magnitude (%)			Trend % Change	Trend Direction
					Min	Trend	Max		
FLOW	60	SK	-	0.433	-	-	-	-	NS
TN	600	FAC	-0.007	<0.001	-21	-17	-13	13-21	Down
TON	605	FAC	-0.031	<0.001	-64	-58	-50	50-64	Down
TNH_3	610	FAC	-0.020	<0.001	-51	-42	-30	N/A	BMDL
TKN	625	FAC	-0.028	<0.001	-60	-54	-47	47-60	Down
TNO_{23}	630	FAC	-0.001	0.448	-7	-2	3	N/A	NS
DN	602	FAC	-0.005	<0.001	-17	-13	-8	8-17	Down
DON	607	FAC	-0.027	<0.001	-58	-52	-45	45-58	Down
DNH_3	608	FAC	-0.020	<0.001	-52	-42	-30	N/A	BMDL
DKN	623	FAC	-0.028	<0.001	-60	-54	-46	46-60	Down
DNO_{23}	631	FAC	0.000	0.794	-4	1	6	N/A	NS
TP	665	FAC	-0.024	<0.001	-56	-49	-40	40-56	Down
DP	666	FAC	-0.027	<0.001	-58	-52	-44	44-58	Down
DOP	671	FAC	0.031	<0.001	78	129	195	78-195	Up
TOC	680	FAC	-0.009	<0.001	-28	-21	-14	14-28	Down
SS	80154	FAC	-0.022	<0.001	-56	-45	-30	30-56	Down

Down = downward/improving trend
Up = Upward/degrading trend
BMDL = Greater than 20% of values were Below Method Detection Limit
NS = No significant trend

INDIVIDUAL SITES: CONESTOGA

Table A36. 2011 Annual and Seasonal Precipitation and Discharge at Conestoga

Season	Precipitation (inches)			Discharge (cfs)		
	2011	LTM	LTM Departure	2011	LTM	% LTM
January-March (Winter)	10.45	8.79	1.66	960	897	107%
April-June (Spring)	14.56	10.96	3.6	1,134	736	154%
July-September (Summer)	23.04	12.96	10.08	1,349	491	275%
October-December (Fall)	11.66	10.73	0.93	1,132	649	174%
Annual Total	59.72	43.44	16.28	1,145	692	165%

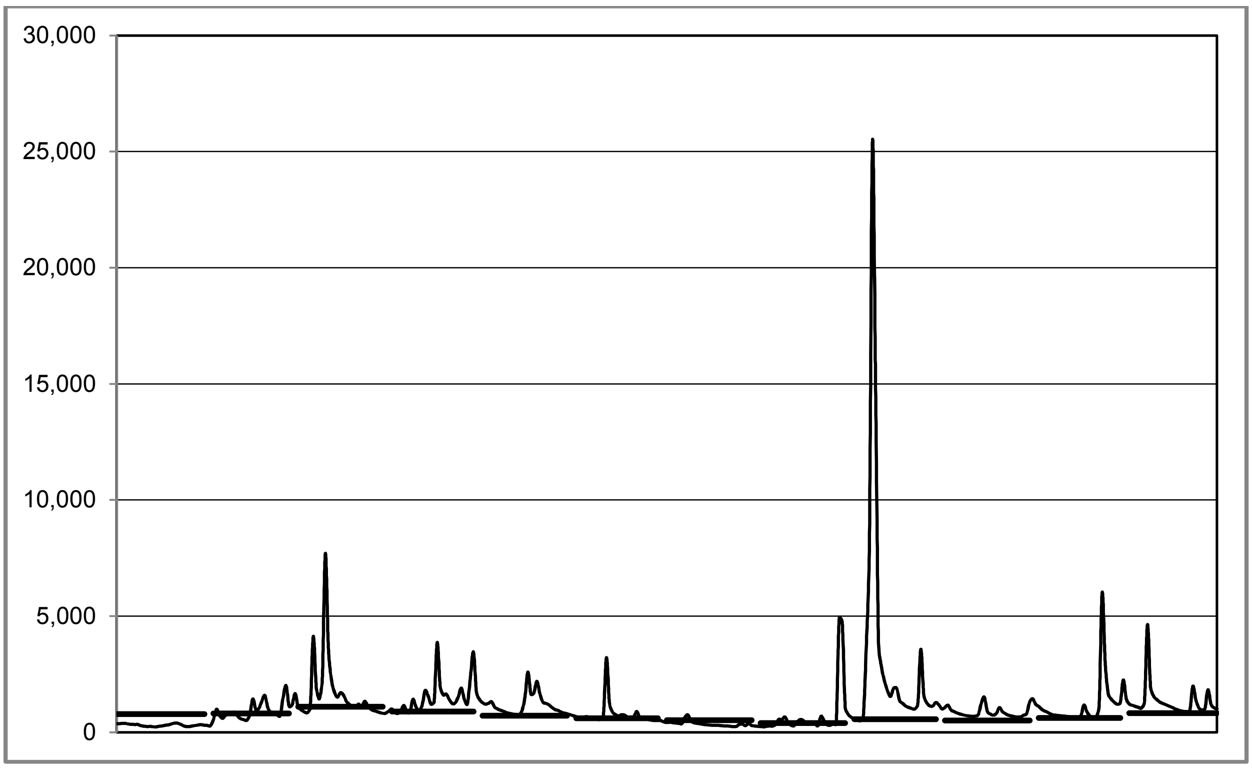

Figure A6. 2011 Daily Average Flow and Monthly LTM at Conestoga

Table A37. 2011 Annual Loads (1000's lbs), Yields (lbs/acre), and Concentrations (mg/L) at Conestoga

Parameter	Load	Load % of LTM	Error %	Yield	LTM Yield	Ave. Conc.	Conc. % of LTM
TN	13,720	132%	3%	46	35	6.09	80%
TON	1,963	107%	13%	6.53	6.13	0.87	64%
TNH_3	293	117%	17%	0.97	0.83	0.13	71%
TNO_{23}	11,392	135%	5%	38	28	5.05	82%
DN	12,584	131%	4%	42	32	5.58	79%
DON	869	77%	11%	2.89	3.75	0.39	47%
DNH_3	263	116%	16%	0.87	0.75	0.12	70%
DNO_{23}	11,438	138%	5%	38	28	5.07	83%
TP	1,887	274%	15%	6.273	2.287	0.837	166%
DP	515	199%	10%	1.712	0.861	0.228	120%
DOP	443	206%	10%	1.473	0.714	0.197	125%
TOC	11,411	152%	7%	38	25	5.06	92%
SS	1,684,696	425%	31%	5,601	1,317	747	257%

Table A38. 2011 Seasonal Loads (1000's lbs) and Yields (lbs/acre) at Conestoga

Parameter	Winter		Spring		Summer		Fall	
	Load	Yield	Load	Yield	Load	Yield	Load	Yield
TN	3,118	10.37	3,451	11.47	3,343	11.11	3,808	12.66
TON	387	1.29	427	1.42	778	2.59	371	1.23
TNH_3	52	0.17	55	0.18	127	0.42	59	0.20
TNO_{23}	2,633	8.75	2,880	9.57	2,560	8.51	3,319	11.04
DN	2,915	9.69	3,222	10.71	2,884	9.59	3,563	11.84
DON	225	0.75	252	0.84	207	0.69	185	0.61
DNH_3	49	0.16	52	0.17	107	0.36	55	0.18
DNO_{23}	2,624	8.72	2,884	9.59	2,580	8.58	3,350	11.14
TP	108	0.359	133	0.442	1,485	4.937	161	0.535
DP	49	0.162	66	0.218	308	1.025	92	0.306
DOP	39	0.130	54	0.181	272	0.906	78	0.258
TOC	1,678	5.58	2,189	7.28	5,448	18.11	2,096	6.97
SS	56,811	189	52,018	173	1,524,970	5,070	50,897	169

Table A39. 2011 Monthly Flow (cfs), Loads (1000's lbs), and Yields (lbs/acre) at Conestoga

Month	Flow		TN			TP			SS		
	2011	% LTM	Load	Yield	% LTM	Load	Yield	% LTM	Load	Yield	% LTM
January	306	39%	386	1.28	36%	6	0.019	11%	499	1.7	2%
February	919	113%	992	3.30	96%	21	0.069	45%	5,563	18.5	30%
March	1,651	151%	1,740	5.78	122%	81	0.268	91%	50,749	168.7	84%
April	1,480	165%	1,492	4.96	132%	58	0.192	106%	26,527	88.2	99%
May	1,172	165%	1,213	4.03	132%	45	0.151	93%	16,112	53.6	55%
June	749	124%	746	2.48	107%	30	0.100	57%	9,379	31.2	28%
July	361	70%	380	1.26	62%	13	0.042	26%	1,463	4.9	5%
August	707	178%	684	2.27	147%	63	0.208	199%	28,684	95.4	261%
September	3,034	541%	2,279	7.58	382%	1,409	4.683	1,313%	1,494,823	4,969	1,613%
October	882	173%	1,005	3.34	164%	37	0.124	77%	6,762	22.5	27%
November	1,197	195%	1,285	4.27	171%	67	0.224	148%	25,857	86.0	152%
December	1,318	160%	1,518	5.05	142%	57	0.189	92%	18,278	60.8	69%
Annual	1,145	165%	13,720	45.61	132%	1,887	0.343	274%	1,684,696	5,601	425%

Table A40. 2011 Annual Comparison to Baselines at Conestoga

Parameter	2011	Period	Y'	Q ratio	R^2
TN	45.61	85-89	65.30	1.83	0.99
		85-97	58.36	1.73	0.98
		98-10	54.40	1.67	0.96
		85-10	56.20	1.70	0.95
TP	6.271	85-89	3.888	1.83	0.67
		85-97	5.377	1.73	0.90
		98-10	3.066	1.67	0.52
		85-10	4.127	1.70	0.61
SS	5,601	85-89	3,180	1.83	0.87
		85-97	3,281	1.73	0.90
		98-10	1,783	1.67	0.27
		85-10	2,478	1.70	0.55

Q = discharge ratio
R^2 = correlation coefficient
* indicates a R^2 that is low and thus is less accurate at predicting

Table A41. 2011 Annual and Seasonal Comparison to Initial 5-Year Baselines at Conestoga

Time Period	Flow Ratio	TN			TP			SS		
		R^2	Y'	Y11	R^2	Y'	Y11	R^2	Y'	Y11
Winter	1.20	1.00	13.31	10.36	0.45*	0.830	0.357	0.25*	262	189
Spring	1.62	1.00	15.69	11.47	0.99	1.209	0.444	0.98	1,027	173
Summer	2.48	1.00	16.22	11.11	0.21*	1.257	4.933	0.16*	1,430	5,070
Fall	2.19	0.98	15.37	12.66	0.85	1.353	0.537	0.95	404	169
Annual	1.83	0.99	65.30	45.61	0.67	3.888	6.271	0.87	3,180	5,601

* indicates a R^2 that is low and thus is less accurate at predicting

Table A42. Trend Statistics for the Conestoga River at Conestoga, Pa., October 1984 Through September 2011

Parameter	STORET Code	Time Series/Test	Slope	P-Value	Slope Magnitude (%)			Trend % Change	Trend Direction
					Min	Trend	Max		
FLOW	60	SK	-	0.315	-	-	-	-	NS
TN	600	FAC	-0.009	<0.001	-26	-22	-19	19-26	Down
TON	605	FAC	-0.034	<0.001	-65	-60	-55	55-65	Down
TNH_3	610	FAC	-0.055	<0.001	-81	-78	-74	74-81	Down
TKN	625	FAC	-0.038	<0.001	-69	-65	-61	61-69	Down
TNO_{23}	630	FAC	0.000	0.930	-6	0	6	N/A	NS
DN	602	FAC	-0.002	0.012	-10	-6	-1	1-10	Down
DON	607	FAC	-0.012	<0.001	-36	-27	-18	18-36	Down
DNH_3	608	FAC	-0.053	<0.001	-81	-77	-73	73-81	Down
DKN	623	FAC	-0.019	<0.001	-47	-40	-33	33-47	Down
DNO_{23}	631	FAC	0.001	0.559	-4	2	8	N/A	NS
TP	665	FAC	-0.033	<0.001	-64	-59	-54	54-64	Down
DP	666	FAC	-0.025	<0.001	-54	-50	-45	45-54	Down
DOP	671	FAC	-0.012	<0.001	-37	-27	-17	17-37	Down
TOC	680	FAC	-0.026	<0.001	-55	-51	-47	47-55	Down
SS	80154	FAC	-0.051	<0.001	-80	-75	-70	70-80	Down

Down = downward/improving trend
Up = Upward/degrading trend
BMDL = Greater than 20% of values were Below Method Detection Limit
NS = No significant trend

APPENDIX B

Summary Statistics

Table B1. Temperature, Dissolved Oxygen, Conductivity, and pH Summary Statistics of Samples Collected During 2011

Station	Temperature (C°)					Dissolved Oxygen (mg/L)					Conductivity (umhos/cm)					pH (S.U.)				
	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD
Chemung	0.10	24.36	10.06	11.93	8.22	6.17	14.97	10.40	10.22	1.96	107	562	195	238	138	7.25	8.90	7.99	8.02	0.41
Cohocton	0.10	20.89	11.98	11.20	7.38	7.74	14.54	10.18	10.36	1.60	175	529	293	316	108	7.55	8.53	8.00	8.02	0.33
Conklin	0.10	24.17	13.31	11.93	7.62	8.24	13.68	10.39	10.25	1.31	77	223	147	145	36	7.19	8.49	7.85	7.83	0.36
Smithboro	0.10	23.38	10.29	12.39	8.13	6.30	13.96	10.46	10.02	1.75	88	254	138	155	56	7.18	8.21	7.72	7.67	0.27
Unadilla	0.10	22.86	12.62	11.23	7.74	8.13	13.68	10.02	10.21	1.32	98	294	148	171	60	7.21	8.26	7.89	7.83	0.27
Castanea	1.12	23.95	9.54	11.48	7.27	9.07	16.59	11.68	11.81	2.02	131	407	254	265	78	6.91	8.64	7.82	7.76	0.42
Conestoga	0.33	25.33	11.83	12.94	7.29	8.26	13.35	10.09	10.29	1.56	224	1,085	510	512	168	7.00	8.53	7.81	7.77	0.34
Danville	0.20	27.59	15.60	13.68	7.78	7.92	13.15	9.92	10.17	1.48	97	334	171	187	58	7.11	8.32	7.81	7.79	0.29
Dromgold	0.34	23.89	10.81	11.35	7.73	7.78	14.95	11.01	11.01	2.22	78	247	160	161	47	7.32	8.37	7.82	7.80	0.25
Hershey	1.29	24.73	14.24	12.46	7.40	6.62	13.39	9.86	10.29	2.27	137	448	237	252	91	7.10	8.05	7.65	7.61	0.28
Hogestown	2.13	23.90	10.64	12.36	7.29	7.56	14.70	10.56	10.74	1.99	179	529	391	366	106	7.09	8.45	7.87	7.83	0.33
Jersey Shore	0.42	27.62	8.65	12.02	8.54	7.79	14.91	11.18	11.13	2.16	118	480	218	229	100	6.56	8.24	7.59	7.49	0.43
Karthaus	1.21	28.36	9.46	12.16	8.62	8.04	13.79	11.23	10.95	1.98	176	667	298	329	146	5.81	7.39	6.99	6.84	0.42
Lewisburg	0.05	27.45	14.20	12.08	7.90	7.13	14.54	10.25	10.57	2.03	86	340	174	182	66	6.73	8.39	7.64	7.54	0.38
Manchester	0.03	24.40	11.07	12.89	8.11	5.99	13.92	10.25	10.22	2.50	111	469	230	239	86	6.81	8.10	7.66	7.58	0.32
Marietta	0.08	29.63	14.46	13.58	7.83	7.90	14.66	10.30	10.70	1.86	112	364	183	202	77	7.28	8.66	7.85	7.92	0.36
Martic Forge	1.36	23.47	11.93	12.89	7.23	8.51	13.39	10.45	10.59	1.57	238	681	454	421	117	7.11	8.25	7.95	7.82	0.35
Newport	0.38	27.54	15.05	13.86	7.45	6.02	15.15	10.14	10.41	1.98	128	378	201	219	67	7.04	8.81	7.82	7.87	0.39
Penns Creek	-0.05	24.55	8.45	10.43	7.60	5.13	14.63	10.94	10.73	2.62	166	244	186	197	26	7.17	8.77	7.90	7.92	0.33
Saxton	3.20	28.70	14.10	15.20	7.94	4.53	14.71	8.93	8.81	3.06	141	384	198	230	80	6.71	8.31	7.22	7.39	0.52
Towanda	0.10	26.38	14.80	12.17	7.68	8.21	13.58	9.84	10.11	1.41	86	325	160	176	58	7.32	8.78	7.85	7.85	0.31
Wilkes-Barre	0.10	26.50	7.85	11.97	8.38	7.94	13.14	10.21	10.12	1.52	127	358	176	196	69	7.29	7.92	7.72	7.71	0.15
Richardsmere	1.15	27.75	12.55	13.89	8.40	8.11	13.44	10.91	10.86	1.68	171	312	234	235	39	7.05	8.85	7.65	7.79	0.57

Table B2. Total Nitrogen Species Summary Statistics of Samples Collected During 2011, in mg/L

Station	Total Nitrogen					Total Ammonium					Total Nitrate plus Nitrite					Total Organic Nitrogen				
	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD
Chemung	0.64	1.57	0.98	0.99	0.25	0.01	0.70	0.03	0.09	0.17	0.36	1.19	0.53	0.56	0.19	0.06	1.05	0.34	0.39	0.25
Cohocton	0.50	2.19	1.32	1.30	0.49	0.02	0.11	0.06	0.06	0.03	0.11	1.62	0.76	0.83	0.39	0.06	1.21	0.37	0.42	0.32
Conklin	0.44	1.24	0.65	0.69	0.20	0.01	0.07	0.03	0.03	0.02	0.17	0.57	0.35	0.36	0.11	0.08	0.94	0.20	0.29	0.24
Smithboro	0.39	1.77	0.86	0.88	0.28	0.01	0.22	0.04	0.05	0.05	0.22	0.68	0.43	0.45	0.14	0.07	1.51	0.36	0.43	0.35
Unadilla	0.48	3.39	1.00	1.13	0.66	0.01	0.08	0.04	0.04	0.02	0.25	3.21	0.53	0.78	0.70	0.07	0.92	0.22	0.31	0.25
Castanea	0.90	2.14	1.44	1.43	0.33	0.02	0.11	0.03	0.04	0.03	0.74	1.91	1.18	1.21	0.34	0.08	0.47	0.15	0.19	0.12
Conestoga	3.72	8.80	6.82	6.74	1.32	0.02	0.79	0.07	0.10	0.13	0.17	8.28	6.17	5.78	1.97	0.04	6.22	0.50	0.86	1.09
Danville	0.59	2.28	0.87	1.00	0.39	0.02	1.10	0.05	0.10	0.19	0.24	1.14	0.50	0.55	0.21	0.09	1.69	0.27	0.36	0.30
Dromgold	1.10	2.92	1.76	1.83	0.41	0.02	0.47	0.05	0.08	0.11	0.76	1.80	1.50	1.43	0.28	0.02	0.87	0.28	0.31	0.25
Hershey	1.91	5.33	3.83	3.71	0.79	0.02	0.33	0.06	0.10	0.08	1.60	4.70	3.26	3.13	0.88	0.09	3.67	0.42	0.64	0.78
Hogestown	2.61	4.95	3.88	3.86	0.70	0.02	0.28	0.05	0.06	0.06	1.94	4.65	3.59	3.44	0.75	0.00	0.81	0.31	0.39	0.24
Jersey Shore	0.40	1.20	0.72	0.76	0.23	0.02	0.07	0.04	0.04	0.01	0.04	0.95	0.52	0.55	0.21	0.01	0.81	0.10	0.17	0.19
Karthaus	0.32	1.00	0.55	0.63	0.21	0.02	0.10	0.05	0.05	0.02	0.04	0.62	0.43	0.40	0.15	0.02	0.73	0.13	0.19	0.19
Lewisburg	0.42	1.72	0.86	0.86	0.29	0.02	0.09	0.05	0.05	0.02	0.07	1.16	0.59	0.62	0.24	0.02	1.00	0.15	0.20	0.18
Manchester	1.27	4.12	2.60	2.61	0.69	0.02	0.53	0.08	0.11	0.12	0.54	3.08	1.77	1.78	0.67	0.19	1.84	0.56	0.71	0.50
Marietta	0.92	1.83	1.29	1.35	0.26	0.02	0.10	0.04	0.05	0.02	0.06	1.42	0.90	0.88	0.27	0.08	1.66	0.30	0.42	0.35
Martic Forge	4.60	9.24	7.44	7.51	1.21	0.02	1.67	0.08	0.22	0.38	3.01	8.54	6.88	6.31	1.92	0.01	3.35	0.77	0.99	0.90
Newport	1.24	5.53	1.50	1.66	0.68	0.02	0.10	0.04	0.04	0.02	0.11	1.55	1.23	1.20	0.26	0.01	4.25	0.26	0.42	0.70
Penns Creek	1.11	2.14	1.55	1.53	0.23	0.02	0.14	0.04	0.05	0.03	0.09	1.58	1.33	1.24	0.33	0.07	1.91	0.14	0.26	0.42
Saxton	1.29	3.07	1.94	2.07	0.55	0.02	0.28	0.05	0.06	0.05	0.90	2.75	1.52	1.62	0.52	0.02	2.63	0.36	0.47	0.57
Towanda	0.54	3.47	0.84	0.94	0.48	0.02	0.17	0.04	0.05	0.03	0.07	0.92	0.50	0.49	0.19	0.05	3.15	0.32	0.42	0.52
Wilkes-Barre	0.54	2.26	0.83	0.94	0.40	0.02	0.08	0.05	0.05	0.02	0.13	0.68	0.46	0.45	0.17	0.07	2.01	0.31	0.44	0.47
Richardsmere	3.80	8.34	6.67	6.42	1.40	0.02	0.59	0.15	0.18	0.17	2.92	7.76	5.76	5.62	1.55	0.03	1.23	0.59	0.61	0.30

Table B3. Dissolved Nitrogen Species Summary Statistics of Samples Collected During 2011, in mg/L

Station	Dissolved Nitrogen					Dissolved Ammonium					Dissolved Nitrate plus Nitrite					Dissolved Organic Nitrogen				
	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD
Chemung	0.46	1.47	0.86	0.89	0.29	0.01	0.07	0.02	0.03	0.03	0.41	1.21	0.62	0.61	0.22	0.15	0.60	0.24	0.28	0.13
Cohocton	0.24	1.94	1.11	1.13	0.45	0.01	0.11	0.05	0.05	0.03	0.11	1.62	0.82	0.85	0.43	0.06	0.46	0.23	0.26	0.13
Conklin	0.19	0.72	0.59	0.54	0.15	0.01	0.06	0.02	0.03	0.02	0.10	0.55	0.35	0.35	0.13	0.08	0.41	0.14	0.17	0.11
Smithboro	0.45	1.18	0.71	0.78	0.20	0.01	0.08	0.03	0.03	0.02	0.22	0.67	0.44	0.46	0.16	0.08	0.76	0.22	0.29	0.20
Unadilla	0.25	1.34	0.81	0.81	0.25	0.01	0.07	0.04	0.03	0.02	0.25	0.93	0.52	0.56	0.20	0.06	0.40	0.20	0.22	0.11
Castanea	0.86	2.09	1.30	1.38	0.34	0.02	0.11	0.03	0.04	0.03	0.75	1.92	1.19	1.21	0.34	0.01	0.32	0.08	0.13	0.09
Conestoga	2.98	8.52	6.71	6.41	1.59	0.02	0.81	0.07	0.10	0.13	0.14	8.13	6.22	5.77	1.96	0.01	6.04	0.39	0.56	0.98
Danville	0.46	2.30	0.81	0.90	0.38	0.02	1.12	0.05	0.09	0.20	0.26	1.11	0.50	0.55	0.20	0.03	1.11	0.25	0.26	0.20
Dromgold	1.07	2.88	1.68	1.71	0.38	0.02	0.46	0.04	0.08	0.11	0.77	1.82	1.50	1.44	0.29	0.03	0.60	0.14	0.20	0.15
Hershey	1.78	5.31	3.61	3.51	0.88	0.02	0.34	0.06	0.09	0.08	1.62	4.67	3.26	3.14	0.84	0.06	0.61	0.26	0.30	0.16
Hogestown	2.19	4.97	3.80	3.72	0.79	0.02	0.27	0.05	0.06	0.06	1.93	4.63	3.54	3.42	0.75	0.04	0.47	0.23	0.24	0.11
Jersey Shore	0.38	1.08	0.64	0.71	0.22	0.02	0.06	0.03	0.04	0.02	0.04	0.95	0.51	0.55	0.21	0.01	0.49	0.09	0.13	0.12
Karthaus	0.29	0.91	0.55	0.58	0.18	0.01	0.09	0.03	0.04	0.02	0.04	0.61	0.43	0.40	0.15	0.02	0.57	0.10	0.15	0.14
Lewisburg	0.30	1.47	0.77	0.81	0.28	0.02	0.09	0.04	0.04	0.02	0.05	1.13	0.59	0.62	0.24	0.01	0.85	0.12	0.16	0.16
Manchester	0.97	3.44	2.30	2.25	0.66	0.02	0.52	0.07	0.11	0.11	0.54	3.08	1.77	1.76	0.63	0.08	0.72	0.38	0.38	0.19
Marietta	0.72	1.69	1.10	1.13	0.23	0.02	0.10	0.04	0.04	0.02	0.06	1.43	0.89	0.88	0.27	0.01	1.42	0.14	0.21	0.30
Martic Forge	4.01	9.08	7.44	7.02	1.69	0.02	1.66	0.08	0.21	0.38	2.98	8.47	7.03	6.28	1.93	0.08	1.22	0.54	0.56	0.34
Newport	1.07	6.00	1.38	1.54	0.79	0.02	0.11	0.04	0.04	0.02	0.10	1.55	1.23	1.20	0.25	0.04	4.73	0.14	0.33	0.81
Penns Creek	1.06	2.16	1.48	1.50	0.24	0.02	0.15	0.03	0.04	0.03	0.06	1.57	1.34	1.24	0.33	0.03	1.95	0.13	0.23	0.43
Saxton	1.31	3.16	1.89	2.04	0.60	0.02	0.28	0.04	0.05	0.06	0.94	2.80	1.52	1.67	0.54	0.08	0.80	0.34	0.34	0.17
Towanda	0.34	2.78	0.75	0.83	0.38	0.02	0.17	0.04	0.05	0.03	0.08	0.92	0.50	0.49	0.18	0.02	2.47	0.24	0.30	0.40
Wilkes-Barre	0.40	1.98	0.74	0.79	0.35	0.02	0.08	0.04	0.04	0.02	0.14	0.67	0.46	0.45	0.16	0.01	1.74	0.21	0.29	0.38
Richardsmere	3.68	8.32	6.37	6.23	1.50	0.02	0.58	0.14	0.18	0.17	2.91	7.78	5.84	5.64	1.57	0.16	0.92	0.42	0.45	0.20

Table B4. Phosphorus Species and Total Suspended Solids Summary Statistics of Samples Collected During 2011, in mg/L

Station	Total Phosphorus					Dissolved Phosphorus					Orthophosphorus					Total Suspended Solids				
	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD
Chemung	0.018	0.439	0.083	0.104	0.099	0.012	0.067	0.024	0.027	0.015	0.005	0.056	0.015	0.019	0.013	1.0	443	26.2	75.9	113.5
Cohocton	0.013	0.325	0.028	0.055	0.078	0.008	0.039	0.016	0.018	0.009	0.005	0.022	0.010	0.011	0.005	1.2	308	8.4	31.8	77.6
Conklin	0.009	0.304	0.045	0.077	0.090	0.006	0.177	0.012	0.028	0.041	0.005	0.153	0.007	0.019	0.036	2.7	283	21.5	50.1	72.3
Smithboro	0.015	0.408	0.061	0.101	0.106	0.006	0.036	0.019	0.021	0.010	0.005	0.024	0.014	0.013	0.006	2.7	467	30.8	78.0	118.8
Unadilla	0.008	0.255	0.038	0.062	0.072	0.005	0.047	0.012	0.016	0.012	0.005	0.032	0.007	0.010	0.008	3.3	249	29.2	49.8	72.3
Castanea	0.010	0.045	0.020	0.025	0.012	0.010	0.016	0.010	0.011	0.001	0.010	0.010	0.010	0.010	0.000	5.0	18	8.0	8.5	3.7
Conestoga	0.043	1.258	0.184	0.289	0.283	0.033	0.387	0.130	0.148	0.079	0.027	0.341	0.115	0.129	0.071	5.0	670	18.0	82.8	158.1
Danville	0.015	0.491	0.061	0.104	0.125	0.010	0.371	0.019	0.034	0.065	0.010	0.297	0.011	0.026	0.052	5.0	594	26.0	59.6	112.8
Dromgold	0.011	0.275	0.040	0.071	0.080	0.010	0.165	0.026	0.041	0.041	0.010	0.146	0.020	0.032	0.035	5.0	114	10.0	20.1	30.6
Hershey	0.019	0.330	0.090	0.114	0.104	0.014	0.109	0.038	0.047	0.031	0.010	0.091	0.033	0.038	0.025	5.0	232	18.0	50.3	68.1
Hogestown	0.014	0.190	0.041	0.064	0.058	0.010	0.059	0.018	0.024	0.014	0.010	0.041	0.014	0.019	0.010	5.0	158	14.0	36.8	45.8
Jersey Shore	0.010	0.102	0.013	0.023	0.024	0.010	0.010	0.010	0.010	0.000	0.010	0.010	0.010	0.010	0.000	5.0	118	8.0	16.7	26.6
Karthaus	0.010	0.067	0.010	0.022	0.020	0.010	0.010	0.010	0.010	0.000	0.010	0.010	0.010	0.010	0.000	5.0	80	10.0	16.9	18.7
Lewisburg	0.010	0.152	0.020	0.034	0.033	0.010	0.167	0.010	0.017	0.027	0.010	0.183	0.010	0.016	0.029	5.0	84	8.0	18.7	22.6
Manchester	0.042	0.603	0.144	0.230	0.173	0.030	0.277	0.100	0.118	0.070	0.027	0.246	0.081	0.099	0.063	5.0	340	18.0	68.3	100.2
Marietta	0.011	0.553	0.059	0.102	0.106	0.010	0.040	0.018	0.018	0.007	0.010	0.030	0.012	0.014	0.005	5.0	304	28.0	68.3	90.8
Martic Forge	0.049	2.048	0.179	0.503	0.631	0.037	0.757	0.125	0.230	0.217	0.035	0.688	0.115	0.208	0.202	5.0	976	25.0	156.1	291.5
Newport	0.014	0.212	0.037	0.055	0.046	0.010	0.071	0.017	0.019	0.011	0.010	0.057	0.013	0.015	0.008	5.0	196	10.0	22.7	37.1
Penns Creek	0.010	0.185	0.021	0.037	0.040	0.010	0.087	0.012	0.022	0.020	0.010	0.071	0.010	0.019	0.018	5.0	70	5.0	10.3	14.9
Saxton	0.010	0.193	0.036	0.059	0.056	0.010	0.061	0.016	0.021	0.016	0.010	0.057	0.010	0.017	0.013	5.0	168	12.0	28.0	39.3
Towanda	0.014	0.522	0.045	0.083	0.098	0.010	0.081	0.018	0.020	0.012	0.010	0.077	0.013	0.015	0.011	5.0	632	26.0	67.6	121.4
Wilkes-Barre	0.011	0.817	0.057	0.108	0.185	0.010	0.030	0.012	0.015	0.006	0.010	0.023	0.011	0.012	0.004	5.0	1,150	26.0	97.1	265.4
Richardsmere	0.046	0.440	0.207	0.203	0.127	0.014	0.261	0.142	0.120	0.082	0.010	0.226	0.114	0.101	0.073	5.0	128	19.0	31.9	36.1

Table B5. Flow, Total Organic Carbon, Total Kjeldahl, and Dissolved Kjeldahl Summary Statistics of Samples Collected During 2011, in mg/L

Station	Flow (cfs)					Total Organic Carbon					Total Kjeldahl Nitrogen					Dissolved Kjeldahl Nitrogen				
	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD
Chemung	349	43,886	4,030	8,490	11,278	2.70	5.50	3.80	3.88	0.85	0.10	1.09	0.37	0.43	0.25	0.16	0.61	0.26	0.31	0.14
Cohocton	102	8,227	539	1,358	2,112	2.40	5.60	4.00	4.12	1.11	0.13	1.30	0.39	0.48	0.32	0.10	0.52	0.32	0.31	0.14
Conklin	759	33,268	9,450	11,842	10,141	2.10	6.50	2.70	3.28	1.37	0.10	0.98	0.23	0.33	0.25	0.10	0.42	0.15	0.20	0.11
Smithboro	3,770	94,820	19,058	28,044	25,850	2.00	6.20	3.20	3.49	1.34	0.01	1.55	0.38	0.43	0.35	0.10	0.80	0.26	0.32	0.21
Unadilla	101	8,860	1,872	2,628	2,521	2.00	7.80	2.80	3.35	1.59	0.10	0.93	0.23	0.34	0.25	0.10	0.46	0.21	0.26	0.11
Castanea	391	6,837	3,426	2,545	1,827	1.34	3.64	1.95	2.04	0.66	0.03	0.53	0.16	0.22	0.15	0.04	0.41	0.11	0.17	0.11
Conestoga	268	9,433	1,450	2,077	2,144	1.54	13.20	3.41	3.87	2.17	0.06	6.33	0.57	0.96	1.12	0.05	6.14	0.48	0.66	1.01
Danville	4,050	262,000	33,500	52,474	55,687	1.92	9.22	3.19	3.43	1.39	0.16	1.76	0.36	0.45	0.36	0.06	1.47	0.29	0.35	0.29
Dromgold	80	8,320	593	1,524	2,314	1.05	8.05	2.69	3.29	1.98	0.04	1.15	0.33	0.40	0.33	0.03	1.06	0.18	0.27	0.25
Hershey	233	9,120	2,001	2,987	2,921	1.34	8.46	3.14	3.48	2.04	0.15	3.94	0.49	0.74	0.83	0.11	0.85	0.34	0.40	0.19
Hogestown	228	6,490	1,009	1,907	1,849	1.44	7.43	2.70	2.95	1.41	0.01	0.89	0.34	0.42	0.26	0.09	0.64	0.27	0.30	0.13
Jersey Shore	3,960	60,520	15,100	20,887	16,053	0.86	4.14	1.63	1.83	0.91	0.03	0.83	0.14	0.21	0.18	0.06	0.51	0.13	0.17	0.11
Karthaus	343	18,558	2,970	4,968	4,642	0.93	5.35	1.54	2.16	1.40	0.04	0.79	0.18	0.23	0.19	0.01	0.59	0.13	0.18	0.14
Lewisburg	1,570	97,370	20,500	25,414	22,418	0.98	4.03	2.00	2.15	0.84	0.05	1.03	0.18	0.24	0.18	0.02	0.87	0.16	0.19	0.16
Manchester	91	18,600	1,983	3,937	4,855	2.33	12.80	5.27	5.66	2.55	0.22	1.92	0.62	0.82	0.56	0.11	1.20	0.43	0.49	0.27
Marietta	8,610	449,000	90,000	128,089	118,024	1.55	8.86	2.91	3.15	1.35	0.14	1.72	0.35	0.47	0.35	0.04	1.47	0.19	0.25	0.30
Martic Forge	105	1,560	318	457	439	1.15	18.40	3.21	4.68	4.23	0.06	3.67	0.82	1.21	1.10	0.06	2.80	0.60	0.74	0.64
Newport	1,090	63,074	11,028	16,200	14,087	1.79	6.94	2.77	2.94	0.88	0.05	4.29	0.31	0.46	0.70	0.01	4.73	0.18	0.35	0.79
Penns Creek	150	2,271	1,197	1,029	673	1.24	4.24	1.94	2.39	0.97	0.02	2.05	0.15	0.29	0.44	0.06	2.10	0.18	0.27	0.46
Saxton	143	15,300	2,025	3,448	3,858	1.51	8.42	2.96	3.46	1.92	0.05	2.65	0.38	0.53	0.58	0.03	0.88	0.35	0.37	0.21
Towanda	1,770	117,034	18,700	31,218	32,728	1.74	6.72	3.04	3.27	1.24	0.02	3.17	0.36	0.45	0.51	0.06	2.49	0.29	0.35	0.39
Wilkes-Barre	3,100	159,293	32,050	38,996	39,919	1.96	7.57	2.99	3.37	1.39	0.15	2.08	0.35	0.49	0.47	0.04	1.78	0.26	0.34	0.38
Richardsmere	68	6,640	353	994	1,768	2.06	6.40	3.79	3.91	1.29	0.05	1.58	0.75	0.80	0.41	0.28	1.50	0.57	0.64	0.31