NUTRIENTS AND SUSPENDED SEDIMENT TRANSPORTED IN THE SUSQUEHANNA RIVER BASIN, 2002, AND TRENDS, JANUARY 1985 THROUGH DECEMBER 2002

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Paul O. Swartz, Executive Director

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**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 (SS) samples were collected under baseflow and stormflow conditions during calendar year 2002. 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, Pennsylvania, and analyzed for nitrogen and phosphorus species and SS.

Precipitation for 2002 was above average for all sites except Lewisburg. Highest departures from the long-term averages were recorded at Towanda and Danville leading to above average flow at these sites. Although precipitation was at or above the long-term means at all sites, water discharge levels for the year were below the long-term means at Lewisburg, Newport, Marietta, and Conestoga. Coupled with the previous drought years, this led to the detection of decreasing trends in flow for both Lewisburg and Conestoga. This was the first time that decreasing trends for flow were detected at any site.

This report has utilized four methods for determining whether nutrient and SS loads and yields were improving; comparison with similar water year 1992, comparison with baseline yields, comparison with the long-term means, and trend analysis through 2002. All four of these approaches agree that total nitrogen (TN) for all sites in 2002 was improving.

When comparing the 2002 loads of total phosphorus (TP) with the similar water year 1992, it was found that TP loads were higher at Towanda, Danville, Marietta, and Conestoga during 2002. Comparison of 2002 yields with the baseline yields also indicated degrading TP conditions for Newport, Marietta, and Conestoga for 2002. TP loads for 2002 at Marietta were higher than the long-term mean, while no significant trend in TP was recorded. These three comparisons were a strong indication that although fluctuations in annual loads have not yielded significant trends, TP loads have not been improving at Marietta. Although this distinction was not as apparent with the other sites, an important trend was apparent with regards to dissolved orthophosphate (DOP). All sites except for Conestoga and Lewisburg have reported degrading trends in DOP for all three trend analyses, while having mixed trends results for dissolved phosphorous (DP) and TP. This suggests that the dissolved fraction of phosphorus is being dominated by DOP.

SS for 2002 showed increasing loads when compared with the 1992 annual loads for Towanda, Lewisburg, Marietta, and Conestoga. SS yields for 2002 showed increases in Newport only when compared to the baselines. SS trend results for 2002 showed decreasing trends at Danville, Lewisburg, and Conestoga. Loads for SS were lower than the long-term means at all sites for 2002. Due to the relationship between flow and constituent loads (Ott and others 1991, Takita and Edwards 1993, Takita 1998), the multiple-year drought that has affected the basin may prove to be the cause of the apparent decreasing trends and improving conditions. Whether or not the drought was the cause for the declining trends will be determined as the basin returns to normal conditions.

INTRODUCTION

Nutrients and SS entering the Chesapeake Bay (Bay) from the Susquehanna River Basin contribute to nutrient enrichment problems in the Bay (USEPA, 1982). The Pennsylvania Department of Environmental Protection’s (Pa. DEP) 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 SS transported to the Bay via the Susquehanna River Basin.

Background

Pennsylvania entered into the Chesapeake Bay Agreement in 1983 with Maryland, Virginia, the District of Columbia, the USEPA, and the Chesapeake Bay Commission to assist in the effort to restore the Bay. This agreement was reaffirmed in 1987 and 1992, and significant efforts were undertaken to reduce nitrogen and phosphorus loads to the Bay.

Portions of the Bay and its tidal tributaries were included in Maryland's 1996 and 1998 lists of impaired waters and in Virginia's 1998 list of impaired waters, as required by the federal Clean Water Act. This action typically results in the development of a regulatory "total maximum daily load" or TMDL for the affected watershed. For the Bay, this means that the TMDL would have to address the upstream causes of impairment in all the states with land areas draining into it.

The Chesapeake 2000 Agreement and a subsequent six-state Memorandum of Understanding committed all six Bay watershed states, the District of Columbia, and USEPA to work together to restore Bay water quality using a jointly defined set of water quality conditions needed to protect aquatic living resources. The new agreement seeks to avoid regulatory approaches by achieving water quality improvements prior to the timeframe when a baywide TMDL would need to be established. The agreement calls for its signatories to, "by 2010, correct the nutrient and sediment-related impairments in the Bay and its tidal tributaries sufficiently to remove the Bay and the tidal portions of its tributaries from the list of impaired waters under the Clean Water Act."

Given that the lower Susquehanna River Basin is a significant source of SS to the Bay, SRBC, in cooperation with the Pa. DEP, USEPA, and the U.S. Geological Survey (USGS), conducted a 5-year intensive study at 14 sites from 1985-89. In 1990, the number of sampling sites was reduced to five long-term monitoring stations. An additional site was included in 1994, and sampling at these six sites has continued to the present day. Calculated annual loads and yields of nutrient and SS showed year-to-year variability that was highly correlated with the variability of the annual water discharge (Ott and others, 1991; Takita, 1996, 1998). These studies also reinforced the indications from earlier studies that the highest nutrient yields come from the lower basin.

The existing Susquehanna River sediment and nutrient sites are important in documenting Pennsylvania's real progress in the Bay cleanup effort. These sites have been used to keep track of trends in water quality improvement. With 50 percent of the Bay's total freshwater inflow coming from the Susquehanna River, these sites are critical calibration sites for the Chesapeake Bay Model, which is being used as a major tool in planning the restoration effort.

Objective of the Study

The objective of SRBC’s monitoring program is to collect monthly baseflow and daily, or more frequent, samples during selected storms from the six long-term monitoring sites in the Susquehanna River Basin. The data are then used to compute annual nutrient and SS loads and trends 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 SS measured during calendar year 2002, and to compare the TN, TP, and SS loads with the baseline established from the 1985-89 study. Seasonal and annual variation in loads is discussed, as well as the results of statistical trend analysis for the period January 1985 through December 2002 for nitrogen, phosphorus, SS, total organic carbon (TOC), and water discharge.

DESCRIPTION OF THE SUSQUEHANNA RIVER BASIN

The Susquehanna River (Figure 1) drains an area of 27,510 square miles (Susquehanna River Basin Study Coordination Committee, 1970), and is the largest tributary to the Bay. The Susquehanna River originates in the Appalachian Plateau of southcentral New York and central Pennsylvania, flows into the Valley and Ridge and Piedmont Provinces of Pennsylvania and Maryland, and joins the Bay at Havre de Grace, Md. The climate in the Susquehanna River Basin varies considerably from the low lands adjacent to the Bay in Maryland to the high elevations, above 2,000 feet, of the northern headwaters in central New York State. The annual mean temperature ranges from 53^{o} F (degrees Fahrenheit) near the Pennsylvania-Maryland border to 45^{o} F in the northern part of the basin. 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, shown in Table 1, is predominantly rural with woodland accounting for 67 percent; agriculture, 29 percent; and urban, 2 percent. Woodland occupies the higher elevations of the northern and western parts of the basin and much of the mountain and ridge land in the Juniata and Lower Susquehanna Subbasins. Woods and grasslands occupy areas in the lower part of the basin that are unsuitable for cultivation because the slopes are too steep, the soils are too stony, or the soils are poorly drained. The lower Susquehanna represents the highest density of agriculture throughout the 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 Susquehanna Subbasin include York, Lancaster, Harrisburg, and Sunbury, Pa. Most of the urban areas in the northern part of the basin are located along river valleys, and they include Binghamton and Elmira-Corning, N.Y., and Scranton and Wilkes-Barre, Pa. The major urban areas in the West Branch Susquehanna River Basin are Williamsport and Lock Haven.

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

Site	Urban	Agricultural	Forested	Other
Towanda	4	35	60	1
Danville	5	33	60	2
Lewisburg	2	15	81	2
Newport	2	28	69	1
Marietta	4	30	64	2
Conestoga	14	60	23	3
Susquehanna River Basin	2	29	67	2

Figure 1. The Susquehanna River Basin, Subbasins, and Population Centers

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 SS transport in the basin, are listed in Table 2, 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 Watershed in northern Pennsylvania and an area along the northern tier counties of eastern Pennsylvania. The drainage area at Towanda is 7,797 square miles of which, 6,262 square miles lie in New York.

The Susquehanna River at Danville, Pa., has a drainage area of 11,220 square miles, and includes part of northcentral Pennsylvania (the Tioga River Watershed) and much of southcentral New York. Data collected at Danville represent the loadings from tributaries between Towanda and Danville.

Data collected from the West Branch Susquehanna River at Lewisburg, Pa., represent the loadings from this major tributary to the mainstem. The West Branch includes much of northcentral Pennsylvania and has a drainage area of 6,847 square miles. The combined drainage areas above Lewisburg and Danville represent 65.7 percent of the total Susquehanna River Basin.

The Juniata River, a major tributary to the mainstem, includes much of southcentral Pennsylvania, and has a drainage area, above Newport, Pa., of 3,354 square miles. This station represents the loadings from the Juniata River. 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 2. 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

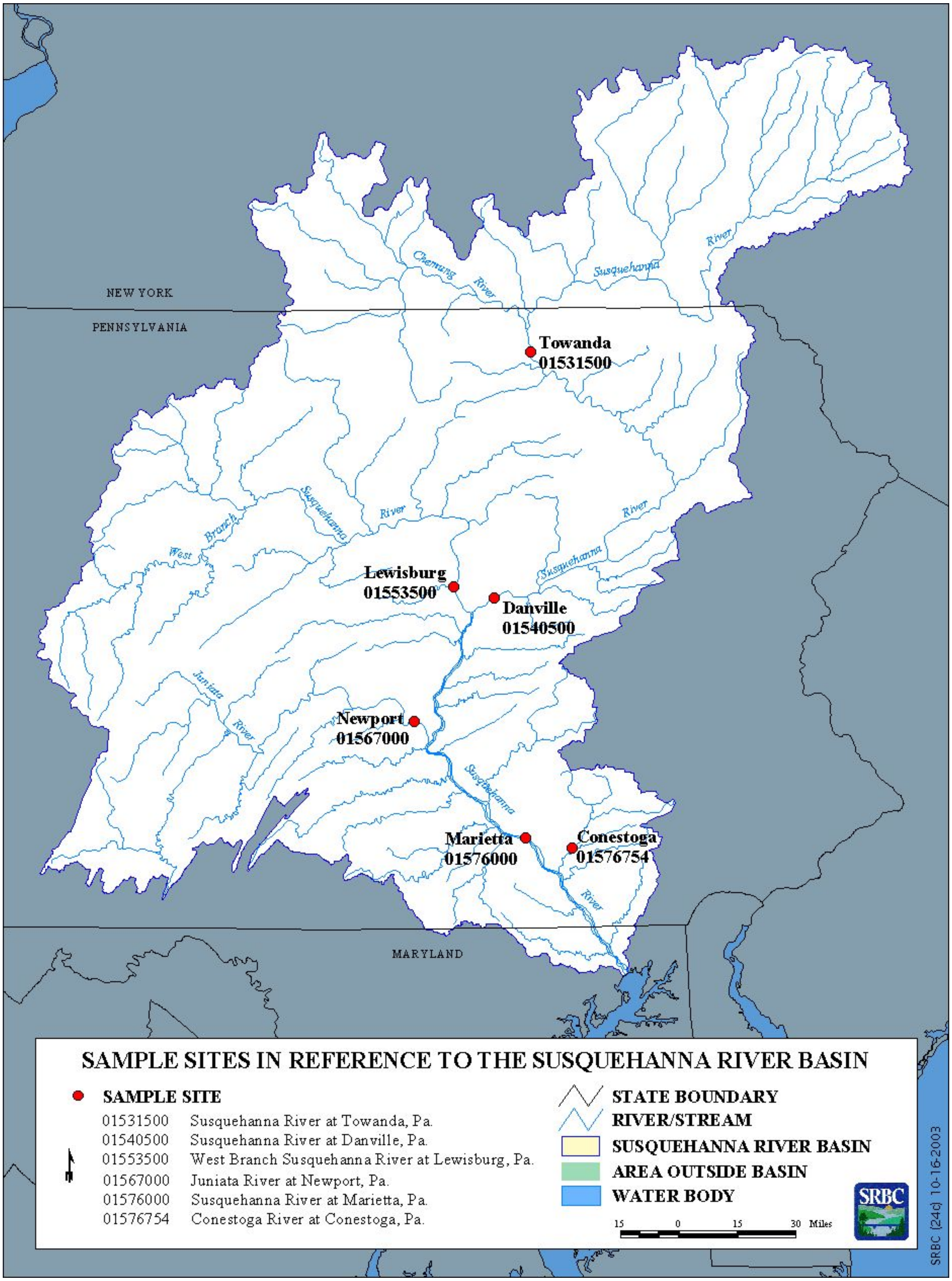


Figure 2. Locations of Sampling Sites on the Susquehanna River and Three Tributaries in the Basin

SAMPLE COLLECTION AND ANALYSIS

Samples were collected to measure nutrient and SS concentrations during various flows. Generally two samples were collected per month; one near the twelfth of the month for trend analysis and one during monthly baseflow conditions. Additionally, a minimum of five high flow events were sampled, targeting one per season. When possible a second high flow event was sampled in accordance with spring planting in the basin. During high flow sampling events, samples were collected daily during the rise and fall of the hydrograph. The goal was to gather a minimum of three samples on the rise and three samples on the fall with one sample as close to peak flow as possible. Sampling continued until flows returned to prestorm levels. All low flow and random samples were collected by hand with USGS depth integrating samplers. Multiple vertical samples were taken at each site and then composited so that a representative sample was attained. Winch operated depth-integrated samplers were used during high flow events to insure that the full water column was sampled.

Whole water samples were collected to be analyzed for TN species, TP species, TOC, and SS. Additionally, filtered samples were collected to analyze for dissolved nitrogen (DN) and dissolved phosphorus (DP) species. All samples were delivered to the Pa. DEP Laboratory in Harrisburg to be analyzed the following workday. The parameters and laboratory methods used are listed in Table 3. SS samples were analyzed at SRBC.

PRECIPITATION

Precipitation data were obtained from long-term monitoring stations operated by the U.S. Department of Commerce. The data are published as Climatological Data—Pennsylvania, and as Climatological Data—New York by the National Oceanic and Atmospheric Administration (NOAA) at the National Climatic Data Center in Asheville, North Carolina. Quarterly and annual data from these sources were compiled across the subbasins of the Susquehanna River Basin and are reported in Table 4. Due to high rainfalls in the spring and fall, precipitation totals exceeded the long-term mean at all sites except Lewisburg for 2002.

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

Parameter	Laboratory	Methodology	Detection Limit (mg/l)	References
Ammonia (total)	Pa. DEP	Colorimetry	0.020	USEPA 350.1
Ammonia (dissolved)	Pa. DEP	Block Digest, Colorimetry	0.020	USEPA 350.1
Nitrogen (total)	Pa. DEP	Persulfate Digestion for TN	0.040	Standard Methods #4500-N_{org}-D
Nitrogen (dissolved)	Pa. DEP	Persulfate Digestion	0.040	Standard Methods #4500-N_{org}-D
Nitrite plus Nitrate (total)	Pa. DEP	Cd-reduction, Colorimetry	0.010	USEPA 353.2
Nitrite plus Nitrate (diss)	Pa. DEP	Cd-reduction, Colorimetry	0.010	USEPA 353.2
Orthophosphate (dissolved)	Pa. DEP	Colorimetry	0.002	USEPA 365.1
Phosphorus (dissolved)	Pa. DEP	Block Digest, Colorimetry	0.010	USEPA 365.1
Phosphorus (total)	Pa. DEP	Persulfate Digest, Colorimetry	0.010	USEPA 365.1
Organic Carbon (total)	Pa. DEP	Combustion/Oxidation	0.50	SM 5310D

Table 4. Summary for Annual Precipitation for Selected Areas in the Susquehanna River Basin, Calendar Year 2002

River Location	Season	Average Long-term Precipitation inches	Calendar Year 2002 Precipitation inches	Departure From Long Term inches
Susquehanna River. above Towanda, Pa	January-March	7.95	7.66	-0.29
	April-June	10.04	14.82	+4.78
	July-September	10.20	8.32	-1.88
	October-December	8.72	10.55	+1.83
	Yearly Total	**36.91**	**41.35**	**+4.25**
Susquehanna River above Danville, Pa.	January-March	7.89	7.28	-0.61
	April-June	10.12	14.32	+4.2
	July-September	10.34	8.69	-1.65
	October-December	8.75	10.85	+2.1
	Yearly Total	**37.10**	**41.13**	**+4.03**
West Branch Susquehanna River above Lewisburg, Pa.	January-March	8.87	7.06	-1.81
	April-June	11.43	14.68	+3.25
	July-September	11.48	7.98	-3.5
	October-December	9.40	10.89	+1.49
	Yearly Total	**41.18**	**40.60**	**-0.58**
Juniata River above Newport, Pa.	January-March	8.80	5.60	-3.2
	April-June	10.98	13.13	+2.15
	July-September	10.81	9.5	-1.31
	October-December	9.11	11.62	+2.51
	Yearly Total	**39.70**	**39.84**	**+0.14**
Susquehanna River above Marietta, Pa.	January-March	8.49	6.84	-1.65
	April-June	10.70	13.83	+3.13
	July-September	10.73	8.84	-1.89
	October-December	9.04	11.88	+2.84
	Yearly Total	**38.96**	**41.38**	**+2.42**
Conestoga River above Conestoga, Pa.	January-March	8.55	6.36	-2.19
	April-June	10.81	11.38	+0.57
	July-September	11.73	7.75	-3.98
	October-December	9.45	17.69	+8.24
	Yearly Total	**40.54**	**43.18**	**+2.64**

WATER DISCHARGE

Water discharge data were obtained from the USGS and are listed in Table 5. Although precipitation was above average for 2002, the discharges were mostly below average. Towanda and Danville showed slightly above average flows for the year. Figure 3 compares the 2002 discharges with the long-term mean discharges for each site.

ANNUAL NUTRIENT AND SUSPENDED-SEDIMENT LOADS AND YIELDS

Loads and yields represent two methods for describing nutrient and SS amounts within a basin. Loads refer to the actual amount of the constituent being transported in the water column past a given point over a specific duration of time and are expressed in pounds. Yields compare the transported load with the acreage of the watershed and are expressed in lbs/acre. This allows for easy watershed comparisons. This project reports loads and yields for the constituents listed in Table 6 as computed by the Minimum Variance Unbiased Estimator (MVUE) described by Cohn and others (1989). This estimator relates the constituent concentration to water discharge, seasonal effects, and long-term trends, and computes the best-fit regression equation. Daily loads of the constituents were then calculated from the daily mean water discharge records. The loads were reported along with the estimates of accuracy. Tables 7-19 show the loads and yields for the six monitoring stations, as well as an associated error value. For TN, TP, and SS, comparisons have been made to the long-term means. As a general note, nutrient and SS loads increase with increasing discharge.

Table 5. Annual Water Discharge, Calendar Year 2002

Site	Years of Record	Long-term Annual Mean cfs[1]	2002 Mean cfs	2002 Percent of LTM[2]
Towanda	89	10,638	10,936	102.8
Danville	98	15,271	15,756	103.2
Lewisburg	63	10,843	9,615	88.7
Newport	103	4,448	3,059	68.8
Marietta	71	36,983	33,407	90.3
Conestoga	18	670	382	57.0

[1] Cubic feet per second
[2] Long-Term Mean

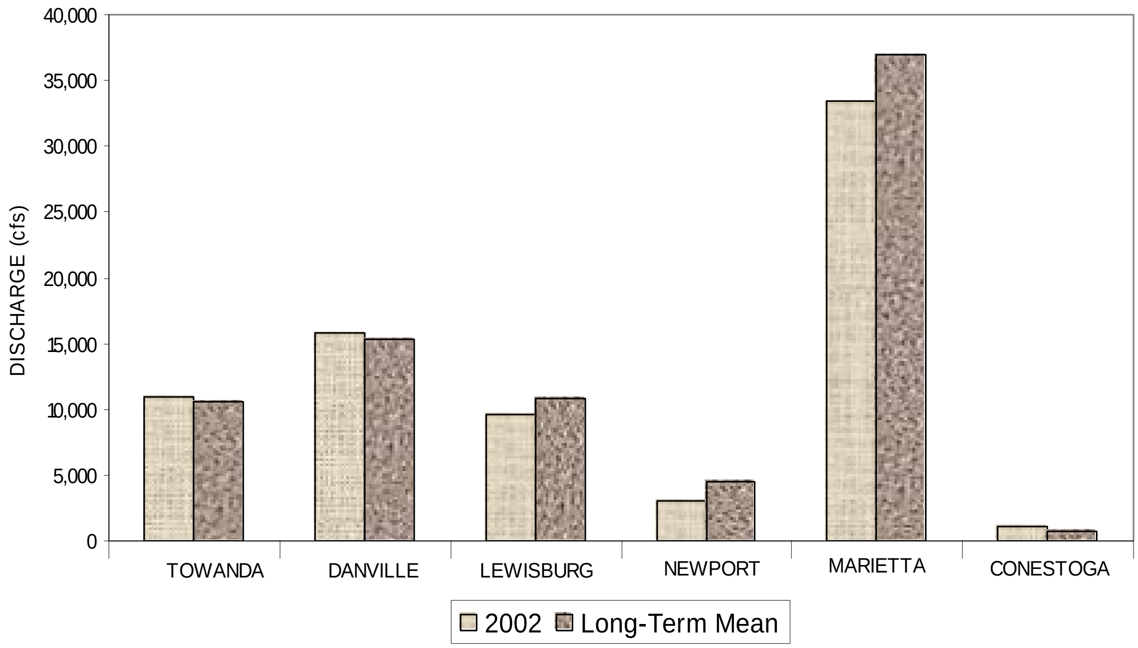


Figure 3. Annual and Long-Term Discharges at Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga, Pa.

Table 6. List of Analyzed Parameters, Abbreviations, and Storet Codes

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

Table 7. Annual Water Discharges and Annual Loads and Yields of Total Nitrogen, Calendar Year 2002

Site	Annual Discharge cfs	Discharge % of LTM	Annual Load thousand lbs	N Load % of LTM	Prediction Error percent	Annual Yield lbs/ac/yr
Towanda	10,936	102.8	22,933	80.3	5.8	4.6
Danville	15,756	103.2	36,081	79.8	6.8	5.02
Lewisburg	9,615	88.7	18,844	80.0	8.4	4.3
Newport	3,059	68.8	11,369	74.6	5.7	5.3
Marietta	33,407	90.3	105,516	84.7	6.7	6.34
Conestoga	382	57.0	5,123	51.7	5.5	17.03

Table 8. Annual Water Discharges and Annual Loads and Yields of Total Phosphorus, Calendar Year 2002

Site	Annual Discharge cfs	Discharge % of LTM	Annual Load thousand lbs	P Load % of LTM	Prediction Error percent	Annual Yield lbs/ac/yr
Towanda	10,936	102.8	1,747	83.2	19.0	0.35
Danville	15,756	103.2	2,794	89.6	19.8	0.389
Lewisburg	9,615	88.7	943	80.3	26.0	0.215
Newport	3,059	68.8	719	98.2	19.9	0.335
Marietta	33,407	90.3	7,789	108.6	18.1	0.468
Conestoga	382	57.0	432	67.4	29.4	1.436

Table 9. Annual Water Discharges and Annual Loads and Yields of Total Suspended Sediment, Calendar Year 2002

Site	Annual Discharge cfs	Discharge % of LTM	Annual Load thousand lbs	SS Load % of LTM	Prediction Error percent	Annual Yield lbs/ac/yr
Towanda	10,936	102.8	1,011,773	45.1	48.9	202.76
Danville	15,756	103.2	1,071,789	43.3	36.3	149.26
Lewisburg	9,615	88.7	400,870	39.6	62.3	62.29
Newport	3,059	68.8	305,682	69.1	41.0	142.41
Marietta	33,407	90.3	4,158,875	81.2	37.7	250.03
Conestoga	382	57.0	153,336	51.2	108.7	509.76

Table 10. Annual Water Discharges and Annual Loads and Yields of Total Ammonia, Calendar Year 2002

Site	Annual Discharge cfs	Annual Load thousand lbs	Prediction Error Percent	Annual Yield lbs/ac/yr
Towanda	10,936	1,246	21.8	0.25
Danville	15,756	1,845	26.1	0.26
Lewisburg	9,615	1,041	24.7	0.24
Newport	3,059	302	28.2	0.14
Marietta	33,407	4,343	24.4	0.26
Conestoga	382	138	37.9	0.46

Table 11. Annual Water Discharges and Annual Loads and Yields of Total Nitrate Nitrite Nitrogen, Calendar Year 2002

Site	Annual Discharge cfs	Annual Load thousand lbs	Prediction Error percent	Annual Yield lbs/ac/yr
Towanda	10,936	13,637	7.5	2.73
Danville	15,756	22,153	7.1	3.09
Lewisburg	9,615	12,291	7.7	2.80
Newport	3,059	8,439	6.26	3.93
Marietta	33,407	71,763	7.45	4.31
Conestoga	382	4,286	7.85	14.25

Table 12. Annual Water Discharges and Annual Loads and Yields of Total Organic Nitrogen, Calendar Year 2002

Site	Annual Discharge cfs	Annual Load thousand lbs	Prediction Error percent	Annual Yield lbs/ac/yr
Towanda	10,936	8,493	11.08	1.702
Danville	15,756	12,825	13.52	1.79
Lewisburg	9,615	5,651	20.83	1.29
Newport	3,059	2,638	16.1	1.23
Marietta	33,407	23,110	15.5	1.39
Conestoga	382	916	26.68	3.05

Table 13. Annual Water Discharges and Annual Loads and Yields of Dissolved Phosphorus, Calendar Year 2002

Site	Annual Discharge cfs	Annual Load thousand lbs	Prediction Error percent	Annual Yield lbs/ac/yr
Towanda	10,936	756	17.05	0.15
Danville	15,756	1,001	19.03	0.14
Lewisburg	9,615	389	18.99	0.09
Newport	3,059	396	19.86	0.18
Marietta	33,407	3,337	17.59	0.20
Conestoga	382	208	14.41	0.69

Table 14. Annual Water Discharges and Annual Loads and Yields of Dissolved Orthophosphate, Calendar Year 2002

Site	Annual Discharge cfs	Annual Load thousand lbs	Prediction Error percent	Annual Yield lbs/ac/yr
Towanda	10,936	746	29.2	0.15
Danville	15,756	1,011	30.37	0.14
Lewisburg	9,615	313	37.7	0.07
Newport	3,059	374	33.82	0.17
Marietta	33,407	4,153	34.19	0.25
Conestoga	382	226	21.05	0.75

Table 15. Annual Water Discharges and Annual Loads and Yields of Dissolved Ammonia, Calendar Year 2002

Site	Annual Discharge cfs	Annual Load thousand lbs	Prediction Error percent	Annual Yield lbs/ac/yr
Towanda	10,936	1,412	17.8	0.283
Danville	15,756	2,153	21.23	0.30
Lewisburg	9,615	1,097	20.01	0.25
Newport	3,059	334	20.40	0.16
Marietta	33,407	4,457	19.24	0.27
Conestoga	382	124	34.2	0.41

Table 16. Annual Water Discharges and Annual Loads and Yields of Dissolved Nitrogen, Calendar Year 2002

Site	Annual Discharge cfs	Annual Load thousand lbs	Prediction Error percent	Annual Yield lbs/ac/yr
Towanda	10,936	21,665	6.03	4.34
Danville	15,756	33,532	6.95	4.67
Lewisburg	9,615	17,262	6.84	3.94
Newport	3,059	10,588	5.43	4.93
Marietta	33,407	94,603	6.91	5.69
Conestoga	382	4,829	6.45	16.05

Table 17. Annual Water Discharges and Annual Loads and Yields of Dissolved Nitrate Nitrite Nitrogen, Calendar Year 2002

Site	Annual Discharge cfs	Annual Load thousand lbs	Prediction Error percent	Annual Yield lbs/ac/yr
Towanda	10,936	13,414	7.36	2.69
Danville	15,756	22,085	7.25	3.08
Lewisburg	9,615	12,063	7.64	2.75
Newport	3,059	8,351	6.33	3.89
Marietta	33,407	70,914	7.61	4.26
Conestoga	382	4,260	8.08	14.16

Table 18. Annual Water Discharges and Annual Loads and Yields of Dissolved Organic Nitrogen, Calendar Year 2002

Site	Annual Discharge cfs	Annual Load thousand lbs	Prediction Error percent	Annual Yield lbs/ac/yr
Towanda	10,936	7,191	10.48	1.441
Danville	15,756	9,940	10.57	1.38
Lewisburg	9,615	4,082	14.7	0.93
Newport	3,059	1,940	11.6	0.90
Marietta	33,407	14,446	16.51	0.87
Conestoga	382	570	28.07	1.90

Table 19. Annual Water Discharges and Annual Loads and Yields of Total Organic Carbon, Calendar Year 2002

Site	Annual Discharge cfs	Annual Load thousand lbs	Prediction Error percent	Annual Yield lbs/ac/yr
Towanda	10,936	72,304	5.2	14.49
Danville	15,756	102,537	5.02	14.28
Lewisburg	9,615	41,035	7.77	9.36
Newport	3,059	21,114	6.66	9.84
Marietta	33,407	211,373	5.65	12.71
Conestoga	382	4,268	11.73	14.19

Comparison of the percent of long-term means of flow versus the percent of long-term means of a specific constituent highlights where improvements might be occurring. For example, Towanda and Danville both recorded above average flows for 2002 but the TN, TP, and SS loads fell well below the long-term means. In comparison, phosphorus percentages of long-term mean at Newport and Marietta are significantly higher than the percentage of long-term discharge. This suggests phosphorus loads may actually be increasing in these watersheds.

Another interesting comparison is that the SS percentages of long-term means were dramatically lower than the corresponding phosphorus values. This contradicts the accepted idea that phosphorus can be controlled by controlling sediment concentrations. Another interesting comparison is between Lewisburg and Newport. These two sites have the same percentage of urban land use but have offsetting agriculture and forest land uses. Newport has approximately 12 percent less forested area and 13 percent more agricultural area. Keeping this in mind, it is interesting to note the differing yield values. Yields were higher in Newport as compared to Lewisburg for all constituents except total organic nitrogen (TON), dissolved organic nitrogen (DON), total ammonia (TNH_3), and dissolved ammonia (DNH_3).

Comparisons also can be made between sites on the mainstem of the Susquehanna. Towanda, Danville, and Marietta have very similar land use percentages, with Marietta having a little less agriculture and a little more forested land. For most parameters, there is an increasing yield value when moving downstream on the Susquehanna. The exceptions were at Marietta for TOC, DON, TON, and DNH_3, which were lower than both Towanda and Danville. This contradicts any conclusions made from the Lewisburg and Newport yields mentioned previously.

Conestoga presents a difficult case. It has the highest yields of all the sites for all parameters, but due to the land use percentages, it does not point to a definite cause. The Conestoga watershed contains the highest concentration of agriculture, but it also contains the highest concentration of urban area as well as the lowest amount of forested land. All three of these factors contribute to the watershed having the highest yields. Figures 4-6 show loads and yields of TN, TP, and SS in comparison with the long-term means for each site.

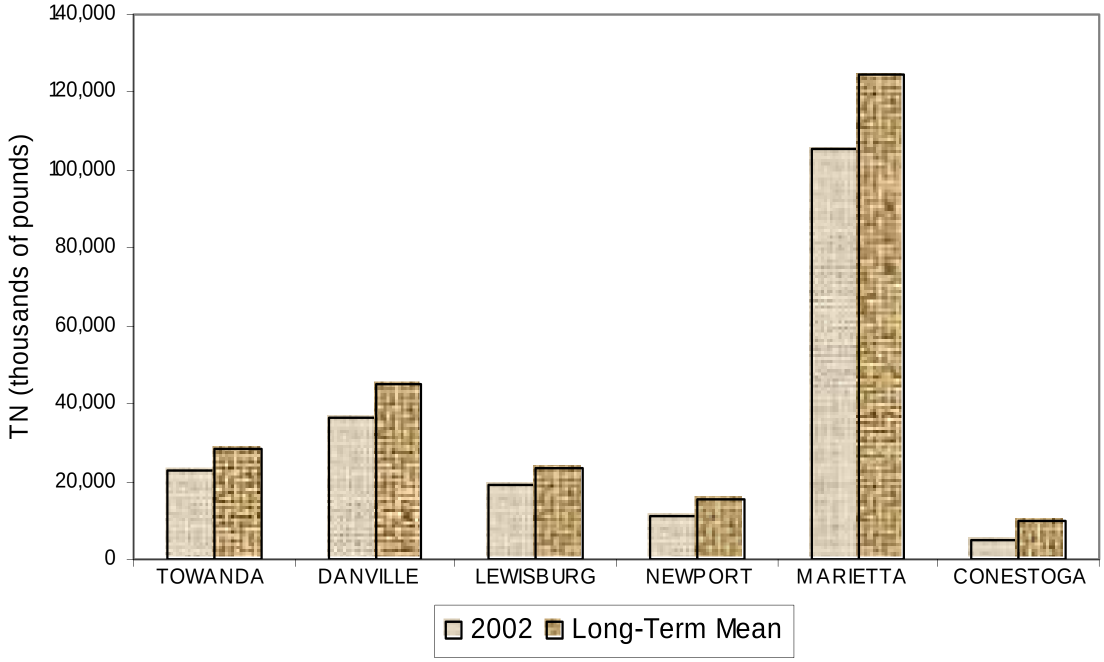


Figure 4A. ***Annual Loads of Total Nitrogen (TN) at Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga, Pa., Calendar Year 2002***

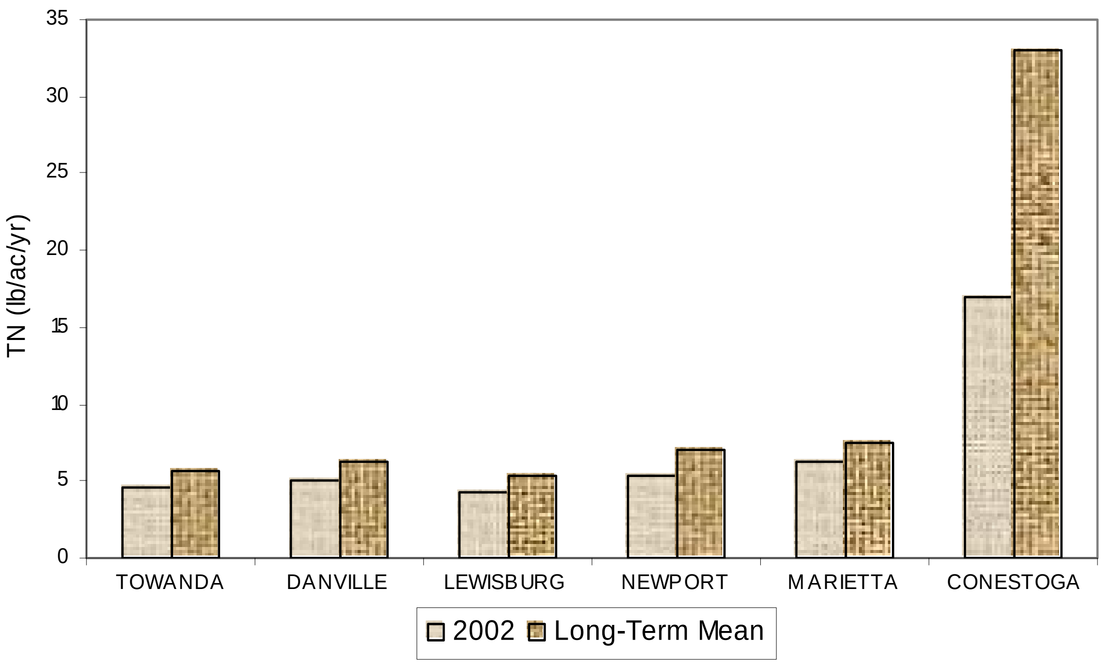


Figure 4B. ***Total Nitrogen (TN) Yields at Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga, Pa., Calendar Year 2002***

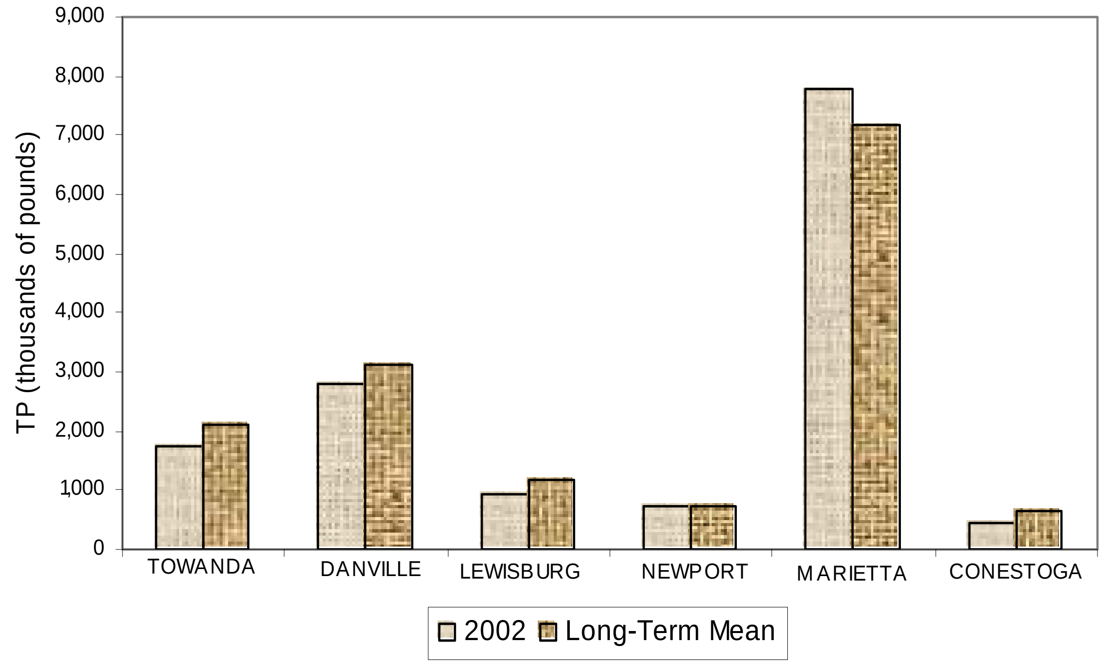


Figure 5A. Annual Loads of Total Phosphorus (TP) at Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga, Pa., Calendar Year 2002

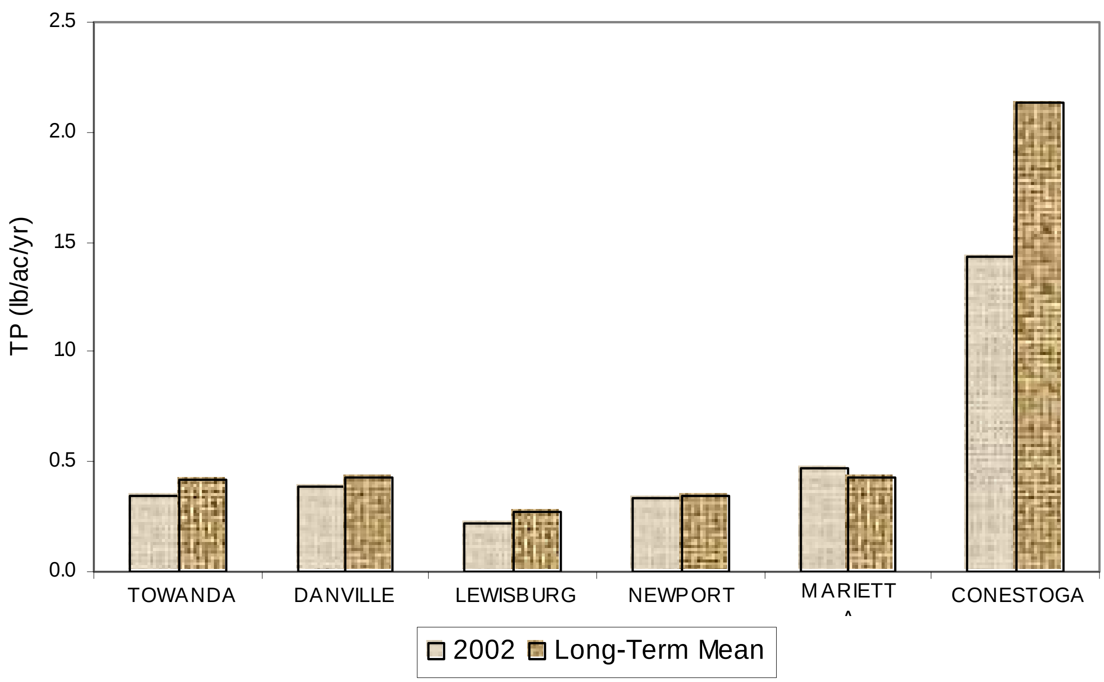


Figure 5B. Total Phosphorus (TP) Yields at Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga, Pa., Calendar Year 2002

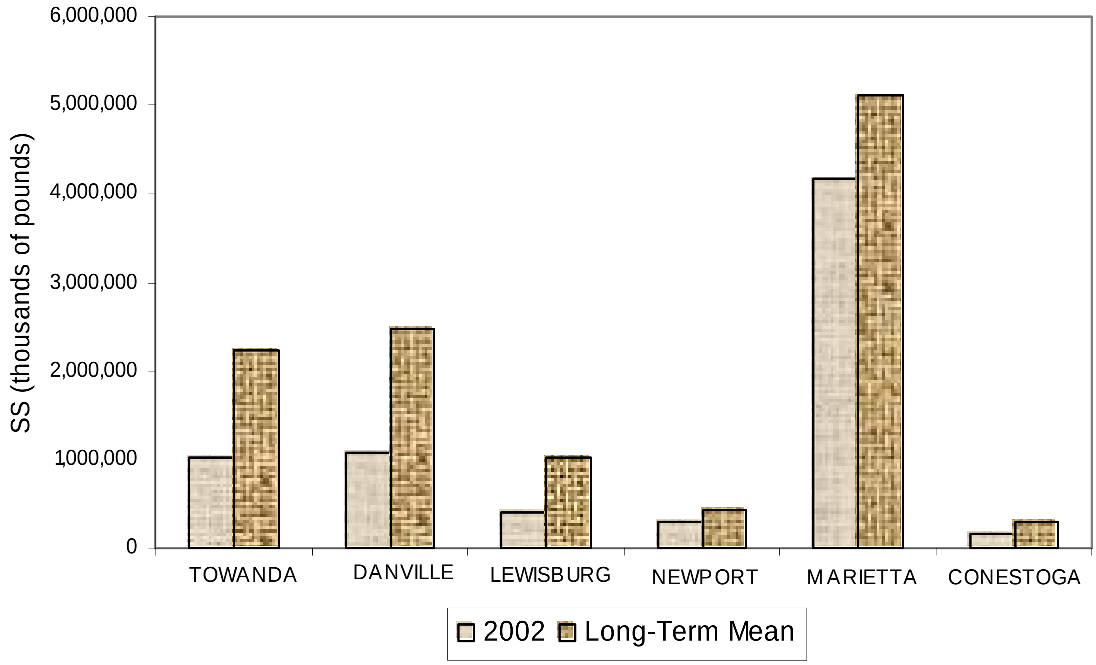


Figure 6A. Annual Loads of Suspended Sediment (SS) at Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga, Pa., Calendar Year 2002

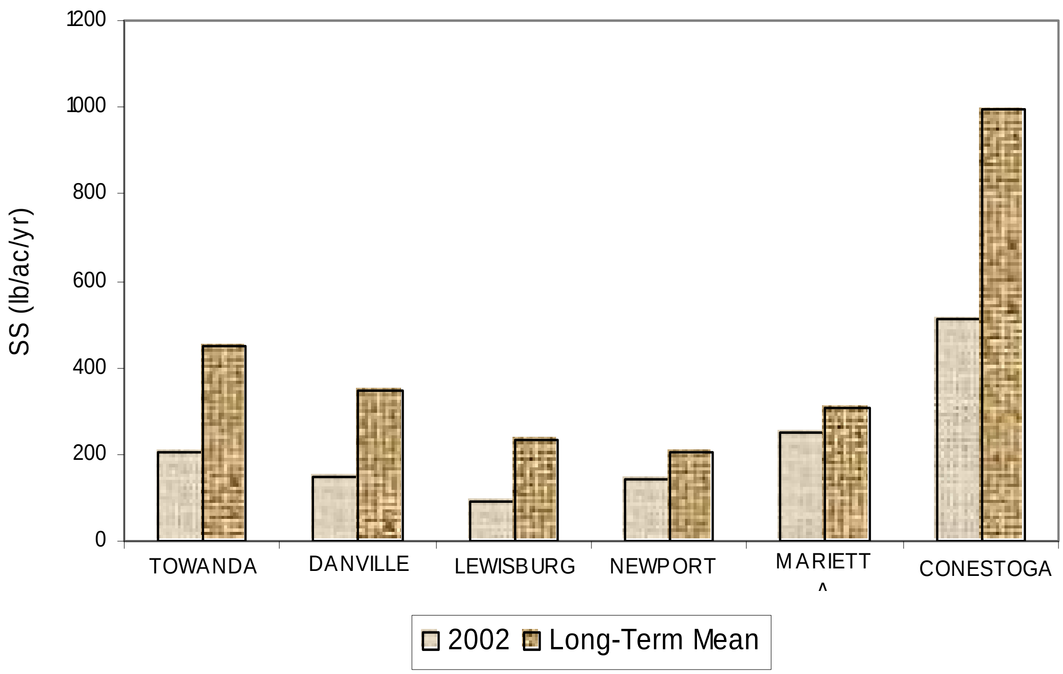


Figure 6B. Suspended Sediment (SS) Yields at Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga, Pa., Calendar Year 2002

When looking at constituent loads, it can be difficult to determine whether improvements are being made due to the variations in flow. Because of this, it is useful to compare the loads from years that had similar amounts of flow. Table 20 lists the flow and TN, TP, and SS loads for 1992 and 2002. Newport was not sampled during 1992 and has been excluded from the table. The fact that constituent loads tend to be higher during higher flow years suggests that the loads for TN, TP, and SS should be higher for all sites during 1992. This was in fact the case for TN. TP, however, was higher during 2002 for all sites except Lewisburg, with a dramatic increase at Marietta. SS loads were higher for all sites in 2002 except for Danville.

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

Seasonal loads for all parameters and all sites are listed in Table 21 (high values in boldface type). For the purposes of this project, January–March is winter, April–June is spring, July–September is summer, and October–December is fall. As a general note, nutrient and SS levels increase with increases in flow. This is very apparent with regard to the seasonal results for Conestoga. Fall was by far the highest flow season for Conestoga, and, due to this, all parameters also were highest during that timeframe. All other sites had highest flow during the spring months. Most parameters followed the general rule of higher discharges resulting in higher nutrient loads, except for TNH_3, DNH_3, DP, and DOP. These parameters were highest during the fall for nearly all sites, leading to the possible conclusion that these constituents are not as flow dependent.

Newport had some variation from the other sites with TN, DN, total nitrate plus nitrite (TNOx), and dissolved nitrate plus nitrite (DNOx) showing highest values during the fall. The values were only slightly below those for spring and were easily explained, given that the flow difference between spring and fall at Newport was small.

Seasonal highs in TP loads corresponded with seasonal highs in SS for all sites, backing the idea that phosphorus can be reduced by reducing SS concentrations. The dissolved fraction, however, is beginning to be dominated by DOP. Figures 7-12 show graphs of discharge, TN, TP, and SS as compared to the long-term means. Discharge values at Towanda and Danville were above the long-term mean for both spring and fall. Corresponding SS values for both sites are dramatically lower than their respective long-term means leading to the conclusion that SS concentrations were improving at these sites. Similar circumstances existed at Lewisburg for 2002. Above average flows at Marietta during the spring and fall seasons led to TP loads well above long-term means for the same months. Conestoga had slightly above average flows for the fall season, producing well above average loads of TP and SS. This was coupled with extremely low loads of these constituents during the winter and summer months.

Figures 13-15 show the seasonal yields for each site. When comparing land uses Lewisburg, (2 percent urban, 15 percent Agricultural, 81 percent forest, 2 percent other) and Newport (2 percent urban, 28 percent Agricultural, 69 percent forest, 1 percent other) are good sites to examine for differences due to forest versus agriculture, since this constitutes the only significant different between the two. When looking at the yields of TN, TP, and SS for these sites, Newport recorded higher yield values for all seasons except winter. By looking at the seasonal discharges for winter, Newport recorded values that were 31.6 percent of the long-term mean for the site, while Lewisburg recorded discharge values that were 67.5 percent of the long-term mean. This could easily account for higher yield values for Lewisburg for the winter season. When looking at the long-term yields, Newport recorded the highest values for all four seasons for TN and TP and highest SS yields for spring and summer. Given the land uses for these two sites, it becomes clear that higher yield values were generally found in watersheds where forested land had been lost to agriculture. It was not possible to determine which factor had more effect on yields;

the loss of forestland or the addition of agricultural land.

There were no consistent seasonal patterns between the mainstem Susquehanna sites at Towanda, Danville, and Marietta. This makes sense considering that the land use percentages for these sites were very comparable. Long-term yield values at Conestoga were highest of all sites for all seasons. Phosphorus and SS yields at Conestoga were not the highest during the winter months for 2002. This was likely due to flows for the season being 23.6 percent of the long-term mean. Figure 16 shows the load percent breakdowns for each season at each site. As a general note, spring was the time of the highest loads of nutrient and SS at all sites while summer was the lowest. This corresponds with the flows for 2002. The exception was at Conestoga where the highest values for flow, nutrients, and SS were during the fall. This emphasizes the significant impact that discharge has on constituent loads.

Table 20. Comparison of 2002 Loads with 1992 Loads for Flow, Total Nitrogen, Total Phosphorus, and Suspended Sediment

Site	Discharge cfs		TN thousands lbs		TP thousand lbs		SS thousands lbs	
	1992	2002	1992	2002	1992	2002	1992	2002
Towanda	11,700	10,936	31,600	22,933	1,600	1,747	879,000	1,011,773
Danville	16,000	15,756	46,100	36,081	2,710	2,794	1,310,000	1,071,789
Lewisburg	10,500	9,615	21,700	18,844	999	943	337,000	400,870
Marietta	34,100	33,407	118,000	105,516	5,070	7,789	2,280,000	4,158,875
Conestoga	417	382	6,710	5,123	277	432	57,500	153,336

Table 21. Seasonal Mean Water Discharges and Loads of Nutrients and Suspended Sediment, Calendar Year 2002

Station	Season	Mean Water Discharge	Total Nitrogen as N	Dissolved Nitrogen as N	Total Ammonia as N	Dissolved Ammonia as N	Total Organic Nitrogen as N	Dissolved Organic Nitrogen as N	Total Nitrate Plus Nitrite as N	Dissolved Nitrate Plus Nitrite as N	Total Phosphorus as P	Dissolved Phosphorus as P	Dissolved Ortho-Phosphate as P	Total Organic Carbon	Suspended Sediment
		cfs	thousands of pounds												
Towanda	Winter	12,521	7,271	7,084	468	394	2,295	2,006	4,730	4,693	453	212	206	16,710	243,789
	Spring	**18,834**	**9,153**	**8,351**	383	384	**3,873**	**3,112**	**4,985**	**4,917**	**738**	241	208	**33,850**	**634,061**
	Summer	1,875	810	689	30	29	430	328	382	380	72	39	44	3,432	8,864
	Fall	10,378	5,699	5,541	**530**	**439**	1,896	1,745	3,540	3,424	484	**264**	**289**	18,311	125,059
Danville	Winter	16,498	10,604	10,292	707	570	3,006	2,513	7,280	7,337	624	251	273	21,171	238,824
	Spring	**26,190**	**13,389**	**11,837**	560	470	**5,531**	**3,956**	**7,586**	**7,546**	**1,108**	304	298	**44,721**	**585,363**
	Summer	2,977	1,248	1,018	43	37	701	476	610	606	89	37	35	5,246	10,556
	Fall	17,228	10,840	10,385	**843**	**769**	3,588	2,995	6,677	6,596	973	**408**	**405**	31,399	237,048
Lewisburg	Winter	10,383	5,381	5,018	**376**	**376**	1,568	1,193	3,541	3,508	261	114	**100**	8,989	86,948
	Spring	**18,094**	**7,965**	**7,035**	353	300	**2,685**	**1,776**	**4,926**	**4,828**	**438**	**133**	96	**20,563**	**282,162**
	Summer	1,884	957	892	36	33	280	220	644	627	32	21	19	2,172	2,419
	Fall	8,129	4,541	4,317	332	332	1,118	894	3,180	3,100	213	121	98	9,311	29,340
Newport	Winter	2,071	1,700	1,627	42	38	396	310	1,284	1,278	82	52	47	2,795	22,788
	Spring	**5,234**	4,480	4,071	123	107	**1,137**	**796**	3,214	3,180	**310**	145	140	**8,574**	**188,828**
	Summer	949	668	609	21	19	220	163	434	427	55	36	30	1,787	8,114
	Fall	4,026	**4,522**	**4,281**	**148**	**139**	886	671	**3,506**	**3,466**	272	**162**	**156**	7,958	85,952
Marietta	Winter	32,066	25,855	24,057	1,202	124	6,340	4,145	18,547	18,373	1,388	703	823	40,294	625,280
	Spring	**57,335**	**39,719**	**34,279**	1,230	1,101	**10,091**	**6,193**	**25,696**	**25,256**	**3,581**	**1,285**	1,534	**92,412**	**2,632,050**
	Summer	6,839	4,118	3,641	117	114	1,012	687	2,344	2,324	286	165	161	12,164	62,232
	Fall	37,381	35,824	32,627	**1,907**	**2,004**	5,668	3,422	25,175	24,961	2,533	1,183	**1,634**	66,503	839,312
Conestoga	Winter	202	783	763	7	7	115	100	669	661	26	18	15	402	2,771
	Spring	432	1,443	1,370	24	26	252	167	1,219	1,209	111	45	51	1,072	57,687
	Summer	124	421	407	3	4	54	43	367	365	31	24	28	311	1,800
	Fall	**773**	**2,477**	**2,288**	**89**	**102**	**495**	**261**	**2,032**	**2,025**	**265**	**121**	**131**	**2,484**	**91,078**

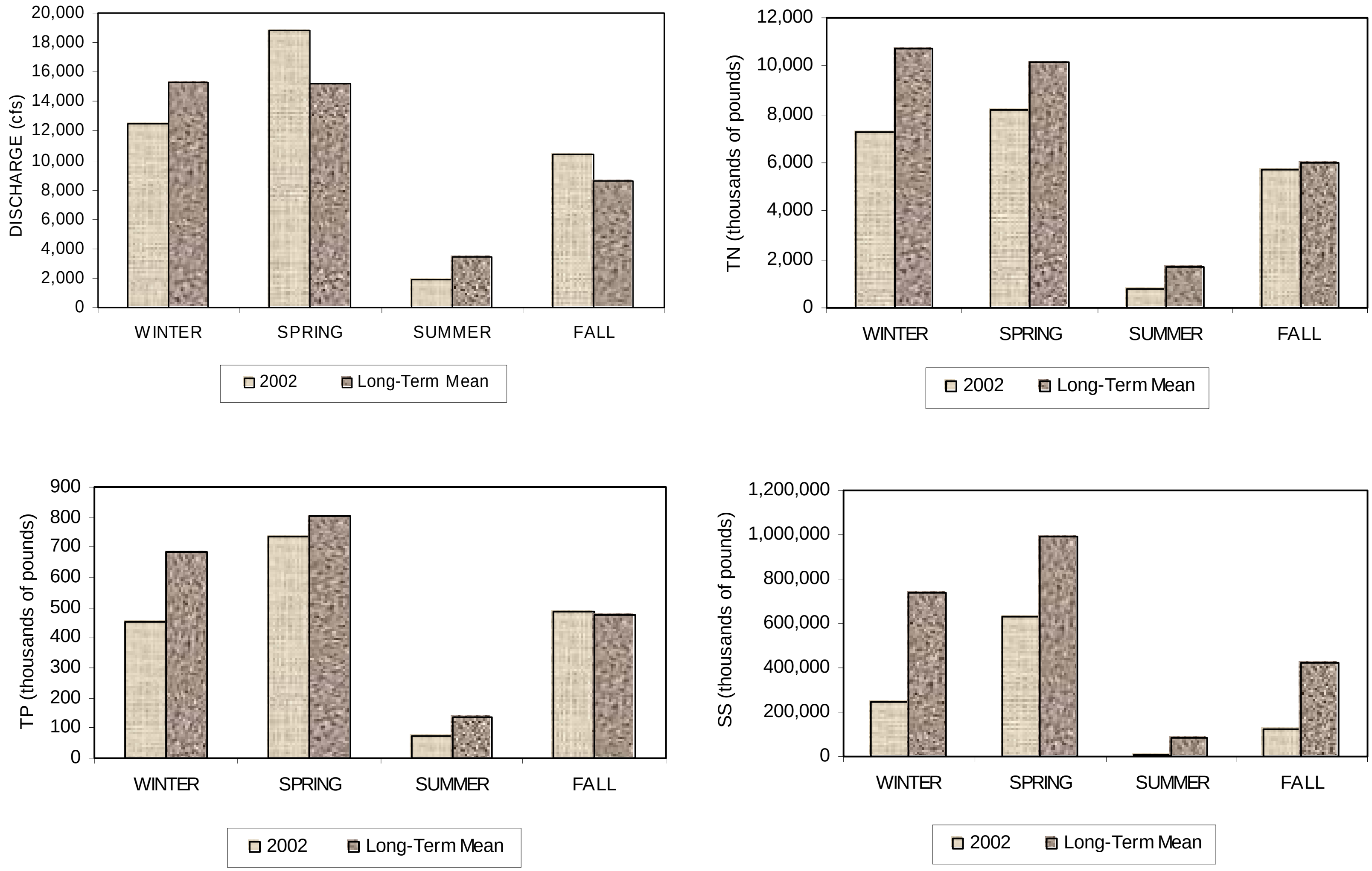


Figure 7. Season Discharges and Loads of Total Nitrogen (TN), Total Phosphorus (TP), Suspended Sediment (SS) at Towanda, Pa., Calendar Year 2002

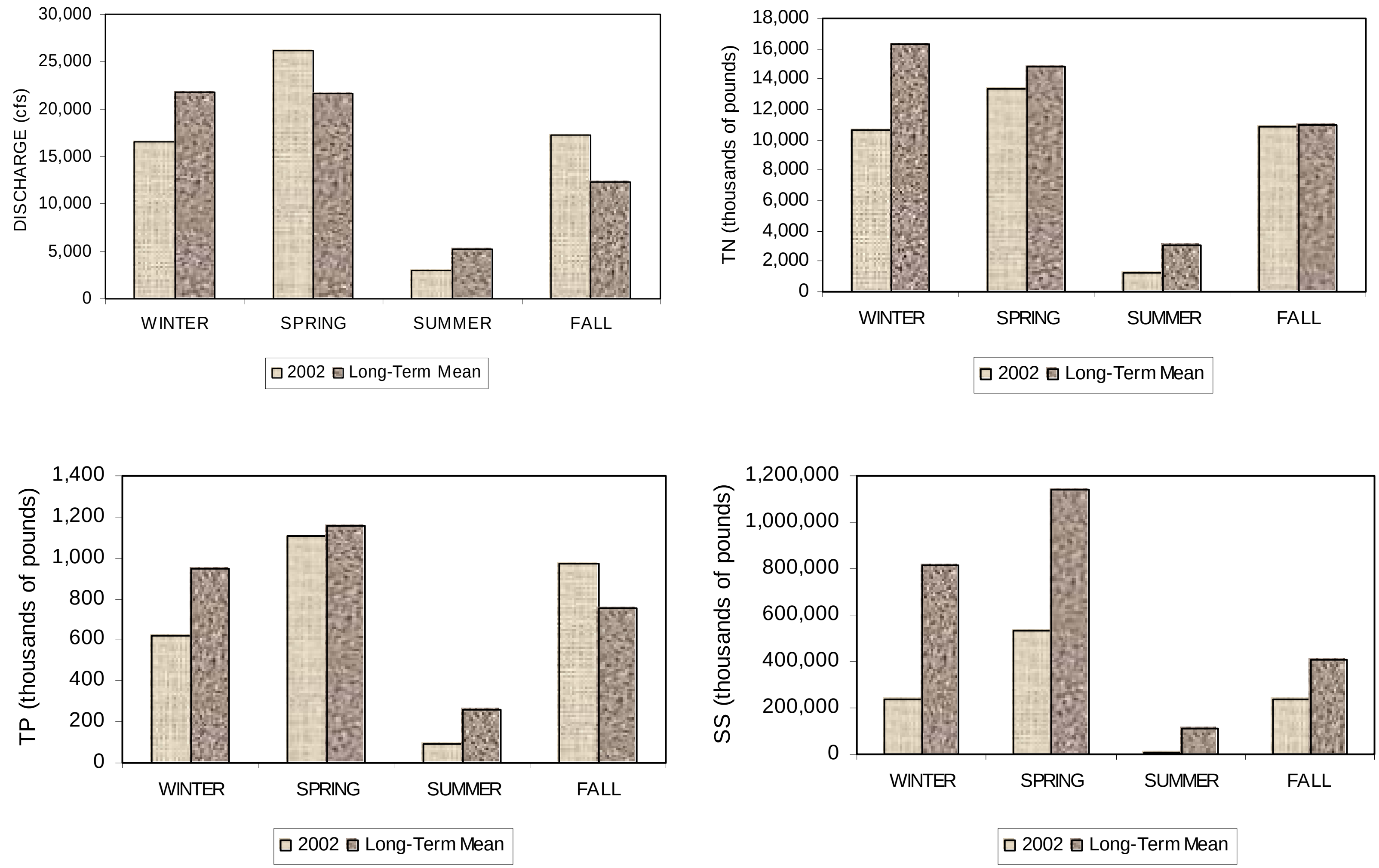


Figure 8. Season Discharges and Loads of Total Nitrogen (TN), Total Phosphorus (TP), Suspended Sediment (SS) at Danville, Pa., Calendar Year 2002

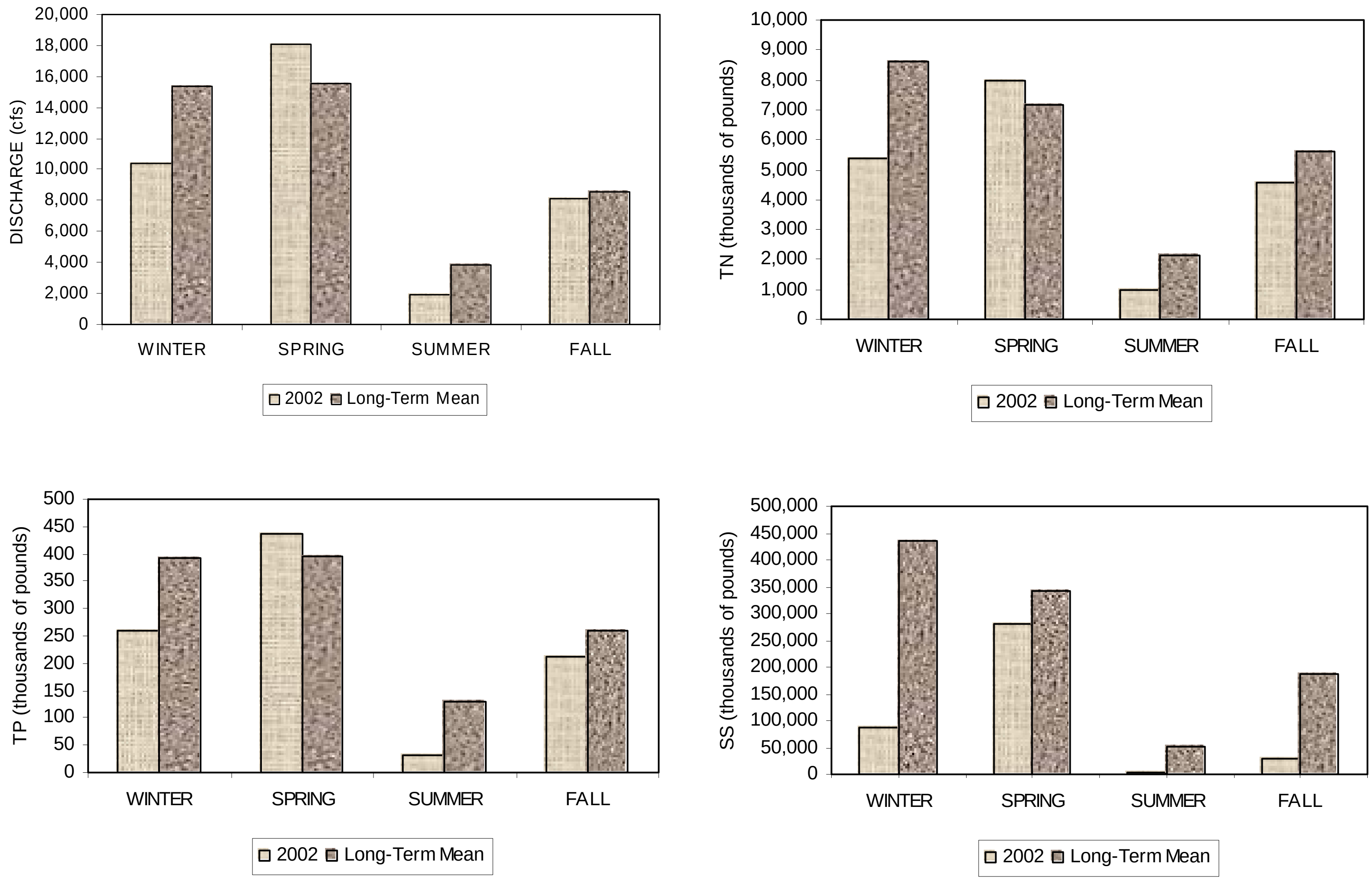


Figure 9. ***Season Discharges and Loads of Total Nitrogen (TN), Total Phosphorus (TP), Suspended Sediment (SS) at Lewisburg, Pa., Calendar Year 2002***

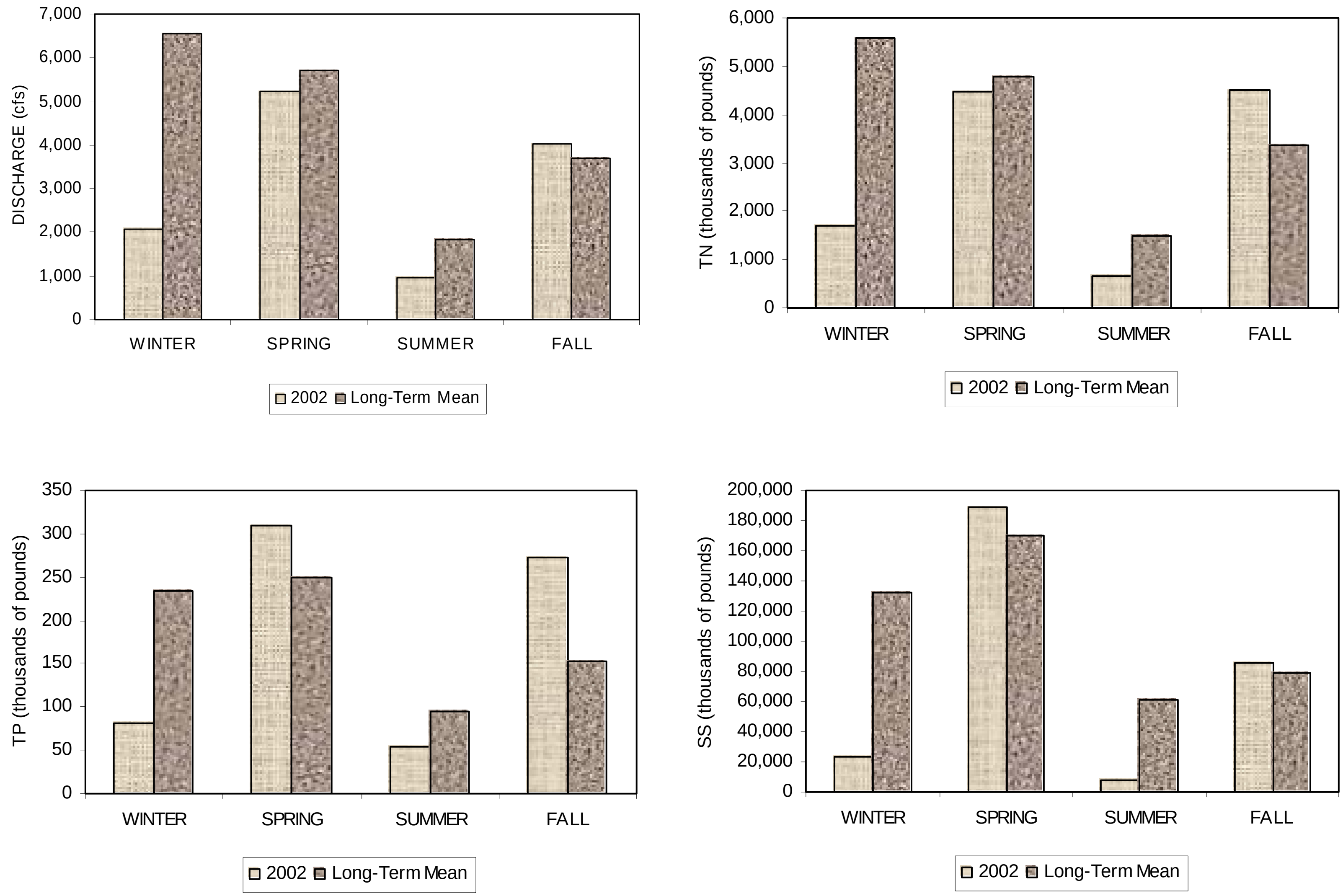


Figure 10. ***Season Discharges and Loads of Total Nitrogen (TN), Total Phosphorus (TP), Suspended Sediment (SS) at Newport, Pa., Calendar Year 2002***

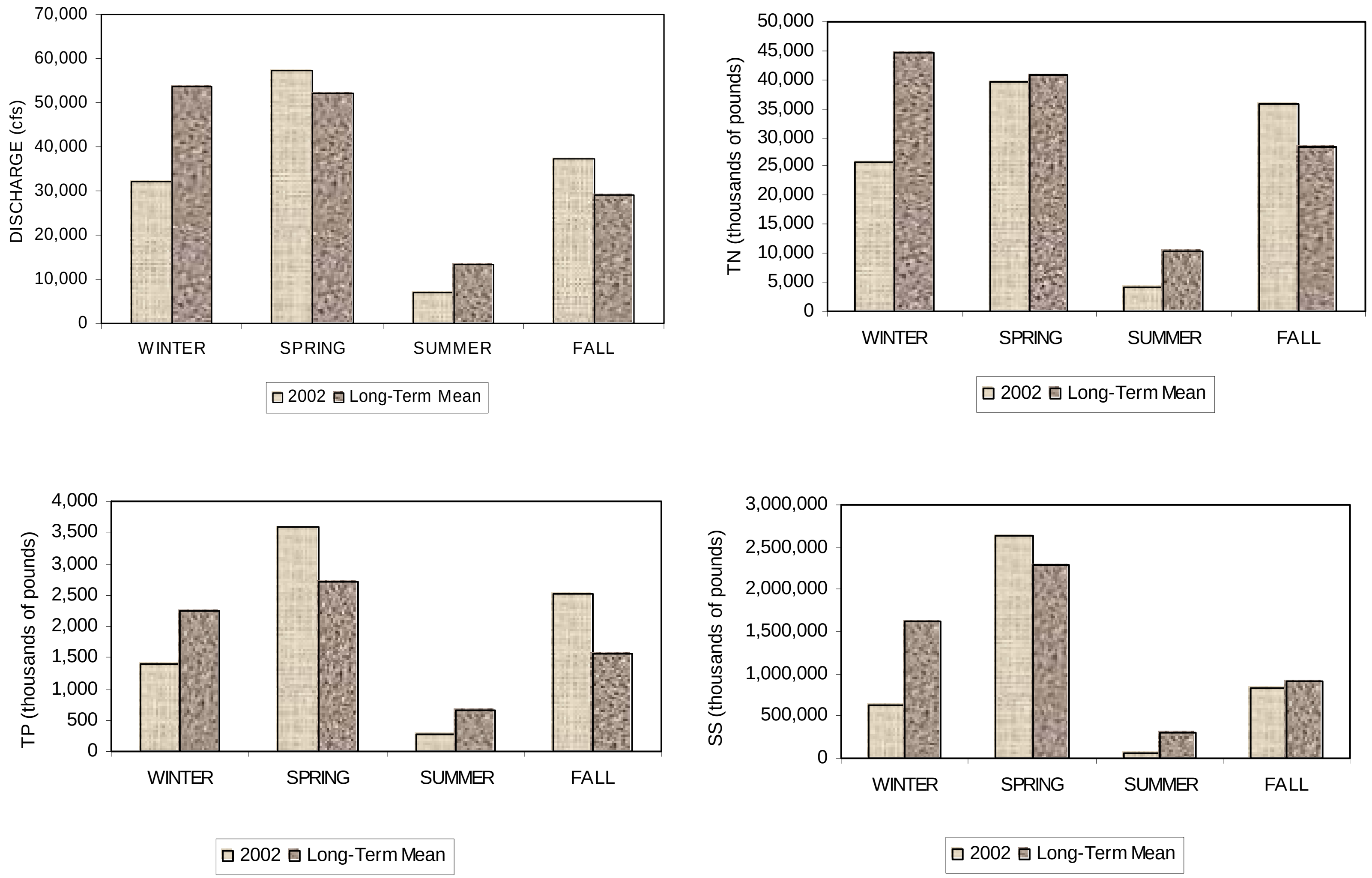


Figure 11. ***Season Discharges and Loads of Total Nitrogen (TN), Total Phosphorus (TP), Suspended Sediment (SS) at Marietta, Pa., Calendar Year 2002***

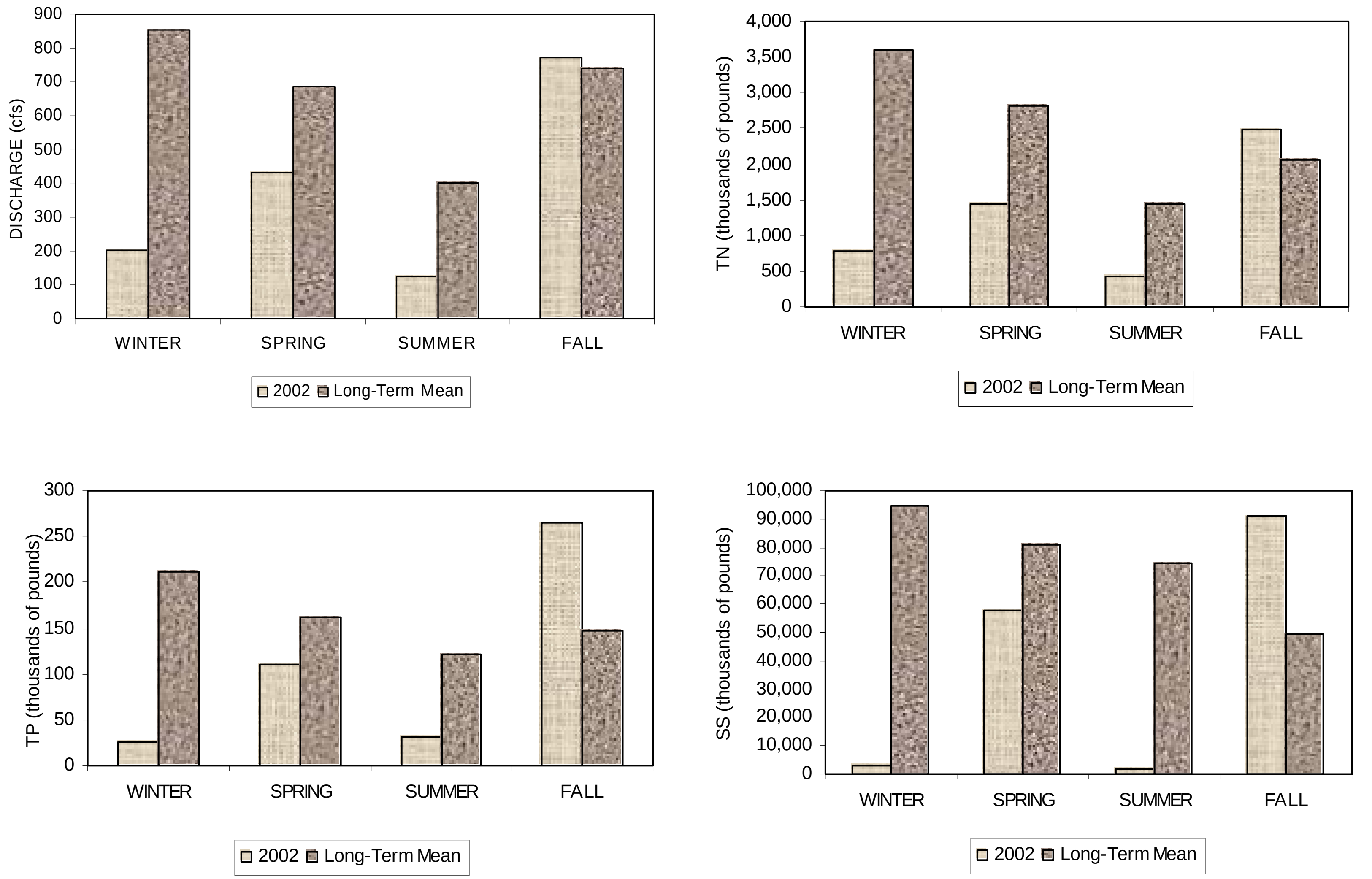


Figure 12. ***Season Discharges and Loads of Total Nitrogen (TN), Total Phosphorus (TP), Suspended Sediment (SS) at Conestoga, Pa., Calendar Year 2002***

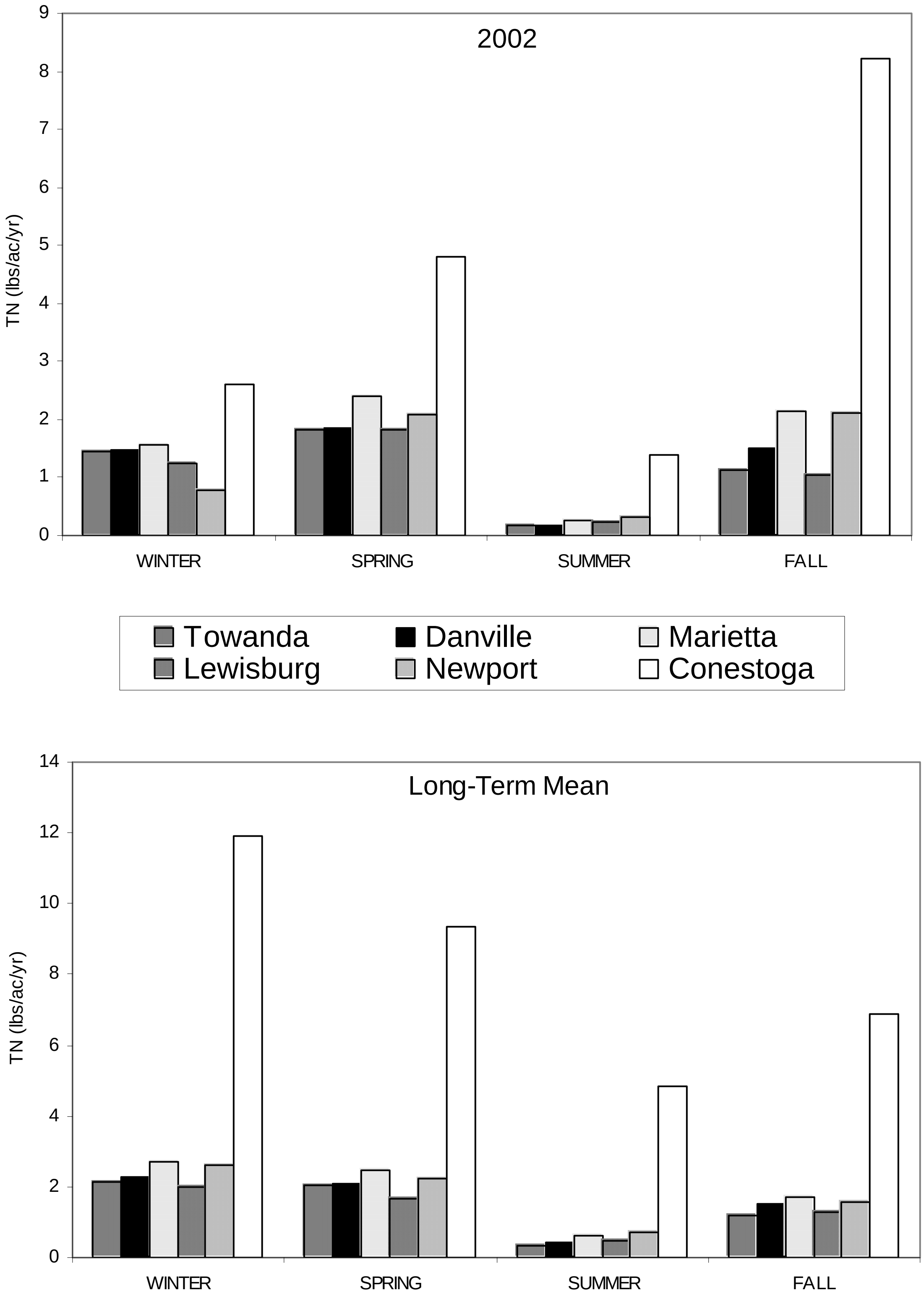
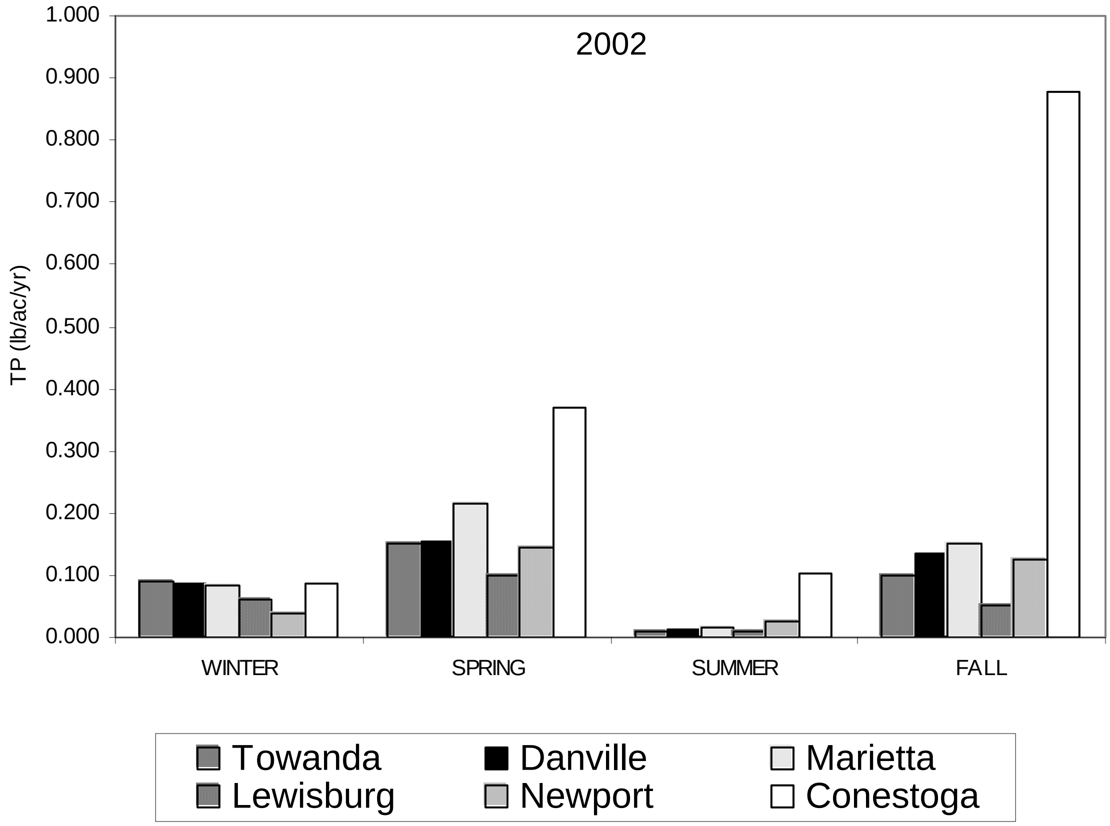


Figure 13. Comparison of Seasonal Yields of Total Nitrogen (TN) at Towanda, Danville, Marietta, Lewisburg, Newport, and Conestoga, Pa.



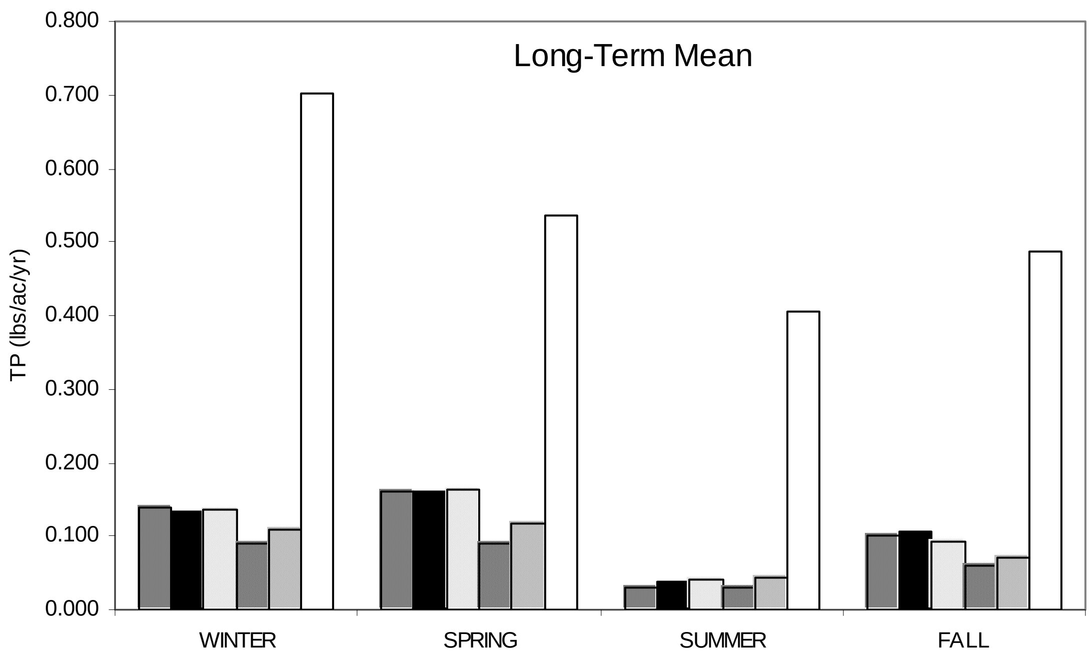


Figure 14. ***Comparison of Seasonal Yields of Total Phosphorus (TP) at Towanda, Danville, Marietta, Lewisburg, Newport, and Conestoga, Pa.***

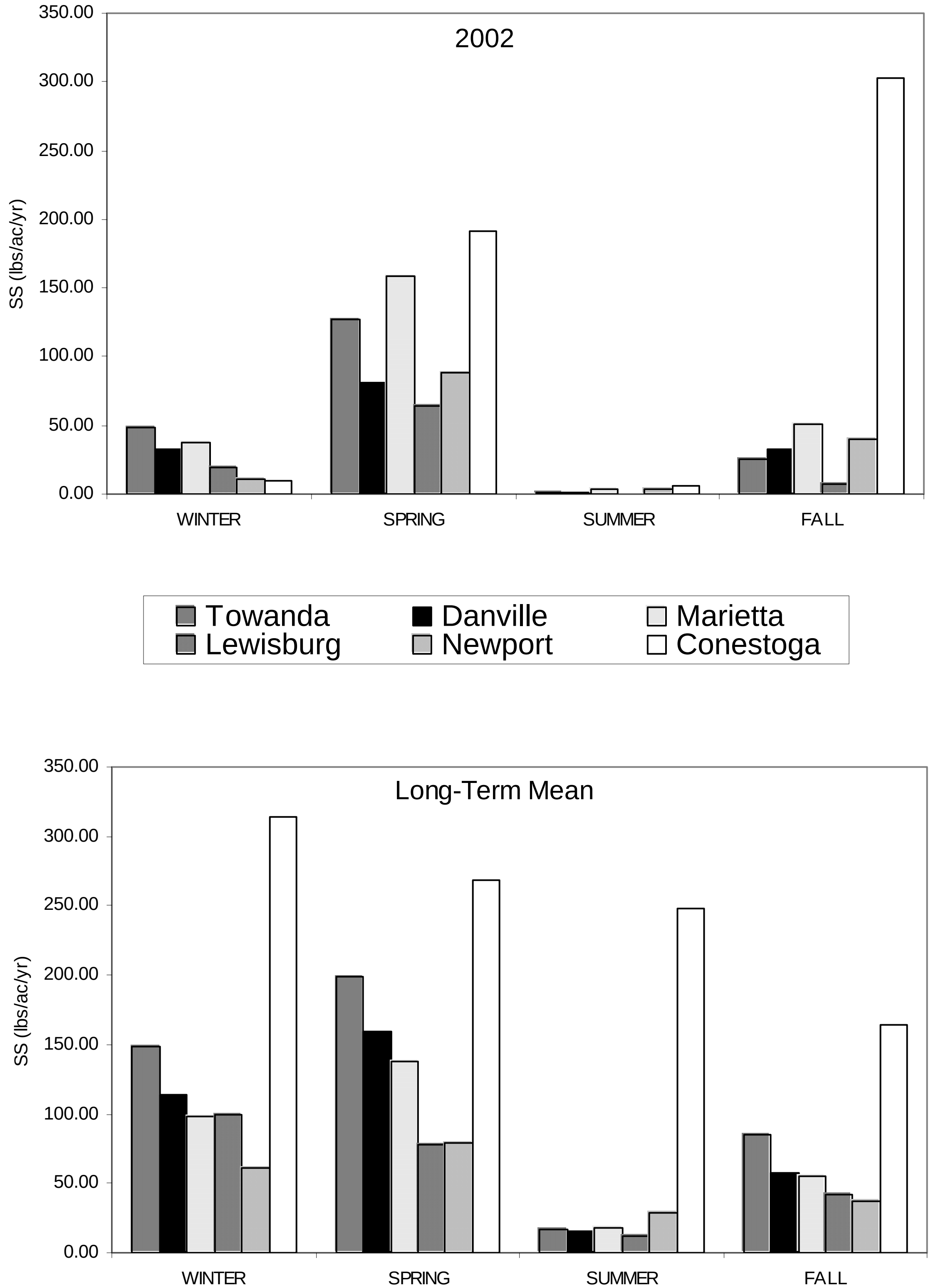


Figure 15. ***Comparison of Seasonal Yields of Suspended Sediment (SS) at Towanda, Danville, Marietta, Lewisburg, Newport, and Conestoga, Pa.***

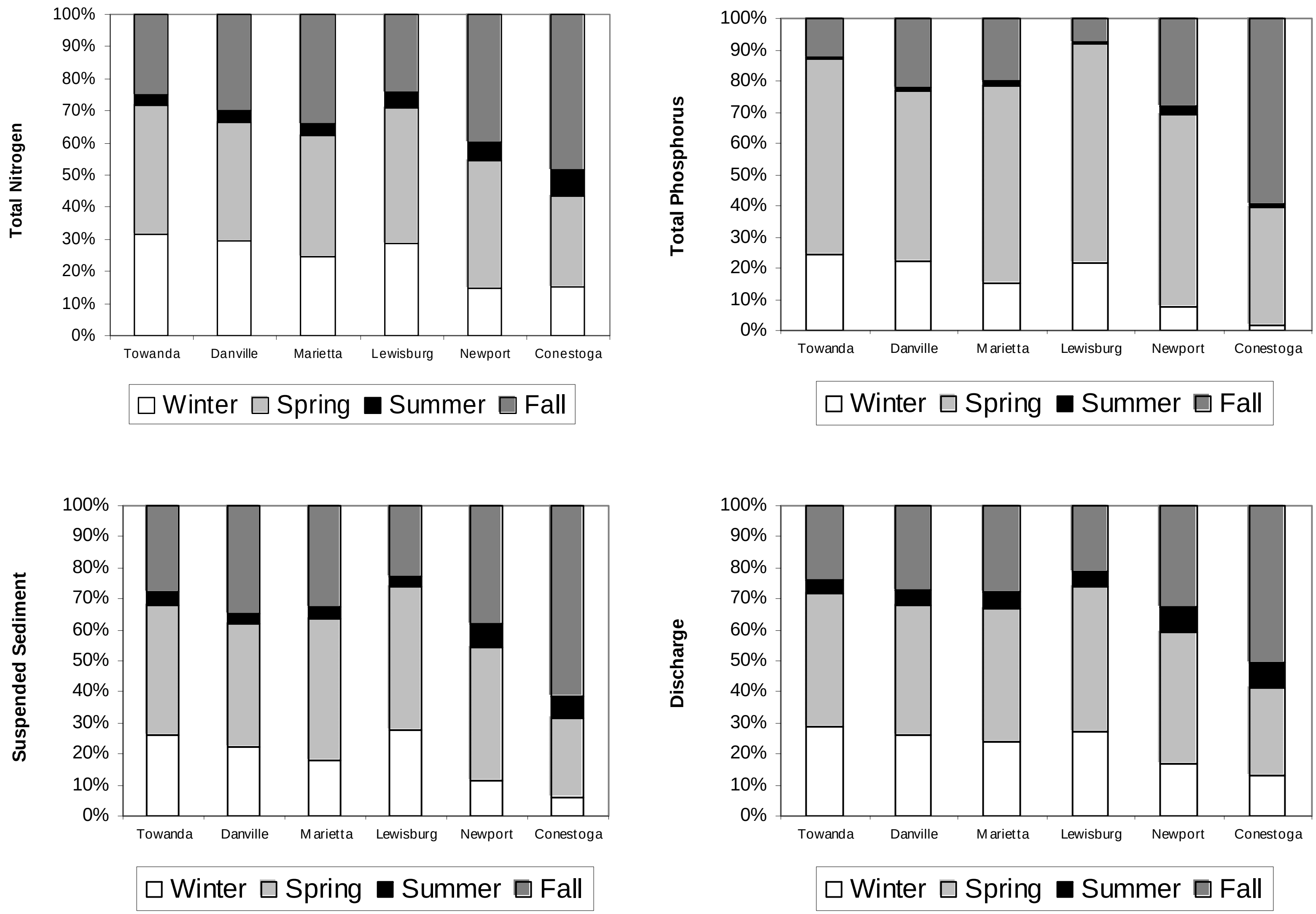


Figure 16. Seasonal Percent of Annual Load of Total Nitrogen, Total Phosphorus, and Suspended Sediment at Towanda, Danville, Marietta, Lewisburg, Newport, and Conestoga, Pa.

COMPARISON OF THE 2002 LOADS AND YIELDS OF TOTAL NITROGEN, TOTAL PHOSPHORUS, AND SUSPENDED SEDIMENT WITH THE BASELINES

The annual fluctuations of nutrient and SS loads and water discharge made it difficult to determine whether the changes were related to land use, nutrient availability, or simply annual water discharge. Ott and others (1991) used the functional relationship between annual loads and annual water discharge to provide a method to reduce the variability of loadings due to discharge. This was accomplished by plotting the annual 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 from the initial 5-year study (1985-89) were used to provide a best-fit linear regression line to be used as the baseline relationship between annual 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 2002 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. Figures 17-22 display the baseline graphs and the 2002 yields.

Susquehanna River at Towanda, Pa.

The 5-year baselines for TN, TP, and SS for the Susquehanna River at Towanda are shown in Figure 17 with the 2002 annual yield. Actual 2002 and baseline yields are listed in Table 22 along with the discharge ratio. Best-fit lines were drawn through the initial 5-year data sets using the following equations:

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

TN Yield = 0.7484 + 6.0967x $R^2 = 0.86$

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

TP Yield = -0.1419 + 0.4999x $R^2 = 0.52$

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

SS Yield = -612.879 + 918.165x $R^2 = 0.43$

Where x = water-discharge ratio and R2 = correlation coefficient

Table 22. Comparison of 2002 TN, TP, and SS Yields With Baseline Yields at Towanda, Pa.

Parameter	Discharge Ratio	Baseline lb/ac/yr	2002 lb/ac/yr
TN	1.028	6.5	4.6
TP	1.028	0.3975	0.35
SS	1.028	371.361	202.76

Susquehanna River at Danville, Pa.

Figure 18 shows the 5-year (1985-89) baselines for TN, TP, and SS and the 2001 yields for the Susquehanna River at Danville. Actual 2002 and baseline yields are listed in Table 23 along with the discharge ratio. The regression equations used to establish the baselines were:

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

TN Yield = -0.1792 + 7.2989x $R^2 = 0.85$

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

TP Yield = -0.1496 + 0.6586x $R^2 = 0.94$

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

SS Yield = -471.893 + 862.484x $R^2 = 0.99$

Table 23. Comparison of 2002 TN, TP, and SS Yields With Baseline Yields at Danville, Pa.

Parameter	Discharge Ratio	Baseline lb/ac/yr	2002 lb/ac/yr
TN	1.032	7.5	5.02
TP	1.032	0.554	0.389
SS	1.032	448.24	149.26

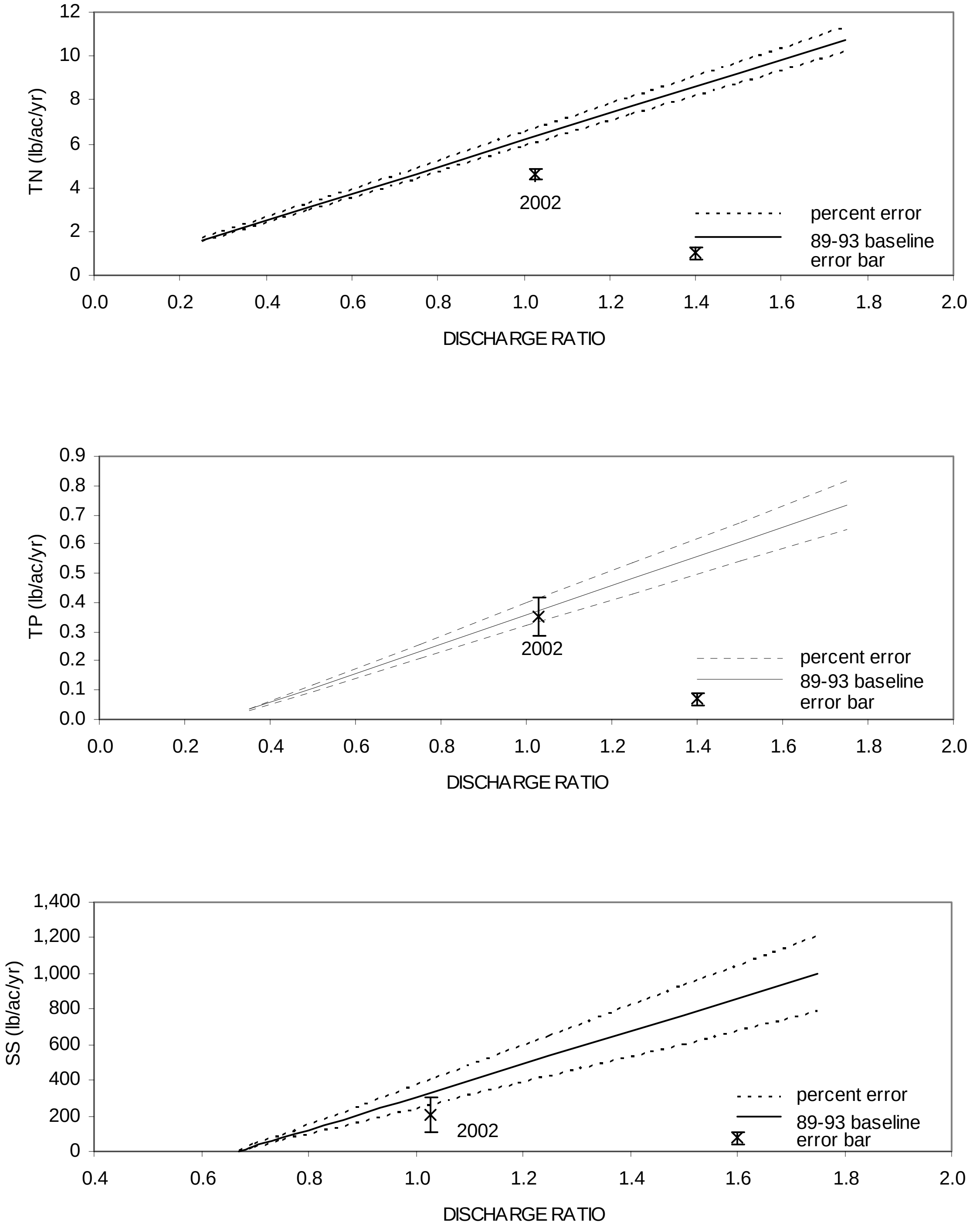


Figure 17. ***Total Nitrogen (TN), Total Phosphorus (TP), and Suspended-Sediment (SS) Yields, Susquehanna River at Towanda, Pa., 1989-1993 and 2002***

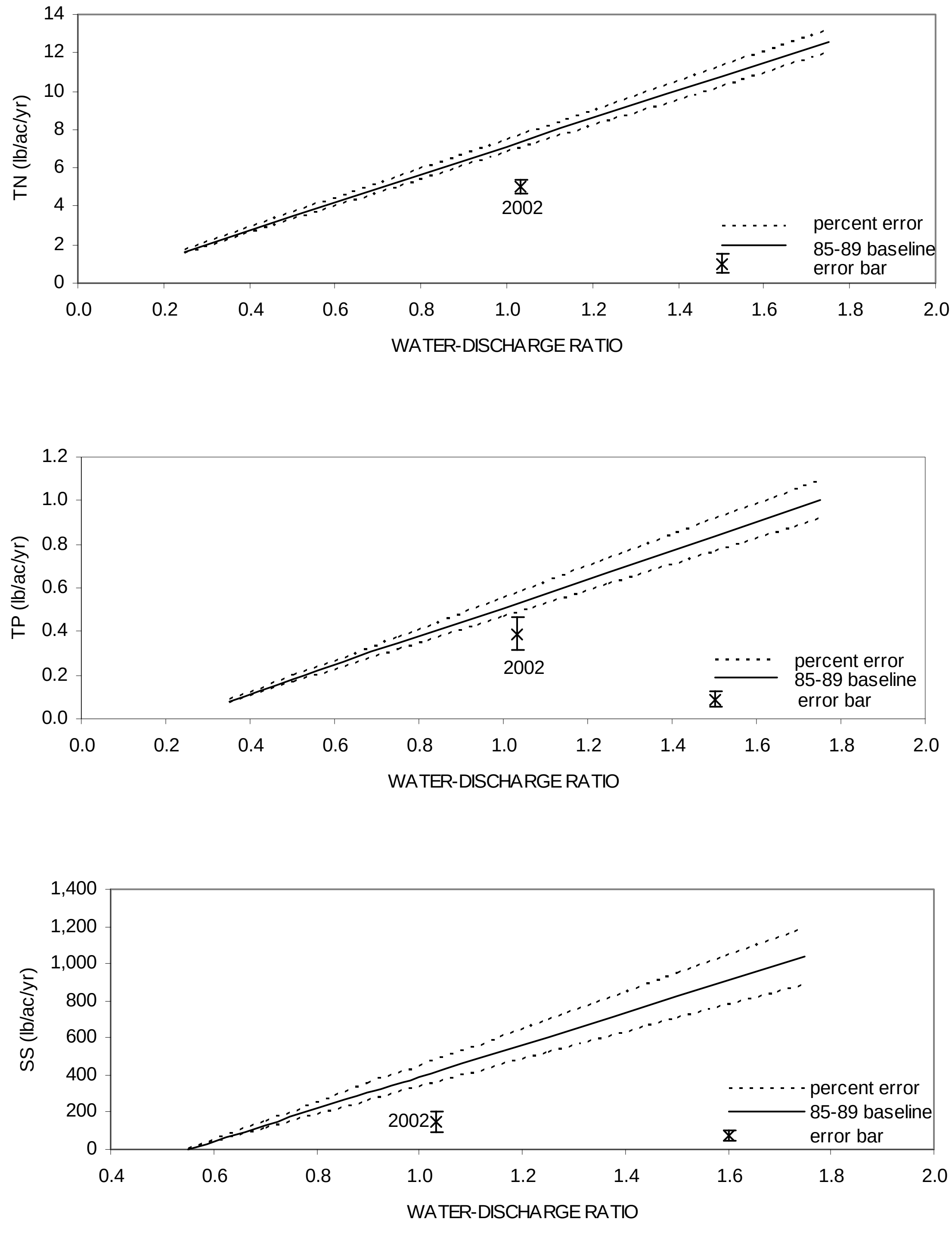


Figure 18. ***Total Nitrogen (TN), Total Phosphorus (TP), and Suspended-Sediment (SS) Yields, Susquehanna River at Danville, Pa., 1985-1989 and 2002***

West Branch Susquehanna River at Lewisburg, Pa.

The 1985-89 baselines and the 2001 yields for TN, TP, and SS are shown in Figure 19. Actual 2002 and baseline yields are listed in Table 24 along with the discharge ratio. 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 $R^2 = 0.66$

Table 24. Comparison of 2002 TN, TP, and SS Yields With Baseline Yields at Lewisburg, Pa.

Parameter	Discharge Ratio	Baseline lb/ac/yr	2002 lb/ac/yr
TN	0.887	5.58	4.3
TP	0.887	0.27	0.22
SS	0.887	152.29	91.48

Juniata River at Newport, Pa.

The 1985-89 baselines and 2001 yields for TN, TP, and SS at Newport, are shown in Figure 20. Actual 2002 and baseline yields are listed in Table 25 along with the discharge ratio. The baselines were defined by 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 $R^2 = 0.89$

Table 25. Comparison of 2002 TN, TP, and SS Yields With Baseline Yields at Newport, Pa.

Parameter	Discharge Ratio	Baseline lb/ac/yr	2002 lb/ac/yr
TN	0.688	5.83	5.3
TP	0.688	0.27	0.335
SS	0.688	94.72	142.21

Susquehanna River at Marietta, Pa.

The TN, TP, and SS baseline for the 5-year period 1987-91 at Marietta and the 2001 yield are shown in Figure 21. Actual 2002 and baseline yields are listed in Table 26 along with the discharge ratio. The baselines were defined by 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 $R^2 = 0.48$

Table 26. Comparison of 2002 TN, TP, and SS Yields With Baseline Yields at Marietta, Pa.

Parameter	Discharge Ratio	Baseline lb/ac/yr	2002 lb/ac/yr
TN	0.903	7.58	6.34
TP	0.903	0.35	0.468
SS	0.903	250.69	250.03

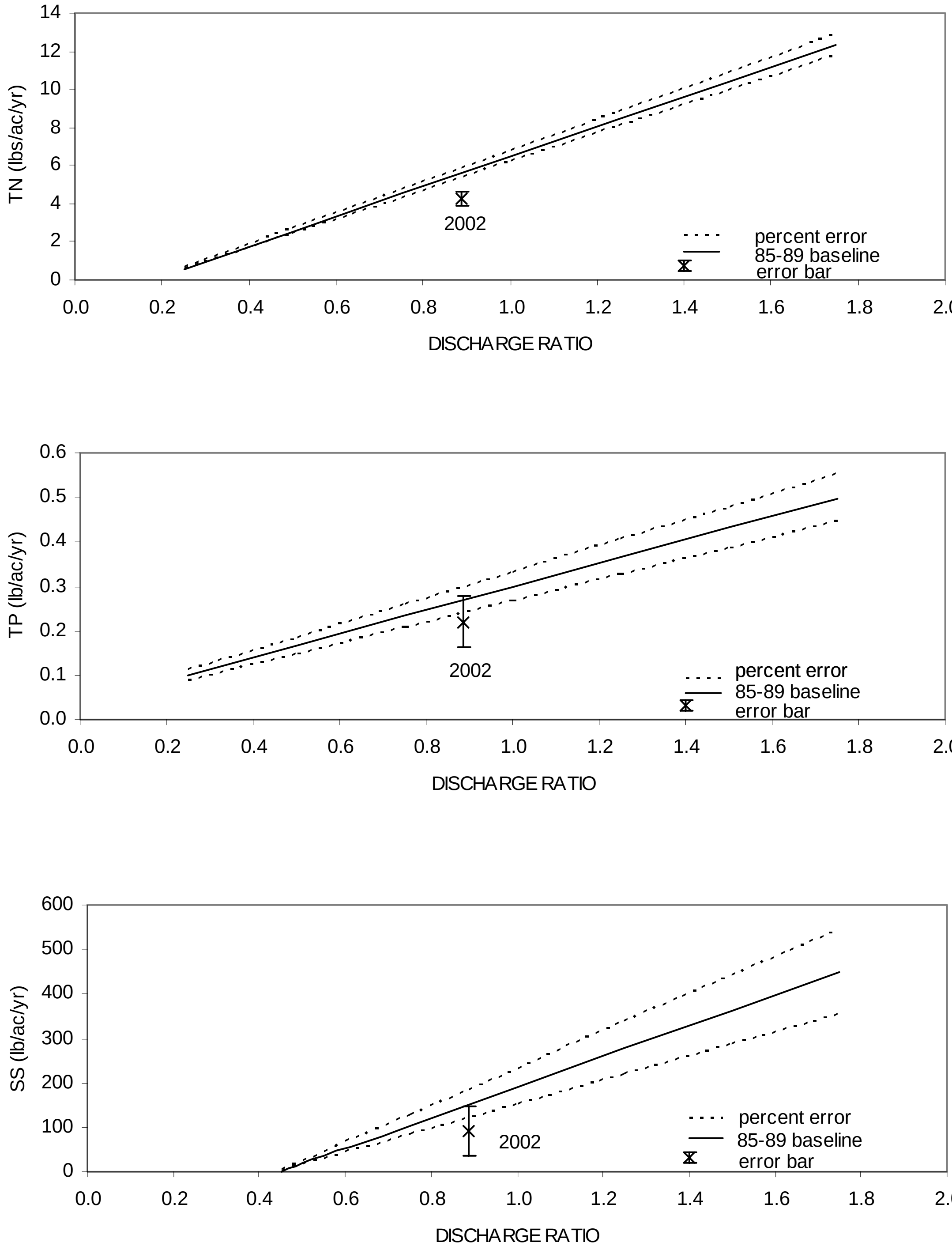


Figure 19. Total Nitrogen (TN), Total Phosphorus (TP), and Suspended-Sediment (SS) Yields, West Branch Susquehanna River at Lewisburg, Pa., 1985-1989 and 2002

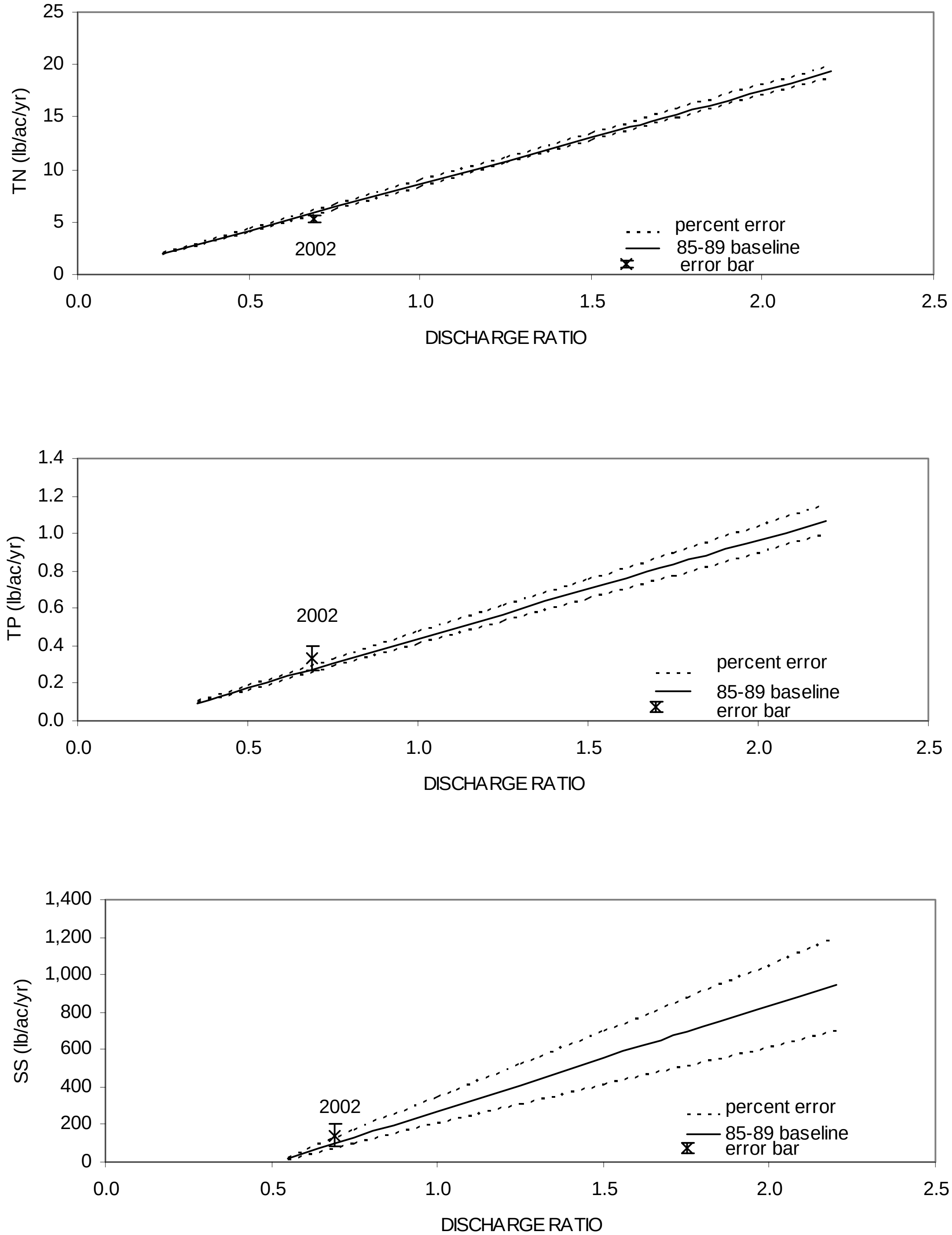


Figure 20. Total Nitrogen (TN), Total Phosphorus (TP), and Suspended-Sediment (SS) Yields, Juniata River at Newport, Pa., 1985-1989 and 2002

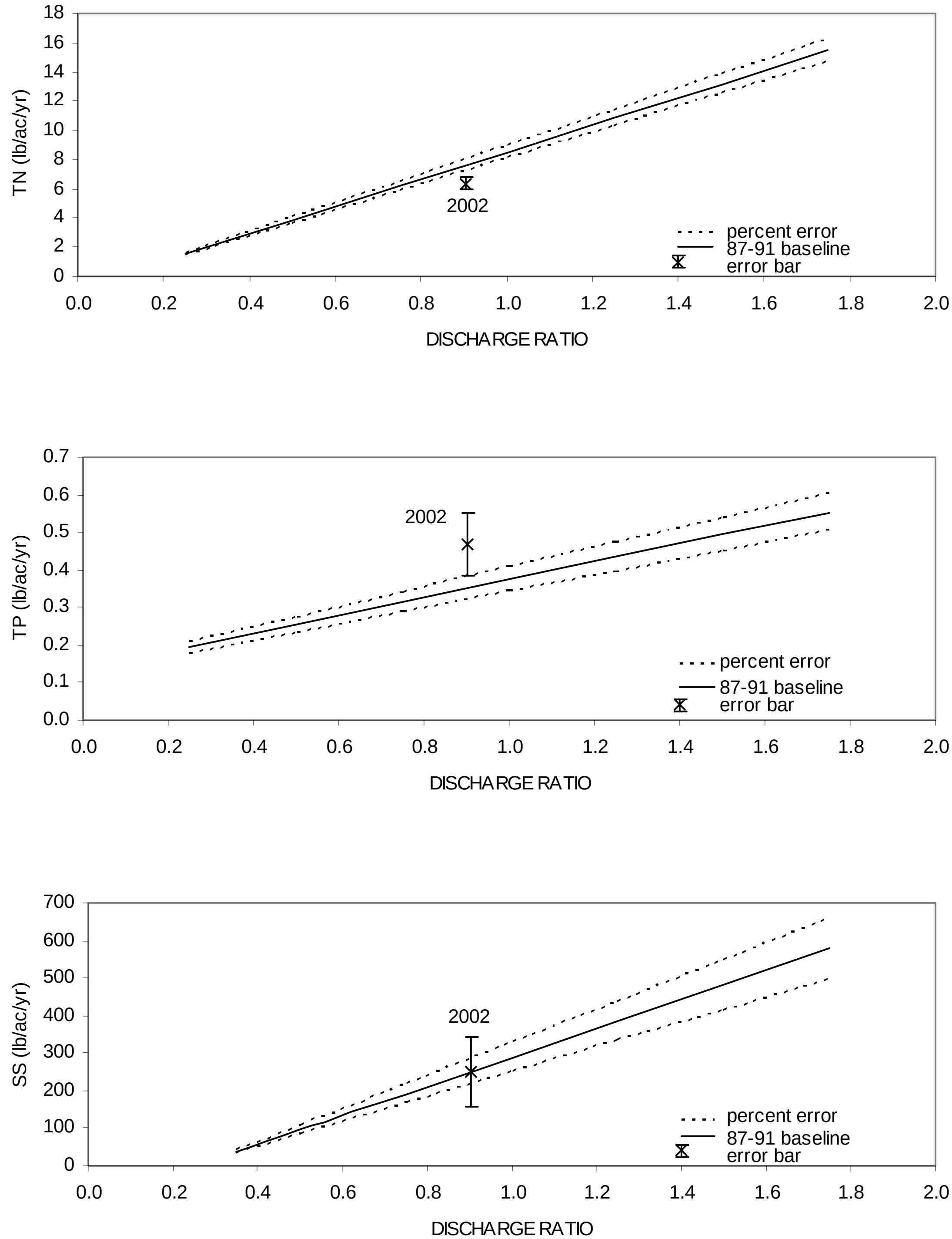


Figure 21. Total Nitrogen (TN), Total Phosphorus (TP), and Suspended-Sediment (SS) Yields, Susquehanna River at Marietta, Pa., 1987-1991 and 2002

Conestoga River at Conestoga, Pa.

Figure 22 shows the TN, TP, and SS baselines. Actual 2002 and baseline yields are listed in Table 27 along with the discharge ratio. The baselines were defined by 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 $R^2 = 0.72$

Table 27. Comparison of 2002 TN, TP, and SS Yields With Baseline Yields at Conestoga, Pa.

Parameter	Discharge Ratio	Baseline lb/ac/yr	2002 lb/ac/yr
TN	0.57	22.47	17.03
TP	0.57	0.49	1.436
SS	0.57	510.2	509.76

DISCHARGE, NUTRIENT, AND SUSPENDED-SEDIMENT TRENDS

Trend analyses of water quality and flow data collected at the six monitoring sites were completed for the period January 1985 through December 2002. Trends were estimated using linear regression techniques and the USGS estimator model (Cohn and others, 1989). These tests were used to estimate the direction and magnitude of trends for discharge, SS, TOC, and several forms of nitrogen and phosphorus. Results were reported for monthly mean discharge (FLOW), monthly load (LOAD), flow-weighted concentration (FWC), and flow-adjusted concentration (FAC).

Trends in FLOW indicate the natural changes in hydrology. Changes in flow and the cumulative sources of flow (baseflow and over land runoff) affect the observed concentrations and the estimated loads of nutrients and SS.

The LOAD represents the amount of a given constituent transported past a given point over a set duration of time. Trends in LOAD indicate the flux of constituents through the system or rates of output. When loads are expressed as yields (load per unit area), the rates of output among watersheds can be compared. The FWC is the result of the LOAD divided by the monthly flow. Trends in FWC indicate changes in stream quality over the period being investigated.

The FWC is an average monthly concentration, rather than a single observed concentration, and is more representative of monthly stream quality conditions. This is the concentration that affects the biological processes of the stream. The FAC is the concentration after the effects of flow are removed from the concentration time series. Trends in FAC indicate that changes have occurred in the processes that deliver constituents to the stream system. After the effects of flow are removed, this is the concentration that relates to the effects of nutrient-reduction activities and other actions taking place in the watershed. A description of the methodology is included in Langland and others (1999).

Trends in FLOW, LOAD, FWC, and FAC represent four diverse approaches to evaluating stream quality. While each trend will not reveal the specific cause of water quality changes, the combined information can improve understanding of the causes influencing water quality trends.

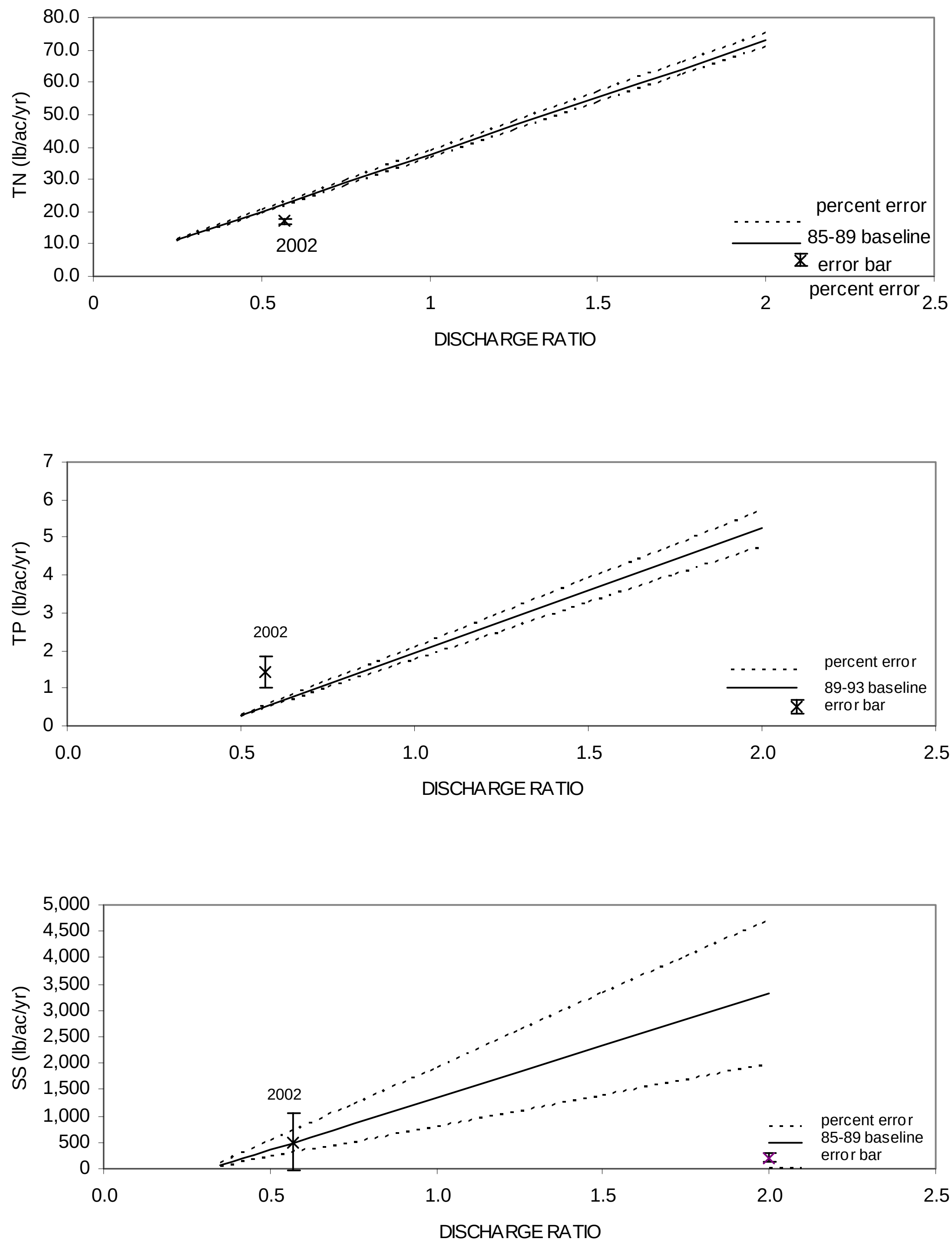


Figure 22. Total Nitrogen (TN), Total Phosphorus (TP), and Suspended-Sediment (SS) Yields, Conestoga River at Conestoga, Pa., 1985-1989 and 2002

Table 28 lists the constituents that showed the same trend results for all three analysis's making them the strongest trends for 2002. Trend results for each monitoring site are presented in Tables 29 through 34. Each table lists the results for flow (Q), the various nitrogen and phosphorus species, TOC, and SS. The level of significance was set by the p-value of 0.01 for LOAD and FWC, and a p-value of 0.05 for FAC (Langland and others, 1999). The magnitude of the slope incorporates a confidence interval and was reported as a range (minimum and maximum). The slope direction was reported as not significant (NS) or, when significant, as improving or degrading. When a time series had greater than 20 percent of its observations below the method detection level (BMDL), a trend analysis could not be completed.

TN and DN showed improving trends for all sites for FACs which suggests that management actions taking place in the watersheds have led to improvements in nitrogen concentrations. These improving trends were likely due to the very strong improving trends in FAC, FWC, and LOAD analysis for TNH_3 and total Kjeldahl nitrogen (TKN) at all sites. The dissolved fractions of these two constituents also recorded significant improving trends at four of six sites. All sites also recorded improving trends for at least one analysis method for TNOx and DNOx. TP showed improving trends in all three analytical methods at Danville, Lewisburg, Newport, and Conestoga. This is interesting to note in that three of these four are tributaries to the Susquehanna River. The actual mainstem of the Susquehanna recorded improving TP trends for all three analyses at Danville while showing no trends at Marietta or Towanda. Strong improving trends were apparent for DP at all sites except Marietta. A highly important trend is apparent when looking at DOP. Even though TP and DP were shown to be improving at most sites, DOP recorded degrading trends for all three analyses at Towanda, Danville, Newport, and Marietta. This indicated that the dissolved fraction of phosphorus was becoming more dominated by inorganic phosphorus. Danville, Lewisburg, and Conestoga each recorded improving trends for SS for all three analyses.

Table 28. List of Parameters Recording the Same Trend Result for Flow Adjusted Concentration, Flow Weighted Concentration, and LOAD

Parameter	Towanda	Danville	Lewisburg	Newport	Marietta	Conestoga
TN	Improving	Improving	Improving		Improving	
TON		Improving				Improving
DON					Degrading	
TNH_3	Improving	Improving	Improving		Improving	Improving
DNH_3		Improving		Improving	Improving	Improving
TKN	Improving	Improving	Improving	Improving	Improving	Improving
DKN	NS	Improving				Improving
TNOx	Improving				Improving	
DNOx	Improving				Improving	
TP	NS	Improving	Improving	Improving	NS	Improving
DP	Improving	Improving	Improving	Improving	NS	Improving
DOP	Degrading	Degrading		Degrading	Degrading	
TOC	NS		NS		NS	Improving
SS		Improving	Improving	NS	NS	Improving

Table 29. Trend Statistics for the Susquehanna River at Towanda, Pa., January 1989 through December 2002

Parameter	Storet Code	Time Series	P-Value	Slope Magnitude (%)		Trend Direction
				Minimum	Maximum	
Q	60	FLOW	0.19	-49	10	NS
TN	600	FAC	0.0000	-37	-27	IMPROVING
TN	600	FWC	0.0000	-27	-27	IMPROVING
TN	600	LOAD	0.0000	-58	-30	IMPROVING
DN	602	FAC	0.0000	-29	-18	IMPROVING
DN	602	FWC	0.0155	-34	-5	NS
DN	602	LOAD	0.0081	-58	-13	IMPROVING
TON	605	FAC	0.0018	-33	-9	IMPROVING
TON	605	FWC	0.030	-32	-2	NS
TON	605	LOAD	0.0159	-57	-9	NS
DON	607	FAC	0.2863	-7	26	NS
DON	607	FWC	.0111	-3	38	NS
DON	607	LOAD	0.5116	-39	28	NS
DNH_3	608	FAC	0.2764	-27	10	NS
DNH_3	608	FWC	0.12	-20	2	NS
DNH_3	608	LOAD	0.01	-48	-7	IMPROVING
TNH_3	610	FAC	0.002	-43	-11	IMPROVING
TNH_3	610	FWC	0.0000	-26	-26	IMPROVING
TNH_3	610	LOAD	0.0000	-60	-27	IMPROVING
DKN	623	FAC	0.8916	-12	16	NS
DKN	623	FWC	0.6	3	3	NS
DKN	623	LOAD	0.07	-40	2	NS
TKN	625	FAC	0.0024	-29	-7	IMPROVING
TKN	625	FWC	0.01	-26	-5	IMPROVING
TKN	625	LOAD	0.0000	-51	-16	IMPROVING
TNOx	630	FAC	0.0000	-40	-29	IMPROVING
TNOx	630	FWC	0.0000	-29	-29	IMPROVING
TNOx	630	LOAD	0.0000	-59	-33	IMPROVING
DNOx	631	FAC	0.0000	-41	-30	IMPROVING
DNOx	631	FWC	0.0000	-29	-29	IMPROVING
DNOx	631	LOAD	0.0000	-60	-33	IMPROVING
TP	665	FAC	0.4523	-22	11	NS
TP	665	FWC	0.28	-17	6	NS
TP	665	LOAD	0.03	-48	-3	NS
DP	666	FAC	0.002	-35	-9	IMPROVING
DP	666	FWC	0.01	-28	-4	IMPROVING
DP	666	LOAD	0.0000	-50	-20	IMPROVING
DOP	671	FAC	0.0000	228	486	Degrading
DOP	671	FWC	0.0000	262	425	Degrading
DOP	671	LOAD	0.0000	161	324	Degrading
TOC	680	FAC	0.3871	-9	4	NS
TOC	680	FWC	0.6815	-18	13	NS
TOC	680	LOAD	0.1448	-51	11	NS
SS	80154	FAC	0.2281	-38	12	NS
SS	80154	FWC	0.0000	-50	-13	IMPROVING
SS	80154	LOAD	0.02	-72	-11	NS

Table 30. Trend Statistics for the Susquehanna River at Danville, Pa., January 1985 through December 2002

Parameter	Storet Code	Time Series	P-Value	Slope Magnitude (%)		Trend Direction
				Minimum	Maximum	
Q	60	FLOW	0.38	-42	23	NS
TN	600	FAC	0.00	-39	-28	IMPROVING
TN	600	FWC	0.00	-24	-24	IMPROVING
TN	600	LOAD	0.01	-54	-13	IMPROVING
DN	602	FAC	0.00	-29	-18	IMPROVING
DN	602	FWC	0.0098	-28	-5	IMRPOVING
DN	602	LOAD	0.0315	-49	-4	NS
TON	605	FAC	0.00	-48	-29	IMPROVING
TON	605	FWC	0.0001	-39	-20	IMPROVING
TON	605	LOAD	0.0015	-57	-19	IMPROVING
DON	607	FAC	0.0293	-25	-2	IMPROVING
DON	607	FWC	0.3637	-19	8	NS
DON	607	LOAD	0.1444	-42	8	NS
DNH_3	608	FAC	0.00	-57	-35	IMPROVING
DNH_3	608	FWC	0.00	-56	-39	IMPROVING
DNH_3	608	LOAD	0.00	-69	-38	IMPROVING
TNH_3	610	FAC	0.00	-65	-46	IMPROVING
TNH_3	610	FWC	0.00	-58	-46	IMPROVING
TNH_3	610	LOAD	0.00	-72	-43	IMPROVING
DKN	623	FAC	0.00	-36	-16	IMPROVING
DKN	623	FWC	0.00	-22	-22	IMPROVING
DKN	623	LOAD	0.00	-52	-10	IMPROVING
TKN	625	FAC	0.00	-47	-30	IMPROVING
TKN	625	FWC	0.00	-31	-31	IMPROVING
TKN	625	LOAD	0.00	-58	-20	IMPROVING
TNOx	630	FAC	0.08	-28	-15	NS
TNOx	630	FWC	0.06	-12	-12	NS
TNOx	630	LOAD	0.00	-47	1	IMPROVING
DNOx	631	FAC	0.06	-28	-16	NS
DNOx	631	FWC	0.05	-13	-13	NS
DNOx	631	LOAD	0.00	-47	-1	IMPROVING
TP	665	FAC	0.00	-50	-29	IMPROVING
TP	665	FWC	0.01	-41	-24	IMPROVING
TP	665	LOAD	0.00	-62	-16	IMPROVING
DP	666	FAC	0.00	-53	-34	IMPROVING
DP	666	FWC	0.00	-40	-40	IMPROVING
DP	666	LOAD	0.00	-63	-29	IMPROVING
DOP	671	FAC	0.00	178	385	Degrading
DOP	671	FWC	0.00	121	257	Degrading
DOP	671	LOAD	0.00	63	244	Degrading
TOC	680	FAC	0.00	-29	-18	IMPROVING
TOC	680	FWC	0.0077	-27	-5	IMPROVING
TOC	680	LOAD	0.0337	-49	-3	NS
SS	80154	FAC	0.00	-66	-45	IMPROVING
SS	80154	FWC	0.00	-65	-36	IMPROVING
SS	80154	LOAD	0.01	-79	-23	IMPROVING

Table 31. Trend Statistics for the West Branch Susquehanna River at Lewisburg, Pa., January 1985 through December 2002

Parameter	Storet Code	Time Series	P-Value	Slope Magnitude (%)		Trend Direction
				Minimum	Maximum	
Q	60	FLOW	0.0105	-46	-8	DOWN
TN	600	FAC	0.0000	-32	-19	IMPROVING
TN	600	FWC	0.0001	-20	-20	IMPROVING
TN	600	LOAD	0.0001	-54	-31	IMPROVING
DN	602	FAC	0.0000	-25	-14	IMPROVING
DN	602	FWC	0.1410	-26	4	NS
DN	602	LOAD	0.0081	-58	-13	IMPROVING
TON	605	FAC	0.0000	-49	-25	IMPROVING
TON	605	FWC	0.0001	-47	-28	IMPROVING
TON	605	LOAD	0.0159	-57	-9	NS
DON	607	FAC	0.0006	-35	-11	IMPROVING
DON	607	FWC	0.0157	-17	-17	NS
DON	607	LOAD	0.5116	-39	28	NS
DNH_3	608	FAC	0.2940	-27	10	NS
DNH_3	608	FWC	0.0129	-14	-14	NS
DNH_3	608	LOAD	0.0001	-49	-25	IMPROVING
TNH_3	610	FAC	0.0066	-42	-8	IMPROVING
TNH_3	610	FWC	0.0001	-27	-27	IMPROVING
TNH_3	610	LOAD	0.0001	-56	-35	IMPROVING
DKN	623	FAC	0.0016	-36	-10	BMDL
DKN	623	FWC	0.0001	-25	-25	IMPROVING
DKN	623	LOAD	0.0001	-56	-34	IMPROVING
TKN	625	FAC	0.0001	-41	-16	IMPROVING
TKN	625	FWC	0.0001	-37	-22	IMPROVING
TKN	625	LOAD	0.0001	-61	-38	IMPROVING
TNOx	630	FAC	0.0000	-25	-12	IMPROVING
TNOx	630	FWC	0.1358	-9	-9	NS
TNOx	630	LOAD	0.0001	-46	-23	IMPROVING
DNOx	631	FAC	0.0000	-25	-13	IMPROVING
DNOx	631	FWC	0.1002	-9	-9	NS
DNOx	631	LOAD	0.0001	-47	-23	IMPROVING
TP	665	FAC	0.0001	-47	-19	IMPROVING
TP	665	FWC	0.0001	-38	-25	IMPROVING
TP	665	LOAD	0.0001	-62	-39	IMPROVING
DP	666	FAC	0.0000	-62	-45	IMPROVING
DP	666	FWC	0.0001	-53	-53	IMPROVING
DP	666	LOAD	0.0001	-71	-58	IMPROVING
DOP	671	FAC	0.0000	118	311	BMDL
DOP	671	FWC	0.0001	120	227	Degrading
DOP	671	LOAD	0.0001	59	123	Degrading
TOC	680	FAC	0.2552	-4	17	NS
TOC	680	FWC	0.5156	-9	21	NS
TOC	680	LOAD	0.1448	-51	11	NS
SS	80154	FAC	0.0179	-49	-6	IMPROVING
SS	80154	FWC	0.0001	-52.588	-28.332	IMPROVING
SS	80154	LOAD	0.0001	-73.964	-35.557	IMPROVING

Table 32. Trend Statistics for the Juniata River at Newport, Pa., January 1989 through December 2002

Parameter	Storet Code	Time Series	P-Value	Slope Magnitude (%)		Trend Direction
				Minimum	Maximum	
Q	60	FLOW	0.21	-37	10	NS
TN	600	FAC	0.0000	-17	-6	IMPROVING
TN	600	FWC	0.10	-7	-7	NS
TN	600	LOAD	0.03	-39	-3	NS
DN	602	FAC	0.0135	-12	-1	IMPROVING
DN	602	FWC	0.7077	-16	13	NS
DN	602	LOAD	0.2095	-41	12	NS
TON	605	FAC	0.0095	-32	-5	IMPROVING
TON	605	FWC	0.0472	-29	-1	NS
TON	605	LOAD	0.0373	-49	-2	NS
DON	607	FAC	0.6929	-15	11	NS
DON	607	FWC	0.6766	-13	24	NS
DON	607	LOAD	0.3518	-35	16	NS
DNH_3	608	FAC	0.0012	-41	-12	IMPROVING
DNH_3	608	FWC	0.00	-36	-18	IMPROVING
DNH_3	608	LOAD	0.00	-53	-23	IMPROVING
TNH_3	610	FAC	0.0000	-56	-30	BDML
TNH_3	610	FWC	0.00	-48	-36	IMPROVING
TNH_3	610	LOAD	0.00	-62	-38	IMPROVING
DKN	623	FAC	0.0072	-30	-5	BMDL
DKN	623	FWC	0.00	-17	-17	IMPROVING
DKN	623	LOAD	0.00	-43	-13	IMPROVING
TKN	625	FAC	0.0135	-28	-4	IMPROVING
TKN	625	FWC	0.00	-25	-5	IMPROVING
TKN	625	LOAD	0.00	-44	-11	IMPROVING
TNOx	630	FAC	0.0053	-14	-3	IMPROVING
TNOx	630	FWC	0.57	-3	-3	NS
TNOx	630	LOAD	0.06	-36	1	NS
DNOx	631	FAC	0.0242	-13	-1	IMPROVING
DNOx	631	FWC	0.84	-1	-1	NS
DNOx	631	LOAD	0.08	-35	3	NS
TP	665	FAC	0.0036	-34	-8	IMPROVING
TP	665	FWC	0.00	-29	-11	IMPROVING
TP	665	LOAD	0.00	-48	-14	IMPROVING
DP	666	FAC	0.0184	-31	-3	IMPROVING
DP	666	FWC	0.02	-25	-3	NS
DP	666	LOAD	0.00	-42	-13	IMPROVING
DOP	671	FAC	0.0000	135	334	Degrading
DOP	671	FWC	0.00	132	246	Degrading
DOP	671	LOAD	0.00	87	202	Degrading
TOC	680	FAC	0.0003	-25	-8	IMPROVING
TOC	680	FWC	0.0921	-27	2	NS
TOC	680	LOAD	0.0389	-47	-2	NS
SS	80154	FAC	0.5227	-30	20	NS
SS	80154	FWC	0.03	-32	-2	NS
SS	80154	LOAD	0.08	-55	5	NS

Table 33. Trend Statistics for the Susquehanna River at Marietta, Pa., January 1987 through December 2002

Parameter	Storet Code	Time Series	P-Value	Slope Magnitude (%)		Trend Direction
				Minimum	Maximum	
Q	60	FLOW	0.48	-30	18	NS
TN	600	FAC	0.0000	-29	-17	IMPROVING
TN	600	FWC	0.00	-25	-25	IMPROVING
TN	600	LOAD	0.00	-47	-16	IMPROVING
DN	602	FAC	0.0000	-22	-10	IMPROVING
DN	602	FWC	0.0013	-30	-9	IMPROVING
DN	602	LOAD	0.0520	-47	0	NS
TON	605	FAC	0.2576	-8	38	NS
TON	605	FWC	0.1288	-3	25	NS
TON	605	LOAD	0.9805	-30	44	NS
DON	607	FAC	0.0000	47	135	Degrading
DON	607	FWC	0.0001	54	108	Degrading
DON	607	LOAD	0.0054	16	128	Degrading
DNH_3	608	FAC	0.0059	-36	-7	IMPROVING
DNH_3	608	FWC	0.00	-33	-17	IMPROVING
DNH_3	608	LOAD	0.00	-46	-15	IMPROVING
TNH_3	610	FAC	0.0000	-49	-22	IMPROVING
TNH_3	610	FWC	0.00	-43	-31	IMPROVING
TNH_3	610	LOAD	0.00	-55	-28	IMPROVING
DKN	623	FAC	0.1069	-25	3	NS
DKN	623	FWC	0.00	-14	-14	IMPROVING
DKN	623	LOAD	0.02	-37	-4	NS
TKN	625	FAC	0.0004	-36	-12	IMPROVING
TKN	625	FWC	0.00	-26	-26	IMPROVING
TKN	625	LOAD	0.00	-47	-14	IMPROVING
TNOx	630	FAC	0.0000	-25	-11	IMPROVING
TNOx	630	FWC	0.00	-21	-21	IMPROVING
TNOx	630	LOAD	0.00	-45	-11	IMPROVING
DNOx	631	FAC	0.0000	-25	-11	IMPROVING
DNOx	631	FWC	0.00	-21	-21	IMPROVING
DNOx	631	LOAD	0.00	-45	-11	IMPROVING
TP	665	FAC	0.3103	-8	29	NS
TP	665	FWC	0.88	-10	10	NS
TP	665	LOAD	0.50	-33	21	NS
DP	666	FAC	0.1417	-4	32	NS
DP	666	FWC	0.14	8	8	NS
DP	666	LOAD	0.78	-22	20	NS
DOP	671	FAC	0.0000	868	1645	Degrading
DOP	671	FWC	0.00	755	1068	Degrading
DOP	671	LOAD	0.00	602	1078	Degrading
TOC	680	FAC	0.2909	-10	3	NS
TOC	680	FWC	0.2768	-19	6	NS
TOC	680	LOAD	0.3038	-39	16	NS
SS	80154	FAC	0.6180	-27	20	NS
SS	80154	FWC	0.05	-34	-1	NS
SS	80154	LOAD	0.18	-53	15	NS

Table 34. Trend Statistics for the Conestoga River at Conestoga, Pa., January 1985 through December 2002

Parameter	Storet Code	Time Series	P-Value	Slope Magnitude (%)		Trend Direction
				Minimum	Maximum	
Q	60	FLOW	0.00	-50	-13	Down
TN	600	FAC	0.0000	-25	-17	IMPROVING
TN	600	FWC	0.06	-25	0	NS
TN	600	LOAD	0.00	-50	-31	IMPROVING
DN	602	FAC	0.0051	-13	-3	IMPROVING
DN	602	FWC	0.9751	-21	27	NS
DN	602	LOAD	0.0003	-47	-34	IMPROVING
TON	605	FAC	0.0000	-44	-23	IMPROVING
TON	605	FWC	0.0001	-37	-15	IMPROVING
TON	605	LOAD	0.0001	-71	-47	IMPROVING
DON	607	FAC	0.6266	-17	12	NS
DON	607	FWC	0.4923	-12	30	NS
DON	607	LOAD	0.0118	-46	-8	NS
DNH_3	608	FAC	0.0000	-75	-62	IMPROVING
DNH_3	608	FWC	0.00	-72	-65	IMPROVING
DNH_3	608	LOAD	0.00	-84	-74	IMPROVING
TNH_3	610	FAC	0.0000	-77	-65	IMPROVING
TNH_3	610	FWC	0.00	-74	-68	IMPROVING
TNH_3	610	LOAD	0.00	-74	-68	IMPROVING
DKN	623	FAC	0.0000	-46	-28	IMPROVING
DKN	623	FWC	0.00	-41	-24	IMPROVING
DKN	623	LOAD	0.00	-64	-46	IMPROVING
TKN	625	FAC	0.0000	-52	-35	IMPROVING
TKN	625	FWC	0.00	-48	-36	IMPROVING
TKN	625	LOAD	0.00	-70	-51	IMPROVING
TNOx	630	FAC	0.0782	-13	1	NS
TNOx	630	FWC	0.84	-10	13	NS
TNOx	630	LOAD	0.00	-41	-20	IMPROVING
DNOx	631	FAC	0.092	-13	1	NS
DNOx	631	FWC	0.75	-10	15	NS
DNOx	631	LOAD	0.00	-40	-19	IMPROVING
TP	665	FAC	0.0365	-29	-1	IMPROVING
TP	665	FWC	0.00	-25	-8	IMPROVING
TP	665	LOAD	0.00	-58	-30	IMPROVING
DP	666	FAC	0.0000	-35	-20	IMPROVING
DP	666	FWC	0.01	-30	-6	IMPROVING
DP	666	LOAD	0.00	-55	-36	IMPROVING
DOP	671	FAC	0.0959	-25	3	NS
DOP	671	FWC	0.49	-19	11	NS
DOP	671	LOAD	0.00	-48	-26	IMPROVING
TOC	680	FAC	0.0000	-48	-35	IMPROVING
TOC	680	FWC	0.0001	-50	-28	IMPROVING
TOC	680	LOAD	0.0001	-71	-47	IMPROVING
SS	80154	FAC	0.0004	-50	-18	IMPROVING
SS	80154	FWC	0.00	-68	-49	IMPROVING
SS	80154	LOAD	0.00	-84	-57	IMPROVING

SUMMARY

Bimonthly and stormflow samples were collected during 2002 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, Pennsylvania. Collected samples were analyzed for various nitrogen and phosphorus species and SS.

Precipitation for 2002 was above average at all sites except Lewisburg, ranging from 4.25 inches above average at Towanda to 0.58 inches below average at Lewisburg. Precipitation amounts were highest during the spring followed by fall at all sites except Conestoga and Newport, which recorded highest amounts during fall followed by spring. This contradicts the long-term means that show the summer season as having the highest amounts for all sites except Newport. Although precipitation was at or above the long-term mean for all sites, the annual water discharge values for the southern four sites were below their respective long-term mean values, while Towanda and Danville discharges were slightly above average. Discharge values ranged from 103.2 percent of the long-term mean at Danville to 57 percent of the long-term mean at Conestoga.

Load and yield values for 2002 were lower than the respective long-term means values for TN, TP, and SS at all sites except for Marietta, which recorded higher 2002 values for loads and yields of TP. Although these results look meaningful, they only attain meaning when compared with the corresponding discharge values. 2002 percentage of long-term means of loads for TN, TP, and SS showed varied results when compared with the 2002 percentage of long-term means for discharge. TN percentage of long-term mean values showed improvements when compared to the long-term means of discharge at all sites except Newport. This indicated that, over the entire history of the program, improvements in TN loads have been made at these sites. Using the same comparison of long-term percentages of discharge and constituent, TP showed improving conditions at Towanda, Danville, and Lewisburg, while showing degrading conditions at Newport, Marietta, and Conestoga. SS improvements were shown at all sites except Newport. The largest improvements for SS were shown at Towanda, Danville, and Lewisburg, which support the reductions in TP shown for 2002.

Another way to attain meaning out of these load values is to compare them to a year of similar water discharge. Throughout the history of this program, the year that corresponds most to 2002 with regard to flow was 1992. 2002 flows ranged from 91.6 percent of the 1992 flows at Conestoga to 98.5 percent of 1992 flows at Danville. Regarding the well established rule that higher flows result in higher constituent loads, TN, TP, and SS loads for 2002 should be lower than the loads for 1992. This was observed to be the case for TN at all sites. The only other constituents to follow this rule were TP at Lewisburg and SS at Danville. TP at Marietta and Conestoga actually recorded 2002 values that were 155 percent of the 1992 values. This dramatic difference also was apparent for SS at these two sites. The 2002 SS values were 182 percent of the 1992 value at Marietta and 267 percent of the 1992 value at Conestoga. Comparison of 1992 and 2002 loads indicated that, although TN improvements were basin wide over this 10-year period, TP and SS improvements were not.

Analyzing the seasonal loads presents a good method of determining where the effects of flow were most apparent. Discharge for 2002 was highest during the spring season for all sites except Conestoga, which recorded significantly higher flows during the fall months, resulting in all constituents having highest load values during fall, as well. The most consistent pattern among the other sites was that TNH3, DNH3, and DOP seemed to be less dependent on flow. For all sites, except Conestoga, the highest seasons for these three constituents did not correspond with the highest flow season. Newport also showed variations with TN, DN, TNOx, and DNOx, but these can be attributed to a small flow difference between the spring and fall seasons.

When dividing the annual mean water discharge by the long-term mean discharge, a value termed the water-discharge ratio is obtained. This value is equivalent to the percentage of long-

term mean discharge referenced earlier. This value can then be used to plot the yield for a given year versus the water-discharge ratio. In order to extract meaning from this value, it must be compared to a previous record of data. To accomplish this, the initial five years for each site were used to develop a best-fit linear regression line, which was then used to form a baseline relationship between annual loads and discharge. By plotting a year's yield value along this line, any improvements or degradations can be revealed. When the 2002 values were compared to their respective baselines, most parameters showed improvements. TP for Conestoga and Marietta was the exception. Yield values for both sites plotted above the baseline values, indicating that phosphorus yields in these two watersheds are degrading.

Trend analysis of water quality parameters and flow data for all six sites were completed for the period 1985 to 2002. Trends results were reported for flow adjusted concentrations, flow weighted concentrations, monthly load, and flow. Significant improving trends were apparent for all three analytical methods for the parameters listed in Table 28. Degrading trends in DOP for all three analyses were found at all sites except Conestoga and Lewisburg. Degrading trends also were apparent for DON at Marietta. Decreasing trends for flow at Lewisburg and Conestoga also appeared. This is the first time during the entire history of the program that decreasing trends in flow were detected. These trends developed due to the multiple-year drought in the basin, which also may be the cause of many of the improving nutrient and SS trends shown for 2002.

The sediment and nutrient monitoring sites on the Susquehanna River will be one of the first places where water quality improvements will be observed due to Pennsylvania's restoration efforts. Because of the threat of a regulatory TMDL cited previously in this report, it will be extremely important to document this progress. Because of the delay time, it is almost certain that observable water quality improvements in the Bay will occur after improvements in the Susquehanna, and that biological responses in the Bay due to improved water quality will occur even later.

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