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	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

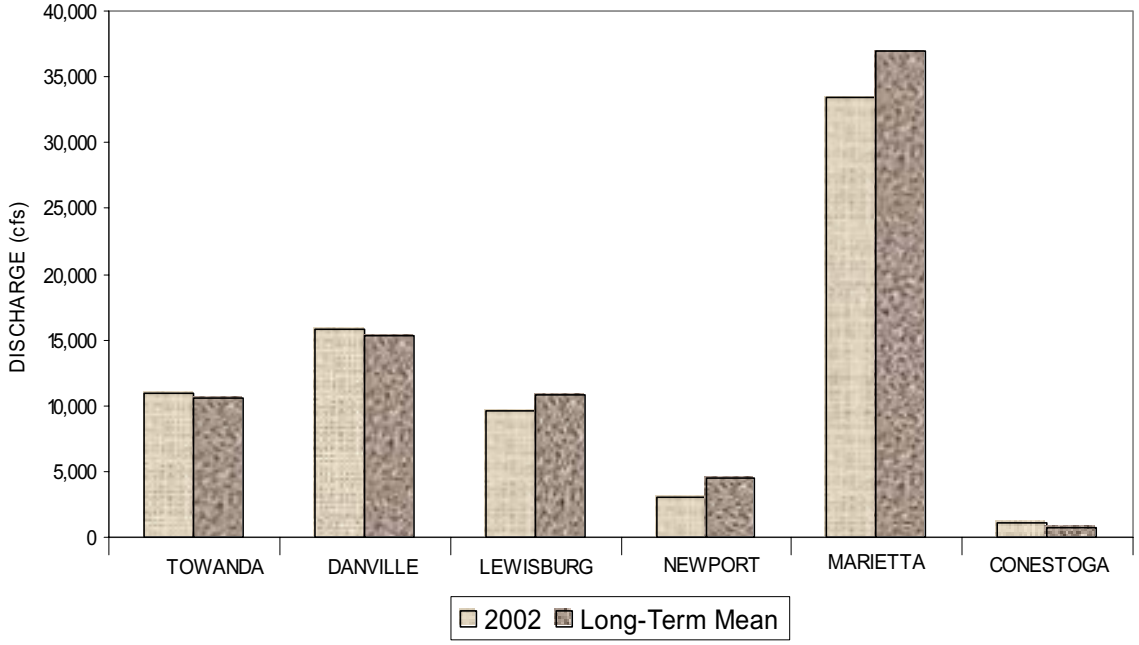

Figure 3. Annual and Long-Term Discharges at Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga, Pa.

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.

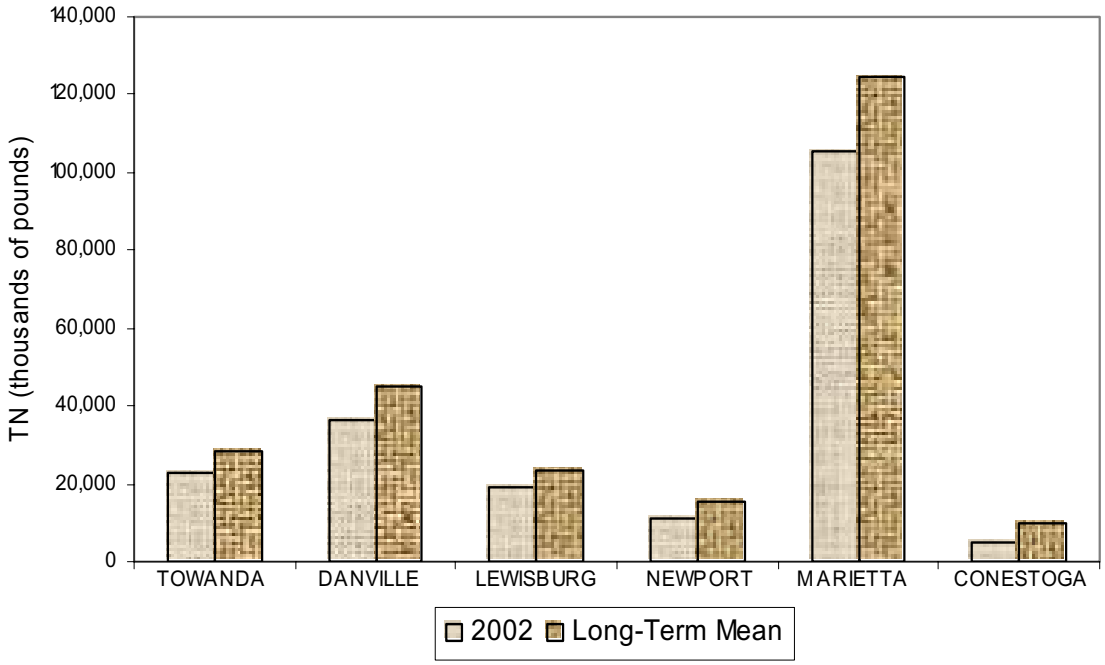

Figure 4A. Annual Loads of Total Nitrogen (TN) at Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga, Pa., Calendar Year 2002

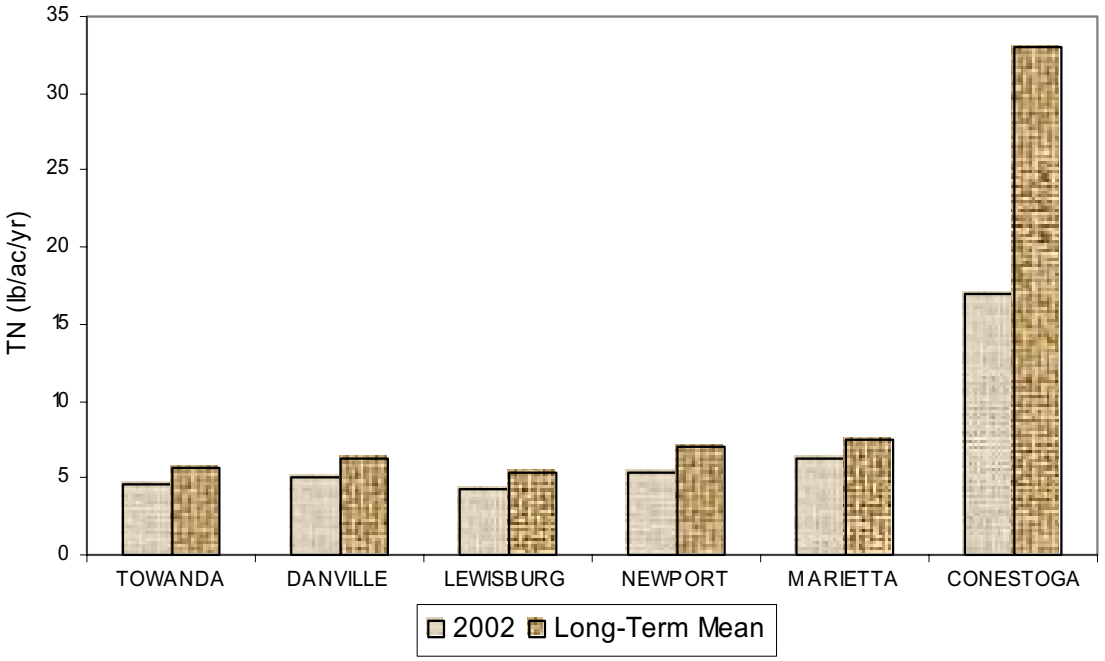

Figure 4B. Total Nitrogen (TN) Yields at Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga, Pa., Calendar Year 2002

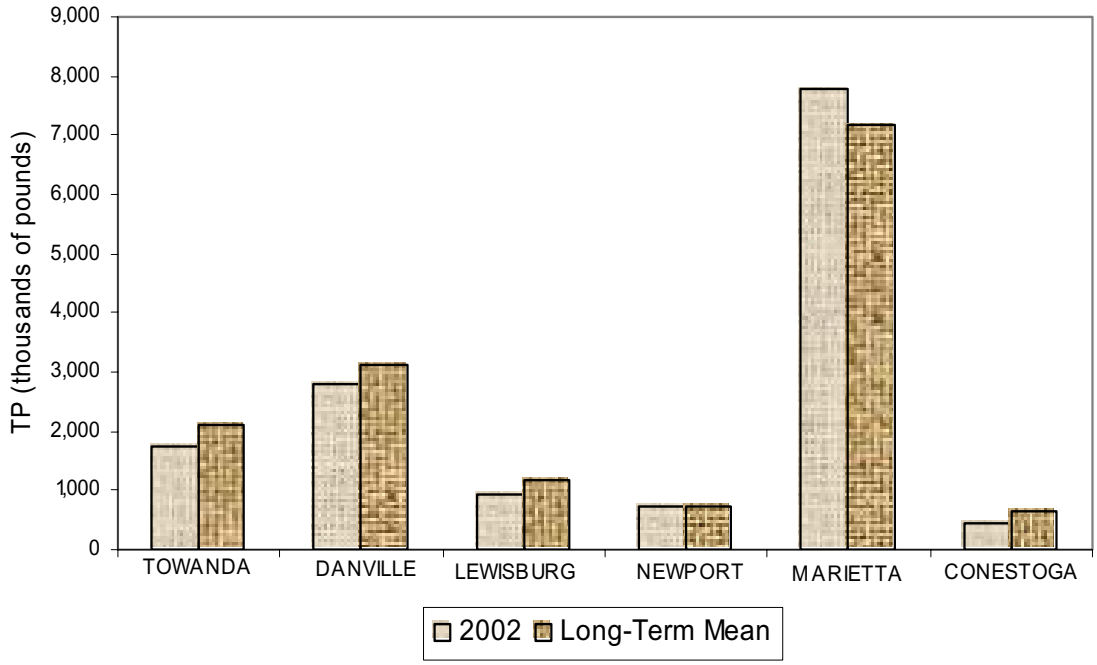

Figure 5A. Annual Loads of Total Phosphorus (TP) at Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga, Pa., Calendar Year 2002

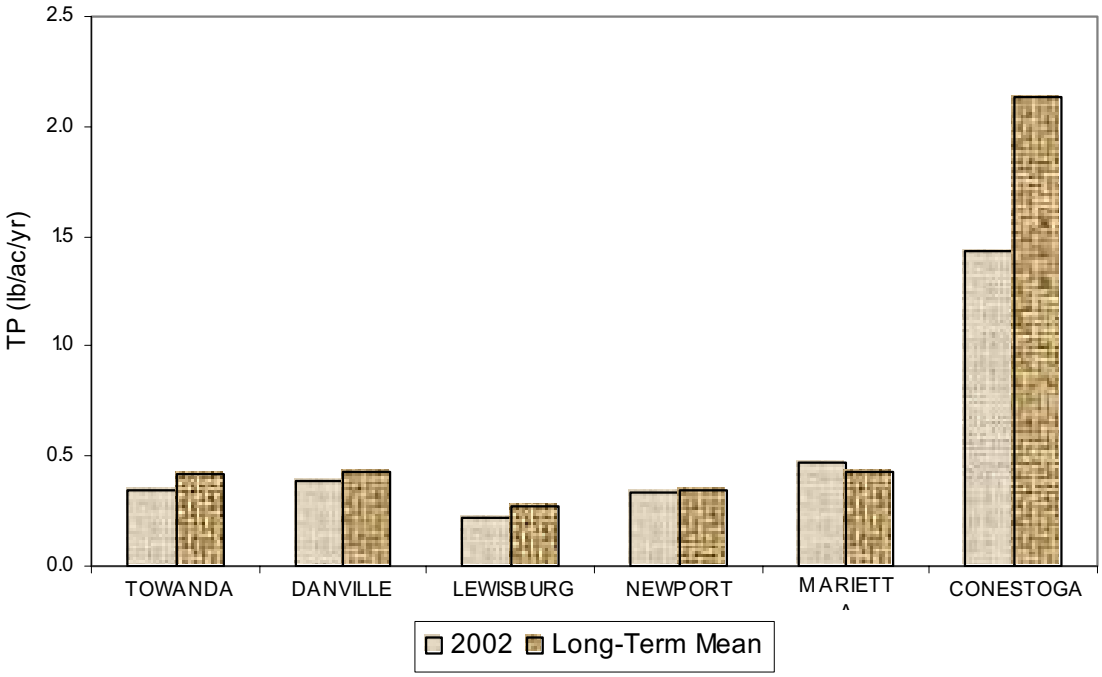

Figure 5B. Total Phosphorus (TP) Yields at Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga, Pa., Calendar Year 2002

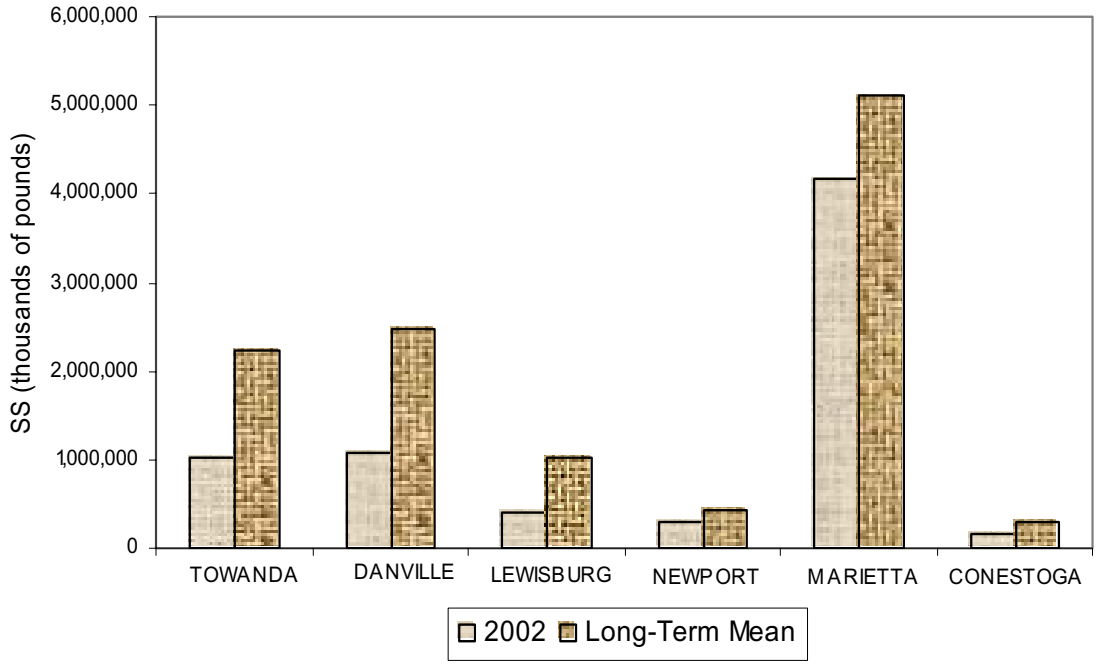

Figure 6A. Annual Loads of Suspended Sediment (SS) at Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga, Pa., Calendar Year 2002

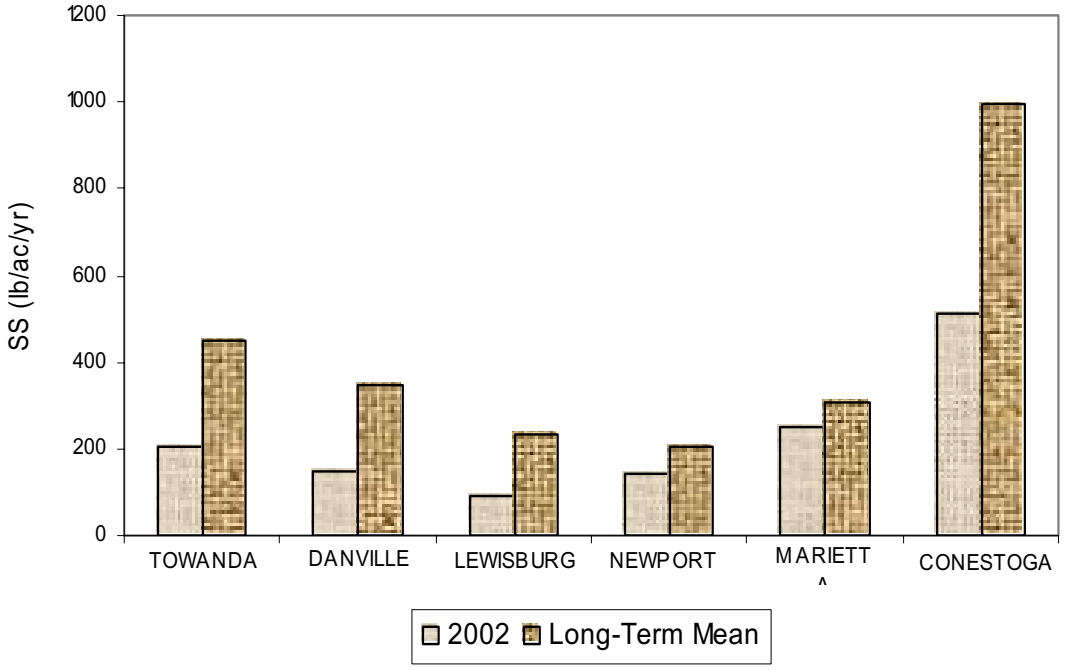

Figure 6B. Suspended Sediment (SS) Yields at Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga, Pa., Calendar Year 2002

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;