NC Division of Water Resources
Water Planning Section
Modeling and Assessment Branch

MEMORANDUM

Date: November 10, 2014

To: Kathy Stecker

From: Narayan Rajbhandari and Adugna Kebede

CC: Tom Fransen, Nora Deamer, Ian McMillan, Heather Patt, and John Huisman

Subject: Trend Analyses of Nutrients in the Tar River, Tar-Pamlico River Basin

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Introduction:

The Modeling and Assessment Branch (MAB) performed trend analysis in the Tar-Pamlico River Basin, focusing on data from the ambient monitoring station on the Tar River near Grimesland (O6500000) for the1991 – 2002 and 1991 – 2008 timeframe in 2003 and 2009, respectively. This station is located approximately seven miles upstream of Washington (Figure 1.1). Results of the 2003 trend analysis indicated that both total nitrogen (TN) and total phosphorus (TP) concentrations were significantly decreasing (MTU, 2003). In contrast, results of the 2009 analysis indicated that there were no significant trends in both TN and TP concentrations (MTU, 2009).

In April 2014, the Basinwide Planning Branch (BPB) requested the MAB to perform a follow-up trend analysis of nutrient concentrations and loads for the 1991 – 2013 timeframe using data collected at the following five ambient stations (Figure 1.1) to evaluate progress towards meeting nutrient reduction goals.

Trend Analysis Study Sites

1. Tar River at SR 1565 near Grimesland (O6500000)
2. Tar River at NC 96 near Tar River (O0100000)
3. Fishing Creek at US 301 near Enfield (O4680000)
4. Tar River near Tarboro (O5250000)
5. Chicod Creek at SR 1960 near Simpson (O6450000)

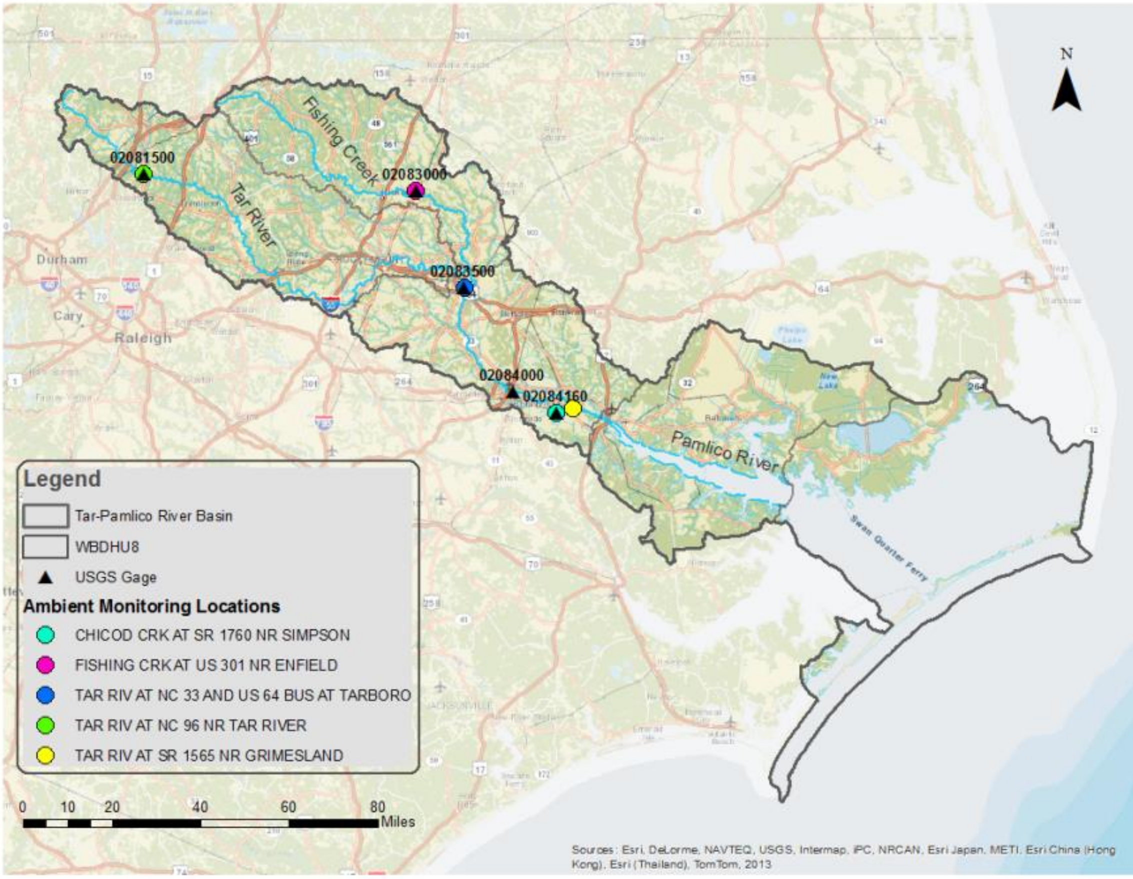


Figure 1.1. Tar-Pamlico River Basin map showing the ambient and USGS stations used for trend analysis.

Statistical trend analysis was performed for concentrations of TN, TP, Total Kjeldahl Nitrogen (TKN), ammonia (NH_3-N), and nitrate plus nitrite (NO_X-N). TN is not directly measured and was calculated as NO_X-N plus TKN. For the 1991 – 2013 timeframe, there were more than 12 months of consecutive data missing at each station (Table 1.1), which could affect the results of the trend analysis.

Table 1.1. Study period for trend analysis.

Ambient Stations	**Trend Period**	**Data Missing Period**	**USGS Flow Station**
O6500000	1/9/1991 to 12/11/2013	10/9/1994 to 2/4/1996	02084000
O0100000	5/15/1991 to 12/18/2013	7/18/2001 to 5/8/2003	02081500
O4680000	9/25/1991 to 12/17/2013	10/3/2001 to 6/13/2002	02083000
O5250000	5/28/1991 to 12/17/2013	10/3/2001 to 6/13/2002	02083500
O6450000	2/23/1993 to 12/11/2013	10/3/2001 to 6/13/2002	02084160

The MAB does not, however, recommend performing statistical trend analysis on load using the same method, because the confounding effects of naturally variable flow could lead to misleading results. Since human impacts, such as those achieved through implementation of best management practices or point source controls, would be captured by changes in concentration, it is appropriate to evaluate concentration when conducting trend analyses. This provides insight into whether or not management actions have resulted in long-term changes in water quality.

While statistical trend analysis on nutrient loading is not recommended as appropriate, an alternative method, flow-normalized loading analysis, can be used to evaluate long-term changes in nutrient loading to the estuary. For this reason, assessments of flow-normalized (FN) annual nutrient loads at the study sites are presented. This analysis provides some useful information on changes associated with different flow regimes and nutrient constituents and provides insight into progress towards meeting the overall loading reduction goal and can help direct where further research is necessary.

As discussed above, this memo is divided into two parts. The first part deals with statistical trend analysis, and the second part with analysis of flow-normalized annual nutrient loads. The results of the flow-normalized loading analysis for the Tar River AMS station near Grimesland is presented in the main body of this report and the results for the other stations are provided in Appendix A. Tables and plots of TN and TP Loads estimated using the USGS LOEDEST Program are also provided in Appendix C for reference.

I. Statistical Trend Analysis

Summary:

Statistical trend analysis is performed to determine whether nutrient concentrations in the Tar-Pamlico River Basin are increasing or decreasing from 1991 through 2013. The Water Quality / Hydrology Graphics / Analysis System (WQHYDRO) software was used to evaluate trends in the basin.

The results of the trend analyses from 1991 through 2013 are summarized in Tables S-1.1 and S-1.2 below. The results show that ammonia (NH_3-N) concentrations were significantly decreasing in the basin at the ambient stations - O6500000 (Tar River), O4680000 (Fishing Creek), O5250000 (Tar River) and O6450000 (Chicod Creek). Nitrate and nitrite (NOx-N) concentrations were significantly decreasing at all the ambient stations included in this study. Total Kjeldahl nitrogen (TKN) concentrations were significantly increasing at O6500000, O0100000 (Tar River), O4680000, and O5250000. Total nitrogen (TKN + NOx-N) concentrations were significantly increasing at O6500000 and O4680000, and total phosphorus (TP) concentrations were significantly increasing at O0100000.

Table S-1.1. Summary of trend analysis aesults for flow-adjusted nutrient concentrations

Constituents	O6500000 (Tar River)	O0100000 (Tar River)	O4680000 (Fishing Creek)	O5250000 (Tar River)	O6450000 (Chicod Creek)
NH_3-N	YES↓	NO	YES↓	YES↓	YES↓
NOx-N	YES ↓	YES↓	YES↓	YES↓	YES↓
TKN	YES↑	YES↑	YES↑	YES↑	NO
TN	YES↑	NO	YES↑	NO	NO
TP	NO	YES↑	NO	NO	NO

Table S-1.2. Percent change over study period for significant trends

Constituents	O6500000 (Tar River)	O0100000 (Tar River)	O4680000 (Fishing Creek)	O5250000 (Tar River)	O6450000 (Chicod Creek)
NH_3-N	-33.31	*	-39.05	-41.36	-38.19
NOx-N	-21.60	-160.05**	-57.75	-41.57	-56.98
TKN	55.40	37.29	60.13	44.39	*
TN	10.86	*	36.00	*	*
TP	*	35.83	*	*	*

* indicate the trend results are not statistically significant.

** Note that NOx-N values are highly variable at this location. While a 160% decrease could not actually occur, this result is statistically valid.

Methods:

The purpose of statistical trend testing is to determine whether a set of data that arise from a particular probability distribution represent a detectable increase or decrease over time (or space). Detecting trends in a water quality data series is not as simple as drawing a line of best fit and measuring the slope. There are likely to be multiple factors contributing to variation in water quality over time, many of which can hide or exaggerate trend components in the data. Changes in water quality brought about by human activity will usually be superimposed on natural sources of variation such as flow and season. Identification and separation of these components is one of the most important tasks in trend testing. Therefore, in this study, the flow-adjusted concentration is estimated based on regression of concentration on some function of discharge to overcome the flow relatedness. The flow-adjusted concentration is then tested for a trend by using the Seasonal Kendall test to overcome seasonality. The basic procedures adopted for this study are as follows:

Flow estimation

Estimation of flow is essential to correct the concentration variation due to streamflow. Except at Grimesland, O6500000, all the remaining four stations have USGS gauge stations to measure daily flow (Table 1.1 and Figure 1.1). As described in DWQ_MTU (2003), flow data for 1991 - 2013 at Grimesland was generated by multiplying flow from the closest upstream gage, which is approximately 13 miles upstream at Greenville (USGS 02084000), by a drainage area (DA) ratio of 1.07 (Grimesland DA divided by Greenville DA). Descriptive statistics of flow during the study periods are presented in Table 1.2 and plots of annual flow volume for these stations are provided in Appendix B.

Table 1.2. Descriptive statistics of flow (cfs) at the study sites in the Tar River Basin

Quantiles	O6500000 (Tar River)	O0100000 (Tar River)	O4680000 (Fishing Creek)	O5250000 (Tar River)	O6450000 (Chicod Creek)
	(1991-2013)	(1991-2013)	(1991-2013)	(1991-2013)	(1992-2013)
100%	77361.00	10800.00	29200.00	70500.00	4860.00
99.5%	20977.46	2619.80	4270.00	18300.50	1200.25
97.5%	12305.00	999.85	2330.00	9760.25	359.00
90%	6014.47	273.00	863.00	4920.00	105.00
75%	2861.15	104.00	449.00	2300.00	43.00
50%	1379.00	34.00	230.00	1060.00	16.00
25%	522.92	7.00	88.00	377.00	4.30
10%	257.76	1.70	39.00	195.90	0.68
2.5%	101.09	0.32	17.00	98.98	0.00
0.5%	21.29	0.00	3.90	54.00	0.00
0%	-52.43	0.00	0.21	28.00	0.00
Mean	2535.91	137.52	422.25	2023.39	55.75
Std Dev	3945.73	433.24	836.88	3293.57	188.66
Std Err Mean	43.11	4.73	9.13	35.94	2.14
Upper 95% Mean	2620.41	146.79	440.15	2093.84	59.94
Lower 95% Mean	2451.41	128.26	404.35	1952.94	51.57
N	8378	8401	8399	8398	7794

Trend Analysis

The Water Quality / Hydrology Graphics / Analysis System (WQHYDRO) software is used to evaluate trends for the selected Tar-Pamlico River Basin stations. The software is a multi-faceted computer program, which is capable of computing flow-adjusted concentration and the Seasonal Kendall test (Aroner, 2000). The model removes the concentration variation related to streamflow with flow-adjusted data by using a robust smoothing technique called Locally Weighted Scatterplot Smooth (LOWESS). The technique describes the relationship between concentration (Y) and flow (X) without assuming linearity or normality. The resulting residuals are considered flow-adjusted concentrations.

The WQHYDRO software also computes the Seasonal Kendall test both for serial correlation data (autocorrelation) and non-serial correlation data. A fundamental assumption of statistical procedures is that observations within or between samples are independent of one another. For that reason, any statistical test on serially correlated data would disclose wrong information. The model has an automatic provision for removing the serial correlation problem using an autocorrelation-corrected version of the Seasonal Kendall test. The technique is known as Seasonal Kendal with Correction (SKWC). For the non-serial correlation data, the model uses Seasonal Kendall without Correction (SKWOC) technique.

Test of Hypothesis

The Seasonal Kendall test as described above was applied to test a null hypothesis of no trend in NH_3-N, NOx-N, TKN, TN, and TP concentrations. An alternative hypothesis is that there was a trend. Upward trend (positive slope ↑) indicates degradation of water quality, whereas downward trend (negative slope ↓) indicates improvement of water quality. The hypothesis was tested at 95% confidence level.

Results:

I. Tar River at SR 1565 near Grimesland (O6500000)

The results of the Seasonal Kendall test for flow-adjusted concentrations of NH_3-N, NOx-N, TKN, TN, and TP at O6500000 are provided in Table 1.3. Except for TP, the results indicate that there were statistically significant trends for nitrogen. TN and TKN showed increasing trends in concentration, while NH_3-N and NOx-N showed decreasing trends.

The downward or upward trend slope in flow-adjusted concentration represents the median rate of change in flow-adjusted concentration for each statistically significant parameter. The trend slope can be expressed as a combined percentage over the study period. This was calculated by dividing the trend slope by the base median concentration (over the first 12 months 1991-2012), and multiplying by 22 years (study period) and then 100 to convert it to a percent. Accordingly, reductions in the base median NH_3-N and NOx-N through 2013 are estimated to be 33% and 22%, respectively; and increases in TN and TKN are estimated to be 11% and 55%, respectively (Table 1.3).

Table 1.3. Result of Seasonal Kendall Trend Analysis for nutrient concentrations at Grimesland (1991-2013).

Station	Water Quality Constituents (mg/L)	Seasonal Sen Trend Slope (mg/L/year)	Significant Trend at 95%	First 12 Month Median	Average % Change in Median
O6500000	NH_3-N	-0.00106	YES↓	0.07	-33.31
	NOx-N	-0.00756	YES ↓	0.77	-21.60
	TKN	0.01259	YES↑	0.50	55.40
	TN	0.00627	YES↑	1.27	10.86
	TP	*	NO	0.16	*

* indicate the trend results are not statistically significant.

II. Tar River at NC 96 near Tar River (O0100000)

The results of the Seasonal Kendall test for flow-adjusted concentrations of NH_3-N, NOx-N, TKN, TN, and TP at O0100000 are provided in Table 1.4. The results indicate that there were statistically significant trends for NOx-N, TKN and TP. TKN and TP showed increasing trends in concentration, while NOx-N showed a decreasing trend. The upward slopes of TKN and TP suggest that the average increase in median concentration represent a 37% and a 36%, respectively, over the 22 years of study period. Conversely, there was a 160% decrease in NOx-N concentration.

Table 1.4. Result of Seasonal Kendall Trend Analysis for nutrient concentrations at NC 96 (1991-2013).

Stations	Water Quality Constituents (mg/L)	Seasonal Sen Trend Slope (mg/L/year)	Significant Trend at 95%	First 12 month Median	Average % Change in Median
O0100000	NH_3-N	*	NO	0.035	*
	NOx-N	-0.00291	YES↓	0.04	-160.05
	TKN	0.00678	YES↑	0.4	37.29
	TN	*	NO	0.49	*
	TP	0.00057	YES↑	0.035	35.83

* indicate the trend results are not statistically significant.

** Note that NOx-N values are highly variable at this location. While a 160% decrease could not actually occur, this result is statistically valid.

III. Fishing Creek at US 301 near Enfield (O4680000)

The results of the Seasonal Kendall test for flow-adjusted concentrations of NH_3-N, NOx-N, TKN, TN, and TP at O4680000 are provided in Table 1.5. There were statistically significant trends for nitrogen. TKN and TN showed increasing trends, while NH_3-N and NOx-N showed decreasing trends. The upward slopes of TKN and TN suggest that the average increase in median concentration represent 60% and a 36%, respectively, over the 22 years of study period. Conversely, there were 39% and a 58% decreases in NH_3 and NOx-N concentrations, respectively.

Table 1.5. Result of Seasonal Kendall Trend Analysis for nutrient concentrations at US 301 (1991-2013).

Stations	Water Quality Constituents (mg/L)	Seasonal Sen Trend Slope (mg/L/year)	Significant Trend at 95%	First 12 month Median	Average % Change in Median
O4680000	NH_3-N	-0.00071	YES↓	0.04	-39.05
	NOx-N	-0.00315	YES↓	0.12	-57.75
	TKN	0.0082	YES↑	0.3	60.13
	TN	0.0072	YES↑	0.44	36.00
	TP	*	NO	0.05	*

* indicate the trend results are not statistically significant.

IV. Tar River near Tarboro (O5250000)

The results of the Seasonal Kendall test for flow-adjusted concentrations of NH_3-N, NOx-N, TKN, TN, and TP at O5250000 are provided in Table 1.6. There were statistically significant trends for NH_3, NOx-N, and TKN. NH_3-N and NOx-N showed decreasing trends, while TKN showed an increasing trend. The downward slopes of NH_3-N and NOx-N suggest that the average decrease in median concentrations were 41% and a 42%, respectively, over the 22 years of study period. Conversely, there was a 44% increase in TKN concentration.

Table 1.6. Result of Seasonal Kendall Trend Analysis for nutrient concentrations at Tarboro (1991-2013).

Stations	Water Quality Constituents (mg/L)	Seasonal Sen Trend Slope (mg/L/year)	Significant Trend at 95%	First 12 month Median	Average % Change in Median
O5250000	NH_3-N	-0.00094	YES↓	0.05	-41.36
	NOx-N	-0.00888	YES↓	0.47	-41.57
	TKN	0.00807	YES↑	0.4	44.39
	TN	*	NO	0.96	*
	TP	*	NO	0.13	*

* indicate the trend results are not statistically significant.

V. Chicod Creek at SR 1760 near Simpson (O6450000)

The results of the Seasonal Kendall test for flow-adjusted concentrations of NH_3-N, NOx-N, TKN, TN, and TP at O6450000 are provided in Table 1.7. There were no statistically significant trends for TKN, TN, and TP. The downward slopes of NH_3-N and NOx-N suggest that the average decreases in median concentration represent 38% and 57%, respectively, over the 22 years of study period.

Table 1.7. Result of Seasonal Kendall Trend Analysis for nutrient concentrations at SR 1760 (1993-2013).

Stations	Water Quality Constituents (mg/L)	Seasonal Sen Trend Slope (mg/L/year)	Significant Trend at 95%	First 12 month Median	Average % Change in Median
O6450000	NH_3-N	-0.00592	YES↓	0.31	-38.19
	NOx-N	-0.02279	YES↓	0.8	-56.98
	TKN	*	NO	1	*
	TN	*	NO	1.9	*
	TP	*	NO	0.42	*

* indicate the trend results are not statistically significant.

Conclusion:

Trend analyses for monthly measured concentrations of NH_3-N, NOx-N, TKN, TN, and TP were performed in the Tar River Basin at the following five ambient stations: O650000 (Tar River), O0100000 (Tar River), O4680000 (Fishing Creek), O5250000 (Tar River), and O6450000 (Chicod Creek). The WQHYDRO statistical program was used to test the null hypothesis that no trends in nutrient concentrations exist at the 95% confidence level.

Overall, TKN concentrations were significantly increasing, whereas NH_3-N and NOx-N concentrations were significantly decreasing in the Tar River. Since TKN is composed of ammonia and organic nitrogen, the increase in TKN must be explained by an increase in organic nitrogen. The increase in organic nitrogen is higher at the Tar River near Grimesland (O6500000) and Fishing Creek near Enfield (O4680000); there were also significantly increasing trends in TN concentrations at these locations. The result at O6500000 is in contrast to the 2003 trend analysis (1991 – 2002 time frame) and the 2009 trend analysis (1991 -2008 time frame), where there were respectively decreasing trend and no trend of TN concentrations.

Furthermore, there were no trends of TP concentrations, except in the Tar River at NC 96 (O0100000) where the concentrations were significantly increasing. The result for the Grimesland station (O6500000) is similar with the results of the 2009 trend analysis which showed that there was no significant trend in TP.

References:

MTU, 11/02/2009. Trend Analyses in the Tar-Pam River Basin in North Carolina. Division of Water Quality, Internal Memo.

MTU, 05/23/2003. Trend Analysis of Nutrient Loading in the Tar-Pamlico Basin. Division of Water Quality, Internal Memo.

Aroner, Eric R. January 2000. Water Quality / Hydrology Graphics / Analysis System. User's Manual. WQHYDRO Consulting, Portland, OR 97218.

II. Flow-Normalized Loading Analysis

Summary
Flow-normalized loading analysis provides useful insights on changes in annual nutrient loading including changes associated with different flow regimes and nutrient constituents. Flow-normalized estimates can be used in the evaluation of progress towards nutrient reduction goals and provide additional insight on the relative effectiveness of nutrient management measures implemented in a watershed.

Analyses of flow-normalized (FN) loading at selected Tar Pamlico River Basin stations were performed to evaluate long term loading trends using a spreadsheet-based tool. A location map and a brief description of the stations are provided in Section I of this report.

The results show that there was a reduction in flow-normalized loading of NOx-N for all the stations included in this analysis. There was a decrease in flow-normalized TKN loads in the first few five-year periods, but the TKN loads gradually increased afterwards in each watershed. The increase in TKN loading was primarily due to an increase in organic nitrogen. The flow-normalized NOx-N, TKN, TN, and TP loads in the Chicod Creek watershed for all five-year time periods were lower than the first five-year (1993-1997) period loads. Flow-normalized TN loading exhibited the combination of the patterns for NOx-N and TKN loadings.

The average flow-normalized loading reduction for all the five-year periods from 1992 to 2013 for four stations (O6500000, O0100000, O4680000, and O5250000) and 1994 to 2013 for Chicod Creek relative to the first five year period (1991-1995 for the four stations and 1993-1997 for Chicod Creek) load is provided in the Table S-2-1 below.

Table S-2-1. Average Flow-Normalized Nutrient Load Reduction Relative to the first five-year period

Station	NH_3-N	NOx-N	TKN	TN	TP
Grimesland (O6500000)	-2%	-18%	13%	-3%	-7%
Tar River (O0100000)	10%	-20%	24%	10%	7%
Fishing Creek (O4680000)	-49%	-24%	13%	-2%	10%
Tar River (O5250000)	-17%	-20%	2%	-7%	7%
Chicod Creek (O6450000)	-73%	-33%	-24%	-28%	-22%

Overall, the current analyses show that substantial reduction of NOx-N loading occurred over the study period, but Org-N loading was not reduced as evidenced by the gradual increase in organic nitrogen in these watersheds. On average the TN loads decreased for all stations except for the Tar River station O0100000 for the study period. The TP loads decreased at station O6500000, and O6450000 and increased at stations O0100000, O4680000, and O5250000, on the average. A gradual increase in TN was observed in the most recent five-year periods at all stations. Similar increases were also observed for TP except at the Chicod Creek Station where it is decreasing.

Method
Assessment of trends in annual nutrient loads at selected Tar Pamlico River Basin stations were performed using flow-normalized (FN) concentrations and loads computed for flow intervals representing low, medium, and high flows. The description of the sites and the data used for this analysis are also provided in Part I. A spreadsheet-based tool was used for this analysis. Tables and plots of annual flow volumes at the USGS gages used for this analysis are presented Appendix B.

Flow-normalized estimates are designed to remove the effect of random stream flow-driven variations and are ideal for evaluating progress toward nutrient reduction goals (Sprague et al., 2011). Recent studies have demonstrated the use of flow-normalized loading assessments to evaluate effectiveness of management actions to reduce nutrients (Hirsch, 2012; Hirsch et al., 2010, Hirsch et al., 2011; Lebo et al., 2011; and Sprague et al., 2011). While some of these studies employed rigorous statistical methods for their analyses, the approach proposed by Lebo et al., (2011) used a simpler method and was selected for the current study. Lebo et al. (2011) used this approach to evaluate progress in achieving the Neuse TMDL reduction goal as well as changes in N fractions associated with different flow regimes. Their study evaluated nutrient loads at Clayton, Hookerton, Trenton, and Streets Ferry Stations in the Neuse River Basin. The same approach was employed to assess nutrient loads at the Fort Barnwell Station in the Neuse River Basin (MAB, 2013).

The current analysis was designed to replicate the same approach used by Lebo et al. (2011) for the data record from the five selected stations in the Tar Pamlico River Basin. Nutrient concentrations were estimated from the mean of available data and flow-weighted average concentrations. Nutrient loads for the long-term flow distribution were computed from the average concentration and the average flow volume calculated from the low, medium, and high flow intervals over the full period of record. The flow data summary for these intervals is given in Table S-2-2. The summary of the flow data used for this analysis for each station is provided in Table 1.2 in Part I of this report. A detailed description of this approach is presented in a peer-reviewed article by Lebo et al. (2011).

Table S-2-2. Summary of flow data used for loading analysis

DWR Station Number	USGS Flow Gage	Flow Period	Flow Averages (cfs)			Flow Period Average
			Low	Middle	High	
O0100000	2081500	1991-2013	4	37	371	138
O4680000	2083000	1991-2013	62	235	969	422
O5250000	2083500	1991-2013	281	1090	4707	2023
O6450000	2084160	1991-2013	2	17	148	55
O6500000	2084000	1991-2013	373	1417	5809	2530

Results

i. Flow-Normalized Loading - DWR Ambient Monitoring Station # O6500000 near Grimesland

Figures 2-1 and 2-2 show annual TN loading at Grimesland. The results show that annual TN loading at Grimesland ranged from 2.2 to 9.3 x 10^6 lbs/year for the 1991–2013 timeframe, with a median value of 4.6 x 10^6 lbs/year. Average contributions of Ammonia–N, NOx-N, and Org-N to the TN load for 1991–2013 period were 8, 45 and 47%, respectively. Organic Nitrogen was computed as TKN minus Ammonia. Overall, there was an increase in the contribution of the Org-N fraction and a decrease in that of the NOx-N fraction to TN loading at Grimesland for the study period (1991-2013). The Org-N contribution increased from 40% of TN for 1991–2002 period to 53% of TN for 2003–2013 period. The contribution from the high-flow fraction of Org-N increased from 50% of TN for the 1991-1995 period to 67% of TN for the 2009-2013 period. The NOx-N contribution decreased from 48% of TN for 1991–2002 period to 42% of TN for 2003–2013 period (Figure 2-1). The contribution from the low-flow fraction of Org-N decreased from 50% of TN for the 1991-1995 period to 33% of TN for the 2009-2013 period.

Figure 2-2 shows annual TN loading at Grimesland by flow interval. The average TN contributions (1991-2003) from low, middle, and high flow interval were 6, 20 and 74%, respectively. The annual TP loading at Grimesland ranged from 0.24 to 1.27 x 10^6 lbs/year, with a median value of 0.55 x 10^6 lbs/year (Figure 2-3). Figure 2-3 shows annual TP loading at Grimesland by flow interval. The average TP contributions from low, middle, and high flows were 6, 19 and 75%, respectively. The high-flow fraction of TP load increased from 76% for the 1991-1995 period to 83% for the 2009-2013 period. These results show that high flow events contribute substantially large amount of nutrients in this watershed.

Figure 2-1. Total N Load the Tar River Station (O6500000) near Grimesland

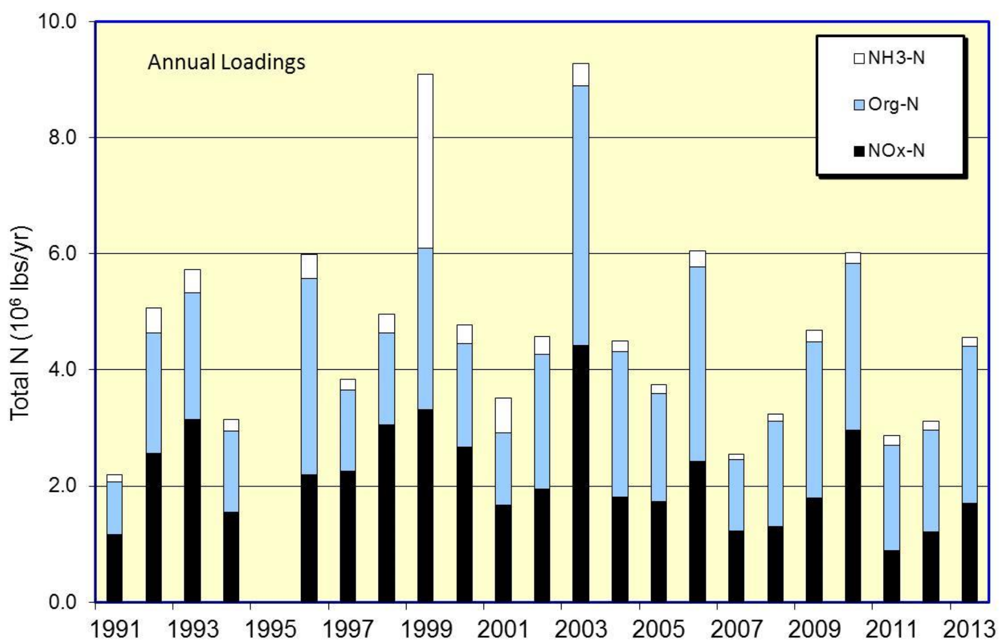


Figure 2-2. Total N Load the Tar River Station (O6500000) near Grimesland

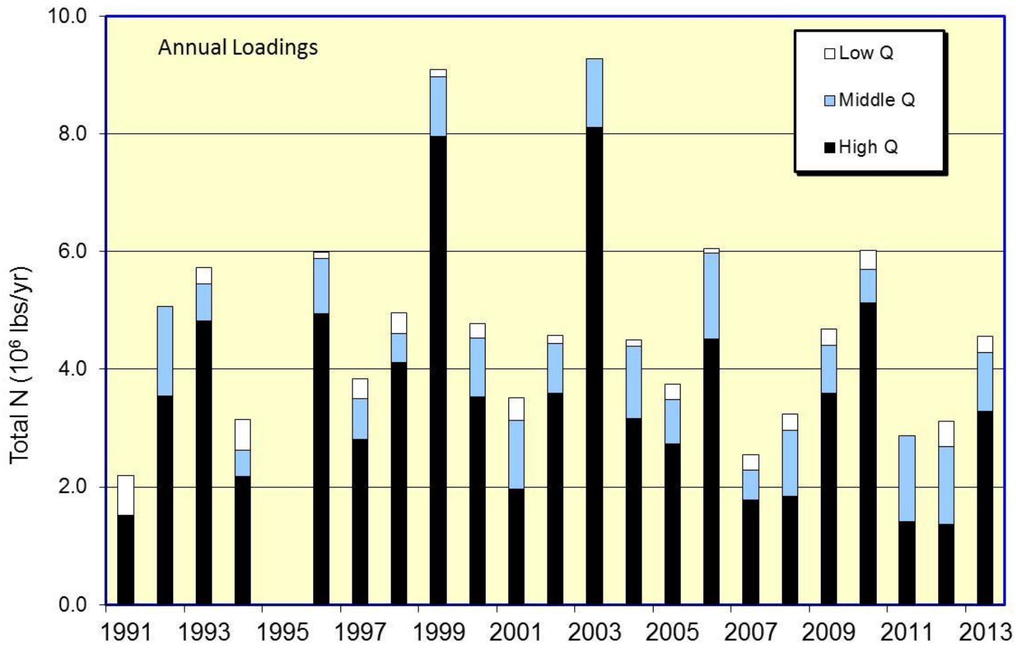
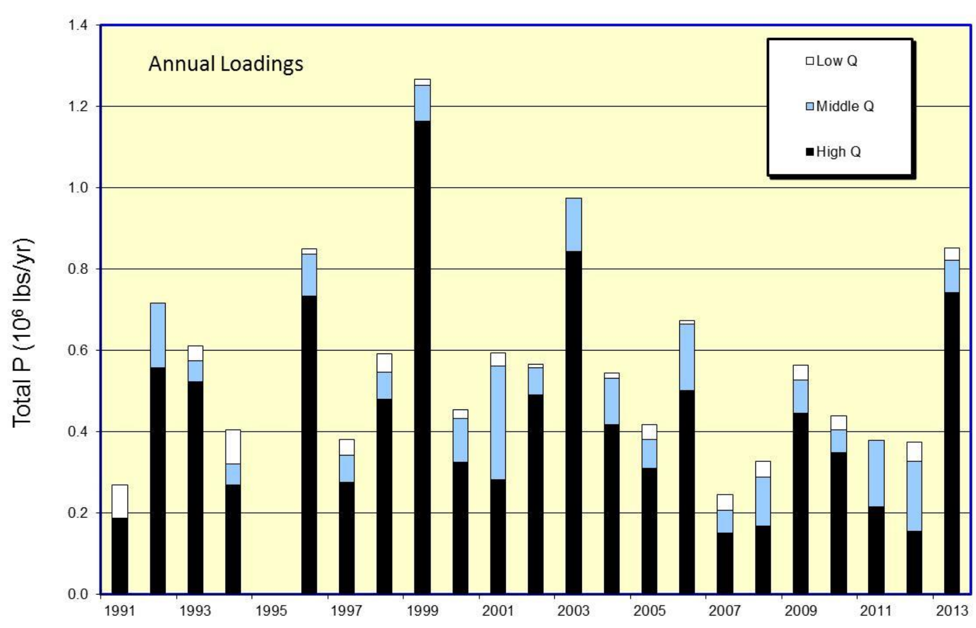


Figure 2-3. Total P Load at Tar River Station (O6500000) near Grimesland

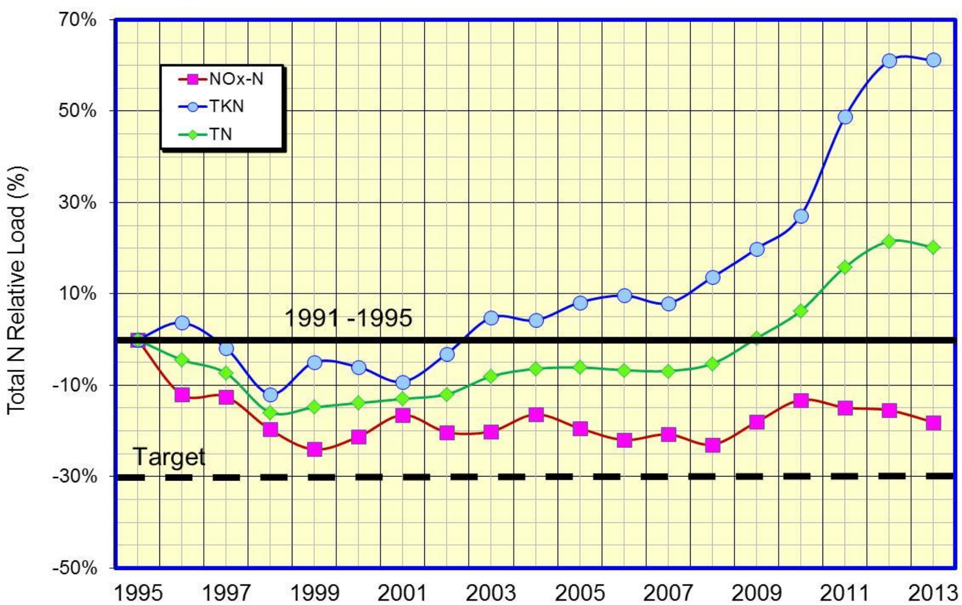


In order to evaluate progress in achieving nutrient reduction goal set by the Tar Pamlico River Basin Nutrient Management Strategy, FN load estimated under long-term average flow conditions were compared to the average load for the 1991-1995 period (Figure 2-4). Five-year moving averages of NOx-N, TKN, TN and TP loads were computed and compared with the corresponding value for the 1991–1995 period.

The results of the FN loading analysis indicate reduction in FN NOx-N loading, but an increase in TKN loading. Flow-normalized NOx-N loading gradually decreased from the 1991-1995 period to the end of the study period. It reached a minimum value of -24.1% in the 1995–1999 time period. The average reduction achieved was approximately 18% for all periods beginning with 1992–1996 (Figure 2-4). Flow-normalized TKN loading at Grimesland decreased from the baseline period and reached the minimum values of -12.0% in the 1994-1998 period and increased substantially afterwards. Flow-normalized TKN loading has been consistently higher than the 1991–1995 period throughout the past 11 five-year periods and increased by about 24% during this period. Since Ammonia loading declined over the same time period, the increase in TKN loading was primarily due to an increase in the Org-N fraction. The recent increase in TKN flow normalized loadings appears to be mainly due to increases for the high flow intervals.

Flow-normalized TN loading exhibited the combination of the patterns for NOx-N and TKN and has been lower than the corresponding 1991-1995 loading until the 2004-2008 period (Figure 2-4). Flow-normalized TN was lower than the 1991-1995 loading through the 2004-2008 period and has been higher than the 1991-1995 loading ever since. The flow-normalized TN loading decreased to a minimum value of -15.9% in the 1994-1998 period and increased gradually afterwards. The average reduction in flow-normalized TN loading for the periods ending in 2004-2008 was approximately 9%. The average increase in flow-normalized TN loading for the periods beginning in 2005-2009 and ending in 2009-2013 was approximately 13%.

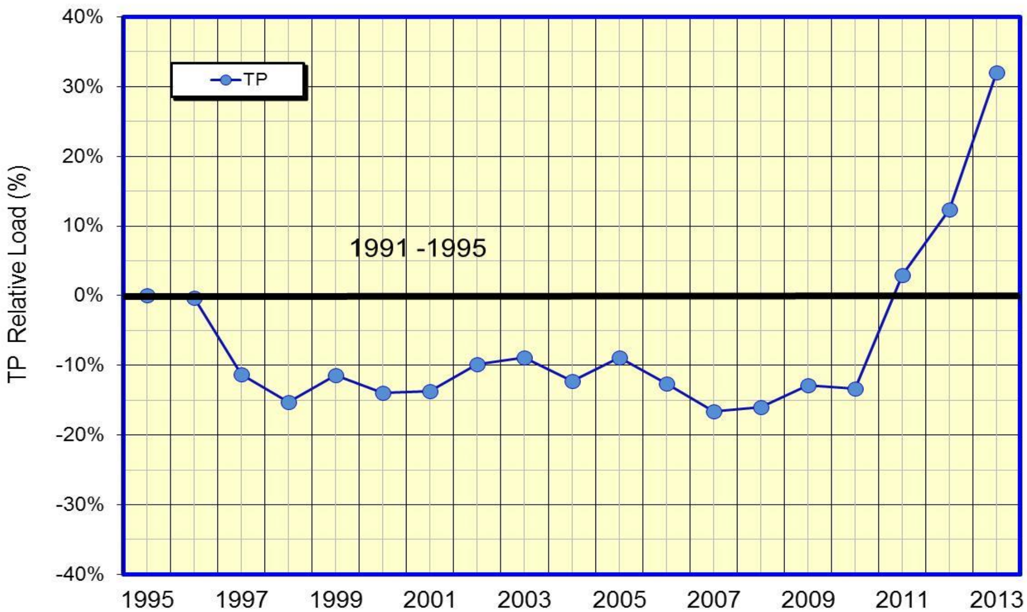
Figure 2-4. Relative N Load Reduction - Comparison to 1991-1995



Flow-normalized TP loading at Grimesland has been consistently lower than the corresponding 1991-1995 loading until the 2007-2011 period and then gradually increased (Figure 2-5). The flow-normalized TP loading decreased to a minimum value of -16.6% in the 2003-2007 period and increased gradually afterwards. The average reduction in flow-normalized TP loading for the periods ending in 2006-2010 was approximately 12%. The average increase in flow-normalized TP loading for the periods beginning in 2007-2011 and ending in 2009-2013 was approximately

16%. The recent increase in flow normalized loadings of TP could be due to increases for the high flow intervals as well as the increases in TP concentration during recent years.

Figure 2-5. Relative P Load Reduction- Comparison to 1991-1995



Average concentrations of N fraction and P by flow interval

Table 2-1 show average concentrations of N fraction and P by flow interval at Tar River station near Grimesland. The results show that changes in N fractions exhibited marked differences for the different flow intervals at Tar River. While the average concentrations of the NOx-N fraction decreased more for the low and middle flow intervals than for high flows, the average concentrations of the TKN fraction increased more for the high flow intervals. For example, reductions in NOx-N for the 2009–2013 period from corresponding values for 1991–1995 were 22, 25, and 16%, respectively, for the low, middle, and high flow interval. Conversely, the increases in TKN concentrations for the 2009-2013 from the corresponding values for 1991-1995 were 39%, 26%, and 71%, respectively, for the low, middle, and high flow interval. The TN concentrations increased by 2% for the low flow intervals and increased by 28% for the high flow intervals. The average concentrations of TP decreased by 14% for the low flow intervals and increased by 43% for the high flow intervals during the same period.

Table 2-1. Average NO3–N, TKN, TN, and TP concentrations (mg/l) at Tar River near Grimesland by five-year period and flow interval				
Constituent	**Period**	**Low**	**Middle**	**High**
NOx-N	1991-1995	0.732	0.621	0.469
NOx-N	1996-2000	0.590	0.562	0.351
NOx-N	2001-2005	0.542	0.503	0.381
NOx-N	2006-2010	0.486	0.480	0.431
NOx-N	2009-2013	0.573	0.466	0.396
TKN	1991-1995	0.466	0.485	0.477
TKN	1996-2000	0.394	0.379	0.470
TKN	2001-2005	0.502	0.506	0.520
TKN	2006-2010	0.657	0.549	0.618
TKN	2009-2013	0.646	0.611	0.817
TN	1991-1995	1.198	1.105	0.946
TN	1996-2000	0.984	0.941	0.820
TN	2001-2005	1.044	1.008	0.901
TN	2006-2010	1.143	1.030	1.050
TN	2009-2013	1.219	1.078	1.213
TP	1991-1995	0.161	0.112	0.123
TP	1996-2000	0.116	0.100	0.107
TP	2001-2005	0.111	0.117	0.111
TP	2006-2010	0.147	0.107	0.104
TP	2009-2013	0.139	0.114	0.176

In summary, the FN loading analysis indicates that substantial reduction of NOx-N loading has been achieved over the study period, but organic Nitrogen loads have not been reduced. Total Nitrogen and total P loads were lower than the 1991-1995 loads for most five-year periods, but there were increases in both TN and TP loads in the three most recent five-year periods. The results of this analysis confirm the nutrient loading trends reported in recent studies (Lebo et al., 2011 and Alameddine et al., 2011).

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Appendix A

Flow-Normalized Loading Analysis

II. Flow-Normalized Loading Analysis

i. Flow-Normalized Loading - DWR AMS O0100000 – Tar River near Tar River

Figures 2-6 and 2-7 show annual TN loading at the Tar River DWR AMS O0100000 near Tar River. The results show that annual TN loading at this station ranged from 0.1 to 4.4 x 10^5 lbs/year for the 1991–2013 timeframe, with a median value of 1.9 x 10^5 lbs/year for (Figure 2.6). Average contributions of Ammonia–N, NOx-N, and Org-N to the TN load for 1991–2013 period were 6, 23 and 71%, respectively. Organic Nitrogen was computed as TKN minus Ammonia. Overall, there was an increase in the contribution of the Org-N fraction and a decrease in that of the NOx-N fraction to TN loading at Tar River for the study period (1991-2013). The Org-N contribution increased from 62% of TN for 1991–2000 period to 79% of TN for 2003–2013 period. The NOx-N contribution decreased from 30% of TN for 1991–2000 period to 17% of TN for 2003–2013 period (Figure 2-6). Figure 2-7 shows annual TN loading at Tar River by flow interval. The average TN contributions (1991-2003) from low, middle, and high flow interval were 1, 7 and 92%, respectively. The annual TP loading at Tar River ranged from 0.06 to 0.7 x 10^5 lbs/year, with a median value of 0.20 x 10^5 lbs/year (Figure 2-8). Figure 2-8 shows annual TP loading at Tar River by flow interval. The average TP contributions (1991-2003) from low, middle, and high flows were 0.6, 6.6 and 92.8%, respectively. These results show that high flow events contribute substantially large amount of nutrients in this watershed.

Figure 2-6. Total N Load at the Tar River Station near Tar River (O0100000)

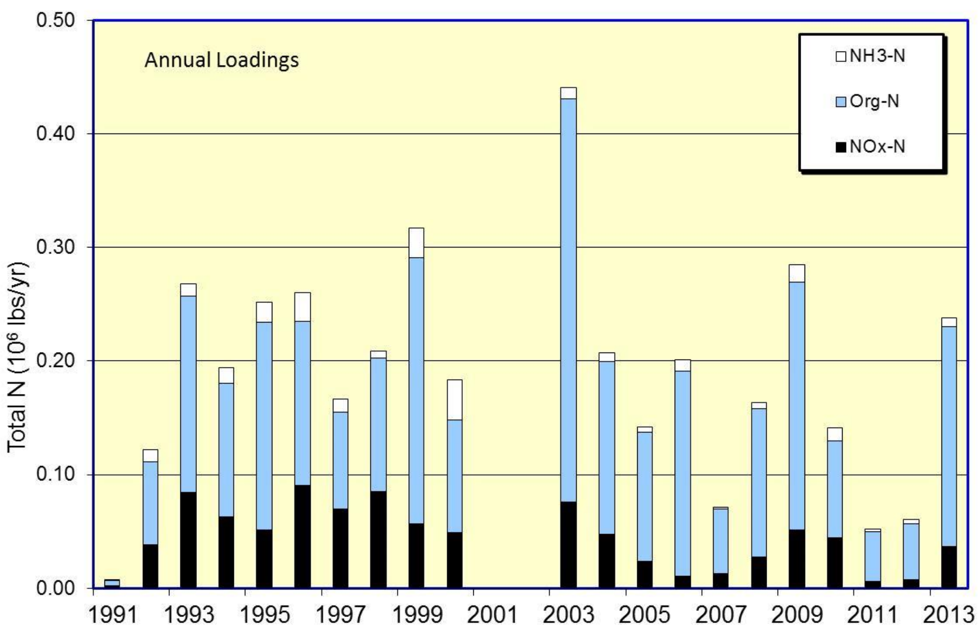


Figure 2-7. Total N Load at the Tar River Station near Tar River (O0100000)

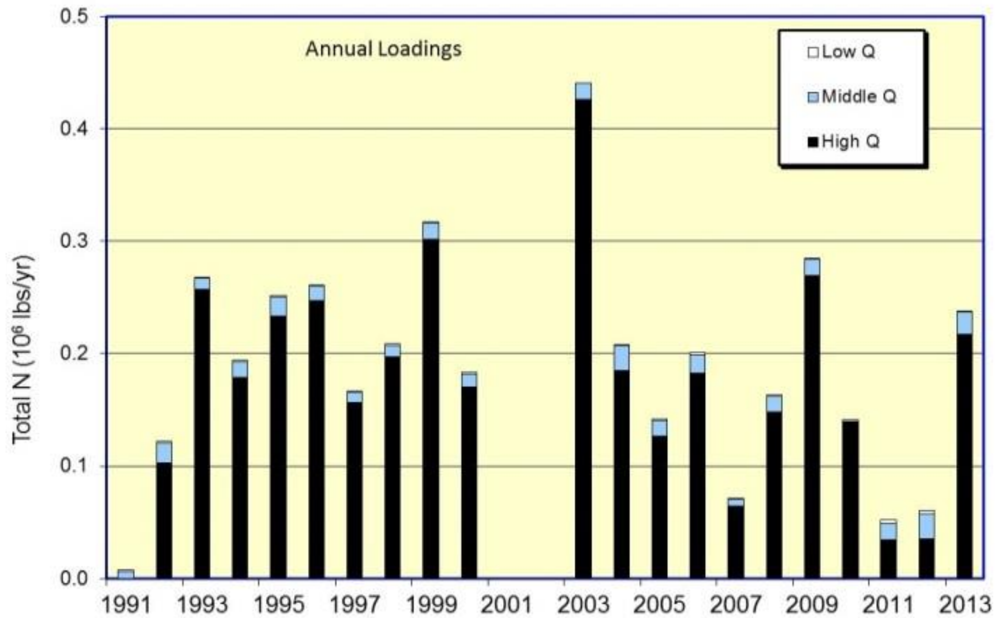
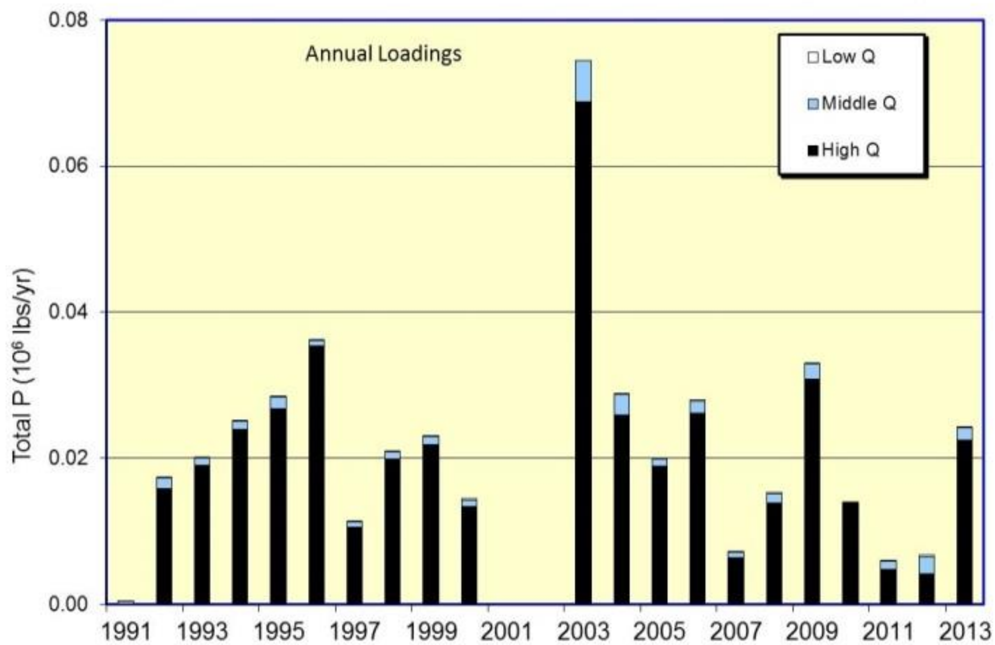


Figure 2-8. Total P Load at the Tar River Station near Tar River (O0100000)

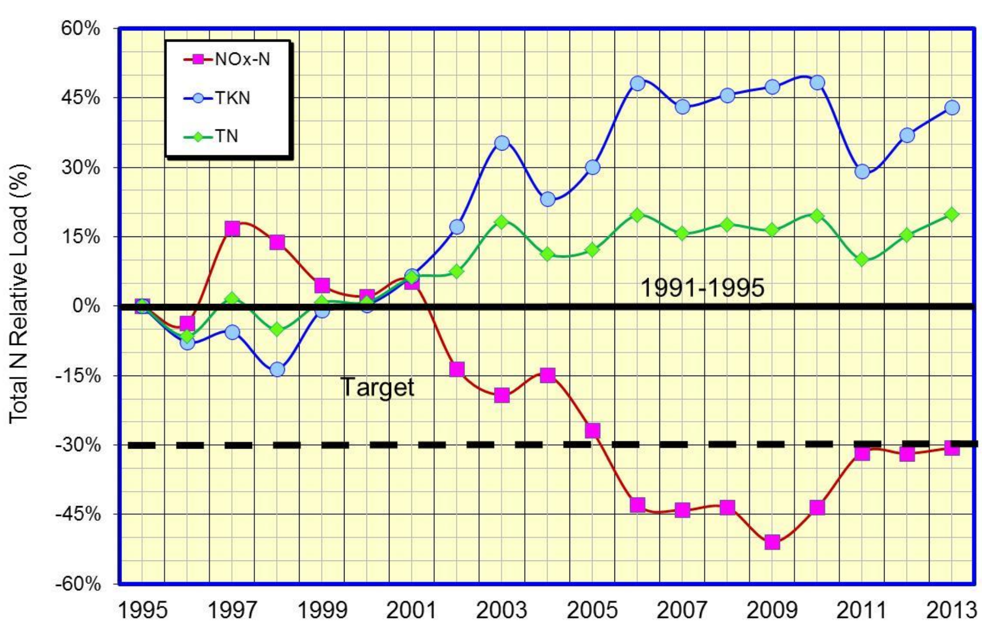


In order to evaluate progress in achieving nutrient reduction goal set by the Tar Pamlico River Basin Nutrient Management Strategy, FN load estimated under long-term average flow conditions were compared to the average load for the 1991-1995 period (Figure 2-9). Five-year moving averages of NOx-N, TKN, TN, and TP loads were computed and compared with the corresponding value for the 1991–1995 period.

The results of the FN loading analysis indicate reduction in FN NOx-N loading, but an increase in TKN loading. Flow-normalized NOx-N loading decreased from the 1991–1995 to the 1992-1996 period and increased back in the 1993-1997 period. It then continued to decrease and reached a minimum value of -50.9% in the 2005–2009 time period. The Flow-normalized NOx–N loadings for the period beginning in the 1993-1997 and ending in the 1997-2001 was higher than the corresponding loading in the 1991-1995 period and was lower thereafter. The average NO3–N reduction achieved was approximately 38% for all periods beginning with 1998–2002 (Figure 2-9). Flow-normalized TKN loading at Tar River decreased from the baseline period and reached the minimum value of -13.6% in the 1994-1998 period and increased gradually afterwards. Flow-normalized TKN loading has been consistently higher than the 1991–1995 baseline period throughout the past 14 five-year periods and increased by about 33% during this period. Since Ammonia loading declined over the same time period, the increase in TKN loading was primarily due to an increase in the Org-N fraction. The recent increase in TKN flow normalized loadings appears to be mainly due to increases for the high flow intervals.

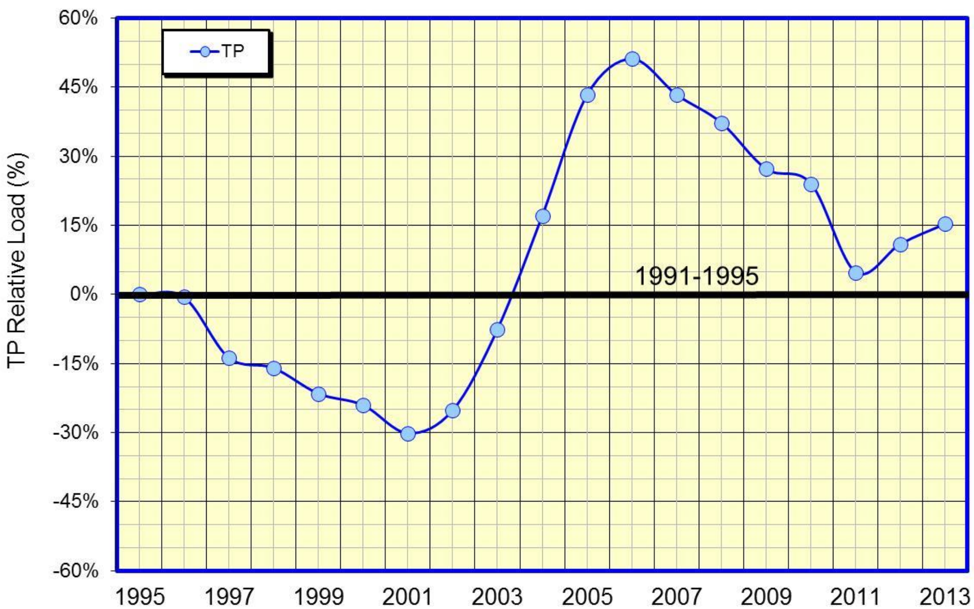
Flow-normalized TN loading exhibited the combination of the patterns for NOx-N and TKN and has been consistently higher than the corresponding 1991-1995 beginning the 1995-1999 period ending with the 2009-2013 period. The FN TN loading decreased to a minimum value of -6.5% in the 1992-1996 period and increased gradually afterwards. The average increase in FN TN loading for the periods beginning in 1995-1999 ending in 2009-2013 was approximately 13% (Figure 2-9).

Figure 2-9. Relative N Load Reduction - Comparison to 1991-1995



Flow-normalized TP loading at Tar River has been consistently lower than the corresponding 1991-1995 loading until the 1997-2001 period and then gradually increased and became higher than the 1991-1995 loading since the 2000-2004 period (Figure 2-10). The flow-normalized TP loading decreased to a minimum value of -16.6% in the 2003-2007 period and increased gradually afterwards. The FN TP loading reached to a maximum value of 51.2% in the 2002-2006 period and declined afterwards, but remained higher than the 1991-1995 period loading. The average reduction in flow-normalized TP loading for the periods ending in 1999-2003 was approximately 17%. The average increase in flow-normalized TP loading for the periods beginning in 2000-2004 and ending in 2009-2013 was approximately 27%.

Figure 2-10. Relative P Load Reduction- Comparison to 1991-1995



Average concentrations of N fraction and TP by flow interval

Table 2-2 show average concentrations of N fraction and P by flow interval at Tar River. The results show that changes in N fractions exhibited marked differences for the different flow intervals at Tar River. While the average concentrations of the NOx-N fraction decreased more for the low and middle flow intervals than for high flows, the average concentrations of the TKN fraction increased more for the middle and high flow intervals. For example, reductions in NOx-N for the 2009-2013 period from corresponding values for 1991–1995 were 61, 12, and 32%, respectively, for the low, middle, and high flow interval. Conversely, the increases in TKN concentrations for the 2007-2011 from the corresponding values for 1991-1995 were 7%, 42%, and 44%, respectively, for the low, middle, and high flow interval. The TN concentrations decreased by 3% for the low flow intervals and increased by 20% for the high flow intervals. The average concentrations of TP decreased by 21% for low flow fraction and increased by 52% for the middle flow fraction during the same period.

Table 2-2. Average NO3–N, TKN, TN, and TP concentrations (mg/l) at Tar River near Tar River by five-year period and flow interval				
Constituent	**Period**	**Low**	**Middle**	**High**
1991-1995	NOx-N	0.064	0.159	0.215
1996-2000	NOx-N	0.058	0.148	0.222
2001-2005	NOx-N	0.050	0.120	0.157
2006-2011	NOx-N	0.044	0.071	0.124
2009-2013	NOx-N	0.025	0.140	0.147
1991-1995	TKN	0.386	0.392	0.462
1996-2000	TKN	0.368	0.289	0.474
2001-2005	TKN	0.423	0.441	0.609
2006-2011	TKN	0.469	0.461	0.699
2009-2013	TKN	0.412	0.555	0.663
1991-1995	TN	0.450	0.551	0.677
1996-2000	TN	0.426	0.437	0.695
2001-2005	TN	0.473	0.561	0.766
2006-2011	TN	0.513	0.532	0.823
2009-2013	TN	0.437	0.695	0.810
1991-1995	TP	0.050	0.046	0.079
1996-2000	TP	0.047	0.034	0.060
2001-2005	TP	0.047	0.094	0.111
2006-2011	TP	0.057	0.057	0.098
2009-2013	TP	0.039	0.070	0.090

In summary, the FN loading analysis indicates that significant reduction of NOx-N loading has been achieved over the study period, but organic Nitrogen loads have not been reduced. Flow-normalized TN and TP loadings has been consistently higher than the corresponding1991-1995 in recent periods. The results of this analysis confirm the nutrient loading trends reported in recent studies. (Lebo et al., 2011 and Alameddine et al., 2011).

ii. Flow-Normalized Loading -DWR AMS O4680000 – Fishing Creek near Enfield

Figures 2-11 and 2-12 show annual TN loading at the Fishing Creek DWR AMS O4680000 near Enfield. The results show that annual TN loading at this station ranged from 0.65 to 9.6 x 10^5 lbs/year for the 1991–2013 timeframe, with a median value of 4.2 x 10^5 lbs/year for (Figure 2-11). Average contributions of Ammonia–N, NOx-N, and Org-N to the TN load for 1991–2013 period were 9, 31 and 60%, respectively. Organic Nitrogen was computed as TKN minus

Ammonia. Overall, there was an increase in the contribution of the Org-N fraction and a decrease in that of the NOx-N fraction to TN loading at Fishing Creek for the study period (1991-2013). The Org-N contribution increased from 55% of TN for 1991–2001 period to 65% of TN for 2002–2013 period. The NOx-N contribution decreased from 33% of TN for 1991–2001 period to 28% of TN for 2002–2013 period. Figure 2-12 shows annual TN loading at Fishing Creek by flow interval. The average TN contributions (1991-2013) from low, middle, and high flow interval were 5, 16 and 79%, respectively. The annual TP loading at Fishing Creek ranged from 0.1 to 1.2 x 10^5 lbs/year, with a median value of 0.43x 10^5 lbs/year (Figure 2-13). Figure 2-13 shows annual TP loading at Fishing Creek by flow interval. The average TP contributions (1991-2013) from low, middle, and high flows were 4, 19 and 77%, respectively. These results show that high flow events contribute substantially large amount of nutrients in this watershed.

Figure 2-11. Total N Load at the Fishing Creek Station (AMS O4680000)

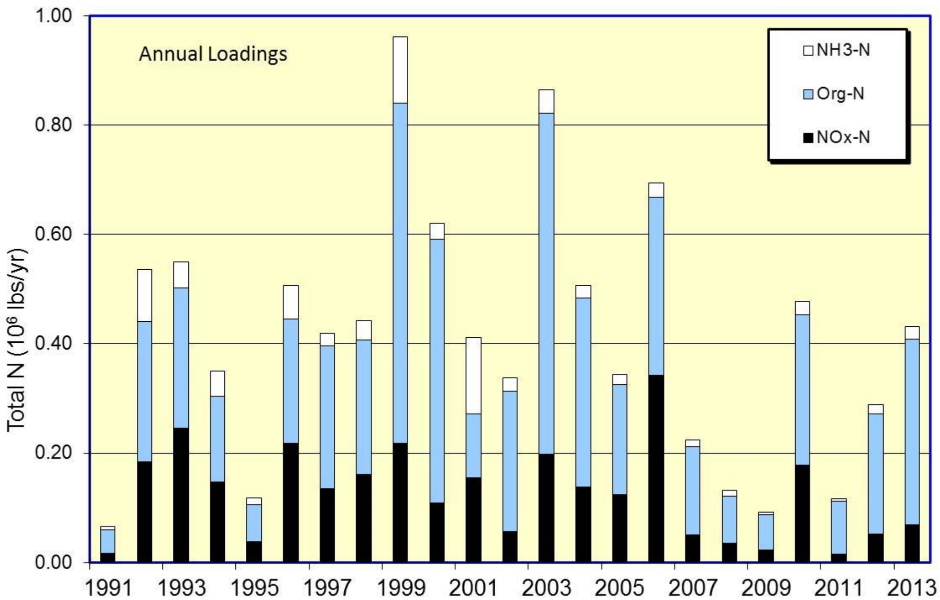


Figure 2-12. Total N Load at the Fishing Creek Station (AMS O4680000)

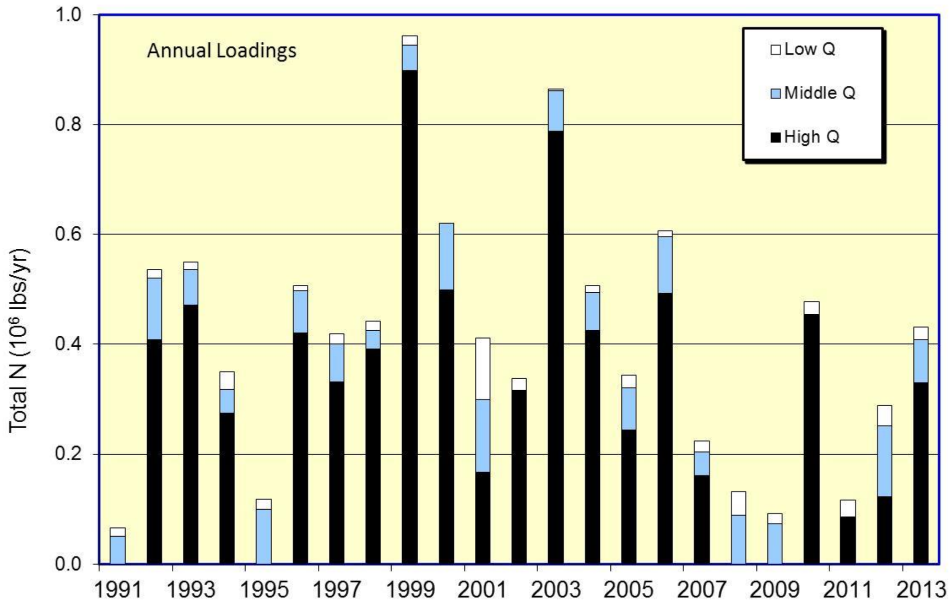
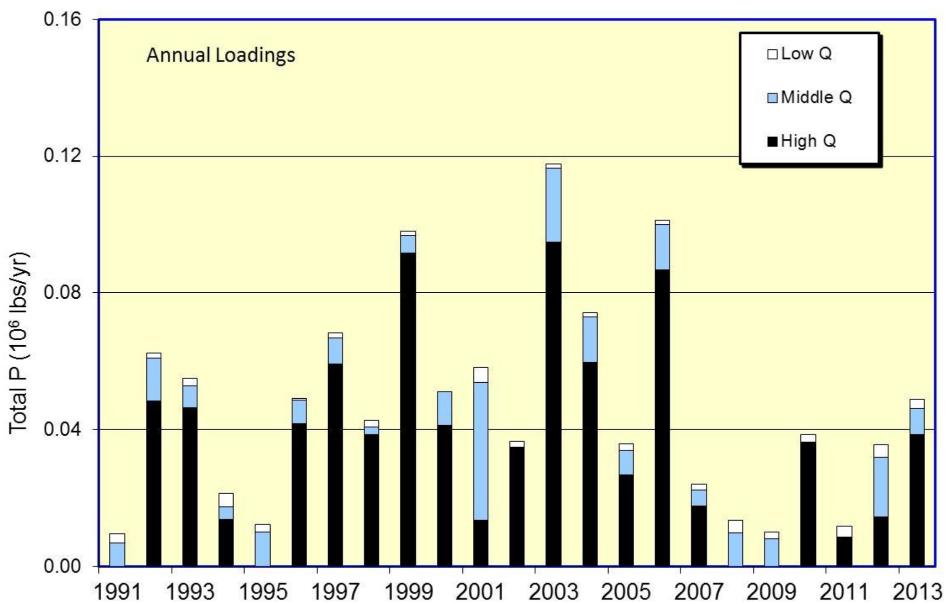


Figure 2-13. Total P Load at the Fishing Creek Station (AMS O4680000)

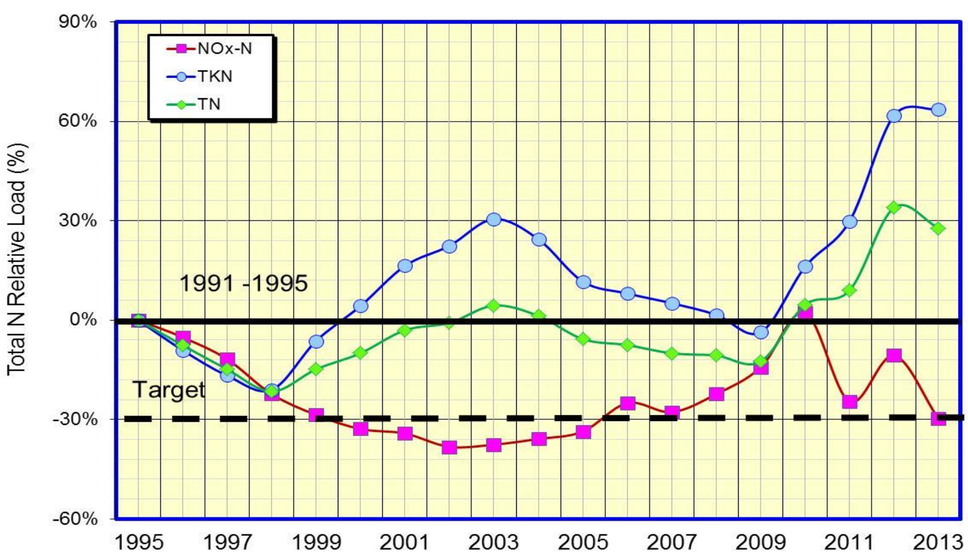


In order to evaluate progress in achieving nutrient reduction goal set by the Tar Pamlico River Basin Nutrient Management Strategy, FN load estimated under long-term average flow conditions were compared to the average load for the 1991-1995 period (Figure 2-14). Five-year moving averages of NOx-N, TKN, TN, and TP loads were computed and compared with the corresponding value for the 1991–1995 period.

The results of the FN loading analysis indicate reduction in FN NOx-N loading, but an increase in TKN loading. Flow-normalized NOx-N loading decreased from the 1991–1995 to the end of the study period. The Flow-normalized NOx-N loading reached a minimum value of -38.2% in the 1998–2002 time period and a maximum values of +2.2% in the 2006-2010 period. The Flow-normalized NO3–N loadings for all periods except the 2006-2010 period were lower than the corresponding loading in the 1991-1995 period. The average reduction in NOx-N achieved was approximately 24% for all periods. Flow-normalized TKN loading at Fishing Creek decreased from the 1991-1995 period and reached the minimum values of -21.0% in the 1994-1998 period and increased gradually afterwards. Flow-normalized TKN loading has been consistently higher than the 1991–1995 period throughout the past 14 five-year periods except in the 2005-2009 period and increased by about 21% during this period (Figure 2-14). Since Ammonia loading declined over the same time period, the increase in TKN loading was primarily due to an increase in the Org-N fraction. The recent increase in TKN flow normalized loadings appears to be mainly due to increases for the high flow intervals.

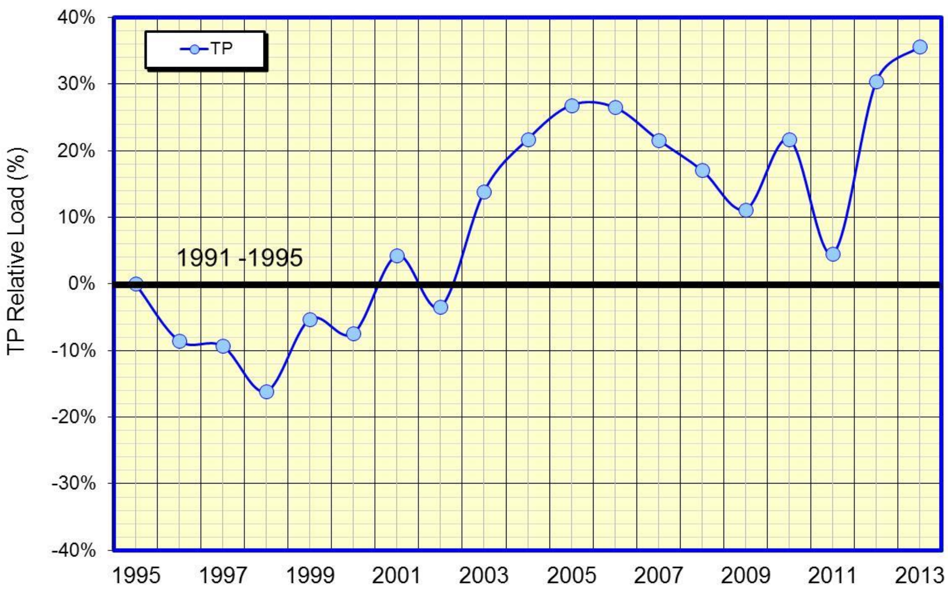
Flow-normalized TN loading exhibited the combination of the patterns for NOx-N and TKN. The FN TN loading decreased to a minimum value of -21.5% in the 1994-1998 period and increased gradually afterwards reaching a maximum values of 34% in the 2008-2012 period. The average decrease in FN TN loading for the periods ending in 2005-2009 was approximately 8% and the average increase for the periods beginning in 2006-2010 and ending in 2009-2013 was about 19% (Figure 2-14).

Figure 2-14. Relative TN Load Reduction - Comparison to 1991-1995



Flow-normalized TP loading at Fishing Creek has been consistently lower than the corresponding 1991-1995 loading until the 1996-2001 period and then gradually increased and became higher than the 1991-1995 loading since the 2002-2007 period. The flow-normalized TP loading decreased to a minimum value of -16.2% in the 1994-1998 period and increased gradually afterwards. The FN TP loading reached to a maximum value of 35.2% in the 2009-2013 period. The average reduction in flow-normalized TP loading for the periods ending in 1996-2000 was approximately 9%. The average increase in flow-normalized TP loading for the periods beginning in 1999-2003 and ending in 2009-2013 was approximately 21.0% (Figure 2-15).

Figure 2-15. Relative TP Load Reduction - Comparison to 1991-1995



Average concentrations of N fraction and P by flow interval

Table 2-3 show average concentrations of N fraction and P by flow interval at Fishing Creek. The results show that changes in N fractions exhibited marked differences for the different flow intervals at Fishing Creek. While the average concentrations of the NOx-N fraction decreased more for the low and middle flow intervals than for high flows, the average concentrations of the TKN fraction increased more for the high flow intervals. For example, reductions in NOx-N for the 2009-2013 period from corresponding values for 1991–1995 were 34, 35, and 29%, respectively, for the low, middle, and high flow interval. Conversely, the increases in TKN concentrations for the 2009-2013 from the corresponding values for 1991-1995 were 47%, 26% and 72%, respectively, for the low, middle and high flow interval. The TN concentrations increased by 19% and 33% for the low flow intervals and high flow intervals, respectively. The average concentrations of TP decreased by 5% for low flow fraction and increased by 44% for the high flow fraction during the same period.

Table 2-3. Average NO3–N, TKN, TN, and TP concentrations (mg/l) at Fishing Creek Station near Enfield by five-year period and flow interval

Constituent	Period	Low	Middle	High
1991-1995	NOx-N	0.148	0.182	0.231
1996-2000	NOx-N	0.153	0.172	0.140
2001-2005	NOx-N	0.344	0.118	0.138
2006-2011	NOx-N	0.163	0.112	0.253
2009-2013	NOx-N	0.098	0.119	0.165
1991-1995	TKN	0.269	0.324	0.362
1996-2000	TKN	0.277	0.295	0.388
2001-2005	TKN	0.456	0.409	0.382
2006-2011	TKN	0.405	0.382	0.413
2009-2013	TKN	0.396	0.409	0.624
1991-1995	TN	0.417	0.506	0.592
1996-2000	TN	0.43	0.467	0.527
2001-2005	TN	0.8	0.528	0.52
2006-2011	TN	0.568	0.494	0.62
2009-2013	TN	0.495	0.528	0.788
1991-1995	TP	0.056	0.052	0.059
1996-2000	TP	0.037	0.043	0.057
2001-2005	TP	0.067	0.111	0.064
2006-2011	TP	0.055	0.057	0.074
2009-2013	TP	0.053	0.059	0.085

In summary, the FN loading analysis for the Fishing Creek station indicates that significant reduction of NOx-N loading has been achieved over the study period, but organic Nitrogen loads have not been reduced. Flow normalized TN and TP loads showed increasing trends in most recent periods. The results of this analysis confirm the nutrient loading trends reported in recent studies (Lebo et al., 2011 and Alameddine et al., 2011).

iii. Flow-Normalized Loading - DWR AMS O5250000 – Tar River near Tarboro

Figures 2-16 and 2-17 show annual TN loading at the Tar River DWR AMS O5250000 near Tarboro. The results show that annual TN loading at this station ranged from 0.74 to 6.2 x 10^6 lbs/year for the 1991–2013 timeframe, with a median value of 2.8 x 10^6 lbs/year for (Figure 2-

16). Average contributions of Ammonia–N, NOx-N, and Org-N to the TN load for 1991–2013 period were 7, 37 and 56%, respectively. Organic Nitrogen was computed as TKN minus Ammonia. Overall, there was a slight increase in the contribution of the Org-N fraction from 1991 to 2001 and a decrease from 2003 to 2013. There was a steady decrease in the NOx-N fraction to TN loading for the study period (1991-2013). The average Org-N contribution increased from 49% of TN for 1991–2001 period to 63% of TN for 2003–2013 period. The NOx-N contribution decreased from 41% of TN for 1991–2001 period to 33% of TN for 2003–2013 period (Figure 2-16). Figure 2-17 shows annual TN loading at Tar River near Tarboro by flow interval. The average TN contributions (1991-2013) from low, middle, and high flow interval were 5, 18 and 77%, respectively. The annual TP loading at Tar River near Tarboro ranged from 0.5 to 8.9 x 10^5 lbs/year, with a median value of 3.3x 10^5 lbs/year (Figure 2-18). Figure 2-18 shows annual TP loading at this station by flow interval. The average TP contributions (1991-2013) from low, middle, and high flows were 4.4, 16.2 and 79.4%, respectively. These results show that high flow events contribute substantially large amount of nutrients in this watershed.

Figure 2-16. Total N load at the Tar River Station (AMS O5250000)

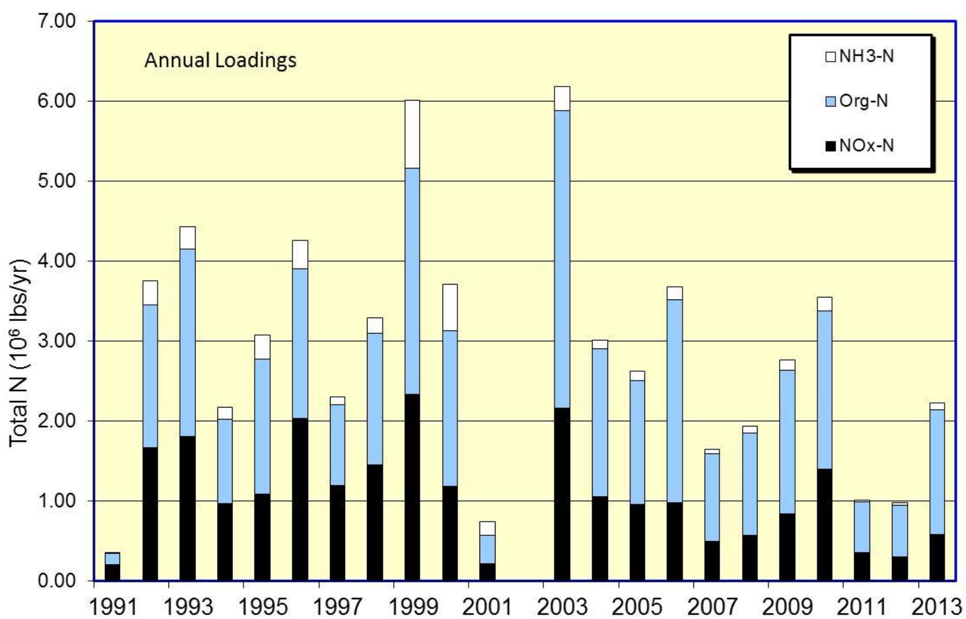


Figure 2-17. Total N load at the Tar River Station (AMS O5250000)

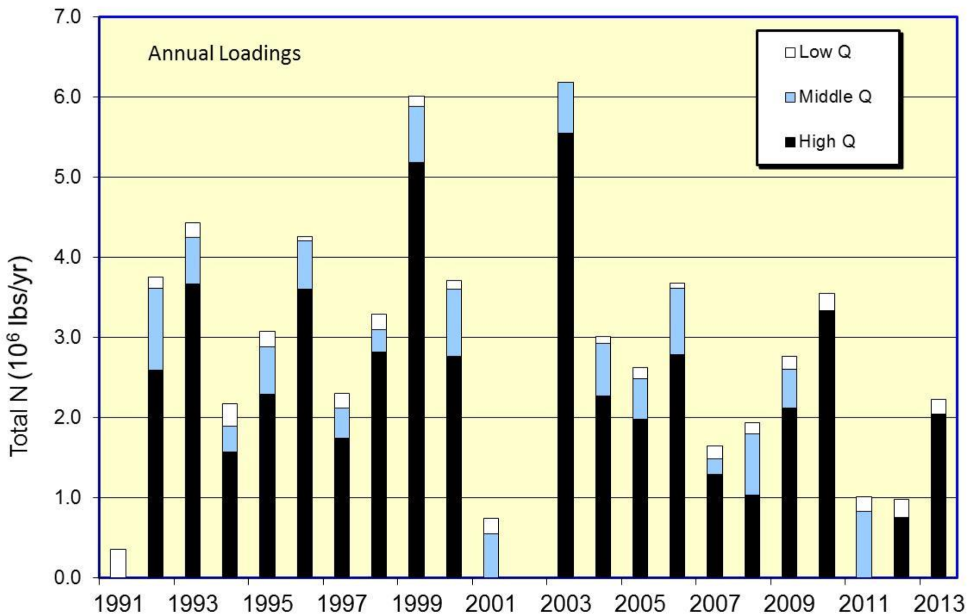
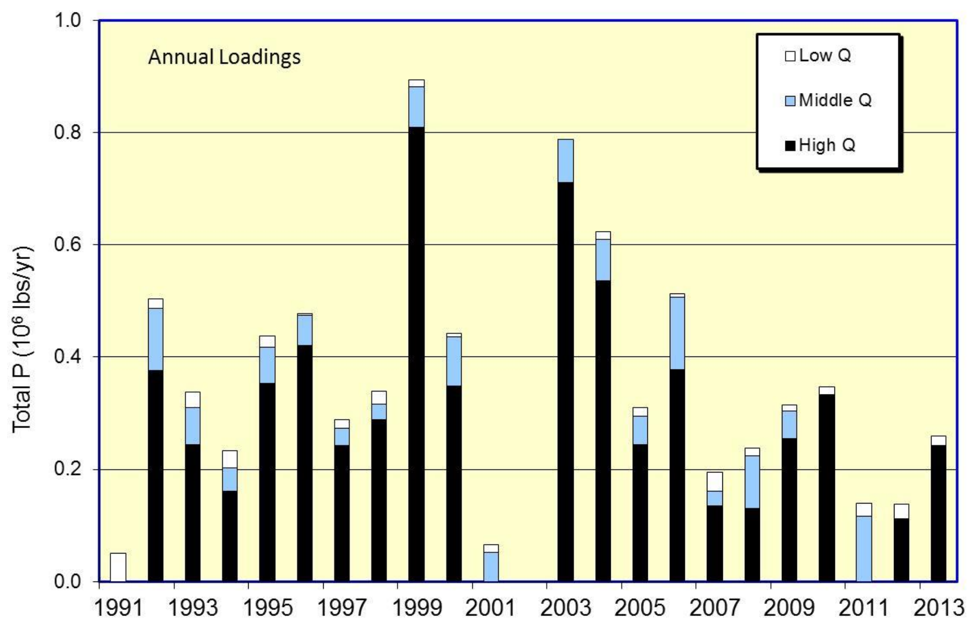


Figure 2-18. Total P load at the Tar River Station (AMS O5250000)

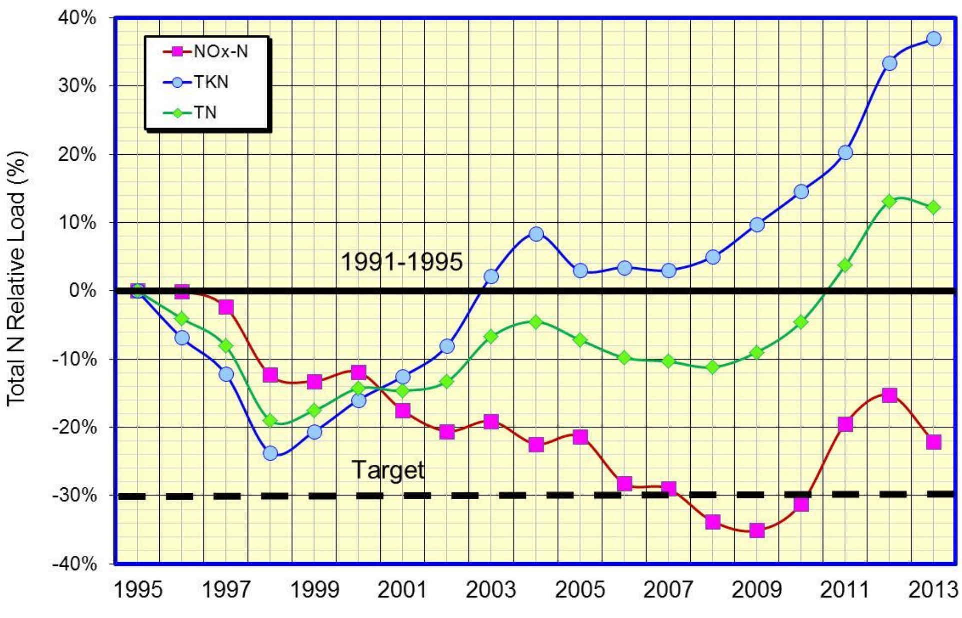


In order to evaluate progress in achieving nutrient reduction goal set by the Tar Pamlico River Basin Nutrient Management Strategy, FN load estimated under long-term average flow conditions were compared to the average load for the 1991-1995 period (Figure 2-19). Five-year moving averages of NOx-N, TKN, TN, and TP loads were computed and compared with the corresponding value for the 1991–1995 period.

The results of the FN loading analysis indicate reduction in FN NOx-N loading, but an increase in TKN loading. Flow-normalized NOx-N loading gradually decreased from the 1991–1995 and reached a minimum value of -35.1% in the 2005–2009 time period and increased afterwards. The Flow-normalized NOx-N loadings for all periods were lower than the corresponding loading in the 1991-1995 period. The average reduction achieved was approximately 20% for all periods. (Figure 2-19). Flow-normalized TKN loading at Tar River near Tarboro decreased from the 1991-1995 period and reached the minimum values of -23.7% in the 1994-1998 period and increased gradually afterwards. Flow-normalized TKN loading has been consistently higher than the 1991–1995 baseline period throughout the past 11 five-year periods and reached a maximum values of 37% in the 2009-2013 period. Ammonia loading declined over the same time period and the increase in TKN loading was primarily due to an increase in the Org-N fraction. The recent increase in TKN flow normalized loadings appears to be mainly due to increases for the high flow intervals.

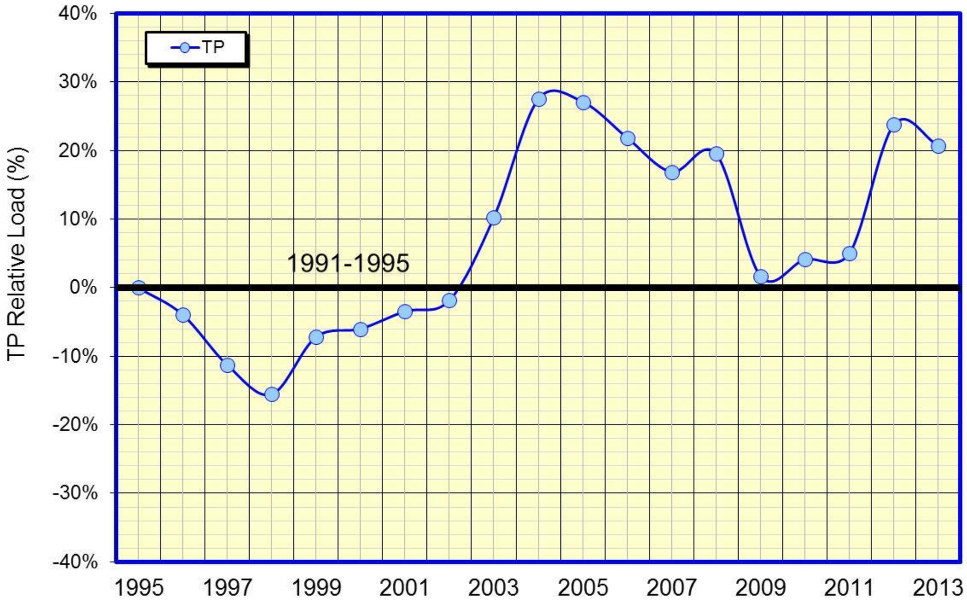
Flow-normalized TN loading exhibited the combination of the patterns for NOx-N and TKN. The FN TN loading decreased to a minimum value of -18.9% in the 1994-1998 period and increased gradually afterwards reaching a maximum values of 13.1% in the 2008-2012 period. The FN TN loading was higher than the corresponding loading of the 1991-1995 period for the last three five-year periods. The average decrease in FN TN loading for the periods ending in 2006-2010 was approximately 11% and the average increase for the periods beginning in 2007-2011 ending in 2009-2013 was about 10% (Figure 2-19).

Figure 2-19. Relative TN Load Reduction - Comparison to 1991-1995



Flow-normalized TP loading at Tar River Station near Tarboro has been consistently lower than the corresponding 1991-1995 loading until the 1998-2002 period and then gradually increased and became higher than the 1991-1995 loading since the 1999-2003 period. The flow-normalized TP loading decreased to a minimum value of -15.6% in the 1994-1998 period and increased gradually afterwards. The FN TP loading reached to a maximum value of 27.5% in the 2000-2004 period. The average reduction in flow-normalized TP loading for the periods ending in 1998-2002 was approximately 7%. The average increase in flow-normalized TP loading for the periods beginning in 1999-2003 and ending in 2009-2013 was approximately 16.0% (Figure 2-20).

Figure 2-20. Relative TP Load Reduction - Comparison to 1991-1995



Average concentrations of N fraction and P by flow interval

Table 2-4 show average concentrations of N fraction and P by flow interval at Tar River near Tarboro. The results show that changes in N fractions exhibited marked differences for the different flow intervals at Tar River near Tarboro. While the average concentrations of the NOx-N fraction decreased more for the low and middle flow intervals than for high flows, the average concentrations of the TKN fraction increased more for the high flow intervals. For example, reductions in NOx-N for the 2009-2013 period from corresponding values for 1991–1995 were 21, 32, and 20%, respectively, for the low, middle, and high flow interval. Conversely, the increases in TKN concentrations for the 2009-2013 from the corresponding values for 1991-1995 were 21%, 6%, and 45%, respectively, for the low, middle, and high flow interval. The TN concentrations decreased by 3% for the low flow intervals and increased by 20% for the high flow intervals. The average concentrations of TP decreased by 27% for low flow fraction and increased by 32% for the high flow fraction during the same period.

Table 2-4. Average NO3–N, TKN, TN, and TP concentrations (mg/l) at Tar River near Tarboro by five-year period and flow interval				
Constituent	**Period**	**Low**	**Middle**	**High**
1991-1995	NOx-N	0.550	0.404	0.327
1996-2000	NOx-N	0.507	0.443	0.266
2001-2005	NOx-N	0.295	0.301	0.269
2006-2011	NOx-N	0.401	0.255	0.229
2009-2013	NOx-N	0.437	0.276	0.263
1991-1995	TKN	0.39	0.53	0.49
1996-2000	TKN	0.30	0.38	0.42
2001-2005	TKN	0.43	0.45	0.52
2006-2011	TKN	0.50	0.54	0.57
2009-2013	TKN	0.47	0.56	0.71
1991-1995	TN	0.94	0.93	0.81
1996-2000	TN	0.81	0.82	0.69
2001-2005	TN	0.72	0.75	0.79
2006-2011	TN	0.90	0.80	0.80
2009-2013	TN	0.910	0.841	0.969
1991-1995	TP	0.119	0.105	0.089
1996-2000	TP	0.078	0.079	0.090
2001-2005	TP	0.090	0.081	0.129
2006-2011	TP	0.108	0.104	0.095
2009-2013	TP	0.087	0.100	0.117

In summary, the FN loading analysis indicates that significant reduction of NOx-N loading has been achieved over the study period, but organic Nitrogen loads have not been reduced Flow normalized TN and TP loads showed increasing trends in most recent periods. The results of this analysis confirm the nutrient loading trends reported in recent studies (Lebo et al., 2011 and Alameddine et al., 2011).

iv. Flow-Normalized Loading - DWR AMS O4650000 – Chicod Creek near Simpson

Figures 2-21 and 2-22 shows annual TN loading at the Chicod Creek DWR AMS O4650000 near Simpson. The results show that annual TN loading at this station ranged from 0.12 to 3.34 x 10^5 lbs/year for the 1993–2013 timeframe, with a median value of 1.17 x 10^5 lbs/year for (Figure 2-21). Average contributions of Ammonia–N, NOx-N, and Org-N to the TN load for 1993–2013 period were 12.6, 42.8 and 44.6%, respectively. Organic Nitrogen was computed as TKN minus

Ammonia. Overall, there was a slight decrease in the contribution of the Org-N fraction from 1993 to 2001 and an increase from 2002 to 2013. There was a steady decrease in the NOx-N fraction to TN loading for the study period (1993-2013). The Org-N contribution increased from 33% of TN for 1993–2002 period to 60% of TN for 2003–2013 period. The NOx-N contribution decreased from 48% of TN for 1993–2002 period to 35% of TN for 2003–2013 period (Figure 2-21). Figure 2-22 shows annual TN loading at Tar River near Simpson by flow interval. The average TN (1991-2013) contributions from low, middle, and high flow interval were 1, 7, and 92%, respectively. The annual TP loading at Chicod Creek ranged from 0.04 to 0.67 x 10^5 lbs/year, with a median value of 0.26 x 10^5 lbs/year (Figure 2-23). Figure 2-23 shows annual TP loading at Chicod Creek by flow interval. The average TP contributions from low, middle, and high flows were 2, 9, and 89%, respectively. These results show that high flow events contribute substantially large amount of nutrients in this watershed.

Figure 2-21. Total N Load at the Chicod Creek Station (AMS O6450000)

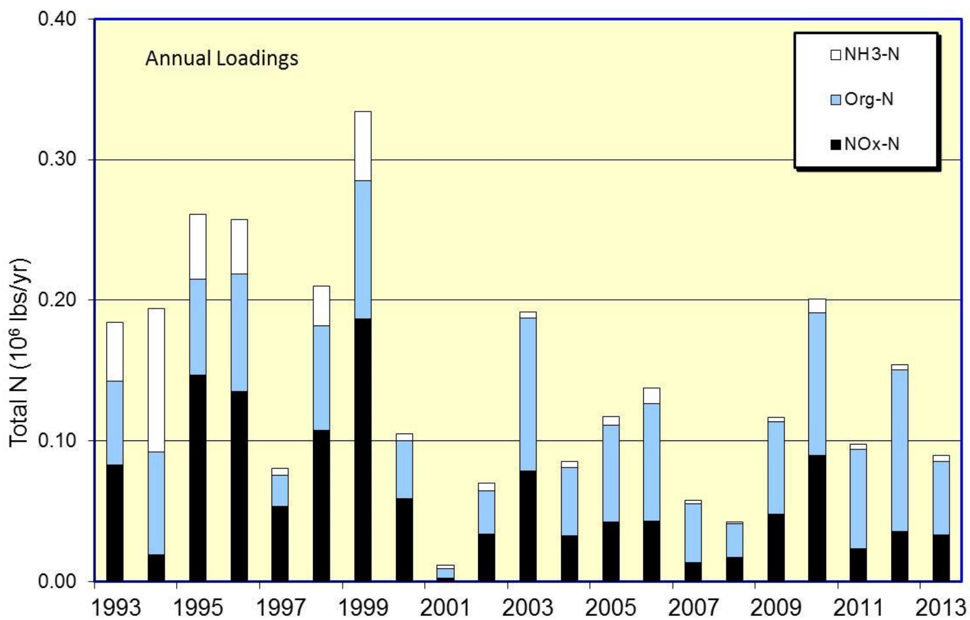


Figure 2-22. Total N Load at the Chicod Creek Station (AMS O6450000)

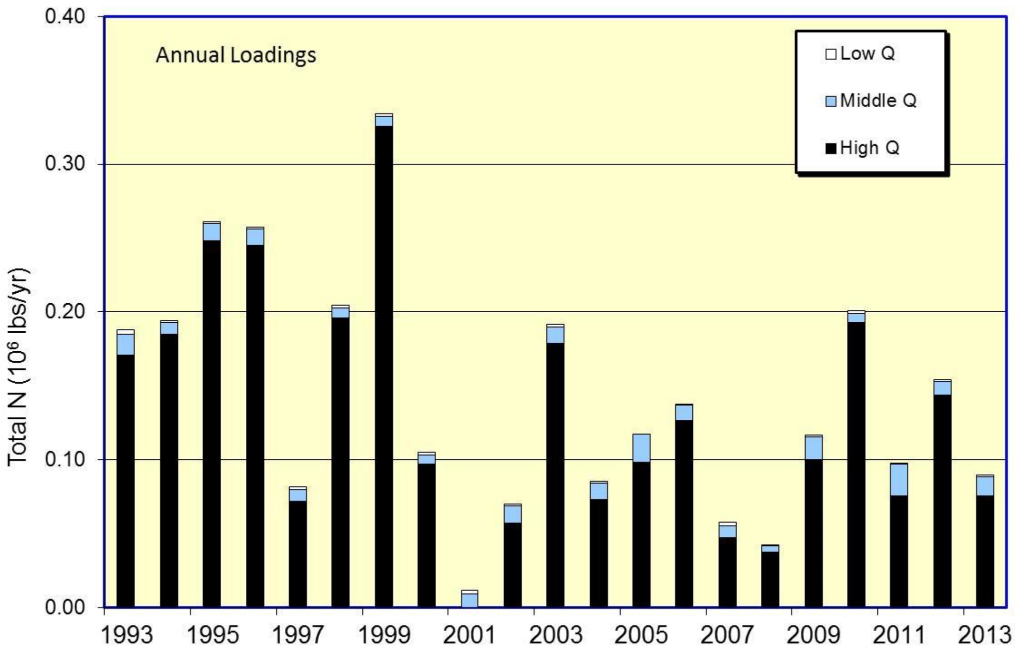
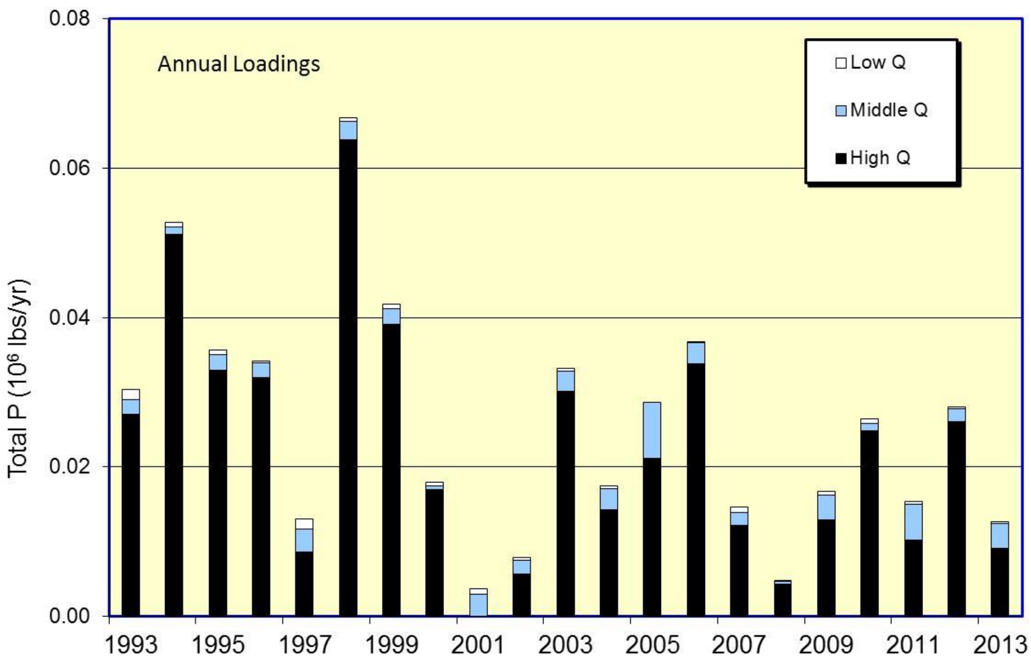


Figure 2-23. Total P Load at the Chicod Creek Station (AMS O6450000)

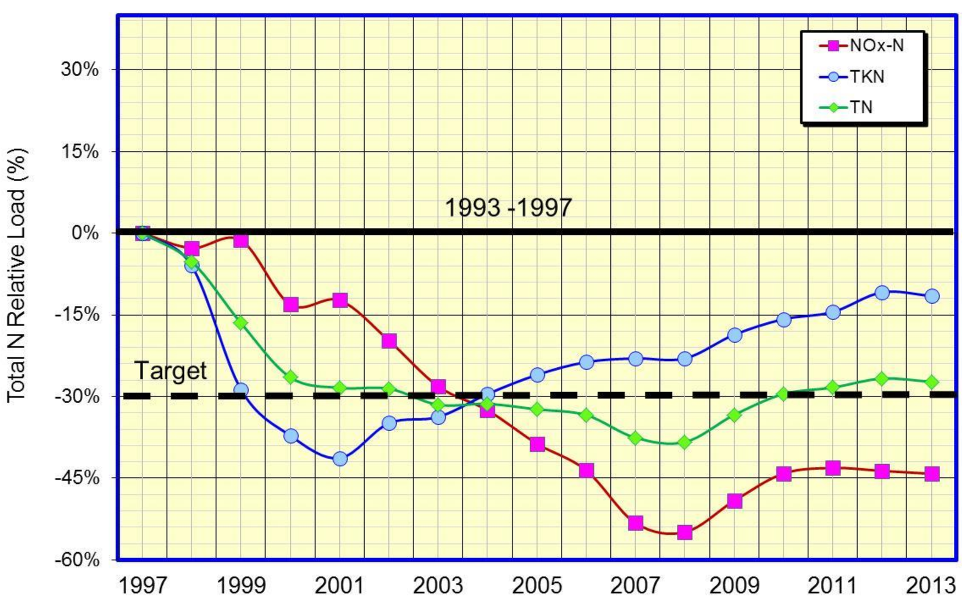


In order to evaluate progress in achieving nutrient reduction goal set by the Tar Pamlico River Basin Nutrient Management Strategy, FN load estimated under long-term average flow conditions were compared to the average load for the 1993-1997 period (Figure 2-24). Five-year moving averages of NOx-N, TKN, TN, and TP loads were computed and compared with the corresponding value for the 1993–1997 period.

The results of the FN loading analysis indicate reduction in FN NOx-N and TKN loadings relative to the 1993-1997 period. Flow-normalized NOx-N loading gradually decreased from the 1993–1997 period and reached a minimum value of -54.9% in the 2004–2008 time period and slightly increased afterwards. The Flow-normalized NOx–N loadings for all periods were lower than the corresponding loading in the 1993-1997 period. The average NOx-N load reduction achieved was approximately 33% for all periods (Figure 2-24). Flow-normalized TKN loading at Chicod Creek near Simpson gradually decreased from the 1993-1997 period and reached the minimum values of -41.3% in the 1997-2001 period and increased gradually afterwards. Flow-normalized TKN and NOx-N loadings have been consistently lower than the 1993–1997 time period throughout the study period. The average TKN load reduction achieved was approximately 24% for all periods (Figure 2-24). Ammonia loading declined over the same time period.

Flow-normalized TN loading exhibited the combination of the patterns for NOx-N and TKN. The FN TN loading decreased to a minimum value of -38.4% in the 2004-2008 period and increased gradually afterwards. The FN TN loading was consistently lower than the corresponding loading of the 1993-1997 period throughout the study period. The average decrease in FN TN loading for the periods ending in 2006-2010 was approximately 11% and the average increase for the periods beginning in 2007-2011 ending in 2009-2013 was about 10%. The average TN load reduction achieved was approximately 28% for all periods (Figure 2-24).

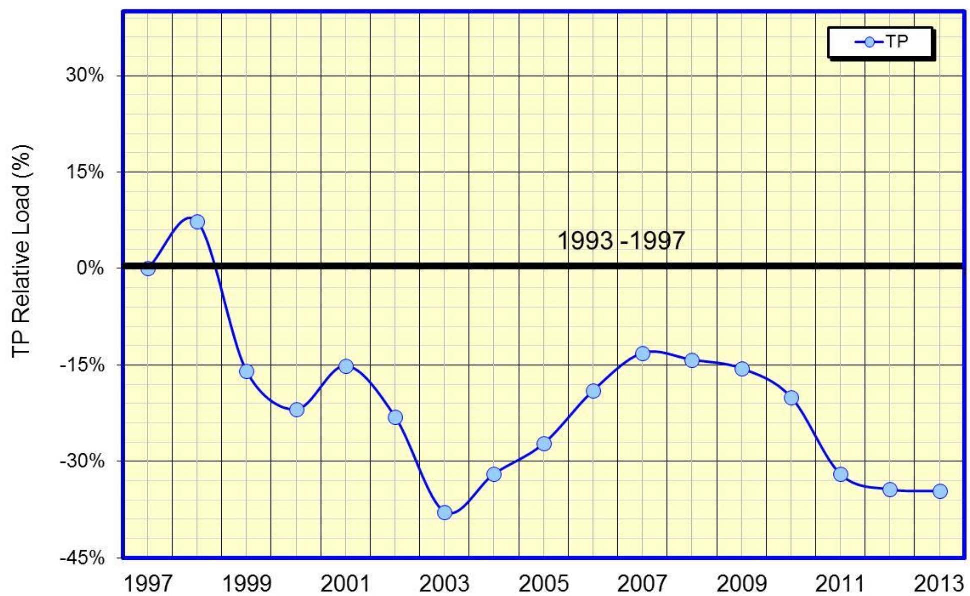
Figure 2-24. Relative TN Load Reduction - Comparison to 1993 -1997



Flow-normalized TP loading at Chicod Creek Station near Simpson has been consistently lower than the corresponding 1993-1998 loading except in the 1994-1998 period. The flow-normalized TP loading decreased to a minimum value of -37.8% in the 1999-2003 period and increased gradually reaching a maximum values of -13.1 in the 2003-2007 period and declined afterwards.

The average reduction in flow-normalized TP loading for all periods was approximately 22%. The average increase in flow-normalized TP loading for the periods beginning in 1999-2003 and ending in 2009-2013 was approximately 16.0% (Figure 2-25).

Figure 2-25. Relative TP Load Reduction - Comparison to 1993 -1997



Average concentrations of N fraction and P by flow interval

Table 2-5 show average concentrations of N fraction and P by flow interval at Chicod Creek. The results show that changes in N fractions exhibited marked differences for the different flow intervals at Chicod Creek. The average concentrations of the NOx-N fraction decreased more for the low and middle flow intervals than for high flows. Unlike the other stations included in this analysis, the average concentrations of the TKN fraction increased more for low and middle flow intervals and decreased for the high flow intervals. For example, reductions in NOx-N for the 2009-2013 period from corresponding values for 1991–1995 were 88, 68, and 42%, respectively, for the low, middle, and high flow interval. Conversely, the increases in TKN concentrations for the 2009-2013 from the corresponding values for 1991-1995 were 18% and 23%, respectively, for the low, middle flow intervals and decreased by 15% for the high flow intervals. The TN concentrations decreased by 13% for the low flow intervals and by 28% for the high flow intervals. The average concentrations of TP decreased by 44% and 37% for low flow fractions and high flow fractions, respectively, during the same period.

Table 2-5. Average NO3–N, TKN, TN, and TP concentrations (mg/l) at Chicod Creek near Simpson by five-year period and flow interval				
Constituent	**Period**	**Low**	**Middle**	**High**
1993-1997	NOx-N	0.340	0.623	0.840
1998-2002	NOx-N	0.160	0.213	0.708
2003-2007	NOx-N	0.104	0.194	0.404
2008-2012	NOx-N	0.037	0.204	0.492
2009-2013	NOx-N	0.040	0.201	0.487
1993-1997	TKN	0.853	0.703	0.940
1998-2002	TKN	0.751	0.609	0.593
2003-2007	TKN	0.948	0.745	0.697
2008-2012	TKN	1.127	0.858	0.808
2009-2013	TKN	1.010	0.868	0.801
1993-1997	TN	1.207	1.340	1.789
1998-2002	TN	0.911	0.821	1.293
2003-2007	TN	1.052	0.939	1.102
2008-2012	TN	1.163	1.061	1.299
2009-2013	TN	1.050	1.069	1.288
1993-1997	TP	0.575	0.264	0.283
1998-2002	TP	0.280	0.235	0.216
2003-2007	TP	0.319	0.266	0.244
2008-2012	TP	0.306	0.214	0.182
2009-2013	TP	0.324	0.231	0.179

In summary, the FN loading analysis for the Chicod Creek indicates that substantial reductions of NOx-N , Organic Nitrogen, TN and TP loadings have been achieved over the study period, but organic Nitrogen loads have started to increase in recent periods.

Appendix B

Annual Flow Volume Plots for Selected Stations in the Tar Pamlico River Basin

Figure B-1. Estimated Annual Flow Volume for Tar River at Grimsland AMS Station

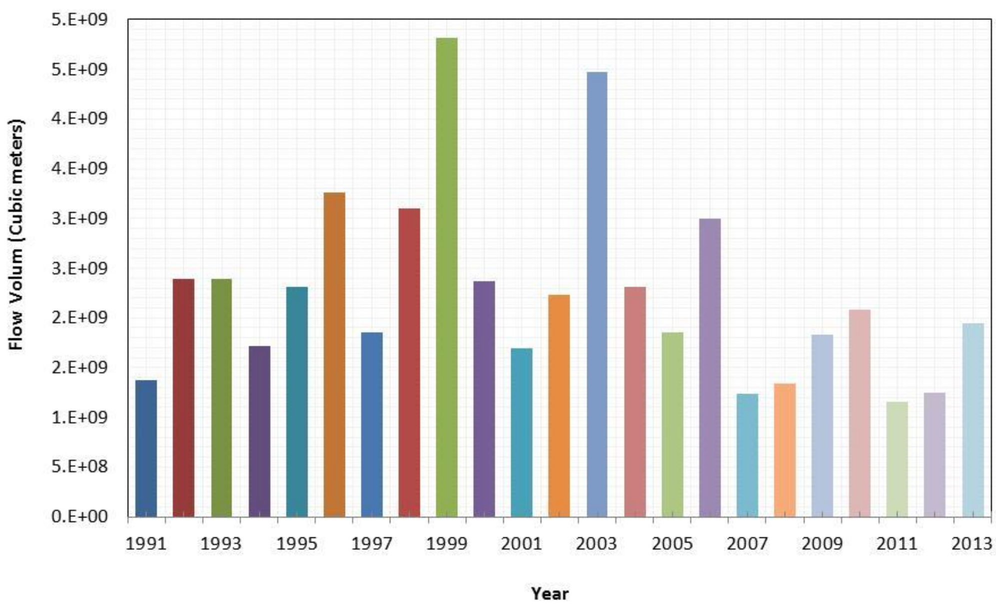
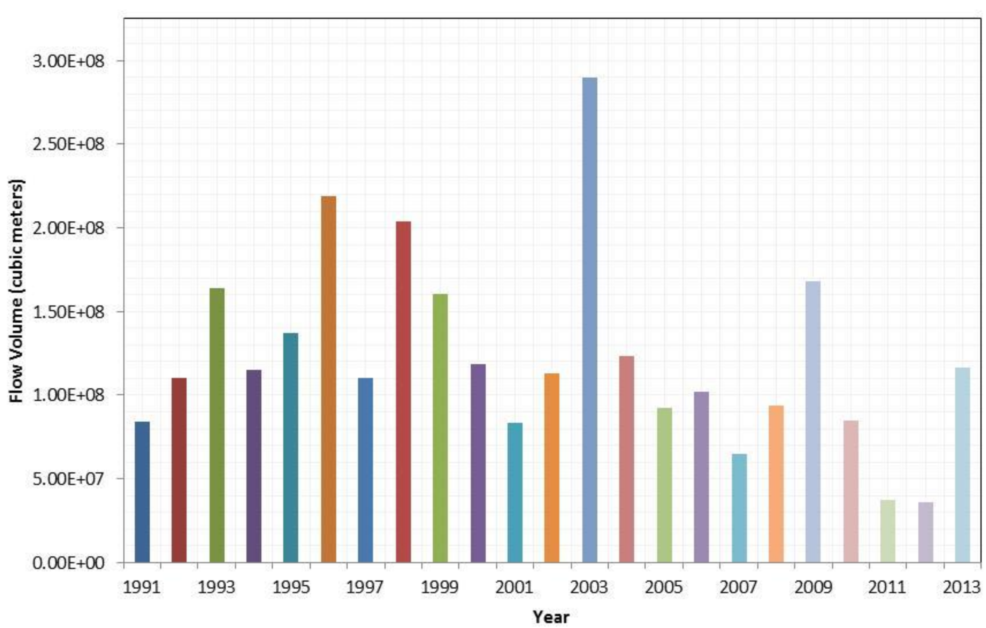


Figure B-2. Annual Flow volume at USGS gage 02081500 - Tar River near Tar River



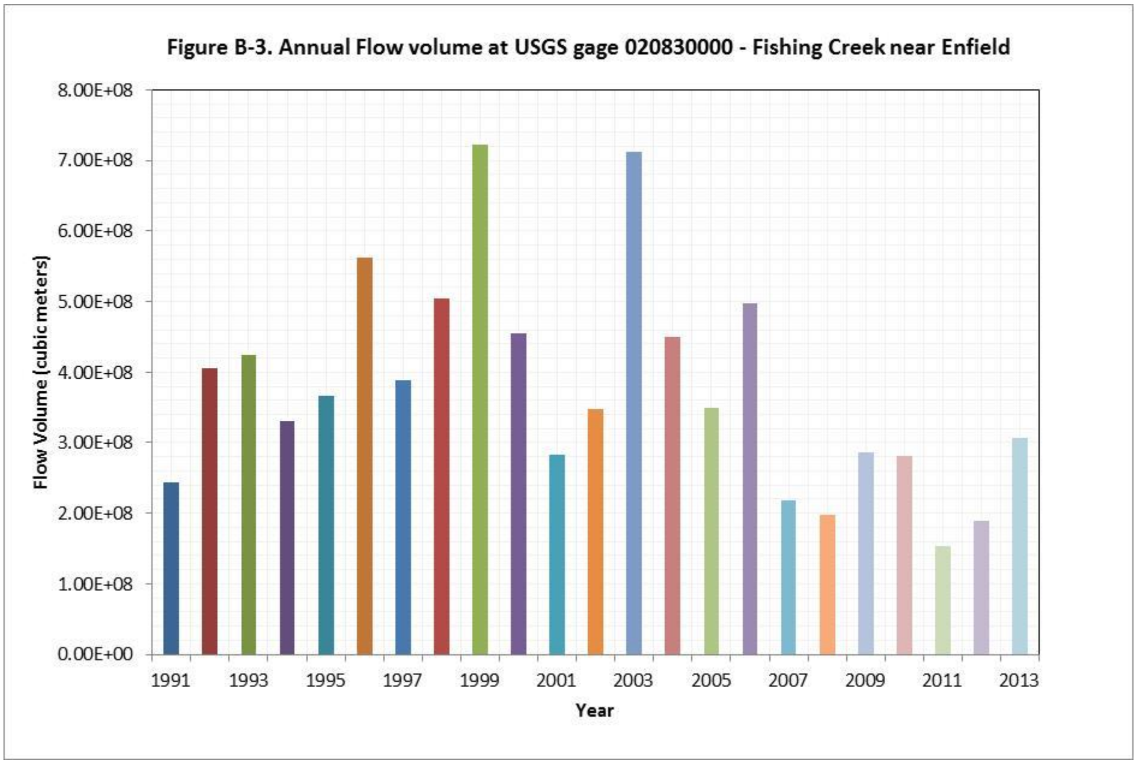


Figure B-3. Annual Flow volume at USGS gage 020830000 - Fishing Creek near Enfield
Flow Volume (cubic meters)
8.00E+08
7.00E+08
6.00E+08
5.00E+08
4.00E+08
3.00E+08
2.00E+08
1.00E+08
0.00E+00
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Year

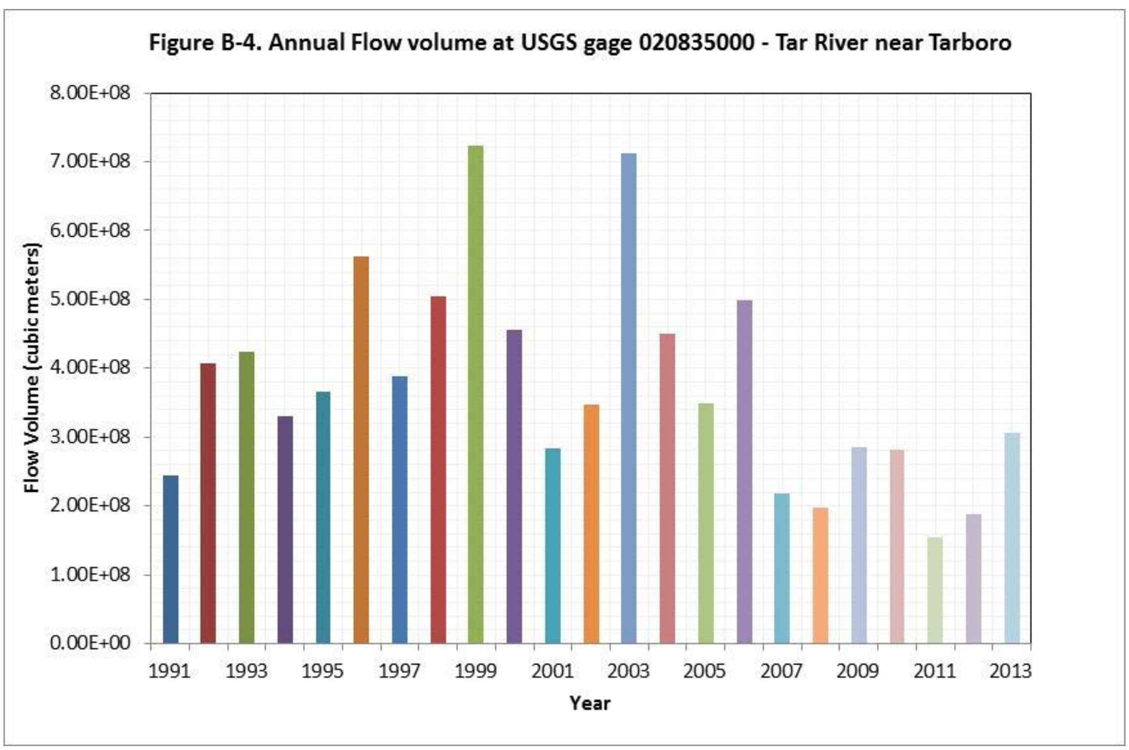


Figure B-4. Annual Flow volume at USGS gage 020835000 - Tar River near Tarboro
Flow Volume (cubic meters)
8.00E+08
7.00E+08
6.00E+08
5.00E+08
4.00E+08
3.00E+08
2.00E+08
1.00E+08
0.00E+00
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Year

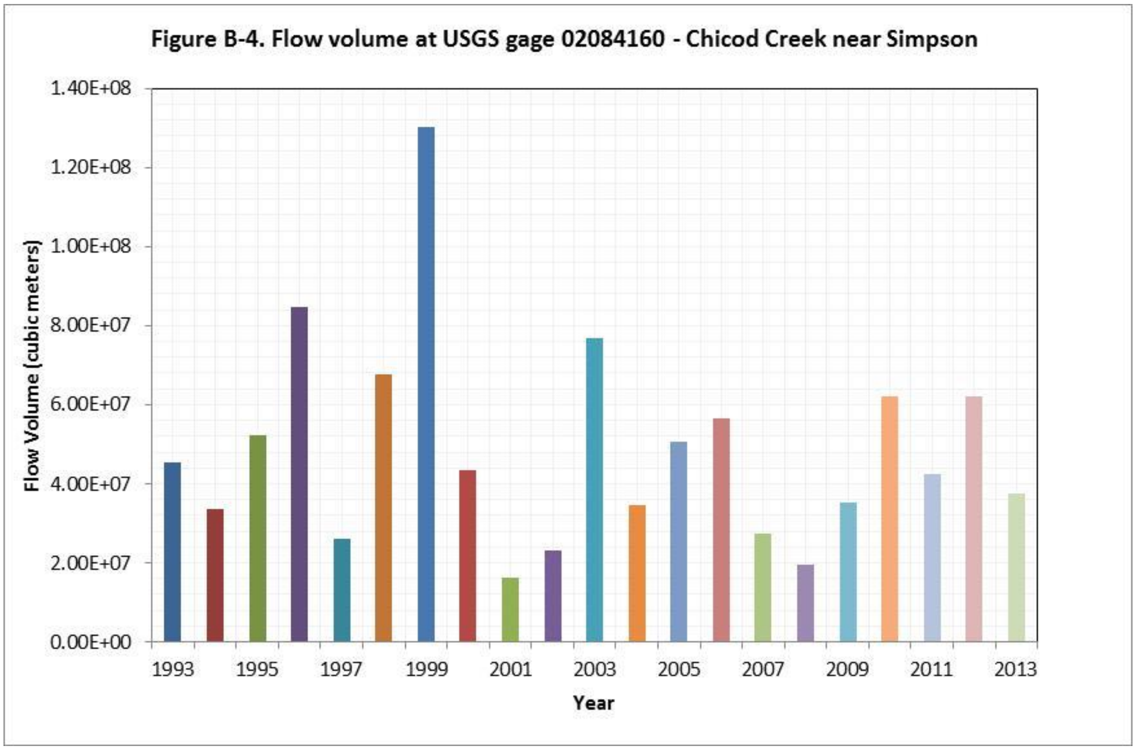


Figure B-4. Flow volume at USGS gage 02084160 - Chicod Creek near Simpson
Flow Volume (cubic meters)
1.40E+08
1.20E+08
1.00E+08
8.00E+07
6.00E+07
4.00E+07
2.00E+07
0.00E+00
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Year

Appendix C

Tables and Plots of Loads Estimated using the USGS LOADEST Program

Annual Total Nitrogen (TN) Load (lbs/yr)															
Station	**O6500000**			**O0100000**			**O4680000**			**O5250000**			**O6450000**		
Year	**Mean**	**LCL***	**UCL***	**Mean**	**LCL***	**UCL***	**Mean**	**LCL***	**UCL***	**Mean**	**LCL***	**UCL***	**Mean**	**LCL***	**UCL***
1991	3272996	2928178	3646907	167577	111083	243794	132312	101127	170295	2347903	2075332	2646037	[redacted]		
1992	5373790	4816305	5977763	227023	144096	343899	115201	85081	153193	4032149	3559081	4551028			
1993	4903616	4433579	5409807	413659	270388	610379	245494	188902	314503	3724864	3332683	4150299	258109	198416	330671
1994	3497303	3168380	3851158	255059	174828	361163	126259	98274	160006	2536929	2273908	2821904	163656	121046	218267
1995	4790361	4332947	5282587	287810	194538	411379	165000	127243	210574	3500471	3124764	3908924	254248	193567	328574
1996	6588950	5990867	7231284	695551	409786	1128968	274113	198537	373416	4785974	4294108	5319250	380862	276630	514859
1997	3751423	3424976	4100589	207815	144109	292208	132860	103940	167813	2578970	2326089	2852026	85960	68202	107062
1998	5441898	4907429	6018878	598219	379276	903607	304863	229120	398850	3930741	3508677	4389519	287109	198267	405156
1999	8062059	7078619	9152443	490213	310102	740851	201938	150807	265226	6402173	5460228	7470190	634519	446004	877846
2000	4705230	4274866	5167221	208003	155194	274119	118356	96651	143649	3204805	2872432	3565243	144527	103433	197437
2001	3293905	2983532	3627548	203610	132516	300186	124689	93187	163542	2276800	2027930	2548040	46968	32705	65975
2002	4459830	4053770	4895649	284515	177087	441063	150884	112746	199177	2789664	2495200	3109472	61416	46604	79581
2003	8319762	7521405	9179533	783009	524870	1126275	362839	282223	459703	5606563	5009860	6254670	231560	168623	311069
2004	4790606	4369195	5241422	260196	178272	369747	142168	110169	181065	3130915	2819363	3467845	87506	67570	111807
2005	3752537	3434025	4092429	166531	121753	223185	110474	88906	135905	2353647	2133976	2589514	142412	104286	190854
2006	6031887	5435795	6675993	231160	158909	326867	120675	93244	153915	4197717	3733346	4704609	154439	117217	200897
2007	2603728	2384019	2838294	120919	87632	163451	116053	92704	143756	1669093	1512304	1837570	68067	54352	84392
2008	2941899	2682224	3219596	245977	156045	372785	133118	98316	177042	1731803	1558501	1919208	53897	40646	70237
2009	3980344	3618630	4368100	444293	306532	624422	261056	205653	327036	2471215	2217712	2745513	103721	78813	134666
2010	4405350	3952367	4896569	193689	130349	279030	108657	84141	138343	2677974	2373161	3011490	267276	159999	429639
2011	2880270	2590136	3195264	65078	46606	88854	45392	35098	57944	1741916	1535434	1968982	167027	111380	243776
2012	3211975	2901659	3546603	70522	46827	103013	47786	34963	64069	1866743	1656473	2096438	230018	161551	320548
2013	4984573	4461161	5552567	365527	228040	562775	234291	170939	314877	3076678	2697588	3494034	127058	94533	167846

** LCL = 95 % Lower Confidence Limit*

** UCL = 95 % Upper Confidence Limit*

Annual Total Phiosphorus (TP) Load (lbs/yr)															
Station	**O6500000**			**O0100000**			**O4680000**			**O5250000**			**O6450000**		
Year	**Mean**	**LCL***	**UCL***	**Mean**	**LCL***	**UCL***	**Mean**	**LCL***	**UCL***	**Mean**	**LCL***	**UCL***	**Mean**	**LCL***	**UCL***
1991	375030	307328	453264	16095	8148	28958	14729	9261	22352	264867	203957	338429			
1992	696696	568167	845906	24346	11417	46707	13674	8109	21888	497344	380218	639746			
1993	575701	480406	684274	43872	21408	81456	27772	17664	41906	419614	331788	523510	29170	21148	39391
1994	390750	326479	464002	28101	14833	49028	14208	9295	20901	282424	223851	351608	18550	13433	25186
1995	597470	496212	713456	34405	17417	61555	19250	12269	28847	431482	338043	542845	36437	26095	49620
1996	840400	702422	998105	112349	43229	249056	38776	21415	66532	607913	480519	759493	83359	55808	120644
1997	401778	340195	471299	23030	12137	40565	13737	8982	20303	294013	235737	362516	11681	8881	15105
1998	651230	539233	779790	72687	33408	140181	34957	21437	54290	452481	355644	567708	40965	25052	64131
1999	1520328	1163010	1959168	79701	35861	155380	28613	17268	44836	953246	670204	1323565	128801	84049	189382
2000	572264	478561	679122	23492	14310	36856	11976	8495	16476	403215	318068	504778	24258	16060	35447
2001	390831	324529	466617	24731	11893	45886	13444	8172	20913	273147	212567	345758	10664	6608	16500
2002	523562	439791	618688	44356	18994	92013	20484	12119	33095	357734	281626	448465	7740	5620	10423
2003	1078662	894968	1289157	102215	51478	183565	41934	27178	62024	704129	553582	883272	44750	30587	63418
2004	583172	492172	686181	37141	18987	66844	17469	11144	26317	405079	323440	501157	18518	13250	25267
2005	394875	336884	459840	19016	11045	30933	11524	7914	16308	273250	222010	332765	27649	18923	39260
2006	850608	698433	1026572	31992	16867	56006	15210	9854	22594	568056	441594	720352	29974	21204	41545
2007	263069	224636	306219	13289	7618	21856	11907	8122	16948	189279	153584	230824	11299	8716	14444

2008	314891	266118	370074	34930	15398	69854	17401	10102	28318	203575	162324	252165	6056	4376	8184
2009	454316	382180	536184	57938	30446	100940	33881	22423	49280	300398	238501	373468	14147	10198	19248
2010	534087	435183	649287	21882	10985	39857	12357	7893	18561	324505	250036	414732	37683	19232	68335
2011	360392	292757	439666	6856	3837	11497	4891	3137	7343	224204	169818	291220	33159	20026	52497
2012	383117	318891	456607	7903	3872	14746	5619	3243	9197	231698	179534	294401	40666	27145	59107
2013	670207	547243	812509	45093	20804	88359	30949	18069	50221	394121	297901	511626	18799	13206	26068

** LCL = 95% Lower Confidence Limit*

** UCL = 95 % Upper Confidence Limit*

Figure C-1. Estimated TN Load using the USGS LOADEST Program

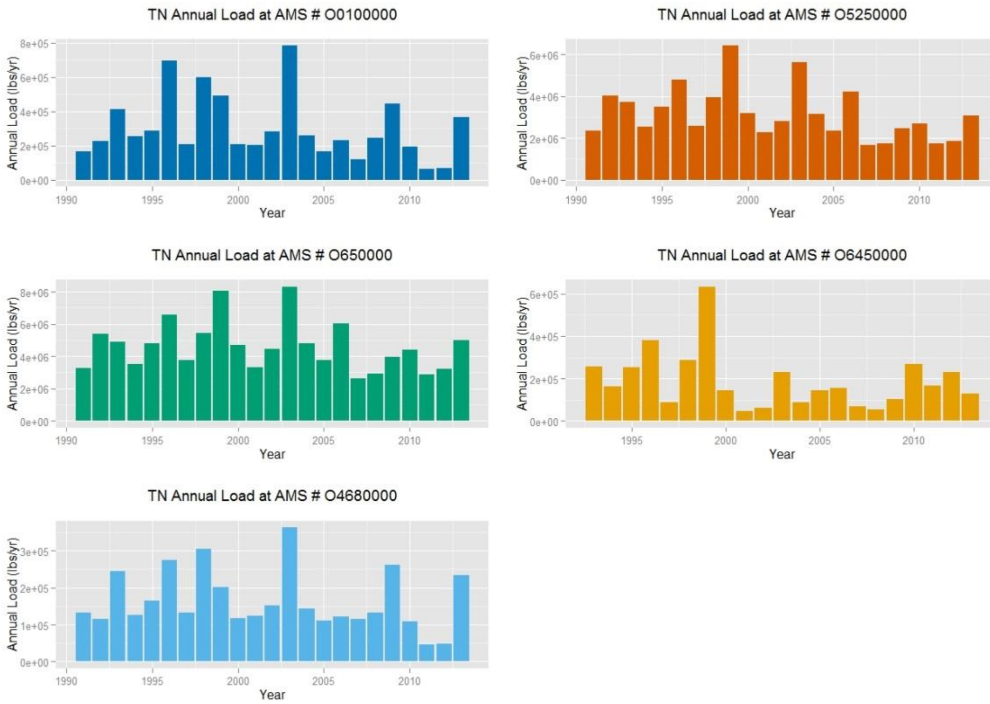


Figure C-1. Estimated TN Unit Area Load (UAL) using the USGS LOADEST Program

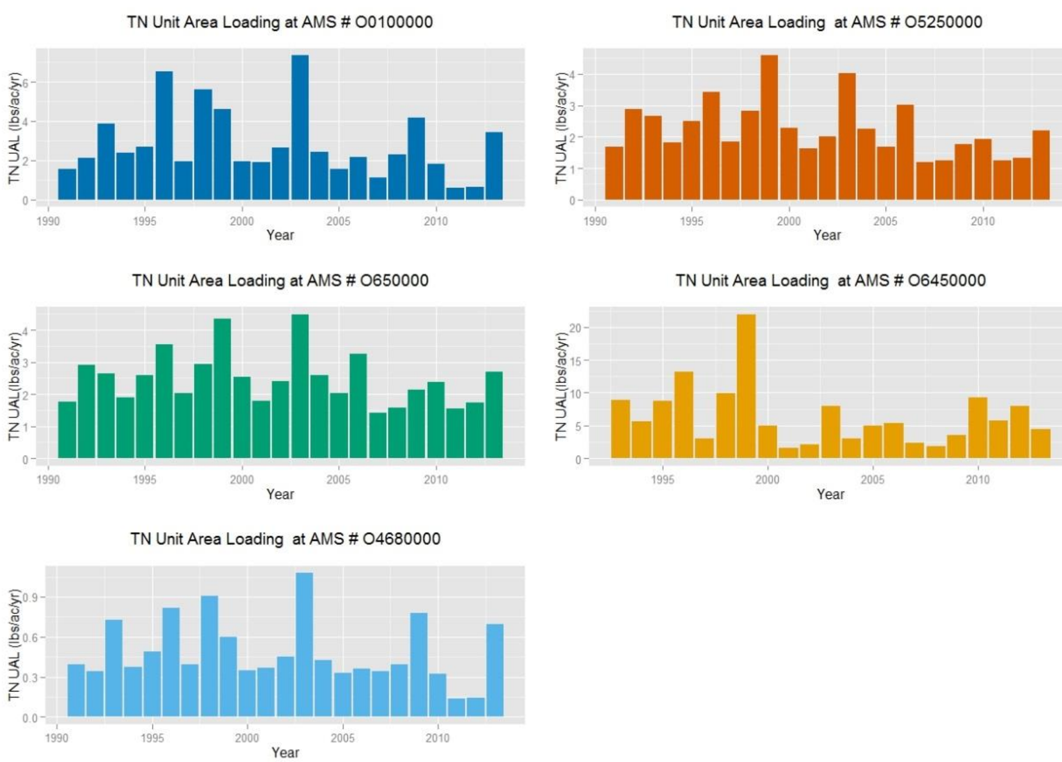


Figure C-1. Estimated TN Load using the USGS LOADEST Program

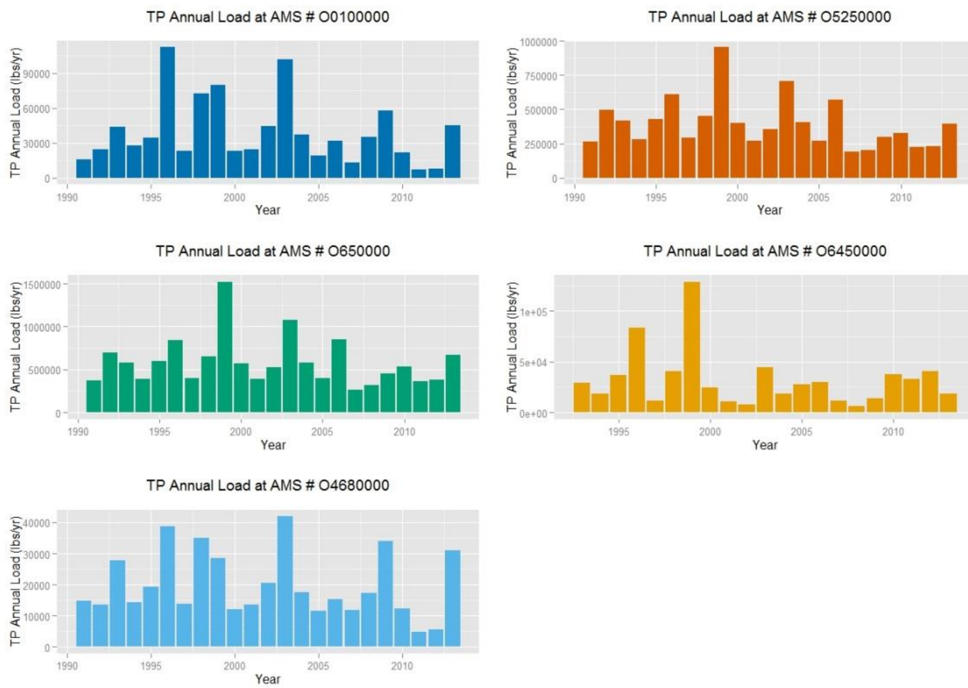


Figure C-1. Estimated TP Unit Area Load (UAL) using the USGS LOADEST Program