NUTRIENT AND SUSPENDED SEDIMENT TRANSPORTED IN THE SUSQUEHANNA RIVER BASIN, 2001, AND TRENDS, JANUARY 1985 THROUGH DECEMBER 2001

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ABSTRACT

Nutrient and suspended-sediment samples were collected in calendar year 2001 during base flow and stormflow conditions at six sites located across the Susquehanna River Basin. Samples were taken 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.

The Susquehanna River at Marietta had the highest loads for both nutrients and suspended sediment. The Susquehanna River at Danville had the next highest nutrient loads while the Susquehanna River at Towanda followed Marietta in suspended-sediment loads. While the Conestoga River at Conestoga had the smallest load, in pounds per year, it had the greatest yield, in pounds per acre per year, of total nitrogen, total phosphorus, and suspended sediment. Seasonal loads of nutrients and suspended sediment generally varied according to the variations in the seasonal water discharges.

Comparison of the 2001 annual yields and the 5-year baselines indicated that there were decreases of total nitrogen at all sites. Total phosphorus yields were higher than the baseline yields at Marietta, Towanda Newport, and Conestoga and remained the same at Lewisburg and Danville. Comparisons of suspend sediment yields indicated that there was an increase at Newport and Towanda and no change at the remaining four sites.

Trends were computed for the period January 1985 through December 2001 for flow, suspended sediment, total organic carbon, and several forms of nitrogen and phosphorus. Results were reported for monthly mean flow, monthly load, monthly flow-weighted concentration, and flow-adjusted concentration. The results showed improving conditions in total nitrogen throughout the Susquehanna River Basin. Total phosphorus showed no trend at Towanda and at Marietta while all other sites showed improving conditions in total phosphorus for 2001. Improving conditions in suspended sediment occurred at Danville and Conestoga while all other sites showed no trend.

INTRODUCTION

Nutrients and suspended sediment entering the Chesapeake Bay (Bay) from the Susquehanna River Basin contribute to nutrient enrichment problems in the Bay (USEPA, 1982). The Bureau of Laboratories in the Pennsylvania Department of Environmental Protection (Pa. DEP), the U.S. Environmental Protection Agency (USEPA), and the Susquehanna River Basin Commission (SRBC) cooperated in a study to quantify nutrient and suspended sediment 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. Normally, this action would result in development of a regulatory "total maximum daily load" or TMDL for the affected watershed. For the Bay, this would mean that the TMDL would have to address the upstream causes of impairment in all the states with land areas draining into the Bay, including Delaware, New York, and West Virginia, which did not sign the agreement in 1983 or in later years.

The success of USEPA's Chesapeake Bay Program is largely due to the cooperative nature of the partnerships involved. Although the Chesapeake Bay Program is taking the lead to coordinate the Bay restoration effort, the nonsignatory states are involved in the Bay cleanup through the Chesapeake Bay Water Quality Steering Committee, which was formed in August 1999. SRBC and the Interstate Commission on the Potomac River Basin both participate on the steering committee in an advisory capacity, but only the states, the District of Columbia, and USEPA have official voting status.

In addition to the steering committee work, the Chesapeake 2000 Agreement and a subsequent 6-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 thought to be the single greatest source of suspended sediment 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 during the period 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 suspended sediment showed year-to-year variability that was highly correlated with the variability of the annual water discharge (Ott and others, 1991; Takita, 1996, 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 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 are then used to compute annual nutrient and suspended-sediment 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 suspended sediment measured during calendar year 2001, and to compare the total nitrogen, total phosphorus, and suspended-sediment 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 2001 for nitrogen, phosphorus, suspended sediment, total organic carbon, 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 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° F (degrees Fahrenheit) near the Pennsylvania-Maryland border to 45° F in the northern part of the basin. Precipitation in the basin averages 39.15 inches per year, and is fairly well distributed throughout the year.

Land use in the Susquehanna River Basin is predominantly rural with woodland accounting for 65 percent; cultivated, 18 percent; urban, 9 percent; and grassland, 7 percent (Ott and others, 1991). 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. Most of the grassland is in the northern part of the basin as the shorter and more uncertain growing season is better suited to pasture and hay production. 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.

Most of the cultivated land is in the lower part of 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, NY and Scranton and Wilkes-Barre, PA. 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 Watershed in northern Pennsylvania and an area along the northern tier counties of eastern Pennsylvania.

Table 1. Data Collection Sites and Their Drainage Areas

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

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

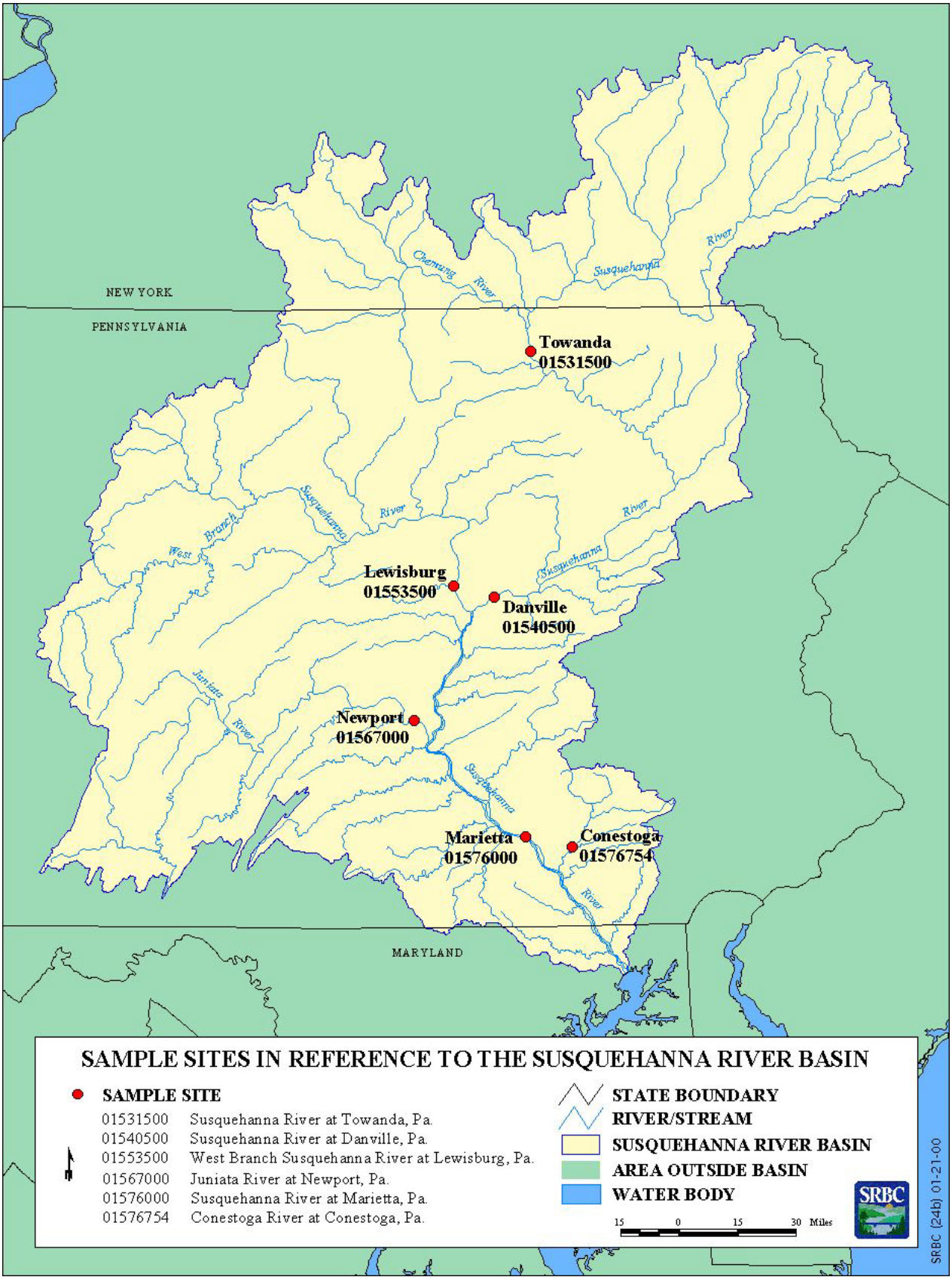

Figure 2. Locations of Sampling Sites on the Susquehanna River and Three Major Tributaries in the Basin

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.

SAMPLE COLLECTION AND ANALYSIS

SRBC staff collected samples at each of the six sites to measure nutrient and suspended-sediment concentrations during periods of low and high flow. Random samples were collected on or near the 12th of the month regardless of flow. Low flow samples were collected at the end of the month during base flow conditions. In the wake of high flow events, collection of low flow samples was delayed until moderate flows prevailed, typically 7 to 10 days. All low flow and random samples were collected by hand with depth-integrating samplers. Storm samples were also taken during high flow events throughout the year. Samples were collected with depth-integrating samplers from the start of the storm to the time when the flow receded to near its prestorm rate. An attempt was made to collect a sample at or near peak flow.

Whole-water samples were analyzed for total nitrogen species, total phosphorus, total organic carbon, and suspended sediment. A portion of each sample was filtered, and the filtrate was analyzed for dissolved nitrogen and phosphorus species. The samples for nutrient analysis were delivered to the Pa. DEP Laboratory in Harrisburg on the day following sample collection. The parameters and laboratory methods used are listed in Table 2. SRBC analyzed the samples collected for suspended-sediment concentration.

Table 2. 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	0.200	USEPA 350.1
Nitrogen (total)	Pa. DEP	Persulfate Digestion for TN	0.040	Standard Methods #4500-N_{org}-D
Nitrite plus Nitrate	Pa. DEP	Cd-reduction, Colorimetry	0.010	USEPA 353.2
Organic Carbon (total)	Pa. DEP	Wet Oxidation	0.100	USEPA 415.2
Orthophosphate (dissolved)	Pa. DEP	Colorimetry	0.002	USEPA 365.1
Phosphorus (dissolved)	Pa. DEP	Block Digest, Colorimetry	0.020	USEPA 365.3
Phosphorus (total)	Pa. DEP	Persulfate Digest, Colorimetry	0.020	USEPA 365.3

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 at the National Climatic Data Center in Asheville, North Carolina. Quarterly and annual precipitation data from these sources were summarized for 2001 for the Susquehanna River Watershed above Towanda and Danville, Pa., the West Branch Susquehanna Subbasin, the Juniata Subbasin, the Susquehanna River Watershed above Marietta, Pa., and the Conestoga River Watershed. This summary is shown in Table 3, along with the long-term mean precipitation values and departure from the long-term values. The 2001 annual precipitation was less than the long-term annual average at all six sites. Precipitation ranged from 19.75 inches below normal in the Juniata Subbasin to 4.46 inches below normal in the watershed above Towanda. Seasonal precipitation was below normal during all seasons for all stations except summer at Towanda, which was above average.

Table 3. Summary for Annual Precipitation for Selected Areas in the Susquehanna River Basin, Calendar Year 2001

		Average Long-term Precipitation	Calendar Year 2001 Precipitation	Departure From Long Term
		inches	inches	inches
Susquehanna River above Towanda, Pa.	January-March	7.96	6.95	-1.01
	April-June	9.98	8.82	-1.16
	July-September	10.22	10.48	+0.26
	October-December	8.70	6.15	-2.55
	Yearly Total	**36.86**	**32.40**	**-4.46**
Susquehanna River above Danville, Pa.	January-March	7.90	6.78	-1.12
	April-June	10.07	8.68	-1.39
	July-September	10.36	10.36	0
	October-December	8.72	6.03	-2.69
	Yearly Total	**37.05**	**31.85**	**-5.2**
West Branch Susquehanna River above Lewisburg, Pa.	January-March	8.90	5.75	-3.15
	April-June	11.38	9.08	-2.3
	July-September	11.53	10.19	-1.34
	October-December	9.38	5.6	-3.78
	Yearly Total	**41.19**	**30.62**	**-10.57**
Juniata River above Newport, Pa.	January-March	8.84	4.67	-4.17
	April-June	10.95	7.12	-3.83
	July-September	10.83	4.73	-6.1
	October-December	9.07	3.42	-5.65
	Yearly Total	**39.69**	**19.94**	**-19.75**
Susquehanna River above Marietta, Pa.	January-March	8.51	6.94	-1.57
	April-June	10.66	8.92	-1.74
	July-September	10.75	9.40	-1.35
	October-December	9.01	5.37	-3.64
	Yearly Total	**38.93**	**30.63**	**-8.3**
Conestoga River above Conestoga, Pa.	January-March	8.58	7.08	-1.5
	April-June	10.80	6.52	-4.28
	July-September	11.78	6.59	-5.19
	October-December	9.35	2.49	-6.86
	Yearly Total	**40.51**	**22.68**	**-17.83**

WATER DISCHARGE

Mean water discharges for calendar year 2001 are listed in Table 4, along with the long-term annual mean discharges and the percent of long-term annual mean discharge for each site. As shown in Table 4 and Figure 3, the annual mean water discharge was below normal for all sites. Streamflow ranged from 57.9 percent of the long-term mean at Conestoga to 72.8 percent at Towanda.

Table 4. Annual Water Discharge, Calendar Year 2001

Site Short Name	Years of Record	Long-term Annual Mean cfs[1]	2001 Mean cfs	2001 Percent of Long-term Mean
Towanda	88	10,617	7,727	72.8
Danville	97	15,224	11,067	72.7
Lewisburg	62	10,809	6,749	62.4
Newport	102	4,305	2,499	58.0
Marietta	70	37,038	24,378	65.8
Conestoga	17	634	367	57.9

[1] Cubic feet per second

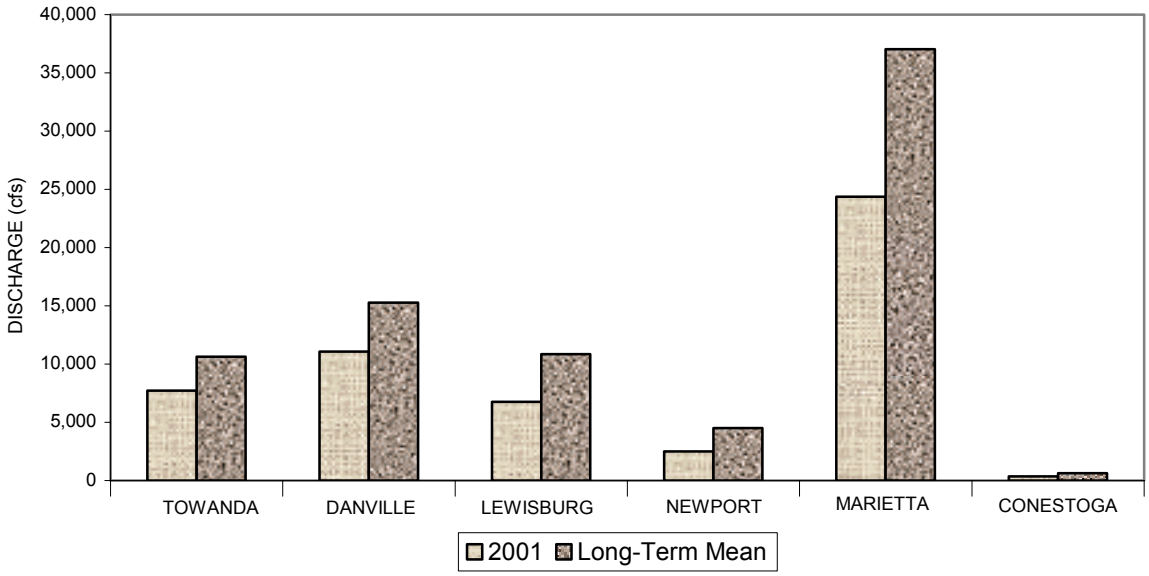

Figure 3. Annual and Long-Term Mean Water Discharge at Towanda, Danville, Lewisburg, Marietta, and Conestoga, Pa., Calendar Year 2001