NUTRIENTS AND SUSPENDED SEDIMENT TRANSPORTED IN THE SUSQUEHANNA RIVER BASIN, 1997

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SUSQUEHANNA RIVER BASIN COMMISSION

Paul O. Swartz, Executive Director

The Susquehanna River Basin Commission was created as an independent agency by a federal-interstate compact* among the states of Maryland, New York, 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 effect coordinated planning, conservation, management, utilization, development and control of basin water resources among the government 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

Nutrient and suspended-sediment samples were collected in calendar year 1997 during base flow and storm flow from the Susquehanna River at Towanda, Danville, and Marietta, the West Branch Susquehanna River at Lewisburg, the Juniata River at Newport, and the Conestoga River at Conestoga, Pa.

Annual loads of nutrients and suspended sediment were highest in the Susquehanna River at Marietta, followed by the Susquehanna River at Danville. The Conestoga River at Conestoga had the smallest load, in pounds per year (lb/yr), but had the greatest yield, in pounds per acre per year (lb/ac/yr), of total nitrogen, total phosphorus, and suspended sediment. Seasonal loads of nutrients and suspended sediment generally varied according to the variations in the seasonal water discharges.

Comparisons of the 1997 yields and the five-year baseline yields indicate that total nitrogen loads decreased at five of the six monitoring sites. Total phosphorus yields were significantly lower than the baseline yields at four of six sites and suspended-sediment yields were lower at two of six sites.

INTRODUCTION

The Pennsylvania Department of Environmental Protection (Pa. DEP), Bureau of Land and Water Conservation and Bureau of Laboratories, the U.S. Environmental Protection Agency (USEPA), and the Susquehanna River Basin Commission (SRBC) cooperated in a study to quantify nutrient and suspended-sediment transport in the Susquehanna River Basin. Nutrients and sediments entering the Chesapeake Bay from the Susquehanna River Basin contribute toward nutrient enrichment problems in the bay (USEPA, 1982).

Background

Pennsylvania, Maryland, Virginia, and the District of Columbia have agreed to reduce nutrient loads to the Chesapeake Bay. The 1987 Chesapeake Bay Agreement states that, by the year 2000, controllable nutrient loads are to be reduced to 60 percent of the loads transported in 1985. Much of the nutrient and suspended sediment that enters the Chesapeake Bay is thought to originate from the lower Susquehanna River Basin.

Studies by Ward and Eckhardt (1979), Lietman and others (1983), and Ward (1987) showed high concentrations of nutrients in streams of the lower Susquehanna River Basin. These studies also showed high suspended-sediment yields from areas in the lower basin. Lang (1982) reported results of water quality sampling of the three major tributaries to the Chesapeake Bay—the Susquehanna, Potomac, and James Rivers. Other studies by Poth (1977), Lloyd and Growitz (1977), and Taylor and Werkheiser (1984) showed high concentrations of nutrients in ground water in the lower basin. Results from these studies indicated that a large nutrient load was being transported by the lower Susquehanna River, and that quantification of the loads was warranted.

The SRBC, in cooperation with the Pa. DEP, USEPA, and the U.S. Geological Survey (USGS), conducted a 5-year intensive study at fourteen sites during the period 1985-89. The scope of the initial 5-year study was reduced in 1990 to five long-term monitoring stations. An additional site was included in 1994, and sampling at these six sites was continued. Calculated annual loads and yields of nutrient and suspended sediment showed year-to-year variability that was highly correlated with the variability of the annual water discharge (Ott and others, 1991; Takita, 1996; Takita, 1998). These studies also reinforced the indications from earlier studies that the highest nutrient yields come from the lower basin.

Objective of the Study

The objective of this study was to collect monthly base flow and daily, or more frequent, samples during selected storms from the six long-term monitoring sites in the Susquehanna River Basin. The data were used to compute annual nutrient and suspended-sediment loads and to evaluate the results of nutrient reduction efforts.

Purpose of Report

The purpose of this report is to present basic information on annual and seasonal loads and yields of nutrient and suspended sediment measured during calendar year 1997, and to compare the total nitrogen, total phosphorus, and suspended-sediment loads with the baseline established from the 1985-89 study. Seasonal and annual variations in loads are discussed.

DESCRIPTION OF THE SUSQUEHANNA RIVER BASIN

The Susquehanna River (Figure 1) drains an area of 27,510 square miles, and is the largest tributary to the Chesapeake Bay.

The climate in the Susquehanna River Basin varies considerably from the low lands adjacent to the Chesapeake 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. Precipitation in the basin averages 39.15 inches per year, and is fairly well distributed throughout the year.

Land use in the Susquehanna River Basin is predominantly rural. Woodland accounts for 65 percent; cultivated, 19 percent; urban, 9 percent and grassland, 7 percent of land use (Ott and others, 1991). Woodland occupies the higher elevations of the northern and western basin and much of the mountain and ridge land in the Juniata River and the lower Susquehanna River Basins. Most of the grassland is in the northern basin. Farmers in the northern basin use more land for pasture and hay, and less for cultivated crops because of the shorter and more uncertain growing season. Woods and grassland occupy areas in the lower basin that are unsuitable for cultivation because the slopes are too steep, the soils are too stony, or the soils are poorly drained.

Most of the cultivated land is in the lower basin. 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.

Major urban areas in the lower basin include York, Lancaster, Harrisburg, and Sunbury, Pa. Most of the urban areas in the northern basin are located along river valleys. These urban areas include Binghamton and Elmira-Corning in New York and Scranton and the Wilkes-Barre area in Pennsylvania. The major urban areas in the West Branch Susquehanna River Basin are Williamsport and Lock Haven.

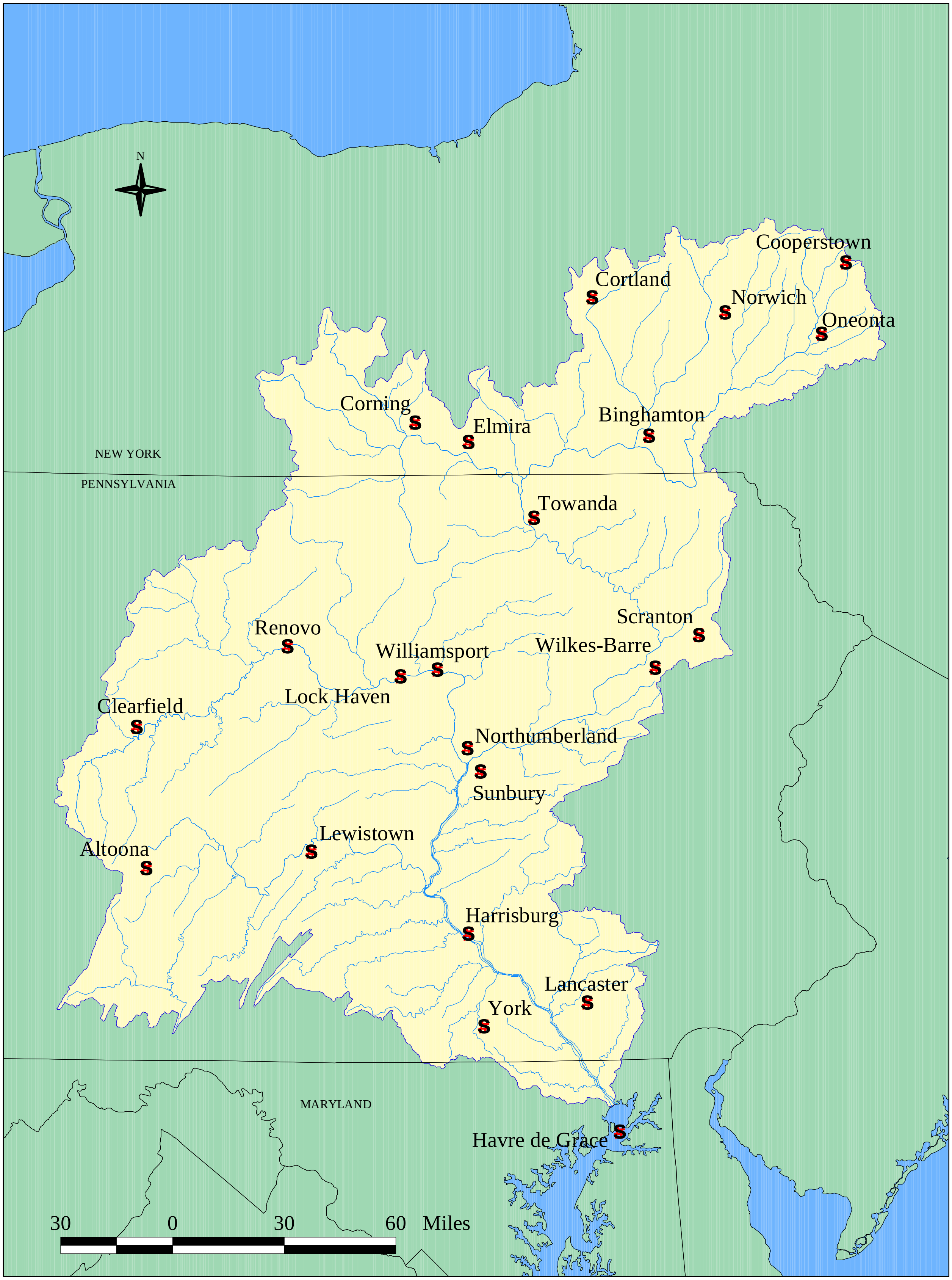


Figure 1. The Susquehanna River Basin

NUTRIENT MONITORING SITES

Data were collected from three sites on the Susquehanna River and three major tributaries in the basin. These six sites, selected for long-term monitoring of nutrient and suspended-sediment transport in the basin, are listed in Table 1, and their general locations are shown in Figure 2.

The Susquehanna River at Towanda, Pa., was selected because it represents the contribution from New York State, although the drainage area does include the Tioga River Basin in northern Pennsylvania and an area along the northern tier counties of eastern Pennsylvania. The drainage area at Towanda is 7,797 square miles.

The Susquehanna River at Danville, Pa., has a drainage area of 11,220 square miles, and includes part of north central Pennsylvania (the Tioga River Basin) and much of south central New York. Data collected at Danville represent the loadings from a major tributary to the main stem Susquehanna River.

Data collected from the West Branch Susquehanna River at Lewisburg, Pa., represent the loadings from another major tributary to the main stem. The West Branch includes much of north central Pennsylvania, and has a drainage area of 6,847 square miles. The drainage areas at Lewisburg and Danville represent 65.7 percent of the total Susquehanna River Basin.

The Juniata River, a major tributary to the main stem, includes much of south central Pennsylvania, and has a drainage area of 3,354 square miles upstream of Newport, Pa. The combined drainage areas at Danville, Lewisburg, and Newport represent 77.9 percent of the Susquehanna River Basin.

The Susquehanna River at Marietta, Pa., is the southern-most sampling site upstream from the reservoirs on the lower Susquehanna River, and represents the inflow to the reservoirs from its 25,990-square-mile drainage area. This drainage area represents 94.5 percent of the total Susquehanna River Basin.

Data collected from the Conestoga River at Conestoga, Pa., provide loadings from a major tributary watershed that is actively farmed and is experiencing an increase in agricultural nutrient management programs. Additionally, this watershed is experiencing an increase in development. The drainage area of this basin at the sampling site is 470 square miles.

Table 1. Data Collection Sites and Their Drainage Areas

USGS Identification Number	Station Name	Short Name	Drainage Area (square mile)
01531500	Susquehanna River at Towanda, Pa.	Towanda	7,797
01540500	Susquehanna River at Danville, Pa.	Danville	11,220
01553500	West Branch Susquehanna River at Lewisburg, Pa.	Lewisburg	6,847
01567000	Juniata River at Newport, Pa.	Newport	3,354
01576000	Susquehanna River at Marietta, Pa.	Marietta	25,990
01576754	Conestoga River at Conestoga, Pa.	Conestoga	470

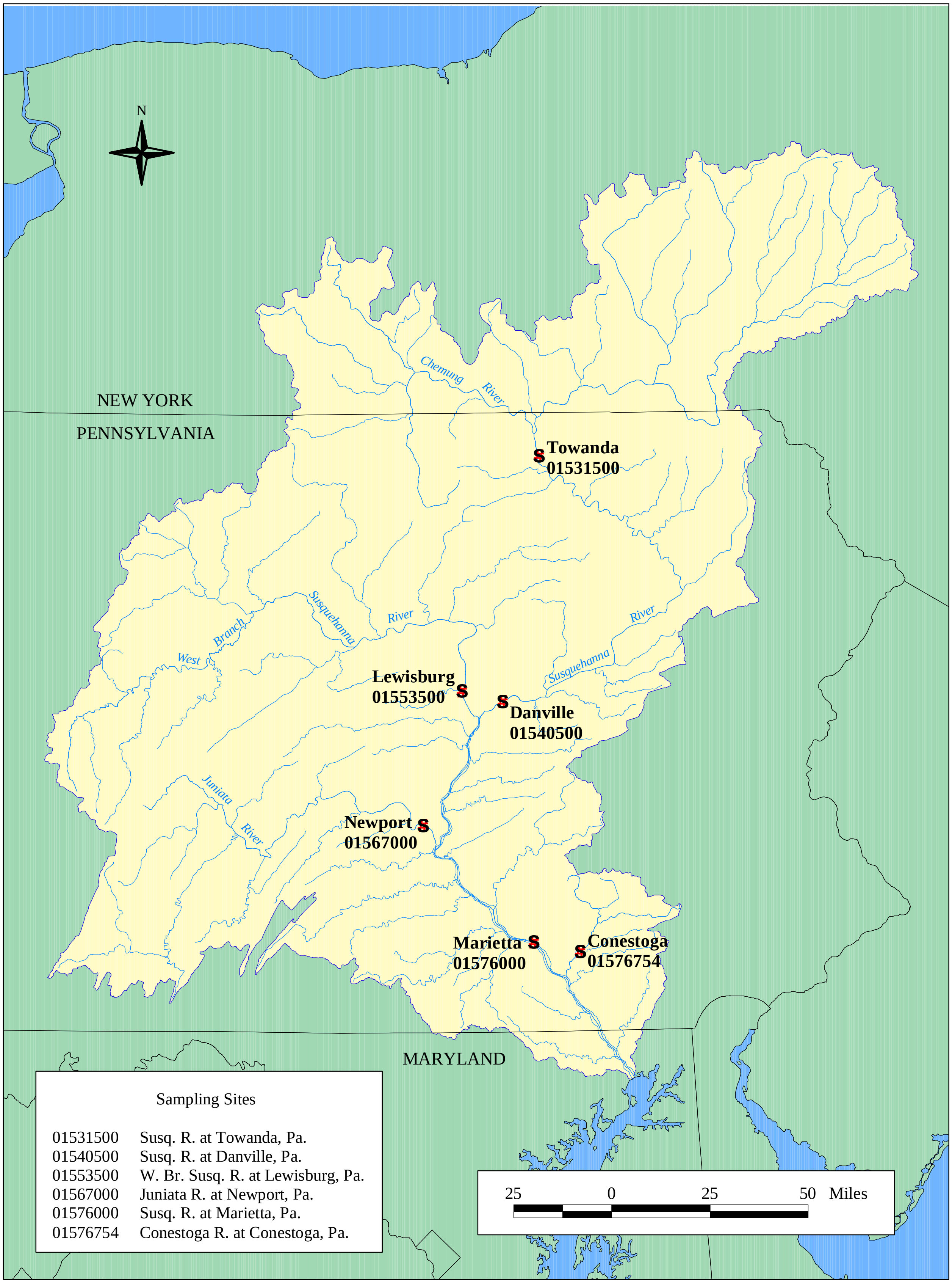


Figure 2. Locations of Sampling Sites on the Susquehanna River and Three Major Tributaries in the Basin

SAMPLE COLLECTION AND ANALYSIS

Samples were collected at each monitoring site to measure nutrient and suspended-sediment concentrations during base flow and storm flow periods. Base flow samples were collected monthly. Collection of base flow samples was delayed 7 to 10 days after a period of storm flow until moderate flows prevailed. All base flow samples were collected by hand with depth-integrating samplers. Calendar year 1997 was a very dry year, and a drought warning was declared by the SRBC. Only one rainfall event that caused significant rises in streamflow at three of the six monitoring sites occurred during the year. Samples were collected daily with depth-integrating samplers from the start of the storm to the time when the flow receded to near its pre-storm rate. An attempt was made to collect a sample at or near peak flow.

A portion of each sample was filtered, and the filtrate was analyzed for dissolved nitrogen and phosphorus species. Whole-water samples were analyzed for total nitrogen species, total phosphorus, total organic carbon, and suspended sediment. Samples for nutrient analysis were chilled on ice and delivered to the Pa. DEP Laboratory in Harrisburg the day after sample collection. The parameters and laboratory methods used are listed in Table 2. Samples collected for suspended-sediment concentration were analyzed by the Susquehanna River Basin Commission using the USGS's gravimetric method for sediment analysis.

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

Parameter	Laboratory	Methodology	Detection Limit (mg/l)	References
Ammonia (total)	Pa. DER	Colorimetry	0.020	USEPA 350.1
Ammonia (dissolved)	Pa. DER	Block Digest, Colorimetry	0.020	USEPA 350.1
Nitrogen (total)	Pa. DER	Persulfate Digestion for Total Nitrogen	0.040	Standard Methods 4500-N_{org}-D
Nitrite plus Nitrate	Pa. DER	Cd-reduction, Colorimetry	0.040	USEPA 353.2
Organic Carbon (total)	Pa. DER	Wet Oxidation	1.000	USEPA 415.2
Orthophosphate (dissolved)	Pa. DER	Colorimetry	0.002	USEPA 365.1
Phosphorus (dissolved)	Pa. DER	Block Digest, Colorimetry	0.020	USEPA 365.1
Phosphorus (total)	Pa. DER	Persulfate Digest, Colorimetry	0.020	USEPA 365.1

PRECIPITATION

Precipitation data were obtained from long-term monitoring stations operated by the U.S. Department of Commerce. The data are published monthly 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 precipitation data from these sources were summarized for 1997 for the Susquehanna River Basin above Towanda, Pa., the Susquehanna River Basin above Danville, Pa., the West Branch Susquehanna River Basin, the Juniata River Basin, the Susquehanna River Basin above Marietta, Pa., and the Conestoga River Basin. This summary is shown in Table 3, along with the average long-term precipitation values. The annual precipitation for 1997 was well below the long-term average in all basins, except the Juniata River Basin. Precipitation ranged from 3.53 inches above normal in the Juniata basin to 10.3 inches below normal in the Conestoga basin.

Table 3. Summary for Annual Precipitation for Selected Subbasins in the Susquehanna River Basin, Calendar Year 1997

Subbasin	Season	Average Long-term Precipitation (inches)	Calendar Year 1997 Precipitation (inches)
Susquehanna River above Towanda	January-March	6.86	7.19
	April-June	9.87	7.62
	July-September	10.71	8.94
	October-December	9.11	8.56
	Yearly Total	**36.55**	**32.31**
Susquehanna River above Danville	January-March	6.93	7.12
	April-June	10.00	7.70
	July-September	11.06	9.46
	October-December	9.21	8.46
	Yearly Total	**37.20**	**32.74**
West Branch Susquehanna River above Lewisburg	January-March	7.93	6.95
	April-June	10.76	6.95
	July-September	12.44	12.50
	October-December	9.98	9.30
	Yearly Total	**41.11**	**35.70**
Juniata River above Newport	January-March	8.15	7.64
	April-June	9.28	9.52
	July-September	10.34	10.89
	October-December	9.97	13.23
	Yearly Total	**37.74**	**41.28**
Susquehanna River above Marietta	January-March	7.62	7.35
	April-June	10.02	7.66
	July-September	11.24	10.44
	October-December	9.63	9.49
	Yearly Total	**38.51**	**34.94**
Conestoga River above Conestoga	January-March	8.52	7.71
	April-June	10.03	6.88
	July-September	12.97	9.13
	October-December	10.45	7.95
	Yearly Total	**41.97**	**31.67**

WATER DISCHARGE

Mean water discharges measured by the USGS for Calendar Year 1997 are listed in Table 4, along with the long-term annual mean discharges and the percent of long-term annual mean discharge for each site.

As shown in Table 4 and Figure 3, the annual mean water discharge was below normal at all sites. Streamflow ranged from 73 percent of normal at Danville to 94 percent of normal at Newport.

Table 4. Annual Water Discharge, Calendar Year 1997

Site Short Name	Years of Record	Discharge Long-Term Annual Mean (cfs)[1]	1997	
			Mean (cfs)	Percent of Long-Term Mean Discharge
Towanda	84	10,600	7,920	75
Danville	93	15,300	11,100	73
Lewisburg	58	10,900	8,640	79
Newport	25	4,570	4,300	94
Marietta	66	37,200	29,000	78
Conestoga	13	666	494	74

[1] Cubic feet per second

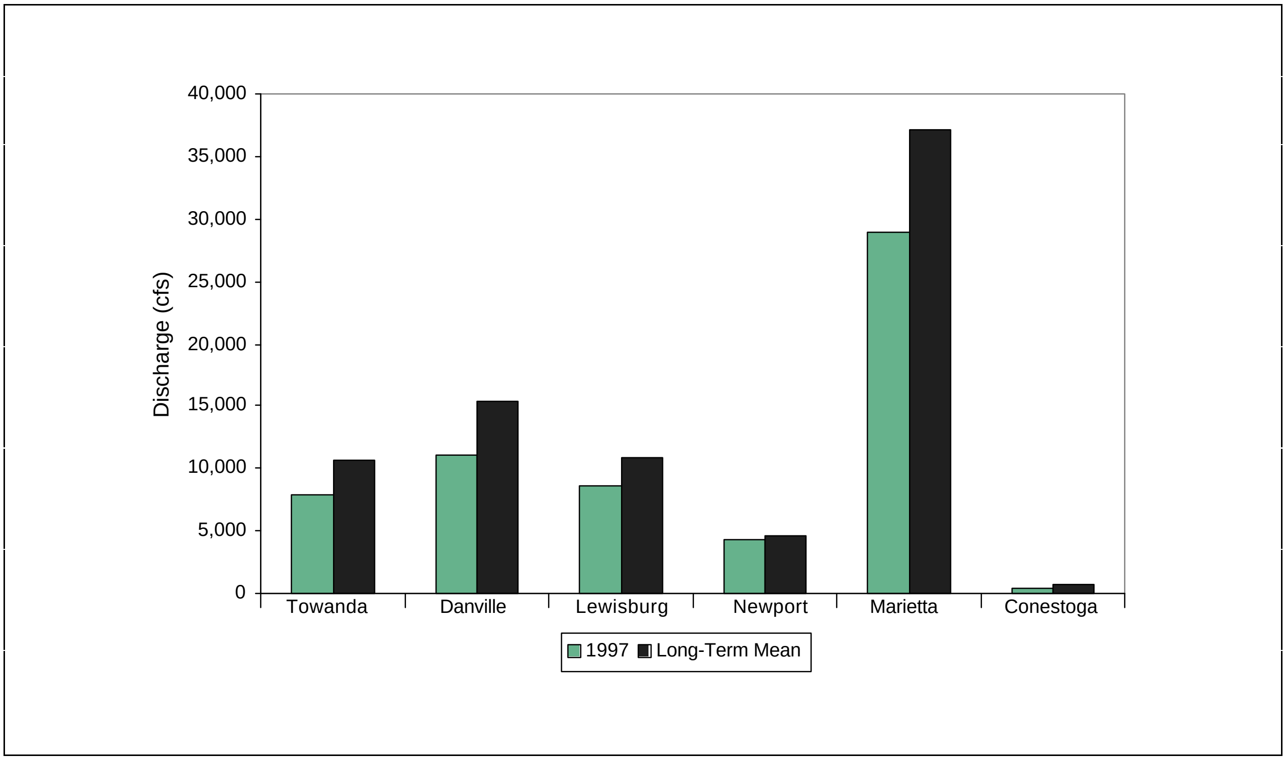


Figure 3. Annual and Long-Term Mean Water Discharge at Towanda, Danville, Lewisburg, Marietta, and Conestoga, Pa., Calendar Year 1997

ANNUAL NUTRIENT AND SUSPENDED–SEDIMENT LOADS AND YIELDS

Nutrient and suspended-sediment loads were computed for total nitrogen, total phosphorus, suspended sediment, total ammonia, total nitrite plus nitrate nitrogen, total organic nitrogen, dissolved phosphorus, dissolved orthophosphate, and dissolved ammonia. The minimum variance unbiased estimator described by Cohn and others (1989) was used to compute the loads. This estimator relates 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.

Tables 5 through 13 list the computed loads, in pounds per year (lb/yr), and corresponding yields, in pounds per acre per year (lb/ac/yr), of the constituents measured at each of the sites. Loads and yields are discussed together because they are mathematically the same values, with different connotations. Load values are equated to the quantity of material carried past a given point during a specific time period. Yield values are equated to the quantity of material derived from a unit of area over a specific time period. Yield values, therefore, readily can be compared between subbasins, regardless of size variations.

The calendar year 1997 and the long-term average annual loads and yields of total nitrogen (TN) are shown in Figures 4A and 4B, respectively.

The 1997 annual loads and yields of TN were smaller than the long-term averages at all sites because of the lower streamflows. The greatest TN loads were measured at Marietta, followed by Danville. The Conestoga River at Conestoga had the smallest TN loads.

The Conestoga River Watershed, with 62.7 percent agricultural and 22.4 percent forest lands, had the highest yield, 28.25 lb/ac/yr, of total nitrogen. Annual yields of TN shown in Figure 4B and Table 4B indicate that the West Branch Susquehanna River at Lewisburg yielded more nitrogen per unit area than the Susquehanna River at Danville, possibly due to the higher rainfall in the West Branch Watershed. The West Branch Susquehanna River Watershed consists of 81 percent forest and 13.9 percent agricultural lands, as compared to 59.8 percent forest and 26.9 percent agricultural lands above Danville. The long-term average yield indicates that the Susquehanna River at Danville normally yields more nitrogen per unit area.

The 1997 annual loads and yields of total phosphorus (TP) also were smaller than the long-term average loads and yields as illustrated in Figure 5A and 5B, respectively. The annual TP load was greatest at Marietta, followed by Danville, and the smallest annual TP load was measured at Conestoga. Although the 1997 annual load from the Susquehanna River at Danville was greater than at Towanda, the yield, in lb/ac/yr, was greater at Towanda. The long-term average yields at Towanda and Danville are nearly the same. The greatest yield of TP occurred at Conestoga.

The annual loads and yields of suspended sediment (SS) are illustrated in Figure 6A and 6B, respectively. The 1997 loads and yields were smaller than the respective long-term average loads, and yields at all sites, except at Newport. The SS loads and yields at Newport were greater than the long-term average. This was probably due to higher than normal rainfall in the watershed during the spring, summer, and fall. Rainfall in all other watersheds was below normal. The highest SS loads were measured at Marietta, followed by Danville, and the smallest load was at Conestoga. The Conestoga River had the highest suspended-sediment yield.

Annual loads of total and dissolved ammonia, total nitrite plus nitrate, total organic nitrogen, dissolved phosphorus, and dissolved orthophosphate were greatest at Marietta. Annual loads of total and dissolved ammonia, total nitrite plus nitrate, dissolved phosphorus and dissolved orthophosphate were greater at Danville than at Lewisburg. The total organic nitrogen load was greater at Lewisburg than at Danville. The Conestoga River had the highest yields of all parameters.

Table 5. Annual Water Discharges and Annual Loads and Yields of Total Nitrogen, Calendar Year 1997

Site Short Name	Annual Discharge (cfs)	Total Nitrogen as N 1997 Annual Load (thousands of pounds)	Prediction Error (percent)	Annual Yield (pounds per acre per year)
Towanda	7,920	19,400	5.66	3.895
Danville	11,100	28,400	5.50	3.954
Lewisburg	8,640	19,200	5.26	4.378
Newport	4,300	13,900	3.80	6.498
Marietta	29,000	75,300	5.03	4.530
Conestoga	494	8,500	4.29	28.252

Table 6. Annual Water Discharges and Annual Loads and Yields of Total Phosphorus, Calendar Year 1997

Site Short Name	Annual Discharge (cfs)	Total Phosphorus as P 1997 Annual Load (thousands of pounds)	Prediction Error (percent)	Annual Yield (pounds per acre per year)
Towanda	7,920	1,610	11.70	0.323
Danville	11,100	1,860	10.55	0.258
Lewisburg	8,640	955	12.44	0.218
Newport	4,300	706	12.40	0.329
Marietta	29,000	3,990	10.02	0.240
Conestoga	494	228	15.05	0.758

Table 7. Annual Water Discharges and Annual Loads and Yields of Suspended Sediment, Calendar Year 1997

Site Short Name	Annual Discharge (cfs)	Suspended Sediment 1997 Annual Load (thousands of pounds)	Prediction Error (percent)	Annual Yield (pounds per acre per year)
Towanda	7,920	720,000	39.16	144.272
Danville	11,100	1,170,000	19.81	162.788
Lewisburg	8,640	734,000	25.77	167.459
Newport	4,300	882,000	39.47	411.121
Marietta	29,000	1,840,000	17.78	110.640
Conestoga	494	81,300	34.34	270.444

Table 8. Annual Water Discharges and Annual Loads and Yields of Total Ammonia, Calendar Year 1997

Site Short Name	Annual Discharge (cfs)	Total Ammonia as N 1997		
		Annual Load (thousands of pounds)	Prediction Error (percent)	Annual Yield (pounds per acre per year)
Towanda	7,920	1,140	13.82	0.228
Danville	11,100	1,780	13.31	0.248
Lewisburg	8,640	1,100	11.83	0.250
Newport	4,300	577	12.12	0.269
Marietta	29,000	3,130	12.20	0.188
Conestoga	494	181	18.11	0.601

Table 9. Annual Water Discharges and Annual Loads and Yields of Total Nitrite Plus Nitrate Nitrogen, Calendar Year 1997

Site Short Name	Annual Discharge (cfs)	Total Nitrite Plus Nitrate as N 1997		
		Annual Load (thousands of pounds)	Prediction Error (percent)	Annual Yield (pounds per acre per year)
Towanda	7,920	12,900	8.34	2.588
Danville	11,100	21,800	7.24	3.042
Lewisburg	8,640	12,000	4.36	2.749
Newport	4,300	9,560	5.37	4.455
Marietta	29,000	60,100	4.83	3.610
Conestoga	494	3,330	9.13	11.069

Table 10. Annual Water Discharges and Annual Loads and Yields of Total Organic Nitrogen, Calendar Year 1997

Site Short Name	Annual Discharge (cfs)	Total Organic Nitrogen as N 1997		
		Annual Load (thousands of pounds)	Prediction Error (percent)	Annual Yield (pounds per acre per year)
Towanda	7,920	5,380	9.27	1.078
Danville	11,100	4,770	8.68	0.664
Lewisburg	8,640	6,040	7.15	1.378
Newport	4,300	3,810	7.10	1.775
Marietta	29,000	12,200	7.35	0.733
Conestoga	494	4,990	10.51	16.589

Table 11. Annual Water Discharges and Annual Loads and Yields of Dissolved Phosphorus, Calendar Year 1997

Site Short Name	Annual Discharge (cfs)	Dissolved Phosphorus as P 1997		
		Annual Load (thousands of pounds)	Prediction Error (percent)	Annual Yield (pounds per acre per year)
Towanda	7,920	594.0	6.58	0.119
Danville	11,100	439.0	9.10	0.061
Lewisburg	8,640	316.0	10.20	0.072
Newport	4,300	251.0	10.76	0.117
Marietta	29,000	1,260.0	8.54	0.076
Conestoga	494	77.6	10.48	0.258

Table 12. Annual Water Discharges and Loads and Yields of Dissolved Orthophosphate, Calendar Year 1997

Site Short Name	Annual Discharge (cfs)	Dissolved Orthophosphate as P 1997		
		Annual Load (thousands of pounds)	Prediction Error (percent)	Annual Yield (pounds per acre per year)
Towanda	7,920	46.6	17.86	0.009
Danville	11,100	142.0	21.48	0.020
Lewisburg	8,640	93.7	24.68	0.021
Newport	4,300	142.0	40.07	0.066
Marietta	29,000	307.0	21.46	0.018
Conestoga	494	21.8	19.53	0.072

Table 13. Annual Water Discharges and Annual Loads and Yields of Dissolved Ammonia, Calendar Year 1997

Site Short Name	Annual Discharge (cfs)	Dissolved Ammonia as N 1997		
		Annual Load (thousands of pounds)	Prediction Error (percent)	Yield (pounds per acre per year)
Towanda	7,920	1,000	15.24	0.202
Danville	11,100	1,530	13.78	0.213
Lewisburg	8,640	946	13.22	0.216
Newport	4,300	402	12.86	0.187
Marietta	29,000	2,880	12.45	0.173
Conestoga	494	145	19.90	0.483

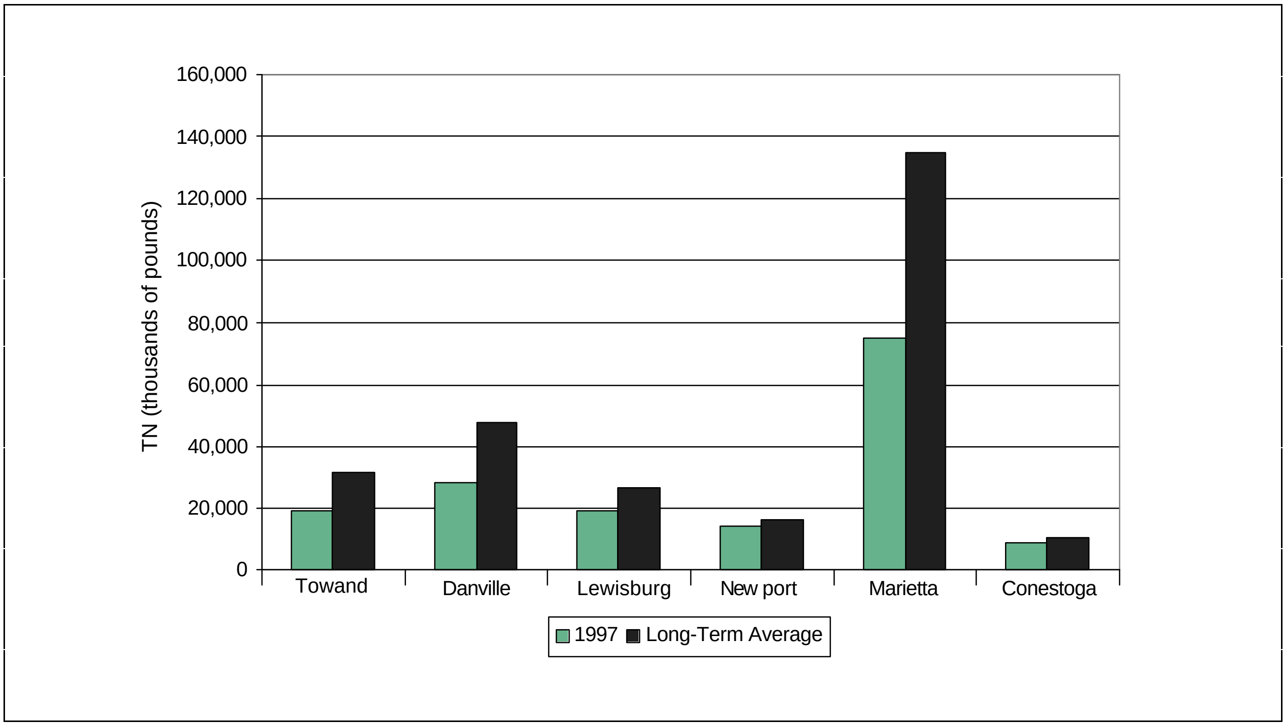


Figure 4A. Annual Loads of Total Nitrogen (TN) at Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga, Pa., Calendar Year 1997

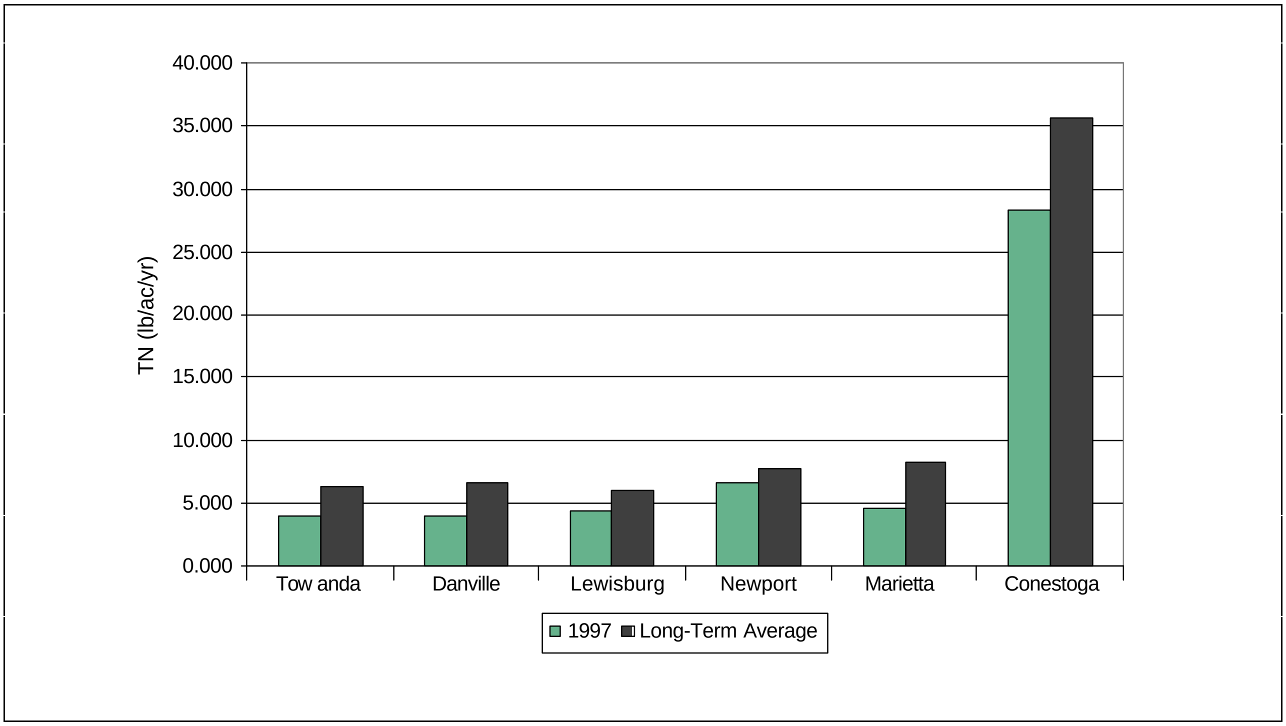


Figure 4B. Total Nitrogen (TN) Yields at Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga, Pa., Calendar Year 1997

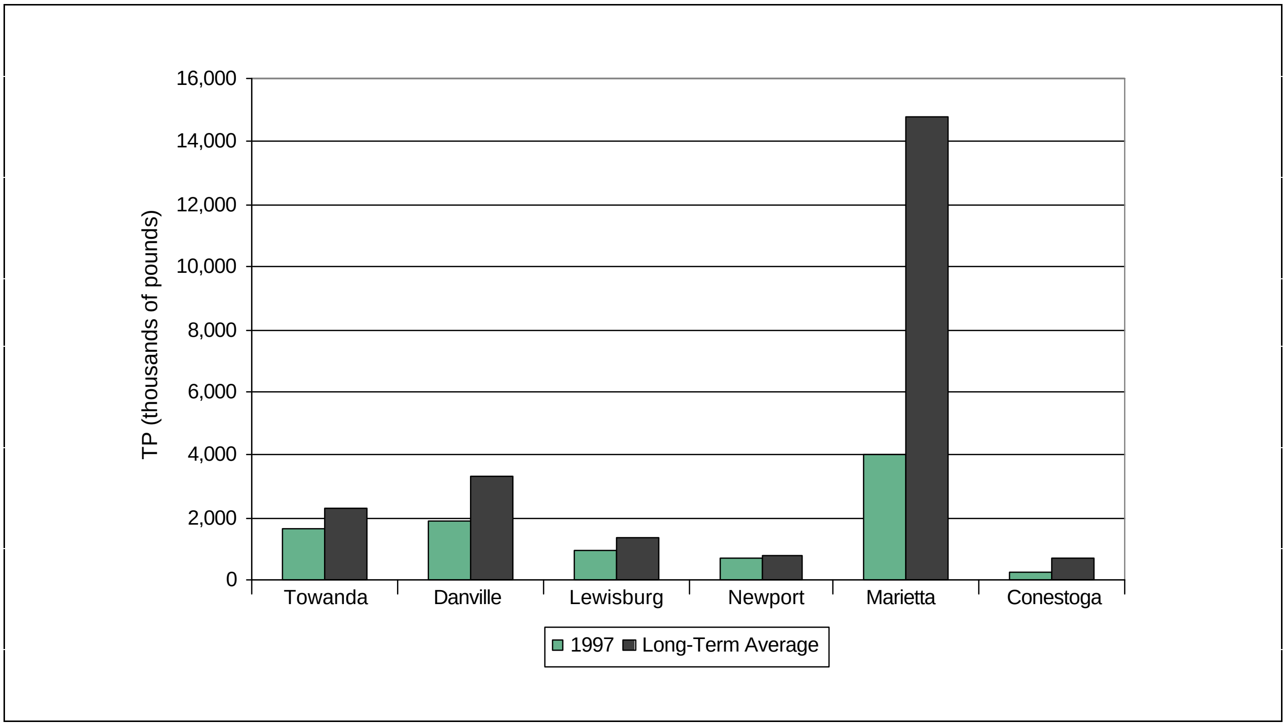


Figure 5A. Annual Loads of Total Phosphorus (TP) at Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga, Pa., Calendar Year 1997

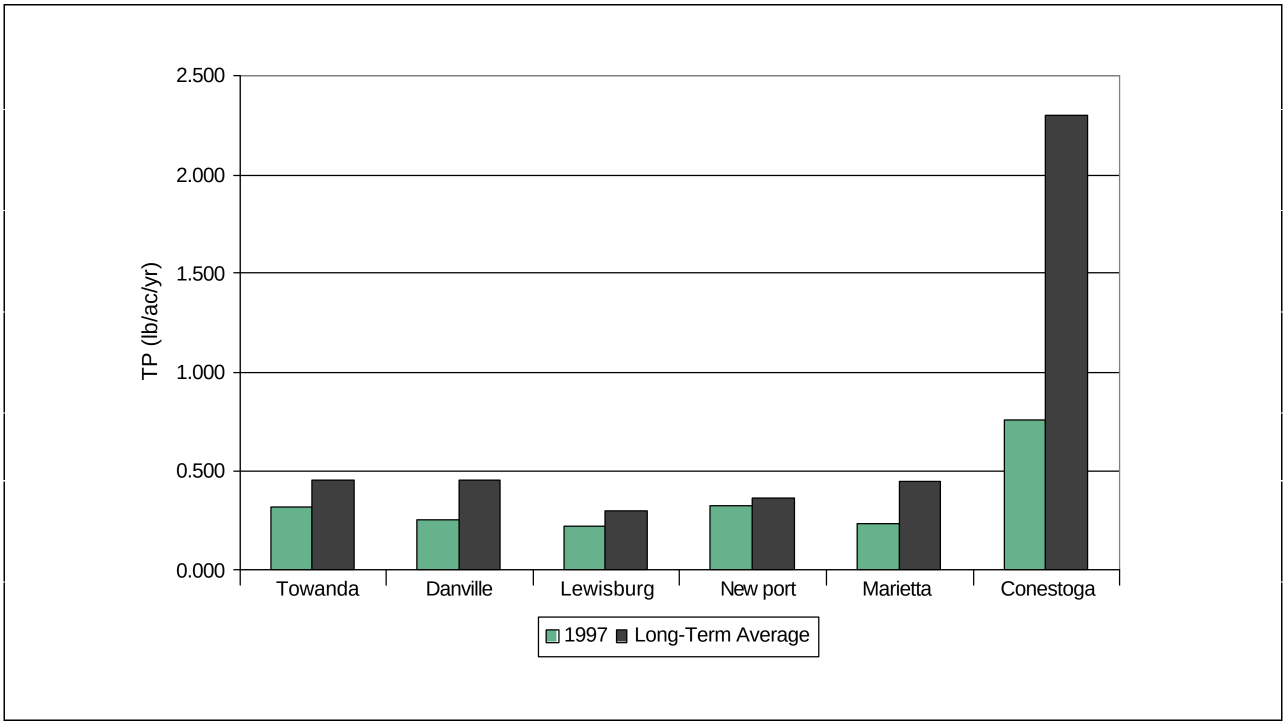


Figure 5B. Total Phosphorus (TP) Yields at Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga, Pa., Calendar Year 1997

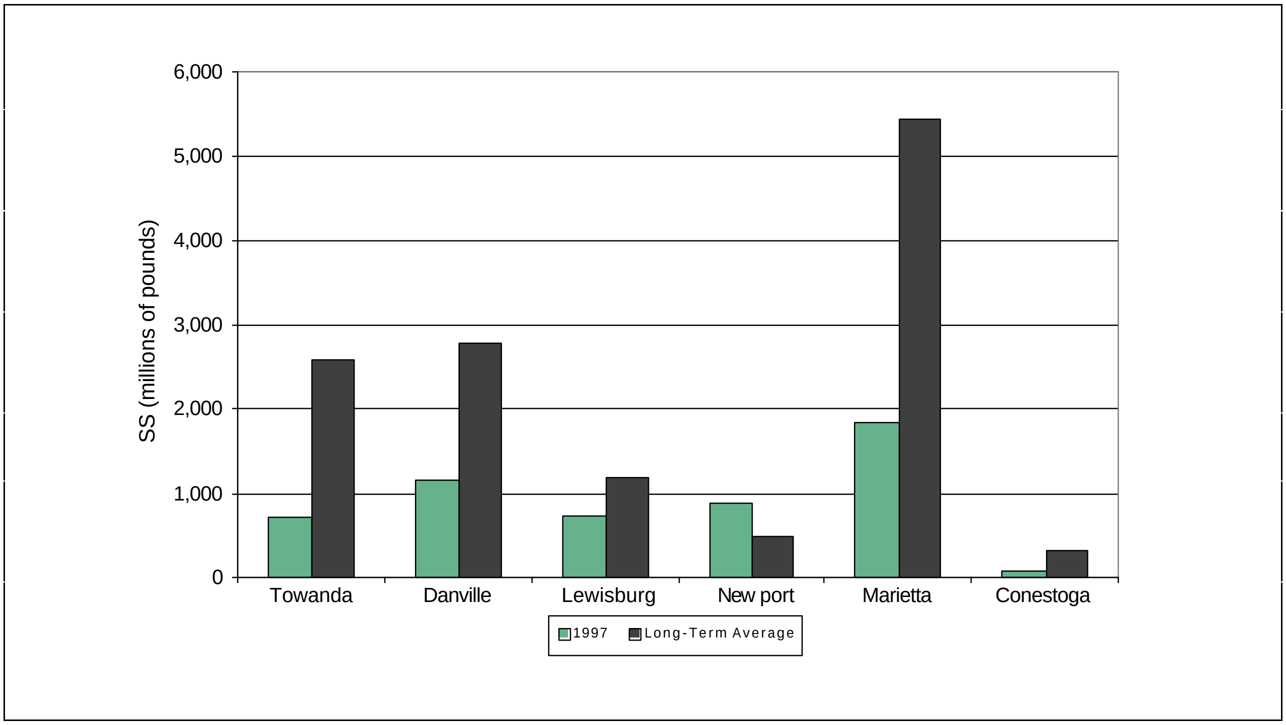


Figure 6A. Annual Loads of Suspended Sediment (SS) at Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga, Pa., Calendar Year 1997

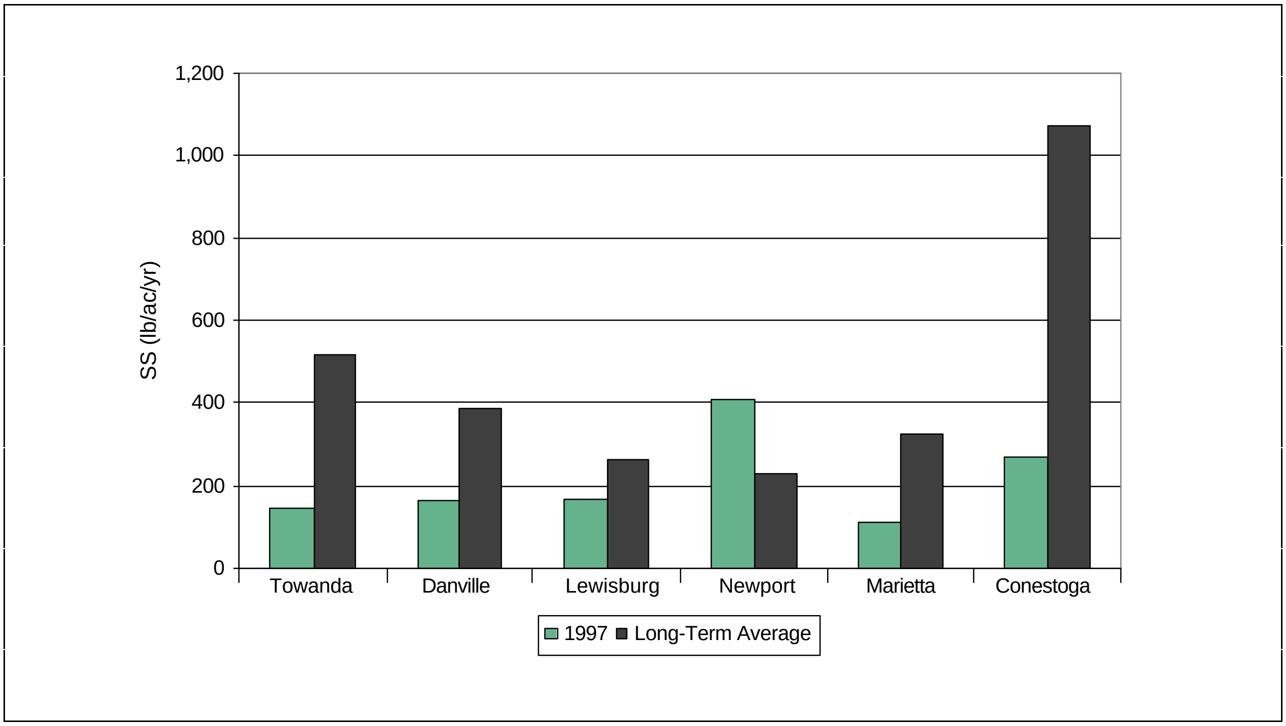


Figure 6B. Suspended-Sediment Yield at Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga, Pa., Calendar Year 1997

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

Seasonal water discharges and loads of nutrients and suspended sediment for calendar year 1997 are listed in Table 14. The calendar year 1997 and long-term seasonal water discharges and loads of total nitrogen, total phosphorus and suspended sediment are illustrated in Figures 7 through 12.

Seasonal mean water discharges for calendar year 1997 at Towanda, Danville, and Marietta were highest in the winter (January through March), followed by spring (April through June), then Fall (October through December). Seasonal discharges at Lewisburg and Newport were highest in the winter, followed by fall, then spring. At Conestoga, seasonal discharges were highest in the winter, then spring and summer. The 1997 seasonal water discharges were generally smaller than the long-term, except for the fall discharge at Newport, which was affected by the higher than normal rainfall.

Total nitrogen consists mostly of the highly soluble nitrite plus nitrate fraction; therefore, the seasonal variation of total nitrogen loads for 1997 corresponded with the seasonal variation of water discharges at all sites. The seasonal loads of total phosphorus and suspended sediment were consistent with seasonal variations of water discharges at Towanda, Danville, Lewisburg, Marietta, and Conestoga. Total phosphorus and suspended-sediment loads were greatest in the fall at Newport, probably due to the above normal rainfall. The 1997 seasonal loads were generally smaller than the long-term average loads. Total nitrogen, total phosphorus, and suspended-sediment loads at Newport during the 1997 fall season were greater than the long-term average, due to the greater than normal rainfall and water discharge.

The long-term seasonal water discharges at most of the sites are highest in the winter, followed by spring, fall, then summer. The one exception is at Lewisburg, where the spring discharge is slightly higher than the winter discharge. The long-term total nitrogen loads at all sites show the same seasonal variation and are consistent with the respective seasonal discharges at most sites. The exception is at Lewisburg, where the total nitrogen load is highest in the winter and the discharge is highest in the spring. The long-term total phosphorus and suspended-sediment loads in the Susquehanna River at Towanda, Danville, and Marietta show the same seasonal variability. The greatest loads occur in the spring, then in the winter, followed by fall and summer, while the highest discharge occurs in the winter followed by spring, fall, and summer. The seasonal variations of the long-term total phosphorus and suspended-sediment loads at Conestoga are consistent with the seasonal discharges.

Figures 13 through 15 provide a comparison of the seasonal yields among the monitoring sites for calendar year 1997 and the long-term seasonal average. The long-term seasonal averages indicate that the Conestoga River at Conestoga has the greatest yields of total nitrogen, total phosphorus, and suspended sediment for all seasons. The long-term average total nitrogen yields in the Susquehanna River at Towanda, Danville, and Marietta generally increased in the downstream order. The West Branch Susquehanna River at Lewisburg, which has the greatest forested area, had the lowest TN yield among the tributary sites. Total nitrogen yields for 1997 generally followed the same pattern. The TN yield at Marietta during the spring was smaller than at Towanda and Danville, and the TN yield at Danville was smaller than at Towanda during the fall.

The long-term total phosphorus and suspended-sediment yields at Towanda, Danville, and Marietta decrease in the downstream order during the winter, spring, and fall. The long-term total phosphorus yields among the tributaries are smallest at Lewisburg for all seasons. Suspended-sediment yields are smallest at Newport during the winter, spring, and fall. The 1997 yields closely follow the long-term seasonal yield patterns, with some exceptions. The most noticeable exceptions were the 1997 total phosphorus and suspended-sediment yields at

Table 14. Seasonal Mean Water Discharges and Loads of Nutrients and Suspended Sediment, Calendar Year 1997

Station	Season	Mean Water Discharge cfs	Total Ammonia as N	Total Organic Nitrogen as N	Total Nitrite Plus Nitrate as N	Total Nitrogen as N	Ortho-phos-phorus as P	Dissolved Phos-Phorus as P	Total Phos-Phorus as P	Dissolved Ammonia as N	Suspended Sediment
			thousands of pounds								
Towanda	Winter	14,500	582.0	2,170	6,530	9,280	21.8	256.0	736.0	512.0	395,000
	Spring	10,800	323.0	1,810	3,980	6,110	14.8	195.0	509.0	291.0	236,000
	Summer	1,340	38.2	407	254	699	2.9	31.2	78.0	28.2	10,200
	Fall	5,000	193.0	1,010	2,150	3,350	7.1	112.0	287.0	177.0	77,800
Danville	Winter	19,500	970.0	1,230	11,300	13,500	61.2	206.0	843.0	859.0	578,000
	Spring	15,000	458.0	2,020	6,680	9,160	42.8	131.0	602.0	370.0	473,000
	Summer	2,480	48.2	673	539	1,260	7.3	22.9	110.0	34.5	22,700
	Fall	7,030	301.0	769	3,360	4,430	30.9	79.2	301.0	267.0	95,500
Lewisburg	Winter	15,100	552.0	2,760	5,700	9,010	32.8	131.0	445.0	485.0	437,000
	Spring	8,220	236.0	1,290	2,620	4,150	15.9	61.1	198.0	198.0	112,000
	Summer	2,200	45.4	357	698	1,100	12.1	24.9	64.5	34.0	11,800
	Fall	8,740	264.0	1,650	3,000	4,910	32.9	98.7	248.0	229.0	173,000
Newport	Winter	6,610	185.0	1,040	4,190	5,410	31.9	88.6	210.0	134.0	167,000
	Spring	3,800	121.0	809	2,000	2,930	18.8	45.3	142.0	89.3	190,000
	Summer	1,190	38.1	293	434	765	12.6	18.1	48.8	29.0	24,000
	Fall	5,440	233.0	1,700	2,910	4,840	79.1	98.7	305.0	152.0	501,000
Marietta	Winter	50,800	1,740.0	4,760	29,500	36,000	119.0	552.0	1,830.0	1,580.0	941,000
	Spring	31,700	589.0	3,210	14,800	18,600	59.1	299.0	988.0	542.0	475,000
	Summer	7,770	99.4	1,060	2,780	3,940	21.5	85.3	222.0	83.4	35,800
	Fall	25,000	701.0	3,200	13,000	16,900	107.0	324.0	948.0	671.0	389,000
Conestoga	Winter	629	122.0	2,160	1,840	4,120	11.4	37.3	106.0	101.0	44,800
	Spring	531	34.7	1,400	886	2,320	5.0	18.5	60.9	27.2	24,900
	Summer	245	8.3	712	320	1,040	3.3	12.4	37.2	5.8	8,770
	Fall	228	15.9	724	280	1,020	2.1	9.4	23.5	11.7	2,880

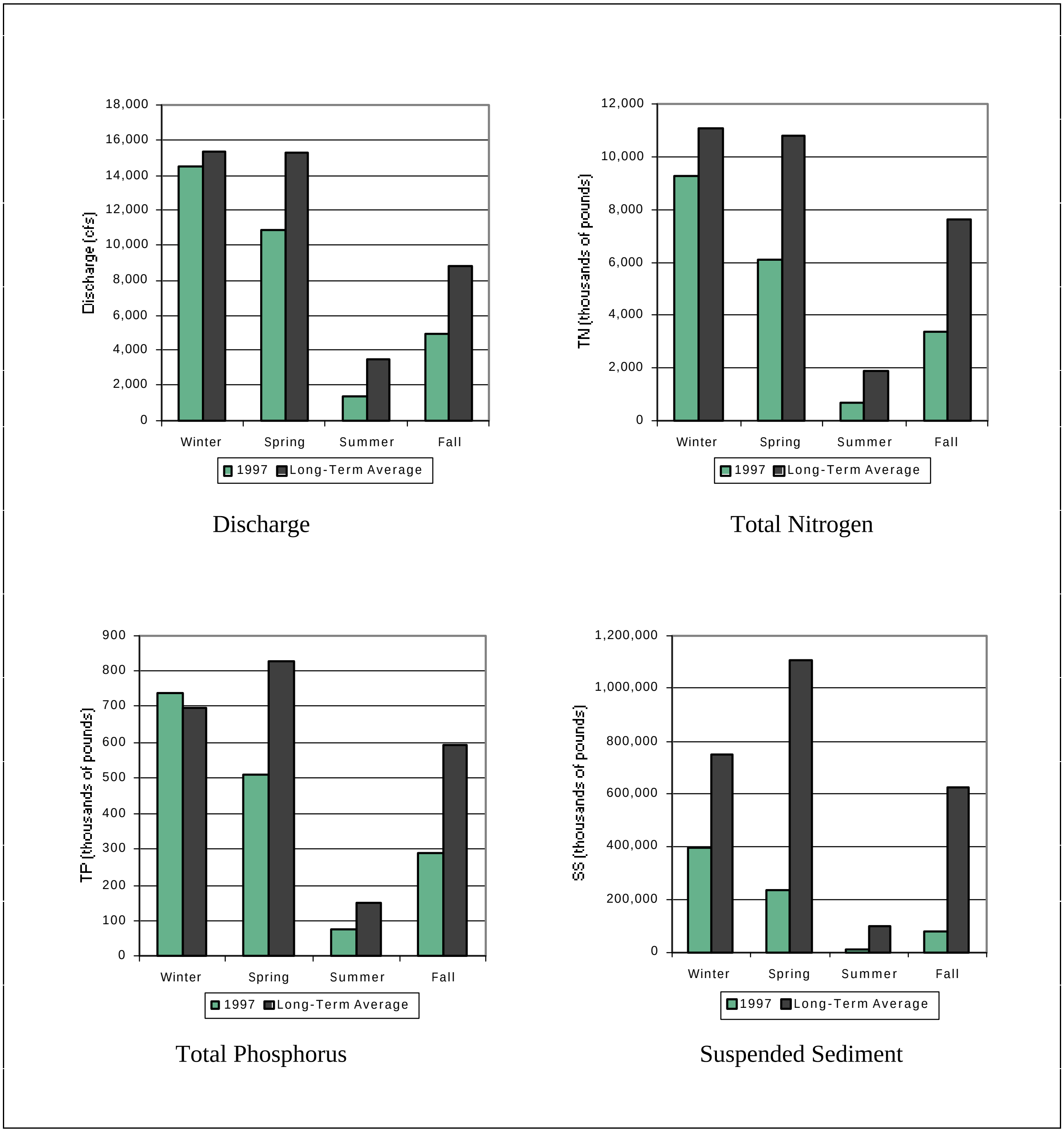


Figure 7. Seasonal Discharges and Loads of Total Nitrogen, Total Phosphorus, and Suspended Sediment at Towanda, Pa., Calendar Year 1997

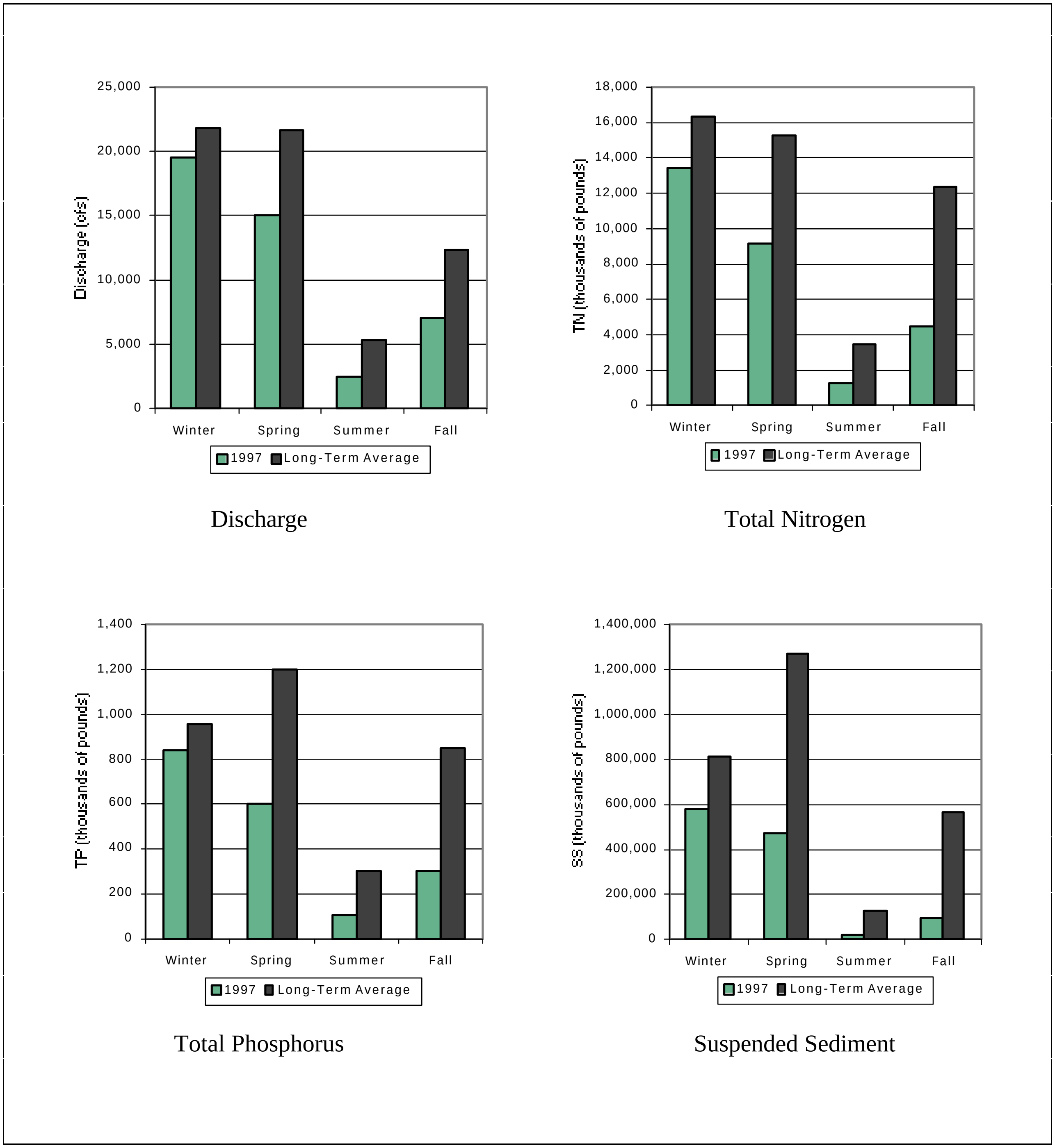


Figure 8. Seasonal Discharges and Loads of Total Nitrogen, Total Phosphorus, and Suspended Sediment at Danville, Pa., Calendar Year 1997

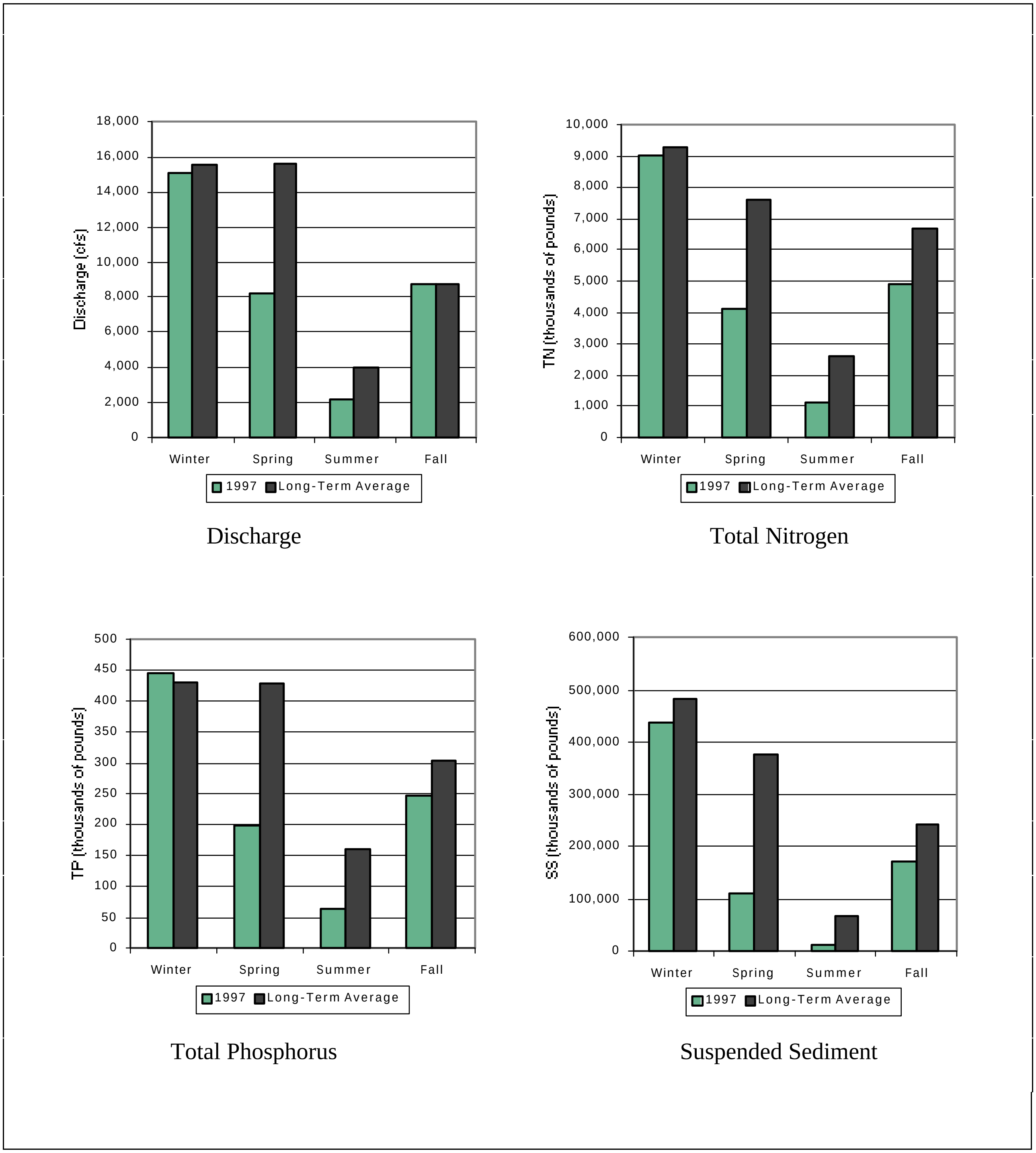


Figure 9. Seasonal Discharges and Loads of Total Nitrogen, Total Phosphorus, and Suspended Sediment at Lewisburg, Pa., Calendar Year 1997

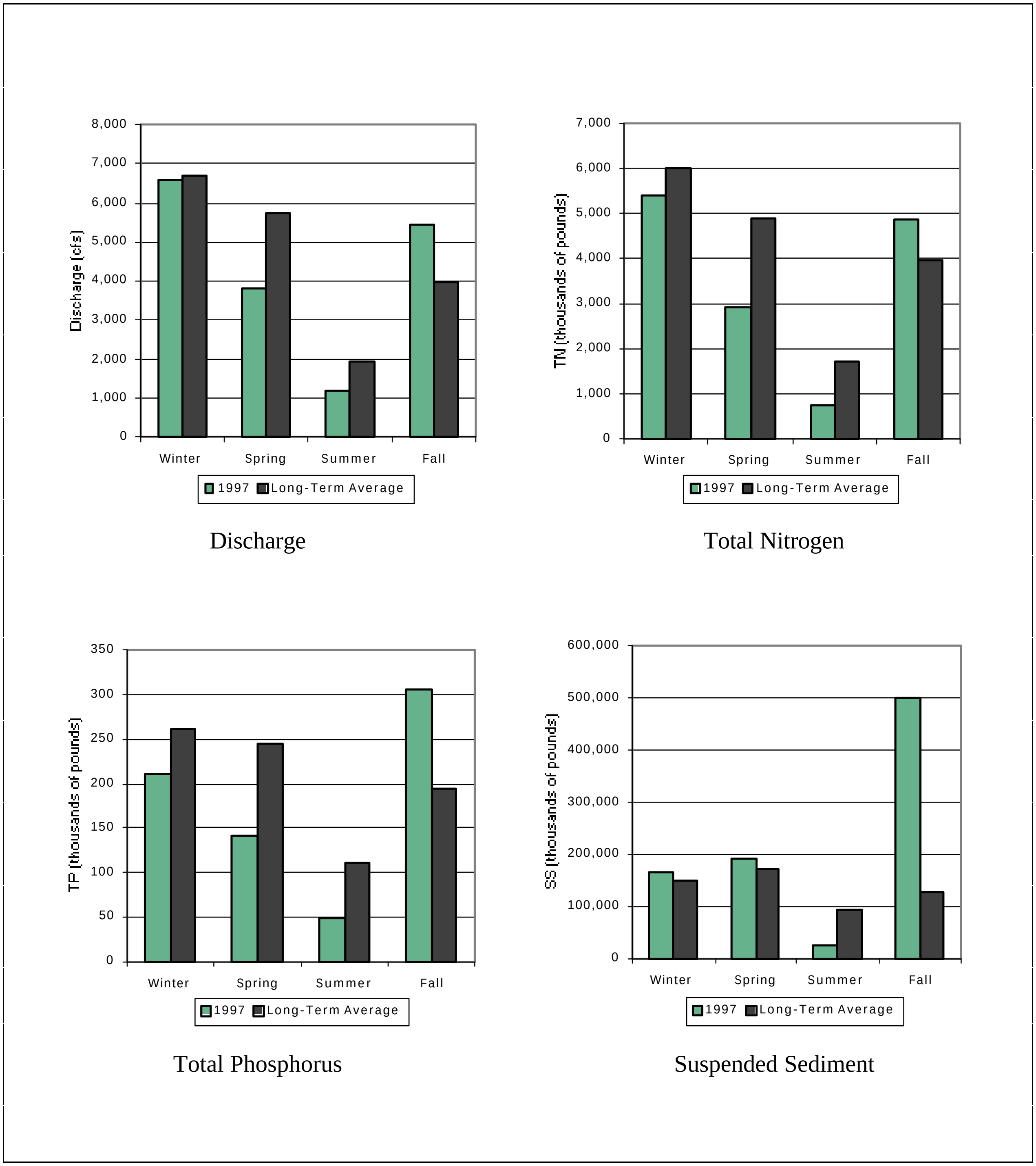


Figure 10. Seasonal Discharges and Loads of Total Nitrogen, Total Phosphorus, and Suspended Sediment at Newport, Pa., Calendar Year 1997

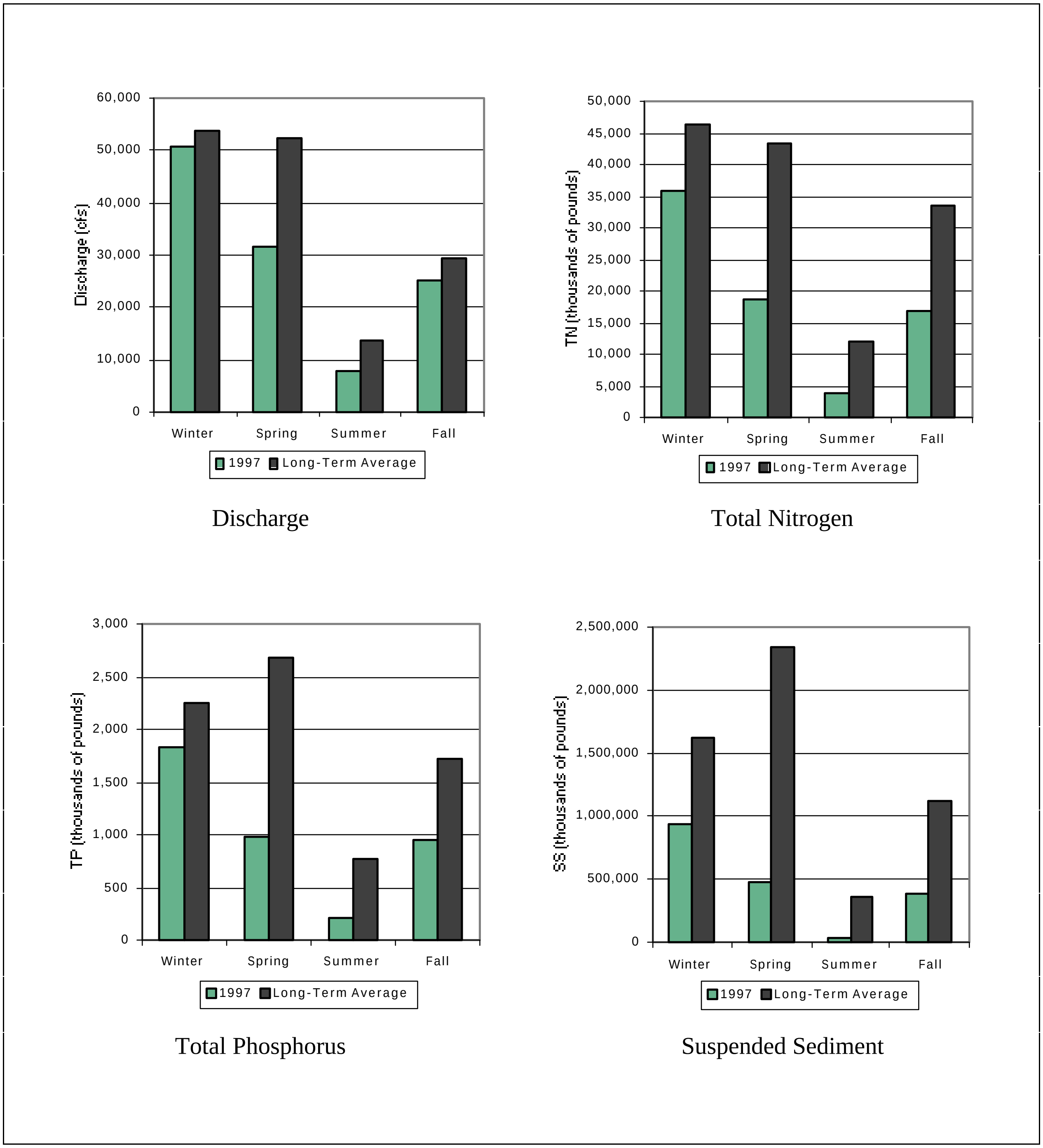


Figure 11. Seasonal Discharges and Loads of Total Nitrogen, Total Phosphorus, and Suspended Sediment at Marietta, Pa., Calendar Year 1997

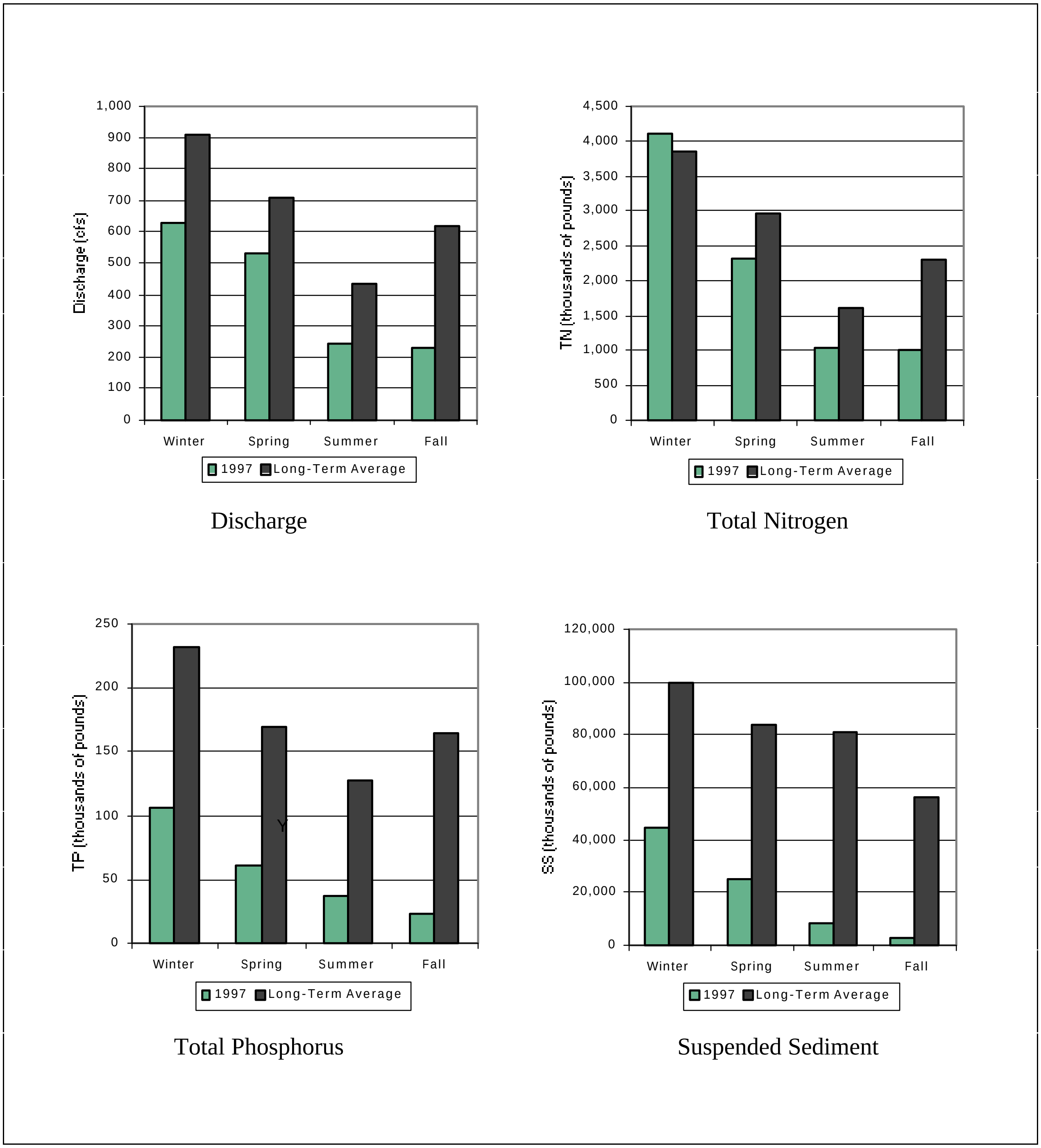
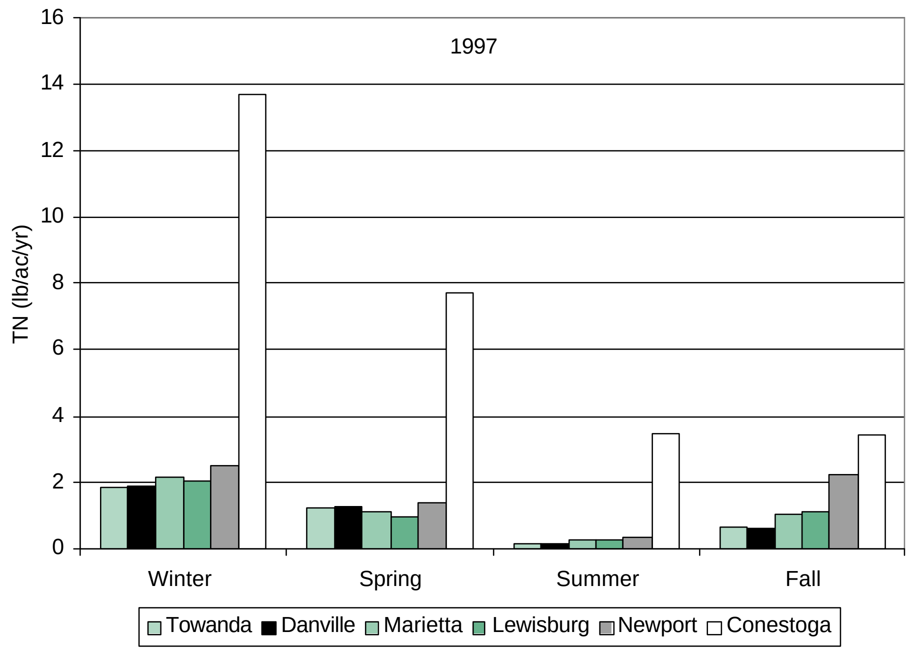


Figure 12. Seasonal Discharges and Loads of Total Nitrogen, Total Phosphorus, and Suspended Sediment at Conestoga, Pa., Calendar Year 1997



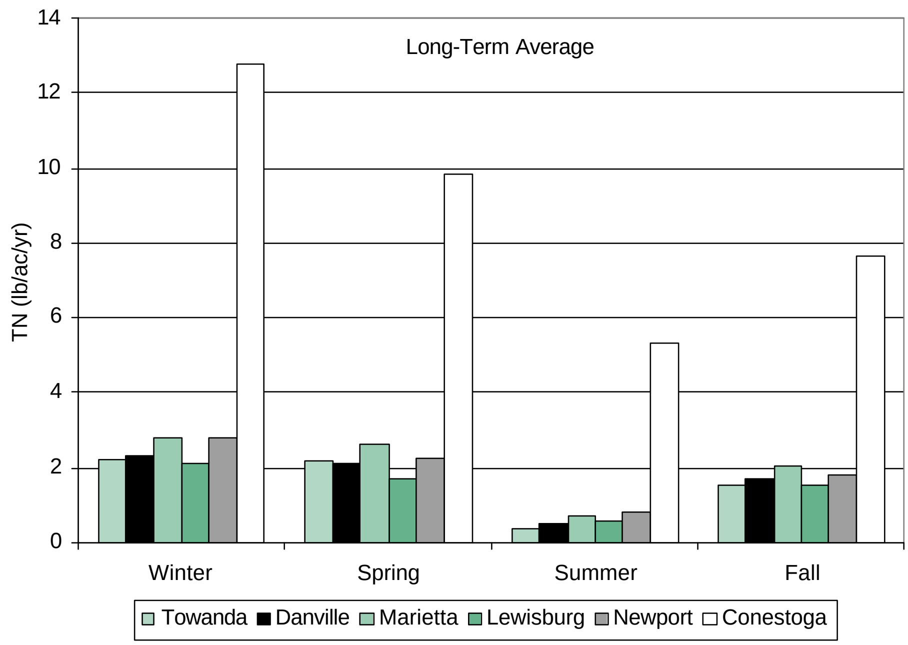


Figure 13. Comparison of Seasonal Yields of Total Nitrogen (TN) at Towanda, Danville, Marietta, Lewisburg, Newport, and Conestoga, Pa.

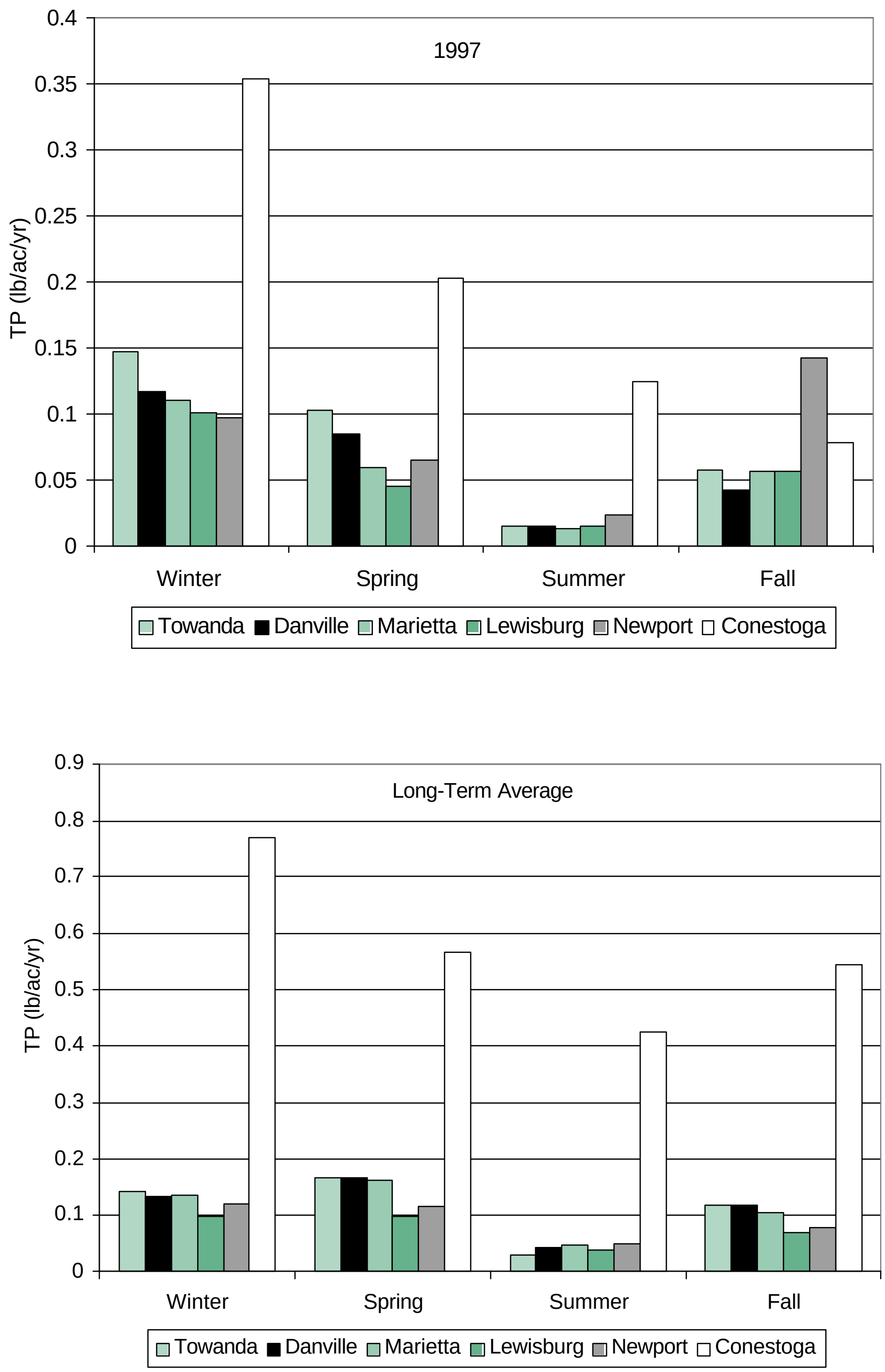


Figure 14. Comparison of Seasonal Yields of Total Phosphorus (TP) at Towanda, Danville, Marietta, Lewisburg, Newport, and Conestoga, Pa.

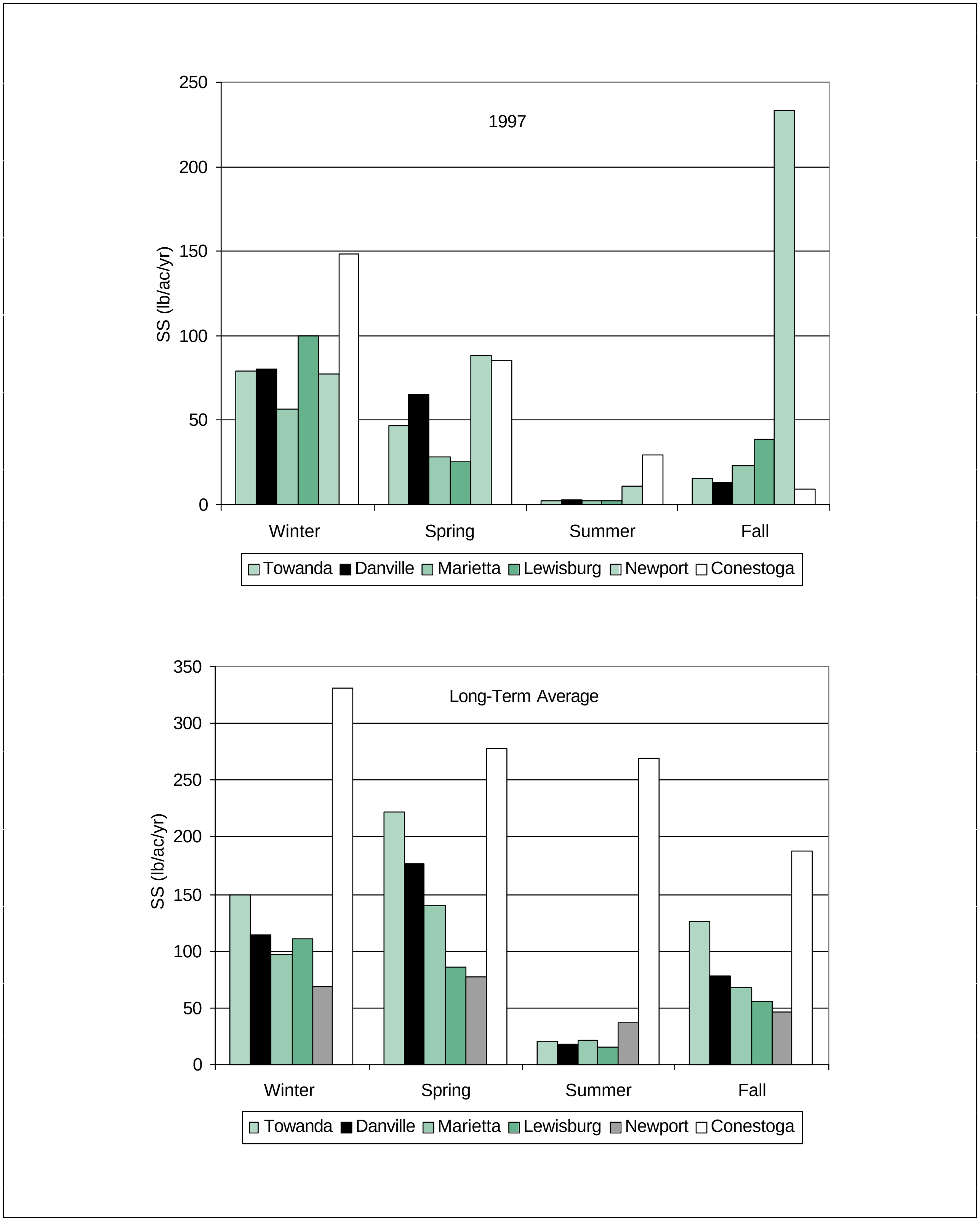


Figure 15. Comparison of Seasonal Yields of Suspended Sediment (SS) at Towanda, Danville, Marietta, Lewisburg, Newport, and Conestoga, Pa.

Newport during the fall. The yields were greater than the yields at Conestoga, probably due to the higher than normal rainfall in the Juniata River Watershed.

COMPARISON OF THE 1997 LOADS AND YIELDS OF TOTAL NITROGEN, TOTAL PHOSPHORUS AND SUSPENDED SEDIMENT WITH THE BASELINES

Several studies, Ott and others (1991), Takita and Edwards (1993), and Takita (1998) have shown that annual loads of total nitrogen, total phosphorus, and suspended sediment change with annual fluctuations in water discharge. The annual fluctuations of nutrient and suspended-sediment loads and water discharge make it difficult to determine whether the changes are related to land use, nutrient availability, or simply annual water discharge. The long-term loads and yields shown in Figures 4 through 6 are the mathematical averages of the annual loads and yields for the period of record and do not account for the effects of fluctuations in the annual discharges. Ott and others (1991) used the functional relationship of 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 loads or yields against the water-discharge ratio. This water-discharge ratio is the ratio of the annual mean discharge to the long-term mean discharge. Data for the five years (1985-89) were used to provide a best-fit linear regression line to be used as the baseline relationship between annual loads and water discharge. It was hypothesized that, as future loads and water-discharge ratios were plotted against the baseline, any significant deviation from the baseline would indicate that some change in the annual load had occurred, and that further evaluations to determine the reason for the change were warranted. The data collected in 1997 were compared with the 1985-89 baseline, 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.

Susquehanna River at Towanda, Pa.

The 5-year (1989-93) baselines for total nitrogen, total phosphorus, and suspended sediment for the Susquehanna River at Towanda are shown in Figure 16 with the 1997 annual yield. Best-fit lines were drawn through the initial five-year data sets using the following equations:

Total Nitrogen (TN)
TN Yield = 0.7484 + 6.0967x $R^2 = 0.86$

Total Phosphorus (TP)
TP Yield = -0.1419 + 0.4999x $R^2 = 0.52$

Suspended Sediment (SS)
SS Yield = -612.879 + 918.165x $R^2 = 0.43$

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

The 1997 total nitrogen yield plots significantly below the 5-year baseline, suggesting that the total nitrogen load decreased. The total nitrogen yield was estimated to be 4.65 lb/ac/yr at a water discharge ratio of 0.75 during the initial five years of monitoring, while the yield for 1997 was 3.89 lb/ac/yr at the same discharge ratio. Total phosphorus and suspended-sediment yields for 1997 were higher than the baseline yields. The baseline total phosphorus yield was 0.23 lb/ac/yr, compared to 0.32 lb/ac/yr for 1997. The suspended-sediment yields were 75.7 and 144.7 lb/ac/yr for the baseline and 1997, respectively.

Susquehanna River at Danville, Pa.

Figure 17 shows the 5-year (1985-89) baselines for total nitrogen, total phosphorus, and suspended sediment and the 1997 yields for the Susquehanna River at Danville. The regression equations used to establish the baselines were:

Total Nitrogen (TN)
TN Yield = -0.1792 + 7.2989x $R^2 = 0.85$

Total Phosphorus (TP)
TP Yield = -0.1496 + 0.6586x $R^2 = 0.94$

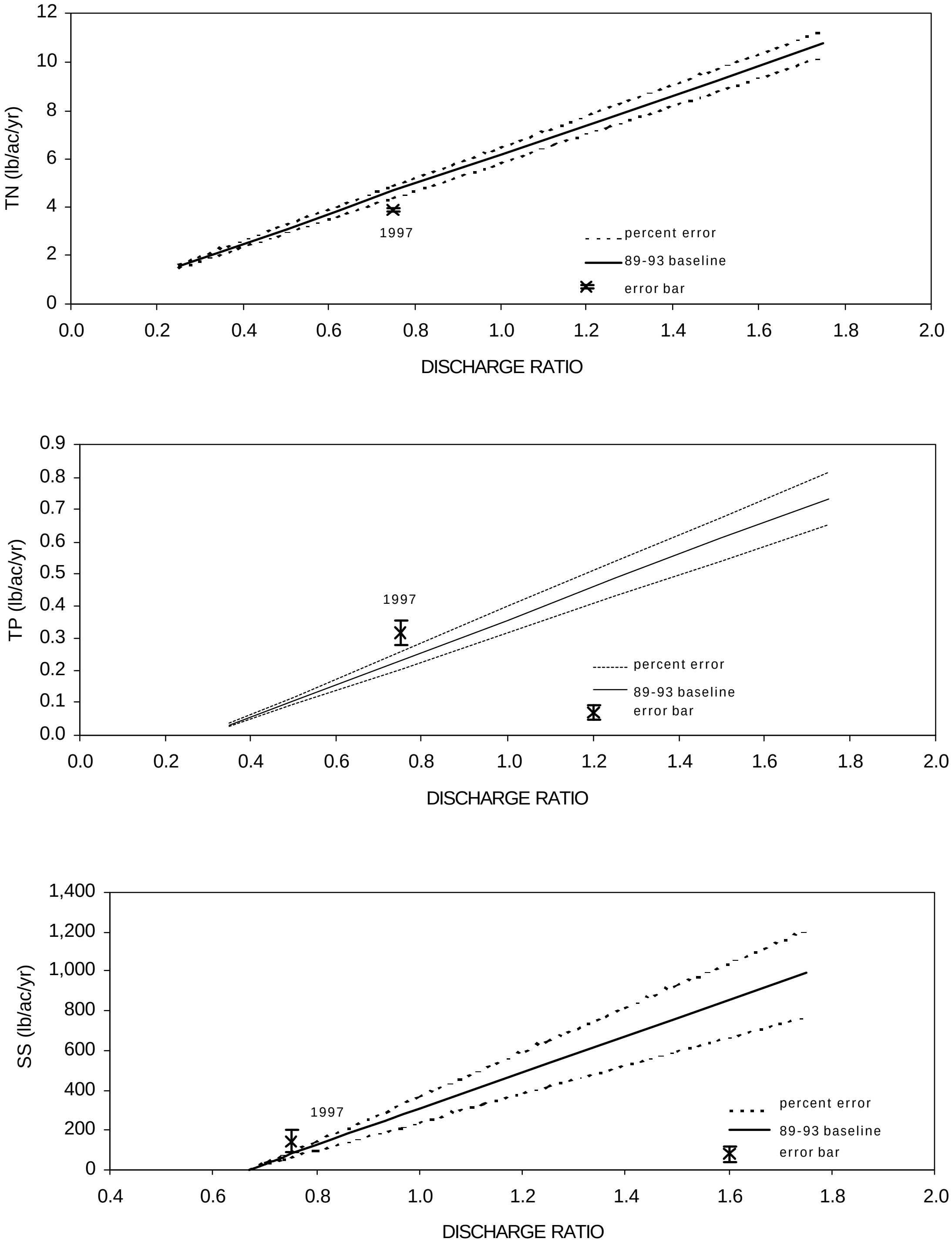


Figure 16. Total Nitrogen (TN), Total Phosphorus (TP), and Suspended-Sediment (SS) Yields, Susquehanna River at Towanda, Pa., 1989-93 and 1997

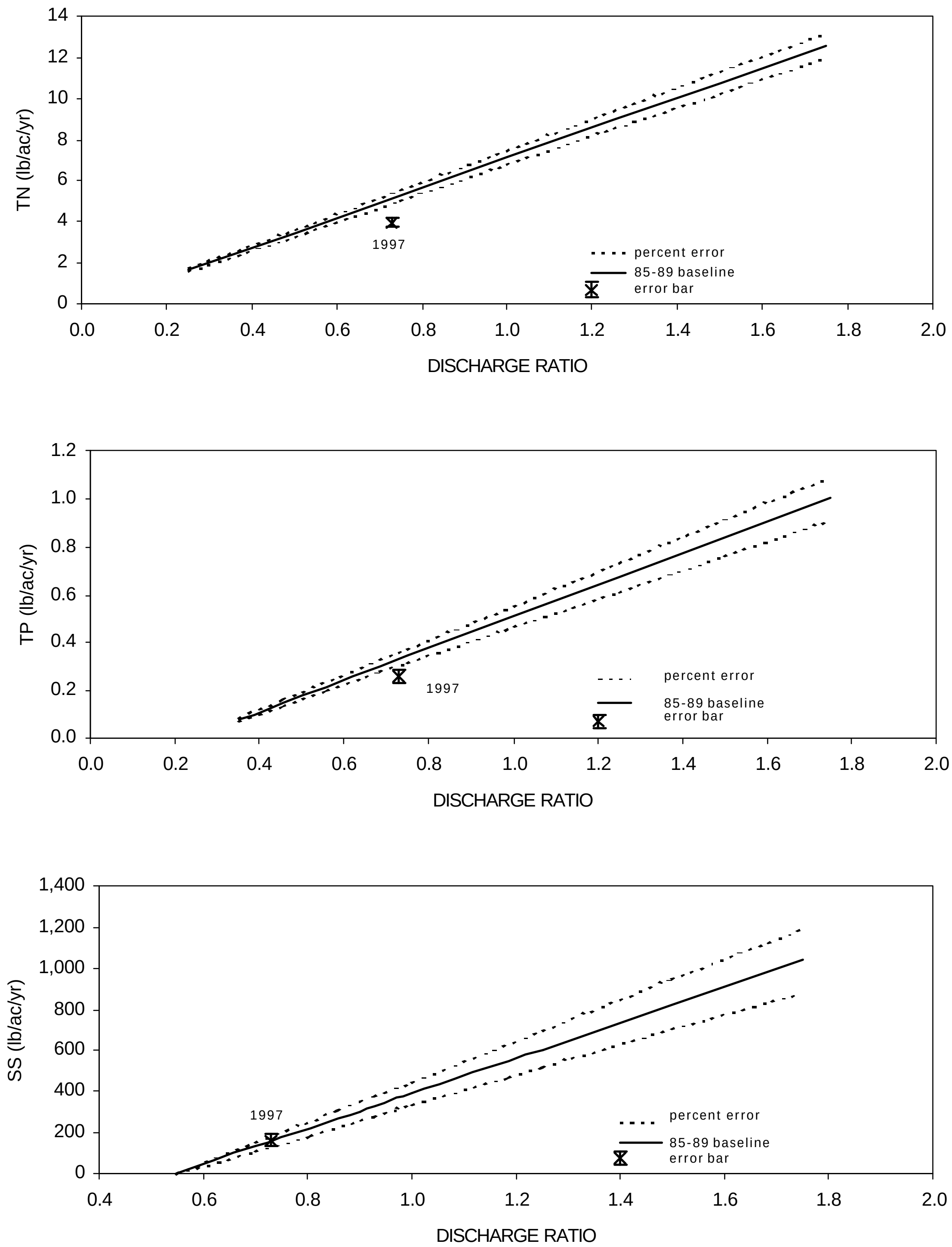


Figure 17. Total Nitrogen (TN), Total Phosphorus (TP), and Suspended-Sediment (SS) Yields, Susquehanna River at Danville, Pa., 1985-89 and 1997

Suspended Sediment (SS)
SS Yield = -471.893 + 862.484 R^2 = 0.99

Total nitrogen and total phosphorus yields for 1997 plotted significantly below the baseline, indicating that there was a decrease in the loads. The baseline yields of total nitrogen and total phosphorus were 5.15 and .033 lb/ac/yr at the discharge of 0.73, compared to 3.95 and 0.26 lb/ac/yr for 1997, respectively. The suspended-sediment yield plotted nearly on the baseline and indicates that there was no significant change in the sediment load. The baseline yield was 157.8 lb/ac/yr, compared to 162.8 lb/ac/yr for 1997.

West Branch Susquehanna River at Lewisburg, Pa.

The 1985-89 baselines and the 1997 yields for total nitrogen, total phosphorus, and suspended sediment are shown in Figure 18. The baselines were defined by the following equations:

Total Nitrogen (TN)
TN Yield = -1.3773 + 7.8447x R^2 = 0.73

Total Phosphorus (TP)
TP Yield = 0.0399 + 0.2660x R^2 = 0.50

Suspended Sediment (SS)
SS Yield = -152.859 + 344.025x R^2 = 0.66

Total nitrogen for 1997 plotted significantly below the baseline, indicating that the nitrogen load decreased. The baseline yield was 4.82 lb/ac/yr at the discharge ratio of 0.79, compared to 4.38 lb/ac/yr for 1997. Total phosphorus shows a decrease, but the decrease may not be significant since it lies within the margin of error. The yields were 0.24 lb/ac/yr for the baseline and 0.22 lb/ac/yr for 1997. Suspended sediment shows a slight increase in 1997, which may not be significant since it lies within the margin of error. The baseline yield was 118.9 lb/ac/yr, and the 1997 yield was 167.5 lb/ac/yr.

Juniata River at Newport, Pa.

The 1985-89 baselines for total nitrogen, total phosphorus, and suspended sediment at Newport, shown in Figure 19, were plotted using the following equations:

Total Nitrogen (TN)
TN Yield = -0.2937 + 8.9052x R^2 = 0.80

Total Phosphorus (TP)
TP Yield = -0.0892 + 0.5268x R^2 = 0.95

Suspended Sediment (SS)
SS Yield = -293.255 + 563.920x R^2 = 0.89

Total nitrogen and total phosphorus yields for 1997 show significant decreases from the baseline. The total nitrogen baseline yield was 8.08 lb/ac/yr at a discharge ratio of 0.94, and the 1997 yield was 6.5 lb/ac/yr. Total phosphorus yields were 0.41 and 0.33 lb/ac/yr for the baseline and 1997, respectively. Suspended sediment shows an increase in 1997 from 236.8 lb/ac/yr for the baseline to 411.1 lb/ac/yr. This increase may not be significant since it lies within the margin of error.

Susquehanna River at Marietta, Pa.

The total nitrogen, total phosphorus, and suspended-sediment baseline for the 5-year period 1987-91 at Marietta and the 1997 yield are shown in Figure 20. The baselines were plotted using the following equations:

Total Nitrogen (TN)
TN Yield = -0.8300 + 9.3087x R^2 = 0.99

Total Phosphorus (TP)
TP Yield = 0.1330 + 0.2405x R^2 = 0.28

Suspended Sediment (SS)
SS Yield = -97.8555 + 385.9816x R^2 = 0.48

Total nitrogen, total phosphorus, and suspended-sediment yields for 1997 plotted significantly below their respective baselines, indicating that there was a decrease in loads. The total nitrogen baseline yield was 6.43 lb/ac/yr at a

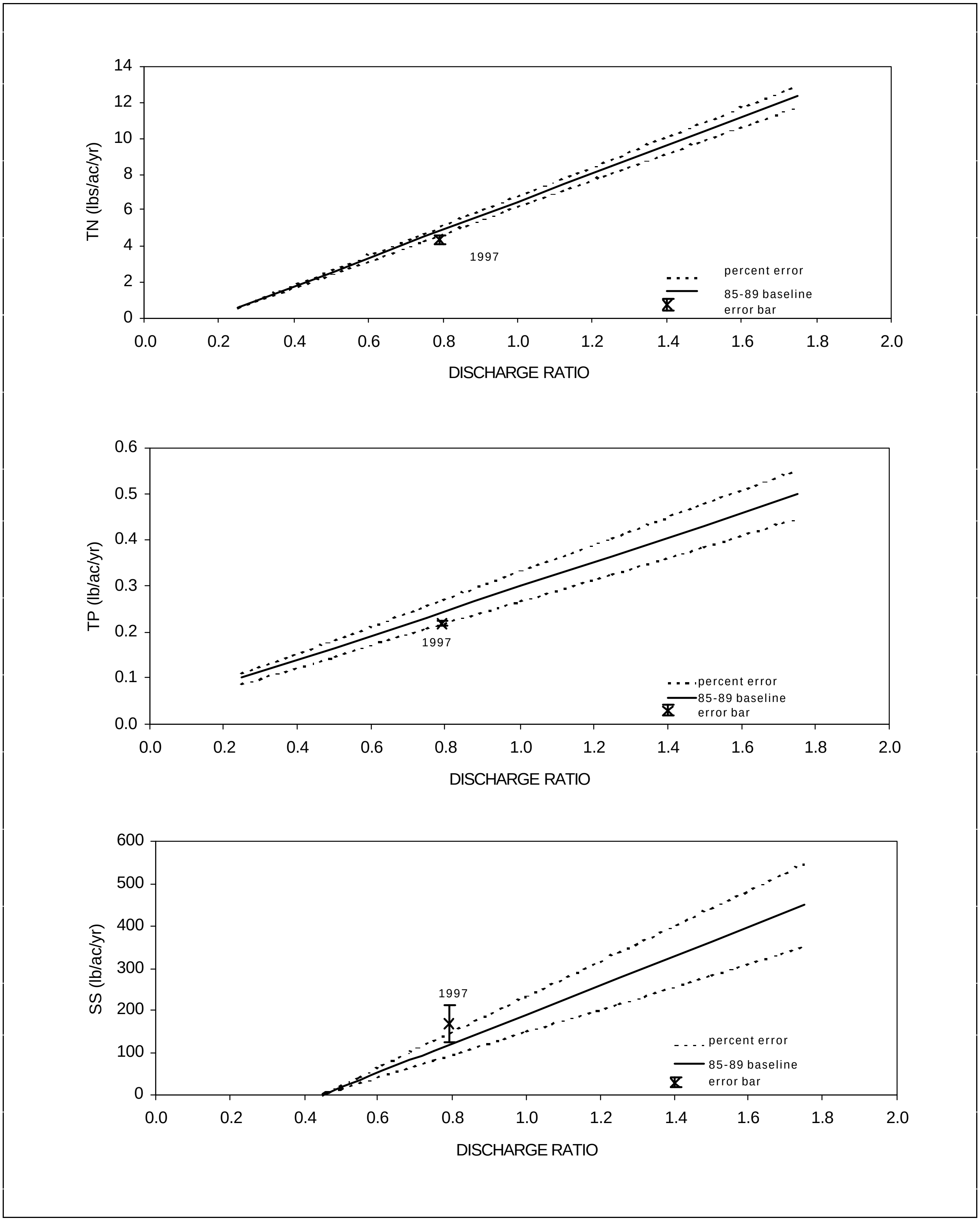


Figure 18. Total Nitrogen (TN), Total Phosphorus (TP), and Suspended-Sediment (SS) Yields, West Branch Susquehanna River at Lewisburg, Pa., 1985-89 and 1997

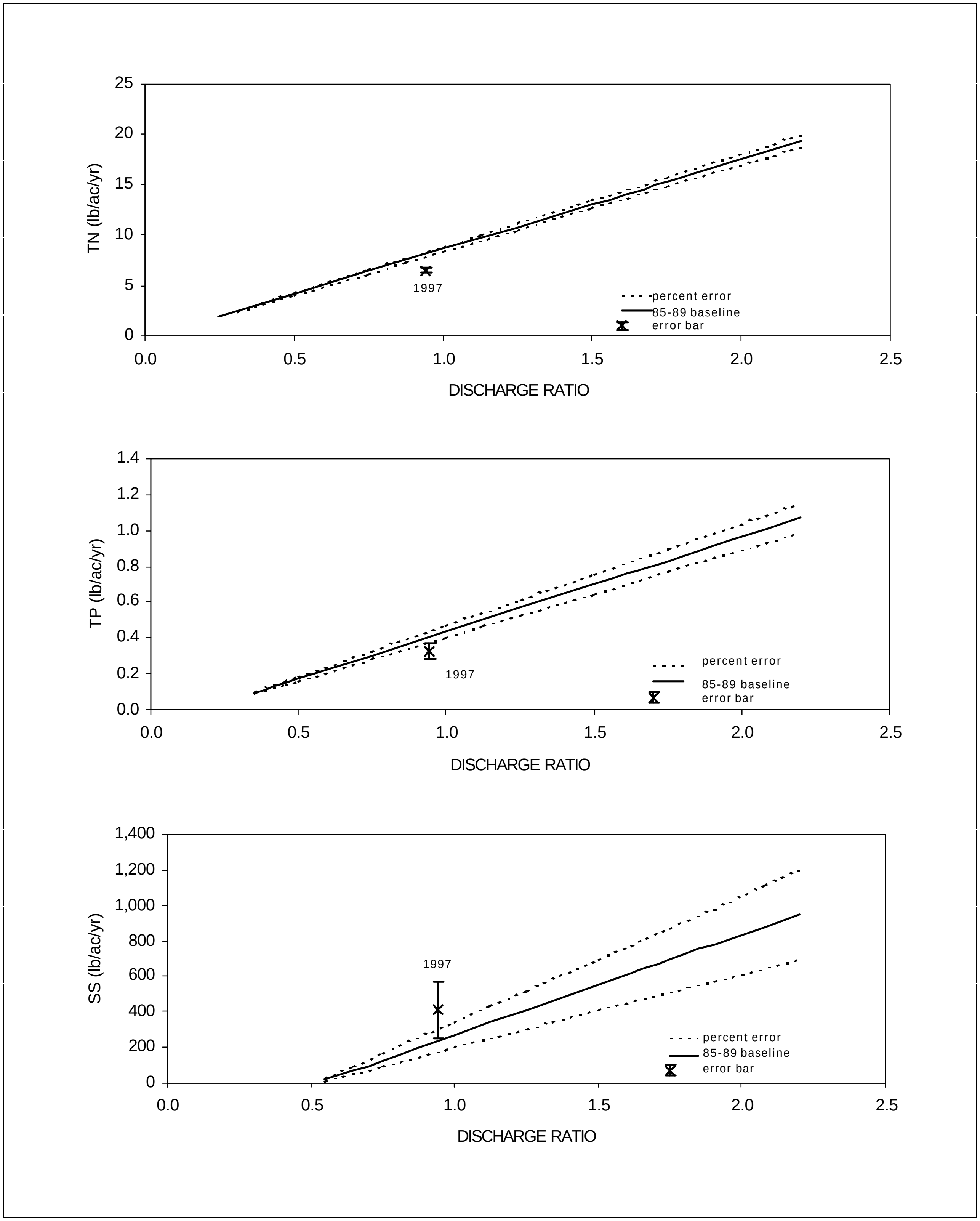


Figure 19. Total Nitrogen (TN), Total Phosphorus (TP), and Suspended-Sediment (SS) Yields, Juniata River at Newport, Pa., 1985-89 and 1997

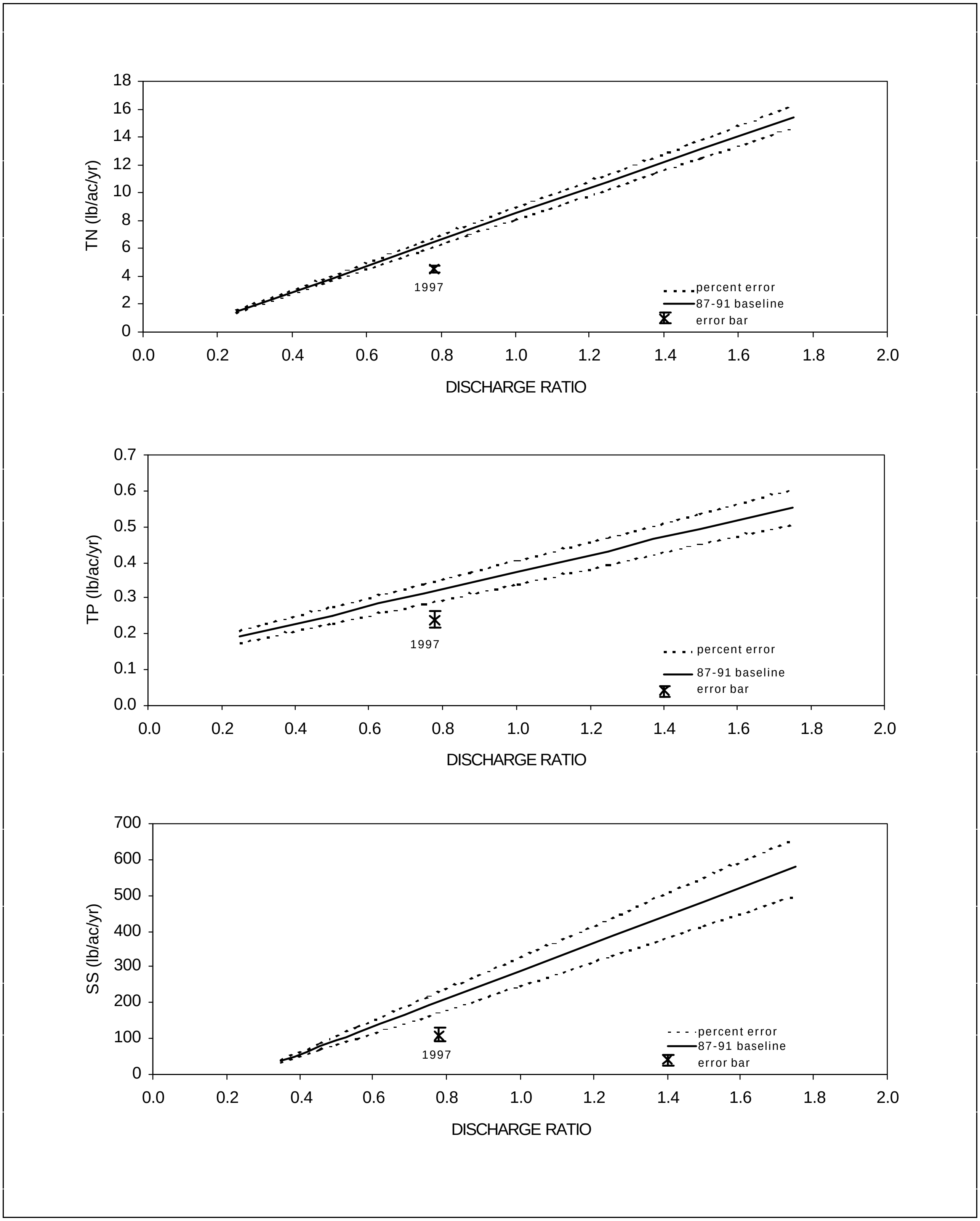


Figure 20. Total Nitrogen (TN), Total Phosphorus (TP), and Suspended-Sediment (SS) Yields, Susquehanna River at Marietta, Pa., 1987-91 and 1997

discharge ratio of 0.78, and the 1997 yield was 4.53. Total phosphorus baseline yield was 0.32 lb/ac/yr, compared to 0.24 for 1997. Suspended-sediment yields were 203.2 and 110.6 lb/ac/yr for the baseline and for 1997, respectively.

Conestoga River at Conestoga, Pa.

Figure 21 shows the total nitrogen, total phosphorus, and suspended-sediment baselines. These baselines were plotted using the following equations:

Total Nitrogen (TN)
TN Yield = 2.3343 + 35.3217x $R^2 = 0.97$

Total Phosphorus (TP)
TP Yield = -1.4013 + 3.3216x $R^2 = 0.92$

Suspended Sediment (SS)
SS Yield = -617.301 + 1978.075x $R^2 = 0.72$

The 1997 total nitrogen yield plotted on the baseline, indicating that there was no change in the total nitrogen yield. The baseline and 1997 yields were 28.47 and 28.25 lb/ac/yr, respectively, at a discharge ratio of 0.74. The total phosphorus and suspended-sediment yield showed significant decreases in 1997. Total phosphorus yields were 1.06 and 0.8 lb/ac/yr for the baseline and 1997, respectively. The suspended-sediment baseline yield was 846.47 lb/ac/yr, and the 1997 yield was 270 lb/ac/yr.

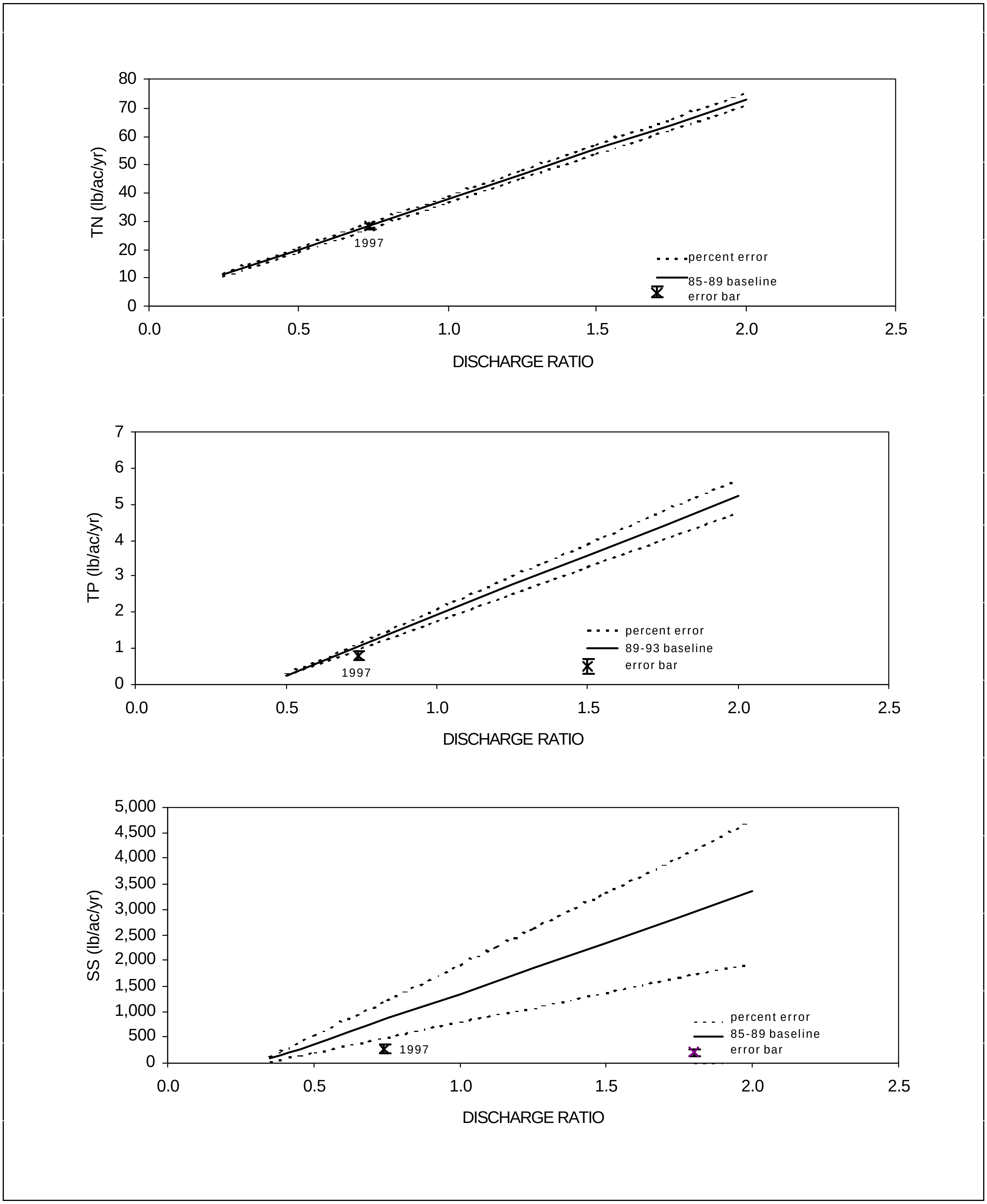


Figure 21. Total Nitrogen (TN), Total Phosphorus (TP), and Suspended-Sediment (SS) Yields, Conestoga River at Conestoga, Pa., 1985-89, 1989-93, and 1997

SUMMARY

Nutrient and suspended-sediment samples were collected during baseflow and storm flow in calendar year 1997. The samples were collected from the Susquehanna River at Towanda, Danville, and Marietta, the West Branch Susquehanna River at Lewisburg, the Juniata River at Newport, and the Conestoga River at Conestoga, Pa.

Annual precipitation was well below normal in 1997 at nearly all sites. The one exception was the Juniata basin, where rainfall averaged 3.53 inches above normal. Rainfall deficits ranged from 3.57 inches in the Susquehanna River Basin above Marietta to 10.3 inches in the Conestoga River Basin. Water discharges ranged from 74 to 94 percent of long-term average discharges.

Annual loads of total nitrogen were highest in the Susquehanna River at Marietta, followed by the Susquehanna River at Danville. The Conestoga River at Conestoga had the smallest total nitrogen load. The total nitrogen yield, in lb/ac/yr, from the West Branch Susquehanna River at Lewisburg, with 81 percent forest and 13.9 percent agriculture, was greater than at Danville, with 59.8 percent forest and 26.9 percent agriculture. The Conestoga River Watershed, with 62.7 percent agricultural and 22.4 percent forest lands, had the highest yields of total nitrogen.

Annual total phosphorus loads were highest at Marietta, followed by Danville. The smallest annual total phosphorus load was measured at Conestoga. Although the total phosphorus load at Danville was greater than at Towanda, the yield, in lb/ac/yr, was greater at Towanda. The highest yield of total phosphorus was found at Conestoga.

Annual loads of suspended sediment were highest at Marietta, followed by Danville. Conestoga had the smallest suspended-sediment load. The annual yield of suspended sediment was highest at Conestoga.

Seasonal mean water discharges in 1997 were highest in the winter, followed by spring, then fall at Towanda, Danville, Lewisburg, and Marietta. Seasonal water discharges at Newport were highest in the winter, followed by fall, then spring. Seasonal water discharges at Conestoga were highest in the winter, then spring and summer. The 1997 seasonal water discharges were generally smaller than the long-term, except for the fall discharge at Newport. This greater than normal discharge was most likely due to the higher than normal rainfall.

The seasonal variation of total nitrogen loads for 1997 corresponded with the seasonal variation of water discharges at all sites. The seasonal loads of total phosphorus and suspended sediment were consistent with seasonal variations of water discharges at Towanda, Danville, Marietta, and Conestoga. Total phosphorus and suspended-sediment loads were greatest in the fall at Newport, probably due to the above normal rainfall. The 1997 seasonal loads were generally smaller than the long-term average loads, except at Newport, where total nitrogen, total phosphorus, and suspended-sediment loads were greater in the fall.

Comparison of seasonal yields among the Susquehanna River monitoring sites indicates that both the long-term and 1997 total nitrogen yields in the Susquehanna River at Towanda, Danville and Marietta increased in the downstream order. Total phosphorus and suspended-sediment yields at Towanda, Danville, and Marietta generally decreased in the downstream order. Comparison of long-term and 1997 seasonal yields among the tributary sites at Lewisburg, Newport, and Conestoga indicates that the total nitrogen and total phosphorus yields are smallest at Lewisburg for all seasons. The long-term suspended-sediment seasonal yields indicate that Newport normally has the smallest yield among the tributary sites, but in 1997, the yields were greatest in the spring and fall.

Comparison of the 1997 annual yields and the 5-year baselines indicates that there were significant decreases of total nitrogen at Towanda, Danville, Lewisburg, Newport, and Marietta. The 1997 total nitrogen yield at Conestoga plotted on the baseline, indicating that there was no change in the load. Total phosphorus yields were significantly lower than the baseline yields at Danville, Newport, Marietta, and Conestoga. The 1997 total phosphorus yield at Lewisburg was lower than the baseline yield, but the decrease may not be significant. The 1997 total phosphorus yield at Towanda was significantly higher than the baseline yield. Comparison of the 1997 suspended-sediment yields, and the baseline yields indicates that there were significant decreases at Marietta and Conestoga. Suspended-sediment yields were higher than the baseline yields at Towanda, Lewisburg, and Newport. The suspended-sediment yield at Danville was nearly the same as the baseline yield, indicating that there was no change.

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