2016 NUTRIENTS AND SUSPENDED SEDIMENT IN THE SUSQUEHANNA RIVER BASIN

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This report is prepared in cooperation with the Pennsylvania Department of Environmental Protection.

The Susquehanna River Basin Commission was created as an independent agency by a federal-interstate compact* among the states of Maryland and New York, the Commonwealth of Pennsylvania, and the federal government. In creating the Commission, the Congress and state legislatures formally recognized the water resources of the Susquehanna River Basin as a regional asset vested with local, state, and national interests for which all the parties share responsibility. As the single federal-interstate water resources agency with basinwide authority, the Commission's goal is to coordinate the planning, conservation, management, utilization, development, and control of Basin water resources among the public and private sectors.

**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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KEY FINDINGS

2016

- Rainfall range -2.5 inches below long-term mean (LTM) at Conestoga and -8.8 inches below LTM at Newport
- Minimum flow 63% of LTM at Newport, maximum flow 83% of LTM at Conestoga
- Highest daily rainfall at Conestoga was 3.82 inches in July
- Total Nitrogen, Total Phosphorus, and Suspended Sediment (TN, TP, and SS, respectively) loads below LTMs at all sites

Long-term

- Flow normalized trends in TN and TP are downward at all six long-term sites
- Flow normalized trends in SS concentration are downward at all six long-term sites
- Flow normalized trends in SS load are downward at all sites except Lewisburg

Short-term

- 5 years of below LTM flows (2012-2016) and associated nutrient and SS loads
- Recent annual flow normalized loads in:
  - Dissolved Nitrogen (DN) is decreasing at all sites except Towanda, which is unchanged
  - SS, Particulate Phosphorus and Particulate Nitrogen (PP and PN, respectively) are increasing at mainstem sites, Newport, and Lewisburg
  - DP is decreasing at Towanda, Danville, Lewisburg, and Newport
  - DP is increasing at Conestoga and unchanged at Marietta

BACKGROUND

In 1985, the Susquehanna River Basin Commission (Commission), as part of a joint effort with partners consisting of the United States Geological Survey (USGS), Pennsylvania Department of Environmental Protection (PADEP), and United States Environmental Protection Agency (USEPA) Chesapeake Bay Program Office (CBPO), implemented a rigorous sampling program to measure nutrient and sediment concentrations at strategic locations within the Susquehanna River Basin (SRB). Comparable sampling programs also were established in the Bay watershed's other tributary river basins as well as in tidal parts of the Chesapeake Bay estuary.

The current SRB network consists of six mainstem river and 20 tributary stations as depicted in Figure 1. The Susquehanna River Basin Non-Tidal Network (NTN) configuration includes five stations in New York, 20 in Pennsylvania, and one in Maryland. The individual NTN stations are categorized as either ***long-term*** (e.g., 6 stations established prior to 1990) or ***enhanced*** (e.g., 20 stations established since 2004).

Table 1 lists the individual SRB NTN long-term stations, along with subbasin, contributing drainage area, co-located USGS gage station number, and the distribution of major land use/land cover classes within the contributing drainage area.

Detailed information regarding the sample collection, processing, lab analyses, and data analyses are available at the updated program website at www.srbc.net. This report contains a summary of estimated nutrient and sediment pollutant loads and yields derived from continuous river flow estimates and pollutant concentrations measured from water samples collected during calendar year 2016 in the SRB. Additionally, the 2016 estimates of pollutant loads and yields are compared to the overall period of record. Long-term (~30-year) datasets are analyzed for trends. Detailed results are listed by site in Appendix A.

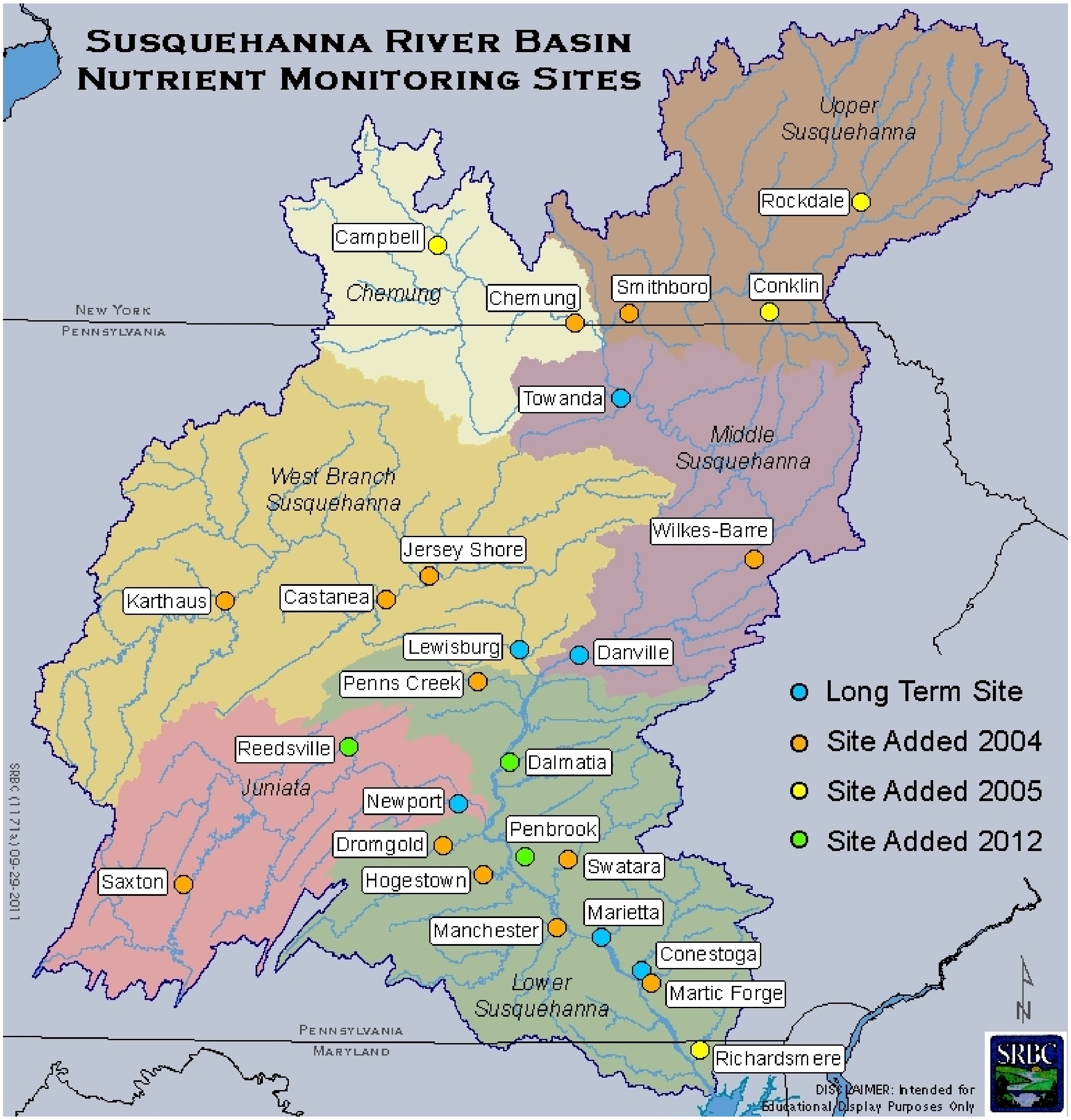

Figure 1. Sediment and Nutrient Monitoring Sites

Table 1. Data Collection Sites and Their Drainage Areas and 2006 Land Use Percentages

Site Location	USGS Site ID	Drainage Area (Sq. Mi.)	Water/ Wetland	Urban	Agricultural			Forest	Other
					Row Crops	Pasture Hay	Total		
Towanda	01531500	7,797	4.1	2.5	10.2	20.2	30.3	62.9	0.14
Danville	01540500	11,220	3.7	3.3	11.2	18.2	29.4	63.4	0.24
Lewisburg	01553500	6,847	0.9	2.0	5.7	7.4	13.1	83.4	0.66
Newport	01567000	3,354	1.0	3.1	13.2	9.4	22.6	73.2	0.13
Marietta	01576000	25,990	2.4	3.9	12.6	13.3	25.9	67.4	0.35
Conestoga	01576754	470	1.3	20.7	41.6	9.2	50.8	26.7	0.53

FINDINGS

Annual precipitation and discharge are the primary drivers of nutrient and sediment loads. Figure 2 includes a set of charts that summarize 2016 seasonal and annual precipitation and discharge at the six long-term stations in comparison to the respective long-term (~30-year) means. 2016 was the fifth consecutive year with below average precipitation and flow. Precipitation was fairly well distributed temporally and comparable to long-term mean (LTMs). Highest daily rainfall occurred in October at Towanda, Danville, Lewisburg, and Marietta, January at Newport, and July at Conestoga. Conestoga recorded the highest daily rainfall with 3.82 inches falling on July 14. Flow was highest during February at all sites. Summer was the lowest flow season at all sites.

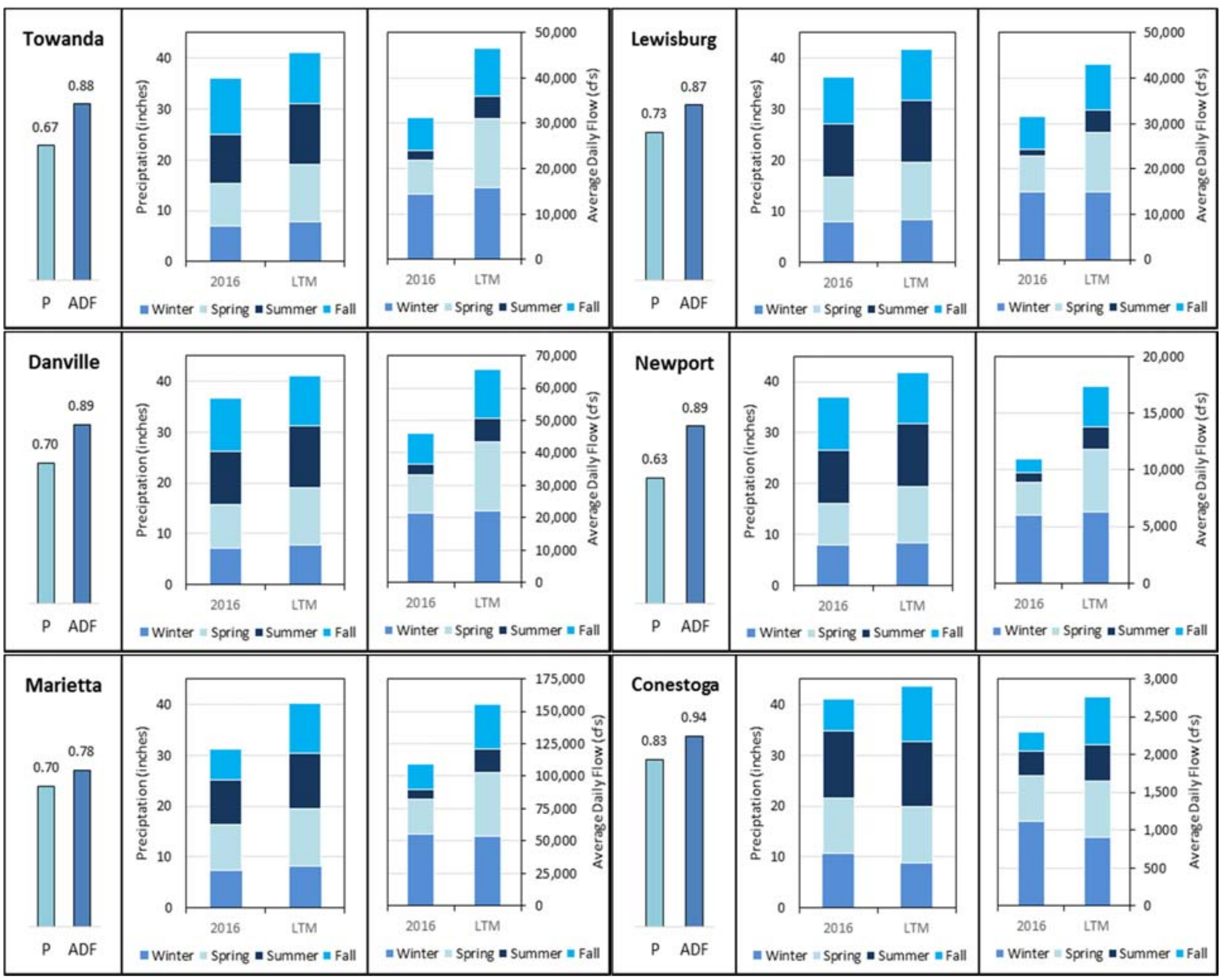

Figure 2. Precipitation and Average Daily Flow (ADF) Seasonal and Annual Statistics for 2016

Load, yield, and trend data for all sites and parameters are presented in Appendix A. Figure 3 compares the 2016 LTM ratios for discharge, total nitrogen (TN), total phosphorus (TP), and suspended sediment (SS) loads at all sites. LTM ratios are derived by dividing the annual result by the LTM for a given parameter. 2016 was the fifth consecutive year with below LTM flows ranging from 63 percent of the LTM at Newport to 83 percent of the LTM at Conestoga. As expected, nutrient and SS LTM ratios also were below their respective LTMs with the largest deviation occurring for SS. Figure 4 shows historical LTM ratios for flow, non-flow normalized SS load, and flow normalized SS load at Marietta. During the last decade, eight years had below LTM flow and nine years had below LTM SS, TN, and TP loads. This period of low flows and loads of nutrient and SS, along with management actions in the watershed, have led to documented improvements in the Bay.

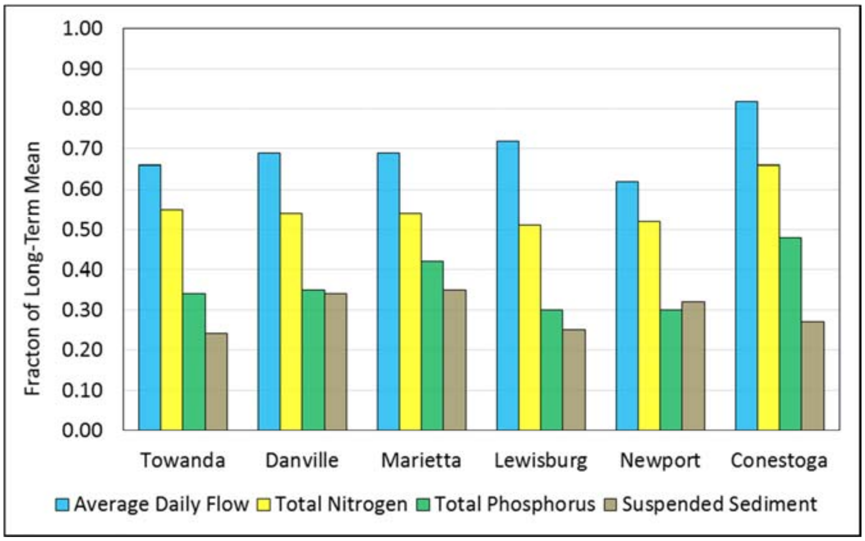

Figure 3. ***2016 Annual Pollutant Loads and Discharge for Group A NTN Monitoring Stations as Fractions of the Long-Term Mean***

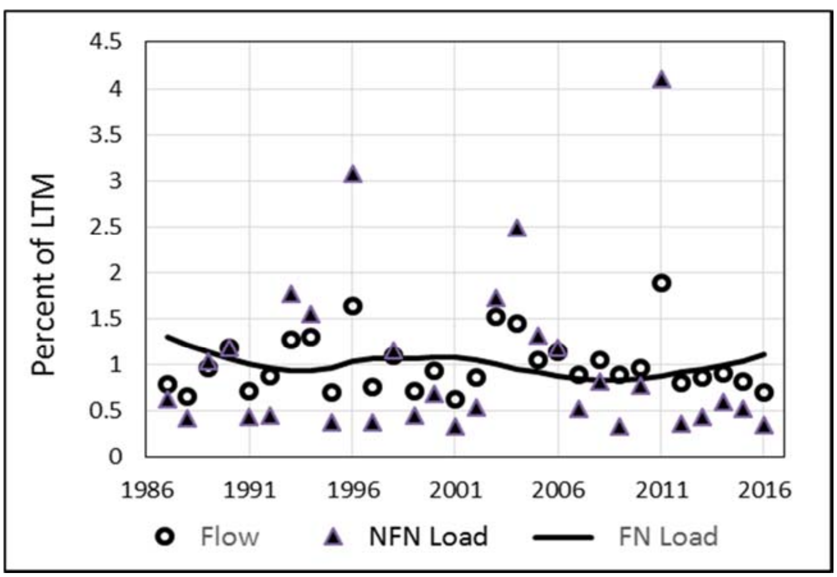

Figure 4. ***Annual Flow, Non-Flow Normalized (NFN), and Flow Normalized (FN) SS Loads at Marietta***

Figure 5 shows the results of 2016 flow normalized trends analyses. Long-term flow normalized trends in load and concentration for TN and TP were downward at all sites. Trends for SS were downward at Towanda, Danville, Newport, Marietta, and Conestoga. Upward trends in flow normalized SS load were found at Lewisburg. Figure 6 shows a more detailed view of the changes in flow normalized SS loads that have occurred at long-term sites. Although downward long-term trends were found at most sites, evidence for increasing loads in the most recent years is apparent.

As mentioned, annual precipitation and stream flow are the main drivers of nutrient and sediment loads. And because nine of the most recent ten years had below-LTM flow, recently-observed lower pollutant loads were likely related to below-normal discharge. Flow-normalizing data, i.e. accounting for and removing the influence to load caused by flow, emphasizes the effects of management activities in the watershed. Resource managers are cautioned to consider the effectiveness of past/current pollutant-reduction activities for watersheds with near-term increases in flow-normalized loads. Such circumstances invite justified skepticism as to whether overall pollutant-reduction management design is: (i) effective (*enough or at all*); (ii) effective, yet lagging (i.e., some designs become more effective through time); (iii) effective, yet being outpaced by changes elsewhere (e.g., development, climate, and population); or, (iv) missing over-looked pollutant sources and/or processes in the watershed.

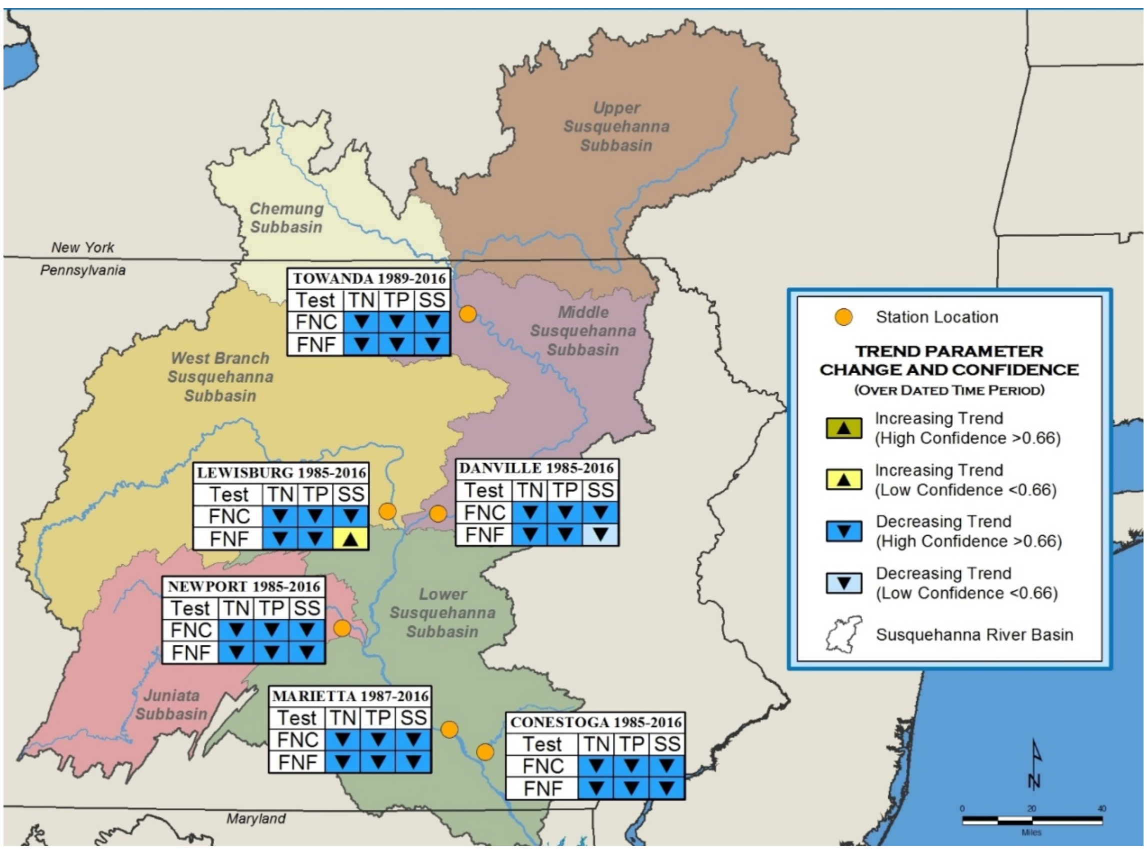

Figure 5. Flow Normalized Trends in Loads and Concentrations

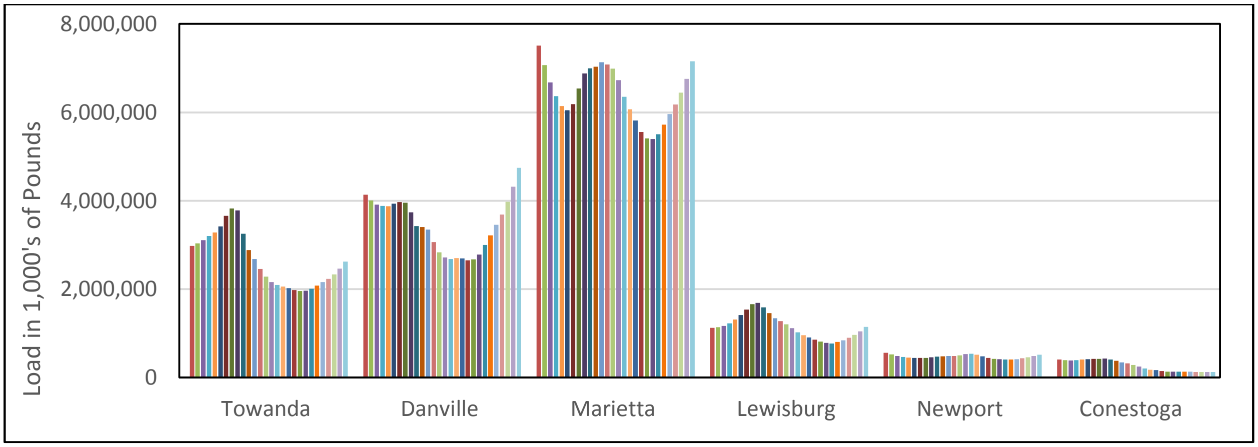

Figure 6. 1989-2016 Annual Flow Normalized SS Loads (Each colored bar represents 1 year)

A major factor in rising sediment loads, as compared to nutrient loads, is the physical nature of sediment particles and the dynamics of sediment transport. Because "suspended sediment" means physical particles comprised of varying densities, shapes, and sizes, as opposed to molecules dissolved in water (e.g., nutrients), movement only occurs once energy thresholds are crossed that lift and entrain each particle into the water column. Sediment transport energy is provided by high flow; typically, storm events.

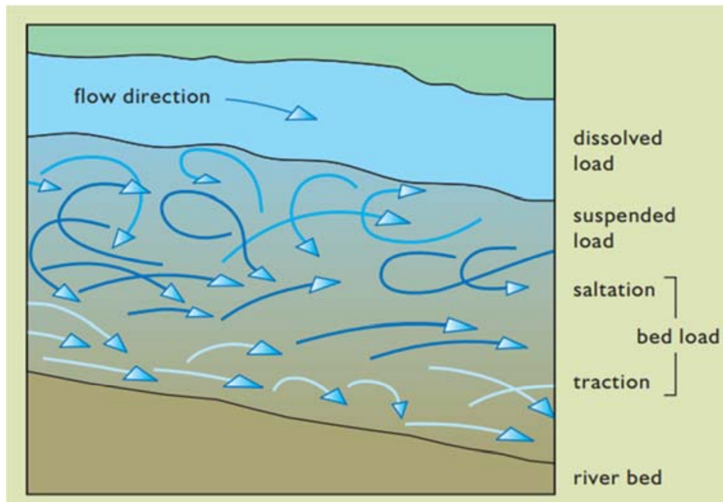

Figure 7. Instream Sediment Load Types (Loucks, 2005)

Once suspended, particles move differently and independently from dissolved and emulsified substances as shown in Figure 7. The general forms of motion that comprise sediment transport are governed by complex interactions among: (i) flowing water; (ii) the shape and form of bed and banks; (iii) physical traits of mobile particles; as well as, (iv) the available supply of suspendable particles. Perhaps more than any abiotic part of the system, suspended sediment exemplifies the sentiment attributed to the ancient Greek philosopher Heraclitus (544-483 b.c.e.) that, "*it is not possible to step twice into the same river*." For a given high flow event, the composition of suspended sediment changes moment-by-moment and from place-to-place. Moreover, each successive event is unlike every preceding one. Although unique due to infinite variability, the overall pattern is that a handful of the highest flow events dominate sediment mass transport through time.

The impact of specific storm events on sediment and nutrient transport is confounded by a multitude of factors including rainfall intensity, duration, and amount as well as preceding hydrological conditions. Figure 8 shows a comparison of daily rainfall, daily mean flow, and month SS concentrations at Conestoga throughout 2011 and 2016. These two years are shown as they represent very distinct years regarding rainfall and flow totals; 2011 was a high flow year and 2016 was a below LTM flow year. A point of similarity exists between these two years in that the peak rainfall events were comparable; i.e., 3.96 inches in September 2011, and 3.82 inches in July 2016. The major difference being that the event in 2011 resulted in a large increase in stream flow and transported the vast majority of the annual sediment load. In contrast, the 2016 event had minimal effect on flow and sediment. From this single comparison, the results suggest that the preceding hydrologic conditions can be more influential than the size and intensity of an individual storm. The September 2011 rainfall produced by Tropical Storm Lee was preceded by 3.18 inches of rain two weeks earlier from Hurricane Irene. This preliminary storm magnified the effects of T.S. Lee, dramatically increasing the events effect on flow and associated SS load. This type of "piggybacking" of storms overwhelms existing management practices.

Additionally, there is the complication of "legacy pollutant accumulations" attributable to prior land and waterway practices. Human behaviors related to sediment and nutrient pollution have evolved and it is tempting to believe that "improved" practices have overridden the effects of antiquated ones. Nutrient processing and sediment transport processes unfold across a history that spans many orders of magnitude; from near-instantaneous biologically-mediated reactions to geologic time scale. For current management strategies and tactics to produce desired outcomes it is necessary that such measures are developed with a strong scientific understanding of the actual processes underway. To such end, the overall management approach must balance realistic implementation constraints with actual conditions – critical source areas, disproportionality, concentrated water flow settings, sensitive receptors, non-compliant and antagonistic stakeholders, etc. – such factors can be expected to interfere with design outcomes.

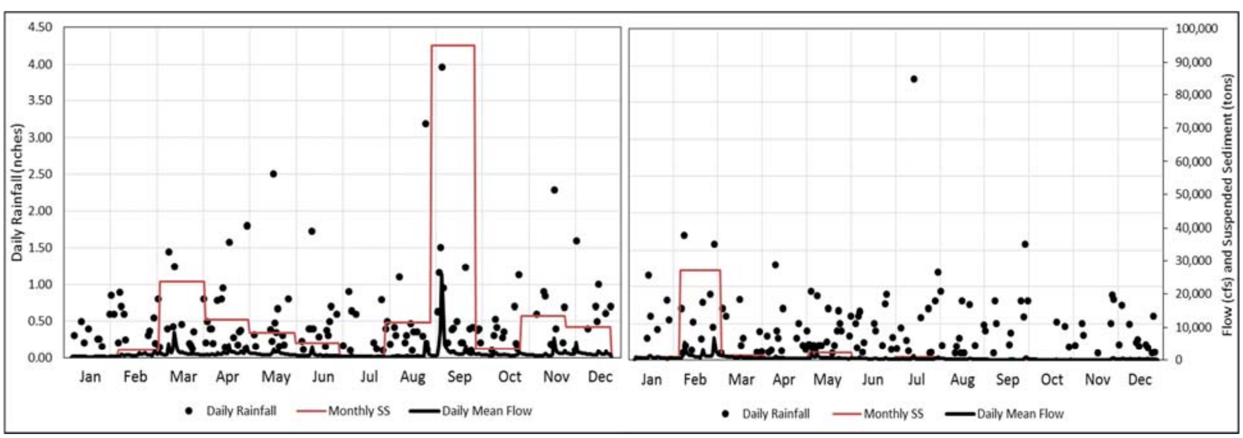

Figure 8. Daily Rainfall, Flow, and Monthly SS Load During 2011 (left) and 2016 (right) at Conestoga

Unfortunately, the effects of these types of high flow events are not isolated to SS. Phosphorus is also increased due to its tendency to bind to sediment particles. Figure 9 shows flow normalized loads of particulate and dissolved phosphorus (PP and DP, respectively) at the six long-term sites. All sites show increases in PP that coincide with the SS changes in Figure 6. This makes sense as phosphorus management typically focuses on minimizing erosion. Of additional interest is that DP at Conestoga appears to be increasing during the past decade while Marietta has remained unchanged. Since Danville, Lewisburg, and Newport show declining DP over the same time period, the leveling off of DP at Marietta may be a result of phosphorus levels in the Lower Susquehanna Watershed.

In contrast to TP and SS, TN loads generally have a more linear and predictable response to changes in flow. TN has shown the most consistent long-term trend of all parameters at all sites although a closer look at the dissolved and particulate fractions shows some variation. Figure 10 shows PN and DN at all six sites. Subtle increases in PN are apparent at all sites as are reductions in DN. This implies that high flow events are having a larger impact on PN similar to the effects they have on PP and SS. Although the PN and DP fractions represent a small portion of TN and TP, they do represent a fraction that is on the rise and as such are a good target for management action. Enhancing stormwater retention/diversion/treatment and coupling nutrient/manure application decisions to soil phosphorus test results as well as actual crop yields could lead to reductions in all three parameters.

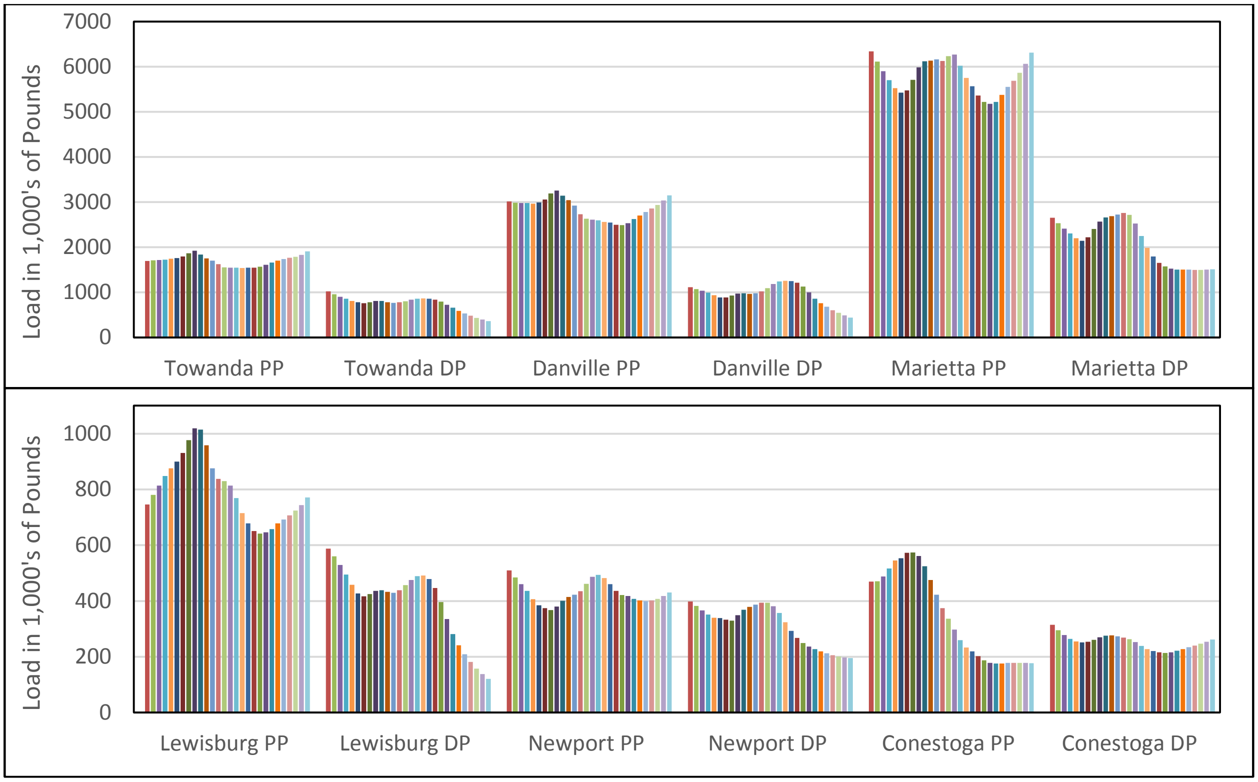

Figure 9. Flow Normalized Loads of Particulate and Dissolved Phosphorus

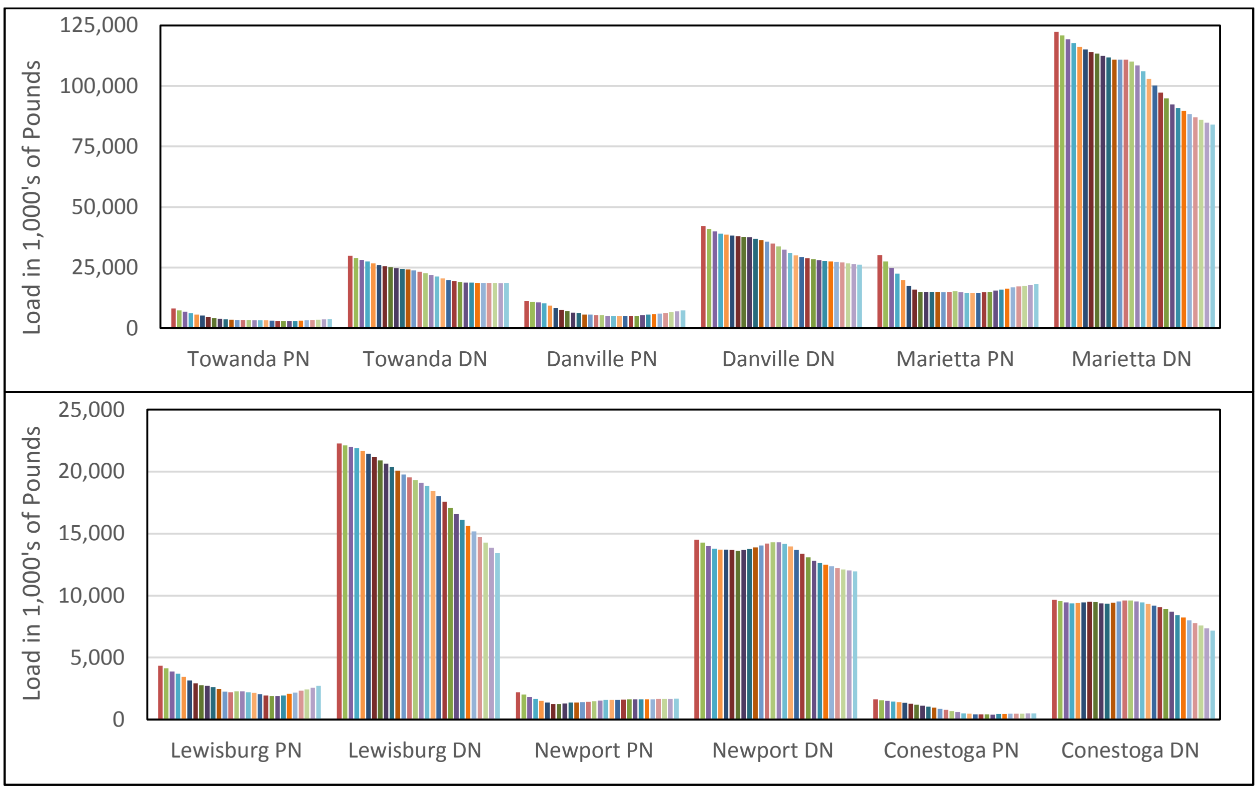

Figure 10. Flow Normalized Loads of Particulate and Dissolved Nitrogen

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APPENDIX A

Individual Long-Term Site Data

INDIVIDUAL SITES: TOWANDA

Table A1. 2016 Annual and Seasonal Precipitation and Discharge at Towanda

Season	Precipitation (inches)			Discharge (cfs)		
	2016	LTM	LTM Departure	2016	LTM	% LTM
January-March (Winter)	7.08	7.76	-0.68	14,386	15,837	0.91
April-June (Spring)	8.19	11.31	-3.12	7,614	15,199	0.50
July-September (Summer)	9.63	12.00	-2.37	2,056	4,876	0.42
October-December (Fall)	11.11	9.94	1.17	7,228	10,479	0.69
Annual Total	36.01	41.01	-5.01	7,785	11,568	0.67

Table A2. 2016 Annual Loads (1000's lbs), Yields (lbs/acre), and Concentrations (mg/L) at Towanda

Parameter	Load	Load % of LTM	Yield	LTM Yield	Conc	FNC
TN	14,539	55%	2.92	5.31	0.85	0.881
TNO_x	9,360	62%	1.88	3.01	0.526	0.533
TON	4,986	49%	1.00	2.06	0.312	0.335
TNH_3	607	48%	0.12	0.26	0.0322	0.0359
DN	13,033	58%	2.62	4.51	0.748	0.765
DNO_x	9,372	63%	1.88	2.98	0.527	0.534
DON	3,273	48%	0.66	1.37	0.207	0.212
DNH_3	601	57%	0.12	0.21	0.0322	0.0352
TP	807	34%	0.162	0.481	0.0392	0.0513
DP	223	30%	0.045	0.150	0.0147	0.0152
DOP	168	39%	0.034	0.085	0.00985	0.0106
TOC	47,745	57%	9.59	16.76	2.84	3.15
SS	577,152	24%	115.90	491.52	16.8	36.6

Table A3. 2016 Monthly Total Precipitation (in), High Daily Average Precipitation During Month (in), Flow (cfs), Loads (1000's lbs), and Yields (lbs/acre) at Towanda

Mon	Precip			Flow		TN			TP			SS		
	Ave	Max	LTM	2015	LTM	Load	Yield	LTM	Load	Yield	LTM	Load	Yield	LTM
Jan	1.57	0.50	2.51	12,338	90%	2,132	0.43	70%	108	0.022	42%	66,374	13.3	22%
Feb	3.89	1.07	2.23	18,775	159%	3,188	0.64	132%	243	0.049	171%	254,707	51.1	236%
Mar	1.62	0.55	3.02	11,864	55%	2,007	0.40	44%	84	0.017	22%	44,614	9.0	10%
Apr	2.90	0.71	3.41	12,024	49%	1,816	0.36	38%	97	0.020	21%	74,184	14.9	12%
May	2.56	0.42	3.51	7,958	64%	1,099	0.22	49%	54	0.011	30%	31,753	6.4	19%
Jun	2.73	0.70	4.39	2,848	33%	330	0.07	24%	16	0.003	11%	5,071	1.0	4%
Jul	3.18	0.73	4.02	1,479	28%	164	0.03	19%	9	0.002	10%	2,013	0.4	3%
Aug	4.74	0.85	3.92	3,415	82%	419	0.08	63%	27	0.005	34%	11,867	2.4	15%
Sept	1.70	0.37	4.06	1,248	24%	140	0.03	17%	6	0.001	4%	1,162	0.2	1%
Oct	5.92	1.83	3.79	4,299	62%	584	0.12	49%	34	0.007	28%	17,984	3.6	18%
Nov	1.79	0.30	3.17	4,874	47%	670	0.13	36%	24	0.005	14%	6,385	1.3	5%
Dec	3.40	0.61	2.98	12,433	91%	1,990	0.40	75%	104	0.021	48%	61,039	12.3	35%

Table A4. Flow and Flow Normalized Trends at Towanda

Towanda	Trend Test	Change	Likelihood Test		
Parameter/code			Value	Descriptor	Trend
FLOW / 60	SMK	-	-	-	NS
TN / 600	FNC	-0.60	0.99	HL	Down
	FNF	-7.08	0.99	HL	Down
TNOx / 630	FNC	-0.31	0.99	HL	Down
	FNF	-3.25	0.99	HL	Down
TON / 605	FNC	-0.21	0.99	HL	Down
	FNF	-3.09	0.99	HL	Down
TNH_3 / 610	FNC	-0.02	0.97	HL	Down
	FNF	-0.35	0.97	VL	Down
DN / 602	FNC	-0.461	0.99	HL	Down
	FNF	-5.13	0.99	HL	Down
DNOx / 631	FNC	-0.31	0.99	HL	Down
	FNF	-3.22	0.99	HL	Down
DON / 607	FNC	-0.11	0.99	HL	Down
	FNF	-1.64	0.99	HL	Down
DNH_3 / 608	FNC	-0.018	0.97	HL	Down
	FNF	-0.25	0.93	VL	Down
TP / 665	FNC	-0.036	0.99	HL	Down
	FNF	-0.20	0.84	L	Down
DP / 666	FNC	-0.029	0.99	HL	Down
	FNF	-0.30	0.99	HL	Down
DOP / 671	FNC	-0.0009	0.66	ALAN	Down
	FNF	0.021	0.66	ALAN	UP
TOC / 680	FNC	-0.45	0.97	HL	Down
	FNF	-0.087	0.58	ALAN	Down
SSC / 80154	FNC	-2.99	0.74	L	Down
	FNF	-162.6	0.71	L	Down

Trend period (Water Year) = 1989-2016
FNC – Flow Normalized Concentration – mg/L
FNF – Flow Normalized Flux – 10^6 kg/yr
FNC/FNF alpha level – 0.1
SMK – Seasonal Mann-Kendall for flow trends, alpha level – 0.05

NS – Not significant, UP – Increasing trend, DOWN – Decreasing trend
HL – Highly Likely ≥0.95 and ≤1.00
VL – Very Likely ≥0.90 and <0.95
L – Likely ≥0.66 and <0.90
ALAN – About as Likely as Not >0.33 and <0.66

INDIVIDUAL SITES: DANVILLE

Table A5. 2016 Annual and Seasonal Precipitation and Discharge at Danville

Season	Precipitation (inches)			Discharge (cfs)		
	2016	LTM	LTM Departure	2016	LTM	% LTM
January-March (Winter)	7.25	7.81	-0.56	21,509	22,213	0.97
April-June (Spring)	8.52	11.33	-2.81	11,810	21,168	0.56
July-September (Summer)	10.41	12.01	-1.59	3,285	7,206	0.46
October-December (Fall)	10.45	9.93	0.52	9,516	15,238	0.62
Annual Total	36.64	41.08	-4.44	11,475	16,416	0.70

Table A6. 2016 Annual Loads (1000's lbs), Yields (lbs/acre), and Concentrations (mg/L) at Danville

Parameter	Load	Load % of LTM	Yield	LTM Yield	Conc	FNC
TN	22,022	54%	3.07	5.72	0.792	0.842
TNO_x	13,528	58%	1.88	3.22	0.465	0.486
TON	7,976	49%	1.11	2.26	0.302	0.336
TNH_3	845	44%	0.12	0.27	0.0293	0.0316
DN	18,772	55%	2.61	4.74	0.683	0.712
DNO_x	13,578	58%	1.89	3.24	0.468	0.489
DON	4,627	48%	0.64	1.34	0.197	0.202
DNH_3	759	45%	0.11	0.24	0.0254	0.0278
TP	1,315	35%	0.183	0.529	0.0389	0.0532
DP	266	27%	0.037	0.137	0.0113	0.012
DOP	188	35%	0.026	0.075	0.0077	0.00833
TOC	68,263	58%	9.50	16.39	2.72	3.02
SS	1,063,065	34%	148.0	440.7	20.0	42.3

Table A7. 2016 Monthly Total Precipitation (in), High Daily Average Precipitation During Month (in), Flow (cfs), Loads (1000's lbs), and Yields (lbs/acre) at Danville

Mon	Precip			Flow		TN			TP			SS		
	Ave	Max	% LTM	2014	% LTM	Load	Yield	% LTM	Load	Yield	% LTM	Load	Yield	% LTM
Jan	1.66	0.58	2.57	18,682	97%	3,530	0.49	76%	187	0.026	46%	123,671	17.2	36%
Feb	4.00	1.18	2.22	27,096	160%	5,192	0.72	138%	424	0.059	190%	523,397	72.9	357%
Mar	1.59	0.53	3.01	18,416	61%	3,305	0.46	47%	155	0.022	26%	106,662	14.9	17%
Apr	2.88	0.80	3.43	17,076	51%	2,595	0.36	36%	145	0.020	21%	106,106	14.8	14%
May	2.75	0.40	3.56	13,367	73%	1,770	0.25	52%	106	0.015	37%	67,507	9.4	30%
Jun	2.89	0.74	4.34	4,937	41%	469	0.07	24%	23	0.003	10%	8,010	1.1	5%
Jul	3.79	0.90	4.00	2,608	34%	209	0.03	17%	10	0.001	7%	2,019	0.3	3%
Aug	4.70	1.08	3.88	5,148	85%	527	0.07	52%	34	0.005	30%	10,946	1.5	17%
Sept	1.92	0.55	4.13	2,059	26%	158	0.02	11%	7	0.001	3%	1,075	0.1	0%
Oct	5.50	1.57	3.79	5,465	54%	669	0.09	35%	41	0.006	22%	19,371	2.7	16%
Nov	1.64	0.30	3.15	6,444	42%	793	0.11	26%	34	0.005	12%	10,165	1.4	6%
Dec	3.32	0.59	2.99	16,539	81%	2,806	0.39	63%	149	0.021	39%	84,135	11.7	35%

Table A8. Flow and Flow Normalized Trends at Danville

Danville	Trend Test	Change	Likelihood Test		
Parameter/code			Value	Descriptor	Trend
FLOW / 60	SMK	-	-	-	NS
TN / 600	FNC	-0.799	0.99	HL	Down
	FNF	-11.77	0.99	HL	Down
TNOx / 630	FNC	-0.321	0.99	HL	Down
	FNF	-4.26	0.99	HL	Down
TON / 605	FNC	-0.469	0.99	HL	Down
	FNF	-7.74	0.97	HL	Down
TNH_3 / 610	FNC	-0.063	0.99	HL	Down
	FNF	-1.0	0.99	HL	Down
DN / 602	FNC	-0.61	0.99	HL	Down
	FNF	-9.25	0.99	HL	Down
DNOx / 631	FNC	-0.34	0.99	HL	Down
	FNF	-4.63	0.97	HL	Down
DON / 607	FNC	-0.27	0.99	HL	Down
	FNF	-4.57	0.99	HL	Down
DNH_3 / 608	FNC	-0.067	0.99	HL	Down
	FNF	-1.02	0.99	HL	Down
TP / 665	FNC	-0.053	0.99	HL	Down
	FNF	-0.403	0.79	L	Down
DP / 666	FNC	-0.022	0.99	HL	Down
	FNF	-0.37	0.99	HL	Down
DOP / 671	FNC	-0.003	0.69	L	Down
	FNF	-0.03	0.56	ALAN	Down
TOC / 680	FNC	-1.55	0.99	HL	Down
	FNF	-15.84	0.99	HL	Down
SSC / 80154	FNC	-10.5	0.89	L	Down
	FNF	-104	0.54	ALAN	Down

Trend period (Water Year) = 1989-2016
FNC – Flow Normalized Concentration – mg/L
FNF – Flow Normalized Flux – 10^6 kg/yr
FNC/FNF alpha level – 0.1
SMK – Seasonal Mann-Kendall for flow trends, alpha level – 0.05

NS – Not significant, UP – Increasing trend, DOWN – Decreasing trend
HL – Highly Likely ≥0.95 and ≤1.00
VL – Very Likely ≥0.90 and <0.95
L – Likely ≥0.66 and <0.90
ALAN – About as Likely as Not >0.33 and <0.66

INDIVIDUAL SITES: MARIETTA

Table A9. 2016 Annual and Seasonal Precipitation and Discharge at Marietta

Season	Precipitation (inches)			Discharge (cfs)		
	2016	LTM	LTM Departure	2016	LTM	% LTM
January-March (Winter)	7.93	8.22	-0.30	54,877	53,478	1.03
April-June (Spring)	8.78	11.40	-2.61	27,690	49,432	0.56
July-September (Summer)	10.31	12.09	-1.78	7,458	18,138	0.41
October-December (Fall)	9.26	10.08	-0.81	18,946	34,565	0.55
Annual Total	36.28	41.79	-5.51	27,090	38,805	0.70

Table A10. 2016 Annual Loads (1000's lbs), Yields (lbs/acre), and Concentrations (mg/L) at Marietta

Parameter	Load	Load % of LTM	Yield	LTM Yield	Conc.	FNC
TN	66,031	54%	3.97	7.34	1.06	1.11
TNO_x	46,818	56%	2.81	5.06	0.733	0.762
TON	28,722	80%	1.73	2.17	0.448	0.478
TNH_3	2,095	50%	0.13	0.25	0.0348	0.0354
DN	57,920	55%	3.48	6.30	0.94	0.969
DNO_x	46,793	56%	2.81	5.04	0.731	0.76
DON	10,031	53%	0.60	1.13	0.195	0.199
DNH_3	1,875	51%	0.11	0.22	0.0303	0.031
TP	3,294	42%	0.198	0.475	0.0474	0.0586
DP	899	42%	0.054	0.129	0.0175	0.0182
DOP	694	59%	0.042	0.071	0.01323	0.01393
TOC	177,184	70%	10.65	15.31	3.27	3.47
SS	2,149,271	35%	129.18	368.15	21.3	35

Table A11. 2016 Monthly Total Precipitation (in), High Daily Average Precipitation During Month (in), Flow (cfs), Loads (1000's lbs), and Yields (lbs/acre) at Marietta

Mon	Precip			Flow		TN			TP			SS		
	Ave	Max	% LTM	2015	% LTM	Load	Yield	% LTM	Load	Yield	% LTM	Load	Yield	% LTM
Jan	2.29	0.88	2.76	46,648	99%	11,426	0.69	80%	519	0.031	61%	328,554	19.7	50%
Feb	4.04	1.10	2.26	74,210	175%	17,633	1.06	160%	1,155	0.069	240%	1,039,458	62.5	350%
Mar	1.59	0.40	3.20	43,248	62%	9,234	0.56	49%	393	0.024	34%	244,650	14.7	25%
Apr	2.47	0.62	3.44	33,213	45%	5,872	0.35	32%	234	0.014	19%	120,089	7.2	11%
May	3.36	0.37	3.81	34,006	73%	5,726	0.34	53%	270	0.016	39%	142,907	8.6	28%
Jun	2.96	0.67	4.14	15,638	55%	2,064	0.12	35%	91	0.005	21%	28,463	1.7	10%
Jul	3.27	0.59	3.98	6,947	37%	846	0.05	20%	42	0.003	14%	6,415	0.4	4%
Aug	4.33	0.88	3.88	9,857	68%	1,356	0.08	41%	76	0.005	33%	18,783	1.1	13%
Sept	2.71	0.66	4.24	5,506	26%	715	0.04	13%	36	0.002	5%	5,844	0.4	1%
Oct	4.61	1.49	3.71	13,821	59%	2,468	0.15	38%	130	0.008	31%	54,983	3.3	18%
Nov	1.29	0.25	3.24	13,485	41%	2,217	0.13	24%	85	0.005	15%	27,465	1.7	7%
Dec	3.36	0.70	3.13	29,355	61%	6,474	0.39	45%	265	0.016	32%	131,661	7.9	24%

Table A12. Flow and Flow Normalized Trends at Marietta

Marietta	Trend Test	Change	Likelihood Test		
Parameter/code			Value	Descriptor	Trend
FLOW / 60	SMK	-	-	-	NS
TN / 600	FNC	-0.72	0.99	HL	Down
	FNF	-26.79	0.99	HL	Down
TNOx / 630	FNC	-0.33	0.97	HL	Down
	FNF	-11.01	0.99	HL	Down
TON / 605	FNC	-0.19	0.99	HL	Down
	FNF	-7.51	0.86	L	Down
TNH_3 / 610	FNC	-0.03	0.99	HL	Down
	FNF	-1.28	0.99	HL	Down
DN / 602	FNC	-0.554	0.99	HL	Down
	FNF	-18.74	0.99	HL	Down
DNOx / 631	FNC	-0.328	0.97	HL	Down
	FNF	-11.37	0.97	HL	Down
DON / 607	FNC	-0.18	0.99	HL	Down
	FNF	-5.62	0.99	HL	Down
DNH_3 / 608	FNC	-0.031	0.99	HL	Down
	FNF	-1.25	0.99	HL	Down
TP / 665	FNC	-0.04	0.99	HL	Down
	FNF	-0.86	0.79	L	Down
DP / 666	FNC	-0.02	0.99	HL	Down
	FNF	-0.64	0.95	HL	Down
DOP / 671	FNC	0.007	0.97	HL	UP
	FNF	0.30	0.99	HL	UP
TOC / 680	FNC	-0.21	0.64	ALAN	Down
	FNF	-0.32	0.59	ALAN	UP
SSC / 80154	FNC	-12.3	0.93	VL	Down
	FNF	-646	0.72	L	Down

Trend period (Water Year) = 1989-2016
FNC – Flow Normalized Concentration – mg/L
FNF – Flow Normalized Flux – 10^6 kg/yr
FNC/FNF alpha level – 0.1
SMK – Seasonal Mann-Kendall for flow trends, alpha level – 0.05

NS – Not significant, UP – Increasing trend, DOWN – Decreasing trend
HL – Highly Likely ≥0.95 and ≤1.00
VL – Very Likely ≥0.90 and <0.95
L – Likely ≥0.66 and <0.90
ALAN – About as Likely as Not >0.33 and <0.66

INDIVIDUAL SITES: LEWISBURG

Table A13. 2016 Annual and Seasonal Precipitation and Discharge at Lewisburg

Season	Precipitation (inches)			Discharge (cfs)		
	2016	LTM	LTM Departure	2016	LTM	% LTM
January-March (Winter)	7.85	8.31	-0.46	15,004	15,021	1.00
April-June (Spring)	8.35	11.22	-2.86	7,829	13,064	0.60
July-September (Summer)	10.33	12.24	-1.91	1,565	4,975	0.31
October-December (Fall)	10.48	9.99	0.50	7,143	9,939	0.72
Annual Total	37.01	41.75	-4.74	7,846	10,723	0.73

Table A14. 2016 Annual Loads (1000's lbs), Yields (lbs/acre), and Concentrations (mg/L) at Lewisburg

Parameter	Load	Load % of LTM	Yield	LTM Yield	Conc.	FNC
TN	11,136	51%	2.55	5.02	0.655	0.669
TNO_x	8,076	58%	1.85	3.20	0.475	0.477
TON	2,957	40%	0.68	1.68	0.165	0.183
TNH_3	333	36%	0.08	0.21	0.0203	0.0212
DN	10,040	53%	2.30	4.37	0.606	0.61
DNO_x	8,085	58%	1.85	3.18	0.477	0.479
DON	1,727	37%	0.40	1.06	0.114	0.117
DNH_3	322	39%	0.07	0.19	0.0195	0.0202
TP	366	30%	0.084	0.283	0.0175	0.0211
DP	84	20%	0.019	0.097	0.00636	0.00615
DOP	96	45%	0.022	0.048	0.00621	0.00594
TOC	27,641	59%	6.33	10.65	1.64	1.79
SS	299,563	25%	68.58	275.38	9.27	16.2

Table A15. 2016 Monthly Total Precipitation (in), High Daily Average Precipitation During Month (in), Flow (cfs), Loads (1000's lbs), and Yields (lbs/acre) at Lewisburg

Mon	Precip			Flow		TN			TP			SS		
	Ave	Max	% LTM	2014	% LTM	Load	Yield	% LTM	Load	Yield	% LTM	Load	Yield	% LTM
Jan	2.03	0.98	2.84	13,734	105%	1,913	0.44	74%	60	0.014	42%	46,739	10.7	26%
Feb	4.13	0.94	2.24	19,242	160%	2,494	0.57	117%	100	0.023	112%	105,332	24.1	145%
Mar	1.69	0.40	3.23	11,825	60%	1,396	0.32	39%	34	0.008	17%	21,949	5.0	9%
Apr	2.21	0.40	3.40	8,490	44%	826	0.19	26%	19	0.004	9%	10,395	2.4	4%
May	3.41	0.57	3.76	10,639	85%	1,008	0.23	55%	31	0.007	30%	19,798	4.5	26%
Jun	2.74	0.72	4.05	4,264	57%	376	0.09	36%	9	0.002	17%	3,426	0.8	13%
Jul	2.40	0.49	4.02	1,477	29%	145	0.03	18%	4	0.001	9%	658	0.2	3%
Aug	4.94	1.17	4.04	1,821	43%	174	0.04	26%	5	0.001	12%	1,224	0.3	4%
Sept	2.98	0.96	4.18	1,392	25%	122	0.03	14%	3	0.001	3%	708	0.2	1%
Oct	6.08	2.92	3.55	6,953	105%	917	0.21	84%	48	0.011	80%	50,851	11.6	128%
Nov	0.80	0.21	3.27	3,813	39%	378	0.09	22%	8	0.002	9%	3,018	0.7	5%
Dec	3.60	0.83	3.17	10,555	79%	1,388	0.32	57%	45	0.010	39%	35,464	8.1	42%

Table A16. Flow and Flow Normalized Trends at Lewisburg

Lewisburg	Trend Test	Change	Likelihood Test		
Parameter/code			Value	Descriptor	Trend
FLOW / 60	SMK	-	-	-	NS
TN / 600	FNC	-0.64	0.99	HL	Down
	FNF	-5.46	0.99	HL	Down
TNOx / 630	FNC	-0.26	0.99	HL	Down
	FNF	-1.80	0.99	HL	Down
TON / 605	FNC	-0.36	0.99	HL	Down
	FNF	-3.55	0.97	HL	Down
TNH_3 / 610	FNC	-0.039	0.99	HL	Down
	FNF	-0.314	0.99	HL	Down
DN / 602	FNC	-0.50	0.99	HL	Down
	FNF	-4.28	0.99	HL	Down
DNOx / 631	FNC	-0.234	0.99	HL	Down
	FNF	-1.76	0.99	HL	Down
DON / 607	FNC	-0.243	0.99	HL	Down
	FNF	-2.35	0.99	HL	Down
DNH_3 / 608	FNC	-0.03	0.99	HL	Down
	FNF	-0.26	0.99	HL	Down
TP / 665	FNC	-0.039	0.99	HL	Down
	FNF	-0.194	0.97	HL	Down
DP / 666	FNC	-0.03	0.99	HL	Down
	FNF	-0.259	0.99	HL	Down
DOP / 671	FNC	-0.009	0.97	HL	Down
	FNF	-0.026	0.76	L	Down
TOC / 680	FNC	-0.51	0.99	HL	Down
	FNF	0.234	0.44	ALAN	UP
SSC / 80154	FNC	-3.43	0.74	L	Down
	FNF	11.74	0.49	ALAN	UP

Trend period (Water Year) = 1989-2016
FNC – Flow Normalized Concentration – mg/L
FNF – Flow Normalized Flux – 10^6 kg/yr
FNC/FNF alpha level – 0.1
SMK – Seasonal Mann-Kendall for flow trends, alpha level – 0.05

NS – Not significant, UP – Increasing trend, DOWN – Decreasing trend
HL – Highly Likely ≥0.95 and ≤1.00
VL – Very Likely ≥0.90 and <0.95
L – Likely ≥0.66 and <0.90
ALAN – About as Likely as Not >0.33 and <0.66

INDIVIDUAL SITES: NEWPORT

Table A17. 2016 Annual and Seasonal Precipitation and Discharge at Newport

Season	Precipitation (inches)			Discharge (cfs)		
	2016	LTM	LTM Departure	2016	LTM	% LTM
January-March (Winter)	7.44	8.16	-0.71	6,024	6,315	0.95
April-June (Spring)	8.99	11.26	-2.27	2,921	5,465	0.53
July-September (Summer)	8.64	10.97	-2.33	807	1,974	0.41
October-December (Fall)	6.20	9.73	-3.53	1,214	3,619	0.34
Annual Total	31.27	40.11	-8.84	2,723	4,331	0.63

Table A18. 2016 Annual Loads (1000's lbs), Yields (lbs/acre), and Concentrations (mg/L) at Newport

Parameter	Load	Load % of LTM	Yield	LTM Yield	Conc.	FNC
TN	7,905	52%	3.69	7.13	1.27	1.37
TNO_x	6,063	54%	2.83	5.21	0.967	1.04
TON	1,907	49%	0.89	1.83	0.296	0.337
TNH_3	155	42%	0.07	0.17	0.0266	0.0289
DN	7,327	54%	3.42	6.36	1.2	1.27
DNO_x	6,053	55%	2.82	5.16	0.963	1.03
DON	1,218	50%	0.57	1.13	0.224	0.235
DNH_3	175	54%	0.08	0.15	0.0287	0.0311
TP	233	30%	0.108	0.358	0.0297	0.0392
DP	94	29%	0.044	0.153	0.0157	0.0183
DOP	77	38%	0.036	0.094	0.0125	0.0147
TOC	15,206	52%	7.09	13.73	2.6	2.85
SS	153,586	32%	71.59	221.78	11.1	19.9

Table A19. 2016 Monthly Total Precipitation (in), High Daily Average Precipitation During Month (in), Flow (cfs), Loads (1000's lbs), and Yields (lbs/acre) at Newport

Mon	Precip			Flow		TN			TP			SS		
	Ave	Max	% LTM	2014	% LTM	Load	Yield	% LTM	Load	Yield	% LTM	Load	Yield	% LTM
Jan	3.06	1.15	2.65	4,438	85%	1,240	0.58	74%	31	0.014	42%	17,702	8.3	39%
Feb	3.05	0.78	2.13	9,450	182%	2,566	1.20	177%	107	0.050	199%	96,547	45.0	357%
Mar	1.34	0.65	3.38	4,210	50%	1,039	0.48	40%	20	0.009	16%	10,172	4.7	12%
Apr	1.76	0.41	3.40	2,202	30%	444	0.21	21%	7	0.003	7%	2,425	1.1	4%
May	3.89	0.59	4.19	4,220	75%	1,003	0.47	64%	30	0.014	38%	16,875	7.9	38%
Jun	3.34	0.52	3.67	2,298	70%	485	0.23	58%	15	0.007	32%	6,068	2.8	24%
Jul	1.95	0.30	3.53	770	37%	109	0.05	19%	3	0.002	10%	379	0.2	2%
Aug	3.63	0.95	3.46	864	61%	146	0.07	40%	4	0.002	20%	553	0.3	9%
Sept	3.05	1.07	3.97	785	32%	124	0.06	17%	3	0.001	4%	331	0.2	1%
Oct	1.91	0.65	3.33	965	43%	179	0.08	26%	4	0.002	11%	599	0.3	3%
Nov	0.92	0.21	3.30	839	24%	142	0.07	13%	2	0.001	3%	235	0.1	1%
Dec	3.37	0.67	3.10	1,825	36%	427	0.20	26%	6	0.003	8%	1,701	0.8	4%

Table A20. Flow and Flow Normalized Trends at Newport

Newport Parameter/code	Trend Test	Change	Likelihood Test		
			Value	Descriptor	Trend
FLOW / 60	SMK	-	-	-	NS
TN / 600	FNC	-0.519	0.99	HL	Down
	FNF	-2.34	0.99	HL	Down
TNOx / 630	FNC	-0.164	0.97	HL	Down
	FNF	-0.892	0.97	HL	Down
TON / 605	FNC	-0.343	0.99	HL	Down
	FNF	-1.45	0.95	HL	Down
TNH_3 / 610	FNC	-0.033	0.99	HL	Down
	FNF	-0.15	0.99	HL	Down
DN / 602	FNC	-0.36	0.99	HL	Down
	FNF	-1.66	0.99	HL	Down
DNOx / 631	FNC	-0.108	0.81	L	Down
	FNF	-0.607	0.99	HL	Down
DON / 607	FNC	-0.213	0.99	HL	Down
	FNF	-0.90	0.99	HL	Down
DNH_3 / 608	FNC	-0.019	0.97	HL	Down
	FNF	-0.103	0.97	HL	Down
TP / 665	FNC	-0.064	0.99	HL	Down
	FNF	-0.217	0.99	HL	Down
DP / 666	FNC	-0.042	0.99	HL	Down
	FNF	-0.123	0.99	HL	Down
DOP / 671	FNC	-0.03	0.99	HL	Down
	FNF	-0.062	0.95	HL	Down
TOC / 680	FNC	-1.82	0.99	HL	Down
	FNF	-7.63	0.95	HL	Down
SSC / 80154	FNC	-14.1	0.93	VL	Down
	FNF	-114.2	0.83	L	Down

Trend period (Water Year) = 1989-2016
FNC – Flow Normalized Concentration – mg/L
FNF – Flow Normalized Flux – 10^6 kg/yr
FNC/FNF alpha level – 0.1
SMK – Seasonal Mann-Kendall for flow trends, alpha level – 0.05

NS – Not significant, UP – Increasing trend, DOWN – Decreasing trend
HL – Highly Likely ≥0.95 and ≤1.00
VL – Very Likely ≥0.90 and <0.95
L – Likely ≥0.66 and <0.90
ALAN – About as Likely as Not >0.33 and <0.66

INDIVIDUAL SITES: CONESTOGA

Table A21. 2016 Annual and Seasonal Precipitation and Discharge at Conestoga

Season	Precipitation (inches)			Discharge (cfs)		
	2016	LTM	LTM Departure	2016	LTM	% LTM
January-March (Winter)	10.76	8.84	1.92	1,113	911	1.22
April-June (Spring)	10.81	11.12	-0.31	613	735	0.83
July-September (Summer)	13.14	12.73	0.41	319	482	0.66
October-December (Fall)	6.23	10.77	-4.54	246	639	0.39
Annual Total	40.94	43.46	-2.52	570	690	0.83

Table A22. 2016 Annual Loads (1000's lbs), Yields (lbs/acre), and Concentrations (mg/L) at Conestoga

Parameter	Load	Load % of LTM	Yield	LTM Yield	Conc.	FNC
TN	6,581	66%	21.88	33.15	6.05	6
TNO_x	6,145	76%	20.43	26.90	5.57	5.51
TON	879	51%	2.92	5.78	0.557	0.58
TNH_3	121	54%	0.40	0.74	0.0684	0.0704
DN	6,627	73%	22.03	30.21	5.91	5.84
DNO_x	6,154	77%	20.46	26.43	5.59	5.52
DON	577	54%	1.92	3.55	0.441	0.446
DNH_3	115	56%	0.38	0.68	0.0641	0.0661
TP	287	48%	0.953	2.001	0.208	0.224
DP	199	75%	0.662	0.878	0.169	0.177
DOP	187	84%	0.621	0.743	0.157	0.167
TOC	4,141	57%	13.77	24.13	2.94	3.07
SS	69,684	27%	231.66	862.49	19.5	24.9

Table A23. 2016 Monthly Total Precipitation (in), High Daily Average Precipitation During Month (in), Flow (cfs), Loads (1000's lbs), and Yields (lbs/acre) at Conestoga

Mon	Precip			Flow		TN			TP			SS		
	Ave	Max	% LTM	2014	% LTM	Load	Yield	% LTM	Load	Yield	% LTM	Load	Yield	% LTM
Jan	3.03	1.16	3.11	670	84%	742	2.47	70%	17	0.058	32%	1,747	5.8	8%
Feb	5.11	1.58	2.36	1,913	226%	1,574	5.23	154%	124	0.411	263%	54,457	181.0	256%
Mar	2.62	0.82	3.28	834	77%	872	2.90	64%	20	0.068	27%	2,760	9.2	7%
Apr	2.62	1.03	3.16	605	70%	602	2.00	58%	13	0.044	27%	1,351	4.5	6%
May	4.22	0.94	3.89	759	105%	708	2.35	80%	28	0.092	55%	4,503	15.0	18%
Jun	3.97	0.76	4.08	469	76%	421	1.40	62%	16	0.054	34%	1,268	4.2	6%
Jul	7.50	3.82	4.58	429	81%	384	1.28	64%	21	0.070	44%	2,012	6.7	9%
Aug	2.15	1.02	3.32	321	81%	297	0.99	66%	15	0.050	49%	652	2.2	8%
Sept	3.49	0.59	4.83	204	39%	192	0.64	36%	9	0.030	17%	217	0.7	1%
Oct	1.24	1.58	4.13	214	40%	217	0.72	36%	9	0.028	19%	271	0.9	2%
Nov	1.45	0.34	3.34	160	28%	169	0.56	24%	5	0.017	12%	71	0.2	1%
Dec	3.54	0.89	3.31	360	45%	402	1.34	40%	9	0.031	16%	373	1.2	2%

Table A24. Flow and Flow Normalized Trends at Conestoga

Conestoga Parameter/code	Trend Test	Change	Likelihood Test		
			Value	Descriptor	Trend
FLOW / 60	SMK	-	-	-	NS
TN / 600	FNC	-2.61	0.99	HL	Down
	FNF	-2.00	0.99	HL	Down
TNOx / 630	FNC	-1.45	0.99	HL	Down
	FNF	-0.929	0.99	HL	Down
TON / 605	FNC	-0.803	0.97	HL	Down
	FNF	-0.82	0.95	HL	Down
TNH_3 / 610	FNC	-0.327	0.99	HL	Down
	FNF	-0.257	0.99	HL	Down
DN / 602	FNC	-1.92	0.97	HL	Down
	FNF	-1.32	0.99	HL	Down
DNOx / 631	FNC	-1.34	0.97	HL	Down
	FNF	-0.85	0.97	HL	Down
DON / 607	FNC	-0.33	0.99	HL	Down
	FNF	-0.224	0.99	HL	Down
DNH_3 / 608	FNC	-0.306	0.99	HL	Down
	FNF	-0.24	0.99	HL	Down
TP / 665	FNC	-0.316	0.97	HL	Down
	FNF	-0.223	0.97	HL	Down
DP / 666	FNC	-0.167	0.99	HL	Down
	FNF	-0.07	0.99	HL	Down
DOP / 671	FNC	-0.17	0.97	HL	Down
	FNF	-0.054	0.89	L	Down
TOC / 680	FNC	-5.66	0.99	HL	Down
	FNF	-4.045	0.99	HL	Down
SSC / 80154	FNC	-101	0.99	HL	Down
	FNF	-185	0.95	HL	Down

Trend period (Water Year) = 1989-2016
FNC – Flow Normalized Concentration – mg/L
FNF – Flow Normalized Flux – 10^6 kg/yr
FNC/FNF alpha level – 0.1
SMK – Seasonal Mann-Kendall for flow trends, alpha level – 0.05

NS – Not significant, UP – Increasing trend,
DOWN – Decreasing trend
HL – Highly Likely ≥0.95 and ≤1.00
VL – Very Likely ≥0.90 and <0.95
L – Likely ≥0.66 and <0.90
ALAN – About as Likely as Not >0.33 and <0.66