Summary of Nutrient Loads, Yields, and Mean Concentrations in the Great Miami River Watershed
2006 - 2016

Introduction

Nutrients are chemical elements critical for the growth of algae and aquatic plants. Two of the most common nutrients in rivers and streams are nitrogen and phosphorus. With enough nitrogen and phosphorus, algae and aquatic plants will grow and multiply providing more than enough plant material to support the food web. However, when too much nitrogen and phosphorus are present a process called eutrophication occurs. Eutrophication results in an overabundance of algae and cyanobacteria (primary producers) and a decline in fish and macroinvertebrate communities.

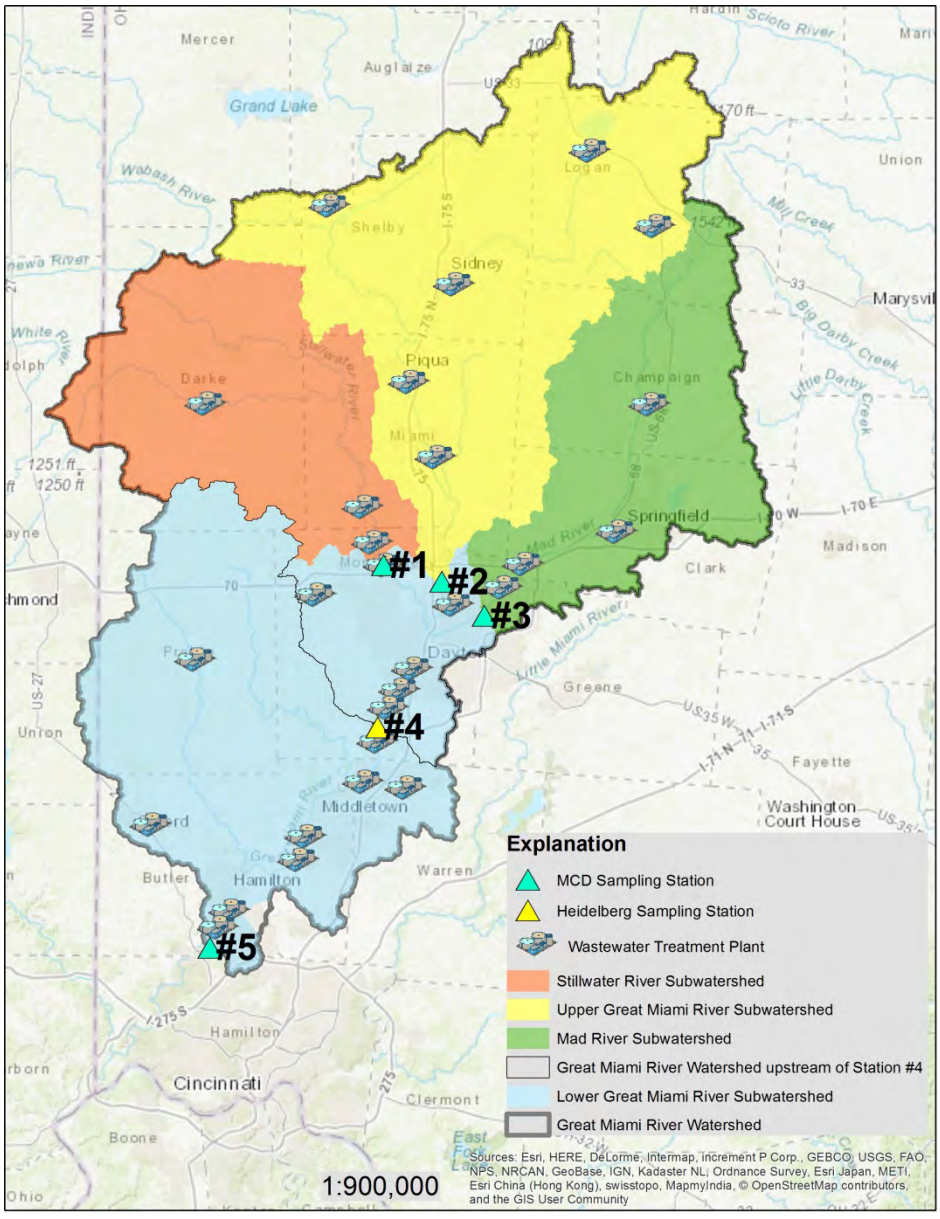
Source of nutrients in the Great Miami River Watershed can generally be divided into two categories – point and nonpoint sources. Point sources of nutrients in the Great Miami River Watershed consist mainly of discharges from municipal wastewater treatment plants. Nonpoint sources of nutrients consist of atmospheric deposition of fossil fuel combustion products, runoff and tile drainage from agricultural lands and livestock operations, home sewage treatment systems, infiltration of nutrients into aquifers beneath agricultural land, and runoff from developed land.

Previous water quality and biological studies of the Great Miami River and its tributaries conclude excessive amounts of nitrogen and phosphorus are present throughout much of the watershed (Ohio Environmental Protection Agency, 2001; 2005; 2007; 2011; 2012a, b; Reutter, 2002; Miami Conservancy District, 2012). Eutrophication is thought to be a major cause of impairment to aquatic biota within the watershed. In order to assess nutrient levels in rivers and streams, The Miami Conservancy District (MCD) conducts a monitoring program designed to provide timely information on nutrient loads and yields from the Great Miami River Watershed.

Nutrient Monitoring Stations

MCD funds five automated nutrient monitoring stations in the Great Miami River Watershed (see figure 1). The Miami Conservancy District (MCD) owns and operates Stations #1, #2, #3, and #5 and provides funding support for Station #4. Heidelberg University's National Center for Water Quality Research (NCWQR) owns and operates Station #4. Each station is equipped with an automated sampler programmed to collect water samples at eight-hour intervals. The stations store all water samples in an onsite refrigerator until staff come by once a week to pick up the samples and deliver them to a laboratory for analysis.

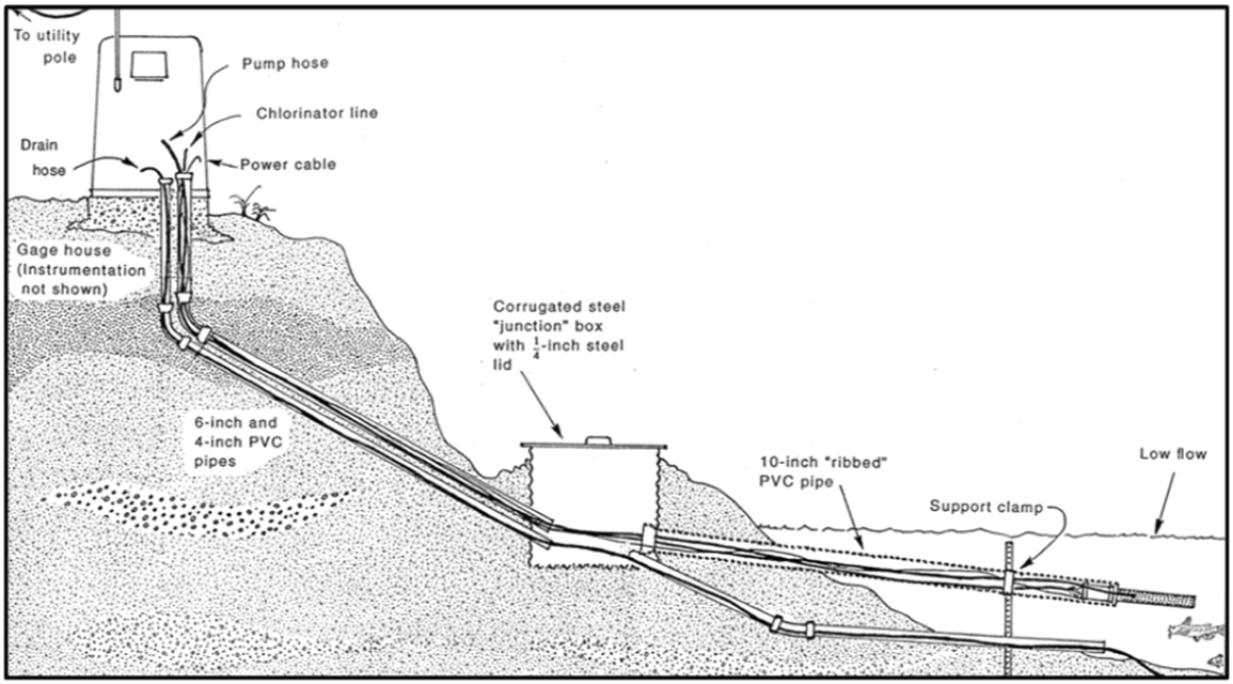
Figure 1 - *Location of watersheds, nutrient monitoring stations, and wastewater treatment plants*



A typical schematic diagram for each of the nutrient monitoring stations is shown in figure 2.

Laboratory analysis of water samples includes the nitrogen species of ammonia, nitrite, nitrate, and total kjeldahl nitrogen. Phosphorus analysis includes total phosphorus and soluble reactive phosphorus. Analysis of nutrient species in water samples is accomplished using spectrophotometric techniques. All sample collection and laboratory analysis is conducted under an Ohio EPA approved Level 3 Project Study Plan and Quality Assurance Project Plan (QAPP).

Figure 2 – *Schematic of a typical nutrient monitoring station*



Watersheds

For the purpose of this study, the Great Miami River Watershed is separated into smaller watersheds or subwatersheds in order to examine variability in nutrient loading within the watershed as a whole. The Stillwater, Upper Great Miami, and Mad River subwatersheds drain much of the headwater areas dominated by agricultural land use. Stations #1, #2, and #3 are installed near the mouths of these subwatersheds and characterize nutrient loading from these drainage areas. The Great Miami River Watershed upstream of station #4 includes all of the Stillwater, Upper Great Miami, and Mad River subwatersheds as well as a portion of the Lower Great Miami River Subwatershed. The Lower Great Miami River Subwatershed includes all of the Great Miami River Watershed downstream of stations #1, #2, and #3 and upstream of station #5 in Fairfield. The Great Miami River Watershed includes the entire drainage area upstream of station #5 used in this study to characterize nutrient loading for the entire Great Miami River Watershed.

Estimation of Nutrient Loads, Yields, and Mean Concentrations

The annual load for a pollutant in a river or stream is defined as the total mass of that pollutant transported by the river or stream in a given year. Calculation of a pollutant load requires information on the streamflow, pollutant concentration, and time window for which the streamflow and pollutant concentration data is to be applied. The pollutant loads are calculated using a numeric integration approach (Richards, 1998).

Mathematically, an annual load for nutrients is estimated by using the equation:

$$\text{Load} = k\sum_{i=1}^{n} c_i q_i t_i$$

Where k is a constant used to convert units to metric tons per year, c_i is the ith observation of concentration, q_i is the corresponding observation of flow, and t_i is the time interval represented by the ith sample.

The total nitrogen concentrations were estimated for this report by adding sample concentrations of ammonia, nitrite, nitrate, and total Kjeldahl nitrogen. Dissolved inorganic nitrogen concentrations were estimated by adding sample concentrations of ammonia, nitrite, and nitrate. Total phosphorus concentrations were measured directly from water samples.

The annual nutrient yield of a watershed is the mass of a particular nutrient exported out of a watershed per unit area of watershed. Annual watershed yields are computed by dividing the annual nutrient load by the watershed area. MCD computed total nitrogen and total phosphorus yields for each of the five watersheds in this study. Yields are useful when comparing nutrient outputs from watersheds of different sizes.

MCD calculated flow-weighted mean nutrient concentrations for watersheds by dividing the mean annual nutrient load of each watershed by the mean annual flow volume. Flow-weighted mean concentrations are useful for estimating the typical concentration of a nutrient in a waterbody adjusted for flow.

MCD calculated the time-weighted mean nutrient concentrations as the average of all water sample nutrient concentrations for the time period of 2006 through 2016.

Flow-weighted and time-weighted concentrations are similar for some watersheds and differ in others depending upon the degree to which nutrient loads are affected by large runoff events. Watersheds with nutrient loads dominated by runoff events typically have flow-weighted concentrations that are greater than time weighted concentrations.

Nutrient loads and yields for 2006 through 2016 are summarized numerically in Appendix A and B of this report.

Stillwater River Subwatershed

The Stillwater River Subwatershed upstream of station #1 has an area of 1,686 km^2 (651 mi^2). Land cover in the subwatershed is mostly agriculture (see figure 3). There are three major (> 1 MGD) water reclamation facilities in the subwatershed upstream of station #1. Point sources discharge an average of 59 metric tons of nitrogen and 6 metric tons of phosphorus to the Stillwater River Subwatershed each year (LimnoTech, 2017).

Based on data collected at station #1, mean annual total nitrogen and total phosphorus loads for the Stillwater River Subwatershed are 4,346 and 229 metric tons respectively. Total nitrogen loads ranged from a high of 6,148 metric tons in 2008 to a low of 2,089 metric tons in 2012. Total phosphorus loads ranged from a high of 519 metric tons in 2008 to a low of 75 metric tons in 2012 (see figure 4).

Mean annual total nitrogen and phosphorus yields for the Stillwater River Subwatershed are 2,565 and 134 kilograms per km^2 respectively. Total nitrogen yields ranged from a high of 3,652 kilograms per km^2 in 2008 to a low of 1,241 kilograms per km^2 in 2012. Total phosphorus yields ranged from a high of 308 kilograms per km^2 in 2008 to 45 kilograms per km^2 in 2012 (see figure 5).

Based on the data collected, nonpoint sources of nutrients are the dominant source of nutrients in the subwatershed comprising over 95% of the mean annual total nitrogen and phosphorus loads. Point sources of nutrients comprise only a small fraction of the total nitrogen and phosphorus annual loads (see figures 6 and 7).

Flow-weighted and time-weighted mean concentrations of nutrients for the subwatershed are shown in the table below.

Constituent	Flow-Weighted Mean Concentration (mg/L)	Time-Weighted Mean Concentration (mg/L)
Total Nitrogen	6.43	4.85
Nitrate + Nitrite	4.86	3.51
Total Phosphorus	0.34	0.22

Figure 3 – *Land use in the Stillwater River Subwatershed*

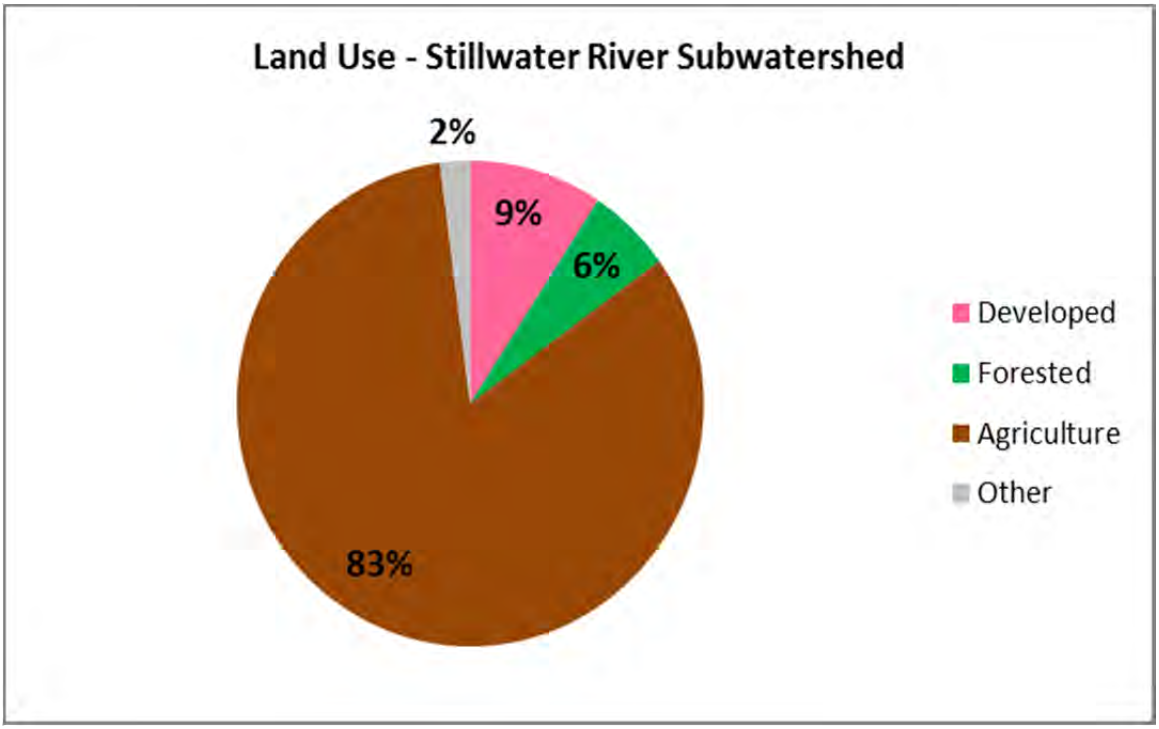


Figure 4 – Total *nitrogen (N) and total phosphorus (P) loads for the Stillwater River Subwatershed*

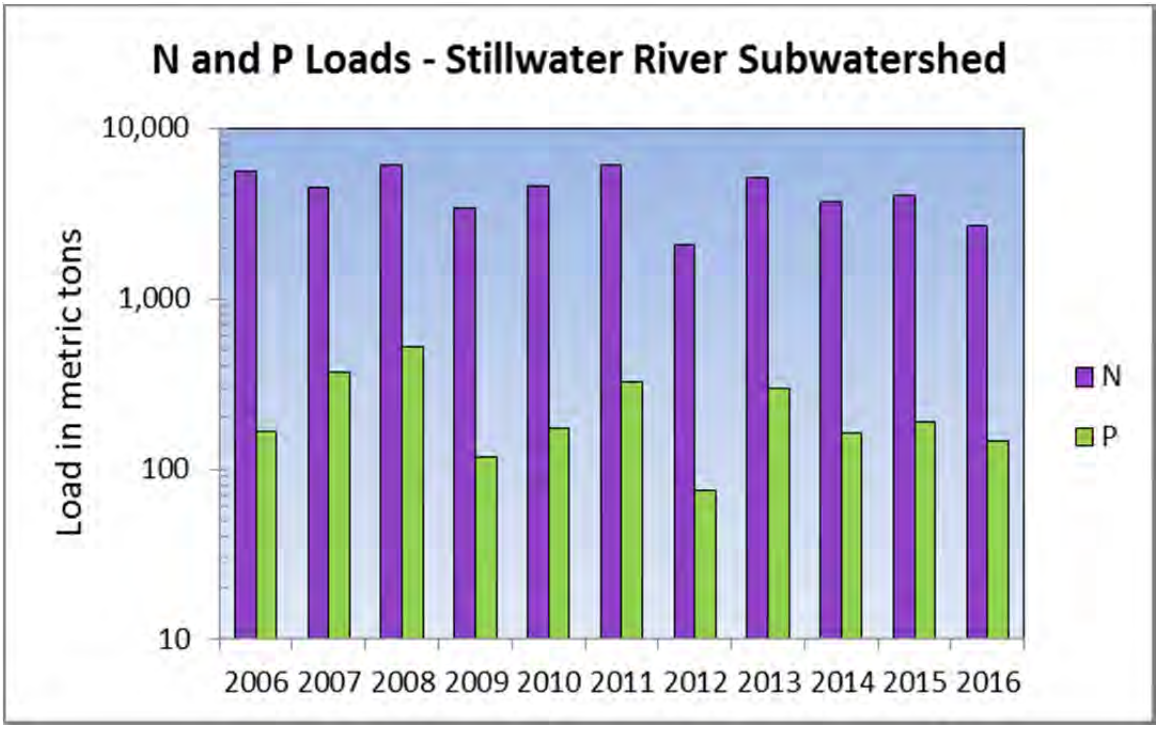


Figure 5 – Total *nitrogen and total phosphorus yields for the Stillwater River Subwatershed*

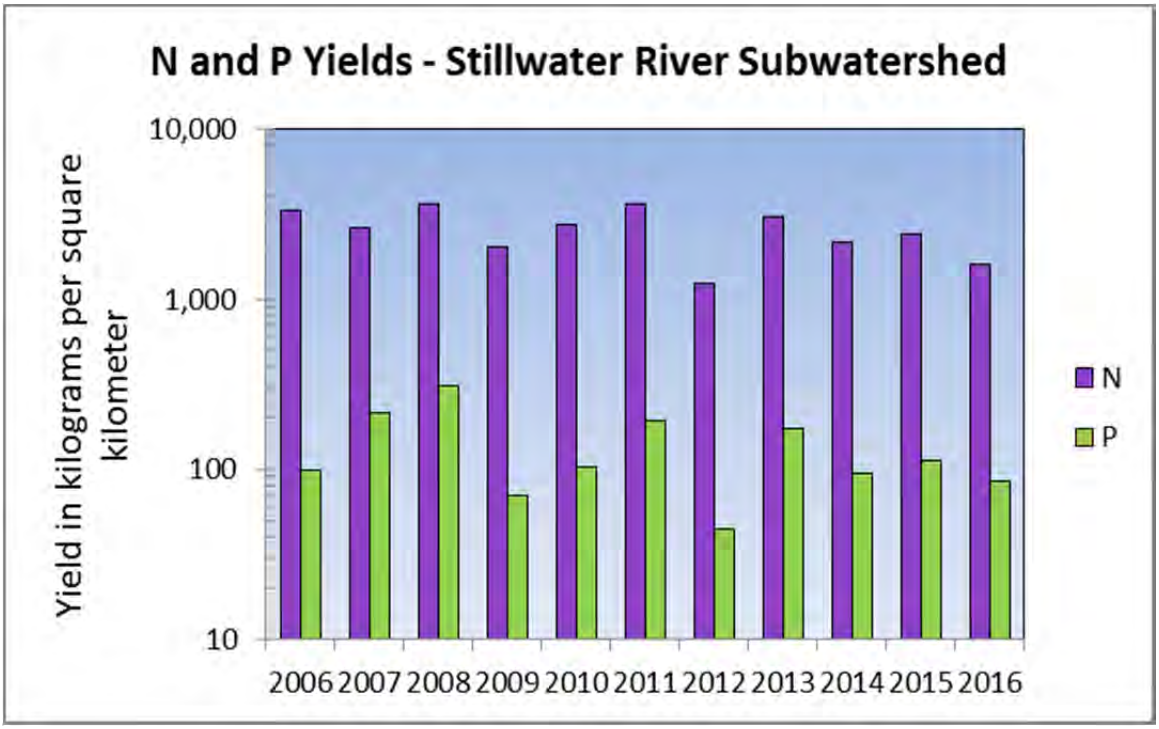


Figure 6 – *Point and nonpoint source contributions to mean total nitrogen load*

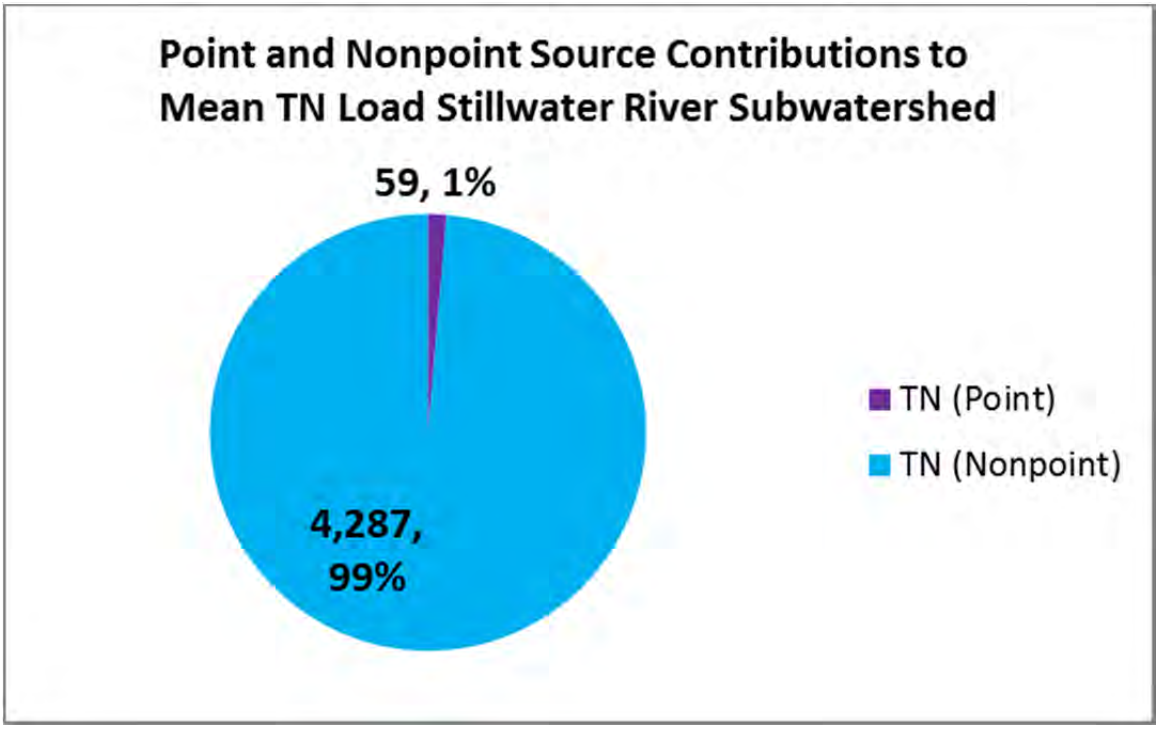
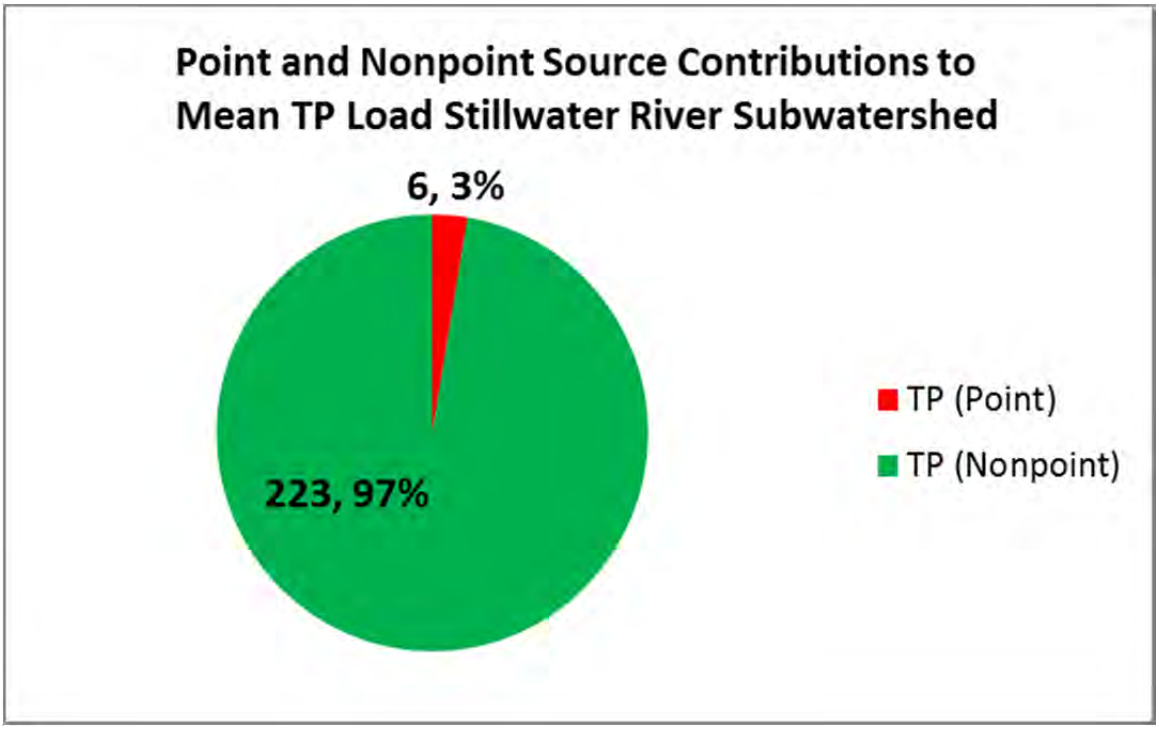


Figure 7 – *Point and nonpoint source contributions to mean total phosphorus load*



Upper Great Miami River Subwatershed

The Upper Great River Subwatershed located upstream of station #2 has an area of 2,997 km^2 (1,157 mi^2). Land cover in the subwatershed is mostly agriculture (see figure 8). There are six major (> 1 MGD) water reclamation facilities in the watershed upstream of station #2 Point sources discharge an average of 360 metric tons of nitrogen and 58 metric tons of phosphorus to the Upper Great Miami River Subwatershed each year (LimnoTech, 2017).

Based on the data collected at station #2, mean annual total nitrogen and total phosphorus loads for the Upper Great Miami River Subwatershed are 5,724 and 402 metric tons respectively. Total nitrogen loads ranged from a high of 9,601 metric tons in 2008 to a low of 2,918 metric tons in 2012. Total phosphorus loads ranged from a high of 780 metric tons in 2011 to a low of 160 metric tons in 2012 (see figure 9).

Mean annual total nitrogen and phosphorus yields for the Upper Great Miami River Subwatershed are 1,923 and 135 kilograms per km^2 respectively. Total nitrogen yields ranged from a high of 3,226 kilograms per km^2 in 2008 to a low of 981 kilograms per km^2 in 2012. Total phosphorus yields ranged from a high of 262 kilograms per km^2 in 2008 to 45 kilograms per km^2 in 2012 (see figure 10).

Based on the data collected, nonpoint sources of nutrients are the dominant source of nutrients in the subwatershed comprising 94% of the mean annual total nitrogen and 86% of the average annual total phosphorus loads. Point sources of nutrients comprise only a small fraction of the total annual nitrogen and phosphorus loads for the Upper Great Miami River Subwatershed (see figures 11 and 12).

Flow-weighted and time-weighted mean concentrations of nutrients for the watershed are shown in the table below.

Constituent	Flow-Weighted Mean Concentration (mg/L)	Time-Weighted Mean Concentration (mg/L)
Total Nitrogen	4.66	3.66
Nitrate + Nitrite	3.52	2.58
Total Phosphorus	0.33	0.25

Figure 8 – *Land use in the Upper Great Miami River Subwatershed*

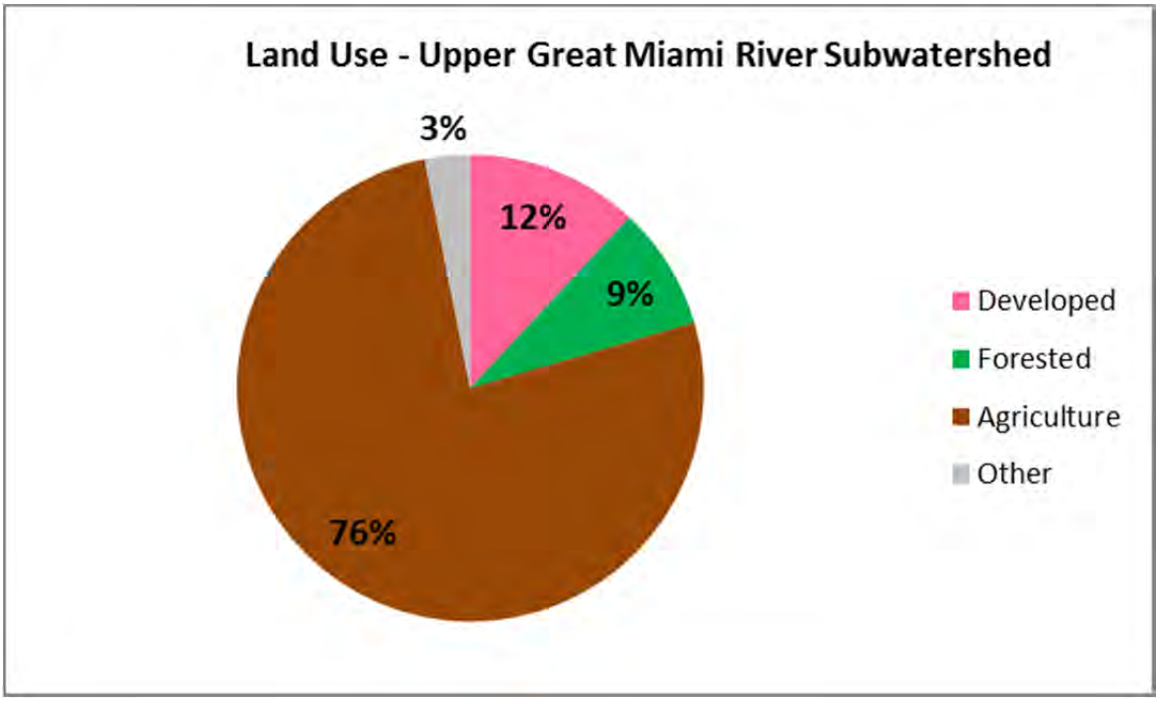


Figure 9 – Total *nitrogen and total phosphorus loads for the Upper Great Miami River Subwatershed*

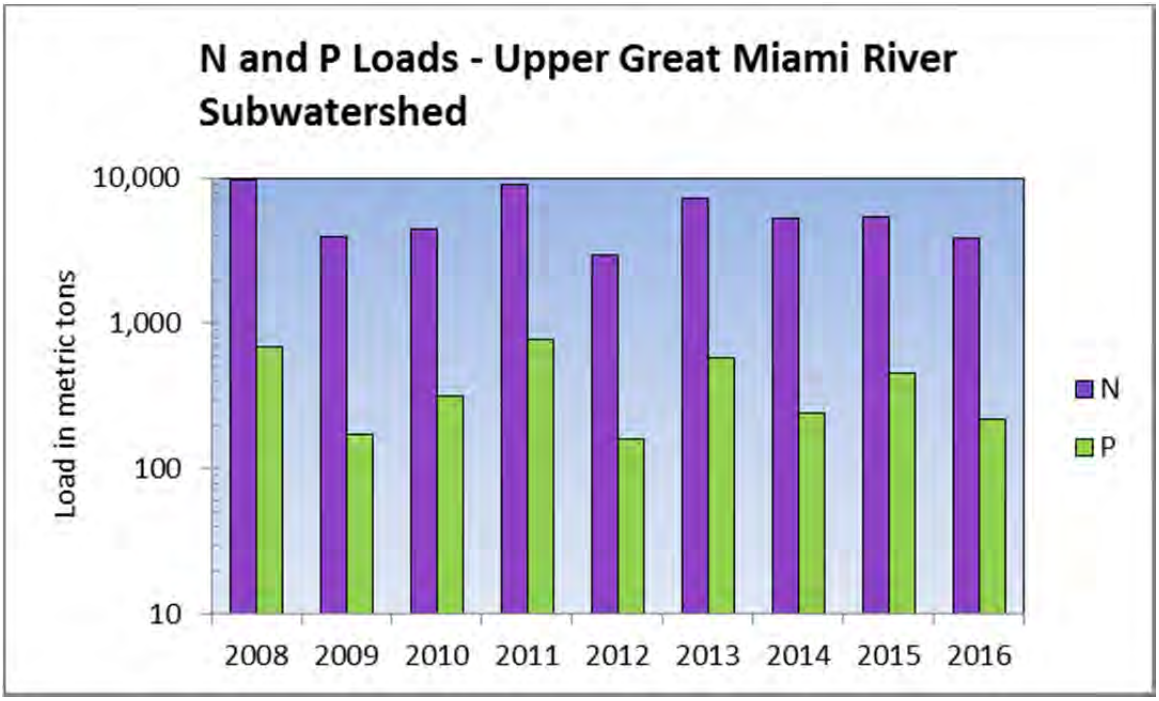


Figure 10 – *Total Nitrogen and total phosphorus yields for the Upper Great Miami River Subwatershed*

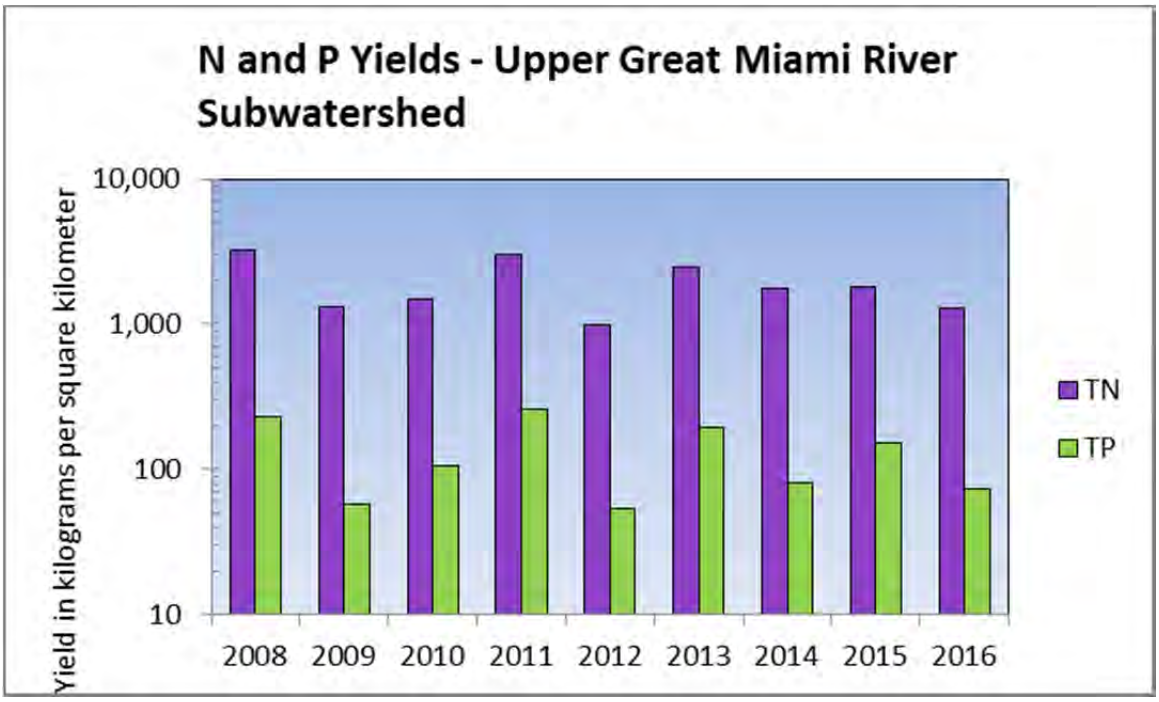


Figure 11 - *Point and nonpoint source contributions to mean total nitrogen load*

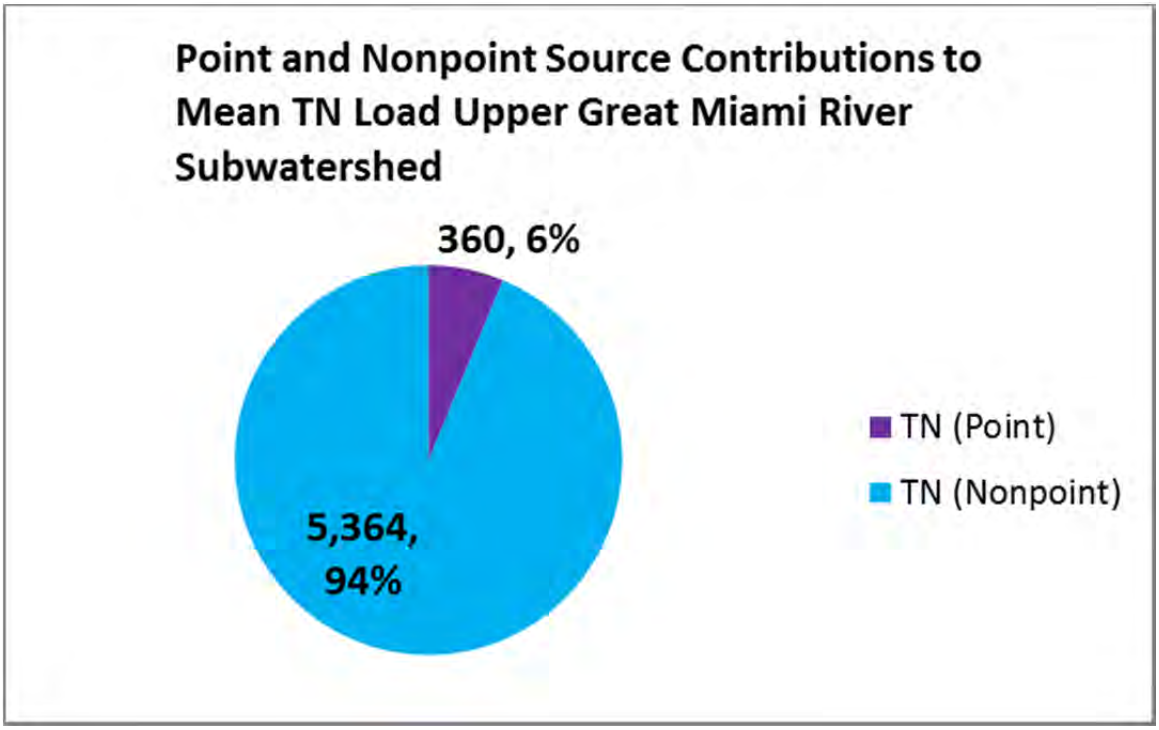
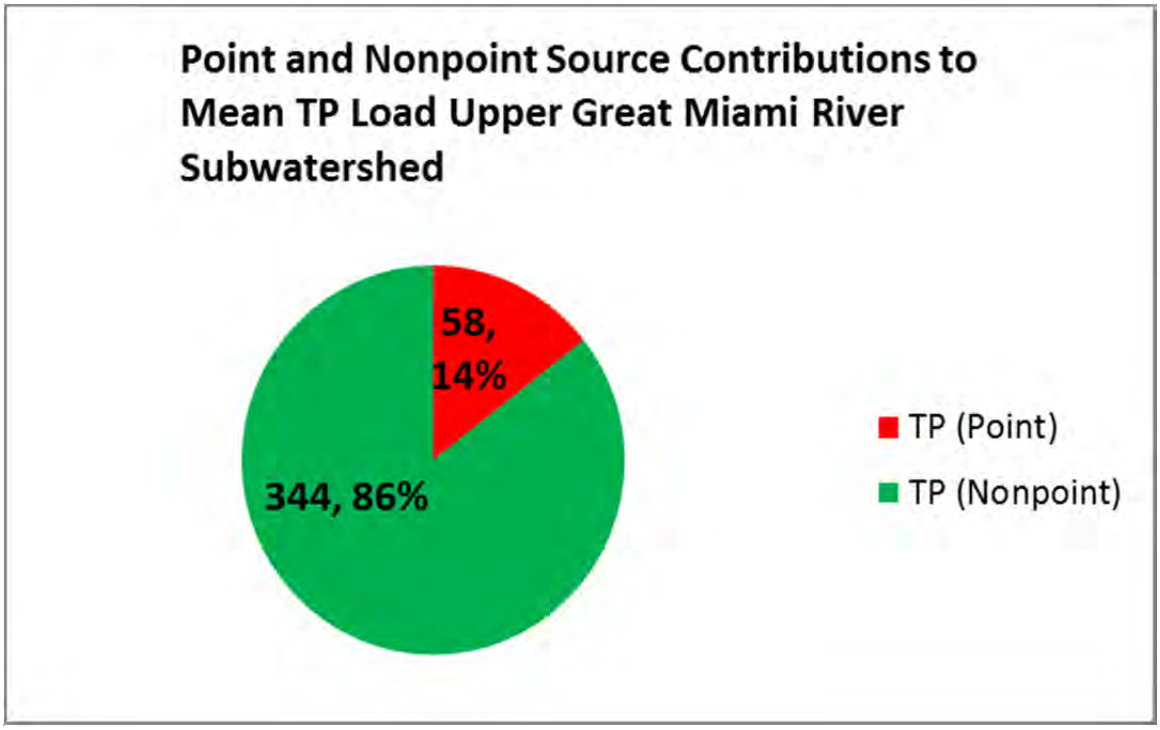


Figure 12 - *Point and nonpoint source contributions to mean total phosphorus load*



Mad River Subwatershed

The Mad River Subwatershed located upstream of station #3 has an area of 1,646 km^2 (636 mi^2). Land cover in the subwatershed is mostly agriculture but developed land is significant (see figure 13).

There are three major (> 1 MGD) water reclamation facilities in the subwatershed upstream of station #3. Point sources discharge an average of 376 metric tons of nitrogen and 54 metric tons of phosphorus to the Mad River Subwatershed each year (LimnoTech, 2017).

MCD installed station #3 in 2007. The station was not in operation in 2009 and 2010 and MCD did not compute nutrient loads and yields for those years.

According to the data collected at station #3, mean annual total nitrogen and total phosphorus loads for the Mad River Subwatershed are 2,958 and 198 metric tons respectively. Total nitrogen loads ranged from a high of 4,144 metric tons in 2008 to a low of 1,887 metric tons in 2012. Total phosphorus loads ranged from a high of 288 metric tons in 2011 to a low of 110 metric tons in 2012 (see figure 14).

Mean annual total nitrogen and phosphorus yields for the Mad River Subwatershed are 1,799 and 120 kilograms per km^2 respectively. Total nitrogen yields ranged from a high of 2,520 kilograms per km^2 in 2008 to a low of 1,147 kilograms per km^2 in 2012. Total phosphorus yields ranged from a high of 175 kilograms per km^2 in 2011 to 67 kilograms per km^2 in 2012 (see figure 15).

According to the data, nonpoint sources of nutrients are the dominant source of nutrients in the watershed comprising 85% of the mean annual total nitrogen and 69% of the average annual total phosphorus loads. While point sources of nutrients comprise a greater fraction of annual nutrient loads than the Stillwater and Upper Great Miami River subwatersheds, they account for a only a small fraction of the total annual nitrogen load. Point source contributions comprise 31% of the annual phosphorus load (see figures 16 and 17).

Flow-weighted and time-weighted mean concentrations of nutrients for the watershed are shown in the table below.

Constituent	Flow-Weighted Mean Concentration (mg/L)	Time-Weighted Mean Concentration (mg/L)
Total Nitrogen	3.79	3.65
Nitrate + Nitrite	2.61	2.58
Total Phosphorus	0.25	0.21

Figure 13 – *Land use in the Mad River Subwatershed*

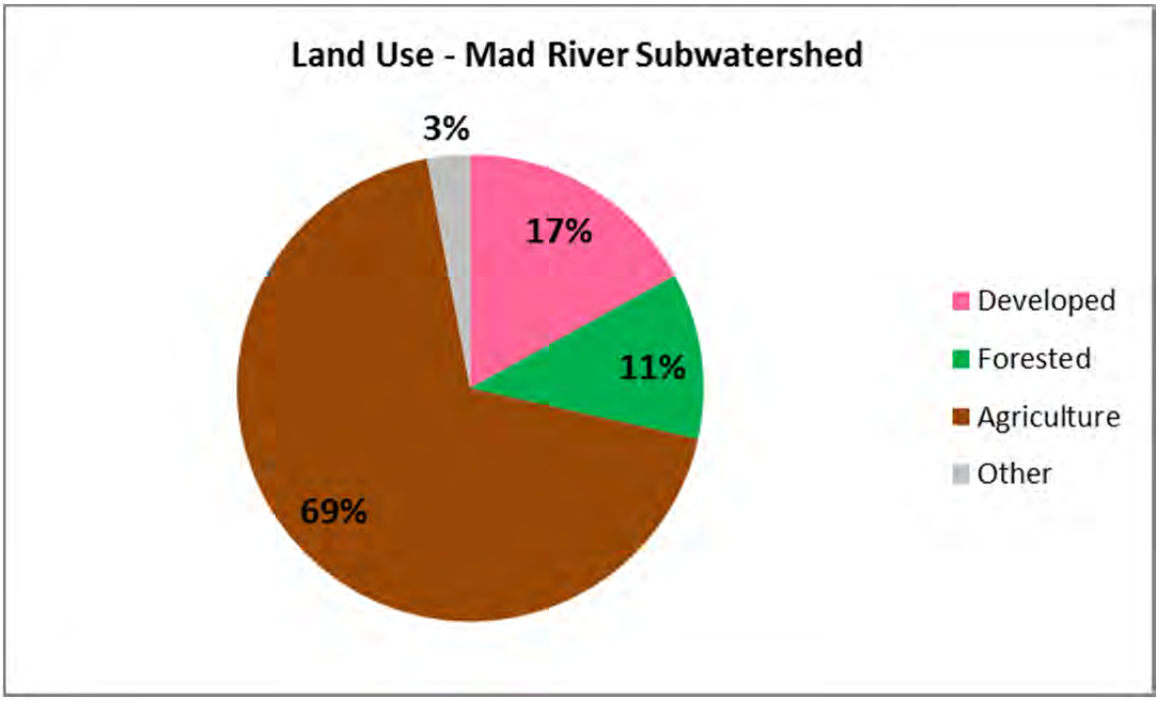


Figure 14 – *Total nitrogen and total phosphorus loads for the Mad River Subwatershed*

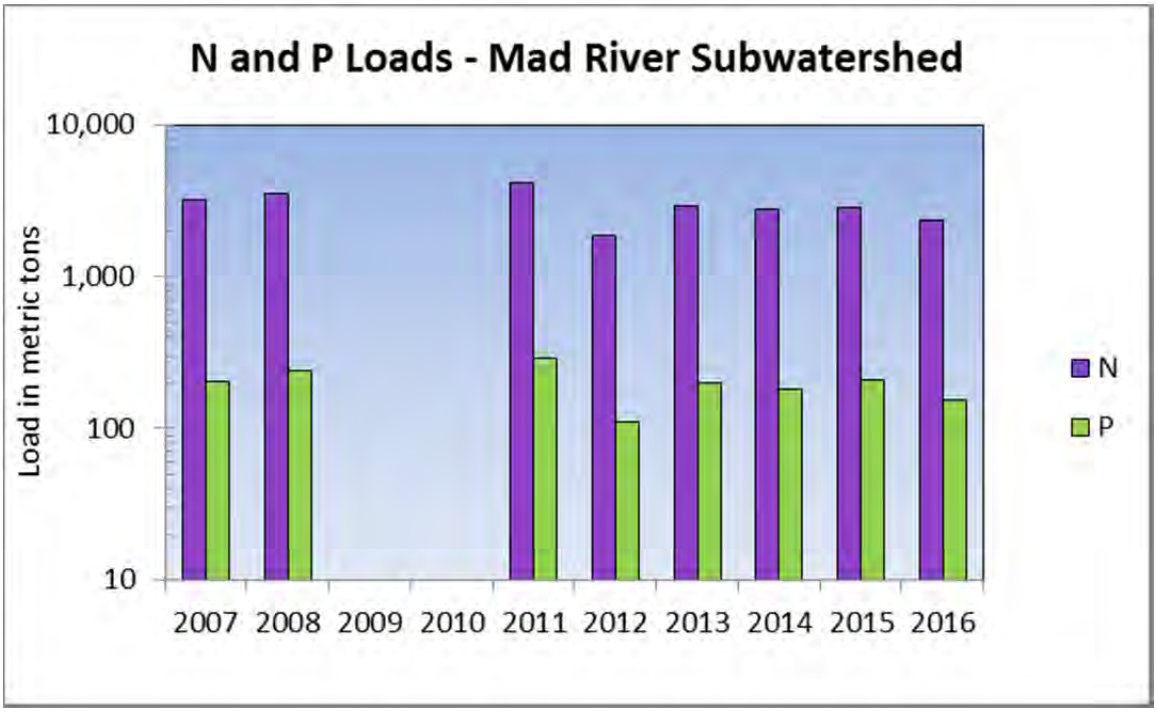


Figure 15 – *Total nitrogen and total phosphorus yields for the Mad River Watershed*

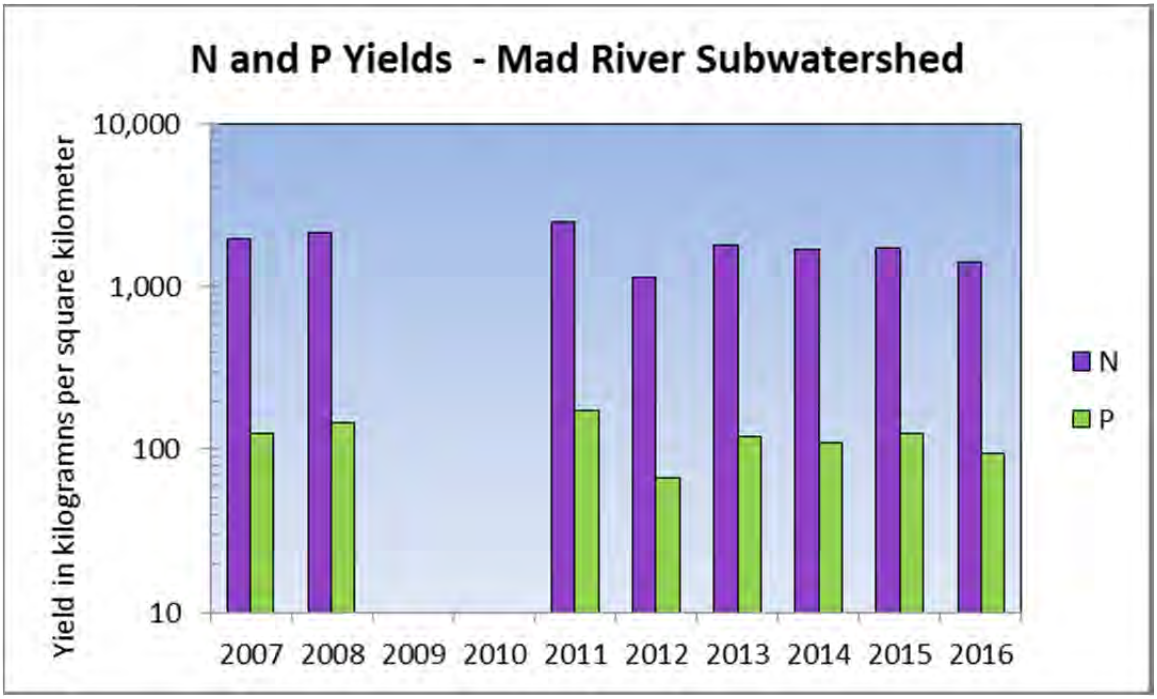


Figure 16 – *Point and nonpoint sources contributions to mean total nitrogen load*

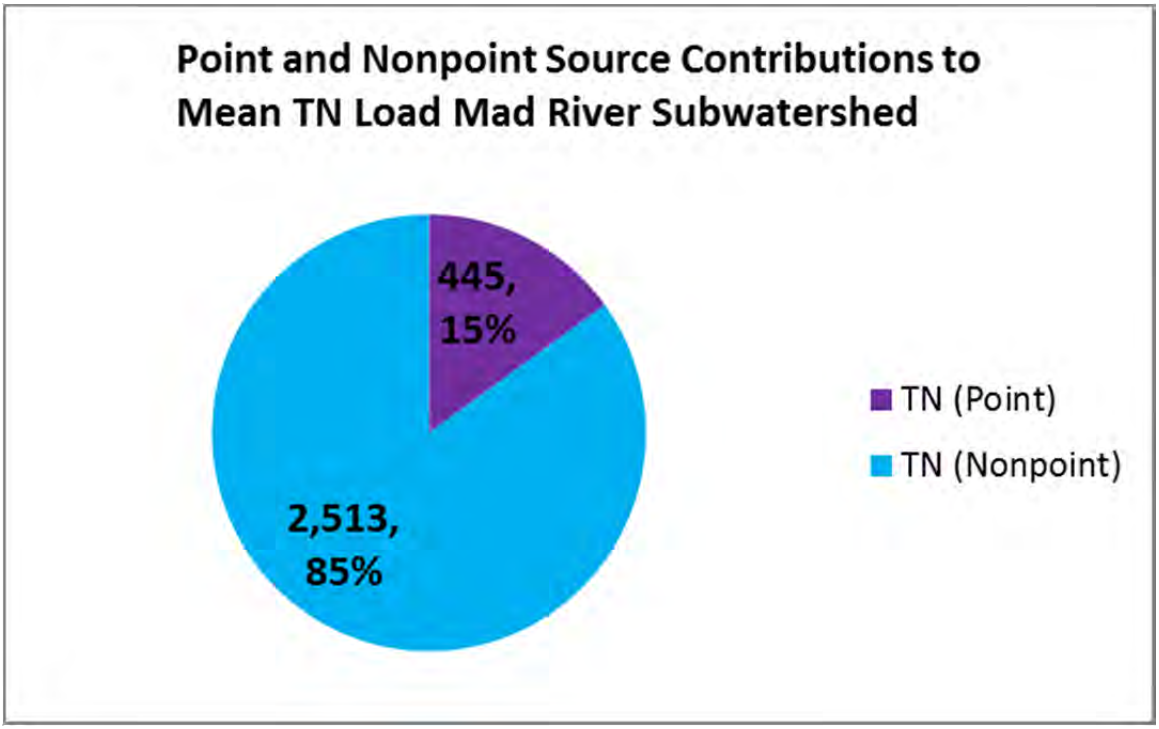
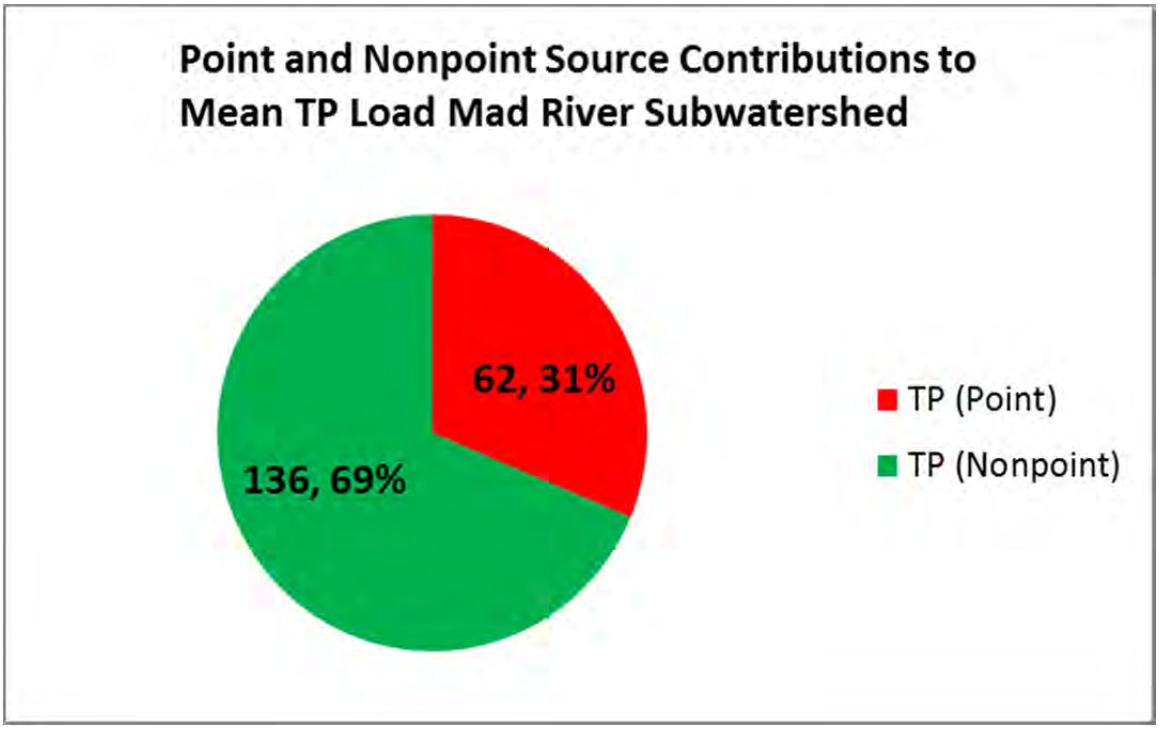


Figure 17 - *Point and nonpoint source contributions to mean total phosphorus load*



Great Miami River Watershed upstream of Station #4

The Great Miami River Watershed located upstream of nutrient monitoring station #4 has an area of 9,518 km^2 (3,675 mi^2). Land cover in the watershed is mostly agriculture, but developed land is significant (see figure 18).

There are 19 major (> 1 MGD) water reclamation facilities in the watershed upstream of station #4. Point sources discharge an average of 2,060 metric tons of nitrogen and 315 metric tons of phosphorus to the watershed each year (LimnoTech, 2017).

According to the data collected, mean annual total nitrogen and total phosphorus loads for the Great Miami River Watershed upstream of station #4 are 13,834 and 1,131 metric tons respectively. Total nitrogen loads ranged from a high of 21,491 metric tons in 2011 to a low of 7,566 metric tons in 2012. Total phosphorus loads ranged from a high of 1,802 metric tons in 2008 to a low of 554 metric tons in 2016 (see figure 19).

Mean annual total nitrogen and phosphorus yields for the Great Miami River Watershed upstream of station #4 are 1,967 and 161 kilograms per km^2 respectively. Total nitrogen yields ranged from a high of 3,056 kilograms per km^2 in 2008 to a low of 1,076 kilograms per km^2 in 2012. Total phosphorus yields ranged from a high of 256 kilograms per km^2 in 2008 to a low of 79 kilograms per km^2 in 2016 (see figure 20).

According to the data, nonpoint sources of nutrients are the dominant source of nutrients in the watershed comprising 85% of the mean annual total nitrogen and 72% of the average annual total phosphorus loads. Point source contributions of phosphorus account for 28% of the annual phosphorus load (see figures 21 and 22).

Flow-weighted and time-weighted mean concentrations of nutrients for the watershed are shown in the table below.

Constituent	Flow-Weighted Mean Concentration (mg/L)	Time-Weighted Mean Concentration (mg/L)
Total Nitrogen	4.70	4.27
Nitrate + Nitrite	3.37	3.18
Total Phosphorus	0.38	0.36

Figure 18 – *Land use in the Great Miami River Watershed upstream of station #4*

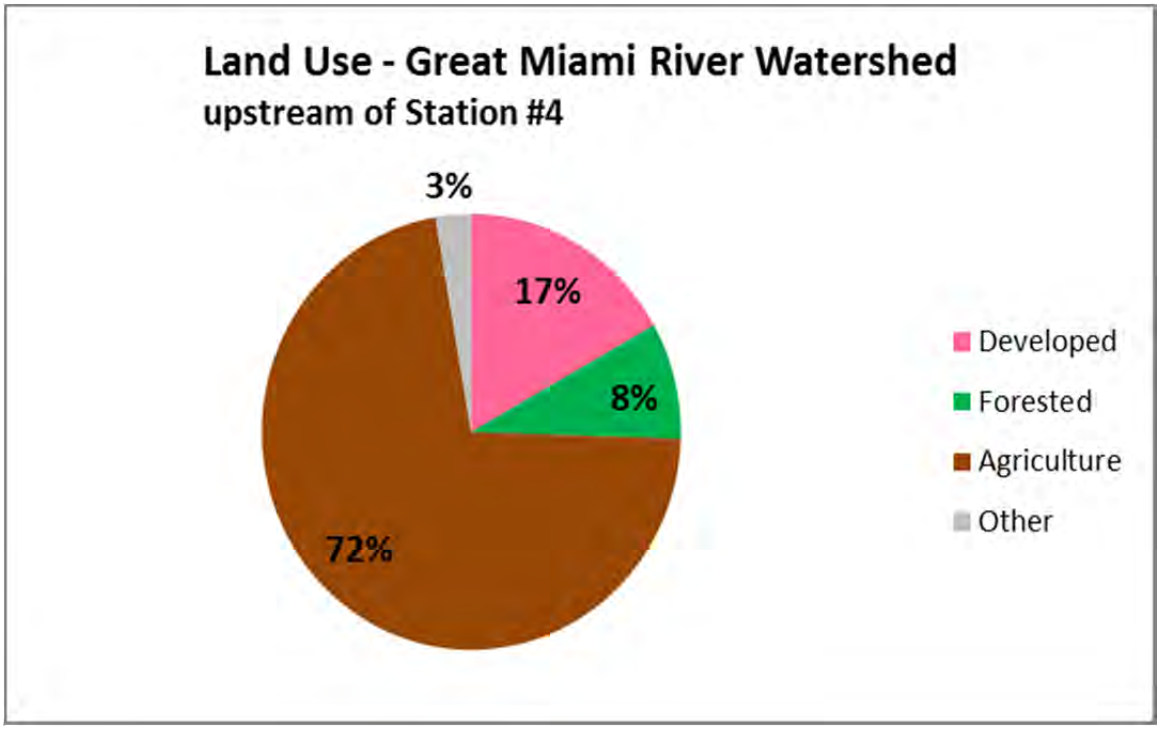


Figure 19 – *Total nitrogen and total phosphorus loads for the Great Miami River Watershed upstream of station #4*

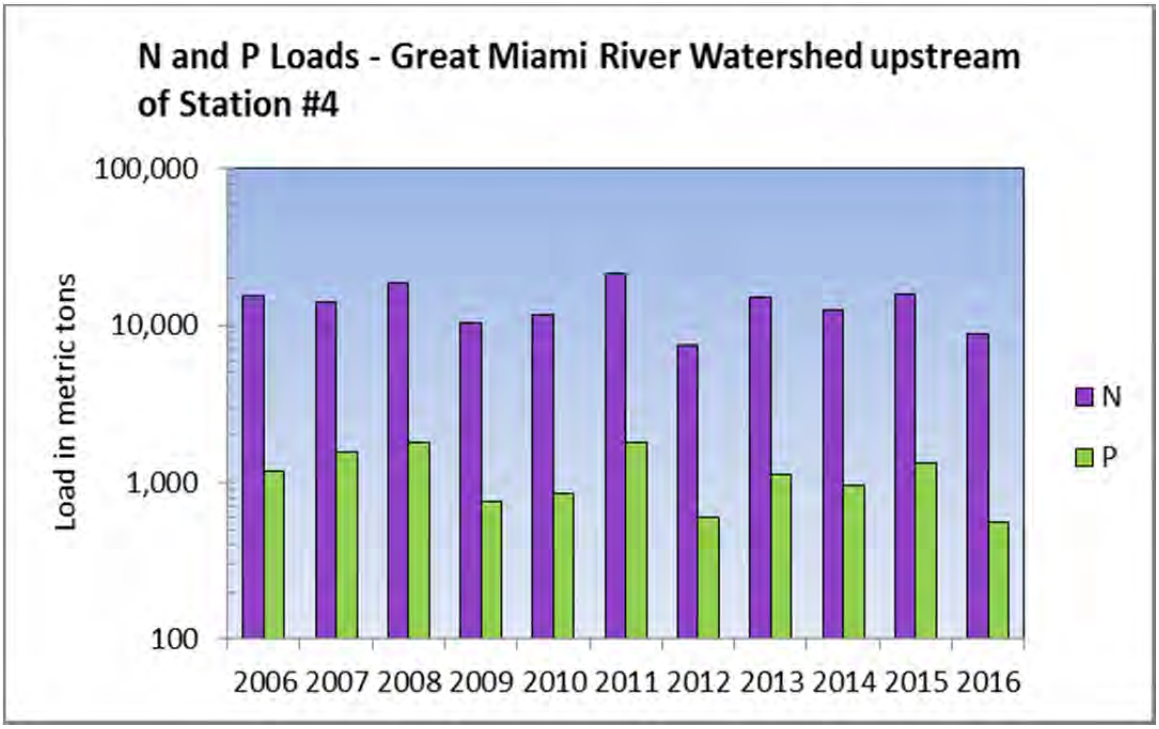


Figure 20 – *Total nitrogen and total phosphorus yields for the Great Miami River Watershed upstream of station #4*

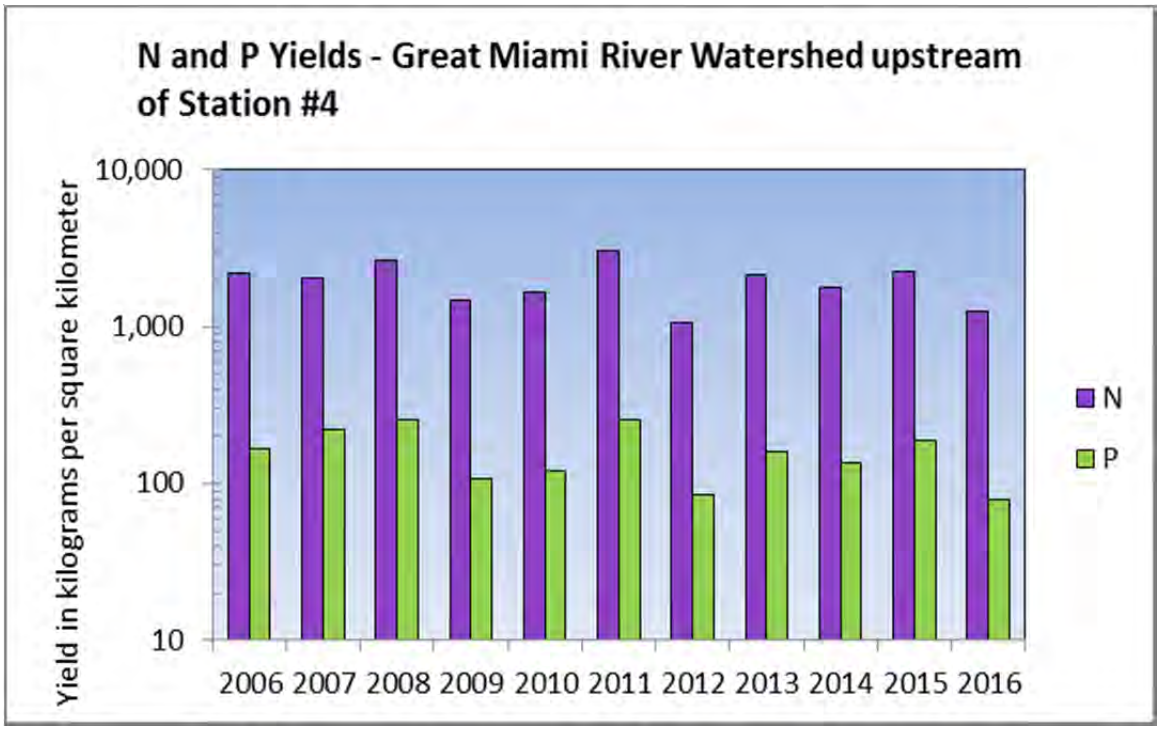


Figure 21 – *Point and nonpoint source contributions to mean total nitrogen load*

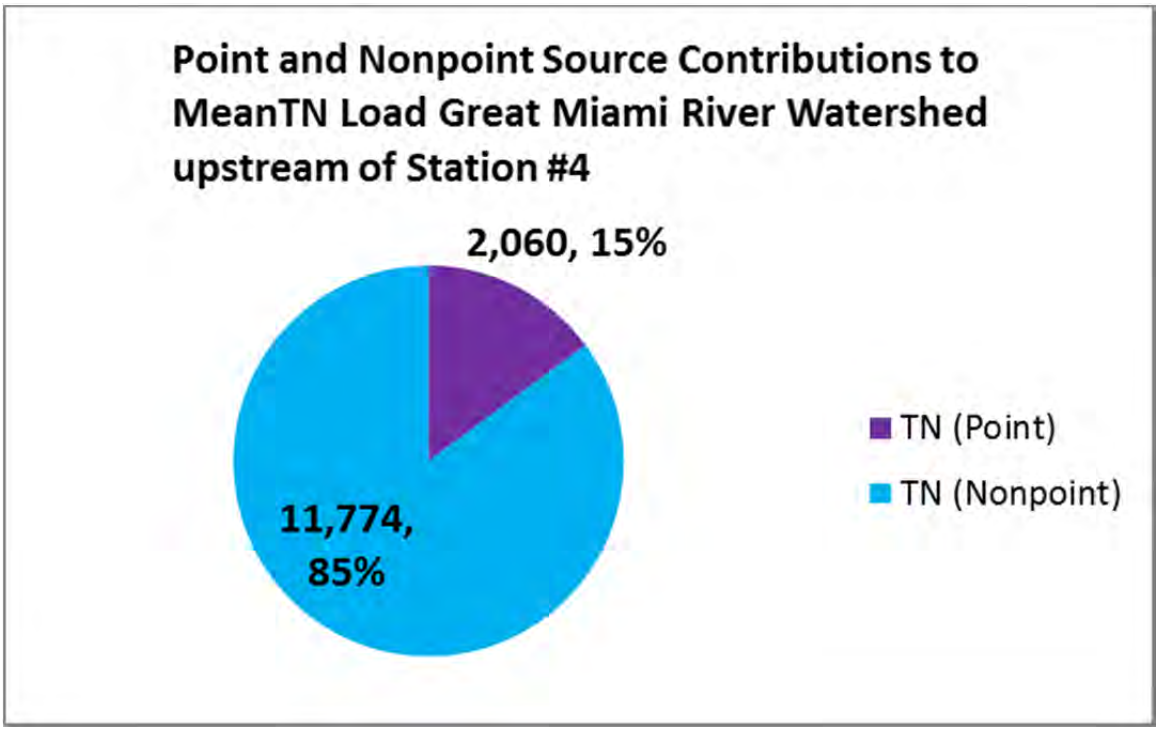
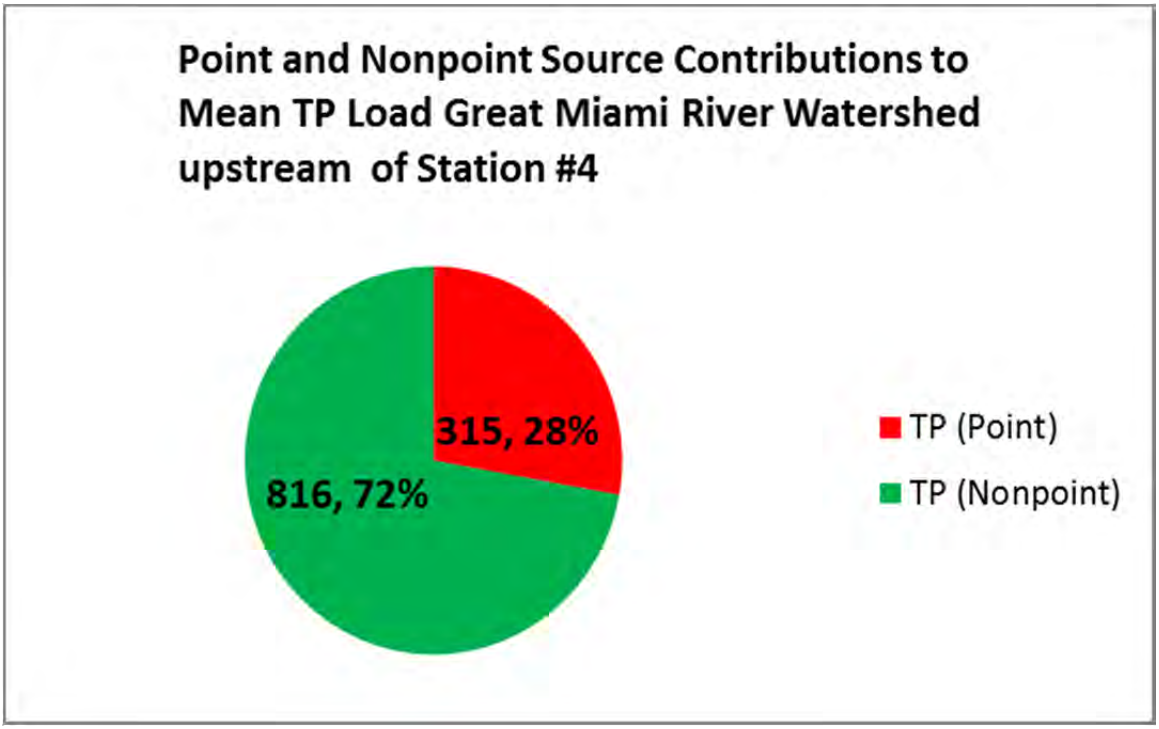


Figure 22 – *Point and nonpoint source contributions to mean total phosphorus load*



Lower Great Miami River Subwatershed

The Lower Great Miami River Subwatershed is defined as the area of the Great Miami River Watershed upstream of station #5 but does not include the watersheds upstream of stations #1, #2, and #3. The Lower Great Miami River Subwatershed drains a land area of 3,189 km^2 (1,231 mi^2). Land cover in the watershed is mostly agriculture, but non-agricultural land is significant and developed land cover in the Lower Great Miami River Subwatershed is greater than any of the upstream subwatersheds (see figure 23).

There are 16 major (> 1 MGD) water reclamation facilities in the watershed. Point sources discharge an average of 2,198 metric tons of nitrogen and 292 metric tons of phosphorus to the Great Miami River Subwatershed each year (LimnoTech, 2017).

MCD estimates the nutrient loads of the Lower Great Miami River Subwatershed by using a mass balance approach where the loads of the watersheds upstream of Stations #1, #2, and #3 are subtracted from the load of the watershed upstream of Station #5. With this approach, loads can only be calculated for the years in which stations #1, #2, #3, and #5 are all operational. Since stations #3 and #5 were not operational in 2009 and 2010, MCD did not calculate Lower Great Miami River loads for those years.

According to the data collected, mean annual total nitrogen and phosphorus loads for the Lower Great Miami River Subwatershed are 7,416 and 936 metric tons respectively. Total nitrogen loads ranged from a high of 9,794 metric tons in 2011 to a low of 3,512 metric tons in 2012. Total phosphorus loads ranged from a high of 1,491 metric tons in 2014 to a low of 327 metric tons in 2012 (see figure 24).

Mean annual total nitrogen and phosphorus yields for the Lower Great Miami River Subwatershed are 2,408 and 304 kilograms per km^2 respectively. Total nitrogen yields ranged from a high of 3,162 kilograms per km^2 in 2011 to a low of 1,134 kilograms per km^2 in 2012. Total phosphorus yields ranged from a high of 481 kilograms per km^2 in 2014 to a low of 106 kilograms per km^2 in 2012 (see figure 20).

According to the data, nonpoint sources of nutrients are the dominant source of nutrients in the subwatershed comprising 70% of the mean annual total nitrogen and 69% of the mean annual total phosphorus loads. Point sources of nitrogen comprise a significantly greater fraction of annual nitrogen loads in comparison with upstream watersheds. However, point sources of nutrients still comprise less than a third of the total mean annual loads for the subwatershed.

Flow-weighted mean concentrations of nutrients for the watershed are shown in the table below. Time-weighted mean concentrations could not be calculated because the Lower Great Miami River Subwatershed is bounded by upstream watersheds.

Constituent	Flow-Weighted Mean Concentration (mg/L)	Time-Weighted Mean Concentration (mg/L)
Total Nitrogen	4.97	NA
Nitrate + Nitrite	3.01	NA
Total Phosphorus	0.63	NA

Figure 23 – *Land use in the Lower Great Miami River Subwatershed*

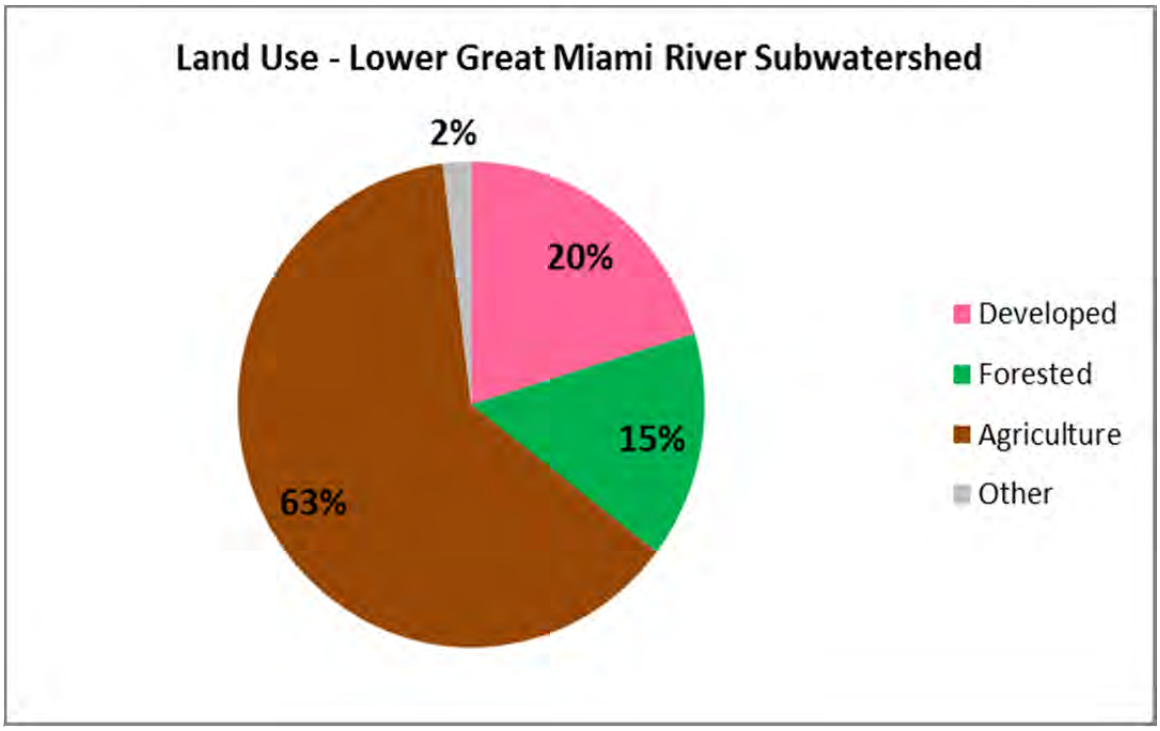


Figure 24 – *Total nitrogen and total phosphorus loads for the Lower Great Miami River Subwatershed*

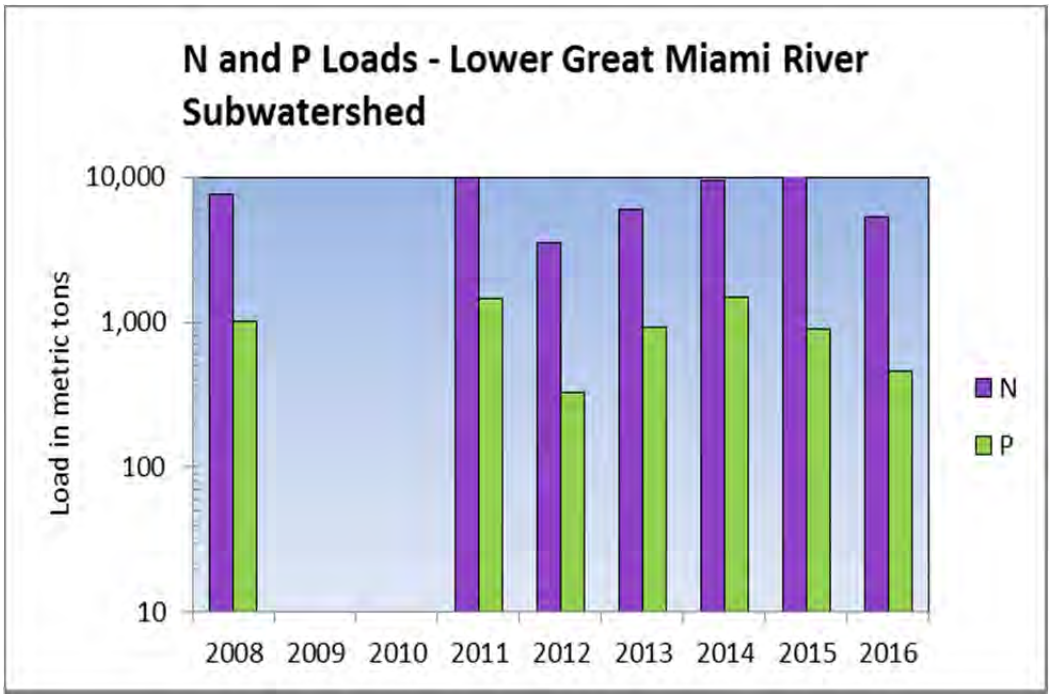


Figure 25 – Total nitrogen and total phosphorus yields for the Lower Great Miami River Subwatershed

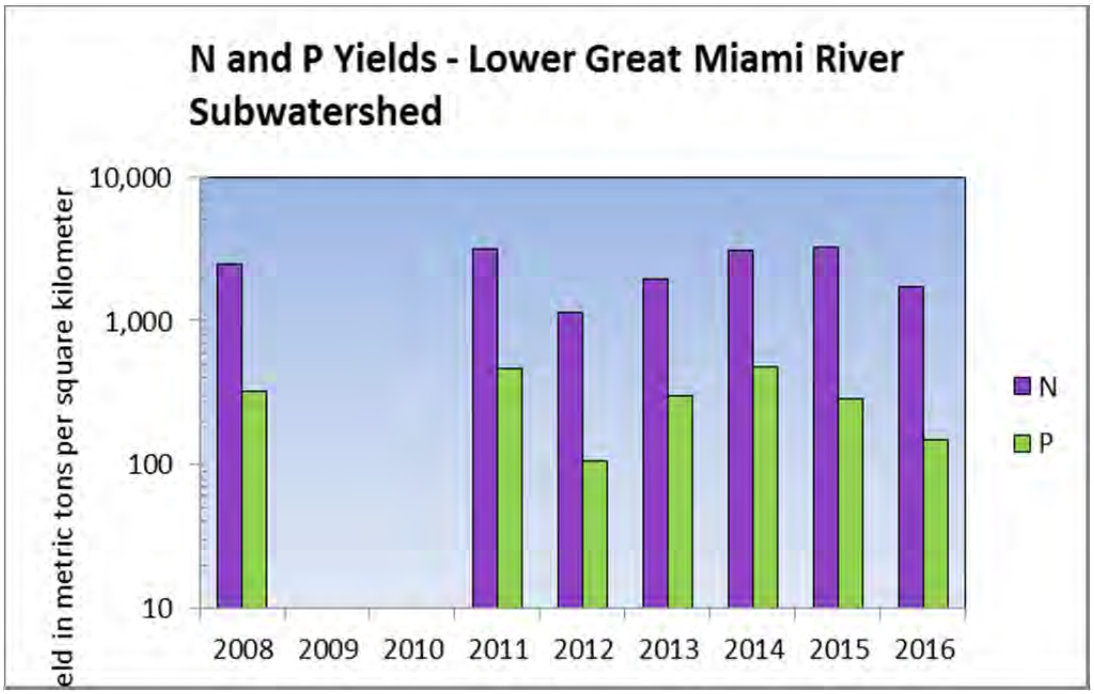


Figure 26 – *Point and nonpoint source contributions to mean total nitrogen load*

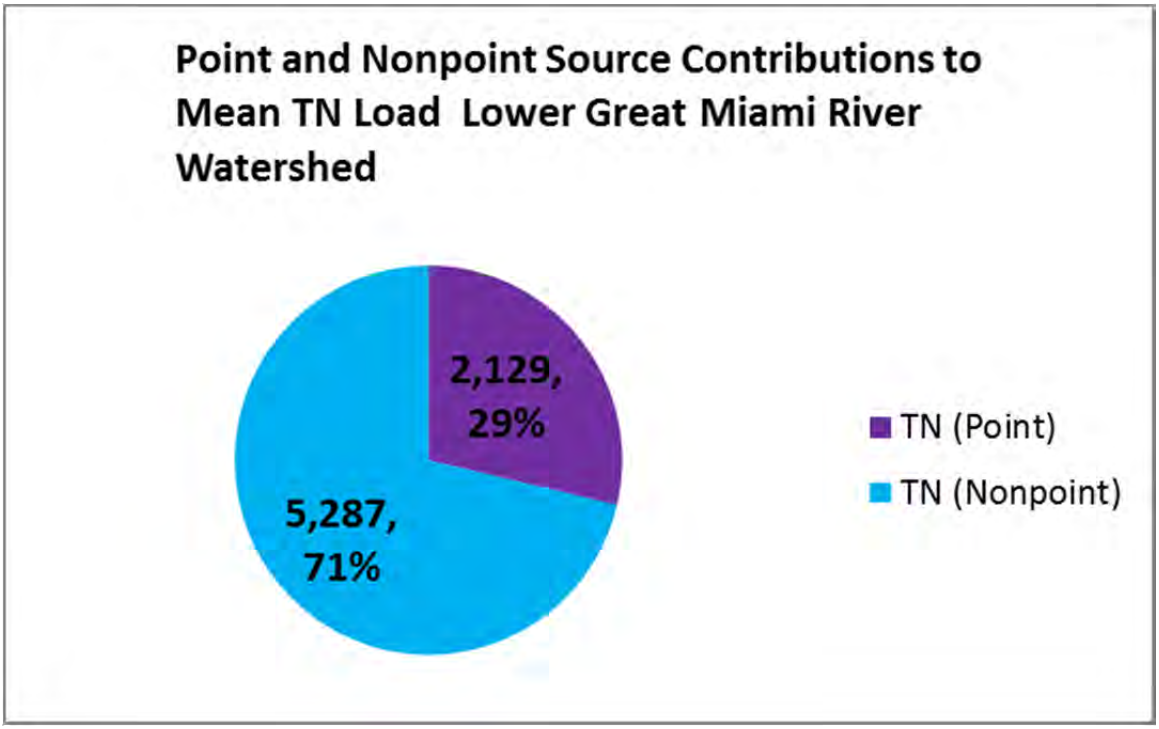
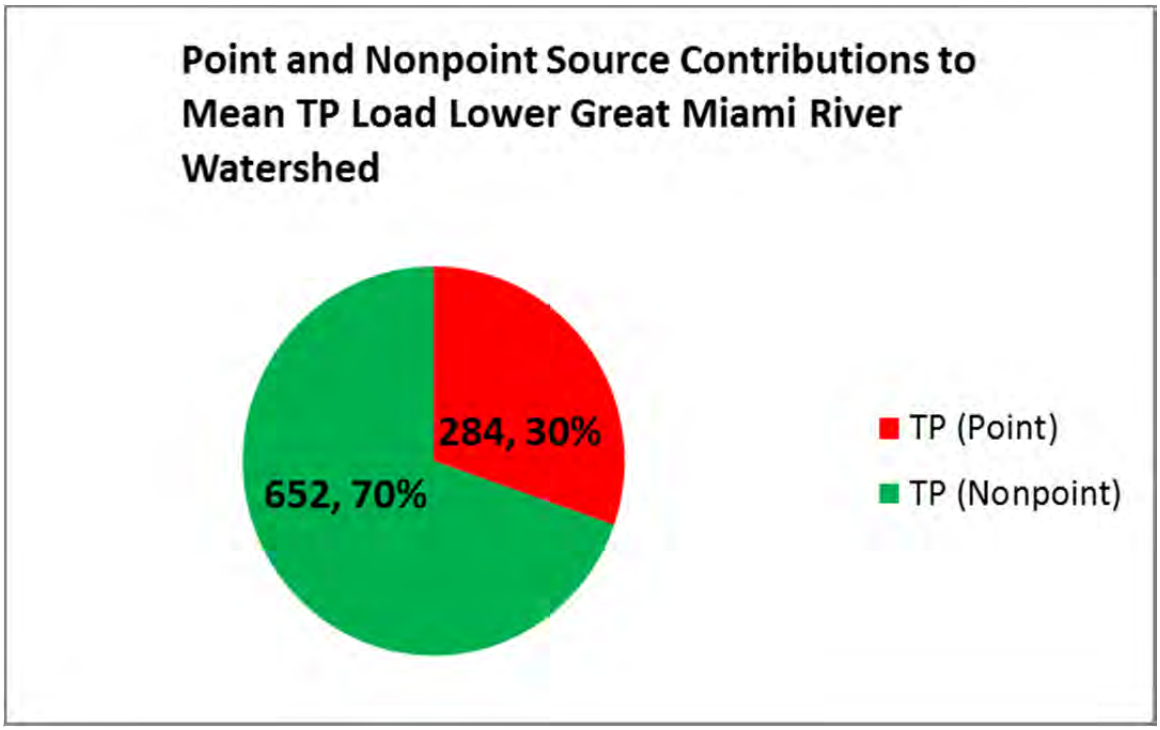


Figure 27 – *Point and nonpoint source contributions to mean total phosphorus load*



Great Miami River Watershed

The Great Miami River Watershed located upstream of station #5 drains a land area of 9,518 km^2 (3,675 mi^2). Land cover in the watershed is mostly agriculture, but developed land is significant (see figure 28). The Great Miami River Watershed drains into the Ohio River Basin. Nutrient loads for the Great Miami River Watershed upstream of station #5 serve as an estimate for nutrient loads exported by the Great Miami River to the Ohio River Basin.

There are 28 major (> 1 MGD) water reclamation facilities in the watershed upstream Station #5. Point sources discharge an average of 3,020 metric tons of nitrogen and 410 metric tons of phosphorus to the Great Miami River Watershed each year (LimnoTech, 2017).

MCD installed Station #5 in 2007. The station was not in operation in 2009 and 2010.

According to the data collected, mean annual total nitrogen and total phosphorus loads for the Great Miami River Watershed are 20,449 and 1,781 metric tons respectively. This is the amount of nitrogen and phosphorus exported by the Great Miami River to the Ohio River annually. Total nitrogen loads ranged from a high of 28,666 metric tons in 2011 to a low of 10,406 metric tons in 2012. Total phosphorus loads ranged from a high of 2,822 metric tons in 2014 to a low of 672 metric tons in 2012 (see figure 29).

Mean annual total nitrogen and phosphorus yields for the Great Miami River Watershed are 2,175 and 189 kilograms per km^2 respectively. These nutrient yields rank among the highest in the Midwest (Lorentz and others, 2009). Total nitrogen yields ranged from a high of 3,049 kilograms per km^2 in 2011 to a low of 1,107 kilograms per km^2 in 2012. Total phosphorus yields ranged from a high of 300 kilograms per km^2 in 2014 to a low of 71 kilograms per km^2 in 2012 (see figure 30).

According to the data, nonpoint sources of nutrients are the dominant source of nutrients in the watershed comprising 85% of the mean annual total nitrogen and 77% of the mean annual total phosphorus loads (see figures 31 and 32).

Flow- weighted and time weighted mean concentrations of nutrients for the watershed are shown in the table below.

Constituent	Flow-Weighted Mean Concentration (mg/L)	Time-Weighted Mean Concentration (mg/L)
Total Nitrogen	4.76	4.39
Nitrate + Nitrite	3.26	2.86
Total Phosphorus	0.41	0.34

Figure 28 – *Land use in the Great Miami River Watershed*

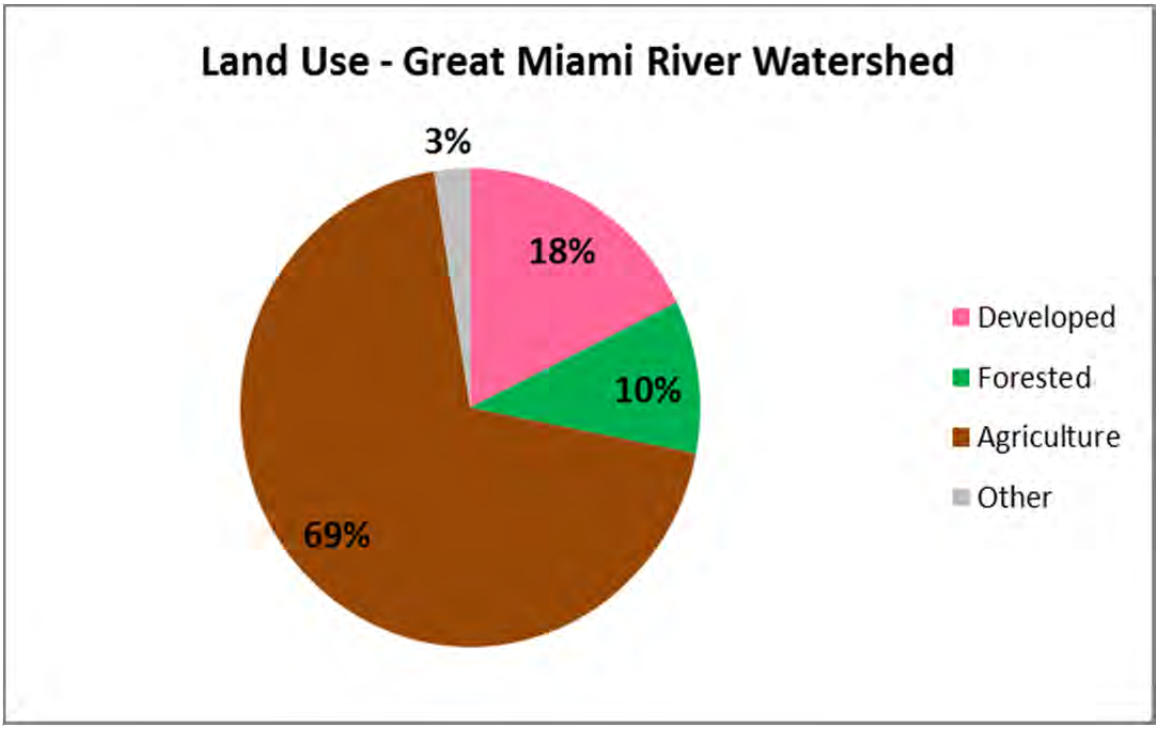


Figure 29 – *Total nitrogen and total phosphorus loads for the Great Miami River Watershed*

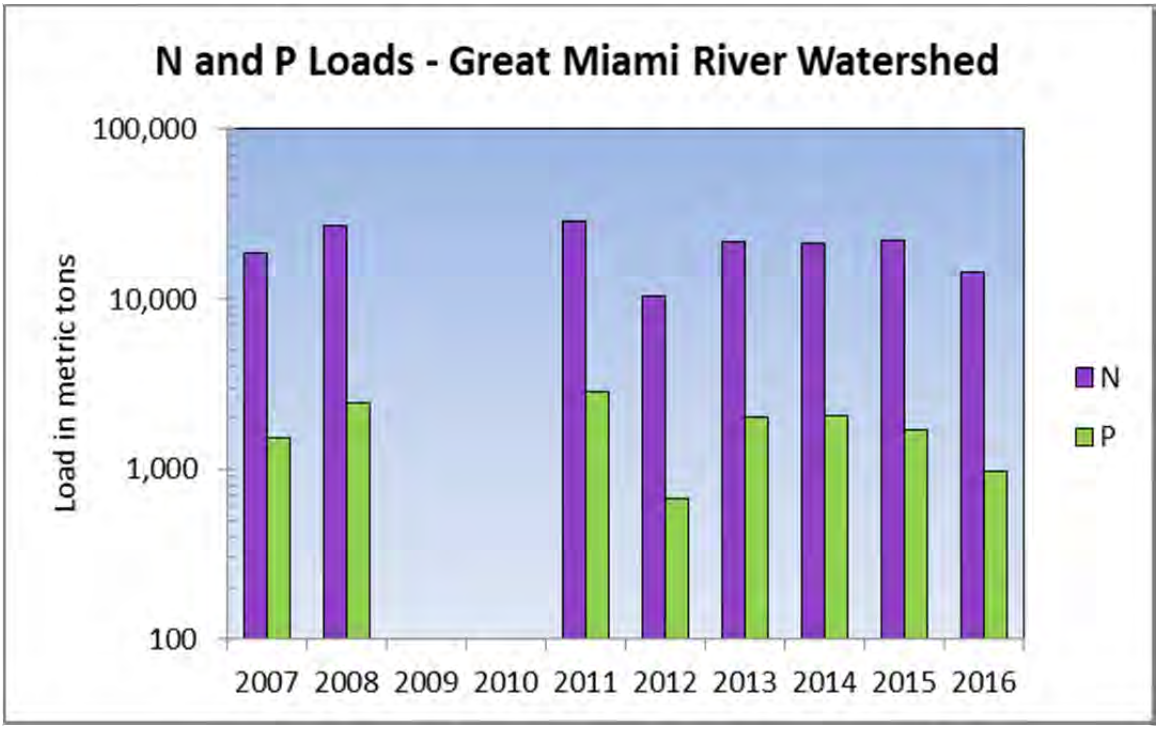


Figure 30 – *Total nitrogen and total phosphorus yields for the Great Miami River Watershed*

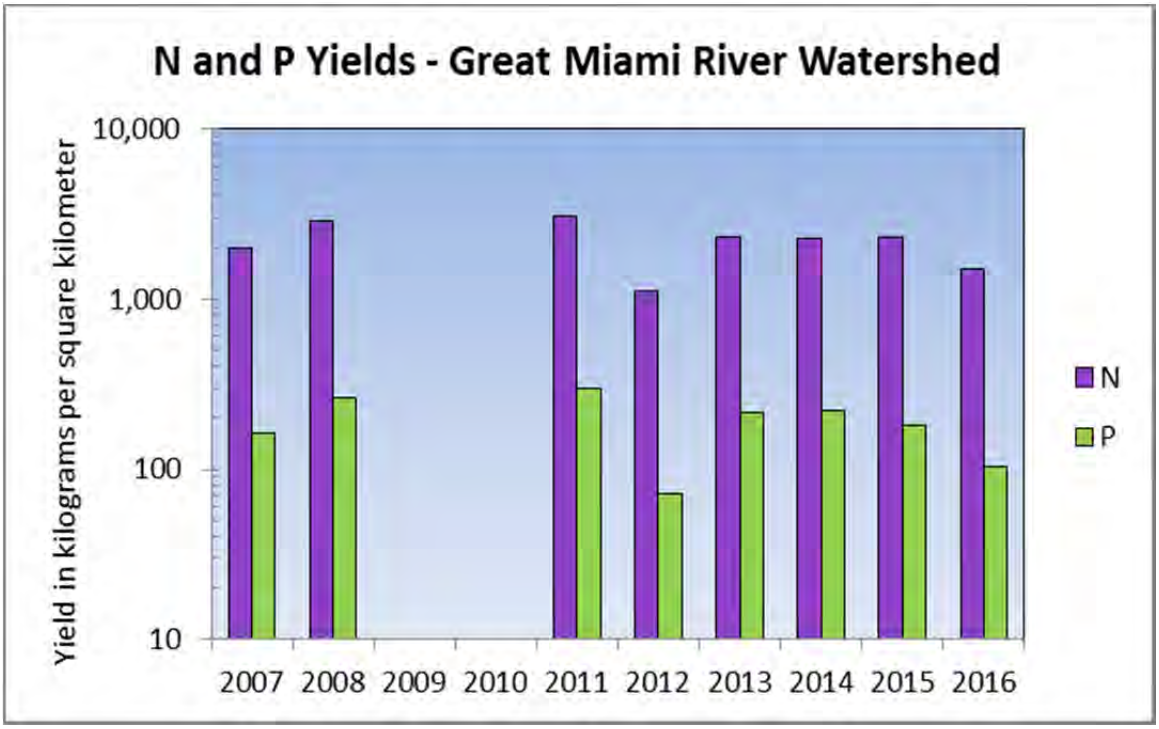


Figure 31 – *Point and nonpoint source contributions to mean total nitrogen load*

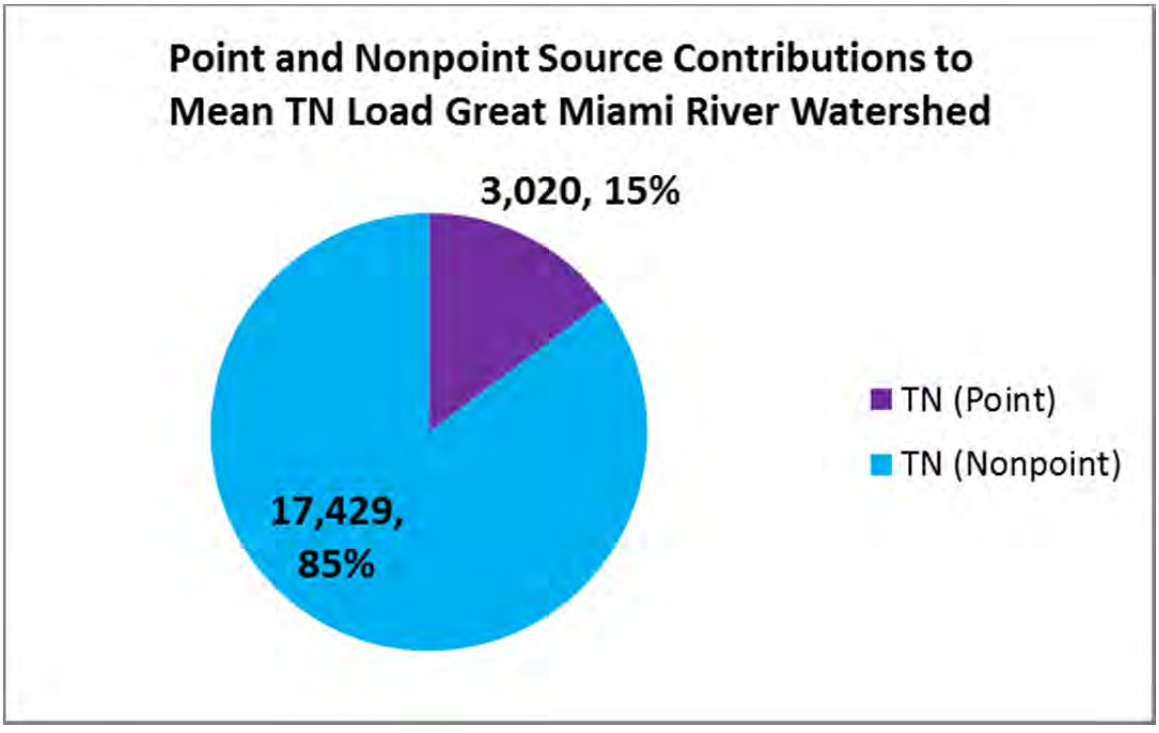
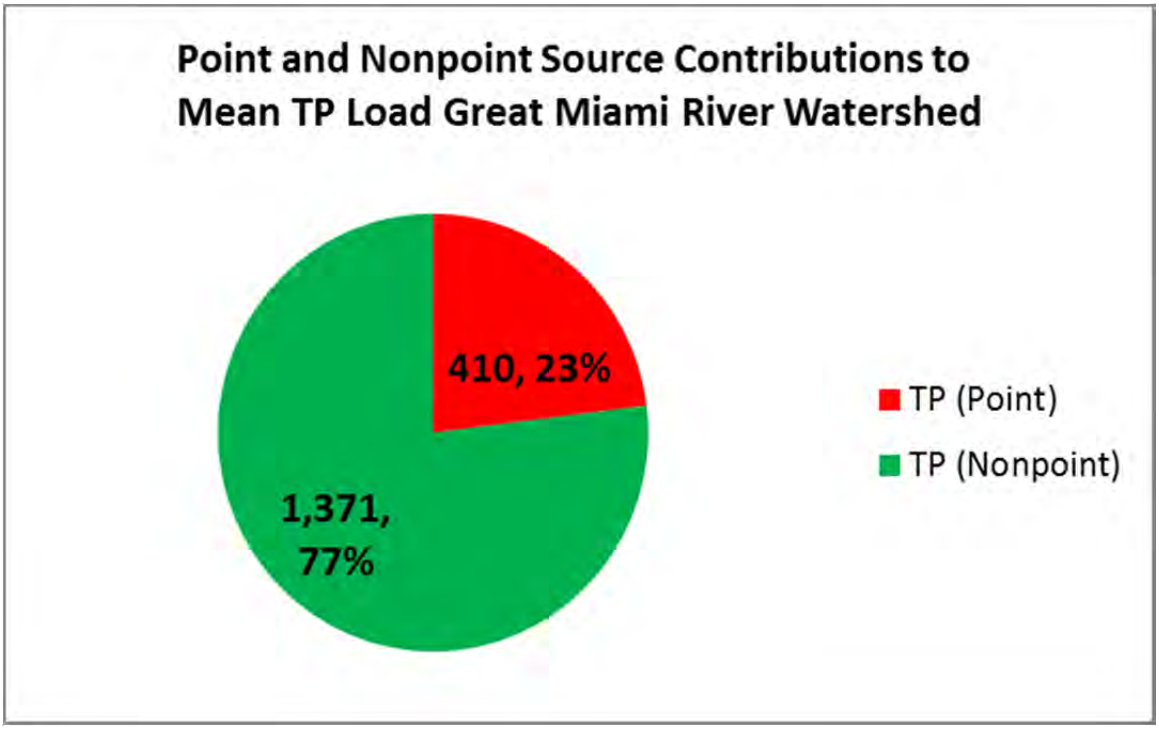


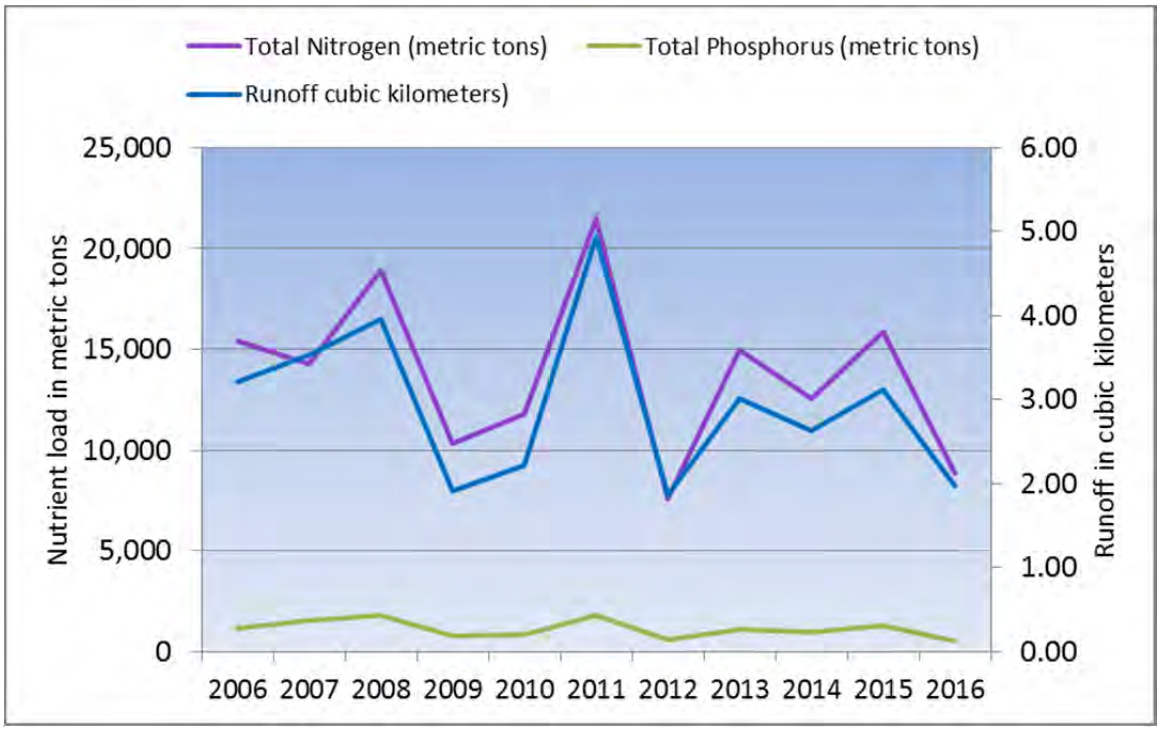
Figure 32 – *Point and nonpoint source contributions to mean total phosphorus load*



Relationship of Nutrients to Runoff and Land Use

Annual nutrient loads in a given watershed are highly dependent upon the amount and timing of runoff. In general, the years with higher runoff are also the years with higher nutrient loads, particularly when the timing of runoff corresponds with nutrient availability. The years 2008 and 2011 had the highest amount of runoff and the highest nitrogen and phosphorus loads throughout the Great Miami River Watershed. The year 2012 had the least amount of runoff and the lowest nitrogen and phosphorus yields. Figure 33 illustrates the correlation between annual runoff and annual nitrogen and phosphorus loads measured at Station #4.

Figure 33 – *Annual loads of nitrogen and phosphorus in conjunction with runoff*



Nonpoint sources of nutrients dominated both nitrogen and phosphorus loading in all of the watersheds evaluated in this study. Nonpoint sources of nutrients comprised 71 – 99% of the average annual nitrogen loads and 69 – 97% of the mean annual phosphorus loads. However, the relative proportion of point source loads of nutrients generally increases as developed land within the watershed increases (see figure 34).

The proportion of developed land in the Great Miami River Watershed generally increases from upstream to downstream. The Lower Great Miami River Subwatershed has the highest

Figure 34 – *Developed land vs percentage of nutrient load from point sources*

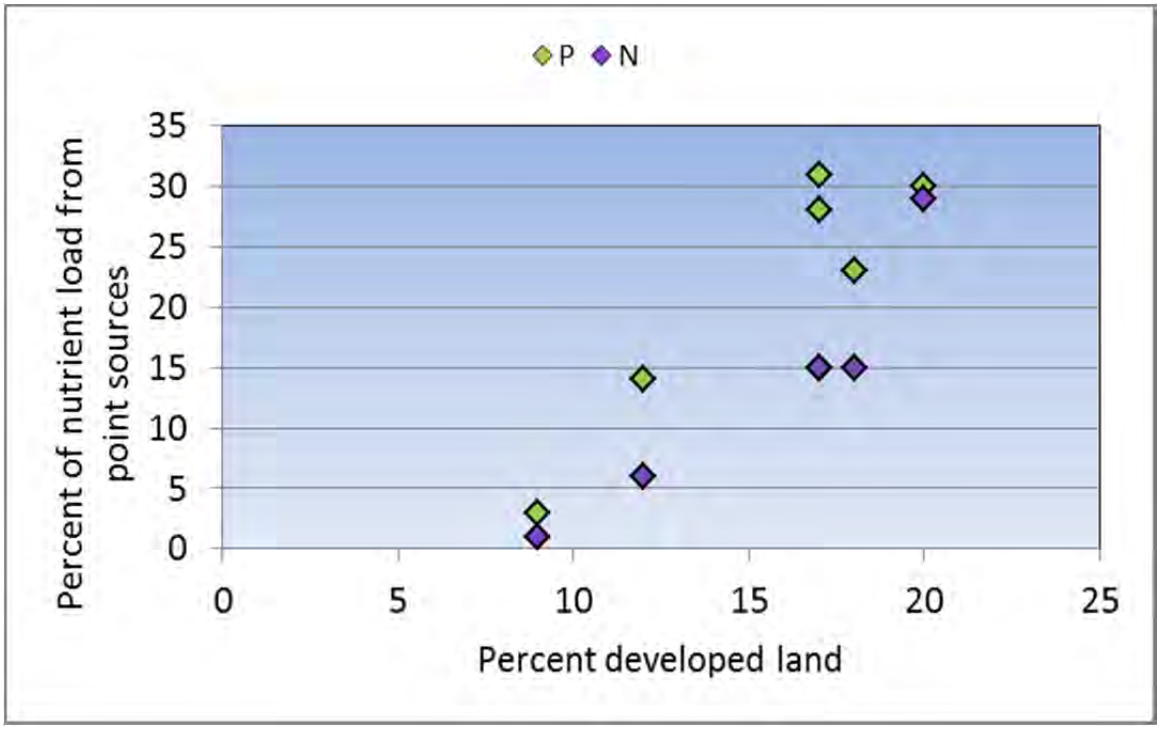
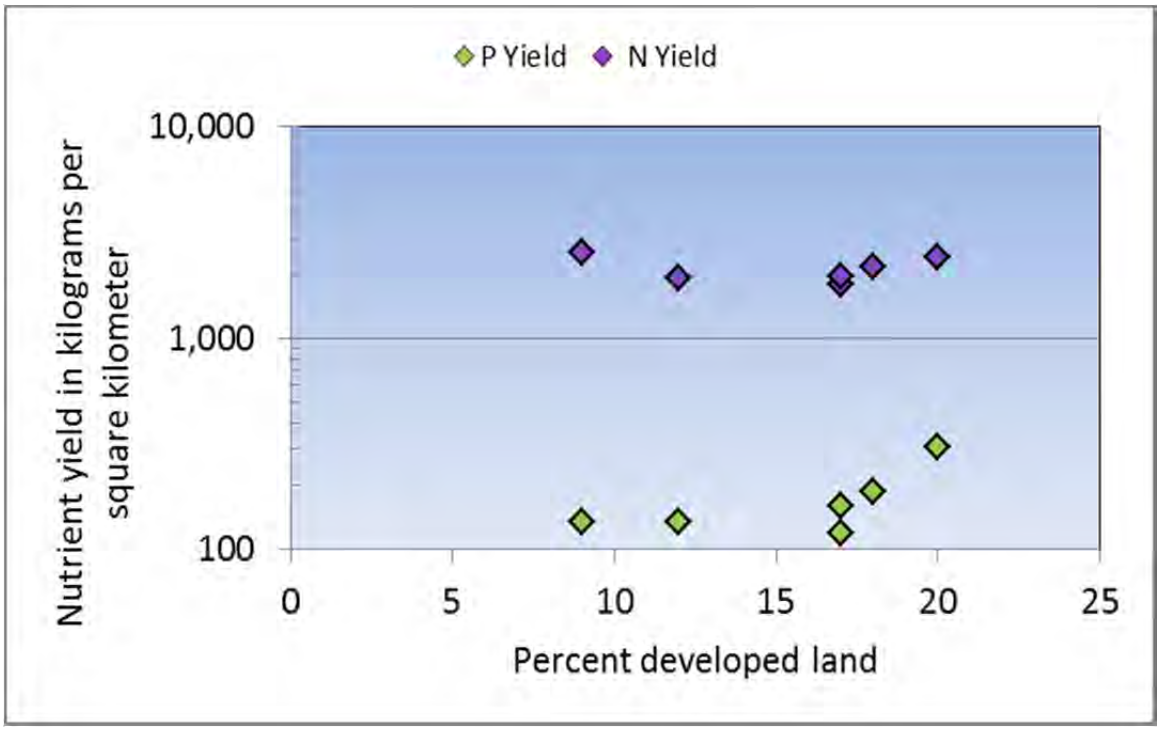


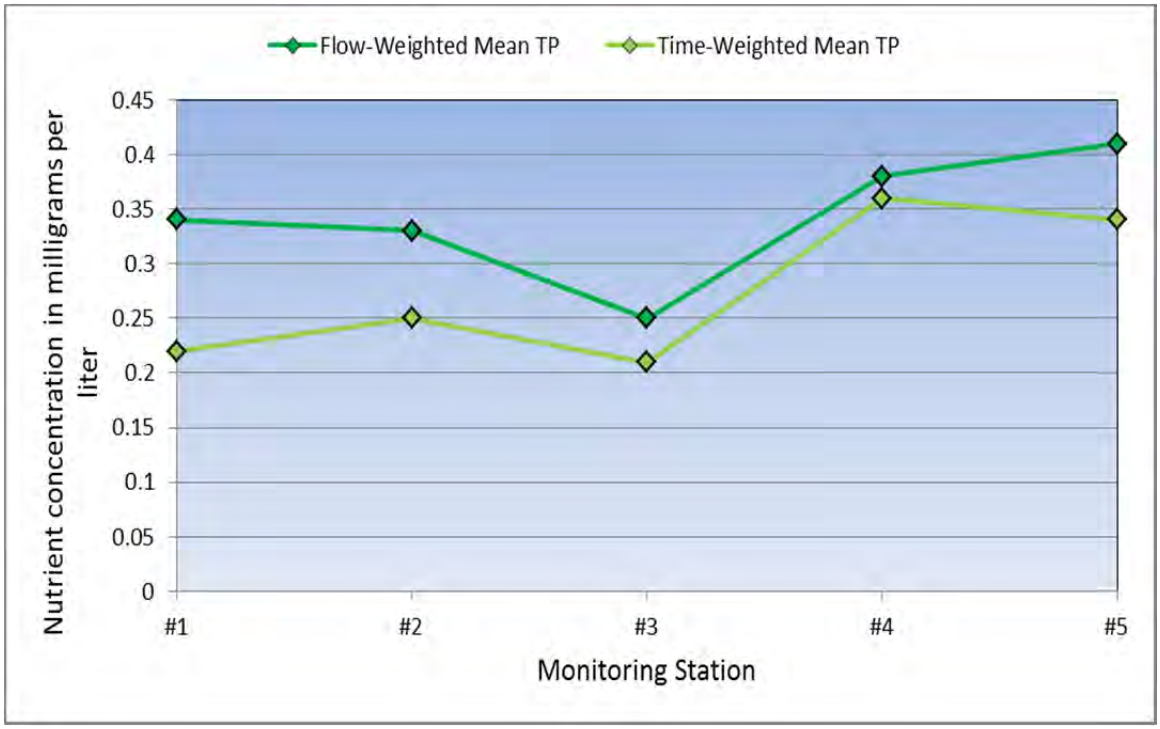
Figure 35– *Developed land vs nutrient yield*



percentage of developed land at 20%. Watersheds with the highest percentage of developed land also had the highest phosphorus yields (see figure 35). However, this relationship did not hold true for nitrogen yields as the Stillwater Subwatershed with only 9% developed land had the highest nitrogen yield out of all of the watersheds in this study.

Flow weighted and time-weighted mean concentrations of phosphorus generally increase from upstream monitoring stations (stations #1, #2, and #3) to downstream stations (stations #4 and #5) (see figure 36). This upstream to downstream trend in mean concentrations is not present for total nitrogen and nitrate plus nitrite (see figure 37). Station #1 (Stillwater River Subwatershed) had the highest flow-weighted and time-weighted mean concentrations of total nitrogen and nitrate plus nitrite.

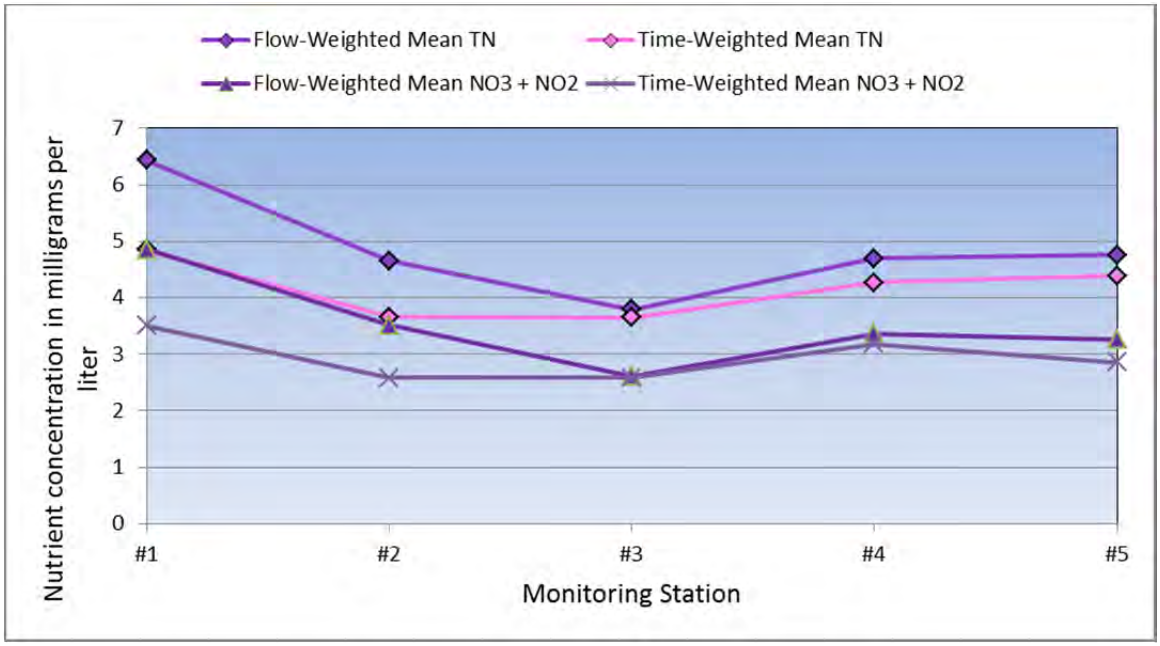
Figure 36 – *Upstream to downstream phosphorus concentrations*



In 1999, the Ohio Environmental Protection Agency published a report on the association between nutrients, habitat, and aquatic biota in streams (Ohio Environmental Protection Agency, 1999). The report made recommendations on target concentrations for nutrients for watersheds of various sizes and biological use designations. The recommended target concentrations are listed in table 1 below. The Stillwater and Upper Great Miami River subwatersheds fall into the small river category and both rivers are designated as exceptional warmwater habitat over much of their lengths. The recommended total phosphorus target concentration is a median of 0.10 mg/L, and the recommended nitrate + nitrite concentration is a median of 1.0 mg/L. The Mad River Subwatershed is also in the small river category but has a designation of warmwater

habitat. The recommended total phosphorus target concentration is a median of 0.17 mg/L while the recommended nitrate + nitrite concentration is 1.5 mg/L.

Figure 37 – *Upstream to downstream mean total nitrogen and nitrate + nitrite concentrations*



The Lower Great Miami Subwatershed falls into the large river category and has a biological use designation of warmwater habitat. The recommended total phosphorus target concentration for the Lower Great Miami River is 0.30 mg/L while the nitrate plus nitrite target concentration is 2.0 mg/L.

According to the data, flow-weighted and time-weighted mean concentrations of phosphorus exceeded the recommended nutrient target concentrations for all watersheds in this study.

Likewise, flow-weighted and time-weighted mean concentrations of nitrate + nitrite also exceeded the recommended target concentrations for all watersheds in this study.

Table 1 – *Proposed nutrient target concentrations for streams*

Stream Type	Drainage Area (mi^2)	EWH* TP* (mg/L)	WWH* TP* (mg/L)	EWH* Nitrate + Nitrite (mg/L)	WWH* Nitrate + Nitrite (mg/L)
Headwaters	< 20	0.05	0.08	0.50	1.0
Wadeable	20 - < 200	0.05	0.10	0.50	1.0
Small River	200 - < 1000	0.10	0.17	1.0	1.5
Large Rivers	> 1000	0.15	0.30	1.5	2.0

*EWH – rivers and streams that are designated as exceptional warmwater habitat

*WWH – rivers and streams that are designated as warmwater habitat

*TP – total phosphorus

Nutrient target concentrations obtained from Tables 1 and 2 of Ohio Environmental Protection Agency, 1999.

Conclusions

A comparison of nutrient data collected from the five nutrient monitoring stations in this study leads to the following conclusions:

1. The Great Miami River Watershed exports on average more than 20,000 metric tons of nitrogen and over 1,700 metric tons of phosphorus to the Ohio River Basin each year.

2. The magnitude of nutrient loads carried by the Great Miami River and its major tributaries are highly dependent upon the amount and timing of runoff.

3. The Stillwater River Subwatershed has the highest mean annual total nitrogen yield while the Lower Great Miami River Subwatershed has the highest mean annual total phosphorus yield.

4. The Stillwater River Subwatershed has the highest flow-weighted and time-weighted mean concentrations of total nitrogen and nitrate + nitrite while the Lower Great Miami

River Subwatershed has the highest flow-weighted mean concentration of total phosphorus.

5. Flow-weighted mean concentrations of total phosphorus are higher at Stations #4 and #5 than stations #1, #2, and #3 and generally increase from upstream to downstream monitoring stations.

6. Flow-weighted and time-weighted mean concentrations of total phosphorus and nitrate + nitrite exceed the recommended nutrient target concentrations published in OEPA Technical Bulletin MAS/1999-1-1 at all monitoring stations.

7. Mean annual total nitrogen and total phosphorus yields for the Great Miami River Watershed rank among the highest nutrient yields in the Midwest.

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Appendix A – Summary of Nutrient Loads

Stillwater River Subwatershed												
Constituent	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**Mean**
Total Nitrogen (metric tons)	5,550	4,464	6,148	3,417	4,642	6,056	2,089	5,135	3,667	3,959	2,674	4,346
Dissolved Inorganic Nitrogen (metric tons)	4,120	3,019	4,292	2,778	3,565	4,697	1,583	4,063	2,704	3,120	2,218	3,287
Total Phosphorus (metric tons)	165	365	519	118	175	322	75	294	161	175	145	229
Total Flow (acre-feet)	614,696	663,828	754,258	377,304	474,368	862,054	252,317	554,173	469,327	624,371	384,789	548,317
Upper Great Miami River Subwatershed												
Constituent	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**Mean**
Total Nitrogen (metric tons)	NA	NA	9,601	3,914	4,434	8,937	2,918	7,301	5,282	5,264	3,864	5,724
Dissolved Inorganic Nitrogen (metric tons)	NA	NA	6,552	3,111	3,497	6,732	2,125	5,522	4,206	3,804	3,285	4,315
Total Phosphorus (metric tons)	NA	NA	688	174	314	780	160	583	242	459	221	402
Total Flow (acre-feet)	NA	NA	1,478,988	528,798	669,138	1,758,911	611,289	1,088,697	921,734	1,200,042	696,462	994,895
Mad River Subwatershed												
Constituent	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**Mean**
Total Nitrogen (metric tons)	NA	3,242	3,493	NA	NA	4,144	1,887	2,951	2,762	2,833	2,354	2,958
Dissolved Inorganic Nitrogen (metric tons)	NA	2,174	2,447	NA	NA	2,996	1,335	2,118	1,844	1,852	1,549	2,039
Total Phosphorus (metric tons)	NA	206	239	NA	NA	288	110	199	181	208	154	198
Total Flow (acre-feet)	NA	697,275	742,710	NA	NA	983,754	437,523	606,212	555,328	588,033	448,352	632,398
Lower Great Miami River Subwatershed												
Constituent	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**Mean**
Total Nitrogen (metric tons)	NA	NA	7,630	NA	NA	9,794	3,512	5,992	9,551	10,105	5,327	7,416
Dissolved Inorganic Nitrogen (metric tons)	NA	NA	4,143	NA	NA	8,748	2,334	3,012	3,834	6,044	3,299	4,488
Total Phosphorus (metric tons)	NA	NA	1,007	NA	NA	1,448	327	928	1,491	888	459	936
Total Flow (acre-feet)	NA	NA	1,164,511	NA	NA	2,291,745	770,624	1,059,953	1,103,992	1,208,001	868,264	1,209,584
Great Miami River Watershed (upstream of Station #4)												
Constituent	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**Mean**
Total Nitrogen (metric tons)	15,435	14,275	18,890	10,359	11,818	21,491	7,566	15,000	12,583	15,857	8,895	13,834
Dissolved Inorganic Nitrogen (metric tons)	11,979	10,117	13,443	7,339	8,816	15,058	5,791	11,191	8,528	9,703	6,992	9,905
Total Phosphorus (metric tons)	1,174	1,546	1,802	756	840	1,790	597	1,115	945	1,321	554	1,131
Total Flow (acre-feet)	2,606,463	2,869,209	3,209,564	1,548,744	1,793,817	3,996,440	1,509,559	2,441,995	2,137,750	2,526,657	1,604,454	2,385,877
Great Miami River Watershed												
Constituent	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**Mean**
Total Nitrogen (metric tons)	NA	18,619	26,879	NA	NA	28,666	10,406	21,378	21,263	22,161	14,219	20,449
Dissolved Inorganic Nitrogen (metric tons)	NA	11,879	17,438	NA	NA	22,967	7,377	14,715	12,588	14,820	10,351	14,017
Total Phosphorus (metric tons)	NA	1,513	2,455	NA	NA	2,822	672	2,004	2,076	1,730	979	1,781
Total Flow (acre-feet)	NA	3,471,558	4,141,823	NA	NA	5,826,493	2,071,753	3,309,034	3,050,381	3,620,446	2,397,868	3,486,169

Appendix B – Summary of Nutrient Yields

Stillwater River Subwatershed												
Constituent	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**Mean**
Total Nitrogen (kg/km^2)	3,297	2,652	3,652	2,030	2,758	3,597	1,241	3,050	2,178	2,173	1,588	2,565
Dissolved Inorganic Nitrogen (kg/km^2)	2,447	1,794	2,549	1,650	2,118	2,790	941	2,414	1,606	1,741	1,318	1,942
Total Phosphorus (kg/km^2)	98	217	308	70	104	191	45	175	96	81	86	134
Total Flow (acre-feet)	614,696	663,828	754,258	377,304	474,368	862,054	252,317	554,173	469,327	585,590	384,789	544,791
Upper Great Miami River Subwatershed												
Constituent	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**Mean**
Total Nitrogen (kg/km^2)	NA	NA	3,226	1,315	1,490	3,003	981	2,453	1,775	1,769	1,298	1,923
Dissolved Inorganic Nitrogen (kg/km^2)	NA	NA	2,202	1,045	1,175	2,262	714	1,855	1,413	1,278	1,104	1,450
Total Phosphorus (kg/km^2)	NA	NA	231	58	105	262	54	196	81	154	74	135
Total Flow (acre-feet)	NA	NA	1,478,988	528,798	669,138	1,758,911	611,289	1,088,697	921,734	1,200,042	696,462	994,895
Mad River Subwatershed												
Constituent	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**Mean**
Total Nitrogen (kg/km^2)	NA	1,971	2,124	NA	NA	2,520	1,147	1,794	1,680	1,723	1,431	1,799
Dissolved Inorganic Nitrogen (kg/km^2)	NA	1,322	1,488	NA	NA	1,822	812	1,288	1,121	1,126	942	1,240
Total Phosphorus (kg/km^2)	NA	125	146	NA	NA	175	67	121	110	127	94	120
Total Flow (acre-feet)	NA	697,275	742,710	NA	NA	983,754	437,523	606,212	555,328	588,033	448,352	632,398
Lower Great Miami River Subwatershed												
Constituent	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**Mean**
Total Nitrogen (kg/km^2)	NA	NA	2,463	NA	NA	3,162	1,134	1,934	3,083	3,359	1,720	2,408
Dissolved Inorganic Nitrogen (kg/km^2)	NA	NA	1,337	NA	NA	2,824	753	994	1,238	2,012	1,065	1,461
Total Phosphorus (kg/km^2)	NA	NA	325	NA	NA	468	106	299	481	299	148	304
Total Flow (acre-feet)	NA	NA	1,164,511	NA	NA	2,291,745	770,624	1,059,953	1,103,992	1,246,782	868,264	1,215,124
Great Miami River Watershed (upstream of Station #4)												
Constituent	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**Mean**
Total Nitrogen (kg/km^2)	2,195	2,030	2,686	1,473	1,681	3,056	1,076	2,133	1,789	2,255	1,265	1,967
Dissolved Inorganic Nitrogen (kg/km^2)	1,704	1,439	1,912	1,044	1,254	2,141	824	1,592	1,213	1,380	994	1,409
Total Phosphorus (kg/km^2)	167	220	256	108	119	254	85	159	134	188	79	161
Total Flow (acre-feet)	2,606,463	2,869,209	3,209,564	1,548,744	1,793,817	3,996,440	1,509,559	2,441,995	2,137,750	2,526,657	1,604,454	2,385,877
Great Miami River Watershed												
Constituent	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**Mean**
Total Nitrogen (kg/km^2)	NA	1,980	2,859	NA	NA	3,049	1,107	2,274	2,262	2,357	1,512	2,175
Dissolved Inorganic Nitrogen (kg/km^2)	NA	1,264	1,855	NA	NA	2,443	785	1,565	1,339	1,576	1,101	1,491
Total Phosphorus (kg/km^2)	NA	161	261	NA	NA	300	71	213	221	184	104	189
Total Flow (acre-feet)	NA	3,471,558	4,141,823	NA	NA	5,826,493	2,071,753	3,309,034	3,050,381	3,620,446	2,397,868	3,486,169