Total Maximum Daily Loads for the Sandusky River (lower) and Bay Tributaries Watershed

Division of Surface Water
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Cover photo: Wolf Creek at Township Line Rd., Sandusky County, Ohio.

Sandusky River and Bay Tributaries Nutrient and Sediment TMDLs

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Abbreviations and Acronyms

ALU	aquatic life use
BADCT	best available demonstrated control technology
CAFF	concentrated animal feeding facility
CAFO	concentrated animal feeding operation
CSO	combined sewer overflow
CSS	combined sewer system
CWA	Clean Water Act
CWH	coldwater habitat
DMR	discharge monitoring report
ECBP	Eastern Corn Belt Plain
HELP	Huron/Erie Lake Plain
HSG	hydrologic soil group
HSTS	household sewage treatment systems
HUC	hydrologic unit code
IBI	Index of Biotic Integrity
ICI	Invertebrate Community Index
LA	load allocation
Lake Erie LaMP	Lake Erie Lake Management Plan
LDCs	load duration curves
LID	low impact design
LRAU	large river assessment unit
LRW	limited resource waters
LTCP	long term control plan
MWH	modified warmwater habitat
MIwb	Modified Index of well-being
NCWQR	National Center for Water Quality Research
NPDES	National Pollutant Discharge Elimination System
OAC	Ohio Administrative Code
ODH	Ohio Department of Health
Ohio EPA	Ohio Environmental Protection Agency
PDWS	public drinking water supply
QHEI	Qualitative Habitat Evaluation Index
RM	river mile
SRP	soluble reactive phosphorus
SRWC	Sandusky River Watershed Coalition
SSO	sanitary sewer overflow
SWAT	Soil and Water Assessment Tool
TMACOG	Toledo Metropolitan Area Council of Governments
TMDL	total maximum daily load
TSS	total suspended solids
USCB	United States Census Bureau (Department of Commerce)
U.S. EPA	United States Environmental Protection Agency
WAU	watershed assessment unit
WLA	wasteload allocation
WRCC	Western Regional Climate Center
WPC	water pollution control
WWH	warmwater habitat
WWTP	wastewater treatment plant

Units of Measure

gpd	gallons per day
lbs/d	pounds per day
mg/L	milligrams per liter
µg/L	microgram per liter
°F	degrees Fahrenheit

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Executive Summary

The Sandusky basin is in northern Ohio and drains to Lake Erie, encompassing approximately 1,827 square miles. Tributaries to Sandusky Bay and frontal Lake Erie, tributaries to the Sandusky River (lower), and the Sandusky River (lower) mainstem are impaired for their designated aquatic life uses by nutrients and sediment. The Sandusky River (lower) mainstem is also impaired for its public drinking water supply use by nitrates. The recreation uses were impaired throughout the project area.

The Clean Water Act and U.S. Environmental Protection Agency (U.S. EPA) regulations require that states develop Total Maximum Daily Loads (TMDLs) for waters that the states list as impaired on their section 303(d) lists. The TMDL and water quality restoration planning process involves several steps including watershed characterization, target identification, source assessment, and allocation of loads.

This document presents the results of a TMDL study for the tributaries to Sandusky Bay, tributaries to the Sandusky River (lower), and the Sandusky River (lower) mainstem, including a summary of available water quality data from the biological studies and water quality investigations conducted on the tributaries. Valuable background information is provided in the technical support documents (Ohio Environmental Protection Agency [Ohio EPA] 2010a, 2011). This document summarizes results for parameters and factors that could contribute to the impairment of biological communities.

Total phosphorus, nitrate plus nitrite, and total suspended solids TMDLs were developed at 24 sites in the basin (Figure 1) to address 16 impaired watershed assessment units (WAUs) and two impaired large river assessment units (LRAUs). Thirty-six load duration curves were generated using Soil and Water Assessment Tool (SWAT) model flow output and pollutant targets selected from *Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams* (Ohio EPA 1999) and Ohio's drinking water criterion for nitrates.

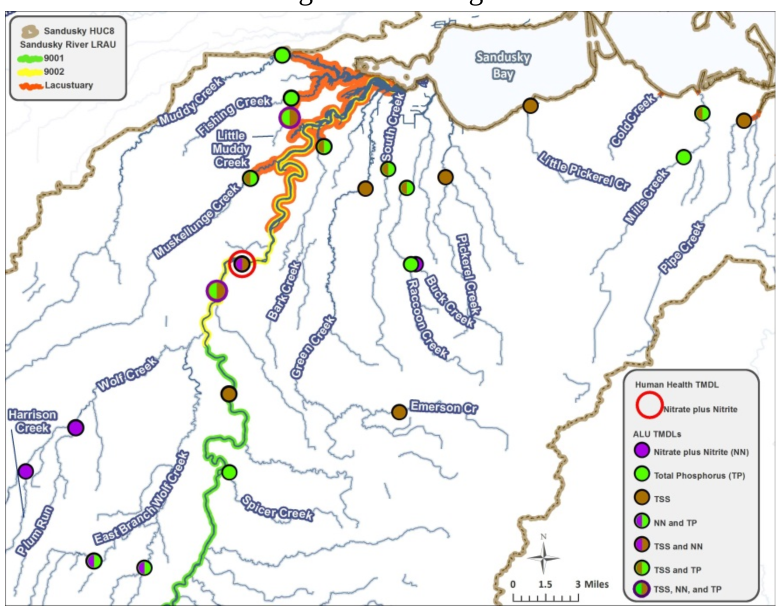


Figure 1. TMDLs in the project area.

Significant reductions are necessary to achieve TMDLs. Where reductions are necessary on the tributaries to Sandusky Bay and tributaries to the Sandusky River (lower), total phosphorus reductions ranged from 6 percent to 98 percent; nitrate plus nitrite, 22 percent to 99 percent; and TSS, 5 percent to 93 percent. Reductions on the Sandusky River (lower) for total phosphorus ranged from 30 percent to 60 percent; nitrate plus nitrite, 28 percent to 74 percent; and TSS, 20 percent to 89 percent.

Implementation of the TMDLs will be accomplished through the National Pollutant Discharge Elimination System program for permitted point sources and through application of best management practices (BMPs) to address agricultural and urban runoff. Agricultural BMPs will focus upon four management strategies for: uplands, livestock, drainage waterways, and riparian corridors. A detailed watershed implementation plan will be developed in a separate report in 2014.

1 Introduction

The Sandusky basin is in northern Ohio and drains to Lake Erie, encompassing approximately 1,827 square miles. The Sandusky basin consists of one 8-digit hydrologic unit (04100011) that is further subdivided into 14 10-digit hydrologic units (Figure 2). The Sandusky basin was subdivided by the Ohio Environmental Protection Agency (Ohio EPA) into three areas—the Sandusky River (upper) watershed, Sandusky River (lower) watershed, and Sandusky Bay tributaries[1]. This TMDL report addresses two of the Sandusky basin subdivisions: the Sandusky River (lower) watershed and Sandusky Bay tributaries, which encompass 870 square miles.

In 2001, Ohio EPA evaluated the biological health and water quality of the Sandusky River (upper) watershed (see Ohio EPA 2003). The results of the 2001 survey showed impairments to the Sandusky River (upper) watershed that were later addressed through total phosphorus, sediment, and bacteria TMDLs (Ohio EPA 2004).

In 2009, Ohio EPA evaluated the Sandusky River (lower) watershed and Sandusky Bay tributaries (see Ohio EPA 2010a, 2011). The results of the 2009 surveys indicated that tributaries to both the Sandusky River (lower) and Sandusky Bay were impaired for their designated aquatic life uses (ALUs) and recreation uses (Ohio EPA 2010a, 2011). Ohio EPA found the Sandusky River LRAUs to be impaired for the designated ALUs, recreation uses, and public drinking water supply (PDWS) uses. The impaired WAUs (equivalent to 12-digit hydrologic units) and LRAUs were placed on Ohio’s Clean Water Act section 303(d) list.

The Clean Water Act and U.S. Environmental Protection Agency (U.S. EPA) regulations require that states develop TMDLs for waters on the section 303(d) lists. The TMDL and water quality restoration planning process involves several steps including watershed characterization, target identification, source assessment, allocation of loads, and prioritization of implementation activities. TMDL targets and allocations are derived from the water quality standards (designated uses, narrative and numeric criteria),. The TMDL allocations are separated into waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources.

The TMDL project area for this study is defined as the (1) tributaries to Sandusky Bay and frontal Lake Erie[2], (2) tributaries to the Sandusky River (lower), and (3) the Sandusky River (lower) mainstem. The Sandusky River (lower) mainstem is composed of two LRAUs. While Lake Erie is not within the project area, TMDL implementation within the project area is anticipated to help improve water quality in Lake Erie’s Western Basin. TMDLs for aquatic life and public drinking water supply uses are developed by Tetra Tech and presented in this report with supporting information found in appendices A through L. Recreation use impairments are addressed by Ohio EPA and that work is presented in Appendix M. The overall goals and objectives in developing the TMDLs for this project area are as follows:

- Assess the water quality within project area and identify key issues associated with the impairments and potential pollutant sources.
- Use the available research and data to identify the water quality conditions that will result in all streams fully supporting their designated uses.

[1] The Sandusky Bay tributaries area was separated from the Sandusky River (lower) watershed area to allow Ohio EPA to better coordinate with the Ohio Department of Health (ODH) in a study in eastern Sandusky County.
[2] Ohio EPA uses the term “frontal Lake Erie” to describe small tributaries to Lake Erie.

- Prepare a final TMDL report that meets the requirements of the Clean Water Act and provides information to the stakeholders that can be used to facilitate implementation activities and improve water quality.
- Provide a framework implementation plan to address the necessary load reductions, with a more detailed Implementation Plan to be developed shortly after finalization of the TMDL.

The results of the TMDL process for the lower Sandusky project area are documented in this report.

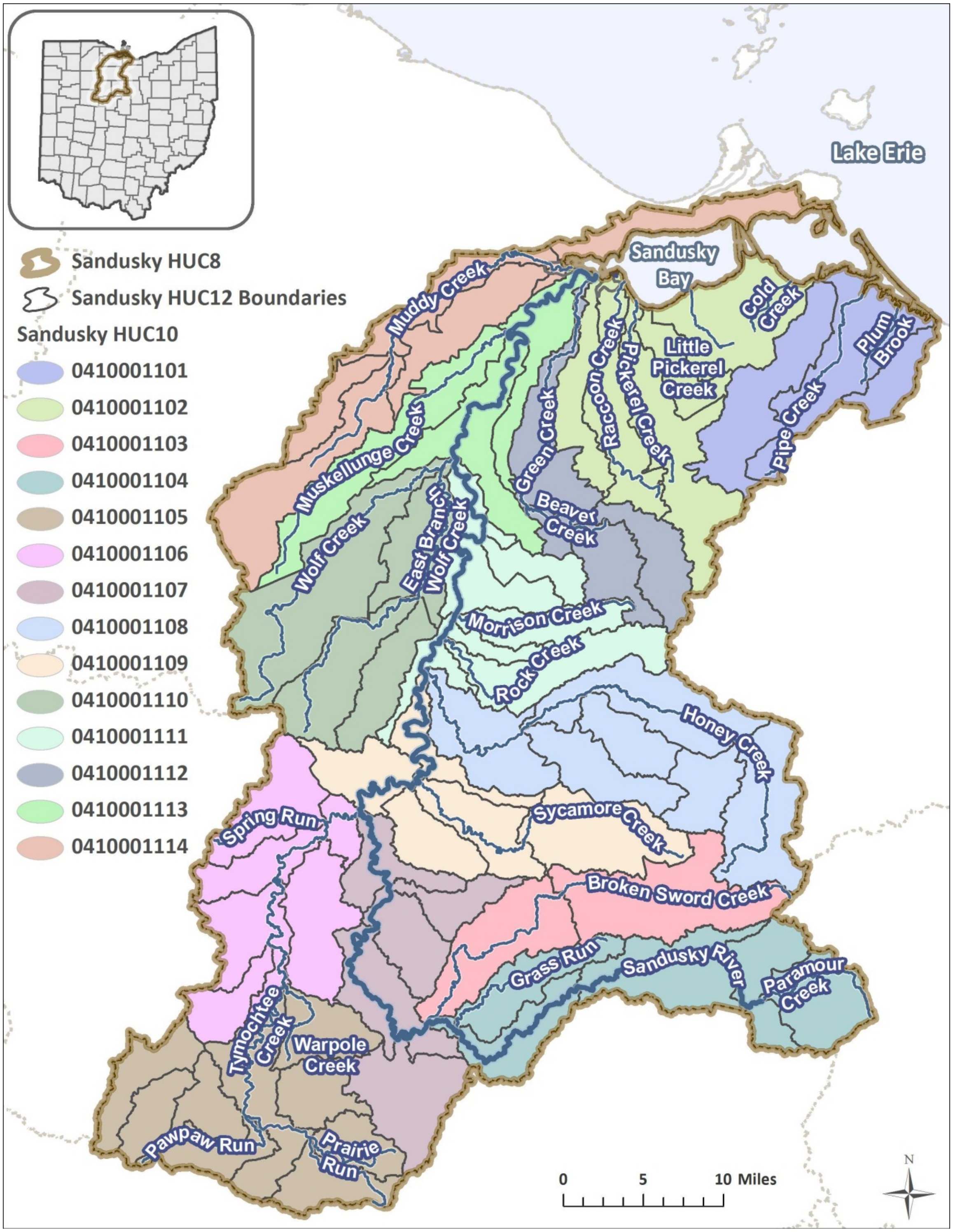


Figure 2. 10-digit hydrologic units in the Sandusky basin.

2 Water Quality Standards and Impairments

This section summarizes the applicable water quality standards for waters in the TMDL project area (Table 1) and provides information on the waterbody impairments. The water quality standards for Ohio are presented in Ohio Administrative Code (OAC) in chapter *3745-1*. For a full analysis of the impairments, see the *Biological and Water Quality Study of the Sandusky Bay Tributaries, 2009, Watershed Assessment Units 0410001 101, 102, 112, 113, and 114, Erie, Sandusky, and Seneca Counties* (Ohio EPA 2010a) and *2009 Biological and Water Quality Study of the Lower Sandusky River Watershed, Including Wolf Creek, Muskellunge Creek, and Muddy Creek, Sandusky and Seneca Counties* (Ohio EPA 2011).

Table 1. Ohio water quality standards

Component [a]	Description
Designated Use [b]	Designated use reflects how the water could be used by humans and how well it supports a biological community. Every water in Ohio has a designated use or uses; however, not all uses apply to all waters (i.e., they are waterbody specific).
Numeric Criteria	Chemical criteria represent the concentration of a pollutant that can be in the water and still protect the designated use of the waterbody. Biological criteria indicate the health of the in-stream biological community by using one of three indices: ▪ Index of Biotic Integrity (IBI) (measures fish community health). ▪ Modified Index of well-being (MIwb) (measures fish community health). ▪ Invertebrate Community Index (ICI) (measures benthic macroinvertebrate community health).
Narrative Criteria	These are the general water quality criteria that apply to all surface waters. These criteria state that all waters must be free from sludge; floating debris; oil and scum; color- and odor-producing materials; substances that are harmful to human, animal or aquatic life; and nutrients in concentrations that can cause algal blooms.
Antidegradation Policy	This policy establishes situations under which Ohio EPA may allow new or increased discharges of pollutants, and requires those seeking to discharge additional pollutants to demonstrate an important social or economic need.

Notes

a. Ohio's water quality standards are available at http://epa.ohio.gov/dsw/wqs/index.aspx

b. According to *OAC 3745-1-07(A)(1)* each waterbody is assigned a designated use. Any streams in Ohio that are undesignated still must attain the chemical criteria associated with the warmwater habitat designation. There is no similar protection for recreation use.

2.1 Designated Uses

Beneficial use designations define the existing and potential uses of a waterbody. They consider the use and value of water for public water drinking supplies, protection and propagation of aquatic life, recreation both in and on the water, human health (fish tissue), agricultural and industrial purposes. Each Ohio waterbody is assigned one or more ALU designations, one or more water supply designations, a recreational designation, and a human health designation. Beneficial uses for the Sandusky basin were promulgated into *OAC-3745-1-12*. The designated ALUs and PDWS uses for waterbodies in the project area are presented in Table A-1 and Table A-2 in Appendix A; warmwater habitat (WWH) is the most common ALU for waterbodies in the Sandusky basin.

2.2 Numeric Criteria

Numeric criteria are based on concentrations of pollutants and degree of aquatic life toxicity allowable in a waterbody without adversely affecting its beneficial uses. They consist of biological criteria, chemical criteria, and whole effluent toxicity levels. The criteria applicable to the project area that are pertinent to the TMDL project are presented in the following sections.

2.2.1 Biological Criteria

The biological water quality criteria (also referred to as biocriteria) in Ohio are numeric and vary by ALU designation and level III ecoregion[3]. ALU designations in Ohio include coldwater habitat (CWH), exceptional warmwater habitat, seasonal salmonid habitat, warmwater habitat (WWH), modified warmwater habitat (MWH), and limited resource waters (LRW). The ability of a waterbody to meet its ALU designation is based primarily on the scores it receives on three community indices, as applicable: the Index of Biological Integrity (IBI), the Modified Index of well-being (MIwb), and the Invertebrate Community Index (ICI). The IBI and MIwb are based on the composition and health of the fish community, and the ICI is based on the composition of the macroinvertebrate community.

Most of the named and evaluated waterbodies in the TMDL project area are designated WWH; a few waterbodies in the project area are designated LRW or MWH. The applicable biocriteria for the project area are shown in Table 2.

Ohio does not have biocriteria for LRW as these waters are substantially degraded and the potential for recovery is minimal (*OAC-3745-1-07(B)(1)(g)*). Note that the numeric biological criteria are not applicable to streams designated as CWH. CWH attainment is determined by evaluating the presence and quality of coldwater fish (e.g., mottled sculpin, brook stickleback, redside dace), additional fish species (e.g., longnose dace, American brook lamprey, central mudminnow), and coldwater macroinvertebrates.

Table 2. Biocriteria for EOLP and HELP

Index	Size	ECBP			HELP		
		WWH	MWH-CM	MWH-I	WWH	MWH-CM	MWH-I
IBI	Boating	42	24	30	34	20	22
	Wading	40	24	--	32	22	--
	Headwaters	40	24	--	28	20	--
MIwb	Boating	8.5	5.8	6.6	8.6	5.7	5.7
	Wading	8.3	6.2	--	7.3	5.6	--
ICI	All [a]	36	22	--	34	22	--

Source: Table 7-15 of *OAC-3745-1-07*
Notes
ECBP = eastern corn belt plain; HELP = Huron/Erie lake plain; IBI = Index of Biotic Integrity; ICI = Invertebrate Community Index; MIwb = Modified Index of Well-being; MWH-CM = modified warmwater habitat due to channel modification; MWH-I = modified warmwater habitat due to impoundment; WWH = warmwater habitat.
a. ICI scoring using the modified Hester-Dendy artificial substrate samplers. See Table 7-15 of *OAC-3745-1-07*.

Finally, Ohio EPA has developed lacustuary benchmarks for the IBI, MIwb, and ICI for small and large rivers (Table 3). The benchmarks have not been adopted into rules and are not considered to be water

[3] North America is delineated into four levels of nested ecoregions. Level I ecoregions are the largest and allow for coarse, continental analyses while level IV ecoregions are the smallest and allow for fine, localized analyses (Commission for Environmental Cooperation 1997). Ohio is in the *Eastern Temperature Forest* level I ecoregion (#8). Portions of four level II ecoregions are in Ohio: *Mixed Wood Plains* (#8.1), *Central USA Plains* (#8.2), *Southeastern USA Plains* (#8.3), and *Ozark Ouachita-Appalachian Forests* (#8.4). The Sandusky basin is in the *Central USA Plains* level II ecoregion (#8.1). Portions of six level III ecoregions are in Ohio: *Eastern Great Lakes and Hudson Lowlands* (#8.1.1 and #61), *Erie Drift Plain* (#8.1.10 and #61), *Huron/Erie Lake Plains* (#8.2.2 and #57), *Eastern Corn Belt Plains* (#8.2.4 and #55), *Interior Plateau* (#8.3.3 and #71), and *Western Allegheny Plateau* (#8.4.3 and #70). The Sandusky basin is in the *Huron/Erie Lake Plains* (#8.2.2) and *Eastern Corn Belt Plains* (#8.2.4) level III ecoregions.

quality standards or numeric criteria. Ohio EPA uses lacustuary benchmarks along with physical habitat quality, and water and sediment chemistry to evaluate ALU attainment in lacustuaries. The lacustuary benchmarks are presented here because they were used to evaluate attainment in the Sandusky River (lower).

Table 3. Lacustuary benchmarks

Index	Size	Excellent	Good	Fair	Poor	Very Poor
IBI	Boating	50	42	31	17	<17
MIwb	Boating	10	8.6	5.6	2.8	<2.8
ICI	All [a]	52	42	25	12	<12

Source: Ohio EPA 2010a, 2011, undated
Note: Lacustuary benchmarks are for small and large rivers and are not water quality standards.

2.2.2 Chemical Criteria

While Ohio has numeric criteria for pollutants of concern that are impairing waterbodies in the project area (e.g., *E. coli* for bacteria impairments to the recreation uses), the scope of most of the TMDL report (including Appendices A through L) is limited to ALU impairments caused by nutrient eutrophication and sedimentation/siltation and PDWS impairments caused by nitrates. Recreation use impairments caused by bacteria are presented in Appendix M.

The nitrate plus nitrite (total, as nitrogen) numeric criterion of the protection of human health is 10 milligrams per liter for all waterbodies in the Lake Erie basin located within 500 yards of a drinking water supply intake (*OAC-3745-1-33(C)(1)(a)*). The nitrate plus nitrite numeric criteria for the protection of human health are applicable within 500 yards of the drinking water intakes for the following cities in the project area:

- Bellevue (Snyder Ditch at river miles [RMs] 5.0 and 5.5)
- Clyde (Beaver Creek at RM 2.88; formerly on Raccoon Creek at RM 13.1)
- Fremont (Sandusky River at RM 18.02)
- Tiffin (Sandusky River at RM 41.08)

Additional drinking water intakes are located on the Sandusky River, Honey Creek, and an unnamed tributary to Brokenknife Creek. These waterbodies are located in the upper portion of the basin and are covered by the upper Sandusky River TMDL (Ohio EPA 2004); they are outside the scope of this TMDL report.

2.3 Narrative Criteria and Guidance

Narrative criteria are the general water quality criteria that apply to all surface waters. Those criteria, promulgated in *OAC-3745-1-04*, state that all waters must be free from sludge, floating debris, oil and scum, color- and odor-producing materials, substances that are harmful to human, animal or aquatic life, and nutrients in concentrations that can cause algal blooms.

2.3.1 Nutrients

Ohio EPA does not have statewide numeric criteria for nutrients. TMDL targets are selected on the basis of evaluating reference stream data published in a technical report titled *Association between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams* (Ohio EPA 1999; referred to throughout as the *Associations* document). The document identifies ranges of concentrations for nitrate plus nitrite nitrogen and total phosphorus on the basis of observed concentrations at all sampled ecoregional reference sites. Those reference stream concentrations will be used as TMDL targets and are shown in Table 4. One of the methods that U.S. EPA recommends is basing nutrient criteria on the 75th percentile of the frequency distribution of reference streams (U.S. EPA 2000). That method was used to set the TMDL nutrient targets. While nutrient targets are not codified in Ohio's water quality standards, Ohio EPA's methodology is very rigorous and the linkage of the targets to the health of the aquatic community is well established in the *Associations* document. Targets from the *Associations* documents have been used in numerous recent TMDLs approved by U.S. EPA[4].

Table 4. Statewide-suggested nutrient targets for the protection of aquatic life

Stream class	Stream size (square miles)	Beneficial use		
		EWH	WWH	MWH
Total phosphorus concentration (mg/L)[a]				
Headwaters	< 20	0.05	0.08	0.34
Wading	20 - 200	0.05	0.10	0.28
Small river	200 - 1,000	0.10	0.17	0.25
Large river	> 1,000	0.15 [c]	0.30	0.32
Nitrate plus nitrite concentrations (mg/L)[b]				
Headwaters	< 20	0.5	1.0	1.0
Wading	20 - 200	0.5	1.0	1.6
Small river	200 - 1,000	1.0	1.5	2.2
Large river	> 1,000	1.5	2.0	2.4

Source: Ohio EPA 1999
Notes:
EWH = exceptional warmwater habitat; mg/L = milligrams per liter; MWH = modified warmwater habitat; WWH = warmwater habitat.
a. Statewide total phosphorus recommendations were generated by Ohio EPA (1999) with ANOVA analyses of statewide pooled data.
b. Statewide nitrate plus nitrite recommendations were calculated by Ohio EPA (1999) as the 75th percentile of statewide pooled reference stream data.
c. Assumes a nitrogen:phosphorus ratio that is greater than or equal to10:1.

2.3.2 Habitat

Habitat data are used to evaluate WAUs impaired by direct habitat alteration and sedimentation/siltation. The Qualitative Habitat Evaluation Index (QHEI) is a quantitative expression of a qualitative, visual assessment of habitat in free-flowing streams and was developed by Ohio EPA to assess available habitat for fish communities (Rankin 1989, 1995). While all the metrics are useful for assessing physical habitat condition, only a few metrics are useful for directly assessing sedimentation and siltation. The QHEI is a composite score of six physical habitat categories:

- Substrate
- In-stream cover
- Channel morphology
- Riparian zone and bank erosion
- Pool/glide and riffle/run quality
- Gradient

Each of those categories is subdivided into specific attributes that are assigned a point value reflective of the attribute's effect on the aquatic life. Highest scores are assigned to the attributes correlated to streams with high biological diversity and integrity and lower scores are progressively assigned to less desirable

[4] The following are examples of recent Ohio TMDLs that used targets from the *Associations* document (Ohio EPA 1999) and were approved by U.S. EPA Region 5: *Maumee River (Lower) Tributaries and Lake Erie Tributaries TMDL Report* (Ohio EPA 2012b), *Total Maximum Daily Loads for the Grand River (Lower) Watershed* (Ohio EPA 2012c), *Total Maximum Daily Loads for the White Oak Creek Watershed* (Ohio EPA 2009b), *Total Maximum Daily Loads for the Swan Creek Watershed* (Ohio EPA 2009a).

habitat features. A QHEI evaluation form[5] is used by a trained evaluator while at the sampling location. Each of the components is evaluated on-site, recorded on the form, the score totaled, and the data later analyzed in an electronic database.

The QHEI is a macro-scale approach that measures the emergent properties of habitat (sinuosity, pool/riffle development) rather than the individual factors that influence the properties (current velocity, depth, substrate size). The QHEI is used to evaluate the characteristics of a short stream segment, as opposed to the characteristics of a single sampling site. As such, individual sites could have poorer physical habitat because of a localized disturbance yet still support aquatic communities closely resembling those sampled at adjacent sites with better habitat, provided water quality conditions are similar. However, QHEI evaluations are segment specific and do not give a strong indication of the quality of the habitat in other stream segments.

QHEI scores can range from 12 to 100. Ohio EPA has determined appropriate QHEI target scores through statistical analysis of Ohio's statewide database of paired QHEI and IBI scores. Simple linear and exponential regressions and frequency analyses of combined and individual components of QHEI metrics in relation to the IBI were examined. The regressions indicate that the QHEI is significantly correlated with the IBI. QHEI scores of more than 75 generally indicate excellent stream habitat, scores between 60 and 75 indicate good habitat quality, and scores of less than 45 demonstrate habitat that is not conducive to WWH. Scores between 45 and 60 need separate evaluation by trained field staff to determine the stream's ALU potential.

2.3.3 Sediment Concentration

Using total suspended solids (TSS) as an indicator of sediment in the water column is fairly common and has been used in numerous TMDL reports; however, TSS concentrations can be an underestimation of sediment loads because they account only for particles small enough to remain suspended in the water column. Larger particles, such as sand and coarser particles, that could have the most influence on aquatic life and stream substrates are often not included in TSS concentrations because they usually settle out of the water column.

Ohio does not have water quality standards for TSS. However, Ohio EPA has calculated TSS statistics for reference sites throughout the HELP ecoregion that can be used to determine targets for TSS loads. Ohio EPA's evaluation of reference data includes only data collected between June 15 and October 15. Data from high-flow events as noted by field personnel or as determined from USGS gages that are excluded (Ohio EPA 1999, p. 18). The 75th percentile statistic for reference sites (non-urban, unmodified) are presented in Table 5.

Table 5. 75th percentile TSS concentrations

Stream class	Stream size (square miles)	Level III ecoregions	
		ECBP	HELP
Headwaters	< 20	14	24
Wading	20 - 200	29	24
Small river	200 - 1,000	41	58
Large river	> 1,000	46	60

Source: Ohio EPA 1999, Appendix I, p. 24
Notes
Displayed targets are the 75th percentile of reference stream data for each ecoregion and are concentrations in milligrams per liter of total suspended solids.
ECBP = Eastern Corn Belt Plain; HELP = Huron/Erie Lake Plain; mg/L = milligrams per liter

[5] The evaluation form is available at http://www.epa.ohio.gov/portals/35/documents/QHEIFieldSheet061606.pdf.

2.4 Lake Erie Targets

The Sandusky River is one of the major tributaries to Lake Erie. Though other tributaries contribute more to the lake by volume, the Sandusky River is a significant contributor of nutrients to the lake. As a result, algal blooms and anoxia/hypoxia threaten Lake Erie. Algal blooms, caused by increased nutrient loads that originally appeared in the mid-20th century, were addressed through the 1972 Great Lakes Water Quality Agreement; algal blooms began to return in the mid-1990s (Lake Erie Lake Management Plan [LaMP] 2009, 2011; Ohio EPA 2010b). Efforts in the 1970s and 1980s reduced total phosphorus loads through point source controls (Lake Erie LaMP 2009, 2011), including a 1 milligram per liter total phosphorus limit for all major (i.e., at least 1.0 MGD) point source dischargers (Ohio EPA 2010b). However, “[p]roblems resurfaced in the mid-1990s but the reasons for the resurgence of the algal blooms are much more complex than in past decades” (Lake Erie LaMP 2011, p. iii).

“In Lake Erie, phosphorus is the primary nutrient causing excessive algae and other water quality associated-impacts” and “[t]he majority of total phosphorus loading to Lake Erie is the result of inputs from a few major tributaries” including the Sandusky River (Lake Erie LaMP 2011, p. 3 and 10). While 80 percent of Lake Erie total inflow is through the Detroit River, only 16 percent of the total phosphorus load to Lake Erie comes from the Detroit River (Lake Erie LaMP 2011, p. 10). The remaining tributaries (e.g., Maumee and Sandusky rivers in Ohio, Grand and Thames rivers in Ontario) contribute 9 percent of the total inflow to Lake Erie (Lake Erie LaMP 2011, p. 3). The Maumee and Sandusky rivers contain the highest concentrations of total phosphorus and soluble reactive phosphorus (SRP; or dissolved phosphorus) of the tributaries to Lake Erie (Ohio EPA 2010b, p. 18)). In the Sandusky River, total phosphorus levels tend to range from 30 micrograms per liter (μg/L) to 150 μg/L and SRP levels exceed 45 μg/L, which are high enough concentrations to lead to algal blooms (Lake Erie LaMP 2009, p. 19).

Phosphorus is the limiting nutrient in Lake Erie and algae respond to phosphorus concentration (Lake Erie LaMP 2009). The Lake Erie LaMP proposed mean annual total phosphorus targets for Lake Erie offshore and nearshore waters, coastal wetlands, and tributaries (Table 6; Lake Erie LaMP 2011, p. 13). The target for tributaries applies upstream of the lacustuary (i.e., upstream of “the zone of water near the mouth of the tributary that contains a mix of Lake Erie water and tributary water” [Lake Erie LaMP 2011, p. 13}). The target was derived from research by Environment Canada for small, agricultural watersheds and its applicability to larger watersheds has not been evaluated.

Table 6. Lake Erie and watershed targets for total phosphorus concentrations

Habitat type	Period to calculate mean total phosphorus concentration	Total phosphorus concentration (μg/L as phosphorus)
Offshore		
West Basin	spring	0.015
Central Basin	spring	0.010
East Basin	spring	0.010
Nearshore	annual ice-free period	0.020
Tributaries	annual	0.032
Coastal wetlands	one recorder per year	<0.030

Source: Lake Erie LaMP 2011, p. 13.
Note: Targets were converted to milligrams per liter for display in this table.

The Lake Erie LaMP target of 0.032 mg/L mean annual total phosphorus is presented for reference and is included in the discussions of waterbody conditions in the project area. However, the Lake Erie LaMP target was not used to develop TMDL loading capacities or to allocate loads. The total phosphorus TMDL targets are derived from the *Associations* document (Ohio EPA 1999) based upon designated ALU, drainage area, and ecoregion; TMDL targets are discussed in Section 2.3.

2.5 Impairments

Tributaries in the Sandusky basin are not attaining their designated ALUs primarily due to excessive nutrients and sediment; these waterbodies are on Ohio's 2012 Clean Water Act section 303(d) list (Ohio EPA 2012a). WAU ALU impairments are summarized in Table 7 and Figure 3 (Section A-3 in Appendix A provides more information for each ALU listing). The Sandusky River (lower) is not attaining its designated ALU due to excessive nutrients and sediment and is not attaining its designated PDWS use at the city of Fremont's water treatment plant raw water intake (see Fremont on Figure 6) due to elevated nitrate levels found in the raw (i.e., in-stream) and finished water .

The scope of the main TMDL report and appendices A through L is limited to impairments to designated ALUs and PDWS uses; recreation uses are addressed by Ohio EPA through bacteria TMDLs presented in Appendix M. TMDLs are developed to address the following causes of impairment[6]: nitrate, nutrient/eutrophication, organic enrichment (sewage), particle distribution (embeddedness), sedimentation/siltation, and total phosphorus (refer to Sections 8 for discussions of TMDL development).

Table 7. Summary of the causes of impairments in the Sandusky basin

WAU	Direct habitat alteration	Natural conditions	Nitrate	Nutrient / Eutrophication	Organic enrichment (sewage)	Other flow regime alterations	Particle Distribution (embeddedness)	Pesticides	Phosphorus	Sedimentation / Siltation
Mills Creek-Frontal Lake Erie										
01 02						X				X
01 03				X	X		X		X	X
Pickerel Creek-Frontal Sandusky Bay										
02 01		X					X			X
02 03							X			X
02 04	X			X	X		X	X	X	X
02 05				X	X		X		X	X
Wolf Creek										
10 01	X		X	X					X	
10 02			X	X					X	
10 04	X		X	X						
Rock Creek-Sandusky River										
11 05				X	X					
Green Creek										
12 02	X									X
12 03										X
Muskellunge Creek-Sandusky River										
13 01				X					X	X
13 03	X			X			X		X	X
Muddy Creek-Frontal Sandusky Bay										
14 03			X	X					X	X
14 04	X					X			X	

[6] Nutrient/eutrophication (nitrate plus nitrite or total phosphorus), organic enrichment (total phosphorus), particle distribution (TSS), and sedimentation/siltation (TSS) will be addressed with TMDLs for surrogate pollutants.

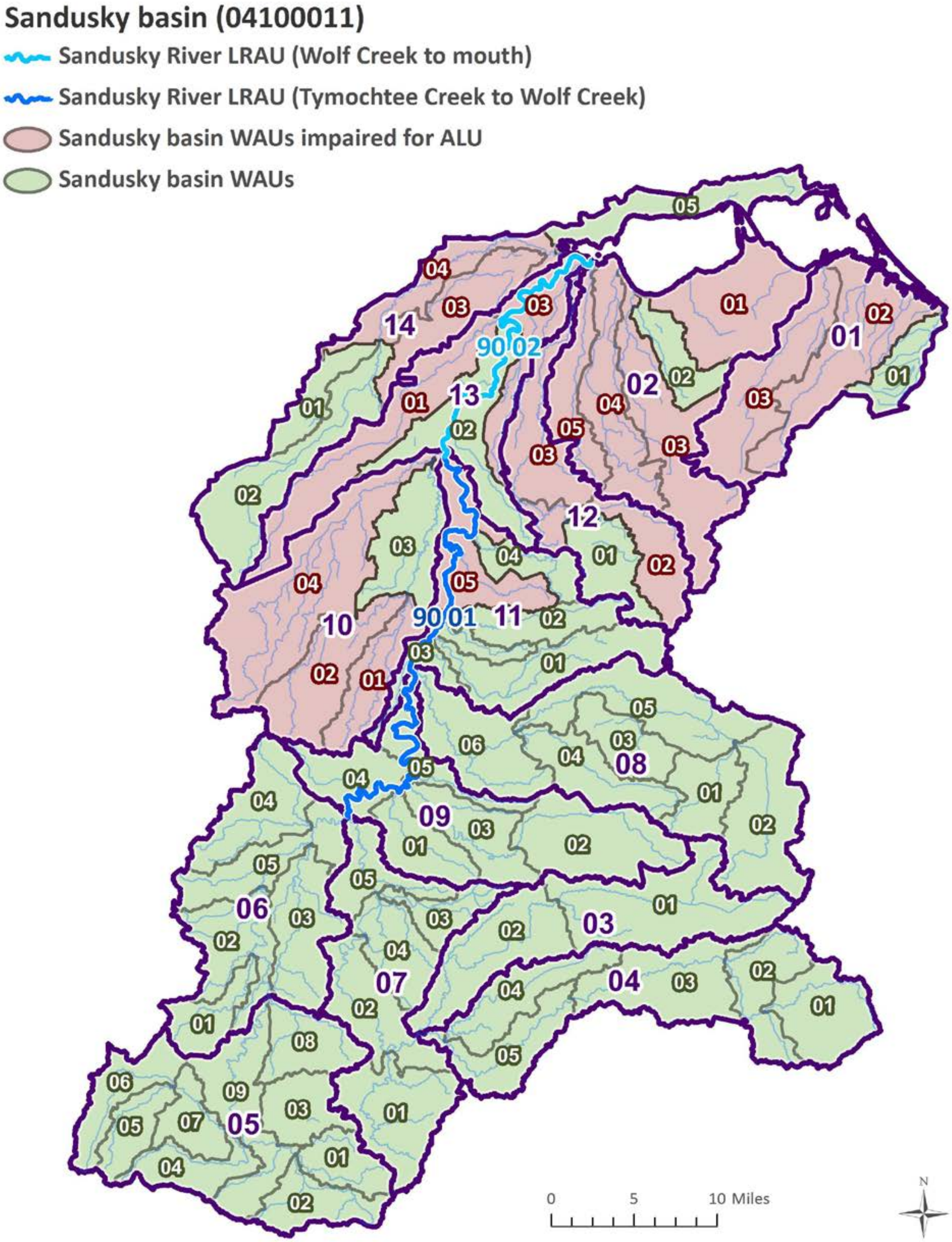


Figure 3. Assessment units in the Sandusky basin.

3 Watershed Characterization

This section characterizes the Sandusky basin with special focus upon the TMDL project area.

3.1 Lake Erie Western Basin

Lake Erie is the smallest, by volume, and shallowest of the Great Lakes. The Lake Erie basin is the most populated of the Great Lakes basins, with about one-third of the total Great Lakes basin population (Lake Erie LaMP 2011). Seventeen large metropolitan areas, including Detroit, MI; Windsor, Ontario; Toledo, OH; Cleveland, OH; and Buffalo, NY are in the Lake Erie basin (U.S. EPA 1995; see Figure 4). The lake provides drinking water to 11 million people (Lake Erie LaMP 2011). Fertile soils are located around the lake and intensely farmed, especially in northwest Ohio and southwest Ontario (U.S. EPA 1995).

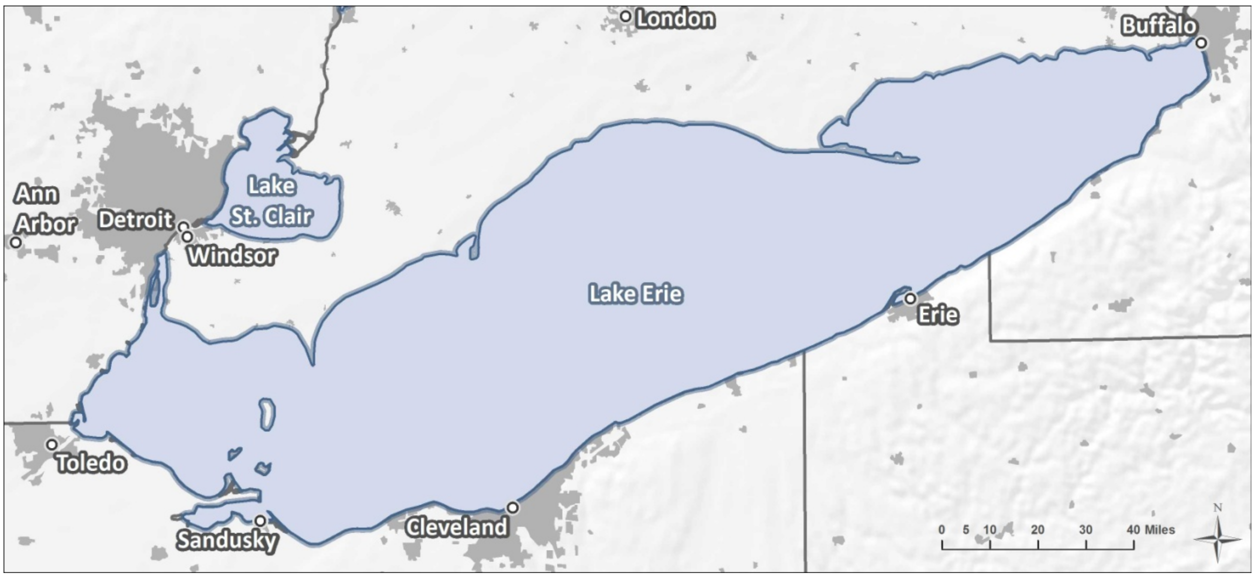


Figure 4. Lake Erie.

Lake Erie is commonly divided into three basins, which are described as follows (Lake Erie LaMP 2011):

- **Western Basin:** shallow with a mean depth of 24 feet and maximum depth of 62 feet
- **Central Basin:** average depth of 60 feet and maximum depth of 82 feet
- **Eastern Basin:** deep with an average depth of 80 feet and maximum depth of 210 feet

The water volume of the western basin is approximately one-fifth of Lake Erie (U.S.EPA 1995) but it drains about 65 percent of the Lake Erie watershed (Ohio EPA 2010b). The lake bottom of the western basin is covered with fine sediment and the western basin is turbid (Lake Erie LaMP 2011). Unlike the central and eastern basins, the western basin does not thermally stratify (Lake Erie LaMP 2011; Ohio EPA 2010b).

Ohio tributaries draining to the western basin (i.e., the Ottawa, Maumee, Toussaint, Portage, and Sandusky rivers) consist primarily of row-crop agriculture whereas tributaries draining to the central basin (i.e., the Huron, Vermillion, Black, Rocky Cuyahoga, Grand, and Ashtabula rivers) are about fairly evenly divided between row-crop agriculture, urban, and forest (Ohio EPA 2010b). The dominant land uses of the Ohio tributaries to Lake Erie is important because the majority of phosphorus loading to Lake Erie is from “storm-pulsed runoff from the landscape into the tributaries that drain to Lake Erie” (Ohio

EPA 201b, p. 35). Ohio EPA (2013, p.5) has found that 61 percent of the total phosphorus load delivered to Lake Erie is from cultivated cropland.

Additional characteristics of the Western Basin of Lake Erie with special focus upon nutrient and other water quality issues is presented in the following documents:

- *Lake Erie Binational Nutrient Management Strategy: Protecting Lake Erie by Managing Phosphorus* (Lake Erie LaMP 2011)
- *Ohio Lake Erie Phosphorus Task Force Final Report* (Ohio EPA 2010b)
- *Ohio Lake Erie Phosphorus Task Force II Final Report* (Ohio EPA 2013a)
- *Status of Nutrients in the Lake Erie Basin* (Lake Erie LaMP 2009)
- *The Great Lakes: An Environmental Atlas and Resource Book* (U.S. EPA 1995)

3.2 Previous Studies

Ohio EPA, Heidelberg University, the Sandusky River Watershed Coalition (SRWC), and other entities have thoroughly studied the Sandusky basin. This section provides a summary of selected previous work. Additional studies regarding specific topics (e.g., Heidelberg University studies of phosphorus in cropland soil) are referenced throughout this report.

3.2.1 Upper Sandusky River Watershed Biological Water Quality Study and TMDLs

In 2001, Ohio EPA collected water quality and biological samples from the WAUs and one LRAU (Tymochtee Creek to Wolf Creek) in the upper Sandusky River watershed. The agency found that many sites were not fully attaining their designated uses. The sources of impairments to ALUs included both agricultural and urban runoff as well as combined sewer overflows (CSOs) and septic systems (Ohio EPA 2003). Recreation uses were impaired by elevated fecal coliform concentrations, including 6 percent of sites exhibiting extreme levels of fecal coliform (i.e., greater than 10,000 counts per 100 mL versus an instantaneous standard of 1,000 counts per 100 mL for primary contact recreation) (Ohio EPA 2003). Finally, iron and manganese exceeded the PDWS criteria for the Sandusky River at Ella Street (RM 41.84).

Ohio EPA developed TMDLs to address impairments to ALUs and recreation uses in 2004. Total phosphorus TMDLs were developed using a load duration curve approach and an across-the-board reduction of 25 percent was set for nonpoint sources (Ohio EPA 2004). TMDLs for fecal coliform were calculated using field monitored fecal coliform data, flows from USGS gages, Ohio's water quality standards, and results from U.S. EPA's Bacteria Indicator Tool. The necessary reductions in fecal coliform loads ranged from 10 to 85 percent (Ohio EPA 2004). Habitat and sediment TMDLs were developed using deviations of median QHEI index and metric scores from monitored sites versus their targets. Habitat target deviations ranged from 3 to 53 percent and sediment target deviations ranged from 6 to 93 percent; a few sites also met their QHEI targets (Ohio EPA 2004).

3.2.2 Honey Creek and Sandusky River-Tiffin Watershed Action Plans

The National Center for Water Quality Research (NCWQR), working with the SRWC, developed the Honey Creek Watershed Action Plan (WAP) to implement the findings and recommendations of the upper Sandusky River TMDL (Ohio EPA 2004). The Honey Creek WAP summarizes the impairments to Honey Creek watershed and the TMDL report and then discusses priority best management practices (BMPs) and implementation. Key BMPs are categorized into the following areas: cropland, streamside, and in-stream (Loftus et al. 2006). Cropland BMPs, like conservation tillage, were recommended to reduce erosion and runoff while streamside BMPs like buffer strips and woody riparian buffers were recommended to trap sediments and nutrients carried in runoff from crop fields.

SRWC, working with NCWQR, developed the Sandusky River - Tiffin WAP. This WAP also addresses the results of the upper Sandusky River TMDL (Ohio EPA 2004) and also presents BMPs that can be used to implement the TMDLs (Riddle 2006)..

3.2.3 Biological and Water Quality Studies of the Lower Sandusky River and its tributaries and the tributaries to Sandusky Bay

Ohio EPA collected water quality, habitat, and biological samples from the WAUs and LRAUs in the lower Sandusky River watershed (Ohio EPA 2011) and from the tributaries to Sandusky Bay (Ohio EPA 2010a). In the lower Sandusky River watershed, excluding the Sandusky Bay tributaries, 32 percent of biological assessment sites were not fully attaining their ALUs and the impairments were caused by elevated nutrients and sedimentation from agricultural practices (Ohio EPA 2011). In the Sandusky Bay tributaries, 70 percent of biological assessment sites did not fully attain their ALUs and impairments were caused by wastewater treatment plants (WWTPs), failing household sewage treatment systems (HSTSs), livestock practices, and row crop production (Ohio EPA 2010a). Recreation uses were not attained at most locations due to CSOs, un-sewered communities, and livestock practices (Ohio EPA 2010a, 2011). With regard to agricultural practices, the agency concluded that “[t]he application of fertilizers for row crop production and subsequent runoff has led to enrichment in many waterways and, subsequently, has contributed to eutrophication of Sandusky Bay and Lake Erie” (Ohio EPA 2011, p. 4).

3.2.4 Watershed Modeling

NCWQR has collected water quality samples at three USGS gages in the Sandusky basin since 1974. This large dataset of water quality and flow has been used to develop SWAT models for the Sandusky basin in recent years. Two pertinent examples of Sandusky basin SWAT models are presented in this section.

SWAT models were developed for six watersheds in the Lake Erie basin to evaluate the SWAT model performance (Bosch et al. 2011). The authors found that “SWAT accurately predicted average stream discharge, sediment loads, and nutrient loads for the Raisin, Maumee, Sandusky, and Grand watersheds” (Bosch et al. 2011, p. 271). For the Sandusky basin, the authors’ model “showed satisfactory to strong performance” for predicting total phosphorus and “marginal” for predicting SRP (Bosch et al. 2011, p. 267-268). Total nitrogen predictions were strongest for agricultural watersheds, including the Sandusky basin, and nitrate predictions were acceptable for the Sandusky basin (Bosch et al. 2011, p. 269).

The study concluded that “SWAT model performance was most satisfactory in agricultural and forested watersheds, and was less so in urbanized settings” (Bosch et al. 2011, p. 263). The authors also concluded that “extensive empirical data of high quality are critical for SWAT model applications” (Bosch et al. 2011, p. 270).

Qi and Grunwald (2005) developed a SWAT model of the Sandusky basin to evaluate spatially variable hydrologic patterns using a spatially distributed calibration and validation. Streamflow from five gages were used to calibrate the SWAT model for water years 1998 and 1999 and to validate for water year 2000 and 2001. The model simulated hydrologic patterns well except for snow accumulation and melting processes. The authors concluded that “calibration and validation of water flow at the drainage outlet do not imply an understanding of hydrologic patterns within the watershed” and that [o]nly a spatially variable calibration and validation procedure” can accurately predict hydrologic patterns (Qi and Grunwald 2005, p. 179).

3.3 Project Setting

The Sandusky basin (HUC 04100011) is in central northern Ohio along Lake Erie. The basin is southeast of the Toledo metropolitan area and west of the Cleveland metropolitan area (Figure 5). The Portage River basin (HUC 04100010) borders the Sandusky basin to the west; the Huron watershed to the east; and the Scioto River (upper) (HUC 05060001) to the south and southeast. The Sandusky River discharges to the southwest side of Sandusky Bay in the western basin of Lake Erie.

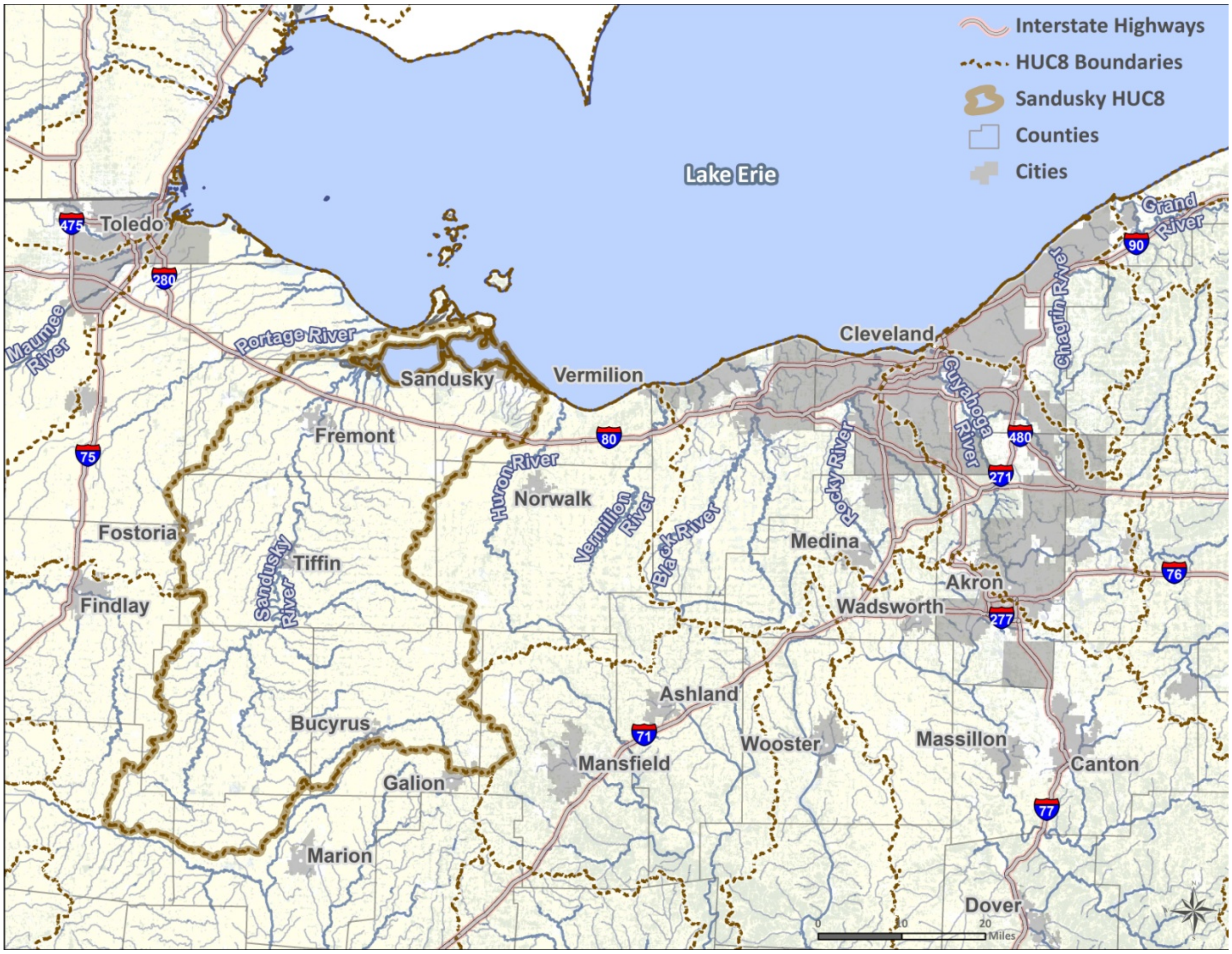


Figure 5. Sandusky basin in northern Ohio.

The Sandusky basin drains 1,827 square miles across 11 counties (Crawford, Erie, Hardin, Huron, Marion, Ottawa, Richland, Sandusky, Seneca, Wood, and Wyandot) and the majority of the basin in five counties (Crawford, Erie, Sandusky, Seneca, and Wyandot). Sandusky is the largest city in the basin, followed by the cities of Tiffin, Fremont, and Bucyrus (Figure 6). The Ohio turnpike (Interstate 80/90) runs through the northern portion of the Sandusky basin; five other major east-west highways are: state route 2 and U.S. routes 6, 20, 30, and 224. The major north-south highways are state route 4 and U.S. route 23.

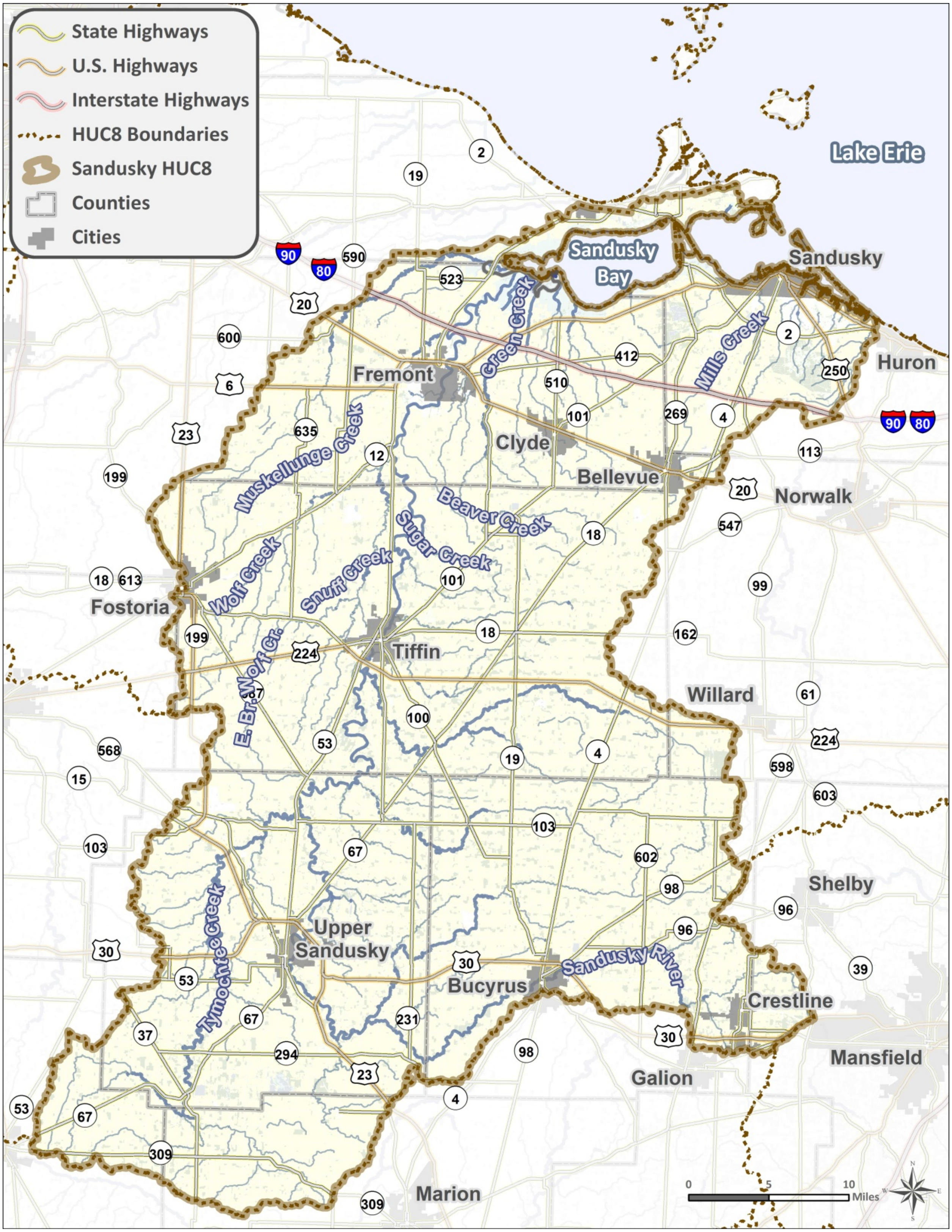


Figure 6. Sandusky basin.

The TMDL project area is defined as the (1) tributaries to Sandusky Bay and frontal Lake Erie, (2) the tributaries to the Sandusky River (lower) (i.e., the tributaries with confluences on the Sandusky River below the confluence with Rock Creek), and the Sandusky River (lower) mainstem (i.e., the Sandusky River LRAUs, which represent the Sandusky River below the confluence of Tymochtee Creek to the mouth on Sandusky Bay). The waterbodies in each WAU are presented in Section A-2 in Appendix A and briefly summarized in the following subsections, along with the LRAUs.

3.3.1 Tributaries to Sandusky Bay and Frontal Lake Erie

The tributaries to Sandusky Bay and frontal Lake Erie are in Ottawa, Sandusky, and Erie counties. The tributaries in the *Mill Creek-Frontal Lake Erie* 10-digit HUC generally flow northeasterly in Erie County to Sandusky Bay and Lake Erie. Mills Creek and Pipe Creek begin near the city of Bellevue, flow through agricultural land, and then discharge to Sandusky Bay within the city of Sandusky.

The tributaries in the *Pickerel Creek-Frontal Sandusky Bay* 10-digit HUC generally flow north (except for HUC 04100011 02 01). Strong, Pickerel, Raccoon, and South creeks begin in the city of Clyde or the surrounding rural, agricultural areas, flow north through agricultural areas, and discharge to Sandusky Bay within large wetland complexes.

The tributaries in the *Muddy-Creek-Frontal Sandusky Bay* 10-digit HUC generally flow northeasterly in Sandusky County and discharge to Sandusky Bay to the west of the mouth of the Sandusky River. Muddy Creek beings in the city of Fremont and flows north, northeast, and east through rural, agricultural lands before discharging to Sandusky Bay within large wetland complexes just east of the mouth of the Sandusky River.

3.3.2 Tributaries to the Sandusky River (Lower)

The tributaries to the Sandusky River (lower) are delineated by four 10-digit HUCs and are primarily in Sandusky and Seneca counties. The *Wolf Creek* 10-digit HUC begins in Seneca County near the city of Fostoria. Wolf Creek and East Branch Wolf Creek flow northeast, with East Branch's confluence with Wolf Creek just southwest of Wolf Creek's confluence with the lower Sandusky River. Tributaries in the *Wolf Creek* 10-digit HUC flow through rural, agricultural areas of Seneca County and southern Sandusky County.

The *Rock-Creek-Sandusky River* 10-digit HUC is in Seneca County and contains both tributaries to the lower Sandusky River and the mainstem of the lower Sandusky River. Rock, Morrison, Sugar, and Spicer creeks generally flow west and join the lower Sandusky River on the right bank; Willow Creek flows northwest with its confluence on the left bank of the lower Sandusky River. Rock, Morrison, and Willow Creek discharge to the lower Sandusky River in the city of Tiffin.

Green Creek is a tributary to the lower Sandusky River and discharges to the Sandusky River just upstream of the mouth of the Sandusky River on Sandusky Bay. The *Green Creek* 10-digit HUC is in Seneca and Sandusky counties and the tributaries generally flow west and north.

The *Muskellunge Creek-Sandusky River* 10-digit HUC is in Seneca and Sandusky counties and contains both tributaries to the lower Sandusky River and the mainstem of the lower Sandusky River. Muskellunge Creek begins in the city of Fostoria, flows northeast through rural, agricultural areas, and discharges to the lower Sandusky River downstream of the city of Fremont.

3.3.3 Sandusky River (Lower) Mainstem

The Sandusky River (lower) mainstem is composed of two LRAUs. Ohio EPA has defined the two LRAUs on the Sandusky River: *Tymochtee Creek to Wolf Creek* (90 01) and *Wolf Creek to Sandusky Bay* (90 02). The upper half of the upper LRAU (i.e., from Tymochtee Creek to Rock Creek) and its tributaries are within the project area of the Sandusky River (upper) TMDL (Ohio EPA 2003). The tributaries from Rock Creek to Wolf Creek are within the scope of this TMDL report. The segment of the Sandusky River below Rock Creek begins in the city of Tiffin, flows north through rural, agricultural lands and the LRAU ends at the confluence of Wolf Creek.

The lower LRAU begins at the confluence of Wolf Creek in rural, agricultural lands, flows north through the city of Fremont then northeast through rural agricultural lands again, and discharges to Sandusky Bay in large wetland complexes. The tributaries to this LRAU are within the scope of this TMDL report.

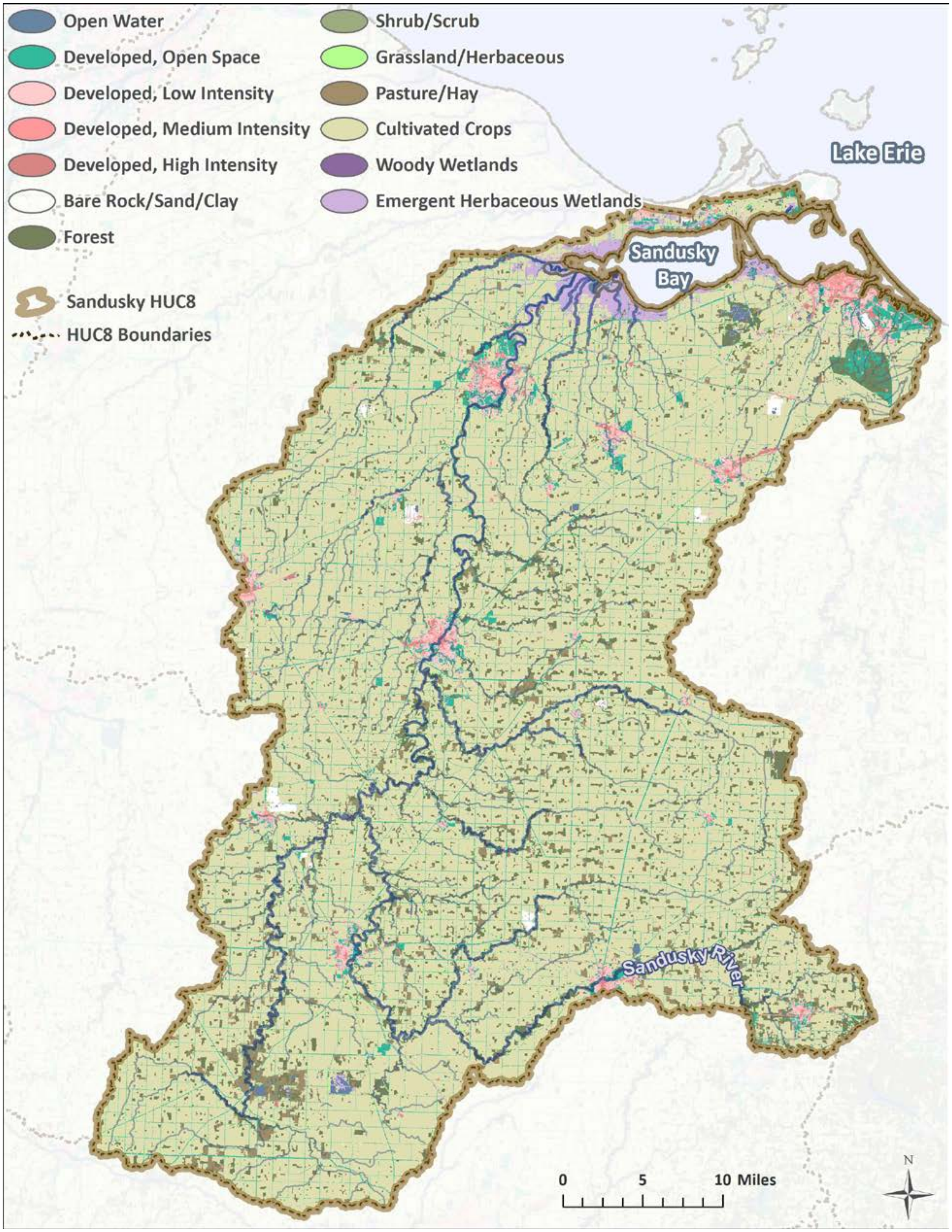
3.4 Land Use and Land Cover

The Sandusky basin, like other watersheds in north-central and northwestern Ohio, is dominated by agricultural land use, including both cultivated row crops and pastureland for livestock grazing (Figure 7). Agricultural drain tiles are installed for row crop agriculture that is practiced in the lake plain areas along Sandusky Bay to manage water levels (Ohio EPA 2010a).

Land use was evaluated for the Sandusky basin, the the project area, and the 16 impaired WAUs (Table 8). The land use in the 16 WAUs that need TMDLs is predominantly agricultural (75 percent) and includes developed open space (7 percent), developed land (6 percent), and forest (6 percent). The remaining 6 percent are small areas of other land uses (e.g., grasslands, open water, wetlands).

Agricultural drain tiles were installed in the Sandusky basin to lower the water table for crop production and channels and ditches were installed to efficiently route water. Both practices significantly affect the hydrology of the region and affect the water quality of the streams due to rapid delivery of excess nutrients into the streams. State wildlife areas and nature preserves are along the Lake Erie shoreline (e.g., Pickerel Creek Wildlife Area, Sheldon Marsh Nature Preserve) and these wetlands and marshes are protected from agricultural development.

Developed land in the TMDL project area also includes rural towns and a few urban cities. Both combined sewer systems and regulated Phase II municipal separate storm sewer systems (MS4s) are in the project area. Phase II MS4s serve populations of fewer than 100,000 and cover the portion of the MS4 located within the Urbanized Area, as defined by the U.S. Census, or as designated by the direct of the Ohio EPA. Combined sewer systems in the project area are discussed in Section 4.2.1.1 and regulated MS4s are discussed in Section 4.2.4.



Source: MRLC 2006

Figure 7. Land cover in the Sandusky basin.

Table 8. Land cover in the Sandusky basin

Land cover class	Sandusky basin[a]		TMDL project area[b]		Impaired WAUs[c]	
	Acres	Percent	Acres	Percent	Acres	Percent
Open Water	9,398	1%	6,176	1%	4,665	1%
Developed, open space	74,798	6%	41,296	7%	27,130	7%
Developed, low intensity	32,105	3%	22,800	4%	14,164	4%
Developed, medium intensity	9,619	1%	7,618	1%	5,011	1%
Developed, high intensity	4,634	<½%	3,815	1%	2,673	1%
Barren land	4,023	<½%	2,255	<½%	1,457	<½%
Deciduous forest	91,957	8%	36,716	7%	22,873	6%
Evergreen forest	517	<½%	139	<½%	95	<½%
Mixed forest	1,130	<½%	9	<½%	9	<½%
Shrub/scrub	40	<½%	--	--	--	--
Grassland/herbaceous	13,242	1%	5,477	1%	3,636	1%
Pasture/hay	28,171	2%	6,331	1%	3,262	1%
Cultivated crops	88,0279	75%	40,7323	73%	27,4913	74%
Woody wetlands	1,350	<½%	756	<½%	533	<½%
Emergent herbaceous wetlands	18,148	2%	16,318	3%	11,341	3%
Total	**1,169,411**		**557,029**		**371,761**	

Source: 2006 NLCD (MRLC 2006).
Notes
Acreages and percentages were rounded to the nearest integer. A double dash ("--") indicates that a land cover was not present.
a. The Sandusky basin is the 8-digit HUC 04100011
b. The TMDL project area consists of the following 10-digit HUCs: 04100011 01, *02, *10, *11, *12, *13, and *14.
c. The impaired watershed assessment units (WAUs) are the 16 WAUs that do not fully attain the ALU designations.

3.5 Geology and Soils

Northern Ohio along Lake Erie, including the Sandusky basin, was subjected to glaciation (Ohio EPA 2011). The glacial advance and retreat were highly influential in the topography, geology, and soils that developed in the region. In general, as glaciers advanced, existing rocks and soils were eroded repeatedly. These materials were re-deposited as sediments during several ice advance, melt, and retreat cycles. Such glacial materials were deposited as sands, gravels, silts, and clays; the melt water created large rivers, which carried and spread the deposited glacial materials throughout the region. Glacial deposits and associated land forms exerted a major effect that influences present day hydrology, soil types, and land cover.

3.5.1 Ecoregion Overview

The Sandusky basin is in the Eastern Corn Belt Plains (ECBP) level III ecoregion #55 and Huron/Erie Lake Plain (HELP) level III ecoregion #57. The general physiography and geology and soils of the three corresponding level IV ecoregions are described in Table B-1 and Table B-2 in Appendix B; a map of these ecoregions is also in Appendix B. Level IV ecoregions are at the finest ecoregional scale and are used to evaluate very localized characteristics.

3.5.2 Bedrock Geology

The Sandusky basin is underlain by Silurian dolostone and Devonian limestone, with Devonian shale and Mississippian limestone in the eastern portion of the basin (Ohio EPA 2010a; Qi and Grunwald 2005).

Columbus limestone, a Devonian formation of nearly pure limestone, is mined from deep deposits throughout the basin (Ohio EPA 2010a). The Bellevue-Castalia Karst Plain underlies portions of southwest Sandusky County and Seneca County and surficial sink holes are located throughout the basin (Ohio EPA 2004, 2010a).

3.5.3 Soils

The physiography of the Sandusky basin varies from lake plain and till plain in the northern areas, closest to Lake Erie, and to glacial till plains in the southern areas (Ohio EPA 2004, 2010a). Old lakebed soils around Lake Erie that are hydric and fertile, and these soils are agriculturally productive when the land is properly drained (i.e., through the installation of drain tiles) (Ohio EPA 2010a). Sand dunes are unique to the Cedar Point area (Ohio EPA). Soils in the upper basin are typically late Wisconsin-age glacial till (Ohio EPA 2004).

Soil surveys contain predictions of soil behavior and provide data related to different soil types, including the hydrologic soil groups (HSGs). HSG refers to the grouping of soils according to their runoff potential. Soil properties that influence HSGs include depth to seasonal high water table, infiltration rate and permeability after prolonged wetting, and depth to slow permeable layer. There are four HSGs: Groups A, B, C, and D (Table 9).

Table 9. HSG descriptions

HSG	Group description
A	Sand, loamy sand or sandy loam types of soils. Low runoff potential and high infiltration rates even when thoroughly wetted. Consist chiefly of deep, well- to excessively drained sands or gravels with a high rate of water transmission.
B	Silt loam or loam. Moderate infiltration rates when thoroughly wetted. Consist chiefly or moderately deep to deep, moderately well- to well-drained soils with moderately fine to moderately coarse textures.
C	Soils are sandy clay loam. Low infiltration rates when thoroughly wetted. Consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine structure.
D	Soils are clay loam, silty clay loam, sandy clay, silty clay or clay. Group D has the highest runoff potential. Low infiltration rates when thoroughly wetted. Consist chiefly of clay soils with high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious material.
A/D B/D C/D	Dual HSGs. Certain wet soils are placed in group D solely on the basis of the presence of a water table within 24 inches of the surface even though the saturated hydraulic conductivity might be favorable for water transmission. If these soils can be adequately drained, they are assigned to dual HSGs (A/D, B/D, and C/D) according to their saturated hydraulic conductivity and the water table depth when drained. The first letter applies to the drained condition and the second to the un-drained condition.

Source: Soil Data Viewer 6.0 (NRCS 2011).

Using the soil surveys for each county (NRCS 2002) and GIS, the HSG was analyzed using the *Soil Data Viewer* (NRCS 2011). Soils in the Sandusky basin are typically Group C/D (Figure 8; Table B-3 in Appendix B), composed of silt, sand, clay, and loam with a low infiltration rate. Due to extensive agricultural drain tiling, much of the A/D, B/D, and C/D soils will act as A, B, or C soils, respectively.

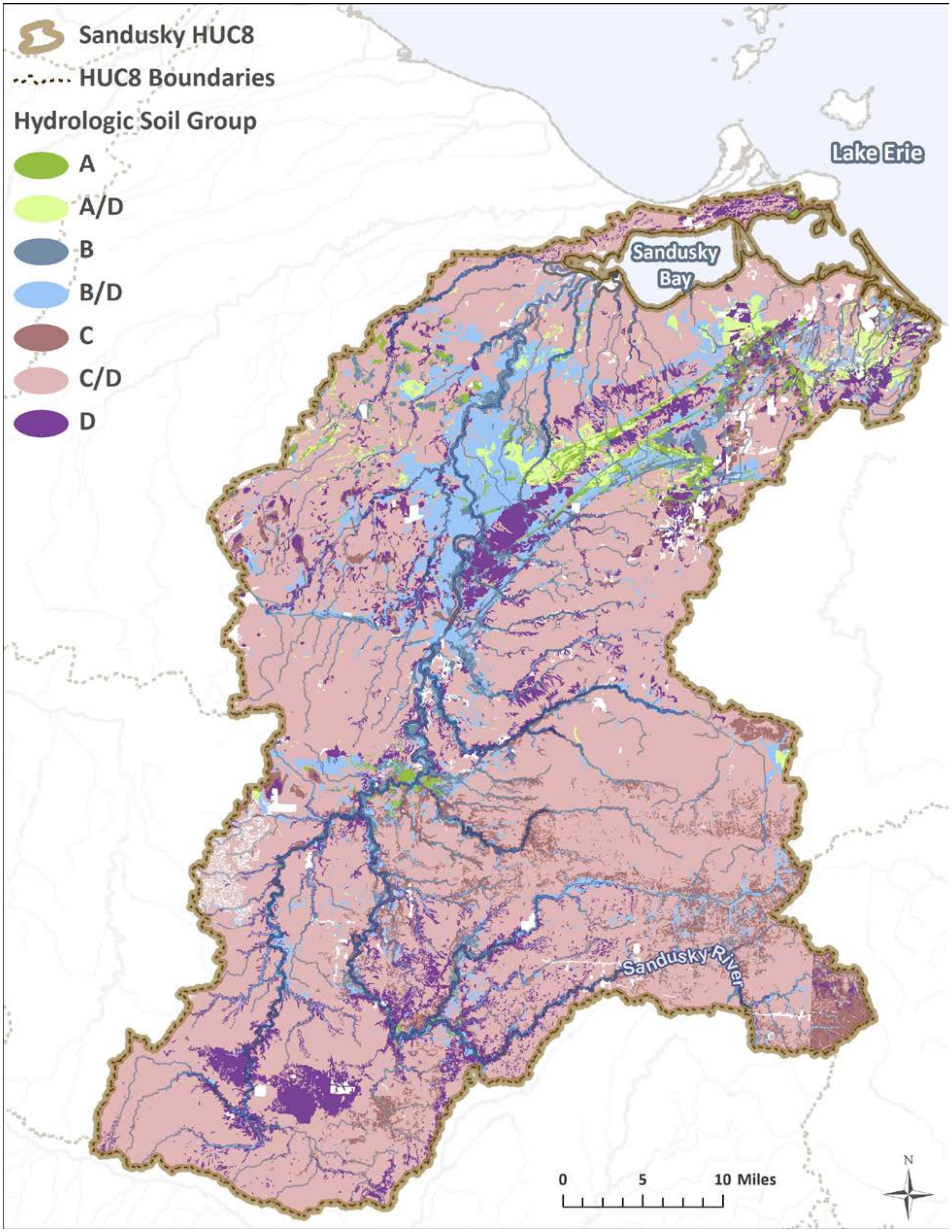


Figure 8. HSGs in the Sandusky basin.

3.6 Climate

The climate of the Great Lakes region is determined primarily by westerly atmospheric circulation, the latitude, and the local modifying influence of nearby Lake Erie (Derecki 1976).

The climate of the Great Lakes basin is described as follows (U.S. EPA 1995 Chapter 2, Section 2)

> The weather in the Great Lakes basin is affected by three factors: air masses from other regions, the location of the basin within a large continental landmass, and the moderating influence of the lakes themselves. The prevailing movement of air is from the west. The characteristically changeable weather of the region is the result of alternating flows of warm, humid air from the Gulf of Mexico and cold, dry air from the Arctic.

These factors tend to increase humidity and can create lake effect precipitation during the cold fall and winter months. Despite that, the proximity to Lake Erie also moderates the local climate as the large waterbody acts as a heat sink or source, warming the air in cold months and cooling the air in the summer.

Weather data from three gages were obtained from the Western Reserve Climate Center (WRCC 2012): Fremont (station 332974; 1901-2012), Sandusky (station 337447; 1936-2012), and Tiffin (station 338313; 1893-2012). The average winter temperatures were 27 to 28 degrees Fahrenheit (°F) and the average summer temperatures were 71 to 72 °F. Precipitation at the three sites ranged from 34 to 37 inches per year with 23 to 31 inches as snowfall. The median growing season (i.e., consecutive days with low temperatures greater than or equal to freezing) ranged from 168 to 188 days. These data for Tiffin are summarized in Figure 9; similar figures for Fremont and Sandusky are in Appendix B.

Table 10. Climate data summary for Tiffin, Ohio (station 338313)

Parameter[a]	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
High	34.3	36.3	47.4	60.2	71.6	80.8	84.9	82.9	76.6	64.2	49.8	37.5
Low	19.1	20.0	28.8	38.6	48.9	58.3	62.4	60.5	53.9	42.8	33.3	23.3
Mean	26.7	28.15	38.1	49.4	60.25	69.55	73.65	71.7	65.25	53.5	41.55	30.4
Precipitation	2.58	2.11	3.07	3.39	3.79	3.88	3.70	3.21	3.20	2.55	2.67	2.61
Snowfall	8.7	7.0	5.1	1.1	0.0	0.0	0.0	0.0	0.0	0.1	2.0	6.9

Source: WRCC 2013.
Notes
Summary of data collected at Tiffin, OH NCDC station 338313 from June 1, 1893 through January 31, 2012.
a. All five parameters are monthly averages. high, low, and mean are in degrees Fahrenheit. Average precipitation is in inches water equivalent. Average snowfall is in inches of snow.

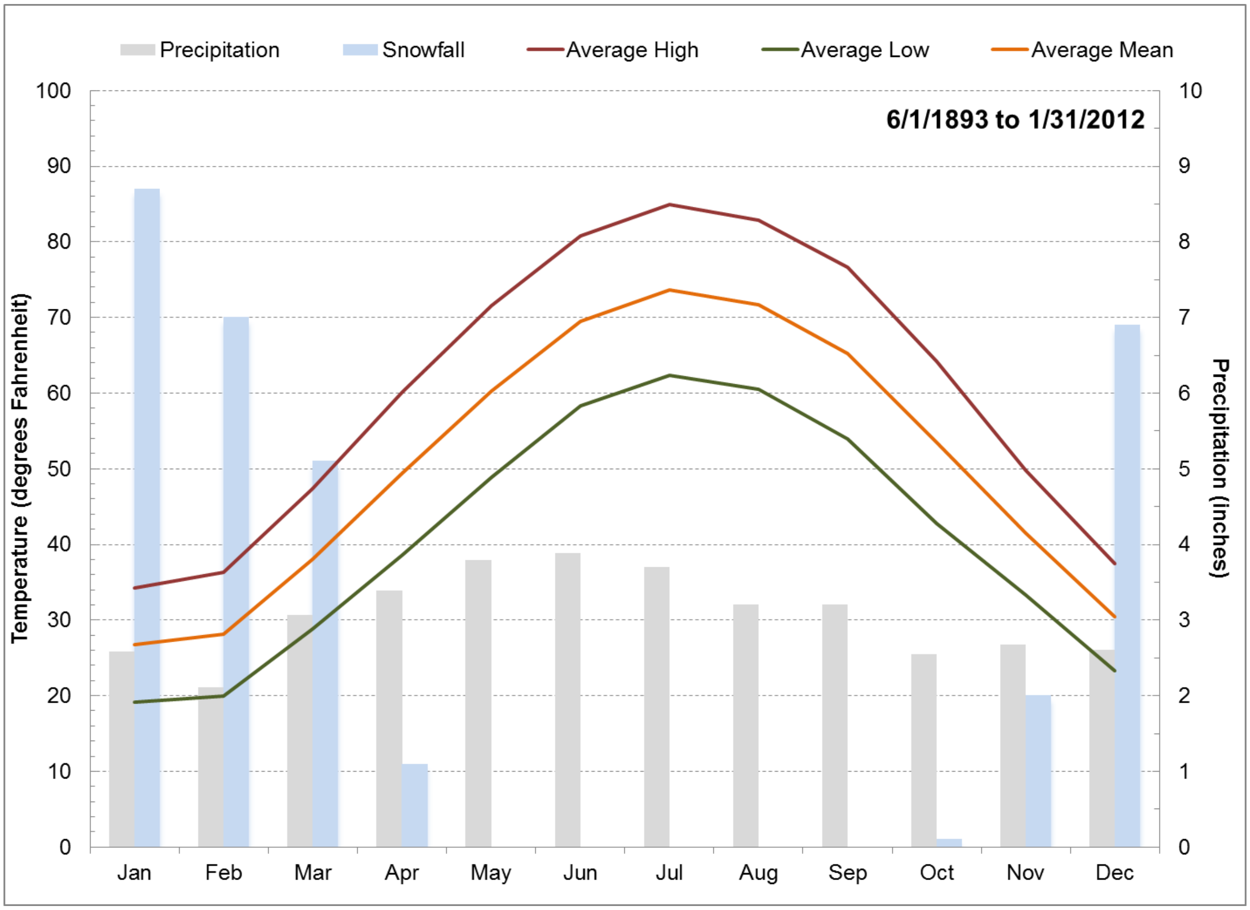


Figure 9. Temperature and precipitation summary at Tiffin, OH (station 338313).

Examination of precipitation patterns is a key part of watershed characterization. In particular, rainfall intensity and timing affect watershed response to precipitation. This information is important in evaluating the effects of storm water on the tributaries. Figure 10 presents one method to assess rainfall intensity; similar figures for Fremont and Sandusky are presented in Appendix B. The WRCC data show that 40 to 46 precipitation events per year are less than 0.1 inches and that 4 to 5 percent are greater than 1 inch.

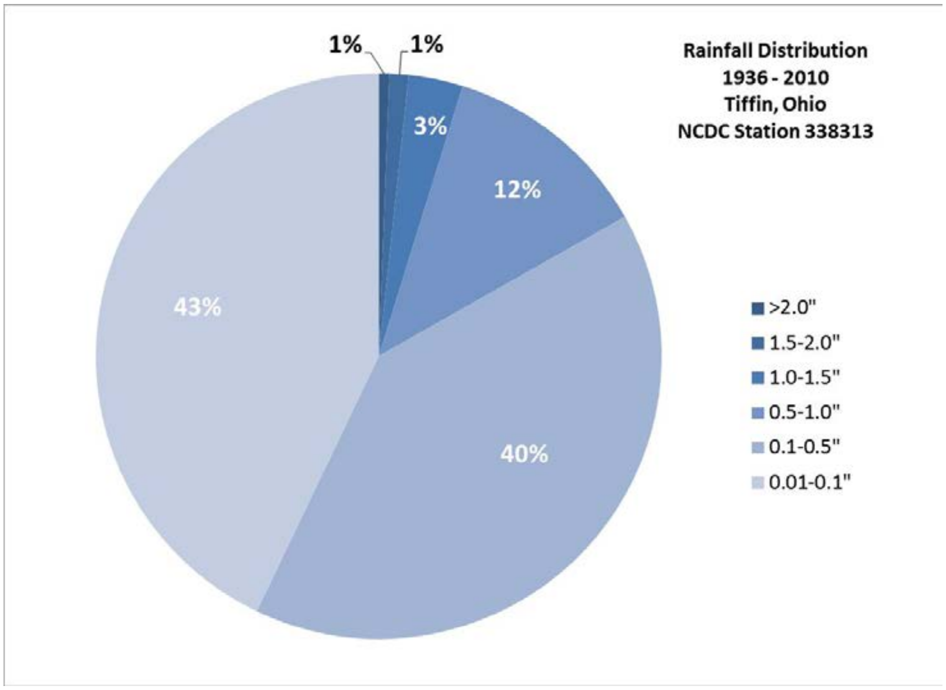


Figure 10. Precipitation intensity at Tiffin, OH (station 338313).

3.7 Hydrology

Hydrology plays an important role in evaluating water quality. In the project area, hydrology is primarily driven by local climate conditions. This includes situations that often result in flashy flows, where the stream responds to and recovers from precipitation events relatively quickly.

The conversion of forest land to agricultural land was helped by installing subsurface tiles to improve drainage. That practice is generally referred to as *field tiling* and involves subsurface drains (e.g., corrugated plastic tile or pipe) installed below the surface that serve as conduits to collect or convey drainage water, either to a stream channel or to a surface field drainage ditch. While the drainage improvements increase the amount of land available for cultivation, they also influence the hydrology, aquatic habitat, and water quality of area streams.

The lower segments of the Sandusky River mainstem and the small direct tributaries to Sandusky Bay and frontal Lake Erie are lacustrine, which means that waters from the streams and Lake Erie mix within a freshwater estuary. These lacustuaries are slack water that can ebb and flow as lake seiches affect water levels; the lacustuaries are generally located between the farthest downstream riffle of the tributary and Lake Erie proper. All tributaries of lacustuaries are considered lacustuaries below the Lake Erie mean high water level. Ohio EPA has estimated where the lacustuaries begin for the tributaries to Sandusky Bay and this information is presented in Table 11.

Table 11. Lacustuaries on tributaries to Sandusky Bay

Watershed Assessment Unit (04100011)[a]	Waterbody	Stream code	River mile [b] (approximate)
01 02	Hemming Ditch	05-065-000	0.9
	Pipe Creek	05-052-000	1.5
	Plum Brook	12-003-000	1.0
01 03	Mills Creek	05-051-000	0.2
02 01	Cold Creek	05-050-000	0.2
13 03	Sandusky River	05-001-000	15.8
14 03	Little Muddy Creek	05-220-000	3.3
14 04	Muddy Creek	05-219-000	4.2

Notes
a. The lacustuaries are within the displayed watershed assessment units; the waterbodies may flow through additional watershed assessment units.
b. The lacustuaries extend from the waterbodies' mouths on Sandusky Bay to the approximate rivermile displayed in the table.

The U.S. Geological Survey (USGS) maintains flow gages at several locations on the Sandusky River (Table 12) and its tributaries (Table 13); the locations of the gages are shown on Figure 11. Average daily mean flow data per day for the three active USGS gages are presented in Figure 12 and flow duration curves are presented in Figure 13.

Table 12. USGS continuously recording stream gages on the Sandusky River

Gage ID	Location	Area ($mi.^2$)	Period of record
04196000	Sandusky River near Bucyrus, OH	88.8	9/1/1925 - Present
04196500	Sandusky River near Upper Sandusky, OH	398	10/1/1921 - Present
04197000	Sandusky River at Mexico, OH	774	3/1/1923 - 10/5/1982
04197137	Sandusky River at Tiffin, OH	966	10/1/2009 - Present
04198000	Sandusky River near Fremont, OH	1,251	10/1/1923 - Present

Notes
Gages are listed from top to bottom from headwaters to mouth.
The period of record for daily mean flows is displayed, and the data are provisional for water year 2013.

Table 13. USGS continuously recording stream gages on tributaries of the Sandusky River

Gage ID	Location	Area ($mi.^2$)	Period of record
04196200	Broken Sword Creek at Nevada, OH	83.8	2/1/1976 - 10/27/1981
04197450	East Branch Wolf Creek near Bettsville, OH	82.4	2/1/1976 - 10/6/1981
04197500	Havens Creek at Havens, OH	4.28	8/21/1946 - 9/30/1949
04197100	Honey Creek at Melmore, OH	149	2/1/1976 - Present
04197020	Honey Creek near New Washington, OH	17.0	6/1/1979 - 10/4/1989
04197170	Rock Creek at Tiffin, OH	34.6	6/1/1983 - Present
04196800	Tymochtee Creek at Crawford, OH	229	6/1/1964 - Present
04197300	Wolf Creek at Bettsville, OH	66.2	2/1/1976 - 10/6/1981

Notes
Gages are listed from top to bottom alphabetically.
The period of record for daily mean flows is displayed, and the data are provisional for water year 2013.

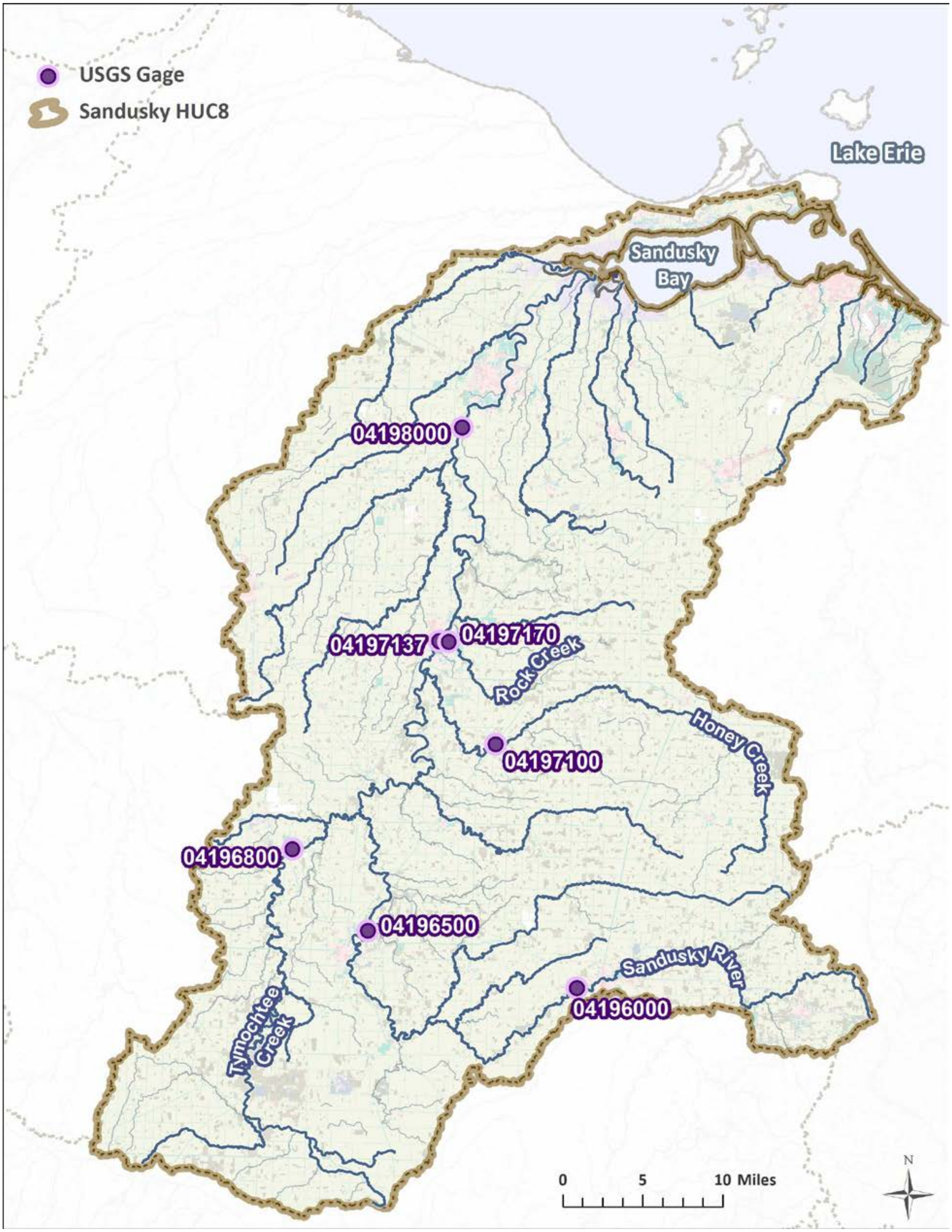


Figure 11. Active USGS gages in the Sandusky basin.

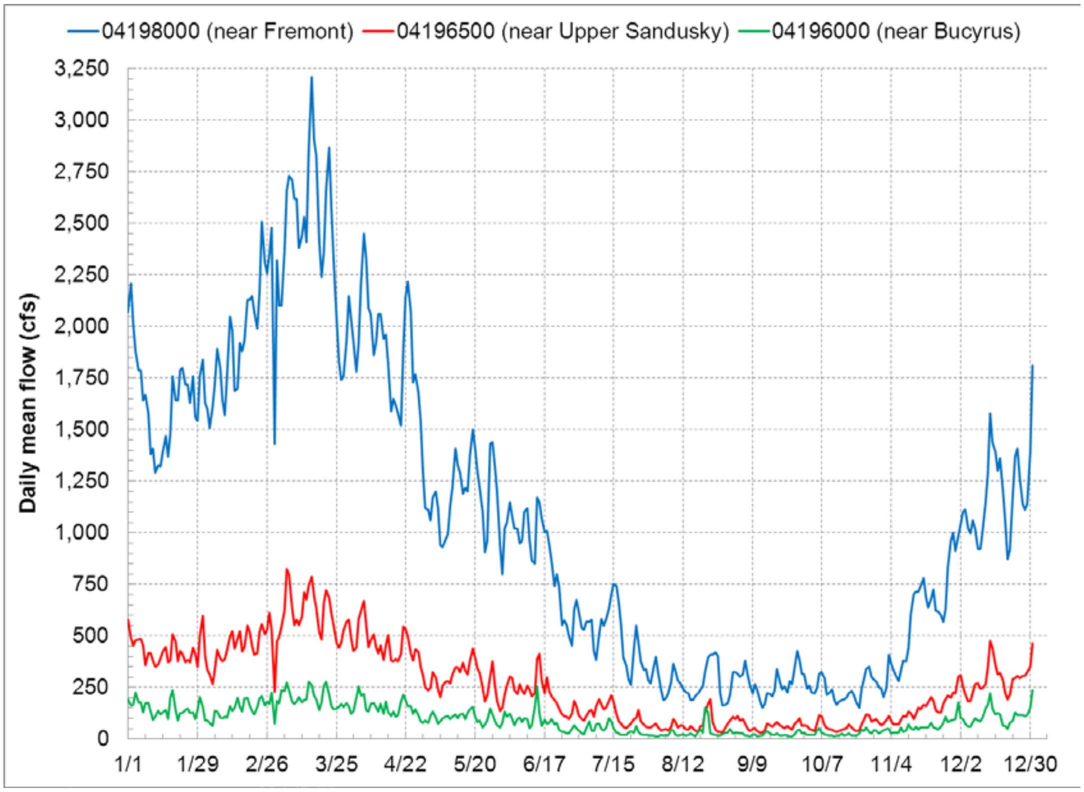


Figure 12. Average daily mean flow for active USGS gages on the Sandusky River.

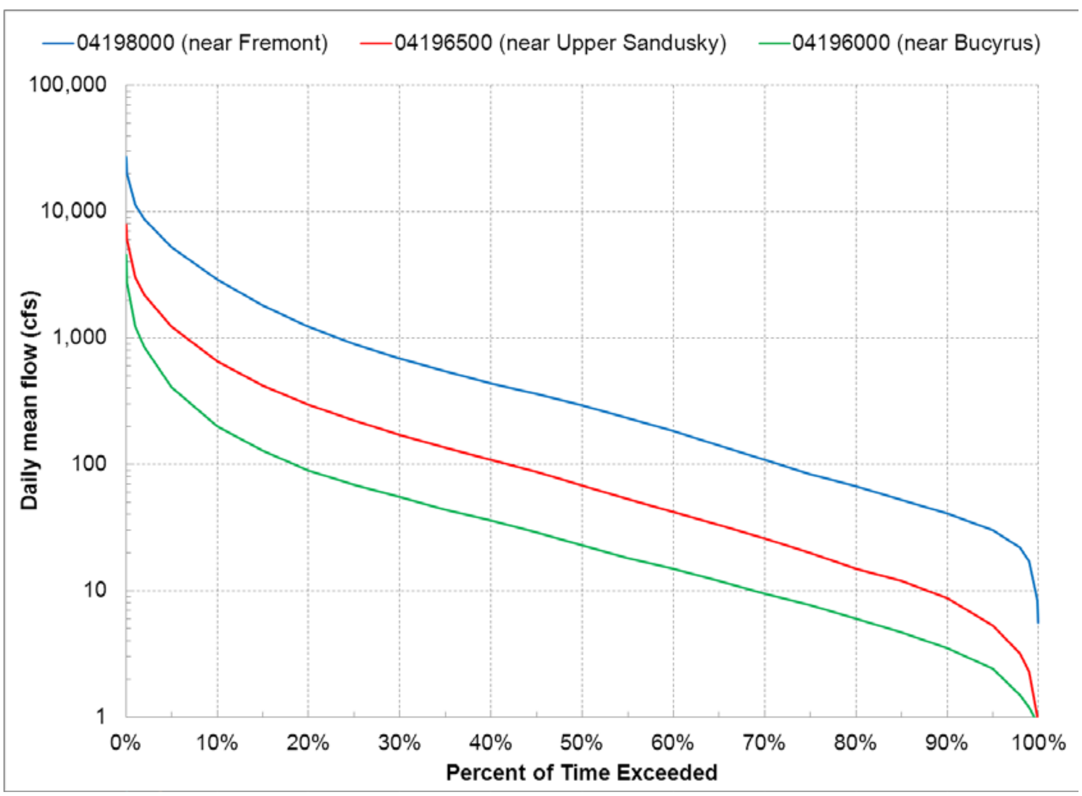


Figure 13. Flow duration curves for the active USGS gages on the Sandusky River.

An evaluation of annual flow at USGS gage 04198000 (Sandusky River near Fremont, OH) from water years 1924 through 2011 showed that annual flow in water year 2009 was nearly at the median (49th percentile); thus, it is assumed that water year 2009 is a typical year. Flow at USGS gage 04198000 is plotted with precipitation from National Climactic Data Center station 332976 (Fremont Ag) for water year 2009 in Figure 14. As expected, due to the lack of large dams and regulating reservoirs, this figure shows that flow in the Sandusky River typically responds to precipitation across the basin.

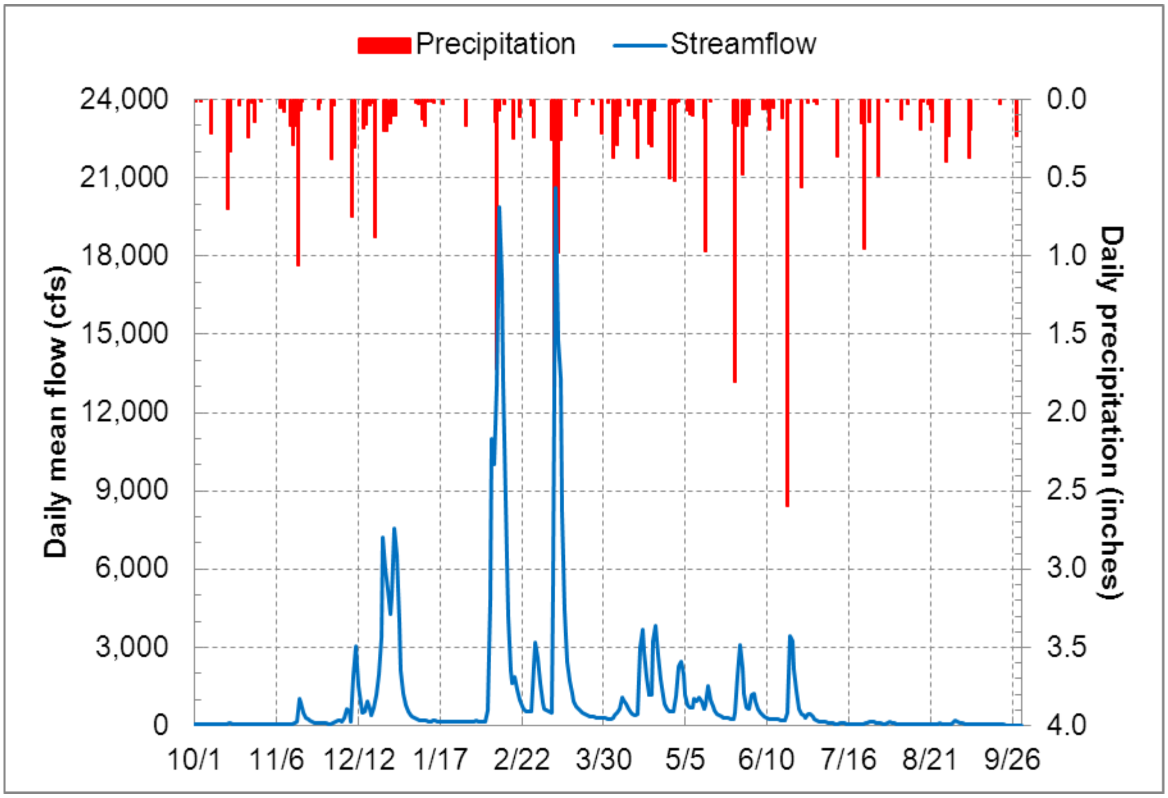


Figure 14. Daily flow for water year 2009 in the Sandusky River near Fremont (USGS gage 04198000) with daily precipitation at Fremont (332976).

3.8 Community Profile

While the Sandusky basin encompasses portions of 11 counties, the basin is mostly contained within five counties: Crawford, Erie, Sandusky, Seneca, and Wyandot. Population trends over the past decade in the Sandusky basin are typical of northern Ohio and the Midwest: most areas lost population (refer to Table B-6 in Appendix B for a table of population by counties and communities). Most of the basin's population is clustered in small rural cities and most of the land area of the basin has low population densities (Figure 15).

Given the nitrate impairments to the public water supply use of the Sandusky River, it is noteworthy that residents in the Sandusky basin rely on both surface- and groundwater as sources for drinking water. In recent years, Northern Ohio Rural Water has expanded its coverage to provide drinking water in Erie and Sandusky counties (Ohio EPA 2010a). Surface water is the source of drinking water for Bellevue, Bucyrus, Clyde, Fremont, New Washington, Tiffin, and Upper Sandusky.

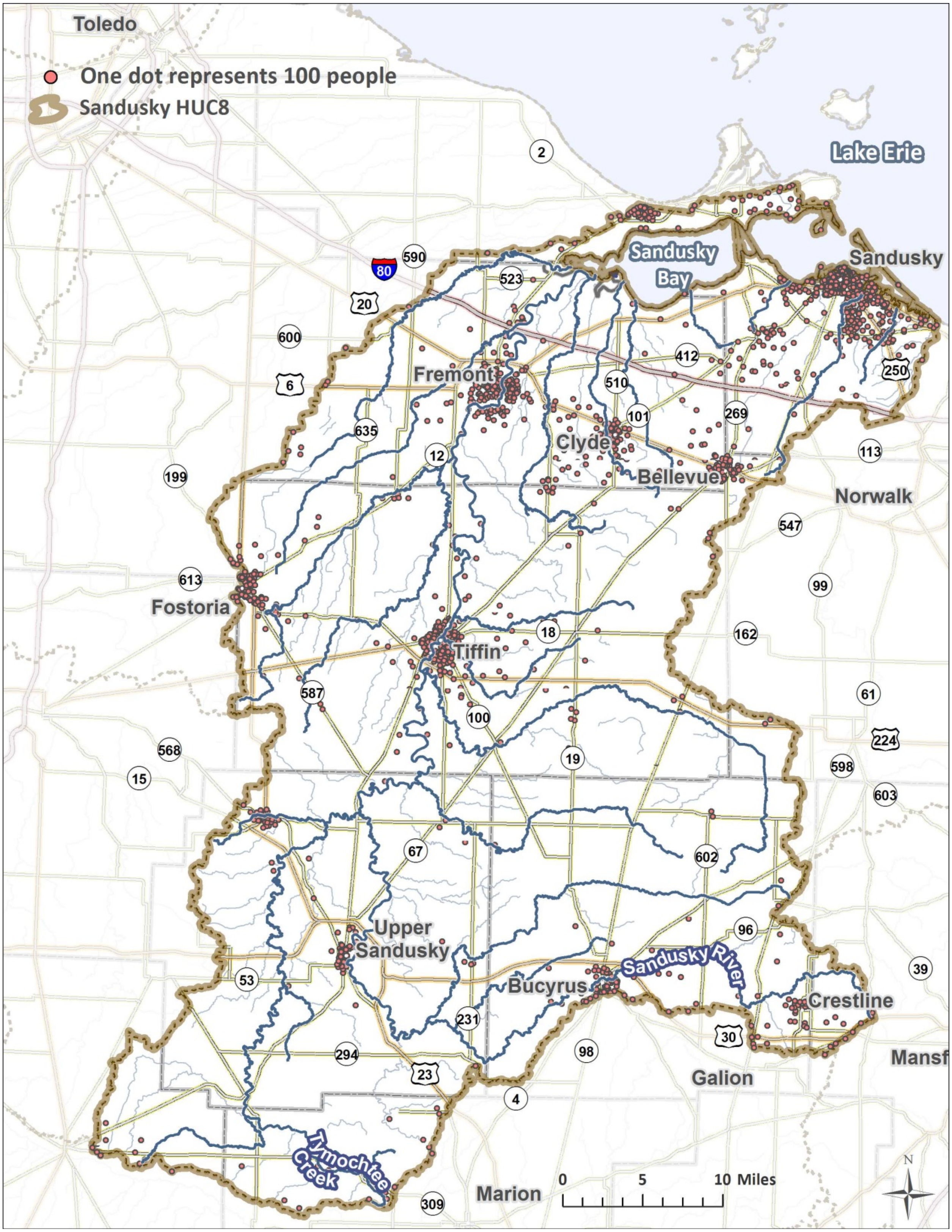


Figure 15. Population density in the Sandusky basin.

4 Source Assessment

Source assessments are an important component of water quality management plans and TMDL development. These analyses are generally used to evaluate the type, magnitude, timing, and location of pollutant loading to a waterbody (U.S. EPA 1999). Source assessment methods vary widely with respect to their applicability, ease of use, and acceptability. The purpose of this section is to identify possible sources in the TMDL project area.

To facilitate the source assessment, sources of impairment are evaluated at the WAU and LRAU level. Using watersheds creates an opportunity for watershed managers to relate source information to water quality monitoring results and sets the stage for the TMDL linkage analysis. The ability to summarize information at different spatial scales strengthens the overall TMDL development process and enables more effective targeting of implementation efforts.

The first section below presents the pollutants of concern that cause impairments in the TMDL project area. The next two sections provide general information regarding point sources and nonpoint sources in the project area. The chapter continues with presentations of two methods for assessing sources: the SWAT model and load duration curves (LDCs). The impaired WAUs and LRAUs are evaluated in Sections 5, 6, and 7, which include SWAT model results and LDC analyses.

4.1 Pollutants of Concern

Pollutants of concern discussed in this source assessment include: sedimentation/siltation, nitrate plus nitrite, and total phosphorus. These three pollutants represent impairments caused by nitrate, nutrient/eutrophication, organic enrichment (sewage), particle distribution (embeddedness), phosphorus, and sedimentation/siltation. These pollutants can originate from an array of sources including point source discharges (e.g., industrial pipes) and surface runoff, particularly storm water and agricultural runoff.

4.1.1 Sedimentation and Siltation

Sedimentation and siltation are controlled by stream hydrology, channel condition, riparian areas, and watershed land use. Impairment occurs when external inputs (e.g., sediment, runoff volume) to the stream become excessive, or when stream characteristics are altered so that the stream can no longer assimilate these stresses, or a combination of both.

Streams with high flows can result in channel scour and erosion of the stream channel. Those steams are also able to transport larger sediment particles further distances. Streams that are dominated by lower flow conditions will deposit sediment and associated pollutants resulting in poor quality habitat and loss of spawning beds. In addition, low flowing streams will have lower dissolved oxygen levels. A stream's assimilative capacity for pollutant loads from the watershed will depend on its ability to balance all those factors.

Stream channels develop in response to hydrologic regimes. When urban flow regimes replace natural flow regimes, streams must change and that usually involves increasing the cross-sectional area to accommodate larger flows (Schueler 1994). Urban streams tend to have impervious surfaces that alter the hydrologic regime (e.g., higher magnitude flows, more frequent high flows), which then increases the erosion of the streambed and banks and increases re-suspension of bed sediment (U.S. EPA 2012). Incision, erosion, channel enlargement, and other such alterations that occur in response to the urban hydrologic regime can be produced slowly over a long time or in response to a single large storm water runoff event (Shaver et al. 2007). Such stream channel alterations result in channel instability that degrades habitat (Schueler 1994).

Hydrology is a major driver for both upland and stream channel erosion and agricultural activities can also alter the hydrologic regime, channel condition, and riparian areas. Agricultural activities such as livestock grazing and the plowing or tilling of crop fields result in de-vegetated, exposed soil that is susceptible to erosion (U.S. EPA 2012). Drain tiles may also increase channel erosion since runoff that travels through tiles has increased peak flows and velocities, both of which increase erosion. Runoff transported by tiles may have higher concentrations of suspended sediment, which may then be deposited (i.e., settle) in the streams or ditches, and thus contribute to sedimentation and habitat issues.

Channelized streams are present throughout the project area. Streams are channelized to purposefully direct and control flow in both urban and rural areas. Channelization results in higher peak flows that travel more rapidly; these more powerful flows have greater capacity to erode the channels banks and can carry more sediment farther. The effects of channelization with regards to erosion and sedimentation are presented in Section 4.3.2.2.

Typical sources of sediment derived from in-stream processes include: incised channels, channel modification, and eroding and collapsing stream banks (U.S. EPA 2012). Sediment is also derived from eroding soil from anthropogenic activities in both agricultural areas (e.g., livestock grazing, plowing) and urban areas (e.g., construction, roads) and eroding soil from natural processes (e.g., landslides, burnt forests) (U.S. EPA 2012).

4.1.2 Nitrate and Nitrite

Ammonia, nitrate, and nitrite are part of the nitrogen cycle, which is critical to any ecosystem; for a brief summary of the nitrogen cycle see the *Associations* document (Ohio EPA 1999, p. 11) and the *Protocol for Developing Nutrient TMDLs* (U.S. EPA 1999, p. 2-3). Basically, molecular nitrogen (N_2) is extremely stable and unreactive; molecular nitrogen must be *fixed* (i.e., combined with other elements) to become biologically available (Spiro and Stigliani 2003, p. 358). “The majority of naturally occurring nitrogen fixation is accomplished by certain bacteria and blue-green algae” that reduce molecular nitrogen to ammonia (NH_3) (Spiro and Stigliani, p. 358). Plants uptake ammonia and use it to create plant proteins. Organic nitrogen from plants and animals that die is converted back to ammonia through bacterial decomposition (i.e., *ammonification*). Other bacteria convert ammonia to nitrite and then to nitrate by oxidation in aerobic conditions (i.e., *nitrification*). Plants can also uptake nitrate: “[t]hus, there is a continual cycling between oxidized and reduced forms of fixed nitrogen in soils” (Spiro and Stigliani, p. 361). In anaerobic conditions, nitrate can be converted back to molecular nitrogen (i.e., *denitrification*). U.S. EPA describes nitrogen cycling in aquatic ecosystems as follows:

> Nitrogen continuously cycles in the aquatic environment, although the rate is temperature-controlled and thus very seasonal. Aquatic organisms incorporate available dissolved inorganic nitrogen into proteinaceous matter. Dead organisms decompose, and nitrogen is released as ammonia ions and then converted to nitrite and nitrate, where the process begins again. If a surface water lacks adequate nitrogen, nitrogen-fixing organisms can convert nitrogen from its gaseous phase to ammonia ions. (U.S. EPA 1999, p. 2-3)

Inorganic nitrogen does not strongly sorb to sediment like phosphorus and can be transported in water either as dissolved ions or as particulates (U.S. EPA 1999). Molecular nitrogen may dissolve directly into surface water while its dissolved forms may be transported through subsurface flow (e.g., interflow, ground water flow). Once nitrogen-species enter surface waters:

> [nitrogen-species] can be taken up by algae, macrophytes and micro-organisms (either in the water column or in the benthos); sorbed to organic or inorganic particles in the water and sediment; accumulated or recycled in the sediment; or transformed and released as a gas from the waterbody (denitrification). (U.S. EPA 2000, p. 7).

The pertinent nitrogen-species in the project area are nitrate and nitrite. Similar to ammonia, nitrate and nitrite are important components of aquatic ecosystems. Both nitrate and nitrite are dissolved forms of nitrogen that are bioavailable (U.S. EPA 1999). Plants and algae uptake mineralized nitrogen in the form of the nitrate ion. Nitrate is more stable than nitrite, which is typically found in very low levels because it is rapidly converted to more stable forms of nitrogen ions.

The effects of high levels of nitrate in drinking water are well known (e.g., Blue Baby Syndrome[7]). The Sandusky River mainstem from Tymochtee Creek to Wolf Creek is in non-attainment of its public drinking water supply use do to elevated nitrate levels near the city of Fremont's water intake. All of the nitrate and nutrient impairments to the tributaries of the Sandusky River (lower), Sandusky Bay, and frontal Lake Erie are for their designated ALUs. Nitrate contributes to eutrophication, which results in decreased dissolved oxygen levels.

Nitrate toxicity to aquatic life is similar to nitrate toxicity to mammals in that oxygen-carrying compounds are converted to other compounds that cannot carry oxygen (Camargo et al. 2005). In a review of studies, Camargo et al. (2005) found that nitrate toxicity to aquatic invertebrates, fish, and amphibians increased as nitrate concentrations and exposure times increased. For aquatic invertebrates, nitrate toxicity decreased with increasing body size and water salinity (Carmargo et al. 2005).

"High loadings of [nitrate as nitrogen] can adversely affect lakes, reservoirs and estuaries, typically through compositional changes in phytoplankton" (Ohio EPA 1999, p. 32). Increased algal production, due to increases in nutrient levels, including nitrate, reduces dissolved oxygen levels, which harms aquatic life.

Sources of nitrate in surface and ground waters include: agricultural runoff, animal or human waste, industrial waste, natural soil inorganic matter, nitrogen fixation, and rain (Camargo et al. 2005; Eby 2004). Both ammonia and nitrate are derived from animal and human waste; bacterial processes control how much of these nitrogen species are reactive. Animal waste may enter surface waterbodies via direct deposition (e.g., waterfowl excretion) or through surface runoff (e.g., pet waste deposition on urban lawns, application of manure to crop fields). Sources of human waste are derived from inadequate treatment (e.g., WWTP without tertiary treatment, failing HSTS). In addition to manure application, nitrogen-bearing fertilizers may also be applied to crop fields; runoff from precipitation events may transport fertilizers on crop fields to streams via overland flow or through drain tiles.

4.1.3 Total Phosphorus

At some level, phosphorus is necessary in a waterbody to sustain aquatic life. The natural amount of phosphorus in a waterbody varies depending on the type of system. A pristine mountain spring might have little to almost no phosphorus, whereas a lowland, mature stream flowing through wetland areas might have naturally high concentrations. Phosphorus can be released into the environment through different anthropogenic sources including septic systems, WWTPs, fertilizer application, and livestock operations. Once released into the environment, phosphorus generally attaches to soil particles and organic matter and is transported with eroded sediments (U.S. EPA 1999).

[7] Blue baby syndrome, or methemoglobinemia, occurs when infants are exposed to high levels of nitrates in drinking water that is used to make formula. Nitrates bond to hemoglobin, which impairs oxygen delivery to tissue and results in blue-colored skin (U.S. EPA 2007a).

Phosphorus, like other nutrients, rarely approaches concentrations in the ambient environment that negatively affect aquatic life; in fact, nutrients are essential in minute amounts for properly functioning, healthy, aquatic ecosystems. However, nutrient concentrations in excess of those minute needs can exert negative effects on the aquatic ecosystem by increasing algal and aquatic plant life production (Sharpley et al. 1994). Increased plant production increases turbidity, decreases average dissolved oxygen concentrations, and increases fluctuations in diurnal dissolved oxygen and pH levels. Such changes shift aquatic species composition away from functional assemblages (composed of intolerant species, benthic insectivores, and top carnivores that are typical of high-quality streams) toward less desirable assemblages of tolerant species, generalists, omnivores, and detritivores that are typical of degraded streams (Ohio EPA 1999). Such a shift in community structure lowers the diversity of the system.

In its evaluation of biological data for reference (i.e., least-affected) streams, Ohio EPA found that IBI and ICI scores do not meet the WWH biocriteria when associated with higher levels of total phosphorus, (Ohio EPA 1999, p. 26). Ohio EPA further concludes that “[t]he processing of nutrients in lotic ecosystems[8] is complex, variable, and affected by abiotic factors such as flow, gradient, ground water quality and quantity, and channel morphology” (Ohio EPA 1999, p.10). In the HELP ecoregion, Ohio EPA (1999, p. 27) finds that low gradient headwaters and wading streams (similar to those in the project area) had higher total phosphorus concentrations than higher gradient streams.

An in-depth summary of the effects of nutrients on aquatic life and the interrelationships of water quality, habitat, and biota are presented in the *Associations* document (Ohio EPA 1999).

Typical sources of total phosphorus are human and animal waste, fertilizer application to agricultural crops and urban lawns/gardens, erosion in stream channels, wetlands, and re-suspension of phosphorus bound to sediment from an upstream source. In an analysis of total phosphorus export coefficients from various studies, Lin (2004) found that feedlots and manure storage yield the largest loads and forestland yields the smallest loads. The ranked land uses are as follows (Lin 2004, Tables 1 and 3):

- Feed lots and manure storage (largest total phosphorus export coefficients)
- Residential
- Industrial
- Row crop agriculture
- Non-row crop agriculture, pasture, and mixed agriculture
- Idle land
- Forest (smallest total phosphorus export coefficients)

It is expected that the results of Lin (2004) would be consistent with the Sandusky basin, which is largely a rural, agricultural watershed. As discussed later in this chapter, there are few large animal operations in the basin and industrial and municipal point sources are limited to a few cities and larger villages. Agricultural activities are expected to contribute the largest relative total phosphorus loads throughout the Sandusky basin, except in subwatersheds with cities and un-sewered towns. The potential sources identified by Ohio EPA in the 303(d) list are failing HSTS, package treatment plants, non-irrigated crop production, and urban runoff/storm sewers.

[8] Lotic refers to flowing water; thus, a lotic ecosystem consists of the biological communities and non-living components of a stream or river.

4.2 Point Sources

Point source pollution is defined by CWA section 502(14) as, "any discernible, confined and discrete conveyance, including any ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation [CAFO], or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include agriculture storm water discharges and return flow from irrigated agriculture."

Point sources can include facilities such as municipal WWTPs, industrial facilities, CAFOs, or regulated storm water, including MS4s. Under the CWA, all point sources are regulated under the National Pollutant Discharge Elimination System (NPDES) program. NPDES permit holders in the Sandusky basin are discussed below. No permitted CAFOs are in the TMDL project area and three CAFOs are permitted in the Sandusky basin, in the upper Sandusky River watershed.

4.2.1 Industrial Facilities with Individual NPDES Permits

Of the 120 facilities that hold individual NPDES permits in the Sandusky basin, 56 facilities are industrial and two of the industrial facilities discharge directly to Lake Erie. Refer to Appendix C for a list of industrial facilities with individual NPDES permits. All individual NPDES permit locations are shown in Figure 16. Ohio EPA (2013, p 18) reports that publicly owned treatment works and CSOs contribute much larger phosphorus loads than industrial facilities.

4.2.1 Public Facilities with Individual NPDES Permits

Sixty-four public facilities hold individual NPDES permits in the Sandusky basin and six of these public facilities discharge directly to Lake Erie (Figure 16). Refer to Appendix C for a list of public facilities with individual NPDES permits. Facilities that are permitted to discharge combined or sanitary sewer overflows or to provide sludge for land application are further evaluated in the following subsections.

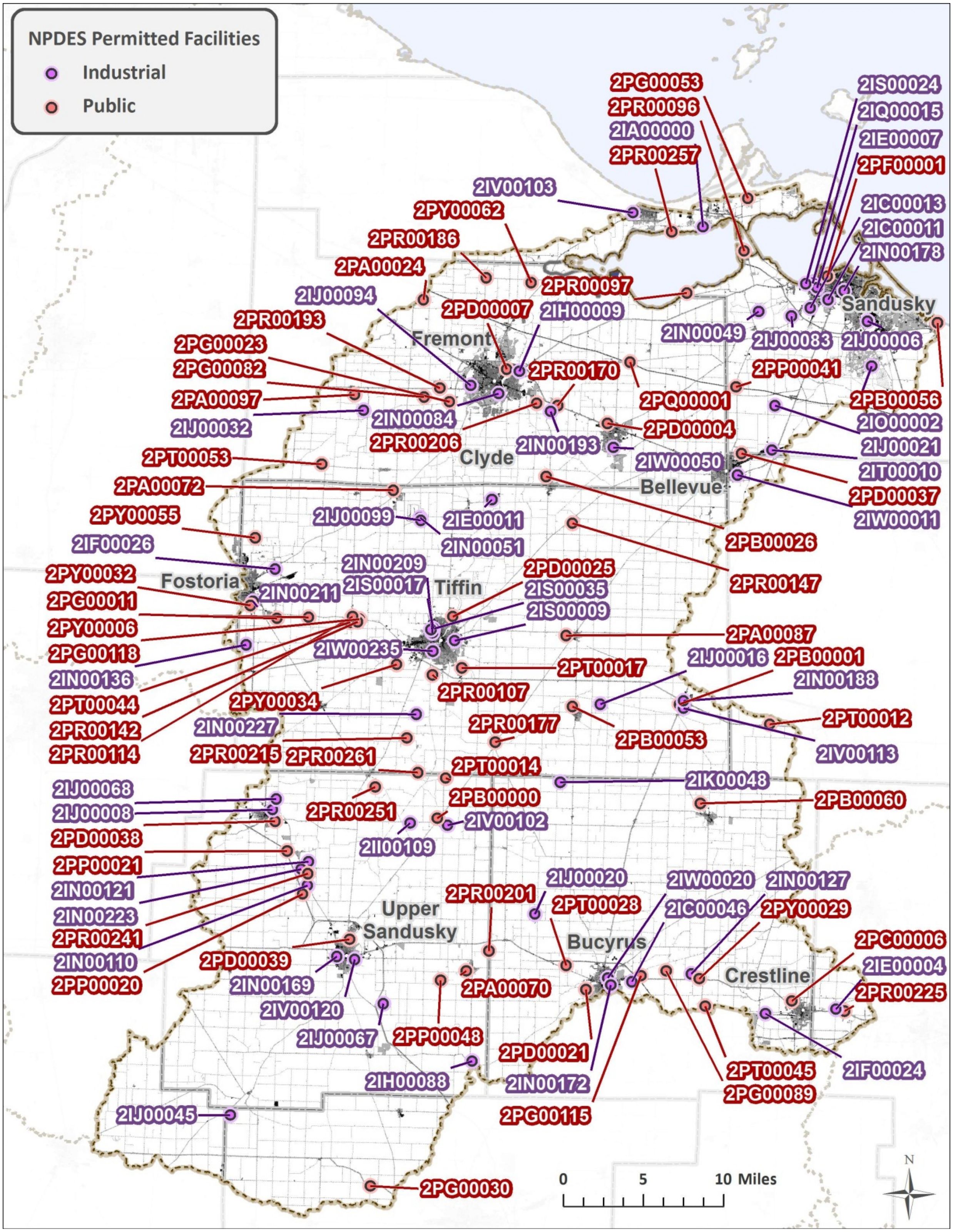


Figure 16. Individual NPDES permits in the Sandusky basin

4.2.1.1 Combined Sewer Systems

Six facilities are permitted to discharge CSOs in the Sandusky basin (Table 14). The Clyde WWTP, Fremont WPCF, Fostoria WWTP, and Sandusky WPC are permitted to discharge through 17 outfalls into four receiving waterbodies located in the TMDL project area. Available CSO data are summarized in Appendix C.

The cities of Bucyrus (2PD00021) and Tiffin (2PD00025) discharge at locations within the Upper Sandusky River watershed TMDL (Ohio EPA 2004). The city of Upper Sandusky (2PD00039) and village of Crestline (2PC00006) were each CSSs, but each has completely separated its sanitary sewers. In the case of Crestline, the previously existing CSO outfalls are now recurring SSO outfalls. The village of Green Springs (2PB00026) partially separated its sewers and pipes its wastewater to the Clyde WWTP[9]. The city of Port Clinton and village of Gibsonburg are CSSs in the Sandusky basin but discharge outside of the basin.

Table 14. Public facilities with CSOs

NPDES ID	Facility	CSO outfall	Receiving waterbody	WAU/LRAU (04100011)
2PD00004	Clyde WWTP	010	Raccoon Creek	02 04
2PD00007	Fremont WPCF	004, 005, 006, 007, 008, 009, 010, 011, 012, 013, 015, 016, 017, 018	Sandusky River	90 02
2PD00021	Bucyrus WWTP	003, 005, 006, 007, 008, 009, ,011, 012, 013, 015, 016, 017, 018, 019, 020, 021, 022, 023, 024, 025, 026, 027[a]	Sandusky River[a]	04 03
2PD00025	Tiffin WWTP	004, 005, 007, 008, 009, 010, 011, 012, 013, 014, 015, 016, 017, 018, 019, 020, 021, 022, 023, 024[b], 025[b], 026[b], 027[b], 028, 030, 031, 032, 033, 034, 037	Sandusky River Rock Creek[b]	11 03 90 01
2PD00031	Fostoria WWTP	004, 005, 006, 008[c]	East Branch Portage River Caples-Flack Ditch[c]	14 02
2PF00001	Sandusky WPC	004, 005, 006, 007, 008, 009, 011, 013, 014, 015, 016, 017, 019[e], 021	Sandusky Bay Mills Creek[d] Pipe Creek[e]	01 02 01 03

Notes

CSO = combined sewer overflow; LRAU = large river assessment unit; WAU = watershed assessment unit; WPCF = water pollution control facility; WWTP = wastewater treatment plant.

a. Bucyrus WWTP CSO outfall 027 discharges to an unnamed tributary of the Sandusky River.

b. Tiffin WWTP CSO outfalls 024, 025, 026, and 027 discharge to Rock Creek.

c. Fostoria WWTP CSO outfall 008 discharges to Caples Flack ditch in the Sandusky basin; outfalls 004, 005, and 006 discharge to the East Branch of the Portage River in the Portage River basin.

d. Sandusky WWTP CSO outfall 018 formerly discharged to Mill Creek; the outfall was eliminated in 2012.

e. Sandusky WWTP CSO outfall 019 discharges to Pipe Creek.

[9] Green Springs (2PB00026) is permitted to discharge overflow through outfall 602 to Flag Run Creek. During prolonged or intense precipitation events that overwhelm a lifting station, the flow is routed to an Imhoff holding tank. If the holding tank overflows, the bypass flow discharges through outfall 602. The bypass and Imhoff holding tank will be eliminated when Green Springs long term control plan is fully implemented.

Clyde CSS (2PD00004)

The Clyde CSS has an approved long term control plan (LTCP) and has been implementing the required programs and capital improvements. Thirteen sanitary sewer separation projects were completed from 1993-2002 that reduce six CSO outfalls to one CSO outfall. Outfall 010 is the last remaining CSO outfall. According to the discharge monitoring report (DMR) data, 135 CSO events occurred from September 2005 through June 2012; volumes ranged from less than 0.001 mgd to almost 7 mgd with an average of 0.5 mgd. The city has a nine year schedule to complete partial sewer separation and reduce overflows to 4 events or less per year.

Figure 17. CSO outfall on Raccoon Creek.

Ohio EPA (2010a) identified the Clyde CSS as a source of impairment to Raccoon Creek (HUC 04100011 02 04). The Clyde CSS was assigned a WLA for outfall 010 for the high flow condition only to address the CSO.

Fremont CSS (2PD00007)

The Fremont CSS has 585,000 linear feet of mainline sewers, with separate sanitary and storm sewers in the newer developed areas (Hitts et al. 2007). The CSS also receives wastewater from nearby rural communities; such communities have separated sanitary and storm sewers. The CSS and its history are discussed in the approved LTCP (Hitts et al. 2007). CSO data are summarized in Appendix C. The city has just started construction of a new 24MGD wastewater treatment plant. Construction is scheduled to be completed by December 31, 2015.

Ohio EPA (2011) did not identify Fremont CSOs as sources of impairment to the ALU or PDWS use of the Sandusky River LRAU from Wolf Creek to the mouth on Sandusky Bay (04100011 09 02)[10]. However, CSOs may contribute TSS and nutrient loads, and thus, may contribute to the sedimentation/siltation and nutrient/eutrophication impairments of the Sandusky River LRAU (90 02). No TMDL was developed on the Sandusky River (lower) downstream of Fremont CSS (due to the lacustuary); therefore, no WLA was developed for the Fremont CSS. Regardless, Fremont CSS must comply with its NPDES permit and LTCP.

Bucyrus CSS (2PD00021)

Of the 22 permitted CSO outfalls in the Bucyrus CSS, 15 outfalls discharged during one or more CSO events in 2011 and 2012. Outfalls 011, 018, and 021 have discharged one to three times since 2002 and none have discharged since 2004. Outfall 020 has discharged 4 times since 2002 and last discharged in 2010. CSO data are summarized in Appendix C. The Bucyrus CSS was addressed in the upper Sandusky River TMDL report (Ohio EPA 2004).

The Bucyrus CSS will be addressed through a boundary condition for the TMDL for the Sandusky River (lower) mainstem and will not be assigned an individual WLA. The CSS, as with all other NPDES permittees in the Sandusky River (upper) watershed, must comply with their NPDES permits to meet the Sandusky River (lower) mainstem TMDL.

[10] Ohio EPA (2011) did identify CSOs at the Fremont CSS as sources of impairment for the recreation use of the LRAUs.

Tiffin CSS (2PD00025)

The Tiffin CSS has 31 CSO outfalls (Table 14) and has an approved LTCP. Sanitary sewers will be separated during multi-phase construction schedule. CSO data are summarized in Appendix C.

Ohio EPA (2011) did not identify Tiffin CSOs as sources of impairment to the ALU of the Sandusky River LRAU from Tymochtee Creek to Wolf Creek (04100011 90 01). However, CSOs may contribute TSS loads, and thus, may contribute sedimentation to the Sandusky River LRAU (90 01). The city of Tiffin was addressed in the upper Sandusky River watershed TMDL (Ohio EPA 2004) and is upstream of the project area that is addressed in this TMDL report. The Tiffin CSS, as with all other NPDES permittees in the upper Sandusky River watershed, must comply with their NPDES permits to meet the Sandusky River (lower) mainstem TMDL; additionally, the Tiffin CSS must comply with its LTCP.

Fostoria CSS (2PD00031)

Only one CSO outfall in the Fostoria CSS is permitted to discharge to the Sandusky basin: outfall 008, which discharges to the Caples-Flack Ditch. DMR data show that no overflow events occurred from 2003 through 2012. In the mid-2000s, the weir at outfall 008 was repaired and raised such that a CSO event could only occur following a very intense storm[11]. Additionally, other CSS improvements (e.g., sewer line cleanings) have resulted in increased system-wide capacity that decreases the likelihood of CSO events.

Ohio EPA (2011) did not identify the Fostoria CSS as contributing to any impairment and Muddy Creek (HUC 04100011 14 02) is in full attainment. As the DMR data indicate that no CSO event has occurred within the past decade, including the years that Ohio EPA sampled, and there is no impairment, no WLAs for the Fostoria CSS will be developed. The Fostoria CSS must continue to comply with its NPDES permit.

Sandusky CSS (2PF00001)

Eleven of the Sandusky CSO outfalls discharge directly to Sandusky Bay, while a single CSO outfall each discharge to Mills Creek (outfall 018) and Pipe Creek (outfall 019). From 2003-2012, at outfall 018, CSO events were only reported in February and March 2011. During the same time period, outfall 019 regularly discharged, with multiple CSO events per month.

Ohio EPA (2010a) identified CSOs as sources of impairment to Mills Creek (HUC 04100011 01 03). However, DMR data do not show any overflows, except in February and March 2011, after Ohio EPA's field monitoring. The outfall was removed in 2012[12].

Ohio EPA (2010a) did not identify CSOs as sources of impairment to Pipe Creek (HUC 04100011 01 02). According to DMR data, 327 CSO events occurred at outfall 019 from January 2003 through June 2012; volumes ranged from 0.001 mgd to over 10 mgd, with an average of 0.3 mgd. The median estimated flow in Pipe Creek at CSO outfall 019 was 8.53 cfs (5.51 mgd) and the high flows were estimated at greater than 114 cfs (74mgd)[13]. Thus, the CSO effluent flow volumes were considerably smaller than in-stream flow volumes and Pipe Creek likely has sufficient assimilative capacity due to the dilution of the CSO effluent flow volumes.

[11] Dan Thornton, city engineer, city of Fostoria, personal communication, June 12, 2013.
[12] Jeff Meinert, WWTP Superintendent, city of Sandusky, personal communication, May 29, 2013.
[13] Monitored flow data are not available for Pipe Creek at CSO outfall 019. The median (50th percentile) and high (10th percentile) were estimated using the drainage area ratio method with SWAT-simulated flows in Pipe Creek at RM 2.32 (U05K15). At CSO outfall 019, Pipe Creek drains approximately 27.6 square miles (17,690 acres). Refer to Section 4.4 for a summary of SWAT modeling and to Appendix D for the SWAT model report).

As outfall 019 is downstream of the most downstream Ohio EPA assessment site on Pipe Creek (RM 2.32, U05K15) where the TMDL was developed, no WLA was assigned to the CSO outfall. However, the Sandusky CSS will still need to comply with Ohio EPA CSO policies and any CSS improvements to outfall 019 may improve water quality in the lower segments of Pipe Creek and Sandusky Bay.

4.2.1.2 Sanitary Sewer Systems with Overflows

Ohio EPA has documented sanitary sewer overflows (SSOs) at 19 of the public facilities with individual NPDES permits in the Sandusky basin (Table 15). The Crestline WWTP permit (2PC00006) identifies multiple recurring SSOs but no SSO event data are available from January 2003 - January 2012.

Table 15. Public facilities with SSOs

NPDES ID	Facility	WAU (04100011)	Period of record	No. of SSO events
2PA00024	Lindsey WWTP	14 04	Apr. 2011 - Dec. 2012	15
2PA00070	Nevada WWTP	03 02	Apr. 2007 - Dec. 2012	3
2PA00072	Bettsville STP	10 04	Oct. 2009 - Dec. 2012	0
2PA00087	Republic WWTP	11 02	Jun. 2007 - Dec. 2012	0
2PA00097	Helena WWTP	14 02	Nov. 2008 - Dec. 2012	0
2PB00000	Sycamore WWTP	09 03	Jan. 2008 - Dec. 2012	0
2PB00056	Sawmill Creek STP	01 01	Feb. 2008 - Dec. 2012	35
2PB00060	New Washington WWTP	08 01	Aug. 2009 - Dec. 2012	0
2PB00053	Bloomville WWTP	08 05	Jun. 2009 - Dec. 2012	0
2PD00004	Clyde WWTP	02 04	May 2007 - Jun. 2012	14
2PD00007	Fremont WPCF	multiple	Aug. 2007 - Dec. 2012	0
2PD00021	Bucyrus WWTP	04 03	Nov. 2004 - Dec. 2012	1
2PD00025	Tiffin WWTP	multiple	Jul. 2005 - Jun. 2012	0
2PD00037	Bellevue WWTP	01 03	Jul. 2007 - Jun. 2012	2
2PD00038	Carey WWTP	06 04	Sep. 2008 - Dec. 2012	0
2PD00039	Upper Sandusky WWTP	multiple	Dec. 2004 - Dec. 2012	0
2PF00001	Sandusky WPC [a]	multiple	May 2008 - Dec. 2012	5
2PG00053	Danbury Township WWTP	14 05	Aug. 2008 - Dec. 2012	7
2PG00118	Bascom WWTP	10 02	Mar. 2011 - Dec. 2012	0

Notes
STP = sewage treatment plant; WPC = water pollution control facility; WWTP = wastewater treatment plant.
a. Five SSO events discharged a total of 97,000 gallons at the Sandusky WWTP on July 27, 2010 through its CSO outfalls as the plant was shut down for 5 hours to repair the final clarifiers.

SSOs do not receive WLAs within the TMDL framework because SSOs are violations of NPDES permits. NPDES-delegated agencies enforce compliance with NPDES permits. In general, TMDLs require all NPDES permittees to fully comply with their NPDES permits.

4.2.1.3 Sludge Fields

WWTP sludge, similar to livestock manure and HSTS septage, is applied as a fertilizer to crop fields. In the Sandusky basin, WWTP sludge is applied to 396 sites across 24 WAUs (Table 16 and Figure 18). Refer to Appendix C for a list of public facilities with individual NPDES permits that apply their sludge to agricultural fields.

Table 16. Summary of sludge application sites by WAU in the TMDL project area

HUC	Name	No. of sludge application sites	Ohio EPA estimated area (acres)
Mills Creek-Frontal Lake Erie (04100011 01)			
01	Sawmill Creek	2	107
02	Pipe Creek - Frontal Sandusky Bay	3	87
03	Mill Creek	38	1,865
Pickerel Creek-Frontal Sandusky Bay (04100011 02)			
01	Frontal south side of Sandusky Bay	29	1,763
02	Strong Creek	34	1,870
03	Pickerel Creek	47	2,296
04	Raccoon Creek	13	1,218
05	South Creek	6	240
Wolf Creek (04100011 10)			
01	East Branch East Branch Wolf Creek	4	351
02	Town of New Riegel - East Branch Wolf Creek	2	202
03	Snuff Creek - East Branch Wolf Creek	7	125
04	Wolf Creek	9	303
Rock Creek-Sandusky River (04100011 11)			
01	Rock Creek	--	--
02	Morrison Creek	8	205
03	Willow Creek - Sandusky River	--	--
04	Sugar Creek	--	--
05	Spicer Creek - Sandusky River	8	209
Green Creek (04100011 12)			
01	Westerhouse Ditch	--	--
02	Beaver Creek	9	289
03	Green Creek	7	612
Muskellunge Creek-Sandusky River (04100011 13)			
01	Muskellunge Creek	6	384
02	Indian Creek - Sandusky River	3	482
03	mouth Sandusky River	11	791
Muddy Creek-Frontal Sandusky Bay (04100011 14)			
01	Gries Ditch	4	222
02	Town of Helena - Muddy Creek	25	1,450
03	Little Muddy Creek	14	842
04	Town of Lindsey - Muddy Creek	5	426
05	North Side Sandusky Bay Frontal	15	760

Notes
Only the watershed assessment units (WAU) in TMDL project area are presented in this table.
A double dash (“--“) indicates that WWTP sludge was not applied to agricultural properties in the given WAU.

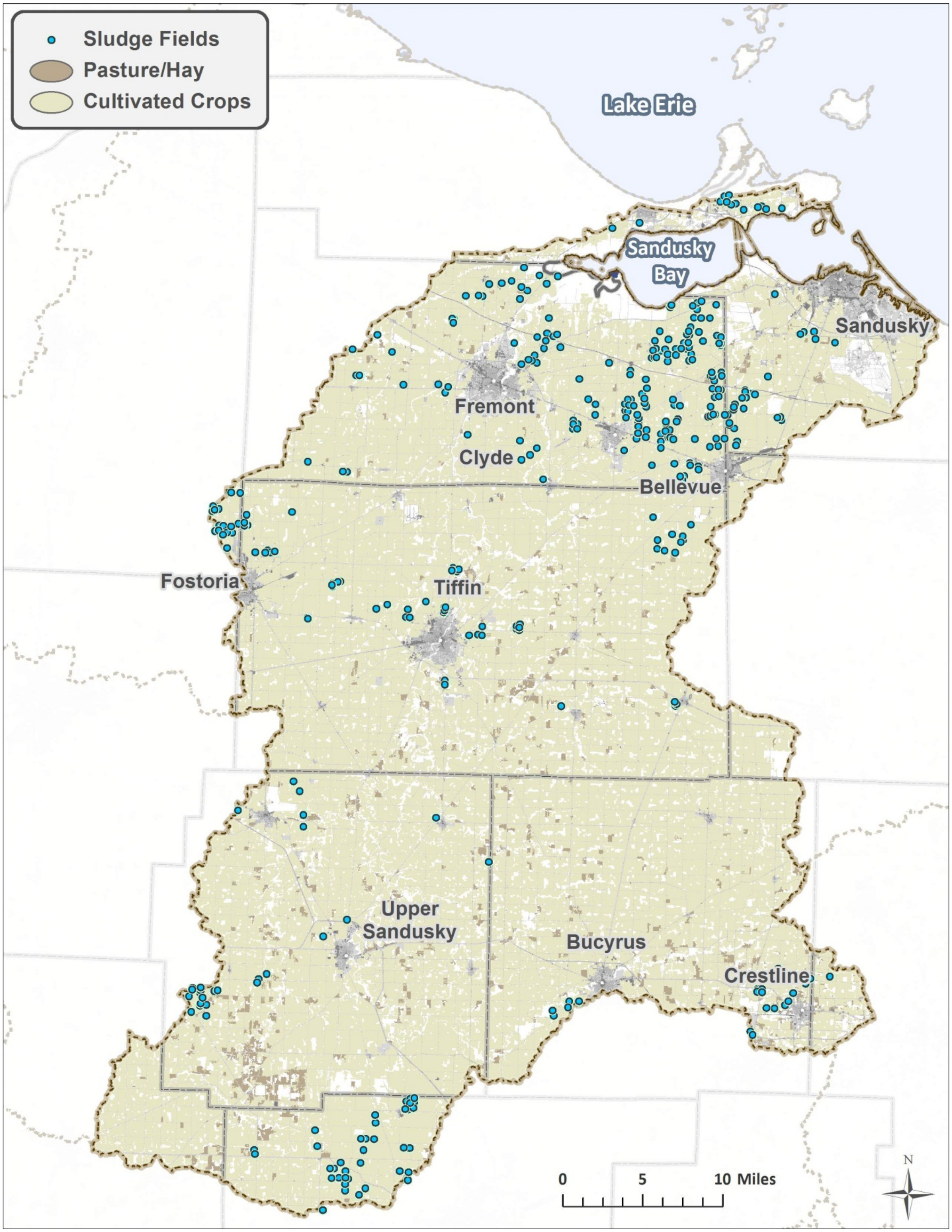


Figure 18. WWTP sludge application fields in the Sandusky basin.

4.2.2 Facilities with General NPDES Permits (Non-Storm Water, Non-HSTS)

Seven facilities in the Sandusky basin are covered by general NPDES permits for non-storm water, non-HSTS discharges (Table 17). The facilities are discussed individually in the following subsections and a map of the Sandusky Basin with these facilities is in Appendix C.

Table 17. Facilities with general NPDES permits (non-storm water)

NPDES ID	Permittee	Permit type	WAU (04100011)
2GB00001	Beck Suppliers, Inc. Sandusky Bulk Plant	petroleum bulk storage facility	02 01
2GB00005	G & L Oil Company, Inc.	petroleum bulk storage facility	11 03
2GH00002[a]	Fremont M&R Station Project	hydrostatic test water	14 03
2GH00008[a]	Fremont Energy Center	hydrostatic test water	13 01
2GS00018	Cranberry Hills Golf Course	small sanitary discharger	08 02
2GV00003	Auburn Lake Park LLC	small sanitary discharger that cannot meet best available demonstrated control technology	08 02
2GW00004	Crestline WTP	water treatment plant	04 01

Note: a. Facilities are no longer active.

Beck Suppliers, Inc. (2GB00001) and G&L Oil Company, Inc. (2GB00005) do not discharge to impaired waters, and Fremont M&R Station Project (2GH00002) and Fremont Energy Center (2GH00008) are no longer active. Therefore, these four facilities will not receive WLAs.

As the Cranberry Hills Golf Course (2GS00018), Auburn Lake Park LLC (2GV00003), and Crestline WTP (2GW00004) are in the upper Sandusky River watershed, they will be addressed through a boundary condition for the TMDL for the Sandusky River (lower) mainstem and will not be assigned individual WLAs. These three facilities, as with all other NPDES permittees in the upper Sandusky River watershed, must comply with their NPDES permits to meet the Sandusky River (lower) mainstem TMDL.

4.2.2.1 Hydrostatic Test Water

Discharges of hydrostatic test waters are not expected to contain nutrients and are not required to monitor nutrients; such facilities may discharge TSS and Ohio EPA has established a maximum limit of 45 mg/L and a monthly mean of 30 mg/L. As the facilities do not actively discharge, they will not be further considered.

4.2.2.2 Petroleum Bulk Storage

Petroleum bulk storage facilities may discharge small concentrations of phosphorus but Ohio EPA found such concentrations to be insignificant and to rarely exceed 1 mg/L. Therefore, Ohio EPA does not assign permit limits to petroleum bulk storage facilities.

Beck Suppliers, Inc. (2GB00001) is in the Cold Creek subwatershed (HUC 04100011 02 01) that is impaired by natural conditions. Ohio EPA (2010a) did not identify this general permitted facility as a source of impairment; thus, it will not be further discussed.

G&L Oil Company, Inc. (2GB00005) is in a WAU that includes the city of Tiffin and the Sandusky River (HUC 04100011 11 03). Ohio EPA (2011) found this WAU to be in full attainment of its designated uses; thus, this facility will not be further discussed.

4.2.2.3 Small Sanitary Sewerage Treatment

Small sanitary dischargers are sewerage treatment facilities that are permitted to discharge treated sanitary wastewaters for up to 25,000 gallons per day. Non-best available demonstrated control technology (BADCT) small sanitary dischargers are sewerage treatment facilities built before July 1, 1993 that are permitted to discharge treated sanitary wastewater for up to 25,000 gallons per day but cannot meet water quality criteria derived from best available demonstrated control technology (BADCT). This permit mandates a three year compliance schedule, after which the small sanitary discharger must meet BADCT and apply for the small sanitary discharger general permit.

The Cranberry Hills Golf Course (2GS00018) is a small sanitary discharger in the *Upper Honey Creek* subwatershed (04100011 08 02). The Auburn Lake Park LLC, a small sanitary discharger that cannot meet BADCT, is also in the *Upper Honey Creek* subwatershed. Thus, Cranberry Hills Golf Course and Auburn Lake Park cannot contribute to any impairment of the tributaries to the Sandusky River (lower) or Sandusky Bay. While both facilities discharges TSS and nutrient loads, it is unlikely these pollutants contribute to the impairments of the Sandusky River LRAUs since the facilities are over 40 miles upstream of the LRAUs and their effluent flow is insignificant compared to the flow in the Sandusky River within the LRAUs.

4.2.2.4 Water Treatment Plants

Water treatment plants (WTPs) are permitted to discharge wastewater associated with production of potable water. Some types of WTPs must be covered under individual NPDES permits. WTPs covered under this general permit may discharge TSS and Ohio EPA has established a maximum limit of 45 mg/L and a monthly mean of 30 mg/L.

The Crestline WTP (2GW00004) is in the *Headwaters Paramour Creek-Sandusky River* subwatershed (HUC 04100011 04 01) within the upper Sandusky River watershed. Thus, the Crestline WTP cannot contribute to any impairment of the tributaries to the lower Sandusky River or Sandusky Bay. The Crestline WTP is over 75 miles upstream of the impaired LRAUs on the Sandusky River. If the Crestline WTP is in compliance with its general NPDES permit and the TMDLs for the upper Sandusky River, then the WTP is not a source of impairment to the Sandusky River LRAUs.

4.2.3 Household Sewage Treatment Systems

HSTS (also known as onsite wastewater treatment systems or septic systems) treat domestic sanitary waste and are common in rural areas without sewer systems. In the past, HSTS were considered nonpoint sources of pollution; however, a subset of HSTS in Ohio is now considered point sources and is regulated by Ohio's NPDES program. Ohio EPA issues general NPDES permits for new or replacement HSTS that discharge to waters of the state.

This section includes discussions of general HSTS information (Section 4.2.3.1), the Ohio Department of Health's (ODH) HSTS study (Section 4.2.3.2), and general permits for HSTS in Ohio (Section 4.2.3.3).

4.2.3.1 Background

HSTS that are properly designed and maintained should not serve as a source of contamination to surface waters. However, onsite systems do fail for a variety of reasons. Common soil-type limitations that contribute to failure are seasonal water tables, compact glacial till, bedrock, coarse sand and gravel outwash and fragipan. When septic systems fail hydraulically due to surface breakouts or inadequate soil filtration, adverse effects on surface waters can result (Horsely and Witten 1996). HSTS contain all the water discharged from homes and business and can be significant sources of pathogens (e.g., bacteria) and nutrients (e.g., total phosphorus and nitrate nitrogen). Effects on surface water from HSTS are dependent on numerous factors, including soil characteristics, topography, hydrography, and their proximity to streams. The Toledo Metropolitan Area Council of Governments (TMACOG) compiled and summarized HSTS information regarding regulations, design, and environmental issues with emphasis on northwest Ohio in their *TMACOG Areawide Water Quality Management Plan* (TMACOG 2011, Chapter 5).

If properly designed, sited, installed, operated, and maintained, HSTS will remove suspended solids, biodegradable organic compounds, and fecal coliforms (U.S. EPA 2002, p.3-22). If HSTS do not sufficiently treat wastewater, then the following pollutants may be found in HSTS wastewater: nitrates, pathogens, and phosphorus (U.S. EPA 2002, p. 3-20). If a subsurface pollutant plume expands to the water table, then these pollutants may be transported via ground water and discharged to surface water.

TSS may also be present in HSTS effluent, though most properly working systems remove most of the TSS (e.g., TSS settles out [i.e., sedimentation occurs] in septic tanks). If too much TSS enters the system, it may clog the system and reduce infiltration. Directly discharging HSTS may contaminate surface waters as the TSS forms sludge that will detrimentally affect benthic macroinvertebrates (U.S. EPA 2002).

Application of domestic septage to farm fields is regulated by local health departments, the Ohio Department of Health, Ohio EPA, and U.S. EPA. Some WWTPs in the Sandusky basin also accept septage for disposal and treatment. Domestic septage that is applied to crop fields may be transported via runoff from precipitation events to surface streams. Crop fields with septage application that are drained by tiles will more rapidly transport runoff containing septage to streams and open ditches. The tile drains yield larger and faster flows that can carry septage farther downstream.

4.2.3.2 Ohio Department of Health 2012 HSTS Study

ODH conducted an HSTS study in 2012 to support Ohio EPA's CWA requirements. As reported in the Household Sewage Treatment System Failures in Ohio (ODH 2013), approximately 31 percent of HSTS in Ohio are failing; results for pertinent areas are displayed in Table 18.

Table 18. HSTS and failure rates in five counties in the Sandusky basin

Area	No. of HSTS	No. of failing HSTS	Failure rate [a]
Ohio	628,493	193,988	31%
Northwest District [b]	117,819	45,560	39%
Erie County	7,433	4,560	61%
Crawford County	13,951	2,073	15%
Sandusky County	5,647	1,979	35%
Seneca County	10,227	7,379	72%
Wyandot County	4,635	4,150	90%

Sources: ODH 2013
Notes
a. The estimate failure rate includes systems that are old or are no longer allowed to be installed (e.g., discharger to dry wells).
b. Ohio EPA's Northwest District consists of the following counties: Allen, Ashland, Auglaize, Crawford, Defiance, Erie, Fulton, Hancock, Hardin, Henry, Huron, Lucas, Marion, Mercer, Ottawa, Paulding, Putnam, Richland, Sandusky, Seneca, Van Wert, Williams, Wood and Wyandot.

The most common types of HSTS in Ohio are *septic tank or pretreatment to leaching* (43 percent) and *septic tank or pretreatment to discharge* (17 percent). *Septic tank or pretreatment to leaching* (47 percent) and *septic tank or pretreatment to unknown* (21 percent) are the most common types of HSTS in

Crawford, Erie, Sandusky, Seneca, and Wyandot counties (Table 19). Privies (outhouses) were not reported in these 5 counties

Table 19. HSTS types and failure rates in five counties in the Sandusky basin

HSTS type	No. of HSTS	No. of failing HSTS	Failure rate [a]
Septic tank or pretreatment to leaching	19,631	5,154	26%
Septic tank or pretreatment to mound system	479	26	5%
Septic tank or pretreatment to sand filter	3,355	2,275	68%
Septic tank or pretreatment to discharge	3,075	1,857	60%
Septic tank or pretreatment to unknown	8,649	6,468	75%
Dry wells	20	20	100%[b]
Unknown	6,675	4,335	65%
Other:	9	6	67%

Sources: ODH 2013
Notes
Refer to Appendix C for additional HSTS type data by county.
a. The estimate failure rate includes systems that are old or are no longer allowed to be installed (e.g., discharger to dry wells).
b. Dry well systems are no longer allowed and are considered to be failing.

Across Ohio, of the known systems[14], 49 percent of *septic tank or pretreatment to discharge* are reported as failing (ODH 2013). Of the known systems in the five counties in the Sandusky basin, 68 percent of *septic tank to or pretreatment to discharge* are reported as failing. HSTS can be reported as failing for one or more reasons. The most common reasons for system failures in Ohio are old systems (44 percent), direct discharges exceed water quality standards (43 percent), and soil limitations (33 percent). Dry well systems are no longer allowed to be installed and all such systems are considered to be failing.

4.2.3.3 HSTS with General NPDES Permits

Two general permits are issued depending on which agency determines HSTS eligibility: Ohio EPA (OHL00001) or local boards of health (OHK00001). Permit coverage is only granted to discharging systems when a residence cannot be served by an onsite soil adsorption system or by sanitary sewers. Permit coverage is granted for new and replacement systems; existing systems do not have to apply for permits.

The Ohio Department of Health conducted an HSTS study in 2012 and 3,075 discharging HSTS were reported in Crawford, Erie, Sandusky, Seneca, and Wyandot counties (ODH 2013). Only 190 discharging HSTS currently have general permit coverage in these five counties (Table 20).

Table 20. Discharging HSTS with general NPDES permits in five counties in the Sandusky basin

County	OHL00001	OHK00001	OHK00002	Total
Crawford	1[a]	11	19	30
Erie	0	36	35	71
Sandusky	0	5	8	13
Seneca	0	29	36	65
Wyandot	1[a]	6	5	11

Note: The two permittees under general permit OHL00001 were formerly permittees under general permit OHK00002.

[14] The type of HSTS can be reported as ‘unknown’; 56 percent of unknown systems were reported as failing. Additionally, 51 percent of *septic tank or pretreatment to unknown* were failing.

4.2.4 Facilities and Entities with Storm Water General NPDES Permits

Regulated storm water runoff can be a significant source of pollutants to the Sandusky basin. Storm water runoff can contain sediment and nutrients, in addition to numerous other pollutants. In addition, storm water runoff rates and volumes can cause impacts to stream channels and habitat. The sections below present general information regarding pollutant transport in urban storm water and a summary of Ohio's storm water program, including information that is specific to the project area.

4.2.4.1 Urban Storm Water

The type of development and land uses generally determine the quality of and constituents in the storm water (Shaver et al. 2007) as does the level of automobile activity (Burton and Pitt 2002). Storm water from transportation land uses (e.g., roads, bridges, service stations) can contain petroleum hydrocarbons or copper derived from brake pads whereas storm water derived from washoff of fertilized residential lawns, golf courses, and manicured or landscaped areas can contain elevated levels of nutrients (Shaver et al. 2007). Urban and suburban storm water runoff characteristics typically differ considerably as compared to rural and undeveloped areas (Pitt et al. 1995; U.S. EPA 1983).

Any constituents that are deposited on impervious surfaces will typically remain there until they are picked up and transported by urban storm water. For example, when pet waste is improperly disposed of, it can be picked up by storm water runoff and washed into storm drains or nearby waterbodies. Since storm drains do not always connect to treatment facilities, untreated animal feces often end up in lakes and streams. In undeveloped areas, some constituents will be transported to shallow aquifers as water infiltrates, as in the karst areas of the Sandusky basin. However, because infiltration cannot occur on impervious surfaces, pollutants that accumulate on impervious surfaces will be rapidly carried to surface waterbodies through runoff or storm water conveyance systems where they can pose a risk to human and ecological health (Shaver et al. 2007; Schueler 1994).

Many toxic constituents bond to particulate matter and can be transmitted in storm water while adsorbed to the sediment. For example, "hydrocarbons are normally attached to sediment particles or organic matter carried in urban runoff" (Shaver et al. 2007 p. 3-48). Because storm water tends to travel rapidly over impervious surfaces, the high-velocity water has an increased "ability to detach sediment and associated pollutants, to carry them off site, and to deposit them downstream" (Burton and Pitt 2002, p. 31). The sediment and adsorbed pollutants can accumulate in bottom sediments "where they are readily available to aquatic organisms and possible re-suspension during future storm events" (Masterson and Bannerman 1994, p. 131). Sedimentation can increase in downstream ponds or slower-moving streams when sediment-laden, high-velocity storm water discharges to the waterbodies.

Pitt et al. (1996, p.4) evaluated urban storm water and found that metals were typically detected in high concentrations. Masterson and Bannerman (1994) generally found that heavy metal concentrations in urban streams in Wisconsin exceeded the concentrations in reference streams. Stress and lethality to aquatic organisms can occur from episodic exposure to storm water laden with metals (Burton and Pitt 2002, p. 77). The typical sources of nutrients (e.g., nitrates and phosphates) in urban runoff include fertilizer washoff from lawns, landscaped areas, and golf courses (Shaver et al. 2007, p. 3-47). Bacteria sources include pet and wildlife waste that are transported via runoff from a precipitation event to storm sewers and streams; illicit connections to the storm sewers are also a potential source of bacteria since the domestic waste from the illicit connection does not get treated. Typical sources of sediment in urban storm water include bank erosion, which increases due to faster and more powerful stream flows caused by urban development, and runoff from construction or industrial sites that is not properly contained (e.g., silt fences) and treated (e.g., settling pond).

4.2.4.2 Ohio's Regulated Storm Water Program

Ohio EPA regulates storm water through various individual and general NPDES permits. There are not any storm water discharges from large or medium MS4s covered by individual NPDES permits. Storm water discharges from small MS4s, industrial facilities, and constructions sites are covered by general NPDES permits and storm water from certain industrial facilities is covered by individual NPDES permits.

The Multi-Sector General Permit, which addresses storm water discharges associated with industrial activities (OHR000005), is effective from January 2012 through December 2016. As of August 2013, 38 facilities in the project area have NPDES general permit coverage for storm water discharges associated with industrial activities (Appendix C).

The NPDES general permit for storm water discharges associated with small and large construction activities (U.S. EPA ID OHC000003) is effective from April 2013 through April 2018. The previous general permit for storm water discharges associated with small and large construction activities (U.S. EPA ID OHC00002) was effective from April 2008 through April 2013. Over 370 construction sites were issued permit coverage between April 2003 and April 2013 in three counties in the Sandusky basin: Erie, Sandusky, and Seneca. Construction sites ranged in size from 1 acre to 698 acres (average: 12 acres; median: 5 acres).

Ohio also has a general NPDES permit for storm water discharges associated with industrial activity from marinas that was renewed in January 2013 (OHRM00002). Only one marina, Riverfront Marina and Campground (2GRM00014), discharges to the Sandusky River, a waterbody of concern. Any facilities (including marinas) that discharge to Sandusky Bay or Lake Erie are not addressed by this TMDL report.

Under Phase I of the NPDES Storm Water Program, MS4s serving populations of over 100,000 people are considered medium or large MS4s.There are not any Phase I MS4s in the Sandusky basin. Phase II of the NPDES Storm Water Program outlines regulations for MS4s serving populations of fewer than 100,000 people. These regulated small MS4s are required to obtain NPDES permit coverage for their storm water discharges when the MS4 is located within the Urbanized Area as defined by the U.S. Census or when they have been designated by the director of the Ohio EPA. In Ohio, regulated small MS4s may operate under the statewide Small MS4 general permit (OHQ000002), which first requires dischargers to file a Notice of Intent and Storm Water Management Program.

The Small MS4 general permit requires MS4s to implement a Storm Water Management Plan designed to reduce the discharge of pollutants to the maximum extent practical, to protect water quality, and to satisfy the appropriate water quality requirements of Ohio Revised Code chapter 6111 and the Clean Water Act, by implementing six minimum control measures. The six minimum control measures are public education, public involvement, illicit discharge detection and elimination programs, control of construction site runoff, post-construction storm water management in new development and redevelopment, and pollution prevention/good housekeeping for municipal operations. Permitted entities operating under the Small MS4 general permit in the Sandusky basin are identified in Table 21. Small MS4s include cities, villages, townships, and county road authorities. Cities, villages, and townships can be co-permittees with county road authorities and are identified in Ohio's Small MS4 permits with the label "and others". The Ohio Department of Transportation (ODOT) and Ohio Turnpike Commission (OTC) are also regulated MS4s in the Sandusky basin. Also, while a portion of Ottawa County is in the Sandusky basin, this portion is not covered under the Ottawa County and Others Small MS4 permit (2GQ00022). The Ohio Turnpike is not within the urbanized area in the Sandusky basin; therefore, the Ohio Turnpike Commission is not a regulated MS4. The regulated small MS4s in the Sandusky basin are presented in Table 21.

Table 21. Regulated small MS4s in the Sandusky basin

NPDES ID	Permittee	County
2GQ00027	Erie County and Others	Erie County
2GQ00031	city of Tiffin	Seneca County
2GQ00032	city of Bucyrus	Crawford County
4GQ00000	ODOT	Erie County

The Sandusky basin is in ODOT Districts 1, 2, 3, and 6. The only regulated areas in the TMDL project area are state and U.S. routes in northern Erie County in ODOT District 3. ODOT's MS4 area in District 3 includes one office, four garages, two outposts, three rest stops, and 194.16 miles of roadway (ODOT 2011).[15] Although ODOT is a nontraditional MS4, it still complies with all the requirements of the Small MS4 general permit; its activities are presented in the *Storm water Management Plan and 2010 Annual Report* (ODOT 2011).

For this report, only entities covered by the Small MS4 general permit in the project area (which excludes the area covered by the upper Sandusky River TMDL) receive individual WLAs. Roadways under the authority of Erie County in Margaretta and Perkins townships (co-permittees of the *Erie County and Others* Small MS4 permit) contribute to the *Erie County and Others* surrogate area when such roadways are within a 2010 Census urbanized cluster. ODOT also receives its own WLA that represents U.S. routes and state routes. A summary of surrogate MS4 areas that will receive WLAs is presented in Table 22.

Table 22. Surrogate MS4 areas in the TMDL project area

NPDES ID	Regulated entity	Description of surrogate MS4 area
2GQ00027	Erie County and Others	▪ city of Sandusky incorporated area ▪ Margaretta Township developed area [a] ▪ Perkins Township developed area [a] ▪ county and township roads [b]
4GQ00000	ODOT	U.S. routes and state routes within the 2010 Census urbanized area Sandusky urban cluster excluding the portions of the routes within the city of Sandusky [c]

Notes

a. The developed area is calculated as the summation of the developed land classes (developed, open; developed, low intensity; developed, medium intensity; and developed, high intensity) from the 2006 NLCD for each township that is within the 2010 urbanized area's Sandusky urban cluster.

b. The areas for road authorities were calculated as a 60-foot buffer around the segments of the roads located within the 2010 Census urbanized area's Sandusky urban cluster.

4.2.5 Concentrated Animal Feeding Operations with Individual NPDES Permits

Three concentrated animal feeding operations (CAFOs) are located in the Sandusky basin and all three are in the upper Sandusky River watershed. The CAFOs are permitted to discharge storm water from production areas caused by a 25-year 24-hour storm or greater; however, such storm water discharges may not cause the receiving waterbody to exceed Ohio's water quality standards. The NPDES permits allow storm water to be discharged from fields with land-applied manure when the land application complies with the manure management plan and NPDES permit. The three CAFOs are not permitted to discharge during dry weather.

As these three CAFOs are located in the Sandusky River (upper) watershed, they will be addressed through a boundary condition for the TMDLs for the Sandusky River (lower) mainstem and will not be

[15] A map of ODOT's MS4 jurisdiction in Districts 1 and 2 is available at: http://www.dot.state.oh.us/storm water/mapping/Pages/default.aspx.

assigned individual WLAs. These three CAFOs, as with all other NPDES permittees in the Sandusky River (upper) watershed, must comply with their NPDES permits to meet the Sandusky River (lower) mainstem TMDL.

4.2.5.1 Tuck Farms

Tuck Farms (2IK00048) is a swine farm that is permitted to have up to 2,100 hogs that are greater than 55 pounds. Tuck Farms is permitted not to land-apply manure; manure is transported off site and distributed to third parties. Ohio EPA conducted an on-site inspection on May 11, 2012 and found the CAFO to be in compliance with its permit.

4.2.5.2 Ohio Fresh Eggs

Trillium Farm Holdings LLC operates multiple facilities in northwest Ohio, including two CAFOs in the Sandusky basin: Marseilles egg farm (2IK00031) and Goshen pullet site (2IK00033). Both CAFOs were inspected by Ohio EPA on June 27, 2012 and were found to be in compliance with their NPDES permits.

As the Marseilles egg farm, storm water is permitted to be discharged from an egg wash water lagoon (i.e., a storm pond) with an outfall on an unnamed ditch to Tymochtee Creek. Storm water that comes into contact with dust and feathers blow outside by barn fans may be discharged while spills of manure or egg wash routed to the egg wash lagoon may not be discharged. The Marseilles egg farm is permitted to land-apply manure to tiled fields.

Egg wash water was over-applied at the Marseilles egg farm on April 22, 2010 and was discharging through the tile system into an unnamed ditch to Carroll Creek. Ohio EPA Division of Surface Water's CAFO Unit and the Ohio Department of Agriculture Livestock Environmental Permitting Program investigated, including sending agents to the CAFO and collecting water quality samples, and issued a notice of violation to Ohio Fresh Eggs for their Marseilles egg farm

At the Goshen pullet site, storm water is permitted to be discharged from three storm ponds with outfalls on an unnamed tributary to Paw Paw Run. Storm water that comes into contact with dust and feathers blow outside by barn fans may be discharged. The Goshen pullet site is not permitted to land-apply manure.

4.3 Nonpoint Sources

The term *nonpoint source pollution* is defined as any source of pollution that does not meet the legal definition of point sources. Nonpoint source pollution typically results from storm water runoff and background conditions. Note that storm water collected and conveyed through a regulated MS4 is considered a point source. Since agricultural practices such as crop cultivation (75 percent) and pasture/hay (2 percent) cover an estimated 77 percent of the Sandusky basin, nonpoint source pollution can contribute a significant amount of the total pollutant load. In addition to runoff and erosion, significant nonpoint sources also include home sewage treatment systems and animals.

4.3.1 Storm Water Runoff (Non-Regulated)

During wet-weather events (snowmelt and rainfall), pollutants are incorporated into runoff and can be delivered to downstream waterbodies. The resultant pollutant loads are linked to the land uses and practices in the watershed. Agricultural and developed areas can have significant effects on water quality if proper best management practices are not in place. The main pollutants of concern associated with agricultural runoff are sediment, nutrients, pesticides, and bacteria. Storm water from developed areas can be contaminated with oil, grease, chlorides, pesticides, herbicides, nutrients, viruses, bacteria, metals, and sediment. In urban areas, some connections to storm sewers are illicit, which includes residences and businesses that discharge untreated wastewater to the storm sewers.

In addition to pollutants, alterations to a watershed's hydrology as a result of land uses changes can detrimentally affect habitat and biological health. Imperviousness associated with developed land uses and agricultural field tiling can result in increased peak flows and runoff volumes and decreased base flow as a result of reduced ground water discharge. The increased peak flows and runoff volumes tend to increase streambank erosion. These more powerful flows have more capacity to move larger sediment particles farther, which may result in downstream sedimentation when the in-stream flow decreases. Drain tiles also transport agricultural runoff directly to ditches and streams, whereas runoff flowing over the land surface may infiltrate to the subsurface and may flow through vegetated riparian areas. Thus, runoff transported through drain tiles will contain all of the pollutants that it contained when the runoff entered the tile system; surficial runoff may lose pollutants as it is filtered during infiltration and passes through the vegetated riparian corridor.

For a general review of the effects of urbanization and storm water and references to additional resources, see the *CADDIS Urbanization Module* (U.S. EPA 2012) and *The Importance of Imperviousness* (Schueler 1994). Regulated storm water sources are discussed in Section 4.2.4. Sources of pollutants in non-regulated storm water are discussed in the sections below.

4.3.2 Erosion

Sedimentation and siltation were identified as causes of impairment for many streams in the project area. For sedimentation (i.e., deposition of sediment) to occur, a source of sediment must be present. Various forms of erosion are a common source of sediment. Typically, erosion will increase as stream velocity and peak flow increases. Runoff over impervious surfaces and through agricultural drain tiles will have higher velocities and peak flows, and thus, increase erosion.

4.3.2.1 Sheet and Rill Erosion

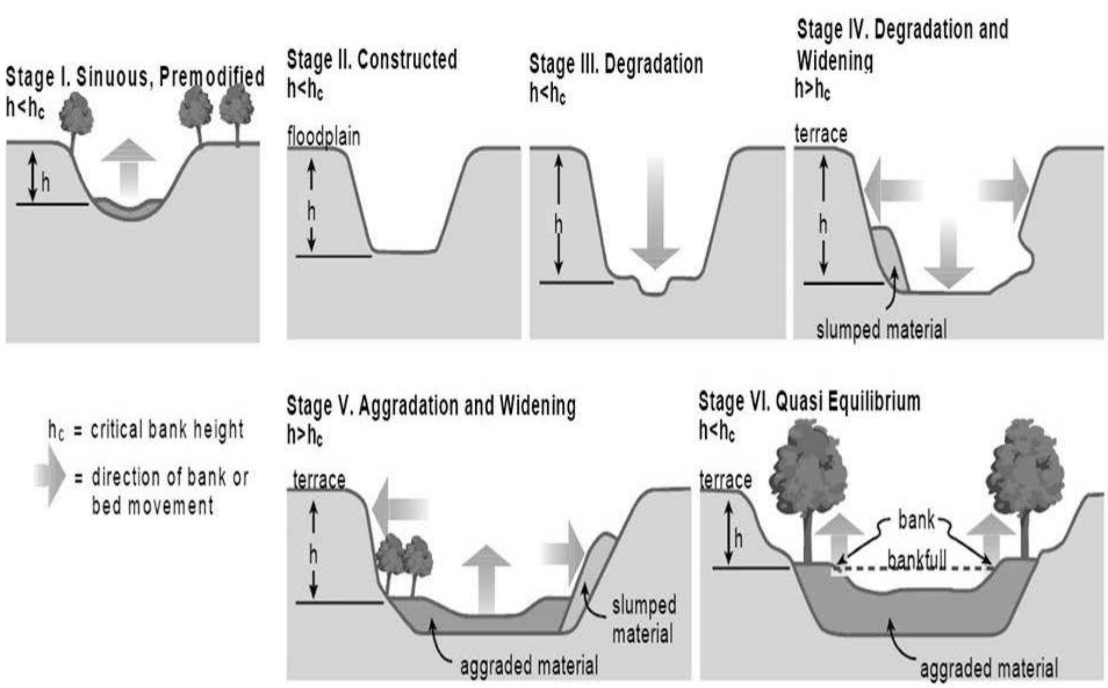
Sheet erosion is the detachment of soil particles by raindrop impact and their removal by water flowing overland as a sheet instead of in channels or rills. Rill erosion refers to the development of small, ephemeral concentrated flow paths, which function as both sediment source and sediment delivery systems for erosion on hillsides. Sheet and rill erosion occur more frequently in areas that lack or have sparse vegetation. Sheet and rill erosion may transport contribute to a phosphorus impairment if the sediment that is eroded includes phosphorus attached to the sediment particles. Sheet or rill erosion may also transport pathogens from animal waste that was deposited by livestock, pets, or wildlife and from manure or septage that is applied to crop fields.

4.3.2.2 Bank and Channel Erosion

Bank and channel erosion refers to the wearing away of the banks and channel of a stream or river. High rates of bank and channel erosion can often be associated with water flow and sediment dynamics being out of balance. This can result from land use activities that either alter flow regimes, adversely affect the floodplain and streamside riparian areas, or a combination of both (Figure 19). Hydrology is a major driver for both sheet/rill and stream channel erosion.

Figure 19. Bank and channel erosion along Pipe Creek with nearby cropland.

Stream geomorphology pertains to the shape of stream channels and their associated floodplains. The capacity of a stream system to assimilate pollutants such as sediment, nutrients, and organic matter depends on features related to its geomorphology. This is especially the case for floodplains which, if connected to the channel, can store large quantities of sediment. A conceptual model of channel evolution was used to characterize varying stages of channel modification through time, as illustrated in Figure 20 (Simon and Hupp 1986). Stage I, undisturbed conditions, is followed by the construction phase (Stage II) where vegetation is removed or the channel is modified significantly (through altered hydrology, for example). Degradation (Stage III) follows and is characterized by channel incision. Channel degradation leads to an increase in bank heights and angles, until critical conditions of the bank material are exceeded. Eventually, stream banks fail by mass wasting processes (Stage IV). Sediments eroded from upstream degrading reaches and tributary streams are deposited along low-gradient downstream segments. This process reflects channel aggradation and begins in Stage V. Aggradation continues until stability is achieved through a reduction in bank heights and bank angles. Stage VI (re-stabilization) is characterized by the relative migration of bank stability upslope, point-bar development, and incipient meandering. Stages I and VI represent two true *reference* or attainment conditions.



Source: Simon and Hupp 1986.

Figure 20. Channel evolution model.

Bank erosion is a natural process. Acceleration of this process, however, leads to a disproportionate sediment supply, channel instability, and aquatic habitat loss (Rosgen 2006). Bank erosion processes are driven by two major components: streambank characteristics (e.g., erodibility) and hydraulic forces. Many land use activities affect both these components, which can lead to increased bank erosion. Riparian vegetation and floodplain protection provide internal bank strength. Bank strength can protect banks from fluvial entrainment and subsequent collapse. For instance, when riparian vegetation is changed from woody species to annual grasses, the internal strength is weakened, thus accelerating bank erosion processes. The material from the eroded banks is later deposited via sedimentation in a segment of the stream that is flowing more slowly or where water stops flowing (e.g., a lake).

Confronted by more frequent and severe floods that increase hydraulic forces, stream channels must respond. They typically increase their cross-sectional area to accommodate the higher flows. As described previously, this is done either through widening of the stream banks, down cutting of the stream bed, or frequently both. This phase of channel instability, in turn, triggers a cycle of stream bank erosion and habitat degradation.

Discharge flow rate is a major factor that affects sediment transport in stream systems. Higher discharge volumes lead to increased flow velocities. As channels are incised and flow velocities increase, shear stress and stream power exerted on the channel bed and banks increases. This effect, combined with channel stability, determines the amount of sediment that is mobilized, which in turn influences habitat and aquatic biota. In many areas of the Sandusky basin, storm flows are higher than occurred under predevelopment conditions because of land use changes and increased efficiency brought about by channelization in urban and rural areas. These storm flows have greater power to erode sediment and can transport larger sediment loads downstream. When the sediment finally settles, within a slowly flowing reach or standing waterbody, it may impair aquatic life by filling in fish and benthic macroinvertebrate stream-bottom habitat.

Channelization increases peak flows as it allows flood waves to pass more quickly through the basin, increasing the volume and the erosive force of the water. Because bank erosion is often a symptom of larger, more complex problems, long-term solutions often involve much more than bank stabilization.

4.3.3 Livestock

Livestock are potential sources of bacteria, nutrients, and sediment (indirectly) to streams, particularly when direct access is not restricted (Figure 21) or where feeding structures are adjacent to or connected to riparian areas. Grazing patterns and the types of cattle operations influence the bacteria, nutrient, and sediment loads that cattle contribute to surface waters. Since livestock grazing patterns vary by season, the pollutant loads derived from livestock vary by season. Runoff from an actively grazed pasture during the spring will yield higher loads than those generated from an unused pasture in the winter when the livestock are in barns.

Figure 21. Cattle with unrestricted access to South Creek.

Livestock with unrestricted access to surface waters may deposit waste directly into streams. While moving along the banks and into streams, hoof shear may loosen soil that is then transported downstream by the creek. Livestock moving along the stream banks may trample or consume vegetation, which contributes to bank instability, and ultimately, downstream sedimentation. Livestock that have restricted access to surface waters may still contribute bacteria and nutrients to streams if sufficient practices are not implement to limit runoff from livestock areas. Finally, runoff on crop fields with manure application can transport bacteria and nutrients in the manure via overland flow or through drain tiles to nearby streams. Manure application varies by season and crop; thus, the magnitude of loads of bacteria, nutrients, and sediment from crop field runoff are controlled by when the manure is applied.

Many agricultural and rural properties have small numbers of livestock which do not require a CAFO[16] or Concentrated Animal Feeding Facility[17] (CAFF) permit. Watershed-specific data are not available for livestock populations. However, countywide data available from the National Agricultural Statistic Service (NASS) were downloaded and area weighted to estimate animal population in the watershed. Results for Erie, Sandusky, and Seneca counties are shown in Table 23; results for all 12 counties in the Sandusky basin are presented in Appendix C.

[16] CAFOs are regulated under the CWA by U.S. EPA and the states through the NPDES program. Three concentrated animal feeding operations (CAFOs) are located in the Sandusky basin.

[17] CAFFs are regulated by the Ohio Department of Agriculture, through the Livestock Environmental Permit Program. CAFF Permits to Operate require CAFF owners to submit plans for manure management, insect and rodent control, mortality management, and emergency response (Ohio Department of Agriculture 2011). CAFFs are prohibited from discharging to surface waters. Four CAFFs are located in the Sandusky basin.

Table 23. Livestock animal units by county in the Sandusky basin

Animal unit	County	County-wide		Sandusky basin	
		No. of animal units	No. of farms	No. of animal units	No. of farms
Cattle and calves	Erie	2,519	96	1,894	72
	Sandusky	4,612	167	159	6
	Seneca	10,096	264	7,725	202
Goats	Erie	72	15	54	11
	Sandusky	131	32	5	1
	Seneca	763	31	584	24
Hogs and pigs	Erie	239	11	180	8
	Sandusky	5,591	37	193	1
	Seneca	42,808	62	32,756	47
Horses and ponies	Erie	646	58	486	44
	Sandusky	772	132	27	5
	Seneca	463	72	354	55
Poultry - Layers	Erie	836	28	628	21
	Sandusky	942	36	32	1
	Seneca	(D)	52	(D)	40
Poultry - Pullets	Erie	(D)	4	(D)	3
	Sandusky	59	4	--	--
	Seneca	159	8	122	6
Poultry - Broilers/Meat	Erie	1,592	8	1,197	6
	Sandusky	(D)	3	--	--
	Seneca	370	6	283	5
Sheep and lambs	Erie	565	17	425	13
	Sandusky	765	41	26	1
	Seneca	2,770	61	2,120	47

Source: 2007 Census of Agriculture (NASS 2009 Ohio's county-level data in Tables 11-17).
Notes
Refer to Appendix C for tables of the animal units by all 12 counties in the Sandusky basin.
Double dashes ("--") indicate that no farms would be in the county's portion of the Sandusky basin using a drainage area ratio.

Four CAFFs are in the Sandusky basin, including the three previously discussed CAFOs (see Section 4.2.5 for a discussion of the CAFOs). The only CAFF that is not also a CAFO is the Kalmbach Wagner Swine Research Farm that is in Wyandot County, north of the city of Upper Sandusky. This CAFF is permitted to have up to 5,150 hogs. As the facility does not have an NPDES CAFO permit, it is not allowed to discharge to surface water (including storm water discharges). Since the facility is in the Sandusky River (upper) watershed, it is accounted for in the Sandusky River (lower) mainstem TMDLs through the boundary condition set for the upper watershed.

4.3.4 Wildlife

Wildlife such as deer, raccoon, waterfowl, riparian small mammals (e.g., beaver, otter) can be sources of bacteria and nutrients. The animal habitat and proximity to surface waters are important factors that determine if animal waste can be transported to surface waters. Waterfowl and riparian mammals deposit waste directly into streams while other riparian species deposit waste in the floodplain, which can be transported to surface waters by runoff from precipitation events. Animal waste deposited in upland areas can also be transported to streams and rivers; however, due to the distance from uplands to surface streams, only larger precipitation events can sustain sufficient amounts of runoff to transport upland animal waste to surface waters.

4.3.5 Pesticides and Fertilizers

Application of chemicals, including pesticides and fertilizers, is a potential source of nitrogen and phosphorus species in both urban and rural environments. In urban areas, pesticides and fertilizers are applied to manage developed areas such as residential lawns and gardens, athletic fields, parks, recreational facilities, and green spaces surrounding larger industrial or commercial complexes[18]. After precipitation events, pesticides and fertilizers can contribute pollutants to runoff that enters streams through the storm sewers.

Cultivated crop fields are present throughout the TMDL project area and along properties adjacent to impaired streams. Fertilizers are potential sources of nitrogen and phosphorus species that can cause nutrient-related impairments. During precipitation events, fertilizers can wash off crop fields and travel overland or through drain tiles to surface streams. Unless ammonia is bound to sediment, it will nitrify to nitrate. Ammonia and total phosphorus can travel downstream while bound to sediment. The effects of fertilizer-derived loads may be seasonal because fertilizers are applied during the growing season, which varies by crop. Phosphorus may remain in the stream system bound to sediment long after phosphorus-fertilizers are applied.

Fertilizer application is dependent on numerous factors (e.g., soil type, soil moisture content, crop type). Across Ohio (Ohio EPA 2013a), the most common fertilization practices are broadcast (no till, 31 percent; till seven or more days after application, 15 percent; and till within seven days of application, 18 percent) and incorporation (with strip tillage, 4 percent; planter, 33 percent). Basin-scale nutrient fertilizer information from the International Plant Nutrition Institute (2012) is presented in Appendix C. The next four sections provide summaries of local fertilizer information for counties with a considerable amount of cropland in the Sandusky basin.[19]

Figure 22. Corn field along Pipe Creek.

4.3.5.1 Corn

Cropland in the Sandusky basin typically consists of a 2-crop rotation of soybean and corn. Phosphorus and nitrogen starter fertilizers are applied during corn planting and the types of application vary by county. Broadcast and planter applications are the most common methods. Corn fields (Figure 22) are typically fertilized with nitrogen again about a month after planting. Manure application is limited across the Sandusky basin with most CAFOs and CAFFs applying manure to their own land; however, manure is distributed throughout the county and a limited number of farmers do apply manure, typically in early spring before planting, to corn fields.

In Crawford County, farmers typically side-dress nitrogen fertilizers with approximately half of the farmers using anhydrous ammonia and half using 28 percent nitrogen. In Seneca County, the most

[18] Scotts Miracle Gro-Company, whose retail sales compose one-half of lawn fertilizer sales in Ohio, eliminated phosphorus from its lawn maintenance products in 2013 (Ohio EPA 2013, p. 10).
[19] Crop information was obtained via personal communications from: Don Fishpaw, Crawford SWCD, February 15, 2013; Tami Hastings, Wyandot SWCD, February 15, 2013; Bret Margraf, Seneca SWCD, March 8, 2013; Tia Rice, Seneca SWCD, March 5, 2013; and Sandy Yohe, Sandusky SWCD, March 1, 2013.

common nitrogen fertilizers are (ranked in order): a solution of urea and ammonium nitrate (UAN), anhydrous ammonia, and urea.

4.3.5.2 Soybean

Potassium fertilizer application is on the decline in the Sandusky basin; when potash is applied, the application is in the spring after planting. Similar to corn fields, manure is applied to soybean fields in the spring before planting but most farmers do not apply manure in the Sandusky basin.

4.3.5.3 Winter Wheat

Winter wheat is also grown in the Sandusky basin and the amounts vary by county. Generally, between a tenth and a quarter of farmers include winter wheat in a 3-crop rotation with corn and soybeans. Fertilizer application varies considerably with some farmers applying, via broadcast, phosphorus and nitrogen fertilizers while many farmers do not fertilize winter wheat in the fall. For farmers who do fertilize, a spring nitrogen application is common. Not many farmers apply manure to their winter wheat fields; if they do, the application occurs after the July harvest.

4.3.5.4 Hay/Alfalfa

Hay is grown throughout the Sandusky basin but in very small amounts as compared to corn and soybeans. Hay production is more common in the Sandusky basin portion of Crawford County. Similar to winter wheat, not many farmers apply manure.

4.3.6 Agricultural Ditches and Drain Tiles

Cropland throughout the Sandusky basin is served by drainage ditches and drain tiles (Figure 23), and while most farms have some form of tiling, only 40 to 50 percent of farms are fully tiled[20]. Since 1875, open ditches and drain tiles have been used in the Basin (Loftus et al. 2006). Typically, agricultural drain tiles are installed for row crop agriculture that is practiced in the lake plain areas along Sandusky Bay to manage water levels (Ohio EPA 2010a). Modern agricultural drainage programs began in Ohio in 1957 following the passage of the Ohio Drainage Laws[21] (Loftus et al. 2006)[22]. Today, drainage ditches and drain tiles are considered to be parts of larger drainage management systems that seek “to improve the soil environment for vegetation growth by managing water for irrigation and drainage” (Ohio EPA 2013a, p. 42).

[20] Agricultural ditch and drain tile information was obtained via personal communications from: Don Fishpaw, Crawford SWCD, February 15, 2013; Tami Hastings, Wyandot SWCD, February 15, 2013; Bret Margraf, Seneca SWCD, March 8, 2013; Tia Rice, Seneca SWCD, March 5, 2013; and Sandy Yohe, Sandusky SWCD, March 1, 2013.

[21] The Ohio Drainage Laws are a colloquial reference to the Ohio County Ditch Law (enacted in 1850) that is composed of ORC Chapters 6131, 6133, 6135, and 6137 (Brown and Stearns 1991).

[22] A brief history of agricultural drainage programs in the Sandusky basin is presented in the *Honey Creek Watershed Action Plan* (Loftus et al. 2006).

Figure 23. Drain tile outlet on Pipe Creek.

Agricultural ditches were constructed for agricultural drainage or conveyance of flood waters that could damage crop fields, and some ditches are channelized streams, while other ditches did not exist prior to implementation of agricultural drainage programs (Loftus et al. 2006). Ditches in the Sandusky basin include both county maintained ditches and privately owned and maintained ditches. County maintenance includes "chemical or physical control of brush and trees from banks, dipping out of sediments that accumulate in the channel bottoms, and planting of grasses on ditch side slopes and as watercourse buffers" (Loftus et al. 2006, p. 18).

4.4 Soil and Water Assessment Tool

A Soil and Water Assessment Tool model was developed for the Sandusky basin (HUC 04100011) following the requirements set forth in the quality assurance project plan (Tetra Tech 2013). Model development, calibration, validation, and quality assurance/quality control are presented in the model report (Appendix D). The following subsections present brief discussion of the modeled results by pollutant; SWAT model results are evaluated in greater detail with load duration curves and other assessments by subwatershed in Sections 5 and 6.

4.4.1 Total Phosphorus

Annual average total phosphorus loads per WAU were typically larger in the tributaries to Sandusky Bay, frontal Lake Erie, and Sandusky River (lower) versus the Sandusky River (upper) tributaries (Appendix E). In the project area, the largest loads were in all the impaired WAUs in *Mills Creek-Frontal Lake Erie* (04100011 01) and *Pickerel Creek-Frontal Sandusky Bay* (04100011 02) and the *Wolf Creek* (04100011 10 04) WAU. The dominant sources of total phosphorus were always agriculture or developed land, with the percentage of average annual load derived from agriculture ranging from 56 to 100 percent.

4.4.2 Soluble Reactive Phosphorus

Annual average soluble reactive phosphorus loads per WAU were typically larger in the Sandusky River tributaries versus the Sandusky Bay tributaries (Appendix E). More WAUs in the tributaries to the Sandusky River (upper) had larger average annual loads than WAUs in the tributaries to the Sandusky River (lower). In the project area, the largest loads were in the *Wolf Creek* (04100011 10 04) WAUs. The dominant sources of soluble reactive phosphorus were always agriculture or developed land, with the percentage of average annual load derived from agriculture ranging from 61 to 100 percent.

4.4.3 Nitrate plus Nitrite

Annual average nitrate loads per WAU varied considerably across the Sandusky basin. Annual average nitrate loads did not vary with annual total phosphorus loads. In the project area, the largest loads were in the *Strong Creek* (04100011 02 02), *Pickerel Creek* (04100011 02 03), *Muskellunge Creek* (04100011 13 01), and *Gries Ditch* (04100011 14 01) WAUs. The dominant sources of nitrate plus nitrite were agriculture, developed land, failing HSTS, and permitted point sources. The percentage of average annual load derived from agriculture ranged from 15 to 93 percent.

4.4.4 Total Kjeldahl Nitrogen

Annual average total Kjeldahl nitrogen loads per WAU varied considerably across the Sandusky basin. The dominant sources of total Kjeldahl nitrogen were agriculture and developed land. The percentage of average annual load derived from agriculture ranged from 44 to 100 percent, with agriculture in the upper Sandusky River tributaries typically contributing 96 percent of the total Kjeldahl nitrogen loads.

4.4.5 Total Suspended Solids

Annual average TSS loads per WAU were typically larger in the Sandusky Bay tributaries versus the Sandusky River tributaries (Appendix E). The largest TSS loads in the project area were in the all the impaired WAUs in *Mills Creek-Frontal Lake Erie* (04100011 01) and *Pickerel Creek-Frontal Sandusky Bay* (04100011 02). The dominant sources of TSS were typically agriculture or developed land, with the percentage of average annual load derived from agriculture ranging from 35 to 99 percent. Agriculture in the upper Sandusky River tributaries typically contributing 88 percent of the TSS loads.

4.5 Load Duration Curves

Load duration curves (LDCs) were developed to assess the sources of impairment and to determine the allowable pollutant loads for the impaired waterbodies. Discussions of load duration curves are in *An Approach for Using Load Duration Curves in the Development of TMDLs* (U.S. EPA 2007b). This approach involves calculating the allowable loadings over the range of flow conditions expected to occur in the impaired stream by taking the following steps:

1. A flow duration curve for the stream is developed by generating a flow frequency table and plotting the data points to form a curve. The data reflect a range of natural occurrences from extremely high flows to extremely low flows. The flows for this project were simulated using SWAT.

2. The flow curve is translated into a load duration (or TMDL) curve by multiplying each flow value (in cubic feet per second) by the water quality standard or target for a contaminant (mg/L), then multiplying by conversion factors to get results in the proper unit (i.e., pounds per day or tons per day). The resulting points are plotted to create a load duration curve.

3. Water quality samples collected by Ohio EPA were plotted as points on the LDC graphs and can be compared to the water quality standard or target, or load duration curve. The corresponding flow for each Ohio EPA sample was selected from the flow timeseries output from SWAT. This flow was then multiplied by the water quality standard/target and conversion factors to calculate loads for Ohio EPA's samples.

4. Points plotting above the curve represent deviations from the water quality standard or target and the daily allowable load. Those plotting below the curve represent compliance with standards and the daily allowable load. For the source assessment, it was determined which flow conditions contribute loads above or below the water quality standard or target.

5. The area below the LDC is interpreted as the loading capacity of the stream. The difference between this area and existing load is the load that must be reduced to meet water quality standards or targets.

6. The final step is to determine where reductions need to occur. Those exceedances at the right side of the graph occur during low-flow conditions and can be derived from sources such as point sources, septic systems and illicit sewer connections. Exceedances on the left side of the graph occur during higher flow events and can be derived from sources such as runoff.

The stream flows displayed on a LDC can be grouped into various flow regimes to aid with interpreting the load duration curves. The flow regimes are typically divided into 10 groups, which can be further categorized into the following five *hydrologic zones* (Cleland 2005, 2007):

- High-flow zone: flows that plot in the 0 to 10 percentile range, related to flood flows
- Moist zone: flows in the 10 to 40 percentile range, related to wet-weather conditions
- Mid-range zone: flows in the 40 to 60 percentile range, median stream flow conditions
- Dry zone: flows in the 60 to 90 percentile range, related to dry-weather flows
- Low-flow zone: flows in the 90 to 100 percentile range, related to drought conditions

An underlying premise of the LDC approach is correlation of water quality impairments to flow conditions. The LDC alone does not consider specific fate and transport mechanisms, which can vary depending on watershed or pollutant characteristics. The load duration approach helps to identify the issues surrounding the impairment and to roughly differentiate between sources. Table 24 summarizes the relationship between the five hydrologic zones and potential contributing source areas (Cleland 2005, 2007).

Table 24. Relationship between load duration curve zones and contributing sources

Contributing source area	Duration curve zone				
	High	Moist	Mid-range	Dry	Low
Point source				M	H
Livestock direct access to streams				M	H
HSTS	M	M-H	H	H	H
Riparian areas		H	H	M	
Storm water: Impervious		H	H	H	
Storm water: Upland	H	H	M		

Note: Potential relative importance of source area to contribute loads under hydrologic conditions (H: High; M: Medium; L: Low)

LDC analyses are discussed by WAU in Section 5 and 6 and are discussed for the Sandusky River LRAUs in Section 7 and Appendix H. LDC charts are presented in Appendix G.

5 Linkage Analysis: Tributaries to Sandusky Bay

Source assessments and linkage analyses are discussed individually in this section for the impaired WAUs east of the Sandusky River. Two WAUs in *Mills Creek-Frontal Lake Erie* (HUC 04100011 01) and four WAUs in *Pickerel Creek-Frontal Sandusky Bay* (HUC 04100011 02) are impaired for their ALUs.

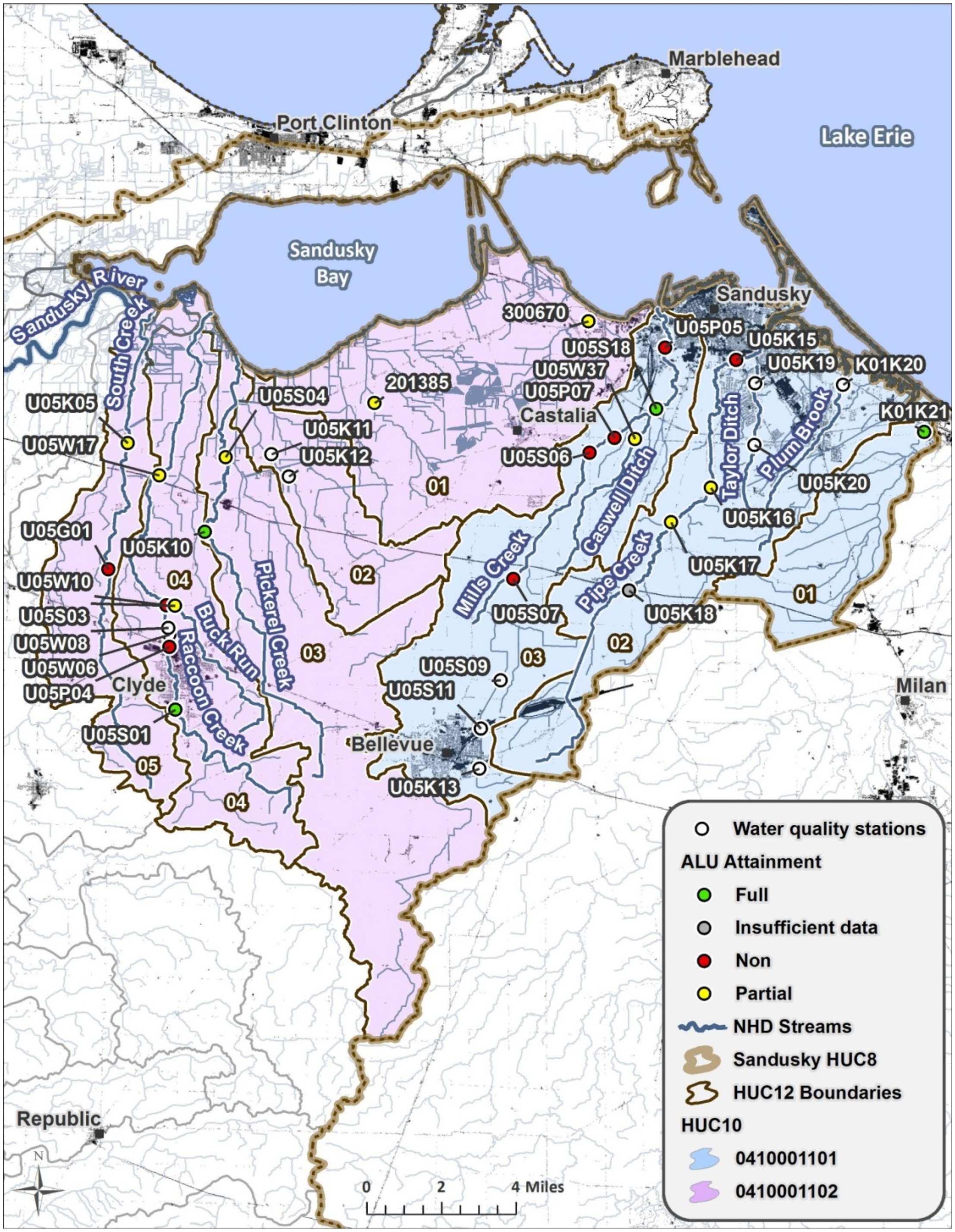


Figure 24. Ohio EPA assessment sites on the tributaries to Sandusky Bay.

5.1 Pipe Creek-Frontal Sandusky Bay (HUC 04100011 01 02)

This WAU is in western Erie County and includes portions of the cities of Sandusky and Bellevue and the unincorporated community of Bloomingville. The lower portion of the WAU is urban (city of Sandusky) while much of the WAU is rural cultivated fields and pastures.

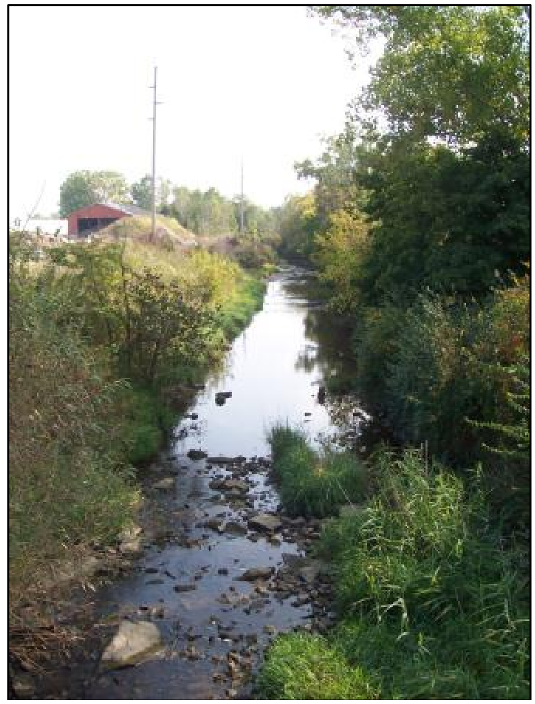


Figure 25. Pipe Creek at U05K15.

5.1.1 Monitoring Data

Ohio EPA collected water chemistry at seven sites and biological data at four sites (Ohio EPA 2010a). Attainment was evaluated at three sites along Pipe Creek and two sites were in partial attainment and one site in nonattainment (Ohio EPA 2010a, Table 2, p. xii). The primary cause of impairment was sedimentation/siltation due to channelization; therefore, only sediment-related monitoring data are presented herein. Additional monitoring data were collected by the Erie Soil and Water Conservation District and are summarized in the *Pipe Creek Report Card* (2013).

Available TSS and QHEI data are summarized in Table 25 and Table 26; refer to Ohio EPA (2010a) for all available water chemistry and QHEI data. It is noteworthy that all four Ohio EPA assessment sites on Pipe Creek are upstream of the lacustuary, which begins at about RM 1.5. Pipe Creek at RM 2.32 (U05K15; Figure 25) is the first sample site. As shown in these tables, Pipe Creek below RM 10.81 (U05K18) has elevated TSS concentrations and degraded habitat.

Table 25. TSS data summary for *Pipe Creek-Frontal Sandusky Bay* (HUC 04100011 01 02)

Stream name	RM	STORET	DA	ALU status	No. samples	Min.	Max.	GM	Exceed[a]
Pipe Creek	10.81	U05K18	9.4	--	2	2.5	2.5	2.5	0%
	8.18	U05K17	14.7	Partial	3	2.5	34.	11.3	33%
	6.70	U05K16	18.4	Partial	5	11	47	25.8	60%
	2.32	U05K15	22.8	Non	8	11	33	18.4	25%
Plum Brook	1.05	K01K20	6.8	--	3	13	33	20.8	33%
Taylor Ditch	2.64	U05K20	1.5	--	2	2.5	10.	5.0	0%
	0.8	U05K19	2.9	--	2	2.5	2.5	2.5	0%

Notes
The TSS detection limit is 5 mg/L and non-detects are evaluated as one-half of the detection limit.
ALU = aquatic life use; GM = geometric mean; H = headwaters; RM = rivermile; STORET = site code for U.S. EPA's STOrage and RETrieval system; W = wading
a. The TSS target is 24 mg/L because Pipe Creek, Plum Brook, and Taylor Ditch are in the HELP ecoregion.

Table 26. QHEI data summary for *Pipe Creek-Frontal Sandusky Bay* (HUC 04100011 01 02)

Stream name	RM	STORET	DA	Status	Score	NR	Comments
Pipe Creek	10.81	U05K18	9.4	--	--	--	
	8.18	U05K17	14.7	Partial	46.5	Fair	Extensively embedded substrates
	6.70	U05K16	18.4	Partial	30	Poor	Poor channel development with moderately heavy silt, extensively embedded substrates, and no riffle
	2.32	U05K15	22.8	Non	41.5	Poor	Poor channel development and sparse instream cover

Source: Ohio EPA 2010a, Table 11, p. 42
Note: ALU = aquatic life use; DA = drainage area, in square miles; H = headwaters; NR = narrative rating; RM = rivermile; STORET = site code for U.S. EPA's STOrage and RETrieval system; W = wading

The LDC analysis shows that one of three samples in the moist conditions and one of three samples in the mid-range flows exceeded the target while neither sample in the dry conditions exceeded target (Appendix G).

5.1.2 Source of Impairment

Ohio EPA (2010a) found the WAU to be impaired by sedimentation/siltation and other flow regime alterations from channelization and urban runoff/storm sewers. The sources of sedimentation/siltation are evaluated in the following sections. Additional source assessment information is provided by the Erie Soil and Water Conservation District in the *Pipe Creek Report Card* (2013).

5.1.2.1 Industrial Facilities and Storm Water

Five industrial facilities are covered by individual NPDES permits (Table 27); these facilities are permitted to discharge TSS (Table 28). Five additional industrial facilities are permitted to discharge storm water associated with industrial activities (Table 29) and their storm water may contain TSS.

Table 27. Industrial facilities with individual NPDES permits in HUC 04100011 01 02

NPDES ID	Permittee	Facility	Receiving waterbody	Size (mgd)
2IO00002	NASA	John H. Glenn Research Center - Plum Brook Station	Kuebler Ditch Plum Brook	--[a]
2IJ00006	Hanson Aggregates Midwest, Inc.	Wagner Quarry	Hemminger Ditch Taylor Ditch	1.9
2IJ00021	Hanson Aggregates Midwest, Inc	Sandusky Quarry	Caswell Ditch [b] Pipe Creek	7.52
2IN00178	Consumers Petroleum	Sandusky Bulk Plant	railroad ditch [c]	--[a]
2IT00010	Norfolk Southern Railway Company	Bellevue Terminal	Pipe Creek	--[d]
2PF00001	city of Sandusky	Sandusky WPC	Sandusky Bay [f]	22[e]

Notes
mgd = million gallons per day; NASA = National Aeronautics and Space Administration; WPC = water pollution control; WWTP = wastewater treatment plant.
a. These facilities are permitted to discharge storm water.
b. The Sandusky Bulk Plant discharges to a railroad ditch that drains to Pipe Creek.
c. Caswell Ditch is in the Mills Creek WAU (HUC 04100011 02 01), which is adjacent to the Pipe Creek WAU.
d. The Bellevue Terminal is permitted to discharge sanitary wastewater and storm water.
e. The Sandusky WPC facility discharges directly to Sandusky Bay and is outside the scope of this TMDL report.
f. The daily design flow is 15.7 mgd and the permitted wet weather flow is 22 mgd.

Table 28. Industrial facilities with TSS data in HUC 04100011 01 02

NPDES ID	Outfall	Receiving waterbody	No. of records	Min.	Max.	Avg.	Median
2IO00002	005[a]	Plum Brook	72	<1	18	3	2
2IJ00006	001	Taylor Ditch	68	1	31	7	6
2IJ00021	001	Caswell Ditch	119	1	39	10	7
	002	Pipe Creek	95	1	35	6	4
2IN00178	001	railroad ditch [c]	18	4	19	9	8
2IT00010	001	Pipe Creek	169	5	59	15	13

Notes
Results are in mg/L.
Results are from January 2003 through December 2012.
a. DMR data are summarized for outfall 005; however, the 2012 NPDES permit only identifies outfalls 001 and 003. Outfall 003 (B-2 Retention Pond) has TSS permit limits; therefore, it is assumed that outfall 003 and 005 are the same.

Table 29. General NPDES permittees for storm water discharges associated with industrial activities in HUC 04100011 01 02

NPDES ID	Permittee	Facility
2GR00391	Spoerr Precast Concrete Inc	Spoerr Precast Concrete Inc
2GR00573	JBT Foodtech	JBT Foodtech
2GR00621	Gerken Materials Inc	Gerken HMA Plant 10
2GR01596	P&T Products Inc	P&T Products Inc
2GR01911	Sandusky Steel & Supply Co	Sandusky Steel & Supply Co

NASA's Plum Brook Station (2IO00002) is required to monitor TSS from outfall 003, discharge from a retention pond. An evaluation with data from Plum Brook RM 1.05 (K01K20) showed that the Plum Brook Station discharged TSS at concentrations considerably lower than in-stream concentrations. As all DMR results are below the Plum Brook TSS target[23] and the facility does not discharge to the impaired Pipe Creek, Plum Brook Station does not contribute to the sedimentation/siltation impairment in this WAU.

Wagner Quarry (2IJ00006) discharges to Taylor Ditch, a tributary to Pipe Creek and 97 percent of samples were at or less than the in-stream TSS target[24]. An evaluation of data from Taylor Ditch RMs 0.8 and 2.64 (above and below Wagner Quarry) shows that Wagner Quarries does not appear to have an effect on Taylor Ditch. As almost all of the DMR results are below the Taylor Ditch TSS target and the facility does not discharge to the impaired Pipe Creek, Wagner Quarry does not contribute to the sedimentation/siltation impairment in this WAU.

Sandusky Quarry (2IJ00021) discharges to Caswell Ditch (outfall 001) and Pipe Creek (outfall 002). Approximately 93 percent of DMR results from outfall 001 and 97 percent from outfall 002 were at or below the TSS targets[25] for Caswell Ditch and Pipe Creek. TSS was non-detect in samples Ohio EPA collected in 2009 from Pipe Creek RM 10.81 (U05K18), which is downstream of Sandusky Quarry. Sandusky Quarry discharges TSS loads to Pipe Creek but is not a significant contributor to the sedimentation/siltation impairments on Pipe Creek.

The Sandusky Bulk Plant (2IN00178) discharges from a storm water basin and oil/water separator to a railroad ditch that is tributary to Pipe Creek. Twelve of 18 records were non-detect. Additionally, the facility is downstream of all of Ohio EPA's assessment sites on Pipe Creek. Therefore, while the

[23] The TSS target for Plum Brook is 24 mg/L. This target is for headwaters streams in the HELP ecoregion (Ohio EPA 1999).
[24] The TSS target for Taylor Ditch is 24 mg/L. This target is for headwaters streams in the HELP ecoregion (Ohio EPA 1999).
[25] The TSS targets for Caswell Ditch and Pipe Creek are 24 mg/L. This target is for headwaters streams in the HELP ecoregion (Ohio EPA 1999).

Sandusky Bulk Plant may contribute TSS loads to Pipe Creek, it is not a significant contributor to the sedimentation/siltation impairments on Pipe Creek.

The Bellevue Terminal (2IT00010) discharges combined sanitary wastewater and storm water through sedimentation ponds and then Pipe Creek. Eighty-seven percent of samples were at or below the TSS target for Pipe Creek. No Ohio EPA assessment sites are near this facility. The Bellevue Terminal discharges TSS loads to Pipe Creek and contributes (to an unknown degree) to the sedimentation/siltation impairment.

5.1.2.2 City of Sandusky

The Sandusky WPC facility (2PF00001) main effluent outfall discharges to Sandusky Bay, and thus, is not a source of impairment to Pipe Creek. However, the city of Sandusky is a CSS and one of its 15 outfalls discharges in this WAU (Section 4.2.1.1). Outfall 019 has regularly discharged to Pipe Creek a few times per month from 2003 through 2012. Ohio EPA (2010a) did not identify CSOs as a source of sedimentation/siltation and other flow regime alterations that are impairing Pipe Creek. Outfall 019 is 0.7 mile downstream of the assessment site at RM 2.32 (U05K15); thus, CSOs cannot directly contribute to the nonattainment at RM 2.32. However, CSOs may contribute to TSS loads and may alter local hydrological regimes as CSOs are precipitation event-driven pulses. Thus, CSOs at outfall 019 may contribute to poor water quality in Pipe Creek or Sandusky Bay.

A portion of the city of Sandusky is designated as a regulated MS4 and is covered under the small MS4 permit for *Erie County and Others* (2GQ00027). However, the regulated MS4 area has not been mapped. SWAT modeling showed that urban developed land within this WAU, which includes the portions of the regulated MS4, contributed an annual average of 8,354 tons/year of TSS, which is 58 percent of the total TSS load to the WAU (Appendix F). However, upstream of the city of Sandusky, developed land only contributes 1,690 tons/year TSS to Pipe Creek, which is 25 percent of the TSS load to this subwatershed.

5.1.2.3 Household Sewage Treatment Systems and Un-sewered Areas

While the city of Sandusky is sewered, the remainder of the WAU is served by HSTS. This WAU is in Erie and Sandusky counties that have HSTS failure rates of 61 percent and 35 percent (ODH 2013). SWAT model results did not show failing HSTS to be impacting this WAU. While failing HSTS are present and may contribute elevated sediment levels to surface waters locally, failing HSTS are not a significant source of TSS in this WAU (9 tons/year; <0.1 percent of the total TSS load)

5.1.2.4 Agriculture

Cultivated crops (43 percent) and developed open space (17 percent) are the dominant land uses in this WAU. Pasture only accounts for 1 percent of the WAU. It is also notable that WWTP sludge is applied to four agricultural fields that drain to Pipe Creek.

SWAT model results show that cultivated cropland contributes an annual average of 5,076 tons/year TSS, which is 35 percent of the TSS load in the WAU (Appendix F). However, cultivated cropland contributes an annual average of 4,526 tons/year TSS to the Pipe Creek watershed upstream of the city of Sandusky., which is 67 percent of the TSS load to this subwatershed. Thus, upstream of the city of Sandusky, agriculture is the dominant source of TSS, while storm water runoff from developed land becomes the dominant source of TSS in Pipe Creek within the city of Sandusky.

5.1.3 Conclusions

Pipe Creek is impaired by sedimentation/siltation and TSS and QHEI monitoring data are representative of this impairment (see Appendix E for a map of assessment site attainment, sedimentation/siltation impairments, and SWAT model results). The anthropogenic sources of TSS loads to Pipe Creek are individually permitted point sources, urban and industrial storm water, failing HSTS, and agriculture. SWAT model results indicate that the dominant sources of TSS loads to the WAU are storm water from developed urban land (58 percent) and cultivated cropland (35 percent). The dominant sources of TSS load to Pipe Creek upstream of the city of Sandusky are cultivated crop land (67 percent) and urban developed land (25 percent). These sources will be addressed through a TSS TMDL on Pipe Creek near the site at Sandusky at Columbus Avenue (RM 2.32, U05K15).

5.2 Mills Creek (HUC 04100011 01 03)

This WAU is in western Erie County and eastern Sandusky County. Mills Creek begins in the city of Bellevue, and then flows through rural agricultural land before entering the city of Sandusky, where it discharges to Lake Erie.

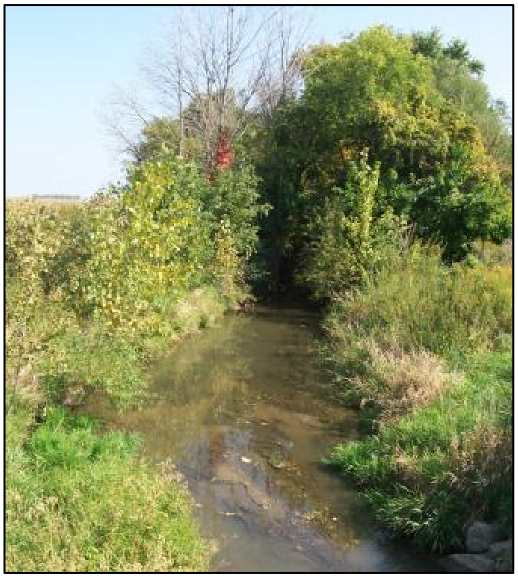


Figure 26. Mills Creek at U05S07.

5.2.1 Monitoring Data

Ohio EPA collected water chemistry at nine sites and biological data at six sites (Ohio EPA 2010a). Attainment was evaluated at one site on Caswell Ditch (partial attainment) and five sites on Mills Creek (one site in full attainment, four sites in non-attainment; see Ohio EPA 2010a, Table 2, p. xii). The primary causes of impairment were related to nutrients and sediment; therefore, only nutrient- and sediment-related monitoring data are presented herein.

Available QHEI (Table 30) and water quality (Table 31) data are summarized in this section and all available QHEI and water quality data are presented in Ohio EPA (2010a). Mills Creek RM 1.35 (U05P05) was also evaluated for dissolved orthophosphate with an average dissolved orthophosphate to total phosphorus ratio of 77 percent[26]. All five Ohio EPA assessment sites on Mills Creek are upstream of the lacustuary, which begins at about RM 0.2. As shown in these tables, all three streams have concentrations of nitrate plus nitrite and phosphorus in excess of the targets and sites on Caswell Ditch and Mills Creek have TSS concentrations in excess of targets.

Table 30. QHEI data summary for *Mills Creek* (HUC 04100011 01 03)

Stream name	RM	STORET	DA	ALU status	Score	NR	Comments
Caswell Ditch	0.85	U05W37	3.9	Partial	34.5	Poor	Moderately heavy silt with extensively embedded riffles and lack of trees in riparian corridor
Mills Creek	10.4	U05S07	21	Non	28.5	Very Poor	Extensively embedded substrates
	6.03	U05S06	29	Non	49	Fair	Extensively embedded substrates
	5.20	U05P07	29	Non	61.5	Good	Extensively embedded substrates
	3.70	U05S18	35	Full	42.5	Poor	Extensively embedded substrates
	1.35	U05P05	41	Non	46.5	Fair	Extensively embedded substrates

Source: Ohio EPA 2010a, Table 11, p. 41-42
Note: ALU = aquatic life use; DA = drainage area, in square miles; NR = narrative rating; RM = rivermile; STORET = site code for U.S. EPA's STOrage and RETrieval system.

[26] Dissolved orthophosphate at Mills Creek RM 1.35 (U05P05) ranged from 0.073 mg/L to 0.478 mg/L phosphorus with a geometric mean of 0.157 mg/L phosphorus (12 samples). The dissolved orthophosphate to total phosphorus ratio ranged from 61 to 93 percent (11 samples), excluding one ratio in excess of 100 percent.

Table 31. Water chemistry data summary for *Mills Creek* (HUC 04100011 01 03)

Stream name	RM	STORET	DA	ALU status	No. samples	Min.	Max.	GM	Exceed[a]
Nitrate plus nitrite (mg/L as nitrogen)									
Caswell Ditch	0.85	U05W37	3.9	Partial	4	0.25	2.45	0.88	50%
Mills Creek	10.40	U05S07	21	Non	4	9.50	10.40	10.05	100%
	6.03	U05S06	29	Non	5	4.62	8.75	6.52	100%
	5.20	U05P07	29	Non	4	3.75	8.35	5.79	100%
	3.70	U05S18	35	Full	5	2.60	8.24	4.79	100%
	1.35	U05P05	41	Non	12	1.07	9.91	3.65	100%
Snyder Ditch	4.98	U05K13	1.5	--	5	0.25	14.10	1.30	60%
	3.85	U05S11	3.1	--	5	1.65	8.72	2.81	100%
	2.46	U05S09	4.3	--	5	8.29	21.60	13.84	100%
Total phosphorus (mg/L as phosphorus)									
Caswell Ditch	0.85	U05W37	3.9	Partial	4	0.02	0.10	0.04	25%
Mills Creek	10.40	U05S07	21	Non	4	0.23	0.81	0.40	100%
	6.03	U05S06	29	Non	5	0.13	0.60	0.30	100%
	5.20	U05P07	29	Non	4	0.15	0.52	0.28	100%
	3.70	U05S18	35	Full	5	0.13	0.57	0.25	100%
	1.35	U05P05	41	Non	12	0.07	0.62	0.19	92%
Snyder Ditch	4.98	U05K13	1.5	--	5	0.02	0.10	0.03	0%
	3.85	U05S11	3.1	--	5	0.02	0.06	0.04	0%
	2.46	U05S09	4.3	--	5	0.29	0.74	0.49	80%
TSS (mg/L) [b]									
Caswell Ditch	0.85	U05W37	3.9	Partial	3	2.5	29	9.80	33%
Mills Creek	10.40	U05S07	21	Non	4	2.5	18	4.10	0%
	6.03	U05S06	29	Non	2	2.5	2.5	2.50	0%
	5.20	U05P07	29	Non	3	2.5	2.5	2.50	0%
	3.70	U05S18	35	Full	4	2.5	11	3.62	0%
	1.35	U05P05	41	Non	10	2.5	32	12.08	10%
Snyder Ditch	4.98	U05K13	1.5	--	5	2.5	11	3.36	0%
	3.85	U05S11	3.1	--	2	2.5	2.5	2.50	0%
	2.46	U05S09	4.3	--	3	2.5	18	7.66	0%

Notes

ALU = aquatic life use; DA = drainage area, in square miles; GM = geometric mean; RM = rivermile; STORET = site code for U.S. EPA's STOrage and RETrieval system.

a. The nitrate plus nitrite targets are: 1.0 mg/L for Caswell Ditch (WWH, headwaters), 1.0 mg/L for Mills Creek (WWH, headwaters and wading), and 1.0 mg/L for Snyder Ditch (MWH due to channel modification, headwaters). The total phosphorus targets are: 0.08 mg/L for Caswell Ditch (WWH, headwaters), 0.08 mg/L and 0.10 mg/L for Mills Creek (WWH, headwaters and wading), and 0.34 mg/L for Snyder Ditch (MWH due to channel modification, headwaters). The TSS targets are 24 mg/L because all three streams are in the HELP ecoregion.

b. The TSS detection limit is 5 mg/L and non-detects are evaluated as one-half of the detection limit.

The LDC analyses shows that none of the six TSS samples in the moist conditions through dry conditions exceed the target and one of four TSS samples exceeds the target in the low flows interval (Appendix G). All four total phosphorus samples (mid-range through low flows) exceed the target in the headwaters. In the wading segment, all but one total phosphorus sample (mid-range flow) exceeded the target from moist conditions through low flows.

5.2.2 Sources of Impairment

Ohio EPA (2010a) found the WAU to be impaired by five nutrient- and sediment-related causes from seven sources related to agriculture and urban development. The sources of nutrient- and sediment-related impairments are evaluated in the following sections. However, storm water typically contains nutrients and these facilities may contribute nutrient loads.

5.2.2.1 Industrial Facilities and Storm Water

Five of the permitted facilities in this WAU are industrial (Table 32). Three facilities are permitted to discharge TSS (Table 33) and none of the facilities have nutrient limits or monitoring requirements. Five additional industrial facilities are permitted to discharge storm water associated with industrial activities (Table 35). Facilities that discharge storm water are potential sources of phosphorus.

Table 32. Industrial facilities with NPDES permits in HUC 04100011 01 03

NPDES ID	Permittee	Facility	Receiving waterbody	Size (mgd)
2IC00011	Kyklos Bearing International, Inc.		Mills Creek	0.12[a]
2IC00013	Ventra Sandusky, LLC		Schowe Ditch	--[a]
2IE00007	Thakar Aluminum Corporation		Mills Creek	1.7
2IQ00015	Okamoto Sandusky Manufacturing LLC		Sandusky Bay Mills Creek	--[a]
2IW00011	city of Bellevue	Bellevue WTP	Snyder’s Ditch	0.09

Notes
LLC = limited liability company; mgd = million gallons per day; WTP = water treatment plant
a. These facilities are permitted to discharge storm water.

Table 33. Industrial facilities with TSS data in HUC 04100011 01 03

NPDES ID	Outfall	Receiving waterbody	No. of records	Min.	Max.	Avg.	Median
2IC00011	001	Mills Creek	150	2.5	39	7	5
2IC00013	001	Schowe Ditch	91	2.5	110	28	21
2IW00011	001	Snyder’s Ditch	73	0.5	54	11	7
	002	Snyder’s Ditch	8	0.5	1	1	0.5
	003	Snyder’s Ditch	58	0.5	27	6	4

Notes
Results are in mg/L.
Detection limits are 5 mg/L for 2IC00011 and 2IC00013 and 1 mg/L for 2IW00011; non-detects were evaluated at one-half of the detection limit.
Results are from January 2003 through December 2012.

Table 34. General NPDES permittees for storm water discharges associated with industrial activities in HUC 04100011 01 03

NPDES ID	Permittee	Facility
2GR00320	Norfolk Southern Railway Co	Sandusky Dock No 3
2GR00490[a]	Tower Automotive Operations USA 1I LLC	Tower Automotive Operations USA 1I LLC
2GR00540	Fireside U Pull It Auto Parts	Fireside U Pull It Auto Parts
2GR01620[a]	RHETECH Colors	RHETECH Colors
2GR01756	The Huron Cement Products Co Inc	H&C Building Supplies Co

Note: a. A portion of each of these facilities is also in HUC 04100011 02 01.

Kyklos Bearing International, Inc. (2IC00011) is permitted to discharge TSS in its storm water. Approximately 95 percent of DMR results were at or below the in-stream TSS target[27]. Kyklos Bearings International, Inc. discharges TSS loads and may discharge nutrient loads but is not a significant contributor to the sediment impairments in the WAU.

Ventra Sandusky, LLC (2IC00013) previously discharged process water and storm water to Schowe Ditch. The facility now discharges process water through an industrial pre-treatment program to the Sandusky WWTP and only storm water is discharged to Schowe Ditch. Almost 58 percent of DMR results are at or below the in-stream TSS target[28]. An evaluation of data suggests that elevated TSS at Mills Creek RM 1.35 (U05P05) may be related to TSS discharges from this facility. However, in 2012, the facility re-routed its storm water discharge through a quarry, which has a larger detention capacity than a sedimentation pond previously used. Ten of 16 TSS samples in 2012 were non-detect and the other six samples ranged from 10 mg/L to 26.5 mg/L. Thus, Ventra Sandusky, LLC discharges sediment loads and may contribute significantly to the sediment impairment of the WAU.

Neither Thakar Aluminum Corporation (2IE00007) nor Okamoto Sandusky Manufacturing LLC (2IQ00015) monitors nutrients or TSS. Thakar discharges effluent from a heat exchanger and is not a source of TSS or nutrients. Okamoto discharges storm water. Both facilities are downstream of all Ohio EPA assessment sites and do not contribute to the impairments identified by Ohio EPA (2010a).

The Bellevue WTP (2IW00011) discharges from three settling lagoons (identified as lime sludge lagoons) and its permit has TSS limits. Approximately 93 percent of results were at or below the in-stream TSS target[29]. An evaluation of in-stream TSS data (Snyder's Ditch at RMs 4.98 and 3.85, above and below the WTP) showed that Bellevue WTP effluent has no effect upon Snyder's Ditch. Therefore, the Bellevue WTP discharges TSS loads to Snyder's Ditch but is not a significant contributor to the sedimentation/siltation impairment.

5.2.2.2 Public Facilities

Two of the permittees in the WAU are public sewerage treatment facilities (Table 35).

Table 35. Facilities with NPDES permits in HUC 04100011 01 03

NPDES ID	Permittee	Facility	Receiving waterbody	Size (mgd)
2PD00037	City of Bellevue	Bellevue WWTP	Snyder's Ditch	2.4
2PP00041	OTC	Castalia Maintenance Building	drainage ditch	0.0015

Note: mgd = million gallons per day; OTC = Ohio Turnpike Commission; WWTP = wastewater treatment plant.

TSS concentrations from the Castalia Maintenance Building (2PP00041) ranged from 3 mg/L to 8 mg/L from quarterly samples collected from December 2010 through December 2012. Nutrient parameters are not monitored at this facility. The average discharge was 6,713 gpd from 2003 through 2012. While the Castalia Maintenance Building contributes TSS loads and may contribute nutrient loads, the facility is not significantly contributing to the nutrient and sediment impairments in this WAU.

Ohio EPA found that nutrient and TDS loads at the Bellevue WWTP (2PD00037)[30]) have been variable and generally increasing from 1995 through 2008 (Ohio EPA 2010a, p. 12). All nitrate plus nitrite and

27 The TSS target for Mills Creek is 24 mg/L. This target is for headwaters and wading streams in the HELP ecoregion (Ohio EPA 1999).
28 The TSS target for Schowe Ditch is 24 mg/L. This target is for headwaters streams in the HELP ecoregion (Ohio EPA 1999).
29 The TSS target for Snyder's Ditch is 24 mg/L. This target is for headwaters streams in the HELP ecoregion (Ohio EPA 1999).
30 For information regarding the Bellevue WWTP facility and operation refer to Ohio EPA (2010a) and TMACOG (2011, p. 179).

total phosphorus results exceeded the in-stream targets[31], while approximately 94 percent of results were at or less than the in-stream TSS target. Evaluations of data showed that the Bellevue WWTP is impacting Snyder's Ditch (Table 36). In-stream nitrate plus nitrite and total phosphorus increased considerably from above to below the WWTP (Snyder's Ditch at RMs 4.98 and 2.46); however, nitrate plus nitrite concentrations upstream of the WWTP were sometimes in excess of the target. In-stream TSS concentrations sometimes increased between sample sites on Snyder's Ditch due to Bellevue WWTP discharges.

Table 36. Bellevue WWTP (2PD00037) DMR data summary

Constituent	Units	No. of records	Min.	Max.	Avg.	Median
Nitrate plus nitrite	mg/L as nitrogen	113	1.3	118.0	14.2	13.5
Total phosphorus	mg/L as phosphorus	1,053	0.1	40.0	0.9	0.6
TSS	mg/L	1,498	0	3,500	13	9

Notes
Non-detects were reported as zero and were evaluated as zero.
Results are from January 2003 through June 2012.

While the Bellevue WWTP does contribute TSS loads to Snyder's Ditch, since Snyder's Ditch TSS concentrations are below the target and Bellevue WWTP effluent TSS concentrations are typically below the target, this facility cannot be the main contributor to the sedimentation/siltation impairment. Bellevue WWTP effluent is contributing to elevated nutrient levels in Snyder's Ditch, which are, in turn, contributing to the elevated levels of nutrients in Mill Creek that are a cause of impairment. Ohio EPA (2010a, p. 21) concluded that the Bellevue WWTP was "[t]he most prominent source of nutrients leading to impairment throughout Mills Creek". The WWTP is also contributing TSS loads to Snyder's Ditch, but its effluent is not the main source causing the TSS impairment.

5.2.2.3 City of Sandusky

The city of Sandusky is a CSS and one of its 15 outfalls discharges in this WAU (Section 4.2.1.1). Outfall 018 discharges to Mills Creek. The only CSO events recorded from 2003 through 2012 were in February and March 2011. Since the Sandusky CSS did not discharge to this WAU during or before Ohio EPA's 2009-2010 assessment, the CSS cannot be the cause of impairment; however, outfall 018 does have the potential to discharge again and could contribute to the impairment in the future.

A portion of the city of Sandusky is designated as a regulated MS4 and is covered under the small MS4 permit for Erie County and Others (2GQ00027). The city of Sandusky and Erie SWCD have not yet mapped the regulated MS4. However, it is assumed that Mills Creek receives storm water runoff from the regulated MS4 and that the storm water runoff contributes to the nutrient and sedimentation impairments.

SWAT modeling showed that urban developed land within this WAU, which includes the portions of the regulated MS4, contributed an annual average of 1,420tons/year of TSS and 7,322 pounds per year (lbs/yr) total phosphorus, which are 37 percent and 15 percent (respectively) of the total loads to the WAU (Appendix F). However, TSS and TP annual average loads are 951 tons/year of TSS and 4,744 pounds per year total phosphorus for the Mills Creek subwatershed upstream of the city of Sandusky; the relative pollutant loads from urban developed land to the subwatershed are 29 percent TSS and 11 percent total phosphorus.

[31] The nitrate plus nitrite target for Snyder's Ditch is 1.0 mg/L as nitrogen and the total phosphorus target is 0.34 mg/L as phosphorus. These targets are for MWH (channel modification) headwaters streams (Ohio EPA 1999).

5.2.2.4 Household Sewage Treatment Systems and Un-sewered Areas

While the city of Sandusky and village of Bellevue are sewered, the remainder of the WAU is served by HSTS. It is noteworthy that the Bellevue WWTP began accepting septage in 2004 (TMACOG 2011, p. 180). This WAU is in Erie and Sandusky counties that have HSTS failure rates of 61 percent and 35 percent (ODH 2013). TMACOG identified a single, un-permitted package treatment plant in its Bellevue facility planning area. SWAT model results did not show failing HSTS to be impacting this WAU. While failing HSTS are present, may contribute elevated sediment and total phosphorus levels to surface waters, and may impact surface waters locally, failing HSTS are not considered significant sources of TSS or total phosphorus in this WAU.

5.2.2.5 Agriculture

The dominant land use in this WAU is cultivated crops (73 percent). Developed land accounts for 20 percent of the WAU and pasture is less than 1 percent. Thirty-one WWTP sludge fields are in this WAU; many of the sludge fields drain to the segment of Snyder's Ditch between the city of Bellevue and the confluence with Mills Creek. Runoff from fields following sludge application may contain elevated levels of TSS and nutrients. SWAT model results show that cultivated cropland contributes an annual average of 2,234 tons/year TSS and 34,731 lbs/yr total phosphorus, which are 61 percent and 73 percent (respectively) of the total loads in the WAU, (Appendix F). Similarly the relative loads of TSS and total phosphorus to the Mills Creek subwatershed upstream of the city of Sandusky are 70 percent and 77 percent.

5.2.3 Conclusions

Mills Creek is impaired by nutrients and sediment, and monitoring data are representative of these impairments (see Appendix E for a map of assessment site attainment, impairments, and SWAT model results). The anthropogenic sources of pollutant loads to Mills Creek are individually permitted point sources, urban and industrial storm water, failing HSTS, and agriculture. SWAT model results indicate that the dominant sources of TSS loads to the WAU are cultivated cropland (61 percent) and developed urban land (37 percent) and that the dominant sources of total phosphorus loads are agriculture (73 percent), developed urban land (15 percent), and permitted point sources (12 percent). These sources will be addressed through TSS and total phosphorus TMDLs on Mills Creek at Sandusky at Perkins Avenue (RM 1.35, U05P05) and through a total phosphorus TMDL on Mills Creek near the site west of Parkertown at Portland Road (RM 10.40, U05S07).

5.3 Frontal south side of Sandusky Bay (HUC 04100011 02 01)

Figure 27. Little Pickerel Creek at Grand Army Highway (U.S. Route 6).

This WAU is in western Erie County and eastern Sandusky County and drains to Sandusky Bay and Lake Erie. The villages of Bay View and Castalia are in this WAU and the city of Sandusky is to the east. The Ohio Department of Natural Area’s Resthaven Wildlife Area is in the middle of this WAU. Cold Creek flows northeast and discharges to Lake Erie while Little Pickerel Creek flows northwest and discharges to Sandusky Bay.

5.3.1 Monitoring Data

Ohio EPA collected water chemistry and biological data at two sites (Ohio EPA 2010a). Attainment was evaluated at each site: Cold Creek (partial attainment due to natural conditions) and Little Pickerel Creek (partial attainment; see Ohio EPA 2010a, Table 2, p. xi). The primary causes of anthropogenic impairment were sedimentation/siltation and particle distribution (embeddedness); therefore, only sediment- and habitat-related monitoring data are presented herein.

Available TSS and QHEI data are summarized in Table 37 and Table 38; refer to Ohio EPA (2010a) for all available water chemistry and QHEI data. It is noteworthy that the Ohio EPA assessment site on Cold Creek is upstream of the lacustuary, which begins at about RM 0.2. As shown in these tables, Little Pickerel Creek habitat is impaired by sedimentation/siltation and TSS data are not indicative of this impairment.

Table 37. TSS data summary for *Frontal south side of Sandusky Bay* (HUC 04100011 02 01)

Stream name	RM	STORET	DA	ALU status	No. samples	Min.	Max.	GM	Exceed[a]
Cold Creek	0.36	300670	2.9	Partial	2	2.5	13	5.7	0%
Little Pickerel Creek	2.00	201385	5.5	Partial	2	11	12	11.5	0%

Notes
Results are in mg/L. The method detection limit is 5 mg/L. Non-detects are evaluated as 2.5 mg/L.
ALU = aquatic life use; DA = drainage area, in square miles; GM = geometric mean; H = headwaters; RM = rivermile; STORET = site code for U.S. EPA’s STOrage and RETrieval system; W = wading
a. The TSS target is 24 mg/L because Cold Creek and Little Pickerel Creek are in the HELP ecoregion.

Table 38. QHEI data summary for *Frontal south side of Sandusky Bay* (HUC 04100011 02 01)

Stream name	RM	STORET	DA	ALU status	Score	NR	Comments
Cold Creek	0.36	300670	2.9	Partial	47	Fair	Heavy silt with extensively embedded substrates
Little Pickerel Creek	2.00	201385	5.5	Partial	50.5	Fair	Heavy silt with extensively embedded substrates

Source: Ohio EPA 2010a, Table 11, p. 42
Note: ALU = aquatic life use; DA = drainage area, in square miles; NR = narrative rating; RM = rivermile; STORET = site code for U.S. EPA’s STOrage and RETrieval system.

The LDC analysis shows that one of two samples in the mid-range flows and the other sample is in the dry conditions and both samples were below the target (Appendix G).

5.3.2 Sources of Impairment

Ohio EPA (2010a) found the WAU to be impaired by sedimentation/siltation and particle distribution (embeddedness) from crop production with subsurface drainage. Cold Creek was found to be in partial attainment due to natural conditions. Therefore, the TMDLs will only be developed for Little Pickerel Creek. The sources of nutrient- and sediment-related impairments for Little Pickerel Creek are evaluated in the following sections.

5.3.2.1 Industrial and Public Facilities and Storm Water

Five facilities are covered by individual NPDES permits (Table 39), three facilities are covered by the general NPDES permit for storm water discharges associated with industrial activity (Table 40), and one facility is covered by a non-storm water general NPDES permit (Sandusky Bulk Plant, permit 2GB00001). None of the permitted point sources discharge to Little Pickerel Creek; therefore, none of the facilities are sources of impairment.

Table 39. Facilities with NPDES permits in HUC 04100011 02 01

NPDES ID	Permittee	Facility	Receiving waterbody	Size (mgd)
2IJ00083	Erie Materials, Inc.		drainage ditch [a]	2.3
2IN00049	ODNR	Castalia State Fish Hatchery	Cold Creek	--
2IS00024	U.S. Tsubaki, Inc.	Engineering Chain Division	Sandusky Bay [b]	--[c]
2PR00096	village of Bayview	Bayview WPC	Sandusky Bay [b]	0.01
2PR00097	Robert Chapman Jr.	Edgewater Estates MHP	Sandusky Bay [b]	0.026

Notes
LLC = limited liability company; mgd = million gallons per day; MHP = mobile home park; ODNR = Ohio Department of Natural Resources.
a. Erie Materials, Inc. discharges to an Erie County drainage ditch to Cold Creek.
b. These facilities discharges directly to Sandusky Bay and are outside the scope of this TMDL report.
c. U.S. Tsubaki, Inc. Engineering Chain Division is permitted to discharge storm water.

Table 40. General NPDES permittees for storm water discharges associated with industrial activities in HUC 04100011 02 01

NPDES ID	Permittee	Facility
2GR00290	American Colors Inc	American Colors Inc
2GR01620	RHETECH Colors	RHETECH Colors
2GR01661	Allied Waste Services of Sandusky	Allied Waste Services of Sandusky

Note: a. A portion of this facility is also in HUC 04100011 01 03.

5.3.2.2 City of Sandusky

The city of Sandusky is covered under the small MS4 permit for Erie County and Others (2GQ00027). However, the impairment is to Little Pickerel Creek in the west side of the WAU, over 3 miles west of Sandusky's city limits. Additionally, Ohio EPA (2009a) identified crop production with subsurface drainage as the source of impairment. Therefore, the city of Sandusky is not considered a source and the regulated MS4 will not receive a TSS WLA since the impairment is well outside of the city limits.

5.3.2.3 Household Sewage Treatment Systems and Un-sewered Areas

While the city of Sandusky and village of Castalia are sewered and the Edgewater Estates MHP is served by a small package treatment plant, the remainder of the WAU is served by HSTS. This WAU is in Erie and Sandusky counties that have HSTS failure rates of 61 percent and 35 percent (ODH 2013). SWAT model results did not show failing HSTS to be impacting this WAU. While failing HSTS are present, may contribute elevated sediment levels to surface waters, and may impact surface waters locally, failing HSTS are not significant sources of TSS in this WAU.

5.3.2.4 Agriculture

The dominant land use in this WAU is cultivated crops (60 percent). Deciduous forest accounts for 9 percent of the WAU and pasture is about 2 percent. Most of the developed land (13 percent) is in the eastern portion of the WAU, in the Cold Creek subwatershed. Agricultural ditches and channelized streams are present throughout the WAU. Additionally, 33 WWTP sludge fields are in this WAU and all but one sludge field is in Sandusky County (i.e., the western portion of the WAU). SWAT model results show that cultivated cropland contributes an annual average of 6,736 tons/year TSS, which is 68 percent of the TSS load in the WAU (Appendix F).

5.3.3 Conclusions

Little Pickerel Creek is impaired by sedimentation/siltation and TSS monitoring data are representative of this impairment (see Appendix E for a map of assessment site attainment, sedimentation/siltation impairments, and SWAT model results). The anthropogenic sources of TSS loads to Little Pickerel Creek are runoff from developed land, industrial storm water, failing HSTS, and agriculture. SWAT model results indicate that the dominant sources of TSS loads to the WAU are cultivated cropland (68 percent) and developed urban land (22 percent. The anthropogenic sources will be addressed through a TSS TMDL on Little Pickerel Creek near the site at Stocker Road (RM 2.00, 201385).

5.4 Pickerel Creek (HUC 04100011 02 03)

Figure 28. Pickerel Creek at TR-247.

This WAU is in western Erie County, northern Seneca County, and northwestern Huron County. The main tributary in the WAU is Pickerel Creek, which drains to Sandusky Bay. Fuller Creek's confluence with Pickerel Creek is near the unincorporated community of Vickery. This WAU is rural and agricultural; the city of Clyde is to the west and the city of Bellevue to the east.

5.4.1 Monitoring Data

Ohio EPA collected water chemistry and biological data at two sites (Ohio EPA 2010a). Attainment was evaluated at each site on Pickerel Creek with the upstream site in full attainment and the downstream site in partial attainment (Ohio EPA 2010a, Table 2, p. xi). The causes of impairment were sedimentation/siltation and particle distribution (embeddedness); therefore, only sediment- and habitat-related monitoring data are presented herein.

Available TSS and QHEI data are summarized in Table 41 and Table 42; refer to Ohio EPA (2010a) for all available water chemistry and QHEI data. As shown in these tables, Pickerel Creek TSS levels exceed targets and habitat is fair. The LDC analysis shows that two of three TSS samples in the moist conditions exceed the target while the single sample in the mid-range flows and none of the five samples in the dry conditions exceed the target (Appendix G).

Table 41. TSS data summary for *Pickerel Creek* (HUC 04100011 02 03)

Stream name	RM	STORET	DA	ALU status	No. samples	Min.	Max.	GM	Exceed[a]
Pickerel Creek	6.26	U05K10	9.5	Full	3	2.5	2.5	2.5	0%
	3.35	U05S04	43.7	Partial	9	2.5	50	15.5	22%

Notes
Results are in mg/L. The method detection limit is 5 mg/L. Non-detects are evaluated as 2.5 mg/L.
ALU = aquatic life use; DA = drainage area, in square miles; GM = geometric mean; H = headwaters; RM = rivermile; STORET = site code for U.S. EPA's STOrage and RETrieval system; W = wading
a. The TSS target is 24 mg/L because Pickerel Creek is in the HELP ecoregion.

Table 42. QHEI data summary for *Pickerel Creek* (HUC 04100011 02 03)

Stream name	RM	STORET	DA	ALU status	Score	NR	Comments
Pickerel Creek	6.26	U05K10	9.5	Full	48	Fair	Poor channel development with unstable riffles and moderately heavy silt
	3.35	U05S04	43.7	Partial	45	Fair	Channel erosion/incision from upstream hydromodifications; bank destabilization

Source: Ohio EPA 2010a, Table 11, p. 42
Note: ALU = aquatic life use; DA = drainage area, in square miles; NR = narrative rating; RM = rivermile; STORET = site code for U.S. EPA's STOrage and RETrieval system.

5.4.2 Sources of Impairment

Ohio EPA (2010a) found the WAU to be impaired by sedimentation/siltation and particle distribution (embeddedness) from sources related to agricultural operations. The sources of sedimentation/siltation and particle distribution (embeddedness) impairments for Pickerel Creek are evaluated in the following sections.

Besides direct drainage from agricultural land (primarily row crop with sparse residences), the Erie Islands WWTP (2PQ00001) and Fuller Creek discharge to the segment of Pickerel Creek above the impaired site and below the fully attaining site. A portion of one industrial facility that is permitted to discharge storm water (2GR00590; Tower Automotive Operations USA I LLC) is in this WAU.

5.4.2.1 Erie Islands WWTP

One facility is covered by individual NPDES permits: OTC's Erie Islands WWTP (2PQ00001). The WWTP discharges to Pickerel Creek and has a design flow of 0.15mgd.TSS at OTC's Erie Islands WWTP ranged from 1 mg/L to 256 mg/L (average: 5 mg/L; median: 6 mg/L; 954 records) from 2003 through 2012 and 99 percent of results were at or below the TSS target[32]. An evaluation of TSS data collected by Ohio EPA on Pickerel Creek at RMs 3.35 and 6.26 (above and below the WWTP) showed that TSS loads discharge to Pickerel Creek from sources along the reach between the two monitoring sites. The concentrations of TSS at the Erie Islands WWTP were typically one-tenth to one-third of the in-stream TSS concentration at RM 3.35. Therefore, while the Erie Islands WWTP does contribute TSS loads to Pickerel Creek, the WWTP is not significantly contributing to the sedimentation/siltation impairment.

5.4.2.2 Household Sewage Treatment Systems and Un-sewered Areas

While the city of Sandusky and village of Bellevue are sewered, the remainder of the WAU is served by HSTS. It is noteworthy that the Bellevue WWTP began accepting septage in 2004 (TMACOG 2011, p. 180). The remainder of the WAU is served by HSTS. This WAU is in Erie and Sandusky counties that have HSTS failure rates of 61 percent and 35 percent (ODH 2013).

TMACOG identified the town of Flat Rock (approximately 80 homes) as being served by individual HSTS that may be discharging into sinkholes in the karst bedrock (TMACOG 2011, p. 180). TMACOG (2011, p. 181) also identified a single, un-permitted package treatment plant in its Bellevue facility planning area. The unincorporated community of Vickery is also served by individual HSTS. The soils have poor HSTS suitability and Ohio EPA found failing HSTS in 2000 (TMACOG 2011, p. 206-207).

SWAT model results did not show failing HSTS to be impacting surface waters in this WAU. The impacts of failing HSTS to groundwater were not evaluated. While failing HSTS are present, may contribute elevated sediment levels to surface water (or groundwater), and may impact surface water (or groundwater) locally, failing HSTS are not significant sources of TSS to surface waters in this WAU.

5.4.2.3 Agriculture

The dominant land use in this WAU is cultivated crops (85 percent). Fifty-seven WWTP sludge fields are in this WAU. Agricultural ditches are present in the lower portion of the WAU with many draining directly to Sandusky Bay. SWAT model results show that cultivated cropland contributes an annual average of 1,050 tons/year TSS, which is 53 percent of the TSS load in the WAU (Appendix F).

[32] The TSS target for Pickerel Creek is 24 mg/L. This target is for headwaters streams in the HELP ecoregion (Ohio EPA 1999).

TSS concentrations monitored by Ohio EPA along Pickerel Creek at RMs 3.35 and 6.26 show that TSS loads are discharged to the creek between the two monitoring sites. Fuller Creek discharges to Pickerel Creek just above the monitoring site at RM 3.35. TSS concentrations at RM 3.35 tended to be highest in June and progressively decrease from June through September. Such a trend may be indicative of row crop practices with higher sediment-laden runoff in the wetter, earlier summer.

5.4.3 Conclusions

Pickerel Creek is impaired by sedimentation/siltation and particle distribution (embeddedness) and TSS monitoring data are representative of these impairments (see Appendix E for a map of assessment site attainment, sedimentation/siltation impairments, and SWAT model results). The anthropogenic sources of TSS loads to Pickerel Creek are the Erie Islands WWTP, urban and industrial storm water, failing HSTS, and agriculture. SWAT model results indicate that the dominant sources of TSS loads to the WAU are cultivated cropland (53 percent) and developed urban land (36 percent). The anthropogenic sources will be addressed through a TSS TMDL on Pickerel Creek at Township Road 247 (RM 3.34, U05S04).

5.5 Raccoon Creek (HUC 04100011 02 04)

Figure 29. Raccoon Creek at Balsizer Road (TR 239).

This WAU is in Sandusky County and northern Seneca County. Raccoon Creek's begins in in rural, agricultural northern Seneca County. The creek flows north into Sandusky County and flows through the city of Clyde. Buck Creek begins east of the city of Clyde, flows northeast, and joins with Raccoon Creek north of the city of Clyde. Raccoon Creek flows through wide forested buffers as it enters the city of Clyde and flows along the WTP and its reservoirs. The forested buffers diminish in the residential developments, and then disappear as Raccoon Creek flows through a municipal park and then large commercial complexes. After Clyde, the creek flows through rural agricultural areas (Figure 29).

5.5.1 Monitoring Data

Ohio EPA collected water chemistry at seven sites and biological data at five sites (Ohio EPA 2010a). Attainment was evaluated at one site on Buck Run (partial attainment) and four sites on Raccoon Creek (two sites in partial attainment, one site each in full attainment and non-attainment; Ohio EPA 2010a, Table 2, p. x-xi). The primary causes of impairment were due to nutrients and sediment; therefore, only nutrient- and sediment-related monitoring data are presented herein.

Available QHEI (Table 43) and water chemistry (Table 44) data are summarized here; refer to Ohio EPA (2010a) for all available water chemistry and QHEI data. Raccoon Creek RM 5.45 (U05W17) was also evaluated for dissolved orthophosphate with an average dissolved orthophosphate to total phosphorus ratio of 75 percent[33].As shown in these tables, nutrient and TSS levels exceed the targets and habitat is impaired; thus, nutrient and TSS are representative of the nutrient and sediment impairments. Total phosphorus data collected on Buck Creek are not representative of the nutrient/eutrophication impairment; however, nitrate plus nitrite data are representative of this impairment.

[33] Dissolved orthophosphate at Raccoon Creek RM 5.45 (U05W17) ranged from 0.035 mg/L to 0.271 mg/L phosphorus with a geometric mean of 0.081 mg/L phosphorus (11 samples). The dissolved orthophosphate to total phosphorus ratio ranged from 51 to 100 percent (11 samples).

Table 43. QHEI data summary for *Raccoon Creek* (HUC 04100011 02 04)

Stream name	RM	STORET	DA	ALU status	Score	NR	Comments
Buck Run	0.20	U05S03	4.5	Partial	45.5	Fair	Moderately heavy silt with extensively embedded riffles
Raccoon Creek	13.26	U05S01	9.9	Full	49.5	Fair	Moderately heavy silt with extensively embedded substrates
	11.32	U05P04	12.7	Non	42	Poor	Heavy silt with extensively embedded substrates
	11.03	U05W06	13.2	--	--	--	--
	10.80	U05W08	13.3	--	--	--	--
	10.18	U05W10	13.8	Non	51.5	Fair	Moderately heavy silt with extensively embedded substrates
	5.45	U05W17	23.6	Partial	66	Good	--

Source: Ohio EPA 2010a, Table 11, p. 41-42
Note: ALU = aquatic life use; DA = drainage area, in square miles; NR = narrative rating; RM = rivermile; STORET = site code for U.S. EPA's STOrage and RETrieval system.

Table 44. Water chemistry data summary for *Raccoon Creek* (HUC 04100011 02 04)

Stream name	RM	STORET	DA	ALU status	No. samples	Min.	Max.	GM	Exceed[a]
Nitrate plus nitrite (mg/L as nitrogen)									
Buck Run	0.20	U05S03	4.5	Partial	4	0.05	6.29	1.11	75%
Raccoon Creek	13.26	U05S01	9.9	Full	4	0.26	5.43	1.49	75%
	11.32	U05P04	12.7	Non	5	1.05	3.29	2.00	100%
	11.03	U05W06	13.2	--	0	--	--	--	--
	10.80	U05W08	13.3	--	4	7.31	14.20	10.52	100%
	10.18	U05W10	13.8	Non	6	7.93	14.10	10.55	100%
	5.45	U05W17	23.6	Partial	10	3.90	7.60	4.95	100%
Total phosphorus (mg/L as phosphorus)									
Buck Run	0.20	U05S03	4.5	Partial	4	0.03	0.06	0.05	0%
Raccoon Creek	13.26	U05S01	9.9	Full	4	0.05	0.13	0.08	75%
	11.32	U05P04	12.7	Non	5	0.06	0.42	0.14	80%
	11.03	U05W06	13.2	--	0	--	--	--	--
	10.80	U05W08	13.3	--	4	0.08	0.93	0.24	75%
	10.18	U05W10	13.8	Non	6	0.11	0.89	0.26	100%
	5.45	U05W17	23.6	Partial	10	0.04	0.32	0.11	60%
TSS (mg/L) [b]									
Buck Run	0.20	U05S03	4.5	Partial	3	2.5	11	4.1	0%
Raccoon Creek	13.26	U05S01	9.9	Full	3	2.5	36	11.1	33%
	11.32	U05P04	12.7	Non	4	12	17	14.4	0%
	11.03	U05W06	13.2	--	0	--	--	--	--
	10.80	U05W08	13.3	--	3	2.5	12	6.7	0%
	10.18	U05W10	13.8	Non	5	2.5	2.5	2.5	0%
	5.45	U05W17	23.6	Partial	6	2.5	28	6.6	17%

Notes
ALU = aquatic life use; DA = drainage area, in square miles; GM = geometric mean; RM = rivermile; STORET = site code for U.S. EPA's STOrage and RETrieval system.
a. The nitrate plus nitrite targets are 1.0 mg/L nitrogen and the total phosphorus targets are 0.08 mg/L and 0.10 mg/L phosphorus because Buck Run is an undesignated and assumed WWH headwaters stream and Raccoon Creek is a WWH headwaters and wading stream. The TSS targets are 24 mg/L because both streams are in the HELP ecoregion.
b. The TSS detection limit is 5 mg/L and non-detects are evaluated as one-half of the detection limit.

The LDC analyses shows that only one (low flow) of the six TSS samples exceed the target (Appendix G). In Buck Run, three of the four nitrate plus nitrite samples (most conditions and dry conditions) exceed the target. All (moist conditions, dry conditions, low flows) of the six total phosphorus samples in the headwaters of Raccoon Creek exceed the target (Appendix G). In the wading segment of Raccoon Creek, three of four samples each in the moist conditions and low flows exceed the target; single samples in the mid-range flows and dry conditions do not exceed the target.

5.5.2 Sources of Impairment

Ohio EPA (2010a) found the WAU to be impaired by seven nutrient-, sediment-, and habitat-related causes from six sources related to crop production and urban development. Ohio EPA sampled five monitoring sites (four sites on Raccoon Creek and one site on Buck Creek) and only the most upstream site (RM 13.26, U05S01) was in full attainment of biocriteria. Given the distribution of Ohio EPA monitoring sites and their attainment, the sources of impairment are likely from within the city of Clyde or the agricultural lands downstream of Clyde. The sources of impairments are evaluated in the following sections.

5.5.2.1 City of Clyde

The city of Clyde is a CSS with a WTP and WWTP. The Clyde WTP (2IW00050) discharges to Norris Ditch (a tributary of Raccoon Creek) via three lagoons and has a design flow of 0.027 mgd. Clyde WWTP (2PD00004) discharges to Raccoon Creek (design flow of 1.9 mgd). Clyde has a single active CSO outfall (010) that also discharges to Raccoon Creek. The village of Green Springs pipes its wastewater to the Clyde WWTP for treatment.

WWTP data (Table 45) were evaluated with Ohio EPA monitoring data from sites upstream and downstream of the WWTP: Raccoon Creek at RMs 11.32 and 10.18 (U05P04 and U05W10). In-stream TSS data (Table 45) were considerably below DMR data on corresponding dates. Nutrients in the effluent were almost always at concentrations in excess of the in-stream targets[34] and nutrient levels increase (sometimes more than doubling) between the sites above and below the WWTP. It is also notable that TSS data collected from CSO outfalls 003 and 010 regularly exceeded the in-stream TSS target[35]. Therefore, it is concluded that (1) typical operations WWTP effluent discharged through outfall 001 does not contribute significant TSS loads to Raccoon Creek, (2) CSO events discharge elevated TSS loads to and contribute to the impairment of biological communities in Raccoon Creek, and (3) typical operations WWTP effluent discharge through outfall 001 contributes considerable nutrient loads to Raccoon Creek.

[34] The nitrate plus nitrite target for Raccoon Creek is 1.0 mg/L nitrogen and the total phosphorus target is 0.08 mg/L. These targets are for WWH headwaters streams (Ohio EPA 1999).
[35] The TSS target for Raccoon Creek is 24 mg/L. This target is for headwaters streams in the HELP ecoregion (Ohio EPA 1999).

Table 45. Clyde WWTP (2PD00004) DMR data summary

Constituent	Units	No. of records	Min.	Max.	Avg.	Median
WWTP						
Nitrate plus nitrite	mg/L as nitrogen	104	2.19	21.90	10.38	10.45
Total phosphorus	mg/L as phosphorus	511	0	4.00	0.26	0.20
TSS	mg/L	1,440	1	32	18	4
CSS						
TSS at CSO 003	mg/L	25	3	396	125	70
TSS at CSO 004	mg/L	59	20	1,520	287	148

Notes
Non-detects were reported as zero and were evaluated as zero.
Results are from January 2003 through June 2012.
a. CSO outfall 003 was eliminated in 2005; data are for 2003-2005.
b. CSO outfall 010 was activated in 2005; data are for 2005-2012.

The WTP permit does not include limits or monitoring requirements for nitrogen or phosphorus species and the WTP is not expected to discharge above ambient levels. TSS data at the WTP ranged from 1 mg/L to 32 mg/L (average: 7 mg/L; median: 5 mg/L) and 98 percent of records were at or below the in-stream target for Raccoon Creek. The WTP discharged at lower TSS concentrations than an upstream Ohio EPA site (RM 13.26, U05S01) and the downstream site was non-detect (RM 11.32, U05P04). Raccoon Creek is in full attainment near the WTP and the WTP typically discharges low TSS concentrations, it is not likely that the WTP is contributing significantly to the sedimentation/siltation impairment.

SWAT modeling showed that urban developed land within this WAU contributed an annual average of 3,949 tons/day of TSS, 7,667 lbs/d total phosphorus, and 8,642 lbs/d nitrate plus nitrite, which are 37 percent, 9 percent, and 7 percent (respectively) of the total loads to the WAU (Appendix F).

5.5.2.2 Industrial Storm Water

Four industrial facilities are permitted to discharge storm water associated with industrial activities (Table 46) and their storm water may contain TSS and phosphorus.

Table 46. General NPDES permittees for storm water discharges associated with industrial activities in HUC 04100011 02 04

NPDES ID	Permittee	Facility
2GR00017	Fireside Auto Service Inc	Fireside Auto Service Inc
2GR00430	Vickery Environmental Inc	Vickery Environmental Inc
2GR00520	ArtiFlex Mfg LLC Gerstco Clyde	ArtiFlex Mfg LLC Gerstco Clyde
2GR01778	Whirlpool Corp	Whirlpool Corp-Clyde Operations

5.5.2.3 Household Sewage Treatment Systems and Un-sewered Areas

The city of Clyde is sewered and the remainder of the WAU is served by HSTSs. TMACOG (2011, p. 185) identified Frank’s Subdivision (also known as Woodland Heights) as a critical sewerage area that was sewered and connected to the Clyde WWTP in 2004. This WAU is in Sandusky County that has an HSTS failure rate of 35 percent (ODH 2013). TMACOG (2011, p. 186) identified the Clyde facility planning area as underlain by karst and the potential for failing HSTS to affect groundwater.
SWAT model results did not show failing HSTS to be impacting surface waters in this WAU. The impacts of failing HSTS to groundwater were not evaluated. While failing HSTS are present, may contribute elevated sediment levels to surface water (or groundwater), and may impact surface water (or

groundwater) locally, failing HSTS are not significant sources of TSS or total phosphorus to surface waters in this WAU.

5.5.2.4 Agriculture

The dominant land use in this WAU is cultivated crops (66 percent). Emergent herbaceous wetlands account for 11 percent of the WAU and pasture less than 1 percent. Most of the developed land (16 percent) is in and around the city of Clyde. Agricultural ditches and channelized streams are present in the lower portion of the WAU, downstream of the Ohio Turnpike (I-80/90). Ten WWTP sludge fields are in this WAU; all of the sludge fields south of the Ohio Turnpike (I-80/90). SWAT model results show that cultivated cropland contributes an annual average of 5,982 tons/year TSS, 64,585 lbs/yr total phosphorus, and 47,005 lbs/yr nitrate plus nitrite, which are 56 percent, 79 percent, and 40 percent (respectively) of the loads in the WAU, (Appendix E).

5.5.3 Conclusions

Raccoon Creek is impaired by nutrients and sedimentation/siltation, and nutrient and TSS monitoring data are representative of these impairments (see Appendix E for a map of assessment site attainment, impairments, and SWAT model results). The anthropogenic sources of total phosphorus and TSS loads to Raccoon Creek are individually permitted point sources (including CSOs), urban and industrial storm water, failing HSTS, and agriculture. SWAT model results indicate that the dominant sources of TSS loads to the WAU are cultivated cropland (56 percent) and storm water from urban developed land (37 percent). The dominant sources of total phosphorus loads are cultivated cropland (79 percent), storm water from urban developed land (9 percent), and permitted point sources (7 percent). The dominant sources of nitrate plus nitrite are permitted point sources (44 percent), cultivated cropland (40 percent), and urban developed land (7 percent).

The anthropogenic sources will be addressed through TSS and total phosphorus TMDLs on Raccoon Creek downstream of the Ohio Turnpike at Township Road 224 (RM 5.45, U05W17). Headwaters TMDLs will be developed for nitrate plus nitrite on Buck Run near the site that is north of Clyde at Township Road 223 (RM 0.30, U05S03) and for total phosphorus on Raccoon Creek near the site that is north of Clyde at Township Road 223 (RM 10.18, U05W10) .

5.6 South Creek (HUC 04100011 02 05)

This WAU is mostly in Sandusky County. South Creek begins southwest of the city of Clyde and flows northerly to Sandusky Bay. The Sandusky County Regional Airport, west of the City of Clyde, is in the WAU. The entire watershed is rural, agricultural; no incorporated communities are in the subwatershed. Ohio EPA (2010a) found the WAU to be impaired by five nutrient- and sediment-related causes from four sources related to agriculture and HSTS.

5.6.1 Monitoring Data

Ohio EPA collected water chemistry and biological data at two sites (Ohio EPA 2010a). Attainment was evaluated at two sites on South Creek with the upstream site in non-attainment and the downstream site in partial attainment (Ohio EPA 2010a, Table 2, p. x). The primary causes of impairment were due to nutrients and sediment; therefore, only nutrient-, sediment-, and habitat-related monitoring data are presented herein.

Available water chemistry (Table 47) and QHEI (Table 48) data are summarized here; refer to Ohio EPA (2010a) for all available water chemistry and QHEI data. South Creek RM 4.04 (U05K01) was also evaluated for dissolved orthophosphate (0.048 mg/L phosphorus) with a dissolved orthophosphate to total phosphorus ratio of 56 percent. As shown in these tables, South Creek nutrient and sediment concentrations exceed targets and habitat is fair to poor. Thus, nutrient and sediment data are representative of the impairments.

Table 47. Water chemistry data summary for *South Creek* (HUC 04100011 02 05)

Stream name	RM	STORET	DA	ALU status	No. samples	Min.	Max.	GM	Exceed[a]
Nitrate plus nitrite (mg/L as nitrogen)									
South Creek	7.92	U05G01	7.1	Non	5	0.27	6.55	1.57	60%
	4.04	U05K05	18.1	Partial	6	0.05	7.37	1.25	67%
Total phosphorus (mg/L as phosphorus)									
South Creek	7.92	U05G01	7.1	Non	5	0.05	0.12	0.09	60%
	4.04	U05K05	18.1	Partial	6	0.01	0.10	0.04	50%
TSS (mg/L) [b]									
South Creek	7.92	U05G01	7.1	Non	3	2.5	12	4.2	0%
	4.04	U05K05	18.1	Partial	6	16	34	22.1	17%

Notes

ALU = aquatic life use; DA = drainage area, in square miles; GM = geometric mean; RM = rivermile; STORET = site code for U.S. EPA's STOrage and RETrieval system.

a. The nitrate plus nitrite target is 1.0 mg/L nitrogen and the total phosphorus target is 0.08 mg/L phosphorus because South Creek is a WWH headwaters stream. The TSS target is 24 mg/L because South Creek is in the HELP ecoregion.

b. The TSS detection limit is 5 mg/L and non-detects are evaluated as one-half of the detection limit.

Table 48. QHEI data summary for *South Creek* (HUC 04100011 02 05)

Stream name	RM	STORET	DA	ALU status	Score	NR	Comments
South Creek	7.92	U05G01	7.1	Non	48.5	Fair	Poor channel development from channelization activities
	4.04	U05K05	18.1	Partial	33.5	Poor	Heavy silt with extensively embedded substrates, no riffle and poor channel development

Source: Ohio EPA 2010a, Table 11, p. 42
Note: ALU = aquatic life use; DA = drainage area, in square miles; NR = narrative rating; RM = rivermile; STORET = site code for U.S. EPA's STOrage and RETrieval system.

The only TSS sample in the moist conditions exceeded the target (Appendix G); five samples from the dry conditions and low flows were below the target. One total phosphorus sample in the moist conditions and one of three samples in the dry conditions exceeded the target.

5.6.2 Sources of Impairment

One facility is covered by individual NPDES permit. No facilities are covered by the general permit for storm water discharges associated with industrial activities in this WAU.

5.6.2.1 Club Rog

The only NPDES permitted facility in the WAU is for R&E Entertainment, Inc.'s Club Rog WWTP (2PR00170). The facility discharges treated sanitary wastewater to a tributary of South Creek[36] with a design flow of 0.002 mgd. DMR records show that TSS ranges from non-detect to 120 mg/L (average: 6 mg/L, median: 30 mg/L, using one-half of the 1.0 mg/L detection limit for non-detects; 98 records). Approximately 96 percent of TSS records at the Club Rog WWTP (2PR00170) were at or below the in-stream target[37].

5.6.2.2 Developed Land

SWAT modeling showed that urban developed land within this WAU contributed an annual average of 577 tons/year of TSS and 2,019 lbs/yr total phosphorus, which are 10 percent and 5 percent (respectively) of the total loads to the WAU (Appendix F).

5.6.2.3 Household Sewage Treatment Systems and Un-sewered Areas

No incorporated municipalities are within the WAU; the entire WAU is served by HSTS. This WAU is in Sandusky County that has an HSTS failure rate of 35 percent (ODH 2013). SWAT model results did not show failing HSTS to be impacting this WAU. While failing HSTS are present, may contribute elevated sediment and total phosphorus levels to surface waters, and may impact surface waters locally, failing HSTS are not significant sources of TSS or total phosphorus in this WAU.

[36] The Club Rog permit (2PR00170) erroneously identifies the receiving waterbody as an unnamed tributary to Green Creek, which is in HUC 04100011 12 03. The facility is in HUC 04100011 02 05 and its treated effluent outfall is on an unnamed tributary to South Creek.
[37] The TSS target for the unnamed tributary to Green Creek is 24 mg/L. This target is for headwaters streams in the HELP ecoregion (Ohio EPA 1999).

5.6.2.4 Agriculture

The dominant land use in this WAU is cultivated crops (80 percent). Developed open space accounts for 6 percent of the WAU and pasture less than 1 percent. Most of the developed land (16 percent) is in and around the city of Clyde. Agricultural ditches and channelized streams are present in the lower portion of the WAU, downstream of the Ohio Turnpike (I-80/90).

Six WWTP sludge fields are in this WAU; five of which are along South Creek, just south of the railroad lines that parallel U.S. Route 20. South Creek runs through or directly adjacent to three of the fields; the other three fields are just over 700 feet from South Creek.

SWAT model results show that cultivated cropland contributes an annual average of 4,616 tons/year TSS and 40,094 lbs/yr total phosphorus, which are 85 percent and 92 percent (respectively) of the total loads in the WAU, (Appendix E).

5.6.3 Conclusions

South Creek is impaired by nutrients and sediment, and nutrient and TSS monitoring data are representative of these impairments (see Appendix E for a map of assessment site attainment, impairments, and SWAT model results). The anthropogenic sources of total phosphorus and TSS loads to South Creek are Club Rog, storm water from developed land, failing HSTS, and agriculture. SWAT model results indicate that the dominant sources of TSS loads to the WAU are cultivated cropland (85 percent) and storm water from developed land (10 percent), and the dominant sources of total phosphorus loads are also cultivated cropland (92 percent) and storm water from developed land (5 percent). These sources will be addressed through TSS and total phosphorus TMDLs on South Creek near Riley Center at Whitmore Road (Township Road 248; RM 4.04, U05K05).

6 Linkage Analysis: Tributaries of the Sandusky River (Lower)

Source assessments and linkage analyses are discussed individually in this section for the impaired WAUs tributary to the Sandusky River (lower). Ten WAUs across the following five 10-digit HUCs are impaired for their ALUs:

- *Wolf Creek* (HUC 04100011 10)
- *Rock Creek-Sandusky River* (HUC 04100011 11)
- *Green Creek* (HUC 04100011 12)
- *Muskellunge Creek-Sandusky River* (HUC 04100011 13)
- *Muddy Creek-Sandusky River* (HUC 04100011 14)

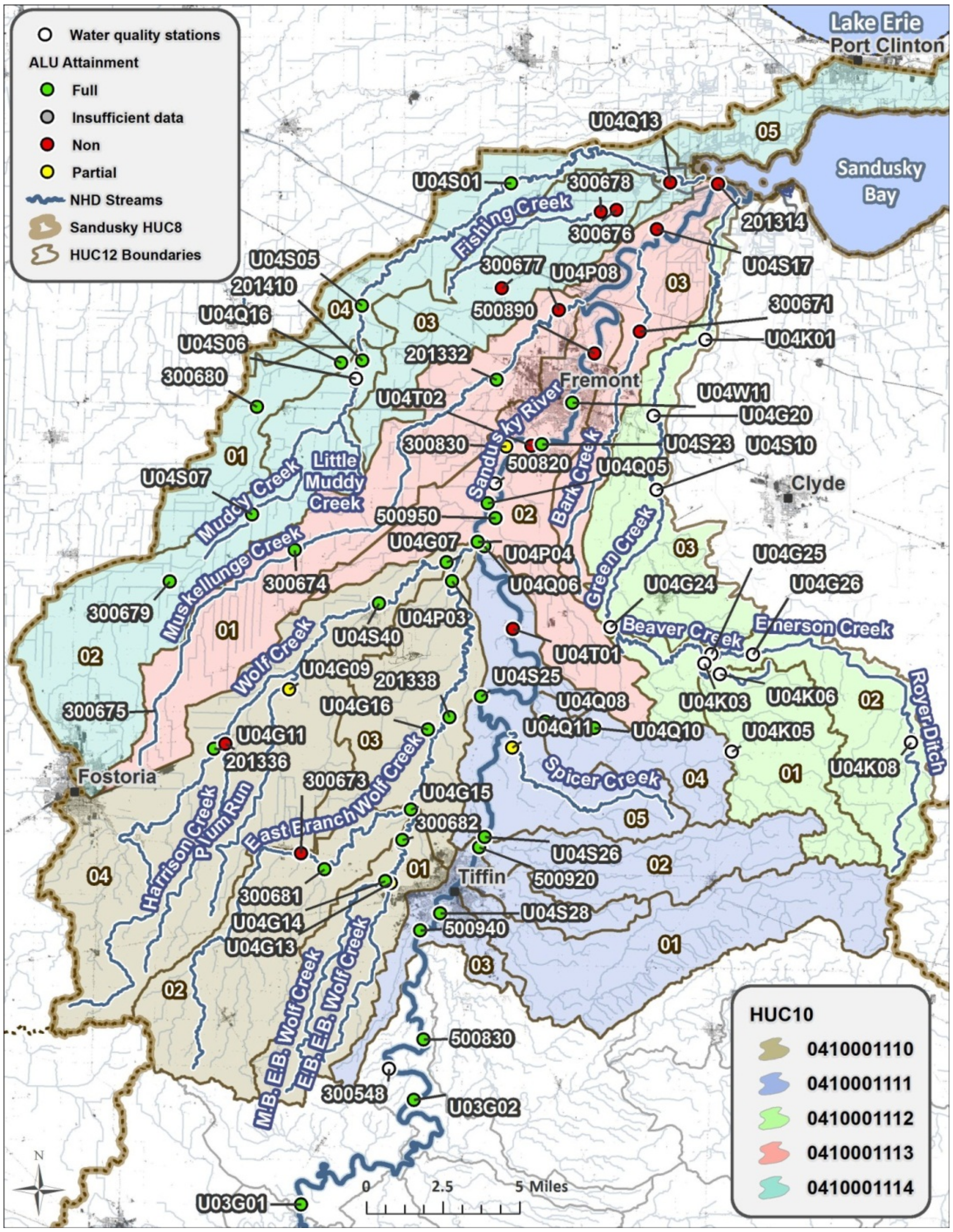


Figure 30. Ohio EPA assessment sites on the Sandusky River (lower) and its tributaries.

6.1 East Branch East Branch Wolf Creek (HUC 04100011 10 01)

This WAU is in Seneca County and its two main tributaries, Middle Branch East Branch Wolf Creek and East Branch East Branch Wolf Creek, flow north to East Branch Wolf Creek. The WAU is mostly rural agricultural, except for the eastern downstream portion that is part of the city of Tiffin. Portions of the city of Tiffin in this WAU drain to East Branch East Branch Wolf Creek and Crum Ditch, which are both tributaries to East Branch Wolf Creek. It is also notable that portions of the Seneca County Airport and Seneca County Fairground are in this WAU in the city of Tiffin.

6.1.1 Monitoring Data

Ohio EPA collected water chemistry and biological data at three sites (Ohio EPA 2011). Attainment was evaluated at one site on Middle Branch East Branch Wolf Creek (full attainment) and two sites on East Branch East Branch Wolf Creek (one site in partial attainment and one site each in full attainment; see Ohio EPA 2011, Table 2, p. 10). The primary causes of impairment were due to nutrients and direct habitat alterations; therefore, only nutrient- and habitat-related monitoring data are presented herein.

Available water chemistry (Table 49) and QHEI (Table 50) data are summarized here; refer to Ohio EPA (2011a) for all available water chemistry and QHEI data. As shown in these tables, nutrient levels exceed the targets and are representative of the nutrient impairments.

Table 49. Water chemistry data summary for *East Branch East Branch Wolf Creek* (HUC 04100011 10 01)

Stream name	RM	STORET	DA	ALU status	No. samples	Min.	Max.	GM	Exceed[a]
Nitrate plus nitrite (mg/L as nitrogen)									
E. Br. E. Br. Wolf Creek	3.52	U04G13	6.8	Partial	5	0.56	9.83	1.58	40%
	1.48	300682	9.7	Full	5	0.17	12.60	1.29	40%
M. Br. E. Br. Wolf Creek	0.46	U04G14	11.3	Full	5	1.61	12.20	3.87	100%
Total phosphorus (mg/L as phosphorus)									
E. Br. E. Br. Wolf Creek	3.52	U04G13	6.8	Partial	5	0.09	0.15	0.11	100%
	1.48	300682	9.7	Full	5	0.08	0.12	0.09	80%
M. Br. E. Br. Wolf Creek	0.46	U04G14	11.3	Full	5	0.07	0.19	0.12	80%
TSS (mg/L)									
E. Br. E. Br. Wolf Creek	3.52	U04G13	6.8	Partial	3	29	47	34.1	100%
	1.48	300682	9.7	Full	3	13	50	26.9	67%
M. Br. E. Br. Wolf Creek	0.46	U04G14	11.3	Full	5	11	55	18.6	60%

Notes

ALU = aquatic life use; DA = drainage area, in square miles; E. Br. E. Br. Wolf Creek = East Branch East Branch Wolf Creek; GM = geometric mean; M. Br. E. Br. Wolf Creek = Middle Branch East Branch Wolf Creek; RM = rivermile; STORET = site code for U.S. EPA's STOrage and RETrieval system.

a. The nitrate plus nitrite targets are 1.0 mg/L nitrogen and the total phosphorus targets are 0.08 mg/L phosphorus because East Branch East Branch Wolf Creek and Middle Branch East Branch Wolf Creek are WWH headwaters streams. The TSS targets are 14 mg/L because both streams are in the ECBP ecoregion.

Table 50. QHEI data summary for *East Branch East Branch Wolf Creek* (HUC 04100011 10 01)

Stream name	RM	STORET	DA	ALU status	Score	NR	Comments
E. Br. E. Br. Wolf Creek	3.52	U04G13	6.8	Partial	42.5	Fair	--
	1.48	300682	9.7	Full	71.5	Excellent	--
M. Br. E. Br. Wolf Creek	0.46	U04G14	11.3	Full	80	Excellent	--

Source: Ohio EPA 2011, Table 12, p. 37-38
Note: ALU = aquatic life use; DA = drainage area, in square miles; E. Br. E. Br. Wolf Creek = East Branch East Branch Wolf Creek; M. Br. E. Br. Wolf Creek = Middle Branch East Branch Wolf Creek; NR = narrative rating; RM = rivermile; STORET = site code for U.S. EPA's STOrage and RETrieval system.

The single high flow sample and one of two mid-range flow nitrate plus nitrite samples exceed the target (Appendix G); neither dry conditions sample exceed the target. All five total phosphorus samples exceed the target.

6.1.2 Sources of Impairment

Ohio EPA (2011) found the WAU to be impaired by five nutrient- and habitat-related causes from crop production with subsurface drainage and unspecified urban storm water. Sources of nutrient and habitat impairments are presented in this section.

6.1.2.1 Industrial Facilities and Storm Water

Three industrial facilities discharge within this WAU (Table 51). All three industrial facilities drain to segments of East Branch East Branch Wolf Creek that are in full attainment of biocriteria. No facilities are covered by the general permit for storm water discharges associated with industrial activities.

Table 51. Facilities with NPDES permits in HUC 04100011 10 01

NPDES ID	Permittee	Facility	Receiving waterbody	Size (mgd)
2IN00209	Buckeye Partners LP	Tiffin Terminal	East Branch Wolf Creek	--[a]
2IS00017	Atlas Industries, Inc.		Houck Ditch [b]	--[a]
2IS00039	Webster Industries		Houck Ditch	--[c]

Notes
mgd = million gallons per day; MHP = mobile home park; WWTP = wastewater treatment plant.
a. These facilities are permitted to discharge storm water.
b. Atlas Industries, Inc. discharges to Houck Ditch via storm sewers.
c. Webster Industries is permitted to discharge non-contact cooling water free from process water and sanitary waste.

Table 52. Industrial facilities with TSS or total phosphorus data in HUC 04100011 10 01

NPDES ID	Outfall	Receiving waterbody	No. of records	Min.	Max.	Avg.	Median
TSS (mg/L)							
2IN00209 [a]	001	E. Br. E. Br. Wolf Creek	22	2	70	9	4
2IS00017 [b]	001	Houck Ditch [c]	27	5	91	24	14
Total phosphorus (mg/L)							
2IN00209 [a]	001	E. Br. E. Br. Wolf Creek	21	0.02	0.20	0.06	0.05
2IS00017 [b]	001	Houck Ditch [c]	28 [d]	0.02	0.20	0.10	0.05

Notes

ALU = aquatic life use; E. Br. E. Br. Wolf Creek = East Branch East Branch Wolf Creek; mg/L = milligram per liter; TSS = total suspended solids.

a. Results are from November 2010 to December 2012. The TSS detection limit 2IN00209 is 4 mg/L and the total phosphorus detection limits are 0.04 mg/L, 0.10 mg/L, and 0.40 mg/L; non-detects were evaluated at one-half of the detection limit. Results

b. Results are from January 2003 through January 2007.

c. Atlas Industries, Inc. discharges to Houck Ditch via storm sewers.

d. Atlas Industries, Inc. (2IS00017) DMR data included a total phosphorus concentration of 10.1 mg/L on 11/19/2003. This datum was assumed to be an error and was excluded from analysis.

Both facilities' individual storm water permits include TSS effluent limits but only include monitoring requirements for total phosphorus. About 84 percent of TSS records and 88 percent of total phosphorus records[38] at Buckeye Partners LP (2IN00209) were at or below in-stream targets[39]. Similarly, 46 percent of TSS records and 83 percent of total phosphorus records at Atlas Industries, Inc. (2IS00017) were at or below in-stream targets[40]. Both of these facilities contribute nutrient and TSS loads and may contribute significantly to the nutrient/eutrophication, nitrate, and phosphorus impairments in the WAU. It should be noted that these facilities are surrounded by other commercial or industrial facilities and residential developments that also discharge storm water.

Webster Industries (2IS00039) is not considered a source of impairment since it only discharges non-contact cooling water.

6.1.2.2 Brookpark Estates MHP

The Brookpark Estates MHP (2PY00034) treats domestic sanitary wastewater and discharges to Davidson Ditch (design flow of 0.010 mgd). The facility does not have permit limits or monitoring requirements for total phosphorus or nitrogen species, except for ammonia. As no Ohio EPA assessment sites are near this facility and urban, rural, and agricultural sources of nutrients are in the area, it is not possible to assess the impact of Brookpark Estates MHP effluent upon East Branch East Branch Wolf Creek. However, as a sanitary sewerage treatment facility, it discharges nutrients and may contribute to the WAU impairments.

6.1.2.3 City of Tiffin

The city of Tiffin is a CSS with 34 CSO outfalls on the Sandusky River and Rock Creek; no outfalls discharge in this WAU (Section 4.2.1.1). Therefore, the Tiffin CSS is not a source of impairment to East Branch East Branch Wolf Creek.

The city of Tiffin is covered under a small MS4 permit (2GQ00031). SWAT modeling showed that urban developed land within this WAU, which includes the portions of the regulated MS4, contributed an

[38] The only detection of total phosphorus at Buckeye Partners LP (2IN00209) occurred on June 16, 2011 at 0.13 mg/L phosphorus.

[39] The TSS target for East Branch East Branch Wolf Creek is 14 mg/L. This target is for headwaters streams in the ECBP ecoregion (Ohio EPA 1999).

[40] The TSS target for Houck Ditch is 14 mg/L. This target is for headwaters streams in the ECBP ecoregion (Ohio EPA 1999).

annual average of 18,627 lbs/yr nitrate plus nitrite, which is 19 percent of the load to the WAU (Appendix F).

6.1.2.4 Household Sewage Treatment Systems and Un-sewered Areas

The city of Tiffin is sewered. The majority of the WAU is unincorporated and served by HSTS. This WAU is in Seneca County that has an HSTS failure rate of 72 percent (ODH 2013). SWAT model results did not show failing HSTS to be impacting this WAU. While failing HSTS are present, may contribute elevated total phosphorus and nitrate plus nitrite levels to surface waters, and may impact surface waters locally, failing HSTS are not significant sources of total phosphorus or nitrate plus nitrite in this WAU.

6.1.2.5 Agriculture

The dominant land use in this WAU is cultivated crops (79 percent). Developed open space accounts for 7 percent of the WAU and pasture is less than 1 percent. Most of the developed land (13 percent) is in and around the city of Tiffin in the lower portion of the WAU.

One WWTP sludge field is in this WAU, which is northwest of Tiffin along East Branch East Branch Wolf Creek. It is just upstream of an Ohio EPA assessment site (RM 1.48, 300682) that is in full attainment but displays elevated levels of nutrients and TSS (Table 49).

SWAT model results show that cultivated cropland contributes an annual average of 32,314 lbs/yr total phosphorus and 50,958 lbs/yr nitrate plus nitrite, which are 94 percent and 52 percent (respectively) of the total loads in the WAU (Appendix E).

6.1.3 Conclusions

East Branch East Branch Wolf Creek is impaired by nutrient/eutrophication, phosphorus, and nitrogen and nutrient monitoring data are representative of these impairments. The anthropogenic sources of nutrient loads to East Branch East Branch Wolf Creek are individually permitted point sources, storm water from developed land, failing HSTS, and agriculture. SWAT model results indicate that the dominant sources of total phosphorus loads to the WAU are cultivated cropland (94 percent) and permitted point sources (6 percent). The dominant sources of nitrate plus nitrite loads are cultivated cropland (52 percent), point sources (27 percent), and storm water from developed land (19 percent). These sources will be addressed through a total phosphorus and nitrate plus nitrite TMDLs on East Branch East Branch Wolf Creek near the site at County Road 26 (RM 3.52, U05G13).

6.2 *Town of New Riegel-East Branch Wolf Creek (HUC 04100011 10 02)*

This WAU is in Seneca County and it is composed of many ditches that discharge to East Branch Wolf Creek. The WAU is mostly rural agricultural, except for the village of New Riegel. The unincorporated community of Bascom is along the northern border of the WAU.

6.2.1 Monitoring Data

Ohio EPA collected water chemistry and biological data at three sites (Ohio EPA 2011). Attainment was evaluated at one site on an unnamed tributary to East Branch Wolf Creek (non-attainment) and two sites on East Branch Wolf Creek (both sites in full attainment; see Ohio EPA 2011, Table 2, p. 10). The causes of impairment were due to nutrients; therefore, only nutrient-related monitoring data are presented herein.

Available nutrient water chemistry (Table 53) data are summarized here; refer to Ohio EPA (2011a) for all available water chemistry data. As shown in these tables, nutrient levels exceed the targets and are representative of the nutrient impairments.

Table 53. Nutrient water chemistry data summary for *Town of New Riegel - East Branch Wolf Creek* (HUC 04100011 10 02)

Stream name	RM	STORET	DA	ALU status	No. samples	Min.	Max.	GM	Exceed[a]
Nitrate plus nitrite (mg/L as nitrogen)									
East Branch Wolf Creek	19.65	300673	19.0	Non	5	0.49	14.30	2.16	60%
	13.63	U04G15	33.0	Full	5	0.27	15.10	1.44	40%
unnamed tributary [b]	0.04	300681	8.1	Full	4	0.21	12.70	1.84	50%
Total phosphorus (mg/L as phosphorus)									
East Branch Wolf Creek	19.65	300673	19.0	Non	5	0.13	4.54	0.61	100%
	13.63	U04G15	33.0	Full	5	0.09	0.40	0.15	80%
unnamed tributary [b]	0.04	300681	8.1	Full	4	0.09	0.30	0.16	100%

Notes
ALU = aquatic life use; DA = drainage area, in square miles; GM = geometric mean; RM = rivermile; STORET = site code for U.S. EPA's STOrage and RETrieval system.
a. The nitrate plus nitrite targets are 1.0 mg/L nitrogen and the total phosphorus targets are 0.08 mg/L and 0.10 mg/L phosphorus because East Branch Wolf Creek is a WWH headwaters and wading stream and the unnamed tributary to East Branch Wolf Creek is an undesignated stream and assumed WWH headwaters stream. The TSS targets are 24 mg/L because both streams are in the HELP ecoregion.
b. Unnamed tributary to East Branch Wolf Creek at RM 18.60

The LDC analysis shows that single nitrate plus nitrite samples in the high flow conditions and mid-range flows exceeded the target and one of three nitrate plus nitrite samples exceeded the target in the dry conditions. All five of the total phosphorus samples exceeded the target (Appendix G).

6.2.2 Sources of Impairment

Ohio EPA (2011) found the WAU to be impaired by nutrient/eutrophication, nitrate, and phosphorus causes from package plant or other permitted small flow discharges and sewage discharges in un-sewered areas. East Branch Wolf Creek at RM 19.65, which is at the unincorporated community of Bascom, was in nonattainment.

6.2.2.1 Public Facilities

Four facilities are covered by individual NPDES permits (Table 54). No facilities are covered by the general permit for storm water discharges associated with industrial activities.

Table 54. Facilities with NPDES permits in HUC 04100011 10 02

NPDES ID	Permittee	Facility	Receiving waterbody	Size (mgd)
2PR00114	Andrew Brickner	PJ's Brickhouse	East Branch Wolf Creek [a]	0.00245
2PG00118	Seneca County Commissioners	Bascom WWTP	East Branch Wolf Creek	0.080
2PR00142	Hopewell Township Trustees	Meadowbrook Park WWTP	East Branch Wolf Creek	0.01
2PT00044	Hopewell Loudon Local Schools	--	East Branch Wolf Creek	0.025

Notes
mgd = million gallons per day; WWTP = wastewater treatment plant.
a. PJ's Brickhouse is in the unincorporated community of Bascom within the *Wolf Creek* WAU (04100011 10 04) but discharges to East Branch Wolf Creek in the *Snuff Creek - East Branch Wolf Creek* WAU (04100011 10 02).

PJ's Brickhouse is a restaurant in the unincorporated community of Bascom; the permit does not have nutrient monitoring requirements. The Bascom WWTP (2PG00118) also does not have nutrient monitoring requirements and the facility has had SSO events.

As of 2012, the Meadowbrook Park WWTP (2PR00142) is now required to sample total phosphorus and nitrate plus nitrite quarterly. Total phosphorus samples from August and December 2012 were 4.6 and 3.4 mg/L, which are well in excess of the in-stream target[41]. This facility is under a compliance schedule to connect to the Bascom Area sanitary sewer system.

Hopewell Loudon facility (2PT00044) also does not have monitoring requirements for total phosphorus or nitrate plus nitrite. This facility is under a compliance schedule to eliminate the on-site wastewater treatment system and connect to the Bascom Area sanitary sewer system.

Given the lack of DMR data, it is not possible to evaluate the impact of these facilities upon East Branch Wolf Creek. However, as they are all sanitary treatment systems, they discharge nutrients and are contributing, possibly significantly, to the nutrient impairments in this WAU.

6.2.2.2 Developed Land

SWAT modeling showed that developed land within this WAU contributed an annual average of 15,991 lbs/yr of nitrate plus nitrite, which is 15 percent of the total nitrate plus nitrite load to the WAU (Appendix F).

6.2.2.3 Household Sewage Treatment Systems and Un-sewered Areas

The WAU is mostly unincorporated and served by HSTS; the village of New Riegel is also served by HSTS. This WAU is in Seneca County that has an HSTS failure rate of 72 percent (ODH 2013). SWAT model results did not show failing HSTS to be impacting this WAU. While failing HSTS are present, may contribute elevated total phosphorus and nitrate plus nitrite levels to surface waters, and may impact

[41] The total phosphorus target for East Branch Wolf Creek is 0.08 mg/L phosphorus. This target is for headwaters WWH streams (Ohio EPA 1999).

surface waters locally, failing HSTS are not significant sources of total phosphorus or nitrate plus nitrite in this WAU.

6.2.2.4 Agriculture

The dominant land use in this WAU is cultivated crops (85 percent). Developed open space accounts for 6 percent of the WAU and pasture is about 1 percent. Most of the developed land (8 percent) is the village of New Riegel and the unincorporated community of Bascom. Undeveloped parcels with deciduous forest compose about 6 percent of the WAU and are present throughout the WAU.

Three WWTP sludge fields are in this WAU; they are in the lower portion of the WAU. All three sludge fields are upstream of the assessment site on East Branch Wolf Creek at RM 13.63 (U04G15), which is in full attainment of its WWH use. However, Ohio EPA monitored elevated nutrient levels at this site. Therefore, these sludge fields are not directly contributing to the nutrient impairment on East Branch Wolf Creek but may contribute nutrient loads to downstream impairments in other WAUs.

SWAT model results show that cultivated cropland contributes an annual average of 57,509 lbs/yr total phosphorus and 87,304 lbs/yr nitrate plus nitrite, which are almost 100 percent and 82 percent (respectively) of the total loads in the WAU, (Appendix E).

6.2.3 Conclusions

East Branch Wolf Creek is impaired by nutrient/eutrophication, phosphorus, and nitrate, and nutrient monitoring data are representative of these impairments. The anthropogenic sources of nutrient loads to East Branch Wolf Creek are individually permitted point sources, storm water from developed land, failing HSTS, and agriculture. SWAT model results indicate that the only significant source of total phosphorus loads to the WAU is cultivated cropland and the dominant sources of nitrate plus nitrite loads are cultivated cropland (82 percent) and runoff from developed land (15 percent). These sources will be addressed through total phosphorus and nitrate plus nitrite TMDLs on East Branch Wolf Creek near the site at Meadowbrook Park (RM 19.65, 300673).

6.3 Wolf Creek (HUC 04100011 10 04)

This WAU is mostly in Seneca County, with small portions of the headwaters in Wood County. The city of Fostoria, village of Bettsville, and unincorporated community of Bascom are in the WAU. The WAU is mostly rural, agricultural and two large golf courses are in the WAU (Loudon Meadows Golf Club and Nature Trails Golf Course). Tributaries to Wolf Creek in this WAU include: Harrison Creek, Lynch Ditch, Plum Run, and Scherger Ditch.

6.3.1 Monitoring Data

Ohio EPA collected water chemistry and biological data at six sites (Ohio EPA 2011). Attainment was evaluated at one site on Harrison Creek (non-attainment), one site on Plum Run (partial attainment), and four sites on Wolf Creek (all four sites in full attainment; see Ohio EPA 2011, Table 2, p. 9). The primary causes of impairment were due to nutrients and direct habitat alterations; therefore, only nutrient- and habitat-related monitoring data are presented herein.

Available QHEI (Table 55) and water chemistry (Table 56) data are summarized here; refer to Ohio EPA (2011a) for all available water chemistry and QHEI data. Wolf Creek RM 1.58 (U04G07) was also evaluated for dissolved orthophosphate with an average dissolved orthophosphate to total phosphorus ratio of 65 percent[42]. As shown in these tables, nutrient levels exceed the targets and are representative of the nutrient impairments. Additionally, Harrison Creek and Plum Run contribute nutrient loads to Wolf Creek, which is in full attainment but also has elevated nutrient levels.

Table 55. QHEI data summary for *Wolf Creek* (HUC 04100011 10 04)

Stream name	RM	STORET	DA	ALU status	Score	NR	Comments
Harrison Creek	0.38	U04G11	13.1	Non	64.5	Good	--
Plum Run	0.79	U04G09	10.1	Partial	37.5	Poor	Shallow, limited cover
Wolf Creek	13.60	201336	27.0	Full	40	Poor	Channelized
	5.15	U04S40	66.0	Full	60.5	Good	--
	1.58	U04G07	71.8	Full	53	Fair	--
	0.04	U04P04	158.0	Full	84	Excellent	--

Source: Ohio EPA 2011, Table 12, p. 37-38
Note: ALU = aquatic life use; DA = drainage area, in square miles; NR = narrative rating; RM = rivermile; STORET = site code for U.S. EPA's STOrage and RETrieval system.

[42] Dissolved orthophosphate at Wolf Creek RM 1.58 (U04G07) ranged from 0.078 mg/L to 0.225 mg/L phosphorus with a geometric mean of 0.114 mg/L phosphorus (4 samples). The dissolved orthophosphate to total phosphorus ratio ranged from 51 to 78 percent (2 samples) excluding two ratios in excess of 100 percent..

Table 56. Water chemistry data summary for *Wolf Creek* (HUC 04100011 10 04)

Stream name	RM	STORET	DA	ALU status	No. samples	Min.	Max.	GM	Exceed[a]
Nitrate plus nitrite (mg/L as nitrogen)									
Harrison Creek	0.38	U04G11	13.1	Non	5	0.05	13.10	0.88	40%
Plum Run	0.79	U04G09	10.1	Partial	5	0.05	9.30	0.49	40%
Wolf Creek	13.60	201336	27.0	Full	5	0.05	11.20	0.55	40%
	5.15	U04S40	66.0	Full	4	0.49	11.90	2.71	75%
	1.58	U04G07	71.8	Full	5	0.05	9.02	0.27	20%
	0.04	U04P04	158.0	Full	4	0.05	14.30	0.93	50%
Total phosphorus (mg/L as phosphorus)									
Harrison Creek	0.38	U04G11	13.1	Non	5	0.02	0.28	0.05	20%
Plum Run	0.79	U04G09	10.1	Partial	5	0.01	0.06	0.03	0%
Wolf Creek	13.60	201336	27.0	Full	5	0.05	0.11	0.07	20%
	5.15	U04S40	66.0	Full	4	0.10	0.67	0.19	75%
	1.58	U04G07	71.8	Full	5	0.08	0.29	0.14	60%
	0.04	U04P04	158.0	Full	4	0.04	0.13	0.09	75%
TSS (mg/L) [b]									
Harrison Creek	0.38	U04G11	13.1	Non	3	2.5	2.5	2.5	0%
Plum Run	0.79	U04G09	10.1	Partial	2	2.5	10	5.0	0%
Wolf Creek	13.60	201336	27.0	Full	5	20.	49	33.2	80%
	5.15	U04S40	66.0	Full	3	2.5	38	11.5	33%
	1.58	U04G07	71.8	Full	5	2.5	42	11.2	20%
	0.04	U04P04	158.0	Full	3	2.5	51	14.1	33%

Notes

ALU = aquatic life use; DA = drainage area, in square miles; E. Br. E. Br. Wolf Creek = East Branch East Branch Wolf Creek; GM = geometric mean; M. Br. E. Br. Wolf Creek = Middle Branch East Branch Wolf Creek; RM = rivermile; STORET = site code for U.S. EPA's STOrage and RETrieval system.

a. The nitrate plus nitrite targets are 1.0 mg/L nitrogen and the total phosphorus targets are 0.08 mg/L and 0.10 mg/L phosphorus because Harrison Creek and Plum Run are undesignated and assumed WWH headwaters streams and Wolf Creek is a WWH wading stream. The TSS targets are 24 mg/L because all three streams are in the ECBP ecoregion.

b. The TSS detection limit is 5 mg/L and non-detects are evaluated as one-half of the detection limit.

The LDC analyses for Plum Run and Harrison Creek both show that single nitrate plus nitrite samples in the high flow conditions and mid-range flows exceeded the target and none of three samples exceeded the target in the dry conditions (Appendix G).

6.3.2 Sources of Impairment

Ohio EPA (2011) found the WAU to be impaired by nutrient/eutrophication, nitrate, and direct habitat alteration from channelization and crop production with subsurface drainage. The sources of nutrients are presented in this section.

6.3.2.1 Industrial Facilities and Storm Water

Two industrial facilities are covered by individual NPDES permits in this WAU: Sunny Farms Landfill, LLC (2IN00136) and IAR Land Fostoria, LLC (2IN00211). Sunny Farms Landfill, LLC discharges storm water (excluding leachate and refuse) from sedimentation ponds to an unnamed tributary to Wolf Creek and an unnamed tributary to the East Branch Portage River (in the Portage River basin). IAR Land Fostoria, LLC discharges storm water from an oil/water separator to an unnamed tributary of Wolf Creek.

Nutrient data are not available for either facility, though Sunny Farms Landfill, LLC does have total phosphorus monitoring requirements. Given the lack of DMR data, it is not possible to evaluate their impact on Wolf Creek. However, storm water discharges from industrial facilities tend to contain phosphorus. The nearest downstream assessment site (Wolf Creek at RM 13.6, 201336) is in full attainment but in-stream total phosphorus levels exceed the target[43] in 40 percent of samples. While neither facility directly contributes to the nutrient impairments on tributaries of Wolf Creek, Wolf Creek contributes elevated nutrient loads to the Sandusky River, which is nutrient-impaired from Wolf Creek to its mouth on Sandusky Bay.

Two additional industrial facilities are permitted to discharge storm water associated with industrial activities: Intermetro Corp (2GR00566) and Norfolk Southern Railway Company's Fostoria Mixing Center (2GR00592). Their storm water may contain phosphorus and nitrogen.

SWAT modeling showed that developed land within this WAU contributed an annual average of 48,168 lbs/yr of nitrate plus nitrite, which is 20 percent of the total nitrate plus nitrite load to the WAU (Appendix F).

6.3.2.2 Public Facilities

Five public facilities are covered by individual NPDES permits (Table 57). PJ's Brickhouse (2PR00114) is in this WAU but discharges to the East Fork Wolf Creek (04100011 10 02); the facility is presented in Section 6.2.2.1.

Table 57. Facilities with NPDES permits in HUC 04100011 10 04

NPDES ID	Permittee	Facility	Receiving waterbody	Size (mgd)
2PG00011	Seneca County Commissioners	Hammer Heinsman Estates WWTP	Wolf Creek	0.030
2PA00072	village of Bettsville	Bettsville WWTP	Wolf Creek	0.175
2PY00006	Hopewell Estates MHP		Harrison Creek	0.016
2PY00032	HAP III, LP	Poplar Village MHP	Keckler Ditch [a]	0.019[b]

Notes
mgd = million gallons per day; MHP = mobile home park; WWTP = wastewater treatment plant.
a. The Poplar Village MHP discharges to Keckler Ditch, a tributary to Wolf Creek.
b. The Poplar Village MHP design flow is 18,750 gallons per day.

The Hammer Heinsman Estates WWTP (2PG00011) serves a small residential development adjacent to the Loudon Meadows Golf Club, which is southeast of the city of Fostoria. Poplar Village MHP (2PY00032) is adjacent to the city of Fostoria and is under a compliance schedule to study excessive infiltration and inflow and to improve sewer system infrastructure. No nutrient data are available for either facility; thus, it is not possible to evaluate their impact on Wolf Creek. However, sanitary treatment systems discharge nutrients and these facilities likely contribute to elevated nutrient loads in Wolf Creek. The nearest downstream assessment site (Wolf Creek at RM 13.6, 201336) is in full attainment but in-stream total phosphorus levels exceed the target in 40 percent of samples, as did nitrate levels[44].

The Bettsville WWTP (2PA00073) has monitoring requirements for total phosphorus but not for nitrate plus nitrite. Total phosphorus ranges from 0.2 mg/L to 5.0 mg/L (average/median: 3.2; 85 samples) and always exceeds the in-stream target for Wolf Creek. This facility also has had SSO events. Wolf Creek at RM 5.15 (U04S40), just downstream of the Bettsville WWTP, and at RMs 1.58 and 0.04 (U04G07 and

[43] The total phosphorus target for Wolf Creek is 0.10 mg/L phosphorus. This target is for wading WWH streams (Ohio EPA 1999).
[44] The nitrate plus nitrite target for Wolf Creek is 1.0 mg/L nitrogen. This target is for wading WWH streams (Ohio EPA 1999).

U04P04) are all in full attainment but regularly have elevated total phosphorus loads in excess of the in-stream target (0.10 mg/L wading WWH). Nitrate levels at these three attainment sites exceeded the target (1.5 mg/L wading WWH) in 20 percent to 75 percent of samples.

The Hopewell Estates MHP (2PY00006) serves a small residential population along state route 18, east of the city of Fostoria. The facility is not required to monitor nutrients; thus, it is not possible to evaluate their impact on Wolf Creek. However, sanitary treatment systems discharge nutrients and these facilities likely contribute to elevated nutrient loads in Harrison Creek. The nearest downstream assessment site (Harrison Creek at RM 0.38, U04G11) is in nonattainment do to a poor score for macroinvertebrates. In-stream total phosphorus and nitrate plus nitrite levels exceeded the targets[45].

Finally, while the three facilities on Wolf Creek discharge nutrient loads to Wolf Creek, they are not directly contributing to an impairment on Wolf Creek. However, Wolf Creek discharges elevated loads to the Sandusky River and contributes to the nutrient impairment of the LRAU.

6.3.2.3 Fostoria CSS

The city of Fostoria is a CSS but does not have any outfalls in this WAU (Section 4.2.1.1). Therefore, the Fostoria CSS is not contributing to the nutrient impairments to Wolf Creek.

6.3.2.4 Household Sewage Treatment Systems and Un-sewered Areas

The city of Fostoria, village of Bettsville, and Hammer Heinsmann Estates subdivision are sewered. The Poplar Village and Hopewell MHPs are served by small package treatment plants and the remainder of the WAU is served by HSTSs. This WAU is mostly in Seneca County that has an HSTS failure rate of 72 percent (ODH 2013). A small, dense subdivision that borders the city of Fostoria to the south is un-sewered with old homes and may have HSTS in need of replacement. Failing HSTS may be impacting surface waters, and thus, may contribute to nutrient-related impairments of this WAU.

SWAT model results did not show failing HSTS to be impacting this WAU. While failing HSTS are present, may contribute elevated nitrate plus nitrite levels to surface waters, and may impact surface waters locally, failing HSTS are not significant sources of nitrate plus nitrite in this WAU.

6.3.2.5 Agriculture

The dominant land use in this WAU is cultivated crops (84 percent). Developed open space accounts for 7 percent of the WAU and pasture is less than 1 percent. Most of the developed land (10 percent) is in and around the city of Fostoria and the village of Bettsville. Undeveloped parcels with deciduous forest compose about 5 percent of the WAU and are present throughout the WAU.

Seven WWTP sludge fields are in this WAU. Two of the sludge field are for Hopewell Estates MHP, are adjacent to the wastewater treatment works, and along with the MHP, drain to Harrison Creek. The other five sludge fields are for the Fostoria WWTP (2PD00031) and are along Plum Run.

SWAT model results show that cultivated cropland contributes an annual average of 182,744 lbs/yr nitrate plus nitrite, which is 78 percent of the nitrate plus nitrite load in the WAU (Appendix E).

[45] The total phosphorus target for Harrison Creek is 0.08 mg/L phosphorus and the nitrate plus nitrite target for Harrison Creek is 1.0 mg/L nitrogen. These targets are for headwaters WWH streams (Ohio EPA 1999).

6.3.3 Conclusions

Wolf Creek is impaired by nutrient/eutrophication and nitrate, and nitrate plus nitrite monitoring data are representative of these impairments. The anthropogenic sources of nitrate plus nitrite loads to Wolf Creek are individually permitted point sources, storm water from developed land, failing HSTS, and agriculture. SWAT model results indicate that the dominant sources of nitrate plus nitrite loads to the WAU are cultivated cropland (78 percent) and storm water from developed urban land (20 percent). These sources will be addressed through nitrate plus nitrite TMDLs on Plum Creek near the site that is east of Fostoria at State Route 635 (RM 0.79, U04G09) and Harrison Creek near the site that is east of Fostoria at County Road 592 (RM 0.38, U04G11).

6.4 Spicer Creek-Sandusky River (HUC 04100011 11 05)

Spicer Creek-Sandusky River (04100011 11 05) is mostly in Seneca County, with a small portion of the lower WAU in Sandusky County. This WAU includes the mainstem of the Sandusky River and a minor tributary to the Sandusky River: Spicer Creek. The WAU includes the outskirts of the city of Tiffin and the unincorporated communities of Old Fort and Fort Seneca. The WAU is mostly rural, agricultural; Spicer Creek is completely rural, agricultural.

6.4.1 Monitoring Data

Ohio EPA collected water chemistry at five sites and biological data at four sites (Ohio EPA 2011). However, four water chemistry sites and three biology sites are on the Sandusky River. A single site on Spicer Creek was sampled for water chemistry and biology and WAU attainment was evaluated here (partial attainment; see Ohio EPA 2011, Table 2, p. 10). The partial attainment was due to the fish community; the ICI and QHEI scored very well. The causes of impairment are nutrient/eutrophication and organic enrichment due to crop production with subsurface drainage and manure runoff; therefore, only nutrient- related monitoring data are presented herein.

Available nutrient water chemistry (Table 58) data are summarized here; refer to Ohio EPA (2011a) for all available water chemistry and QHEI data. As shown in these tables, nutrient levels exceed the targets and are representative of the nutrient impairments.

Table 58. Water chemistry data summary for *Spicer Creek-Sandusky River* (HUC 04100011 11 05)

Stream name	RM	STORET	DA	ALU status	No. samples	Min.	Max.	GM	Exceed[a]
Nitrate plus nitrite (mg/L as nitrogen)									
Spicer Creek	0.80	U04Q11	12.3	Partial	5	0.05	7.64	0.72	40%
Total phosphorus (mg/L as phosphorus)									
Spicer Creek	0.80	U04Q11	12.3	Partial	5	0.01	0.18	0.03	40%

Notes
ALU = aquatic life use; DA = drainage area, in square miles; GM = geometric mean; RM = rivermile; STORET = site code for U.S. EPA's STOrage and RETrieval system.
a. The nitrate plus nitrite targets are 1.0 mg/L nitrogen and the total phosphorus targets are 0.08 mg/L and 0.10 mg/L phosphorus because Spicer Creek is a WWH headwaters stream.

The LDC analysis for shows that single total phosphorus samples in the high flow conditions exceeded the target and one of three samples exceeded the target in the dry conditions (Appendix G).

6.4.2 Sources of Impairment

Ohio EPA (2011) found the WAU to be impaired by nutrient/eutrophication and organic enrichment (sewage) from crop production with subsurface drainage and manure runoff. The impairments to this WAU are due to Spicer Creek; impaired mainstem Sandusky River segments are part of the LRAU.

No facilities are covered by individual or general NPDES permits. One facility is covered by the general permit for storm water discharges associated with industrial activities: Quick Tab II (2GR01604).

6.4.2.1 City of Tiffin CSS and MS4

The city of Tiffin is a CSS but it does not have any CSO outfalls this WAU (Section 4.2.1.1). CSO outfalls 004 and 032 discharge to the Sandusky River immediately upstream of the WAU boundary but no CSO outfalls discharge to Spicer Creek.

The city of Tiffin is covered under a small MS4 permit (2GQ00031). A small portion of the city is within the upper portion of this WAU; however, this portion of Tiffin drains to the Sandusky River, not to Spicer Creek. SWAT modeling showed that urban developed land within this WAU, which includes portions of the regulated MS4, contributed an annual average of 533 lbs/yr of total phosphorus, which is 1 percent of the total phosphorus load to the WAU (Appendix F).

6.4.2.2 Household Sewage Treatment Systems and Un-sewered Areas

A small portion of the city of Tiffin is in the WAU and this area is sewered. The remainder of the WAU is served by HSTS. This WAU is in Seneca County that has an HSTS failure rate of 72 percent (ODH 2013). SWAT model results did not show failing HSTS to be impacting this WAU. While failing HSTS are present, may contribute elevated total phosphorus levels to surface waters, and may impact surface waters locally, failing HSTS are not significant sources of total phosphorus in this WAU.

6.4.2.3 Agriculture

The dominant land use in this WAU is cultivated crops (75 percent). Deciduous forest accounts for 11 percent of the WAU (as undeveloped parcels throughout the WAU) and pasture is 2 percent. Most of the developed land (7 percent) is in and around the city of Tiffin and two unincorporated communities. Eight WWTP sludge fields are in this WAU; all eight are in the upstream half of the WAU; however, none of the fields drain to Spicer Creek. SWAT model results show that cultivated cropland contributes an annual average of 43,591 lbs/yr total phosphorus, which is 97 percent of the total phosphorus load in the WAU, (Appendix E).

6.4.3 Conclusions

Spicer Creek is impaired by nutrient/eutrophication and total phosphorus monitoring data are representative of this impairment. The anthropogenic sources of total phosphorus loads to Pipe Creek are individually permitted point sources, storm water from developed land (including small portions of the Tiffin MS4), industrial storm water, failing HSTS, and agriculture. SWAT model results indicate that the dominant source of total phosphorus loads to the WAU is cultivated cropland (97 percent). These sources will be addressed through a total phosphorus TMDL on Spicer Creek near the site that is north of Tiffin at County Road 23 (RM 0.80, U04Q11).

6.5 Beaver Creek (HUC 04100011 12 02)

This WAU is in Seneca County. The WAU is rural, agricultural and is without any incorporated communities. Ohio EPA (2010a) found the WAU to be impaired by direct habitat alteration and sedimentation/siltation from channelization and crop production with subsurface drainage. While assessment sites on Beaver Creek are in full attainment (RMs 3.48 and 4.00, U04G25 and U04K03), assessment sites on Emerson Creek (RM 1.83, U04G26) and Royer Ditch (RM 6.85, U04K07) are in non-attainment. Attainment was not determined at Royer Ditch RM 10.12 (U04K08) due to insufficient data; however, the narrative macroinvertebrate score was low-fair.

6.5.1 Monitoring Data

Ohio EPA collected water chemistry at four sites and biological data at five sites (Ohio EPA 2010a). Attainment was evaluated at two sites on Beaver Creek (full attainment), one site on Emerson Creek (non-attainment) and one site on Royer Ditch (non-attainment; see Ohio EPA 2010a, Table 2, p. xii). The primary cause of impairment was sedimentation siltation; therefore, only sediment-related monitoring data are presented herein.

Available QHEI (Table 59) and water chemistry (Table 60) data are summarized in this section and all available QHEI and water quality data are presented in Ohio EPA (2010a). Beaver Creek RM 3.48 (U04G25) was also evaluated for dissolved orthophosphate with an average dissolved orthophosphate to total phosphorus ratio of 47 percent[46]. As shown in these tables, Emerson Creek nutrient and sediment levels exceed targets and, while there are considerable data gaps, Royer Creek also exceeds some targets. The LDC analysis for Emerson Creek shows that two of three TSS samples exceeded the target in the dry conditions (Appendix G).

Figure 31. Beaver Creek downstream of Leafy Oaks MHP.

Table 59. QHEI data summary for *Beaver Creek* (HUC 04100011 12 02)

Stream name	RM	STORET	DA	ALU status	Score	NR	Comments
Beaver Creek	4.00	U04K03	20.9	Full	68	Good	--
	3.48	U04G25	43.4	Full	62.5	Good	--
Emerson Creek	1.83	U04G26	22.0	Non	67	Good	--
Royer Ditch	10.12	U04K08	6.4	--[a]	--	--	--
	6.85	U04K07	15.2	Non	30.5	Poor	Heavy silt with extensively embedded substrates

Source: Ohio EPA 2010a, Table 11, p. 41-42
Notes
ALU = aquatic life use; DA = drainage area, in square miles; NR = narrative rating; RM = rivermile; STORET = site code for U.S. EPA's STOrage and RETrieval system.
a. Insufficient biological data were collected to determine attainment.

[46] Dissolved orthophosphate at Beaver Creek RM 3.48 (U04G25) ranged from non-detect to 0.272 mg/L phosphorus with a geometric mean of 0.024mg/L phosphorus (9 samples). The detection limit was 0.10 mg/L and non-detects were evaluated as one-half of the detection limit. The dissolved orthophosphate to total phosphorus ratio ranged from 12 to 83 percent (8 samples) excluding one ratio in excess of 100 percent.

Table 60. Water chemistry data summary for *Beaver Creek* (HUC 04100011 12 02)

Stream name	RM	STORET	DA	ALU status	No. samples	Min.	Max.	GM	Exceed[a]
Nitrate plus nitrite (mg/L as nitrogen)									
Beaver Creek	4.00	U04K03	20.9	Full	5	0.55	6.34	1.67	0%
	3.48	U04G25	43.4	Full	9	0.05	8.44	0.29	0%
Emerson Creek	1.83	U04G26	22.0	Non	4	0.05	6.37	0.55	50%
Royer Ditch	10.12	U04K08	6.4	--	1	15.00	15.00	15.00	100%
	6.85	U04K07	15.2	Non	5	0.55	6.34	1.67	0%
Total phosphorus (mg/L as phosphorus)									
Beaver Creek	4.00	U04K03	20.9	Full	5	0.04	0.07	0.05	0%
	3.48	U04G25	43.4	Full	9	0.01	0.64	0.04	0%
Emerson Creek	1.83	U04G26	22.0	Non	4	0.06	0.12	0.08	25%
Royer Ditch	10.12	U04K08	6.4	--	0	--	--	--	--
	6.85	U04K07	15.2	Non	1	0.07	0.07	0.07	0%
TSS (mg/L)									
Beaver Creek	4.00	U04K03	20.9	Full	3	13	18	14.9	0%
	3.48	U04G25	43.4	Full	5	11	444	26.2	20%
Emerson Creek	1.83	U04G26	22.0	Non	3	12	36	24.7	67%
Royer Ditch	10.12	U04K08	6.4	--	0	--	--	--	--
	6.85	U04K07	15.2	Non	0	--	--	--	--

Notes

ALU = aquatic life use; DA = drainage area, in square miles; GM = geometric mean; RM = rivermile; STORET = site code for U.S. EPA's STOrage and RETrieval system.

a. The nitrate plus nitrite target is 0.5 mg/L nitrogen and the total phosphorus target is 0.05 mg/L phosphorus because Beaver Creek is a CWH wading stream. The nitrate plus nitrite targets are 1.0 mg/L nitrogen and the total phosphorus targets are 0.08 mg/L and 0.10 mg/L phosphorus because Emerson Creek is a WWH wading stream and Royer Ditch is a WWH headwaters and wading stream. The TSS targets are 24 mg/L because all three streams are in the HELP ecoregion.

6.5.2 Sources of Impairment

Ohio EPA (2010a) found the WAU to be impaired sedimentation/siltation and direct habitat alterations due to crop production with subsurface drainage and channelization. The sources of sediment-related impairments are evaluated in the following sections.

6.5.2.1 Leafy Oaks Campground

One facility is covered by individual NPDES permits and no facilities are covered by general NPDES permits: Leafy Oak Campground (2PR00147) discharges to Westerhouse Ditch; its design flow is 0.01 mgd. TSS at the facility ranges from 2 mg/L to 60 mg/L (average: 12 mg/L; median: 10 mg/L; 67 samples) and 94 percent of records are at or below the TSS target[47] for nearby Beaver Creek. As the facility is along Beaver Creek (specifically, between assessment sites RMs 3.48 and 4.00), it cannot be contributing to the impairments along Emerson Creek and Royer Ditch.

6.5.2.2 Industrial and Urban Storm Water

No facilities are covered by the general permit for storm water discharges associated with industrial activities in this WAU.

[47] The TSS target for Beaver Creek is 24 mg/L. This target is for headwaters and wading streams in the HELP ecoregion (Ohio EPA 1999).

SWAT modeling showed that urban developed land within this WAU contributed an annual average of 552 tons/year of TSS, which is 13 percent of the total TSS load to the WAU (Appendix F).

6.5.2.3 Household Sewage Treatment Systems and Un-sewered Areas

This WAU is served by HSTS. This WAU is in Seneca County that has an HSTS failure rate of 72 percent (ODH 2013). SWAT model results did not show failing HSTS to be impacting this WAU. While failing HSTS are present, may contribute elevated TSS levels to surface waters, and may impact surface waters locally, failing HSTS are not significant sources of TSS in this WAU.

6.5.2.4 Agriculture

The dominant land use in this WAU is cultivated crops (84 percent). Deciduous forest accounts for 4 percent of the WAU and pasture is about 1 percent. Row crop fields dominate this WAU and many of the streams are channelized and without forested riparian corridors. Beaver Creek and the lower reaches of Emerson Creek, however, do tend to have forested riparian corridors. The creeks and ditches flow through various properties that are completely forested but the properties are not contiguous. Beaver Creek and Emerson Creek tend to have more natural flow paths (e.g., meanders), while portions of Royer Ditch and many of the tributaries throughout the WAU are channelized and flow along roads or along row crop fields.

Seven WWTP sludge fields are in this WAU. Six sludge fields are immediately upstream of the assessment site on Royer Ditch that is in non-attainment. Three tributaries to Royer Ditch flow through WWTP sludge fields and Royer Ditch flows adjacent to a fourth sludge field. WWTP sludge application, along with manure and septage application, may contribute to the sedimentation/siltation impairment, especially from fields with tile drainage.

SWAT model results show that cultivated crop land contributes an annual average of 2,772 tons/year TSS, which is 65 percent of the TSS load in the WAU. Pastureland contributes 52 tons/year TSS, which is about 1 percent of the TSS load in the WAU (Appendix E).

6.5.3 Conclusions

This WAU is impaired by sedimentation/siltation and TSS monitoring data are representative of this impairment. The anthropogenic sources of TSS loads are storm water from developed lands, failing HSTS, and agriculture. SWAT model results indicate that the dominant source of TSS loads to the WAU is cultivated cropland (65 percent). The sources will be addressed through a TSS TMDL on Emerson Creek at Township Road 129 (RM 1.83, U04G26).

6.6 Green Creek (HUC 04100011 12 03)

This WAU is mostly in Sandusky County. Green Creek flows northerly from the confluence with Beaver Creek to Green Creek's mouth on the Sandusky River, just upstream of the Sandusky River's mouth on Sandusky Bay. The WAU is mostly rural agricultural, with the city of Fremont to the west and the city of Clyde to the east. The eastern outskirts of the city of Fremont are in the WAU, as is the village of Green Springs.

6.6.1 Monitoring Data

Ohio EPA collected water chemistry and biological data at four sites (Ohio EPA 2010a). Attainment was evaluated at four sites on Green Creek (two sites in full attainment and two sites in partial attainment; see Ohio EPA 2010a, Table 2, p. xii). The primary cause of impairment was sedimentation siltation; therefore, only sediment-related monitoring data are presented herein.

Available QHEI (Table 61) and water chemistry (Table 62) data are summarized in this section and all available QHEI and water quality data are presented in Ohio EPA (2010a). As shown in these tables, TSS levels exceed targets.

Table 61. QHEI data summary for *Green Creek* (HUC 04100011 12 03)

Stream name	RM	STORET	DA	ALU status	Score	NR	Comments
Green Creek	18.80	U04G24	53.0	Full	67	Good	--
	12.85	U04S10	71.0	Partial	73	Good	--
	9.08	U04G20	74.0	Full	67.5	Good	--
	5.06	U04K01	78.3	Partial	64	Good	--

Source: Ohio EPA 2010a, Table 11, p. 41-42
Note: ALU = aquatic life use; DA = drainage area, in square miles; NR = narrative rating; RM = rivermile; STORET = site code for U.S. EPA's STOrage and RETrieval system.

Table 62. TSS data summary for *Green Creek* (HUC 04100011 12 03)

Stream name	RM	STORET	DA	ALU status	No. samples	Min.	Max.	GM	Exceed[a]
Green Creek	18.80	U04G24	53.0	Full	4	2.5	2.5	2.5	0%
	12.85	U04S10	71.0	Partial	4	13	28	17.3	25%
	9.08	U04G20	74.0	Full	6	15	51	31.2	67%
	5.06	U04K01	78.3	Partial	8	21	66	39.1	88%

Notes
Results are in mg/L. The TSS detection limit is 5 mg/L and non-detects are evaluated as one-half of the detection limit.
ALU = aquatic life use; DA = drainage area, in square miles; GM = geometric mean; RM = rivermile; STORET = site code for U.S. EPA's STOrage and RETrieval system.
a. The TSS target is 24 mg/L because Green Creek is in the HELP ecoregion.

The LDC analysis shows that seven of eight TSS samples exceeded the target in the wet conditions through dry conditions (Appendix G).

6.6.2 Sources of Impairment

Ohio EPA (2011) found the WAU to be impaired by sedimentation/siltation from crop production with subsurface drainage and channel erosion/incision from upstream hydromodifications. Four assessment sites are on Green Creek, including at RM 18.8 (U04G24) at the upstream boundary of this WAU that is in full attainment (i.e., the sources of impairment to the assessment sites along the lower segments of Green Creek are within this WAU).

6.6.2.1 Industrial and Public Facilities

Three facilities are covered by individual NPDES permits and no facilities are covered by general NPDES permits (Table 63). The city of Green Springs was formerly a CSS but now has partially separated its sanitary sewers and is not permitted to discharge CSOs[48]. CSOs may have contributed to impairments historically but are no longer a source of impairment.

Table 63. Facilities with NPDES permits in HUC 04100011 12 03

NPDES ID	Permittee	Facility	Receiving waterbody	Size (mgd)
2IN000193	Cornerstone Industrial Group, LLC	Green Springs Plant	unnamed tributary [a]	0.003
2PB00026	village of Green Springs	Green Springs WWTP	Flag Run Creek	0.24
2PR00206	Fremont Baptist Temple		unnamed tributary [b]	0.008

Notes
LLC = limited liability company; mgd = million gallons per day; WWTP = wastewater treatment plant.
a. Cornerstone Industrial Group, LLC discharges to an unnamed tributary of Green Creek.
b. Fremont Baptist Temple discharges to an unnamed tributary of Ferguson Ditch.

Table 64. Facilities with TSS data in HUC 04100011 12 03

NPDES ID	Outfall	Receiving waterbody	No. of records	Min.	Max.	Avg.	Median
2IN000193	001	unnamed tributary [a]	34	2.5	27	6	5
2PB00026	001 [b]	Flag Run Creek	671	2	232	37	31
2PR00206	001	unnamed tributary [c]	18	8	84	36	29

Notes
Results are in mg/L. Detection limits are 5 mg/L for 2IN00193; non-detects were evaluated at one-half of the detection limit. Results are from January 2003 through December 2012.
a. Cornerstone Industrial Group, LLC discharges to an unnamed tributary of Green Creek.
b. The Green Springs WWTP data are from 2003 through 2009. Since 2009 the facility has discharged to the Clyde WWTP.
c. Fremont Baptist Temple discharges to an unnamed tributary of Ferguson Ditch.

Cornerstone Industrial Group, LLC (2IN000193) has a small sanitary wastewater treatment works and the property abuts Green Creek. Approximately 93 percent of detections were at or below the in-stream TSS target[49]. The facility typically discharges a few hundred to a few thousand gpd. The closest downstream assessment site on Green Creek is at RM 9.08 (U05G20) and is in full attainment. Cornerstone Industrial Group, LLC does contribute TSS loads to the unnamed tributary of Green Creek, but, due to the small volume of flow, is not likely a significant contributor to the sedimentation/siltation impairments in this WAU.

From 2003 to 2009, 67 percent of the TSS records the Green Springs WWTP (2PB00026) exceed the in-stream target[50]. This facility has separated its sanitary and storm sewers and now sends sanitary wastewater to the Clyde WWTP. While this facility had contributed TSS loads to Flag Run Creek, and thus to Green Creek, as it no longer discharges, it cannot be a source of TSS to the Green Creek sedimentation/siltation impairments anymore.

[48] Green Springs (2PB00026) is permitted to discharge overflow through outfall 602 to Flag Run Creek. The bypass overflow will be eliminated when Green Springs long term control plan is fully implemented.
[49] The TSS target for the unnamed tributary to Green Creek is 24 mg/L. This target is for headwaters streams in the HELP ecoregion (Ohio EPA 1999).
[50] The TSS target for the Flag Run Creek is 24 mg/L. This target is for headwaters streams in the HELP ecoregion (Ohio EPA 1999).

The Fremont Baptist Temple (2PR00206) discharges to an unnamed tributary of Ferguson Ditch; the unnamed tributary is channelized and flows through row crop fields and a golf course (Fremont Country Club). TSS samples were collected quarterly from 2006-2011 and only a third of the records were at or below the in-stream TSS target[51]. The treatment works typically discharge a few hundred gpd. The Fremont Baptist Temple does contribute TSS loads to the unnamed tributary of Ferguson Ditch, but, due to the small volume of flow, is not likely a significant contributor to the sedimentation/siltation impairments in this WAU.

6.6.2.2 Industrial and Urban Storm Water

No facilities are covered by the general permit for storm water discharges associated with industrial activities in this WAU. SWAT modeling showed that urban developed land within this WAU contributed an annual average of 1,706 tons/day of TSS, which is 14 percent of the total TSS load to the WAU (Appendix F).

6.6.2.3 Household Sewage Treatment Systems and Un-sewered Areas

While the city of Clyde is sewered, the remainder of the WAU is served by HSTS. This WAU is in Sandusky and Seneca counties that have HSTS failure rates of 35 percent and 72 percent (ODH 2013). SWAT model results did not show failing HSTS to be impacting this WAU. While failing HSTS are present, may contribute elevated sediment levels to surface waters, and may impact surface waters locally, failing HSTS are not significant sources of TSS in this WAU.

6.6.2.4 Agriculture

The dominant land use in this WAU is cultivated crops (79 percent). Developed open space accounts for 7 percent of the WAU and pasture is less than 1 percent. Most of the developed land (10 percent) is in the village of Green springs. Green Creek typically flows through forested riparian corridors and does not flow through row crop fields. However, the many tributaries to Green Creek do flow through or along row crop fields and likely contribute sediment loads, especially for crop fields with tile drainage. SWAT model results show that cultivated cropland contributes an annual average of 8,607 tons/year TSS, which is 73 percent of the TSS load in the WAU, (Appendix F).

Five WWTP sludge fields are in this WAU; they are in agricultural areas between the village of Green Springs and city of Fremont. Three sludge fields drain to the headwaters of Ferguson Ditch; the other two sludge fields drain to Green Creek between assessment sites at RMs12.85 and 18.8 (U04S10 and U04G24).

6.6.3 Conclusions

Green Creek is impaired by sedimentation/siltation and TSS monitoring data are representative of this impairment. The anthropogenic sources of TSS loads to Green Creek are individually permitted point sources, storm water from developed land, failing HSTS, and agriculture. SWAT model results indicate that the dominant sources of TSS loads to the WAU are cultivated cropland (73 percent) and storm water from developed urban land (14 percent). These sources will be addressed through a TSS TMDL on Green Creek northeast of Fremont at Township Road 239 (RM 5.06, U04K01).

[51] The TSS target for the unnamed tributary to Ferguson Ditch is 24 mg/L. This target is for headwaters streams in the HELP ecoregion (Ohio EPA 1999).

6.7 Muskellunge Creek (HUC 04100011 13 01)

This WAU is in Sandusky and Seneca counties. Muskellunge Creek begins near the city of Fostoria and flows northeasterly to and then through the city of Fremont before it discharges to the Sandusky River. In addition to the cities of Fremont and Fostoria, the village of Burgoon and the unincorporated communities of Amsden and Kansas are in the WAU. This subwatershed is mostly rural, agricultural. Muskellunge Creek flows through the Sycamore Hills Golf Club, west of the city of Fremont.

6.7.1 Monitoring Data

Ohio EPA collected water chemistry and biological data at four sites (Ohio EPA 2011). Attainment was evaluated at three of four assessment sites on Muskellunge Creek (see Ohio EPA 2011, Table 2, p. 9). The WAU impairment is based upon the nonattainment at the most downstream assessment site on Muskellunge Creek, at RM 1.23 (U04P08), where the fish indices met biocriteria but the ICI scored very poorly. Muskellunge Creek at RMs 5.40 and 16.7 (201332 and 300674) are in full attainment. Thus, the significant sources of impairment are likely downstream of RM 5.40, which is in the city of Fremont. The primary causes of impairment were nutrient eutrophication and sedimentation siltation; therefore, only nutrient- and sediment-related monitoring data are presented herein.

Available QHEI (Table 65) and water chemistry (Table 66) data are summarized in this section and all available QHEI and water quality data are presented in Ohio EPA (2011). Muskellunge Creek RM 5.40 (U04P08) was also evaluated for dissolved orthophosphate with an average dissolved orthophosphate to total phosphorus ratio of 71 percent[52]. As shown in these tables, nitrate plus nitrite, total phosphorus, and TSS levels exceed targets. It is notable that TSS levels in the lower segments of Muskellunge Creek do not exceed in-stream targets.

Table 65. QHEI data summary for *Muskellunge Creek* (HUC 04100011 13 01)

Stream name	RM	STORET	DA	ALU status	Score	NR	Comments
Muskellunge Creek	24.44	300675	2.3	--	--	--	--
	16.70	300674	17.7	Full	38.5	Poor	Silt substrates
	5.40	201332	37.0	Full	58.5	Fair	--
	1.23	U04P08	44.0	Non	69	Good	Lacustuary

Source: Ohio EPA 2011, Table 12, p. 37-38
Note: ALU = aquatic life use; DA = drainage area, in square miles; NR = narrative rating; RM = rivermile; STORET = site code for U.S. EPA's STOrage and RETrieval system.

[52] Dissolved orthophosphate at Muskellunge Creek RM 5.40 (U04P08) ranged from 0.020 mg/L to 0.098 mg/L phosphorus with a geometric mean of 0.046 mg/L phosphorus (11 samples). The dissolved orthophosphate to total phosphorus ratio ranged from 52 to 96 percent (9 samples) excluding two ratios in excess of 100 percent.

Table 66. Water chemistry data summary for *Muskellunge Creek* (HUC 04100011 13 01)

Stream name	RM	STORET	DA	ALU status	No. samples	Min.	Max.	GM	Exceed[a]
Nitrate plus nitrite (mg/L as nitrogen)									
Muskellunge Creek	24.44	300675	2.3	--	4	0.05	6.04	0.52	50%
	16.70	300674	17.7	Full	5	0.11	8.16	0.73	40%
	5.40	201332	37.0	Full	11	0.05	9.17	0.47	36%
	1.23	U04P08	44.0	Non	5	0.11	9.66	0.64	40%
Total phosphorus (mg/L as phosphorus)									
Muskellunge Creek	24.44	300675	2.3	--	4	0.35	1.11	0.77	100%
	16.70	300674	17.7	Full	5	0.05	0.10	0.07	40%
	5.40	201332	37.0	Full	11	0.03	0.09	0.06	0%
	1.23	U04P08	44.0	Non	5	0.05	0.17	0.08	40%
TSS (mg/L) [b]									
Muskellunge Creek	24.44	300675	2.3	--	2	13	120	39.5	50%
	16.70	300674	17.7	Full	4	12	34	16.5	25%
	5.40	201332	37.0	Full	7	2.5	12	3.9	0%
	1.23	U04P08	44.0	Non	4	10	16	11.5	0%

Notes
ALU = aquatic life use; DA = drainage area, in square miles; GM = geometric mean; RM = rivermile; STORET = site code for U.S. EPA's STOrage and RETrieval system.
a. The nitrate plus nitrite target is 1.0 mg/L nitrogen and the total phosphorus targets are 0.08 mg/L and 0.10 mg/L phosphorus because Muskellunge Creek is a WWH headwaters and wading stream. The TSS targets are 24 mg/L because this stream is in the HELP ecoregion.
b. The TSS detection limit is 5 mg/L and non-detects are evaluated as one-half of the detection limit.

The LDC analyses show that the single TSS sample in the moist conditions exceeded the target while both the samples in the mid-range flows and the single sample in the dry conditions did not exceed the target. The single total phosphorus sample in the moist conditions exceeded the target while the single sample in the high flow, two samples in the mid-range flows, and single sample in the dry conditions did not exceed the target.

6.7.2 Sources of Impairment

Ohio EPA (2010a) found the WAU to be impaired by nutrient/eutrophication, phosphorus, and sedimentation/siltation from crop production with subsurface drainage. The sources of nutrients and sediment are presented in this section.

6.7.2.1 Industrial Facilities and Storm Water

One facility is covered by an industrial individual NPDES permit: POET Plant Management (2IF00026; Fostoria Ethanol, LLC, design flow 0.185 mgd) discharges to an unnamed tributary of Muskellunge Creek (outfalls 001 and 002, process water and storm water) and an unnamed tributary of Muddy Creek (outfall 003). TSS from outfall 001 was always below the in-stream target[53] , whereas TSS frequently exceeded the in-stream target in the storm water effluent from outfalls 002 and 003 (Table 67). All total phosphorus concentrations in the process water effluent (outfall 001) exceed the in-stream target[54]. The nearest downstream assessment site (Muskellunge Creek at RM 16.7) is in full attainment; however, in-stream levels do exceed TSS and total phosphorus targets. In April 2011, the facility stopped discharging process effluent through its 001 outfall; therefore, while its process effluent may have contributed to the phosphorus and nutrient/eutrophication impairments, it no longer contributes phosphorus loads. The storm water outfalls do contribute to the TSS impairment.

[53] The TSS target for Muskellunge Creek is 24 mg/L. This target is for headwaters streams in the HELP ecoregion (Ohio EPA 1999).
[54] The total phosphorus target for Muskellunge Creek is 0.08 mg/L phosphorus. This target is for headwaters WWH streams (Ohio EPA 1999).

Table 67. POET Plant Management (2IF00026) DMR data summary

Constituent	Units	No. of records	Min.	Max.	Avg.	Median
Outfall 001 [a]						
Total phosphorus	mg/L as phosphorus	30	0.11	3.80	2.2	2.0
TSS	mg/L	47	1	10	2.8	2.0
Outfall 002 [b]						
TSS	mg/L	20	3	54	13.3	9.4
Outfall 003 [b]						
TSS	mg/L	23	1	43	12.1	9.0

Notes
a. Results are from October 2008 through March 2011.
b. Results are from December 2008 through December 2012.

One facility is covered by a general NPDES permit for hydrostatic test water: Fremont Energy Center (2GH00008). The permit is inactive and would not be a source of nutrients. Therefore, the facility is not further evaluated.

Six additional industrial facilities are permitted to discharge storm water associated with industrial activities (Table 68) and their storm water may contain TSS or phosphorus.

Table 68. General NPDES permittees for storm water discharges associated with industrial activities in HUC 04100011 13 01

NPDES ID	Permittee	Facility
2GR00048[a]	Curwood Inc	Curwood Inc
2GR00290	P. H. Glatfelter Co	P. H. Glatfelter Co - Fremont Facility
2GR00629	ABC INOAC Exterior Systems LLC	ABC INOAC Exterior Systems LLC
2GR01647[b]	American Municipal Power Inc	AMP Fremont Energy Center (AFEC)
2GR01777	Green Bay Packaging Inc Fremont Div	Green Bay Packaging Inc Fremont Div
2GR01865	Rexam Beverage Can Co	Rexam Beverage Can Co

Notes
a. A portion of this facility is also in HUC 04100011 13 02.
b. A portion of this facility is also in HUC 04100011 14 03.

6.7.2.2 Public Facilities

Three public facilities are covered by individual NPDES permits (Table 69).

Table 69. Public facilities with NPDES permits in HUC 04100011 13 01

NPDES ID	Permittee	Facility	Receiving waterbody	Size (mgd)
2PG00023	Sandusky County Commissioners	Westwood Subdivision	unnamed tributary [a]	0.02
2PG00082	Sandusky County Commissioners	Adam's Acres Subdivision	Muskellunge Creek	0.035
2PR00193	Sycamore Hills Golf Club	Clubhouse	Muskellunge Creek	0.0075

Notes
mgd = million gallons per day.
a. Westwood Subdivision discharges to an unnamed tributary of Muskellunge Creek.

Table 70. Public facilities with TSS or total phosphorus data in HUC 04100011 13 01

NPDES ID	Outfall	Receiving waterbody	No. of records	Min.	Max.	Avg.	Median
TSS (mg/L) [a]							
2PG00023	001	unnamed tributary [b]	291	0.7	47	2.9	1.2
2PG00082	001	Muskellunge Creek	239	0.3	120	3.9	1.0
2PR00193 [c]	001	Muskellunge Creek	38	5	30	3.8	2.5
Total phosphorus (mg/L)							
2PG00082	001	Muskellunge Creek	17	0.88	6.9	2.0	1.3

Notes
Results are from January 2003 through December 2012.
a. Detection limits are 0.1 mg/L for 2PG00023 and 2PG00082 and 5 mg/L for 2PR00193; non-detects were evaluated at one-half of the detection limit.
b. Westwood Subdivision discharges to an unnamed tributary of Muskellunge Creek.
c. Results are from November 2009 to December 2012.
d. Results are from September 2011 through November 2012.

All three public sewerage systems are west of Fremont and the Sandusky River. The following percent of TSS records are at or below the applicable in-stream target[55]: Westwood Subdivision (2PG00023), 99 percent; Adam's Acre Subdivision (2PG00082), 96 percent; and Sycamore Hills Golf Club[56] (2PR00193), 85 percent[57]. All three public sewerage systems are upstream of Ohio EPA's assessment site on Muskellunge Creek at RM 5.40 (201332) that is in full attainment; all but two of the TSS samples collected at this site were below the detection limit of 5.0 mg/L (Table 66). Additionally, the samples collected at Muskellunge Creek RM 1.24 (U04P08) also do not show impairment based upon TSS samples. Thus, it is concluded that, while the three facilities do discharge TSS loads, they are not significantly contributing to the downstream impairment of Muskellunge Creek.

All of the total phosphorus records at Adam's Acre Subdivision exceed the in-stream target[58]. Muskellunge Creek at RM 5.40 is in full attainment and none of Ohio EPA's samples exceed the in-stream target. This facility contributes total phosphorus loads to Muskellunge Creek but is not significantly contributing to the impairment.

Though only one public sewerage system has nutrient limits, all three discharge nutrients in their effluent. Samples at the downstream impaired assessment site (Muskellunge Creek at RM 1.24) are in excess of the in-stream target[59]. Therefore, it is concluded that, while point sources discharge nutrient loads, they are not the main source of impairment to the lower reaches of Muskellunge Creek.

6.7.2.3 Fremont and Fostoria

The cities of Fremont and Fostoria are CSSs (Section 4.2.1.1). None of the city of Fremont's CSO outfalls are in this WAU and one of the city of Fostoria's CSO outfalls (008) is in this WAU. As discussed in Section 4.2.1.1, the Fostoria CSS has not discharged from outfall 008 during the past decade; therefore, CSS cannot be a source of impairment.

[55] The TSS targets for the unnamed tributary to Muskellunge Creek and Muskellunge Creek are 24 mg/L. This target is for headwaters and wading streams in the HELP ecoregion (Ohio EPA 1999).
[56] The Sycamore Hills Golf Club is permitted for sanitary wastewater treatment works at its clubhouse. The club also receives WWTP sludge from the Fremont WWTP for land application onto the golf course.
[57] Only one record (30 mg/L on 5/24/2010) exceeded the TSS target for Muskellunge Creek
[58] The total phosphorus target for Muskellunge Creek is 0.10 mg/L. This target is for wading WWH streams (Ohio EPA 1999).
[59] The total phosphorus target for Muskellunge Creek is 0.10 mg/L. This target is for wading WWH streams (Ohio EPA 1999).

SWAT modeling showed that urban developed land within this WAU contributed an annual average of 2,748 tons/year of TSS and 8,069 lbs/yr total phosphorus, which are 31 percent and 12 percent (respectively) of the total loads to the WAU (Appendix F).

6.7.2.4 Household Sewage Treatment Systems and Un-sewered Areas

The cities of Fremont and Fostoria and village of Burgoon are sewered. The village of Burgoon sends its wastewater to the Bettsville WWTP (2PA00072; in HUC 04100011 10 04) for treatment. The Fremont service area has been expanding to eliminate package treatment plans and adjacent un-sewered areas.

The majority of the WAU is unincorporated and served by HSTS. This WAU is in Sandusky County that has an HSTS failure rate of 35 percent (ODH 2013). SWAT model results did not show failing HSTS to be impacting this WAU. While failing HSTS are present, may contribute elevated sediment and total phosphorus levels to surface waters, and may impact surface waters locally, failing HSTS are not significant sources of TSS or total phosphorus in this WAU.

6.7.2.5 Agriculture

The dominant land use in this WAU is cultivated crops (79 percent). Developed open space accounts for 9 percent of the WAU and pasture is about 1 percent. Most of the developed land (14 percent) is in the cities of Fremont and Fostoria. SWAT model results show that cultivated cropland contributes an annual average of 6,060 tons/year TSS and 61,648 lbs/yr total phosphorus, which are 69 percent and 88 percent (respectively) of the TSS and total phosphorus load in the WAU (Appendix E).

Five WWTP sludge fields are in this WAU and they all receive sludge from the Fremont WWTP. Muskellunge Creek flows through and adjacent to two sludge fields; the assessment site on Muskellunge Creek (RM 16.70, 300674) just downstream of these sludge fields is in full attainment. The other three WWTP sludge fields are west of the city of Fremont, including the Sycamore Hills Golf Club.

6.7.3 Conclusions

Muskellunge Creek is impaired by nutrient/eutrophication, phosphorus, and sedimentation/siltation, and total phosphorus and TSS monitoring data are representative of these impairments. The anthropogenic sources of TSS loads to Muskellunge Creek are individually permitted point sources, urban and industrial storm water, failing HSTS, and agriculture. SWAT model results indicate that the dominant sources of TSS loads to the WAU are cultivated cropland (69 percent) and storm water from developed urban land (31 percent). The dominant sources of total phosphorus loads are also cultivated cropland (88 percent) and storm water from developed land (12 percent)[60]. These sources will be addressed through TSS and total phosphorus TMDLs on Muskellunge Creek at Oak Harbor Road (State Route 19). This site was selected because Muskellunge Creek near Fremont at Fangboner Road (RM 1.23; U04P08) is in the lacustuary and SWAT cannot simulate flows in a lacustuary.

[60] DMR data for POET Plant Management (2IF00026) began in October 2008 and were excluded from the SWAT modeling due to the limited available data during the model period (2000-2010). While total phosphorus concentrations were previously elevated (see Table 78), as of April 2011 the facility stopped discharging through outfall 001. The process effluent is no longer a source of total phosphorus.

6.8 Mouth Sandusky River (HUC 04100011 13 03)

This WAU is mostly in Sandusky and the downstream boundary is Muddy Creek Bay. The Sandusky River flows from the city of Fremont into the large wetland complexes along Muddy Creek Bay. Green Creek joins the Sandusky River just upstream of the Sandusky River's mouth. A portion of this watershed includes the rural, agricultural land between the Sandusky River and Green Creek, east of the city of Fremont.

6.8.1 Monitoring Data

Ohio EPA collected water chemistry and biological data at three sites, with two sites on the Sandusky River (Ohio EPA 2011). WAU attainment was evaluated at a single site on Bark Creek (non-attainment; see Ohio EPA 2011, Table 2, p. 9). LRAU attainment is discussed in Section 7. The primary causes of WAU impairment were nutrient- and sediment-related; therefore, only nutrient- and sediment-related monitoring data are presented herein.

The QHEI score at Bark Creek RM 3.20 (300677) was 32, which is fair, due to channelization and silt substrates (Ohio EPA 2011, Table 12, p. 37-38).Water chemistry (Table 71) data are summarized in this section and all available QHEI and water quality data are presented in Ohio EPA (2011). As shown in this table, nitrate plus nitrite, total phosphorus, and TSS levels exceed targets.

Table 71. Water chemistry data summary for *mouth Sandusky River* (HUC 04100011 13 03)

Stream name	RM	STORET	DA	ALU status	No. samples	Min.	Max.	GM	Exceed[a]
Nitrate plus nitrite (mg/L as nitrogen)									
Bark Creek	3.20	300677	10.0	Non	4	0.14	6.20	1.27	75%
Total phosphorus (mg/L as phosphorus)									
Bark Creek	3.20	300677	10.0	Non	4	0.02	0.10	0.03	25%
TSS (mg/L)									
Bark Creek	3.20	300677	10.0	Non	4	15	81	29.2	50%

Notes

ALU = aquatic life use; DA = drainage area, in square miles; GM = geometric mean; RM = rivermile; STORET = site code for U.S. EPA's STOrage and RETrieval system.

a. The nitrate plus nitrite target is 1.0 mg/L nitrogen and the total phosphorus target is 0.08 mg/L phosphorus because Bark Creek is a WWH headwaters stream. The TSS target is 24 mg/L because this stream is in the HELP ecoregion.

The LDC analysis shows that the single TSS sample in the mid-range flows and one of two samples in the dry conditions exceeded the target (Appendix G). Only the single total phosphorus sample in the mid-range flows exceeded the target.

6.8.2 Sources of Impairment

Ohio EPA (2010a) found the WAU to be impaired by five nutrient-, sediment, and habitat-related causes from crop production with subsurface drainage, channelization, and sewage discharges in un-sewered areas. The sources of nutrients and sediment are presented in this section.

No facilities are covered by individual NPDES permits. One facility is covered by the general permit for storm water discharges associated with industrial activities: Woodbridge Corp (2GR00614). Industrial storm water may contain TSS or phosphorus.

6.8.2.1 Fremont CSS

The city of Fremont is a CSS but none of the CSO outfalls are in this WAU (Section 4.2.1.1).

6.8.2.2 Developed Land

SWAT modeling showed that urban developed land within this WAU contributed an annual average of 1,535 tons/year of TSS and 4,588 lbs/yr total phosphorus, which are 25 percent and 10 percent (respectively) of the total loads to the WAU (Appendix F).

6.8.2.3 Household Sewage Treatment Systems and Un-sewered Areas

The city of Fremont is sewered and the service area has been expanding to eliminate package treatment plans and adjacent un-sewered areas. The majority of the WAU is unincorporated and served by HSTS. This WAU is in Sandusky County that has an HSTS failure rate of 35 percent (ODH 2013). The unincorporated communities of Barkshire Hill and Wightman's Grove are served by HSTS, including privies, and are underlain by soils that are not suitable for HSTS. The Sandusky County Health Department declared both communities to be critical sewerage areas (TMACOG 2011, p. 209).

SWAT model results did not show failing HSTS to be impacting this WAU. While failing HSTS are present, may contribute elevated sediment and total phosphorus levels to surface waters, and may impact surface waters locally, failing HSTS are not significant sources of TSS or total phosphorus in this WAU.

6.8.2.4 Agriculture

The dominant land use in this WAU is cultivated crops (63 percent). Emergent herbaceous wetlands accounts for 15 percent of the WAU and pasture is less than 1 percent. Most of the developed land (13 percent) is in the city of Fremont. Agricultural canals are located throughout the lower portion of the WAU and they discharge to the Sandusky River or Sandusky Bay. SWAT model results show that cultivated cropland contributes an annual average of 4,246 tons/year TSS and 40,427 lbs/yr total phosphorus, which are 69 percent and 85 percent (respectively) of the total loads in the WAU, (Appendix F).

Twelve WWTP sludge fields are in this WAU; they are all northeast of the city of Fremont. All 12 fields receive WWTP sludge from the Fremont WPCF. Five WWTP sludge fields drain to Bark Creek upstream of the assessment site.

6.8.3 Conclusions

Bark Creek is impaired by nutrients and sediment, and the nutrient and TSS monitoring data are representative of these impairments. The anthropogenic sources of TSS loads to Bark Creek are urban and industrial storm water, failing HSTS, and agriculture. SWAT model results indicate that the dominant sources of TSS loads to the WAU are cultivated cropland (69 percent) and storm water from developed urban land (25 percent); similarly, the dominant sources of total phosphorus loads are cultivated cropland (85 percent) and storm water form developed land (10 percent). These sources will be addressed through TSS and total phosphorus TMDLs on Bark Creek near the site at Kelly Road (County Road 245; RM 3.20, 300671).

6.9 Little Muddy Creek (HUC 04100011 14 03)

Figure 32. Little Muddy Creek at Booktown Road (CR 89).

This WAU is mostly in Sandusky County. Little Muddy Creek begins west of the city of Fremont and flows north and east to Muddy Creek; its confluence with Muddy Creek is just upstream of Muddy Creek's mouth on Sandusky Bay. The WAU is rural, agricultural (Figure 32) and is without incorporated municipalities.

6.9.1 Monitoring Data

Ohio EPA collected water chemistry and biological data at three sites (Ohio EPA 2011). Attainment was evaluated at three assessment sites on Fishing Creek (one site in non-attainment) and Little Muddy Creek (two sites in non-attainment; see Ohio EPA 2011, Table 2, p. 10). The ICI scores were poor at all three assessment sites and the IBI score at Little Muddy Creek at RM 2.50 (300676) was very poor (score of 20 with a biological criterion of 32). The primary causes of impairment were nutrients and sedimentation/siltation; therefore, only nutrient- and sediment-related monitoring data are presented herein.

Available QHEI (Table 72) and water chemistry (Table 73) data are summarized in this section and all available QHEI and water quality data are presented in Ohio EPA (2011). It is noteworthy that one Ohio EPA assessment site on Little Muddy Creek (RM 2.50) is within the lacustuary, which begins at about RM 3.3. As shown in these tables, nitrate plus nitrite, total phosphorus, and TSS levels exceed targets and habitat is generally poor.

Table 72. QHEI data summary for *Little Muddy Creek* (HUC 04100011 14 03)

Stream name	RM	STORET	DA	ALU status	Score	NR	Comments
Fishing Creek	0.20	300678	7.0	Non	21.5	Very poor	Channelized, silt substrates, limited cover
Little Muddy Creek	7.55	300677	12.4	Non	39	Poor	Channelized, limited cover
	2.50	300676	25.0	Non	47.5	Fair	Lacustuary

Source: Ohio EPA 2011, Table 12, p. 37-38
Note: ALU = aquatic life use; DA = drainage area, in square miles; NR = narrative rating; RM = rivermile; STORET = site code for U.S. EPA's STOrage and RETrieval system.

Table 73. Water chemistry data summary for *Little Muddy Creek* (HUC 04100011 14 03)

Stream name	RM	STORET	DA	ALU status	No. samples	Min.	Max.	GM	Exceed[a]
Nitrate plus nitrite (mg/L as nitrogen)									
Fishing Creek	0.20	300678	7.0	Non	5	0.05	8.00	0.63	60%
Little Muddy Creek	7.55	300677	12.4	Non	4	0.71	8.47	3.89	75%
	2.50	300676	25.0	Non	5	0.05	8.72	0.84	60%
Total phosphorus (mg/L as phosphorus)									
Fishing Creek	0.20	300678	7.0	Non	5	0.07	0.23	0.12	80%
Little Muddy Creek	7.55	300677	12.4	Non	4	0.03	0.06	0.05	0%
	2.50	300676	25.0	Non	5	0.07	0.20	0.11	40%
TSS (mg/L) [b]									
Fishing Creek	0.20	300678	7.0	Non	5	16	50	32.3	80%
Little Muddy Creek	7.55	300677	12.4	Non	2	10	21	14.5	0%
	2.50	300676	25.0	Non	5	25	36	30.3	100%

Notes

ALU = aquatic life use; DA = drainage area, in square miles; GM = geometric mean; RM = rivermile; STORET = site code for U.S. EPA's STOrage and RETrieval system.

a. The nitrate plus nitrite target is 1.0 mg/L nitrogen and the total phosphorus target is 0.08 mg/L phosphorus because Fishing Creek is a WWH headwaters stream. The nitrate plus nitrite target is 1.0 mg/L nitrogen and the total phosphorus targets are 0.08 mg/L and 0.10 mg/L phosphorus because Little Muddy Creek is a WWH headwaters and wading stream. The TSS targets are 24 mg/L because both streams are is in the HELP ecoregion.

b. The TSS detection limit is 5 mg/L and non-detects are evaluated as one-half of the detection limit.

The LDC analyses for Little Muddy Creek shows that all five TSS samples exceeded the target in the wet conditions through dry conditions (Appendix G). For both total phosphorus and nitrate plus nitrite, the single sample in the moist conditions, one of two samples in the mid-range flows, and one of two samples in the dry conditions exceed the target. Four of five total phosphorus samples from Fishing Creek exceeded the target; only the single sample in the mid-ranges flows did not exceed the target.

6.9.2 Sources of Impairment

Ohio EPA (2010a) found the WAU to be impaired by nutrient/eutrophication, phosphorus, nitrate, and sedimentation/siltation from crop production with subsurface drainage and channelization. Sources of nutrients and sediment are presented in this section.

6.9.2.1 Industrial and Public Facilities and Storm Water

One facility is covered by an individual NPDES permits and one facility is covered by a non-storm water general NPDES permit). The general permittee is Fremont M&R Station Project (2GH00002). The permit is inactive and would not be a source of nutrients or sediment. Therefore, the facility is not further evaluated.

The individual permittee is the Apollo MHP (2PY00062) that discharges to Little Muddy Creek at a design flow of 0.015 mgd. From March 2006 through December 2012, 81 TSS records are reported (non-detect[61] to 72 mg/L; average 11 mg/L, median 5 mg/L. About 86 percent of TSS records are at or below the in-stream target[62]); since September 2009, no record has exceeded 10 mg/L (39 records). The MHP is not required to monitor nutrients; however, as a sanitary sewage treatment facility, it discharges nutrients. As the Apollo MHP discharges to Little Muddy Creek below the assessment sites, it is not causing the

[61] The detection limit was 5 mg/L; 2/5 mg/L was used for the calculation of the average and median. Note that 38 or 81 records were non-detects.
[62] The TSS target for the Little Muddy Creek is 24 mg/L. This target is for headwaters streams in the HELP ecoregion (Ohio EPA 1999).

nonattainment at the two assessment sites. However, the Apollo MHP is discharging effluent loads to Little Muddy Creek and Little Muddy Creek is contributing to the impairments on Muddy Creek.

Two facilities are covered by the general permit for storm water discharges associated with industrial activities: American Municipal Power Inc.'s Fremont Energy Center (2GR01647) and Carbo Forge Inc. (2GR01867). Industrial storm water may contain TSS and phosphorus.

6.9.2.2 Developed Land

SWAT modeling showed that developed land within this WAU contributed an annual average of 639 tons/day of TSS, 2,434 lbs/yr total phosphorus, and 3,783 lbs/yr nitrate plus nitrite, which are 10 percent, 4 percent, and 8 percent (respectively) of the total loads to the WAU (Appendix F).

6.9.2.3 Household Sewage Treatment Systems and Un-sewered Areas

The majority of the WAU is unincorporated and served by HSTS. This WAU is in Sandusky County that has an HSTS failure rate of 35 percent (ODH 2013). SWAT model results did not show failing HSTS to be impacting this WAU. While failing HSTS are present, may contribute elevated sediment and nutrient levels to surface waters, and may impact surface waters locally, failing HSTS are not significant sources of TSS, total phosphorus, or nitrate plus nitrite in this WAU.

6.9.2.4 Agriculture

The dominant land use in this WAU is cultivated crops (81 percent). Open developed land accounts for 5 percent of the WAU and pasture is about 2 percent. The developed land (8 percent) does not represent any incorporated municipalities. Agricultural canals are located throughout the lower half of the WAU. Fifteen WWTP sludge fields are in this WAU and they are present throughout the WAU. WWTP sludge fields are in near proximity to each assessment site in non-attainment. SWAT model results show that cultivated cropland contributes an annual average of 5,265tons/year TSS, 53,962 lbs/yr total phosphorus, and 41,074 lbs/yr nitrate plus nitrite, which are 85 percent, 93 percent, and 84 percent (respectively) of the total loads in the WAU, (Appendix E).

6.9.3 Conclusions

Little Muddy Creek is impaired by nutrients and sediment, and nutrient and TSS monitoring data are representative of these impairments. The anthropogenic sources of the nutrient and TSS loads to Little Muddy Creek are the Apollo MHP, storm water runoff from developed land and industrial facilities, failing HSTS, and agriculture. SWAT model results indicate that cultivated crops are the dominant sources of TSS (88 percent), total phosphorus (93 percent), and nitrate plus nitrite (84 percent) loads to the WAU. These sources will be addressed through TSS, total phosphorus, and nitrate plus nitrite TMDLs on Little Muddy Creek at Weikert Road (County Road 174). This site was selected because Little Muddy Creek at Kline Road (RM 2.50; 300676) is in the lacustuary and SWAT cannot simulate flows in a lacustuary. A headwaters total phosphorus TMDL will also be developed for Fishing Creek at Weickert Road (RM 0.20, 300678).

6.10 Town of Lindsay-Muddy Creek (HUC 04100011 14 04)

This WAU is mostly in Sandusky County, with small portions in Ottawa County. The WAU begins when Gries Ditch discharges to Muddy Creek, which then flows north and east before it discharges to Sandusky Bay. The WAU is rural, agricultural and the only incorporated municipality is the village of Lindsey.

6.10.1 Monitoring Data

Ohio EPA collected water chemistry and biological data at three sites (Ohio EPA 2011). Attainment was evaluated at all three assessment sites on Muddy Creek (see Ohio EPA 2011, Table 2, p. 10). Only the most downstream site on Muddy Creek (RM 1.23, U04Q13) is in non-attainment. The IBI and ICI scores (21 and 12) were very poor at the non-attainment site (biological criteria of 32 and 34). It is also noteworthy that the upstream WAUs are also in full attainment: both assessment sites in *Gries Ditch* (HUC 04100011 14 01) and all three sites in *Town of Helena-Muddy Creek* (HUC 04100011 14 02) are in full attainment. Thus, the significant sources of impairment are in the lower segments of Muddy Creek, upstream of its mouth on Sandusky Bay. The primary causes of impairment were phosphorus, direct habitat alterations, and other flow regime alterations. As such, phosphorus and sediment-related monitoring data are presented herein.

Available QHEI (Table 74) and water chemistry (Table 73) data are summarized in this section and all available QHEI and water quality data are presented in Ohio EPA (2011). Muddy Creek RM 9.79 (U04S01) was also evaluated for dissolved orthophosphate with an average dissolved orthophosphate to total phosphorus ratio of 63 percent[63]. It is noteworthy that one of the Ohio EPA assessment sites on Muddy Creek is within the lacustuary, which begins at about RM 4.2. As shown in these tables, total phosphorus and TSS levels exceed targets and habitat is only degraded in the lower segments of Muddy Creek.

Table 74. QHEI data summary for *Town of Lindsey-Muddy Creek* (HUC 04100011 14 04)

Stream name	RM	STORET	DA	ALU status	Score	NR	Comments
Muddy Creek	18.68	U04S05	63	Full	76	Excellent	--
	9.79	U04S01	74	Full	62	Good	--
	1.23	U04Q13	110	Non	50.5	Fair	Lacustruary

Source: Ohio EPA 2011, Table 12, p. 37-38
Note: ALU = aquatic life use; DA = drainage area, in square miles; NR = narrative rating; RM = rivermile; STORET = site code for U.S. EPA's STOrage and RETrieval system.

[63] Dissolved orthophosphate at Muddy Creek RM 9.79 (U04S01) ranged from 0.018 mg/L to 0.079 mg/L phosphorus with a geometric mean of 0.039 mg/L phosphorus (7 samples). The dissolved orthophosphate to total phosphorus ratio ranged from 53 to 69 percent (7 samples).

Table 75. Water chemistry data summary for Muddy Creek (HUC 04100011 14 04)

Stream name	RM	STORET	DA	ALU status	No. samples	Min.	Max.	GM	Exceed[a]
Total phosphorus (mg/L as phosphorus)									
Muddy Creek	18.68	U04S05	63	Full	5	0.03	0.13	0.04	20%
	9.79	U04S01	74	Full	7	0.03	0.14	0.06	14%
	1.23	U04Q13	110	Non	5	0.08	0.40	0.16	80%
TSS (mg/L) [b]									
Muddy Creek	18.68	U04S05	63	Full	5	2.5	15	3.6	0%
	9.79	U04S01	74	Full	5	2.5	33	12.6	40%
	1.23	U04Q13	110	Non	5	83.00	105	88.5	100%

Notes
ALU = aquatic life use; DA = drainage area, in square miles; GM = geometric mean; RM = rivermile; STORET = site code for U.S. EPA's STOrage and RETrieval system.
a. The nitrate plus nitrite target is 1.0 mg/L nitrogen and the total phosphorus target is 0.10 mg/L phosphorus because Muddy Creek is a WWH wading stream. The TSS target is 24 mg/L because this stream is in the HELP ecoregion.
b. The TSS detection limit is 5 mg/L and non-detects are evaluated as one-half of the detection limit.

The LDC analysis shows that six of seven TSS samples exceeded the target in the wet conditions through dry conditions (Appendix G).

6.10.2 Sources of Impairment

Ohio EPA (2010a) found the WAU to be impaired by direct habitat alteration, other flow regime alterations, and phosphorus from channelization. The sources of phosphorus and sediment are presented in this section.

6.10.2.1 Public Facilities

One facility is covered by an individual NPDES permits and no facilities are covered by general NPDES permits (Table 76). Both facilities are permitted to discharge TSS (Table 77).

Table 76. Public facilities with NPDES permits in HUC 04100011 14 04

NPDES ID	Permittee	Facility	Receiving waterbody	Size (mgd)
2PA00024	village of Lindsey	Lindsey WWTP	Muddy Creek	0.215
2PR00186	FPM Tooling and Automation		ditch along state route 523	0.004

Note: mgd = million gallons per day; WWTP = wastewater treatment plant.

Table 77. Public facilities with water quality data in HUC 04100011 14 04

NPDES ID	Outfall	Receiving waterbody	No. of records	Min.	Max.	Avg.	Median
Total phosphorus (mg/L as phosphorus)							
2PA00024	001 [a]	Muddy Creek	115	0.9	70	2.3	1.5
TSS (mg/L)							
2PA00024	001 [a]	Muddy Creek	477	0.5	44	3.8	1.8
2PR00186	001 [b]	ditch along state route 523	36	2.5	20	4.2	2.5

Notes
a. Results are from January 2003 through December 2012. The TSS detection limits varied. Non-detects are evaluated as 0.5 mg/L.
b. Results are from January 2010 through December 2012. The TSS detection limit is 5 mg/L and non-detects are evaluated as one-half of the detection limit.

The Lindsey WWTP (2PA00024) and its sanitary sewer infrastructure were affected by excessive infiltration and inflow, poor plant performance, hydraulic overloading, and overflowing and surcharging (TMACOG 2011). Storm sewers are being replaced in an effort to reduce infiltration and inflow into the sanitary sewers (TMACOG 2011).

All total phosphorus records at the Lindsey WWTP exceeded the in-stream target[64]. The effluent discharges to Muddy Creek about half a mile upstream of the assessment site at RM 9.79 (U04S01), which is in full attainment but does exceed in-stream targets. The Lindsey WWTP always discharges high levels of total phosphorus, but due to its small flow (as compared to Muddy Creek) and the fact that the nearest downstream assessment site is in full attainment, the WWTP is not a significant contributor to elevated phosphorus loads in Muddy Creek.

TSS records at the Lindsey WWTP (99 percent) and FPM Tooling and Automation (100 percent) were typically below the in-stream targets[65]. While both facilities discharge TSS loads, they are not significantly contributing to the impairment.

6.10.2.2 Urban and Industrial Storm Water

One facility is covered by the general permit for storm water discharges associated with industrial activities: Miarer Transportation Inc. (2GR01670). Industrial storm water may contain phosphorus. Urban storm water was modeled in SWAT. The modeling showed that urban developed land within this WAU contributed an annual average of 2,657 lbs/yr of total phosphorus, which is 6 percent of the total phosphorus load to the WAU (Appendix F).

6.10.2.3 Household Sewage Treatment Systems and Un-sewered Areas

The villages of Gibsonburg and Lindsey are sewered. Two unpermitted package treatment plants are in the Lindsey facilities planning area (TMACOG 2011, p. 201). The majority of the WAU is unincorporated and served by HSTS. This WAU is in Sandusky County that has an HSTS failure rate of 35 percent (ODH 2013).

The unincorporated community of Hessville is un-sewered and served by HSTS. The Sandusky County Health Department identified the community as a critical sewerage area due to dysfunctional leachfields that were polluting surface waters (TMACOG 2011, p. 203).

SWAT model results did not show failing HSTS to be impacting this WAU. While failing HSTS are present, may contribute elevated total phosphorus levels to surface waters, and may impact surface waters locally, failing HSTS are not significant sources of total phosphorus in this WAU.

6.10.2.4 Agriculture

The dominant land use in this WAU is cultivated crops (71 percent). Deciduous forest accounts for 8 percent of the WAU (both as undeveloped parcels and in riparian corridors) and pasture is 2 percent. Much of the developed land (8 percent) is in the village of Lindsey. Agricultural canals are located throughout the lower reaches of the WAU. Four WWTP sludge fields are in this WAU; two sludge fields are near Sandusky Bay and two sludge fields are near the upstream boundary of the WAU. The SWAT model results show that cultivated cropland contributes an annual average of 32,645 lbs/yr total phosphorus, which is 77 percent of the total phosphorus load in the WAU, (Appendix E).

[64] The total phosphorus target the Muddy Creek is 0.10 mg/L. This target is for WWH wading streams (Ohio EPA 1999).
[65] The TSS targets for Muddy Creek and the ditch along state route 523 are 24 mg/L. These targets are for headwaters and wading streams in the HELP ecoregion (Ohio EPA 1999).

6.10.3 Conclusions

Muddy Creek is impaired by phosphorus and total phosphorus monitoring data are representative of this impairment. The anthropogenic sources of TSS loads to Muddy Creek are individually permitted point sources, storm water runoff from developed land and an industrial facility, failing HSTS, and agriculture. SWAT model results indicate that the dominant sources of total phosphorus loads to the WAU are cultivated cropland (77 percent), permitted point sources (13 percent), and storm water from developed urban land (6 percent). These sources will be addressed through a total phosphorus TMDL on Muddy Creek at South Bolinger Road (County Road 168). This site was selected because Muddy Creek at the east side of State Route 53 (RM 1.23; U04K13) is in the lacustuary and SWAT cannot simulate flows in a lacustuary.

7 Linkage Analysis: Sandusky River (Lower)

Source assessments and linkage analyses are discussed in this section for the impaired LRAUs of the Sandusky River. Generally, the free-flowing reaches of the Sandusky River (lower) had good habitat and water quality (Ohio EPA 2011, p. 39-40). However, the *Sandusky River mainstem from Tymochtee Creek to Wolf Creek* (04100011 90 01) is impaired for its ALU and the *Sandusky River mainstem from Wolf Creek to Sandusky Bay* (04100011 90 02) is impaired for its ALU and PDWS use. Ohio EPA assessment sites with ALU attainment and the lacustuary are shown in Figure 33.

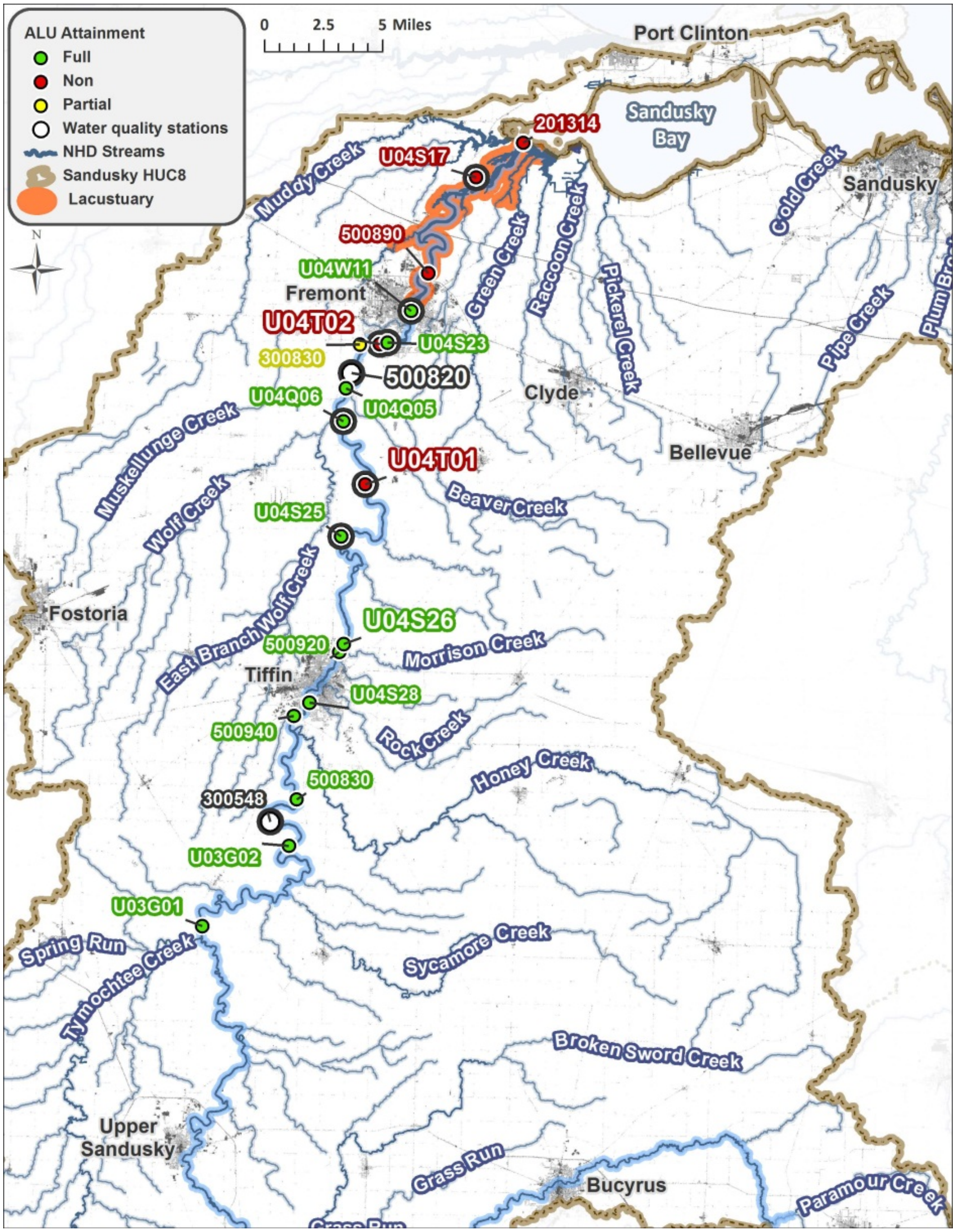


Figure 33. Ohio EPA assessment sites on the mainstem of the Sandusky River (lower).

7.1 Ohio EPA Monitoring Data

Ohio EPA and the National Center for Water Quality Research (NCWQR) at Heidelberg University have collected water quality data in the Sandusky basin. The Ohio EPA data were used to assess attainment and are used to develop TMDLs.

Ohio EPA collected water chemistry at nine sites and biological data at 18 sites (Ohio EPA 2011). Attainment was evaluated at 18 sites: 6 sites were impaired (see Ohio EPA 2011, Table 2, p. 10). Four sites (RMs 1.00, 4.70, 12.96, and 15.40) are in the lacustuary. The causes of ALU impairment were nutrient/eutrophication, sedimentation/siltation, direct habitat alteration, and particle distribution (embeddedness). As such, phosphorus and sediment-related monitoring data are presented herein. The cause of PDWS impairment was nitrates.

Available QHEI (Table 78), nutrient (Table 79), and TSS (Table 80) data are summarized in this section and all available QHEI and water quality data are presented in Ohio EPA (2010a, 2011). As shown in these tables, nitrate plus nitrite levels often exceed targets, total phosphorus levels only occasionally exceed targets, and TSS levels often exceed targets; habitat is generally good to excellent except at a few sites where habitat is fair.

Table 78. QHEI data summary for the Sandusky River LRAUs (HUC 04100011 90)

WAU [a]	RM	STORET	DA	ALU status	Score	NR	Comments
Sandusky River mainstem from Tymochtee Creek Wolf Creek (04100011 90 01)							
09 04	65.01	U03G01	655	Full	81.5	Excellent	--
09 05	52.58	U03G02	770	Full	60.5	Good	--
09 05	50.20	300548	772	--	--	--	--
09 05	47.75	500830	774	Full	86.5	Excellent	--
11 03	42.92	500940	960	Full	45.5	Fair	Impounded
11 03	41.84	U04S28	964	Full	83	Excellent	--
11 03	38.90	500920	1,008	Full	82.5	Excellent	--
11 05	38.50	U04S26	1,028	Full	--	--	--
11 05	31.95	U04S25	1,046	Full	69	Good	--
11 05	26.94	U04T01	1,067	Non	65	Good	--
Sandusky River mainstem from Wolf Creek to Sandusky Bay (04100011 90 02)							
11 05	23.00	U04Q06	1,073	Full	83.5	Excellent	--
13 02	21.30	U04Q05	1,238	Full	76	Excellent	--
13 02	20.25	500820	1,251	--	--	--	--
13 02	19.00	300830	1,255	Partial	59	Fair	
13 02	18.05	U04T02	1,255	Non	52	Fair	Impounded
13 02	17.70	U04S23	1,256	Full	93	Excellent	--
13 02	15.40	U04W11	1,260	Full	67	Good	Lacustuary
13 02	12.96	500890	1,264	Non	67	Good	Lacustuary
13 03	4.70	U04S17	1,330	Non	60	Good	Lacustuary
13 03	1.00	201314	1,335	Non	64.5	Good	Lacustuary

Sources: Ohio EPA 2011, Table 12, p. 37-38
Notes
ALU = aquatic life use; DA = drainage area, in square miles; NR = narrative rating; RM = rivermile; STORET = site code for U.S. EPA's STOrage and RETrieval system.
a. WAU that the mainstem Sandusky River monitoring site is in.

Table 79. Nutrient water quality data summary for the Sandusky River LRAUs (HUC 04100011 90)

WAU [a]	RM	STORET	DA	ALU status	No. samples	Nitrate plus nitrite (mg/L as nitrogen)				Total phosphorus (mg/L as phosphorus			
						Min.	Max.	GM	Exceed[b]	Min.	Max.	GM	Exceed[c]
Sandusky River mainstem from Tymochtee Creek Wolf Creek (04100011 90 01)													
09 04	65.01	U03G01	655	Full	0	--	--	--	--	--	--	--	--
09 05	52.58	U03G02	770	Full	0	--	--	--	--	--	--	--	--
09 05	50.20	300548	772	--	2 [d]	0.61	--	--	0%	0.02	0.04	0.03	0%
09 05	47.75	500830	774	Full	0	--	--	--	--	--	--	--	--
11 03	42.92	500940	960	Full	0	--	--	--	--	--	--	--	--
11 03	41.84	U04S28	964	Full	0	--	--	--	--	--	--	--	--
11 03	38.90	500920	1,008	Full	0	--	--	--	--	--	--	--	--
11 05	38.50	U04S26	1,028	Full	0	--	--	--	--	--	--	--	--
11 05	31.95	U04S25	1,046	Full	13	0.05	9.82	1.75	46%	0.03	0.19	0.07	0%
11 05	26.94	U04T01	1,067	Non	5	0.05	9.82	0.70	60%	0.06	0.25	0.10	0%
Sandusky River mainstem from Wolf Creek to Sandusky Bay (04100011 90 02)													
11 05	23.00	U04Q06	1,073	Full	5	0.05	9.73	0.74	60%	0.03	0.19	0.08	0%
13 02	21.30	U04Q05	1,238	Full	0	--	--	--	--	--	--	--	--
13 02	20.25	500820	1,251	--	88	0.05	12.50	2.76	77%	0.01	0.76	0.09	11%
13 02	19.00	300830	1,255	Partial	0	--	--	--	--	--	--	--	--
13 02	18.05	U04T02	1,255	Non	4	0.05	8.39	1.46	75%	0.03	0.14	0.09	0%
13 02	17.70	U04S23	1,256	Full	5	0.05	8.36	0.78	60%	0.03	0.15	0.07	0%
13 02	15.40	U04W11	1,260	Full	8	0.05	8.93	0.63	38%	0.03	0.18	0.08	0%
13 02	12.96	500890	1,264	Non	0	--	--	--	--	--	--	--	--
13 03	4.70	U04S17	1,330	Non	5	0.39	9.75	3.25	80%	0.07	0.13	0.09	0%
13 03	1.00	201314	1,335	Non	0	--	--	--	--	--	--	--	--

Notes
ALU = aquatic life use; DA = drainage area, in square miles; GM = geometric mean; RM = rivermile; STORET = site code for U.S. EPA's STOrage and RETrieval system.
a. WAU that the mainstem Sandusky River monitoring site is in.
b. The nitrate plus nitrite targets are 1.5 mg/L and 2.0 mg/L nitrogen because the Sandusky River is a small river and large river designated as WWH.
c. The total phosphorus targets are 0.17 mg/L and 0.30 mg/L phosphorus because the Sandusky River is a small river and large river designated as WWH.
d. Only one of two samples was evaluated for nitrate plus nitrite.

Table 80. TSS data summary for the Sandusky River LRAUs (HUC 04100011 90)

WAU	RM	STORET	DA	ALU status	No. samples	Min.	Max.	GM	Exceed
Sandusky River mainstem from Tymochtee Creek Wolf Creek (04100011 90 01) [a]									
09 04	65.01	U03G01	655	Full	0	--	--	--	--
09 05	52.58	U03G02	770	Full	0	--	--	--	--
09 05	50.20	300548	772	--	0	--	--	--	--
09 05	47.75	500830	774	Full	0	--	--	--	--
11 03	42.92	500940	960	Full	0	--	--	--	--
11 03	41.84	U04S28	964	Full	0	--	--	--	--
11 03	38.90	500920	1,008	Full	0	--	--	--	--
11 05	38.50	U04S26	1,028	Full	0	--	--	--	--
11 05	31.95	U04S25	1,046	Full	11	27	258	39.5	9%
11 05	26.94	U04T01	1,067	Non	5	39	263	65.4	60%
Sandusky River mainstem from Wolf Creek to Sandusky Bay (04100011 90 02) [b]									
11 05	23.00	U04Q06	1,073	Full	5	28	149	52.5	40%
13 02	21.30	U04Q05	1,238	Full	0	--	--	--	--
13 02	20.25	500820	1,251	--	77	2.5	572.	36.7	26%
13 02	19.00	300830	1,255	Partial	0	--	--	--	--
13 02	18.05	U04T02	1,255	Non	4	16	104	37.0	25%
13 02	17.70	U04S23	1,256	Full	5	19	140	41.1	20%
13 02	15.40	U04W11	1,260	Full	8	23	115	42.9	38%
13 02	12.96	500890	1,264	Non	0	--	--	--	--
13 03	4.70	U04S17	1,330	Non					
13 03	1.00	201314	1,335	Non	0	--	--	--	--

Notes
The TSS detection limit is 5 mg/L and non-detects are evaluated as one-half of the detection limit.
ALU = aquatic life use; DA = drainage area, in square miles; GM = geometric mean; RM = rivermile; STORET = site code for U.S. EPA's STOrage and RETrieval system.
a. The TSS target is 46 mg/L because the Sandusky River is a large river in the ECBP ecoregion.
b. The TSS target is 60 mg/L because the Sandusky River is a large river in the HELP ecoregion.

7.2 National Center for Water Quality Research Monitoring Data

Over the past thirty years, the NCWQR at Heidelberg University has conducted one of the most comprehensive water quality monitoring programs found anywhere in the United States. A part of their effort includes more than 30 years of intensive sampling at three locations in the Sandusky basin (Honey Creek near Melmore, Sandusky River at Fremont, and Rock Creek at Tiffin). Several parameters measured relevant to the TMDL effort in include flow, TSS, nitrate plus nitrite, total phosphorus, and dissolved phosphorus. This section provides a brief summary of the evaluations of the long-term data collected by NCWQR. Refer to Appendix H for full discussions of the evaluations.

An analysis of hydrologic characteristics for the three NCWQR monitoring locations shows that total flow in the watershed is dominated by storm-related runoff (i.e., surface- and inter-flow). This is consistent with the relatively high Richards-Baker flashiness index values[66] for each site compared to other watersheds of similar size. Seasonally, the greatest flows occur from December through April.

A monthly analysis of the water quality data shows that the highest TSS, nitrate plus nitrite, total phosphorus and dissolved phosphorus loads occur from December through May/June. The high concentrations roughly coincide with the periods of greatest flows in the basin.

[66] The Richards-Baker flashiness index is a measure of the frequency and rapidity of short term changes in streamflow based upon mean daily flow (Baker et al. 2004).

Samples influenced by storm events were differentiated from those dominated by base flow conditions through hydrograph separation. Seasonal storm versus base load patterns were examined under a duration curve framework. TSS and total phosphorus storm loads were generally more than 50 percent greater than base flow loads across all zones and seasons; indicative of surface erosion processes. In contrast, storm loads for nitrate plus nitrite and dissolved phosphorus were generally more than 50 percent greater only under moist conditions across all seasons; indicative of their dissolved nature and the role of interflow processes.

7.3 Sources of Impairment

Ohio EPA (2010a, 2011) found both LRAUs to be impaired for their ALUs by sedimentation/siltation and for the lower LRAU (HUC 0410001190 02) to also be impaired by direct habitat alterations, nutrient/eutrophication, and particle distribution (embeddedness). Additionally, the lower LRAU is impaired for its PDWS use by nitrate (Ohio EPA 2010a, 2011). The sources of nutrients and sediment are presented in this section.

7.3.1 Industrial and Public Facilities

Twenty-two industrial and public facilities with individual NPDES permits discharge to the Sandusky River or its tributaries along the LRAU from Tymochtee Creek to Wolf Creek (HUC 04100011 90 01). An additional 17 industrial and public facilities with individual NPDES permits discharge to the Sandusky River or its tributaries along the non-lacustuary[67] portion of the LRAU from Wolf Creek to Sandusky Bay (HUC 04100011 90 02). Refer to Appendix C for lists of these facilities.

SWAT model results indicate that point sources typically contribute about 1 percent of the total phosphorus load and less than 1 percent of the TSS loads to the Sandusky River LRAUs upstream of the lacustuary. Point sources contribute 10 percent to 11 percent of the nitrate plus nitrite loads to the non-lacustuary LRAUs; however, much of these loads are derived from point sources in the Sandusky River (upper) watershed as most point sources that discharge to the Sandusky River (lower) mainstem discharge to the lacustuary portion of the Sandusky River (lower).

7.3.2 Combined Sewer Systems

Of the six CSSs in the basin, only three CSSs discharge directly to the Sandusky River (refer back to Section 4.2.1.1 for a discussion of the CSSs). The Fremont and Tiffin CSSs directly discharge to the Sandusky River mainstem; however, the Tiffin CSS was addressed in the upper Sandusky River TMDL (Ohio EPA 2004) and will not be further discussed here.

The Fremont CSS discharges from 14 CSO outfalls to the Sandusky River (lower) along the downstream (northern) side of Fremont. The Sandusky River (lower) in the city of Fremont below the Ballville Dam and above the CSO outfalls is in full attainment of its ALU (assessment sites U04S23 and U04W11 are in full attainment). The Sandusky River (lower) below Fremont is in nonattainment and is lacustrine. While water chemistry was evaluated in the Sandusky River (lower) upstream of the CSO outfalls and lacustuary (sites U04S23 and U04W11), no water chemistry samples were collected immediately below the city of Fremont, in the lacustuary at site 500890. Therefore, it is not possible to directly evaluate the impacts of the Fremont CSS upon the Sandusky River (lower).

The biological data show that water quality degrades from full attainment within the city of Fremont (below the Ballville Dam) to nonattainment below Fremont (and within the lacustuary). Given that no

[67] The non-lacustuary portion of the LRAU from Wolf Creek to Sandusky Bay is defined as from Wolf Creek to RM 15.8.

major tributaries discharge to the Sandusky River just below Fremont, it is reasonable to assume that Fremont and the lacustuary contribute to the impairment. Besides CSOs, regulated storm water and channel modifications that affect habitat may also contribute to the impairments.

7.3.3 Regulated Storm Water

The city of Tiffin Small MS4 (2GQ00031) discharges to the Sandusky River LRAU from Tymochtee Creek to Wolf Creek (HUC 04100011 90 01). No other regulated MS4s discharge directly to either LRAU. As the city of Tiffin was addressed in the upper Sandusky River TMDL (Ohio EPA 2004), it will not be further discussed here.

No facilities discharge storm water associated with industrial activities to the Sandusky River or its tributaries between the city of Tiffin and RM 38.50 (U04S26) in the LRAU from Tymochtee Creek to Wolf Creek (HUC 04100011 90 01). Fourteen facilities (seven with individual NPDES permits) discharge storm water to the Sandusky River or its tributaries upstream of RM 18.05 (U04T02) on the non-lacustuary portion of the LRAU from Wolf Creek to Sandusky Bay (HUC 04100011 90 02). Refer to Appendix C for lists of these facilities. No marinas discharge to the Sandusky River upstream of the lacustuary.

While individual and general NPDES storm water permittees were not explicitly modeled in SWAT, the storm water runoff from developed land classes of the NLCD was simulated. SWAT model results were evaluated at four key sites on the Sandusky River (Table 81). The Sandusky River at RM 38.50 (U04S26) represents the developed land loads derived from the upper Sandusky River while the Sandusky River at RM 26.94 (U04T01) is impaired by TSS. The other two sites (RMs 20.25 [500820] and 18.05 [U04T02]) are impaired by nutrients and TSS and are upstream of the lacustuary.

Table 81. SWAT model results from developed land for the Sandusky River mainstem

RM	STORET	DA	ALU status	TP load (ton/yr)	NN load (ton/yr)	TSS load (10^3 ton/yr)
38.50	U04S26	1,028	Full	5.0	286	4.2
26.94	U04T01	1,067	Non	5.2	292	4.3
20.25	500820	1,251	--	8.9	343	6.8
18.05	U04T02	1,255	Non	11.2	346	8.3

Notes
ALU = aquatic life use; DA = drainage area, in square miles; NN = nitrate plus nitrite, as nitrogen; RM = rivermile; STORET = site code for U.S. EPA's STOrage and RETrieval system; TP = total phosphorus; TSS = total suspended solids.

The SWAT results show that 1 percent of the total phosphorus load, 15 percent to 16 percent of the nitrate plus nitrite load, and 4 percent to 6 percent of the TSS load at each site is derived from developed land. The large increase in loads between RMs 20.25 and 26.94 is from the city of Fremont while the city of Tiffin is just upstream of RM 38.50 (U04S26).

7.3.4 Household Sewage Treatment Systems and Un-sewered Areas

Areas draining directly to the two Sandusky River LRAUs are served by WWTPs, package treatment plants, and HSTS. Permitted WWTP and package treatment plants that discharge to tributaries of the Sandusky River (lower) are discussed in Section 6 by WAU. The Sandusky River flows through the city of Tiffin, which is served by the Tiffin WWTP, in the LRAU from Tymochtee Creek to Wolf Creek and flows through the city of Fremont, which is served by the Fremont WPCF, in the LRAU from Wolf Creek to Sandusky Bay.

While a few cities, villages, and towns are sewered and a few subdivisions use package treatment plants, the majority of the residential land draining to the LRAUs is served by HSTS. The Sandusky River flows through the Fremont and Wightman's Grove facility planning areas (TMACOG 2011). The LRAU from Tymochtee Creek to Wolf Creek is in Crawford, Seneca, and Wyandot counties that have HSTS failure rates of 15 percent, 72 percent, and 90 percent (ODH 2013). The LRAU from Wolf Creek to Sandusky Bay is in Sandusky County that has an HSTS failure rate of 35 percent (ODH 2013).

SWAT model results indicate that failing HSTS contribute about 0.3 percent of the nitrate plus nitrite load to the Sandusky River in the LRAU from Tymochtee Creek to Wolf Creek and contribute considerably less than 0.1 percent of the total phosphorus and TSS loads. At two key sites (RMs 18.05 and 20.25) in the LRAU from Wolf Creek to the mouth, SWAT model results indicated that 0.6 percent to 1.1 percent of the nitrate plus nitrate load was derived from failing HSTS. Failing HSTS may be impacting surface waters, and thus, may contribute to the nutrient- and sediment-related impairments of two LRAUs; however nutrient and sediment loads derived from failing HSTS are insignificant compared to such loads from agricultural activities, individual NPDES permittees, and storm water from developed land. It is noteworthy that HSTS have higher nitrate plus nitrite unit area loads than developed land and cultivated crops.

7.3.5 Agriculture

The dominant land use in this Sandusky basin is cultivated crops (75 percent). SWAT model results were evaluated at four key sites on the Sandusky River (Table 82). The Sandusky River at RM 38.50 (U04S26) represents the agricultural loads derived from the upper Sandusky River while the Sandusky River at RM 26.94 (U04T01) is impaired by TSS. The other two sites (RMs 20.25 [500820] and 18.05 [U04T02]) are impaired by nutrients and TSS. All four of the sites are bolded in Figure 33.

The SWAT results show that 95 percent of the total phosphorus load at each site is derived from cultivated crops and 1 percent of the total phosphorus load at each site is derived from pasture and hay. Cultivated crops are the sources of 69 percent to 70 percent of the nitrate plus nitrite load and 93 percent to 96 percent of the TSS load. Pasture and hay are the sources of 2 percent of the nitrate plus nitrite load and less than 0.1 percent of the TSS load. The total phosphorus and TSS unit area loads for cultivated crops are higher than those of developed land and HSTS.

Table 82. SWAT model results from cultivated crops for the Sandusky River mainstem

RM	STORET	DA	ALU status	TP load (ton/yr)	NN load (ton/yr)	TSS load (10^5 ton/yr)
38.50	U04S26	1,028	Full	660	1,291	2,147
26.94	U04T01	1,067	Non	668	1,334	2,234
20.25	500820	1,251	--	797	1,540	2,557
18.05	U04T02	1,255	Non	806	1,545	2,593

Notes
ALU = aquatic life use; DA = drainage area, in square miles; NN = nitrate plus nitrite, as nitrogen; RM = rivermile; STORET = site code for U.S. EPA's STOrage and RETrieval system; TP = total phosphorus; TSS = total suspended solids.

The SWAT model agricultural load results also indicate that a vast majority (i.e., over 80 percent) of each pollutant's load at RMs 18.05, 20.25, and 26.94 is derived from the upper Sandusky River. Thus, a basin-wide approach to address agricultural runoff will be necessary to improve water quality in the Sandusky River (lower).

7.3.1 Conclusions

The Sandusky River from Tymochtee Creek to Wolf Creek (HUC 04100011 90 01) is impaired by sedimentation and the monitoring data at RM 26.94 (U04T01) are representative of this impairment. The anthropogenic sources of TSS loads to this LRAU are individually permitted point sources, storm water from developed land[68], failing HSTS, and agriculture. SWAT model results indicate that the dominant source of TSS loads to this LRAU is cultivated cropland (96 percent). This source will be addressed through a TSS TMDL on the Sandusky River at RM 26.94.

The Sandusky River from Wolf Creek to the mouth (HUC 04100011 90 02) is impaired by sedimentation/siltation, nutrient/eutrophication, particle distribution (embeddedness), and direct habitat alteration. Total phosphorus data collected at RM 20.25 (500820) are representative of the nutrient/eutrophication impairment. Nitrate plus nitrite and TSS data collected at RMs 18.05 and 20.25 (500820 and UO4T02) are representative of the impairments. The anthropogenic sources of pollutant loads to this LRAU are individually permitted point sources, storm water from developed land, failing HSTS, and agriculture. SWAT model results indicate that the dominant source of loads to this LRAU is cultivated cropland: 95 percent of total phosphorus loads, 69 percent to 70 percent of nitrate plus nitrite loads, and 93 percent to 96 percent of TSS loads. Storm water from developed land (15 percent to 16 percent) and permitted point sources (10 percent) contributed the nitrate plus nitrite loads. These sources will be addressed through the following TMDLs: total phosphorus TMDL at RM 20.25, nitrate plus nitrite TMDLs at 18.05 and 20.25, and TSS TMDLs at 18.05 and 20.25.

The PDWS use at RM 18.02 in the Sandusky River from Wolf Creek to the mouth (90 02) is impaired by nitrate and data at RM 18.05 are representative of the PDWS impairment. The anthropogenic sources of nitrate loads to this LRAU are: individually permitted point sources, storm water from developed land, failing HSTS, and agriculture. SWAT model results indicate that the dominant sources of nitrate plus nitrite loads at RM 18.05 are cultivated cropland (69 percent), storm water from developed land (16 percent), and permitted point sources (10 percent). These sources will be addressed through a nitrate plus nitrite TMDL on the Sandusky River at RM 18.05. Additionally, the nitrate numeric criterion for the protection of human health (10 mg/L nitrate as nitrogen) applies 500 yards upstream and downstream of the PDWS intake at RM 18.02.

[68] The storm water from developed land includes both regulated and non-regulated urban storm water. Regulated storm water is from regulated MS4s, industrial facilities (individual and general NPDES permits), construction sites. Regulated storm water from MS4s and industrial facilities are addressed in the upper Sandusky River TMDL (Ohio EPA 2004).

8 TMDL and Allocations

A TMDL is the total amount of a pollutant that a receiving waterbody can assimilate while still achieving water quality standards. TMDLs can be expressed in terms of mass per time or by other appropriate measures. TMDLs are composed of the sum of individual wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. When future growth (FG) is a concern and can be quantified, it is also included. Conceptually, this is defined by the following equation:

$$TMDL = \sum WLA + LA + MOS + FG$$

The TMDL was calculated at the target, which is typically the most conservative numeric criterion for a given constituent, multiplied by the flow and converted to appropriate units. For example, the total phosphorus TMDL for a hypothetical headwaters stream at the 50th percentile flow (10 cfs) would be calculated as

$$\begin{aligned} TMDL = \quad & (50^{th} \text{ percentile flow}) \times (\text{target}) \times (\text{conversion factors}) \\ & (10 \text{ cfs}) \times (0.08 \text{ mg/L}) \times (86{,}400 \text{ s/d}) \times (21.3168 \text{ L/ft}^3) \times (2.205 \times 10^{-6} \text{ lb/mg}) \\ & 4.32 \text{ lb/d} \end{aligned}$$

All loads are reported on a daily time-scale. TMDLs are calculated at the flow duration interval that represents the midpoint of the flow zone (e.g., for the high-flow zone [0 to 10th percentile], the TMDL was calculated at the 5th percentile).

8.1 Load Duration Curves

Allowable pollutant loads in the Sandusky River and Bay tributaries project area were determined using load duration curves. Discussions of load duration curves are in *An Approach for Using Load Duration Curves in the Development of TMDLs* (U.S. EPA 2007b). The load duration curve approach for this project was presented in Section 4.5. Load duration curves for the impaired WAUs are presented in Appendix G and the curves for the Sandusky River LRAUs are presented in Appendix H.

8.2 Allocations

Load duration analyses were conducted for impaired WAUs and LRAUs at sites upstream of the lacustrine zones. Sites with a sufficient number of samples were selected to determine necessary reductions to meet the TMDLs. In-stream water quality data were obtained from Ohio EPA. Data were used only if Ohio EPA accepted them as level 3 credible via the Ohio Credible Data Program. TMDLs were not generated in the lacustuaries because the ebb and flow of water in these areas makes the loadings less predictable. Additionally, the objective of developing TMDLs is to address sources of pollution in the impaired streams; the objective does not include addressing any pollutants present in Lake Erie backwaters.

Most TMDLs were generated at individual assessment sites. Due to subbasin delineation during SWAT model development, sometimes TMDLs were generated at model subbasin outlets that were a few tenths of a mile from the assessment sites. Additionally, on Muddy, Little Muddy, and Muskellunge creeks, TMDLs were developed just upstream of the lacustuaries because the most downstream Ohio EPA assessment sites were within the lacustuaries.

For TMDLs at assessment sites, the necessary percent reductions were calculated as the subtraction of the TMDL from the observed load and then divided by the observed load; this calculation generates the portion of the observed load that must be reduced to achieve the TMDL. Observed loads are based on the available water quality samples. In most cases, only one sample was collected in each flow zone. In cases where more than one sample was collected, the sample requiring the most reduction was selected to calculate the necessary percent reduction. For TMDLs at sites that were not sampled by Ohio EPA, the necessary percent reduction was calculated at the downstream-most assessment site with data, using the previously discussed methodology.

A summary of the allowable loads and allocations in the project area is presented in this chapter. TMDL allocation tables are presented in Appendix J.

8.2.1 TMDL Targets

TMDL targets for total phosphorus, nitrate plus nitrite, and TSS were derived from the *Associations* document (Ohio EPA 1999) for the ALU impairments. The targets varied by ALU designation and stream size (refer back to Section 2.3). The targets for each TMDL are presented in Table 83 in Section 8.3 and Table G-1, Table G-2, and Table G-3 in Appendix G.

The TMDL target for nitrate plus nitrite for the PDWS impairment was the numeric criterion for the protection of human health (10 mg/L as nitrogen). The target is presented in Table 83.

8.2.2 Wasteload Allocations

Waste loads were allocated for permitted point sources, including facilities with individual NPDES permits and regulated storm water (MS4s, construction and industrial). For all TMDLs, the non-storm water WLAs, MOS, and FG were allocated first. The remaining load was then allocated to storm water WLAs and LAs.

8.2.2.1 Facilities with Individual NPDES Permits

The WLAs for facilities with individual NPDES permits (excluding storm water) were calculated by multiplying the design flow by the TMDL target concentration and converting to proper units (pounds per day or tons per day). The TMDL target concentration was based upon the in-stream water quality target (e.g., 24 mg/L TSS) and the monthly average concentration or load limit from the NPDES permit. For NPDES permittees without nutrient limits, the initial TMDL target concentration was set to 3.0 mg/L phosphorus or nitrogen, and then if necessary, the concentration was decreased to balance the TMDL (i.e., the sum of WLAs, LA, MOS, and FG was equal to the TMDL). The WLA for facilities with individual NPDES permits for storm water were calculated on the basis of the area of each facility as a proportion to the area of the TMDL subwatershed (industrial storm water permittees are presented in Appendix I).

8.2.2.2 Construction Sites Storm Water

Construction storm water was assigned a gross allocation that is applicable to all construction storm water permittees. The WLAs are calculated on the basis of the average area of the watershed that is regulated under Ohio's general permit for construction site storm water (OHC000003) from 2003 through 2012. The average annual summation of construction areas was calculated for each county's portion of the project area. For each TMDL subwatershed, the summation of average year construction areas was less than 0.1 percent of the TMDL subwatershed. To account for uncertainty in the construction site storm water WLA estimation methodology, an area ratio of 0.5 percent was used to calculate the WLA for each TMDL subwatershed.

8.2.2.3 Industrial Facilities Storm Water

Regulated industrial storm water facilities are assigned a gross WLA. The WLAs were calculated on the basis of the area of each facility that is regulated under the Ohio Multi-Sector General Permit (OHR00005). Each of the permitted facilities was located with geographic information system information, and county parcel data[69] were used to calculate the area of each facility. The WLA was calculated as the proportion of the subwatershed that is industrial facilities (i.e., the summation of the areas of parcels for the industrial facilities); see Appendix I for a table of the facilities and ratios. When the WLA was calculated, the area ratio was rounded up to the next one-half percent to account for uncertainty in the methodology. For example, the area ratio for Raccoon Creek at RM 5.45 (U05W17) was 4.6 percent, which was rounded up to 5.0 percent to calculate the WLA.

8.2.2.4 Marinas Storm Water

Only one marina was in the project area (Riverfront Marina and Campground); the marina is on the Sandusky River (lower) mainstem downstream of Fremont. Since it was downstream of the TMDL sites, a marina storm water WLA was not calculated.

8.2.2.5 MS4s Storm Water[70]

MS4 storm water WLAs were developed for the Erie County and Others (2GQ00027) and ODOT (4GQ00000) Small MS4s. For each entity, the WLA was calculated using a ratio the surrogate MS4 area to the drainage area of the TMDL watershed (Section 4.2.4.2 and Appendix I).

8.2.3 Margin of Safety

The CWA requires that a TMDL include an MOS to account for uncertainty in the relationship between LAs and WLAs and water quality. U.S. EPA guidance explains that the MOS may be implicit (i.e., incorporated into the TMDL through conservative assumptions in the analysis) or explicit (i.e., expressed in the TMDL as loadings set aside for the MOS).

The nitrate plus nitrite, total phosphorus, and TSS targets were derived from recommendations in the *Associations* document (Ohio EPA 1999) that were based upon analyses of normal, summer and fall low flow conditions. The averaging period of these recommendations was not reported. The recommendations were conservatively applied as daily targets, which provide an implicit MOS.

An explicit MOS of 10 percent of the TMDL was included for all three pollutants. This moderate explicit MOS was specified because the use of the load duration curves is expected to provide reasonably accurate information on the loading capacity of the stream, but the estimate of the loading capacity could be subject to potential error associated with the SWAT modeling used to estimate flows in the project area.

Ohio's section 303(d) listing process also provides an implicit MOS. Ohio EPA determines aquatic life use attainment from biological sampling using biological criteria. A waterbody is considered to be in attainment when its biological criteria are met. If the aquatic communities do not meet the biological criteria after the implementation of a TMDL (i.e., in-stream water chemistry meets TMDL pollutant loads but the aquatic communities do not meet the biological criteria), then the stream will remain on Ohio's section 303(d) list, and the TMDL will be re-evaluated. Thus, Ohio's section 303(d) listing and aquatic life use attainment processes will help to address the uncertainty associated with TMDLs.

[69] Parcel GIS data were obtained from the Erie County Auditor's Office in August 2013, the Sandusky County Auditor's Office in July 2013, and the Seneca Regional Planning Office in April 2013.
[70] A load allocation representing non-regulated MS4 storm water from the city of Fremont was calculated using the area-based methodology for developing regulated MS4 storm water WLAs; refer to Appendix I for the estimated surrogate MS4 area.

8.2.4 Future Growth

Allocations for FG were assigned to all TMDLs to account for potential new sources. An FG of 1 percent was assumed for all TMDLs based upon best professional judgment. An evaluation of 2000 and 2010 Census data showed that Crawford, Erie, Sandusky, Seneca, and Wyandot counties are losing population (refer to Section 3.8). While significant population growth in not anticipated in the near future, FG was allocated in case populations in the Sandusky basin do begin to grow again.

In addition to the explicit FG, an implicit FG is present in each TMDL with individual NPDES WLAs. As discussed in Section 8.2.2.1, the WLA for each individual, non-storm water NPDES permittee was developed using the permitted design flow. The facilities are all discharging below design flow; therefore, the facilities have additional capacity that can be used in the future, if necessary.

8.2.5 Critical Conditions and Seasonality

The CWA requires that TMDLs take into account critical conditions for stream flow, loading, and water quality parameters as part of the analysis of loading capacity. Through the load duration curve approach, it has been determined that load reductions are needed for specific flow conditions; however, the critical conditions (the periods when the greatest reductions are required) vary by location and are inherently addressed by specifying different levels of reduction according to flow.

When calculated, the allocation of point source loads (i.e., the WLA) will also take into account critical conditions by assuming that the facilities will always discharge at their maximum design flows. In reality, many facilities discharge below their design flows.

The CWA also requires that TMDLs be established with consideration of seasonal variations. Seasonal variations are addressed in this TMDL through the load duration approach that accounts for seasonality by evaluating daily allowable loads over the entire range of observed flows and by presenting daily allowable loads that vary by flow.

8.3 Summary of TMDLs

Sixteen WAUs and two LRAUs were not in full attainment of their ALUs and one LRAU was not in full attainment of its PDWS use. Load duration curves were developed for each waterbody-pollutant combination (i.e., 36 load duration curves). TMDLs were generated for both the watersheds (upstream of the lacustrine zone) and headwaters areas, which are subject to different targets and tended to have different causes of impairment than downstream impaired sites. The ALU impairments were addressed through TMDLs for total phosphorus (13 for WAUs and 1 for a LRAU), nitrate plus nitrite (5 for WAUs and 2 for a LRAU), and TSS (11 for WAUs and 3 for the LRAUs). A single nitrate plus nitrite TMDL was developed to address the PDWS use impairment. TMDLs were developed at 24 sites (Figure 34).

The load reductions necessary to achieve the TMDLs are shown in Table 84.

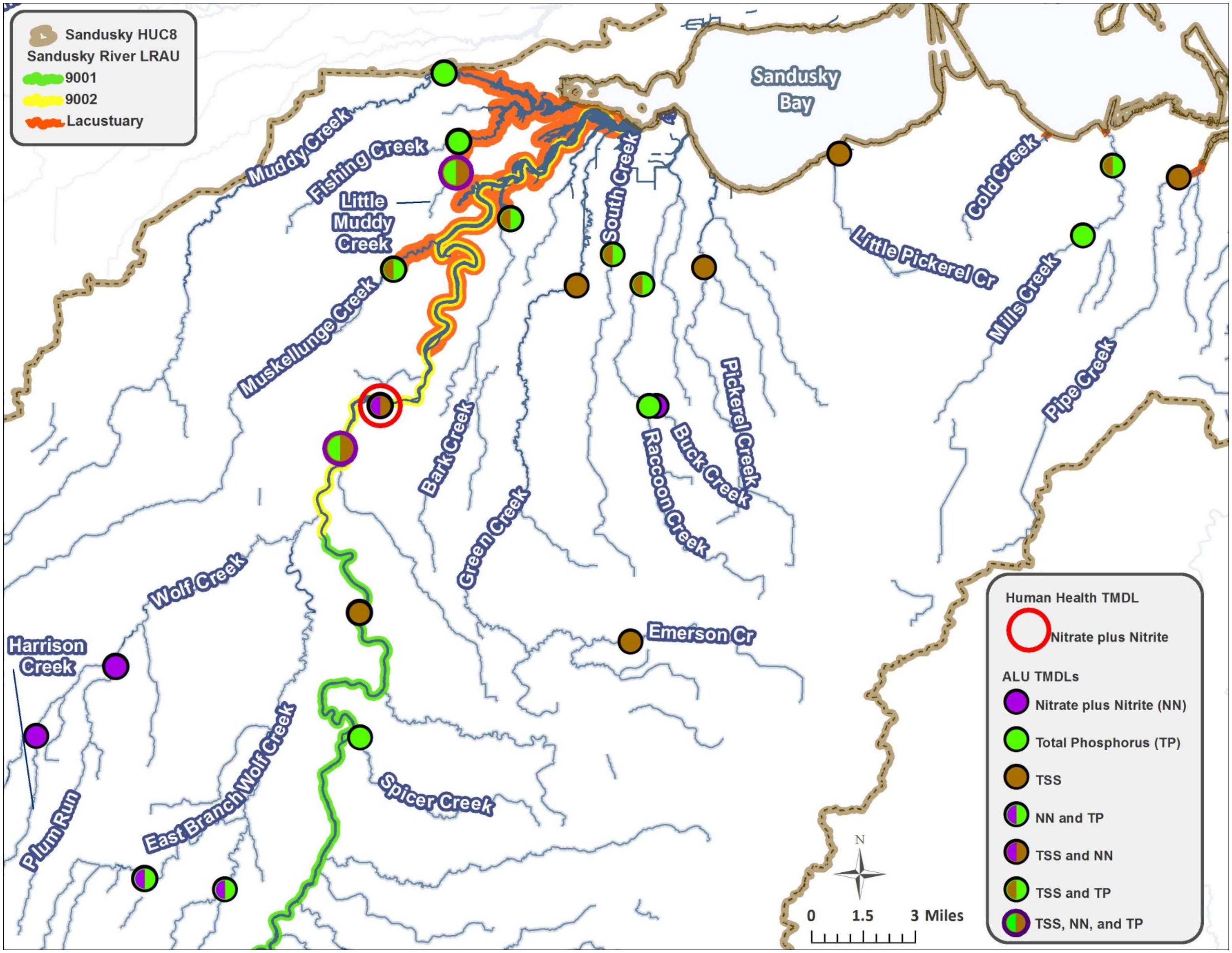


Figure 34. TMDLs in the TMDL project area.

Table 83. Locations and targets for LDCs and TMDLs

Site ID	Site name	RM	Size	Pollutant	Target [a] (mg/L)	Upstream impaired site(s)	TMDL site
Mills Creek-Frontal Lake Erie (HUC 04100011 01)							
Pipe Creek-Frontal Sandusky Bay (HUC 04100011 01 02)							
U05K15	Pipe Creek at Sandusky at Columbus Avenue	2.32	W	TSS	24	U05K16, U05K17	U05K15
Mills Creek (HUC 04100011 01 02)							
U05S07	Mill Creek west of Parkertown at Portland Road	10.40	H	TP [b]	0.08	--	at confluence with Caswell Ditch (1.2 miles downstream of site U05S07)
U05P05	Mills Creek at Sandusky at Perkins Avenue	1.35	W	TP [b]	0.10	U05P07, U05S06 U05W37[d]	U05P05
				TSS [c]	24		
Pickerel Creek-Frontal Lake Erie (HUC 04100011 02)							
Frontal south side of Sandusky Bay (HUC 04100011 02 01)							
201385	Little Pickerel Creek at Stocker Road	2.00	H	TSS [c]	24	--	at frontal Lake Erie (1.9 miles downstream of site 201385)
Pickerel Creek (HUC 04100011 02 03)							
U05S04	Pickerel Creek at TR-247	3.35	W	TSS [c]	24	--	U05S04
Raccoon Creek (HUC 04100011 02 04)							
U05S03	Buck Run north of Clyde at TR-223	0.20	H	NN [e]	1.0	--	at mouth (0.3 mile downstream of U05S03)
U05W10	Raccoon Creek north of Clyde at TR-223	10.18	H	TP [b]	0.08	U05P04	at confluence with Buck Run (0.1 mile downstream of site U05W10)
U05W17	Raccoon Creek downstream of Ohio Turnpike at TR-244	5.45	W	TP [b]	0.10	--	U05W17
				TSS [c,]	24	U05S03[d], U05P04[d], U05W10[d]	
South Creek (HUC 04100011 02 05)							
U05K05	South Creek near Riley Center at Whitmore Road (TR-247)	4.04	H	TP [b]	0.08	U05G01	U05K05
				TSS [c]	24		

Site ID	Site name	RM	Size	Pollutant	Target [a] (mg/L)	Upstream impaired site(s)	TMDL site
Wolf Creek (HUC 04100011 10)							
East Branch East Branch Wolf Creek (HUC 04100011 10 01)							
U04G13	East Branch East Branch Wolf Creek at CR-26	3.52	H	NN [f]	1.0	--	at confluence with Middle Br. EBWC (0.4 mile downstream of site U04G13)
				TP [f]	0.08		
Town of New Riegel-East Branch Wolf Creek (HUC 04100011 10 02)							
300673	East Branch Wolf Creek at Meadowbrook Park	19.65	H	NN [f]	1.0	--	at confluence with unnamed tributary (1.0 mile downstream of site 300673)
				TP [f]	0.08		
Wolf Creek (HUC 04100011 10 04)							
U04G09	Plum Run east of Fostoria at SR-635	0.79	H	NN [f]	1.0	--	at mouth (0.9 mile downstream of site U04G09)
U04G11	Harrison Creek east of Fostoria at CR-592	0.38	H	NN [f]	1.0	--	at mouth (0.4 mile downstream of site U04G11)
Rock Creek-Sandusky River (HUC 04100011 11)							
Spicer Creek-Sandusky River (HUC 04100011 11 05)							
U04Q11	Spicer Creek north of Tiffin at CR-33	0.80	H	TP [g]	0.08	--	at mouth (0.8 mile downstream of site U04Q11)
Green Creek (HUC 04100011 12)							
Beaver Creek (HUC 04100011 12 02)							
U04G26	Emerson Creek at TR-129	1.83	W	TSS	24	U04K07 [d]	U04G26
Green Creek (HUC 04100011 12 03)							
U04K01	Green Creek northeast of Fremont at TR-239	5.06	W	TSS	24	U04S10	U04K01
Muskellunge Creek-Sandusky River (HUC 04100011 13)							
Muskellunge Creek (HUC 04100011 13 01)							
U03P08 [h]	Muskellunge Creek near Fremont at Fangboner Road	1.23	W	TP [f]	0.10	--	at Oak Harbor Road (SR-19). (1.7 mile upstream of site 300674)
				TSS	24		
mouth Sandusky River (HUC 04100011 13 03)							
300671	Bark Creek at Kelley Road (County Road 245)	3.20	H	TP [f]	0.08	--	at mouth (3.0 miles downstream of site 300671)
				TSS [c]	24		

Site ID	Site name	RM	Size	Pollutant	Target [a] (mg/L)	Upstream impaired site(s)	TMDL site
Muddy Creek-Frontal Sandusky Bay (04100011 14)							
Little Muddy Creek (04100011 14 03)							
300676 [i]	Little Muddy Creek at Kline Road	2.50	W	TP [f]	0.10	300677	at Weickert Road (CR-174) (1.0 mile upstream of site 300676)
				NN	1.0		
				TSS	24	300677 [d] 300678 [d]	
300678	Fishing Creek at Weickert Road	0.20	H	TP [f]	0.08	--	300678
Muddy Creek (04100011 14 04)							
U04Q13[j]	Muddy Creek at east side of SR-53	1.23	W	TP	0.10	--	at South Bolsinger Road (CR-168) (4.1mile upstream of site U04Q14)
Sandusky River mainstem from Tymochtee Creek to Wolf Creek (04100011 90 01)							
U04T01	Sandusky River at Old Fort at County Road 51	26.94	LR	TSS	46	--	U04T01
Sandusky River mainstem from Wolf Creek to Sandusky Bay (041000 90 02)							
500820	Sandusky River at Fremont	20.25	LR	NN [e]	2.0	--	500820
				TP [e]	0.30		
				TSS	60		
U04T02	Sandusky River just upstream of Ballville Dam	18.05	LR	NN [e]	2.0	U04T02, 300830	U04T02
				TSS	60		
			n/a	NN [k]	10	n/a	

Notes

CR = county road; H = headwaters (less than 20 square miles); HUC = hydrologic unit code; mg/L = milligram per liter; RM = river mile; SR = state route; TP = total phosphorus; TR = township road; TSS = total suspended solids; W = wading (greater than 20 square miles and smaller than requiring a boat).

a. Refer to Sections 2.3 and 8.2.1 for discussions of the TMDL targets. Total phosphorus targets are mg/L as phosphorus; NN targets are nitrate plus nitrite as nitrogen.

b. The total phosphorus TMDL also serves as a surrogate for the nutrient/eutrophication and organic enrichment (sewage) impairments.

c. The TSS TMDL also serves as a surrogate for the particle distribution (embeddedness) impairment.

d. Since the headwaters and wading TSS targets are both 24 mg/L for WWH streams in the HELP ecoregion, separate sediment TMDLs for the headwaters sites were unnecessary. This impaired headwaters sites were addressed through the sediment TMDL for the wading site.

e. The total phosphorus TMDL or nitrate plus nitrite TMDL serves as a surrogate for the nutrient/eutrophication impairments.

f. The total phosphorus TMDL or nitrate plus nitrite TMDL also serves as a surrogate for the nutrient/eutrophication impairment.

g. The total phosphorus TMDL serves as a surrogate for the nutrient/eutrophication and organic enrichment (sewage) impairments.

h. TMDLs were developed at Oak Harbor Road (SR-19) because site U04P08, which is in nonattainment, is in the lacustuary and flows cannot be modeled within the lacustuary.

i. TMDLs were developed at Weikert Road (CR-174) because site 300676, which is in nonattainment, is in the lacustuary and flows cannot be modeled in the lacustuary.

j. The TMDL was developed at South Bolsinger Road (CR-168) because site U04Q13, which is in nonattainment, is in the lacustuary and flows cannot be modeled within the lacustuary.

k. The nitrate plus nitrite TMDL addresses the nitrate impairment to the public drinking water supply use at RM 18.02 and is only applicable with 500 feet of the public drinking water supply intake at RM 18.02.

Table 84. Necessary reductions to achieve TMDLs

Site ID	Site name	RM	Size	TMDL	High flow (0-10)	Moist cond. (10-40)	Mid-range flows (40-60)	Dry cond. (60-90)	Low flow (90-100)
Mills Creek-Frontal Lake Erie (HUC 04100011 01)									
Pipe Creek-Frontal Sandusky Bay (HUC 04100011 01 02)									
U05K15	Pipe Creek at Sandusky at Columbus Avenue	2.32	W	TSS	--	**93%**	**28%**	0%	--
Mills Creek (HUC 04100011 01 02)									
U05S07	Mill Creek west of Parkertown at Portland Road	10.40	H	TP	--	--	**93%** [a]	**92%** [a]	**93%** [a]
U05P05	Mills Creek at Sandusky at Perkins Avenue	1.35	W	TP	--	**69%**	**32%**	0%	**83%**
				TSS	--	0%	0%	0%	**26%**
Pickerel Creek-Frontal Lake Erie (HUC 04100011 02)									
Frontal south side of Sandusky Bay (HUC 04100011 02 01)									
201385	Little Pickerel Creek at Stocker Road	2.00	H	TSS	--	--	0% [a]	0% [a]	--
Pickerel Creek (HUC 04100011 02 03)									
U05S04	Pickerel Creek at Township Road 247	3.35	W	TSS	--	**52%**	0%	0%	--
Raccoon Creek (HUC 04100011 02 04)									
U05S03	Buck Run north of Clyde at TR-223	0.20	H	NN	--	**84%** [a]	--	**60%** [a]	--
U05W10	Raccoon Creek north of Clyde at TR-223	10.18	H	TP	--	**27%** [a]	**25%** [a]	**37%** [a]	**91%** [a]
U05W17	Raccoon Creek downstream of Ohio Turnpike at TR-244	5.45	W	TP	--	**42%**	0%	**69%**	**32%**
				TSS	--	0%	0%	**15%**	0%
South Creek (HUC 04100011 02 05)									
U05K05	South Creek near Riley Center at Whitmore Road (TR-247)	4.04	H	TP	--	**6%**	0%	**20%**	0%
				TSS	--	**30%**	0%	0%	0%
Wolf Creek (HUC 04100011 10)									
East Branch East Branch Wolf Creek (HUC 04100011 10 01)									
U04G13	East Branch East Branch Wolf Creek at CR-26	3.52	H	NN	**89%** [a]	--	**79%** [a]	0% [a]	--
				TP	**20%** [a]	--	**47%** [a]	**32%** [a]	--
Town of New Riegel-East Branch Wolf Creek (HUC 04100011 10 02)									
300673	East Branch Wolf Creek at Meadowbrook Park	19.65	H	NN	**93%** [a]	--	**86%** [a]	**22%** [a]	--
				TP	**44%** [a]	--	**38%** [a]	**98%** [a]	--
Wolf Creek (HUC 04100011 10 04)									
U04G09	Plum Run east of Fostoria at SR-635	0.79	H	NN	**89%** [a]	--	**82%** [a]	0% [a]	--
U04G11	Harrison Creek east of Fostoria at CR-592	0.38	H	NN	**92%** [a]	--	**85%** [a]	0% [a]	--
Rock Creek-Sandusky River (HUC 04100011 11)									
Spicer Creek-Sandusky River (HUC 04100011 11 05)									
U04Q11	Spicer Creek north of Tiffin at CR-33	0.80	H	TP	--	**6%** [a]	--	**56%** [a]	--

Site ID	Site name	RM	Size	TMDL	High flow (0-10)	Moist cond. (10-40)	Mid-range flows (40-60)	Dry cond. (60-90)	Low flow (90-100)
Green Creek (HUC 04100011 12)									
Beaver Creek (HUC 04100011 12 02)									
U04G26	Emerson Creek at TR-129	1.83	W	TSS	--	--	--	**31%**	**35%**
Green Creek (HUC 04100011 12 03)									
U04K01	Green Creek northeast of Fremont at TR-239	5.06	W	TSS	--	**63%**	**56%**	**38%**	--
Muskellunge Creek-Sandusky River (HUC 04100011 13)									
Muskellunge Creek (HUC 04100011 13 01)									
U04P08	Muskellunge Creek near Fremont at Fangboner Road	16.70	H	TP	--	**40%** [a]	0% [a]	0% [a]	**3%** [a]
				TSS	--	0% [a]	0% [a]	0% [a]	--
mouth Sandusky River (HUC 04100011 13 03)									
300671	Bark Creek at Kelley Road (CR-245)	3.20	H	TP	--	0% [a]	**18%** [a]	--	0% [a]
				TSS	--	0% [a]	**70%** [a]	--	**32%** [a]
Muddy Creek-Frontal Sandusky Bay (04100011 14)									
Little Muddy Creek (04100011 14 03)									
300676	Little Muddy Creek at Kline Road	2.50	W	NN	--	**99%** [a]	**98%** [a]	**97%** [a]	--
				TP	--	--	**42%** [a]	**52%** [a]	--
				TSS	--	**5%** [a]	**34%** [a]	**37%** [a]	--
300678	Fishing Creek at Weickert Road	0.20	H	TP	--	0%	**50%**	**64%**	--
Muddy Creek (04100011 14 04)									
U04S01	Muddy Creek downstream of Lindsey at CR-153	9.79	W	TP	--	0% [a]	0% [a]	**28%** [a]	--
Sandusky River mainstem from Tymochtee Creek to Wolf Creek (04100011 90 01)									
U04T01	Sandusky River at Old Fort at County Road 51	26.94	LR	TSS	--	**85%**	**33%**	**20%**	--
Sandusky River mainstem from Wolf Creek to Sandusky Bay (041000 90 02)									
500820	Sandusky River at Fremont	20.25	LR	NN	**64%**	**74%**	**55%**	**28%**	--
				TP	**30%**	**60%**	**45%**	0%	--
				TSS	**89%**	**81%**	**37%**	0%	--
U04T02	Sandusky River just upstream of Ballville Dam	18.05	LR	NN	--	**76%**	**42%**	**37%**	--
				TSS	--	**42%**	0%	0%	--
			n/a	NN	--	0%	0%	0%	--

Notes

CR = county road; H = headwaters (less than 20 square miles); HUC = hydrologic unit code; mg/L = milligram per liter; RM = river mile; SR = state route; TP = total phosphorus; TR = township road; TSS = total suspended solids; W = wading (greater than 20 square miles and smaller than requiring a boat).

A double dash ("--") indicates that Ohio EPA water chemistry results are not available for the specified flow zone.

A zero ("0%") indicates that all of the loads calculated from Ohio EPA water chemistry results for the specified flow zone were less than the TMDL.

a. Necessary reductions were calculated at *TMDL sites* using data from the listed *Ohio EPA assessment sites*, with the assumption that the water quality monitored at the *Ohio EPA assessment sites* were representative of water quality at the *TMDL sites*.

9 Water Quality Improvement Strategy

Restoration methods to bring an impaired waterbody into attainment with water quality standards generally involve an increase in the waterbody' s capacity to assimilate pollutants, a reduction of pollutant loads to the waterbody, or some combination of both. A water quality improvement strategy has been developed to identify the priority activities that can be undertaken to achieve water quality improvements, and eventually attainment of the designated use.

Several causes of impairment were identified in the project area; they are summarized in Table 85. The sources of pollutants are further discussed in the source assessment (Section 4) and linkage analyses (Section 5, Section 6, and Section7). The anthropogenic sources of impairment are:

- Agricultural runoff
  - Crop production with subsurface drainage (11 WAUs and both LRAUs)
  - Channelization (8 WAUs)
  - Livestock (feeding or grazing operations) (2 WAUs)
  - Specialty crop production (1 WAU)
  - Manure runoff (1 WAU)
  - Channel erosion/incision from upstream hydromodifications (2 WAUs)
  - Streambank modification/destabilization (1 WAU)
  - Loss of riparian habitat (1 WAU)
- Urban runoff and storm sewers
  - Urban runoff and storm sewers (3 WAUs)
  - Municipal point source dischargers (2 WAUs and 1 LRAU)
  - Combined sewer overflows (2 WAUs)
  - Unspecified urban storm water (1 WAU)
- Failing HSTS and unsewered communities
  - On-site treatment systems (septic systems and similar decentralized systems) (2 WAUs)
  - Sewage discharges in un-sewered areas (2 WAUs)
  - Package plant or other permitted small flows discharges (1 WAU)

Recommended implementation activities, by pollutant source, are presented in the following sections. A detailed watershed implementation plan will be developed after the TMDL development in a separate report.

Table 85. TMDL and necessary reduction summary

WAU or LRAU (04100011)	Waterbody	TMDL Pollutant	Pollutant reduction requirements	Cause(s) of impairment
Tributaries to Sandusky Bay				
01 02	Pipe Creek	TSS	28% - 93%	▪ Sedimentation/siltation
01 03	Mills Creek	TP	69% - 95%	▪ Phosphorus ▪ Organic enrichment (sewage) ▪ Nutrient/eutrophication ▪ Sedimentation/siltation
		TSS	25%	
02 01	Little Pickerel Creek	TSS	--	▪ Sedimentation/siltation ▪ Particle distribution
02 03	Pickerel Creek	TSS	51%	▪ Sedimentation/siltation ▪ Particle distribution
02 04	Buck Creek	$NO_3 + NO_2$	60% - 84%	▪ Phosphorus ▪ Organic enrichment (sewage) ▪ Nutrient/eutrophication ▪ Sedimentation/siltation
	Raccoon Creek	TP	25% - 91%	
		TSS	15%	
02 05	South Creek	TP	8% - 20%	▪ Phosphorus ▪ Organic enrichment (sewage) ▪ Nutrient/eutrophication ▪ Sedimentation/siltation ▪ Particle distribution
		TSS	30%	
Tributaries to the Sandusky River (Lower)				
10 01	East Branch East Branch Wolf Creek.	$NO_3 + NO_2$	79% - 89%	▪ Nutrient/eutrophication ▪ Nitrate ▪ Phosphorus
		TP	20% - 47%	
10 02	East Branch Wolf Creek	$NO_3 + NO_2$	22% - 96%	▪ Nutrient/eutrophication ▪ Nitrate ▪ Phosphorus
		TP	38% - 98%	
10 04	Plum Creek	$NO_3 + NO_2$	82% - 89%	▪ Nitrate ▪ Nutrient/eutrophication
	Harrison Creek	$NO_3 + NO_2$	85% - 92%	
11 05	Spicer Creek	TP	6% - 56%	▪ Nutrient/eutrophication ▪ Organic enrichment (sewage)
12 02	Emerson Creek	TSS	33%	▪ Sedimentation/siltation
12 03	Green Creek	TSS	49% - 63%	▪ Sedimentation/siltation
13 01	Muskellunge Creek	TP	8% - 16%	▪ Nutrient/eutrophication ▪ Phosphorus ▪ Sedimentation/siltation
		TSS	43%	
13 03	Bark Creek	TP	16%	▪ Nutrient/eutrophication ▪ Sedimentation/siltation ▪ Phosphorus
		TSS	32% - 70%	
14 03	Fishing Creek	TP	50% - 64%	▪ Nitrates ▪ Nutrient/eutrophication ▪ Phosphorus ▪ Sedimentation/siltation
	Little Muddy Creek	$NO_3 + NO_2$	97% - 99%	
		TP	42% - 52%	
		TSS	5% - 37%	
14 04	Muddy Creek	TP	28%	▪ Phosphorus
Sandusky River (Mainstem)				
90 01	Sandusky River	TSS	20% - 85%	▪ Sedimentation
90 02		$NO_3 + NO_2$	28% - 74%	▪ Nutrient/eutrophication ▪ Particle distribution ▪ Sedimentation/siltation
		TP	30% - 60%	
		TSS	37% - 89%	

Notes
$NO_3 + NO_2$ = nitrate plus nitrite; TP = total phosphorus; TSS = total suspended solids.
Necessary reductions of zero percent are excluded from this table..

9.1 Point Sources

This section summarizes recommendations that can be implemented using Ohio EPA's regulatory authority to address point sources, excluding regulated storm water.

Additional total phosphorus reductions will be necessary at several facilities according to calculated TMDLs in locations where total phosphorus contributes to ALU impairment. Recommendations for NPDES permits, according to calculated TMDLs, are summarized by discharger and watershed in Appendix K Table K-1 (total phosphorus) and Table K-2 (nitrate plus nitrite). Ohio EPA will work with permit holders to accomplish any needed reductions in loadings. Existing permit conditions involving total phosphorus for facilities not listed in Table K-1 and Table K-2 should remain unchanged.

Many facilities do not have total phosphorus or nitrate plus nitrite monitoring requirements or effluent limits. Thus, the potential load contribution from these facilities to the impaired streams is unknown. The first phase of the recommended permit conditions is monthly effluent sampling to determine total phosphorus effluent loads. Depending on the results of the monthly sampling during the first phase (i.e., a five-year permit cycle), the sampling requirements can be continued or altered and total phosphorus limits of 1 mg/L can be incorporated into the permit.

All the non-storm water point sources discharging wastewater have effluent limits on TSS; however, several facilities have exceedances of permitted effluent limits and discharge at rates exceeding the permit design flow. Recommendations for NPDES permits, according to calculated TMDLs, are summarized by discharger and watershed for TSS in Table K-3 of Appendix K. Existing permit limits for TSS were retained (i.e., no changes were recommended) for facilities with non-storm water individual NPDES permits if the permits were at or below the in-stream targets (Ohio EPA 1999). Recommendations for regulated MS4 storm water are summarized in Table K-3 of Appendix K.

CSOs and SSOs were documented at many permitted treatment facilities. Through Ohio's regulatory authority, required improvements and compliance schedules are written into these facilities' NPDES permits. As the long term control plans are implemented and SSOs are eliminated, the potential impacts of CSOs and SSOs upon water quality will be reduced considerably.

Finally, malfunctioning HSTS, some of which are covered under Ohio's general permit, contribute pollutant loads to some impaired WAUS. While malfunctioning HSTS are located throughout the Sandusky basin, at the basin-scale along the Sandusky River, their loads are not as significant as the loads from agriculture and urban storm water runoff. Malfunctioning HSTS do contribute elevated nitrate loads and are more significant at a finer scale. Locally, county health departments, SWCDs and ODH are addressing malfunctioning HSTS and un-sewered communities

9.2 Agricultural Runoff

Ohio's approach to address nonpoint source loading concerns in agricultural watersheds that discharge to the Sandusky River (lower) includes practices and actions designed to reduce sources of nutrients and sediment. The agricultural nonpoint sources program focuses on several broad strategies including:

- Upland management
- Livestock management
- Drainage water management
- Riparian management

In addition, new information regarding excessive nutrient levels that result in harmful algae blooms has elevated the importance of educational activities such as the "4R Initiative" on nutrient stewardship. The 4Rs include the right source of nutrients, the right rate, at the right time, and the right place.

The sections that follow summarize key aspects of Ohio's program to control agricultural runoff and reduce pollutant loads in the tributaries to Sandusky Bay and frontal Lak Erie, tributaries to the Sandusky River (lower), and Sandusky River (lower) mainstem. Additional details are described in the *Ohio Nutrient Reduction Strategy* (Ohio EPA, 2013b) and in the *Ohio Lake Erie Phosphorus Task Force II Final Report* (Ohio EPA 2013a).

9.2.1 Upland Management Strategies

The emphasis of upland management strategies is on conservation planning so that water quality related resource concerns are prioritized for agricultural BMP selection and implementation. In particular, upland management strategies recognize the importance of soil health. As stated in the *Ohio Lake Erie Phosphorus Task Force II Final Report*, soil health determines how rainwater and dissolved nutrients either infiltrate or run off into ditches and streams (Ohio EPA 2013a).

- Increase whole farm conservation planning so that water quality resource concerns are prioritized for agricultural BMP selection and implementation.
- Reduce erosion and sediment loss to achieve measurable improvements in water quality through:
  - Grassed waterways in strategically located areas
  - Treatment filter areas
  - Cover crops
  - Reduced tillage practices
  - Install retention devices to interrupt surface runoff and drainage tile discharge
  - Controlled traffic farming
- Nutrient management by limiting manure and fertilizer application to only those levels that meet the agronomic need of crops in the rotation.
- Increase the retirement of marginal and highly vulnerable lands.

9.2.2 Livestock Management Strategies

Improper management of livestock manure and continued over-application of manure on saturated or frozen soils presents significant challenges. In addition, uncontrolled runoff from livestock feeding areas or other livestock production areas often flows directly into ditches or small streams. Finally, improperly managed grazing is a source of both erosion and nutrient loading into streams.

Recommended livestock management practices identified in the *Ohio Nutrient Reduction Strategy* (Ohio 2013b) include:

- Improve manure management practices.
- Effectively manage runoff in livestock production areas.
- Improve grazing practices.
- Reduce phosphorus content in animal feed.

9.2.3 Drainage Water Management Strategies

The *Ohio Lake Erie Phosphorus Task Force II Final Report* describes drainage management as those practices designed to improve the soil environment for vegetative growth by managing water for irrigation and drainage (Ohio EPA 2013a). Drainage management encompasses both surface and subsurface practices. Some practices function to move water quickly off fields (e.g., subsurface tile) while others function to provide water retention (e.g., wetlands and drainage water management structures), runoff dispersal and infiltration (e.g., grassed buffers). These practices are intended to improve productivity of poorly drained soils by providing greater soil aeration and enabling faster soil drying and warming in the spring.

Recommended drainage water management practices identified in the *Ohio Nutrient Reduction Strategy* (Ohio EPA 2013b) include:

- Reduce the rate and amount of runoff through:
    - Designing and installing more effective edge of field buffer areas to retain and/or disperse stormwater runoff from fields (e.g., filter strips / areas)
    - Install water control devices that retain nutrient laden waters in subsurface drain tiles prior to release into streams
    - Increase cover crop planting as part of a long-term conservation crop rotation designed to rebuild the soil's organic matter and increase the soil's water holding capacity
    - Install drainage water devices on surface and subsurface tile drain outlets
    - Enable implementation of 2-stage ditch and self-formed channels in channelized systems where appropriate
- Increase treatment of field runoff through:
    - Direct concentrated field runoff and drainage from livestock feeding areas through wetland and/or infiltration areas
    - Enable implementation of 2-stage and self-formed channels in channelized systems where appropriate
    - Increase the use of fixed-bed bioreactors containing coarse sand and organic carbon such as tree bark or wood chips
    - Increase the use of soil amendments such as alum, gypsum or water treatment residuals to increase the absorption of phosphorus and decrease the amount of phosphorus in runoff.

9.2.4 Riparian Management Strategies

The buffering capacity of riparian areas has steadily declined as riparian forested and wetland areas have been converted to agriculture under increasing pressure to increase production rates. Reestablishing, restoring and enhancing existing riparian wetlands to serve as detention areas for tile discharges and other drainage from agricultural fields is critical to reducing the adverse effects of nutrient and sediment laden discharge water.

Recommended riparian management practices identified in the *Ohio Nutrient Reduction Strategy* (Ohio EPA 2013b) include:

- Increase riparian wetland retention areas.
- Increase riparian forested areas.
- Establish "no-plow" zones in riparian area.

Several U.S. Department of Agriculture programs offer cost-sharing incentives for increasing and/or restoring riparian wetland areas. Similarly, Department programs such as the Conservation Reserve Enhancement Program (CREP), the Conservation Reserve Program (CRP), the Environmental Quality Incentive Program (EQIP), and others provide cost-share incentives for the reestablishment and expansion of riparian forests.

9.3 Urban Runoff

Urban runoff, including runoff that is regulated through Ohio EPA general permits (i.e. MS4, construction, and industrial), has been identified as a primary source of pollutants including nutrients and sediment in the project area. In addition to runoff, illicit connections between sanitary and storm sewers are also a potential source of pollutants in the urban environment. Recommended activities to address these sources include storm water management and education and outreach programs.

9.3.1 Storm Water Management

Storm water management, including retrofitting of BMPs and planning for future development, can be used to address the sources of pollutants derived from urban runoff and storm sewers. Retrofitting urban areas with storm water BMPs, especially those practices that reduce the volume of runoff from urban areas, can address pollutant loads from existing developed areas. Controlling runoff associated with development typically consists of end-of-pipe measures such as storm water detention and retention. Those controls abate flooding and reduce erosion, thus providing some water quality protection. However, studies show that water quality degradation occurs in developing watersheds despite those controls because of the altered hydrologic regime (Brabec et al. 2002; Booth 2005).

On-site, or decentralized, storm water management increases infiltration and reduces runoff generation by decreasing imperviousness. That is accomplished through appropriate planning, such as that used for low impact development (LID). LID is based on maximizing contiguous open space, protecting sensitive areas—namely floodplains, ground water recharge areas, and wetlands—and preserving existing vegetation (especially trees). Yoder et al. (2000) found that riparian buffers in Ohio can preserve or enhance in-stream habitat and thus mitigate the detrimental effects of high levels of urbanization. A Web-based resource for LID is http://www.lowimpactdevelopment.org/. In LID, houses are closer to one another, roadways are narrower, and bioretention and infiltration techniques are used. LID reduces runoff and can provide cost savings in storm water infrastructure. Additional non-environmental benefits include above average increases in property values.

Decentralized best management practices that promote infiltration and filtration, also referred to as green infrastructure, include bioretention, bioswales, rain gardens, green roofs, infiltration basins and trenches, underground storage, permeable pavement, and storm water wetlands. In addition, rainwater harvesting from using rain barrels and cisterns can reduce the volume of runoff being generated and provide other benefits such as reduced potable water supply demand.

Watersheds that retain relatively large areas of forest are able to better mitigate the effects of increasing imperviousness than those with little forest cover (Booth 2005). Procuring conservation easements and establishing parkland and nature preserves can help retain some of the existing forest cover and facilitate the conversion from open land to forest. Although land preservation alone is not likely to occur at a level necessary to mitigate development effects, it will augment other measures that are taken (e.g., LID or discrete, on-site storm water management).

At the scale of individual residences or business, diverting drainage from rooftops, driveways, and other impervious surfaces away from a centralized collection system (e.g., outlets to either curb-and-gutter drains or storm water sewer lines) to green infrastructure techniques can be used to retain runoff and provide water quality treatment. Minimizing the extent of impervious surfaces by limiting their size or substituting them with permeable surfaces will also achieve the benefit of reduced storm water runoff.

In cases where stream channels are directly altered by development, green infrastructure and regional practices that reduce storm water runoff might not be sufficient to restore biological integrity. In-stream restoration activities, such as stream bank stabilization or dam removal, are used to restore stream channels to more natural conditions and will vary depending on which physical features are impairing aquatic life.

9.3.2 Education and Outreach

Successful implementation of the TMDLs will rely heavily on effective public education and outreach activities that will encourage participation and produce changes in behavior. It is imperative to raise stakeholders' awareness about issues in the watershed and develop strategies to change their behavior in a manner that will promote voluntary participation. Changes in awareness and behavior are surrogate indicators for longer term changes in water quality.

Awareness can be increased through signage, brochures, radio and television advertisements, websites, ordinance enforcement, and a pledge program. The effectiveness of the program could be evaluated through surveys (online or mail-in), focus groups, and evaluating the number of bags used at pet waste stations at parks.

9.4 Watershed Specific Recommendations

Ohio EPA recommends five categories of restoration activities for impaired WAUs and LRAUs in the TMDL project area:

- Bank and riparian restoration
- Home sewage planning and improvement
- Agricultural BMPs
- Storm water BMPs
- Regulatory point source controls

Table L-1 in Appendix L summaries the restoration categories by WAU and LRAU. Specific implementation activities are presented in Tables L-2 through L-9, which are organized by 10-digit HUC and LRAU.

These actions are intended to be inclusive of possible methods to improve water quality in the watershed based on identified causes and sources of impairment. Because Ohio EPA recognizes that actions taken in any individual subwatershed may depend on a number of factors (including socioeconomic, political and ecological factors), these recommendations are not intended to be prescriptive of actions to be taken, and any number or combination might contribute to improvement, whether applied at sites where actual impairment was noted or other locations where sources contribute indirectly to water quality impairment. Further details about individual practices can be found in Appendix L.

9.5 Reasonable Assurances

The recommendations made in this TMDL report will be carried out if the appropriate entities work to implement them. In particular, activities that do not fall under regulatory authority require that state and local agencies, governments, and private groups mount a committed effort to carry out or facilitate such actions. For successful implementation, adequate resources must also be available.

When a TMDL is developed for waters impaired by point sources only, the issuance of a NPDES permit(s) provides the reasonable assurance that the WLAs contained in the TMDL will be achieved. This is because title 40 of the *Code of Federal Regulations* section 122.44(d)(1)(vii)(B) requires that effluent limits in permits be consistent with the assumptions and requirements of any available WLA in an approved TMDL.

When a TMDL is developed for waters impaired by both point and nonpoint sources and the WLA is based on an assumption that nonpoint source load reductions will occur, U.S. EPA's 1991 TMDL guidance states that the TMDL should provide reasonable assurances that nonpoint source control measures will achieve expected load reductions. To that end, Ohio EPA coordinates with organizations and programs that have an important role or can provide assistance for meeting the goals and recommendations of this TMDL. Efforts specific to this watershed are described below.

9.5.1 Local Zoning and Regional Planning

Local zoning is typically controlled at the county or municipality level. Local zoning can be a useful tool for implementing some recommendations of the TMDL, such as stream bank setbacks for developing land. Local governments typically conduct planning to meet the sewage disposal needs of the community. Ohio EPA has established guidelines for planning that are useful in the context of Section 208 and the State Water Quality Management Plan. Local governments that follow these guidelines are more likely to have the results of their planning work incorporated into the Section 208 plan prepared by Ohio EPA. The Areawide Planning Agencies have established their own operating protocols, committees and processes to involve local governments in shaping their 208 plans.

Planning should account for long-range sewer and treatment needs by looking at projections for community growth and development. Comprehensive land use planning, where available, is an excellent tool that can help those assessing the sewage disposal needs of a community or group of communities. In highly populated areas, regional solutions involving several communities have proven to be a cost-effective means to solve sewage disposal problems.

TMACOG is one of Ohio's areawide agencies; it has a local role in developing areawide water quality plans—a portion of the project area is in their service area. TMACOG's website (http://www.tmacog.org/enviro_body.htm) describes the role of the Environmental Council, which oversees and manages the environmental planning functions of TMACOG:

> The Council recommends regional environmental policies and procedures to define and achieve TMACOG's mission for adoption by the Board of Trustees. Through these policies, the strategic, long-term Environmental Council goals of TMACOG are established, and the methods to achieve short-term tactical objectives are determined. The Environmental Council also establishes the administrative support necessary to achieve these goals and objectives.

9.5.2 Local Watershed Groups

The Sandusky River Watershed Coalition, the Firelands Coastal Tributaries Watershed Program, TMACOG, and their many partners have been active in engaging the public in protecting the tributaries to the Sandusky Bay and frontal Lake Erie, tributaries to the Sandusky River (lower), and the Sandusky River (lower) mainstem. These organizations emphasize educating stakeholders, and planning and implementing projects to control nonpoint source pollution from agricultural and rural home sewage sources.

9.5.3 Past and Ongoing Water Resources Evaluation

Ohio EPA has surveyed various sections of the project area. The tributaries to Sandusky Bay and frontal Lake Erie, tributaries to the Sandusky River (lower), and the Sandusky River (lower) mainstem were sampled in 2009 and 2010 (Ohio EPA 2010a, 2011).

According to the *Ohio 2012Integrated Water Quality Monitoring and Assessment Report* (Ohio EPA 2013a), the next scheduled Ohio EPA evaluation of this watershed is in 2024. Because of a number of factors, schedules are subject to change.

All NPDES-permitted wastewater treatment facilities are required to routinely sample their effluent as a condition of their permits. Monitoring parameters and frequencies vary and are dictated by individual permit requirements according to pollutants of concern, plant design flow, and other considerations. In many cases, entities are also required to collect ambient water quality samples upstream and downstream of their discharge location to provide data regarding potential effects on stream water quality. NPDES-permitted dischargers are required to report their self-monitoring results to Ohio EPA monthly as a condition of their permits.

Early communications should take place between Ohio EPA and any potential collaborators to discuss research interests and objectives. Areas of overlap should be identified, and ways to make all parties' research efforts more efficient should be discussed. Ultimately, important questions can be addressed by working collectively and through pooling resources, knowledge, and data.

9.5.4 Adaptive Management

The watershed would benefit from an adaptive management approach to restoring water quality. An adaptive management approach allows for changes in the management strategy if environmental indicators suggest that the strategy is inadequate or ineffective. Adaptive management is recognized as a viable strategy for managing natural resources (Baydack et al. 1999).

If chemical water quality does not show improvement or waterbodies are still not attaining water quality standards after the improvement strategy has been carried out, a TMDL revision would be initiated. Ohio EPA would initiate the revision if no other parties wish to do so.

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