NUTRIENTS AND SUSPENDED SEDIMENT TRANSPORTED IN THE SUSQUEHANNA RIVER BASIN, 2005, AND TRENDS, JANUARY 1985 THROUGH DECEMBER 2005

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Nutrients and Suspended Sediment Transported in the Susquehanna River Basin, 2005, and Trends, January 1985 Through December 2005

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ABSTRACT

Nutrient and suspended-sediment (SS) samples were collected under base flow, fixed date, and stormflow conditions during calendar year 2005 for Group A sites listed in Table 2. Fixed date and storm samples also were collected at sites listed in Group B. All samples were analyzed for nitrogen and phosphorus species, total organic carbon (TOC), and SS.

Precipitation for 2005 was above average at all Group A sites except Lewisburg and Newport. The highest departure from the long-term precipitation average was recorded at Towanda with 16.49 inches above the long-term mean (LTM). Highest departure from LTM for discharge was 115 percent above LTM at both Danville and Conestoga. Precipitation and flows were above LTM largely due to heavy rainfalls in January and April. Lowest departure from the mean was at Newport with 3.43 inches below LTM for rainfall and flows at 91 percent of the LTM. Low rainfall during the spring and summer months in the western part of the basin led to below LTM rainfall and flows at Lewisburg and Newport.

This report utilizes four methods to analyze nutrient and SS loads and yields: (1) comparison with the LTM; (2) comparison with dataset baseline yields; (3) comparison to similar flow years; and (4) flow-adjusted trend analysis through 2005. Comparison with the LTM showed increases in total phosphorus (TP) and SS for Towanda and Danville. All sites showed decreases in total nitrogen (TN) and total organic nitrogen, except for TN at Newport. Baseline comparisons showed decreases in TN at Towanda and Danville when the second half of the dataset was compared to the first half. Additionally, improvements were found at Conestoga for TP and SS for 2005 when compared to all baselines. Trends in flow-adjusted concentrations (FACs) were found to be decreasing for TN, TP, and SS at all sites except for TP at Marietta, which showed no significant trends and SS at Lewisburg, which had greater than 20 percent of the values below the method detection limit. No significant trends were found for flow.

INTRODUCTION

Nutrients and SS entering the Chesapeake Bay (Bay) from the Susquehanna River Basin contribute to nutrient enrichment problems in the Bay (USEPA, 1982). The Pennsylvania Department of Environmental Protection (PADEP) Bureau of Laboratories, the U.S. Environmental Protection Agency (USEPA), the U.S. Geological Survey (USGS), and the Susquehanna River Basin Commission (SRBC) conducted a 5-year intensive study at 12 sites from 1985-89 to quantify nutrient and SS transported to the Bay via the Susquehanna River Basin. In 1990, the number of sampling sites was reduced to five long-term monitoring stations. An additional site was added in 1994.

In October 2004, 13 additional sites (two in New York and eleven in Pennsylvania) were added as part of the Chesapeake Bay Program's Non-tidal Water Quality Monitoring Network. In October 2005, four more sites (three in New York and one in Maryland) were added to the existing network. This project involves an effort conducted by all six Bay state jurisdictions, the USEPA, USGS, and SRBC to create a uniform non-tidal monitoring network for the entire Bay watershed.

Purpose of Report

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 2005. Comparisons are made to: LTM; baseline data calculated from the 1985-89 study; baseline data calculated from the first half of the dataset; baseline data calculated from the second half of the dataset; and data from similar flow years. Seasonal and annual variations in loads are discussed, as well as the results of flow-adjusted trend analyses for the period January 1985 through December 2005 for various forms of nitrogen and phosphorus, SS, TOC, and discharge.

DESCRIPTION OF THE SUSQUEHANNA RIVER BASIN

The Susquehanna River (Figure 1) drains an area of 27,510 square miles (Susquehanna River Basin Study Coordination Committee, 1970) and is the largest tributary to the 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 40.4 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. The Susquehanna River Basin, Subbasins, and Population Centers

Table 1. 2000 Land Use Percentages for the Susquehanna River Basin and Selected Tributaries

Site Location	Waterbody	Water/ Wetland	Urban	Agricultural			Forest	Other
				Row Crops	Pasture/Hay	Total		
Towanda	Susquehanna	2	5	17	5	22	71	0
Danville	Susquehanna	2	6	16	5	21	70	1
Lewisburg	West Branch Susquehanna	1	5	8	2	10	84	0
Newport	Juniata	1	6	14	4	18	74	1
Marietta	Susquehanna	2	7	14	5	19	72	1
Conestoga	Conestoga	1	24	12	36	48	26	1
Wilkes-Barre	Susquehanna	2	6	16	5	21	71	0
Karthaus	West Branch Susquehanna	1	6	11	1	12	80	1
Castanea	Bald Eagle	1	8	11	3	14	76	1
Jersey Shore	West Branch Susquehanna	1	4	6	1	7	87	1
Penns Creek	Penns	1	3	16	4	20	75	1
Saxton	Raystown Branch Juniata	< 0.5	6	18	5	23	71	0
Dromgold	Shermans	1	4	15	6	21	74	0
Hogestown	Conodoguinet	1	11	38	6	44	43	1
Hershey	Swatara	2	14	18	10	28	56	0
Manchester	West Conewago	2	13	12	36	48	36	1
Martic Forge	Pequea	1	12	12	48	60	25	2
Richardsmere	Octoraro	1	10	16	47	63	24	2
Campbell	Cohocton	3	4	13	6	19	74	0
Rockdale	Unadilla	3	2	22	6	28	66	0
Conklin	Susquehanna	3	3	18	4	22	71	1
Smithboro	Susquehanna	3	5	17	5	22	70	0
Chemung	Chemung	2	5	15	5	20	73	0
Entire Basin	Susquehanna River Basin	2	7	14	7	21	69	1

Major urban areas in the Lower Susquehanna Subbasin include York, Lancaster, Harrisburg, and Sunbury, Pa. Most of the urban areas in the northern part of the basin are located along river valleys, including Binghamton, Elmira, and Corning, N.Y. Urban areas in the Middle Susquehanna subbasin include Scranton and Wilkes-Barre, Pa. The major urban areas in the West Branch Susquehanna Subbasin are Williamsport, Renovo, and Clearfield, Pa. Lewistown and Altoona are the major urban areas within the Juniata Subbasin.

NUTRIENT MONITORING SITES

Data were collected from six sites on the Susquehanna River, three sites on the West Branch Susquehanna River, and fourteen sites on smaller tributaries in the basin. These 23 sites, selected for long-term monitoring of nutrient and SS transport in the basin, are listed in Table 2, and their general locations are shown in Figure 2.

Table 2. Data Collection Sites and Their Drainage Areas

USGS ID Number	Original Sites (Group A)	Subbasin	Short Name	Drainage Area (Sq Mi)
01531500	Susquehanna River at Towanda, Pa.	Middle Susquehanna	Towanda	7,797
01540500	Susquehanna River at Danville, Pa.	Middle Susquehanna	Danville	11,220
01553500	West Branch Susquehanna River at Lewisburg, Pa.	W Branch Susquehanna	Lewisburg	6,847
01567000	Juniata River at Newport, Pa.	Juniata	Newport	3,354
01576000	Susquehanna River at Marietta, Pa.	Lower Susquehanna	Marietta	25,990
01576754	Conestoga River at Conestoga, Pa.	Lower Susquehanna	Conestoga	470
	Enhanced Sites (Group B)			
01502500	Unadilla River at Rockdale, NY	Upper Susquehanna	Rockdale	520
01503000	Susquehanna River at Conklin, NY	Upper Susquehanna	Conklin	2,232
01515000	Susquehanna River at Smithboro, NY	Upper Susquehanna	Smithboro	4,631
01529500	Cohocton River at Campbell, NY	Chemung	Campbell	470
01531000	Chemung River at Chemung, NY	Chemung	Chemung	2,506
01536500	Susquehanna River near Wilkes-Barre, Pa.	Middle Susquehanna	Wilkes-Barre	9,960
01542500	West Branch Susquehanna River near Karthaus, Pa.	W Branch Susquehanna	Karthaus	1,462
01548085	Bald Eagle Creek near Castanea, Pa.	W Branch Susquehanna	Castanea	420
01549760	West Branch Susquehanna River at Jersey Shore, Pa.	W Branch Susquehanna	Jersey Shore	5,225
01555000	Penns Creek at Penns Creek, Pa.	Lower Susquehanna	Penns Creek	301
01562000	Raystown Branch Juniata River at Saxton, Pa.	Juniata	Saxton	756
01568000	Shermans Creek near Dromgold, Pa.	Lower Susquehanna	Dromgold	200
01570000	Conodoguinet Creek near Hogestown, Pa.	Lower Susquehanna	Hogestown	470
01573560	Swatara Creek near Hershey, Pa.	Lower Susquehanna	Hershey	483
01574000	West Conewago Creek near Manchester, Pa.	Lower Susquehanna	Manchester	510
01576787	Pequea Creek near Martic Forge, Pa.	Lower Susquehanna	Martic Forge	155
01578475	Octoraro Creek at Richardsmere, Md.	Lower Susquehanna	Richardsmere	177

SAMPLE COLLECTION AND ANALYSIS

Samples were collected to measure nutrient and SS concentrations during various flows in 2005. For Group A sites, two samples were collected per month: one near the twelfth of the month and one during monthly base flow conditions. Additionally, at least four high flow events were sampled, targeting one per season. When possible, a second high flow event was sampled after spring planting in the basin. During high flow sampling events, samples were collected daily during the rise and fall of the hydrograph. The goal was to gather a minimum of three samples on the rise and three samples on the fall, with one sample as close to peak flow as possible. Sampling continued until flows returned to near pre-storm levels. All samples were collected by hand with USGS depth integrating samplers. At each site between 3 and 10 depth integrated verticals were collected across the water column and then composited to obtain a representative sample of the entire waterbody. For Group B sites, fixed date monthly samples also were collected near the twelfth of each month during 2005, except for Rockdale, Campbell, Conklin, and Richardsmere, where samples were collected only during the last three months of 2005. Additionally, fours storms were sampled (one storm/season and two samples/storm) at all enhanced sites except for those beginning in October, which had two storm samples collected during that season. Samples were collected using the same protocols as at Group A sites.

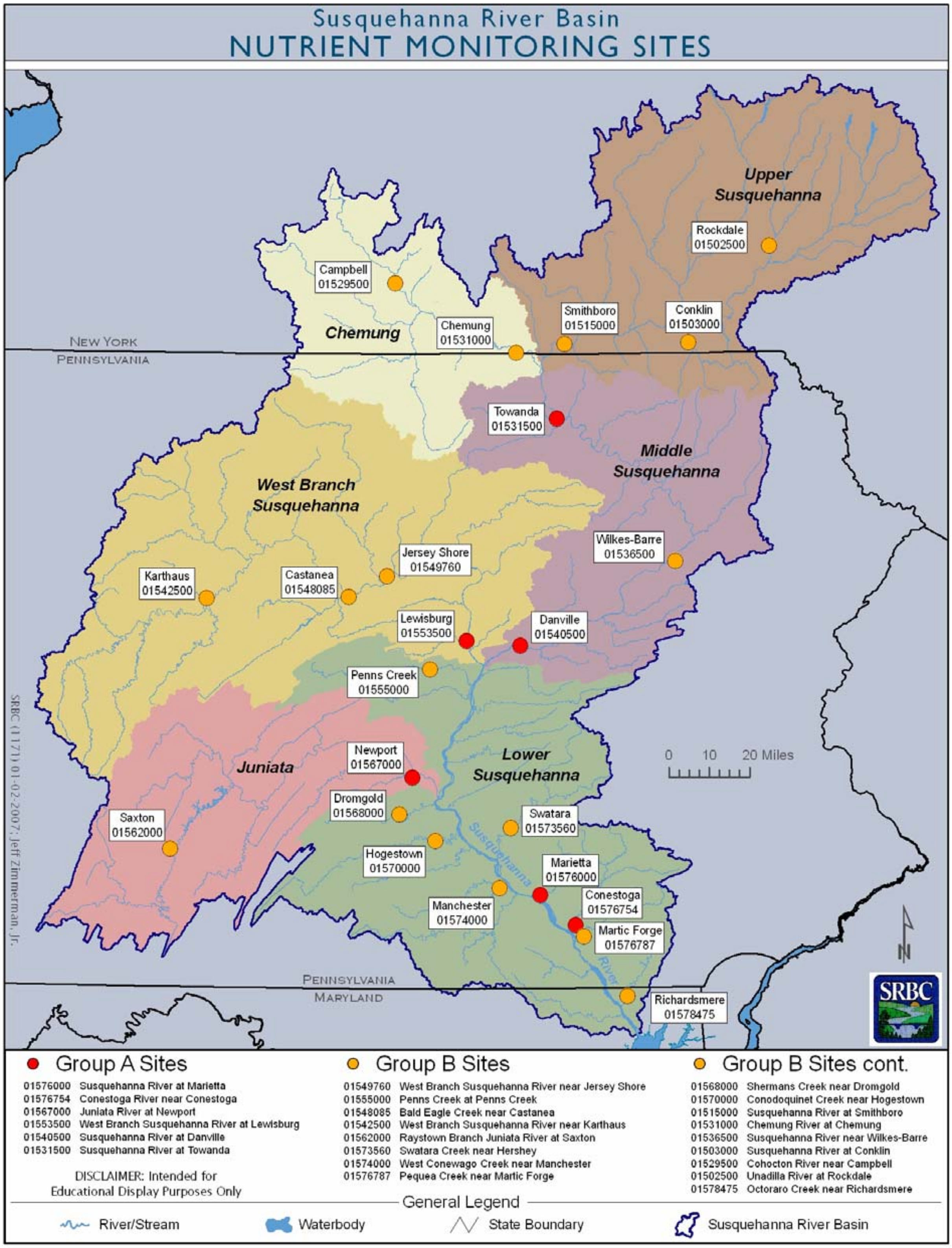

Figure 2. Locations of Sampling Sites Within the Susquehanna River Basin

Whole water samples were collected to be analyzed for TN species, TP species, TOC, TSS, and SS. For Group B sites, SS samples were collected only during storm events, and half of the samples were further analyzed for sand and fine fractions. Additionally, filtered samples were collected to be analyzed for dissolved nitrogen (DN) and dissolved phosphorus (DP) species. All Pennsylvania samples were delivered to the PADEP Laboratory in Harrisburg, Pa., to be analyzed the following workday. New York samples were sent to Columbia Analytical Services in Rochester, N.Y., for analysis the following workday. SS concentrations for Group A sites were analyzed by SRBC, and SS concentrations for Group B sites were analyzed by the USGS sediment laboratory in Kentucky. The parameters and laboratory methods used are listed in Table 3.

Table 3. Water Quality Parameters, Laboratory Methods, and Detection Limits

Parameter	Laboratory	Methodology	Detection Limit (mg/l)	References
Total Ammonia (TNH4)	PADEP	Colorimetry	0.020	USEPA 350.1
	CAS*		0.050	USEPA 350.1
Dissolved Ammonia (DNH4)	PADEP	Block Digest, Colorimetry	0.020	USEPA 350.1
	CAS*		0.050	USEPA 350.1
Total Nitrogen (TN)	PADEP	Persulfate Digestion for TN	0.040	Standard Methods #4500-N_{org}-D
Dissolved Nitrogen (DN)	PADEP	Persulfate Digestion	0.040	Standard Methods #4500-N_{org}-D
Total Kjeldahl Nitrogen (TKN)	CAS*	Block Digest, Flow Injection	0.050	USEPA 351.2
Dissolved Kjeldahl Nitrogen (DKN)	CAS*	Block Digest, Flow Injection	0.050	USEPA 351.2
Total Nitrite plus Nitrate (TNOx)	PADEP	Cd-reduction, Colorimetry	0.010	USEPA 353.2
	CAS*	Colorimetric by LACHAT	0.002	USEPA 353.2
Dissolved Nitrite plus Nitrate (DNOx)	PADEP	Cd-reduction, Colorimetry	0.010	USEPA 353.2
	CAS*	Colorimetric by LACHAT	0.002	USEPA 353.2
Dissolved Orthophosphate (DOP)	PADEP	Colorimetry	0.002	USEPA 365.1
	CAS*	Colorimetric Determination	0.002	USEPA 365.1
Dissolved Phosphorus (DP)	PADEP	Block Digest, Colorimetry	0.010	USEPA 365.1
	CAS*	Colorimetric Determination	0.002	USEPA 365.1
Total Phosphorus (TP)	PADEP	Persulfate Digest, Colorimetry	0.010	USEPA 365.1
	CAS*	Colorimetric Determination	0.002	USEPA 365.1
Total Organic Carbon (TOC)	PADEP	Combustion/Oxidation	0.50	SM 5310D
	CAS*	Chemical Oxidation	0.05	GEN 415.1/9060
Suspended Sediment (Fine)	USGS	**		
Suspended Sediment (Sand)	USGS	**		
Suspended Sediment (Total)	SRBC	**		
	USGS	**		

* Columbia Analytical Services, Rochester, NY (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

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 (NOAA) at the National Climatic Data Center in Asheville, North Carolina. Quarterly and annual data from these sources were compiled across the subbasins of the Susquehanna River Basin and are reported in Table 4 for Group A sites.

Table 4. Summary for Annual Precipitation for Selected Areas in the Susquehanna River Basin, Calendar Year 2005

River Location	Season	Calendar Year 2005 Precipitation inches	Average Long-term Precipitation inches	Departure From Long-term inches
Susquehanna River above Towanda, Pa.	January-March	12.56	7.45	+5.11
	April-June	12.57	10.69	+1.88
	July-September	13.36	11.33	+2.03
	October-December	16.58	9.09	+7.49
	Yearly Total	**55.07**	**38.56**	**+16.51**
Susquehanna River above Danville, Pa.	January-March	12.15	7.49	+4.66
	April-June	11.27	10.73	+0.54
	July-September	12.05	11.51	+0.54
	October-December	16.25	9.15	+7.10
	Yearly Total	**51.72**	**38.88**	**+12.84**
West Branch Susquehanna River above Lewisburg, Pa.	January-March	11.67	8.23	+3.44
	April-June	6.99	11.03	-4.04
	July-September	9.11	12.49	-3.38
	October-December	13.40	9.58	+3.82
	Yearly Total	**41.17**	**41.33**	**-0.16**
Juniata River above Newport, Pa.	January-March	9.10	7.73	+1.37
	April-June	5.77	9.47	-3.70
	July-September	7.15	10.01	-2.86
	October-December	10.66	8.89	+1.77
	Yearly Total	**32.68**	**36.10**	**-3.42**
Susquehanna River above Marietta, Pa.	January-March	11.35	8.11	+3.24
	April-June	8.60	10.70	-2.10
	July-September	10.10	11.63	-1.53
	October-December	14.07	9.34	+4.73
	Yearly Total	**44.12**	**39.78**	**+4.34**
Conestoga River above Conestoga, Pa.	January-March	10.46	8.90	+1.56
	April-June	8.68	10.46	-1.78
	July-September	9.04	12.64	-3.60
	October-December	17.79	10.42	+7.37
	Yearly Total	**45.97**	**42.42**	**+3.55**

WATER DISCHARGE

Water discharge data were obtained from the USGS and are listed in Table 5. Water discharges were above the LTM for all mainstem sites ranging from 105 percent of the LTM at Marietta to 115 percent of the LTM at Danville. Conestoga flows were 115 percent of the LTM. The two long-term most western sites recorded less than the long-term flows; 93 percent of LTM for Lewisburg and 91 percent of the LTM for Newport. Figure 3 compares the 2005 discharges with the LTM discharges for each site.

Table 5. Annual Water Discharge, Calendar Year 2005

Site	Years of Record	Long-term Annual Mean cfs[1]	2005	
			Mean cfs	Percent of LTM[2]
Towanda	17	11,811	13,230	112
Danville	21	16,393	18,839	115
Lewisburg	21	11,151	10,380	93
Newport	21	4,504	4,115	91
Marietta	19	39,023	40,999	105
Conestoga	21	675	774	115

[1] Cubic feet per second
[2] Long-term mean

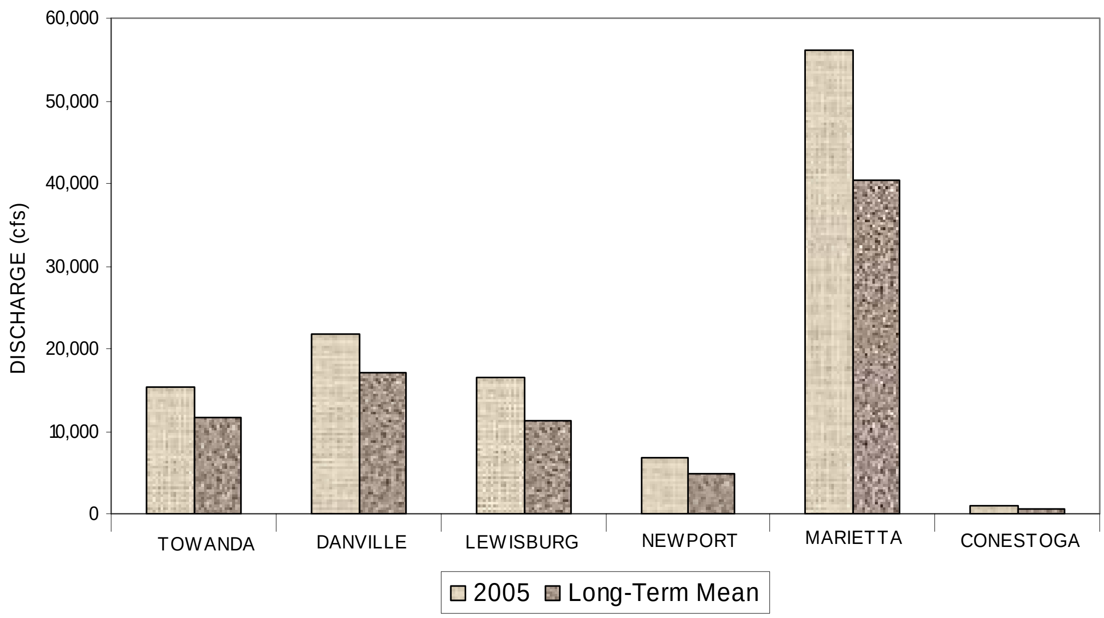

Figure 3. Annual and Long-Term Discharges at Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga, Pa.

ANNUAL NUTRIENT AND SUSPENDED-SEDIMENT LOADS AND YIELDS

Loads and yields represent two methods for describing amounts of nutrient and SS 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 6 as computed by the Minimum Variance Unbiased Estimator (MVUE) 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 then were calculated from the daily mean water discharge records. The loads were reported along with the estimates of accuracy.

Identifying sites where the percentage of LTM for a constituent was different than the percentage of LTM for discharge may show potential areas where improvements or degradations have occurred for that particular constituent. One item to note is that nutrients and SS increase with increased flow (Ott and others, 1991; Takita, 1996, 1998). This is especially significant during single high flow events.

Tables 7-19 show the loads and yields for the six Group A monitoring stations, as well as an associated error value. They also show the average annual concentration for each constituent. Comparisons have been made to the LTMs for all constituents. Figures 4A-6B show graphs of 2005 loads and yields versus LTMs. Statistics for the Group B sites are listed in Table 20 for summary statistics, Table 21 for average concentrations, and Table 22 for seasonal concentrations. Table 23 shows monthly loads for TN, TP, and SS and monthly flow for Group A sites.

Load values were rounded and expressed in one thousand pound increments causing some small variations when comparing monthly, seasonal, and annual loads among tables. Due to issues related to the model, LTM of loads for October at Danville and December at Conestoga were used in place of 2005 data. Additionally, SS loads for Conestoga were taken from USGS analysis due to the same model related issues.

Table 6. List of Analyzed Parameters, Abbreviations, and STORET Code

Parameter	Abbreviation	STORET Code
Total Nitrogen as N	TN	00600
Dissolved Nitrogen as N	DN	00602
Total Organic Nitrogen as N	TON	00605
Dissolved Organic Nitrogen as N	DON	00607
Total Ammonia as N	TNH_3	00610
Dissolved Ammonia as N	DNH_3	00608
Total Nitrate + Nitrite as N	TNOx	00630
Dissolved Nitrate + Nitrite as N	DNOx	00631
Total Phosphorus as P	TP	00665
Dissolved Phosphorus as P	DP	00666
Dissolved Orthophosphate as P	DOP	00671
Total Organic Carbon	TOC	00680
Suspended Sediment (fine)	SSF	70331
Suspended Sediment (sand)	SSS	70335
Suspended Sediment (total)	SS	80154

Table 7. Annual Water Discharges, Annual Loads, Yields, and Average Concentration of Total Nitrogen, Calendar Year 2005

Site	2005 Discharge cfs	Discharge % of LTM	2005 Load thousands of lbs	Load % of LTM	Prediction Error percent	2005 Ave. Conc. mg/l	LTM Conc. mg/l	2005 Yield lbs/ac/yr	LTM Yield lb/ac/yr
Towanda	13,230	112	27,893	97	6.13	1.07	1.25	5.59	5.78
Danville	18,839	115	40,468	91	6.47	1.09	1.38	5.64	6.19
Lewisburg	10,380	93	21,148	87	8.09	1.04	1.12	4.83	5.53
Newport	4,115	91	15,988	96	5.77	1.97	1.87	7.45	7.74
Marietta	40,999	105	138,790	104	7.18	1.72	1.73	8.34	7.00
Conestoga	774	115	11,816	112	5.53	7.75	7.96	39.28	36.00

Table 8. Annual Water Discharges and Annual Loads and Yields of Total Phosphorus, Calendar Year 2005

Site	2005 Discharge cfs	Discharge % of LTM	2005 Load thousands of lbs	Load % of LTM	Prediction Error percent	2005 Ave. Conc. mg/l	LTM Conc. mg/l	2005 Yield lbs/ac/yr	LTM Yield lb/ac/yr
Towanda	13,230	112	3,159	132	26.64	0.121	0.104	0.633	0.479
Danville	18,839	115	5,191	144	26.08	0.140	0.112	0.723	0.503
Lewisburg	10,380	93	1,248	94	31.44	0.061	0.061	0.285	0.303
Newport	4,115	91	489	57	23.68	0.060	0.095	0.228	0.396
Marietta	40,999	105	7,824	90	23.15	0.097	0.113	0.470	0.522
Conestoga	774	115	533	77	38.56	0.363	0.544	1.840	2.391

Table 9. Annual Water Discharges and Annual Loads and Yields of Total Suspended Sediment, Calendar Year 2005

Site	2005 Discharge cfs	Discharge % of LTM	2005 Load thousands of lbs	Load % of LTM	Prediction Error percent	2005 Ave. Conc. mg/l	LTM Conc. mg/l	2005 Yield lbs/ac/yr	LTM Yield lb/ac/yr
Towanda	13,230	112	5,173,852	153	60.85	198.6	146.5	1,036.8	677.9
Danville	18,839	115	4,427,656	144	47.91	119.4	95.4	616.6	429.0
Lewisburg	10,380	93	534,581	49	77.65	26.2	50.2	122.0	247.9
Newport	4,115	91	271,377	56	53.95	33.5	54.8	126.4	227.7
Marietta	40,999	105	5,542,226	80	51.12	68.7	90.3	333.2	417.7
Conestoga	774	115	285,570	71	26.6	187.4	302.9	949.4	1,331.1

Table 10. Annual Water Discharges and Annual Loads and Yields of Total Ammonia, Calendar Year 2005

Site	2005 Discharge cfs	Discharge % of LTM	2005 Load thousands of lbs	Load % of LTM	Prediction Error percent	2005 Ave. Conc. mg/l	LTM Conc. mg/l	2005 Yield lbs/ac/yr	LTM Yield lb/ac/yr
Towanda	13,230	112	1,711	117	25.06	0.066	0.063	0.343	0.293
Danville	18,839	115	2,737	94	26.04	0.074	0.090	0.381	0.407
Lewisburg	10,380	93	1,228	112	24.70	0.060	0.051	0.280	0.250
Newport	4,115	91	481	118	30.47	0.059	0.046	0.224	0.190
Marietta	40,999	105	7,349	143	28.87	0.091	0.067	0.442	0.310
Conestoga	774	115	205	74	41.85	0.134	0.208	0.680	0.915

Table 11. Annual Water Discharges and Annual Loads and Yields of Total NO_x Nitrogen, Calendar Year 2005

Site	2005 Discharge cfs	Discharge % of LTM	2005 Load thousands of lbs	Load % of LTM	Prediction Error percent	2005 Ave. Conc. mg/l	LTM Conc. mg/l	2005 Yield lbs/ac/yr	LTM Yield lb/ac/yr
Towanda	13,230	112	18,800	109	7.24	0.722	0.747	3.767	3.458
Danville	18,839	115	27,397	105	7.61	0.739	0.708	3.815	3.633
Lewisburg	10,380	93	17,505	112	7.23	0.857	0.724	3.995	3.575
Newport	4,115	91	14,228	112	5.63	1.756	1.432	6.628	5.946
Marietta	40,999	105	115,965	123	7.19	1.437	1.223	6.972	5.655
Conestoga	774	115	10,350	119	7.60	6.792	6.593	34.408	28.975

Table 12. Annual Water Discharges and Annual Loads and Yields of Total Organic Nitrogen, Calendar Year 2005

Site	2005 Discharge cfs	Discharge % of LTM	2005 Load thousands of lbs	Load % of LTM	Prediction Error percent	2005 Ave. Conc. mg/l	LTM Conc. mg/l	2005 Yield lbs/ac/yr	LTM Yield lb/ac/yr
Towanda	13,230	112	7,760	75	14.68	0.298	0.450	1.555	2.081
Danville	18,839	115	11,242	66	16.14	0.303	0.524	1.566	2.358
Lewisburg	10,380	93	3,730	48	23.95	0.183	0.358	0.851	1.769
Newport	4,115	91	1,995	47	21.72	0.246	0.472	0.929	1.961
Marietta	40,999	105	24,031	50	14.39	0.298	0.629	1.445	2.908
Conestoga	774	115	1,761	92	27.03	1.155	1.444	5.853	6.347

Table 13. Annual Water Discharges and Annual Loads and Yields of Dissolved Phosphorus, Calendar Year 2005

Site	2005 Discharge cfs	Discharge % of LTM	2005 Load thousands of lbs	Load % of LTM	Prediction Error percent	2005 Ave. Conc. mg/l	LTM Conc. mg/l	2005 Yield lbs/ac/yr	LTM Yield lb/ac/yr
Towanda	13,230	112	911	115	20.71	0.035	0.035	0.183	0.160
Danville	18,839	115	1,750	170	23.97	0.047	0.032	0.244	0.143
Lewisburg	10,380	93	496	99	22.18	0.024	0.023	0.113	0.114
Newport	4,115	91	217	50	19.73	0.027	0.049	0.101	0.202
Marietta	40,999	105	1,718	64	18.34	0.021	0.035	0.103	0.162
Conestoga	774	115	215	77	17.35	0.141	0.210	0.714	0.925

Table 14. Annual Water Discharges and Annual Loads and Yields of Dissolved Orthophosphate, Calendar Year 2005

Site	2005 Discharge cfs	Discharge % of LTM	2005 Load thousands of lbs	Load % of LTM	Prediction Error percent	2005 Ave. Conc. mg/l	LTM Conc. mg/l	2005 Yield lbs/ac/yr	LTM Yield lb/ac/yr
Towanda	13,230	112	655	154	24.59	0.025	0.019	0.131	0.086
Danville	18,839	115	1,215	243	26.93	0.033	0.016	0.169	0.070
Lewisburg	10,380	93	385	191	30.92	0.019	0.009	0.088	0.046
Newport	4,115	91	160	51	23.71	0.020	0.035	0.074	0.145
Marietta	40,999	105	1,180	67	23.42	0.015	0.023	0.071	0.105
Conestoga	774	115	135	57	19.77	0.089	0.179	0.449	0.787

Table 15. Annual Water Discharges and Annual Loads and Yields of Dissolved Ammonia, Calendar Year 2005

Site	2005 Discharge cfs	Discharge % of LTM	2005 Load thousands of lbs	Load % of LTM	Prediction Error percent	2005 Ave. Conc. mg/l	LTM Conc. mg/l	2005 Yield lbs/ac/yr	LTM Yield lb/ac/yr
Towanda	13,230	112	1,478	129	19.76	0.057	0.050	0.296	0.230
Danville	18,839	115	2,304	131	19.89	0.062	0.055	0.321	0.246
Lewisburg	10,380	93	1,075	103	18.00	0.053	0.048	0.245	0.238
Newport	4,115	91	383	92	19.86	1.824	1.801	6.884	7.480
Marietta	40,999	105	5,696	132	20.54	0.071	0.056	0.342	0.259
Conestoga	774	115	184	95	36.01	0.121	0.147	0.611	0.644

Table 16. Annual Water Discharges and Annual Loads and Yields of Dissolved Nitrogen, Calendar Year 2005

Site	2005 Discharge cfs	Discharge % of LTM	2005 Load thousands of lbs	Load % of LTM	Prediction Error percent	2005 Ave. Conc. mg/l	LTM Conc. mg/l	2005 Yield lbs/ac/yr	LTM Yield lb/ac/yr
Towanda	13,230	112	22,576	96	6.56	0.867	1.017	4.524	4.705
Danville	18,839	115	33,785	83	6.39	0.911	1.128	4.705	5.073
Lewisburg	10,380	93	18,869	84	7.13	0.923	1.039	4.306	5.130
Newport	4,115	91	14,778	92	5.17	1.824	1.801	6.884	7.480
Marietta	40,999	105	126,456	108	7.32	1.457	1.516	7.602	7.014
Conestoga	774	115	11,407	116	6.89	7.486	7.468	37.923	32.819

Table 17. Annual Water Discharges and Annual Loads and Yields of Dissolved NO_x Nitrogen, Calendar Year 2005

Site	2005 Discharge cfs	Discharge % of LTM	2005 Load thousands of lbs	Load % of LTM	Prediction Error percent	2005 Ave. Conc. mg/l	LTM Conc. mg/l	2005 Yield lbs/ac/yr	LTM Yield lb/ac/yr
Towanda	13,230	112	18,307	117	7.62	0.703	0.678	3.669	3.137
Danville	18,839	115	26,843	106	7.42	0.724	0.782	3.738	3.518
Lewisburg	10,380	93	17,410	106	7.19	0.852	0.761	3.973	3.757
Newport	4,115	91	13,985	105	5.63	1.726	1.496	6.515	6.213
Marietta	40,999	105	113,343	128	7.26	1.404	1.147	6.814	5.305
Conestoga	774	115	10,051	119	7.67	6.596	6.415	33.414	28.192

Table 18. Annual Water Discharges and Annual Loads and Yields of Dissolved Organic Nitrogen, Calendar Year 2005

Site	2005 Discharge cfs	Discharge % of LTM	2005 Load thousands of lbs	Load % of LTM	Prediction Error percent	2005 Ave. Conc. mg/l	LTM Conc. mg/l	2005 Yield lbs/ac/yr	LTM Yield lb/ac/yr
Towanda	13,230	112	4,204	56	17.07	0.161	0.323	0.843	1.493
Danville	18,839	115	6,074	58	13.92	0.164	0.327	0.846	1.470
Lewisburg	10,380	93	2,558	49	17.37	0.125	0.241	0.584	1.190
Newport	4,115	91	1,242	45	15.49	0.153	0.310	0.579	1.289
Marietta	40,999	105	14,602	41	19.16	0.181	0.464	0.878	2.147
Conestoga	774	115	1,700	145	24.43	1.115	0.887	5.650	3.896

Table 19. Annual Water Discharges and Annual Loads and Yields of Total Organic Carbon, Calendar Year 2005

Site	2005 Discharge cfs	Discharge % of LTM	2005 Load thousands of lbs	Load % of LTM	Prediction Error percent	2005 Ave. Conc. mg/l	LTM Conc. mg/l	2005 Yield lbs/ac/yr	LTM Yield lb/ac/yr
Towanda	13,230	112	89,076	108	5.44	3.420	3.574	17.851	16.538
Danville	18,839	115	121,878	110	4.87	3.286	3.419	16.973	15.379
Lewisburg	10,380	93	40,715	88	8.24	1.992	2.141	9.291	10.571
Newport	4,115	91	21,356	68	7.95	2.636	3.526	9.949	14.642
Marietta	40,999	105	220,018	90	6.51	2.726	3.174	13.227	14.680
Conestoga	774	115	6,456	82	11.24	4.237	5.946	21.462	26.133

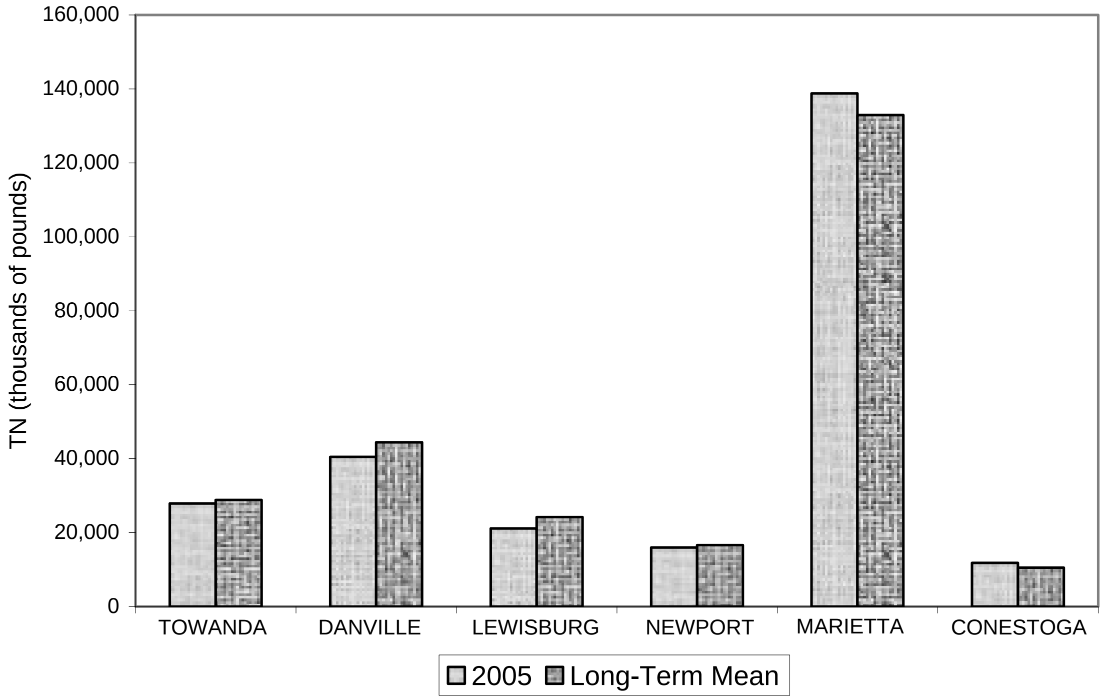

Figure 4A. ***Annual Loads of Total Nitrogen (TN) at Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga, Pa., Calendar Year 2005***

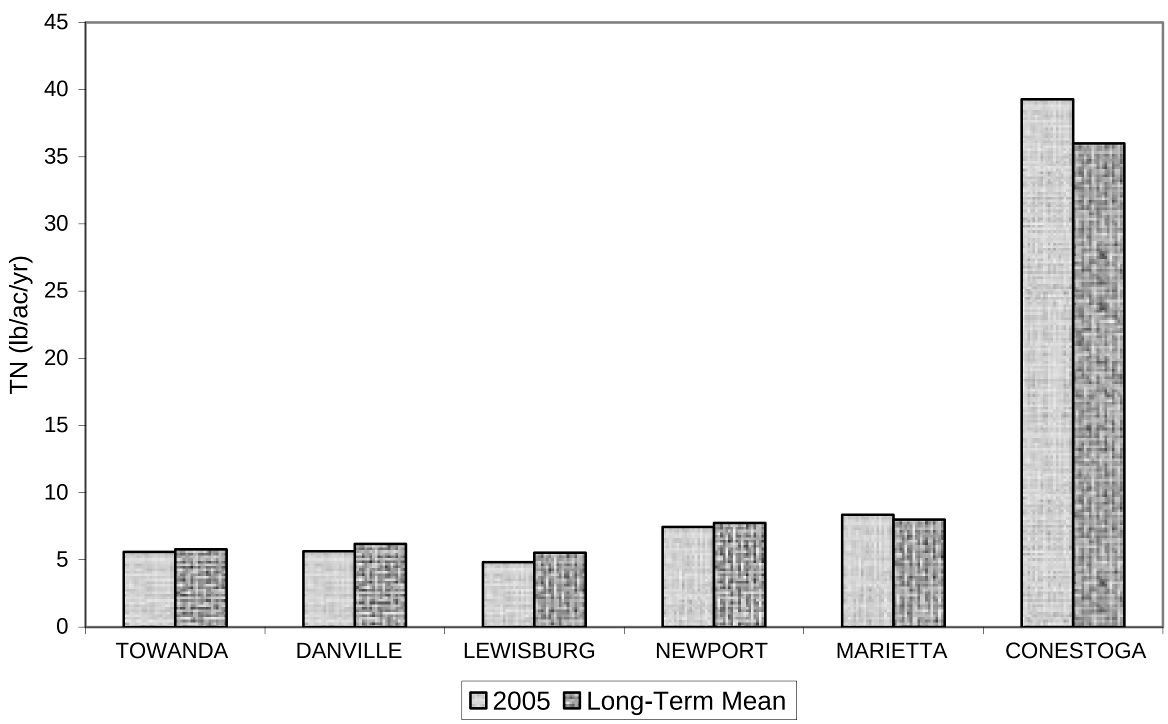

Figure 4B. ***Total Nitrogen (TN) Yields at Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga, Pa., Calendar Year 2005***

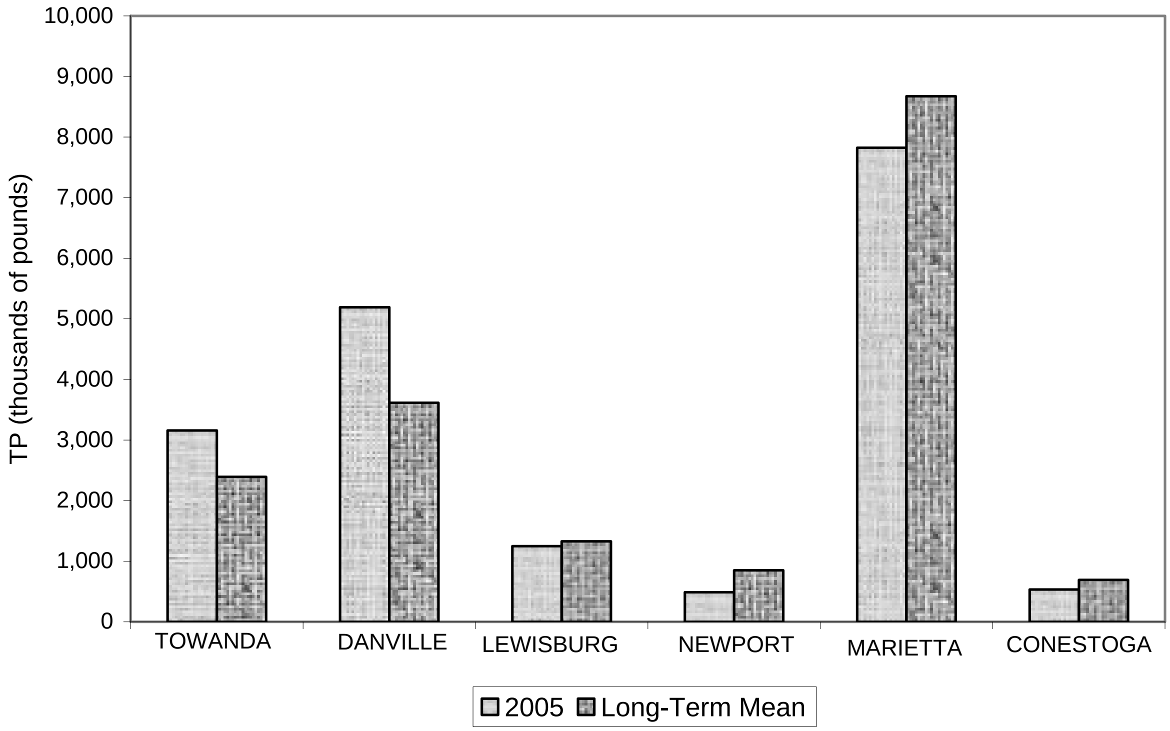

Figure 5A. ***Annual Loads of Total Phosphorus (TP) at Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga, Pa., Calendar Year 2005***

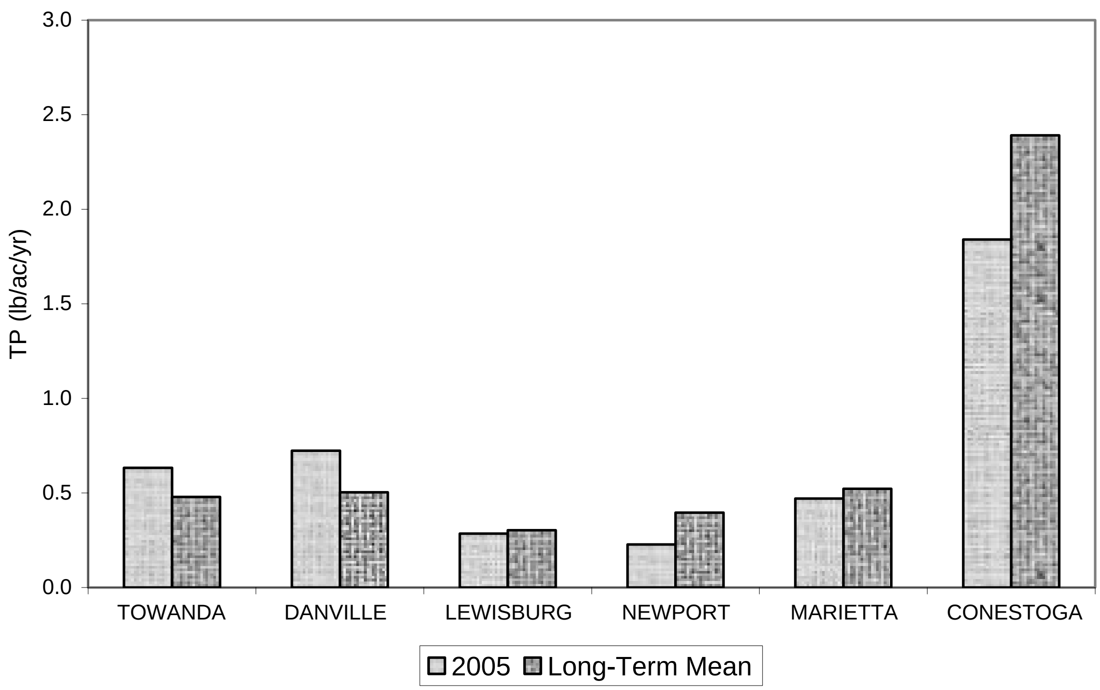

Figure 5B. ***Total Phosphorus (TP) Yields at Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga, Pa., Calendar Year 2005***

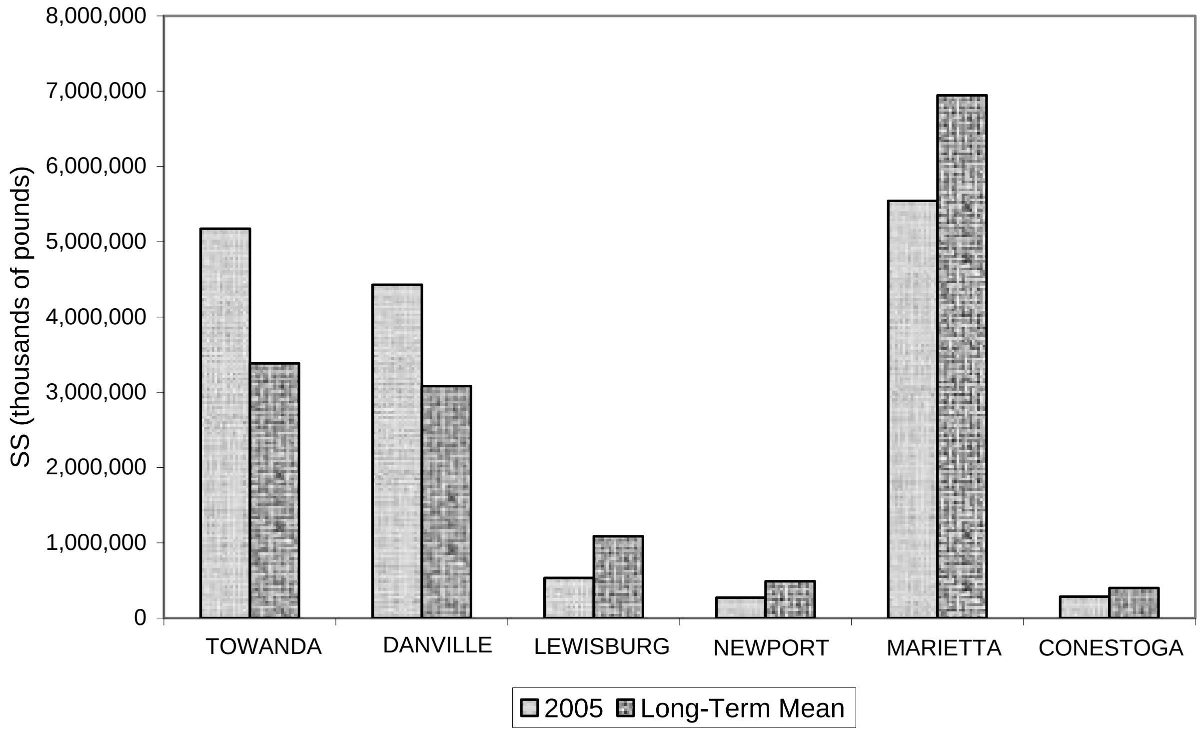

Figure 6A. Annual Loads of Suspended Sediment (SS) at Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga, Pa., Calendar Year 2005

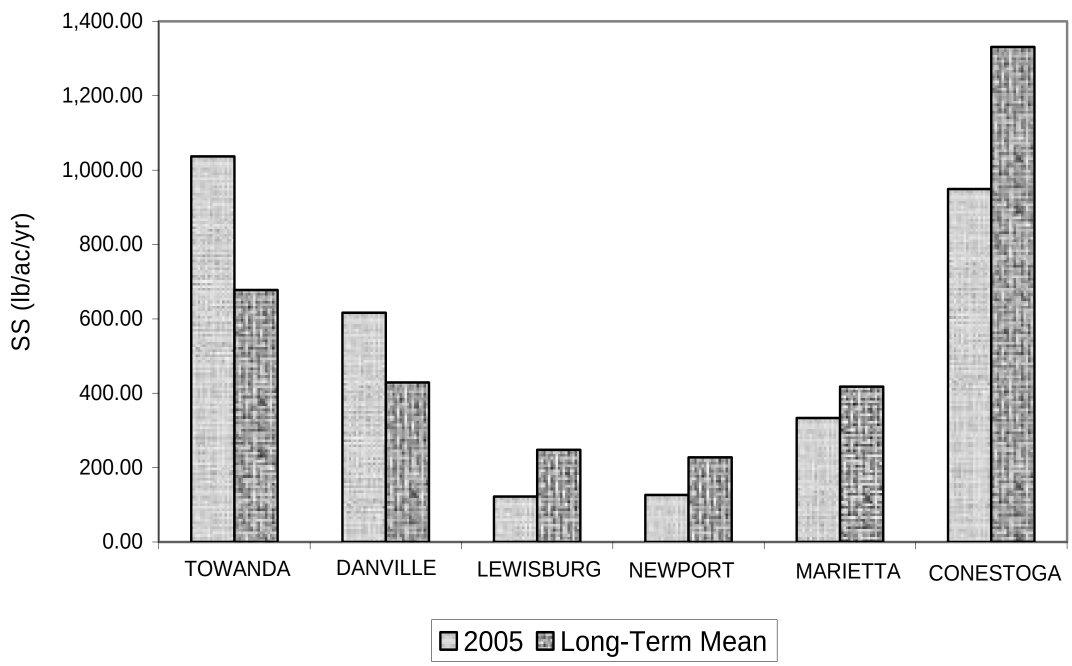

Figure 6B. Suspended Sediment (SS) Yields at Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga, Pa., Calendar Year 2005

Table 20. Enhanced Monitoring Station Concentration Summary Statistics Data from All 2005 Samples in mg/L

Station Location	Minimum Value			Maximum Value			Median Value			Mean Value			Standard Deviation		
	TN	TP	TSS	TN	TP	TSS	TN	TP	TSS	TN	TP	TSS	TN	TP	TSS
Rockdale	0.74	0.015	6	1.60	0.104	47	0.97	0.052	36	1.10	0.053	28	0.40	0.035	18
Campbell	0.89	0.028	4	2.13	0.110	88	1.47	0.054	11	1.43	0.067	28	0.49	0.039	40
Conklin	0.59	0.025	7	1.82	0.089	55	0.81	0.040	9	0.99	0.051	19	0.49	0.027	20
Richardsmere	3.39	0.059	-	7.45	1.118	-	6.02	0.570	-	5.39	0.515	-	1.75	0.450	-
Smithboro	0.78	0.265	6	1.76	0.294	335	1.00	0.071	14	1.06	0.086	49	0.28	0.071	88
Chemung	0.37	0.014	3	1.50	0.237	318	1.07	0.077	23	1.11	0.091	57	0.27	0.060	83
Wilkes-Barre	0.59	0.025	2	5.02	0.636	466	0.93	0.099	16	1.18	0.146	73	1.03	0.147	123
Karthaus	0.27	0.010	2	0.79	0.128	34	0.48	0.027	10	0.52	0.034	12	0.16	0.028	11
Castanea	1.02	0.022	2	2.14	0.111	50	1.60	0.061	10	1.57	0.063	15	0.33	0.023	16
Jersey Shore	0.43	0.010	2	1.01	0.072	88	0.72	0.045	6	0.68	0.043	16	0.18	0.020	24
Penns Creek	0.57	0.010	2	1.96	0.203	68	1.45	0.075	4	1.35	0.078	14	0.42	0.049	20
Saxton	1.98	0.010	2	3.60	0.412	728	2.28	0.023	10	2.38	0.060	92	0.42	0.101	203
Dromgold	1.04	0.010	2	2.65	0.322	300	1.91	0.034	4	1.89	0.072	34	0.47	0.090	76
Hogestown	3.53	0.010	2	5.54	0.270	312	4.49	0.036	2	4.42	0.062	45	0.57	0.067	89
Hershey	2.93	0.022	2	6.49	0.419	478	4.01	0.058	6	4.26	0.111	66	0.87	0.120	147
Manchester	1.86	0.020	2	3.86	0.798	752	2.58	0.146	10	2.72	0.204	91	0.50	0.189	215
Martic Forge	4.21	0.020	2	9.82	2.192	2064	8.14	0.136	18	7.77	0.471	300	1.62	0.723	652

Table 21. *Enhanced Monitoring Station Average Concentration Data for 2005 Monthly Samples*

Station Location	Flow	Temp	Cond	pH	TN	DN	TNH_4	DNH_4	TNOx	DNOx	TP	DP	DOP	TOC	TSS
	cfs	C°			mg/L										
Average for Fall Only															
Rockdale	1,338	7.1	200	7.47	1.30	1.13	0.026	0.024	0.977	0.834	0.040	0.016	0.013	3.52	25
Campbell	434	-	339	7.60	1.54	1.39	0.036	0.035	1.134	1.094	0.057	0.020	0.013	4.22	-
Conklin	4,556	8.8	176	7.30	1.12	0.88	0.028	0.264	0.813	0.567	0.033	0.015	0.008	3.04	10
Richardsmere	-	9.8	216	7.38	5.84	5.81	0.070	0.080	5.510	5.460	0.239	0.216	0.188	4.60	-
Average for Entire Year															
Smithboro	10,663	-	-	-	1.13	0.83	0.047	0.043	0.592	0.565	0.076	0.018	0.011	3.42	39
Chemung	4,389	-	-	-	1.10	0.99	0.028	0.024	0.709	0.691	0.088	0.036	0.030	3.08	56
Wilkes-Barre	12,457	12.5	298	7.23	1.30	1.08	0.070	0.064	0.805	0.787	0.132	0.066	0.057	3.38	65
Karthaus	2,408	13.8	505	6.40	0.49	0.43	0.060	0.049	0.393	0.365	0.035	0.020	0.019	1.45	8
Castanea	-	11.9	332	7.52	1.72	1.70	0.050	0.037	1.586	1.574	0.063	0.043	0.038	1.89	9
Jersey Shore	7,455	13.8	281	7.14	0.72	0.65	0.040	0.037	0.590	0.585	0.043	0.033	0.030	1.49	8
Penns Creek	411	14.2	244	8.01	1.32	1.26	0.040	0.037	1.056	1.052	0.056	0.047	0.041	2.47	6
Saxton	705	16.8	286	7.70	2.27	2.16	0.040	0.033	1.980	1.968	0.019	0.012	0.011	2.42	6
Dromgold	217	15.0	206	7.43	1.75	1.69	0.040	0.043	1.516	1.489	0.027	0.016	0.014	2.24	6
Hogestown	492	-	366	7.66	4.65	4.60	0.045	0.043	4.425	4.335	0.026	0.018	0.016	2.42	-
Hershey	606	15.0	333	7.43	4.57	4.50	0.070	0.062	4.358	4.324	0.053	0.035	0.030	2.49	5
Manchester	537	16.8	263	7.70	2.66	2.62	0.050	0.051	2.346	2.308	0.113	0.091	0.084	4.57	7
Martic Forge	173	16.1	452	7.90	8.52	8.50	0.060	0.058	7.756	7.613	0.108	0.075	0.067	3.13	13

Table 22. Enhanced Monitoring Station Average Seasonal Concentration Data from 2005 Monthly Samples in mg/L

Station Location	Winter			Spring			Summer			Fall			Annual		
	TN	TP	TSS	TN	TP	TSS	TN	TP	TSS	TN	TP	TSS	TN	TP	TSS
Rockdale	-	-	-	-	-	-	-	-	-	1.30	0.040	25	1.3	0.040	25
Campbell	-	-	-	-	-	-	-	-	-	1.54	0.057	-	1.542	0.057	-
Conklin	-	-	-	-	-	-	-	-	-	1.12	0.033	10	1.118	0.033	10
Richardsmere	-	-	-	-	-	-	-	-	-	5.84	0.239	-	5.84	0.239	-
Smithboro	1.64	0.143	119	0.91	0.045	13	0.92	0.064	8	1.05	0.052	16	1.128	0.076	39
Chemung	1.10	0.129	136	1.08	0.047	12	1.03	0.113	21	1.18	0.064	-	1.096	0.088	56
Wilkes-Barre	1.09	0.079	11	2.48	0.264	161	0.73	0.098	-	0.90	0.088	23	1.3	0.132	65
Karthaus	0.70	0.028	17	0.45	0.031	8	0.33	0.020	5	0.48	0.061	3	0.49	0.035	8
Castanea	1.54	0.077	25	2.00	0.052	5	1.85	0.063	5	1.48	0.061	2	1.72	0.063	9
Jersey Shore	0.80	0.045	20	0.66	0.041	5	0.71	0.038	2	0.74	0.046	3	0.72	0.043	8
Penns Creek	1.73	0.046	15	1.52	0.072	4	0.61	0.058	2	1.41	0.042	2	1.32	0.056	6
Saxton	2.21	0.018	9	2.36	0.021	5	2.39	0.021	-	2.10	0.016	3	2.27	0.019	6
Dromgold	2.25	0.029	17	1.85	0.024	3	1.31	0.033	3	1.59	0.023	23	1.75	0.027	6
Hogestown	4.32	0.021	2	4.78	0.032	2	4.89	0.026	-	4.59	0.024	13	4.647	0.026	-
Hershey	4.20	0.038	3	4.31	0.058	4	5.30	0.065	-	4.49	0.049	7	4.57	0.053	5
Manchester	2.78	0.077	16	2.32	0.086	4	2.34	0.150	-	3.19	0.140	2	2.66	0.146	7
Martic Forge	9.20	0.111	23	8.93	0.084	13	7.38	0.138	9	8.60	0.099	9	8.52	0.108	13

Table 23. 2005 Monthly Flow in Cubic Feet per Second and Total Nitrogen, Total Phosphorus, and Suspended Sediment in Thousands of Pounds

Site	Parameter	January	February	March	April	May	June	July	August	September	October	November	December	Annual[#]
Towanda	Q	22,519	14,360	19,120	37,744	6,092	3,371	2,483	905	1,810	15,196	18,154	16,941	13,230
	TN	4,487	2,530	3,567	6,637	947	461	336	124	246	2,429	3,013	3,115	27,893
	TP	448	124	353	1,129	47	28	26	15	24	360	313	294	3,159
	SS	525,605	47,454	551,426	3,016,368	11,806	5,217	4,550	1,444	4,298	442,632	282,675	280,377	5,173,852
Danville	Q	36,313	21,025	26,945	54,717	8,578	4,813	3,675	1,591	2,374	18,534	21,280	25,952	18,839
	TN *	7,692	3,913	5,061	9,398	1,287	603	445	178	288	2,944	3,670	4,989	40,468
	TP *	974	248	644	1,892	79	42	38	18	29	179	405	669	5,191
	SS *	712,678	65,241	596,830	2,416,140	13,372	5,252	4,492	1,277	3,379	120,361	126,139	396,052	4,427,656
Lewisburg	Q	27,563	13,310	16,134	22,554	4,379	2,814	2,256	1,137	1,975	6,187	10,432	15,430	10,380
	TN	5,133	2,196	2,716	3,456	684	420	351	204	325	1,039	1,796	2,830	21,148
	TP	362	87	146	234	21	14	12	8	13	51	104	197	1,248
	SS	172,943	19,633	66,220	134,705	2,407	1,226	1,001	426	1,289	9,362	34,395	90,975	534,581
Newport	Q	10,931	5,593	9,299	7,588	2,029	1,615	1,295	912	833	1,747	2,332	4,929	4,115
	TN	4,120	1,770	2,907	2,266	519	383	313	213	197	585	794	1,921	15,988
	TP	141	37	108	71	13	12	11	8	7	16	22	43	489
	SS	78,787	10,904	99,087	41,801	2,707	2,422	1,968	1,152	869	3,097	10,636	17,948	271,377
Marietta	Q	91,119	48,196	63,452	108,960	20,242	11,878	11,995	5,051	6,136	29,718	36,330	57,648	40,999
	TN	29,963	13,125	16,762	26,128	4,457	2,325	2,540	1,000	1,366	9,454	11,853	19,816	138,790
	TP	1,828	358	1,089	2,568	121	70	89	38	47	396	331	888	7,824
	SS	1,165,755	112,579	935,428	2,528,153	29,534	13,773	19,143	5,044	7,128	156,870	89,031	479,788	5,542,226
Conestoga	Q	1,297	823	1,091	1,625	506	369	544	244	146	1,230	547	832	774
	TN **	1,766	1,053	1,407	1,908	667	460	685	318	185	1,400	767	1,047	11,816
	TP **	57	21	49	86	13	10	19	7	4	198	14	72	533
	SS ***	29,752	22,983	58,757	30,577	42,729	24,226	42,557	13,547	46,397	13,406	18,487	30,449	285,570

Annual flow is average for the year; Annual loads are total for the year

* LTM values were used for Danville for October due to model related issues

** LTM values were used for Conestoga for December due to model related issues

*** Values for Suspended Sediment at Conestoga for 2005 were taken from USGS analysis due to model related issues

SEASONAL WATER DISCHARGES AND NUTRIENT AND SUSPENDED-SEDIMENT LOADS AND YIELDS

Seasonal loads for all parameters and all sites are listed in Table 24 for loads and Table 25 for percentages (high values in boldface type). For the purposes of this project, January through March is winter, April through June is spring, July through September is summer, and October through December is fall. As a general note, nutrient and SS levels increase with increases in flow. 2005 and LTM nutrient and SS yields are shown in Figures 7–9 for group A sites.

Table 24. Seasonal Mean Water Discharges and Loads of Nutrients and Suspended Sediment, Calendar Year 2005

Station	Season	Mean Water Discharge	Total Nitrogen as N	Dissolved Nitrogen as N	Total Ammonia as N	Dissolved Ammonia as N	Total Organic Nitrogen as N	Dissolved Organic Nitrogen as N	Total Nitrate Plus Nitrite as N	Dissolved Nitrate Plus Nitrite as N	Total Phosphorus as P	Dissolved Phosphorus as P	Dissolved Ortho-Phosphate as P	Total Organic Carbon	Suspended Sediment ***
		cfs	thousands of pounds												
Towanda	Winter	**18,810**	**10,585**	**9,020**	**635**	**567**	2,541	**1,523**	**7,654**	**7,535**	924	303	230	27,223	1,124,485
	Spring	15,629	8,045	6,024	415	357	**2,928**	1,323	4,604	4,494	**1,203**	231	154	26,783	**3,033,391**
	Summer	1,732	705	516	29	27	271	142	383	367	64	37	29	3,050	10,292
	Fall	16,749	8,557	7,016	632	528	2,019	1,216	6,159	5,910	967	**339**	**242**	**32,019**	1,005,684
Danville	Winter	**28,330**	**16,665**	**14,604**	**1,174**	**1,015**	4,103	**2,403**	**12,004**	**11,820**	1,866	**635**	**477**	**40,604**	1,374,749
	Spring	22,547	11,288	8,706	682	583	**4,288**	1,937	6,526	6,455	**2,013**	443	297	37,379	**2,434,763**
	Summer	2,549	912	686	43	41	409	208	455	463	85	49	41	4,191	9,148
	Fall *	21,929	11,603	9,788	837	665	1,834	1,068	8,411	8,106	1,227	623	399	39,704	608,996
Lewisburg	Winter	**19,192**	**10,044**	**8,971**	**594**	**525**	**1,885**	**1,284**	**8,073**	**8,038**	**594**	**222**	**166**	**17,896**	**258,796**
	Spring	9,855	4,560	4,013	210	206	893	592	3,577	3,548	268	92	68	9,034	138,338
	Summer	1,787	879	810	41	36	137	114	739	734	34	24	21	1,852	2,715
	Fall	10,686	5,665	5,075	383	308	815	567	5,116	5,090	352	157	130	11,933	134,732
Newport	Winter	**8,708**	**8,798**	**8,068**	**239**	**196**	**1,153**	**679**	**7,715**	**7,609**	**286**	**115**	**86**	**11,106**	**188,778**
	Spring	3,725	3,168	2,921	95	79	446	283	2,759	2,704	95	42	29	4,518	46,930
	Summer	1,015	722	671	33	25	113	84	587	567	26	16	12	1,550	3,988
	Fall	3,010	3,299	3,117	114	83	283	195	3,168	3,105	81	44	32	4,182	31,682
Marietta	Winter	**68,236**	**59,851**	**54,963**	**3,273**	**2,573**	**10,407**	**6,516**	**50,448**	**49,394**	**3,275**	**728**	**526**	**84,996**	2,213,763
	Spring	46,732	32,910	28,336	1,666	1,307	6,801	3,610	24,598	23,942	2,759	443	269	63,441	**2,571,460**
	Summer	7,744	4,906	4,513	186	161	912	588	3,459	3,403	174	83	49	11,448	31,315
	Fall	41,286	41,124	38,643	2,224	1,655	5,911	3,887	37,458	36,603	1,615	465	336	60,133	725,689
Conestoga	Winter	**1,070**	**4,226**	**4,083**	68	64	**637**	**654**	**3,604**	**3,508**	127	57	35	2,027	**111,492**
	Spring	830	3,035	2,942	44	40	458	455	2,699	2,604	108	43	26	1,607	97,532
	Summer	313	1,189	1,212	9	9	106	136	1,193	1,152	30	22	16	557	102,501
	Fall **	873	3,366	3,170	**83**	**72**	559	454	2,854	2,788	**288**	**92**	**59**	**2,266**	62,342

* LTM values were used for Danville for October due to model related issues

** LTM values were used for Conestoga for December due to model related issues

*** Values for Suspended Sediment at Conestoga for 2005 were taken from USGS analysis due to model related issues

Table 25. ***Seasonal Mean Water Discharge and Nutrients and Suspended Sediment Load Percentages, Calendar Year 2005***

Station	Season	Mean Water Discharge	Total Nitrogen as N	Dissolved Nitrogen as N	Total Ammonia as N	Dissolved Ammonia as N	Total Organic Nitrogen as N	Dissolved Organic Nitrogen as N	Total Nitrate Plus Nitrite as N	Dissolved Nitrate Plus Nitrite as N	Total Phosphorus as P	Dissolved Phosphorus as P	Dissolved Ortho-Phosphate as P	Total Organic Carbon	Suspended Sediment
		%													
Towanda	Winter	36	38	40	37	38	33	36	41	41	29	33	35	31	22
	Spring	29	29	27	24	24	38	32	24	25	38	26	24	30	59
	Summer	3	3	2	2	2	3	3	2	2	2	4	4	3	< 0.1
	Fall	32	31	31	37	36	26	29	33	32	31	37	37	36	19
Danville	Winter	38	41	43	43	44	39	43	43	44	36	36	39	33	31
	Spring	30	28	26	25	25	40	34	24	24	39	25	25	31	55
	Summer	3	2	2	1	2	4	4	2	2	2	3	3	3	< 0.1
	Fall	29	29	29	31	29	17	19	31	30	23	36	33	33	14
Lewisburg	Winter	46	47	48	49	49	50	50	46	46	48	45	43	44	48
	Spring	24	22	21	17	19	24	23	21	21	21	18	18	22	26
	Summer	4	4	4	3	3	4	4	4	4	3	5	5	5	1
	Fall	26	27	27	31	29	22	22	29	29	28	32	34	29	25
Newport	Winter	53	55	55	49	51	58	55	54	55	59	53	54	52	70
	Spring	23	20	20	20	21	22	23	20	19	19	19	18	21	17
	Summer	6	5	5	7	6	6	7	4	4	5	8	8	7	1
	Fall	18	21	21	24	22	14	16	22	22	17	20	20	20	12
Marietta	Winter	42	43	43	44	45	43	45	44	44	42	42	45	39	40
	Spring	28	24	22	23	23	28	25	21	21	35	26	23	29	46
	Summer	5	3	4	3	3	4	4	3	3	2	5	4	5	1
	Fall	25	30	31	30	29	25	26	32	32	21	27	28	27	13
Conestoga	Winter	35	36	36	33	34	36	38	35	35	23	27	26	31	30
	Spring	27	26	26	22	22	26	27	26	26	20	20	19	25	26
	Summer	10	10	10	4	5	6	8	11	11	5	10	12	9	27
	Fall	28	28	28	41	39	32	27	28	28	52	43	43	35	17

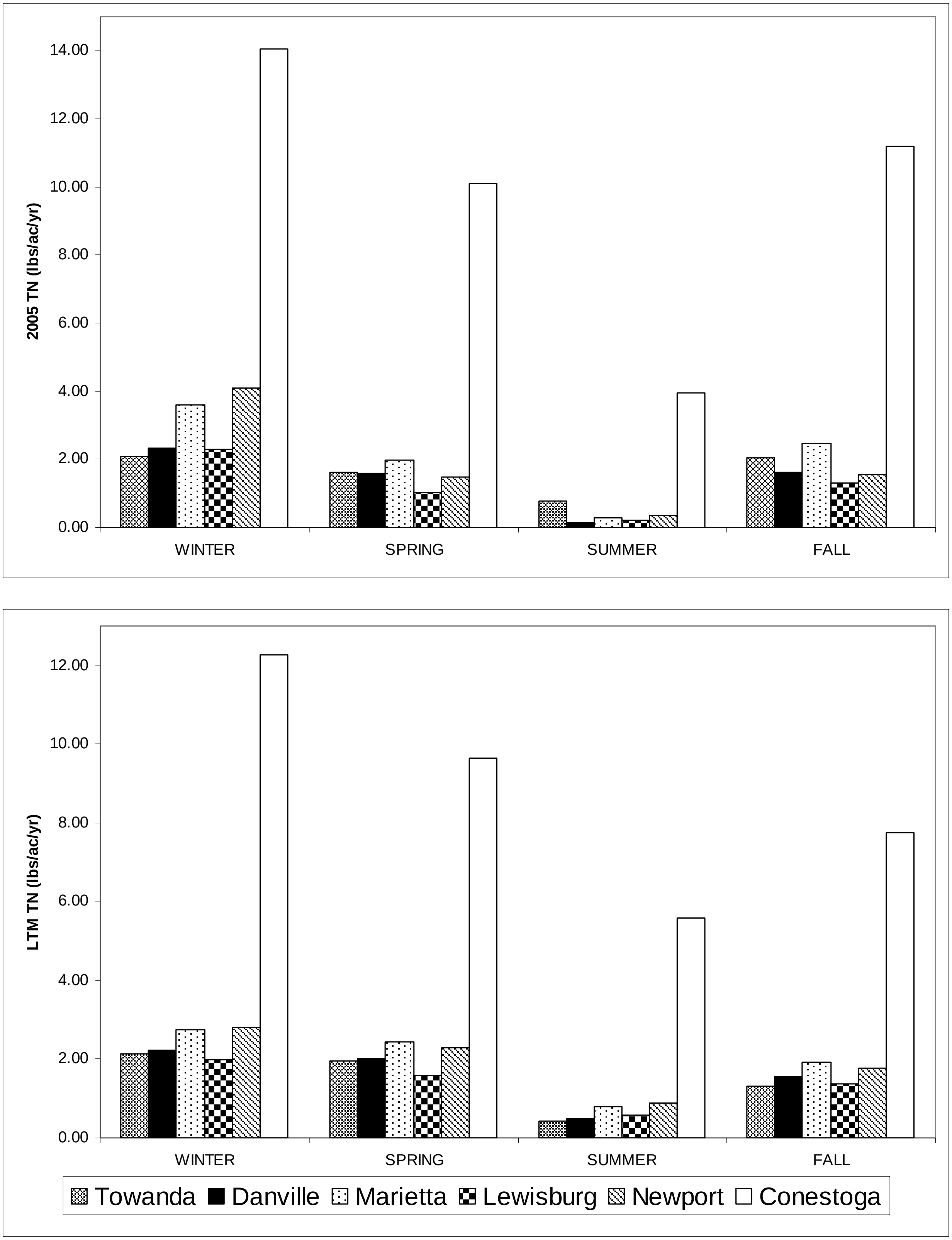

Figure 7. Comparison of Seasonal Yields of Total Nitrogen (TN) at Towanda, Danville, Marietta, Lewisburg, Newport, and Conestoga, Pa.

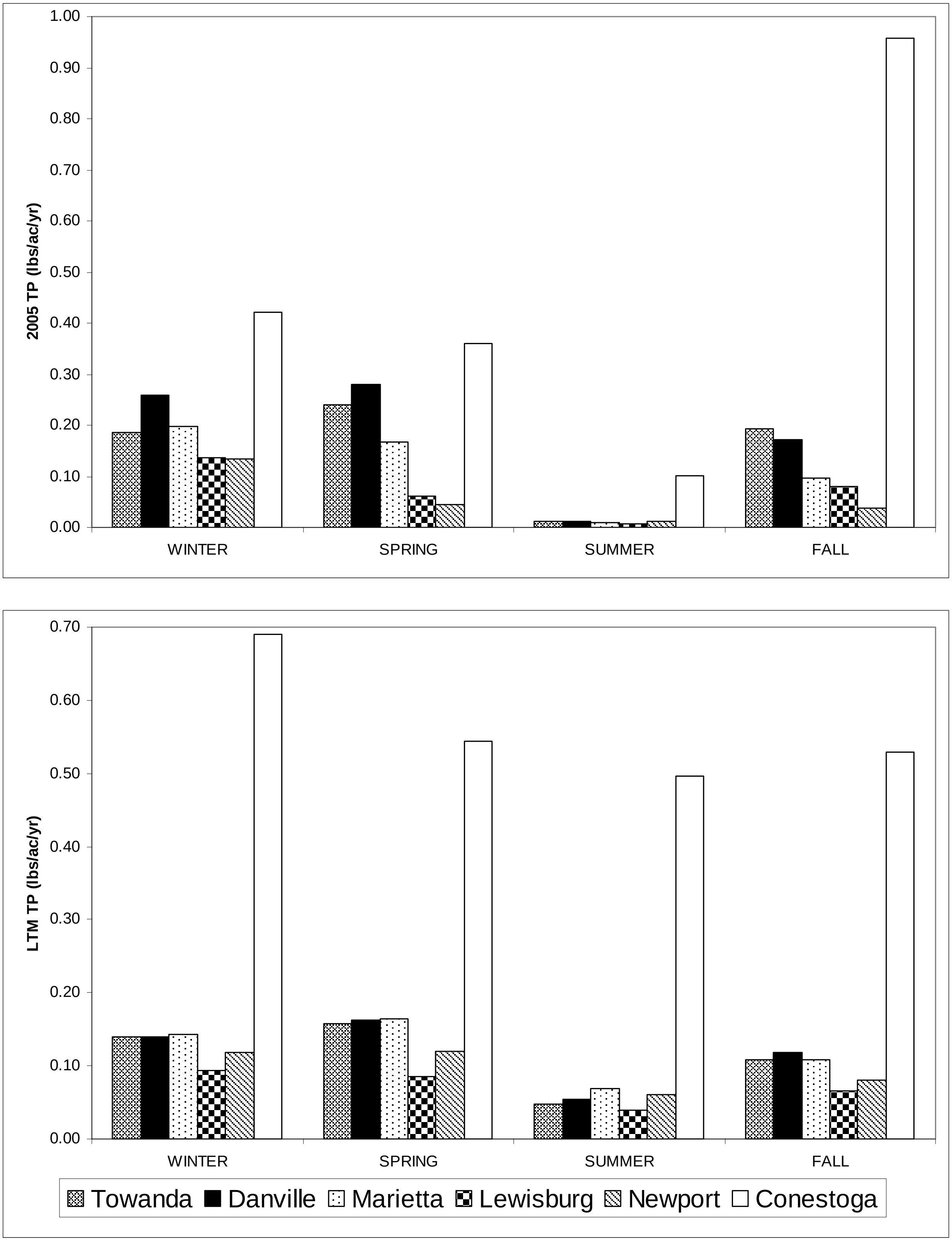

Figure 8. Comparison of Seasonal Yields of Total Phosphorus (TP) at Towanda, Danville, Marietta, Lewisburg, Newport, and Conestoga, Pa.

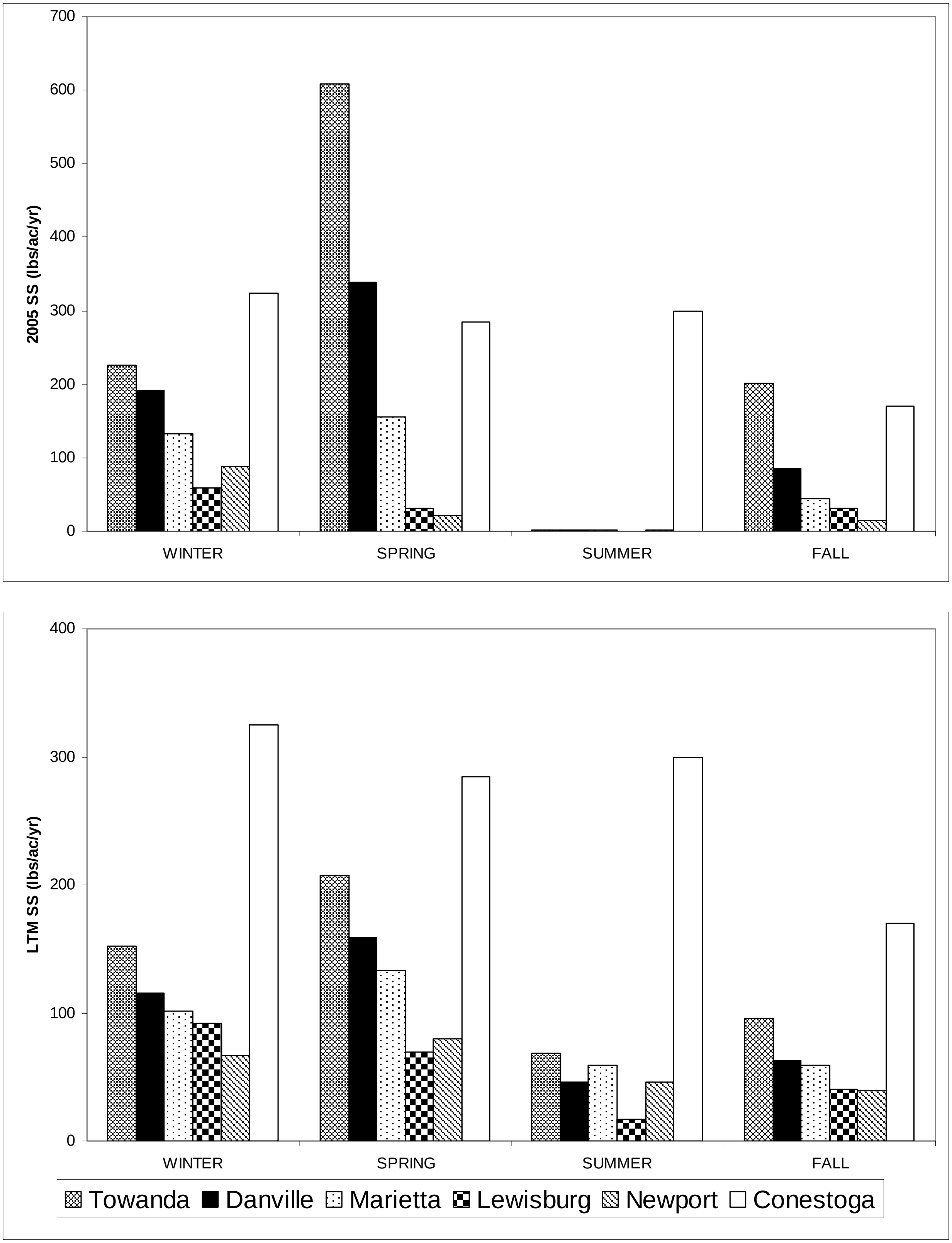

Figure 9. ***Comparison of Seasonal Yields of Suspended Sediment (SS) at Towanda, Danville, Marietta, Lewisburg, Newport, and Conestoga, Pa.***

COMPARISON OF THE 2005 LOADS AND YIELDS OF TOTAL NITROGEN, TOTAL PHOSPHORUS, AND SUSPENDED SEDIMENT WITH THE BASELINES

Annual fluctuations of nutrient and SS loads and water discharge create difficulties in determining whether the changes observed were related to land use, nutrient availability, or simply annual water discharge. Ott and others (1991) used the relationship between annual loads and annual water discharge to provide a method to reduce the variability of loadings due to discharge. This was accomplished by plotting the annual yields against the water-discharge ratio. The water-discharge ratio is the ratio of the annual mean discharge to the LTM discharge. Data from the initial 5-year study (1985-89) were used to provide a best-fit linear regression 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. The data collected in 2005 were compared with the 1985-89 baselines, where possible. Monitoring at some of the stations was started after 1987; therefore, a baseline was established for the 5-year period following the start of monitoring. 2005 yield values also were plotted against two other baselines, one created from the first half of each dataset and one created from the second half of each dataset. Figures 10 - 21 display the baseline graphs and the 2005 yields.

Susquehanna River at Towanda, Pa.

The baselines for TN, TP, and SS for the Susquehanna River at Towanda are shown in Figures 10 and 11 with the 2005 annual yield. Actual 2005 and baseline yields are listed in Table 26 along with the discharge ratio. Best-fit lines were drawn through the data sets using the following equations:

Where x = water-discharge ratio and R^2 = correlation coefficient

1989-1993 Baselines;

Total Nitrogen (TN)
TN Yield = 6.2113x + 0.6168 $R^2 = 0.7868$
Total Phosphorus (TP)
TP Yield = 0.7947x - 0.3135 $R^2 = 0.7178$
Suspended Sediment (SS)
SS Yield = 2079.2x - 1312.7 $R^2 = 0.4125$

1989-1996 Baselines;

Total Nitrogen (TN)
TN Yield = 5.5766x + 0.8554 $R^2 = 0.8212$
Total Phosphorus (TP)
TP Yield = 0.844x - 0.3493 $R^2 = 0.8592$
Suspended Sediment (SS)
SS Yield = 2297.4x - 1464.5 $R^2 = 0.6701$

1997-2004 Baselines;

Total Nitrogen (TN)
TN Yield = 4.1303x + 1.0532 $R^2 = 0.9310$
Total Phosphorus (TP)
TP Yield = 0.4964x - 0.052 $R^2 = 0.7755$
Suspended Sediment (SS)
SS Yield = 832.17x - 373.88 $R^2 = 0.5834$

Table 26. Comparison of 2005 Total Nitrogen, Total Phosphorous, and Suspended Sediment Yields with Baseline Yields at Towanda, Pa.

Parameter	Discharge Ratio	1989 – 1993 Baseline lb/ac/yr	1989 – 1996 Baseline lb/ac/yr	1997 - 2004 Baseline lb/ac/yr	2005 lb/ac/yr
TN	1.129	7.63	7.15	5.72	5.59
TP	1.129	0.584	0.604	0.509	0.633
SS	1.129	1035	1130	566	1037

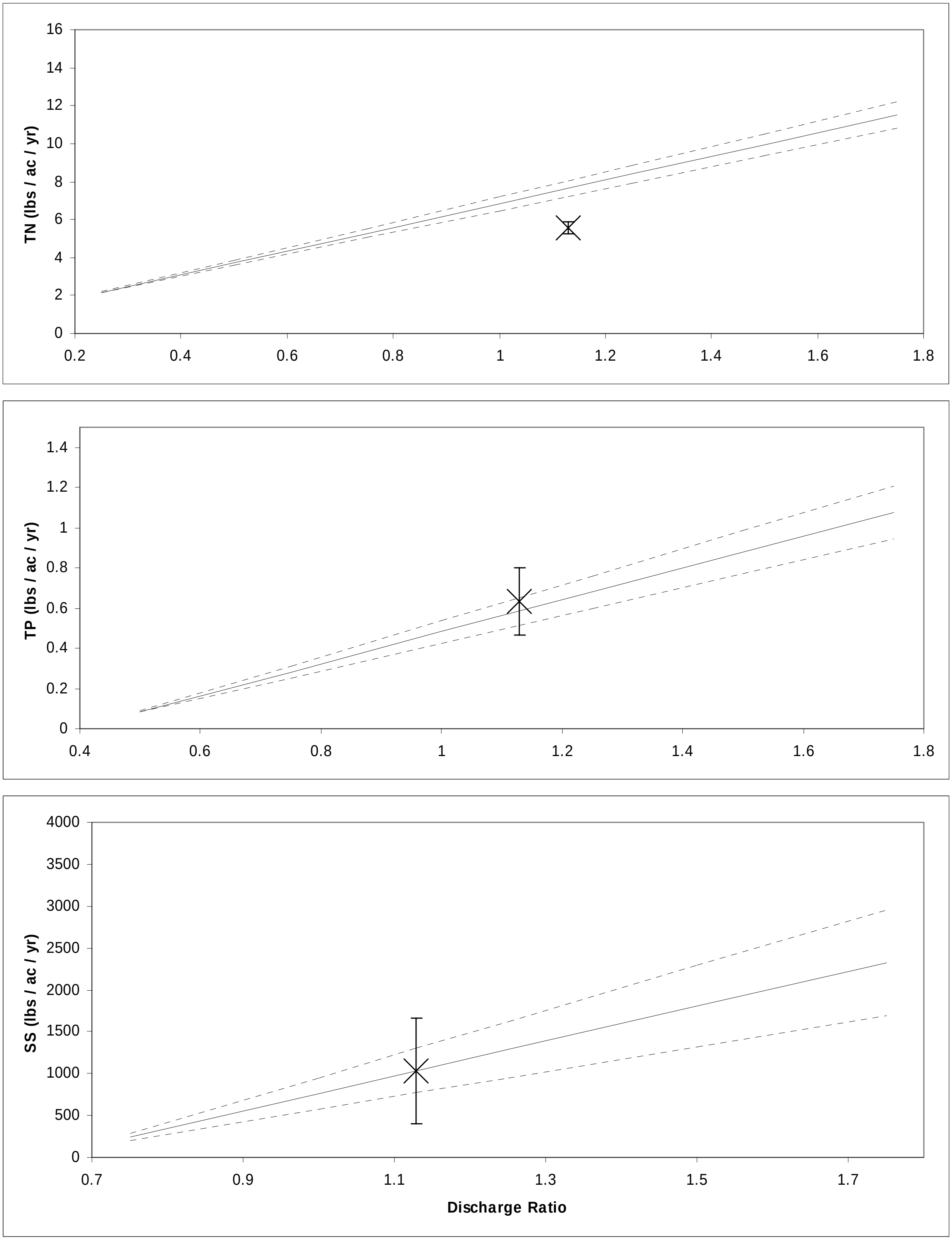

Figure 10. ***Total Nitrogen (TN), Total Phosphorus (TP), and Suspended-Sediment (SS) Yields, Susquehanna River at Towanda, Pa., 2005 Yield Compared to 1989-1993 Baseline***

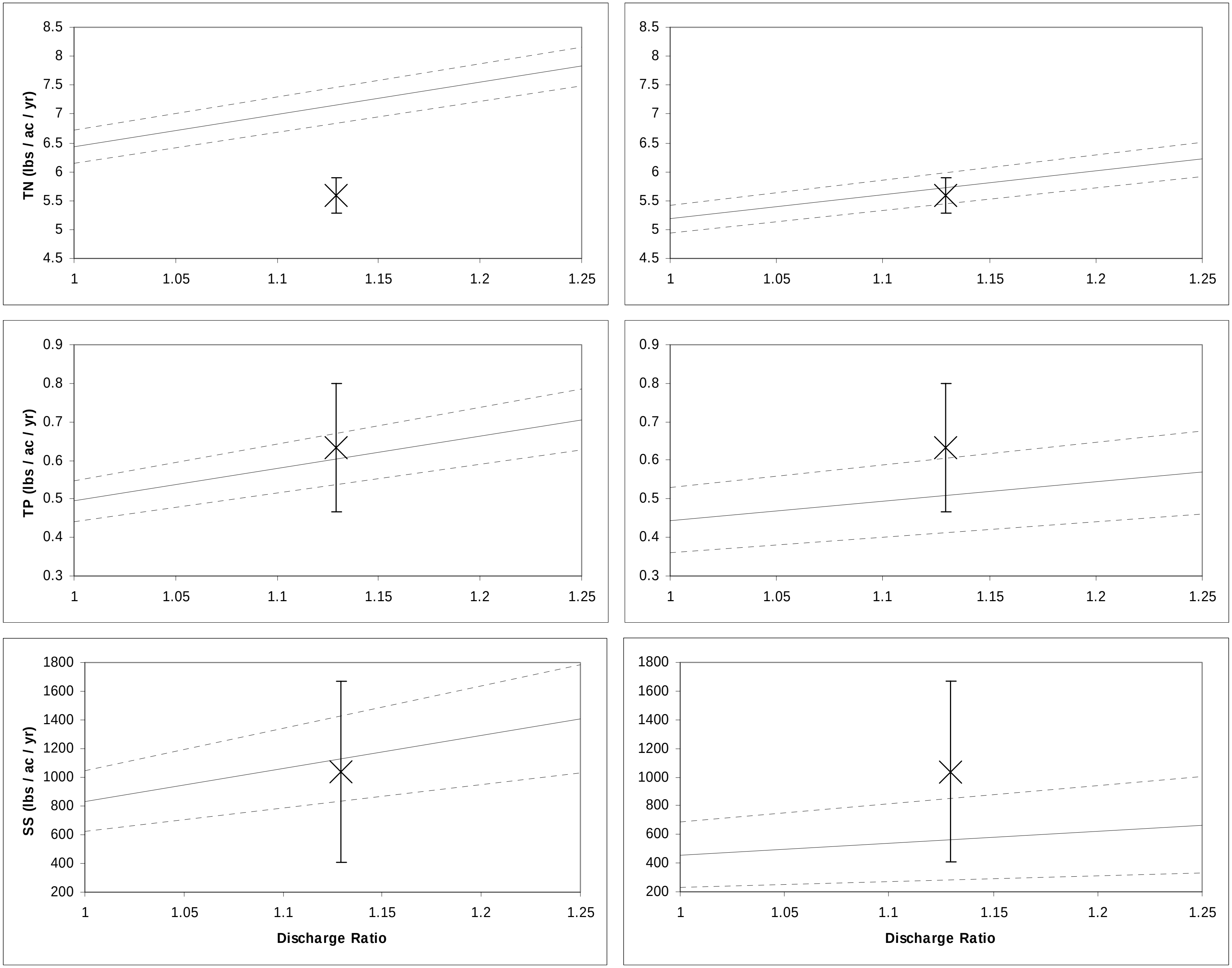

Figure 11. ***Total Nitrogen (TN), Total Phosphorus (TP), and Suspended-Sediment (SS) Yields, Susquehanna River at Towanda, Pa., 2005 Yield Compared to 1989-1996 Baseline (left) and Compared to 1997-2004 (right)***

Susquehanna River at Danville, Pa.

The baselines for TN, TP, and SS for the Susquehanna River at Danville are shown in Figures 12 and 13 with the 2005 annual yield. Actual 2005 and baseline yields are listed in Table 27 along with the discharge ratio. Best-fit lines were drawn through the data sets using the following equations:

Where x = water-discharge ratio and R^2 = correlation coefficient

1985-1989 Baselines;

<u>Total Nitrogen (TN)</u>

TN Yield = 7.8576x - 0.2294 $R^2 = 0.8499$

<u>Total Phosphorus (TP)</u>

TP Yield = 0.7126x - 0.1582 $R^2 = 0.9504$

<u>Suspended Sediment (SS)</u>

SS Yield = 750.23x - 353.67 $R^2 = 0.9503$

1985-1994 Baselines;

<u>Total Nitrogen (TN)</u>

TN Yield = 6.3883x + 0.8479 $R^2 = 0.8478$

<u>Total Phosphorus (TP)</u>

TP Yield = 0.5451x - 0.0669 $R^2 = 0.6798$

<u>Suspended Sediment (SS)</u>

SS Yield = 944.86x - 536.86 $R^2 = 0.6518$

1995-2004 Baselines;

<u>Total Nitrogen (TN)</u>

TN Yield = 4.7736x + 0.8011 $R^2 = 0.8800$

<u>Total Phosphorus (TP)</u>

TP Yield = 0.6863x - 0.2359 $R^2 = 0.7991$

<u>Suspended Sediment (SS)</u>

SS Yield = 805.91x - 451.21 $R^2 = 0.6930$

Table 27. Comparison of 2005 Total Nitrogen, Total Phosphorous, and Suspended Sediment Yields with Baseline Yields at Danville, Pa.

Parameter	Discharge Ratio	1985 – 1989 Baseline lb/ac/yr	1985 - 1994 Baseline lb/ac/yr	1995 - 2004 Baseline lb/ac/yr	2005 lb/ac/yr
TN	1.15	8.81	8.19	6.29	5.64
TP	1.15	0.661	0.560	0.553	0.723
SS	1.15	400	550	476	617

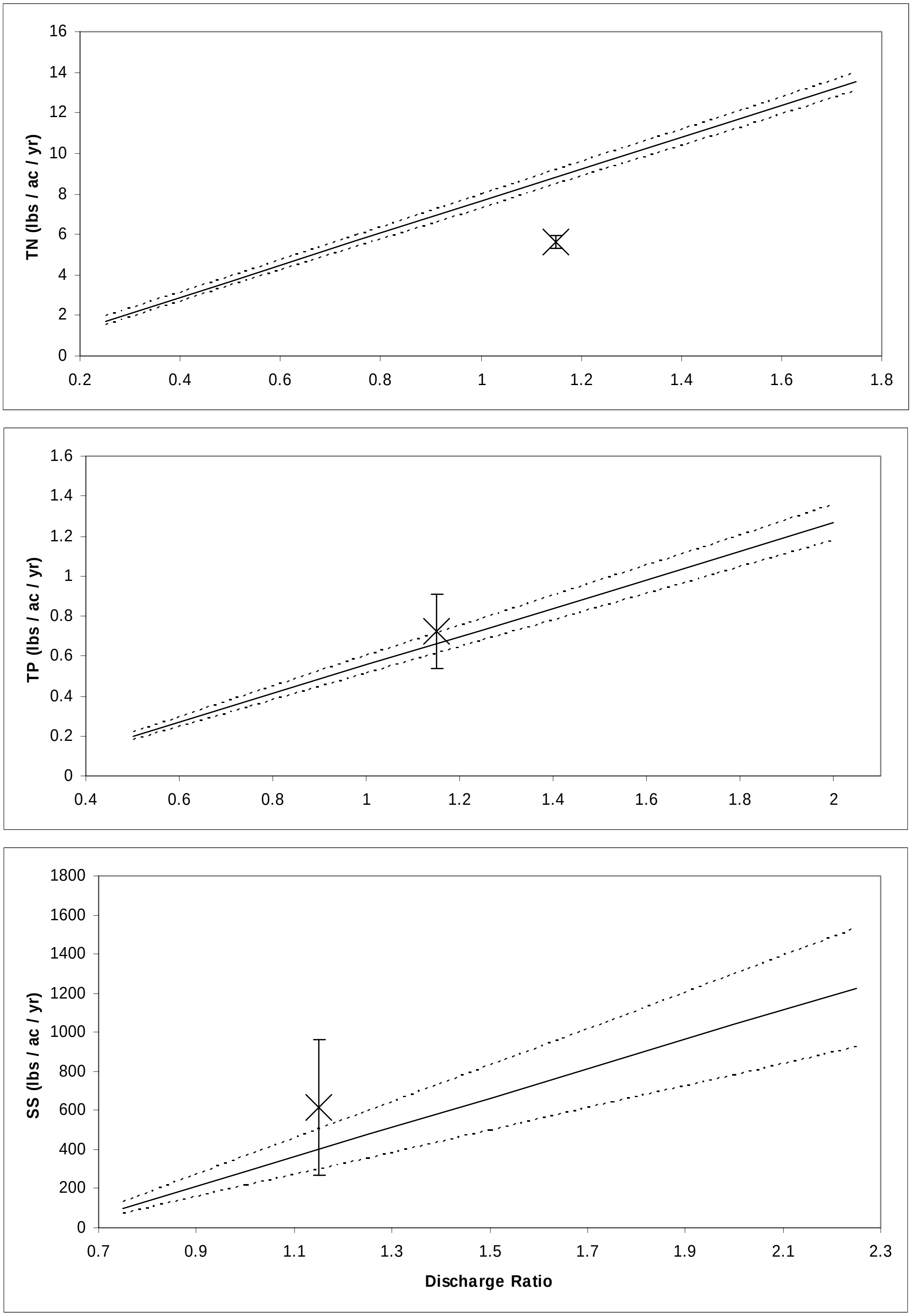

Figure 12. ***Total Nitrogen (TN), Total Phosphorus (TP), and Suspended-Sediment (SS) Yields, Susquehanna River at Danville, Pa., 2005 Yield Compared to 1985-1989 Baseline***

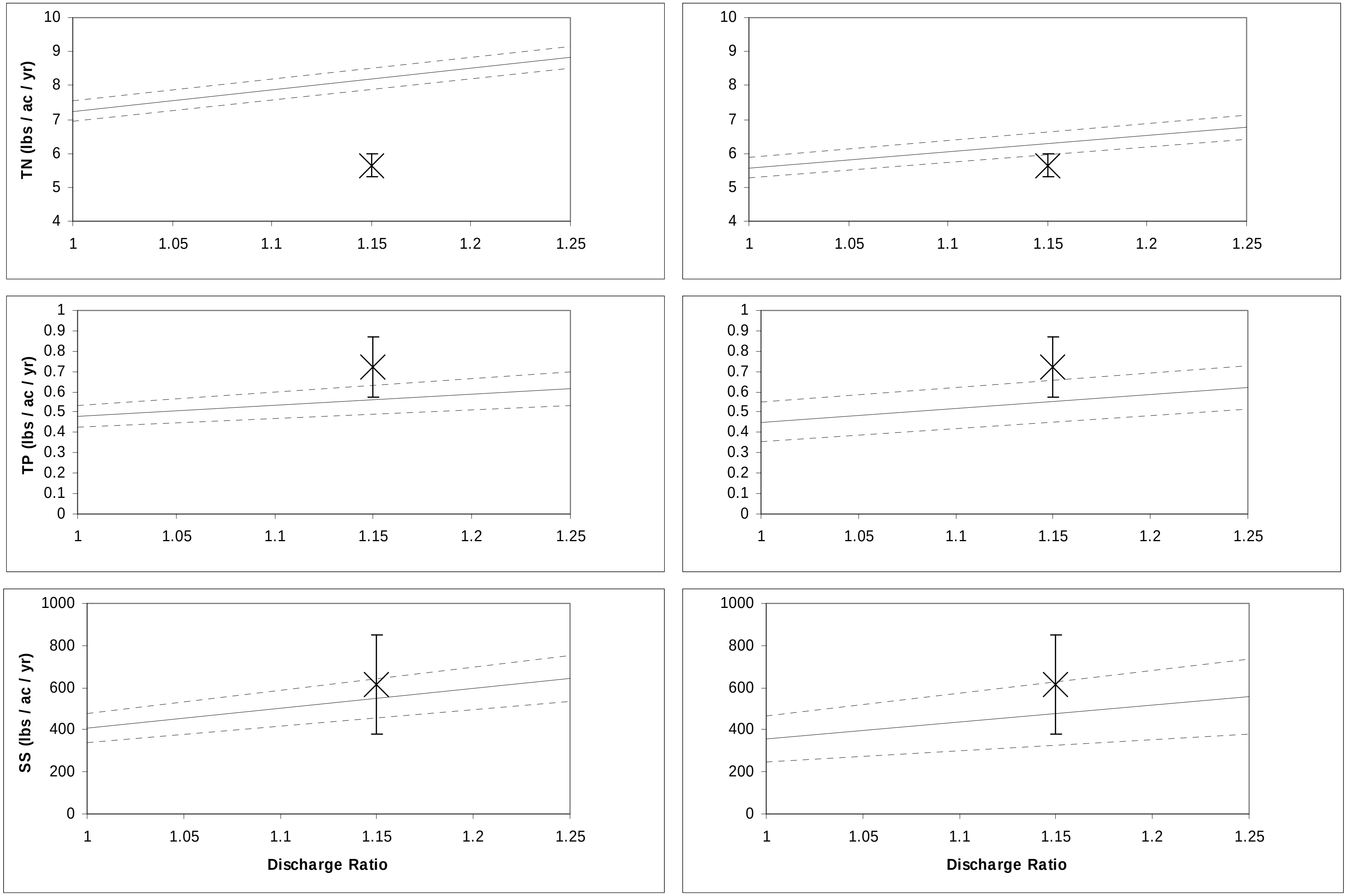

Figure 13. ***Total Nitrogen (TN), Total Phosphorus (TP), and Suspended-Sediment (SS) Yields, Susquehanna River at Danville, Pa., 2005 Yield Compared to 1985-1994 Baseline (left) and Compared to 1995-2004 (right)***

West Branch Susquehanna River at Lewisburg, Pa.

The baselines for TN, TP, and SS for the West Branch Susquehanna River at Lewisburg are shown in Figures 14 and 15 with the 2005 annual yield. Actual 2005 and baseline yields are listed in Table 28 along with the discharge ratio. Best-fit lines were drawn using the following equations:

Where x = water-discharge ratio and R^2 = correlation coefficient

1985-1989 Baselines;

Total Nitrogen (TN)
TN Yield = 7.9538x - 1.436 $R^2 = 0.7274$

Total Phosphorus (TP)
TP Yield = 0.2774x + 0.0253 $R^2 = 0.5306$

Suspended Sediment (SS)
SS Yield = 438x - 243.12 $R^2 = 0.8084$

1985-1994 Baselines;

Total Nitrogen (TN)
TN Yield = 5.3007x + 0.6364 $R^2 = 0.7767$

Total Phosphorus (TP)
TP Yield = 0.3379x - 0.0554 $R^2 = 0.6224$

Suspended Sediment (SS)
SS Yield = 612.83x - 404.09 $R^2 = 0.7005$

1995-2004 Baselines;

Total Nitrogen (TN)
TN Yield = 5.6034x - 0.4074 $R^2 = 0.9498$

Total Phosphorus (TP)
TP Yield = 0.426x - 0.1387 $R^2 = 0.7968$

Suspended Sediment (SS)
SS Yield = 462.12x - 227.23 $R^2 = 0.3436$

Table 28. Comparison of 2005 Total Nitrogen, Total Phosphorus, and Suspended-Sediment Yields With Baseline Yields at Lewisburg, Pa.

Parameter	Discharge Ratio	1985 – 1989 Baseline lb/ac/yr	1985 - 1994 Baseline lb/ac/yr	1995 - 2004 Baseline lb/ac/yr	2005 lb/ac/yr
TN	0.95	6.09	5.65	4.90	4.83
TP	0.95	0.288	0.264	0.264	0.285
SS	0.95	171	175	210	122

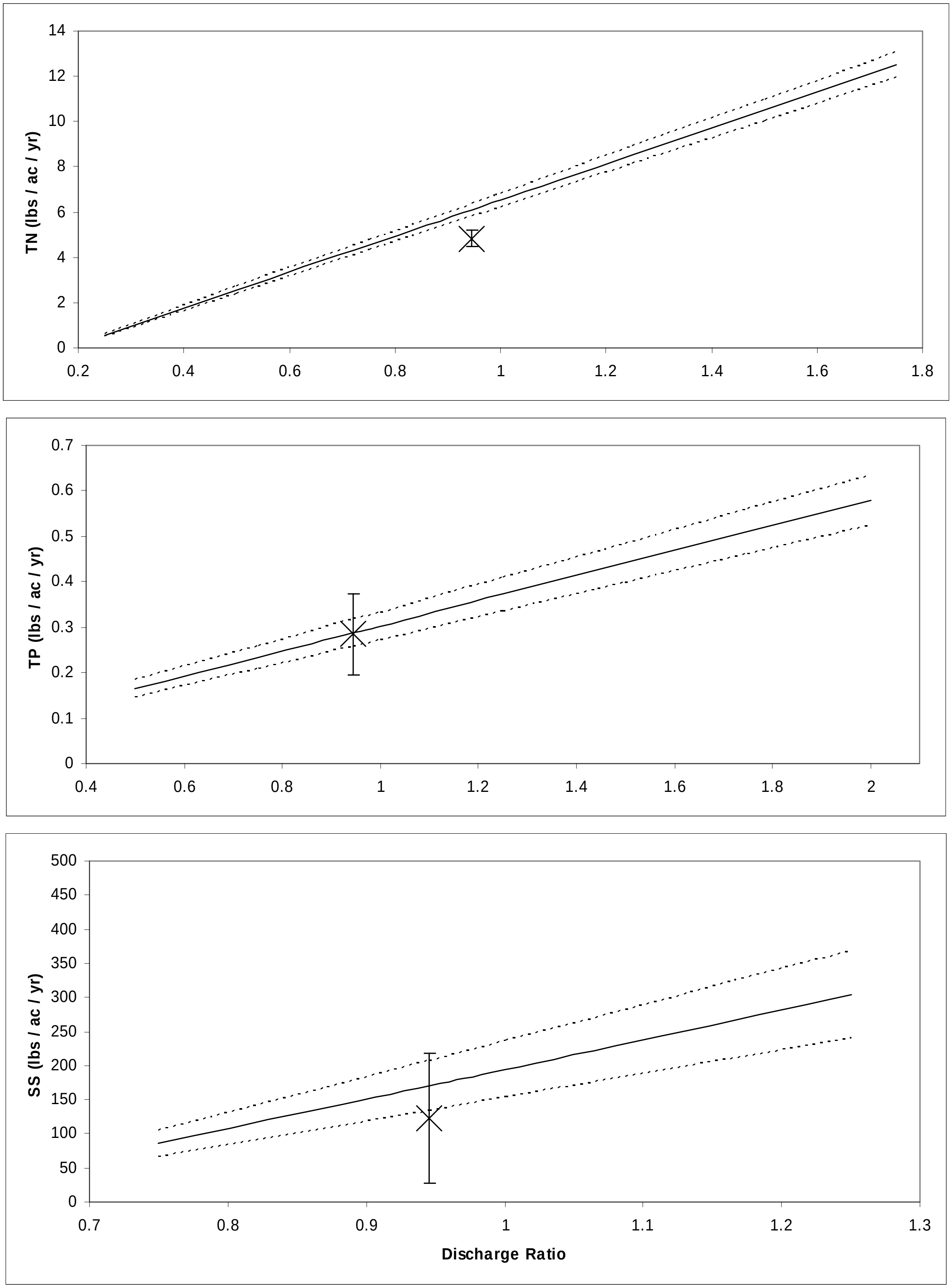

Figure 14. ***Total Nitrogen (TN), Total Phosphorus (TP), and Suspended-Sediment (SS) Yields, West Branch Susquehanna River at Lewisburg, Pa., 2005 Yield Compared to 1985-1989 Baseline***

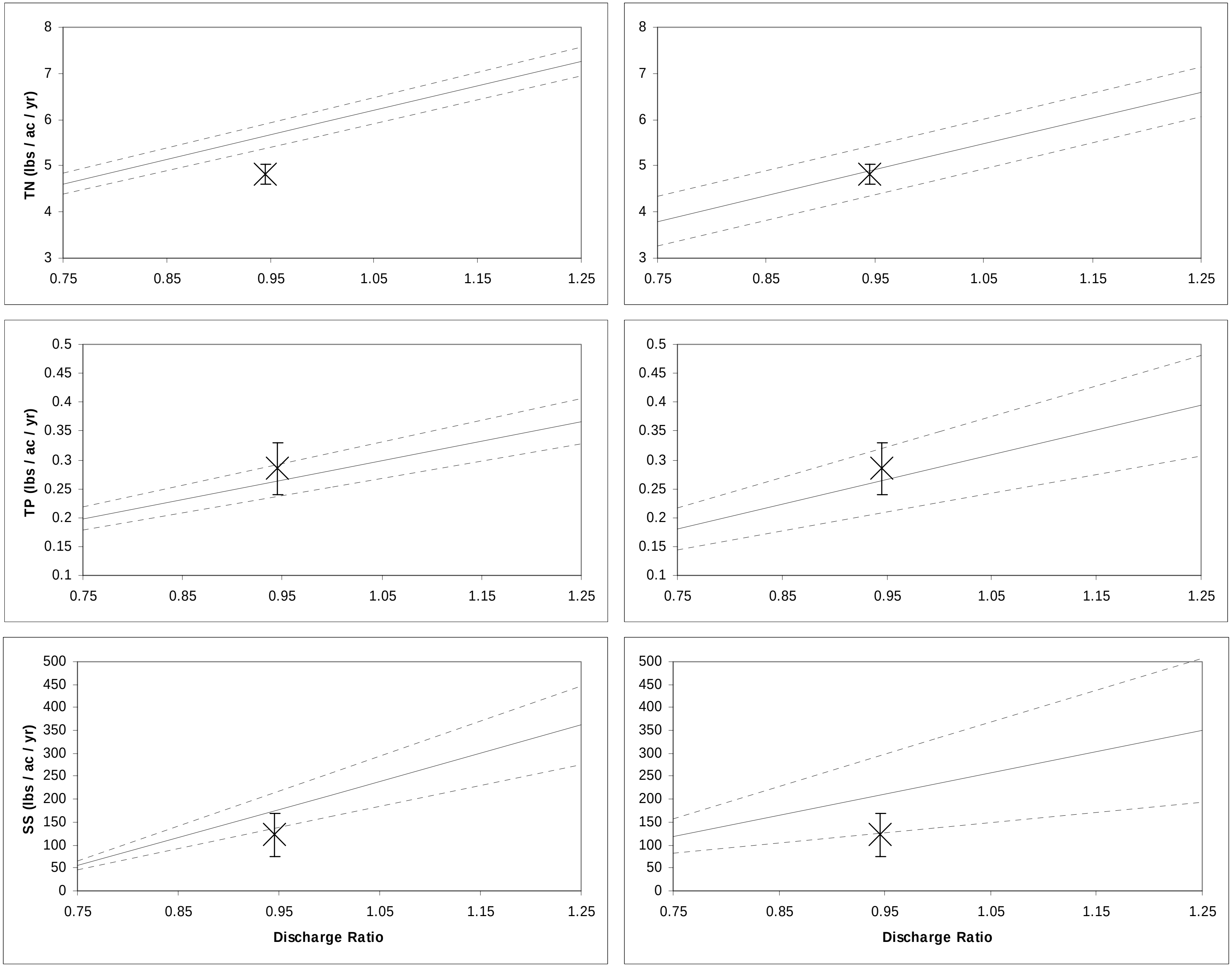

Figure 15. ***Total Nitrogen (TN), Total Phosphorus (TP), and Suspended-Sediment (SS) Yields, West Branch Susquehanna River at Lewisburg, Pa., 2005 Yield Compared to 1985-1994 Baseline (left) and Compared to 1995-2004 (right)***

Juniata River at Newport, Pa.

The baselines for TN, TP, and SS for the Juniata River at Newport are shown in Figures 16 and 17 with the 2005 annual yield. Actual 2005 and baseline yields are listed in Table 29 along with the discharge ratio. Best-fit lines were drawn through the data sets using the following equations:

Where x = water-discharge ratio and R^2 = correlation coefficient

1985-1989 Baselines;

Total Nitrogen (TN)

TN Yield = 8.8923x - 0.3266 $R^2 = 0.7968$

Total Phosphorus (TP)

TP Yield = 0.5069x - 0.0732 $R^2 = 0.9589$

Suspended Sediment (SS)

SS Yield = 561.06x - 293.83 $R^2 = 0.8895$

1985-1994 Baselines;

Total Nitrogen (TN)

TN Yield = 7.8925x + 0.1029 $R^2 = 0.8693$

Total Phosphorus (TP)

TP Yield = 0.4219x - 0.0404 $R^2 = 0.8063$

Suspended Sediment (SS)

SS Yield = 396.15x - 186.71 $R^2 = 0.7502$

1995-2004 Baselines;

Total Nitrogen (TN)

TN Yield = 8.9249x - 0.8592 $R^2 = 0.9794$

Total Phosphorus (TP)

TP Yield = 0.3813x + 0.0144 $R^2 = 0.6246$

Suspended Sediment (SS)

SS Yield = 363.42x - 98.515 $R^2 = 0.8376$

Table 29. Comparison of 2005 Total Nitrogen, Total Phosphorous, and Suspended Sediment Yields With Baseline Yields at Newport, Pa.

Parameter	Discharge Ratio	1985 – 1989 Baseline lb/ac/yr	1985 - 1994 Baseline lb/ac/yr	1995 - 2004 Baseline lb/ac/yr	2005 lb/ac/yr
TN	0.91	7.76	7.28	7.26	7.45
TP	0.91	0.388	0.343	0.361	0.228
SS	0.91	217	174	232	126

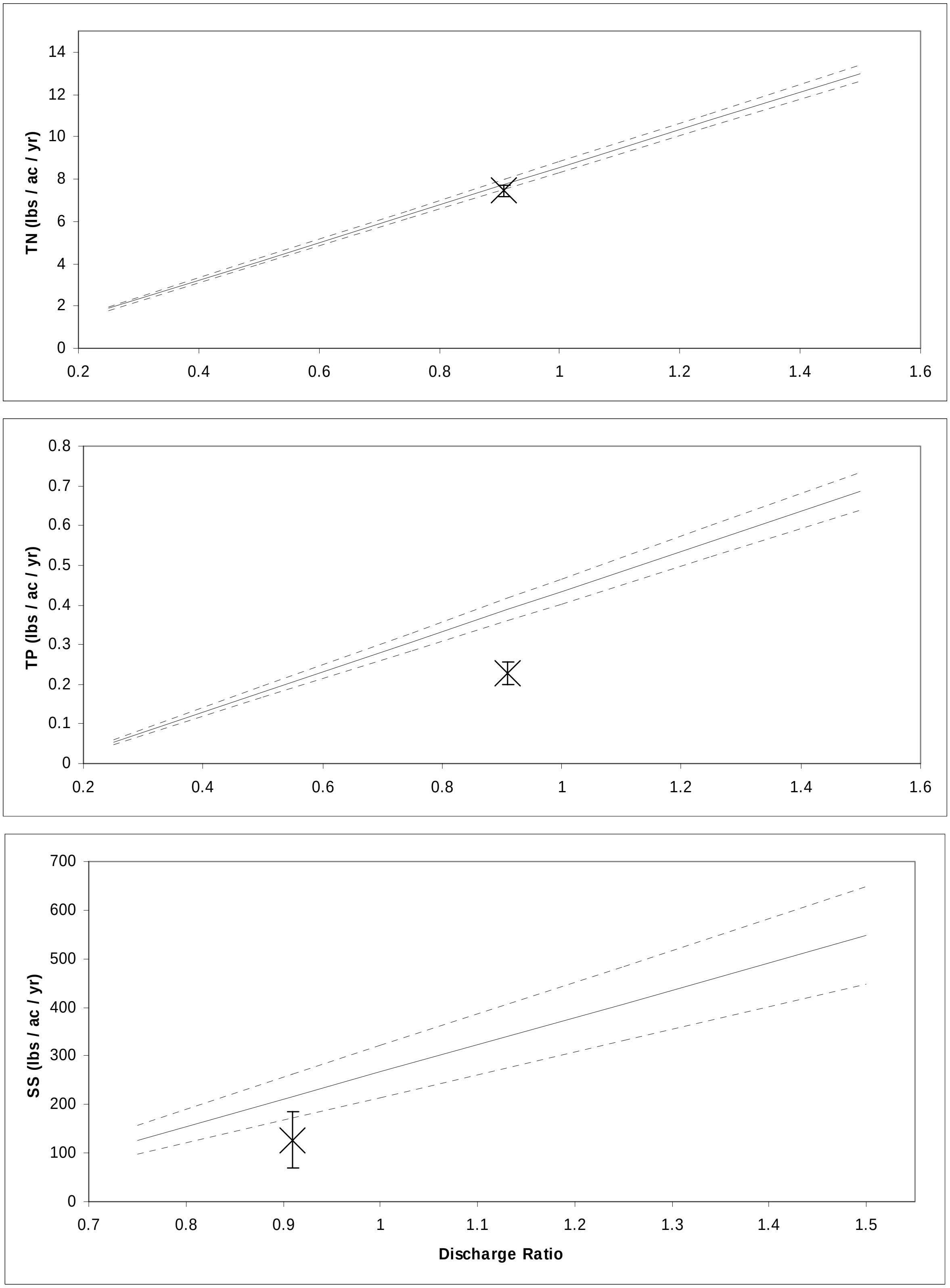

Figure 16. ***Total Nitrogen (TN), Total Phosphorus (TP), and Suspended-Sediment (SS) Yields, Juniata River at Newport, Pa., 2005 Yield Compared to 1985-1989 Baseline***

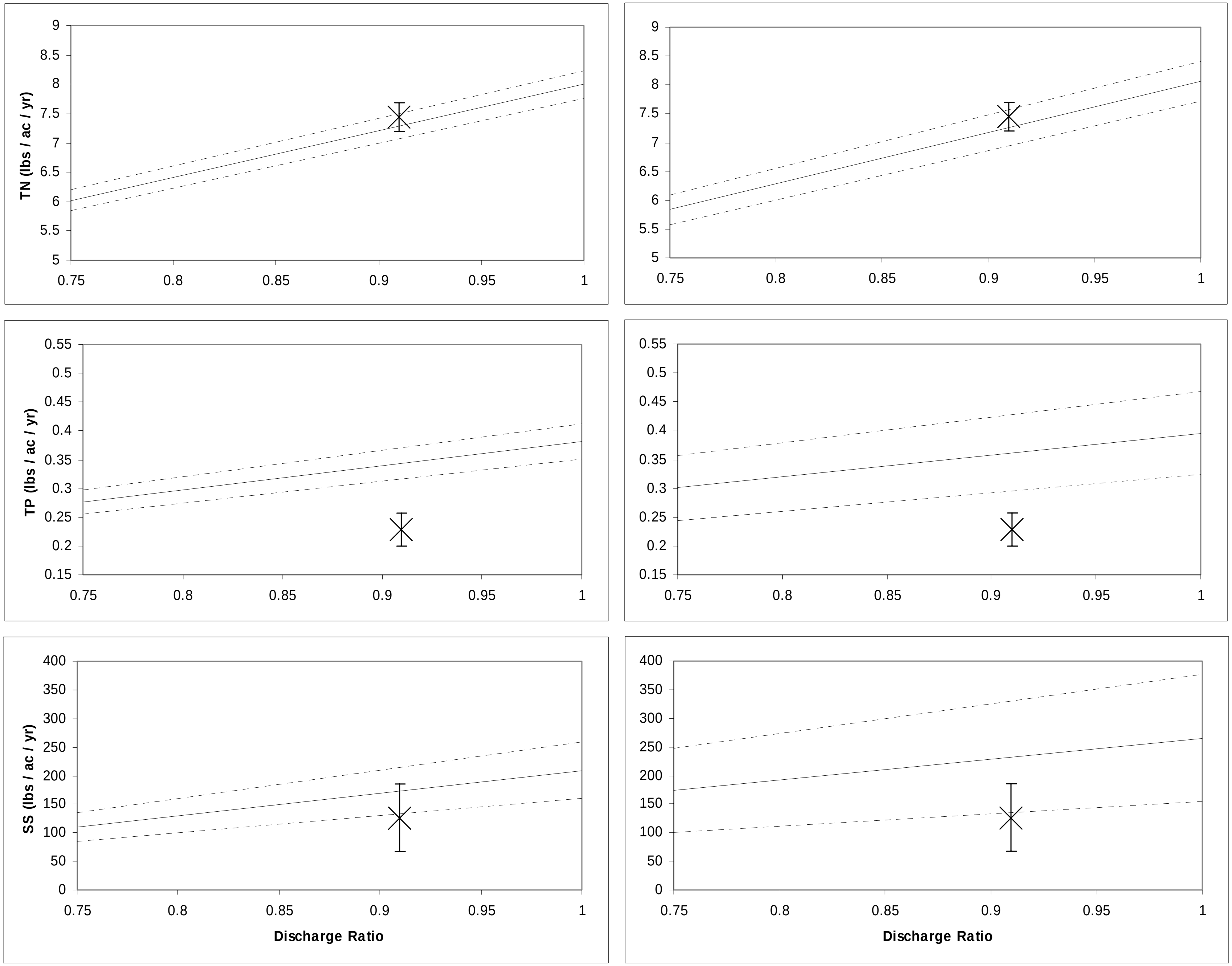

Figure 17. Total Nitrogen (TN), Total Phosphorus (TP), and Suspended-Sediment (SS) Yields, Juniata River at Newport, Pa., 2005 Yield Compared to 1985-1994 Baseline (left) and Compared to 1995-2004 (right)

Susquehanna River at Marietta, Pa.

The baselines for TN, TP, and SS for the Susquehanna River at Marietta are shown in Figures 18 and 19 with the 2005 annual yield. Actual 2005 and baseline yields are listed in Table 30 along with the discharge ratio. Best-fit lines were drawn through the data sets using the following equations:

Where x = water-discharge ratio and R^2 = correlation coefficient

1987-1991 Baselines;

Total Nitrogen (TN)

TN Yield = 9.4692x - 0.6063 $R^2 = 0.9897$

Total Phosphorus (TP)

TP Yield = 0.5386x - 0.0693 $R^2 = 0.9159$

Suspended Sediment (SS)

SS Yield = 488.92x - 143.49 $R^2 = 0.6409$

1987-1995 Baselines;

Total Nitrogen (TN)

TN Yield = 8.6008x - 0.1443 $R^2 = 0.9631$

Total Phosphorus (TP)

TP Yield = 0.6978x - 0.2208 $R^2 = 0.8983$

Suspended Sediment (SS)

SS Yield = 704.31x - 340.17 $R^2 = 0.8186$

1996-2004 Baselines;

Total Nitrogen (TN)

TN Yield = 7.941x - 0.3542 $R^2 = 0.9944$

Total Phosphorus (TP)

TP Yield = 0.7679x - 0.1963 $R^2 = 0.9412$

Suspended Sediment (SS)

SS Yield = 979.39x - 511.23 $R^2 = 0.7255$

Table 30. Comparison of 2005 Total Nitrogen, Total Phosphorous, and Suspended Sediment Yields With Baseline Yields at Marietta, Pa.

Parameter	Discharge Ratio	1987 – 1991 Baseline lb/ac/yr	1987 - 1995 Baseline lb/ac/yr	1996 - 2004 Baseline lb/ac/yr	2005 lb/ac/yr
TN	1.05	9.36	8.90	8.00	8.34
TP	1.05	0.498	0.514	0.612	0.470
SS	1.05	371	401	520	333

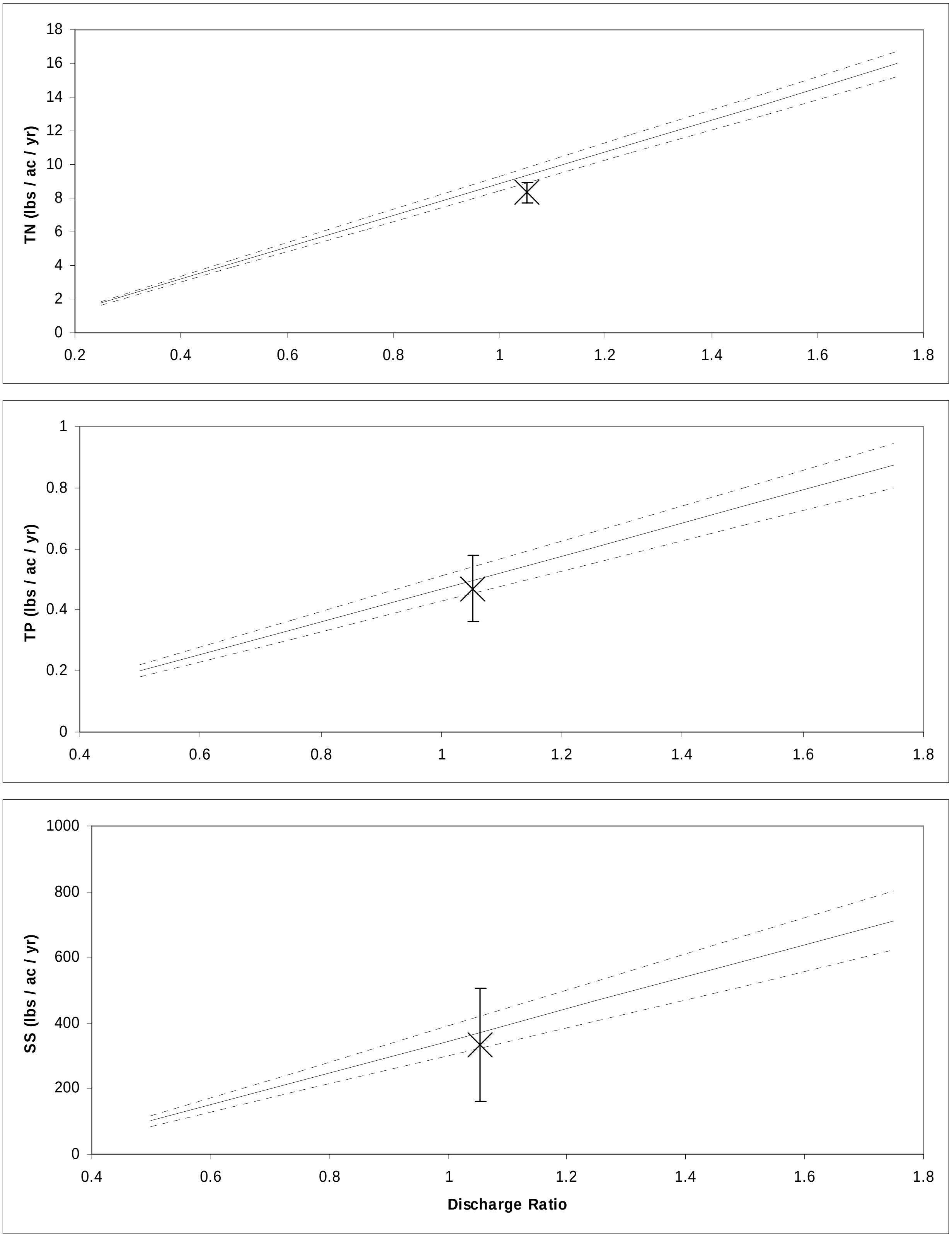

Figure 18. Total Nitrogen (TN), Total Phosphorus (TP), and Suspended-Sediment (SS) Yields, Susquehanna River at Marietta, Pa., 2005 Yield Compared to 1987-1991 Baseline

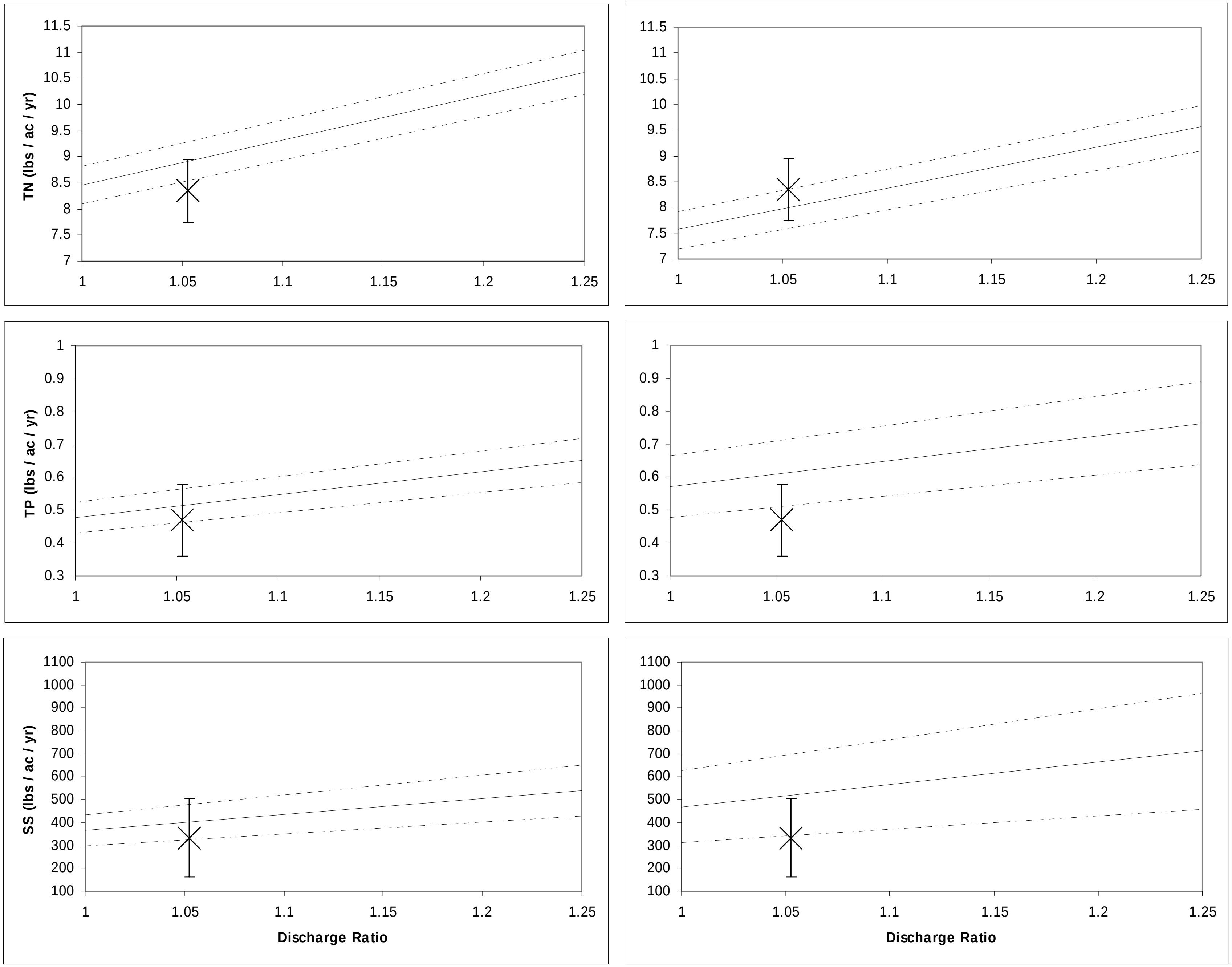

Figure 19. Total Nitrogen (TN), Total Phosphorus (TP), and Suspended-Sediment (SS) Yields, Susquehanna River at Marietta, Pa., 2005 Yield Compared to 1987-1995 Baseline (left) and Compared to 1996-2004 (right)

Conestoga River at Conestoga, Pa.

The baselines for TN, TP, and SS for the Conestoga River at Conestoga are shown in Figures 20 and 21 with the 2005 annual yield. Actual 2005 and baseline yields are listed in Table 31 along with the discharge ratio. Best-fit lines were drawn through the data sets using the following equations:

Where x = water-discharge ratio and R^2 = correlation coefficient

1985-1989 Baseline;

Total Nitrogen (TN)
TN Yield = 29.91x + 7.087 $R^2 = 0.9752$

Total Phosphorus (TP)
TP Yield = 2.6126x + 0.0672 $R^2 = 0.8461$

Suspended Sediment (SS)
SS Yield = 2976.9x - 1309.3 $R^2 = 0.6957$

1985-1994 Baselines;

Total Nitrogen (TN)
TN Yield = 32.879x + 3.3409 $R^2 = 0.9763$

Total Phosphorus (TP)
TP Yield = 3.3094x - 0.9592 $R^2 = 0.7652$

Suspended Sediment (SS)
SS Yield = 2908.8x - 1522.2 $R^2 = 0.7499$

1995-2004 Baselines;

Total Nitrogen (TN)
TN Yield = 33.045x + 0.8061 $R^2 = 0.9920$

Total Phosphorus (TP)
TP Yield = 3.0592x - 0.5039 $R^2 = 0.7332$

Suspended Sediment (SS)
SS Yield = 2037.9x - 721.39 $R^2 = 0.5469$

Table 31. Comparison of 2005 Total Nitrogen, Total Phosphorous, and Suspended Sediment Yields With Baseline Yields at Conestoga, Pa.

Parameter	Discharge Ratio	1985 – 1989 Baseline lb/ac/yr	1985 - 1994 Baseline lb/ac/yr	1995 - 2004 Baseline lb/ac/yr	2005 lb/ac/yr
TN	1.15	41.39	41.05	38.71	39.28
TP	1.15	3.064	2.837	3.005	1.840
SS	1.15	2,105	1,814	1,616	949

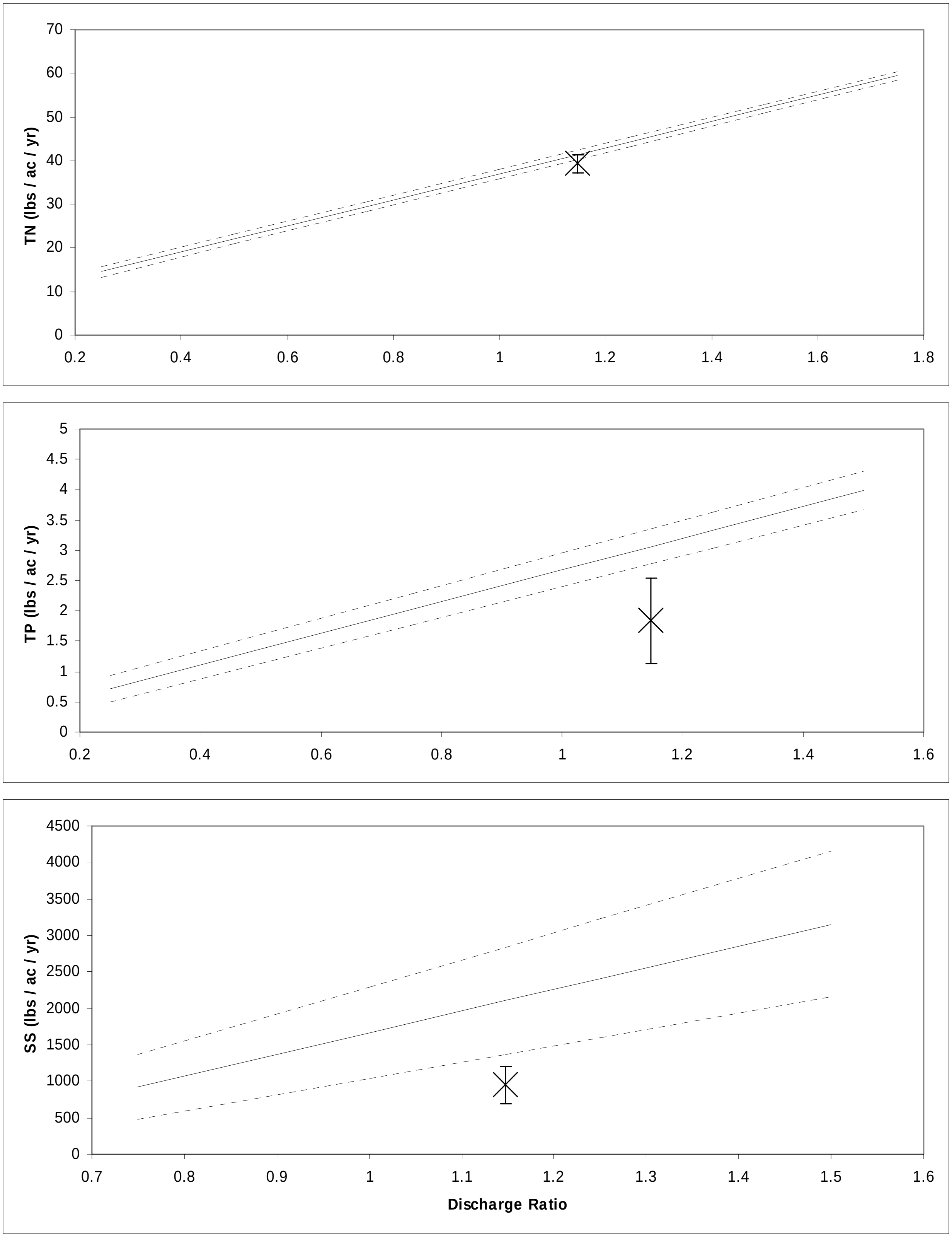

Figure 20. ***Total Nitrogen (TN), Total Phosphorus (TP), and Suspended-Sediment (SS) Yields, Conestoga River at Conestoga, Pa., 2005 Yield Compared to 1985-1989 Baseline***

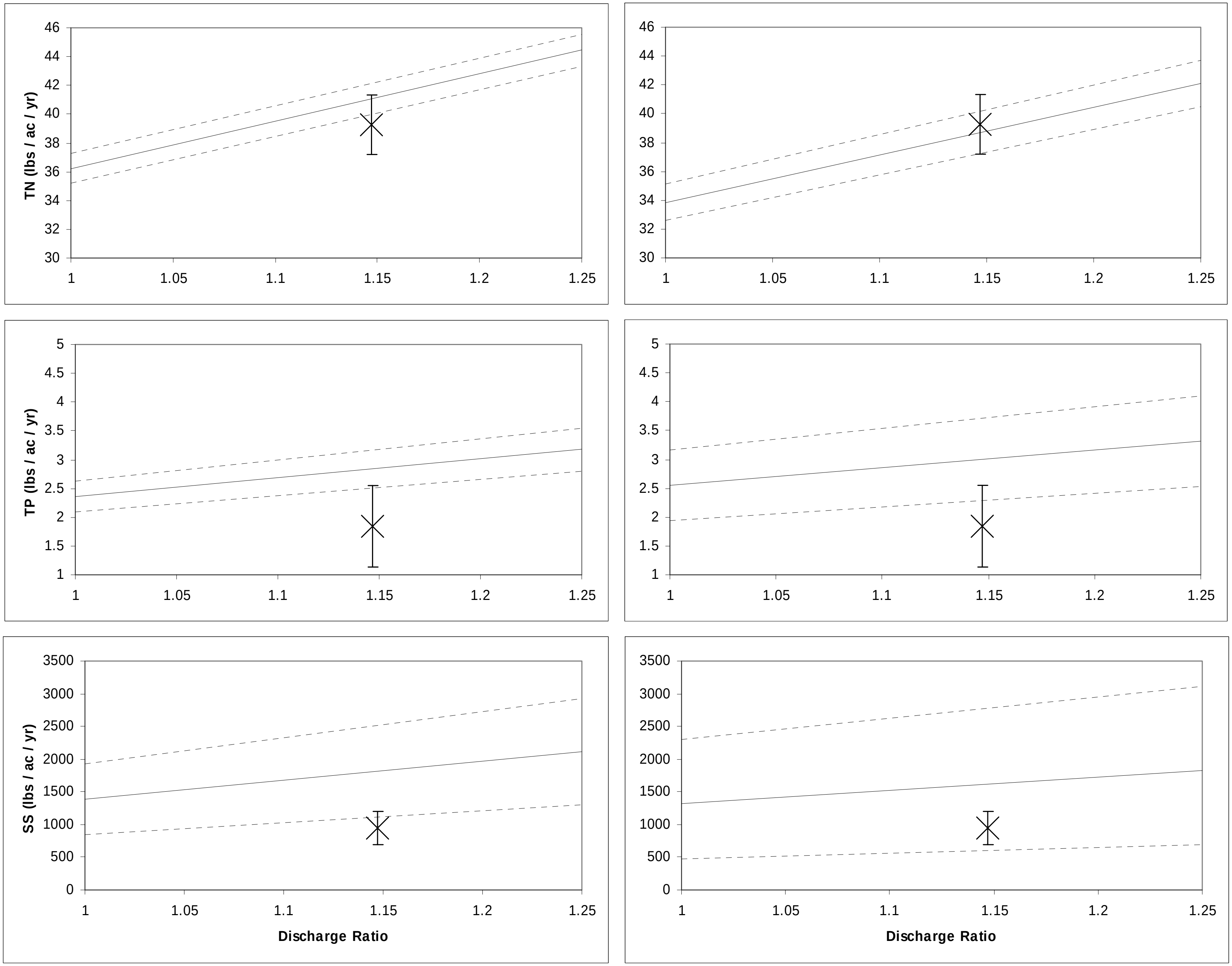

Figure 21. Total Nitrogen (TN), Total Phosphorus (TP), and Suspended-Sediment (SS) Yields, Conestoga River at Conestoga, Pa., 2005 Yield Compared to 1985-1994 Baseline (left) and Compared to 1995-2004 (right)

DISCHARGE, NUTRIENT, AND SUSPENDED-SEDIMENT TRENDS

Trend analyses of water quality and flow data collected at the six Group A monitoring sites were completed for the period January 1985 through December 2005. FAC trends were estimated using the USGS 7-parameter, log-linear regression model (ESTIMATOR) developed by Cohn and others (1989) and described in Langland and others (1999). This 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. Trends in FAC are directly taken from ESTIMATOR output. Trends in flow are calculated by using the Seasonal Kendall (SK) trend test within S-Plus, including the USGS ESTREND library addition (Shertz and others, 1991). Results were reported for monthly mean discharge (FLOW) and FAC.

Trends in FLOW indicate the 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).

Trend results for each monitoring site are presented in Tables 32 through 37. Each table lists the results for flow, the various nitrogen and phosphorus species, TOC, and SS. The level of significance is set at the p-value of 0.05 for FAC (Langland and others, 1999). The magnitude of the slope incorporates a confidence interval and is reported as a range (minimum and maximum). The slope direction is reported as not significant (NS) or, when significant, as improving or degrading. When a time series had greater than 20 percent of its observations below the method detection level (BMDL), a trend analysis could not be completed. Additional results from USGS are listed for TN, TNOx, TP, and SS for all sites. Due to model related issues only, the USGS trend value is given for SS at Conestoga.

Table 32. Trend Statistics for the Susquehanna River at Towanda, Pa., January 1989 Through December 2005

Parameter	STORET Code	Time Series	Slope	P-Value	Slope Magnitude (%)			Trend Direction
					Minimum	Trend	Maximum	
FLOW	60	SK	66.208	0.519	-	-	-	NS
TN	600	FAC		<0.0001	-39	-35	-31	IMPROVING
*TN	600	*FAC	-0.4586	<0.0001	-41	-37	-32	IMPROVING
DN	602	FAC		<0.0001	-35	-31	-26	IMPROVING
TON	605	FAC		<0.0001	-54	-46	-38	IMPROVING
DON	607	FAC		<0.0001	-41	-31	-18	IMPROVING
DNH_3	608	FAC		0.088	-27	-13	2	NS
TNH_3	610	FAC		<0.0001	-51	-41	-29	IMPROVING
DKN	623	FAC		<0.0001	-51	-44	-34	IMPROVING
TKN	625	FAC		<0.0001	-50	-43	-36	IMPROVING
TNOx	630	FAC		<0.0001	-37	-31	-25	IMPROVING
DNOx	631	FAC		<0.0001	-37	-32	-26	IMPROVING
*DNOx	631	*FAC	-0.4252	<0.0001	-47	-35	-20	IMPROVING
TP	665	FAC		0.0457	-26	-14	0	IMPROVING
*TP	665	*FAC	-0.3862	<0.0001	-42	-32	-21	IMPROVING
DP	666	FAC		0.0003	-34	-24	-12	IMPROVING
DOP	671	FAC		<0.0001	376	500	658	DEGRADING
TOC	680	FAC		0.0001	-15	-10	-5	IMPROVING
SS	80154	FAC		0.0029	-46	-31	-12	IMPROVING
*SS	80154	*FAC	-0.2431	0.0447	-38	-21	-0.01	IMPROVING

* These results were reported by USGS after additional analysis

Table 33. Trend Statistics for the Susquehanna River at Danville, Pa., January 1985 Through December 2005

Parameter	STORET Code	Time Series/Test	Slope	P-Value	Slope Magnitude (%)			Trend Direction
					Minimum	Trend	Maximum	
FLOW	60	SK	134.434	0.265	-	-	-	NS
TN	600	FAC		<0.0001	-45	-41	-37	IMPROVING
*TN	600	*FAC	-0.464	<0.0001	-41	-37	-33	IMPROVING
DN	602	FAC		<0.0001	-38	-34	-29	IMPROVING
TON	605	FAC		<0.0001	-60	-54	-47	IMPROVING
DON	607	FAC		<0.0001	-51	-44	-36	IMPROVING
DNH_3	608	FAC		<0.0001	-48	-38	-27	IMPROVING
TNH_3	610	FAC		<0.0001	-62	-55	-46	BMDL
DKN	623	FAC		<0.0001	-57	-50	-43	IMPROVING
TKN	625	FAC		<0.0001	-58	-53	-47	IMPROVING
TNOx	630	FAC		<0.0001	-35	-30	-24	IMPROVING
DNOx	631	FAC		<0.0001	-36	-30	-35	IMPROVING
*DNOx	631	*FAC	-0.3578	<0.0001	-38	-30	-21	IMPROVING
TP	665	FAC		<0.0001	-42	-33	-22	IMPROVING
*TP	665	*FAC	-0.4942	<0.0001	-47	-39	-30	IMPROVING
DP	666	FAC		0.0005	-35	-24	-11	IMPROVING
DOP	671	FAC		<0.0001	467	619	813	DEGRADING
TOC	680	FAC		<0.0001	-26	-22	-17	IMPROVING
SS	80154	FAC		<0.0001	-68	-60	-51	IMPROVING
*SS	80154	*FAC	-0.54	<0.0001	-51	-42	-31	IMPROVING

* These results were reported by USGS after additional analysis

Table 34. Trend Statistics for the West Branch Susquehanna River at Lewisburg, Pa., January 1985 Through December 2005

Parameter	STORET Code	Time Series	Slope	P-Value	Slope Magnitude (%)			Trend Direction
					Minimum	Trend	Maximum	
FLOW	60	SK	13.932	0.908	-	-	-	NS
TN	600	FAC		<0.0001	-33	-28	-23	IMPROVING
*TN	600	*FAC	-0.2438	<0.0001	-27	-22	-16	IMPROVING
DN	602	FAC		<0.0001	-28	-23	-18	IMPROVING
TON	605	FAC		<0.0001	-61	-54	-45	IMPROVING
DON	607	FAC		<0.0001	-53	-45	-36	IMPROVING
DNH_3	608	FAC		0.3639	-21	-7	9	NS
TNH_3	610	FAC		<0.0001	-47	-35	-21	BMDL
DKN	623	FAC		<0.0001	-59	-51	-42	BMDL
TKN	625	FAC		<0.0001	-57	-49	-40	IMPROVING
TNOx	630	FAC		0.0167	-14	-8	-2	IMPROVING
DNOx	631	FAC		0.0195	-14	-8	-1	IMPROVING
*DNOx	631	*FAC	0.0075	0.8502	-7	0.4	9	NS
TP	665	FAC		<0.0001	-46	-35	-22	IMPROVING
*TP	665	*FAC	-0.6246	<0.0001	-55	-46	-36	IMPROVING
DP	666	FAC		<0.0001	-55	-47	-38	IMPROVING
DOP	671	FAC		<0.0001	307	432	595	BMDL
TOC	680	FAC		0.8116	-7	1	10	NS
SS	80154	FAC		<0.0001	-73	-64	-53	BMDL
*SS	80154	*FAC	-0.0864	0.4518	-27	-8	15	NS

* These results were reported by USGS after additional analysis

Table 35. Trend Statistics for the Juniata River at Newport, Pa., January 1985 Through December 2005

Parameter	STORET Code	Time Series	Slope	P-Value	Slope Magnitude (%)			Trend Direction
					Minimum	Trend	Maximum	
FLOW	60	SK	20.264	0.461	-	-	-	NS
TN	600	FAC		0.0001	-14	-9	-5	IMPROVING
*TN	600	*FAC	-0.1102	0.0001	-15	-11	-6	IMPROVING
DN	602	FAC		0.1073	-8	-4	1	NS
TON	605	FAC		<0.0001	-53	-45	-36	IMPROVING
DON	607	FAC		<0.0001	-48	-40	-30	IMPROVING
DNH_3	608	FAC		0.001	-36	-24	-10	IMPROVING
TNH_3	610	FAC		<0.0001	-52	-42	-29	BMDL
DKN	623	FAC		<0.0001	-57	-49	-40	BMDL
TKN	625	FAC		<0.0001	-49	-41	-32	IMPROVING
TNOx	630	FAC		0.032	0	6	12	DEGRADING
DNOx	631	FAC		0.0065	2	7	13	DEGRADING
*DNOx	631	*FAC	0.0973	0.0369	0	10	20	DEGRADING
TP	665	FAC		<0.0001	-40	-30	-19	IMPROVING
*TP	665	*FAC	-0.461	<0.0001	-47	-38	-26	IMPROVING
DP	666	FAC		0.0001	-37	-26	-14	IMPROVING
DOP	671	FAC		<0.0001	197	286	403	DEGRADING
TOC	680	FAC		<0.0001	-31	-25	-18	IMPROVING
SS	80154	FAC		0.0015	-46	-32	-14	IMPROVING
*SS	80154	*FAC	-0.5778	0.0002	-59	-45	-25	IMPROVING

* These results were reported by USGS after additional analysis

Table 36. Trend Statistics for the Susquehanna River at Marietta, Pa., January 1987 Through December 2005

Parameter	STORET Code	Time Series	Slope	P-Value	Slope Magnitude (%)			Trend Direction
					Minimum	Trend	Maximum	
FLOW	60	SK	-85.645	0.7511	-	-	-	NS
TN	600	FAC		<0.0001	-28	-23	-17	IMPROVING
*TN	600	*FAC	-0.1649	<0.0001	-21	-15	-9	IMPROVING
DN	602	FAC		<0.0001	-19	-13	-7	IMPROVING
TON	605	FAC		<0.0001	-48	-39	-28	IMPROVING
DON	607	FAC		0.2436	-28	-11	9	NS
DNH_3	608	FAC		0.0626	-27	-14	1	NS
TNH_3	610	FAC		<0.0001	-43	-32	-18	IMPROVING
DKN	623	FAC		<0.0001	-44	-35	-25	IMPROVING
TKN	625	FAC		<0.0001	-48	-41	-32	IMPROVING
TNOx	630	FAC		0.0187	-16	-9	-2	IMPROVING
DNOx	631	FAC		0.0186	-16	-9	-1	IMPROVING
*DNOx	631	*FAC	0.0451	0.5205	-9	5	10	NS
TP	665	FAC		0.1802	-21	-9	5	NS
*TP	665	*FAC	-0.2788	<0.0001	-34	-25	-14	IMPROVING
DP	666	FAC		0.2883	-20	-7	7	NS
DOP	671	FAC		<0.0001	923	1218	1598	DEGRADING
TOC	680	FAC		<0.0001	-18	-12	-7	IMPROVING
SS	80154	FAC		0.0001	-48	-35	-20	IMPROVING
*SS	80154	*FAC	-0.3225	0.0017	-41	-28	-11	IMPROVING

* These results were reported by USGS after additional analysis

Table 37. Trend Statistics for the Conestoga River at Conestoga, Pa., January 1985 Through December 2005

Parameter	STORET Code	Time Series	Slope	P-Value	Slope Magnitude (%)			Trend Direction
					Minimum	Trend	Maximum	
FLOW	60	SK	3.7705	0.508	-	-	-	NS
TN	600	FAC		<0.0001	-22	-18	-14	IMPROVING
*TN	600	*FAC	-0.2069	<0.0001	-22	-19	-15	IMPROVING
DN	602	FAC		0.4919	-3	2	6	NS
TON	605	FAC		<0.0001	-50	-43	-35	IMPROVING
DON	607	FAC		0.5953	-9	4	18	NS
DNH_3	608	FAC		<0.0001	-77	-73	-69	IMPROVING
TNH_3	610	FAC		<0.0001	-79	-76	-72	IMPROVING
DKN	623	FAC		<0.0001	-35	-27	-18	IMPROVING
TKN	625	FAC		<0.0001	-56	-50	-44	IMPROVING
TNOx	630	FAC		0.2314	-3	4	10	NS
DNOx	631	FAC		0.0801	-1	6	12	NS
*DNOx	631	*FAC	0.0751	0.055	-0.2	8	16	NS
TP	665	FAC		<0.0001	-48	-41	-33	IMPROVING
*TP	665	*FAC	-0.5665	<0.0001	-50	-43	-36	IMPROVING
DP	666	FAC		<0.0001	-44	-39	-34	IMPROVING
DOP	671	FAC		0.003	-26	-17	-6	IMPROVING
TOC	680	FAC		<0.0001	-51	-47	-42	IMPROVING
SS	80154	FAC		-	-	-	-	-
*SS	80154	*FAC	-0.9426	<0.0001	-69	-60.7	-51.7	IMPROVING

* These results were reported by USGS after additional analysis

DISCUSSION

Precipitation values above the LTM were recorded at all stations during the fall and winter months in 2005. Specifically, precipitation at Towanda was 16.49 inches above the LTM, with the highest rainfall occurring during the fall months and second highest during the winter months. Danville followed the same pattern, with a total of 12.86 inches above the annual LTM. Conestoga was 3.52 inches above the LTM with significant rainfall (7.36 inches above LTM) during the fall months. High precipitation upstream of Towanda, Danville, and Conestoga led to discharges of 112 percent, 115 percent, and 115 percent of the LTM respectively. Newport and Lewisburg both showed discharges lower than their respective LTMs.

Since flow is the most important influence over nutrient and suspended sediment loads, comparing load and flow to the LTM is a good way to find changes in transported load. In making this comparison, the current year's flow divided by the LTM flow is converted to a percentage and compared with the current year's load for a particular constituent divided by the LTM, expressed as a percentage. By comparing percentages of LTMs, the need for units on the values is removed. Thus, a load percentage that is greater than a flow percentage indicates that the increase in constituent load as compared to the LTM is greater than that of the discharge as compared to the LTM.

For example, 2005 average annual discharge at Towanda was 13,230 cfs. Dividing this value by the LTM for annual discharge at Towanda gives 112 percent of the LTM. When doing the same for the TN loads at Towanda during the same time period, it is found that the 2005 TN load was 96.7 percent of the LTM for TN. Thus, although the discharge was higher than the LTM for 2005, the TN was much lower, which indicates possible improvements. This is also apparent when looking at Danville for TN, which shows even greater variance with percent of LTM for discharge at 115 percent and that of TN at 91.1 percent.

In making the above comparison at all sites for TN, reductions were found at all sites except Newport. The same comparison made at Towanda and Danville for TP and SS showed extreme opposite results with percent of LTMs of 132.1 percent and 143.6 percent for TP and 152.9 percent and 143.7 percent for SS, respectively. Using this same approach, increases were found at Lewisburg, Newport, and Marietta for total ammonia. All six sites showed improvements for total organic nitrogen and dissolved nitrate + nitrite. Conestoga recorded substantially higher DON loads at 145 percent of LTM. All other sites were substantially lower than their respective LTMs for DON.

Due to a very high flow event in early April, monthly comparisons of flow, nutrients, and suspended sediment show highs during April for Towanda, Danville, Marietta, and Conestoga, except for TN at Marietta, which was higher during January. Lewisburg and Newport, the most western sites in the watershed, also had high TN values during April, but not as high as during January, when the highest flow, nutrients, and suspended sediment values were recorded for the two sites. When comparing seasonal averages, flow was highest at all sites during the winter. This resulted in the majority of the nutrient and sediment loads being transported during winter, especially at Lewisburg and Newport, which recorded highest loads of all constituents during the winter months. Interestingly, total organic nitrogen, total phosphorus, and suspended sediment all had the highest loads during the spring at Towanda and Danville. Since spring was the time period for the year's highest flow event at Towanda and Danville, this supports the idea that these three parameters were influenced not only by high average flows but more so by single high flow events.

Comparisons with the baselines can be performed in two ways to look for improvements in water quality. The first involves comparing the 2005 yield values to three different baselines. The first baseline uses the first five years of each dataset, the second uses the first half of the dataset, and the third uses the second half of each dataset.

The second comparison is between the first and second half of the datasets and utilizes the entire dataset which reduces any error inherent in using only one year worth of data. Thus, if the baselines created by the second half of the dataset are lower than those created by the first half, there is an indication of improvements.

In comparing 2005 yields to the baselines, Towanda and Danville, showed no substantial improvements when compared to baselines for the second half of each dataset but did show improvements as compared to the first five year and first half of dataset baselines. Comparison of the second half to the first half indicated that concentrations of TN at these sites had been reduced by approximately 2 mg/L. This analysis also indicated major reductions in SS at Towanda. This reduction may not be as dramatic as the plot indicates as the two highest load years for SS (which accounted for 60% of total load for the 8 year period) fell within the first half baseline, skewing the comparison. This same comparison also showed a 2 mg/L reduction at Conestoga. These results indicate that improvements had been made with respect to the earlier years of monitoring, but that, in more recent years, improvements have not been as obvious. Modest improvements are apparent also for TP at these sites, although specific 2005 values were higher than predicted due to the impacts of storms in April. Conestoga, the watershed with the highest percentages of agriculture and urban land uses, showed significant improvements regarding TP and SS.

Although Towanda and Danville both had higher than predicted loads for 2005, all trends for these sites show improving conditions, except DOP, which also was degrading at Newport and Marietta. Additionally, Newport showed degrading trends in TNOx and DNOx. Trends for TN, TP, and SS were improving at all sites, except for TP at Marietta and SS at Lewisburg, which had no significant trends.

When considering one year at a time, it is necessary to look not only at the annual flow but also to pay attention to any single high flow events that may have occurred, as they tend to contribute the most to nutrient and SS loads. Table 38 lists LTM percentages for 1989 through 2005 for flow, TN, TP, and SS at the Susquehanna main stem sites; Towanda, Danville, and Marietta. Q shows the years flow divided by the LTM for all years. Q* shows the highest daily average flow divided by the LTM of each year's high average flow day and is meant to show how the year's highest single flow event compared to those in other years. TN, TP, and SS show the year's load divided by the LTM for all years for that parameter. Of interest is the comparison that can be made between 2005 and 1993. Although values for Towanda and Danville were higher than the LTM for TP and SS during 2005, a comparison to 1993 shows that the 2005 values are not extreme, given the average flow for the year and the daily high event for the year.

Table 39 specifically shows comparisons of April 2005's storm event to other high flow events at Marietta. As a general note, the data indicates that TN may be more dependent upon high average flows, whereas TP and SS appear to be more dependent upon single high flow events. This is seen when comparing years with similar average monthly flows and substantially different sized high flow events. Of interest concerning 2005 is the comparison of the April storm to the storms in March 1998 and May 1989. Both of these storms had lower average monthly flows and high storm flows that were significantly lower than those of the April 2005 storm. Since all of the storms occur during the same time of year, seasonal variation of loads is not an issue. Thus, it would be expected that the April 2005 storm would have the higher loads of TN, TP, and SS. In comparison to the May 1989 storm event, 2005 values for TN, TP, and SS were lower than 1989, despite the substantial difference in flows indicating that there likely have been improvements regarding these parameters. This is also apparent when comparing the TN loads from April of 2005 to March of 1998.

Table 40 compares the results from all analyses using the 2005 data. It is notable that all five ways of analyzing the data showed improvements in TN at Towanda, Danville, and Lewisburg. Towanda and Danville showed degradations for TP and SS for most analyses except for trends, which were improving for each. This is because the trends analysis takes all years into consideration, blending the current year that was higher than average. Lewisburg, Newport, Marietta, and Conestoga showed improvements for all analyses for SS except for trends in Lewisburg, which were not detected because more than 20 percent of the values were below the method detection limit. Newport, Marietta, and Conestoga showed improvements for all analyses for TP except for trends at Marietta, which were not significant. This is strong evidence that improvements are being made for all parameters at all sites. The only substantial exceptions were Towanda, Danville, and Lewisburg for TP and Towanda and Danville for SS. However, as noted before, these exceptions may be due to the anomalous high flows during April for Towanda and Danville and during January for Lewisburg.

Table 38. Comparison of Percentages of Flows and Loads of Total Nitrogen, Total Phosphorous, and Suspended Sediment for 1989-2005

Year	Towanda					Danville					Marietta				
	Q	Q*	TN	TP	SS	Q	Q*	TN	TP	SS	Q	Q*	TN	TP	SS
1989	86	87	106	83	65	88	87	100	102	111	96	82	103	102	117
1990	121	104	149	126	98	117	92	140	132	114	118	78	134	118	104
1991	72	76	87	56	28	71	70	84	61	41	71	73	75	55	41
1992	99	75	108	82	44	94	68	103	82	50	87	62	89	67	46
1993	116	152	131	180	333	116	147	133	160	294	12	159	132	162	256
1994	119	108	124	130	148	125	109	134	137	170	130	132	129	142	188
1995	60	53	61	45	22	65	55	68	48	26	70	69	68	51	34
1996	144	178	146	191	264	145	162	155	172	217	163	205	168	200	252
1997	68	48	65	45	19	65	46	64	41	19	75	50	69	51	31
1998	99	111	95	95	85	102	109	102	91	83	109	122	102	102	102
1999	63	86	59	45	23	68	87	66	47	26	71	86	65	51	33
2000	111	101	100	98	82	109	101	100	91	73	93	80	82	76	58
2001	67	86	59	53	42	65	77	57	46	31	63	58	54	45	28
2002	93	60	80	69	40	92	66	79	70	42	86	57	77	73	50
2003	139	93	121	129	91	141	102	121	138	109	151	105	146	177	145
2004	130	130	111	135	144	127	162	105	138	155	143	184	139	205	233
2005	113	149	96	137	173	110	158	89	144	138	105	140	103	96	81

Q* equals the high average daily flow during the given year divided by the average of all 17 high average daily flows

Table 39. Storm Events at Marietta with High Daily Average Flow Similar to April 2005 Storm Event

Month of Storm Event	Average Monthly Flow	High Daily Average Flow	Monthly TN	Monthly TP	Monthly SS
January-98	90,668	330,000	29,703,419	2,012,526	1,988,703,397
March-98	99,623	162,000	28,394,908	1,581,592	1,251,858,082
May-89	103,394	223,000	31,865,456	2,688,797	3,650,150,412
March-03	110,171	284,000	30,975,194	2,533,858	2,380,539,985
September-04	110,893	497,000	32,748,690	6,257,286	9,908,945,265
December-96	114,261	259,000	39,493,417	2,899,857	2,879,200,958
January-96	116,852	556,000	40,092,507	4,162,444	6,333,728,265
March-94	142,681	357,000	43,639,904	3,601,068	5,172,513,799
April-94	147,303	248,000	41,387,595	3,315,784	4,335,937,656
April-93	235,133	431,000	68,743,015	7,259,275	12,371,847,860
April-05	108,960	380,000	26,127,702	2,568,258	2,528,153,081

Table 40. Summary of 2005 Data Comparison to Percentage of LTM, Initial 5-Year Baseline, 1st Half of Dataset Baseline, 2nd Half of Dataset Baseline, and Trends in Flow-Adjusted Concentration for Total Nitrogen, Total Phosphorous, and Suspended Sediment

Parameter	Site	LTM %	Baseline 89	Baseline 1st half	Baseline 2nd half	Trend
FLOW	Towanda	Above	N/A	N/A	N/A	NS
	Danville	Above	N/A	N/A	N/A	NS
	Lewisburg	Below	N/A	N/A	N/A	NS
	Newport	Below	N/A	N/A	N/A	NS
	Marietta	Above	N/A	N/A	N/A	NS
	Conestoga	Above	N/A	N/A	N/A	NS
TN	Towanda	IMP	IMP	IMP	IMP	IMP
	Danville	IMP	IMP	IMP	IMP	IMP
	Lewisburg	IMP	IMP	IMP	IMP	IMP
	Newport	IMP	IMP	DEG	DEG	IMP
	Marietta	IMP	IMP	IMP	DEG	IMP
	Conestoga	IMP	IMP	IMP	DEG	IMP
TP	Towanda	DEG	DEG	DEG	DEG	IMP
	Danville	DEG	DEG	DEG	DEG	IMP
	Lewisburg	DEG	IMP	DEG	DEG	IMP
	Newport	IMP	IMP	IMP	IMP	IMP
	Marietta	IMP	IMP	IMP	IMP	NS
	Conestoga	IMP	IMP	IMP	IMP	IMP
SS	Towanda	DEG	DEG	IMP	DEG	IMP
	Danville	DEG	DEG	DEG	DEG	IMP
	Lewisburg	IMP	IMP	IMP	IMP	BMDL
	Newport	IMP	IMP	IMP	IMP	IMP
	Marietta	IMP	IMP	IMP	IMP	IMP
	Conestoga	IMP	IMP	IMP	IMP	IMP

IMP = Improving DEG = Degrading N/A = Not Applicable NS = Not Significant
BMDL = Below Method Detection Limit

Table 41. Summary of 2005 Flow-Adjusted Concentration Trends at All Sites

Parameter	Towanda	Danville	Lewisburg	Newport	Marietta	Conestoga
TN	IMPROVING	IMPROVING	IMPROVING	IMPROVING	IMPROVING	IMPROVING
*TN	IMPROVING	IMPROVING	IMPROVING	IMPROVING	IMPROVING	IMPROVING
DN	IMPROVING	IMPROVING	IMPROVING	NS	IMPROVING	NS
TON	IMPROVING	IMPROVING	IMPROVING	IMPROVING	IMPROVING	IMPROVING
DON	IMPROVING	IMPROVING	IMPROVING	IMPROVING	NS	NS
DNH_3	NS	IMPROVING	NS	IMPROVING	NS	IMPROVING
TNH_3	IMPROVING	BMDL	BMDL	BMDL	IMPROVING	IMPROVING
DKN	IMPROVING	IMPROVING	BMDL	BMDL	IMPROVING	IMPROVING
TKN	IMPROVING	IMPROVING	IMPROVING	IMPROVING	IMPROVING	IMPROVING
TNOx	IMPROVING	IMPROVING	IMPROVING	DEGRADING	IMPROVING	NS
DNOx	IMPROVING	IMPROVING	IMPROVING	DEGRADING	IMPROVING	NS
*DNOx	IMPROVING	IMPROVING	NS	DEGRADING	NS	NS
TP	IMPROVING	IMPROVING	IMPROVING	IMPROVING	NS	IMPROVING
*TP	IMPROVING	IMPROVING	IMPROVING	IMPROVING	IMPROVING	IMPROVING
DP	IMPROVING	IMPROVING	IMPROVING	IMPROVING	NS	IMPROVING
DOP	DEGRADING	DEGRADING	BMDL	DEGRADING	DEGRADING	IMPROVING
TOC	IMPROVING	IMPROVING	NS	IMPROVING	IMPROVING	IMPROVING
SS	IMPROVING	IMPROVING	BMDL	IMPROVING	IMPROVING	-
*SS	IMPROVING	IMPROVING	NS	IMPROVING	IMPROVING	IMPROVING

* These results were reported by USGS after additional analysis

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