DISCUSSION

Nutrient and sediment loads for 2006 were influenced greatly by individual high flow events. In late June and early July, Tropical Storm Ernesto caused significant flooding in the northern portion of the basin. Figure 3 shows that high flows were recorded at Towanda and Danville, as well as at Conestoga in the southern basin area. Monthly flows ranged from 250 percent of the LTM at Conestoga to more than 350 percent of the LTM flow at Danville. These high flows produced large loads of TP and SS. Annual flows for the basin ranged from 81 percent of the LTM at Newport to 129 percent and 132 percent of the LTM at Towanda and Danville, respectively. Whereas TN loads were below LTM at theses sites, TP and SS loads were much higher at both Towanda and Danville. The southern sites, which were not affected as dramatically by Ernesto, had TP and SS loads that were well below the LTMs, including both Marietta and Newport. Conestoga showed similar results even though Ernesto did produce high flows in the watershed. Lewisburg had higher than LTM loads of TP and lower than LTM loads of SS. This is the opposite of what is expected, as usually TP and SS are positively correlated. These results may be due to the highly forested watershed nature of the West Branch Susquehanna Subbasin. Interestingly, TNH_3 and DNH_3 loads were higher than the LTMs for the three sites that had the lowest annual percentage of LTM for flow–Lewisburg, Newport, and Marietta–while Towanda and Danville had lower than the LTM loads of TNH_3 compared with higher than LTM flow values. The northern three sites, Towanda, Danville, and Lewisburg, showed dramatically higher loads of DP and DOP as compared to the LTMs. This is opposed to the three southern sites, which reported lower values for both when compared to their respective LTMs. TON loads were lower than the LTM for all sites.

Closer inspection of the loads at the seasonal level suggest that nearly all fractions of nitrogen, including TN, DN, TNH_3, DNH_3, DON, TNOx, and DNOx, had highest loads corresponding to the highest flow season during 2006, which was winter for all sites. At Towanda and Danville, TON, TP, TOC, and SS all had highest load values during the spring, which caught the beginning of Tropical Storm Ernesto. Conestoga showed the same pattern for all of these constituents, as well as TNH_3, DP, and DOP, which were highest during spring. This provides substantial evidence that whereas nitrogen tends to have the highest loads during extended periods of high flow, phosphorus, sediment, TOC, and TON tend to have their highest loads during very high individual peak flow events. This also can be seen upon closer inspection of Danville during the June 2006 and April 2005 storm events shown in Table 35.

Table 35. High Flow Events at Towanda and Danville, 2004-2006

Date	Peak Q	Daily Ave	Monthly Q	TN	TP	SS
Susquehanna River at Towanda						
Sep-04	154,000	127,000	27,943	4,122,557	1,157,923	3,274,241,652
Apr-05	162,000	146,000	37,744	6,612,034	1,254,475	2,861,470,602
Jun-06	141,000	138,000	25,666	3,545,918	1,204,632	4,288,922,530
Susquehanna River at Danville						
Sep-04	220,000	205,000	40,628	6,420,878	2,013,116	4,481,046,982
Apr-05	202,000	199,000	54,717	9,726,602	1,925,590	2,339,994,129
Jun-06	260,000	264,000	36,057	5,005,701	2,237,289	6,184,266,179

It has been well established that nutrient and sediment loads increase with increasing flow, but a closer look at these storms shows that high flows have an even more specific impact on loads when considering single high flow events. The April 2005 storm event had higher monthly average flow than the June 2006 storm event, whereas it had much lower values of instantaneous peak flow and peak average daily flow. The April storm, however, produced a much larger amount of TN while producing much lower loads of TP and SS. This suggests that consistent high flows produce higher amounts of TN, while single high flow events are the major producers of TP and SS. This makes sense as high flows produce higher energy waters that can erode soil and TP along with it.

This type of comparison also can be made comparing June 2006 and January 2006 for Marietta from Table 22. Monthly average flows were 58,620 cfs and 90,187 cfs for June and January, respectively. January had approximately 230 percent the TN load, 74 percent of the TP load, and 21 percent of the SS load as compared to June's loads. Some of this can be accounted for by seasonal variation of temperature, such as frozen versus thawed ground, but the numbers still suggest that TN is dependent upon high average flows, whereas TP, and more so SS, are dependent upon high peak flows. Another interesting comparison is between the high and low monthly loads at Danville. By dividing the highest monthly value of a parameter by the lowest monthly value of the same parameter, a measure of the range of the loads is obtained. At Danville, the differences between the high and low monthly values for the year were 706 percent for TN, 1,586 percent for TP, and 27,469 percent for SS. This means that the highest monthly load of TN was 706 times the size of the lowest monthly value, while the highest SS monthly load was 27,469 times the size of the lowest monthly load for SS. Clearly, there is a vast difference between TN and SS reactions to flow.

Considering that high flow affects these constituents differently, it would seem that managerial approaches to reducing TN and SS need to focus on different types of flows. Nutrient management practices that focus on nutrient reduction would be the best management practices for reducing TN whereas management practices that soften the surge of a fast and high hydrograph stage would be most effective at curbing SS. TP could be reduced by applying both nutrient reduction and flow amelioration techniques as reductions in SS also would result in reductions in TP.

Yields for 2006 at each site were compared with several different baselines, including an initial five year baseline, a baseline created from the first half of the site's dataset, one from the second half of the dataset, and one from the entire dataset. These comparisons indicated that 2006 yields for TP and SS at Towanda and Danville were higher than all the baselines predicted they should be for the given flow. Additionally, TP was higher at Lewisburg for all baseline comparisons. These values were due mostly to the high flows recorded in June 2006 when the majority of the loads of TP and SS were transported at these sites. This can be seen in Table 27, which compares seasonal yields with the initial five year baselines. Both spring and summer yields at Towanda and Danville were above the baselines. As mentioned before, the high flows from Tropical Storm Ernesto were spread over the end of June and beginning of July and, thus, likely accounted for the majority of these results.

Flows during the summer season are generally the lowest of the year. For 2006, however, flows were above the LTM at all sites except Newport, which was 83 percent of the LTM. Danville and Towanda had flows that were 248 percent and 259 percent of the LTM, respectively. Seasonal comparison with the initial baselines showed dramatic decreases in winter yields for SS. Additionally, dramatic reductions were found at Conestoga for both TP and SS during all seasons except spring. Interestingly, this was the time of highest flow at Conestoga, but still the SS yields compared with those predicted by the baselines, with the TP values being slightly higher. Given that the Conestoga River watershed is an area of high agricultural activity, this may be an indication of the success of erosion reducing management strategies. Large reductions also were implied by the baselines comparison of 2006 fall yields of TP and SS at Marietta and Newport.

The majority of the trends for 2006 remained unchanged from 2005. Specifically, Lewisburg and Conestoga recorded no changes from 2005 trends. Downward trends for TN, TP, and SS occurred at Conestoga, while TN and TP have downward trends at Lewisburg. Several trends that existed for the datasets from the beginning of monitoring at each site through 2005 were not found when analyzed through 2006. At Towanda, no trends were found for TP, DP, and TOC. The Danville 2005 downward trend in DP changed to a NS trend in 2006, while a new downward trend appeared for TNH_3, which previously did not show a trend due to greater than 20 percent of the values being BMDL. A 2005 degrading trend for TNOx changed to NS at Newport, while Marietta showed four new downward trends for DON, DNH_3, TP, and DP. Additionally, DOP has continued to show an increasing trend at all sites except for Conestoga, which has a downward trend, and Lewisburg, which had no trend due to greater than 20 percent of the data being BMDL.

Appendix A shows a graph of annual loads for all years for each parameter. Additionally, the LTM for each constituent load for all years is shown by a dotted line, and annual flow for each year is shown by a solid line with triangles. The graphs have been depicted so that improvements can be found by looking for a separation between the flow and loads plots. Such improvements can be seen when looking at the TN plots for Towanda and Danville, Figures 1 and 2, respectively. The graphs show the flow line at the top of the loads bars for the beginning years of the graph. In later years, they show that the loads have separated from the associated annual flows. Although this is a vague comparison, it does show valuable information implying that TN levels have decreased. In fact, all forms of nitrogen appear to have been reduced at both Towanda and Danville. Additionally, DON and TON have decreased over the given time periods at all sites except for DON at Conestoga, which has been increasing. These graphs indicate that all forms of phosphorus have either not changed or, as in the case of DOP, have increased at all sites except for Conestoga, which was the only site that indicated reductions in all forms of phosphorus as well as SS and TOC. Other common changes included decreasing loads of TNH_3 and DNH_3 at all sites except for Marietta, with improvements only in TON and DON over the time period. Towanda and Danville both show increases in SS loads over the past three years. However, this was mostly due to high peak flow events that occurred during each of the three years at these sites. Probably the most visually dramatic changes were shown for DOP. All sites except for Conestoga seem to show dramatic increases in DOP through the later years of each dataset.

When comparing the annual loads of TP and SS to the LTMs and flow, 2006 marks the third year in a row that both Towanda and Danville had increasing loads for both. Although each one of these years had a single high flow event that contributed a majority of the loads of these two constituents, the fact that this occurred three years in a row also has led to the loss of previous downward trends in TP and DP for Towanda and DP for Danville. Interestingly, although these are two of the three mainstem sites, the third and downstream site at Marietta has recorded new improving trends for both TP and DP through 2006. DOP also has continued to show degradations during the past several years with degrading trends continuing to show at four of the six sites, including Towanda, Danville, Newport, and Marietta. Improving conditions continue for TN at all six sites, regardless of the single high flow events that have been occurring in the northern basin.