NUTRIENTS AND SUSPENDED SEDIMENT TRANSPORTED IN THE SUSQUEHANNA RIVER BASIN, 1994-96, AND LOADING TRENDS, CALENDAR YEARS 1985-96

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Charles S. Takita

ABSTRACT

Nutrient and suspended-sediment samples were collected during base flow and storm flow in calendar years 1994, 1995, and 1996. The samples were collected from the Susquehanna River at Towanda, Danville, and Marietta, the West Branch Susquehanna River at Lewisburg, Juniata River at Newport, and the Conestoga River at Conestoga, Pennsylvania.

Annual loads of nutrients and suspended sediment computed for calendar years 1994-96 fluctuated directly with annual water discharge at all sites. The loads, in thousands of pounds per year, and water discharge were highest in 1996, and lowest in 1995. Annual yields of nutrients and suspended sediment in pounds per acre per year were highest at Conestoga. The Susquehanna River at Danville had a higher yield of nutrients and suspended sediment than the West Branch Susquehanna River at Lewisburg. Seasonal loads of total nitrogen, total phosphorus, and suspended sediment generally varied according to the variations in the seasonal water discharges.

Annual yields and water discharge ratios for 1994, 1995, and 1996 were plotted against baselines developed from the initial five years of data collection. Total nitrogen yields and water discharge ratios for 1994, 1995, and 1996 plotted below the initial five-year baselines at all sites, indicating some changes may be occurring. Total phosphorus yields for Towanda, Lewisburg, and Conestoga plotted above the five-year baseline, suggesting that the load increased in calendar years 1994-96. Total phosphorus yields for Danville and Newport plotted below the baseline, indicating that the loads decreased. The total phosphorus and suspended-sediment yields at Marietta plotted above the baseline in 1994 and 1996 and below the baseline in 1995. Suspended-sediment yields at Towanda and Lewisburg plotted above the baseline, suggesting that the loads increased in calendar years 1994-96. The suspended-sediment yields at Danville, Newport, and Conestoga plotted below the baseline, indicating that a decrease in load occurred.

Double-mass comparisons of total nitrogen, total phosphorus, and suspended-sediment discharges with water discharges were used to illustrate several trends occurring during the period 1985-96.

INTRODUCTION

The Pennsylvania Department of Environmental Protection (Pa. DEP), Bureau of Water Quality Protection, and Bureau of Laboratories, the U.S. Environmental Protection Agency (US EPA), 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 (US EPA, 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, and subsequent amendments to that 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 nutrients and suspended sediment that enter the Chesapeake Bay are thought to originate from the lower Susquehanna River Basin.

Several studies, 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, 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, US EPA, and the U.S. Geological Survey (USGS), conducted a five-year intensive study during the period 1985-89. 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). This study also reinforced the indications from earlier studies that the highest nutrient yields come from the lower basin. The scope of the initial five-year study was reduced in 1990 to five long-term monitoring stations. An additional site was included in 1994, and sampling at these sites was continued.

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 nutrients and suspended sediment measured during calendar years 1994, 1995, and 1996, 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 and loading trends for calendar years 1985-96 also 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° F (degrees Fahrenheit) near the Pennsylvania-Maryland border to 45° F in the northern part of the basin. Annual precipitation in the basin averages 39.15 inches, and is fairly well distributed throughout the year.

Land use in the Susquehanna River Basin is predominantly rural. Woodland accounts for 65 percent; cultivated lands, 18 percent; urban lands, 9 percent and grassland, 7 percent of land use, respectively (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 subbasins. 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 grasslands occupy areas in the lower

Figure 1. Map Showing the Susquehanna River Basin

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. They include the Binghamton and Elmira-Corning areas in New York and the Scranton and Wilkes-Barre area in Pennsylvania. The major urban areas in the West Branch Susquehanna River Basin are Williamsport and Lock Haven.

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 at Newport. 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.

Table 1. Data Collection Sites and Their Drainage Areas

USGS Identification Number	Station Name	Short Name	Drainage Area (square miles)
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

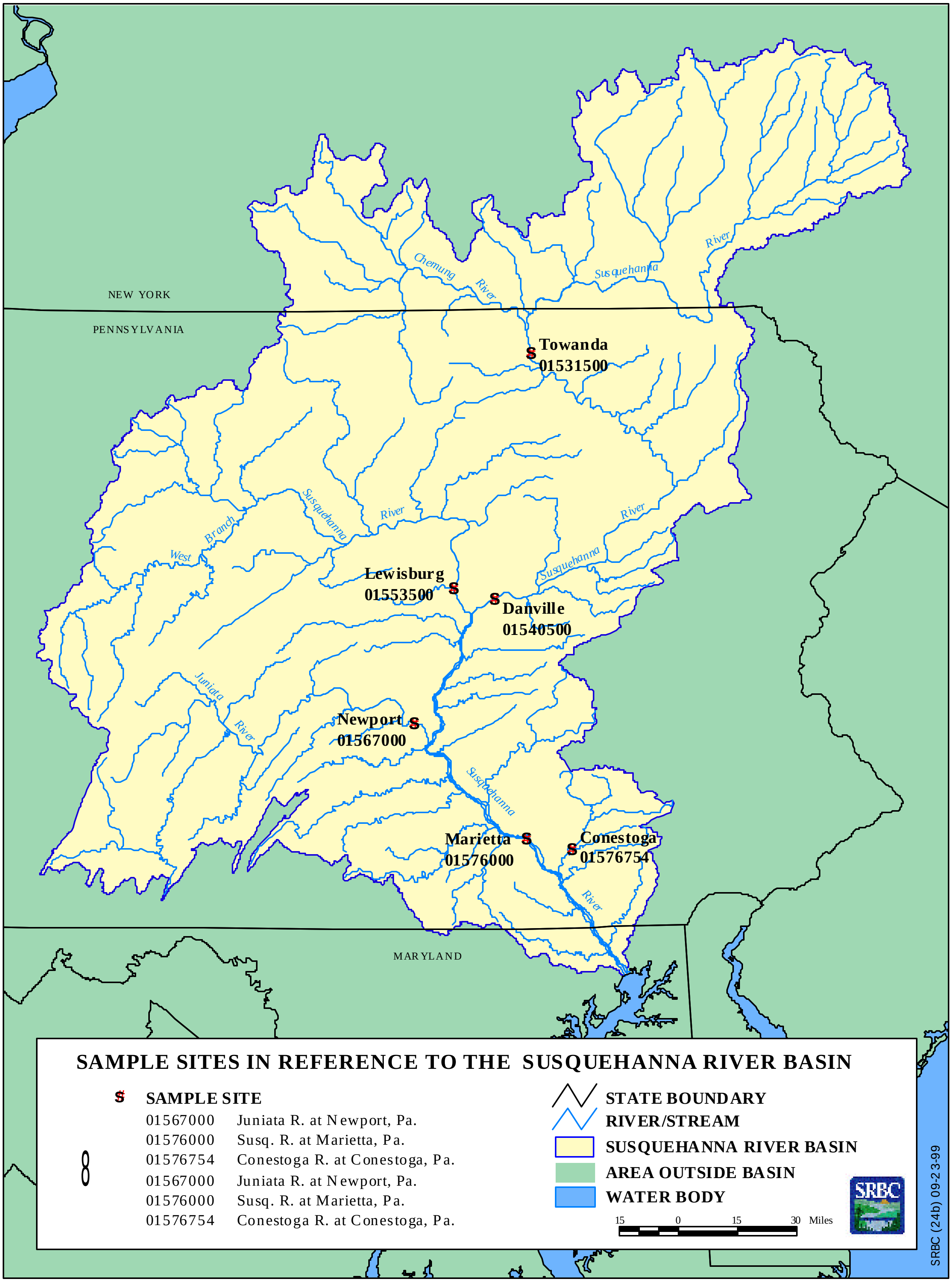


Figure 2. Map Showing Locations of Sampling Sites on the Susquehanna River and Three Major Tributaries in the Basin

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.

SAMPLE COLLECTION AND ANALYSIS

Samples were collected at each of the sites to measure nutrient and suspended-sediment concentrations during periods of low and high flow. Samples at low flow were collected monthly. Collection of low flow samples was delayed 7 to 10 days after a period of high flow until moderate flows prevailed. All low flow samples were collected by hand with depth-integrating samplers. Samples were collected during three to eight periods of high flow each year. Storm or high flow samples were normally collected on a daily basis from the start of the storm to the time when the flow receded to near its pre-storm rate. An attempt was always made to collect a sample at or near peak flow. Storm samples were collected by hand with depth-integrating samplers at four of the Susquehanna River sites. The Conestoga River site was equipped with an automatic pumping sampler, which collected a sample every half-hour. Four of these samples were then composited to provide sufficient water for laboratory analysis.

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 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.

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

Parameter	Laboratory	Methodology	Detection Limit (mg/l)	References
Ammonia	Pa. DEP	Colorimetry	0.02	Standard Methods #4170
Kjeldahl Nitrogen (dissolved)	Pa. DEP	Block Digest, Colorimetry	0.20	US EPA 351.2
Kjeldahl Nitrogen (total)	Pa. DEP	Block Digest, Colorimetry	0.20	US EPA 351.2
Nitrite plus Nitrate	Pa. DEP	Cd-reduction, Colorimetry	0.01	US EPA 353.2
Organic Carbon (total)	Pa. DEP	Wet Oxidation	0.10	US EPA 415.2
Orthophosphate (dissolved)	Pa. DEP	Colorimetry	0.002	US EPA 365.2
Phosphorus (dissolved)	Pa. DEP	Block Digest, Colorimetry	0.02	US EPA 365.4
Phosphorus (total)	Pa. DEP	Persulfate Digest, Colorimetry	0.02	Standard Methods, 1985

PRECIPITATION

Precipitation data were obtained from long-term 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 1994, 1995, and 1996 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. Annual precipitation exceeded the long-term average in all basins in 1994 and 1996, with 1996 being the wetter year. Precipitation in 1995 was below the normal annual mean in all basins. Precipitation in 1994 ranged from 1.9 inches above normal in the Juniata basin to 6.62 inches above normal in the Conestoga basin. In 1995, precipitation ranged from 0.7 inches below normal for the Conestoga basin to 15.08 inches below normal for the Juniata basin. The greatest precipitation occurred in the Conestoga basin in 1996. Precipitation totaled 58.92 inches, which was 16.16 inches above normal. Precipitation in 1996 ranged from 6.49 inches above normal in the area above Towanda to 16.16 inches above normal in the Conestoga basin. Precipitation was highest in the Conestoga basin in all three years.

Table 3. Summary for Annual Precipitation for Selected Subbasins in the Susquehanna River Basin, Calendar Years 1994, 1995, and 1996

Subbasin	Season	Average Long-term Precipitation	Calendar Year		
			1994	1995	1996
		inches	inches		
Susquehanna River above Towanda	January-March	6.83	9.32	4.37	7.32
	April-June	10.05	12.68	5.29	12.61
	July-September	10.85	13.55	6.28	11.60
	October-December	9.15	6.78	9.65	11.84
	Yearly Total	**36.88**	**42.33**	**25.59**	**43.37**
Susquehanna River above Danville	January-March	6.92	9.68	4.72	7.93
	April-June	10.17	12.75	5.77	12.97
	July-September	11.18	14.19	5.97	11.77
	October-December	9.26	6.95	10.05	12.48
	Yearly Total	**37.54**	**43.58**	**26.50**	**45.16**
West Branch Susquehanna River above Lewisburg	January-March	8.01	11.82	6.65	10.96
	April-June	11.06	13.35	10.19	12.61
	July-September	12.43	14.96	5.22	15.35
	October-December	10.03	7.71	12.54	13.00
	Yearly Total	**41.53**	**47.84**	**34.60**	**51.92**
Juniata River above Newport	January-March	8.19	11.57	4.74	12.59
	April-June	9.26	6.90	7.44	8.73
	July-September	10.30	13.88	2.46	16.43
	October-December	9.72	7.03	7.75	12.25
	Yearly Total	**37.47**	**39.37**	**22.39**	**50.00**
Susquehanna River above Marietta	January-March	7.64	10.86	5.66	10.13
	April-June	10.20	11.31	8.16	12.92
	July-September	11.30	14.45	6.23	14.24
	October-December	9.64	7.53	10.96	13.22
	Yearly Total	**38.78**	**44.14**	**31.01**	**50.51**
Conestoga River above Conestoga	January-March	8.58	14.67	8.61	11.49
	April-June	10.28	9.51	8.86	14.90
	July-September	13.27	17.01	10.12	15.53
	October-December	10.64	8.18	14.47	17.00
	Yearly Total	**42.76**	**49.38**	**42.06**	**58.92**

WATER DISCHARGE

Mean water discharges for calendar years 1994, 1995, and 1996 are listed in Table 4, along with the long-term annual mean discharge 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 greatest in 1996. Streamflows were above normal in 1994 and 1996, and below normal in 1995 at all sites. Streamflow ranged from 129 percent of normal at Newport to 149 percent of normal at Conestoga in 1994, from 67 percent of normal in the Susquehanna River at Towanda to 92 percent of normal at Conestoga in 1995 and from 157 percent of normal at Lewisburg to 203 percent at Newport in 1996.

Table 4. Annual Water Discharge, Calendar Years 1994, 1995, and 1996

Site Short Name	Years of Record	Long-term Annual Mean	Annual Water Discharge 1994 Mean	1994 Long-term Mean	1995 Mean	1995 Long-term Mean	1996 Mean	1996 Long-term Mean
		cfs[1]	cfs	percent	cfs	percent	cfs	percent
Towanda	92	10,600	14,000	132	7,050	67	17,000	160
Danville	91	15,200	21,200	139	11,000	72	24,800	163
Lewisburg	56	10,900	15,000	138	7,790	71	17,100	157
Newport	97	4,260	5,500	129	3,400	80	8,660	203
Marietta	64	37,300	50,500	135	27,300	73	63,600	171
Conestoga	66[2]	598	894	149	550	92	1,120	187

[1] Cubic feet per second
[2] Adjusted based on Conestoga River at Lancaster

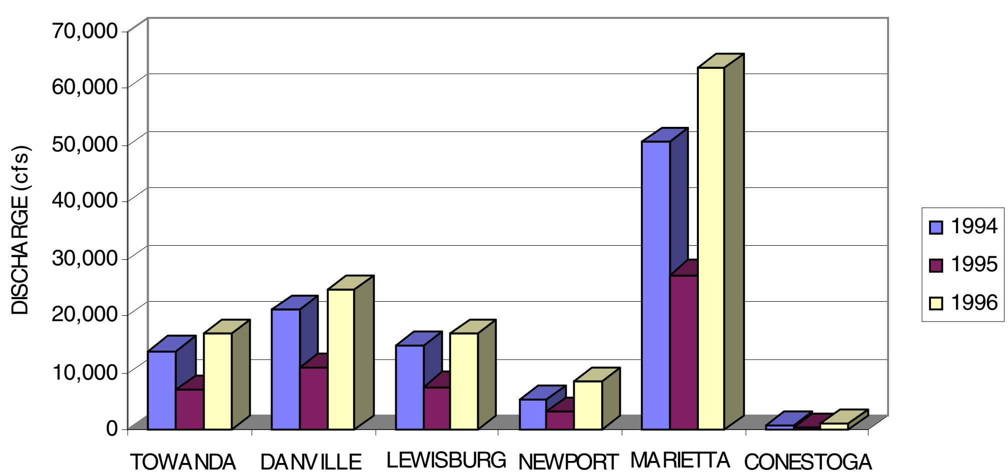


Figure 3. Annual Mean Water Discharge for Calendar Years 1994, 1995, and 1996 at Towanda, Danville, Lewisburg, Marietta, and Conestoga, Pa.

ANNUAL NUTRIENT AND SUSPENDED–SEDIMENT LOADS AND YIELDS

Nutrient and suspended-sediment loads were computed for each site for calendar years 1994, 1995, and 1996. Loads were computed for total ammonia, dissolved ammonia, total nitrite plus nitrate nitrogen, total nitrogen, total organic nitrogen, dissolved organic nitrogen, dissolved orthophosphate, total phosphorus, dissolved phosphorus, and suspended sediment. 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 14 list the computed loads in pounds per year and corresponding yields in pounds per acre per year 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 annual loads and yields of total nitrogen (TN) are illustrated in Figures 4A and 4B, respectively.

As seen in Figure 4A and Table 5A, the annual loads of TN were greatest at all sites in 1996, followed by the loads in 1994. The fluctuation in loads generally corresponded with the changes in water discharges. The greatest TN loads were measured at Marietta, followed by Danville. The Conestoga River at Conestoga had the smallest TN loads.

Annual yields of TN shown in Figure 4B and Table 5B indicate the West Branch Susquehanna River at Lewisburg yielded more nitrogen per unit area than the Susquehanna River at Danville in 1995 and 1996. Since nitrogen is highly soluble, the greater rainfall in the West Branch watershed during 1995 and 1996 probably transported more nitrogen to the streams. 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 Conestoga River Watershed, with 62.7 percent agricultural and 22.4 percent forest lands had the highest yields of total nitrogen.

The annual loads and yields of total phosphorus (TP) are illustrated in Figure 5A and 5B, respectively.

Annual TP loads were highest in 1996, with the greatest TP load occurring at Marietta, followed by Danville. The smallest annual TP loads were found at Newport and Conestoga.

Annual TP yields shown in Figure 5B and Table 6B also indicate the Susquehanna River at Danville yields more phosphorus per unit area than the West Branch Susquehanna River at Lewisburg and the greatest yield of TP occurs at Conestoga.

The annual loads and yields of suspended-sediment (SS) loads are illustrated in Figure 6A and 6B, respectively.

The highest SS loads were measured at Marietta, followed by Danville in 1994 and 1995, and by Towanda in 1996. The Conestoga River had the smallest SS loads.

Annual yields of SS were highest from the Conestoga River at Conestoga, as shown in Figure 6B and Table 7B.

Annual loads of total and dissolved ammonia, total and dissolved organic nitrogen, dissolved phosphorus, dissolved orthophosphate, and total organic carbon were higher in 1996, followed by the loads in 1994, and then 1995. Annual loads of all parameters were higher at Danville than at Lewisburg. The Conestoga River had the highest yields of all parameters.

Table 5A. Annual Water Discharges and Annual Loads of Total Nitrogen, Calendar Years 1994, 1995, and 1996

Site Short Name	Total Nitrogen as N								
	1994			1995			1996		
	Annual Discharge	Load	Prediction Error	Annual Discharge	Load	Prediction Error	Annual Discharge	Load	Prediction Error
	cfs	thousands of pounds	percent	cfs	thousands of pounds	percent	cfs	thousands of pounds	percent
Towanda	14,000	35,300	3.09	7,050	17,200	3.33	17,000	43,400	3.14
Danville	21,200	59,700	1.83	11,000	28,100	2.04	24,800	64,600	4.37
Lewisburg	15,000	35,200	3.63	7,790	17,300	4.00	17,100	40,800	5.03
Newport	5,500	18,900	3.07	3,400	11,400	2.57	8,660	30,500	2.71
Marietta	50,500	174,000	3.01	27,300	84,800	3.22	63,600	221,000	3.81
Conestoga	894	13,200	2.23	550	8,170	2.31	1,120	16,300	2.72

Table 5B. Annual Yields of Total Nitrogen, Calendar Years 1994, 1995, and 1996

Site Short Name	Total Nitrogen as N		
	1994	1995	1996
	pounds per acre per year		
Towanda	7.074	3.447	8.637
Danville	8.314	3.913	8.996
Lewisburg	8.033	3.948	9.311
Newport	8.805	5.311	14.209
Marietta	10.461	5.098	13.286
Conestoga	43.883	27.161	54.189

Table 6A. Annual Water Discharges and Annual Loads of Total Phosphorus, Calendar Years 1994, 1995, and 1996

Site Short Name	Total Phosphorus as P								
	1994			1995			1996		
	Annual Discharge	Load	Prediction Error	Annual Discharge	Load	Prediction Error	Annual Discharge	Load	Prediction Error
	cfs	thousands of pounds	percent	cfs	thousands of pounds	percent	cfs	thousands of pounds	percent
Towanda	14,000	2,900	7.87	7,050	1,100	7.97	17,000	4,800	11.76
Danville	21,200	4,780	7.57	11,000	1,840	7.78	24,800	6,890	10.34
Lewisburg	15,000	2,090	10.23	7,790	788	9.97	17,100	2,810	14.69
Newport	5,500	851	10.84	3,400	649	11.50	8,660	1,270	11.91
Marietta	50,500	10,800	7.53	27,300	3,870	7.10	63,600	16,200	9.15
Conestoga	894	1,120	10.94	550	510	10.78	1,120	1,580	14.26

Table 6B. Annual Yields of Total Phosphorus, Calendar Years 1994, 1995 and 1996

Site Short Name	Total Phosphorus as P		
	1994	1995	1996
	pounds per acre per year		
Towanda	0.581	0.220	0.962
Danville	0.666	0.256	0.960
Lewisburg	0.477	0.180	0.641
Newport	0.396	0.302	0.592
Marietta	0.649	0.233	0.974
Conestoga	3.723	1.695	5.253

Table 7A. Annual Water Discharges and Annual Loads of Suspended Sediment, Calendar Years 1994, 1995, and 1996

Site Short Name	Suspended Sediment								
	1994			1995			1996		
	Annual Discharge	Load	Prediction Error	Annual Discharge	Load	Prediction Error	Annual Discharge	Load	Prediction Error
	cfs	thousands of pounds	percent	cfs	thousands of pounds	percent	cfs	thousands of pounds	percent
Towanda	14,000	3,650,000	20.35	7,050	642,000	28.04	17,000	8,680,000	29.53
Danville	21,200	5,060,000	16.06	11,000	867,000	16.61	24,800	7,450,000	20.29
Lewisburg	15,000	2,610,000	23.79	7,790	456,000	27.96	17,100	4,560,000	40.56
Newport	5,500	637,000	30.44	3,400	370,000	44.01	8,660	1,270,000	30.63
Marietta	50,500	8,940,000	13.24	27,300	1,770,000	12.92	63,600	14,000,000	15.09
Conestoga	894	615,000	26.82	550	167,000	31.76	1,120	759,000	33.71

Table 7B. Annual Yields of Suspended Sediment, Calendar Years 1994, 1995, and 1996

Site Short Name	Suspended Sediment		
	1994	1995	1996
	pounds per acre per year		
Towanda	731.0	129.0	1,720.0
Danville	705.0	121.0	1,040.0
Lewisburg	596.0	104.0	1,040.0
Newport	297.0	172.0	592.0
Marietta	537.0	106.0	842.0
Conestoga	2,040.0	555.0	2,520.0

Table 8A. Annual Water Discharges and Annual Loads of Total Ammonia, Calendar Years 1994, 1995, and 1996

Site Short Name	Total Ammonia as N								
	1994			1995			1996		
	Annual Discharge	Load	Prediction Error	Annual Discharge	Load	Prediction Error	Annual Discharge	Load	Prediction Error
	cfs	thousands of pounds	percent	cfs	thousands of pounds	percent	cfs	thousands of pounds	percent
Towanda	14,000	2,010	9.33	7,050	879	9.80	17,000	2,550	13.27
Danville	21,200	2,730	8.78	11,000	1,320	9.38	24,800	3,920	12.01
Lewisburg	15,000	1,470	8.65	7,790	816	9.71	17,100	1,860	11.55
Newport	5,500	460	12.15	3,400	289	12.01	8,660	681	11.35
Marietta	50,500	6,230	7.77	27,300	3,050	8.13	63,600	9,070	9.92
Conestoga	894	465	10.87	550	198	10.65	1120	470	12.16

Table 8B. Annual Yields of Total Ammonia, Calendar Years 1994, 1995, and 1996

Site Short Name	Total Ammonia as N		
	1994	1995	1996
	pounds per acre per year		
Towanda	0.403	0.176	0.511
Danville	0.380	0.184	0.546
Lewisburg	0.335	0.186	0.424
Newport	0.214	0.135	0.317
Marietta	0.375	0.183	0.545
Conestoga	1.546	0.658	1.563

Table 9A. Annual Water Discharges and Annual Loads of Total Nitrite Plus Nitrate Nitrogen, Calendar Years 1994, 1995, and 1996

Site Short Name	Total Nitrite Plus Nitrate Nitrogen as N								
	1994			1995			1995		
	Annual Discharge	Load	Prediction Error	Annual Discharge	Load	Prediction Error	Annual Discharge	Load	Prediction Error
	cfs	thousands of pounds	percent	cfs	thousands of pounds	percent	cfs	thousands of pounds	percent
Towanda	14,000	20,800	5.10	7,050	11,800	4.78	17,000	25,900	5.79
Danville	21,200	34,500	3.91	11,000	19,500	4.67	24,800	41,000	5.42
Lewisburg	15,000	22,100	2.56	7,790	12,700	2.97	17,100	26,900	3.63
Newport	5,500	15,280	3.34	3,400	8,910	2.69	8,660	23,700	2.92
Marietta	50,500	122,000	2.79	27,300	66,700	3.08	63,600	164,000	3.55
Conestoga	894	10,600	2.84	550	7,030	3.08	1,120	12,800	3.49

Table 9B. Annual Yields of Total Nitrite Plus Nitrate Nitrogen, Calendar Years 1994, 1995, and 1996

Site Short Name	Total Nitrite Plus Nitrate Nitrogen as N		
	1994	1995	1996
	pounds per acre per year		
Towanda	4.168	2.365	5.190
Danville	4.809	2.716	5.709
Lewisburg	5.043	2.896	6.139
Newport	7.118	4.151	10.994
Marietta	7.335	4.010	9.860
Conestoga	35.239	23.371	42.553

Table 10A. Annual Water Discharges and Annual Loads of Total Organic Nitrogen, Calendar Years 1994, 1995, and 1996

Site Short Name	Total Organic Nitrogen as N								
	1994			1995			1996		
	Annual Discharge	Load	Prediction Error	Annual Discharge	Load	Prediction Error	Annual Discharge	Load	Prediction Error
	cfs	thousands of pounds	percent	cfs	thousands of pounds	percent	cfs	thousands of pounds	percent
Towanda	14,000	13,000	7.07	7,050	5,180	7.23	17,000	16,700	9.94
Danville	21,200	22,600	6.73	11,000	8,170	7.10	24,800	21,600	9.06
Lewisburg	15,000	10,700	3.67	7,790	3,750	9.04	17,100	11,400	11.95
Newport	5,500	3,100	13.65	3,400	2,420	13.60	8,660	7,140	13.84
Marietta	50,500	45,500	7.51	27,300	16,400	7.50	63,600	48,200	9.27
Conestoga	894	2,360	9.87	550	1,040	9.57	1,120	2,900	12.51

Table 10B. Annual Yields of Total Organic Nitrogen, Calendar Years 1994, 1995, and 1996

Site Short Name	Total Organic Nitrogen as N		
	1994	1995	1996
	pounds per acre per year		
Towanda	2.603	1.038	3.337
Danville	3.143	1.138	3.005
Lewisburg	2.449	0.857	2.611
Newport	1.444	1.128	3.326
Marietta	2.734	0.983	2.900
Conestoga	7.829	3.464	9.641

Table 11A. Annual Water Discharges and Annual Loads of Dissolved Organic Nitrogen, Calendar Years 1994, 1995, and 1996

Site Short Name	Dissolved Organic Nitrogen as N								
	1994			1995			1996		
	Annual Discharge	Load	Prediction Error	Annual Discharge	Load	Prediction Error	Annual Discharge	Load	Prediction Error
	cfs	thousands of pounds	percent	cfs	thousands of pounds	percent	cfs	thousands of pounds	percent
Towanda	14,000	9,500	6.33	7,050	4,140	6.55	17,000	11,500	8.52
Danville	21,200	12,400	5.96	11,000	5,440	6.67	24,800	14,000	8.12
Lewisburg	15,000	6,160	6.11	7,790	2,640	6.74	17,100	6,470	8.34
Newport	5,500	3,230	14.17	3,400	1,470	8.53	8,660	4,100	8.85
Marietta	50,500	22,800	7.03	27,300	9,710	7.23	63,600	23,700	8.72
Conestoga	894	1,300	6.40	550	777	6.51	1,120	1,710	7.49

Table 11B. Annual Yields of Dissolved Organic Nitrogen, Calendar Years 1994, 1995, and 1996

Site Short Name	Dissolved Organic Nitrogen as N		
	1994	1995	1996
	pounds per acre per year		
Towanda	1.904	0.829	2.307
Danville	1.732	0.758	1.952
Lewisburg	1.406	0.603	1.476
Newport	1.502	0.683	1.908
Marietta	1.369	0.583	1.423
Conestoga	4.332	2.583	5.675

Table 12A. Annual Water Discharges and Annual Loads of Dissolved Phosphorus, Calendar Years 1994, 1995, and 1996

Site Short Name	Dissolved Phosphorus as P								
	1994			1995			1996		
	Annual Discharge	Load	Prediction Error	Annual Discharge	Load	Prediction Error	Annual Discharge	Load	Prediction Error
	cfs	thousands of pounds	percent	cfs	thousands of pounds	percent	cfs	thousands of pounds	percent
Towanda	14,000	832	5.04	7,050	402	5.54	17,000	982	7.42
Danville	21,200	1,100	5.42	11,000	491	6.24	24,800	1,060	7.66
Lewisburg	15,000	547	5.82	7,790	258	6.73	17,100	533	8.51
Newport	5,500	430	12.35	3,400	300	11.54	8,660	514	12.59
Marietta	50,500	2,590	4.99	27,300	1,260	5.47	63,600	2,990	6.50
Conestoga	894	314	4.36	550	180	4.77	1,120	394	5.66

Table 12B. Annual Yields of Dissolved Phosphorus, Calendar Years 1994, 1995, and 1996

Site Short Name	Dissolved Phosphorus as P		
	1994	1995	1996
	pounds per acre per year		
Towanda	0.167	0.081	0.197
Danville	0.153	0.068	0.148
Lewisburg	0.125	0.059	0.122
Newport	0.200	0.140	0.239
Marietta	0.156	0.076	0.180
Conestoga	1.044	0.598	1.310

Table 13A. Annual Water Discharges and Loads of Dissolved Orthophosphate, Calendar Years 1994, 1995 and 1996

Site Short Name	Dissolved Orthophosphate as P								
	1994			1995			1996		
	Annual Discharge	Load	Prediction Error	Annual Discharge	Load	Prediction Error	Annual Discharge	Load	Prediction Error
	cfs	thousands of pounds	percent	cfs	thousands of pounds	percent	cfs	thousands of pounds	percent
Towanda	14,000	161	13.59	7,050	81	15.72	17,000	196	20.63
Danville	21,200	221	13.19	11,000	112	15.68	24,800	275	18.39
Lewisburg	15,000	93.7	15.64	7,790	58.1	16.86	17,100	145	23.71
Newport	5,500	188	34.77	3,400	90.3	37.46	8,660	254	39.03
Marietta	50,500	565	22.84	27,300	287	15.83	63,600	851	18.75
Conestoga	894	206	9.33	550	93.5	10.72	1,120	151	12.68

Table 13B. Annual Yields of Dissolved Orthophosphate, Calendar Years 1994, 1995, and 1996

Site Short Name	Dissolved Orthophosphate as P		
	1994	1995	1996
	pounds per acre per year		
Towanda	0.032	0.016	0.040
Danville	0.031	0.016	0.038
Lewisburg	0.021	0.013	0.033
Newport	0.088	0.042	0.118
Marietta	0.034	0.017	0.051
Conestoga	0.685	0.311	0.502

Table 14A. Annual Water Discharges and Annual Loads of Dissolved Ammonia, Calendar Years 1994, 1995, and 1996

Site Short Name	Dissolved Ammonia as N								
	1994			1995			1995		
	Annual Discharge	Load	Prediction Error	Annual Discharge	Load	Prediction Error	Annual Discharge	Load	Prediction Error
	cfs	thousands of pounds	percent	cfs	thousands of pounds	percent	cfs	thousands of pounds	percent
Towanda	14,000	1,300	8.77	7,050	662	9.62	17,000	1,690	12.60
Danville	21,200	1,860	8.38	11,000	979	9.36	24,800	2,380	11.51
Lewisburg	15,000	1,170	7.87	7,790	706	9.11	17,100	1,500	10.70
Newport	5,500	345	11.05	3,400	243	10.95	8,660	545	10.20
Marietta	50,500	4,730	7.39	27,300	2,590	7.99	63,600	6,930	9.35
Conestoga	894	397	10.91	550	171	10.65	1,120	403	12.35

Table 14B. Annual Yields of Dissolved Ammonia, Calendar Years 1994, 1995, and 1996

Site Short Name	Dissolved Ammonia as N		
	1994	1995	1996
	pounds per acre per year		
Towanda	0.261	0.133	0.339
Danville	0.259	0.136	0.331
Lewisburg	0.267	0.161	0.342
Newport	0.161	0.113	0.254
Marietta	0.284	0.156	0.417
Conestoga	1.320	0.568	1.340

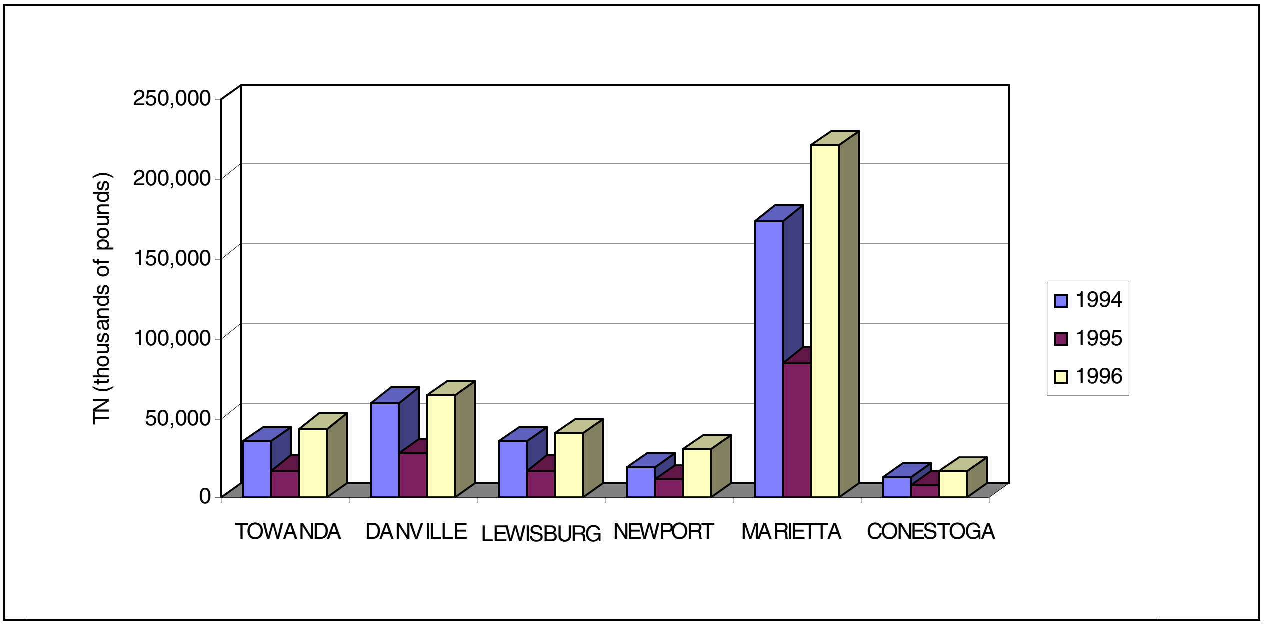


Figure 4A. Annual Loads of Total Nitrogen (TN) for Calendar Years 1994, 1995, and 1996 at Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga, Pa.

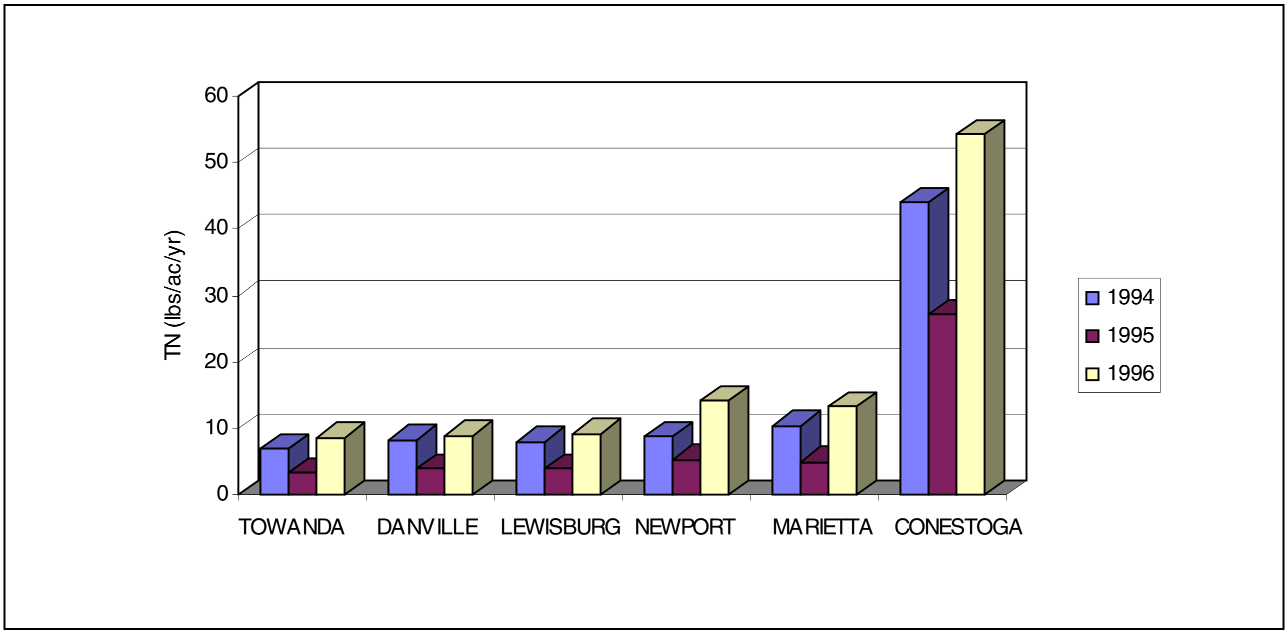


Figure 4B. Total Nitrogen (TN) Yields for Calendar Years 1994, 1995, and 1996 at Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga, Pa.

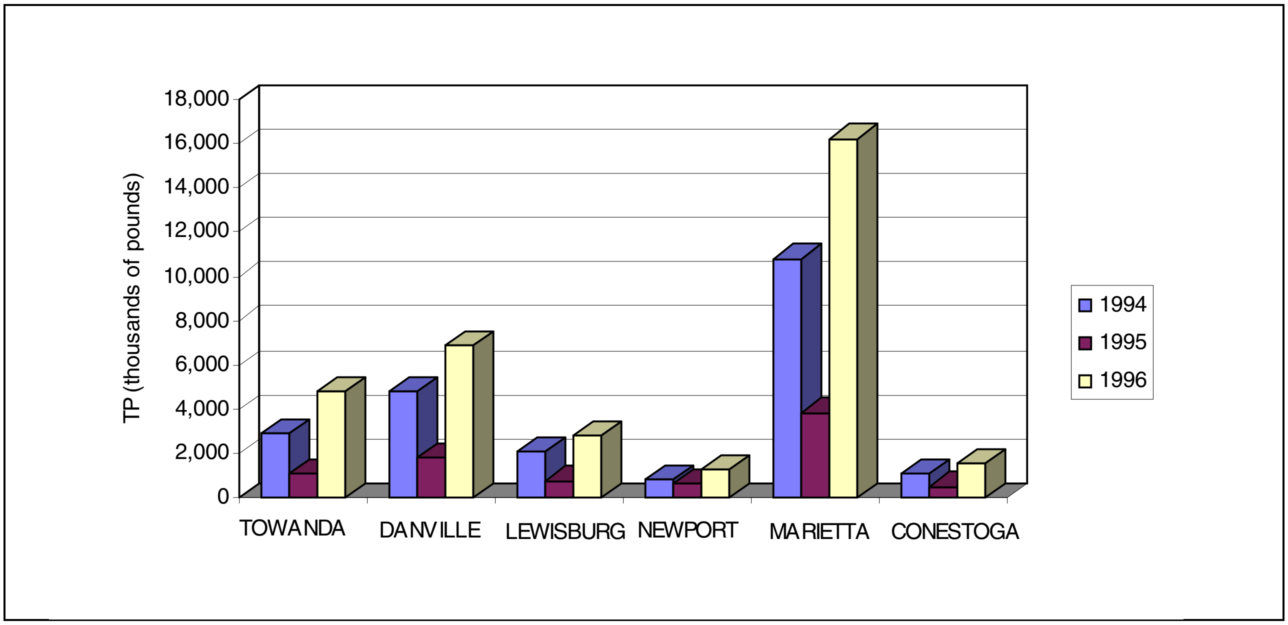


Figure 5A. ***Annual Loads of Total Phosphorus (TP) for Calendar Years 1994, 1995, and 1996 at Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga, Pa.***

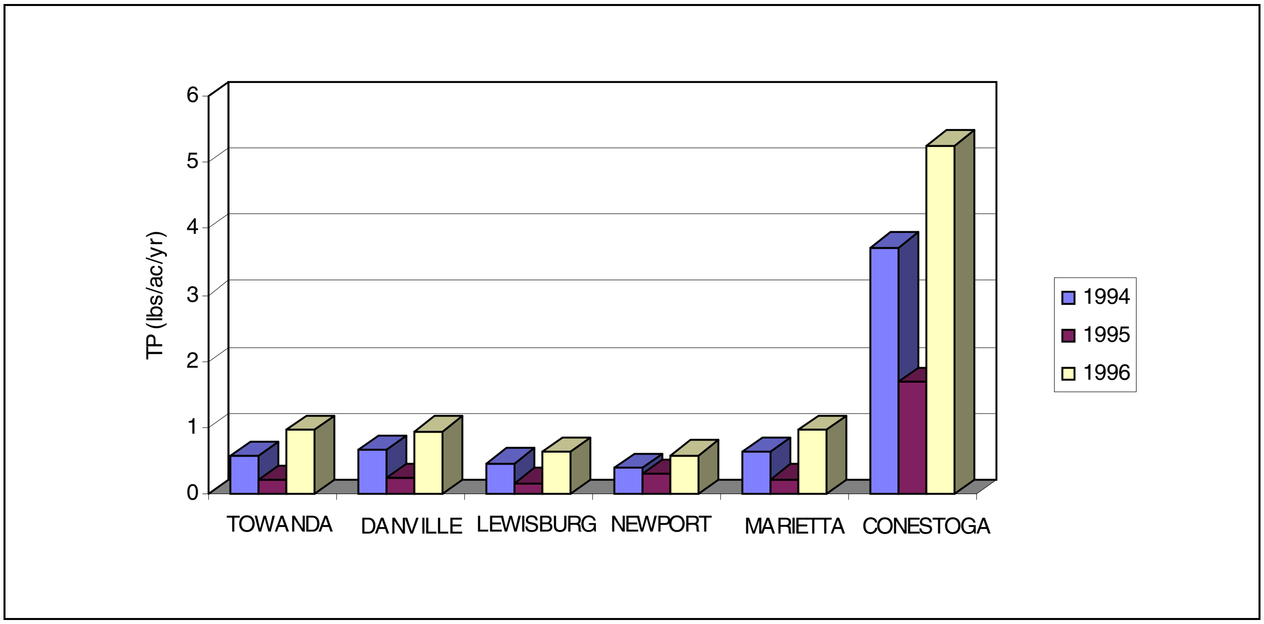


Figure 5B. Total Phosphorus (TP) Yields for Calendar Years 1994, 1995, and 1996 at Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga, Pa.

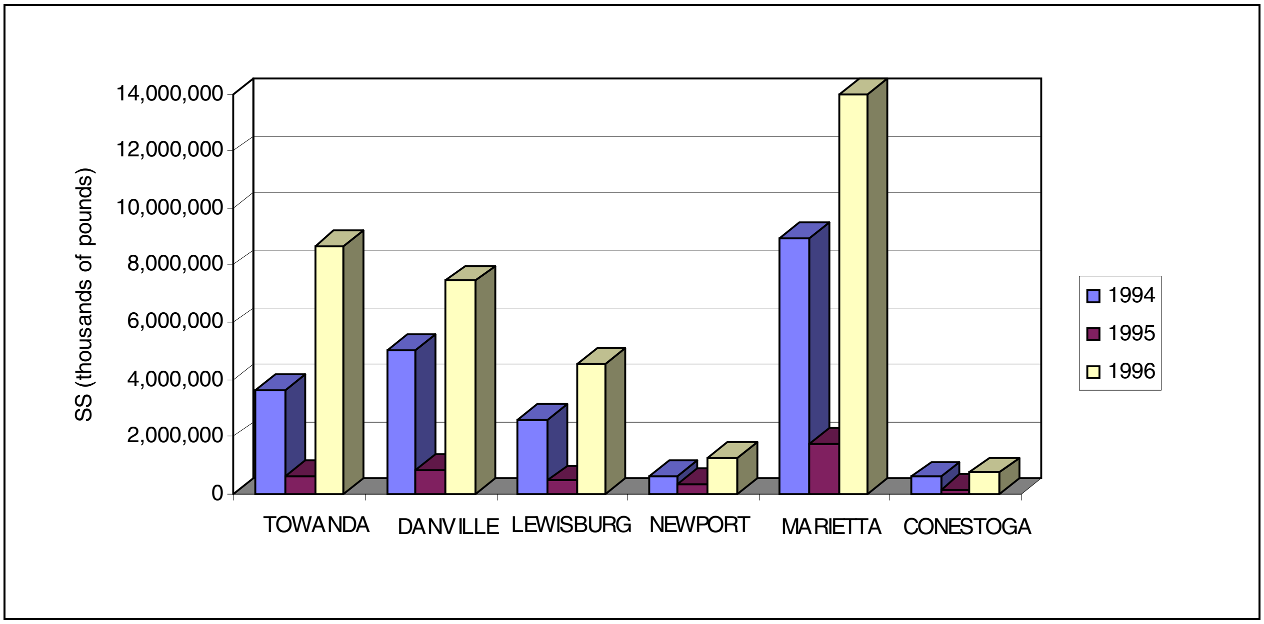


Figure 6A. Annual Loads of Suspended Sediment (SS) for Calendar Years 1994, 1995, and 1996 at Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga, Pa.

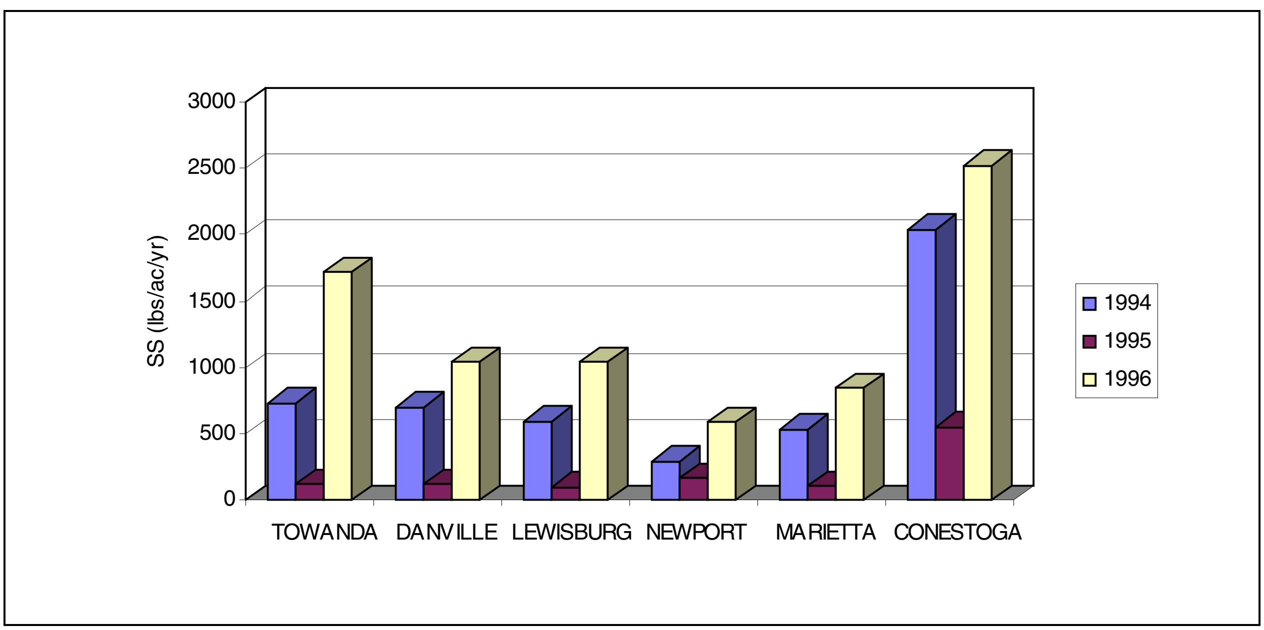


Figure 6B. Suspended-Sediment Yields for Calendar Years 1994, 1995, and 1996 at Towanda, Danville, Lewisburg, Newport, Marietta and Conestoga, Pa.

SEASONAL WATER DISCHARGES AND NUTRIENT AND SUSPENDED-SEDIMENT LOADS

Seasonal water discharges and loads of nutrients and suspended sediment are listed in Tables15 through 20. 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 1994 were highest in the spring (April-June) at Towanda, Danville, and Lewisburg, followed by winter (January-March), then summer (July-August). Mean discharges in the lower basin sites at Newport, Marietta, and Conestoga were highest in the winter followed by spring. The seasonal variations in the total nitrogen, total phosphorus, and suspended-sediment loads for 1994 corresponded with the seasonal water discharges at nearly all stations. The exceptions were suspended sediment at Newport and Conestoga, and total nitrogen at Towanda, Danville, and Lewisburg, where the summer and fall loads did not correspond with the respective seasonal discharges.

The seasonal mean water discharge for calendar year 1995 was highest in the winter at all sites, followed by fall, then spring. In 1995, the seasonal variations in total nitrogen and total phosphorus loadings generally corresponded with the variations in seasonal discharges. Exceptions were total phosphorus at Danville and Newport. The seasonal variation of suspended-sediment loads did not correspond well with seasonal variations in water discharges. This may be due to rainfall patterns in 1995, which was a dry year. Precipitation may have been sufficient to cause rises in streamflow, but rainfall intensity probably was not sufficient to dislodge soil particles and carry them to the streams.

Seasonal discharges in 1996 were nearly the same during winter, spring, and fall. Discharges at each site appear to vary according to the amount of precipitation during each season and its affect on soil moisture following a dry year. Seasonal variations in total nitrogen, total phosphorus, and suspended-sediment loadings corresponded with seasonal changes in discharges at Danville, Lewisburg, and Marietta. Seasonal loads of total nitrogen at Newport and total phosphorus at Conestoga also varied with their respective seasonal water discharges.

Table 15. Seasonal Mean Water Discharge and Loads of Nutrients and Suspended Sediment, Susquehanna River at Towanda, Pa., Calendar Years 1994, 1995, and 1996

Year	Season	Mean Water Discharge	Total Ammonia as N	Dissolved Organic Nitrogen as N	Total Organic Nitrogen as N	Nitrite Plus Nitrate as N	Total Nitrogen as N	Ortho-phos-phate as P	Dissolved Phos-phorus as P	Total Phos-phorus as P	Dissolved Ammonia	Suspended Sediment
		cfs	thousands of pounds									
1994	Winter	17,500	743	2,840	3,710	7,680	11,900	40.90	264.0	887.0	525.0	1,080,000
	Spring	21,600	789	3,840	5,340	7,640	13,800	47.10	300.0	1210.0	466.0	1,780,000
	Summer	8,740	204	1,540	2,330	2,270	4,620	36.80	130.0	465.0	105.0	654,000
	Fall	8,090	277	1,240	1,590	3,200	4,970	35.80	138.0	336.0	207.0	138,000
1995	Winter	12,500	455	1,770	2,090	6,010	8,120	28.30	175.0	457.0	362.0	257,000
	Spring	6,170	129	855	1,020	2,350	3,430	10.80	69.5	172.0	90.5	66,700
	Summer	955	13.6	1,470	248	137	456	4.68	154.0	48.3	6.7	3,700
	Fall	8,670	281	1,360	1,830	3,300	5,220	37.70	142.0	425.0	203.0	314,000
1996	Winter	20,600	992	3,450	4,850	8,990	14,300	52.10	315.0	1,590.0	683.0	2,930,000
	Spring	20,900	583	3,500	4,860	7,500	12,500	37.20	243.0	1,160.0	351.0	2,310,000
	Summer	4,740	78.4	708	1,000	1,250	2,320	15.80	58.5	183.0	43.4	83,500
	Fall	21,700	906	3,900	6,780	8,150	14,200	92.90	366.0	1,860.0	612.0	3,250,000

Table 16. Seasonal Mean Water Discharge and Loads of Nutrients and Suspended Sediment, Susquehanna River at Danville, Pa., Calendar Years 1994, 1995, and 1996

Year	Season	Mean Water Discharge	Total Ammonia as N	Dissolved Organic Nitrogen as N	Total Organic Nitrogen as N	Nitrite Plus Nitrate as N	Total Nitrogen as N	Ortho-phos-phate as P	Dissolved Phos-phorus as P	Total Phos-phorus as P	Dissolved Ammonia	Suspended Sediment
		cfs	thousands of pounds									
1994	Winter	25,800	1,040.0	3,530	6,170	12,000	19,200	60.50	346.0	1,430.0	759.0	1,600,000
	Spring	31,700	1,010.0	4,760	8,450	12,000	22,400	70.10	393.0	1,920.0	650.0	2,460,000
	Summer	13,900	242.0	2,250	4,480	4,190	8,650	44.00	173.0	812.0	138.0	757,000
	Fall	13,500	437.0	1,880	2,940	6,210	9,340	46.50	187.0	626.0	317.0	242,000
1995	Winter	18,800	673.0	2,200	3,100	9,500	12,700	43.90	217.0	728.0	534.0	374,000
	Spring	9,500	173.0	1,060	1,610	3,480	5,300	16.10	82.8	284.0	132.0	108,000
	Summer	2,030	23.8	215	507	320	943	3.37	18.1	83.7	13.9	8,370
	Fall	13,900	466.0	1,970	2,970	6,120	9,150	49.00	174.0	740.0	299.0	377,000
1996	Winter	30,600	1,590.0	4,090	6,330	14,400	21,700	77.80	360.0	2,200.0	1,010.0	2,650,000
	Spring	29,200	756.0	3,990	6,240	10,700	17,400	58.90	258.0	1,620.0	465.0	2,020,000
	Summer	7,380	99.9	932	1,520	1,980	3,640	17.70	60.7	307.0	59.3	106,000
	Fall	31,900	1,480.0	503	7,450	13,900	21,800	120.00	385.0	2,730.0	846.0	2,670,000

Table 17. ***Seasonal Mean Water Discharge and Loads of Nutrients and Suspended Sediment, West Branch Susquehanna River at Lewisburg, Pa., Calendar Years 1994, 1995, and 1996***

Year	Season	Mean Water Discharge	Total Ammonia as N	Dissolved Organic Nitrogen as N	Total Organic Nitrogen as N	Nitrite Plus Nitrate as N	Total Nitrogen as N	Ortho-phos-phate as P	Dissolved Phos-phorus as P	Total Phos-phorus as P	Dissolved Ammonia	Suspended Sediment
		cfs	thousands of pounds									
1994	Winter	17,700	519.0	1,840	3,290	7,130	11,300	26.00	162.0	671.0	417.0	953,000
	Spring	21,600	519.0	2,240	4,140	7,510	12,700	27.00	176.0	810.0	399.0	1,120,000
	Summer	11,000	181.0	1,120	1,910	3,390	5,470	19.60	105.0	351.0	137.0	389,000
	Fall	9,760	257.0	962	1,360	4,070	5,710	21.10	105.0	262.0	212.0	146,000
1995	Winter	12,000	372.0	1,040	1,540	5,220	7,210	18.50	101.0	326.0	324.0	253,000
	Spring	8,560	193.0	663	924	3,110	4,280	10.40	56.8	184.0	170.0	76,800
	Summer	1,850	28.3	168	196	690	917	8.42	16.9	48.9	23.4	5,670
	Fall	8,850	223.0	792	1,090	3,640	4,890	20.80	83.4	229.0	189.0	121,000
1996	Winter	24,200	808.0	2,490	4,810	10,700	16,800	51.40	203.0	1,260.0	649.0	2,690,000
	Spring	14,800	347.0	1,170	1,890	5,150	7,540	18.40	85.6	419.0	295.0	413,000
	Summer	7,790	135.0	647	975	2,520	3,610	17.00	57.0	210.0	110.0	135,000
	Fall	21,800	566.0	2,170	3,780	8,510	12,900	58.30	18.7	927.0	446.0	1,320,000

Table 18. Seasonal Mean Water Discharge and Loads of Nutrients and Suspended Sediment, Juniata River at Newport, Pa., Calendar Years 1994, 1995, and 1996

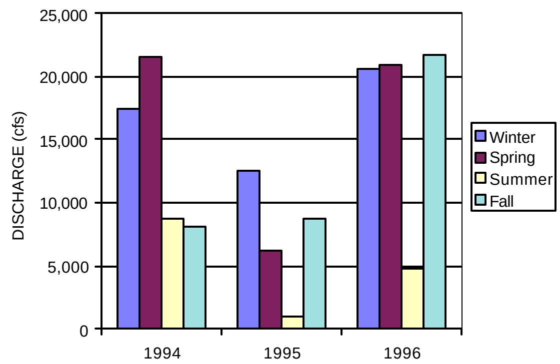
Year	Season	Mean Water Discharge cfs	Total Ammonia as N	Dissolved Organic Nitrogen as N	Total Organic Nitrogen as N	Nitrite Plus Nitrate as N	Total Nitrogen as N	Ortho-phos-phate as P	Dissolved Phos-phorus as P	Total Phos-phorus as P	Dissolved Ammonia	Suspended Sediment
			thousands of pounds									
1994	Winter	11,600	258.0	1,760	1,650	8,370	10,200	83.00	206.0	462.0	182.0	449,000
	Spring	5,870	117.0	779	716	3,440	4,850	38.20	89.9	194.0	90.9	127,000
	Summer	1,800	38.2	300	386	1,010	1,440	29.30	52.0	95.1	31.6	40,800
	Fall	2,830	46.0	387	350	1,960	2,370	37.60	81.8	100.0	40.6	20,800
1995	Winter	4,730	88.5	478	567	3,310	3,920	23.80	48.5	179.0	73.5	67,900
	Spring	3,460	92.4	331	791	2,050	2,810	11.80	64.4	218.0	74.8	197,000
	Summer	1,480	35.2	172	409	782	1,160	7.20	34.7	93.2	29.1	47,900
	Fall	3,970	72.9	487	652	2,760	3,470	47.50	103.0	158.0	65.4	57,100
1996	Winter	12,700	296.0	1,270	2,630	9,130	11,600	42.30	227.0	618.0	228.0	496,000
	Spring	6,260	117.0	553	1,080	3,910	5,030	17.50	64.0	190.0	92.3	172,000
	Summer	6,470	157.0	1,020	2,100	4,090	6,020	93.90	115.0	300.0	126.0	462,000
	Fall	9,210	111.0	1,250	1,330	6,560	7,900	101.00	108.0	162.0	93.7	138,000

Table 19. Seasonal Mean Water Discharge and Loads of Nutrients and Suspended Sediment, Susquehanna River at Marietta, Pa., Calendar Years 1994, 1995, and 1996

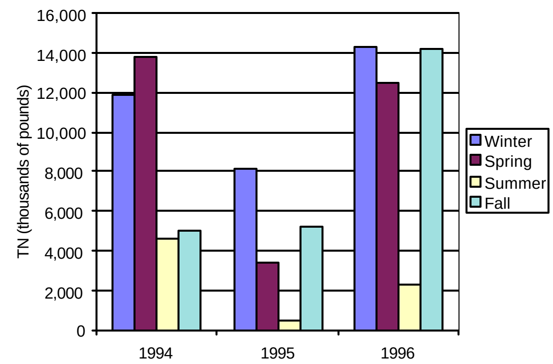
Year	Season	Mean Water Discharge (cfs)	Total Ammonia as N	Dissolved Organic Nitrogen as N	Total Organic Nitrogen as N	Nitrite Plus Nitrate as N	Total Nitrogen as N	Ortho-phos-phate as P	Dissolved Phos-phorus as P	Total Phos-phorus as P	Dissolved Ammonia	Suspended Sediment
			thousands of pounds									
1994	Winter	71,600	2,7600.0	7,660	15,200	46,500	64,600	171.0	912.0	4,160	2,060.0	3,700,000
	Spring	69,500	1,920.0	7,910	15,600	40,100	57,900	154.0	823.0	3,780	1,440.0	3,290,000
	Summer	29,900	506.0	3,970	8,680	14,800	23,500	119.0	402.0	1,600	390.0	1,400,000
	Fall	27,200	1,040.0	3,210	5,980	20,900	27,800	121.0	450.0	1,260	848.0	546,000
1995	Winter	44,600	1,560.0	3,580	5,990	30,100	36,700	100.0	518.0	1,590	1,310.0	793,000
	Spring	25,000	418.0	2,190	3,270	13,000	16,300	40.3	239.0	669	384.0	226,000
	Summer	7,850	99.3	880	1,340	3,150	4,670	19.3	83.7	231	82.9	48,100
	Fall	32,000	971.0	3,020	5,760	20,500	27,100	127.0	421.0	1,380	808.0	708,000
1996	Winter	96,600	4,360.0	8,230	16,800	65,200	86,300	269.0	1,120.0	6,460.0	3,200.0	5,750,000
	Spring	62,000	1,270.0	5,340	9,590	33,700	44,200	119.0	575.0	2,770.0	1,080.0	2,220,000
	Summer	27,000	421.0	2,720	5,250	13,100	18,900	95.3	292.0	1,210.0	358.0	745,000
	Fall	79,100	3,020.0	7,360	16,600	51,500	71,800	368.0	1,000.0	5,740.0	2,290.0	5,310,000

Table 20. Seasonal Mean Water Discharge and Loads of Nutrients and Suspended Sediment, Conestoga River at Conestoga, Pa., Calendar Years 1994, 1995, and 1996

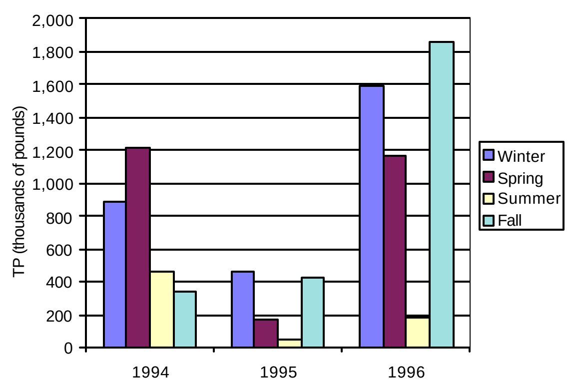
Year	Season	Mean Water Discharge	Total Ammonia as N	Dissolved Organic Nitrogen as N	Total Organic Nitrogen as N	Nitrite Plus Nitrate as N	Total Nitrogen as N	Ortho-phos-phate as P	Dissolved Phos-phorus as P	Total Phos-phorus as P	Dissolved Ammonia	Suspended Sediment
		cfs	thousands of pounds									
1994	Winter	1,600	291.0	581.0	1,300	4,520	6,090	75.1	133.0	611.0	25.1	409,000
	Spring	865	92.6	317.0	458	2,750	3.220	36.5	64.5	214.0	77.7	90,800
	Summer	601	39.2	220.0	357	1,710	2,060	58.3	65.9	185.0	31.8	93,700
	Fall	517	41.6	185.0	236	1,640	1,880	35.8	50.7	106.0	36.7	22,000
1995	Winter	874	108.0	312.0	428	2,830	3,290	29.3	64.3	202.0	95.1	73,300
	Spring	432	28.2	145.0	166	1,490	1,660	12.2	27.5	79.9	24.0	18,100
	Summer	299	13.3	98.4	131	922	1,090	16.4	26.2	68.9	10.9	20,500
	Fall	599	47.7	221.0	315	1,780	2,130	35.5	61.5	159.0	41.3	54,800
1996	Winter	1,410	205.0	527.0	995	4,160	5,390	39.7	111.0	520.0	178.0	25,900
	Spring	1,010	87.9	380.0	508	3,110	3,720	23.6	70.7	277.0	72.7	122,000
	Summer	563	26.2	201.0	266	1,640	1,950	24.2	52.1	151.0	21.4	50,100
	Fall	1,490	152.0	597.0	1,130	3,880	5,270	64.0	160.0	635.0	130.0	327,000



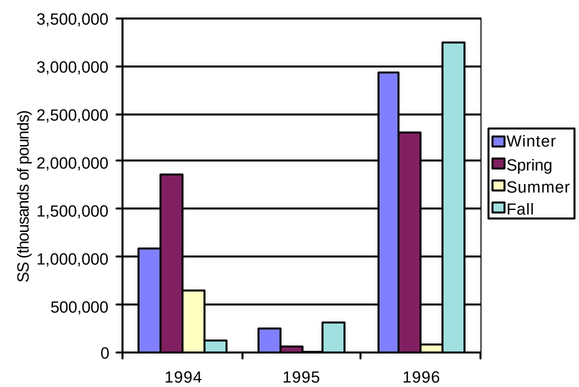
Discharge



Total Nitrogen



Total Phosphorus



Suspended Sediment

Figure 7. Seasonal Discharges and Loads of Total Nitrogen, Total Phosphorus, and Suspended Sediment for Calendar Years 1994, 1995, and 1996 at Towanda, Pa.

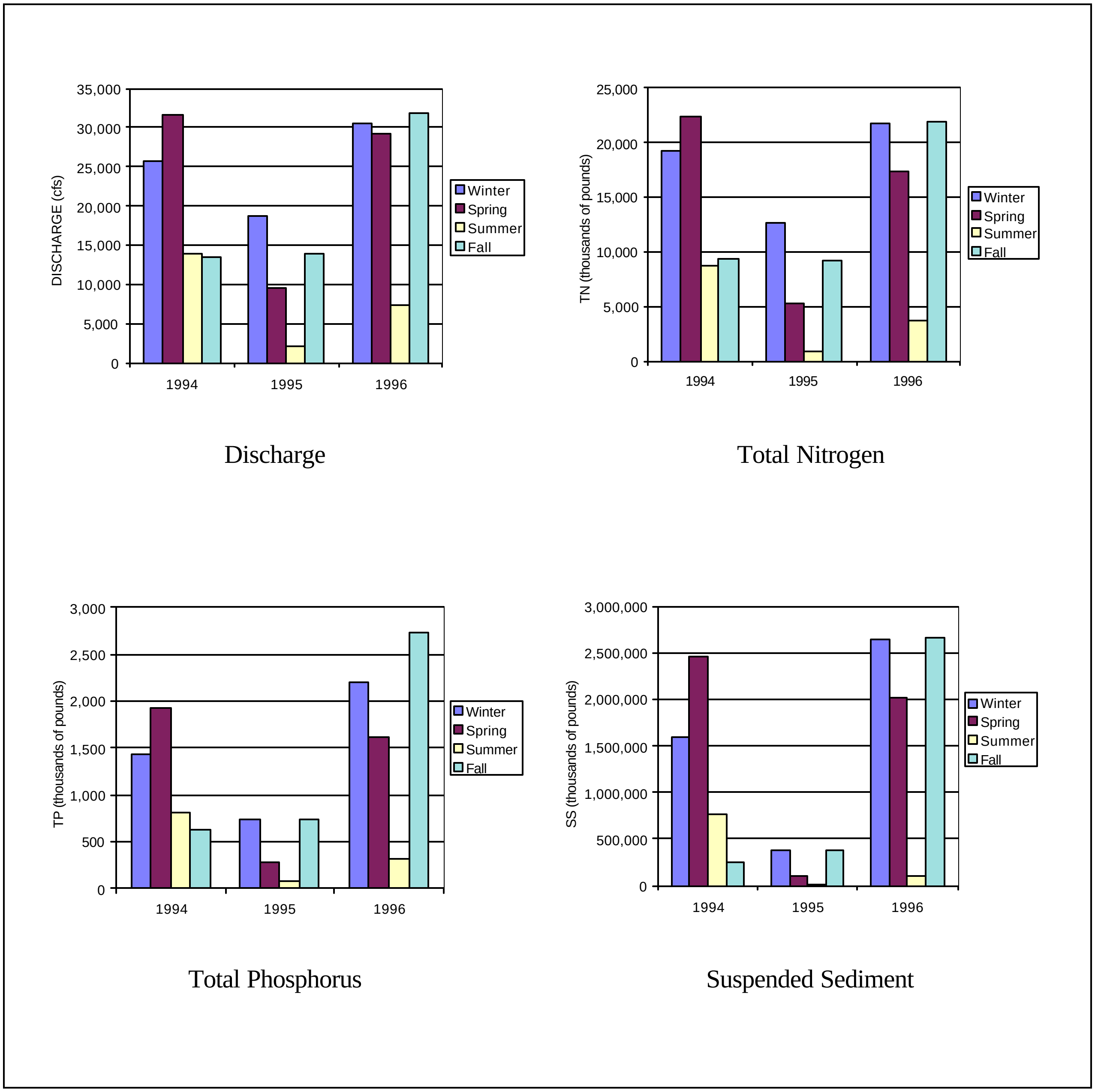


Figure 8. ***Seasonal Discharges and Loads of Total Nitrogen, Total Phosphorus, and Suspended Sediment for Calendar Years 1994, 1995, and 1996 at Danville, Pa.***

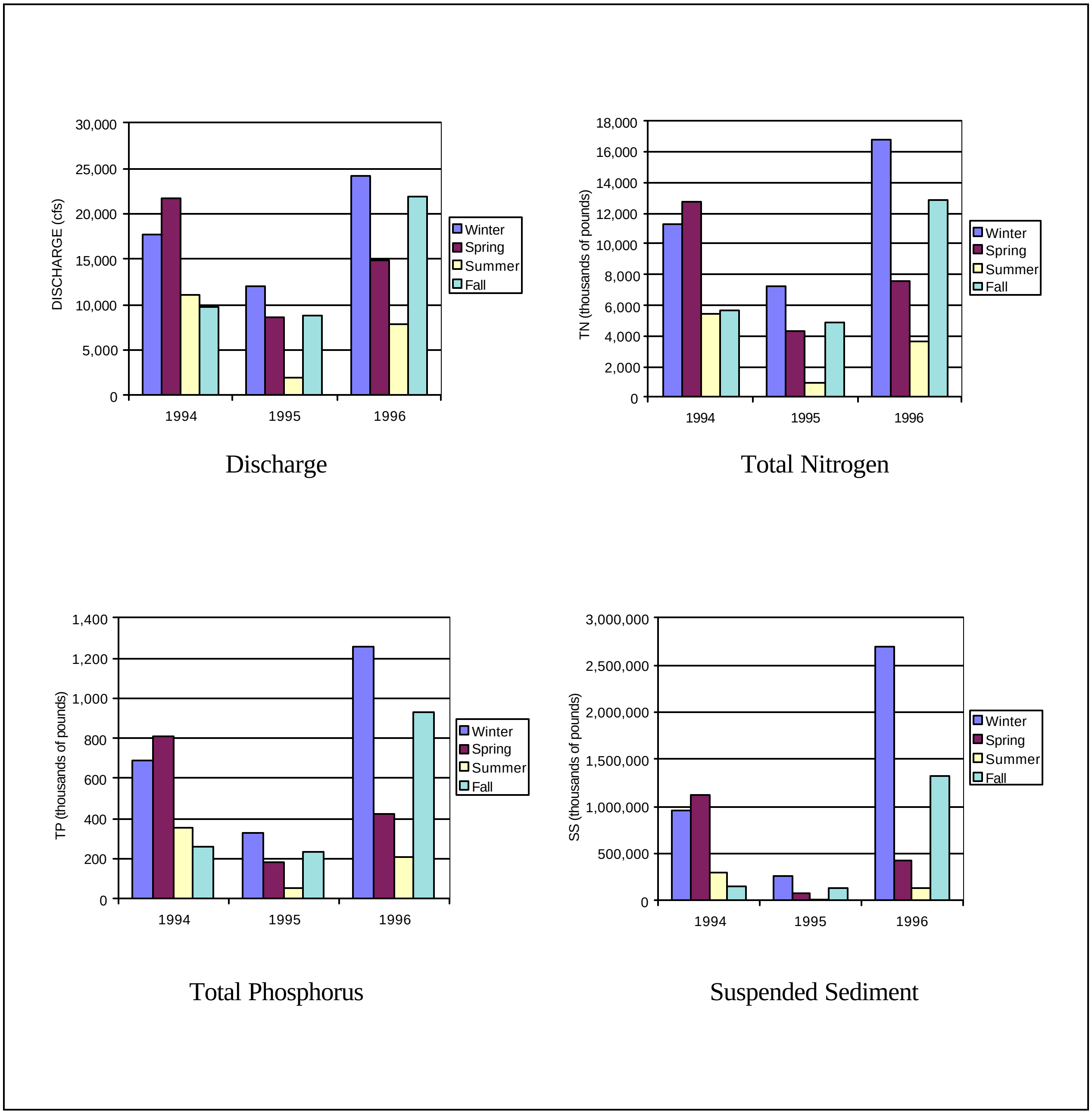


Figure 9. Seasonal Discharges and Loads of Total Nitrogen, Total Phosphorus, and Suspended Sediment for Calendar Years 1994, 1995, and 1996 at Lewisburg, Pa.

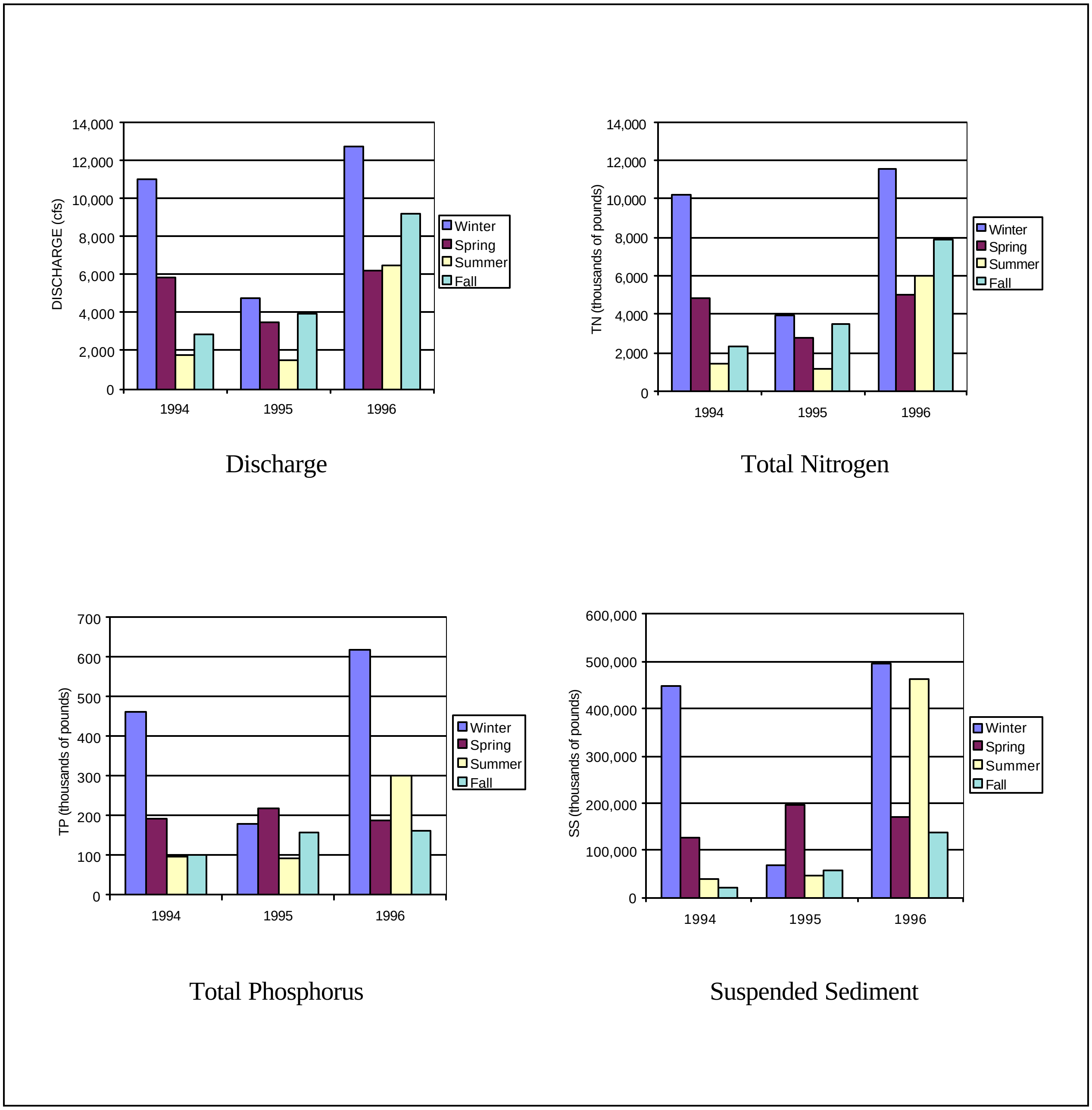


Figure 10. Seasonal Discharges and Loads of Total Nitrogen, Total Phosphorus, and Suspended Sediment for Calendar Years 1994, 1995, and 1996 at Newport, Pa.

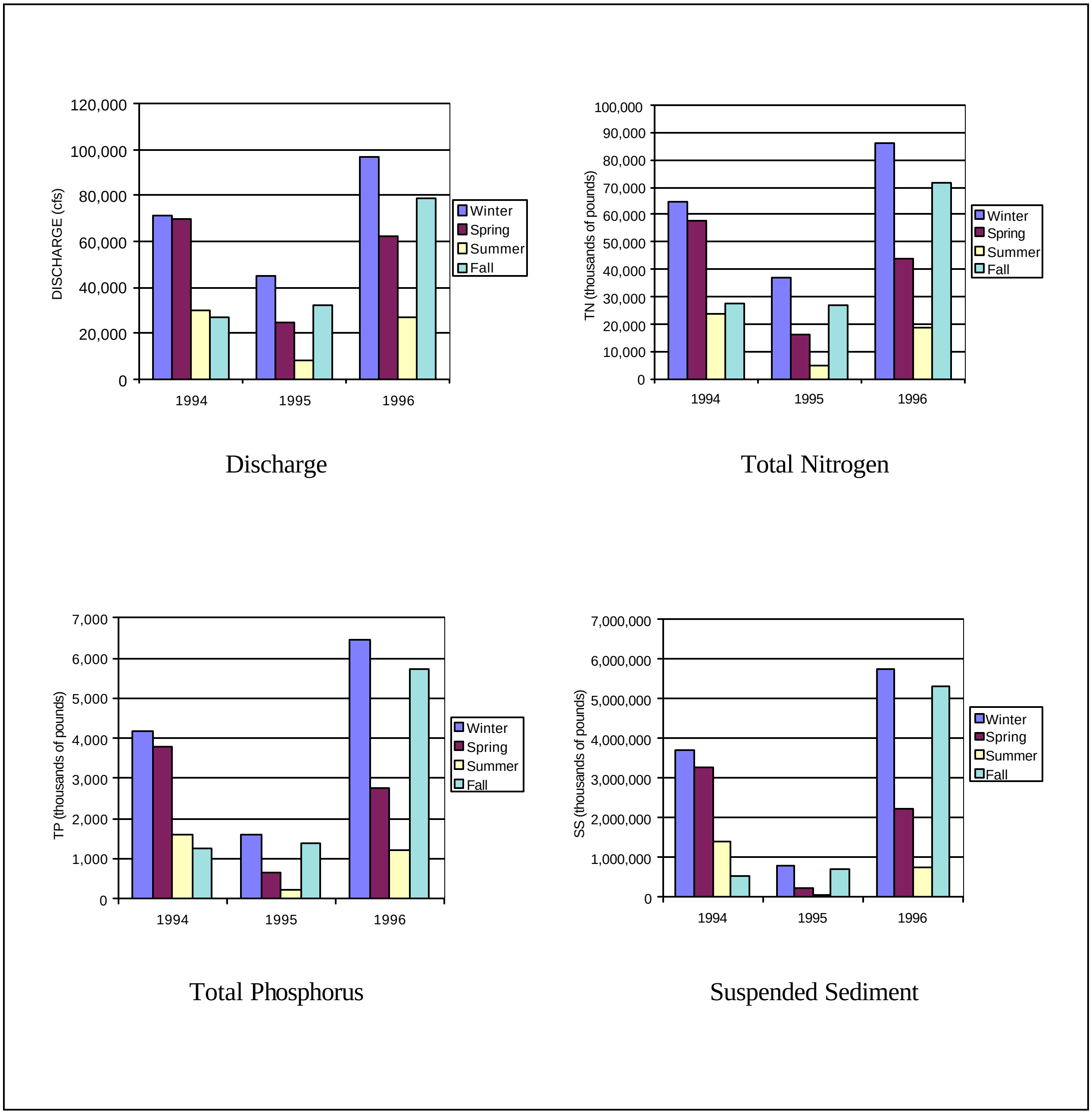


Figure 11. Seasonal Discharges and Loads of Total Nitrogen, Total Phosphorus, and Suspended Sediment for Calendar Years 1994, 1995, and 1996 at Marietta, Pa.

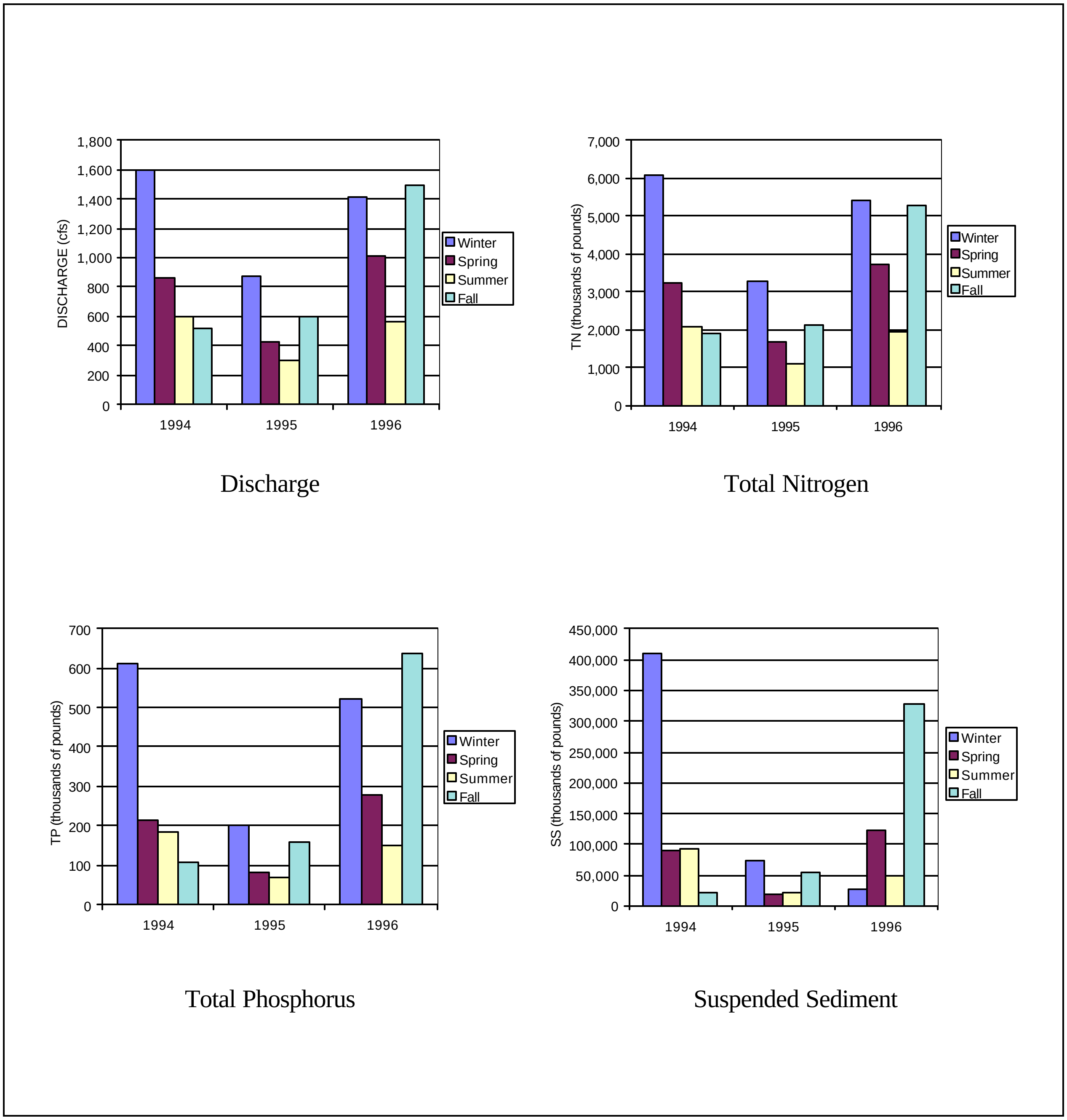


Figure 12. Seasonal Discharges and Loads of Total Nitrogen, Total Phosphorus, and Suspended Sediment for Calendar Years 1994, 1995, and 1996 at Conestoga, Pa.

COMPARISON OF THE 1994-96 LOADS AND YIELDS OF TOTAL NITROGEN, TOTAL PHOSPHORUS, AND SUSPENDED SEDIMENT WITH THE BASELINES

The annual loads of total nitrogen, total phosphorus, and suspended sediment measured in 1994, 1995, and 1996 fluctuated with annual fluctuations in water discharge as reported by Ott and others (1991) using data for 1985-89, and by Takita and Edwards (1993) for data collected in 1990 and 1991 and Takita (1996) for data collected in 1992 and 1993. Seasonal load fluctuations also corresponded with fluctuations in seasonal water discharges.

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. 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 1994, 1995, and 1996 were compared with the 1985-89 baseline, where possible. Monitoring at some of the stations was started after 1989; therefore, a baseline was established for the five-year period following the start of monitoring.

Susquehanna River at Towanda, Pa.

The five-year (1989-93) baselines for total nitrogen, total phosphorus, and suspended sediment for the Susquehanna River at Towanda are shown in Figure 13 with the respective annual yields for 1994, 1995, and 1996.

The best-fit lines were drawn through the data points using the following equations:

<u>Total Nitrogen (TN)</u>
TN Yield = 0.1111 + 6.0302x $R^2 = 0.90$

<u>Total Phosphorus (TP)</u>
TP Yield = -0.3761 + 0.7703x $R^2 = 0.69$

<u>Suspended Sediment (SS)</u>
SS Yield = -769.722 +1215.941x $R^2 = 0.42$

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

The total nitrogen yields and the water discharge ratios for 1994, 1995, and 1996 at Towanda were 1.32 and 7.07 pounds per acre per year (lb/ac/yr), 0.67 and 3.45 lb/ac/yr, and 1.60 and 8.64 lb/ac/yr, respectively. The yields for 1994 through 1996 plot significantly below the five-year baseline, suggesting that TN yields have decreased. According to the baseline, the TN yields should be 8.07 lb/ac/yr at a water discharge ratio of 1.32, 4.15 lb/ac/yr at 0.67, and 9.76 lb/ac/yr at 1.60. The differences in the yields amount to 301,000 lb, 211,000 lb and 337,000 lb less than the five-year baseline loads for 1994, 1995, and 1996, respectively. Since nitrogen is very soluble, the load/discharge relationship should be very stable, and any variance from this relationship would indicate that some change has occurred.

The total phosphorus and suspended-sediment yields show similar relationships with their respective baselines in 1994, 1995, and 1996. Figure 13 shows a significant increase of total phosphorus and suspended-sediment yields in 1995. The total phosphorus yield measured in 1995 was 0.22 lb/ac/yr at a discharge ratio of 0.67. The yield calculated from the baseline regression was 0.14 lb/ac/yr at the same discharge ratio. This difference amounted to 24,000 lb more than the baseline load in 1995. The suspended-sediment yield measured in 1995 was 129 lb/ac/yr, compared to 44 lb/ac/yr, or an

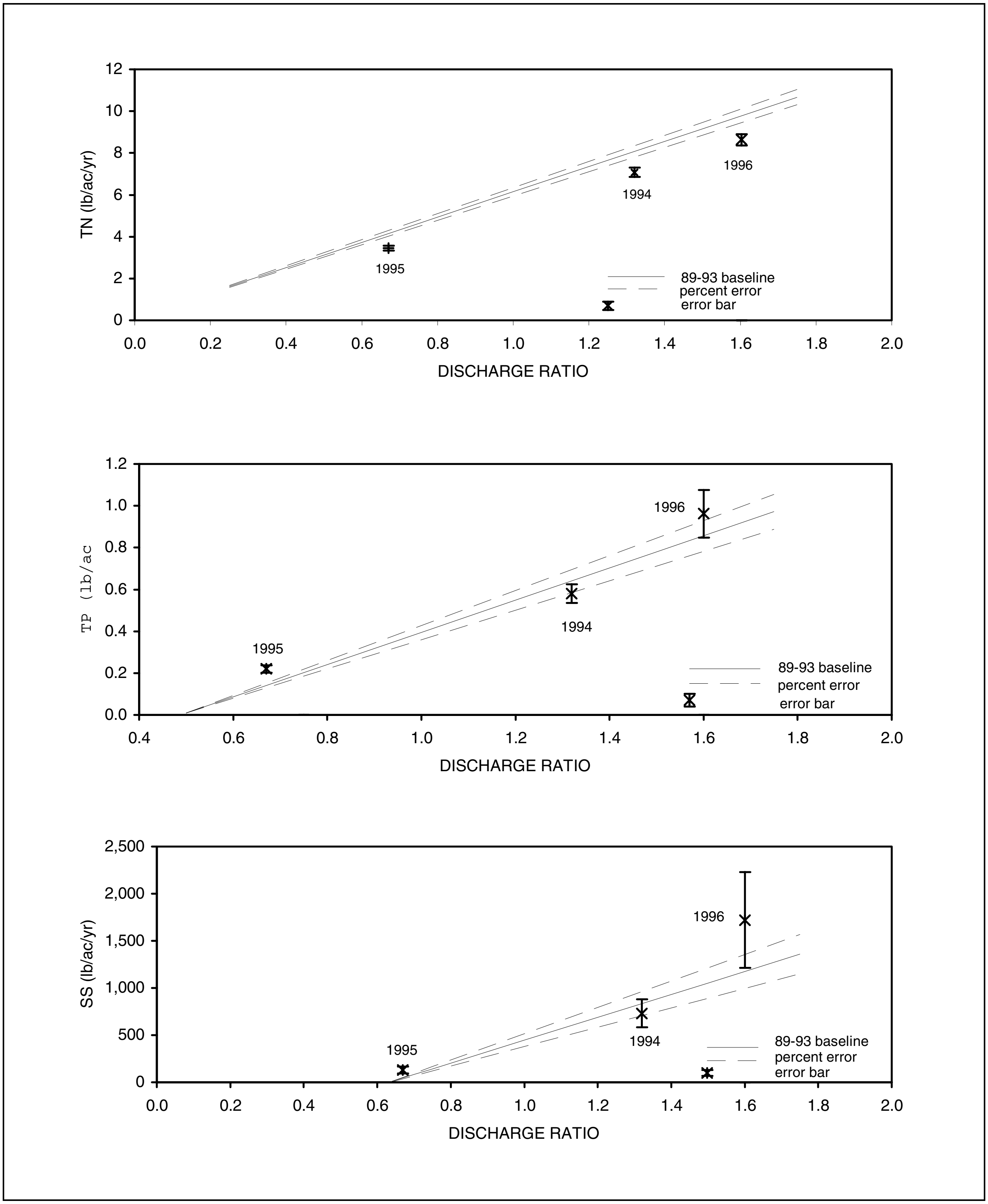


Figure 13. Total Nitrogen (TN), Total Phosphorus (TP), and Suspended-Sediment (SS) Yields, Susquehanna River at Towanda, Pa., 1989-93 and 1994-96

increase of 1,600,000 lb of suspended sediment in 1995. Total phosphorus and suspended-sediment yields for 1994, as seen in Figure 13, suggest that a slight decrease has occurred, but this change may not be significant since it falls within the error of prediction for the baseline. Phosphorus and sediment yields for 1996 suggest that there may have been an increase over what was expected from the five-year baseline. The similarity of the total phosphorus and suspended-sediment plots illustrates the affinity between phosphorus and sediment.

Susquehanna River at Danville, Pa.

Figure 14 shows the five-year (1985-89) baseline plots for total nitrogen, total phosphorus, and suspended sediment and the 1994-96 data points for the Susquehanna River at Danville. The equations used to fit the regression lines through the data points are as follows:

Total Nitrogen (TN)
TN Yield = -0.7325 + 7.7647 x R^2 = 0.95

Total Phosphorus (TP)
TP Yield = -0.2633 + 0.7906 x R^2 = 0.95

Suspended Sediment (SS)
SS Yield = -680.273 + 1168.772 x R^2 = 0.99

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

The total nitrogen yield data plotted in Figure 14 show significant decreases in 1994-96. The total nitrogen yields and the water discharge ratios for 1994, 1995, and 1996 at Danville were 8.31lb/ac/yr at 1.39, 3.91 lb/ac/yr at 0.72 and 8.99 lb/ac/yr at 1.63, respectively. According to the baseline, the TN yields should be 10.06 lb/ac/yr at a water discharge ratio of 1.39, 4.86 lb/ac/yr at 0.72 and 11.92 lb/ac/yr at 1.63. The differences in the yields amount to 12,600,000 lb of TN in 1994, 6,610,000 lb in 1995, and 21,000,000 lb in 1996. Since nitrogen is very soluble, the load/discharge relationship should be very stable, and any variance from this relationship would indicate that some change has occurred.

The total phosphorus yields for 1994 and 1995 in Figure 14 show a significant decrease from the baseline. The total phosphorus yield measured in 1994 was 0.67 lb/ac/yr at a discharge ratio of 1.39, compared to 0.84lbs/ac/yr calculated from the baseline regression. The 1995 measured yield was 0.26 lb/ac/yr at 0.72, compared to 0.29 lb/ac/yr from the baseline. These differences in TP yields amount to a decrease of 1,220,000 lb of total phosphorus in 1994 and 215,000 lb in 1995. The yield in 1996 suggests a decrease in the load, but is not significant since it lies within the error of prediction.

The plots of suspended-sediment yields show some similarity with that of total phosphorus. The yields measured in 1994, 1995, and 1996 indicate that a decrease in sediment loads occurred in those years. The overlap in the margins of error suggest that the decrease may not be significant.

West Branch Susquehanna River at Lewisburg, Pa.

The 1985-89 baselines for total nitrogen, total phosphorus, and suspended sediment and the 1994-96 yields at Lewisburg are shown in Figure 15.

The baselines shown in Figure 15 were defined by the following equations:

Total Nitrogen (TN)
TN Yield = -0.5310 + 6.5398 x R^2 = 0.94

Total Phosphorus (TP)
TP Yield = -0.0763 + 0.3933 x R^2 = 0.91

Suspended Sediment (SS)
SS Yield = - 229.90 + 468.38 x R^2 = 0.82

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

The 1994 and 1995 total nitrogen yields of 8.03 and 3.95 lb/ac/yr at water discharge ratios of 1.38 and 0.71, respectively, show a decrease from the baseline. According to the baseline, the total nitrogen yields should be 8.67 and 4.29 lb/ac/yr, or decreases of 2,800,000 and 1,490,000 lb of total nitrogen in 1994 and 1995, respectively. The

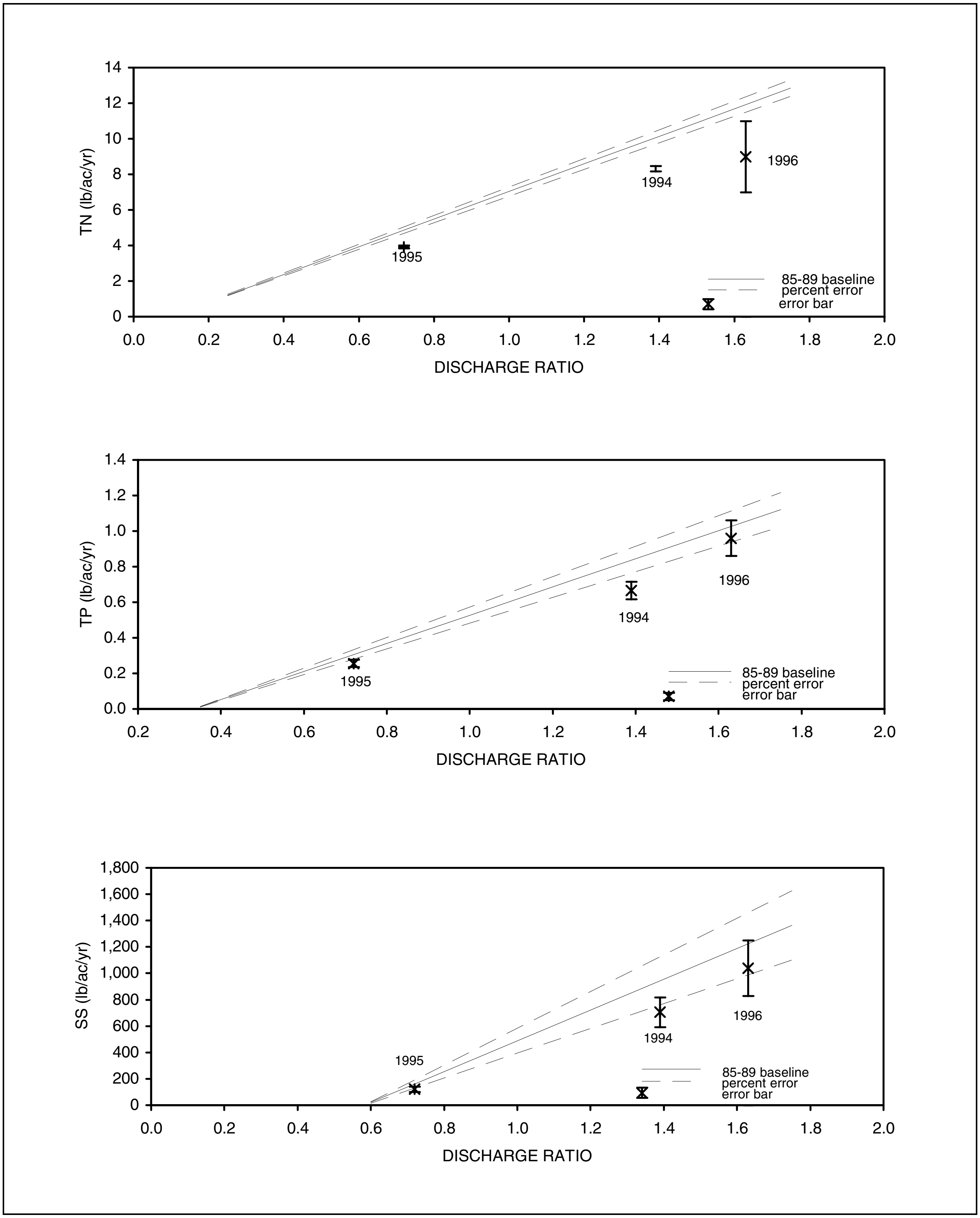


Figure 14. Total Nitrogen (TN), Total Phosphorus (TP), and Suspended-Sediment (SS) Yields, Susquehanna River at Danville, Pa., 1985-89 and 1994-96

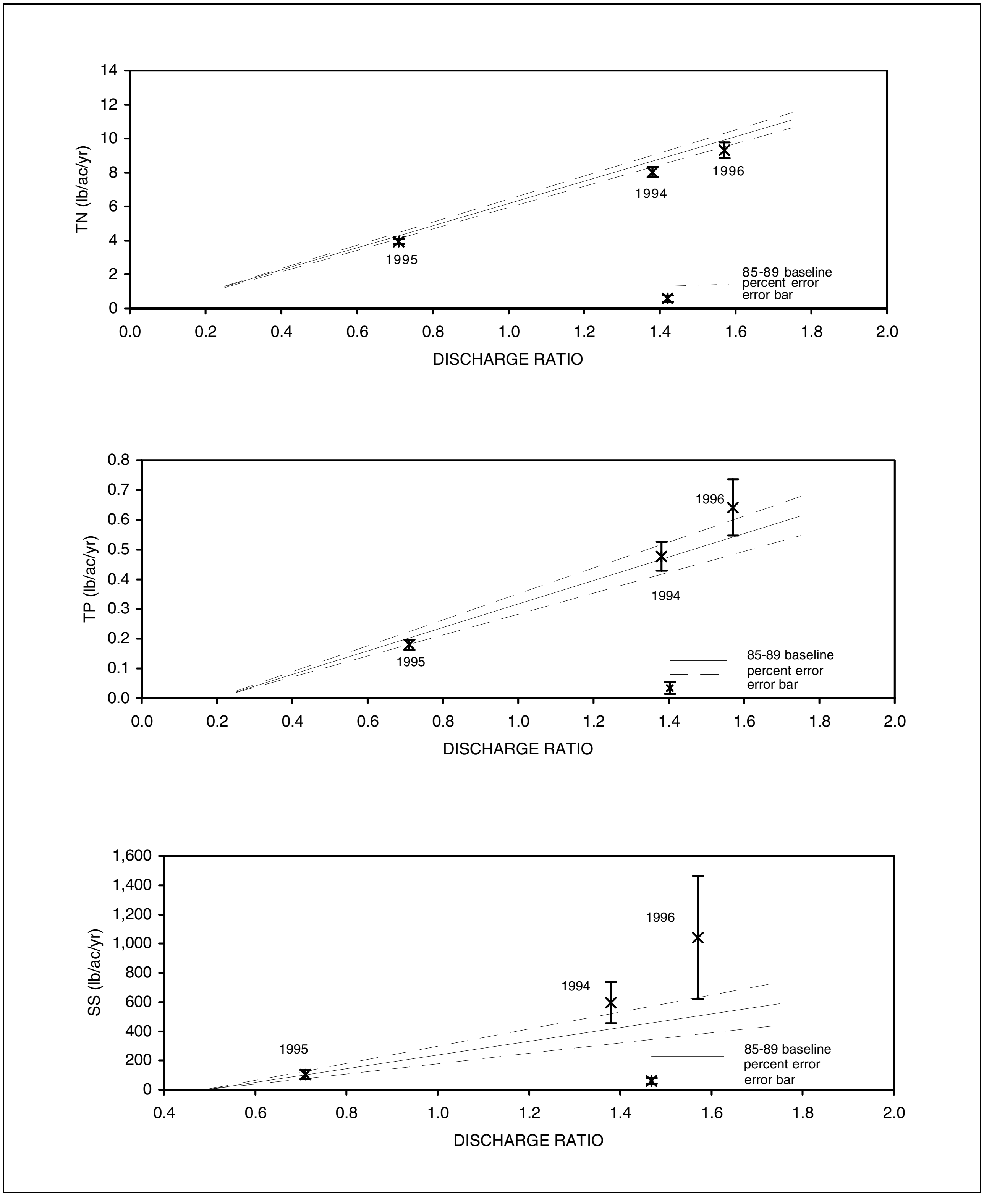


Figure 15. Total Nitrogen (TN), Total Phosphorus (TP), and Suspended-Sediment (SS) Yields, West Branch Susquehanna River at Lewisburg, Pa., 1985-89 and 1994-96

1996 total nitrogen yield amounts to a decrease of 2,670,000 lb. The decreases indicated in Figure 15 may not be significant and somewhat less since the errors of prediction overlap.

Total phosphorus yields for 1994 and 1995 in Figure 15 indicate that no significant change from the baseline yields occurred. There was a slight increase from the baseline in 1996.

The suspended-sediment yield measured in 1995 showed no change from the predicted yield. There was a slight increase in the suspended sediment in 1994, and a significant increase in 1996. The increase in sediment load amounted to 2,350,000,000 in 1996.

Juniata River at Newport, Pa.

The 1985-89 baselines for total nitrogen, total phosphorus, and suspended sediment and the 1994-96 yields at Lewisburg are shown in Figure 16.

The baselines shown in Figure 16 were defined by the following equations:

Total Nitrogen (TN)
TN Yield = -0.4602 + 8.3723 x R^2 = 0.91

Total Phosphorus (TP)
TP Yield = -0.1993 + 0.6207 x R^2 = 0.98

Suspended Sediment (SS)
SS Yield = - 357.44 + 630.20 x R^2 = 0.96

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

Total nitrogen yields shown in Figure 16 show that significant decreases occurred during 1994-96. Comparison of the measured yields and the baseline yield at the corresponding discharge ratios shows that there was a decrease of 3,280,000 lb in 1994, 2,000,000 lb in 1995, and 5,000,000 lb in 1996.

Total phosphorus yields decreased significantly from baseline predictions in 1994 and 1996. Measured yields in 1994 and 1996 were 0.40 and 0.59 lb/ac/yr, respectively. The baseline yields at the corresponding discharge ratios were 0.60 and 1.06 lb/ac/y, which amounts to 429,000 lb in 1994 and 1,000,000 lb in 1996. There was no change in the yield for 1995.

The responses of suspended-sediment yields were similar to that of total phosphorus. There was no difference in the 1995 measured suspended-sediment yield and the baseline yield. The 1994 and 1996 yields showed a decrease, when compared with the baseline yields at the corresponding discharge ratios

Susquehanna River at Marietta, Pa.

The total nitrogen, total phosphorus and suspended-sediment baselines for the five-year period, 1987-91, at Marietta are shown in Figure 17 with the 1994-96 yields.

The best-fit lines were drawn through data points, determined by using the following regression equations:

Total Nitrogen (TN)
TN Yield = -0.5908 + 9.1106 x R^2 = 0.99

Total Phosphorus (TP)
TP Yield = -0.1073 + 0.5518 x R^2 = 0.94

Suspended Sediment (SS)
SS Yield = -147.88 + 436.6466.77 x R^2 = 0.68

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

The 1994, 1995, and 1996 total nitrogen yields and water discharge ratios shown in Figure 17 for the Susquehanna River at Marietta indicate that there was a significant decrease in nitrogen transported in during these years. Comparison of the measured yields with the baseline yields at the corresponding discharge ratios shows that total nitrogen loads decreased by 20,800,000 lb, 16,000,000 lb, and 37,300,000 lb in 1994-96, respectively.

There was no change in the total phosphorus yield in 1994, compared to the predicted yield from the baseline. The 1995 yield was less than expected according the baseline, and the 1996

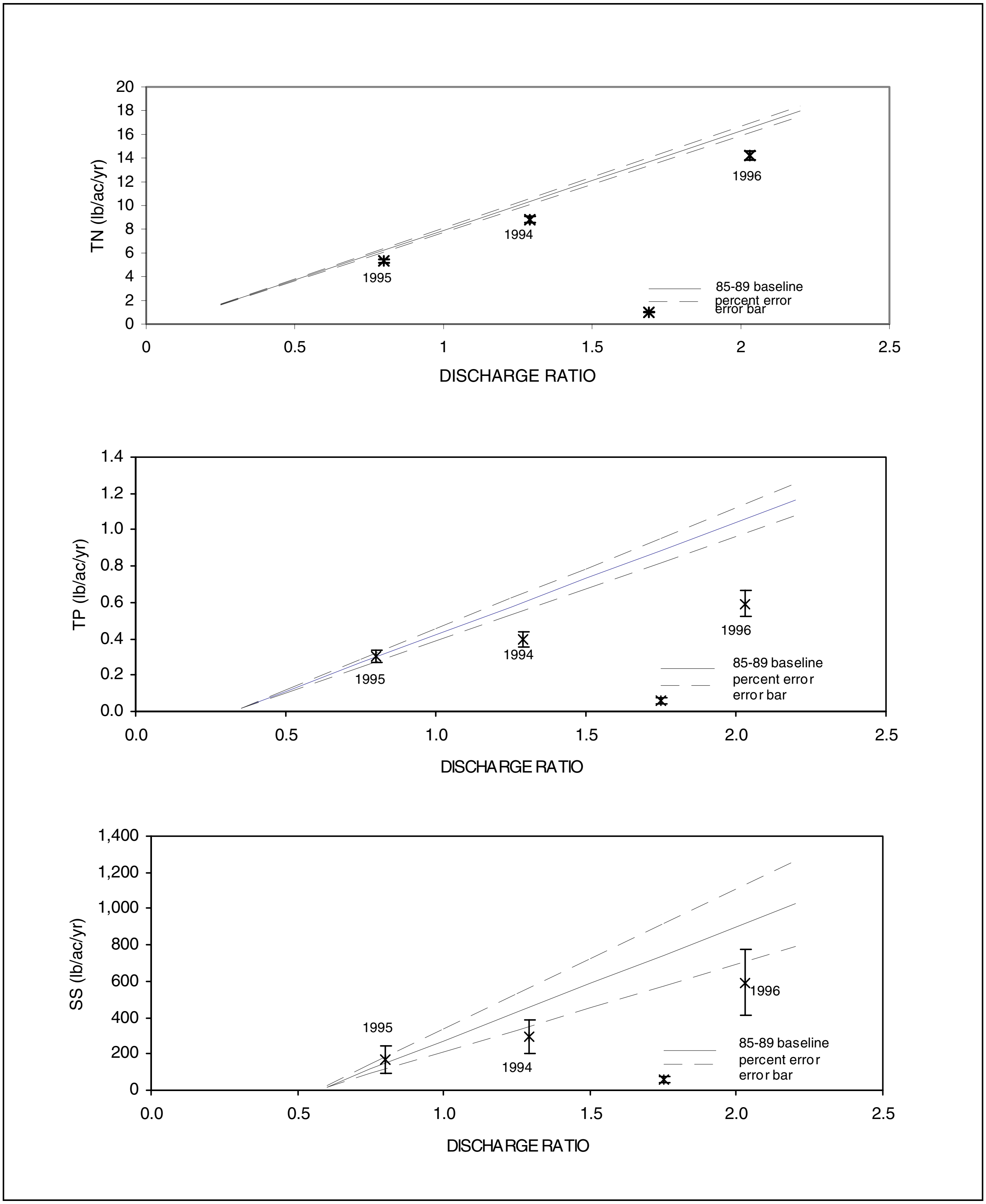


Figure 16. Total Nitrogen (TN), Total Phosphorus (TP), and Suspended-Sediment (SS) Yields, Juniata River at Newport, Pa., 1985-89 and 1994-96

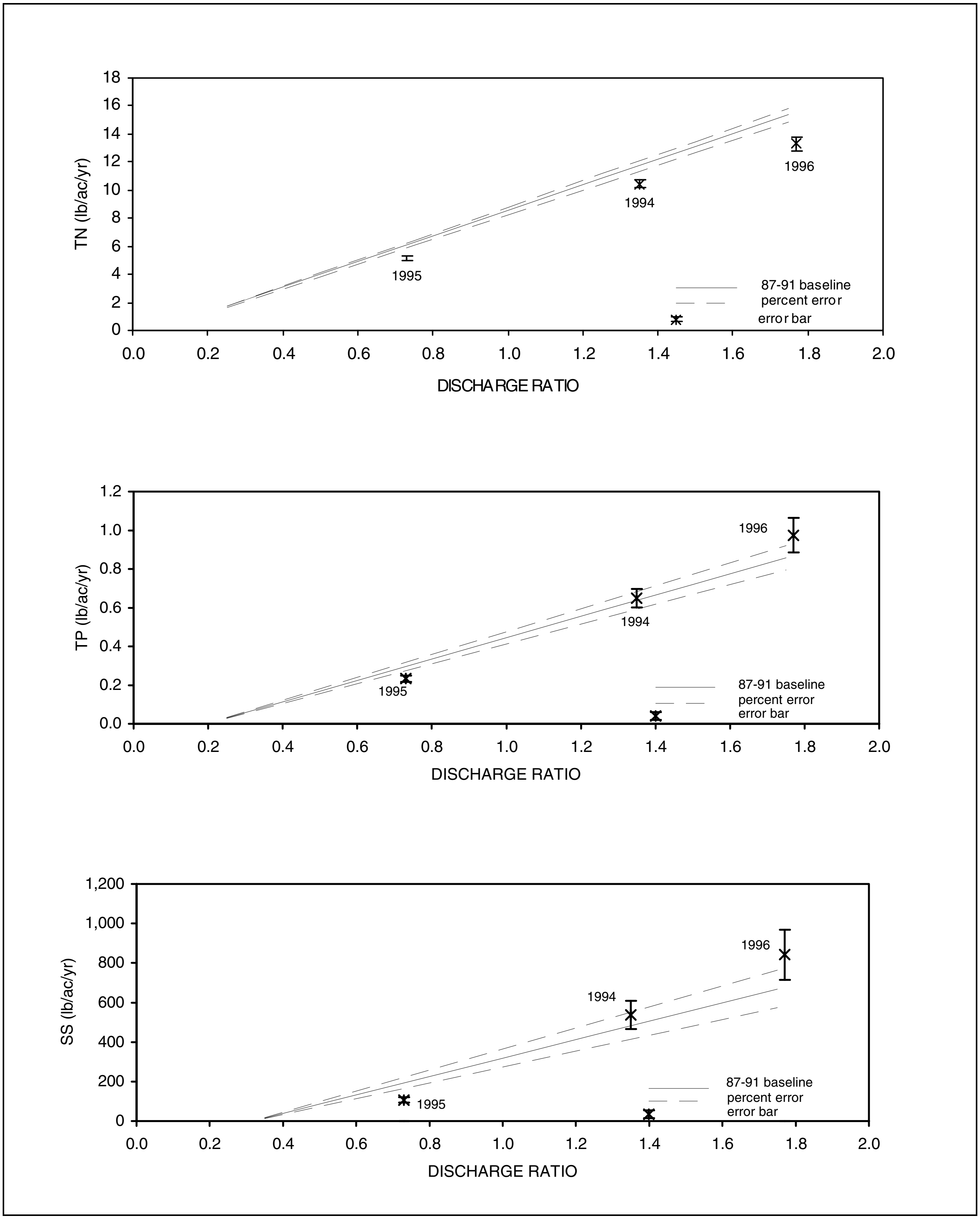


Figure 17. Total Nitrogen (TN), Total Phosphorus (TP), and Suspended-Sediment (SS) Yields, Susquehanna River at Marietta, Pa., 1987-91 and 1994-96

yield was slightly higher than the baseline. The 1995 total phosphorus yield was 0.23 lb/ac/yr at a water discharge ratio of 0.73, which was less than the 0.30 lb/ac/yr from the baseline. This difference amounted to a load of 1,160,000 lb of total phosphorus. The 1996 total phosphorus yield of 0.97 lb/ac/yr at a water discharge ratio of 1.77 was slightly higher than the 0.87 lb/ac/yr on the baseline, a difference of 1,660,000 lb of TP.

Suspended-sediment yields at Marietta for 1994-96 had the same pattern as total phosphorus. The 1994 yield of 537.5 lb/ac/yr showed some increase, but it was not considered significant since the yield was within the error of prediction for the baseline. The 1995 yield of 106.4 lb/ac/yr was lower than the 192.9 lb/ac/yr from the baseline. The 1996 yield of 841.7 lb/ac/yr was considerably higher than the baseline yield of 678.3 lb/ac/yr, although there was some overlap in the margins of error. These differences in yields amounted to 1,440,000,000 lb and 2,720,000,000 lb of suspended sediment in 1995 and 1996, respectively.

Conestoga River at Conestoga, Pa.

Figure 18 shows the total nitrogen, total phosphorus and suspended-sediment baselines.

These baselines were plotted using the following equations:

Total Nitrogen (TN)
TN Yield = 5.3924 + 28.2905 x R^2 = 0.97

Total Phosphorus (TP)
TP Yield = -1.5844 + 3.3717 x R^2 = 0.90

Suspended Sediment (SS)
SS Yield = -668.608 + 2090.979 x R^2 = 0.90

where x = water discharge ratio and R^2 = correlation coefficient;
TP = Total phosphorus yield for 1989-93 period

As seen in Figure 18, the 1994-96 total nitrogen yields show significant decreases in loads. The 1994 total nitrogen yield was 43.9 lb/ac/yr, compared to 47.5 from the baseline, a difference of 1,080,000 lbs. The 1995 and 1996 yields were 27.2 and 54.2 lb/ac/yr, compared to 31.4 and 58.3, respectively. These differences in yields amounted to 1,260,000 lb and 1,230,000 lb for 1995 and 1996, respectively.

Data collected during the initial five-year (1985-89) period showed a significant reduction in the phosphorus load in 1989. The reduction measured in 1989 was attributed, in part, to the phosphorus reduction in the Lancaster Regional Treatment Plant (Ott and others, 1991; Ott, 1991). Comparison of the average annual yield adjusted to the long-term mean discharge for the original 1985-88, which is considered the baseline prior to phosphorus management, and the average annual yield adjusted to the long-term mean discharge for the 1989-93 period indicated that the total phosphorus decreased by 0.8 lb/ac/yr, or 241,000 lb/yr. Ott (1991) reported a reduction of 142,000 lb/yr of total phosphorus from the treatment plant. The 1989-93 baseline is used for this report to evaluate changes in total phosphorus loads. The 1989-93 baseline and the 1994-96 yield data in Figure 18 indicate that there was a slight increase in total phosphorus. These increases do not appear to be very significant in that the computed values lie within the percent error of the baseline.

Suspended-sediment yields for 1994-96 plotted below the 1985-96 five-year baseline, however they all fell within the margin of error.

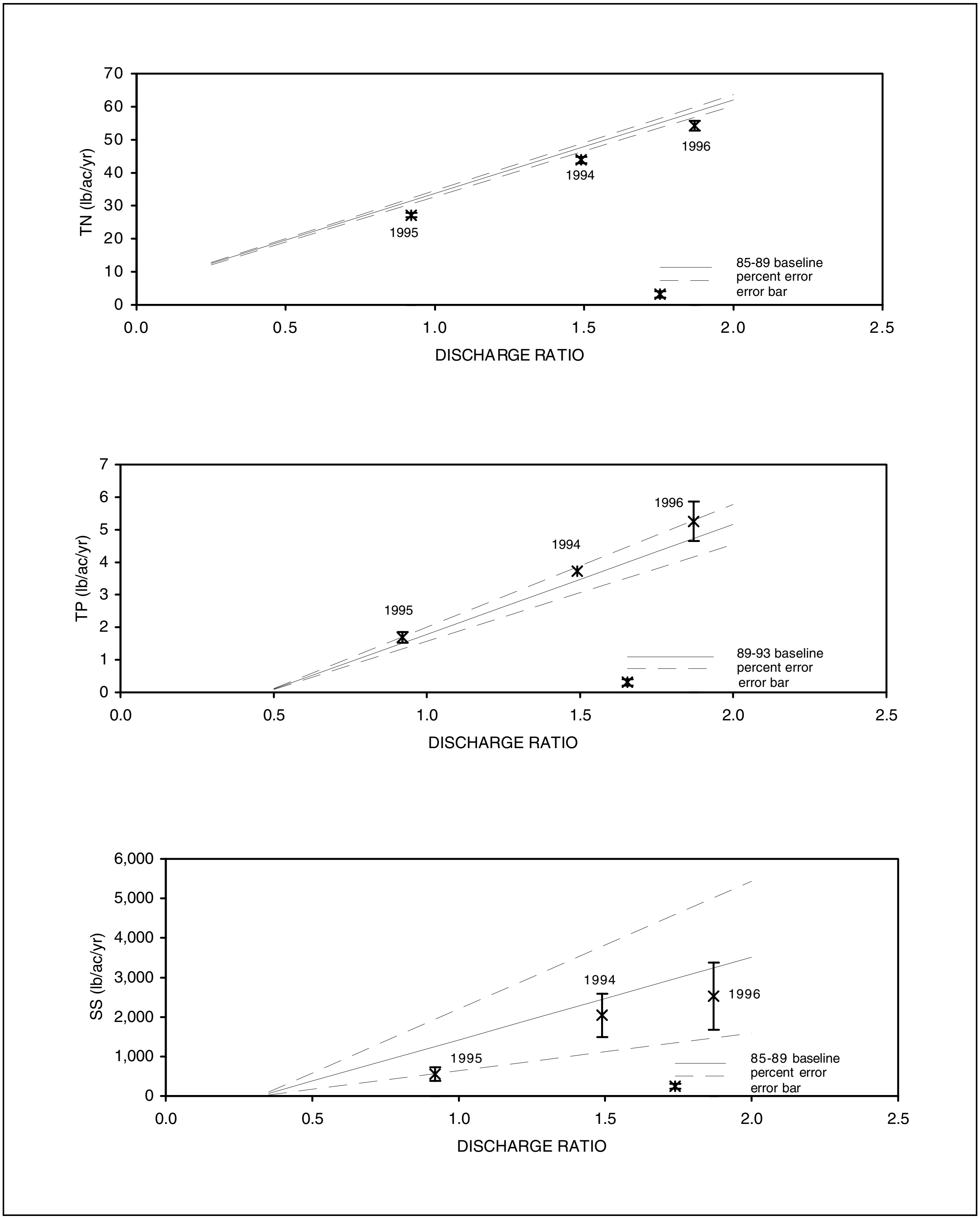


Figure 18. Total Nitrogen (TN) and Suspended-Sediment (SS) Yields, 1985-89 and 1994-96, and Total Phosphorus (TP) Yield, 1989-93 and 1994-96, Conestoga River at Conestoga, Pa.

TOTAL NITROGEN, TOTAL PHOSPHORUS, AND SUSPENDED-SEDIMENT LOADING TRENDS, CALENDAR YEARS 1985-96

Comparison of the 1994 through 1996 annual yields with the initial five-year baseline show that changes in discharge rates of total nitrogen, total phosphorus, and suspended sediment are occurring. Williams and Reed (1972) used a double-mass comparison of suspended-sediment load and direct runoff to describe a pattern of decreasing sediment loads in the Juniata basin. The double-mass comparison of constituent loads and water discharge was used in this report to describe changes in discharge rates at each of the monitoring sites.

The double-mass comparison is made by plotting the cumulative constituent discharge against the cumulative water discharge as shown in Figure 19(a).

As seen in Figure 19(a), the double-mass curve provides an insight to trends in the discharge rate over time. The discharge rate during the years 1 to 5 remained constant, then decreased during years 6 and 8. The discharge rate began increasing between year eight and nine, then remained constant during years 9 through 12 at nearly the same rate as the period 1 through 5. The double-mass comparison is useful in that it shows the year-by-year change in the discharge rate. The overall trend for a given period, as determined by statistical or other methods, may indicate a downward trend, but the double-mass comparison graph may show that the rate of constituent discharge may be creeping upward, or vice versa, to a point where the overall trend could be reversed.

Determination of the average baseline loads for each of the periods showing a change in discharge rates in Figure 19(a) was accomplished using the baseline relationships described by Ott and others (1991). Figure 19(b) shows the baseline relationships for years 1-5, 6-8 and 9-12 in Figure 19(a). As seen in Figure 19(a), there was a decrease in the discharge rate during years 6-8 and the baseline load at the water discharge ratio of 1 (Figure 19(b)) is less than the average load for years 1-5. The discharge rate increased between year 8 and 9 and remained at a constant rate less than the rate for years 1-5 (Fig. 19(a)). Figure 19(b) shows the baseline load for years 9-12, adjusted to the long-term average discharge (ratio of 1) is less than the average load for the base years 1-5 and greater than that for years 6-8.

Susquehanna River at Towanda, Pa.

Double-mass comparisons for total nitrogen, total phosphorus, suspended sediment, and water discharge and the corresponding annual yield baselines for the Susquehanna River at Towanda are illustrated in Figures 20 through 22. Total nitrogen (Figure 20) shows a decrease in the discharge rate beginning in 1993 or 1994. A comparison of the average annual baseline yields (Ott and others, 1991) for the periods 1989-93 and 1994-96, adjusted to the long-term mean discharge, indicates that total nitrogen decreased by 4.1 million pounds. Figures 21 and 22 show that, beginning about 1992 or 1993, an increase in the total phosphorus and suspended-sediment discharge rate occurred. Comparison of average annual baseline yields for the periods 1989-92 and 1993-96 indicates that total phosphorus increased by 543,000 pounds, and suspended sediment increased by 3.3 million tons. Langland and others (1998) completed a statistical trend analysis of a number of monitoring sites in the Chesapeake Bay drainage basin. Their analysis showed a decreasing trend for total nitrogen concentrations. The results of their total phosphorus and suspended-sediment concentration data analysis suggested that there may be an increasing trend, however, the results were not considered to be significant and were reported as no change. The significance of the double-mass comparison results are not known; however both methods of analysis arrived at similar results.

Susquehanna River at Danville, Pa.

Figures 23 and 24 show decreasing discharges of total nitrogen and total phosphorus at Danville beginning about 1989 or 1990. Total nitrogen baseline yields for the periods 1985-89 and 1990-96, adjusted to the long-term mean

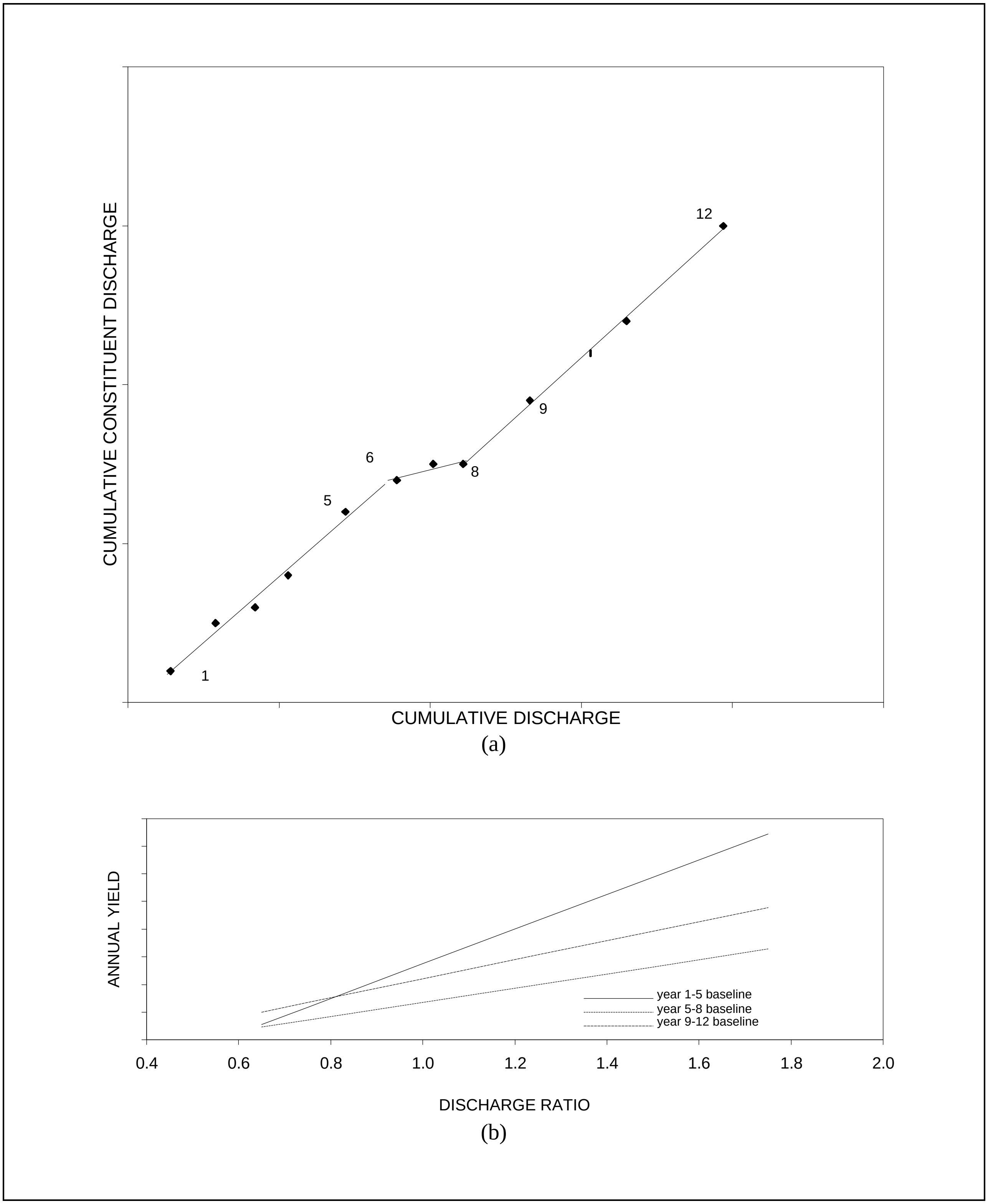


Figure 19. Example for the Use of Double-mass Comparison of Constituent Discharge and Water Discharge (a) and Annual Yield Baselines (b)

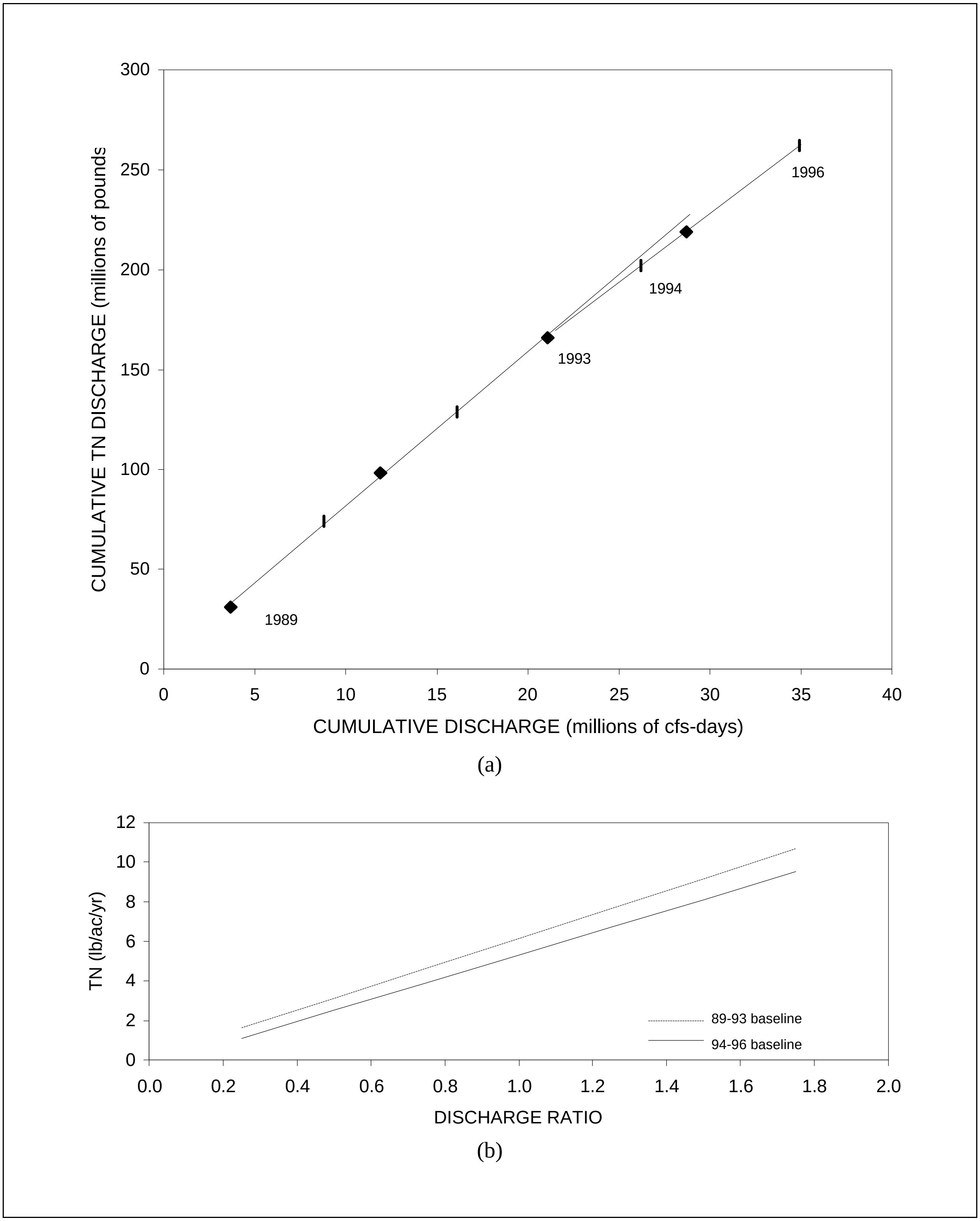


Figure 20. Double-mass Comparison of Total Nitrogen Discharge and Water Discharge (a) and Annual Yield Baselines (b) for the Susquehanna River at Towanda, Pa.

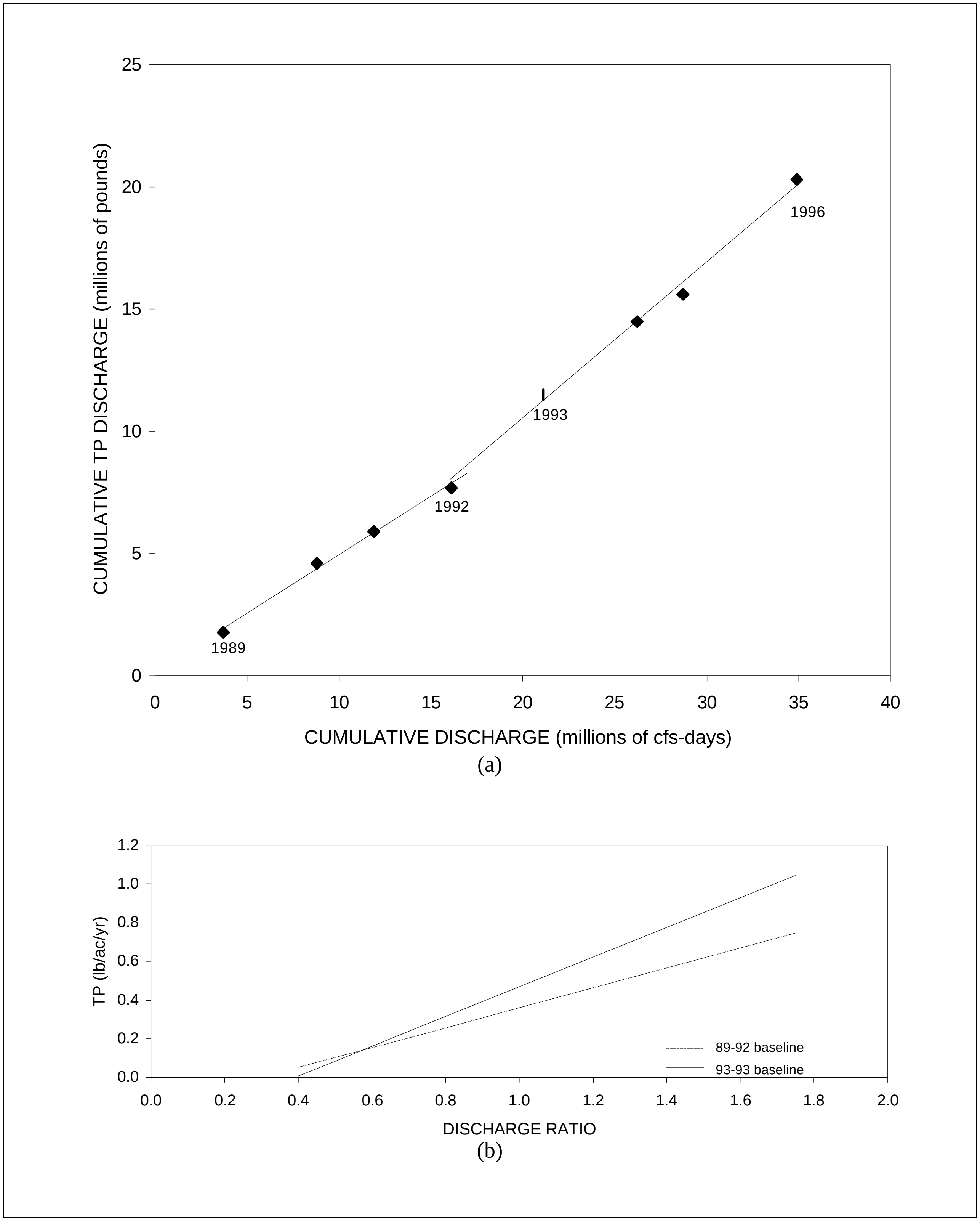


Figure 21. Double-mass Comparison of Total Phosphorus Discharge and Water Discharge (a) and Annual Yield Baselines (b) for the Susquehanna River at Towanda, Pa.

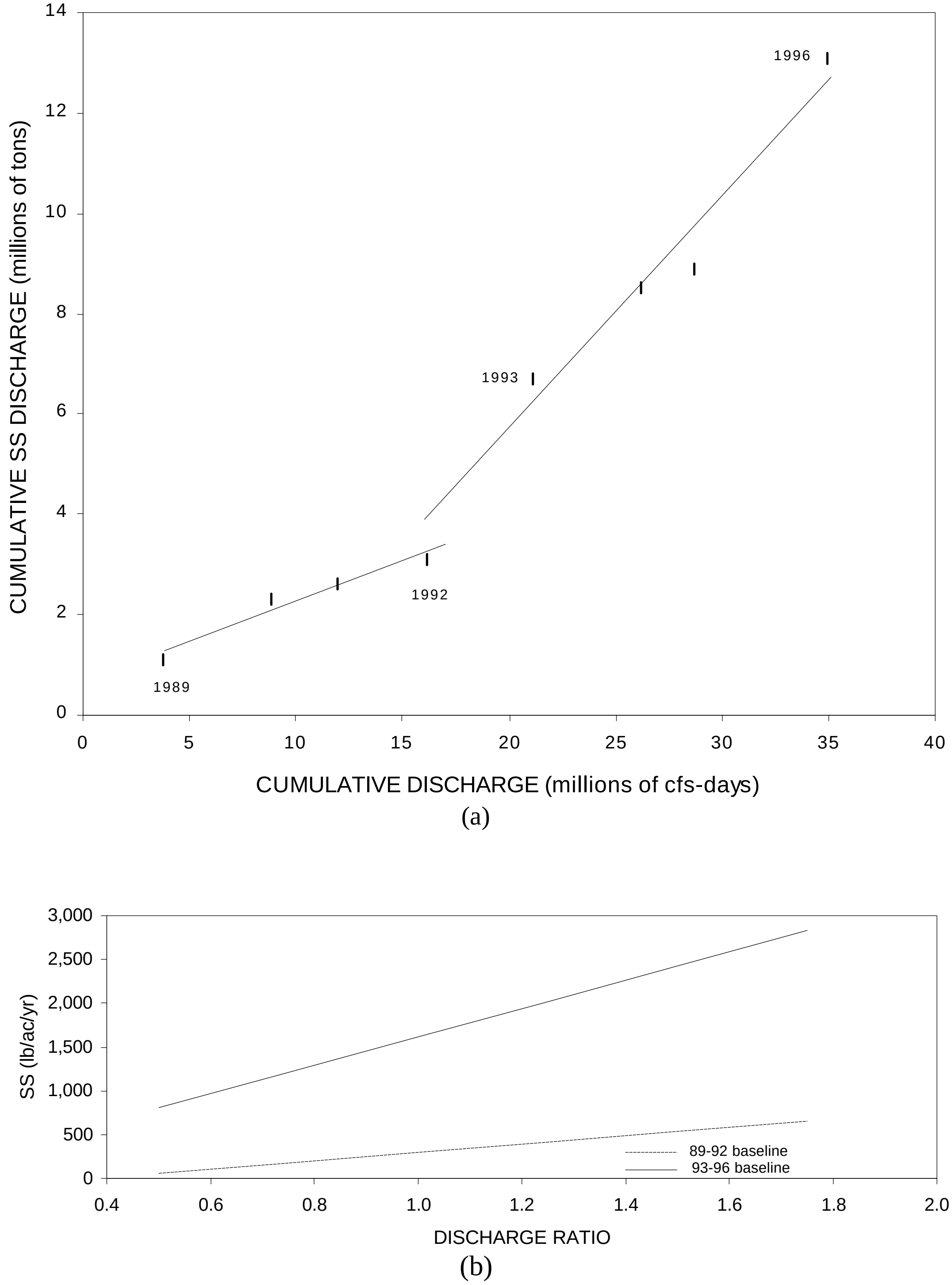


Figure 22. Double-mass Comparison of Suspended-Sediment Discharge and Water Discharge (a) and Annual Yield Baselines (b) for the Susquehanna River at Towanda, Pa.

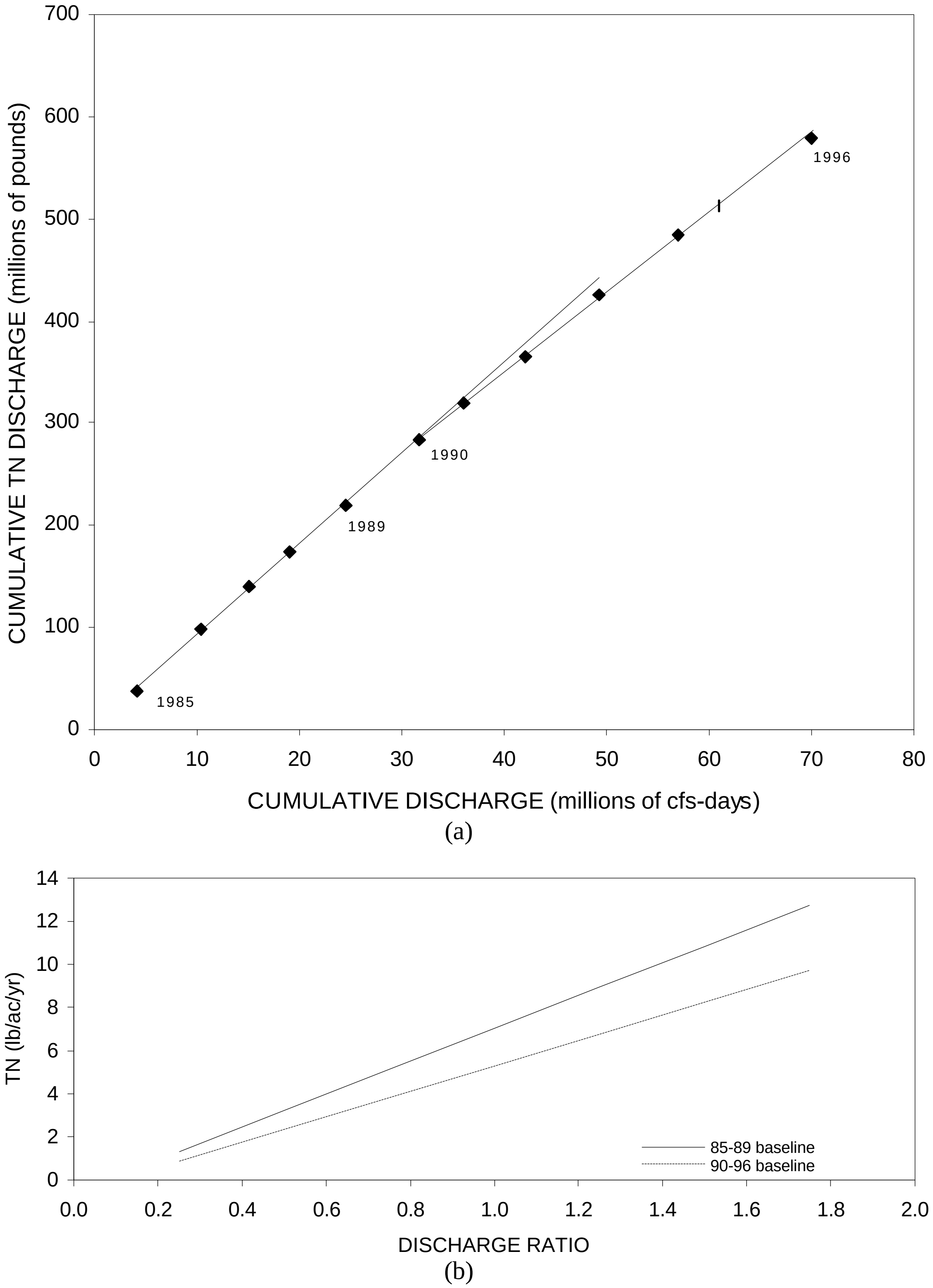


Figure 23. Double-mass Comparison of Total Nitrogen Discharge and Water Discharge (a) and Annual Yield Baselines (b) for the Susquehanna River at Danville, Pa.

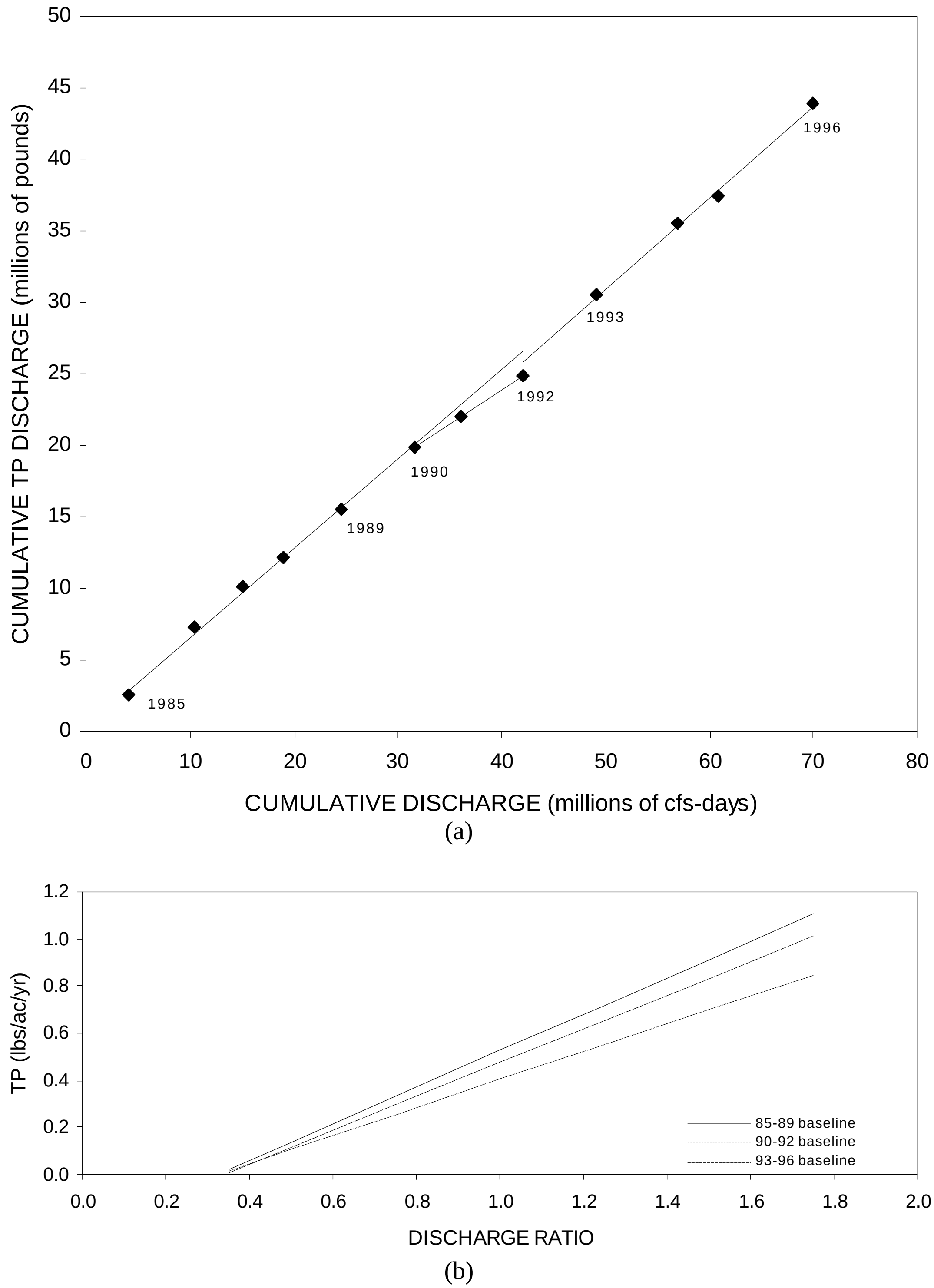


Figure 24. Double-mass Comparison of Total Phosphorus Discharge and Water Discharge (a) and Annual Yield Baselines (b) Discharge for the Susquehanna River at Danville, Pa.

discharge, indicate that a 12.5-million-pound reduction occurred. Total phosphorus discharge rates appear to have decreased during the 1990-92 period, and then began increasing sometime after 1992, but continued to be less than the 1985-89 baseline discharge rate. Total phosphorus baseline yields for the 1985-89, 1990-92, and 1993-96 periods, adjusted to the long-term mean discharge, indicate that a 872,000-pound reduction occurred during the 1990-92 period and a 369,000-pound reduction occurred in the 1993-96 period, when compared to the 1985-89 baseline. The suspended-sediment discharge rate (Figure 25) decreased during the 1990-92 period, and then began increasing after 1992 to levels nearly equal to the 1985-89 period. Annual suspended-sediment baseline yields for the 1985-89, 1990-92, and 1993-96 periods indicate that a 918,000-ton reduction in suspended-sediment discharge occurred during 1990-92. Suspended sediment increased by 24,000 tons during 1993-96, when compared to the 1985-89 baseline period. This increase is small and is not significant. The statistical trend analysis by Langland and others (1998) shows downward trends for total nitrogen, total phosphorus and suspended sediment concentrations. The difference in the trend predictions may be due to the fact that loads are used in the double-mass comparison and concentrations are used in the statistical analysis. The downward trend in the suspended-sediment concentration, reported by Langland and others (1998), may not have been sufficient to offset a similar change in the discharge rate.

West Branch Susquehanna River at Lewisburg, Pa.

Double-mass comparison of total nitrogen and water discharge for the West Branch Susquehanna River at Lewisburg (Figure 26) shows no change in the discharge rate from 1985-1996. Total phosphorus and suspended-sediment discharge rates in Figures 27 and 28, respectively, show an increase beginning about 1992 or 1993. Annual baseline yields of total phosphorus during the periods 1985-92 and 1993-96, adjusted to the long-term mean discharge, indicate that a 138,000-pound increase occurred during 1993-96. Suspended sediment increased about 399,000 tons during the same period. Langland and others (1998) showed a downward trend for total nitrogen and total phosphorus concentrations. The downward trend for total phosphorus was not considered to be significant, so it was reported as no change. The differences in the trend predictions between the double-mass comparison and the statistical analysis methods are probably due to the use of loads in one and concentrations in the other. The changes in the concentrations may not have been sufficient to significantly offset changes in the discharge rate. Langland and others (1998) reported an increasing trend for suspended sediment; however, the test for significance indicated that the change was not significant so it was reported as no change. The double-mass comparison also shows an increasing trend in the discharge rate, but the change is small and may not be significant.

Juniata River at Newport, Pa.

Figure 29 shows that total nitrogen decreased by 2.9 million pounds in the Juniata River at Newport between 1985 and 1996. Total phosphorus shows a reduction in the discharge rate beginning in 1989 or 1990. Figure 30 shows that total phosphorus decreased by 213,000-pounds during 1990-96. Suspended-sediment discharge rate decreased in 1990-92, then began to increase during 1993-96. Baseline yields for the periods 1985-89, 1990-92, and 1993-96, adjusted to the long-term mean discharge, show that suspended sediment decreased by 148,000 tons during 1990-92, and by 57,700 tons during 1993-96. Although the average baseline yields show a reduction during the 1993-96 period when compared to the 1985-89 baseline, the suspended-sediment discharge could exceed that of the 1985-89 period if the discharge rate continues to increase, as indicated in Figure 31. The statistical analysis conducted by Langland and others (1998) also shows downward trends in concentrations for all three parameters.

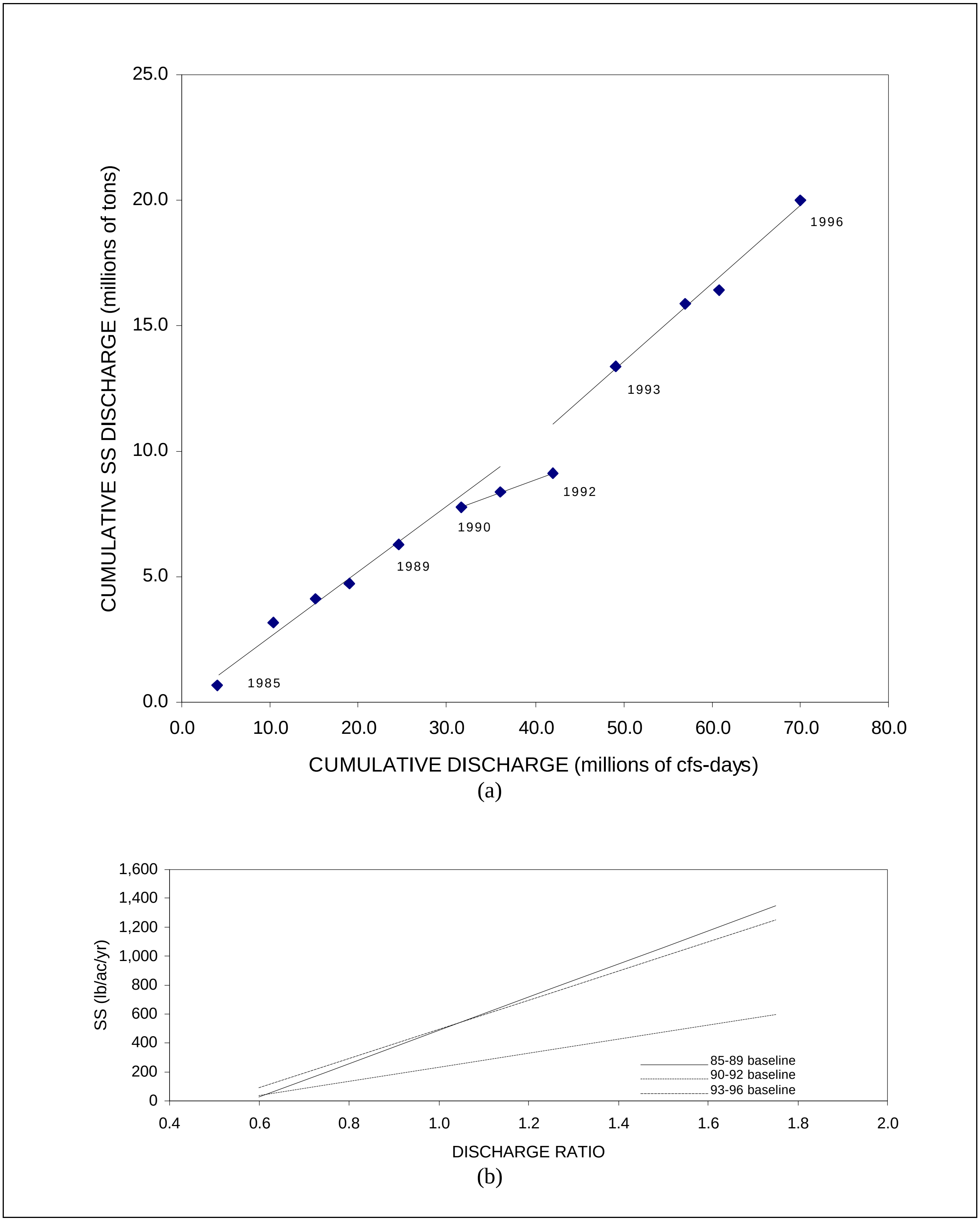


Figure 25. Double-mass Comparison of Suspended-Sediment Discharge and Water Discharge (a) and Annual Yield Baselines (b) for the Susquehanna River at Danville, Pa.

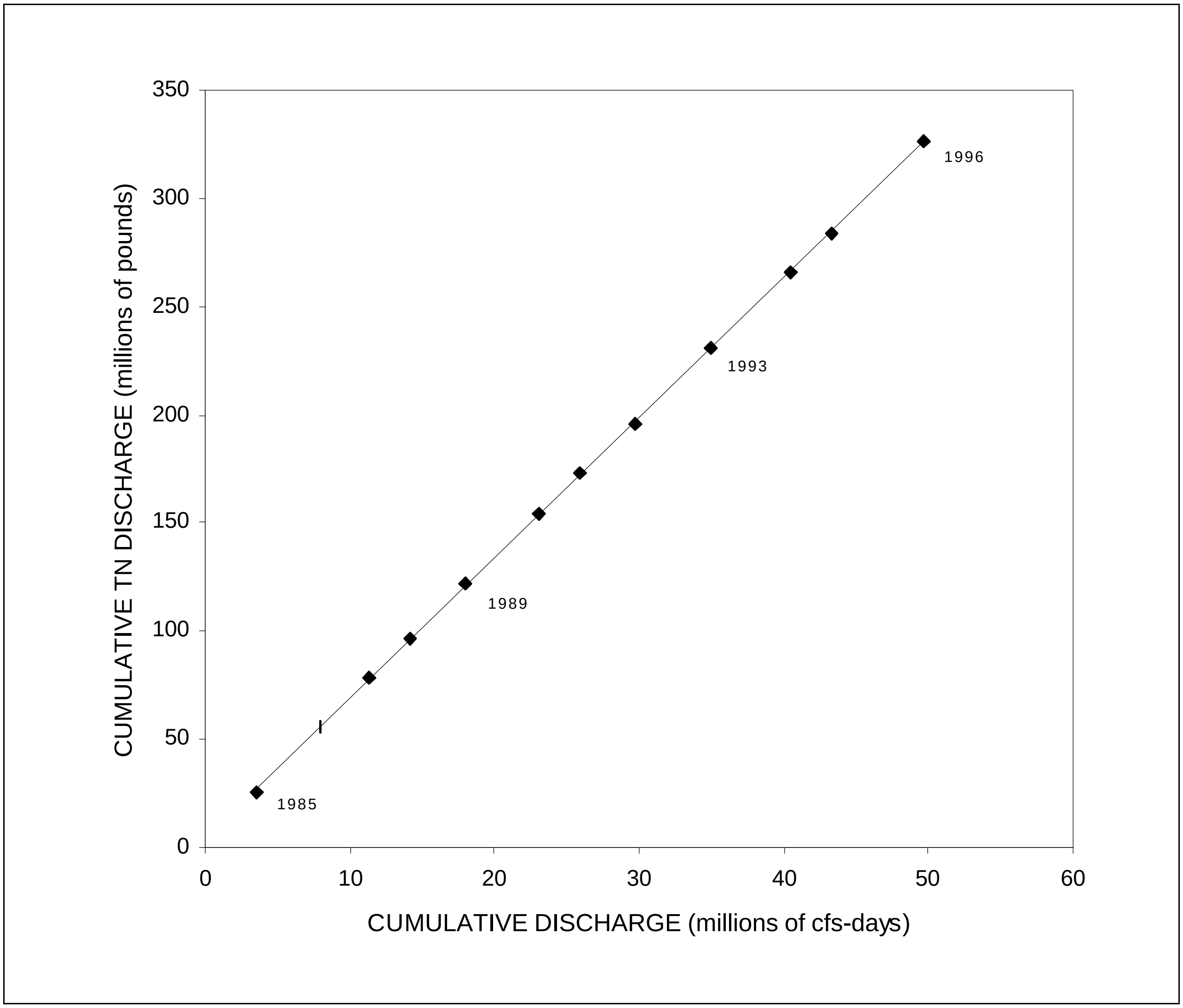


Figure 26. Double-mass Comparison of Total Nitrogen Discharge and Water Discharge for the West Branch Susquehanna River at Lewisburg, Pa.

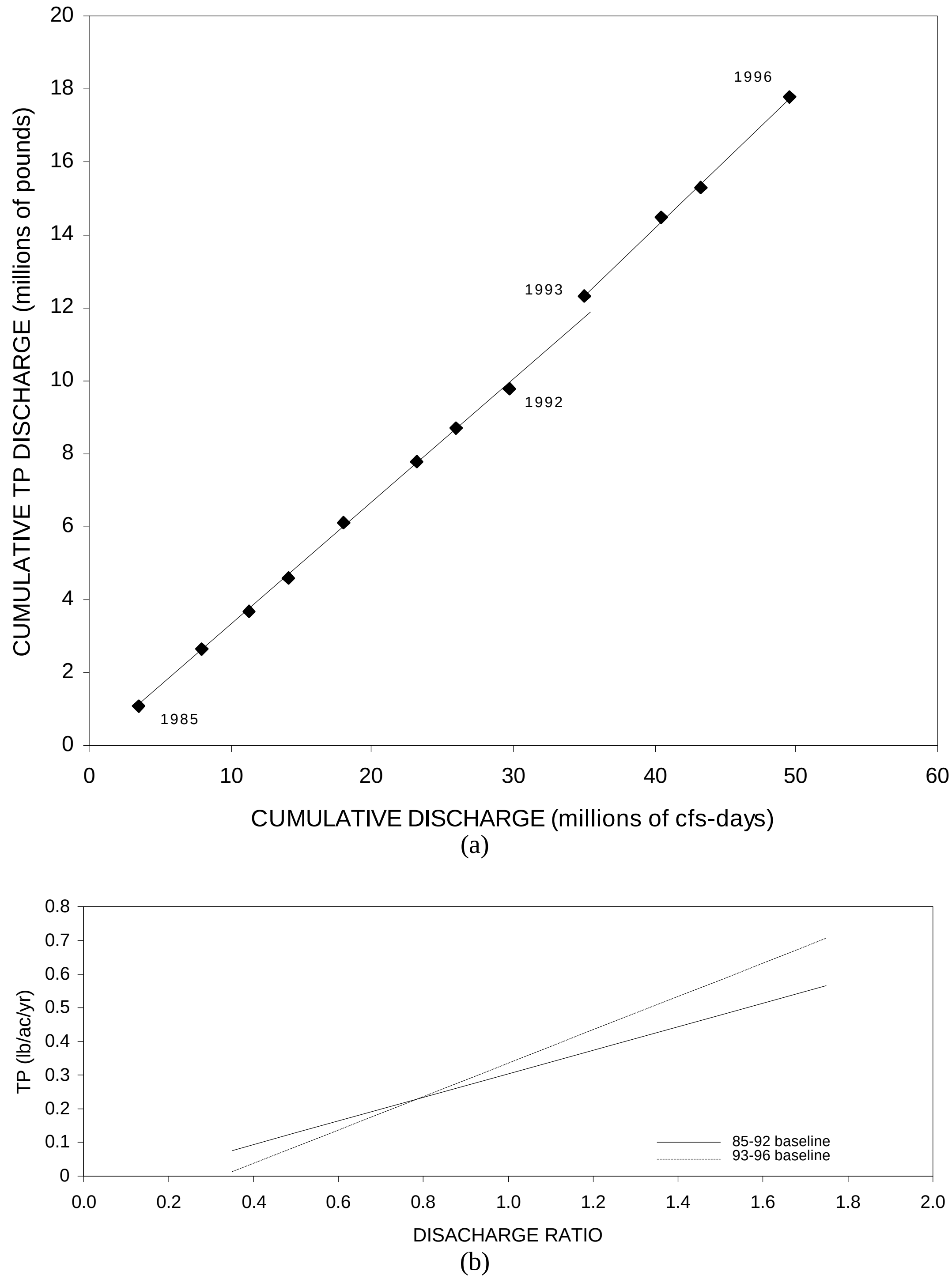
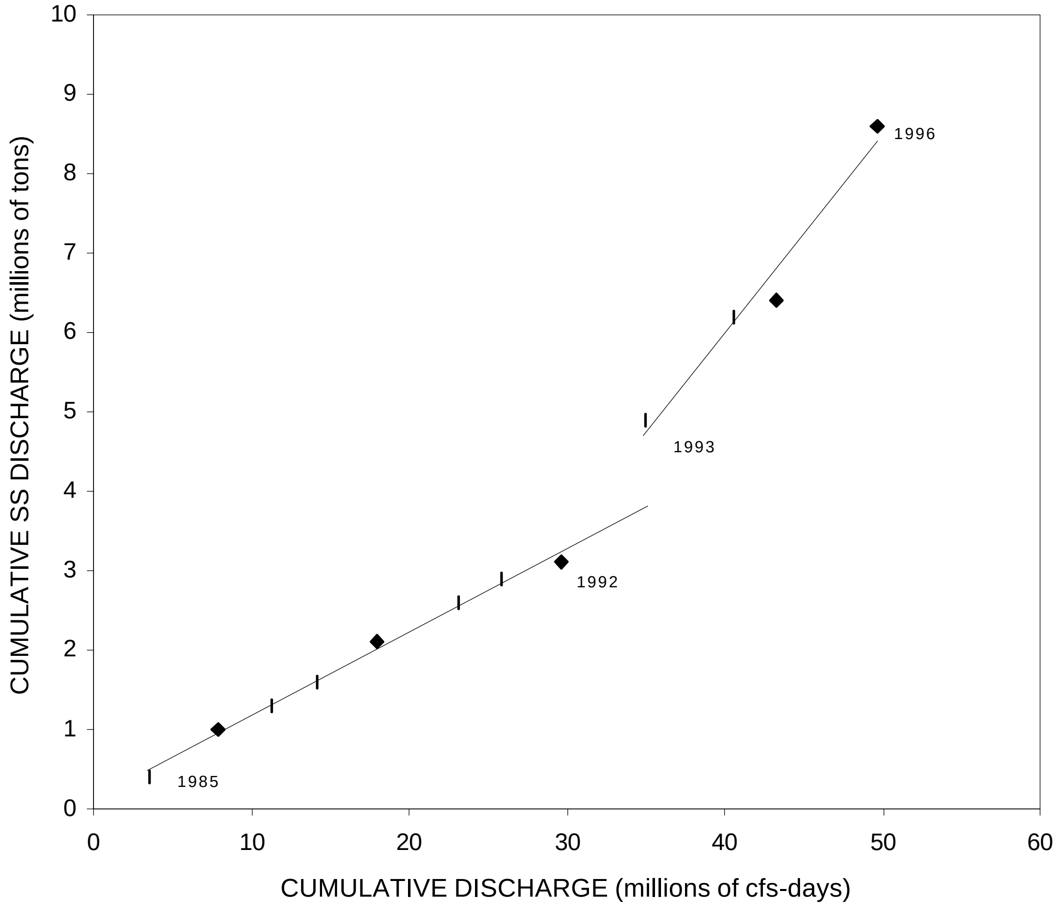
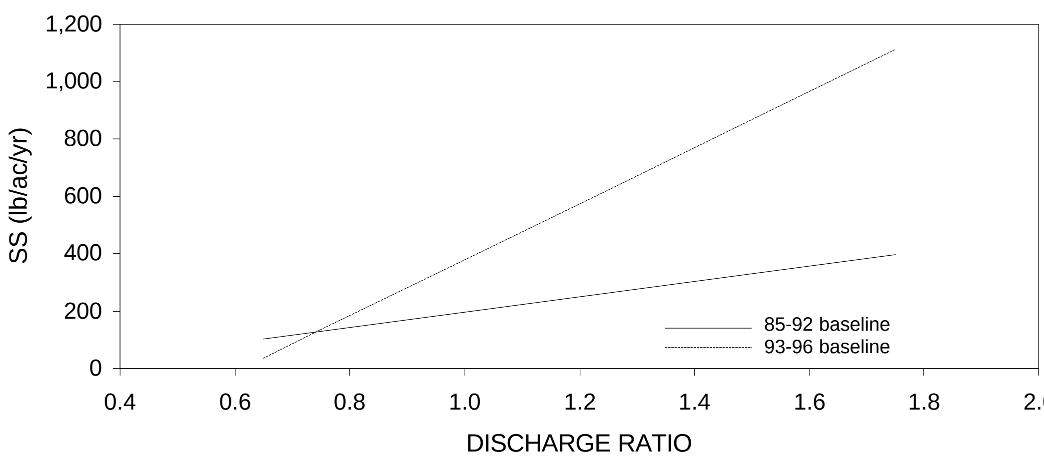


Figure 27. Double-mass Comparison of Total Phosphorus Discharge and Water Discharge (a) and Annual Yield Baselines (b) for the West Branch Susquehanna River at Lewisburg, Pa.

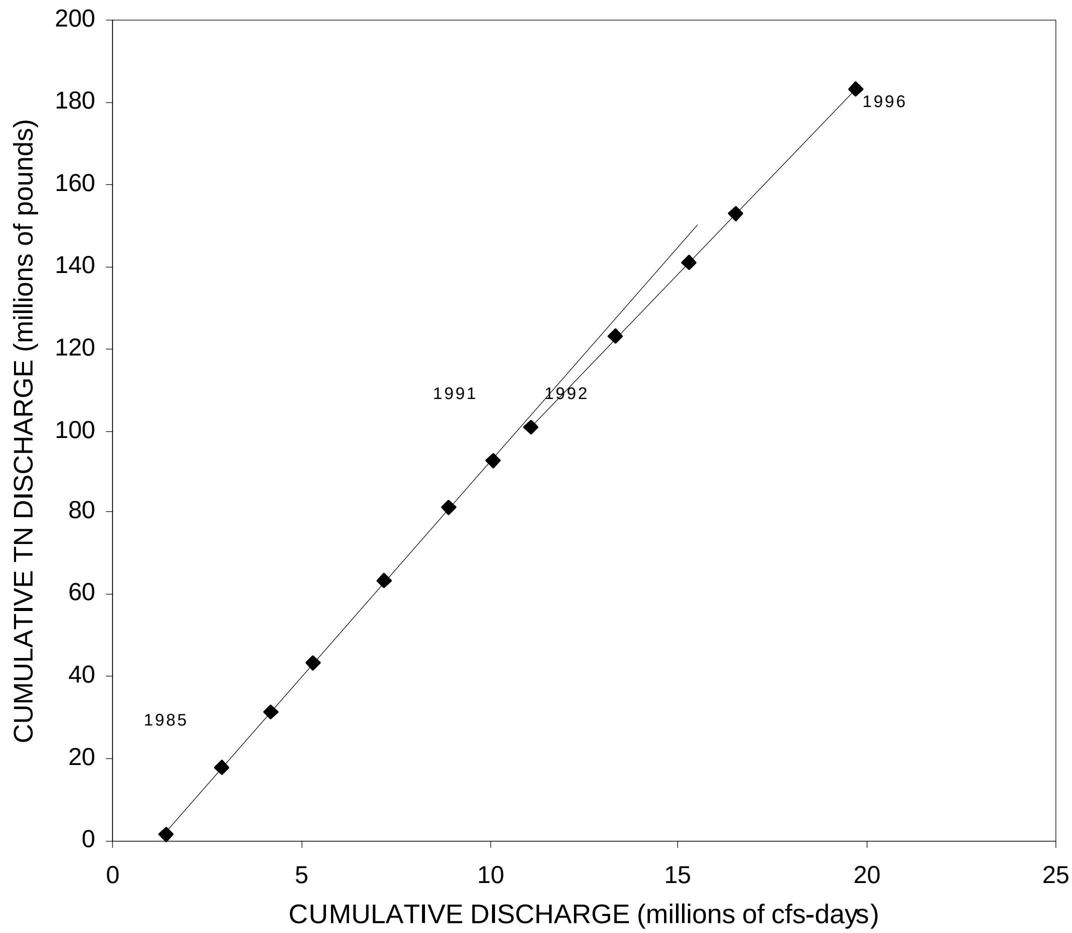


(a)

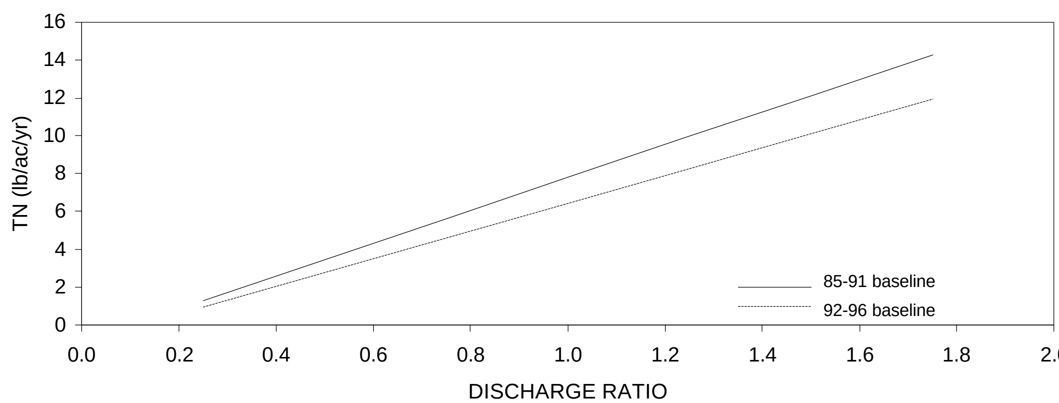


(b)

Figure 28. Double-mass Comparison of Suspended-Sediment Discharge and Water Discharge and Annual Yield Baselines for the West Branch Susquehanna River at Lewisburg, Pa.



(a)



(b)

Figure 29. Double-mass Comparison of Total Nitrogen Discharge and Water Discharge (a) and Annual Yield Baselines (b) for the Juniata River at Newport, Pa.

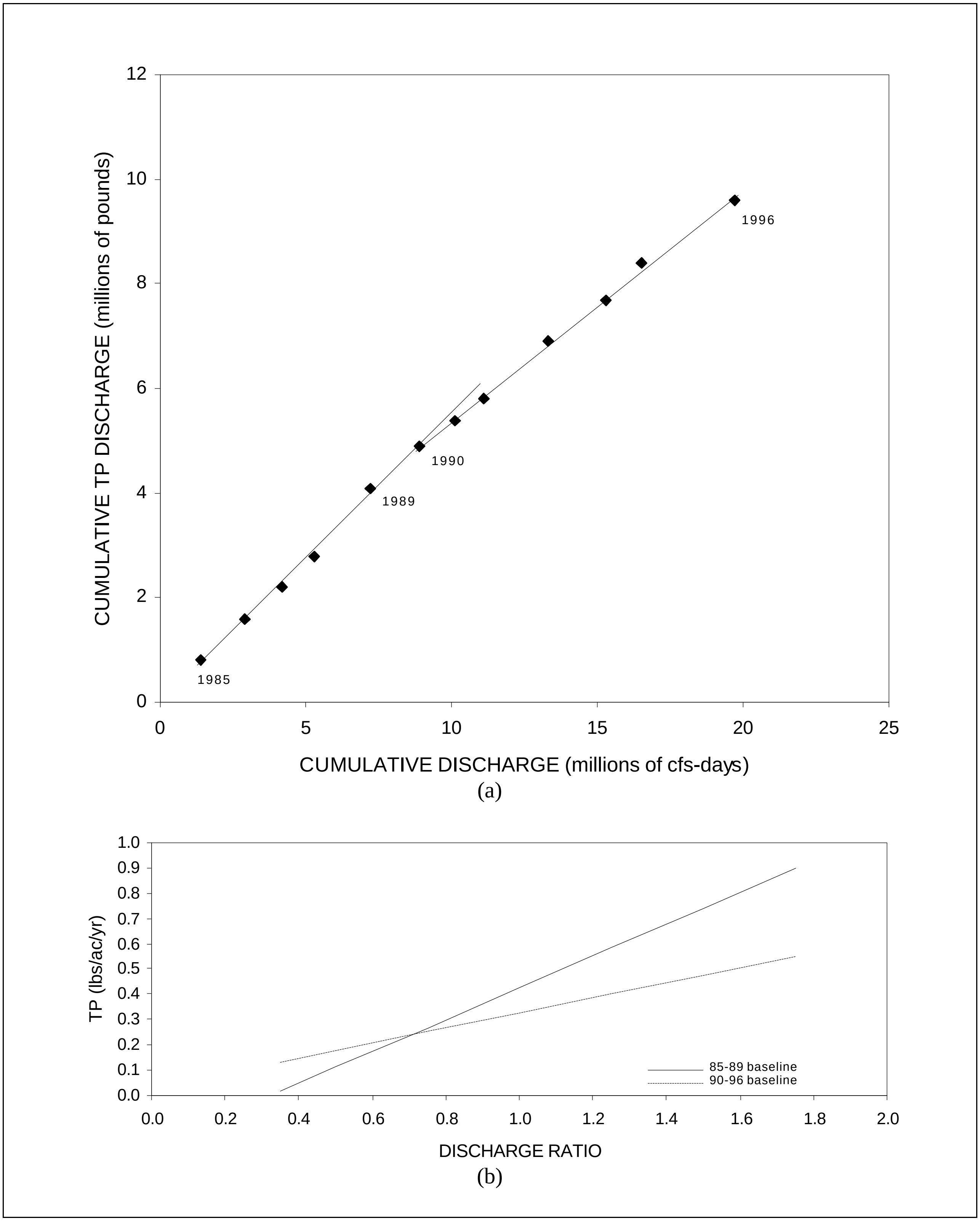


Figure 30. Double-mass Comparison of Total Phosphorus Discharge and Water Discharge (a) and Annual Yield Baselines (b) for the Juniata River at Newport, Pa.

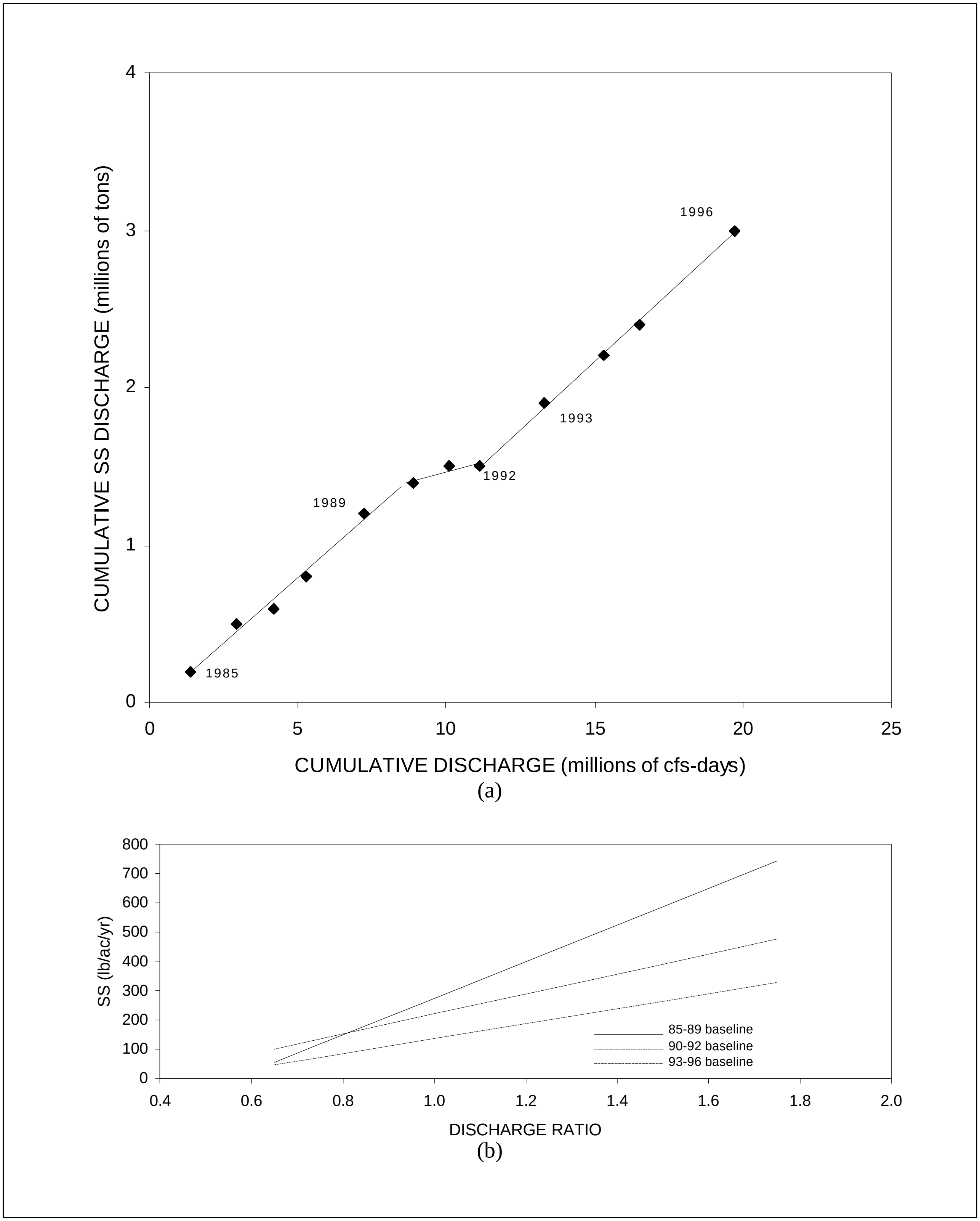


Figure 31. Double-mass Comparison of Suspended-Sediment Discharge and Water Discharge (a) and Annual Yield Baselines (b) for the Juniata River at Newport, Pa.

Susquehanna River at Marietta, Pa.

The total nitrogen discharge rate (Figure 32) decreased beginning in 1991 or 1992. Comparison of the average baseline yields for the periods 1987-91 and 1992-96 indicates that a 13.6-million-pound reduction occurred during the 1992-96 period. Double-mass comparisons of total phosphorus and suspended sediment in Figures 33 and 34 show that the discharge rate began increasing sometime between 1991 and 1992. Although increases in discharge rates are indicated, comparison of the adjusted baseline yields during the 1987-91 and 1992-96 periods indicates that total phosphorus decreased by 346,000 pounds, and suspended sediment decreased 88,600 tons. If the discharge rate continues as indicated, total phosphorus and suspended-sediment discharges will exceed that of the 1987-91 baseline period. Langland and others (1998) reported decreasing trends in the concentrations of total nitrogen, total phosphorus and suspended sediment.

Conestoga River at Conestoga, Pa.

Total nitrogen (Figure 35) shows a decreasing trend in the discharge rate beginning in 1989 or 1990. The average baseline yields of total nitrogen for the 1985-89 and 1990-96 period show that an 867,000-pound reduction occurred. The total phosphorus and suspended-sediment (Figures 36 and 37) discharge rates decreased sometime after 1989 until 1992, and increased after 1992. Although the discharge rates increased after 1992, the discharge rates are still below that of the 1985-89 period. Comparison of the adjusted baseline yields for total phosphorus for the 1985-89 period against the 1990-92 and 1993-96 periods shows a 262,000-pound decrease in the 1990-92 period, and a 227,000-pound decrease in the 1993-1996 period. Suspended sediment shows a 122,000-ton reduction during 1990-92, and a 92,500-ton reduction during 1993-96. Langland and others (1998) reported decreasing trends in the concentrations of total nitrogen, total phosphorus, and suspended sediment.

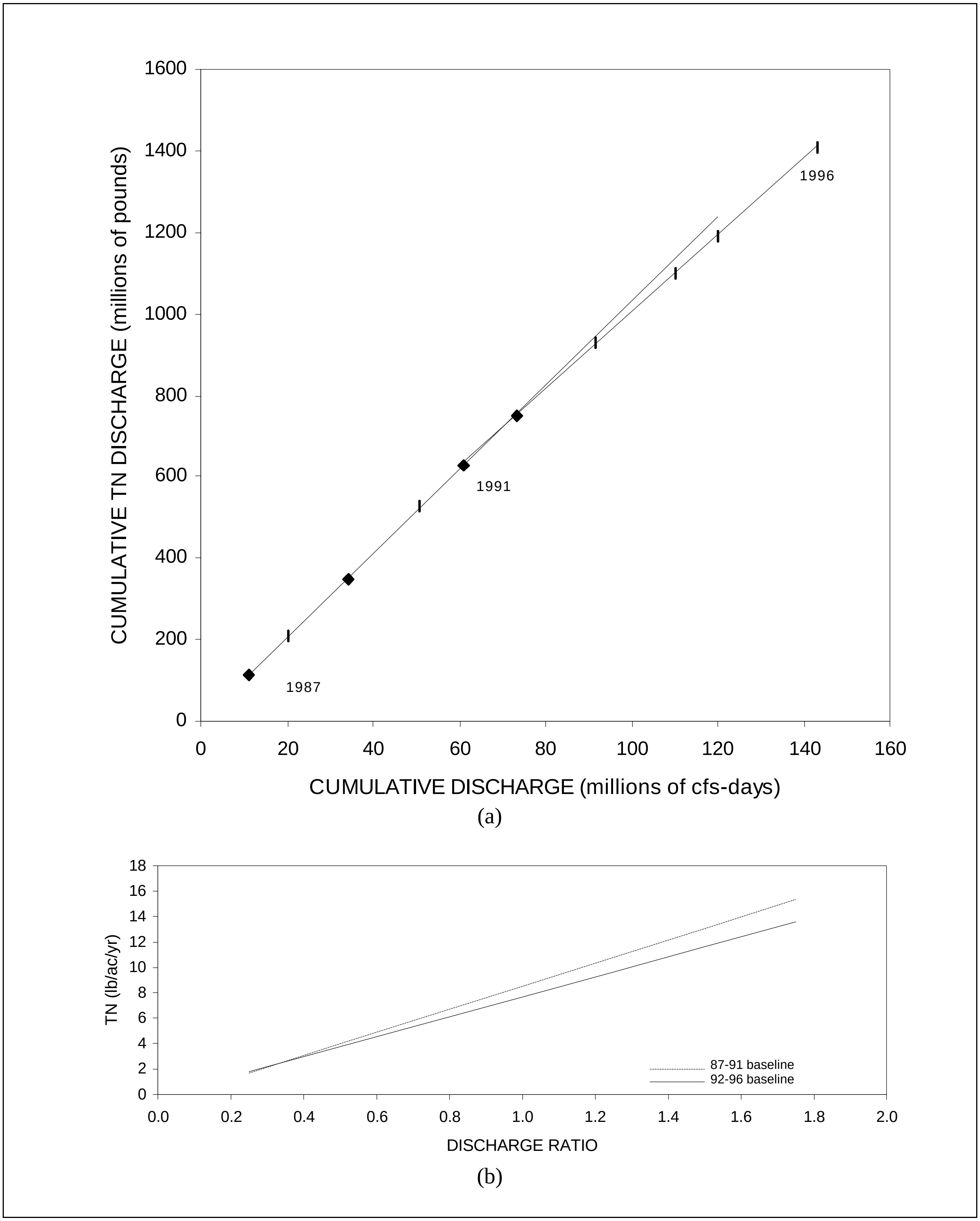
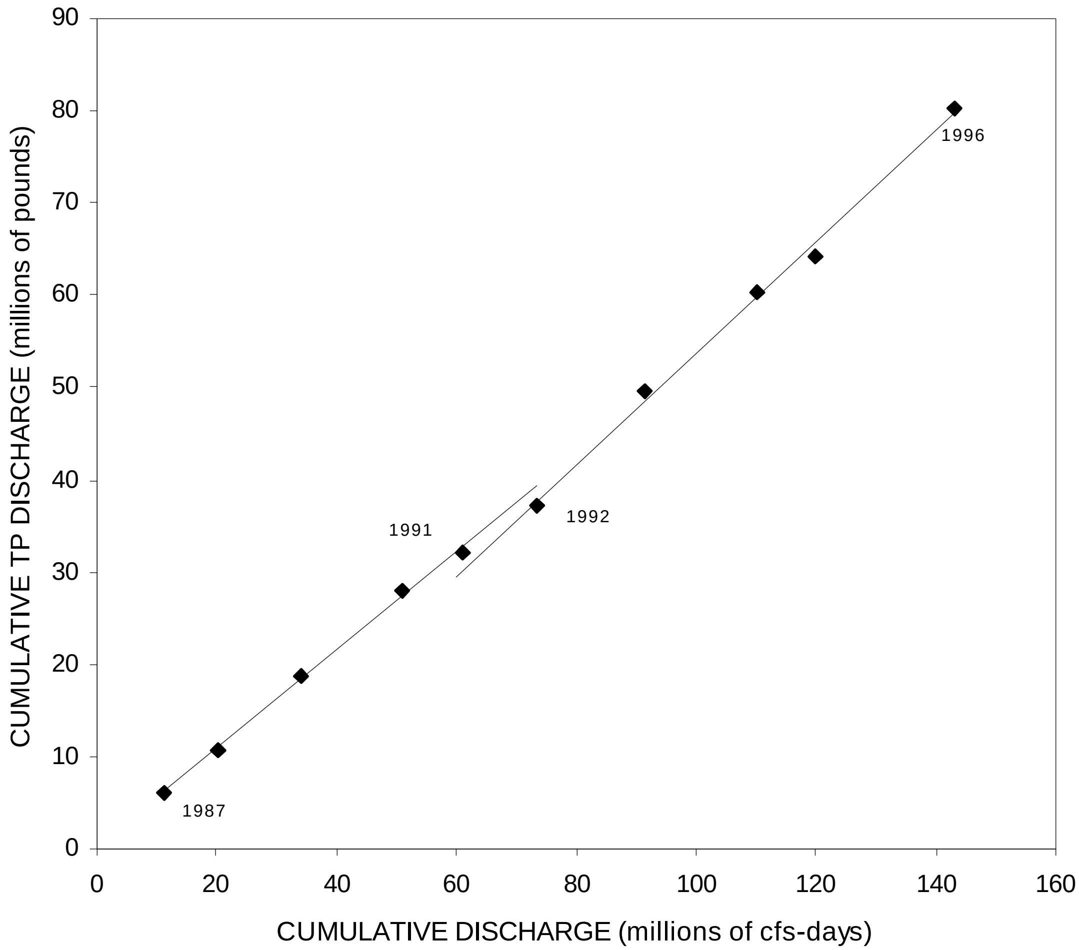
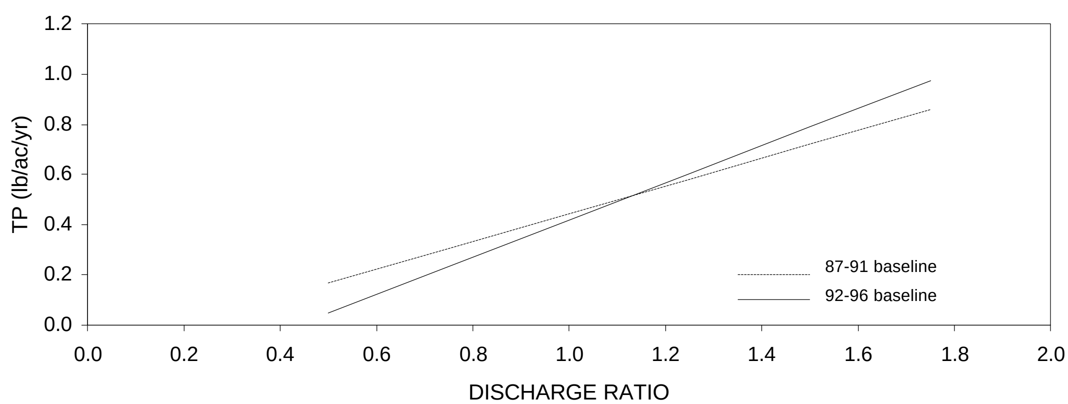


Figure 32. Double-mass Comparison of Total Nitrogen Discharge and Water Discharge (a) and Annual Yield Baselines (b) for the Susquehanna River at Marietta, Pa.



(a)



(b)

Figure 33. Double-mass Comparison of Total Phosphorus Discharge and Water Discharge (a) and Annual Yield Baselines (b) for the Susquehanna River at Marietta, Pa.

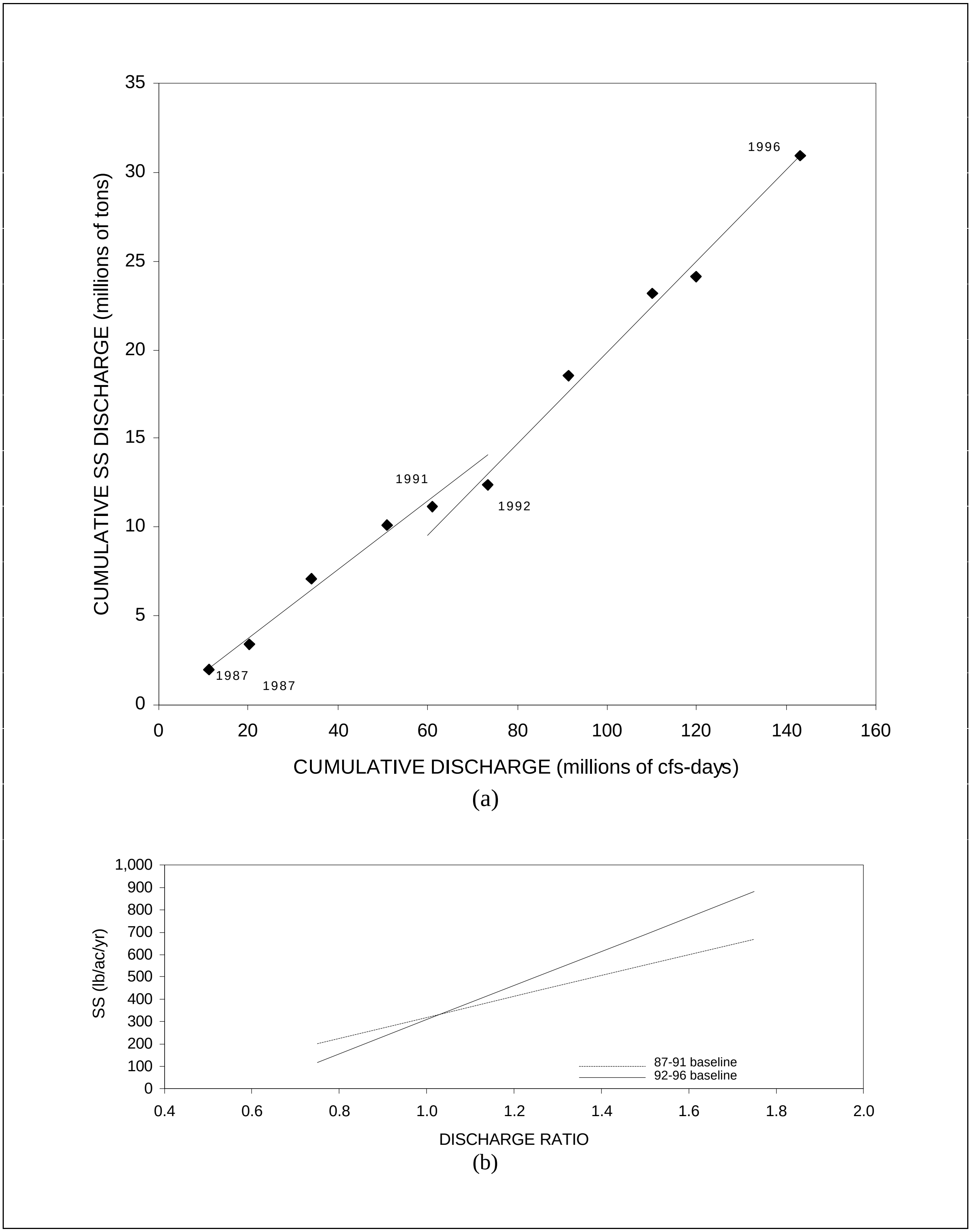
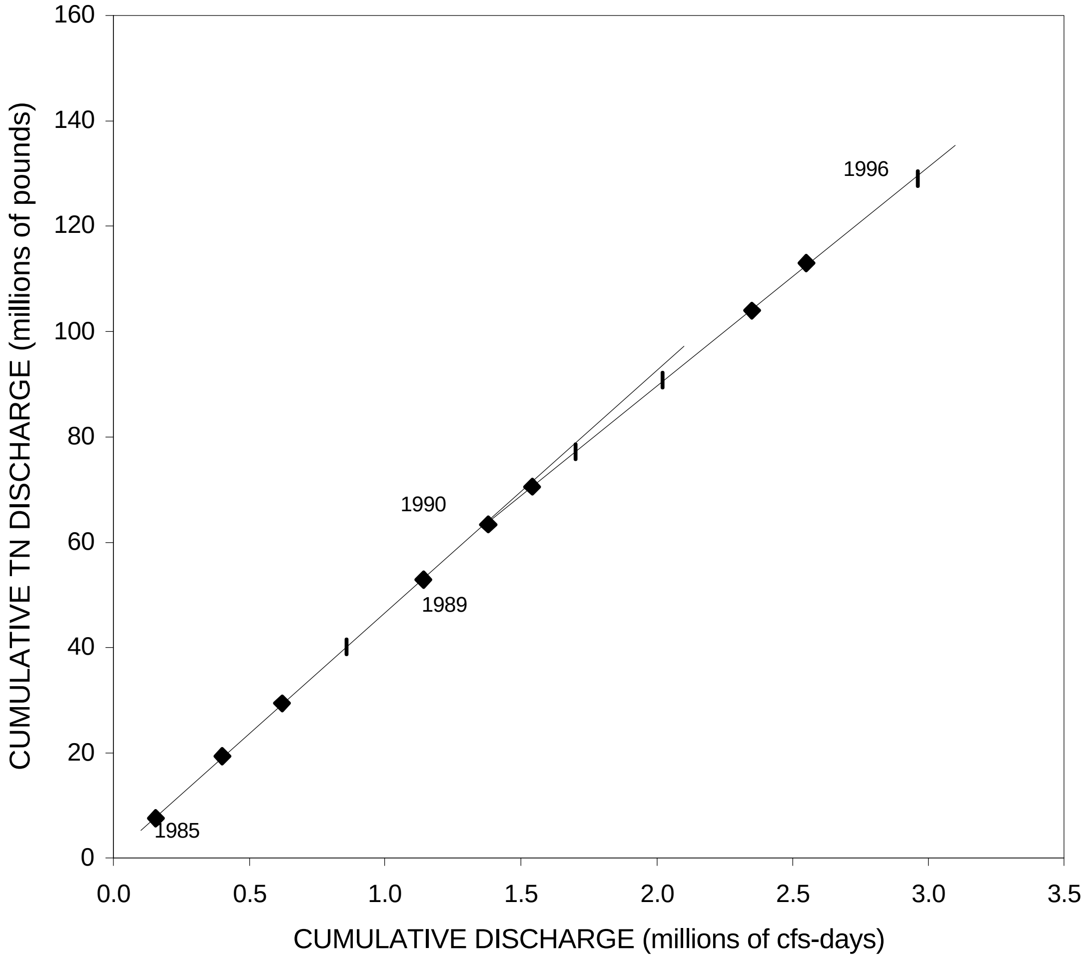


Figure 34. Double-mass Comparison of Suspended-Sediment Discharge and Water Discharge (a) and Annual Yield Baselines (b) for the Susquehanna River at Marietta, Pa.



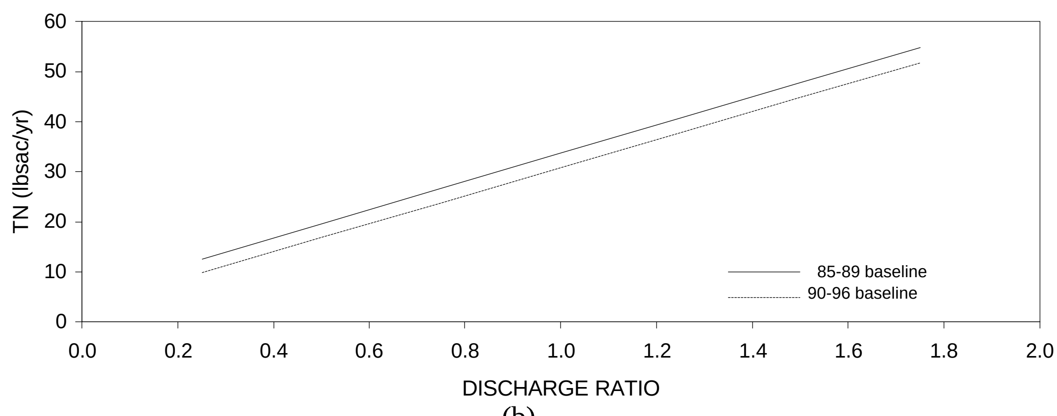


Figure 35. Double-mass Comparison of Total Nitrogen Discharge and Water Discharge l (a) and Annual Yield Baselines (b) for the Conestoga River at Conestoga, Pa.

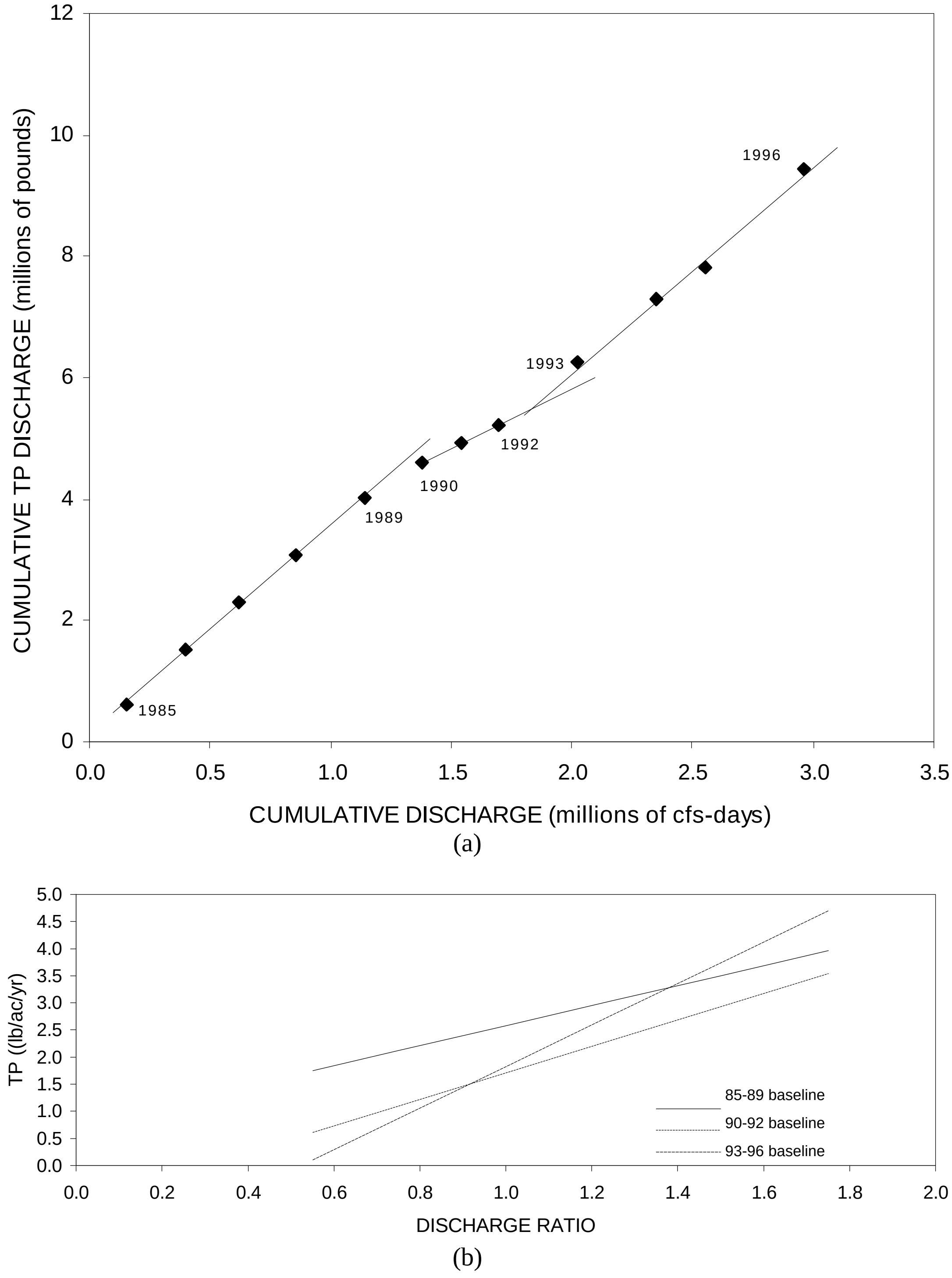


Figure 36. Double-mass Comparison of Total Phosphorus Discharge and Water Discharge (a) and Annual Yield Baselines (b) for the Conestoga River at Conestoga, Pa.

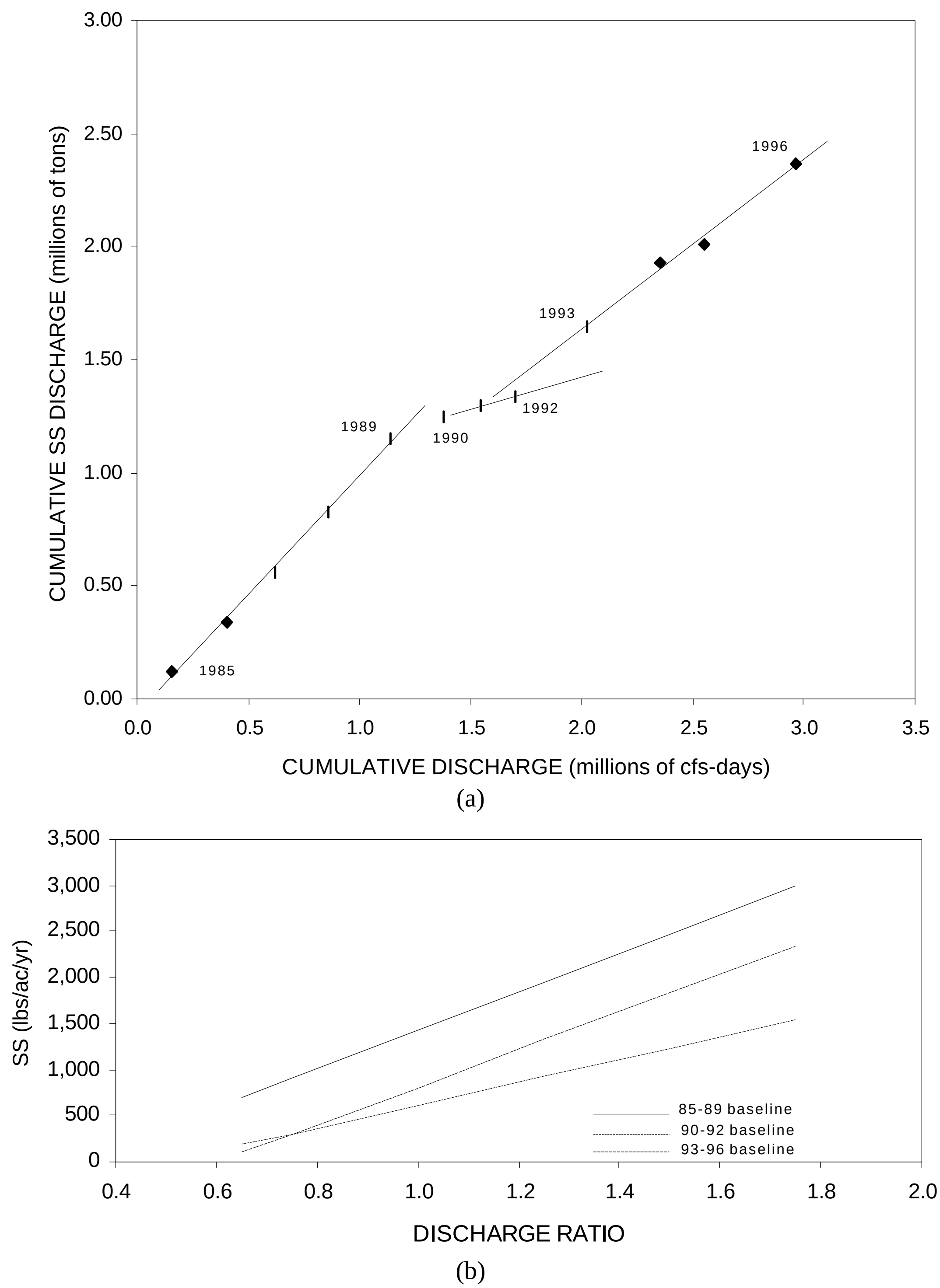


Figure 37. Double-mass Comparison of Suspended-Sediment Discharge and Water Discharge (a) and Annual Yield Baselines (b) for the Conestoga River at Conestoga, Pa.

SUMMARY

Nutrient and suspended-sediment samples were collected during baseflow and stormflow in calendar years 1994, 1995, and 1996. The samples were collected from the Susquehanna River at Towanda, Danville, and Marietta, the West Branch Susquehanna River at Lewisburg, and the Conestoga River at Conestoga, Pennsylvania.

Annual loads of nutrients and suspended sediment computed for calendar years 1994-96 fluctuated directly with annual water discharge at all sites. The loads and water discharge were highest in 1996, and lowest in 1995.

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 pounds per acre per year, at Danville, with 59.8 percent forest and 26.9 percent agriculture, were greater than from the West Branch Susquehanna River at Lewisburg, with 81 percent forest and 13.9 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 loads were measured in the Juniata River at Newport and at Conestoga. Total phosphorus yields at Danville were greater than the yields at Lewisburg. 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. The Susquehanna River at Danville yielded a higher suspended-sediment load, in pounds per acre per year, than the West Branch Susquehanna River.

Seasonal loads of total nitrogen, total phosphorus, and suspended sediment generally varied according to the variations in the seasonal water discharges. In calendar year 1994, the seasonal mean water discharge was highest in the spring at Towanda, Danville, and Lewisburg, followed by winter, then summer. Seasonal mean water discharge in the lower basin sites at Newport, Marietta, and Conestoga was highest in the winter, followed by spring. Nutrient and suspended-sediment loads varied according to variations in water discharge at nearly all sites. Seasonal mean water discharge in 1995 was highest in the winter at all sites, followed by fall, then spring. Seasonal loads of total nitrogen and total phosphorus generally corresponded with variations in seasonal flows. Seasonal variations of suspended sediment did not correspond well with seasonal discharges. In 1996, seasonal discharges at each site appeared to vary according to the amount of precipitation during each season and its effect on soil moisture following a dry year. Total nitrogen, total phosphorus, and suspended-sediment loads corresponded with variations in seasonal discharges at nearly all sites

Annual yields and water discharge ratios for 1994, 1995, and 1996 were plotted against baselines developed from the initial five years of data collection. Total nitrogen yields and water discharge ratios for 1994, 1995, and 1996 plotted significantly below the initial five-year baselines for Towanda, Danville, Newport, Marietta, and Conestoga, indicating some changes may be occurring. The data for Lewisburg suggest that a decrease may be occurring, but it may not be significant. Total phosphorus yields for Towanda, Lewisburg, and Conestoga plotted above the five-year baseline, suggesting that the load increased in calendar years 1994-96.. Total phosphorus yields for Danville and Newport plotted below the baseline, indicating that the loads decreased. The total phosphorus and suspended-sediment yields at Marietta plotted above the baseline in 1994 and 1996 and below the baseline in 1995, and did not show a definite pattern. Suspended-sediment yields at Towanda and Lewisburg plotted above the baseline, suggesting that the loads increased in calendar years 1994-96. The sediment yields at Danville, Newport, and Conestoga plotted below the baseline, indicating that a decrease in load may be occurring.

Double-mass comparisons of total nitrogen, total phosphorus, and suspended-sediment discharges with water discharges illustrate several trends occurring during the period 1985-96. The double-mass comparison is useful in that it shows the year-by-year change in the discharge rate. The overall trend for a given period, as determined by statistical or other methods, may indicate a downward trend, but the double-mass comparison graph may show that the rate of constituent discharge may be creeping upward, or vice versa, to a point where the trend could be reversed. Total nitrogen loads show a decrease in the discharge rates at all sites, except at Lewisburg, where no change in the discharge rate was noted. Total phosphorus loads show an increasing discharge rate at Towanda, Lewisburg, and Marietta. Newport shows a decrease in total phosphorus discharge rate. Total phosphorus discharge rates began decreasing in 1989 or 1990 at Danville and Conestoga, then began increasing in 1992 or 1993. Although the discharge rates began increasing, the average loads of total phosphorus at Danville and Conestoga for the 1993-96 period were less than the 1985-89 base period. The suspended-sediment discharge rate increased at Towanda and Lewisburg beginning in 1992 or 1993. Suspended-sediment discharge rates decreased beginning in 1989 and 1990, then increased sometime in 1992 or 1993 at Danville, Newport, and Conestoga. Marietta also shows an increase in the discharge rate. However, the average suspended-sediment loads for the period of increasing discharge rates were less than the 1985-89 base period at Newport, Conestoga, and Marietta. Danville had a slightly higher load than the base period, but the increase may not be significant. Comparisons with results from a statistical trend analysis completed by Langland and others (1998) show similar results in most cases. Where differences occur, it is believed to be due to differences in methodology, one uses constituent loads, while the other uses constituent concentrations.

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