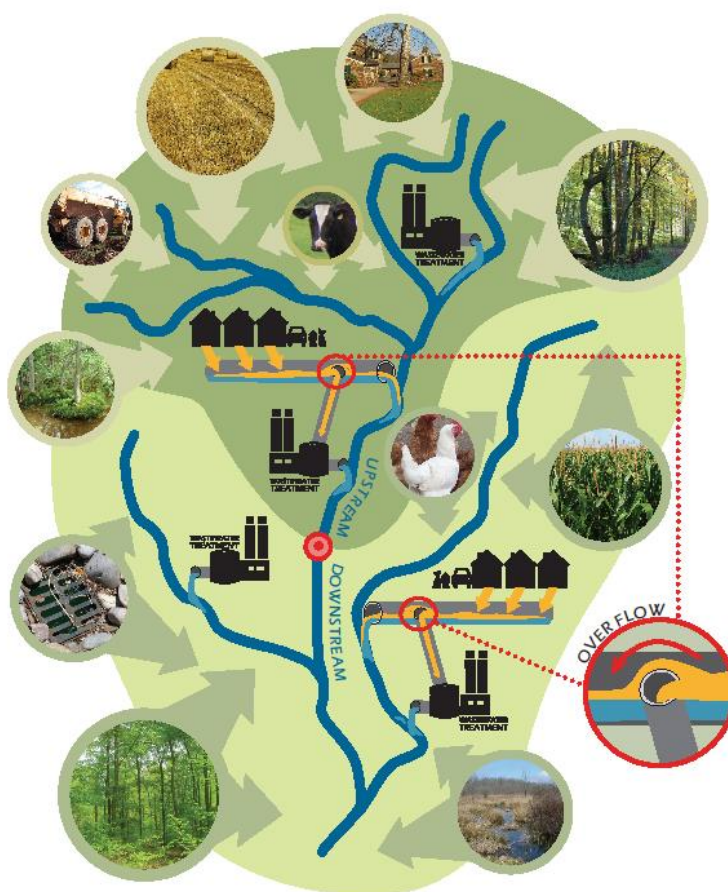# Nutrient Mass Balance Study for Ohio's Major Rivers

Division of Surface Water
Modeling and Assessment Section
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Executive Summary

Background and Purpose

Excess nutrients (nitrogen and phosphorus) stimulate algal growth affecting water quality. Ohio EPA completed this study to identify the most environmentally beneficial and cost-effective mechanisms for nutrient reduction. For example, if *nonpoint source* nutrients are found to be the major contributor of downstream total phosphorus load, as is the case in the Maumee River and other northwest Ohio watersheds, then only focusing remediation on *point source* nutrients would neither be prudent or efficient to protect downstream waters. While it is too early to detect statistically sound trends, the results of this study show no clear decrease in loading yet, especially in nonpoint source dominated watersheds like the Maumee where the loading in 2017 was the highest of the years reported. This study, along with the other data related to current and past nutrient loadings, can and should serve as a tool to focus research, investment, and policy/legislation decisions to curb phosphorus and nitrogen loading in both the Lake Erie watershed and the Ohio River basin.

This mass balance study computes annual total nitrogen (N) and phosphorus (P) loads originating from Ohio watersheds draining to Lake Erie and the Ohio River. The 2016 edition included the Maumee, Portage, Sandusky, Cuyahoga, Great Miami, Scioto and Muskingum watersheds. This 2018 edition adds frontal tributaries to Lake Erie west of the Vermilion River (herein Frontal Lake Erie Tributaries) and the Vermilion River watershed itself. All of Ohio's drainage area to the western Lake Erie Basin (WLEB) except for the Ottawa River (Toledo area) are now included in the study. Loads were allocated to three major contributor groups: nonpoint source (NPS); point sources (NPDES); and household sewage treatment systems (HSTS).

The current (2018) edition computes loading totals on a water-year basis from 2013-2017. The sum of the watersheds included in the 2018 study comprise 66 percent of Ohio's land area. The timing, location, duration and amounts of precipitation, especially rainfall, can be a significant variable influencing stream discharges that affect source loads, especially from nonpoint sources, although point sources may also be affected. This variable is addressed under the section 3.1 subsection Relationship of Annual Water Yield to Annual Load.

Substantial state and federal dollars continue to be allocated to nutrient reduction and nutrient management efforts at both the point and nonpoint level in many of the watersheds referenced in this report, especially those in the WLEB. Programs are underway to track potential water quality improvements resulting from these practices. There is an expected lag between implementation and observed load reductions at stream gages as the effects of legacy practices diminish with time.

A compilation of the programs and policy initiatives related to nutrient management for both point source and nonpoint sources are listed in Appendix C.

Important Findings

The Maumee and Scioto watersheds generated the highest annual total P load when averaged for the five water years in the study (2013-2017) – an average of 2,200 and 2,000 metric tons per annum (mta), respectively. The Muskingum watershed, though the largest area among the seven, was only the fourth highest total P load contributor – an average of 1,340 mta. In-stream reservoirs and a high proportion of natural land cover may be contributing to lower total P loading in the Muskingum watershed.

When examining the sources of total P load, nonpoint sources were the highest contributors to the phosphorus load in the Vermilion (94 percent of its total load), Sandusky (93 percent), Maumee (88 percent) and Portage (87 percent) watersheds. The Cuyahoga had the lowest relative contribution of total P from nonpoint sources.

The highest proportions of total P NPDES load was in the Cuyahoga River basin (45 percent and 136 mta), one of Ohio's most urban watersheds. The rest of the watersheds with the highest NPDES proportions are in the Ohio River basin – led by the Muskingum watershed (39 percent of its total load and 529 mta). The Great Miami and Scioto watersheds are close behind, in terms of percent, at 32 (455 mta) and 34 (686 mta) percent of their total loads.

The role of home sewage treatment systems (HSTS) was less than NPDES loads – occupying an average of 6.3 percent of the total P load. The relative proportions of HSTS total P load was highest in the Cuyahoga and Frontal Lake Erie watersheds (11 percent) and lowest in the Sandusky watershed (three percent).

For total N load, the results are very similar to those found for total P load – the Maumee watershed ranked highest and produced an average of 41,100 mta. The Scioto watershed ranked second highest in total N load producing an average of 24,000 mta. When considering all three Ohio River watersheds together (Great Miami, Scioto and Muskingum), the total N load was 61,600 mta averaged over the five water years.

In terms of sources of total N load and their relative proportions, NPDES load generally occupied the same percentage of total load within the Ohio River basin (around 17 percent) and within the Lake Erie basin (around nine percent and excluding the Cuyahoga) watersheds. We found the Cuyahoga watershed to be an anomaly – producing an average of 83 percent of the total N load. For the three other Lake Erie watersheds, nonpoint source load dominated the total N load (90 percent). For the Ohio River watersheds, nonpoint sources contributed an average of 79 percent of the total N load.

The HSTS load was a smaller proportion (3.5 percent overall) of the total N load compared to the same for total P. This ranged from a low of one percent in the Maumee watershed to a high of eight percent in the Muskingum watershed.

When nonpoint source loads were normalized by watershed area, the watersheds in the Lake Erie basin dominated by agricultural production (excluding Cuyahoga) had the highest yields – averaging 1.1 pounds per acre compared to 0.6 pounds per acre in the Ohio River basin. The clear differences in nonpoint source yields corresponds to these watersheds having the highest percentage of their area dedicated to agricultural production in the state. Similar results were shown for total N when normalized for watershed area; averaging 18.6 pounds per acre in the Lake Erie basin and 10 pounds per acre in the Ohio River basin. When the human-sewage sourced load (NPDES + HSTS) were standardized by the contributing population in the watershed, the yields were highest in the Ohio River basin – averaging 0.8 pounds per person compared to 0.5 pounds per person in the Lake Erie basin. The human-sewage sources of total N were not notably different across the watersheds – averaging 7.1 pounds per person.

To compare the differences highlighted in the watershed analysis between the Lake Erie and Ohio River basins, a supplemental analysis was completed for the statewide municipal NPDES total P loadings by major basin. The apparent differences observed were highlighted when the loads were normalized by total discharge to report a flow-weighted mean concentration for municipal effluents. The municipal facilities in the Lake Erie basin averaged 0.49 mg-P/L and the municipal facilities in the Ohio River basin averaged 1.60 mg-P/L.

Future Actions

The next edition (in 2020) will compute loadings for the subsequent two water years (a total of seven years), which will improve trend discussions. Future editions of this study will consider other monitored watersheds, expanding beyond these nine watersheds, and assessing the additional load generated by the remaining third of Ohio's land area. These other watersheds may not be monitored daily but will need to have a sufficient monitoring frequency and capture of storm events to generate reliable load estimates. Refinement of the subcomponents of nonpoint source load including agriculture, residential development, urban areas and industry will also be pursued.

1 Introduction

The objectives of this study are to determine nutrient (nitrogen and phosphorus) loads and the relative proportions of point source and nonpoint source contributions to Lake Erie and the Ohio River on an annual basis. Excess nutrients stimulate algal growth, and when in excess, subsequently affect the physical, chemical and biological health of aquatic systems. The current (2018) edition extends the analysis from seven major watersheds (published in 2016; Ohio EPA 2016) to include additional Lake Erie tributaries (about 1,100 sq. mi in drainage area), and all with discharge points in Ohio. To calculate total loads, we identified load sources originating from all known major contributors (municipal wastewater, industrial wastewater, nonpoint sources). The current (2018) edition computes loading totals on a water-year[1] basis – five total, for each of water years 2013 through 2017 (designated, herein, as wyNN where NN is the water year). For this edition, we recompute the analysis from wy13 and wy14 and bring an additional three years of loading analysis to the present time by ending with wy17 on this past September 2017.

There are numerous benefits to performing such a study. One benefit is that identifying load sources provides information for determining the most environmentally beneficial and cost-effective mechanisms for nutrient reduction. For example, if nonpoint nutrients are found to be the major contributor of downstream total phosphorus load, then focusing remediation on point source nutrients would neither be prudent or efficient. The study will also serve national and regional U.S. goals manifested by the 2012 Great Lakes Water Agreement Annex 4 (nutrients) and the Gulf of Mexico Hypoxia Task Force 2008 Action Plan. Annex 4 goals address both nuisance algal blooms and hypoxia in Lake Erie. Results could also aid in the management of nuisance algal blooms for the Ohio River.

The need to understand total nutrient load and sources for Ohio was earlier recognized by the Point Source and Urban Runoff Nutrient Workgroup (Ohio EPA, 2012; pp 8-9, 16-17), developed as part of Ohio EPA's Nutrient Reduction Strategy. The state legislature then considered this recommendation from the work group and subsequently codified it into a statutory requirement [ORC 6111.03 (U)]. The requirement was passed by the Ohio General Assembly in June 2015 and states that Ohio EPA shall "study, examine, and calculate nutrient loading from point and nonpoint sources in order to determine comparative contributions by those sources, and report every two years." The study watersheds must include data on ambient water quality and streamflow and point source discharges. Subsequent studies carried out biennially will be used to document nutrient loading trends.

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[1] A water year (wy) is a 12-month period that starts on October 1 of each year and is named for the year of its September-ending date. The beginning of a water year differs from the calendar year so that precipitation and its associated subsequent runoff are accounted for in the same 12-month period. Late autumn and winter snowfall that may accumulate in the ensuing months will not drain and discharge until the following spring (or summer) snowmelt.

As in the 2016 edition of the nutrient mass balance study, the 2018 edition considers watersheds based on availability of discharge and water quality. They were expected to be major contributors of nutrient load to the Lake Erie and the Ohio River systems. The seven major watersheds are monitored for water quality on a daily (and sometimes more frequent) basis by the National Center for Water Quality Research (NCWQR) at Heidelberg University (Ohio). Sub-hourly discharge (stream flow) is monitored by the USGS for all seven watersheds. These sources of data were critical in developing a meaningful procedure for a biennial analysis of loading sources. These watersheds include the Maumee River, Portage River, Sandusky River and Cuyahoga River of the Lake Erie system and the Great Miami River, Scioto River and Muskingum River of the Ohio River system (Figure 1). The additional drainage area for Lake Erie recognizes the increasingly important need to document contributions to the Western and Central (western-half) portions of this ecosystem. Here, the Vermilion River (Lake Erie system) is monitored for water quality and flow by the USGS, and an additional contribution from direct Lake Erie tributaries is partially estimated (Figure 1). Thus, in total, the 2018 nutrient mass balance study examines nutrient loads from nine watersheds.

In addition to adding new watersheds, several changes occurred between the 2016 and 2018 editions and are detailed in the methods section. In some cases, results for water years 2013 and 2014 shown in the 2016 report are different in the 2018 report. For one, nutrient loads calculated for coal-fired power plants were removed in the 2018 report. In the 2016 report, concentrations used in these calculations were taken from self-monitoring submitted in NPDES permit applications (the standard Form 2-C). In 2018 after additional inspection, these concentrations largely reflect background (ambient) stream concentrations and are now considered pass-through rather than load generated by processing operations of the plant. In another area, new monitoring data was available to estimate total P concentrations in combined sewer overflow (CSO) discharges. The result was a 66 percent reduction in CSO loading than reported in the 2016 edition. The final substantial change was the development of a contributing population based on people contributing waste to the watershed. Previously, a simple population count within the watershed drainage divide was made. Contributing population is used in the denominator of a per-capita yield discussed in the methods section.

The within-Ohio area of these nine watersheds comprises 66 percent of the total land area of Ohio. However, all sources outside the state boundary and within the entire watershed area were included in the analysis. Any pollutant source draining directly or indirectly (for example, through connecting tributaries) to the mainstem river segment of these basins was included in the 2018 edition. With the exception of the direct Lake Erie tributary watersheds, direct discharges to Lake Erie or the Ohio River were not included in the watershed results but could be in subsequent editions. Some of the data sources used to define source loads were taken from Ohio Department Health survey of home septic systems and the National Pollution Discharge Elimination System (NPDES) self-monitoring program.

A major assumption in identifying sources of loads and computing total load at the outlet to a major system such as Lake Erie is that no loss in load occurs from source to outlet. Nutrient load losses may occur from assimilation into the floodplain, river or stream substrate or plant uptake (both macrophytes and algae). However, the assumption of no load loss is reasonable when accounting for total nutrient quantity (for example, total phosphorus) over a 12-month period. On a water year basis, this assumption is acceptable because sources and sinks of nutrients tend to reconcile to the same total load over longer time intervals such as a year. Other more permanent losses may arise from denitrification (for nitrogen) in floodplain and stream bank soils or from fish harvest; future editions may quantify these components, too.

Past Studies and Associated Work

The focus in Lake Erie and other Great Lakes has been on phosphorus and its corresponding blue-green algae blooms, while the focus on the Gulf of Mexico nutrient loading has been toward nitrogen loads and hypoxia of the northern Gulf of Mexico (Mississippi River/Gulf of Mexico Watershed Nutrient Task Force, 2008).

Several historical and ongoing studies characterizing total nutrient loads from Great Lakes tributaries have been conducted for various reporting periods (Dolan 1993; Dolan and Richards, 2008, Maccoux et al. 2016). The earliest study of Lake Erie loadings was conducted by the Pollution from Land Use Activities Reference Group in 1978 (PLUARG, 1978).

A detailed analysis of Lake Erie total phosphorus loadings was presented by Dolan and McGunagle (2005) and subsequently updated in Maccoux and others (2016). Both direct and watershed loadings were considered. For unmonitored tributaries, a unit-area load was used to estimate the total load. The 2005 work was advanced for all of the Great Lakes and updated in 2008 by Dolan and Chapra (2012a, 2012b), and is planned to continue. We anticipate that the past 2016 and current (2018) Ohio efforts will aid in more frequent updates to Lake Erie and Great Lake total load accounting.

The earliest studies on hypoxia in the Gulf of Mexico addressed nitrogen loads (Goolsby and Battaglin, 2001; Scavia et al., 2003, Aulenbach et al., 2007) as recommended by 2008 Action Plan (see above). However, more recent assessments (2007, 2013) of hypoxia causes suggest a dual nutrient strategy and call for concurrent nitrogen and phosphorus reductions (U.S. Environmental Protection Agency Science Advisory Board, 2008).
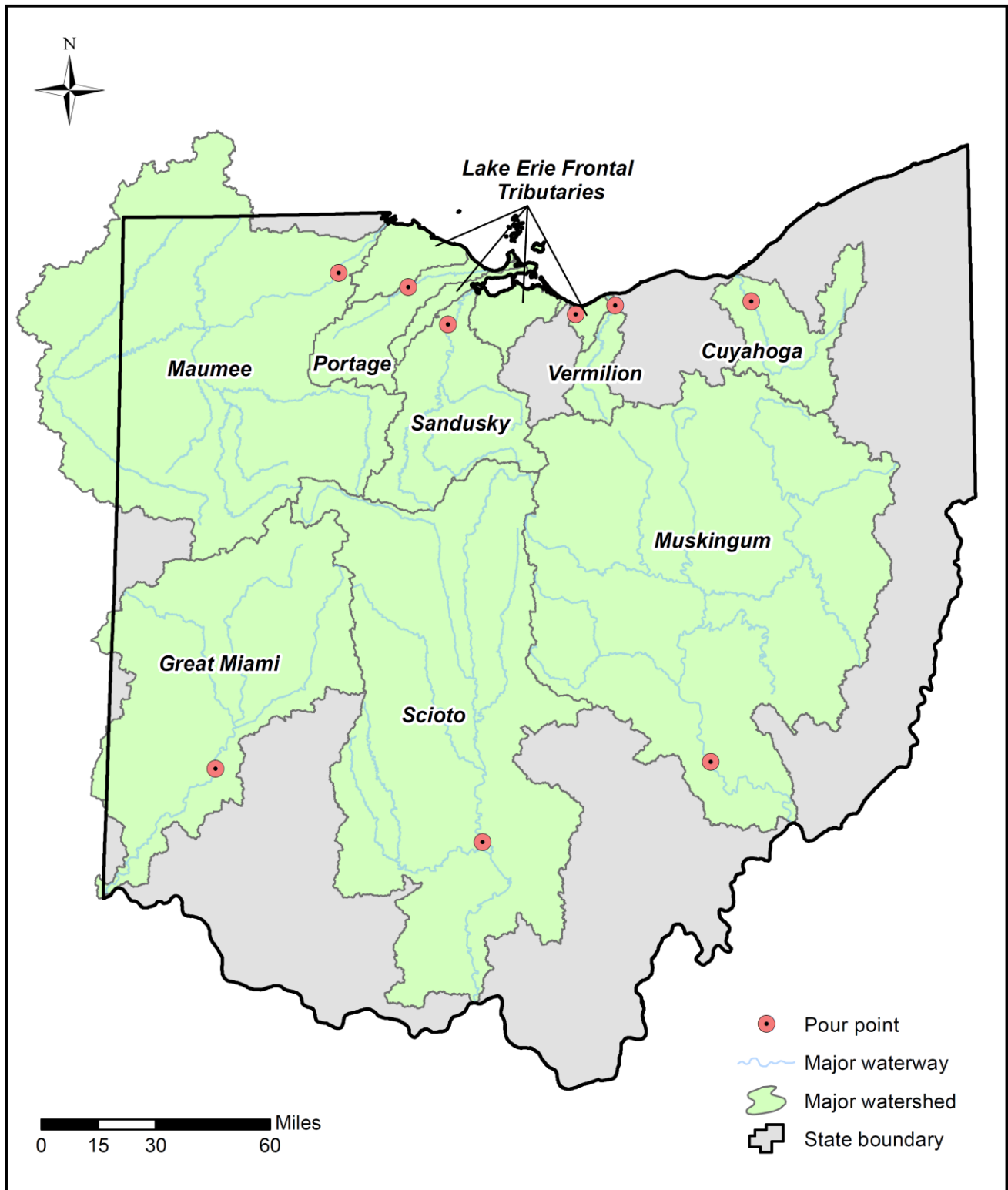
Figure 1 — Map of nutrient mass balance watersheds and associated pour points.

2 Methods

2.1 Overall Loading Calculation

The mass balance equation used to calculate watershed loading is presented as Equation 1 below.

$$Total\ Load = NPDES + HSTS + NPS_{upst} + NPS_{dst}\ (1)$$

The load discharged by entities with National Pollutant Discharge Elimination System (NPDES) permits, which are within the regulatory authority of Ohio EPA, is represented as the point source load (named NPDES) in Equation 1. Household Sewage Treatment System (HSTS) contributions are estimated separately. The nonpoint source (NPS) loads are separated into two categories: nonpoint source, which is calculated upstream from the pour point (NPS_{upst}) and nonpoint source, calculated downstream of the pour point (NPS_{dst}). The timing, location, duration and amounts of precipitation, especially rainfall, are important variables influencing stream discharges that affect source loads, especially from nonpoint sources, although point sources may also be affected. These variables are discussed in section 3.1, subsection Relationship of Annual Water Yield to Annual Load.

2.2 Point Source Loading

The NPDES program requires permittees to report operational data to Ohio EPA via discharge monitoring reports (DMR). All facilities are required to report flow volume. To varying degrees, nutrient concentrations are also monitored and reported. This is dependent on factors such as reasonable potential of elevated concentrations and facility size. The varied reporting from different facilities requires that loads be estimated using a method which is flexible and can account for missing data. Equation 2 estimates the generic loading from an NPDES permitted facility.

$$Annual\ Load = Q(in\ MG) * [Nutrient] * cf\ (2)$$

In Equation 2, Q represents a facility's flow volume in million gallons (MG). The cf term, equal to 3.78451, is a conversion factor used to convert MG and nutrient concentration from milligrams per liter into kilograms per day.

To estimate the nutrient concentration, denoted [*Nutrient*], in Equation 2, each facility is placed into one of four groups, depending on the type of plant and available nutrient monitoring data. The groups and approaches for calculating nutrient concentrations are: 1) industrial facilities reporting nutrient concentrations – use the median concentration of nutrients reported during the calculation period; 2) industrial facilities not reporting nutrient concentrations – assume a de minimis nutrient concentration set equal to 0; 3) sewage treatment facilities reporting nutrient concentrations – use the median nutrient concentration from the calculation period; and 4) sewage treatment facilities not reporting nutrient concentrations – use the median nutrient concentration from similar facilities. Nutrient concentrations were estimated for three size classes of municipal effluent and are defined in Table 1. Note that in the 2016 edition, five size classes of municipal effluent were defined. The simple breakdown shown here is more consistent with how Ohio EPA administers its NPDES program.

Table 1 — Facility classes by design flow.

Group	Type	Design Flow (mgd)
Industrials	All Industrial Permits	--
Major Municipal	Sewage Treatment	≥ 1.0
Minor Municipal	Sewage Treatment	0.1 to 1.0
Package Plant	Sewage Treatment	< 0.1

Nutrient loads in this report are estimated as total phosphorus (total P) and total nitrogen (total N). Facilities with phosphorus monitoring typically report total P, which can be used directly for loading estimates. Of note, all major municipal facilities have monitoring requirements for total phosphorus. However, to determine total N, estimates are needed for ammonia, nitrite + nitrate and organic N. Most facilities, however, are only required to report ammonia and nitrite + nitrate with limited data available for organic N. In the approach used here, organic N is estimated as the difference between Total Kjeldahl Nitrogen (TKN) and ammonia. A statewide analysis of paired TKN and ammonia samples from NPDES sewage treatment facilities from wy11 – wy15 (9,110 samples) was performed to provide an estimate of organic N. Different sized facilities had similar data so a common median of the statewide dataset of 1.37 mg/L was used for an organic N estimate for all sewage treatment facilities.

Wet-weather events often result in increased wastewater flows within collection networks, either by design in combined sewer communities or as increased flows to sanitary sewers through inflow and infiltration (I&I). The result of increased flows is reduced treatment at the plant (usually a bypass of secondary treatment), wastewater bypasses at the plant headworks (raw bypasses), overflows of combined sewers (CSOs) and overflows of sanitary sewers (SSOs). Note that SSOs are only included when overflow volume is reported. Loads are estimated at NPDES facilities reporting discharge for these wet-weather events at assigned stations. This report uses a wet-weather loading nutrient concentration of 0.73 mg/L for total P, the median concentration of 131 samples reported from September 2014 to August 2017 by two sewer districts that are required to monitor TP at select CSO outfalls in their NPDES permit. For total N, 20 mg/L was used at stations designated as SSOs, CSOs and raw bypasses (U.S. Environmental Protection Agency, 2004; Tchobanoglous et al., 2003). For bypasses that pass through primary treatment, 15 percent removal is assumed to account for settling and sludge removal.

One watershed analyzed in the mass balance study, the Maumee, included NPDES sources that are outside of the state of Ohio. Data on monthly loads was available from the Integrated Compliance Information System (ICIS) maintained by U.S. EPA. These monthly loads were summed for each facility within the watershed and are reported as out-of-state (OOS) NPDES loads. Facilities identified as controlled dischargers were excluded from the OOS analysis because the data maintained in ICIS is an average of discharge on days a discharge occurred. There is no associated count of days that discharge occurred, resulting in gross overestimation of discharge volume. This load contains a CSO load estimate where the overflow volumes are reported, and combined sewer systems were assumed to have the same concentration as those within Ohio.

2.3 HSTS Loads

The population served by HSTS is estimated using a spatial analysis of census data (U.S. Census, 2010), combined with an assessment of populations that are likely served by sewer systems of NPDES permitted facilities. The populations served by NPDES facilities are estimated using two methods. The first is that census designated places (CDPs) are assessed as sewered or not. The second method is applied to NPDES sewage treatment facilities that are not associated with a CDP. In this case, the population served by the facilities is estimated by determining the average flow for facilities associated primarily with households and then dividing by 70.1 gal/day/person (Lowe et al., 2009). Facilities serving mobile home parks and subdivisions were included in the latter approach while facilities serving highway rest stops and recreation facilities were excluded. The HSTS population is then estimated to be the remaining population when NPDES CDP population and non-CDP NPDES population are subtracted from the total population of the watershed. Equation 3 explains this overall method.

$$Load_{HSTS} = Pop_{HSTS} * Nut_{Yield}$$
$$* \left[percentPop_{discharge} * DR_{discharge} + percentPop_{onsite-working} * DR_{onsite-working} \right.$$
$$\left. + percentPop_{onsite-failed} * DR_{onsite-failed} \right] (3)$$

where,

Pop_{HSTS} = Total population served by HSTS in watershed (persons)

Nut_{Yield} = Annual yield of nutrient per person ($\frac{\frac{lb}{year}}{person}$)

$percentPop_{discharge}$ = percent of population served by discharging HSTS

$DR_{discharge}$ = nutrient delivery ratio for discharging systems

$percentPop_{onsite-working}$ = percent of population served by onsite working HSTS

$DR_{onsite-working}$ = nutrient delivery ratio for onsite working systems

$percentPop_{onsite-failing}$ = percent of population served by onsite failing HSTS

$DR_{onsite-failing}$ = nutrient delivery ratio for onsite failing systems

The per capita nutrient yield in household wastewater was determined by literature review. A study by Lowe and others (2009) reported a median nutrient yield as 0.511 kg-P/capita/year and 3.686 kg-N/capita/year. In a similar effort to this mass balance study, the Minnesota Pollution Control Agency (MPCA) estimated the annual per capita nutrient yield to be 0.8845 kg-P/capita/year and 9.1 kg-N/capita/year (Wilson and Anderson, 2004). The MPCA study used estimated values based on different household water use activities while the Lowe study reported statistics on data measured on actual systems. The Lowe study median concentrations were used because the methodology uses actual sampling data of septic tank effluents.

Phosphorus delivery ratios for three different system types were also estimated by literature review. One system type is properly operating soil adsorption systems. In these systems, wastewater percolates through the soil matrix where physical, chemical and biological processes treat pollutants. Phosphorus is usually considered to be effectively removed in these systems. Beal and others (2005) reviewed several studies and reported several findings including: >99 percent P removal; 83 percent P removal; and slow P movement to ground water. In a nutrient balance study, MPCA assumed that HSTS with soil adsorption systems removed phosphorus at 80 percent efficiency (MPCA, 2004). For this study, 80 percent efficiency will be used because the studies reviewed by Beal used fresh soil columns and did not consider a reduction in efficiency with system age.

Another category of systems included in the mass balance study is soil adsorption systems that are failing to function as designed. Failure of systems is caused by a myriad of problems, so literature values are not available for phosphorus removal. For this mass balance study, the assumption is made that failing systems still involve some level of soil contact; therefore, total P removal will in between the value of a direct discharge and a soil adsorption system. The value used for the mass balance study was 40 percent total P removal for failing soil adsorption systems, or half that is assumed for properly working systems.

A third group of HSTS is systems that are designed to discharge directly to a receiving stream. These systems use mechanical treatment processes to treat wastewater and discharge directly to streams. Similar to septic tanks, they are designed to remove suspended solids, but sludge removal is limited to periodic pumping. Lowe and others (2009) studied septic tank influent and effluent and determined that there was

a six percent reduction in total P. This study will use the same six percent reduction observed by Lowe and others (2009).

Nitrogen delivery ratios are different from phosphorus delivery ratios and, like phosphorus, are estimated by literature review. Soil type and flow path affect the delivery of nitrogen from soil adsorption systems. Beal and others (2005) reviewed several studies and reported nitrogen removal from 0 to 80 percent. For this mass balance study, 40 percent removal of nitrogen in working soil adsorption systems is used. Again, since failing soil adsorption systems are considered failing for many reasons, they are not well studied relative to removal efficiency of different pollutants. However, since soil contact and lateral water movement are still involved, this nutrient mass balance study will use the same, yet moderate, 40 percent removal efficiency used for working soil adsorption systems. As noted above, discharging HSTS are not designed to remove sludge from the system. Rather, they mineralize organic material and therefore the median total nitrogen outflow of septic tanks is not significantly different from the inflow (Lowe, 2009). For this reason, the discharging HSTS will not be considered as providing any reduction of total N in the mass balance study.

The final component needed to estimate HSTS loading is the relative proportion of system types, split into three categories: 1) working soil adsorption systems; 2) failing soil adsorption systems; and 3) systems designed to discharge. The Ohio Department of Health (ODH) is the state agency tasked with regulating the treatment of household sewage. ODH completed a survey of county health districts in 2012 and published the results as an inventory of existing HSTS in the state by Ohio EPA district (Table 2). The district with the largest areal overlap with a watershed is used to determine the relative proportions of different system types.

Table 2 — Proportions of total HSTS systems grouped into categories for nutrient mass balance study. Adapted from the 2012 ODH statewide inventory (ODH, 2013).

Ohio EPA District	Working Soil Adsorption (%)	Failing Soil Adsorption (%)	Discharging (%)
Northwest	41.5	26.5	32
Northeast	44	27	29
Central	42.8	25.2	32
Southwest	64	14	22
Southeast	61.2	10.8	28

2.4 Nonpoint Source Loading
Central to estimating the nonpoint source load is a monitoring point, herein the pour point, where near-continuous data is collected by the NCWQR. Data collected at a fine temporal resolution results in the ability to calculate a very accurate annual load at that location. The nonpoint source load is separated into two categories based on the nonpoint source load upstream of the pour point (NPS_{up}) and that downstream of the pour point (NPS_{dn}). There are different assumptions made to estimate the nonpoint source load up- and downstream of the pour point. The nonpoint source load upstream of the pour point (NPS_{up}) is estimated as the residual load at the pour point. The residual load is the difference between the total pour point load and the sum of the NPDES and HSTS loads upstream of the pour point. The nonpoint source load downstream of the pour point (NPS_{dn}) is estimated as the product of the yield from the upstream nonpoint source load and the downstream area. The upstream yield is NPS_{up} divided by the total watershed area upstream of the pour point. In the Frontal Lake Erie watersheds where no pour point exists among any of the sub-basins, a NPS yield is applied from the adjacent watershed having a pour point load.

It was important to separate the two types of nonpoint source loads (NPS_{up} and NPS_{dn}) because the load downstream is estimated with the assumption of having the same areal yield as the upstream load. Yield equivalency is a weaker assumption than that of mass conservation (discussed below). Watersheds with a larger proportion of drainage area downstream from the pour point are subject to more influence from the assumption of yield equivalency. The percent of total area downstream of the pour point, from highest to lowest, for the seven watersheds is: Scioto (41); Great Miami (30); Portage (27); Cuyahoga (13); Sandusky (12); Muskingum (8); Maumee (4) and Vermilion (3). Therefore, the nonpoint source load calculation is weaker for the Scioto and Great Miami than the Maumee and Vermilion watersheds. Weakness in the yield assumption is compounded when the land use distribution between up and downstream of the pour point is considerably different.

A key assumption of the mass balance method is conservation of nutrient mass throughout the watershed. While this adds ease in computation over large areas having limited or no data on assimilative capacity, it is also seen as a weakness. Consequently, the nonpoint source load includes both nonpoint sources and sinks of nutrients. Nutrient sources included within the nonpoint source estimate include: agricultural sources; storm water runoff from developed lands; MS4 (municipal separate storm sewer system) areas; mining activities; natural sources and others. Nutrient sinks could include: wetlands (total P and total N); biomass – both terrestrial and aquatic (total P and total N); sedimentation (total P); atmospheric losses (total N); and others. Some of the nutrients assimilated within nonpoint sinks are undoubtedly from point sources or HSTS. Because the point source and HSTS terms in Equation 1 are computed directly at their source and no assimilation is considered, the mass balance method will overestimate the annual delivery of the load from these sources.

2.5 Pour Point Load Estimation

Pour point loads were computed by two methods. The first approach applied to the seven major watersheds where daily (and frequently sub-daily) nutrient concentrations are monitored by the NCWQR. The annual load represents the sum of daily loads based on the product of USGS daily flow and NCWQR daily nutrient concentrations. Flows, but not concentration, were missing in some dates in the period of record. Here flows were then interpolated using simple linear interpolation if the time period was less than three days; otherwise that period was excluded from the initial estimate. For other dates in a given water year, concentration was missing (for example, ice cover) but not flow - again these dates were excluded from the initial data analysis. To account for the days that were missing flow, a ratio of the USGS annual flow to sum of daily flow reported with NCWQR monitoring is used to adjust the annual nutrient load.

The second method is a regression-based estimator using LOADEST (Runkel et al. 2004). For the Vermilion River, using USGS monthly (and occasional sub-monthly) chemical concentrations and USGS daily flow, an estimate of daily load is based on the relationship of flow and concentration for days in which both were sampled. Using the regression analysis, the annual loads are estimated using the annual flow record.

3 Results and Discussion

3.1 Statewide Analysis

Total phosphorus loading is presented as total load grouped by major source, nonpoint source yields calculated, and per capita yield (Figure 2); all values are reported as an average of five years of loading. The tabular results used to create Figure 2 are in Appendix B. Besides nutrient loads, which relate to the overall goal of the study, yields have also been reported to standardize the load by watershed area and human population count. Thus, a yield represents the intensity of the load; both are computed for the same

timeframe. The categories of sources are: 1) HSTS; 2) total NPDES; and 3) nonpoint source. The annual nonpoint source yield is computed as the annual nonpoint source load divided by the watershed area; both numerator and denominator are calculated at the pour point. Thus, when a watershed did not have a pour point there is no associated yield reported. The annual per capita yield is the sum of NPDES and HSTS loads divided by the total human population contributing waste in the watershed; both are calculated at the watershed outlet. The per capita yield represents the *human waste-sourced* nutrient load and for NPDES load, includes all population residing in the service (collection) area of each facility. The total N loads are presented similarly (Figure 3).

More detailed discussion of relative differences *within* each watershed will appear in Sections 3.2-3.10, and for the Maumee watershed includes a more explicit analysis of loads from selected subwatersheds. The following discussion focuses on differences in total and relative load *among* the nine watersheds with respect to watershed area, annual water yield, nonpoint source nutrient yield, per capita nutrient yield and population density. There is also an analysis highlighting proportional contributions within the NPDES permitted community and preliminary discussions about major differences in loadings statewide.

Watershed Area
In order to compare across watersheds of vastly different areas, the size of the watershed should be considered when examining loading totals. Generally speaking, watersheds with greater drainage area have the potential to produce the largest nonpoint source load (Figure 2 and Figure 3). It is important to note watershed area when comparing total loads from watersheds that have much different areas. For example, an exception to this relationship is the Muskingum watershed. The Muskingum has the largest drainage area of any of the nine watersheds yet yields a smaller total load than the Maumee, Scioto and Great Miami watersheds. Other watershed characteristics are responsible for these differences and are discussed further as follows.

Relationship of Annual Water Yield to Annual Load
Load is calculated as the product of flow and concentration, so it is important to understand the variability in flow and how it may affect load. Watersheds with higher drainage areas generally have higher flows so one way to compare watersheds by flow is to compute water yield. Water yield is the annual discharge normalized by watershed area. The annual discharge is affected primarily by fluctuations in precipitation from year to year and regional precipitation patterns. The typical yield for each watershed is presented in Table 3 as the median of the last 20 years of discharge data (16 years for the Muskingum and Vermilion). The typical water yield was generally lowest for the northwest Ohio (13.5 – 13.9 in), compared to the Ohio River watershed (14.5 – 16.1 in) but highest in the Cuyahoga watershed (21.6 in). Hence, for equivalent yields across watersheds in a typical year, those with higher water yields will have lower flow-weighted mean concentrations (FWMC); the Cuyahoga watershed demonstrates this.

Normal in hydrology is often defined as an event being within the inner-quartile range (25th – 75th percentile) of the observed dataset. Many of the water years for a given watershed fall within this range (Table 3). However, wy16 was dry statewide, with only the Scioto and Great Miami rivers reaching the low end of their inner-quartile range. Both wy15 and wy17 were wet for the Maumee River (although not exceeding the 90th percentile), but normal for other northwest Ohio watersheds.

When extending this discussion to loads, the total phosphorus load in wy16 is the lowest loading year for all watersheds whereas wy15 and 17 were the highest loading years for the Maumee River (Table 4; Figure 2). The total nitrogen loadings reflected these same trends (Table 5; Figure 3). These observations highlight the importance of considering the annual flows when evaluating nutrient loads. FWMC is a way to

normalize the influence of flow from year to year. FWMC can be calculated in different ways but it is equivalent to the annual load divided by the total annual flow. While this dampens the impact of flow when interpreting results, the positive relationship that typically exists between flow and concentration tends to increase FWMC in wet years as well, but to a lesser extent. FWMC is calculated within sections 3.2-3.10 to discuss inter-annual variability for each of the specific regions examined.

Table 3 — Annual water yield (in) and median long-term water yield (in/yr), for the seven watersheds calculated at the pour point (PP) of each.

Watershed	Drainage Area at PP (sq. mi.)	Water Yield (in)					
		Median (1998-2017)	wy13	wy14	wy15	wy16	wy17
Maumee	6,330	13.9	12.1	14.0	16.0	9.5	16.5
Portage	428	13.5	13.3	15.6	15.6	10.6	14.0
Sandusky	1,251	13.8	18.1	17.2	12.8	10.5	14.3
Old Woman's Creek[a]	22	14.2	16.5	16.6	14.3	11.4	13.0
Vermilion	262	15.3[b]	16.9	18.3	11.3	10.8	13.7
Cuyahoga	707	21.1	21.3	22.4	20.9	16.1	23.9
Great Miami	2,685	16.1	13.6	18.2	15.7	13.2	15.2
Scioto	3,854	14.5	14.0	17.7	15.1	13.2	15.4
Muskingum	7,420	15.0[b]	14.9	18.7	15.0	11.6	14.5

a: Old Woman's Creek is the only U.S. Geological Survey gaging station in the Lake Erie Frontal Tributaries area.
b: median computed from 2002-2017.

Table 4 — Annual total phosphorus load in metric tons per year (by water year and average of 5 years) for the nine watersheds examined in this study.

Watershed	wy13	wy14	wy15	wy16	wy17	Average
Maumee	2,278	2,036	2,356	1,315	3,076	2,212
Portage	170	222	173	144	211	184
Sandusky	693	572	382	324	592	513
Frontal Lake Erie	161	194	149	128	172	161
Vermilion	141	146	84	68	87	105
Cuyahoga	304	359	312	214	354	309
Great Miami	1,230	1,784	1,745	883	1,412	1,411
Scioto	2,017	2,402	1,969	1,485	2,118	1,998
Muskingum	1,327	1,630	1,543	883	1,314	1,340

Table 5 — Annual total nitrogen load in metric tons per year (by water year and average of 5 years) for the nine watersheds examined in this study.

| Watershed	wy13	wy14	wy15	wy16	wy17	Average
Maumee	43,422	37,433	44,746	30,813	49,313	41,146
Portage	3,927	3,121	4,066	3,239	5,374	3,945
Sandusky	11,418	8,202	7,106	6,474	9,862	8,612
Frontal Lake Erie	3,212	2,568	2,928	2,515	3,879	3,020
Vermilion	1,513	1,573	900	918	1,201	1,221
Cuyahoga	5,996	5,788	4,939	4,578	5,545	5,369
Great Miami	18,345	20,743	21,486	14,733	22,139	19,489
Scioto	22,737	27,682	23,924	17,784	28,083	24,042
Muskingum	18,699	22,153	18,060	12,578	18,759	18,050
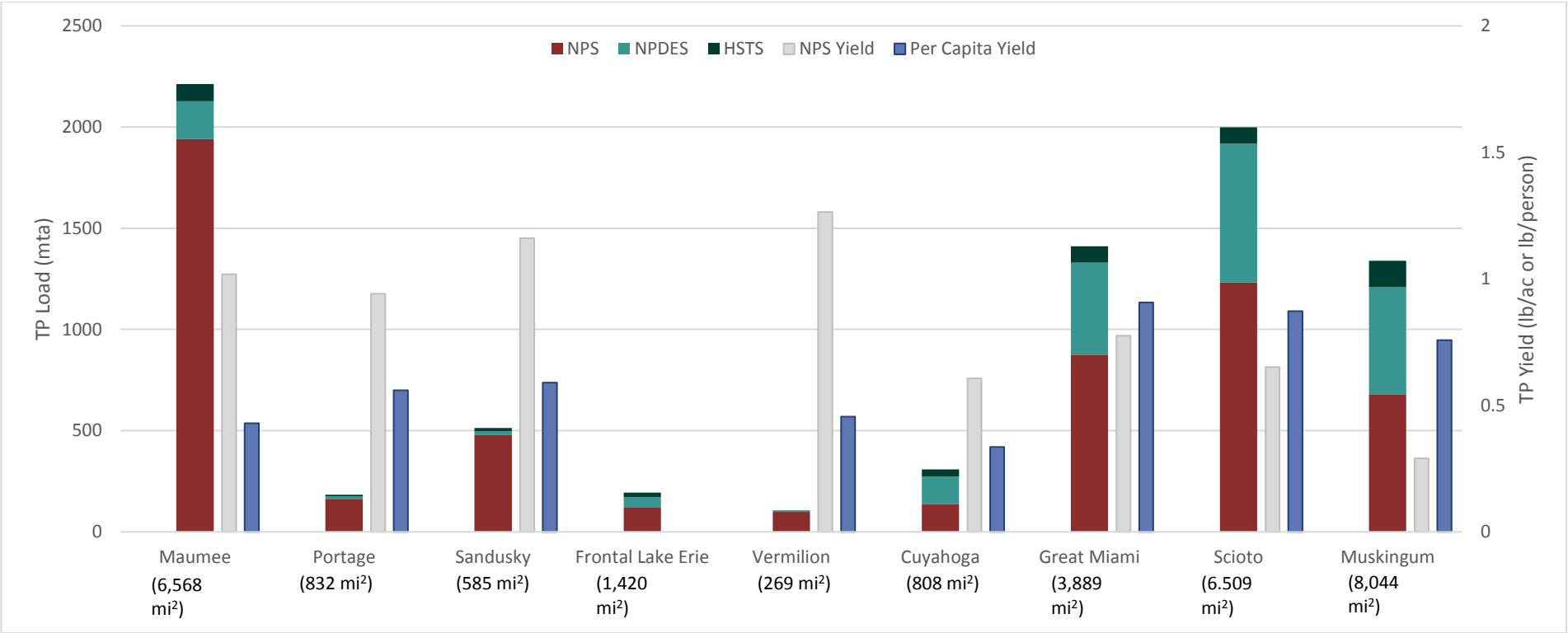
Figure 2 — Total phosphorus loading using simplified nutrient balance methods as the average of the loads calculated from water year 2013-2017.
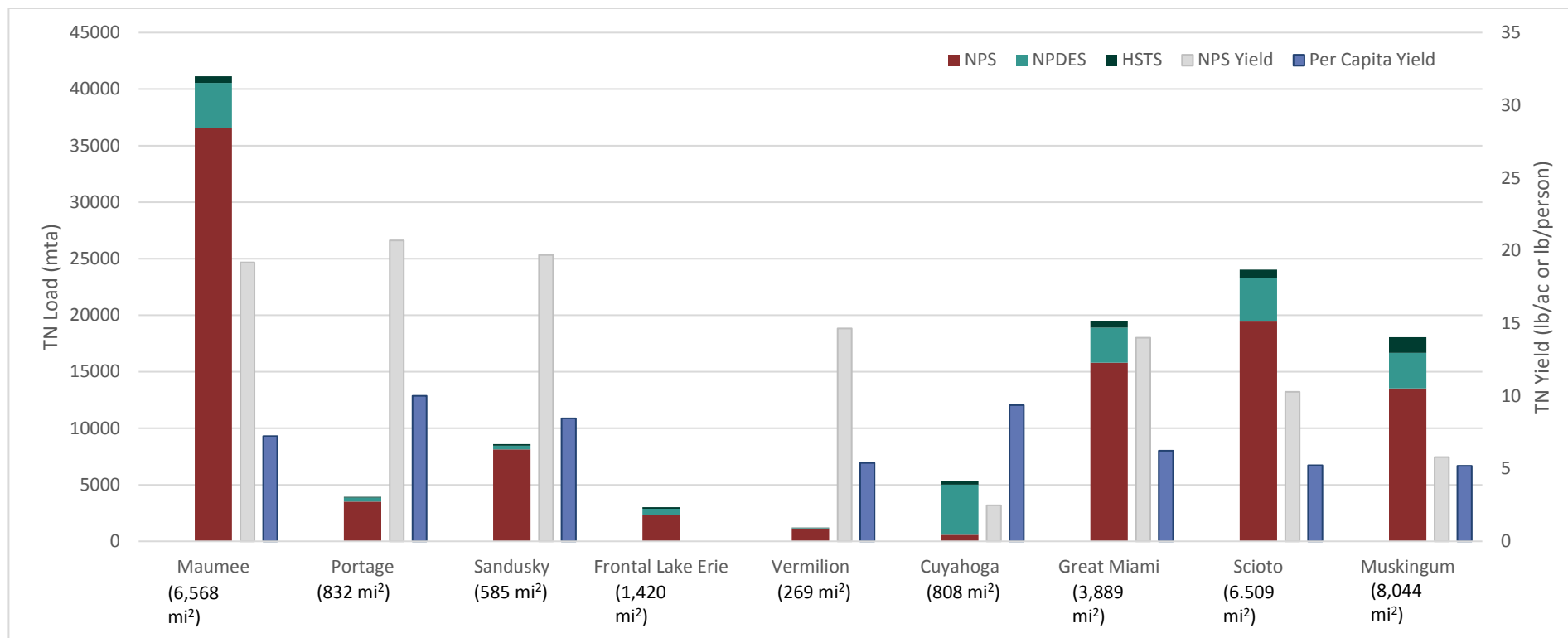
Figure 3 — Total nitrogen loading using simplified nutrient balance methods as the average of the loads calculated from water year 2013-2017.

Nonpoint Source Nutrient Yield

The Muskingum watershed shows the lowest nonpoint source nutrient yields (see grey bar in Figure 2 and Figure 3) – for both water years. The Great Miami and Scioto watersheds also had slightly lower yields than the four watersheds in the Lake Erie drainage, excepting the Cuyahoga basin which produced the second lowest nonpoint source yield. In the Muskingum and Scioto watersheds, the presence of large run-of-river reservoirs may be a confounding factor for nonpoint source yields. In-stream reservoirs trap nonpoint source sediment with associated nutrients and prevent their movement downstream to the pour point. Because no pour point load was available, yield estimates for the Frontal Lake Erie watersheds were not computed.

Further, natural land cover (comprising wetlands, forest, shrub and herbaceous land) comprised more than 47 percent of the Muskingum total watershed area (Figure 4). These types of land covers are not large generators of nonpoint nutrient loads. As alluded to above, the Cuyahoga watershed was a low generator of nonpoint source N yield (Figure 3) and to some extent showed a low P yield (Figure 2). Natural land cover was also high for both the Cuyahoga and Vermilion watersheds and comprised more than 38 and 27 percent of their total area, respectively. Yet the Vermilion watershed nonpoint P yield was the highest among all watersheds (Figure 3). While Vermilion approaches the Cuyahoga in terms of natural land cover, it is also similar in that it receives more annual precipitation than other Lake Erie watersheds, particularly for wy 13 and wy14 (Table 3). The higher precipitation combines with its higher percentage of agricultural land than the Cuyahoga (Figure 4) to produce a higher P yield.

In the remaining six watersheds, natural land typically comprised only 10-15 percent of the total watershed area. The Sandusky, Portage and Maumee watersheds, where agricultural land comprises the majority of watershed area, exhibited the highest nonpoint source yields averaged over the five water years, for both total P and total N (Figure 2 and Figure 3).
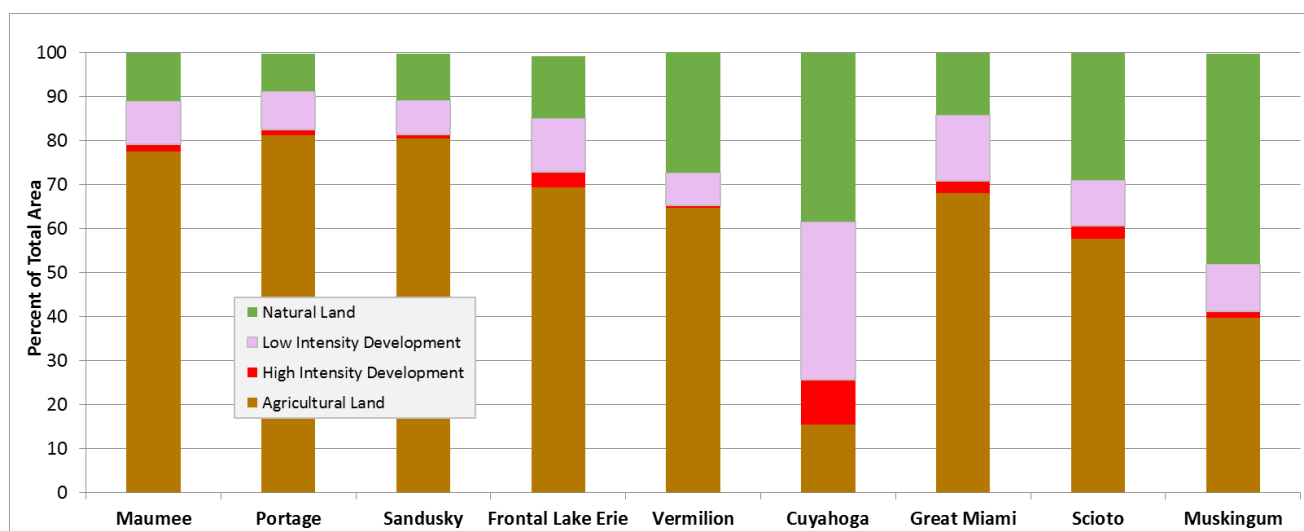

*Figure 4 — Distribution of major land use and land cover categories by major watershed
(shown as percent of total watershed area). Land use/cover data taken from National Land Cover Dataset
for year 2011 (NLCD 2011; Homer et al., 2015).*

Per Capita Nutrient Yield

As mentioned above, the per capita yield is the sum of NPDES and HSTS loads divided by the total human population contributing waste in the watershed. The per capita yield thus represents the *human waste-sourced* nutrient load. For total P, per capita yield is considerably highest for the Ohio River watersheds at 0.75 to 1 lb/person (see blue bar in Figure 2). In these watersheds, the NPDES load from major WWTPs, for the most part, is not subject to a total P concentration limit. The Cuyahoga watershed exhibits the lowest per capita total P yield, a primarily urban watershed with a low percentage of the population served by HSTS and high percentage served by major NPDES WWTPs and corresponding total P concentration limits. The remaining Lake Erie watersheds (Maumee, Portage, Sandusky and Vermilion) have moderate per capita total P yields (Figure 2). These watersheds have rural and small-town populations containing HSTS and non-major WWTPs, respectively, not subject to total P concentration limits in their discharges. Differences in total N per capita yield (see blue bar in Figure 3) are less apparent among the study watersheds, though the Portage watershed has the highest total N yield (about 10 lb/person) relative to the remaining seven watersheds.

Population Density

Estimates of population density were made using the contributing population and the total watershed area (Table 6). The Cuyahoga watershed exhibits the highest population density among the seven watersheds and is over four times greater than the density of the next highest watershed. The Great Miami and Scioto watersheds exhibit the next highest population density and are similar in magnitude. When exploring the highest relative contribution of total NPDES and HSTS load to total watershed load (Table 7), the Cuyahoga watershed has the highest total N load (89 percent of total load). No other watershed is close to this percent contribution of NPDES and HSTS to total N load. For total P, the Cuyahoga watershed also has the highest load, 55 percent of total load, contributed by NPDES and HSTS (Table 7); the Muskingum is a close second at 49 percent of total load.

Table 6 — Population density calculated as the contributing watershed population divided by total watershed area.

Watershed	Contributing Population (# persons)	Population Density (persons/sq. mi.)
Maumee	1,391,251	212
Portage	94,674	162
Sandusky	127,737	90
Frontal Lake Erie	117,444	141
Vermilion	31,126	116
Cuyahoga	1,126,170	1,394
Great Miami	1,302,134	335
Scioto	1,937,401	298
Muskingum	1,473,708	183

Relative Loadings

There are differences in relative contributions of total P and total N when comparing loads originating from HSTS, NPDES and nonpoint sources to the total load in different watersheds (Figure 2 and Figure 3). Among the seven basins, the proportional loadings differ when comparing the same source of total P and total N within each watershed (Table 7). For example, in the Cuyahoga watershed, NPS plays a greater role in total P load than total N load – a difference of 34 percent between P and N. The opposite is true for the Muskingum (24 percent), Great Miami (19 percent) and Scioto (19 percent) watersheds where NPS plays a greater role in total N load.

There are also differences in relative importance of sources among the basins for each of total P and total N (Figure 2 and Figure 3; Table 7). The primary difference in relative contributions of total P and total N loads from NPDES sources is between the Ohio River and Lake Erie drainage basins. Relative to total N, NPDES loads have lower total P contributions, at least for the Lake Erie basin. A likely cause is the NPDES limit on total P for major WWTPs located in the Lake Erie drainages in Ohio. Major WWTPs managing for phosphorus to meet NPDES limits typically exceed reduction efforts to assure compliance, further reducing their load. Baker and others (2006) concluded the same regarding monitored differences in P concentration and total P limits on major WWTPs. However, among the Lake Erie watersheds, the Cuyahoga and, to some extent, Frontal Lake Erie watersheds are slightly anomalous (Table 7) because of the higher density of NPDES facilities.

Since the 2016 report, a statewide analysis of NPDES loads was completed and not exclusive to the watersheds detailed in this report. As previously noted, there is an apparent difference in NPDES for total P between the Lake Erie and the Ohio River drainage systems. One advantage of estimating the NPDES loads statewide is that absolute loading comparisons can be made without concern for or excluding major sources that discharge outside of the area covered by the watersheds evaluated in this report (Figure 5 and Figure 6). In both the Lake Erie and Ohio River basins, major WWTPs (municipal systems discharging >1.0 MGD) are the largest source of total P (76 and 85 percent, respectively) and total N (85 and 81 percent, respectively). Also, the Lake Erie basin was influenced more by wet weather loads (CSOs and bypasses) compared to the Ohio River basin for both total P and total N.

Additionally, NPDES loads were normalized by total discharge (in essence, a FWMC) so that a comparison of Lake Erie and Ohio River drainages that differ in both population and watershed area could be made. Since industrial sources and CSOs were smaller components of the total load and it is difficult to accurately estimate the contributing flow from these sources, they were excluded from the analysis. The total P FWMC from NPDES final outfalls of municipal sources was 0.49 mg/L and 1.67 mg/L in the in the Lake Erie and Ohio River basins, respectively. This concentration difference in municipal effluent is a substantial driver of the differences in the relative influence of NPDES sources in the Lake Erie and Ohio River basins. The total N FWMC was 13.20 mg/L and 12.38 mg/L for the for the Lake Erie and Ohio River basins, respectively. For total N, the differences in per capita yields and relative contributions were overall more similar in the watersheds examined in this report (Figure 3).

Finally, those watersheds with higher population density (Table 6) also exhibit a higher proportion of NPDES load (Table 7) and this is true for both total P and total N.

Table 7 — Total phosphorus and total nitrogen contributions from household sewage treatment systems (HSTS), NPDES permitted sources (NPDES) and nonpoint sources (NPS) relative to the total load at the watershed outlet (expressed as percent). Values reported as the average of water years 2013-2017.

Watershed	Total P (percent of total)			Total N (percent of total)		
	HSTS	NPDES	NPS	HSTS	NPDES	NPS
Maumee	4	8	88	1	10	89
Portage	4	9	87	2	9	89
Sandusky	3	4	93	2	4	94
Frontal Lake Erie	13	11	76	5	18	77
Vermilion	4	2	94	2	4	94
Cuyahoga	11	44	45	6	83	11
Great Miami	6	32	62	3	16	81
Scioto	4	34	62	3	16	81
Muskingum	10	39	51	8	17	75

Figure 5 — Relative total phosphorus (TP) loads from NPDES permitted facilities grouped by type and separated by Lake Erie (LE) and Ohio River (OR) Watersheds as the average of water years 2013-2017. Categories: 1 – municipal >1.0 MGD, 2- Municipal 0.1 to 1.0 MGD, 3 – Package Plants <0.1 MGD, I – Industrial Facilities, CSO – combined sewer overflows and wet weather bypasses.

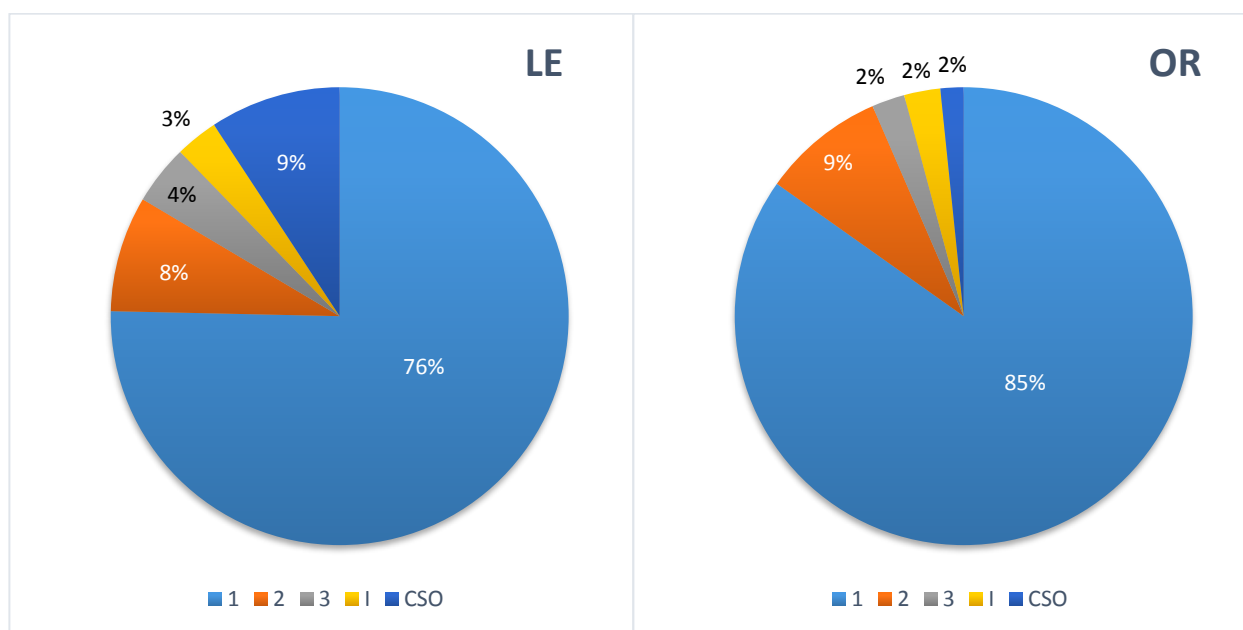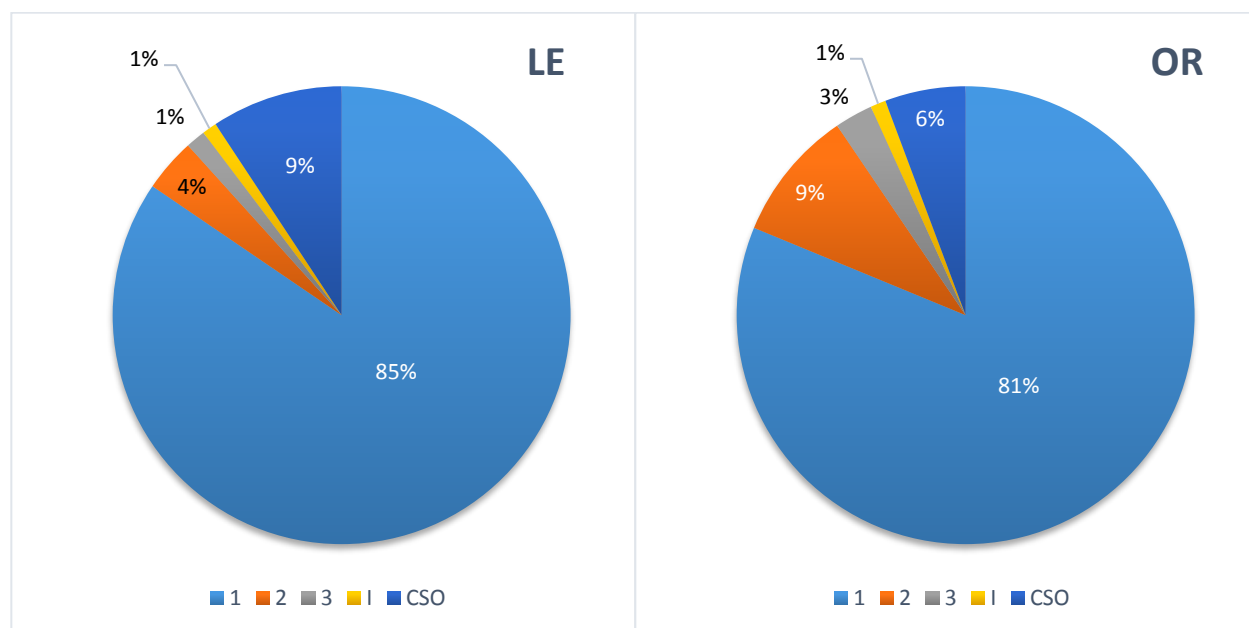*Figure 6 — Relative total nitrogen (TN) loads from NPDES permitted facilities grouped by type and separated by Lake Erie (LE) and Ohio River (OR) Watersheds as the average of water years 2013-2017. Categories: 1 – municipal >1.0 MGD, 2- Municipal 0.1 to 1.0 MGD, 3 – Package Plants <0.1 MGD, I – Industrial Facilities, CSO – combined sewer overflows and wet weather bypasses.*

3.2 Maumee River

The Maumee River drains 6,568 sq. mi. in northwestern Ohio, southeastern Michigan and northeastern Indiana (Figure 7). The NCWQR maintains a water quality sampling station at a USGS gaging station in Waterville, Ohio which was used as a pour point for nutrient mass balance calculations. The watershed area upstream of the pour point is 6,297 sq. mi. and 271 sq. mi. downstream of the pour point.

Agricultural production dominates the landscape in the watershed, which includes the fertile drained lands of the Great Black Swamp. There is a notable shift in land use in the areas up and downstream of the pour point as the river enters the Toledo metropolitan area downstream of Waterville. Downstream of the pour point, the proportion of agricultural production reduces from 79 percent to 49 percent whereas both high/low intensity development and natural lands increase in proportion.

Figure 7 — Project area represented in Maumee River mass balance. The pour point along with up and downstream drainage areas are shown.

Total P loads from the Maumee River were a maximum of 3,076 metric tons per year (mta) in wy17 and a minimum of 1,315 mta for wy16 (Figure 8 and Table 8). Total N loads from the Maumee River were a maximum of 49,313 mta in wy17 and a minimum of 30,813 mta for wy16 (Figure 9 and Table 8).
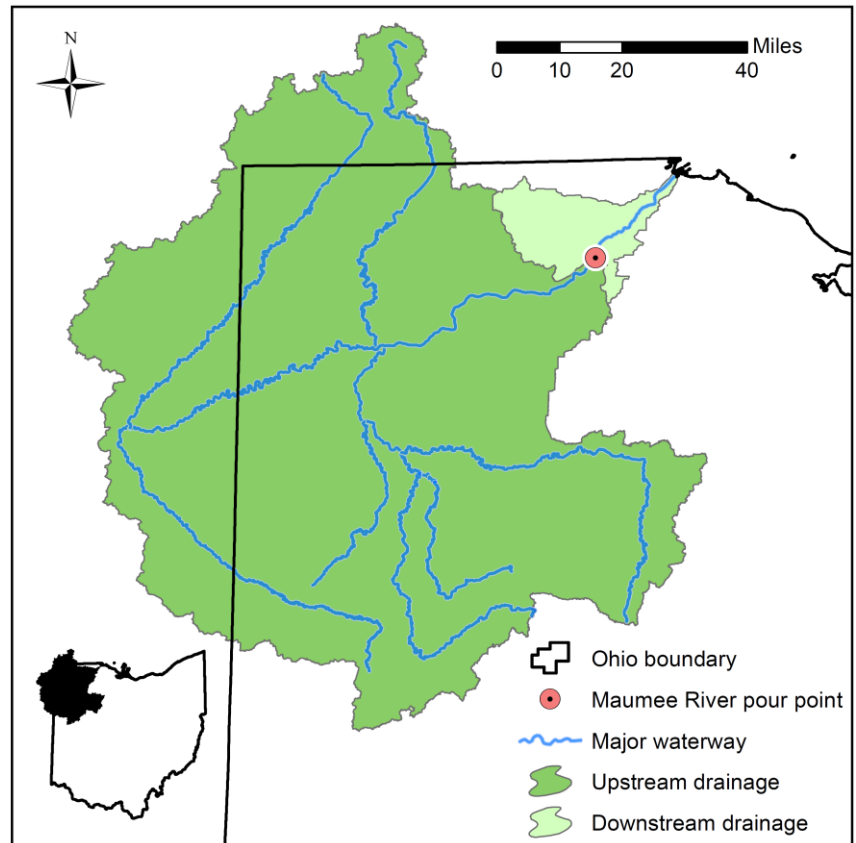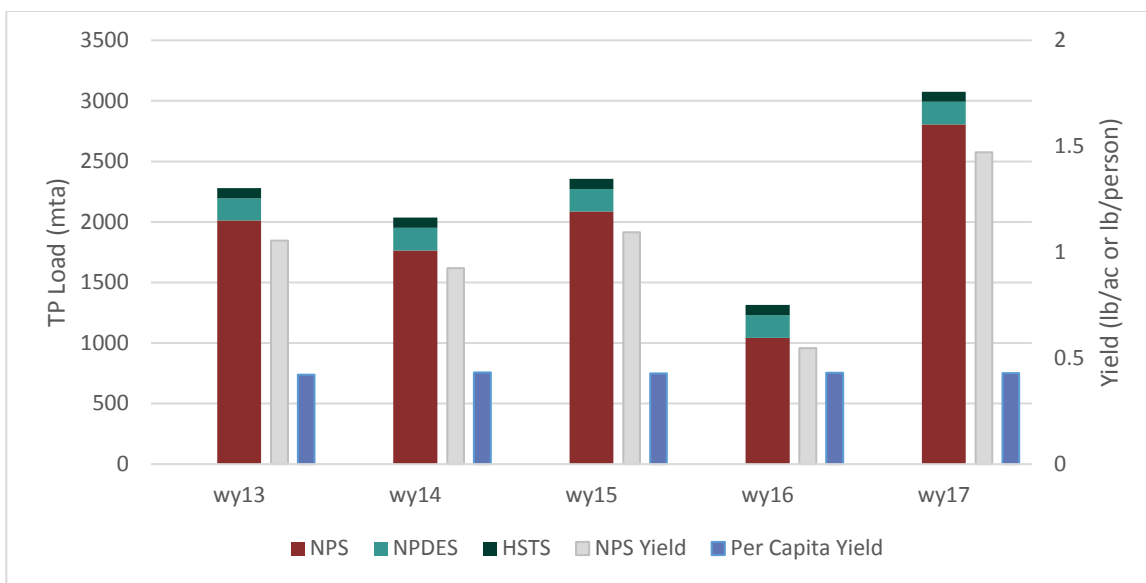
Figure 8 — Total phosphorus loads for the Maumee River for water year 2013-2017. Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.
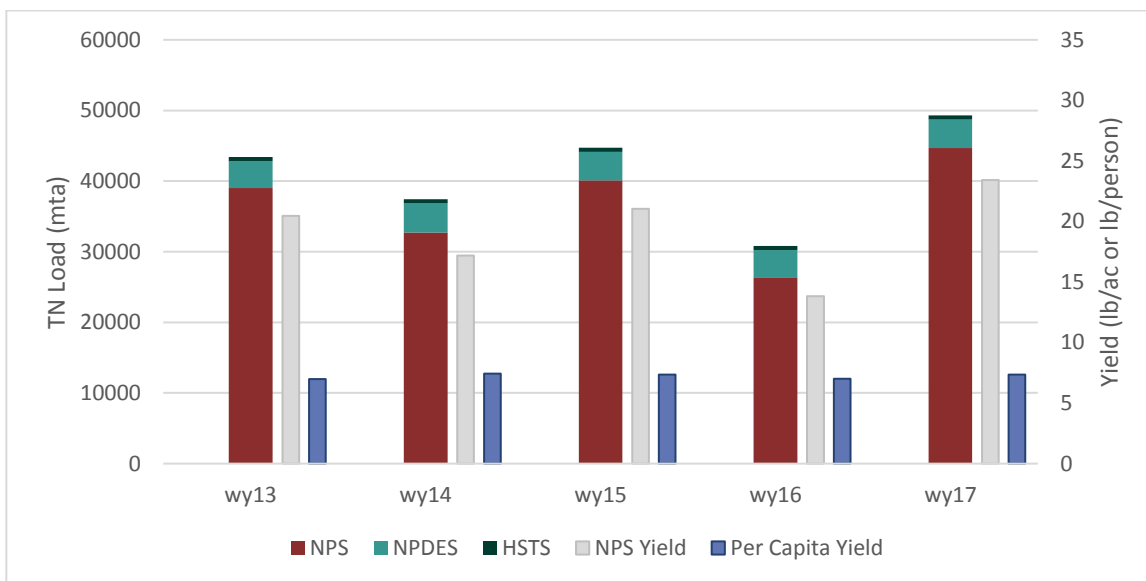
Figure 9 — Total nitrogen loads for the Maumee River for water year 2013-2017. Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

There are no apparent trends in the loadings observed for total P or total N in the Maumee River watershed. The importance of total discharge is highlighted in the observed data where the highest two loading years, wy15 and wy17, are also the highest two loading years. However, the influence on timing of precipitation is highlighted in the observed decrease in load when the annual discharge increased between wy13 and wy14. This was true for both total P and total N. It is not yet possible to fit statistically valid trends to the data presented in this project identifying net directional change in loads or FWMCs. Generally, the higher the change in reduction the shorter the time frame it will take to detect changes (Betanzo, 2015). For example, if the change is 20 percent the expected timeframe to detect the change in a large watershed

is 13-26 years, while, if the change is 40 percent the expected timeframe to detect the change is reduced to 5-10 years. As the 10-year timeframe is approached it is possible to start to propose that loads or concentrations are probably increasing, probably decreasing or just as likely increasing as decreasing. USGS's EGRET tool is one option that allows these types of analysis and could be applied once a minimum of ten years of data exists. In the decade preceding the NMB calculations (1992-2012) USGS applied the EGRET tool to the data in the Maumee River and identified that total P was about as likely as not increasing or decreasing and that total N was likely down (Oelsner, 2017).

Table 8 — Annual flow-weighted mean concentration (FWMC), total load and water yield for wy13 through wy17. Water yield is annual discharge normalized by watershed area (in units of inches/yr). FWMC and annual discharge are calculated at the pour point and do not include downstream drainage area.

Parameter	wy13	wy14	wy15	wy16	wy17
Water Yield (in/yr)	12.1	14.0	16.0	9.5	16.5
20-yr Median Water Yield (in) – 13.9					
Total P					
FWMC (mg/L)	0.42	0.33	0.33	0.31	0.43
Annual Load (mta)	2,278	2,036	2,356	1,315	3,076
Total N					
FWMC (mg/L)	8.01	5.87	6.25	7.08	6.70
Annual Load (mta)	43,422	37,433	44,746	30,813	49,313

The relative proportion of nonpoint source, total NPDES and HSTS loads for both total P and total N averaged over the five years of the study are presented in Figure 10. As was readily observed in Figure 8 and Figure 9, the nonpoint source is the largest proportion of the load in the Maumee River at 88 and 89 percent, respectively, for total P and total N. The NPDES sources comprised eight percent of the total P and 10 percent of the total N load. Finally, the HSTS community contributed four percent of the annual total P and one percent of the total N loads.
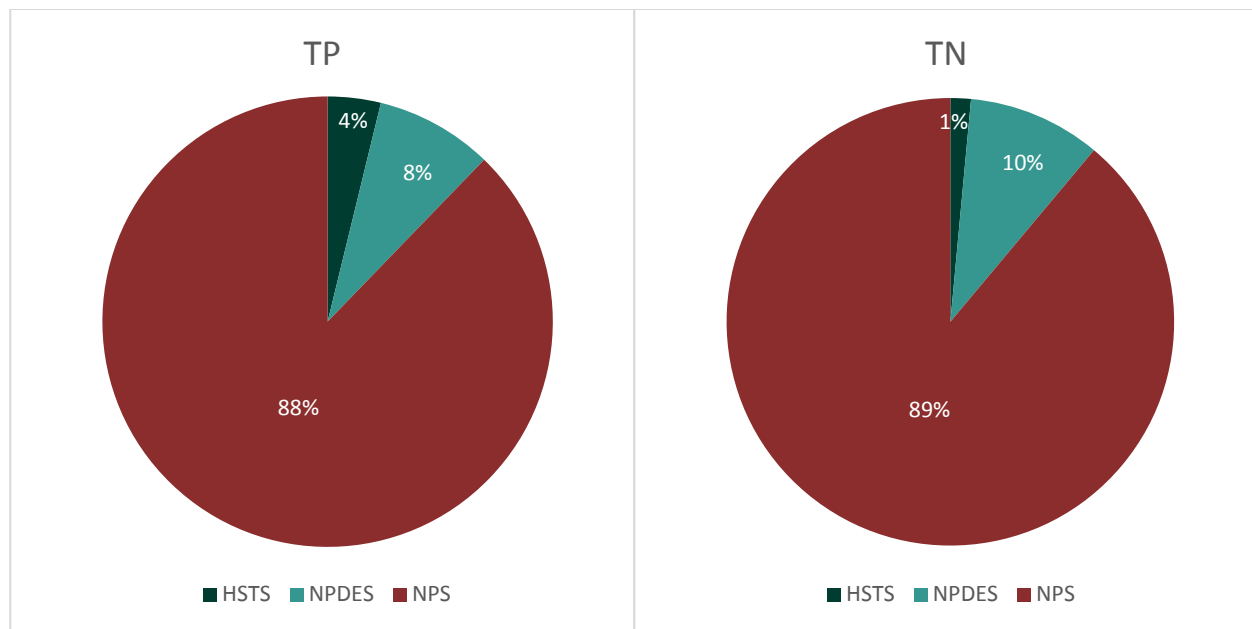
Figure 10 — Proportion of total phosphorus and nitrogen load from different sources for the Maumee watershed, average of 5-years (wy13-wy17).

The Maumee River is a critical source of Western Lake Erie Basin (WLEB) nutrient loading (Dolan and McGunagle, 2005). Other studies have supported the Ohio EPA finding that nonpoint sources dominate the load in the Maumee watershed. Scavia and others (2016) calculated a conservative mass balance of phosphorus loading in the Maumee River averaged over nine years. They estimated seven percent of total P load was from point sources, three percent from HSTS and the remainder was from other nonpoint nutrient inputs, which is similar to the total P proportions found in the Ohio EPA study. Using NCWQR data, Baker and others (2006) attributed high FWMCs relative to time-weighted mean concentrations to the dominance of nonpoint source loading. The FWMC weights the sample concentration by flow in addition to time. Therefore, when the concentration is higher at high flows the FWMC increases, as was the case for the Maumee River. Nutrient reduction efforts currently being pursued in the Maumee River Basin have emphasized the importance of nonpoint source nutrient reductions and this study supports that approach.

3.2.1 Maumee Subwatersheds

The Maumee River has been a center piece for focusing nutrient reductions to the western basin of Lake Erie (Annex 4 of the 2012 Great Lakes Water Quality Agreement). Part of the state of Ohio's response has be a substantial investment in stream nutrient monitoring to better understand the issues as they relate to different parts of the larger watershed. The expanded monitoring network allows for mass balance calculations in sub-regions of the watershed (Figure 11). The additional pour points at the next tier above the Waterville pour point are: Auglaize River at Defiance, Tiffin River near Evansport and the Maumee River at Antwerp. These stations allow regional calculations for the Upper Maumee River (2,276 mi²), Tiffin River (779 mi²), Auglaize River (2,440 mi²) and the Lower Maumee River (1,079 mi²). The Waterville pour point not only represents the nearfield contributing

Figure 11 — Project areas represented in Maumee River Subwatersheds mass balance. The pour point along with up and downstream drainage areas are shown.

area but also the entire watershed, consequently, to compute the nutrient mass balance for the Lower Maumee, the annual yields from the adjacent Portage River watershed were used.

In general, the Maumee River watershed is dominated by agricultural production, with occupies 79 percent of the total watershed (Figure 4). While agricultural land use is the majority of each of the subwatersheds there are a couple of differences to note (Figure 12). The Upper Maumee contains one of the two largest cities in the Maumee watershed (Ft. Wayne, IN) and has two principle tributaries, the St. Marys and the St. Joseph. In the Upper Maumee watershed agricultural production is more prevalent in the St. Marys watershed than the St. Josephs watershed, which has a higher prevalence of natural areas. The Tiffin River watershed has more natural areas than the other subwatersheds, the prevalence of which increase further into the headwaters of the watershed. When examining the components of agricultural land (Figure 12), both the Tiffin and Upper Maumee watersheds have the highest percentage of hay/pasture (around 10 percent each) and the lowest percentage of cultivated crops (about 65 to 67 percent of total). The Auglaize River watershed has the highest percent of the landscape dedicated to agricultural production (80 percent in cultivated crops) of any of the subwatersheds (Figure 12). The Lower Maumee River starts with similar percentages of agriculture to the Auglaize in its headwaters but transitions into more natural areas through the Oak Openings Region and then to more developed areas as is moves into the other large city in the watershed, Toledo, Ohio.

The total P and total N loads in the subwatersheds were all highest in wy17 (Figure 13 and Figure 14; Table 9), which also had the highest load for the total watershed, the only exception being an anomalously high total P load for the Upper Maumee in wy15. This load exceeded that of downstream monitoring stations suggesting that the source of the load may have been sediment-related and it has either been assimilated or more slowly routed downstream. Even when wy15 was excluded, the Upper Maumee still had the highest total P when normalized as a yield of any of the subwatersheds. However, the Auglaize River watershed consistently had the highest total N when normalized as a yield. The Tiffin River watershed consistently had the lowest P and N when normalized as a yield.
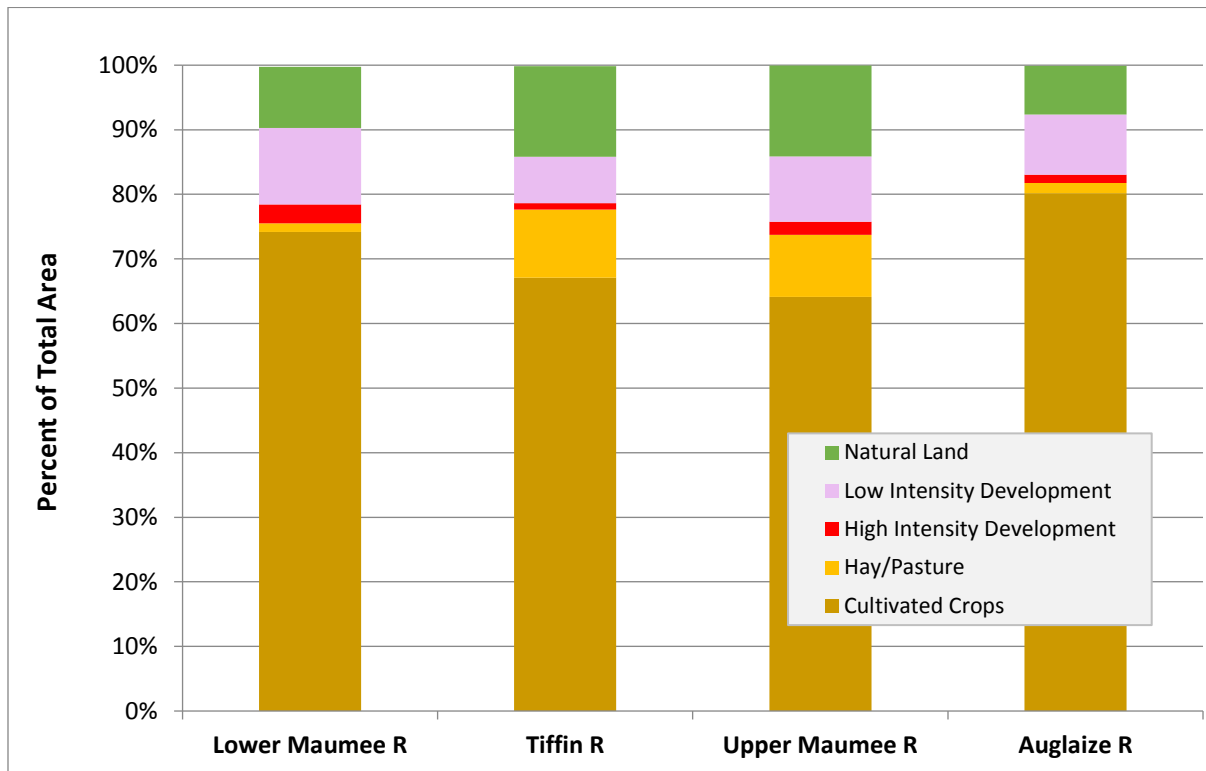
Figure 12 — Distribution of major land use and land cover categories Maumee River sub-watersheds, including a sub-division of agricultural land into cultivated crop and hay/pasture. (shown as percent of total watershed area). Land use/cover data taken from National Land Cover Dataset for year 2011 (NLCD 2011; Homer et al., 2015).
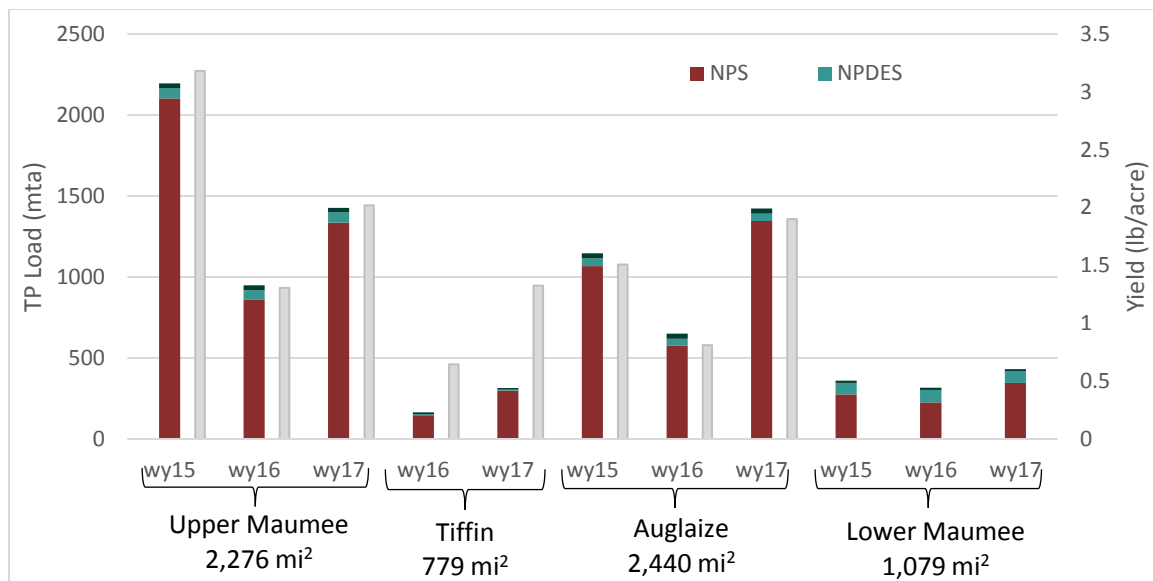
Figure 13 — Total phosphorus loads for subwatersheds of the Maumee River for water year 2015-2017 (no water year 2015 for the Tiffin). Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Yields are absent from Lower Maumee because they are not based on a local pour point.
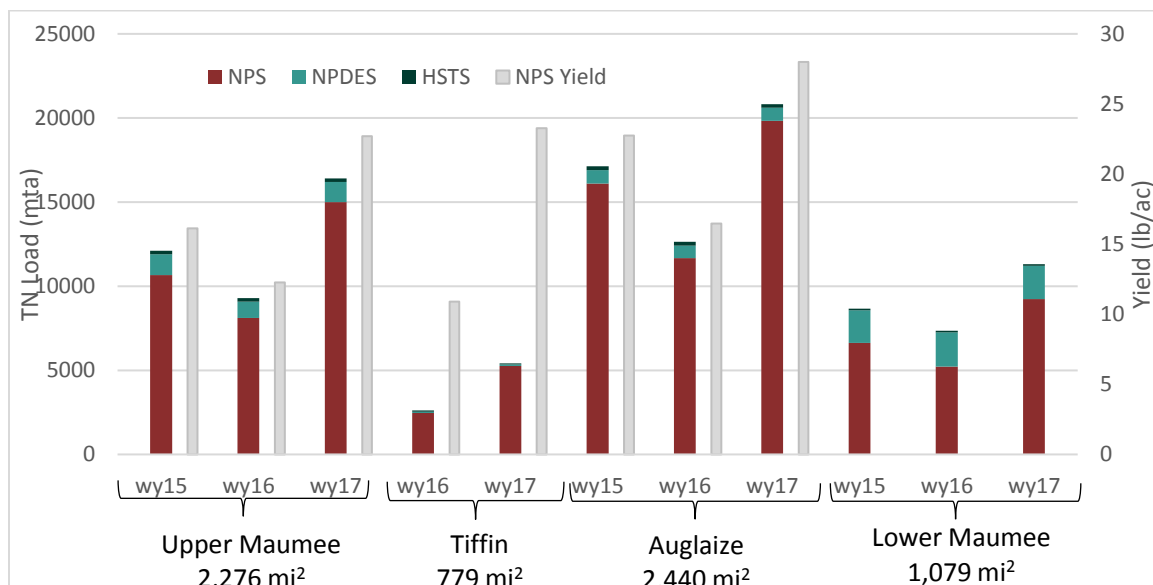
Figure 14 —Total nitrogen loads for subwatersheds of the Maumee River for water year 2015-2017 (no water year 2015 for the Tiffin). Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Yields are absent from Lower Maumee because they are not based on a local pour point.

Figure 13 shows that the nonpoint source clearly dominated the total P loading in all subwatersheds. In fact, over the three years only the Lower Maumee ever had a nonpoint source load that was <90 percent of the total load, more often in the Upper Maumee, Tiffin and Auglaize watersheds the nonpoint source contribution was >95 percent of the total annual load. This is attributed to the dominance of agricultural production on the landscape and the existence of total P controls at major wastewater treatment plants in the watershed. Total N loads (Figure 14) were similarly dominated by nonpoint sources; however, the proportions were slightly lower for the NPS in all subwatersheds. Most notably the total N contribution from NPDES sources increased by five percent in the Upper Maumee watershed and 10 percent in the Lower Maumee watershed when compared to the total P contribution. Both the Auglaize and Tiffin River remained at >95 percent of the annual load being from the nonpoint sources.

Table 9 — Annual flow-weighted mean concentration (FWMC), total load and water yield for wy15 through wy17. Water yield is annual discharge normalized by watershed area (in units of inches/yr). FWMC and annual discharge are calculated at the pour point and do not include downstream drainage area.

	Upper Maumee			Tiffin		Auglaize			Lower Maumee		
Parameter	wy15	wy16	wy17	wy16	wy17	wy15	wy16	wy17	wy15	wy16	wy17
Water Yield (in/yr)	14.4	9.6	17.4	7.9	15.9	18.5	10.1	15.9	N/A	N/A	N/A
Total P											
FWMC (mg/L)	1.01	0.64	0.54	0.37	0.37	0.38	0.38	0.55	N/A	N/A	N/A
Annual Load (mta)	2,194	948	1,428	164	315	1,146	651	1,423	360	317	432
Total N											
FWMC (mg/L)	5.66	6.47	6.33	6.31	6.62	5.78	7.81	8.15	N/A	N/A	N/A
Annual Load (mta)	12,109	9,288	16,402	2,609	5,418	17,120	12,642	20,829	8,575	7,270	11,225

3.2.2 Auglaize River Subwatersheds

The investment by the state of Ohio in monitoring extends to smaller watershed areas as well. Since the Auglaize River watershed is largely contained in Ohio, some of the initial focus was on that area. Starting in wy15 USGS has been monitoring at pour points on the Blanchard, Ottawa and Upper Auglaize rivers (Figure 15). In wy16, sampling was initiated on the Little Auglaize River. The sampling data collected in these watersheds is used in a load estimation program to predict daily loads and the wy17 loads have only been released for the Upper Auglaize River, even though the data collection continues at the other locations. In wy18 data collection began for the St. Joseph and St. Marys Rivers at the Ohio-Indiana state line that will allow future analysis at this scale to occur for these watersheds as well.

Agricultural production dominates the landscape in the Auglaize subwatersheds. Agricultural land ranges

Figure 15 — Project areas represented in Auglaize River Subwatersheds mass balance. The pour point along with up and downstream drainage areas are shown.

from a low of 71 percent (Ottawa watershed) to a high of 87 percent (Little Auglaize watershed) of each watershed's total land area. The two largest developed areas in the area are Lima (Ottawa watershed with almost 19 percent developed land) and Findlay (Blanchard watershed with almost 11 percent developed land). Natural land comprises around 8 to 10 percent for the Blanchard, Upper Auglaize and Ottawa River watersheds whereas it only comprises about four percent for the Little Auglaize watershed.

Generally, loading for both total P (Figure 16 and Table 10) and total N (Figure 17 and Table 10) was much higher in wy15 than wy16. The difference in loading was largely driven by the difference in flow between the two years. However, the Upper Auglaize having data to wy17 had the highest loads observed in that year even though the flows were 21 percent lower than wy15 (Table 10), showing that timing and intensity of precipitation events can drive total loading.

Figure 16 — Available total phosphorus loads for subwatersheds of the Auglaize River in water years 2015-2017. Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area.

Figure 17 — Total nitrogen loads for the Maumee River for water year 2015-2017. Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area.

Proportionally each of the loadings were dominated by the NPS loads with over 90 percent of the total load being attributed to NPS, with the exception being the Ottawa River. The Ottawa River contains Lima, OH, the largest population center with associated point sources in any of the watersheds. However, the nonpoint source total P and total N loadings for the Ottawa River were still over 80 percent of the total.

Table 10 —Annual flow-weighted mean concentration (FWMC), total load and water yield when available for water year 2015-2017. Water yield is annual discharge normalized by watershed area (in units of inches/yr). FWMC and annual discharge are calculated at the pour point and do not include downstream drainage area.

Parameter	Little Auglaize wy16	Blanchard wy15	Blanchard wy16	Ottawa wy15	Ottawa wy16	Upper Auglaize wy15	Upper Auglaize wy16	Upper Auglaize wy17
Water Yield (in/yr)	14.6	14.2	10.0	22.0	11.0	21.8	10.3	16.0
Total P								
FWMC (mg/L)	0.28	0.37	0.42	0.34	0.39	0.42	0.35	0.58
Annual Load (mta)	114	275	221	177	104	204	84	209
Total N								
FWMC (mg/L)	4.82	6.24	8.03	5.15	7.26	5.95	6.49	8.48
Annual Load (mta)	1,860	4,434	3,991	2,616	1,845	2,848	1,473	2,978

3.3 Portage River

The Portage River drains 585 sq. mi. in northwest Ohio (Figure 18). It is the smallest watershed considered in this study. The NCWQR maintains a water quality station at a USGS gaging station in Woodville, Ohio which was used as a pour point for nutrient mass balance calculations. The watershed area upstream of the pour point is 428 sq. mi. and 157 sq. mi. downstream of the pour point.

Agricultural production dominates the landscape, with 81 percent of the total land area being dedicated to agricultural production. Natural areas and low intensity development were similar at 8.4 percent and 8.7 percent respectively. The area downstream of the pour point had similar land use with the largest change being a reduction in agricultural lands of 11 percent, which was replaced largely by natural areas increasing by 10 percent.

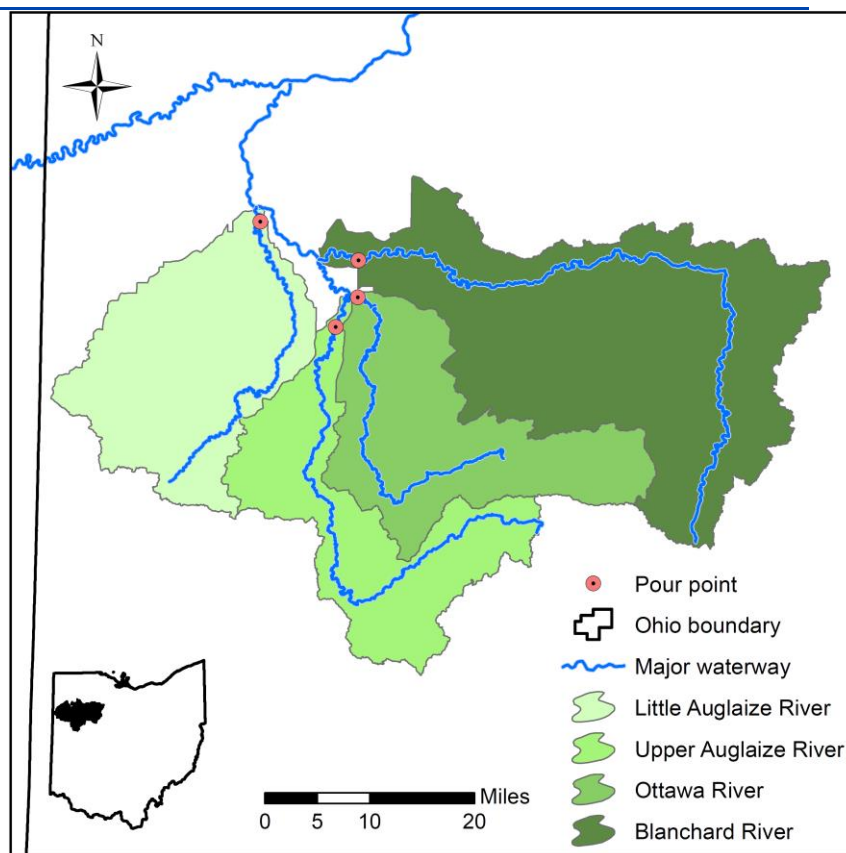Total P loads from the Portage River were a maximum of 222 metric tons per year (mta) in wy14 and a minimum of 144 mta

Figure 18 — Project area represented in the Portage River mass balance. The pour point along with up and downstream drainage areas are shown.
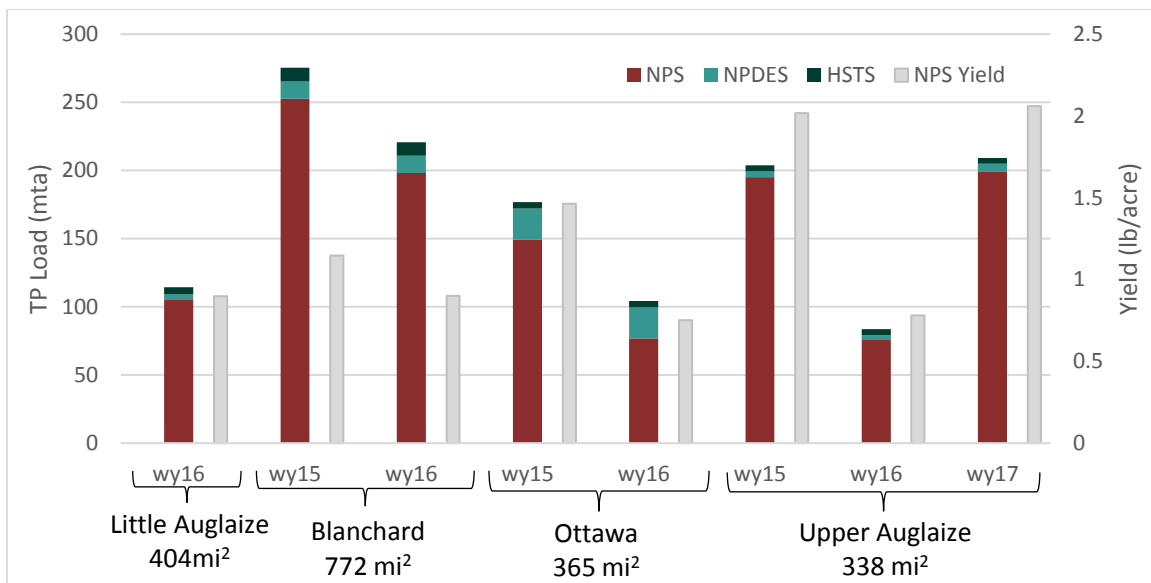
for wy16 (Figure 19 and Table 11). Total N loads from the Portage River were a maximum of 5,374 mta in wy17 and a minimum of 3,121 mta for wy14 (Figure 20 and Table 11).
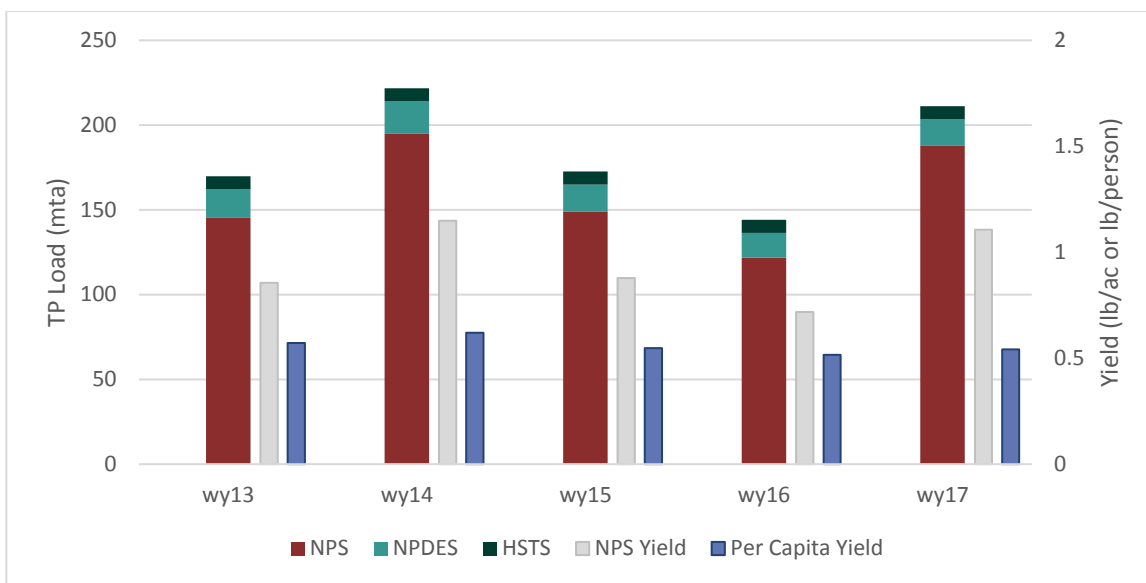
Figure 19 — Total phosphorus loads for the Portage River for water year 2013-2017. Nonpoint source yields are calculated using the 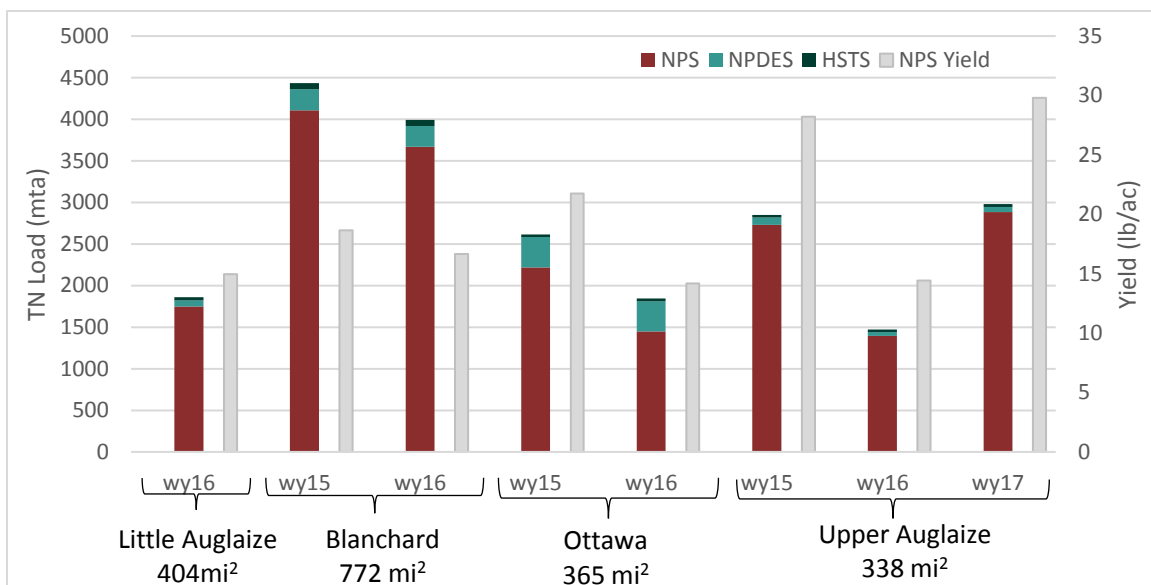total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.
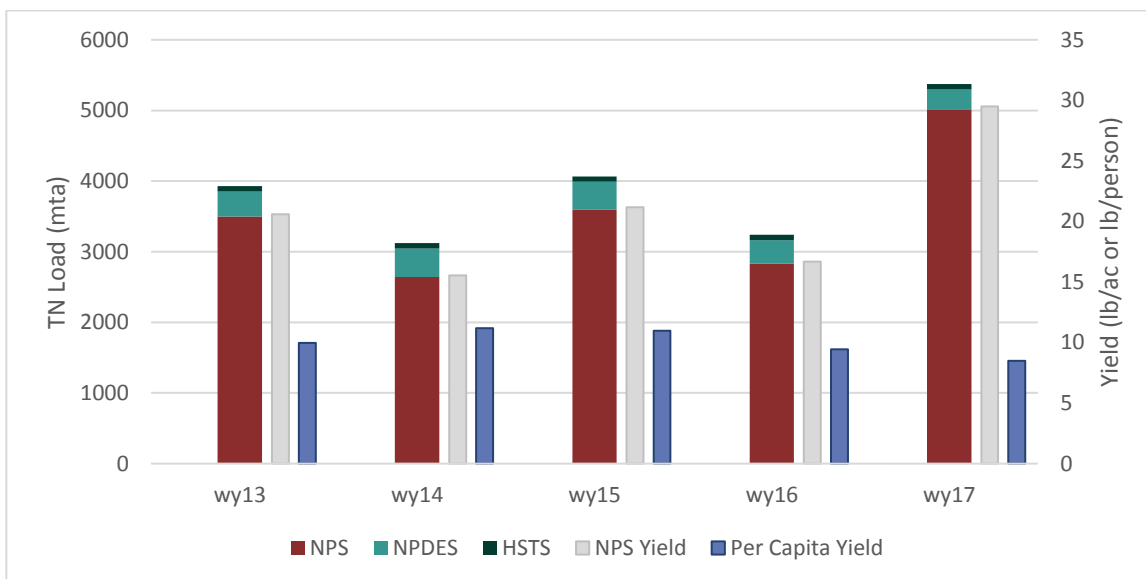
Figure 20 — Total nitrogen loads for the Portage River for water year 2013-2017. Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

There were no apparent trends in the loadings observed for total P or total N in the Portage River watershed. The importance of total discharge is highlighted in the observed data where the highest loading years; wy14, wy15 and wy17, are also the highest loading years. However, the influence on timing of precipitation is highlighted in the observed decrease in total P load when the annual discharge remained static between wy14 and wy15. The influence of timing becomes more apparent at the smaller scale of the Portage River where single events are more likely to affect a larger percentage of the total watershed. There was also a decoupling of the highest loading years for total P and total N. The highest loading year for total P was wy14 and the highest loading year for total N was wy17. This reflects the different mechanisms

that the two nutrients are exported from the landscape with total P more prone to surface runoff losses and total N more prone to drainage losses. It is not yet possible to fit statistically valid trends to the data presented in this project identifying net directional change in loads or FWMCs. Generally, the higher the change in reduction the shorter the time frame it will take to detect changes (Betanzo, 2015). For example, if the change is 20 percent the expected timeframe to detect the change in a large watershed is 13-26 years, while, if the change is 40 percent the expected timeframe to detect the change is reduced to 5-10 years. As the 10-year timeframe is approached it is possible to start to propose that loads or concentrations are probably increasing, probably decreasing or just as likely increasing as decreasing. USGS's EGRET tool is one option that allows these types of analysis and could be applied once a minimum of 10 years of data exists. NCWQR started collecting data in 2010 so it was excluded from the trend analysis using USGS's EGRET tool (Oelsner, 2017), no other trend analysis has been performed on the data.

Table 11 — Annual flow-weighted mean concentration (FWMC), total load and water yield Annual flow-weighted mean concentration (FWMC), total load and water yield for wy13 through wy17 for the Portage Watershed. Water yield is annual discharge normalized by watershed area (in units of inches/yr). FWMC and annual discharge are calculated at the pour point and do not include downstream drainage area.

Parameter	wy13	wy14	wy15	wy16	wy17
Water Yield (in/yr)	13.3	15.6	15.6	10.6	14.0
20-yr Median Water Yield (in) – 13.5					
Total P					
FWMC (mg/L)	0.32	0.36	0.28	0.35	0.39
Annual Load (mta)	170	222	173	144	211
Total N					
FWMC (mg/L)	7.63	5.18	6.71	7.88	9.89
Annual Load (mta)	3,927	3,121	4,066	3,239	5,374

The relative proportion of nonpoint source, total NPDES and HSTS loads for both total P and total N as an average of five years of data are presented in Figure 21. The figure shows the nonpoint source is the largest proportion of the load in the Portage River at 87 and 89 percent for total P and total N, respectively. The NPDES sources comprised nine percent of both the total P and total N loads, respectively. Finally, the HSTS community contributed four and two percent of the total P and total N loads, respectively.
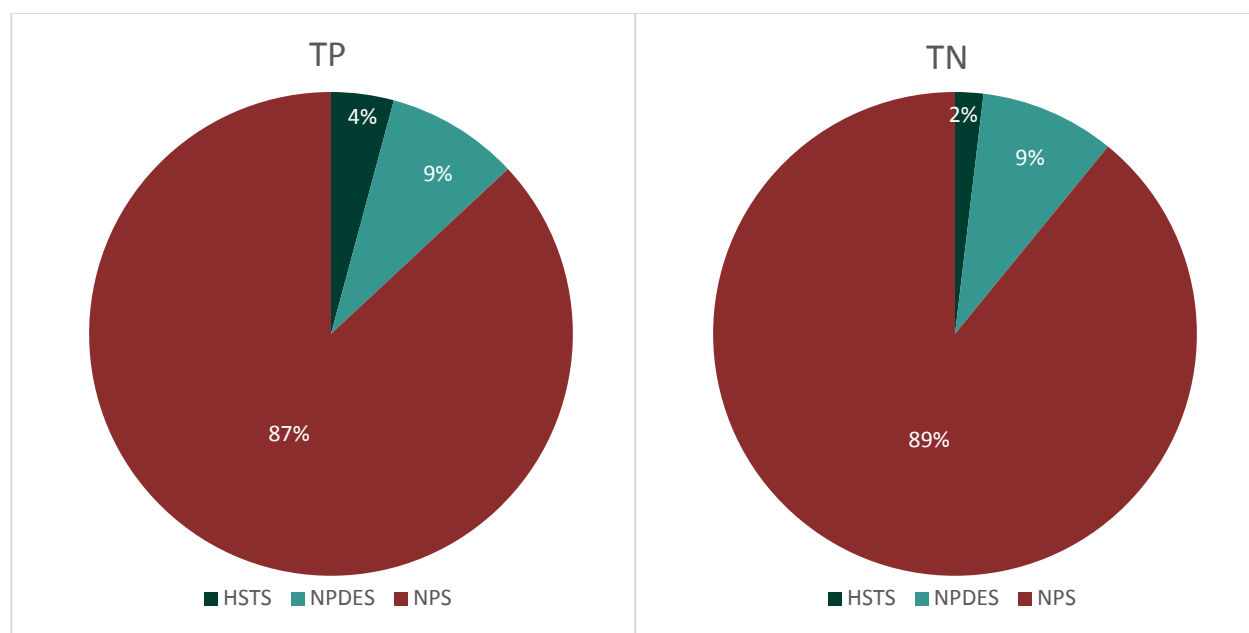
Figure 21 — Proportion of total phosphorus and nitrogen load from different sources for the Portage watershed, average of 5-years (wy13-wy17).

The Portage River is considered a priority watershed for nutrient reduction to the western basin of Lake Erie (Annex 4 of the 2012 Great Lakes Water Quality Agreement). However, because of its relatively small size (less than 10 percent of the area of the Maumee River watershed) it has been studied less. However, the results of this study show that the Portage watershed had loads to the Maumee River when normalized for watershed area. Therefore, the Portage River is highlighted as an important part of nutrient reductions to the western basin of Lake Erie.

3.4 Sandusky River

The Sandusky River drains 1,420 sq. mi. in north central Ohio (Figure 22). The NCWQR maintains a water quality station at a USGS gaging station in Fremont, Ohio which was used as a pour point for nutrient mass balance calculations. The watershed area upstream of the pour point is 1,251 sq. mi. and 170 sq. mi. downstream of the pour point.

Agricultural production dominates the landscape, with 80 percent of the total land area being dedicated to agricultural production. Natural areas are the second leading land use at 11 percent and the remainder are developed lands. The land use distribution downstream of the pour point is similar to that upstream of the pour point, where the largest change is less than three percent for any given land use.

Figure 22 — Project area represented in the Sandusky River mass balance. The pour point along with up and downstream drainage areas are shown.

Total P loads from the Sandusky River were a maximum of 693 metric tons per year (mta) in wy13 and a minimum of 324 mta in wy16 (Figure 23 and Table 12). Total N loads from the Sandusky River were a maximum of 11,418 mta in wy13 and a minimum of 6,474 mta in wy16 (Figure 24 and Table 12).
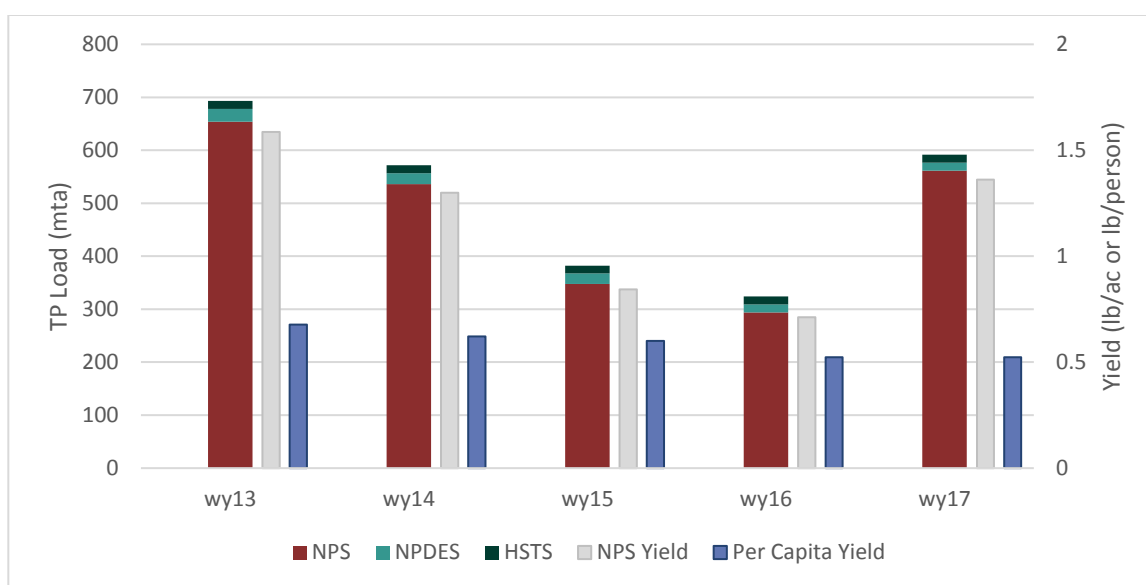
Figure 23 — Total phosphorus load, nonpoint source yield and per capita yield for the Sandusky River for water year 2013-2017. Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.
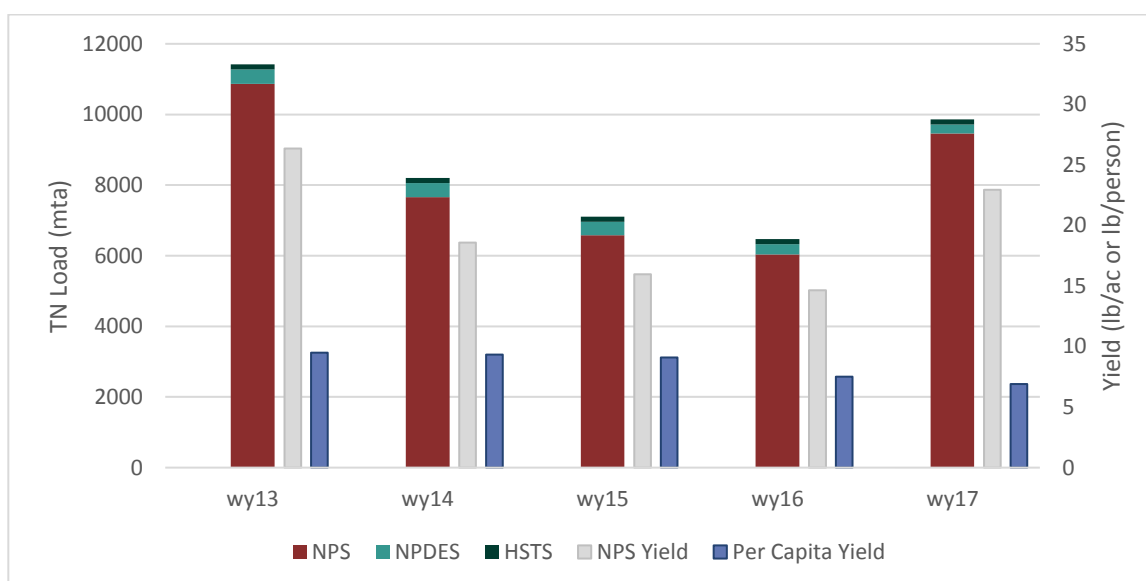
Figure 24 — Total nitrogen load, nonpoint source yield and per capita yield for the Sandusky River for water year 2013-2017. Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

The only apparent trends in the loadings observed for total P or total N is a reduction in per capita yields (Figure 23 and Figure 24). Upon a review of the NPDES sources the top four loading facilities of total P in the watershed all discharged less phosphorus in wy17 than in wy13. These sources discharged 25 percent less phosphorus in wy17 than wy13, while this trend cannot be statistically validated at this time it shows a consistent directional decrease. For total N, the three highest loading NPDES sources all had a higher load in wy13 than wy17 showing a 14 percent decrease. Again, this trend cannot be statistically validated at this time, but a directional decrease is shown. The point sources are however a small percentage of the total annual load, so this trend is not apparent in total loadings.

The importance of total discharge is highlighted in the observed data where the ranking of years by flow and both total P and total N loads are all the same. It is not yet possible to fit statistically valid trends to the data presented in this project identifying net directional change in loads or FWMCs. Generally, the higher the change in reduction the shorter the time frame it will take to detect changes (Betanzo, 2015). For example, if the change is 20 percent the expected timeframe to detect the change in a large watershed is 13-26 years, while, if the change is 40 percent the expected timeframe to detect the change is reduced to 5-10 years. As the 10-year timeframe is approached it is possible to start to propose that loads or concentrations are probably increasing, probably decreasing or just as likely increasing as decreasing. USGS's EGRET tool is one option that allows these types of analysis and could be applied once a minimum of 10 years of data exists. In the decade preceding the NMB calculations (1992-2012) USGS applied the EGRET tool to the data in the Sandusky River and identified that total P was about as likely as not increasing or decreasing and that total N was likely down (Oelsner, 2017).

Table 12 — Annual flow-weighted mean concentration (FWMC), total load and water yield Annual flow-weighted mean concentration (FWMC), total load and water yield for wy13 through wy17 for the Sandusky Watershed. Water yield is annual discharge normalized by watershed area (in units of inches/yr). FWMC and annual discharge are calculated at the pour point and do not include downstream drainage area.

Parameter	wy13	wy14	wy15	wy16	wy17
Water Yield (in/yr)	18.1	17.2	12.8	10.5	14.3
20-yr Median Water Yield (in) – 13.8					
Total P					
FWMC (mg/L)	0.41	0.35	0.31	0.33	0.44
Annual Load (mta)	693	572	382	324	592
Total N					
FWMC (mg/L)	6.66	5.02	5.81	6.53	7.37
Annual Load (mta)	11,418	8,202	7,106	6,474	9,862

The relative proportion of nonpoint source, total NPDES and HSTS loads for both total P and total N as an average of the five years analyzed are presented in Figure 25. This figure shows that the nonpoint source is the largest proportion of the load in the Sandusky River at 93 and 94 percent, respectively, for total P and total N. The NPDES sources comprised four percent for both total P and total N loads. Finally, the HSTS community contributed three and two percent for total P and total N, respectively.
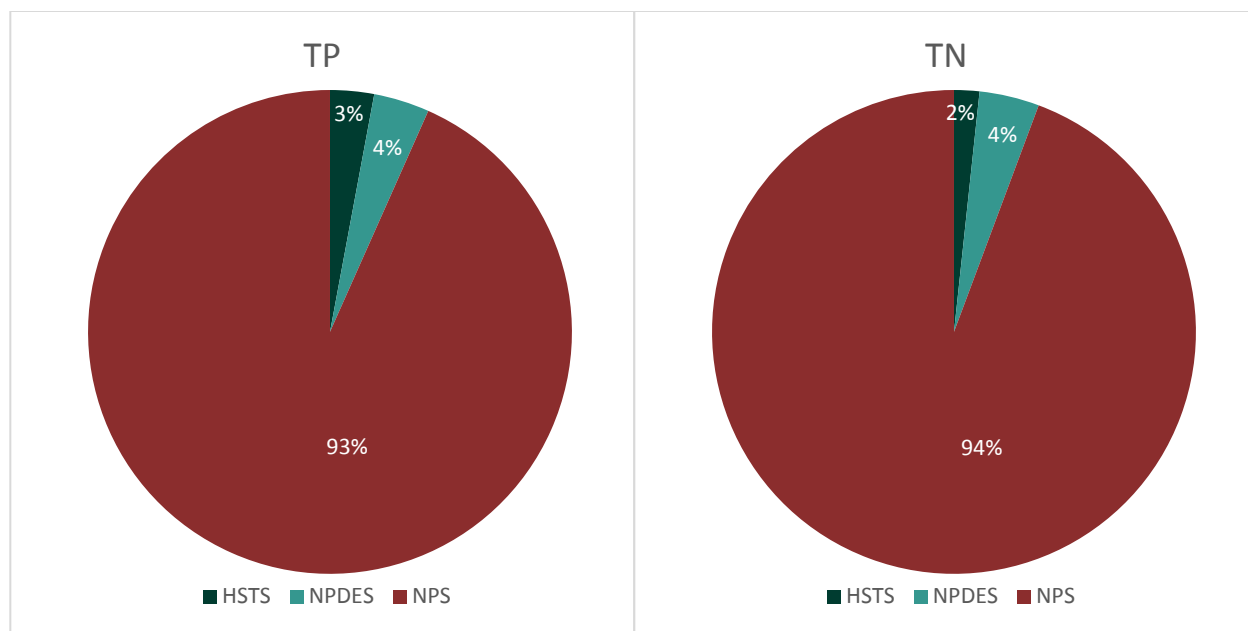
Figure 25 — Proportion of total phosphorus and nitrogen load from different sources for the Sandusky watershed, average of 5-years (wy13-wy17).

The Sandusky River is a central Lake Erie basin tributary and is targeted for a 40 percent reduction in annual loads to curb central basin hypoxia as well as a 40 percent reduction of spring total and dissolved phosphorus to curb nearshore cyanobacteria blooms (Annex 4 of the 2012 Great Lakes Water Quality Agreement). The NCWQR is located in Tiffin, Ohio in the center of the Sandusky River watershed and the river has been central to many of their loading studies. A NCWQR study estimated that only four percent of the annual phosphorus export in the Sandusky River was from point sources (Baker, 2006). Baker and others (2006) also presented a FWMC for total P as being the highest amongst the watersheds the Ohio EPA mass balance study. Also, the 2016 Ohio EPA mass balance study identified the Sandusky River as having the highest nonpoint source total P yields among the seven watersheds studied. Further, the Sandusky River had one of the highest relative loadings of total P and total N attributed to nonpoint sources in this study. The results identified highlight the importance of nonpoint source loadings in a watershed that has 80 percent of its land use dedicated to agricultural production.

3.5 Frontal Lake Erie Tributaries

The Frontal Lake Erie Tributaries are the sum of three sub areas: frontal tributaries of the Cedar-Portage HUC8; frontal tributaries of the Sandusky HUC8; and frontal tributaries of the Huron-Vermilion HUC8. Together they drain 833 sq. mi. spanning from Toledo to Vermilion (Figure 26). The sub areas were separated from the larger tributaries because there were unique assumptions applied to estimate loads. For each sub area a nonpoint source yield was assigned using the judgement of what was most appropriate based on land use and geography. The nonpoint source yields from the Portage River pour point were used to estimate the yields for the Cedar-Portage frontal tributaries and the Sandusky frontal tributaries. Sampling at a pour point on Old Woman's Creek was initiated by the NCWQR with complete data

Figure 26 — Project area represented in the Frontal Lake Erie tributaries mass balance. A pour point is identified in one of the watersheds and yield calculations were used in the other two watershed areas.

starting in wy15, which was used for the standard mass balance calculations for the Huron-Vermilion HUC8. To estimate loads for the two years preceding the onset of sampling, the yield estimated from the Vermilion River was used. These methods are less precise than when pour points are available for the watersheds, but the effort still provides a picture of the overall loading landscape in these areas.

Agricultural production dominates the landscape in the area represented by these Frontal Lake Erie tributaries at 69 percent of the total area. Notably when compared to the HUC8's the frontal tributaries are attached to, there is an uptick in developed and natural areas. This reflects the presence of large wildlife areas and nature preserves associated with the lake and the communities that are associated with the lake.

Total P load from the Frontal Lake Erie Tributaries were a maximum of 194 metric tons per year (mta) in wy14 and a minimum of 128 mta in wy16 (Figure 27 and Table 13). Total N load from the Frontal Lake Erie Tributaries was a maximum of 3,879 mta in wy17 and a minimum of 2,515 mta in wy16 (Figure 28 and Table 13).

Figure 27 — Total phosphorus load for the Frontal Lake Erie Tributaries for water year 2013-2017.
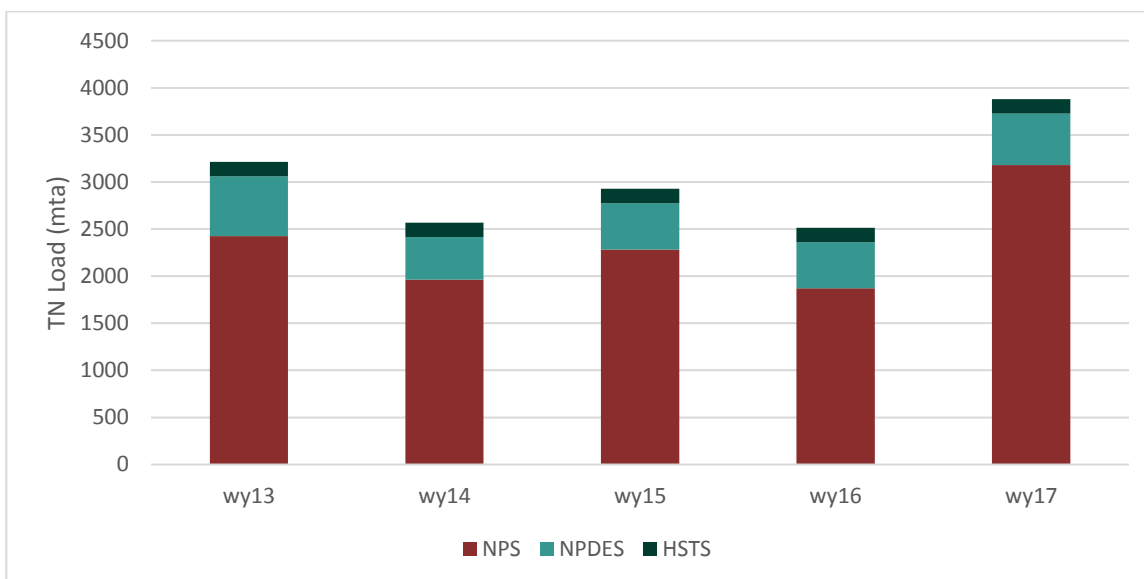
Figure 28 — Total phosphorus load for the Frontal Lake Erie Tributaries for water year 2013-2017.

Trends were not apparent in the loading data from the Frontal Lake Erie Tributaries. Also, the way the loads were calculated future trends in nonpoint loading would not reflect changes in this watershed, rather it would relate to general changes that have occurred in the region. The NPDES loads could be subject to trends discussion in this reporting area but unlike some of the other watersheds no major changes were noted.

Table 13 — Total loads for wy13 through wy17 for the Frontal Lake Erie Tributaries.

Parameter	wy13	wy14	wy15	wy16	wy17
Total P					
Annual Load (mta)	161	194	149	128	172
Total N					
Annual Load (mta)	3,212	2,568	2,928	2,515	3,879

The relative proportion of nonpoint source, total NPDES and HSTS loads for both total P and total N averaged over the five years of this study are presented in Figure 29. The figure shows the nonpoint source is the largest proportion of the total P load at 76 percent and the largest component for the total N load at 78 percent. The NPDES sources comprised 11 percent of the total P load and 17 percent of the total N load. Finally, the HSTS community contributed 13 percent of the total P and five percent of the total N load.

Figure 29 — Proportion of total phosphorus and nitrogen load from different sources for the Frontal Lake Erie Tributaries watersheds, average of 5-years (wy13-wy17).

These watersheds were separated for discussion because they contain the transition from the largely rural agricultural areas that still dominate but to a lesser extent than the larger adjacent watersheds that extend further inland. As expected, the contributions from HSTS and NPDES sources increase in these frontal tributaries when compared to the adjacent larger watersheds. However, the nonpoint source community still dominates the loading.

3.6 Vermilion River

The Vermilion River drains 269 sq. mi. in north central Ohio (Figure 30). The USGS maintains a water quality station at a gaging station in Vermilion, Ohio which was used as a pour point for nutrient mass balance calculations. The watershed area upstream of the pour point is 262 sq. mi. and seven sq. mi. downstream of the pour point.

Agricultural land dominates the land use of the Vermilion watershed at 65 percent. There is also a notable uptick in natural areas when the Vermilion is compared to the watersheds lying to its west. The area downstream of the pour point is <three percent of the land area in the watershed so loading assumptions have little impact on the total loading calculations.

Figure 30 — Project area represented in the Vermilion River mass balance. The pour point along with up and downstream drainage areas are shown.

Total P loads from the Vermilion River were a maximum of 147 metric tons per year (mta) in wy14 and a minimum of 68 mta in wy16 (Figure 31 and Table 14). Total nitrogen loads from the Vermilion River were a maximum 1,573 mta in wy14 and a minimum of 900 mta in wy15 (Figure 32 and Table 14).

Figure 31 — Total phosphorus load, nonpoint source yield and per capita yield for the Vermilion River for water year 2013-2017. Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

Figure 32 — Total nitrogen load, nonpoint source yield and per capita yield for the Vermilion River for water year 2013-2017. Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

There were no apparent trends in loading in the Vermilion River through the period of this study. The link between water yield and load is apparent in the data with the highest loading years occurring in the wettest years and the lowest loading years occurring in the driest years. The wettest year for the Vermilion River in this study had the highest total P nonpoint source yield of any watershed included in this study. It is not yet possible to fit statistically valid trends to the data presented in this project identifying net directional change in loads or FWMCs. Generally, the higher the change in reduction the shorter time frame it will take to detect changes (Betanzo, 2015). For example, if the change is 20 percent, the expected timeframe to detect the change in a large watershed is 13-26 years, while, if the change is 40 percent, the

expected timeframe to detect the change is reduced to 5-10 years. As the 10-year timeframe is approached it is possible to start to propose that loads or concentrations are probably increasing, probably decreasing or just as likely increasing as decreasing. The USGS's EGRET tool is one option that allows these types of analysis and could be applied once a minimum of 10 years of data exists. The USGS started collecting data in 2011 so it was excluded from the trend analysis using USGS's EGRET tool (Oelsner, 2017), no other trend analysis has been performed on the data.

Table 14 —Annual flow-weighted mean concentration (FWMC), total load and water yield for wy13 through wy17 for the Vermilion Watershed. Water yield is annual discharge normalized by watershed area (in units of inches/yr). FWMC and annual discharge are calculated at the pour point and do not include downstream drainage area.

Parameter	wy13	wy14	wy15	wy16	wy17
Water Yield (in/yr)	16.9	18.3	11.3	10.8	13.7
20-yr Median Water Yield (in) – 15.3					
Total P					
FWMC (mg/L)	0.47	0.45	0.42	0.35	0.35
Annual Load (mta)	141	147	84	68	87
Total N					
FWMC (mg/L)	4.95	4.75	4.38	4.69	4.85
Annual Load (mta)	1,513	1,573	900	918	1,201

The relative proportion of nonpoint source, total NPDES and HSTS loads for both total P and total N as an average of the five years included in this study are presented in Figure 33. The figure shows the nonpoint source is the largest proportion of the total P and total N load in the Vermilion River at 94 percent for both. The NPDES sources contributed two percent of the annual total P and four percent of the annual total N. Finally, the HSTS community contributed four percent of the annual total P load and two percent of total N.

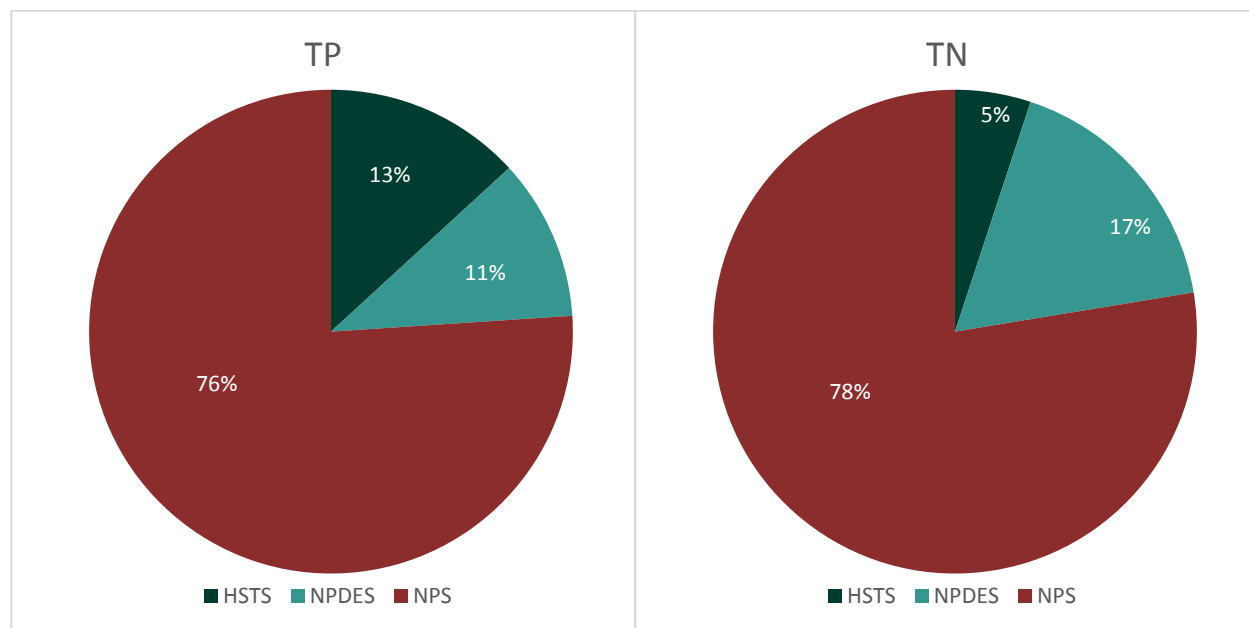*Figure 33 — Proportion of total phosphorus and nitrogen load from different sources for the Vermilion watershed, average of 5-years (wy13-wy17).*

The Vermilion River was the smallest watershed assessed in this study. The data collected by the USGS was robust enough to allow for a load estimate to be derived, however, in part due to its size it has not been widely studied outside of the USGS's current effort. The Vermilion River is a central Lake Erie basin tributary and is targeted for a 40 percent reduction in annual loads to curb central basin hypoxia (Annex 4 of the 2012 Great Lakes Water Quality Agreement).

3.7 Cuyahoga River

The Cuyahoga River drains 808 sq. mi. in northeast Ohio (Figure 34). The NCWQR maintains a water quality station at a USGS gaging station in Independence, Ohio which was used as a pour point for nutrient mass balance calculations. The watershed area upstream of the pour point is 707 sq. mi. and 101 sq. mi. downstream of the pour point.

Natural areas and low intensity development dominate the land use of the Cuyahoga watershed at 38 percent and 36 percent, respectively. Downstream of the pour point there was a notable shift in land use with a reduction of natural and agricultural areas to largely low and high intensity development, 56 percent and 36 percent, respectively.
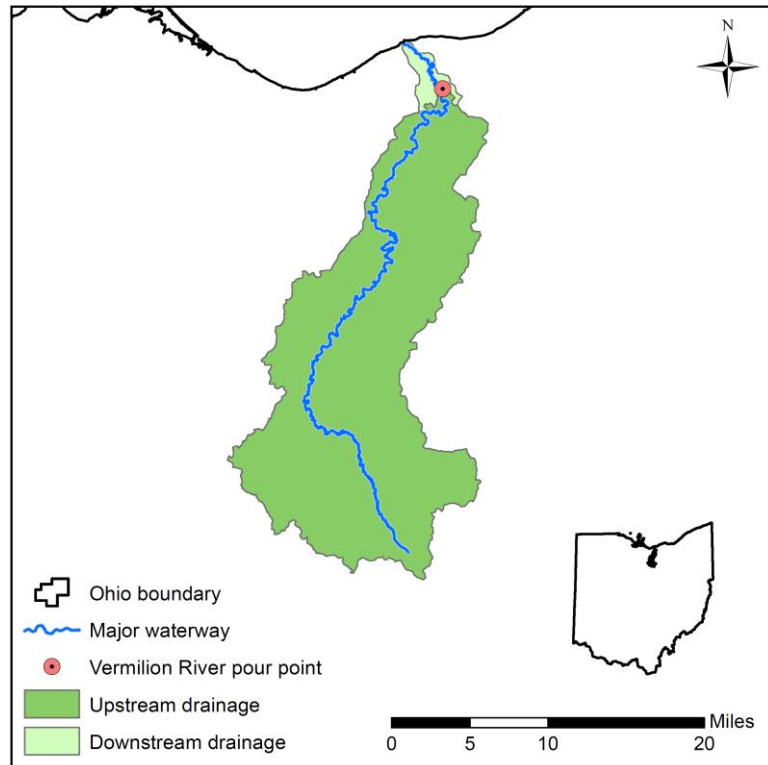

Figure 34 — Project area represented in the Cuyahoga River mass balance. The pour point along with up and downstream drainage areas are shown.

Total P loads from the Cuyahoga River were a maximum of 359 metric tons per year (mta) in wy14 and a minimum of 214 mta in wy16 (Figure 35 and Table 15). Total nitrogen loads from the Cuyahoga River were a maximum of 5,996 mta in wy13 and 4,578 mta in wy16 (Figure 36 and Table 15).
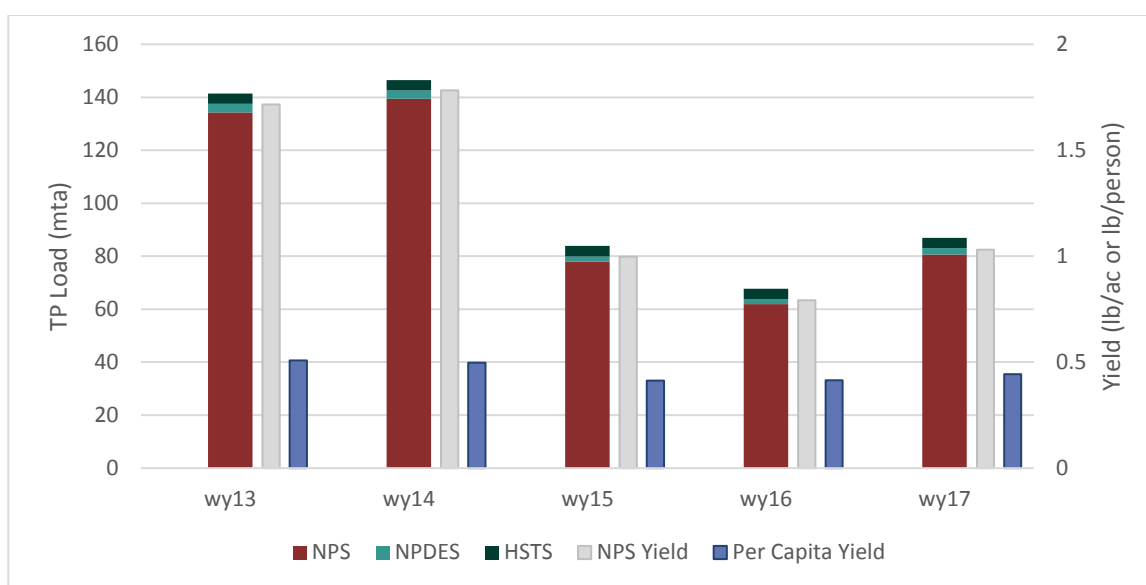
Figure 35 — Total phosphorus load, nonpoint source yield and per capita yield for the Cuyahoga River for water year 2013-2017. Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.
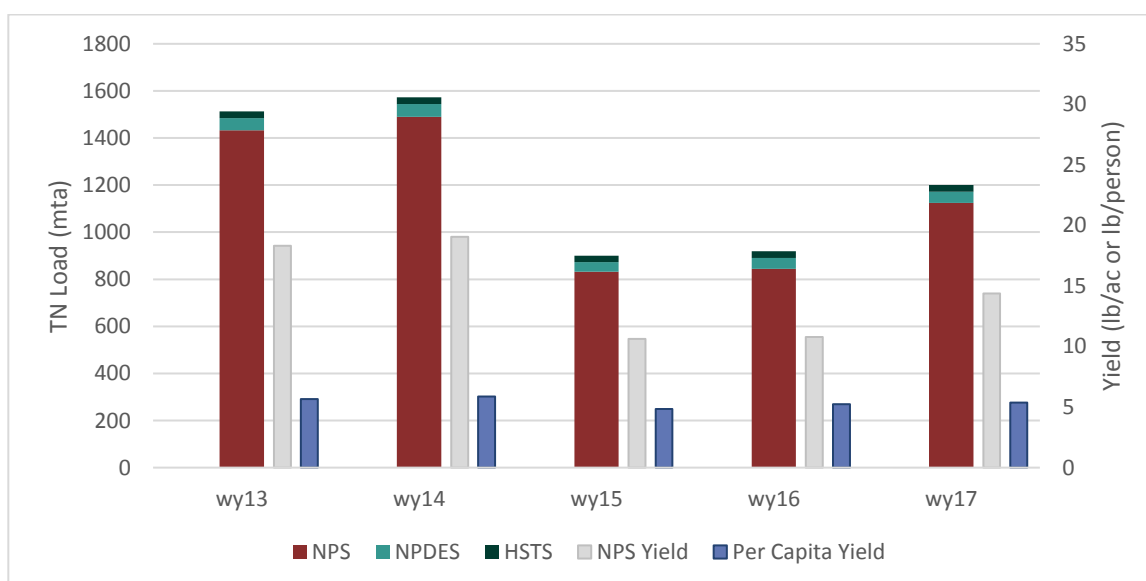

Figure 36 — Total nitrogen load, nonpoint source yield and per capita yield for the Cuyahoga River for water year 2013-2017. Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

There were no apparent trends in the loadings observed for total P or total N in the Cuyahoga River watershed. The importance of total discharge is muted to some extent in the watershed due to the high proportion of point sources, especially for total N. The driest year did still yield the lowest loads. It is not yet possible to fit statistically valid trends to the data presented in this project identifying net directional change in loads or FWMCs. Generally, the higher the change in reduction the shorter the time frame it will take to detect changes (Betanzo, 2015). For example, if the change is 20 percent, the expected timeframe to detect the change in a large watershed is 13-26 years, while, if the change is 40 percent, the expected timeframe to detect the change is reduced to 5-10 years. As the 10-year timeframe is approached it is

possible to start to propose that loads or concentrations are probably increasing, probably decreasing or just as likely increasing as decreasing. USGS's EGRET tool is one option that allows these types of analysis and could be applied once a minimum of 10 years of data exists. In the decade preceding the NMB calculations (1992-2012) USGS applied the EGRET tool to the data in the Cuyahoga River and identified that both total P and total N were likely down (Oelsner, 2017).

Table 15 — Annual flow-weighted mean concentration (FWMC), total load and water yield for wy13 through wy17 for the Cuyahoga Watershed. Water yield is annual discharge normalized by watershed area (in units of inches/yr). FWMC and annual discharge are calculated at the pour point and do not include downstream drainage area.

Parameter	wy13	wy14	wy15	wy16	wy17
Water Yield (in/yr)	21.3	22.4	20.9	16.1	23.9
20-yr Median Water Yield (in) – 21.1					
Total P					
FWMC (mg/L)	0.23	0.25	0.21	0.16	0.22
Annual Load (mta)	304	359	312	214	354
Total N					
FWMC (mg/L)	2.78	2.83	2.42	2.66	2.44
Annual Load (mta)	5,996	5,788	4,939	4,578	5,545

The relative proportion of nonpoint source, total NPDES and HSTS loads for both total P and total N as an average of five years are presented in Figure 37. The figure shows the nonpoint source is 45 percent of the total P load and 11 percent of the total N load. The NPDES sources were 44 and 83 percent of the total P and total N loads, respectively. This was the highest proportion of the total load for in all the watersheds examined in this report for both total P and total N. Finally, the HSTS community contributed 11 and six percent of the total load, again the highest of the watersheds analyzed.

The mass balance methods attribute assimilative capacity to the nonpoint source recognizing that some parts of the landscape serve as sources of total P and total N and others as sinks. In wy16, for total N, this assumption led to a net negative yield for the nonpoint source. This was the only watershed and water year where the mass balance resulted in a negative nonpoint source yield.
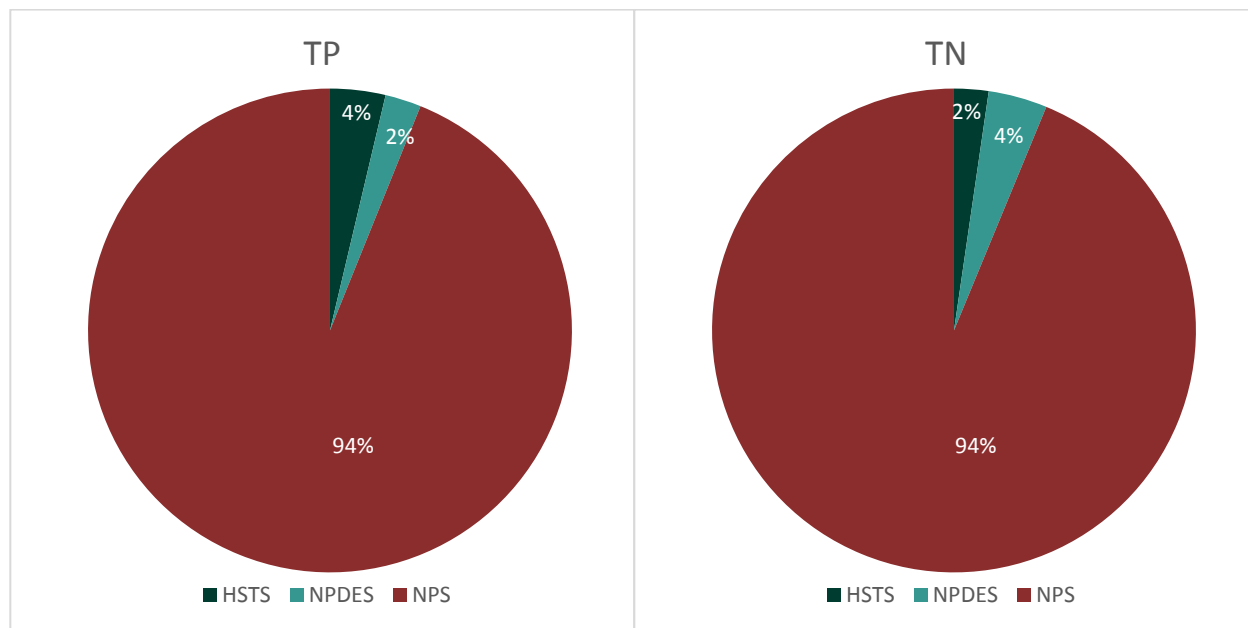
Figure 37 — Proportion of total phosphorus and nitrogen load from different sources for the Cuyahoga watershed, average of 5-years (wy13-wy17).

The Cuyahoga River is one of the most urbanized watersheds in Ohio with more than 1,200 people/sq. mi., nearly four times greater than any other watershed in this study. The relative point source loading is consequently among the highest of the seven watersheds studied. However, the relative loading of total P is much lower than that of total N, an indication of phosphorus limits at the WWTPs discharging greater than 1.0 mgd. Even with the higher flow contribution of point sources relative to watershed size, the time-weighted mean concentration of total phosphorus (indicative of high low flow phosphorus concentrations) was lower than that of the Scioto and Great Miami rivers (Baker et al., 2006).

3.8 Great Miami River

The Great Miami River drains 3,889 sq. mi., excluding drainage area of the Whitewater River, in southwest Ohio and southeast Indiana (Figure 38). The NCWQR maintains a water quality station at a USGS gaging station in Miamisburg, Ohio which was used as a pour point for nutrient mass balance calculations. The watershed area upstream of the pour point is 2,685 sq. mi. and 1,204 sq. mi. downstream of the pour point.

Agricultural land use dominates the Great Miami River watershed, with 68 percent of the land being in agricultural production. Downstream of the pour point, the largest shift in land use was from agricultural production to natural areas.
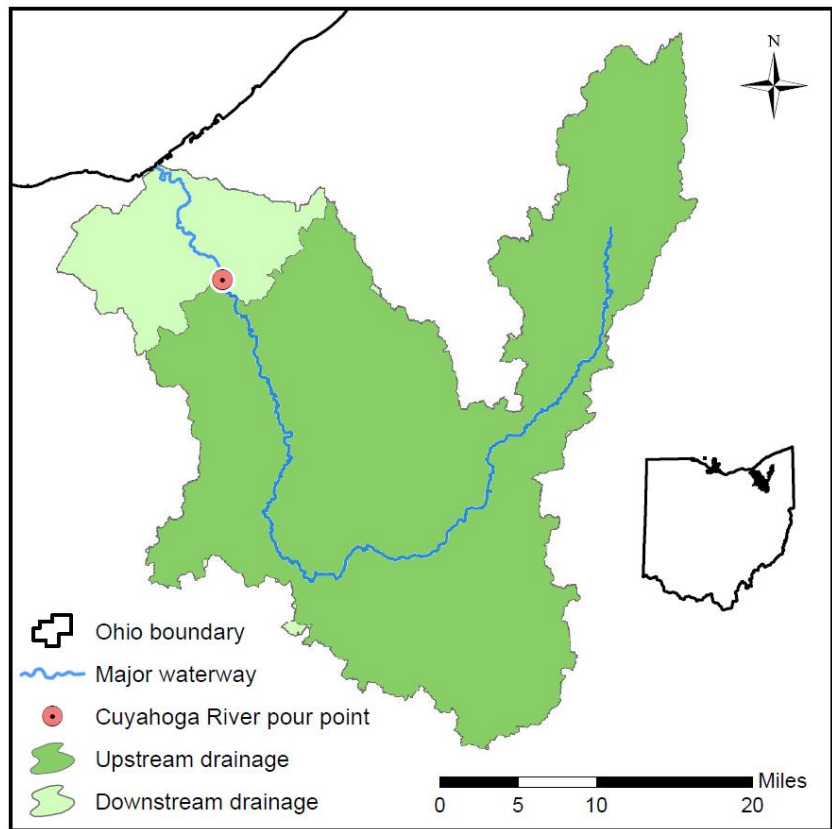

Figure 38 — Project area represented in the Great Miami River mass balance. The pour point along with up and downstream drainage areas are shown.

Total P loads from the Great Miami River were a maximum of 1,745 metric tons per year (mta) in wy14 and a minimum of 883 mta in wy16 (Figure 39 and Table 16). Total N loads from the Great Miami River were a maximum of 22,139 mta in wy17 and a minimum of 14,733 mta in wy16 (Figure 40 and Table 16).
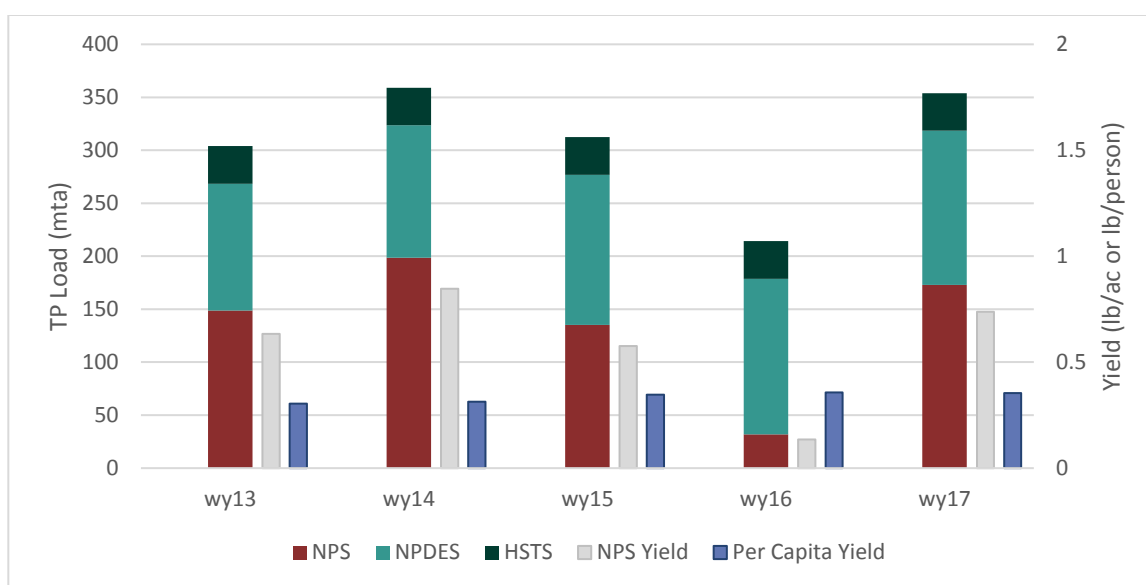
Figure 39 — Total phosphorus load, nonpoint source yield and per capita yield for the Great Miami River for water year 2013-2017. Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.
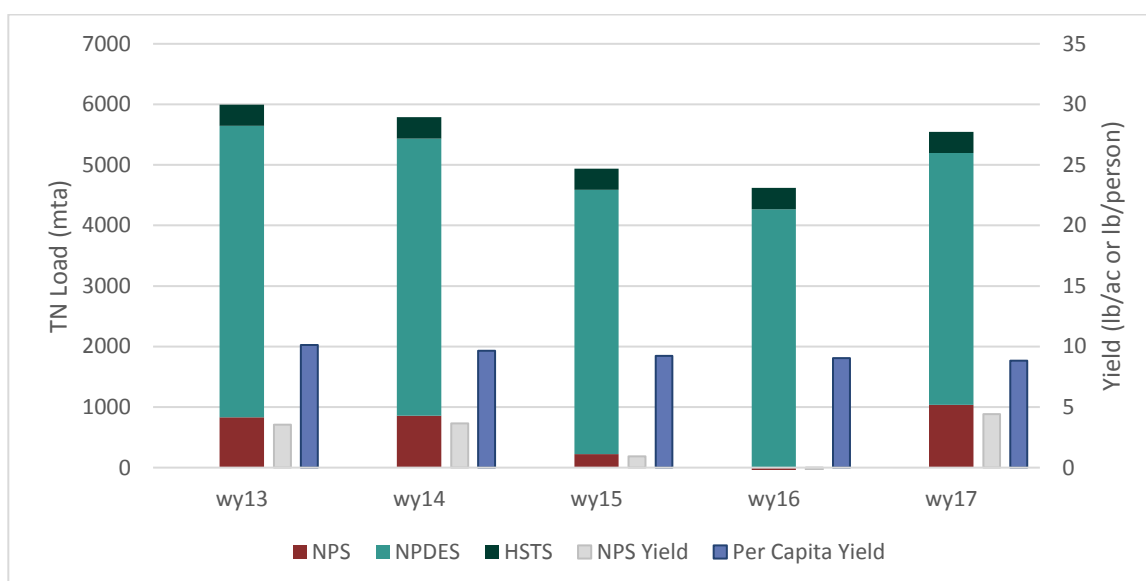

Figure 40 — Total nitrogen load, nonpoint source yield and per capita yield for the Great Miami River for water year 2013-2017. Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

There were no apparent trends in the loadings observed for total P or total N in the Great Miami River watershed. The importance of total discharge is highlighted in the observed data for total P, where the ranking of years by flow and both total P are the same. The relationship was not as clear for total N and annual flow, highlighting the different mechanics in total P and total N loading. It is not yet possible to fit statistically valid trends to the data presented in this project identifying net directional change in loads or FWMCs. Generally, the higher the change in reduction the shorter time frame it will take to detect changes (Betanzo, 2015). For example, if the change is 20 percent, the expected timeframe to detect the change in a large watershed is 13-26 years, while, if the change is 40 percent, the expected timeframe to detect the

change is reduced to 5-10 years. Alternatively, as the 10-year timeframe is approached it is possible to start to propose that loads or concentrations are probably increasing, probably decreasing or just as likely increasing as decreasing. USGS's EGRET tool is one option that allows these types of analysis and could be applied once a minimum of 10 years of data exists. While data collection started as part of the NCWQR tributary loading program in 1996, the site was not included in USGS's surface water trends effort (Oelsner, 2017). In the future work could be done to understand historical trends and once 10 years of data is available within this study it will be possible to start to consider if trends are statistically valid.

Table 16 — Annual flow-weighted mean concentration (FWMC), total load and water yield for wy13 through wy17 for the Great Miami Watershed. Water yield is annual discharge normalized by watershed area (in units of inches/yr). FWMC and annual discharge are calculated at the pour point and do not include downstream drainage area.

Parameter	wy13	wy14	wy15	wy16	wy17
Water Yield (in/yr)	13.6	18.2	15.7	13.2	15.2
20-yr Median Water Yield (in) – 16.1					
Total P					
FWMC (mg/L)	0.36	0.39	0.45	0.27	0.38
Annual Load (mta)	1,230	1,784	1,745	883	1,413
Total N					
FWMC (mg/L)	5.29	4.40	5.31	4.30	5.71
Annual Load (mta)	18,345	20,743	21,486	14,733	22,139

The relative proportion of nonpoint source, total NPDES and HSTS loads for both total P and total N as the average of the five years included in this study are presented in Figure 41. The figure shows the nonpoint source is the largest proportion of the total P and total N load in the Great Miami River at 62 and 81 percent, respectively. The NPDES sources comprised 32 percent of the total P load and 16 percent of the total N load. Finally, the HSTS community contributed six percent of the total P load and three percent of the total N load.
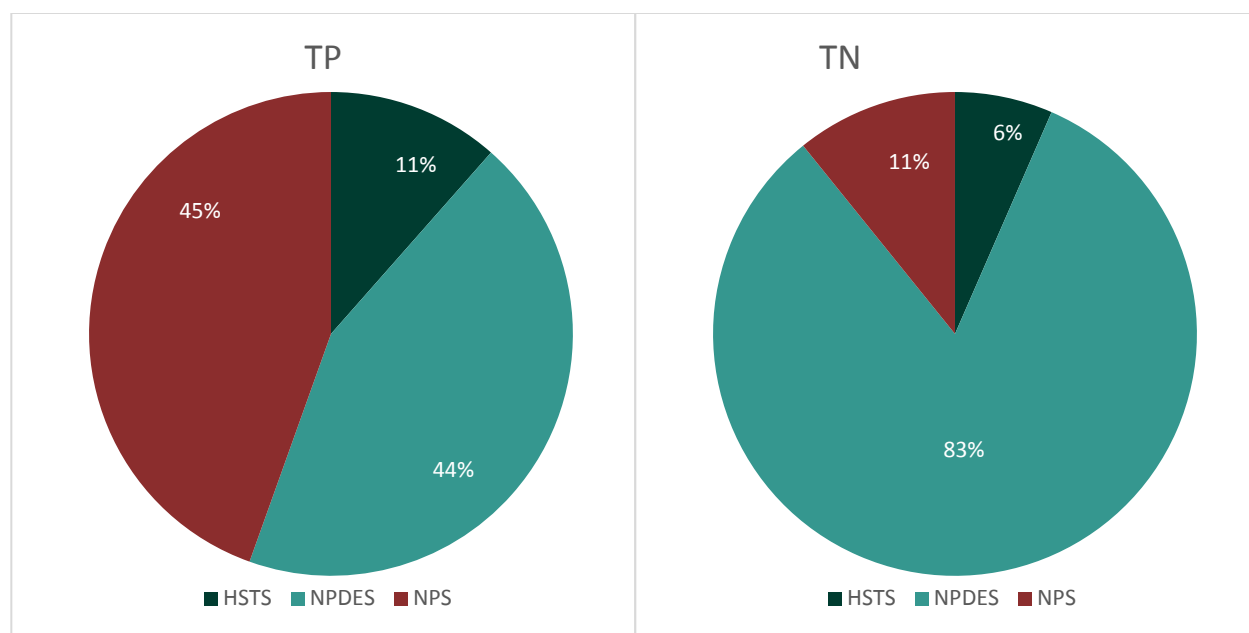
Figure 41 — Proportion of total phosphorus and nitrogen load from different sources for the Great Miami watershed, average of 5-years (wy13-wy17).

The Great Miami River has been studied as a contributor of nutrients to the Gulf of Mexico. A National Oceanic and Atmospheric Administration (NOAA) study (Goolsby, 1999) found the watershed had both total P and dissolved phosphorus yield among the five highest out of 42 watersheds studied in the Mississippi-Atchafalaya River basin. A NCWQR study found the Great Miami River to have the highest soluble reactive phosphorus concentrations and the highest time weighted average total P concentration amongst 10 streams studied in Ohio (Baker, 2006). A study by the Miami Conservancy District highlighted that the dissolved orthophosphate was the dominant form of phosphorus in their samples at 63 percent of the total P and that total P concentrations increased at both high and low flows (MCD, 2012). These studies demonstrate an increased prevalence of NPDES sources for TP, supporting the findings of the Ohio EPA mass balance efforts.

3.9 Scioto River

The Scioto River drains 6,509 sq. mi. in central and south-central Ohio (Figure 42). The NCWQR maintains a water quality station at a USGS gaging station in Chillicothe, Ohio which was used as a pour point for nutrient mass balance calculations. The watershed area upstream of the pour point is 3,854 sq. mi. and 2,655 sq. mi. downstream of the pour point.

Agricultural land use dominates the Scioto watershed, with 58 percent of the land being in agricultural production. Downstream of the pour point, the largest shift in land use was from agricultural production to natural areas.

Total P loads from the Scioto River were a maximum of 2,402 metric tons per year (mta) in wy14 and a minimum of 1,485 mta in wy16 (Figure 43 and Table 17). Total nitrogen loads from the Scioto River were a maximum of 28,083 mta in wy17 and a minimum of 17,784 mta in wy16 (Figure 44 and Table 17).
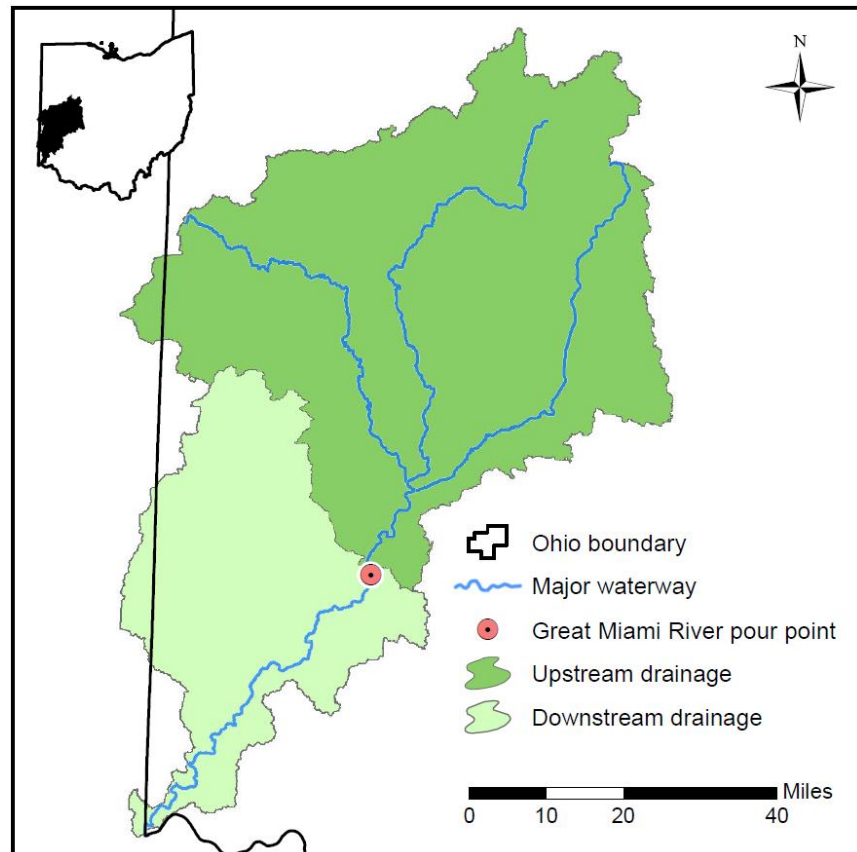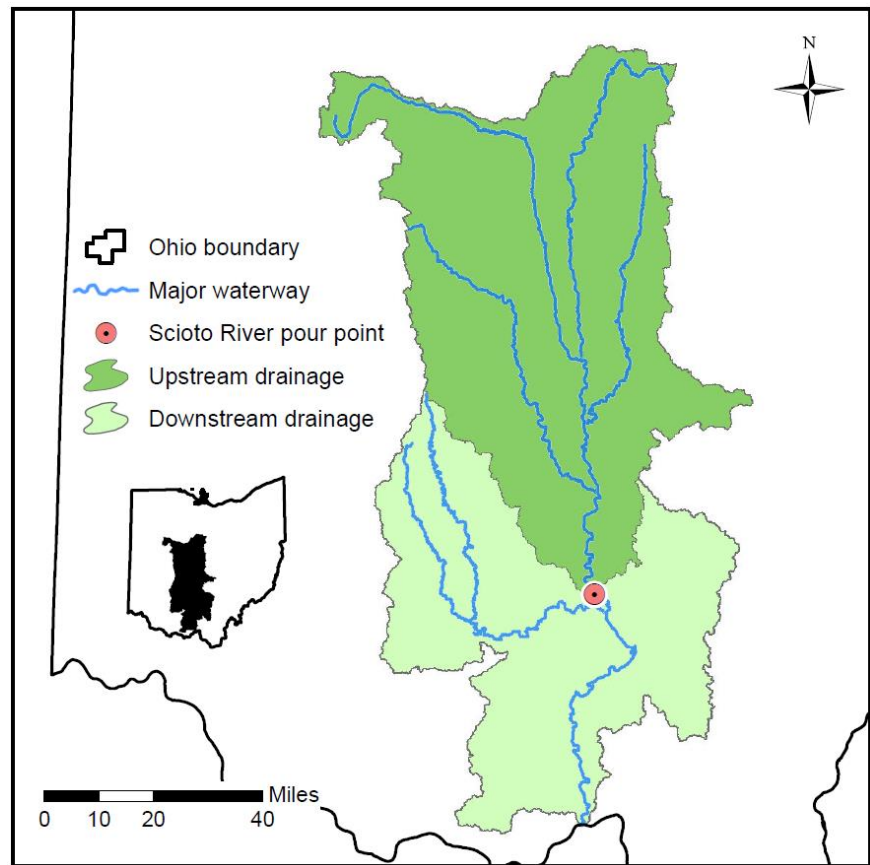

Figure 42 — Project area represented in the Scioto River mass balance. The pour point along with up and downstream drainage areas are shown.
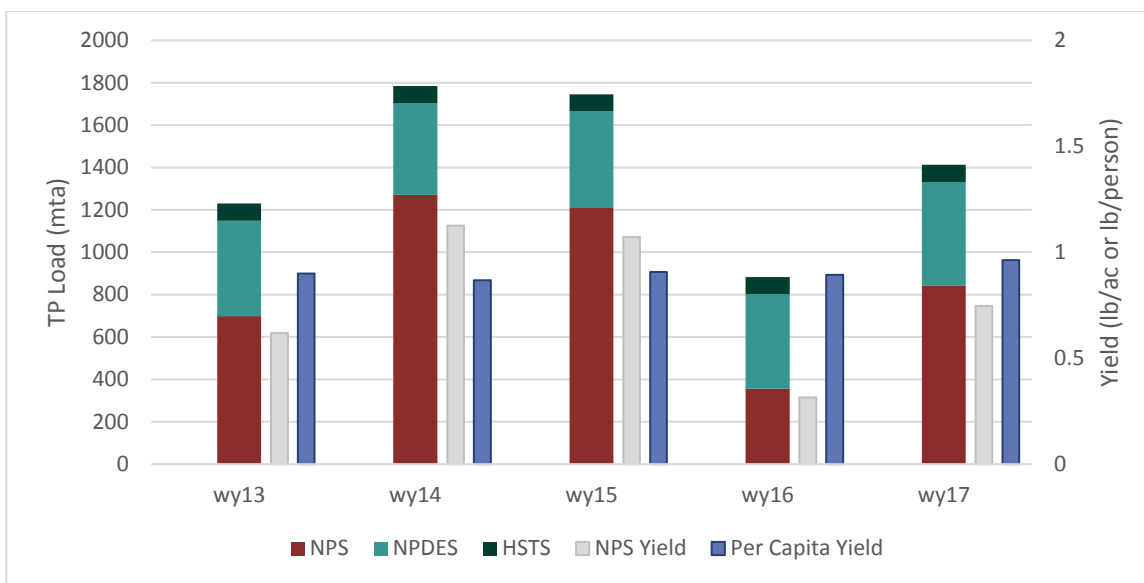
Figure 43 — Total phosphorus load, nonpoint source yield and per capita yield for the Scioto River for water year 2013-2017. Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.
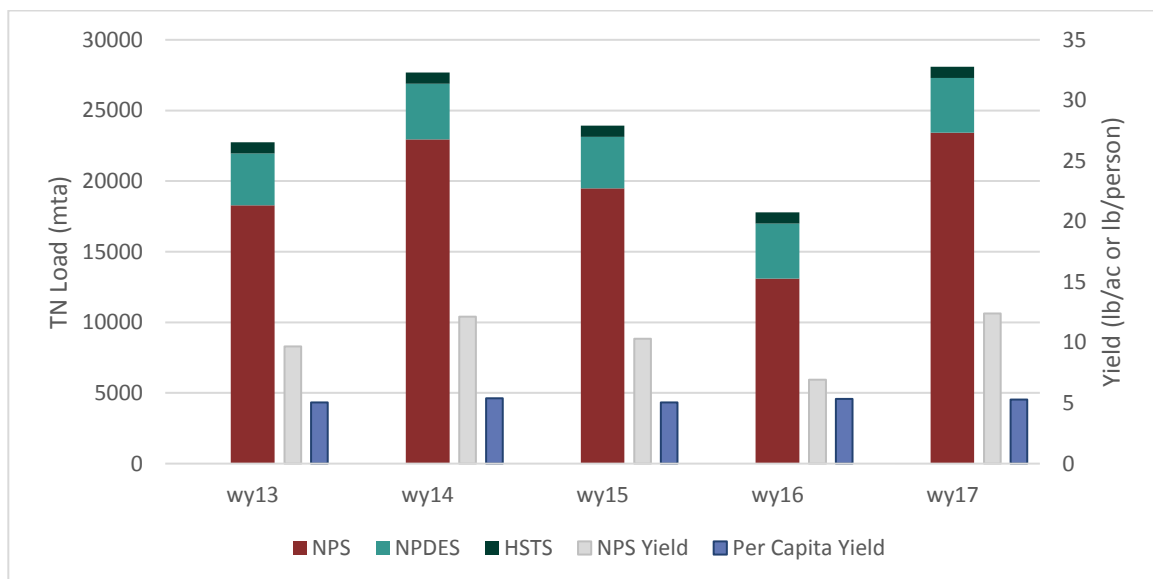
Figure 44 — Total nitrogen load, nonpoint source yield and per capita yield for the Scioto River for water year 2013-2017. Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.
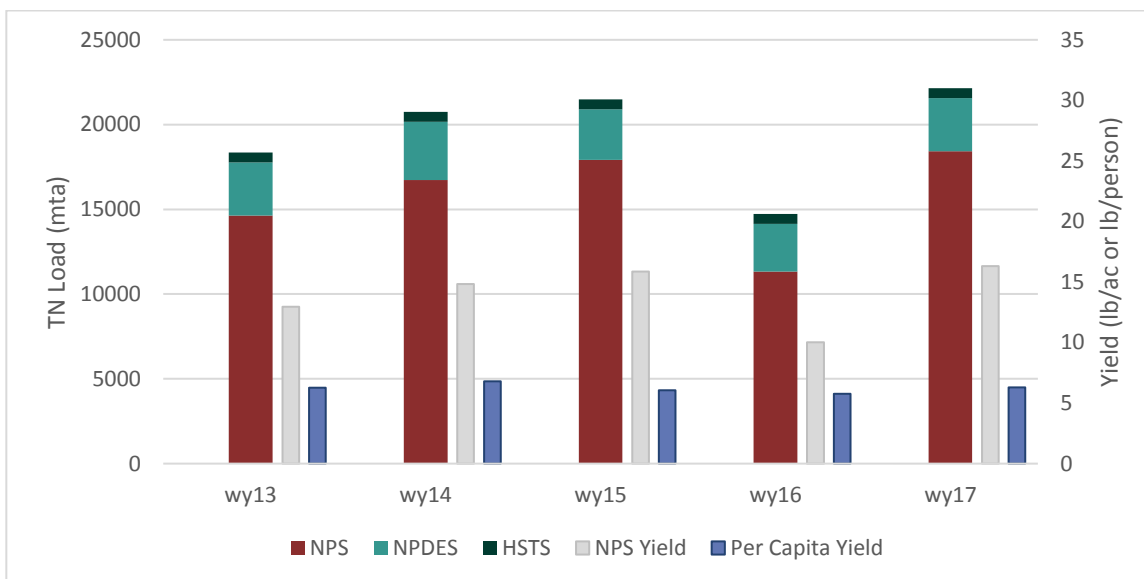
There were no apparent trends in the loadings observed for total P or total N in the Scioto River watershed. The importance of total discharge is highlighted in the observed data for total P, where the ranking of years by flow and both total P are the same, with the exception of wy13. The relationship was not as clear for total N and annual flow, highlighting the different mechanics in total P and total N loading. It is not yet possible to fit statistically valid trends to the data presented in this project identifying net directional change in loads or FWMCs. Generally, the higher the change in reduction the shorter time frame it will take to detect changes (Betanzo, 2015). For example, if the change is 20 percent, the expected timeframe to detect the change in a large watershed is 13-26 years, while, if the change is 40 percent, the expected

timeframe to detect the change is reduced to 5-10 years. Alternatively, as the 10-year timeframe is approached it is possible to start to propose that loads or concentrations are probably increasing, probably decreasing or just as likely increasing as decreasing. USGS's EGRET tool is one option that allows these types of analysis and could be applied once a minimum of 10 years of data exists. While data collection started as part of the NCWQR tributary loading program in 1996, the site was not included in USGS's surface water trends effort (Oelsner, 2017). In the future, work could be done to understand historical trends and once 10 years of data is available within this study it will be possible to start to consider if trends are statistically valid.

Table 17 — Annual flow-weighted mean concentration (FWMC), total load and water yield for wy13 through wy17 for the Scioto Watershed. Water yield is annual discharge normalized by watershed area (in units of inches/yr). FWMC and annual discharge are calculated at the pour point and do not include downstream drainage area.

Parameter	wy13	wy14	wy15	wy16	wy17
Water Yield (in/yr)	14.0	17.7	15.1	13.2	15.4
20-yr Median Water Yield (in) – 14.5					
Total P					
FWMC (mg/L)	0.39	0.37	0.37	0.33	0.38
Annual Load (mta)	2,017	2,402	1,969	1,485	2,118
Total N					
FWMC (mg/L)	4.11	3.94	4.00	3.52	4.58
Annual Load (mta)	22,737	27,682	23,924	17,784	28,083

The relative proportion of nonpoint source, total NPDES and HSTS loads for both total P and total N averaged over the five years of this study are presented in Figure 45. The nonpoint source contributed 62 percent of the annual total P load and 81 percent of the annual total N load. The figure shows the NPDES sources contributed 34 percent of the total P and 16 percent of the total N loads. Finally, the HSTS community contributed four percent of the total P and three percent of the total N loads.
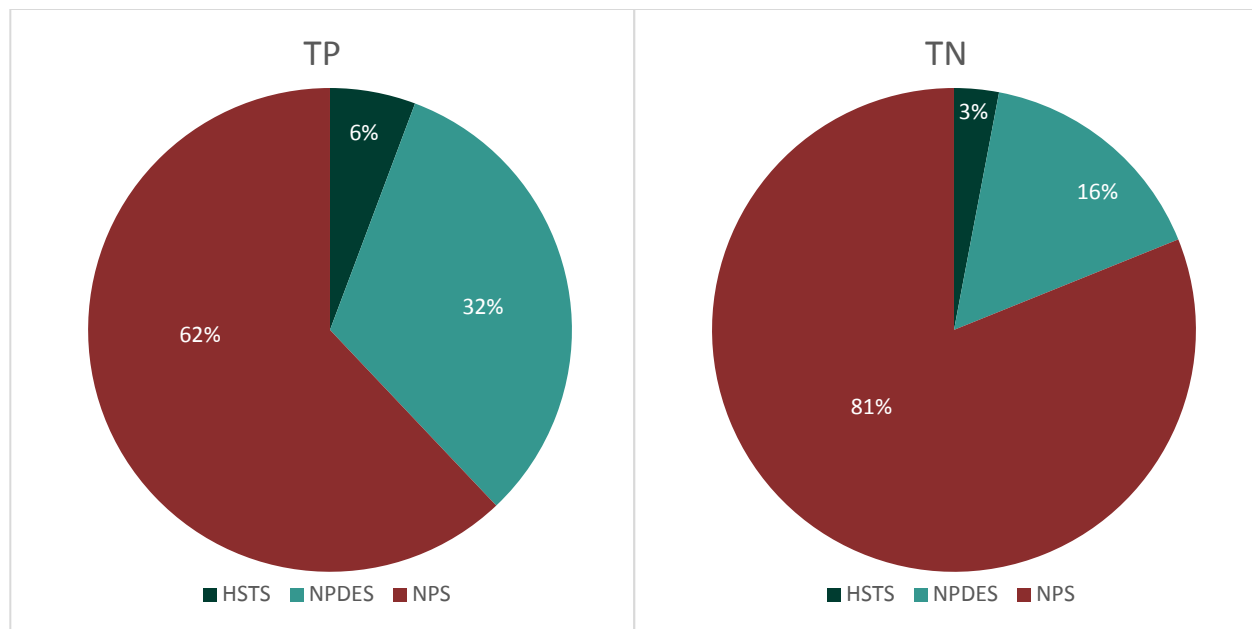
Figure 45 — Proportion of total phosphorus and nitrogen load from different sources for the Scioto watershed, average of 5-years (wy13-wy17).

The Scioto River is the second largest watershed in Ohio that drains to the Ohio River. Baker and others (2006) found a time-weighted mean contribution of total phosphorus that was greater than the flow-weighted mean. They suggest that this occurs with an increased influence from point sources. This supports the Ohio EPA study identifying a high influence of point sources.

3.10 Muskingum River

The Muskingum River drains 8,044 sq. mi. primarily in northeast and southeast Ohio (Figure 46). The NCWQR maintains a water quality station at a USGS gaging at McConnelsville, Ohio which was used as a pour point for nutrient mass balance calculations. The watershed area upstream of the pour point is 7,420 sq. mi. and 624 sq. mi. downstream of the pour point.

Natural and agricultural land use dominates the Muskingum River watershed, with 48 percent and 40 percent respectively. Downstream of the pour point, the largest shift in land use was from agricultural production to natural areas.

Total phosphorus loads from the Muskingum River were a maximum of 1,630 metric tons per year (mta) in wy14 and a

Figure 46 — Project area represented in the Muskingum River mass balance. The pour point along with up and downstream drainage areas are shown.

minimum of 883 mta in wy16 (Figure 47 and Table 18). Total N loads from the Muskingum River were a maximum of 22,153 mta in wy14 and a minimum of 12,578 mta in wy16 (Figure 48 and Table 18).
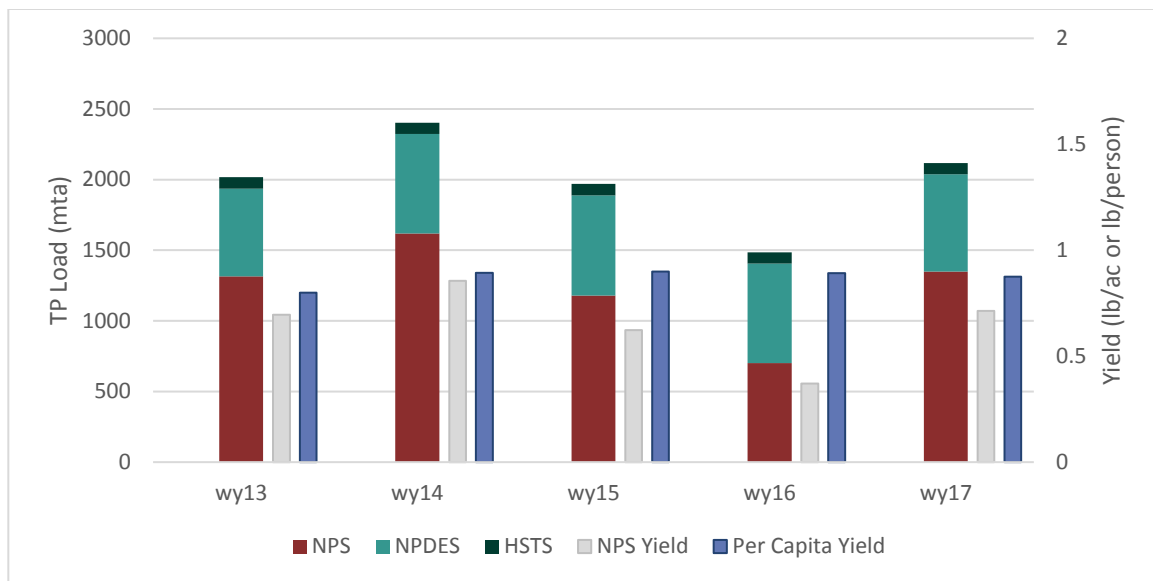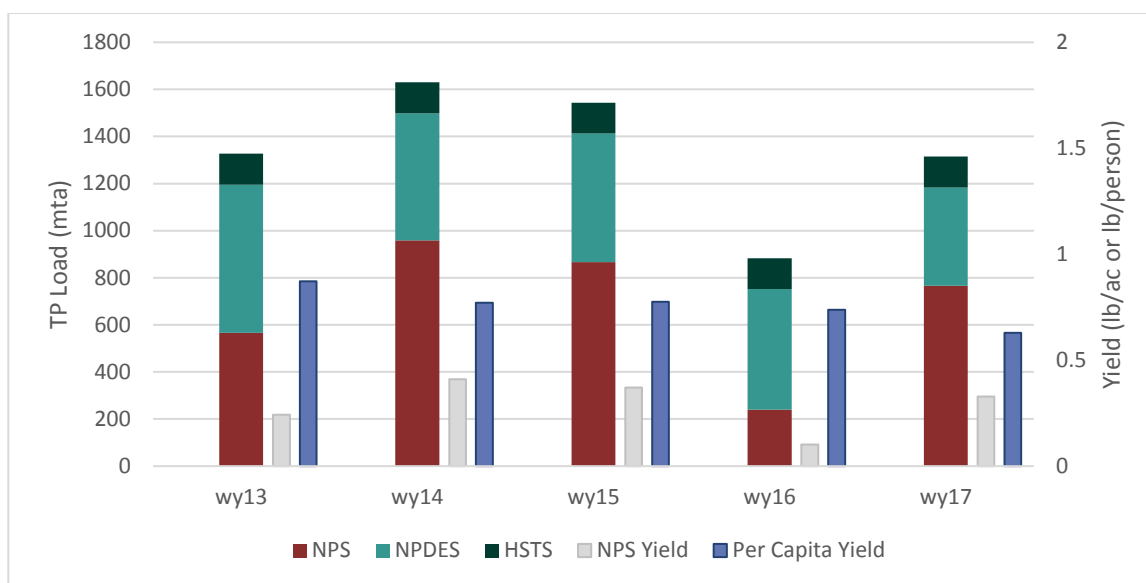
Figure 47 — Total phosphorus load, nonpoint source yield and per capita yield for the Muskingum River for water year 2013-2017. Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.
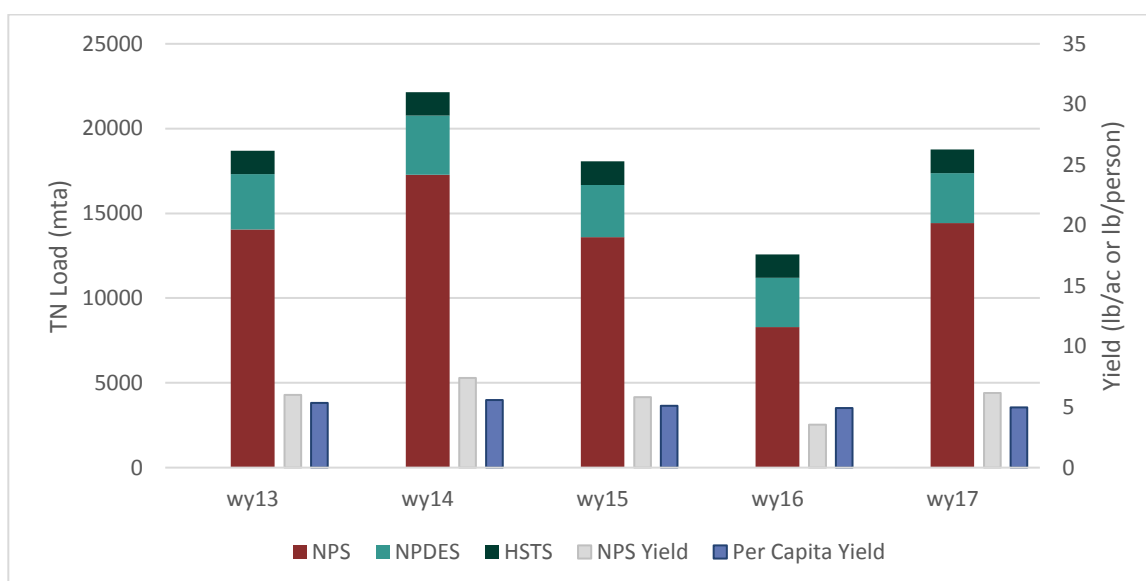
Figure 48 — Total nitrogen load, nonpoint source yield and per capita yield for the Muskingum River for water year 2013-2017. Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

The only apparent trends in the loadings observed for total P or total N was a reduction in per capita total P yields (Figure 47). Upon a review of the NPDES sources the top three loading facilities of total P in the watershed all discharged less phosphorus in wy17 than in wy13. The NPDES community as a whole discharged 34 percent less phosphorus in wy17 than wy13, while this trend cannot be statistically validated at this time it shows a consistent directional decrease. This reduction is 15 percent of the average annual load, so it will still take a number of years to identify a statistically valid trend in total loading, even if the whole reduction is detected at the pour point rather than assimilated upstream.

The importance of total discharge is highlighted in the observed data for total P, where the ranking of years by flow and both total P are the same. The relationship was not as clear for total N and annual flow, highlighting the different mechanics in total P and total N loading. It is not yet possible to fit statistically valid trends to the data presented in this project identifying net directional change in loads or FWMCs. Generally, the higher the change in reduction, the shorter time frame it will take to detect changes (Betanzo, 2015). For example, if the change is 20 percent, the expected timeframe to detect the change in a large watershed is 13-26 years, while, if the change is 40 percent, the expected timeframe to detect the change is reduced to 5-10 years. Alternatively, as the 10-year timeframe is approached it is possible to start to propose that loads or concentrations are probably increasing, probably decreasing or just as likely increasing as decreasing. USGS's EGRET tool is one option that allows these types of analysis and could be applied once a minimum of 10 years of data exists. In the decade preceding the NMB calculations (1992-2012) USGS applied the EGRET tool to the data in the Muskingum River and identified that total P was somewhat likely up and that total N was likely down (Oelsner, 2017).

Table 18 — Annual flow-weighted mean concentration (FWMC), total load and water yield for wy13 through wy17 for the Muskingum Watershed. Water yield is annual discharge normalized by watershed area (in units of inches/yr). FWMC and annual discharge are calculated at the pour point and do not include downstream drainage area.

Parameter	wy13	wy14	wy15	wy16	wy17
Water Yield (in/yr)	14.9	18.7	15.0	11.6	14.5
20-yr Median Water Yield (in) – 15.0					
Total P					
FWMC (mg/L)	0.18	0.17	0.20	0.15	0.18
Annual Load (mta)	1,327	1,630	1,543	883	1,314
Total N					
FWMC (mg/L)	2.41	2.27	2.30	2.09	2.48
Annual Load (mta)	18,699	22,153	18,060	12,578	18,759

The relative proportion of nonpoint source, total NPDES and HSTS loads for both total P and total N as an average of the five-year total in this study are presented in Figure 49. The nonpoint source contributed 51 percent of the annual total P load and 75 percent of the annual total N load. The figure shows the NPDES sources contributed 39 percent of the total P and 17 percent of the total N loads. Finally, the HSTS community contributed 10 percent of the total P and eight percent of the total N load.

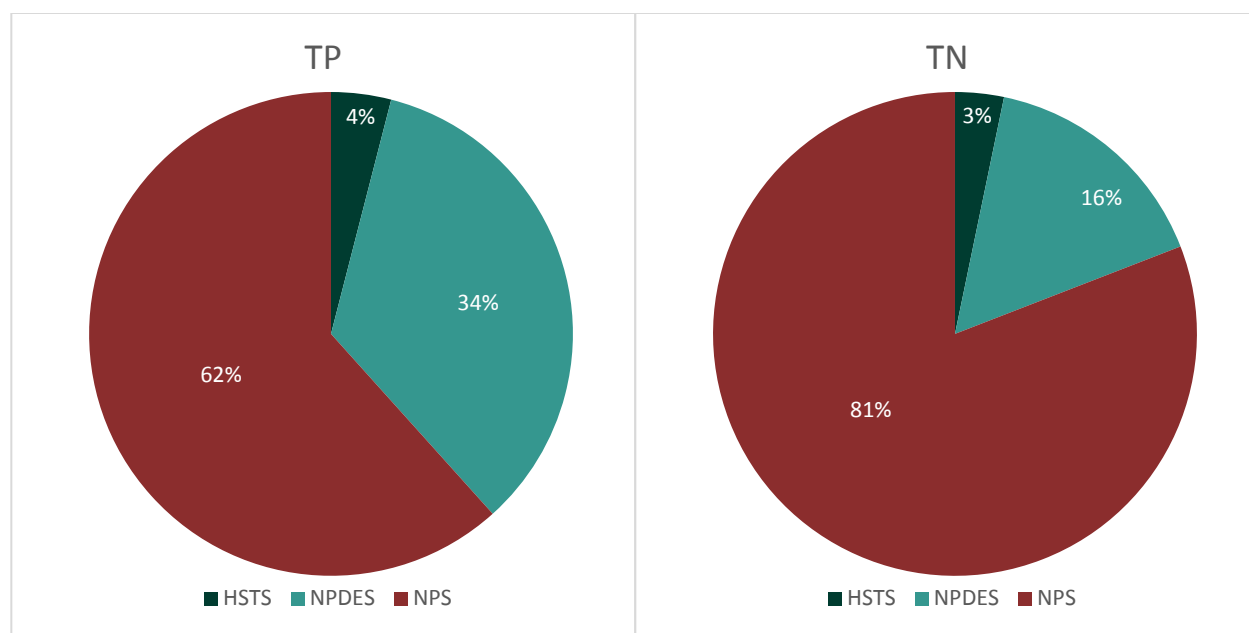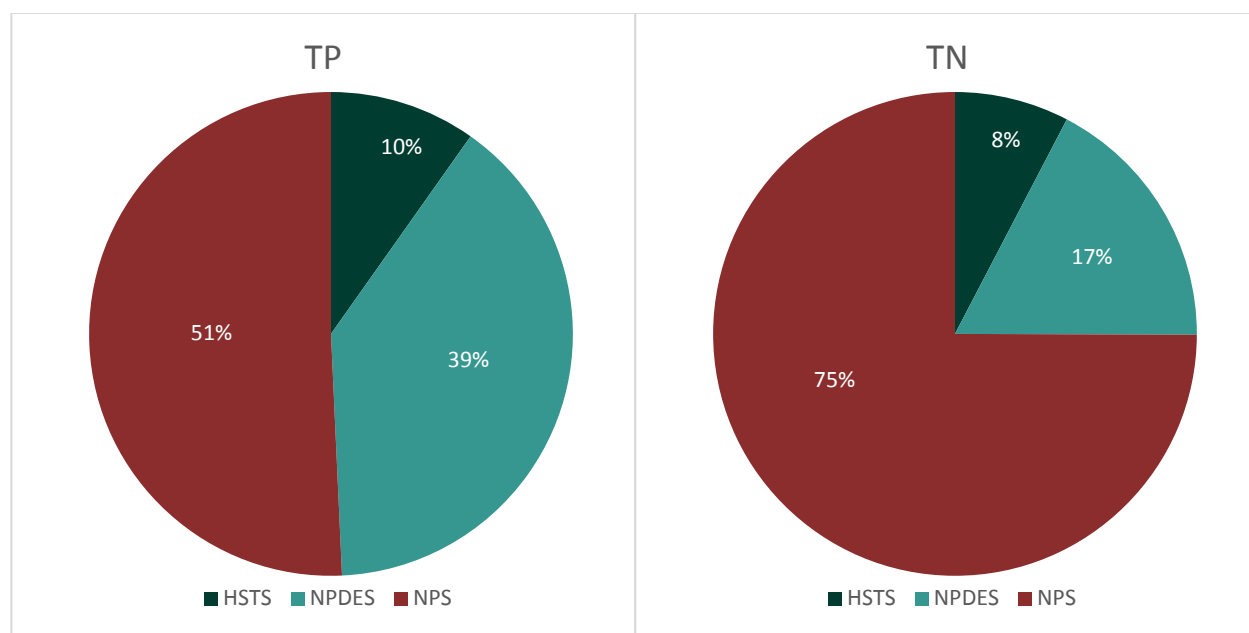*Figure 49 — Proportion of total phosphorus and nitrogen load from different sources for the Muskingum watershed, average of 5-years (wy13-wy17).*

The Muskingum River has the highest proportion of natural areas of any watershed in this study. It was also the stream with the lowest nonpoint source yield for both total P and total N. This was reflected in the lowest FWMC for both total P and total N in the study.

4 Summary and Future Work

Nutrient loads (total P and total N) were estimated and divided into major contributing sources for nine watersheds in Ohio, covering 66 percent of the land area of Ohio. This study noted several factors that influence watershed loading, including: watershed size; annual water yield; nonpoint source yield; land use; per capita yield; and population density. These factors help describe the total load from a watershed and the breakdown of sources contributing to those loads. The nine watersheds studied varied both in total loads contributed relative to the watershed size and the relative role of each of their sources. Understanding these differences will help inform future decisions as nutrient reduction efforts are pursued to meet the goals of national and international agreements for the Gulf of Mexico and Lake Erie.

Pursuant to the requirements of ORC 6111.03 (U), Ohio EPA is required to update this work biennially and coinciding with the release of the *Integrated Report*[2]. External feedback on our approach and results produced valuable suggestions for future editions of the biennial nutrient balance report. Specific items are shown in Table 19 and include relative priority and the party that can help address it. In general, future editions will strive to cover more land area, including some areas that are not currently monitored with the same level of detail as the nine watersheds in the current version. This may require new means to estimate loads that require an expanded work effort. Note that all new efforts listed in Table 19 are contingent on funding, labor support, and institutional cooperation.

Future editions will consider any new information that becomes available for attributing loads to appropriate sources. Some areas where refined information would improve the ability to estimate loads would be CSOs, HSTS and the breakdown of nonpoint source loads. The total N concentration data for CSOs that are currently available came from studies in the early 1990s; newer studies would improve the estimates for CSO loading. The total P concentration data has been updated from the 2016 report to use data from the last three years reported to Ohio EPA from two permitted entities; more data from these and other entities will help refine the updated concentration. HSTS accounting is limited by the lack of available data describing the system locations and types. Much of this information does exist at the county level, if this data was compiled into a common format it could be used to refine future versions of this report. Assessing the NPS runoff from developed areas compared to natural and agricultural areas is not possible in the current version. Defining the relative contributions from NPS sources will require better monitoring and modeling data that quantifies the loading from the different sources. If data becomes available for any of the defined needs, Ohio EPA will consider it in future developments of the nutrient mass balance effort.

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[2] *Integrated Water Quality Monitoring and Assessment Report* which satisfies the Clean Water Act requirements for both Section 305(b) for biennial reports on the condition of the State's waters and Section 303(d) for a prioritized list of impaired waters.

Table 19 — Proposed additions and modifications to the biennial nutrient balance approach including priority and potential parties to accomplish same objective. Priority is a goal defined by each subsequent report cycle (for example, priority 1 goal is the 2018 report).

Objective	Priority	Primary Role
Spatial Extent		
Expand LE watersheds –Huron R, Grand R (wy 2019[a])	1	Mass balance effort – Ohio EPA Pour-point monitoring – NCWQR
Initiate use of further downstream pour point on Scioto River[a]	1	Mass balance effort – Ohio EPA Pour-point monitoring – NCWQR
Expand OR watersheds – Hocking R, Little Miami R, Mahoning R (at most for wy 2019 and beyond[a])	1	Ohio EPA, other – based on funding
Expand LE watersheds – Black R, Toussaint Ck, Rocky R, Chagrin R	2	Ohio EPA, USGS WQ monitoring, other – based on funding
Expand OR watersheds – Wabash R (Ohio portion), Mill Ck (Cincinnati)	2	Ohio EPA, other – based on funding
Methodology / Approach		
Evaluate data reported to Ohio EPA at upstream monitoring stations from NPDES permitted sources for use in load estimation tools.	1	Ohio EPA
Data Input / Parameterization		
Further improve estimate of CSO total P and total N concentrations	1	Ohio municipalities, AOMWA
Separate NPS load estimation into agricultural and urban/suburban components; estimate urban component from field monitoring	2	Ohio EPA, Ohio areawide planning agencies, ODA, Ohio Farm Bureau
Differentiate NPS agricultural component by nutrient source (i.e., organic manure vs. synthetic fertilizer)	3	Ohio EPA, ODA, Ohio Farm Bureau, county SWCD

Notes:
a. Funding has been secured at the time of publication, but sampling has not yet started.
Abbreviations:
LE=Lake Erie, OR= Ohio River, R=river, Ck=Creek, IR=Integrated Report, WQ=water quality, AOMWA=Association of Ohio Metropolitan Wastewater Agencies, CSO=combined sewer overflow, ODH=Ohio Department of Health, USGS=US Geological Survey, NCWQR=National Center for Water Quality Research, ODA=Ohio Department of Agriculture, SWCD=soil and water conservation district

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Appendix A - Spring Nutrient Loading for Selected Lake Erie Tributaries

The 2012 Great Lakes Water Quality Agreement (GLWQA) via the Nutrients Annex Subcommittee (Annex 4; herein Annex) and their Objectives and Targets Task Team set specific loading targets for priority Lake Erie tributaries. Three of the watersheds in this study have priority spring season loading targets set forth by the Annex: Maumee, Portage and Sandusky. Each of these watersheds has a targeted 40 percent reduction of spring total and dissolved reactive phosphorus relative to 2008 levels. Since the load is influenced by the total flow, the Annex also suggests that achieving a 40 percent reduction from the 2008 value in flow weighted mean concentration (FWMC) would meet the loading targets. The Annex defines the spring season different from the typical seasonal spring using instead the March 1 – July 31 time-frame. All loading and FWMC calculations were done using a calculation tool developed by the National Center for Water Quality Research (NCWQR). The tool used NCWQR's water quality data and streamflow from the corresponding USGS gaging station. Since the mass balance analysis in the main report does not allow for speciation to sources for dissolved reactive phosphorus, these targets will not be presented. Further the Annex proposed tracking progress towards the targets at the pour points in the mass balance study. For this reason, the loads downstream of the pour points are not included in this appendix.

Maumee River

For the Maumee River, the 2008 spring total phosphorus load was 1,438 metric tons (MT) with the 40 percent reduction resulting in a target of 860 MT. The spring loads from wy13 to wy17 reached a maximum of 1,918 mta in wy15 and a minimum of 662 mta in wy16. While the load met the loading target in wy16 the cause was the drier conditions rather than the concentrations observed in the streams, as the FWMC still required a 30-percent reduction to meet the target. The wy17 FWMC was the highest observed in the five years with the second highest total load. The total loads exceeded the target in four out of five years and the FWMCs exceeded the target in all years. While there is not enough data to report statistically valid trends, there does not appear to be any changes in FWMC in the last five years and the resulting loading patterns.
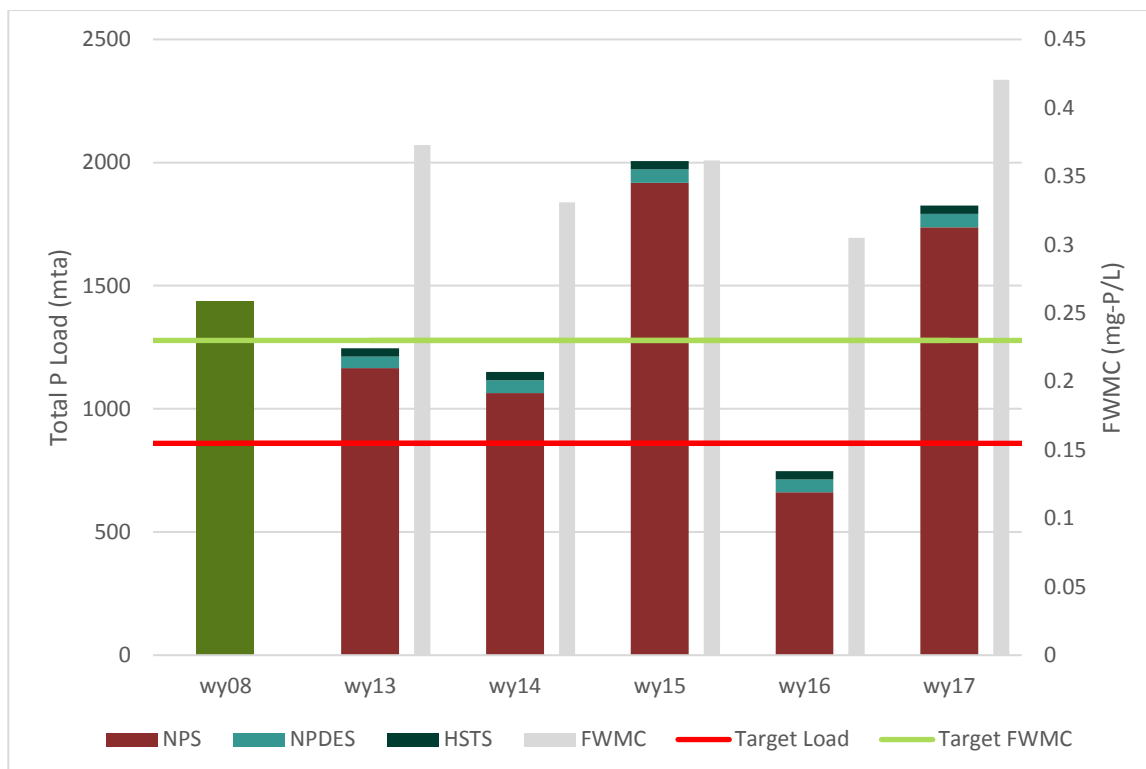
Figure A1 — Maumee River spring load and flow weighted mean concentrations (FWMC) using water quality data from the NCWQR and streamflow from the USGS gage at Waterville, Ohio. Point source and HSTS loads are presented separately for the five years covered in the nutrient mass balance report, but not for the 2008 base year. A 2008 base year and targets from the recommendations of the Annex 4 (Nutrients) Objectives and Targets Task Team of the GLWQA of 2012 are also presented.

Portage River

Continuous monitoring of nutrient concentrations did not begin in the Portage River until 2010, after the index year of 2008. Consequently, the spring loads cannot be compared to a target without a different approach to estimate the 2008 load. Figure A2 presents the spring loads for both the five water years covering analyzed in this report. The spring load reached a maximum of 113 mta in wy15 and a minimum of 62.3 mta in wy14. Without a loading target there is also no FWMC target however the FWMC's observed exceeded the target for the Maumee and Sandusky rivers in all five years. While there is not enough data to report statistically valid trends, there does not appear to be any changes in FWMC in the last five years and the resulting loading patterns.
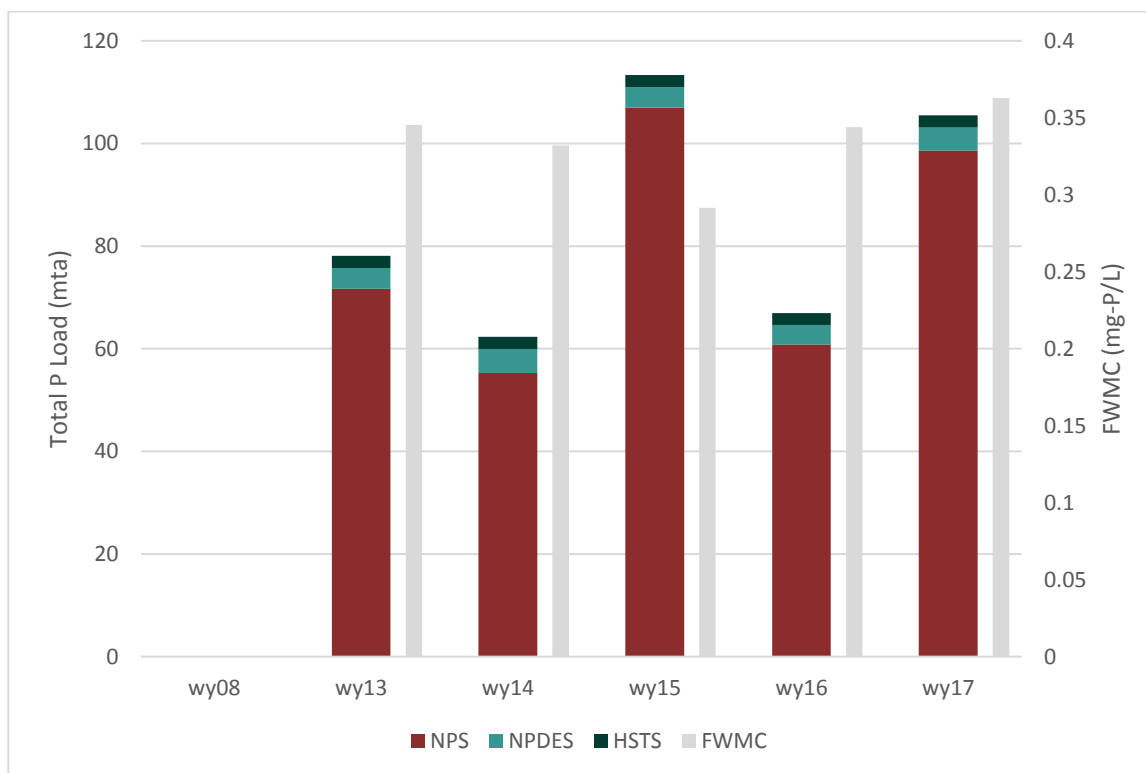
Figure A2 — Portage River spring load and flow weighted mean concentrations using water quality data from NCWQR and streamflow from the USGS gage at Woodville, Ohio. Point source and HSTS loads are presented separately for the five years.

Sandusky River

The 2008 spring total phosphorus load was 350 MT with the 40 percent reduction resulting in a target of 210 MT. The spring loads reached a maximum of 364 mta in wy13 and a minimum of 162 mta in wy16. These values are presented on Figure A3. The flow weighted mean concentrations (FWMC) are also presented in Figure A3. While the load met the loading target in wy16 the cause was the drier conditions rather than the concentrations observed in the streams, as the FWMC still required a 26-percent reduction to meet the target. The wy17 FWMC was the highest observed in the five years with the second highest total load. The total loads exceeded the target in four out of five years and the FWMCs exceeded the target in all years. While there is not enough data to report statistically valid trends, there does not appear to be any changes in FWMC in the last five years and the resulting loading patterns.
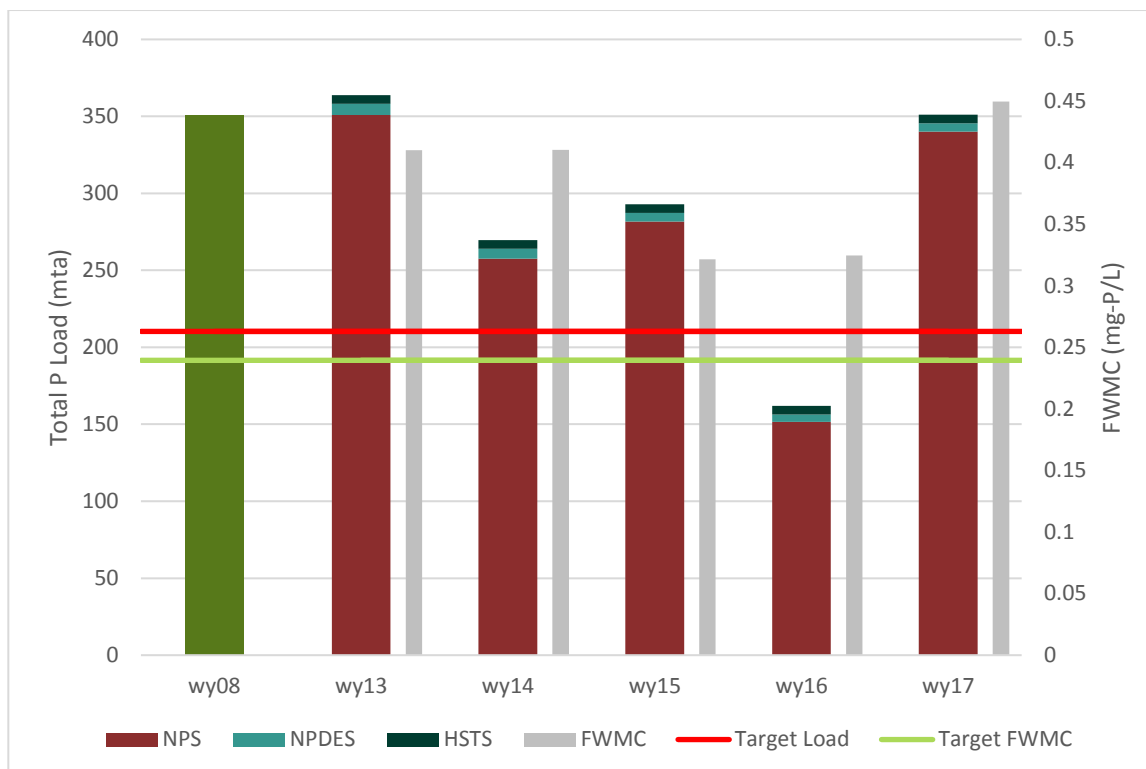
Figure A3 — Spring load and flow weighted mean concentrations at the Fremont USGS gage on the Sandusky River. Point source and HSTS loads are presented separately for the five years covered in the nutrient mass balance report but not for the 2008 base year. Targets based on the 2008 base year are also identified.

Appendix B – Summary Tables for Mass Balance Calculations

Table B1 — Summary of loading components for calculating the nutrient mass balance in the Maumee River watershed.

Source	TP Load (mta)					TN Load (mta)				
	wy13	wy14	wy15	wy16	wy17	wy13	wy14	wy15	wy16	wy17
Upstream of Pour Point										
NPDES 1 – Municipal ≥1.0 mgd	31.6	39.5	36.3	34.2	35.0	794.0	797.9	776.5	803.0	889.2
NPDES 2 – Municipal 0.1-1.0 mgd	17.3	19.7	17.1	20.8	17.9	141.9	132.0	137.1	146.1	124.2
NDPES 3 – Municipal <0.1 mgd	8.2	8.9	8.2	7.4	8.5	67.7	54.2	52.4	53.8	53.8
NPDES – Industrial	11.9	11.8	11.8	12.7	13.0	54.0	52.5	57.6	58.4	56.9
Wet Weather UPST Pour Point	1.5	1.5	3.3	2.0	2.9	39.8	40.0	86.8	52.1	77.5
OOS Point Source	33.0	34.9	42.7	44.1	46.8	793.3	864.5	912.9	811.6	928.7
OOS Wet Weather	7.8	9.3	10.0	3.9	7.2	206.8	246.9	267.7	104.1	192.5
Total NPDES UPST Pour Point	111.3	125.6	129.3	125.1	131.3	2097.5	2188.0	2291.0	2029.1	2322.8
HSTS UPST Pour Point	80.7	80.7	80.7	80.7	80.7	582.2	582.2	582.2	582.2	582.2
Load @ Pour Point	2130.7	1905.4	2220.2	1210.6	2915.6	40275.8	34323.6	41520.8	28042.2	45958.5
NPS UPST Pour Point	1938.7	1699.1	2010.2	1004.8	2703.6	37596.0	31553.4	38647.6	25430.9	43053.5
Downstream of Pour Point										
NPDES 1 – Municipal ≥1.0 mgd	68.4	60.3	54.3	61.7	54.2	1667.3	1860.0	1698.4	1765.4	1683.2
NPDES 2 – Municipal 0.1-1.0 mgd	1.7	1.6	0.7	0.6	0.4	12.9	11.6	9.7	12.4	12.1
NDPES 3 – Municipal <0.1 mgd	0.2	0.3	0.2	0.3	0.3	1.3	1.4	2.0	2.1	2.2
NPDES – Industrial	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.1	0.1	0.1
Wet Weather DST Pour Point	1.0	0.9	1.4	0.4	0.5	25.6	25.2	37.4	10.0	13.4
Total NPDES DST Pour Point	71.3	63.1	56.7	63.0	55.4	1707.2	1898.2	1747.5	1790.0	1710.9
HSTS DST Pour Point	3.5	3.5	3.5	3.5	3.5	25.0	25.0	25.0	25.0	25.0
NPS DST Pour Point	72.9	63.9	75.6	37.8	101.7	1413.6	1186.4	1453.1	956.2	1618.8
Totals										
HSTS	84.2	84.2	84.2	84.2	84.2	607.2	607.2	607.2	607.2	607.2
Total NPDES	182.5	188.6	186.0	188.1	186.7	3804.7	4086.2	4038.5	3819.1	4033.7
NPS Total	2011.6	1763.0	2085.8	1042.6	2805.3	39009.6	32739.8	40100.7	26387.0	44672.2
Total Load	2,278	2,036	2,356	1,315	3,076	43,422	37,433	44,746	30,813	49,313
% HSTS	4%	4%	4%	6%	3%	1%	2%	1%	2%	1%
% NPDES	8%	9%	8%	14%	6%	9%	11%	9%	12%	8%
% of NPDES – Municipal ≥ 1.0 mgd	54.8%	52.9%	48.7%	51.0%	47.8%	64.7%	65.0%	61.3%	67.3%	63.8%
% of NPDES – Municipal 0.1-1.0 mgd	10.4%	11.2%	9.6%	11.4%	9.8%	4.1%	3.5%	3.6%	4.1%	3.4%
% of NPDES – Municipal <0.1 mgd	4.6%	4.9%	4.5%	4.1%	4.7%	1.8%	1.4%	1.3%	1.5%	1.4%
% of NPDES – Industrial	6.5%	6.3%	6.3%	6.8%	6.9%	1.4%	1.3%	1.4%	1.5%	1.4%
% of NPDES – Wet Weather	1.3%	1.3%	2.5%	1.2%	1.8%	1.7%	1.6%	3.1%	1.6%	2.3%
% NPS	88%	87%	89%	79%	91%	90%	87%	90%	86%	91%
Yield UPST Pour Point (lb/acre)	1.06	0.92	1.09	0.55	1.47	20.46	17.17	21.03	13.84	23.43
Per Capita Yield (lb/person)	0.42	0.43	0.43	0.43	0.43	6.99	7.44	7.36	7.01	7.35

Table B2 — Summary of loading components for calculating the nutrient mass balance in the Portage River watershed.

Source	TP Load (mta)					TN Load (mta)				
	wy13	wy14	wy15	wy16	wy17	wy13	wy14	wy15	wy16	wy17
Upstream of Pour Point										
NPDES 1 – Municipal ≥1.0 mgd	6.0	6.3	6.8	6.6	6.9	192.4	206.1	225.8	202.4	142.7
NPDES 2 – Municipal 0.1-1.0 mgd	1.8	1.8	1.4	1.1	2.0	20.5	21.1	16.7	16.4	16.6
NDPES 3 – Municipal <0.1 mgd	0.8	0.7	0.7	0.7	0.7	6.6	6.0	5.8	3.4	3.4
NPDES – Industrial	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Wet Weather UPST Pour Point	1.3	2.4	0.8	0.6	1.1	33.7	63.6	20.7	16.2	29.8
OOS Point Source										
OOS Wet Weather										
Total NPDES UPST Pour Point	9.8	11.2	9.6	9.0	10.7	253.2	296.9	268.9	238.6	192.6
HSTS UPST Pour Point	5.6	5.6	5.6	5.6	5.6	54.4	54.4	54.4	54.4	54.4
Load @ Pour Point	121.4	159.2	124.1	103.7	153.4	2861.4	2279.4	2947.1	2360.9	3903.4
NPS UPST Pour Point	106.0	142.4	108.8	89.0	137.1	2553.9	1928.2	2623.9	2068.0	3656.5
Downstream of Pour Point										
NPDES 1 – Municipal ≥1.0 mgd	0.5	0.4	0.3	0.4	0.3	37.0	34.2	39.8	38.4	35.7
NPDES 2 – Municipal 0.1-1.0 mgd	3.1	3.4	3.2	3.5	3.3	17.1	16.9	17.1	17.2	21.1
NDPES 3 – Municipal <0.1 mgd	3.2	3.1	1.3	1.2	1.1	10.7	9.9	7.7	7.5	8.3
NPDES – Industrial	0.0	0.0	0.0	0.0	0.0	28.2	25.3	26.2	21.4	26.2
Wet Weather DST Pour Point	0.3	0.8	1.4	0.3	0.2	7.4	22.3	37.4	8.3	5.9
Total NPDES DST Pour Point	7.0	7.7	6.2	5.4	4.9	100.4	108.6	128.2	92.9	97.3
HSTS DST Pour Point	2.1	2.1	2.1	2.1	2.1	20.1	20.1	20.1	20.1	20.1
NPS DST Pour Point	39.2	52.7	40.3	32.9	50.7	944.8	713.4	970.7	765.1	1352.8
Totals										
HSTS	7.7	7.7	7.7	7.7	7.7	74.5	74.5	74.5	74.5	74.5
Total NPDES	16.8	18.9	15.8	14.4	15.6	353.6	405.5	397.1	331.4	289.8
NPS Total	145.2	195.1	149.1	121.9	187.8	3498.7	2641.5	3594.6	2833.1	5009.3
Total Load	170	222	173	144	211	3,927	3,121	4,066	3,239	5,374
% HSTS	5%	3%	4%	5%	4%	2%	2%	2%	2%	1%
% NPDES	10%	9%	9%	10%	7%	9%	13%	10%	10%	5%
% of NPDES – Municipal ≥ 1.0 mgd	38.5%	35.4%	44.9%	48.5%	46.1%	64.9%	59.3%	66.9%	72.7%	61.6%
% of NPDES – Municipal 0.1-1.0 mgd	28.8%	27.3%	28.9%	31.5%	33.8%	10.6%	9.4%	8.5%	10.1%	13.0%
% of NPDES – Municipal <0.1 mgd	23.5%	20.2%	12.3%	13.6%	11.4%	4.9%	3.9%	3.4%	3.3%	4.0%
% of NPDES – Industrial	0.0%	0.1%	0.1%	0.1%	0.1%	8.0%	6.2%	6.6%	6.5%	9.1%
% of NPDES – Wet Weather	9.1%	17.0%	13.8%	6.4%	8.6%	11.6%	21.2%	14.6%	7.4%	12.3%
% NPS	86%	88%	86%	85%	89%	89%	85%	88%	87%	93%
Yield UPST Pour Point (lb/acre)	0.86	1.15	0.88	0.72	1.11	20.60	15.55	21.17	16.68	29.50
Per Capita Yield (lb/person)	0.57	0.62	0.55	0.52	0.54	9.97	11.18	10.98	9.45	8.48

Table B3 — Summary of loading components for calculating the nutrient mass balance in the Sandusky River watershed.

Source	TP Load (mta)					TN Load (mta)				
	wy13	wy14	wy15	wy16	wy17	wy13	wy14	wy15	wy16	wy17
Upstream of Pour Point										
NPDES 1 – Municipal ≥1.0 mgd	12.8	9.9	8.1	6.7	8.2	165.6	152.7	138.2	124.7	138.3
NPDES 2 – Municipal 0.1-1.0 mgd	2.0	2.4	2.5	2.3	2.1	19.1	19.0	20.7	23.6	15.4
NDPES 3 – Municipal <0.1 mgd	1.0	1.0	1.0	0.9	1.0	7.4	7.5	7.7	6.8	7.9
NPDES – Industrial	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.4
Wet Weather UPST Pour Point	1.8	2.2	1.9	1.6	1.7	48.0	59.7	50.4	42.6	45.1
OOS Point Source										
OOS Wet Weather										
Total NPDES UPST Pour Point	17.7	15.6	13.6	11.5	13.1	240.3	239.0	217.2	198.0	207.1
HSTS UPST Pour Point	13.2	13.2	13.2	13.2	13.2	128.1	128.1	128.1	128.1	128.1
Load @ Pour Point	607.1	500.9	333.0	283.5	520.8	9943.2	7116.2	6141.6	5646.8	8670.6
NPS UPST Pour Point	576.2	472.1	306.2	258.7	494.5	9574.8	6749.2	5796.3	5320.7	8335.4
Downstream of Pour Point										
NPDES 1 – Municipal ≥1.0 mgd	2.6	1.3	1.0	1.1	1.0	62.8	48.3	27.8	21.8	18.0
NPDES 2 – Municipal 0.1-1.0 mgd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NDPES 3 – Municipal <0.1 mgd	0.1	0.1	0.1	0.1	0.1	0.5	0.5	0.6	0.6	0.6
NPDES – Industrial	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wet Weather DST Pour Point	3.8	4.1	5.1	2.6	1.1	100.5	108.1	135.8	68.7	29.1
Total NPDES DST Pour Point	6.5	5.4	6.2	3.8	2.2	163.8	156.9	164.2	91.1	47.7
HSTS DST Pour Point	1.8	1.8	1.8	1.8	1.8	17.4	17.4	17.4	17.4	17.4
NPS DST Pour Point	77.8	63.8	41.4	34.9	66.8	1293.5	911.8	783.0	718.8	1126.0
Totals										
HSTS	15.0	15.0	15.0	15.0	15.0	145.5	145.5	145.5	145.5	145.5
Total NPDES	24.2	21.0	19.8	15.3	15.3	404.1	396.0	381.4	289.1	254.8
NPS Total	654.0	535.9	347.5	293.6	561.3	10868.3	7660.9	6579.4	6039.5	9461.4
Total Load	693	572	382	324	592	11,418	8,202	7,106	6,474	9,862
% HSTS	2%	3%	4%	5%	3%	1%	2%	2%	2%	1%
% NPDES	3%	4%	5%	5%	3%	4%	5%	5%	4%	3%
% of NPDES – Municipal ≥ 1.0 mgd	63.9%	53.3%	45.8%	51.0%	60.1%	56.5%	50.8%	43.5%	50.7%	61.3%
% of NPDES – Municipal 0.1-1.0 mgd	8.2%	11.4%	12.8%	14.8%	13.4%	4.7%	4.8%	5.4%	8.2%	6.0%
% of NPDES – Municipal <0.1 mgd	4.6%	4.9%	5.6%	6.2%	7.1%	2.0%	2.0%	2.2%	2.6%	3.3%
% of NPDES – Industrial	0.4%	0.4%	0.6%	0.7%	1.2%	0.0%	0.0%	0.1%	0.1%	0.2%
% of NPDES – Wet Weather	23.0%	30.0%	35.3%	27.3%	18.2%	36.7%	42.4%	48.8%	38.5%	29.1%
% NPS	94%	94%	91%	91%	95%	95%	93%	93%	93%	96%
Yield UPST Pour Point (lb/acre)	1.59	1.30	0.84	0.71	1.36	26.36	18.58	15.96	14.65	22.95
Per Capita Yield (lb/person)	0.68	0.62	0.60	0.52	0.52	9.49	9.34	9.09	7.50	6.91

Table B 4 — Summary of loading components for calculating the nutrient mass balance in the Frontal Lake Erie watersheds; n/a: not applicable.

Source	TP Load (mta)					TN Load (mta)				
	wy13	wy14	wy15	wy16	wy17	wy13	wy14	wy15	wy16	wy17
NPDES										
NPDES 1 – Municipal ≥1.0 mgd	10.5	13.3	13.1	13.7	10.5	586.2	409.2	449.2	438.8	492.6
NPDES 2 – Municipal 0.1-1.0 mgd	2.0	2.4	2.2	2.2	1.9	18.9	14.5	18.5	19.7	19.1
NDPES 3 – Municipal <0.1 mgd	2.2	2.6	2.2	2.3	2.4	29.1	25.6	25.5	31.0	35.4
NPDES – Industrial	0.1	0.3	1.1	0.9	0.6	0.1	1.1	0.2	0.1	0.1
Wet Weather DST Pour Point	0.1	0.0	0.0	0.0	0.0	1.4	1.3	0.7	0.3	0.3
Totals										
HSTS	21.2	21.2	21.2	21.2	21.2	152.9	152.9	152.9	152.9	152.9
Total NPDES	14.8	18.7	18.7	19.2	15.4	635.8	451.8	494.1	489.9	547.5
NPS Total	125.0	154.6	108.8	87.6	135.7	2423.6	1963.2	2281.0	1872.2	3178.1
Total Load	161	194	149	128	172	3,212	2,568	2,928	2,515	3,879
% HSTS	13%	11%	14%	17%	12%	5%	6%	5%	6%	4%
% NPDES	9%	10%	13%	15%	9%	20%	18%	17%	19%	14%
% of NPDES – Municipal ≥ 1.0 mgd	70.9%	71.3%	70.4%	71.5%	68.0%	92.2%	90.6%	90.9%	89.6%	90.0%
% of NPDES – Municipal 0.1-1.0 mgd	13.4%	12.9%	11.8%	11.7%	12.4%	3.0%	3.2%	3.7%	4.0%	3.5%
% of NPDES – Municipal <0.1 mgd	14.9%	13.9%	11.6%	12.1%	15.5%	4.6%	5.7%	5.2%	6.3%	6.5%
% of NPDES – Industrial	0.4%	1.7%	6.1%	4.7%	4.0%	0.0%	0.3%	0.0%	0.0%	0.0%
% of NPDES – Wet Weather	0.3%	0.3%	0.1%	0.1%	0.1%	0.2%	0.3%	0.1%	0.1%	0.0%
% NPS	78%	79%	73%	68%	79%	75%	76%	78%	74%	82%
Yield UPST Pour Point (lb/acre)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Per Capita Yield (lb/person)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Table B5 — Summary of loading components for calculating the nutrient mass balance in the Vermilion River watershed.

Source	TP Load (mta)					TN Load (mta)				
	wy13	wy14	wy15	wy16	wy17	wy13	wy14	wy15	wy16	wy17
Upstream of Pour Point										
NPDES 1 – Municipal ≥1.0 mgd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NPDES 2 – Municipal 0.1-1.0 mgd	2.1	2.0	0.9	0.8	0.9	13.7	15.2	12.6	14.0	15.0
NDPES 3 – Municipal <0.1 mgd	0.6	0.6	0.7	0.5	0.5	5.3	5.7	5.3	5.9	4.7
NPDES – Industrial	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wet Weather UPST Pour Point	0.1	0.1	0.0	0.1	0.1	1.8	2.8	0.3	2.8	4.0
OOS Point Source										
OOS Wet Weather										
Total NPDES UPST Pour Point	2.8	2.6	1.6	1.4	1.6	20.9	23.7	18.3	22.7	23.7
HSTS UPST Pour Point	3.8	3.8	3.8	3.8	3.8	27.3	27.3	27.3	27.3	27.3
Load @ Pour Point	137.1	142.1	81.2	65.4	83.8	1441.6	1500.0	854.8	871.1	1144.9
NPS UPST Pour Point	130.6	135.7	75.9	60.2	78.4	1393.4	1449.0	809.2	821.1	1093.9
Downstream of Pour Point										
NPDES 1 – Municipal ≥1.0 mgd	0.5	0.5	0.4	0.6	0.8	30.9	31.0	21.9	23.3	23.9
NPDES 2 – Municipal 0.1-1.0 mgd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NDPES 3 – Municipal <0.1 mgd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NPDES – Industrial	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wet Weather DST Pour Point	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total NPDES DST Pour Point	0.5	0.5	0.4	0.6	0.8	30.9	31.0	21.9	23.3	23.9
HSTS DST Pour Point	0.1	0.1	0.1	0.1	0.1	0.8	0.8	0.8	0.8	0.8
NPS DST Pour Point	3.7	3.8	2.1	1.7	2.2	39.4	40.9	22.9	23.2	30.9
Totals										
HSTS	3.9	3.9	3.9	3.9	3.9	28.1	28.1	28.1	28.1	28.1
Total NPDES	3.3	3.1	1.9	2.0	2.4	51.7	54.7	40.1	46.0	47.6
NPS Total	134.2	139.5	78.0	61.9	80.6	1432.8	1489.9	832.1	844.3	1124.8
Total Load	141	147	84	68	87	1,513	1,573	900	918	1,201
% HSTS	3%	3%	5%	6%	4%	2%	2%	3%	3%	2%
% NPDES	2%	2%	2%	3%	3%	3%	3%	4%	5%	4%
% of NPDES – Municipal ≥ 1.0 mgd	14.8%	16.1%	19.5%	29.0%	34.0%	59.7%	56.7%	54.5%	50.7%	50.2%
% of NPDES – Municipal 0.1-1.0 mgd	63.3%	62.4%	45.5%	40.1%	40.0%	26.4%	27.7%	31.5%	30.4%	31.4%
% of NPDES – Municipal <0.1 mgd	19.8%	18.1%	34.5%	25.6%	19.8%	10.3%	10.5%	13.3%	12.9%	9.9%
% of NPDES – Industrial	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
% of NPDES – Wet Weather	2.1%	3.4%	0.5%	5.3%	6.3%	3.5%	5.1%	0.7%	6.0%	8.4%
% NPS	95%	95%	93%	91%	93%	95%	95%	92%	92%	94%
Yield UPST Pour Point (lb/acre)	1.72	1.78	1.00	0.79	1.03	18.32	19.05	10.64	10.80	14.38
Per Capita Yield (lb/person)	0.51	0.50	0.41	0.41	0.44	5.65	5.87	4.83	5.25	5.36

Table B6 — Summary of loading components for calculating the nutrient mass balance in the Cuyahoga River watershed.

Source	TP Load (mta)					TN Load (mta)				
	wy13	wy14	wy15	wy16	wy17	wy13	wy14	wy15	wy16	wy17
Upstream of Pour Point										
NPDES 1 – Municipal ≥1.0 mgd	64.7	58.8	53.6	59.4	57.2	1604.6	1796.9	1754.0	1641.7	1395.3
NPDES 2 – Municipal 0.1-1.0 mgd	1.1	1.1	1.1	1.2	1.4	52.0	51.6	56.0	50.4	50.0
NDPES 3 – Municipal <0.1 mgd	1.8	1.2	1.4	1.4	1.4	26.2	25.1	28.6	28.6	28.2
NPDES – Industrial	0.1	0.1	0.1	0.1	0.2	2.2	0.3	0.3	0.6	20.9
Wet Weather UPST Pour Point	3.2	2.9	2.3	1.8	2.2	84.6	78.5	60.9	48.6	59.5
OOS Point Source										
OOS Wet Weather										
Total NPDES UPST Pour Point	70.9	64.2	58.4	63.9	62.3	1769.7	1952.2	1899.8	1769.9	1553.9
HSTS UPST Pour Point	25.9	25.9	25.9	25.9	25.9	256.3	256.3	256.3	256.3	256.3
Load @ Pour Point	227.1	263.9	202.6	117.7	239.6	2751.3	2957.3	2349.8	1991.2	2715.7
NPS UPST Pour Point	130.2	173.8	118.3	27.8	151.4	725.4	748.8	193.7	-35.0	905.5
Downstream of Pour Point										
NPDES 1 – Municipal ≥1.0 mgd	41.1	53.0	75.8	73.2	74.3	2790.7	2384.6	2222.6	2198.8	2342.0
NPDES 2 – Municipal 0.1-1.0 mgd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NDPES 3 – Municipal <0.1 mgd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NPDES – Industrial	0.0	0.0	0.0	0.0	0.1	51.3	38.8	46.4	38.2	31.4
Wet Weather DST Pour Point	7.7	7.7	7.4	9.8	8.7	204.4	205.5	197.5	260.4	231.9
Total NPDES DST Pour Point	48.8	60.7	83.3	83.0	83.1	3046.5	2628.9	2466.5	2497.3	2605.3
HSTS DST Pour Point	9.6	9.6	9.6	9.6	9.6	94.8	94.8	94.8	94.8	94.8
NPS DST Pour Point	18.6	24.8	16.9	4.0	21.6	103.6	107.0	27.7	-5.0	129.4
Totals										
HSTS	35.5	35.5	35.5	35.5	35.5	351.2	351.2	351.2	351.2	351.2
Total NPDES	119.7	124.9	141.7	146.9	145.4	4816.1	4581.1	4366.3	4267.2	4159.3
NPS Total	148.8	198.7	135.2	31.8	173.0	829.0	855.7	221.3	-40.0	1034.9
Total Load	304	359	312	214	354	5,996	5,788	4,939	4,578	5,545
% HSTS	12%	10%	11%	17%	10%	6%	6%	7%	8%	6%
% NPDES	39%	35%	45%	69%	41%	80%	79%	88%	93%	75%
% of NPDES – Municipal ≥ 1.0 mgd	88.4%	89.5%	91.4%	90.2%	90.5%	91.3%	91.3%	91.1%	90.0%	89.9%
% of NPDES – Municipal 0.1-1.0 mgd	0.9%	0.9%	0.8%	0.8%	0.9%	1.1%	1.1%	1.3%	1.2%	1.2%
% of NPDES – Municipal <0.1 mgd	1.5%	1.0%	1.0%	0.9%	1.0%	0.5%	0.5%	0.7%	0.7%	0.7%
% of NPDES – Industrial	0.1%	0.1%	0.1%	0.1%	0.1%	1.1%	0.9%	1.1%	0.9%	1.3%
% of NPDES – Wet Weather	9.1%	8.5%	6.8%	7.9%	7.5%	6.0%	6.2%	5.9%	7.2%	7.0%
% NPS	49%	55%	43%	15%	49%	14%	15%	4%	-1%	19%
Yield UPST Pour Point (lb/acre)	0.63	0.85	0.58	0.14	0.74	3.53	3.65	0.94	-0.17	4.41
Per Capita Yield (lb/person)	0.30	0.31	0.35	0.36	0.35	10.12	9.66	9.24	9.04	8.83

Table B7 — Summary of loading components for calculating the nutrient mass balance in the Great Miami River watershed.

Source	TP Load (mta)					TN Load (mta)				
	wy13	wy14	wy15	wy16	wy17	wy13	wy14	wy15	wy16	wy17
Upstream of Pour Point										
NPDES 1 – Municipal ≥1.0 mgd	313.8	291.2	323.2	297.0	357.3	2121.5	2001.5	1731.0	1569.2	2090.0
NPDES 2 – Municipal 0.1-1.0 mgd	17.8	16.9	15.5	17.0	17.1	106.7	114.7	136.0	144.9	133.3
NDPES 3 – Municipal <0.1 mgd	2.8	2.5	2.5	2.9	2.7	17.7	17.0	17.7	20.4	18.8
NPDES – Industrial	1.6	1.4	2.8	3.3	3.6	0.7	1.1	3.2	3.9	5.3
Wet Weather UPST Pour Point	3.3	7.3	5.7	6.2	3.1	88.6	195.1	153.1	166.1	81.7
OOS Point Source										
OOS Wet Weather										
Total NPDES UPST Pour Point	339.4	319.3	349.7	326.4	383.8	2335.2	2329.3	2041.0	1904.6	2329.0
HSTS UPST Pour Point	57.7	57.7	57.7	57.7	57.7	416.2	416.2	416.2	416.2	416.2
Load @ Pour Point	879.5	1254.7	1242.2	629.5	1023.8	12858.5	14297.9	14822.0	10136.7	15468.3
NPS UPST Pour Point	482.4	877.8	834.8	245.4	582.4	10107.1	11552.4	12364.8	7815.8	12723.1
Downstream of Pour Point										
NPDES 1 – Municipal ≥1.0 mgd	84.4	89.8	79.0	79.4	75.4	646.1	923.1	677.6	789.6	643.5
NPDES 2 – Municipal 0.1-1.0 mgd	15.4	14.2	12.3	10.5	9.9	78.6	92.2	75.2	59.3	76.7
NDPES 3 – Municipal <0.1 mgd	3.4	3.6	3.6	3.4	3.3	25.8	26.6	24.5	19.5	16.5
NPDES – Industrial	7.4	4.0	5.4	25.6	14.6	23.0	27.3	32.4	23.7	25.5
Wet Weather DST Pour Point	0.5	1.1	5.4	1.3	1.4	14.6	29.9	144.0	33.5	37.3
Total NPDES DST Pour Point	111.1	112.7	105.6	120.2	104.6	788.0	1099.1	953.7	925.6	799.4
HSTS DST Pour Point	23.0	23.0	23.0	23.0	23.0	165.8	165.8	165.8	165.8	165.8
NPS DST Pour Point	216.3	393.6	374.3	110.0	261.1	4532.2	5180.3	5544.6	3504.8	5705.3
Totals										
HSTS	80.7	80.7	80.7	80.7	80.7	582.0	582.0	582.0	582.0	582.0
Total NPDES	450.5	432.0	455.4	446.6	488.3	3123.2	3428.4	2994.7	2830.2	3128.5
NPS Total	698.7	1271.4	1209.2	355.5	843.5	14639.3	16732.6	17909.4	11320.6	18428.3
Total Load	1,230	1,784	1,745	883	1,413	18,345	20,743	21,486	14,733	22,139
% HSTS	7%	5%	5%	9%	6%	3%	3%	3%	4%	3%
% NPDES	37%	24%	26%	51%	35%	17%	17%	14%	19%	14%
% of NPDES – Municipal ≥ 1.0 mgd	88.4%	88.2%	88.3%	84.3%	88.6%	88.6%	85.3%	80.4%	83.3%	87.4%
% of NPDES – Municipal 0.1-1.0 mgd	7.4%	7.2%	6.1%	6.2%	5.5%	5.9%	6.0%	7.1%	7.2%	6.7%
% of NPDES – Municipal <0.1 mgd	1.4%	1.4%	1.3%	1.4%	1.2%	1.4%	1.3%	1.4%	1.4%	1.1%
% of NPDES – Industrial	2.0%	1.2%	1.8%	6.5%	3.7%	0.8%	0.8%	1.2%	1.0%	1.0%
% of NPDES – Wet Weather	0.9%	2.0%	2.4%	1.7%	0.9%	3.3%	6.6%	9.9%	7.1%	3.8%
% NPS	57%	71%	69%	40%	60%	80%	81%	83%	77%	83%
Yield UPST Pour Point (lb/acre)	0.62	1.13	1.07	0.31	0.75	12.97	14.82	15.86	10.03	16.32
Per Capita Yield (lb/person)	0.90	0.87	0.91	0.89	0.96	6.27	6.79	6.06	5.78	6.28

Table B8 — Summary of loading components for calculating the nutrient mass balance in the Scioto River watershed.

Source	TP Load (mta)					TN Load (mta)				
	wy13	wy14	wy15	wy16	wy17	wy13	wy14	wy15	wy16	wy17
Upstream of Pour Point										
NPDES 1 – Municipal ≥1.0 mgd	528.4	599.1	604.1	604.6	584.8	2870.3	2978.0	2710.8	2984.3	3011.0
NPDES 2 – Municipal 0.1-1.0 mgd	26.1	27.0	24.9	26.1	29.5	272.5	298.1	263.8	279.3	305.0
NDPES 3 – Municipal <0.1 mgd	13.1	15.0	13.2	13.0	12.9	113.7	121.6	116.6	120.1	121.7
NPDES – Industrial	0.2	0.3	0.2	0.2	0.1	0.3	0.6	1.0	1.2	0.5
Wet Weather UPST Pour Point	2.9	7.6	7.6	6.9	4.4	77.6	201.6	203.2	184.9	118.1
OOS Point Source										
OOS Wet Weather										
Total NPDES UPST Pour Point	570.7	648.9	650.0	650.8	631.7	3334.4	3599.9	3295.4	3569.7	3556.3
HSTS UPST Pour Point	47.3	47.3	47.3	47.3	47.3	462.4	462.4	462.4	462.4	462.4
Load @ Pour Point	1394.8	1652.4	1393.9	1112.2	1476.0	14609.1	17621.0	15273.1	11769.5	17864.5
NPS UPST Pour Point	776.8	956.1	696.6	414.1	797.0	10812.3	13558.8	11515.3	7737.4	13845.7
Downstream of Pour Point										
NPDES 1 – Municipal ≥1.0 mgd	25.9	27.6	28.8	22.3	25.5	216.0	253.0	242.7	221.2	196.4
NPDES 2 – Municipal 0.1-1.0 mgd	6.3	6.5	6.1	6.6	6.1	43.3	47.9	43.6	50.1	48.0
NDPES 3 – Municipal <0.1 mgd	5.8	5.8	5.4	5.9	5.6	57.9	50.0	47.8	56.1	59.4
NPDES – Industrial	13.9	15.5	19.9	18.7	20.2	9.5	8.4	29.1	13.2	14.6
Wet Weather DST Pour Point	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total NPDES DST Pour Point	51.9	55.4	60.2	53.4	57.5	326.6	359.3	363.2	340.5	318.3
HSTS DST Pour Point	32.8	32.8	32.8	32.8	32.8	320.0	320.0	320.0	320.0	320.0
NPS DST Pour Point	537.5	661.6	482.0	286.5	551.5	7481.6	9382.0	7968.1	5353.9	9580.6
Totals										
HSTS	80.1	80.1	80.1	80.1	80.1	782.5	782.5	782.5	782.5	782.5
Total NPDES	622.6	704.3	710.2	704.2	689.2	3661.0	3959.2	3658.6	3910.3	3874.6
NPS Total	1314.2	1617.7	1178.6	700.6	1348.5	18293.9	22940.8	19483.4	13091.3	23426.3
Total Load	2,017	2,402	1,969	1,485	2,118	22,737	27,682	23,924	17,784	28,083
% HSTS	4%	3%	4%	5%	4%	3%	3%	3%	4%	3%
% NPDES	31%	29%	36%	47%	33%	16%	14%	15%	22%	14%
% of NPDES – Municipal ≥ 1.0 mgd	89.0%	89.0%	89.1%	89.0%	88.6%	84.3%	81.6%	80.7%	82.0%	82.8%
% of NPDES – Municipal 0.1-1.0 mgd	5.2%	4.8%	4.4%	4.6%	5.2%	8.6%	8.7%	8.4%	8.4%	9.1%
% of NPDES – Municipal <0.1 mgd	3.0%	3.0%	2.6%	2.7%	2.7%	4.7%	4.3%	4.5%	4.5%	4.7%
% of NPDES – Industrial	2.3%	2.2%	2.8%	2.7%	3.0%	0.3%	0.2%	0.8%	0.4%	0.4%
% of NPDES – Wet Weather	0.5%	1.1%	1.1%	1.0%	0.6%	2.1%	5.1%	5.6%	4.7%	3.0%
% NPS	65%	67%	60%	47%	64%	80%	83%	81%	74%	83%
Yield UPST Pour Point (lb/acre)	0.70	0.86	0.62	0.37	0.71	9.68	12.13	10.31	6.92	12.39
Per Capita Yield (lb/person)	0.80	0.89	0.90	0.89	0.88	5.06	5.40	5.05	5.34	5.30

Table B9 — Summary of loading components for calculating the nutrient mass balance in the Muskingum River watershed.

Source	TP Load (mta)					TN Load (mta)				
	wy13	wy14	wy15	wy16	wy17	wy13	wy14	wy15	wy16	wy17
Upstream of Pour Point										
NPDES 1 – Municipal ≥1.0 mgd	526.3	456.1	461.0	440.6	339.7	2782.7	2941.3	2563.9	2436.9	2416.3
NPDES 2 – Municipal 0.1-1.0 mgd	53.3	53.0	50.5	50.8	56.3	364.9	405.0	356.5	361.4	385.0
NDPES 3 – Municipal <0.1 mgd	9.6	10.3	10.4	7.5	9.4	91.2	93.2	94.7	45.0	85.2
NPDES – Industrial	37.9	18.4	21.1	10.7	9.2	18.2	18.6	20.1	23.9	29.9
Wet Weather UPST Pour Point	0.2	0.6	1.0	0.7	0.9	5.6	16.7	25.8	18.9	23.4
OOS Point Source										
OOS Wet Weather										
Total NPDES UPST Pour Point	627.4	538.5	544.0	510.4	415.5	3262.5	3474.8	3061.0	2886.2	2939.7
HSTS UPST Pour Point	120.9	120.9	120.9	120.9	120.9	1272.9	1272.9	1272.9	1272.9	1272.9
Load @ Pour Point	1270.8	1543.4	1464.4	852.7	1243.2	17488.0	20687.1	16877.0	11812.0	17515.3
NPS UPST Pour Point	522.5	884.0	799.5	221.4	706.8	12952.6	15939.5	12543.1	7653.0	13302.8
Downstream of Pour Point										
NPDES 1 – Municipal ≥1.0 mgd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NPDES 2 – Municipal 0.1-1.0 mgd	1.5	1.7	1.2	1.1	1.3	12.2	14.8	15.4	11.9	13.7
NDPES 3 – Municipal <0.1 mgd	0.2	0.5	0.3	0.2	0.1	1.5	0.9	1.8	1.1	1.7
NPDES – Industrial	0.1	0.1	0.1	0.1	0.1	0.1	1.6	2.9	1.8	1.7
Wet Weather DST Pour Point	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total NPDES DST Pour Point	1.8	2.3	1.5	1.5	1.5	13.8	17.2	20.1	14.8	17.1
HSTS DST Pour Point	10.2	10.2	10.2	10.2	10.2	107.9	107.9	107.9	107.9	107.9
NPS DST Pour Point	43.9	74.3	67.2	18.6	59.4	1089.3	1340.5	1054.8	643.6	1118.7
Totals										
HSTS	131.2	131.2	131.2	131.2	131.2	1380.7	1380.7	1380.7	1380.7	1380.7
Total NPDES	629.2	540.8	545.5	511.8	417.0	3276.3	3492.0	3081.0	2900.9	2956.9
NPS Total	566.4	958.3	866.8	240.0	766.2	14041.9	17280.0	13598.0	8296.6	14421.5
Total Load	1,327	1,630	1,543	883	1,314	18,699	22,153	18,060	12,578	18,759
% HSTS	10%	8%	9%	15%	10%	7%	6%	8%	11%	7%
% NPDES	47%	33%	35%	58%	32%	18%	16%	17%	23%	16%
% of NPDES – Municipal ≥ 1.0 mgd	83.7%	84.3%	84.5%	86.1%	81.5%	84.9%	84.2%	83.2%	84.0%	81.7%
% of NPDES – Municipal 0.1-1.0 mgd	8.7%	10.1%	9.5%	10.1%	13.8%	11.5%	12.0%	12.1%	12.9%	13.5%
% of NPDES – Municipal <0.1 mgd	1.5%	2.0%	2.0%	1.5%	2.3%	2.8%	2.7%	3.1%	1.6%	2.9%
% of NPDES – Industrial	6.1%	3.4%	3.9%	2.1%	2.2%	0.6%	0.6%	0.7%	0.9%	1.1%
% of NPDES – Wet Weather	0.0%	0.1%	0.2%	0.1%	0.2%	0.2%	0.5%	0.8%	0.7%	0.8%
% NPS	43%	59%	56%	27%	58%	75%	78%	75%	66%	77%
Yield UPST Pour Point (lb/acre)	0.24	0.41	0.37	0.10	0.33	6.01	7.40	5.82	3.55	6.18
Per Capita Yield (lb/person)	0.87	0.77	0.78	0.74	0.63	5.34	5.59	5.12	4.91	4.98

Appendix C - Summary of Initiatives to Address Nutrients and Harmful Algal Blooms

Recognizing that Ohio's watersheds provide a significant amount of nutrients to Lake Erie and that its communities are bearing the brunt of algal bloom impacts, Ohio launched a series of initiatives at the state level in 2010 and has expanded the scope and scale of implementation, developed a statewide strategy, targeted funding and undertaken legislative action to address the problem. As part of the more than $3 billion Ohio has invested comprehensively in the Lake Erie watershed, more than $150 million was made available starting in 2014 to help to public water systems keep drinking water safe and wastewater facilities reduce the amount of phosphorus they discharge into the Lake Erie watershed. In addition, Ohio continues to target millions of dollars to support local health departments to find and fix faulty residential septic systems that are contributing nutrients to Ohio waters.

The following is a list of several state-led and statewide water quality improvement activities underway to address nutrients and harmful algal blooms.

1. **Statewide Nutrient Reduction Strategy:** Ohio's environmental, agricultural and natural resource agencies worked together to create a statewide strategy to reduce nutrient loading to streams and lakes, including Lake Erie. The strategy was submitted to U.S. EPA Region 5 in 2013. Ohio EPA updated the strategy in 2016 to address gaps identified through U.S. EPA's review. The strategy and more information are available at *epa.ohio.gov/dsw/wqs/NutrientReduction.aspx*.

2. **Water Quality Bill:** Senate Bill 1 became effective July 3, 2015, requires major publicly owned treatment works (POTWs) to conduct technical and financial capability studies to achieve 1.0 mg/L total phosphorus; establishes regulations for fertilizer or manure application for persons in the western basin[3]; designates the director of Ohio EPA as coordinator of harmful algae management and response and requires the director to implement actions that protect against cyanobacteria in the western basin and public water supplies; prohibits the director of Ohio EPA from issuing permits for sludge management that allow placement of sewage sludge on frozen ground; and prohibits the deposit of dredged material in Lake Erie on or after July 1, 2020, with some exceptions.

3. **Agriculture Water Quality Bill**: SB 150, effective August 21, 2014, requires that beginning September 31, 2017, fertilizer applicators must be certified and educated on the handling and application of fertilizer and authorizes a person who owns or operates agricultural land to develop a voluntary nutrient management plan or request that one be developed for him or her.

4. **State Budget Bill**: HB 64, effective June 30, 2015, requires the development of a biennial report on mass loading of nutrients delivered to Lake Erie and the Ohio River from Ohio's point and nonpoint sources. This requirement can be found in the Ohio Revised Code at *codes.ohio.gov/orc/6111.03v1*.

"Western basin" is defined in this Senate Bill as consisting of the following 11 watersheds: Ottawa watershed, HUC 04100001; River Raisin watershed, HUC 04100002; St. Joseph watershed, HUC 04100003; St. Mary's watershed, HUC 04100004; Upper Maumee watershed, HUC 04100005; Tiffin watershed, HUC 04100006; Auglaize watershed, HUC 04100007; Blanchard watershed, HUC 04100008; Lower Maumee watershed, HUC 04100009; Cedar-Portage watershed, HUC 04100010; and Sandusky watershed, HUC 04100011.

5. **Great Lakes Restoration Initiative Demonstration and Nutrient Reduction Projects:** Nine grants totaling more than $13.9 million were awarded to Ohio. Highlights include: installation of the first two saturated buffer installed in Ohio; installation of approximately 70 controlled drainage structures; development of 52 whole farm conservation plans; planting of more than 9,000 acres of cover crops; installation and planting of 50 acres of reconstructed or restored wetlands; restoration of 3,500 linear feet of stream and 500 feet of streambank stabilization; installation of 4,400 feet of two-stage ditches; installation of rain gardens and vegetated infiltration basins in the Toledo area; and completion of 29 storm water, wetland and stream restoration projects in Cuyahoga County.

6. **Ohio Clean Lakes Initiative:** In 2012 the Departments of Natural Resources, Agriculture and Ohio EPA created the Ohio Clean Lakes Initiative. The Ohio General Assembly provided more than $3.5 million for projects to reduce nutrient runoff in the Western Lake Erie Basin beginning in 2013.

7. **Healthy Lake Erie Fund**: In 2014 the Ohio General Assembly, provided $10 million to the Healthy Lake Erie Fund to reduce the open lake placement of dredge material into Lake Erie. These sediments often contain high levels of nutrients or other contaminants so finding alternative use or disposal options is a priority.

8. **Western Basin of Lake Erie Collaborative Plan:** This agreement between Ohio, Michigan and Ontario served as a precursor to the Great Lakes Water Quality Agreement Domestic Action Plan. The Collaborative established an implementation plan with the goal to achieve a 40% reduction for total and dissolved reactive phosphorus from entering Lake Erie by 2025.

9. **Ohio's Domestic Action Plan for Lake Erie:** The State of Ohio's Domestic Action Plan expanded upon the *Collaborative Implementation Plan* and was submitted to U.S. EPA on February 7, 2018. The commitment to meet the Collaborative Agreement phosphorus reduction goals of 20 percent by 2020 and 40 percent by 2025 was also incorporated into this plan. The plan is not intended to static but to be revised following the adaptive management philosophy. The plan is available at *lakeerie.ohio.gov/LakeEriePlanning/OhioDomesticActionPlan2018.aspx*.

10. **Directors' Agricultural Nutrients and Water Quality Working Group:** A collaborative working group consisting of experts from Ohio EPA, ODA and ODNR developed the group's 2012 report, which contains a number of recommendations to be implemented during the next several years. For example, the report recommends ways for farmers to better manage fertilizers and animal manure and also provides the state with the means to assist farmers in the development of nutrient management plans and to exert more regulatory authority over the farmers who are not following the rules. The report is available at
agri.ohio.gov/topnews/waterquality/docs/FINAL_REPORT_03-09-12.pdf.

11. **Ohio Lake Erie Phosphorus Task Force 2**: The Task Force, which includes participants from Ohio EPA, ODA and ODNR, came together in 2012 to build on its previous work and make recommendations for improving water quality in the Lake Erie watershed. The task force finalized a report in 2014 recommending a 40% reduction for total and dissolved reactive phosphorus. The report is available at
lakeerie.ohio.gov/Portals/0/Reports/Task_Force_Report_October_2013.pdf.

12. **Ohio Point Source and Urban Runoff Workgroup:** Businesses, municipalities and Ohio EPA came together to initiate the "Point Source and Urban Runoff Workgroup" in 2012 to identify actions that can be taken immediately to reduce phosphorus loadings from WWTPs, industrial discharges and urban storm water. The group's full report is available at
epa.ohio.gov/portals/35/documents/point_source_workgroup_report.pdf.