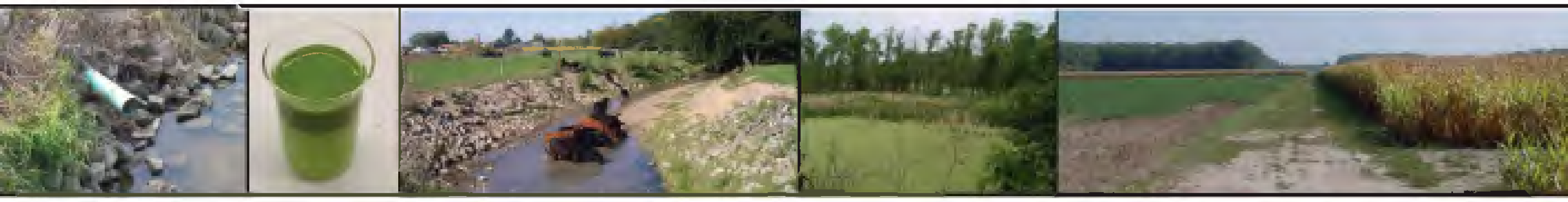
June 30, 2019

# Sandusky Bay Nutrient Reduction Implementation Plan



Prepared for:

Ohio Department of Natural Resources, Office of Coastal Management

Ohio Environmental Protection Agency

U.S. Environmental Protection Agency

Prepared by: Tetra Tech, Inc.

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# Sandusky Bay

# Nutrient Reduction Implementation Plan

Draft Report
Version 1.0
June 30, 2019

**PRESENTED TO**


**Ohio Department of Natural Resources**
Office of Coastal Management
105 West Shoreline Drive
Sandusky, OH 44870

**Ohio Environmental Protection Agency**
P.O. Box 1049
Columbus, OH 43216-1049

**U.S. Environmental Protection Agency**
Headquarters
1200 Pennsylvania Avenue, N. W.
Mail Code: 4101M
Washington, DC 20460

Region 5
77 West Jackson Boulevard
Mail Code: WW-16J
Chicago, IL 60604


**PRESENTED BY**


**Tetra Tech, Inc.**
1468 W. 9th Street, Suite 620
Cleveland, OH 44113

**(216) 861-2950**
tetratech.com



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# ABBREVIATIONS AND ACRONYMS

| Acronyms/Abbreviations | Definition |
|---|---|
| ALU | aquatic life use |
| BMP | best management practices |
| DRP | dissolved reactive phosphorus |
| DSW | Division of Surface Water (Ohio EPA) |
| DWM | drainage water management |
| GLERL | Great Lakes Environmental Research Laboratory (NOAA) |
| HUC<br>HUC12 | hydrologic unit code<br>12-digit hydrologic unit code (also referred to as a “subwatershed” in this report) |
| IBI<br>L-IBI or N-IBI | Index of Biotic Integrity<br>Lacustrine Index of Biotic Integrity or Nearshore Index of Biotic Integrity |
| ICI<br>L-ICI | Invertebrate Community Index<br>Lacustrine Invertebrate Community Index |
| LaMP | Lakewide Management Plan |
| LEAU | Lake Erie assessment unit |
| MIwb<br>L-MIwb or N-MIwb | Modified Index for well-being<br>Lacustrine Modified Index for well-being or Nearshore Modified Index of well-being |
| NOAA | National Oceanic and Atmospheric Administration (U.S. Department of Commerce) |
| NRIP | nutrient reduction implementation plan |
| ODNR<br>-OCM | Ohio Department of Natural Resources<br>Office of Coastal Management |
| Ohio EPA | Ohio Environmental Protection Agency |
| PSS | project summary sheet |
| QHEI<br>L-QHEI | Qualitative Habitat Evaluation Index<br>Lacustrine Qualitative Habitat Evaluation Index |
| SRP | soluble reactive phosphorus |
| SWAT | Soil and Waters Assessment Tool |
| TP | total phosphorus |
| TSD | technical support document |
| TSS | total suspended solids |
| U.S. EPA | U.S. Environmental Protection Agency |
| WWH | warmwater habitat |

| Unit of measure | Definition |
|---|---|
| mg/L | milligram per liter |
| MT | metric ton (1,000 kilograms) |

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# 1 INTRODUCTION

Sandusky Bay is a shallow, freshwater embayment (Figure 1) in northern Ohio along the coast of Lake Erie which is impacted by harmful algal blooms (HABs). Elevated nutrient loads from the Sandusky watershed (hydrologic unit code [HUC] 04100011; Figure 2) contribute to HABs in Sandusky Bay as well as hypoxia in Lake Erie (see definitions in the boxes on this page). The Sandusky watershed is composed of the Sandusky River and several small tributaries that discharge directly to Sandusky Bay. The watershed is over 1,800 square miles and spans portions of 11 counties. The Sandusky watershed is predominantly agricultural and includes several small urban centers (e.g., cities of Fremont, Sandusky, and Tiffin). Most of the nutrient load from the Sandusky River watershed is derived from nonpoint source (NPS) pollution.

This nutrient reduction implementation plan (NRIP) was developed to identify projects to reduce or assimilate nutrient loads that are transported from the Sandusky watershed into Sandusky Bay. Reducing nutrient loads in the uplands and nearshore should help achieve the overarching goals of reducing HABs in Sandusky Bay and hypoxia in the Central Basin of Lake Erie.

State and federal NPS funding for such projects is now closely tied to strategic implementation-based planning that meets the U.S. Environmental Protection Agency's (U.S. EPA) nine minimum elements of a watershed plan for impaired waters. U.S. EPA and the Ohio Department of Natural Resources (ODNR) Office of Coastal Management has provided contract resources to have Tetra Tech, Inc. prepare this NRIP, in close consultation with the Ohio Environmental Protection Agency (Ohio EPA) Division of Surface Water. ODNR and Ohio EPA are working with federal, state, and local government agencies, municipalities, and watershed groups to collaborate with the identification and development of planning efforts and projects to reduce HABs in Sandusky Bay and to reduce hypoxia in the Central Basin of Lake Erie.

**What is a harmful algal bloom?**

Harmful algal blooms occur when colonies of algae grow out of control and produce toxic or harmful effects on people, fish, shellfish, marine mammals and birds.

(NOAA 2016)

**What is hypoxia?**

Low or depleted oxygen in a water body often leads to 'dead zones'—regions where life cannot be sustained.

(NOAA 2017b)

Figure 1: Sandusky Bay (west side, looking west).

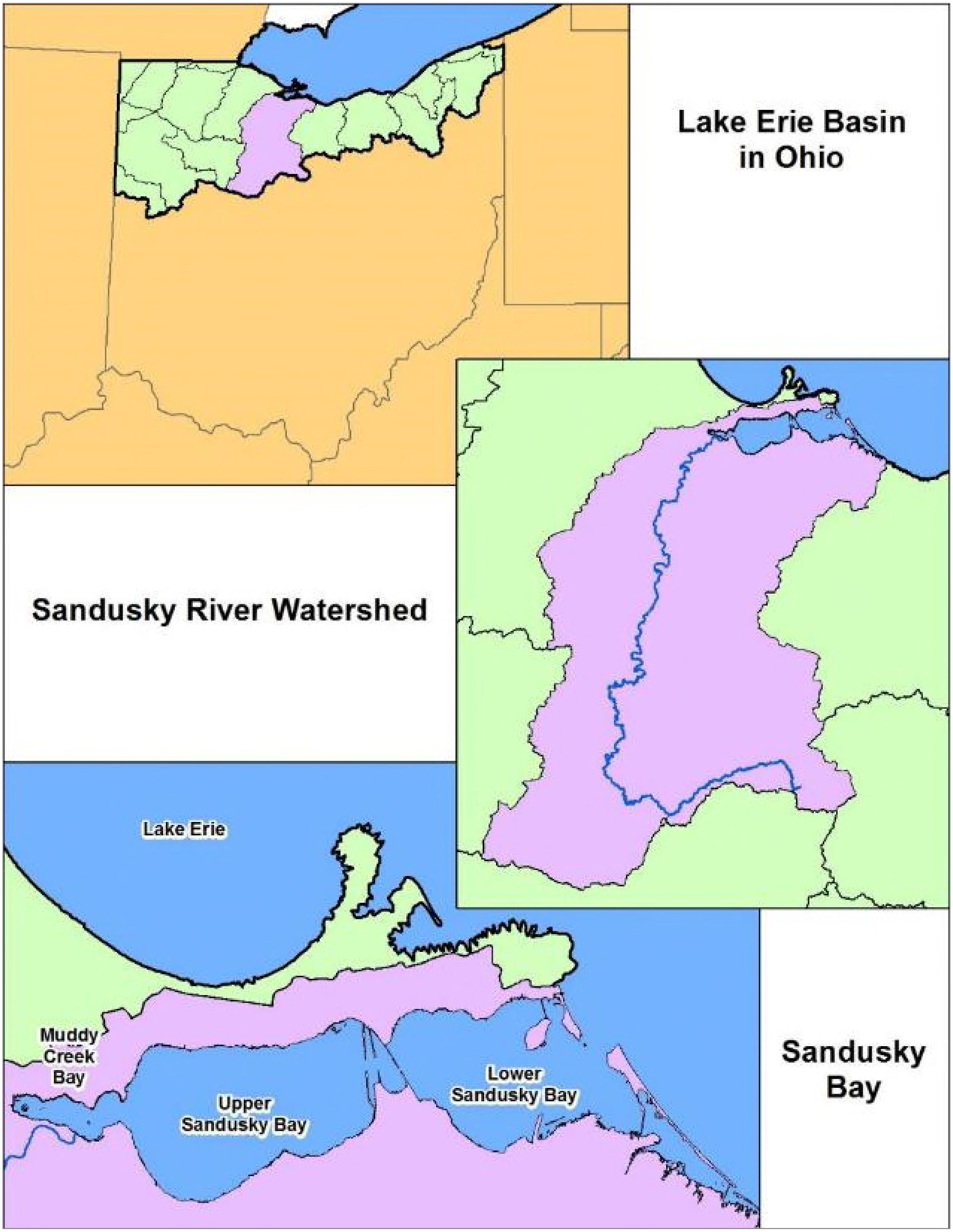



Figure 2. Sandusky watershed.

## 1.1 REPORT BACKGROUND

*Source*: NOAA 2017f.

Figure 3. Satellite image of Lake Erie from March 23, 2012 that shows algal blooms.

This NRIP is the first document of its kind for Sandusky Bay. Many previous studies of the Sandusky watershed focused upon in-stream impairment of biological communities in the Sandusky River, its tributaries, and tributaries to Sandusky Bay. Such studies only considered the near-field effects of the in-stream impairments and did not consider the far-field effects upon Sandusky Bay and Lake Erie. As the HABs develop annually in Sandusky Bay (Figure 3), the focus has shifted to include Sandusky Bay. A more holistic approach for the Sandusky watershed is needed and implementation of best management practices (BMPs) in upland areas and in-water/nearshore areas must be connected to improvements in Sandusky Bay and Lake Erie.

Previous studies of Sandusky Bay, the Sandusky River, or their tributaries with a focus on nutrient and sediment impairments and agricultural BMPs to address such impairments include: technical support documents (Ohio EPA 2003, 2010, 2011), total maximum daily loads (TMDLs; Ohio EPA 2004, 2014b), and watershed action plans (Loftus et al. 2006; Riddle 2006).

Watershed-based plans are typically developed for impaired rivers, streams, and inland lakes. Such planning has not been developed for any of the unique embayments and drowned river mouths that drain to the Great Lakes. Watershed-based planning for Sandusky Bay is more complex than planning for typical watersheds because Lake Erie can flow into Sandusky Bay (see Section 2.2 for a discussion of seiches), because Sandusky Bay can flow into the Sandusky River and smaller tributaries (see Section 3.1.1.1 for a discussion of lacustuaries), and because much of the Sandusky watershed was historically wetlands (see Section 3.1.1.2 for a discussion of the Great Black Swamp). Results from two water quality models were used to represent the complexities of the Sandusky Bay system and evaluate nutrient loading:

- A three-dimensional water quality model was developed for Sandusky Bay to evaluate nutrient distribution and movement within the bay and evaluate nutrient loading to Lake Erie.
- A water quality model for the Sandusky watershed, created to support the development of TMDLs, was updated to help determine the impacts of upland loads upon Sandusky Bay.

This NRIP considers far-field effects of nutrient loading from the Sandusky watershed to Sandusky Bay and Lake Erie. Nutrient concentrations and loads are quantified for both (1) watershed tributaries that discharge to Sandusky Bay and (2) Sandusky Bay net discharge to Lake Erie. Unlike traditional watershed-based planning for impaired waters, this NRIP addresses Sandusky Bay, in addition to impaired watershed tributaries and the impaired bay shoreline and nearshore. Sandusky Bay water quality is characterized, the bay itself is included within critical areas, and in-water BMPs to address nutrient loading are identified.

## 1.2 WATERSHED PROFILE AND HISTORY

The Sandusky watershed drains 1,827 square miles across 11 counties (Crawford, Erie, Hardin, Huron, Marion, Ottawa, Richland, Sandusky, Seneca, Wood, and Wyandot), with most 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. The Sandusky River flows through the cities of Bucyrus, then Upper Sandusky, Tiffin (Figure 4), and Fremont; the Sandusky River is a state scenic river from Upper Sandusky to Fremont. The Ohio turnpike (Interstate 80/90) runs through the northern portion of the Sandusky watershed (Figure 5); 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 4: Sandusky River in Tiffin.

The persistent impact of HABs in Sandusky Bay and hypoxia in Lake Erie are due to upland phosphorus-loading; the need to increase focused implementation efforts drove the development of this NRIP. The landscape of the Sandusky watershed has been significantly altered over the past century as the watershed was developed. Streams were straightened and channelized and crop fields were tiled (i.e., systematically drained via subsurface drainage tiles). The Sandusky Bay coastline has also been altered: in the west, coastal wetlands were drained and diked to prevent flooding of crop fields. To the east, the city of Sandusky developed and is now heavily urbanized with coastal infrastructure (e.g., piers, marinas).

Crop fields and drain tiles alter the natural hydrologic regime and result in flashy flows with higher streamflow velocities and less baseflow. Altered hydrology combined with degraded habitat and nutrient enrichment in the Sandusky watershed have impaired aquatic community health. These flashy flows carry elevated nutrient loads to Sandusky Bay and directly contribute to in-bay nutrient eutrophication, which then leads to HABs and hypoxia.


*Source:* Ohio EPA 2014, Figure 6.

Figure 5. Major roads and municipalities in the Sandusky watershed.

## 1.3 PUBLIC PARTICIPATION AND INVOLVEMENT

It is important to have diverse involvement in the development of any restoration plan. This should include not only the public but businesses, academia, and non-profit groups among others. In the Sandusky watershed, many organizations and people are working to restore the watershed and Sandusky Bay.

For the past six decades, the health of Lake Erie has been the concern of many businesses, government agencies, academia, and local organizations. Much of the attention has been focused upon algal blooms and hypoxia, with great efforts to reduce point source nutrient loads in the 1960s through 1980s. Since the mid-1990s when algal blooms returned, the focus has shifted to nonpoint sources.

Ohio EPA (2003, 2010, 2011) evaluated aquatic community health in the Sandusky watershed and identified causes and sources of impairment to in-stream designated uses. TP, nitrate + nitrite, and total suspended solids TMDLs were developed to address impairments caused by nutrient enrichment or eutrophication, phosphorus, nitrate, sedimentation/siltation, and low dissolved oxygen (Ohio EPA 2004, 2014b).

The Sandusky River Watershed Coalition (SRWC) is a grassroots watershed group that seeks to "to provide leadership for the conservation and enhancement of the Sandusky River watershed and its natural resources through community-based planning, education and action" (SRWC 2017). The organization was formed in 1997 and is presently administered as part of Heidelberg University's National Center for Water Quality Research. SRWC was involved with the TMDL process and is in the process of working with partners to develop new projects to address impairments in the watershed. SRWC develops and distributes educational materials focused upon nutrient- and sediment-load reduction.

The Sandusky Bay Initiative developed a Strategic Restoration Implementation Plan and designed in-water habitat restoration projects. The city of Sandusky coordinated the Initiative and involved key stakeholders as the plan and projects were developed. In the Sandusky project area, key partners to develop and implement projects to reduce nutrient and sediment loads included:

- **Federal agencies:** National Oceanic and Atmospheric Administration (NOAA), U.S. EPA, U.S. Geological Survey
- **State agencies:** Ohio Department of Agriculture, ODNR, Ohio EPA
- **Local agencies:** Erie County, Ottawa County, Sandusky County, city of Sandusky
- **Universities:** Bowling Green State University, Heidelberg University, Ohio State University
- **Non-profit organizations:** Black Swamp Conservancy, SRWC, The Nature Conservancy, Western Reserve Land Conservancy

This Sandusky Bay NRIP covers Muddy Creek Bay, Upper Sandusky Bay, Lower Sandusky Bay and the lower segments of many tributaries to Muddy Creek Bay and Upper Sandusky Bay. Key partners are anticipated to develop NPS-IS plans for the HUC-12 subwatersheds throughout the Sandusky watershed. These future NPS-IS plans will address upland nutrient and sediment loading from across the Sandusky watershed, including the upper portions of several HUC-12 subwatersheds whose lower segments are addressed in this NRIP.

This NRIP was authored by Tetra Tech, Inc., under contracts with U.S. EPA Headquarters and the ODNR-OCM, with assistance from U.S. EPA Region 5, ODNR, and Ohio EPA. Much of Sections 1, 2, and 3 relied upon technical support documents (TSDs) published by Ohio EPA, TMDLs developed by Tetra Tech and Ohio EPA, information from ODNR-OCM, and publications by several federal and state agencies. Section 4 relied upon project information provided by ODNR-OCM and local partner organizations.

# 2 BAY CHARACTERIZATION AND ASSESSMENT SUMMARY

Sandusky Bay is in northern Ohio along the Lake Erie coast. Ohio has 262 miles of shores (mainland and island) along Lake Erie, including Sandusky Bay, and 3,277 square miles of Lake Erie water (ODNR 2007b). Sandusky Bay is part of the Western Basin of Lake Erie[1] and discharges to the Sandusky Subbasin of Lake Erie.

## 2.1 SUMMARY OF THE WESTERN BASIN OF LAKE ERIE

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). Several major urban centers are on the shores of Lake Erie (Figure 6). 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).

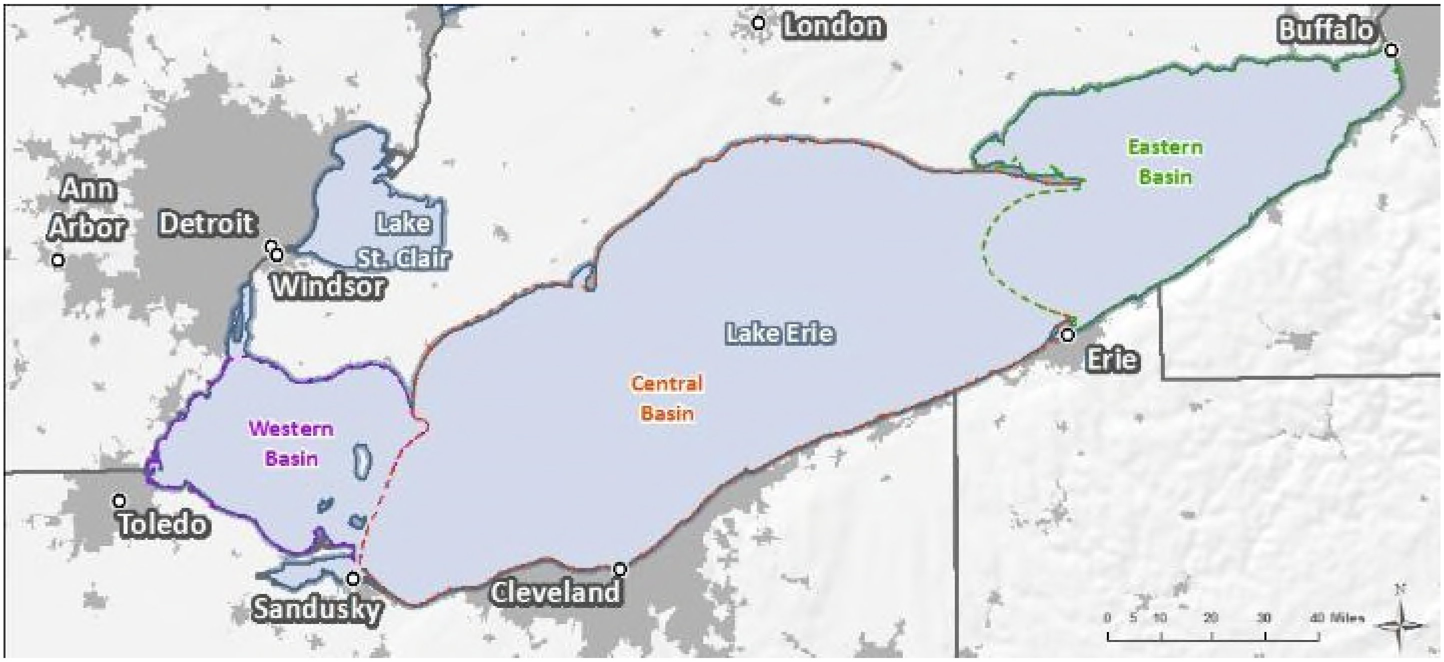



Figure 6. Lake Erie and major urban areas along the lake.

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 2010). 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 2010).

[1] By rule, Ohio considers the Sandusky watershed to be in the Western Basin of Lake Erie: Ohio Revised Code 905.326(E)(4). U.S. EPA and other organizations consider the Sandusky watershed to be part of the Central Basin of Lake Erie.

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, Vermilion, Black, Rocky Cuyahoga, Grand, and Ashtabula rivers) are about evenly divided between row-crop agriculture, urban, and forest (Ohio EPA 2010). The dominant land uses of the Ohio tributaries to Lake Erie are important because most phosphorus loading to Lake Erie is from “storm-pulsed runoff from the landscape into the tributaries that drain to Lake Erie” (Ohio EPA 2010, p. 35). Ohio EPA (2013a, p.5) has found that 61 percent of the total phosphorus load delivered to Lake Erie is from cultivated cropland.

Additional characteristics of Lake Erie with special focus upon nutrient and other water quality issues are 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 II Final Report* (Ohio EPA 2013b)
- *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)

## 2.2 SUMMARY OF SANDUSKY BAY

Sandusky Bay is a 15.8-mile-long freshwater embayment that is shallow with a relatively flat bottom and easily erodible clay banks (Lee 1986; Figure 7). Sandusky Bay is composed of two basins "connected by a narrow constriction" (Lee 1986, p. 61). "This narrows is further constricted by causeways" (Richards 1985, p. 10): the Thomas A. Edison Memorial Bridge (state routes 2 and 269), the former Sandusky Bay Bridge[2], and the Norfolk Southern railroad bridge (Figure 8). Sandusky Bay upstream and west of the narrow constriction is referred to as *Upper Sandusky Bay* (also known as the Western or Inner bay), while the bay downstream and east of the constriction is called *Lower Sandusky Bay* (also known as the Eastern or Outer bay). *Lower Sandusky Bay* east of the Cedar Point Road causeway is also referred to as *East Sandusky Bay*. Upper Sandusky Bay has a larger surface area but is shallower than Lower Sandusky Bay (Table 1).

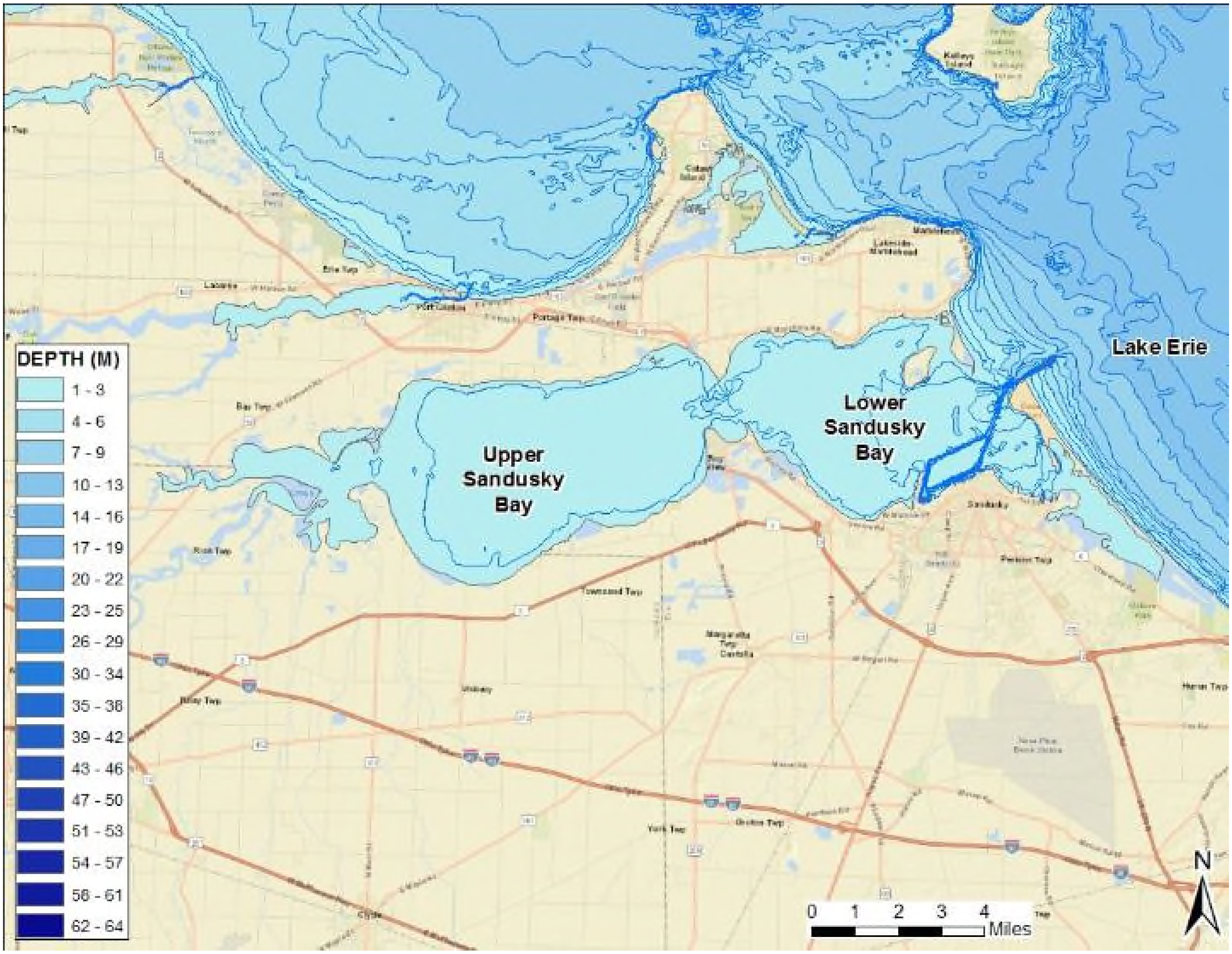



Figure 7. Bathymetry of Sandusky Bay and Lake Erie.

[2] The former two-lane bridge was decommissioned and the middle section removed. The northern causeway approach is now an ODNR-managed public access fishing pier (ODNR 2017).


Source: Sandusky Bay Initiative.

Figure 8. Bridge corridor at constriction between Upper and Lower bays (looking west).

Table 1. Sandusky Bay depth and area

| Characteristic | Sandusky Bay (Upper and Lower Bays) | Upper Sandusky Bay (Western) [a] | Lower Sandusky Bay (Eastern) [b] |
|---|---|---|---|
| Mean depth (feet) [c] | 5.25 | 1.0 | 10.0 |
| Shoreline lengths (miles) [d] | 99.4 | 36.1 | 66.3 |
| Surface Area (square miles) [c] | 56.7 | 32.2 | 24.5 |
| Drainage area (square miles) | 1,813 [e] | 1,702 [f] | 111 [g] |

*Notes*

a. Upper Sandusky Bay, also known as Western Sandusky Bay or Inner Sandusky Bay, includes Muddy Creek Bay.

b. Lower Sandusky Bay, also known as Eastern Sandusky Bay or Outer Sandusky Bay, includes East Sandusky Bay.

c. Lee 1986, p. 61-62.

d. Lengths were calculated using the waterbodies of the National Hydrography Dataset, excluding islands, bridges, and causeways.

e. Area of the Sandusky watershed (HUC 04100011) less the Sawmill Creek subwatershed (HUC 04100011 01 01).

f. Area of the Sandusky watershed (HUC 04100011) less the Mills Creek-Frontal Lake Erie subwatershed (HUC 04100011 01), less 31 percent of the Frontal South Side Sandusky Bay subwatershed (HUC 04100011 02 01), and less 27 percent of the North Side Sandusky Bay Frontal subwatershed (HUC 04100011 14 05).

g. Area of the Mills Creek-Frontal Lake Erie subwatershed (HUC 04100011 01), 69 percent of the Frontal South Side Sandusky Bay subwatershed (HUC 04100011 02 01), and 73 percent of the North Side Sandusky Bay Frontal subwatershed (HUC 04100011 14 05)

"Water flow in the bay is influenced strongly by lake level and by wind stresses in the bay" (Richards 1985, p. 10). Seiches in Sandusky Bay are caused by both wind across the bay and from seiches in Lake Erie. Seiches are important from a nutrient perspective because they can lead to re-suspension of bottom sediment, which includes sediment-bound phosphorus.

**What is a seiche?**

A seiche is a standing wave oscillating in a body of water.

Seiches are typically caused when strong winds and rapid changes in atmospheric pressure push water from one end of a body of water to the other. When the wind stops, the water rebounds to the other side of the enclosed area. The water then continues to oscillate back and forth for hours or even days.

(NOAA 2017e)

Sandusky Bay supports a diverse fishery including bluegill, bullhead, carp, channel catfish, crappie, freshwater drum, largemouth bass, northern pike, yellow perch, and white bass (ODNR n.d.). Every spring, walleye swim up the Sandusky River to spawn. Abundant waterfowl along the shoreline include black duck, blue-winged teal, green-winged teal, mallard, wood duck (ODNR n.d.). Songbirds, shorebirds, and raptors migrate during the fall and winter.

## 2.3 SUMMARY OF BIOLOGICAL TRENDS

Lake Erie, and thus Sandusky Bay, is designated exceptional warmwater habitat. While biological criteria were established for rivers and streams throughout the state, Ohio EPA has not promulgated biological criteria for lacustuaries or nearshore areas of the Lake Erie assessment units (LEAU). Instead, Ohio EPA uses biological benchmarks to assess attainment of aquatic life uses (ALU) for lacustuaries and nearshore areas. The bottom substrate of nearshore Sandusky Bay is sand and considered soft. The soft, nearshore Index of Biotic Integrity (N-IBI-soft) benchmark is a score of 31 and the soft, nearshore Modified Index of well-being (N-MIwb-soft) benchmark is a score of 7.2 (Ohio EPA 2016a).

Fish data were collected from 10 sites between 1996 and 2016[3] (Figure 9) but only data published in Ohio's *Integrated Report* (Ohio EPA 2016c,d) were evaluated in this NRIP. Fish data for Upper Sandusky Bay (Table 2) and Lower Sandusky Bay (Table 3) often do not attain biological benchmarks. Captured fish species are reflective of high turbidity.[4]

[3] ODNR and the University of Toledo collected fish data in 2017 that was not available before the publication of this NRIP. Data for the following sites are also available.

Site 301568 was sampled in 1996 (n=3), 2011 (n=3), 2012 (n=4), 2013 (n=1), 2014 (n=1), and 2015 (n=1).

Sites 301570 and 301572 were sampled in 1996 (n=3) and 2012 (n=2).

Site 302432 was sampled in 2011 (n=3), 2012 (n=4), 2013 (n=1), 2014 (n=1), 2015 (n=1), and 2016 (n=1).

Site 302433 was sampled in 2011 (n=2), 2012 (n=1), 2013 (n=1), 2014 (n=1), and 2015 (n=1).

Site 302433 was sampled in 2011 (n=2) and 2012 (n=1).

Site 302435 was sampled in 2011 (n=2), 2012 (n=4), and 2014 (n=1).

Site 302436 was sampled in 2011 (n=2), 2012 (n=2), and 2016 (n=1).

Site 302437 was sampled in 2011 (n=3), 2012 (n=2), and 2016 (n=1).

Site 302446 was sampled in 2012 (n=1).

[4] Scott Winkler, Ohio EPA, electronic communication, January 24, 2018.

Table 2. Overall biological indices scores in Upper Sandusky Bay

| Location | Year | N-IBI | N-MIwb | Status | Site ID |
|---|---|---|---|---|---|
| Southeast of Port Clinton at End of Willow Inn Road | 2012 | 28 | 7.7 | Partial | 302436 |
| South of Port Clinton at Bay/Portage Township Line | 2012 | 31 | 8.7 | Full | 301570 |
| Between White's Landing and Sunset Harbor | 2012 | 30 | 7.5 | Partial | 302437 |
| At east edge of Willow Point Wildlife Area | 2012 | 28 | 7.7 | Partial | 301572 |

*Source:* Ohio EPA 2016d.

*Note:* Scores in green meet the lacustrine benchmarks while scores in red do not meet lacustrine benchmarks.

Table 3. Overall biological indices scores in Lower Sandusky Bay

| Location | Year | N-IBI | N-MIwb | Status | Site ID |
|---|---|---|---|---|---|
| West of Sandusky between Venice and Bay Bridge | 2012 | 18 | 8.8 | Partial | 302446 |
| At southern tip of Johnson's Island | 2014 | 30 | 8.8 | Partial | 301568 |
| At Cedar Point Causeway | 2014 | 34 | 9.1 | Full | 302435 |
| East of Sandusky just west of Plum Brook | 2011 | 31 | 8.4 | Full | 302434 |
| East of Sandusky at city boundary causeway | 2014 | 29 | 8.8 | Partial | 302432 |
| East of Sandusky at farthest east point of bay | 2015 | 18 | 5.5 | NON | 302433 |

*Source:* Ohio EPA 2016d.

*Note:* Scores in green meet the lacustrine benchmarks while scores in red do not meet lacustrine benchmarks.


Figure 9. Fish sampling sites in Upper Sandusky Bay and Lower Sandusky Bay.

## 2.4 SUMMARY OF HARMFUL ALGAL BLOOMS AND HYPOXIA

Since the beginning of the Industrial Revolution, anthropogenic phosphorus loading to Lake Erie had been increasing, until the 1960s and 1970s when HABs began to form in Lake Erie. The Great Lakes Water Quality Agreement (GLWQA) originally addressed HABs through the reduction of phosphorus loading from point sources in the 1970s and 1980s (Lake Erie LaMP 2011). However, in the "mid- to late-1990s, large late-summer algal blooms began to reappear sporadically in western Lake Erie and have been increasing in frequency ever since" (Lake Erie LaMP 2011, p. 7). The more recent and larger algal blooms may be caused by increasing levels of dissolved reactive phosphorus (DRP) derived from farm practices and DRP loading may be exacerbated by more intense runoff events (Scavia et al. 2014).

Figure 10. Lake Erie water sample from September 19, 2017

The *Binational Nutrient Management Strategy* (Lake Erie LaMP 2011, p. 10) describes the nutrient loading to Lake Erie from its tributaries, such as the Sandusky River, as follows

> The majority of total phosphorus loading to Lake Erie is the result of inputs from a few major tributaries [...] These larger rivers contain a mix of non-point source pollution, including agricultural and urban runoff, and point source pollution, such as treated municipal sewage. While phosphorus inputs from these tributaries may be the key driver of intensifying central basin hypoxia and eutrophication on a lakewide basis, localized inputs from smaller tributaries and other sources play a primary role in exacerbating nuisance *Cladophora* growth in the nearshore waters. As well, the nearshore phosphorus shunt, and changes in the timing, frequency and intensity of storm events (possibly related to changes in global climate patterns) may be exacerbating total phosphorus inputs, resulting in accelerated eutrophication.

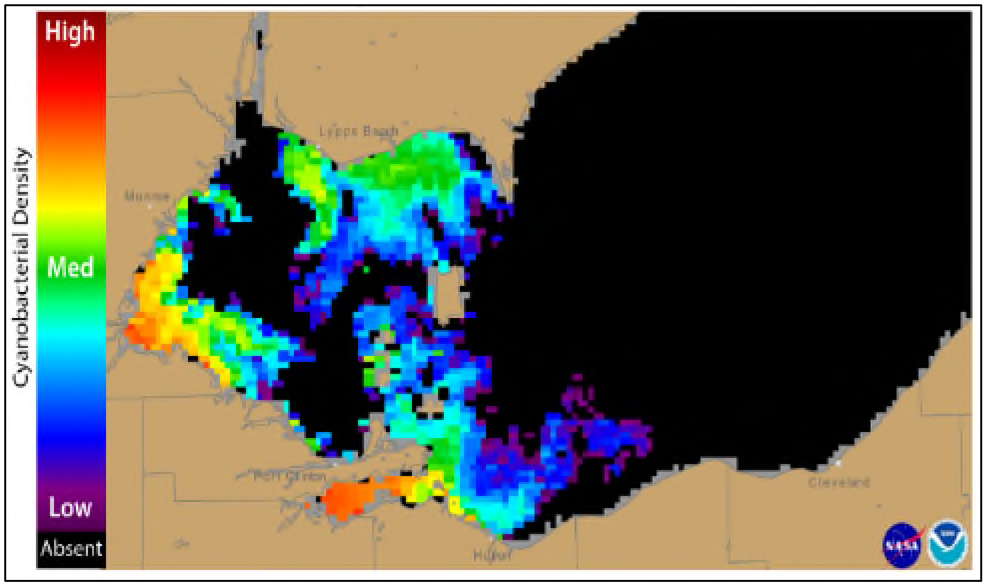
Today, the National Oceanic and Atmospheric Administration (NOAA) Great Lakes Environmental Research Laboratory (GLERL) forecasts and monitors HABs and hypoxia in Lake Erie and Sandusky Bay. GLERL works with the Cooperative Institute for Great Lakes Research to study HABs and hypoxia using satellite imagery, remote sensing, buoys, and advanced genetic techniques (NOAA 2017a). GLERL maintains a web portal (NOAA 2017a)[5] where information regarding Lake Erie HABs and hypoxia is presented, including the weekly Lake Erie HAB Bulletin and the Lake Erie Hypoxia Warning System.

### 2.4.1 Harmful Algal Blooms in Sandusky Bay and Lake Erie

Sandusky Bay is hypereutrophic (Conroy et al. 2007) and cyanobacteria blooms often persist in the bay for much of the summer and into early fall (Figure 11). In 2016 and 2017, cyanobacteria blooms of *Planktothrix* persisted in Sandusky Bay from June or July through October (NOAA 2017a)[6]. For much of the summer and early fall, the cyanobacteria blooms extended into Lake Erie.

[5] Great Lakes Harmful Algal Blooms (HABs) and Hypoxia. https://www.glerl.noaa.gov/res/HABs_and_Hypoxia/.

[6] Other cyanobacterial genera (*Aphanizomenon*, *Chroococcus*, *Microsystis*, and *Oscillatoria*) were also identified in Sandusky Bay (Conroy et al. 2007).




*Source:* NOAA 2017a

Figure 11. Cyanobacteria index from data collected October 1, 2017

The objective of Annex 4 (i.e., the Nutrients Annex) of the GLWQA is to develop "load reduction strategies on Western Basin cyanobacteria blooms, Central Basin hypoxia, and Eastern Basin *Cladophora*" (GLWQA 2015, p. 1). Annex 4 used ensemble modeling and phosphorus loading data to select a phosphorus load target that would result in a mild bloom (or smaller), like the blooms that occurred in the years 2004 and 2012. Annex 4 set spring (March - July) goals of 860 MT TP and 186 MT DRP for the Maumee River at Waterville and a 40 percent reduction of TP and DRP for tributaries to the Western Basin (GLWQA 2015). The 40 percent reduction is derived from spring TP and DRP loads from the Maumee River and their relationship to HABs in the Wester Basin. The 40 percent spring reduction is applicable to the nearshore of Sandusky Bay, even though it is not part of the Western Basin in Annex 4 publications. Annex 4 (GLWQA 2015, p. 38) states that

> The Sandusky River flows into Sandusky Bay that empties into the Central Basin. It carries a large phosphorus load and is an obvious priority to reduce Central Basin hypoxia. However, the cyanobacteria blooms that occur annually in Sandusky Bay start the earliest, last the longest, and reach the greatest algal cell densities of any in Lake Erie. For this reason, while not contributing to Western Basin cyanobacteria blooms, the Task Team believes that spring reductions in P loads should be a priority for this watershed in addition to annual reductions.

Annex 4 further qualifies the 40 percent reduction for the Sandusky River by stating that "the impacts in confined Sandusky Bay may require even more than the 40% load reduction" (GLWQA 2015, p. 43).

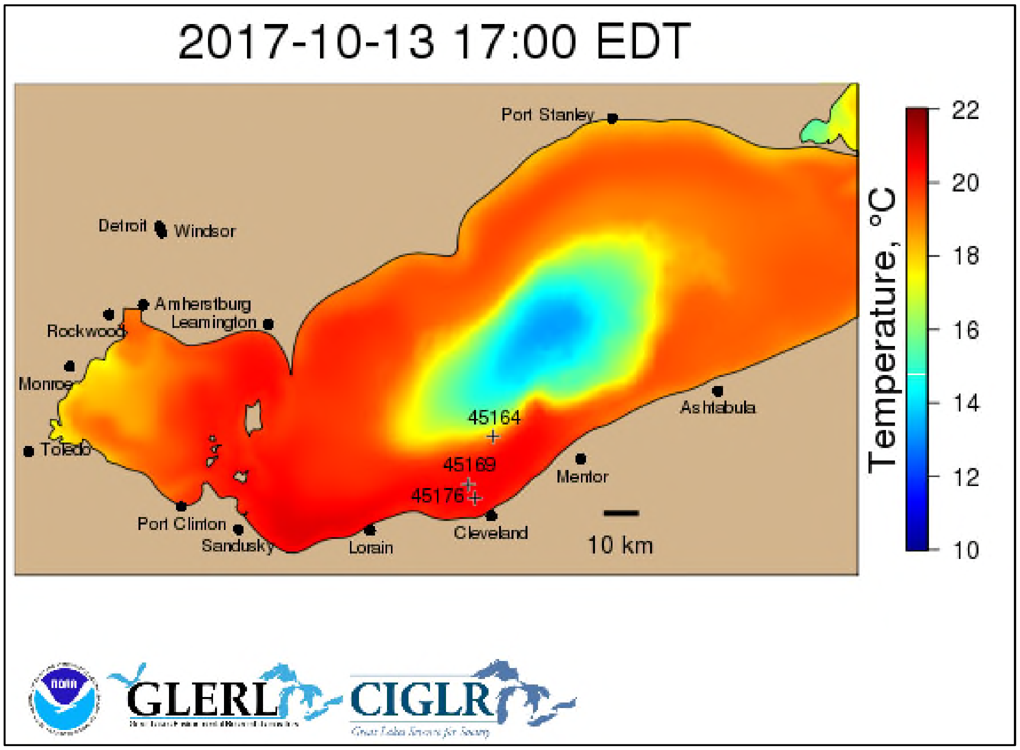
## 2.4.2 Hypoxia in the Central Basin of Lake Erie

Hypoxia affects the Central Basin of Lake Erie when the cold bottom waters become anoxic during the late summer (ODNR 2007a). Research has shown that dissolved oxygen depletion rates from 1987 through 2005 reflect TP loads (Scavia et al. 2014). Nutrient loads discharged from the Sandusky watershed to Sandusky Bay and ultimately Lake Erie result in eutrophication and algal blooms. During the evening, thick layers of algae prevent oxygen from dissolving into the water and after the algae die and sink, oxygen is consumed in the deeper, cooler water when bacteria decompose the algae.

Hypoxia occurs in the Central Basin because its cold bottom layer is relatively small and bacteria can consume all the dissolved oxygen in this layer in a single summer (ODNR 2007a). As discussed in Section 2.1, the Western Basin is shallow, and the Eastern Basin is considerably deeper than the Central Basin. Water in the Western Basin is well-mixed, without an isolated, cold bottom layer. "The Eastern Basin of the lake is much deeper, so bacteria have a greater volume of cold, well- oxygenated water to use in the short time period when conditions are right for an anoxic layer of water to occur" (ODNR 2007a, p. 103).

Several abiotic and biotic factors influence Central Basin hypoxia. The resulting hypoxic waters in the Central Basin can then be moved by wind, seiches, and internal waves (NOAA 2017c; Scavia et al. 2014). Exotic species (e.g., zebra mussels) can exacerbate the hypoxia because they affect nutrient cycling and availability (ODNR 2007a). Climate change may also affect hypoxia by affecting precipitation patterns that yield runoff events that transport nutrients to Sandusky Bay and Lake Erie (Scavia et al. 2014).

Annex 4 evaluated the ensemble modeling and determined that “the best load-response relationship is derived from the annual [TP] load to the Western Basin + Central Basin because of their combined effect on phytoplankton production in the Central Basin, regardless of when that load is input” (GLWQA 2015, p. 34). Annex 4 also found that physical factors significantly impact stratification and the hypolimnion and that it is likely impossible to eliminate hypoxia. Analysis of the models and data indicated that a combined Western and Central basin load of 6,000 MT TP should yield hypolimnion dissolved oxygen concentrations of 2.0 mg/L or more. Thus, to reduce Central Basin hypoxia, Annex 4 set a goal of 6,000 metric tons TP per year from the tributaries in the Western and Central basins, which is a 40 percent reduction of the 9,577 MT TP from the 2008 baseline year (GLWQA 2015). The 40 percent reduction in annual TP loads applies to all the tributaries to Sandusky Bay. Reducing Central Basin hypoxia is an overarching goal of this NRIP.




*Source:* NOAA 2017c

Figure 12. Lake Erie bottom temperature.

## 2.4.3 NRIP Phosphorus Goals

Some research indicates that nitrogen and light-penetration are important factors that may affect algal blooms in Sandusky Bay. Recently, Davis et al. (2015) collected water samples from two locations in Lower Sandusky Bay and added orthophosphate, various forms of nitrogen, or a combination thereof to determine how the nutrients affect plankton, chlorophyll *a*, and microcystin. After the samples were incubated in temperature and light conditions like those in Lower Sandusky Bay, Davis et al (2015, p. 7197) found that chlorophyll *a* and microcystin increased significantly, mostly due to nitrogen amendments and concluded that nitrogen “may significantly impact cyanobacterial bloom size and toxicity” in Sandusky Bay. In contrast, Schindler (2012, p. 2) previously found that these types of bottle bioassays “exclude many nutrient fluxes and algal successions that determine the ultimate response of a lake to changes in nutrient supply”. Schindler (2012) concluded that it is not appropriate to (1) extrapolate short-term bottle experiments to whole lake ecosystems and (2) draw conclusions about reversing eutrophication from *adding* nutrients to water. Sterner (2008) contends that most whole-ecosystem studies that identify phosphorus limitation are for naturally oligotrophic lakes. He goes on to conclude “that even if [phosphorus] is limiting over multi-annual time scales, over shorter but still meaningful time scales, co-limitation of multiple nutrients [...] is very common” (Sterner 2008, p. 433). These issues will likely continue to be debated in the scientific community.

Nutrient concentrations in Sandusky Bay are extremely high, which may indicate that phytoplankton growth is not limited by nitrogen or phosphorus concentrations (Conroy et al. 2007; Schindler 2012). Cyanobacteria species of the genus *Planktothrix* typically dominate Sandusky Bay because *Planktothrix* prefer “turbid, eutrophic, shallow waters” (Davis et al.

2015, p. 7204). Similarly, in an evaluation of *Cylindrospermopsis*, another genus of cyanobacteria present in Sandusky Bay, Conroy et al (2007) "identified increased water temperature and shallower depths as most important to the success" of *Cylindrospermopsis*, when sufficient nutrients were available. In an evaluation of the classic model of tributary-bay interactions, Conroy et al. (2017, p. 1) found that "phytoplankton biomass was best predicted by the ratio of total inorganic nitrogen to total phosphorus" and that sediment discharged from direct tributaries to Sandusky Bay decreased light penetration in the lacustuary resulting in phytoplankton adapted to low-light conditions. High concentrations of phosphate, nitrate, and chlorophyll *a* suggest nutrient saturation and that "phytoplankton are probably limited by light" (Schindler 2012, p. 3). Additional research will be necessary to further assess the controllable factors that significantly impact HABs in Sandusky Bay.

Annex 4 set goals for phosphorus reduction, based upon the load-response relationships of bioavailable phosphorus. However, Annex 4 also acknowledged that other factors (including nitrogen reductions) may also be important and advocated for adaptive management as more is learned about how nitrogen loading affects HABs and hypoxia in Lake Erie. (GLWQA 2015, p. 42). The objective of this NRIP is to identify projects to reduce or assimilate nutrient loads that are transported into Sandusky Bay to reduce HABs in Sandusky Bay and hypoxia in the Central Basin. To this end, Annex 4 phosphorus goals are set as the numeric goals for each critical area. However, projects that reduce all three pollutants of concern (i.e., phosphorus, nitrogen, and sediment) are encouraged and will be prioritized.

## 2.5 SUMMARY OF PHOSPHORUS TRENDS

Limited observed phosphorus data (Section 2.5.1) are available to evaluate phosphorus trends. A model for Sandusky Bay was developed to evaluate nutrient and chlorophyll conditions; TP results are discussed in Section 2.5.2.

### 2.5.1 Observed Phosphorus Trends

ODNR maintains two long-term monitoring sites each in Upper Sandusky Bay (ODNR 4 and ODNR 6) and Lower Sandusky Bay (ODNR 1 and ODNR 2; Figure 13). Ohio EPA maintains a long-term monitoring site in Lower Sandusky Bay near Johnson's Island (300900). Bowling Green State University provided nutrient sampling results for the summers (June through August) of 2015 and 2016, while Ohio EPA provided nutrient sampling results for 2014 through 2016.

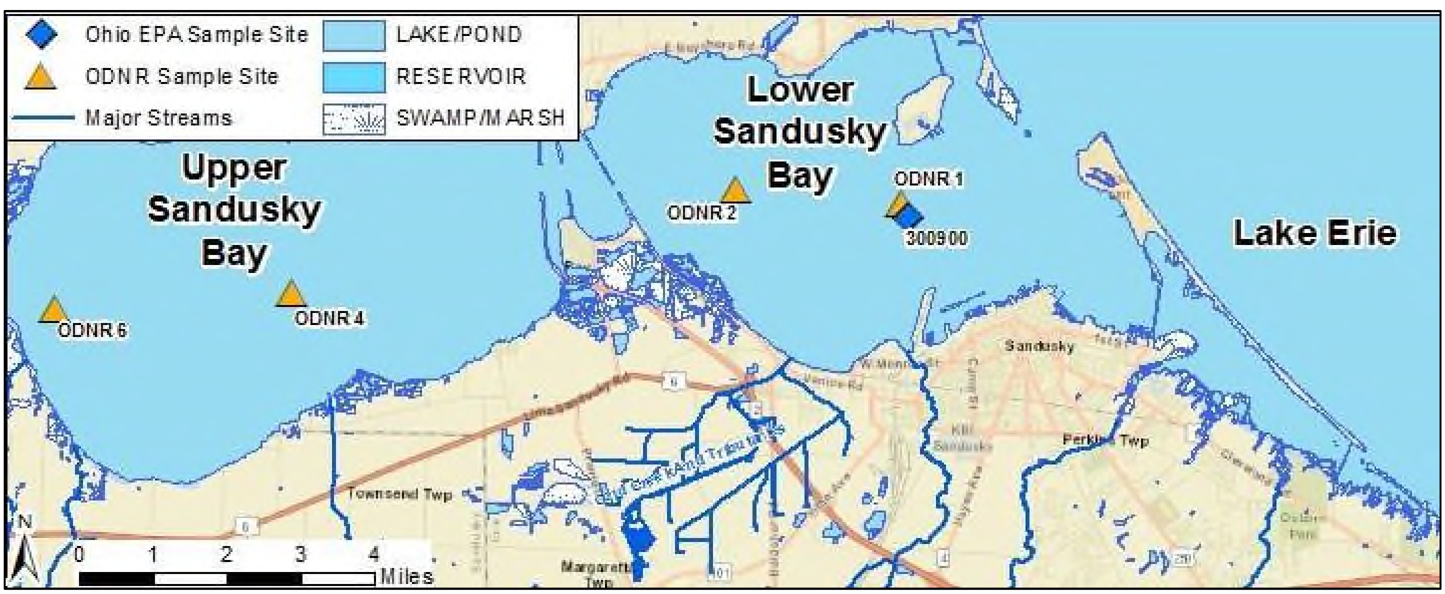



Figure 13. Water chemistry sampling sites in Upper Sandusky Bay and Lower Sandusky Bay.

All nine ODNR sample events in June through August 2016 yielded TP concentrations more than the Sandusky Bay shoreline target (Ohio EPA 2014a, Table I5-4, p. I-36). Samples in the Upper Sandusky Bay had larger TP concentrations and exceed the target by more than the samples in the Lower Sandusky Bay (Figure 14). Cursory evaluation of other parameters (e.g. soluble reactive phosphorus [SRP], total suspended solids [TSS]) did not yield any apparent trends, except the general trend that TP concentrations were related to TSS concentrations when the SRP-fraction of TP was smaller.

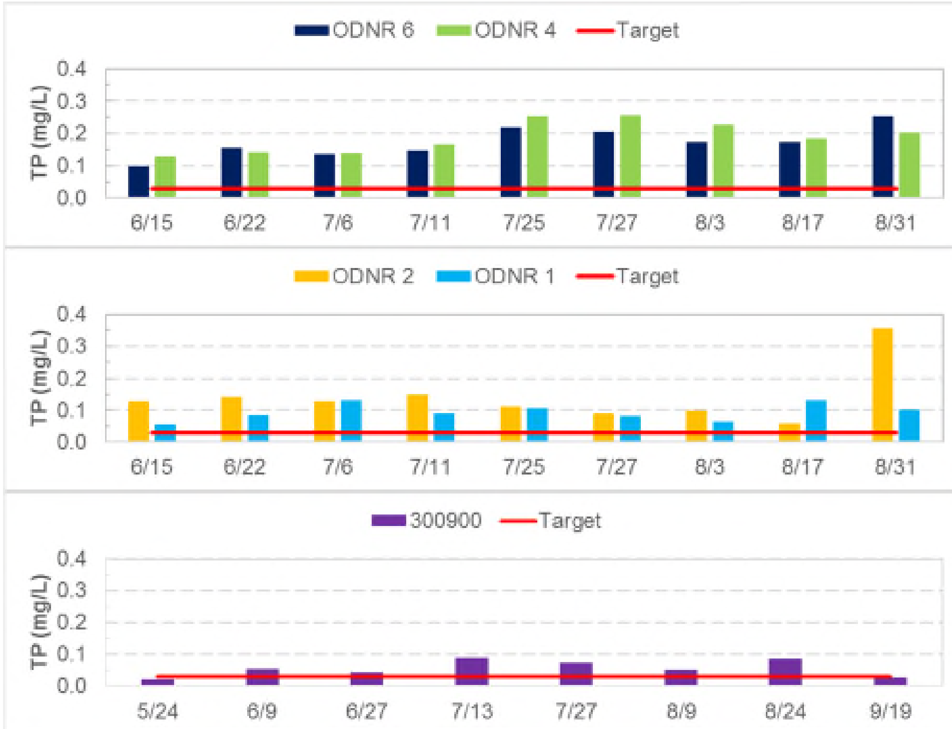



Figure 14. Summer 2016 TP concentrations in Upper Sandusky Bay (top) and Lower Sandusky Bay (middle and bottom).

## 2.5.2 Simulated Phosphorus Trends

A three-dimensional Environmental Fluid Dynamics Code (EFDC) model was developed for Sandusky Bay. EFDC is a numerical model that solves governing equations of fluid dynamics, heat transport, and water quality kinetics using finite-difference/finite-volume methods. Configuration calibration of the Sandusky Bay EFDC model is summarized in the following bullets:

- **Domain:** The model domain includes lacustrine segments of the Sandusky River and other tributaries and the portion of Lake Erie near the outlet of Lower Sandusky Bay.
- **Simulation period:** The EFDC model simulates (and was calibrated for) calendar years 2015, 2016, and 2017.
- **Grid:** The model includes 1,717 grid cells with a longitudinal range of 78- to 1,190 meters and a lateral range of 130- to 1,238-meters. Each cell is composed of two vertical layers.
- **Boundary conditions:** Bathymetry (ODNR, originally NOAA) and meteorological (NOAA) datasets were used to develop boundary conditions. Lake Erie is simulated as an open boundary condition using water level and water temperature data from NOAA and water quality data collected by Bowling Green State University. Tributary boundary conditions were developed using Soil and Water Assessment Tool (SWAT; see Section 3.3) model flow and water quality results. The Sandusky Water Pollution Control wastewater treatment facility was simulated as a boundary condition using discharge monitoring report data provided by Ohio EPA.
- **Calibration:** Water chemistry data collected by Bowling Green State University (at ODNR monitoring sites) and Environment Canada were used to calibrate the EFDC model. Calibration data included continuous monitoring data from several buoys deployed in 2017.

### 2.5.2.1 Total Phosphorus Migration

Animations, at a 6-hour interval, were developed to evaluate TP, dissolved oxygen, and chlorophyll-*a* concentrations in calendar years 2015 and 2016. Screenshots of the TP animation are presented throughout this section. An example, with important hydrography labeled, is presented below (Figure 15).

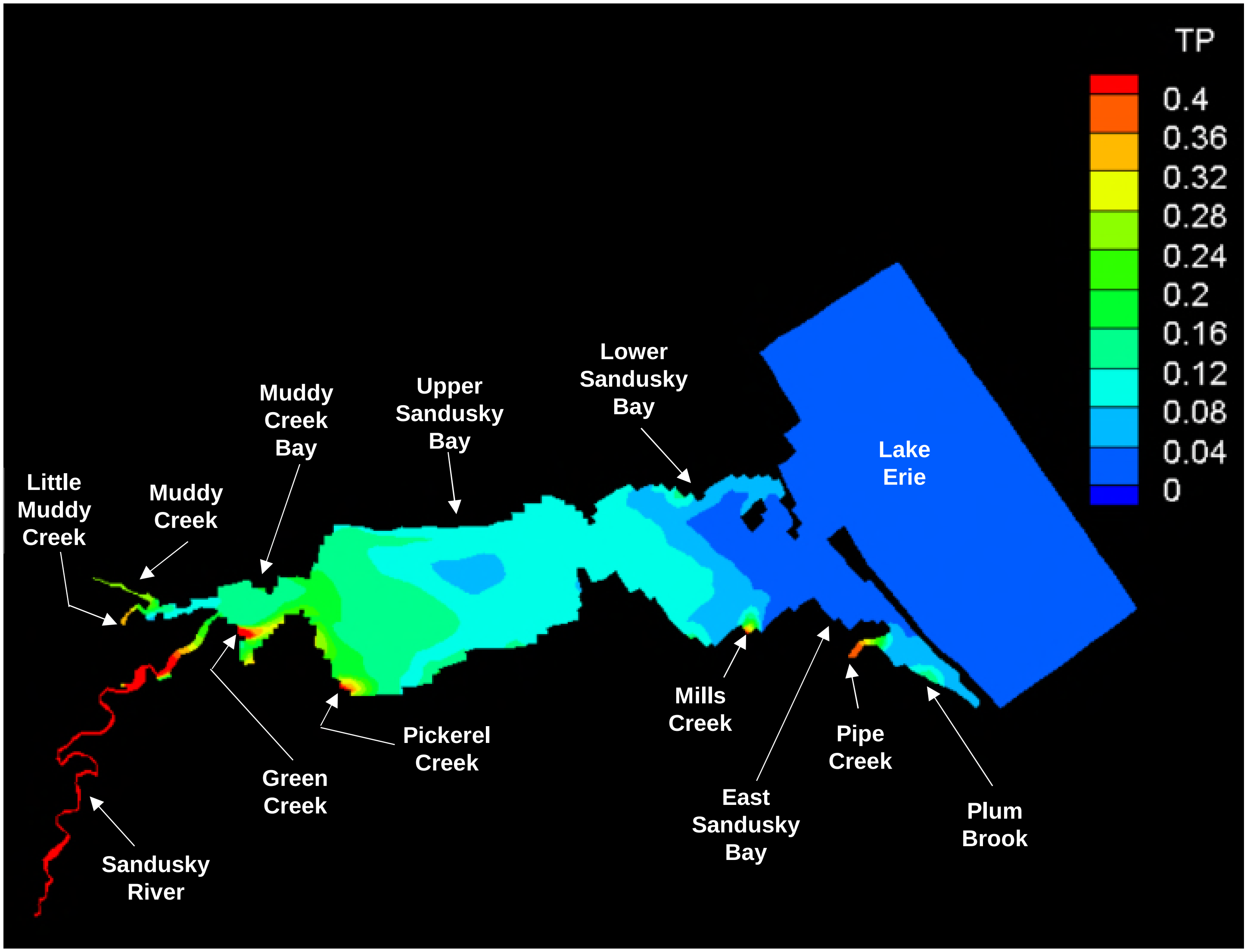



Figure 15. Visual representation of EFDC model results on February 25, 2016.

The results indicate that very few pulses of water with high nutrient concentrations migrate from the Sandusky River all the way into Lake Erie without dilution and that most pulses result in plumes that dissipate in Upper Sandusky Bay. The following general conclusions were drawn regarding TP simulation:

- **Muddy Creek Bay:** No pulse from Muddy Creek, without a corresponding pulse from the Sandusky River (which generally obscures the pulse from Muddy Creek), ever migrates out of Muddy Creek Bay.
- **Upper Sandusky Bay:** Most TP pulses from the Sandusky River that enter Upper Sandusky Bay never migrate entirely through Upper Sandusky Bay (Figure 16). Most plumes are stopped either just after entering Upper Sandusky Bay or about half way through Upper Sandusky Bay.

  Very few plumes even migrate to the constriction between Upper Sandusky Bay and Lower Sandusky Bay. The influence of this constriction is readily apparent in Figure 17, beginning on March 25$^{th}$.
- **Lower Sandusky Bay:** With a couple exceptions, the few plumes that extended into Lower Sandusky Bay were typically the result of several pulses from the Sandusky River.

  Pulses from Mills Creek form plumes in Lower Sandusky Bay that do not migrate very far (Figure 15) and are often dissipated quickly.
- **East Sandusky Bay:** Plumes entering Lower Sandusky Bay from Upper Sandusky Bay do not usually migrate east beyond the Cedar Point Causeway.

  Pulses from Pipe Creek sometimes form plumes in Castaway Bay of East Sandusky Bay (Figure 15; Figure 16 and Figure 17 also). With a few exceptions, TP concentrations of such plumes are considerably smaller than plumes derived from the Sandusky River.
- **Lake Erie:** Only a couple TP pulses from the Sandusky River migrated to Lake Erie. Such pulses took weeks to traverse Sandusky Bay (Figure 17).

  Seiches often migrate into Sandusky Bay. The low TP concentrations due to dilution caused by Lake Erie water migrating into Lower Sandusky Bay are readily apparent in Figure 16 from May 5$^{th}$ through May 11.

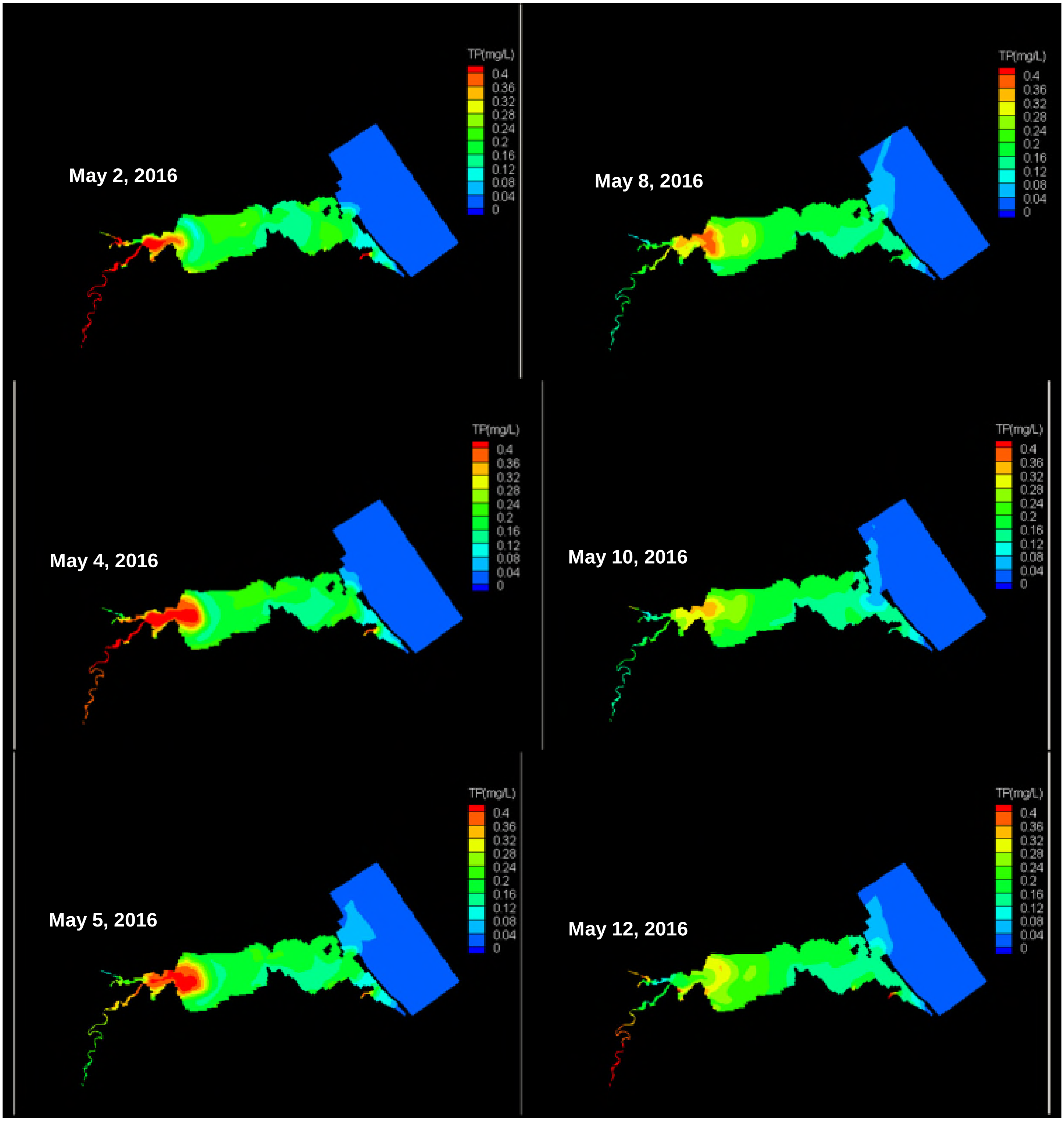



Figure 16. Visual representation of EFDC model results for a storm pulse in May 2016.

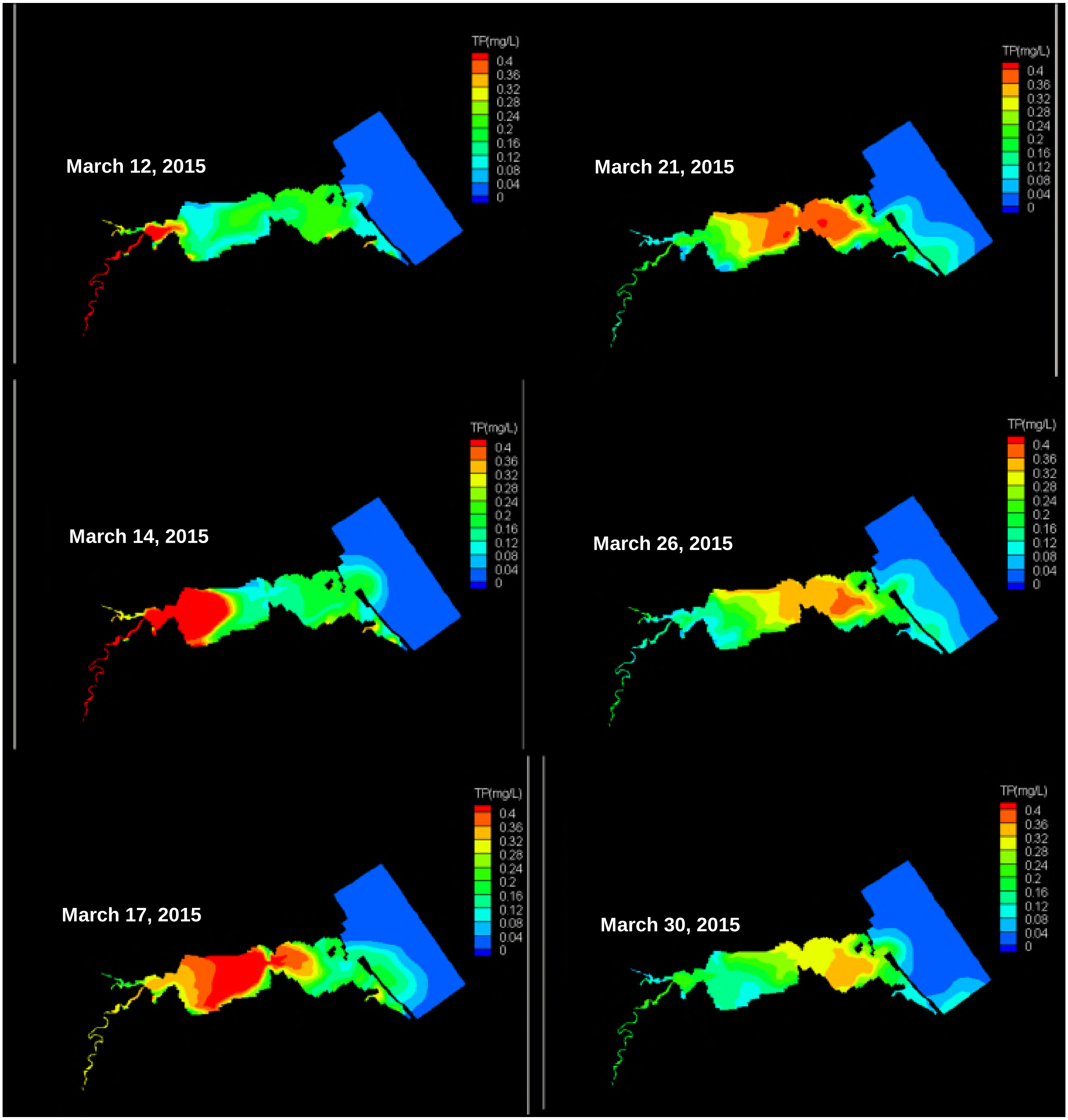



Figure 17. Visual representation of EFDC model results for a large storm event in the spring of 2015.

Elevated concentrations in Sandusky Bay are typically sustained through the summer despite the lack of TP pulses from the Sandusky River (Figure 18). In July and August 2015, during periods without any pulses from the Sandusky River, TP concentrations in Muddy Creek Bay ranged from 0.04 to 0.16 mg/L and concentrations in Upper Sandusky Bay and Lower Sandusky Bay ranged from 0.12 to 0.24 mg/L. Similarly, in July and August 2016, without any pulses from the Sandusky River, TP concentrations in Muddy Creek Bay, Upper Sandusky Bay, and Lower Sandusky Bay steadily increase over time until they stabilize at 0.20 to 0.24 mg/L. Sometimes concentrations in East Sandusky Bay are larger than in Lower Sandusky Bay.

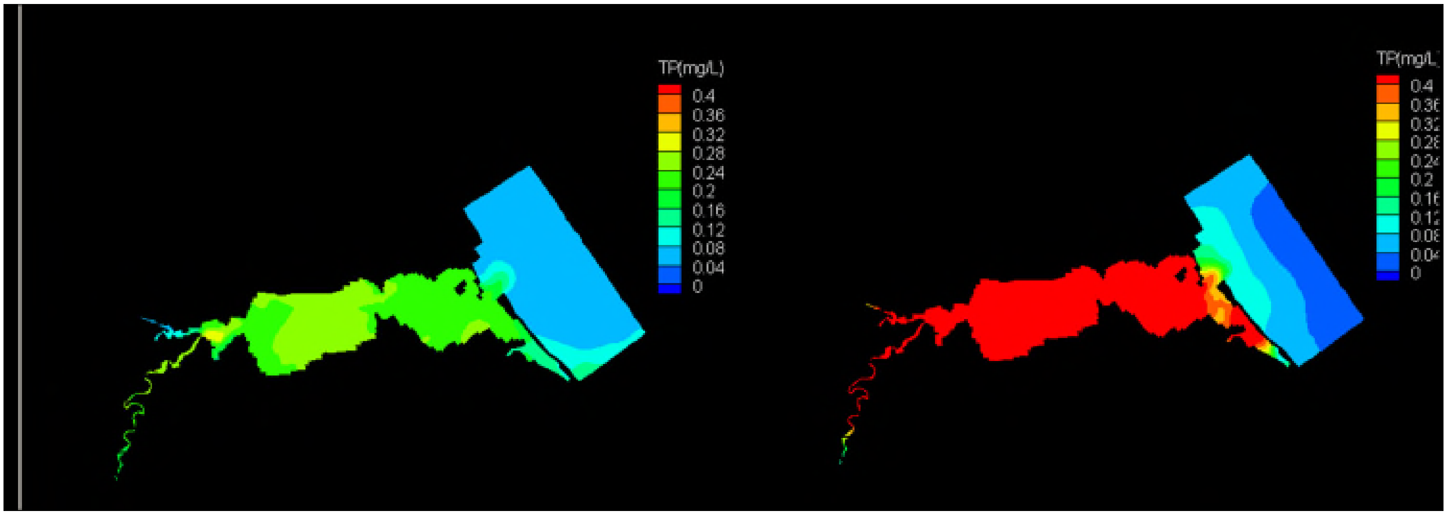



Figure 18. Visual representation of EFDC model results on July 6, 2015 (left) and August 9, 2016 (right).

Elevated summer and early fall TP concentration begin to decrease in October. Concentrations in November and December are lower (Figure 19), typically below 0.08 mg/L, but often still greater than the *Sandusky Basin Shoreline* TP concentration target of 0.03 mg/L (Ohio EPA 2014a, Table I5-4, p. I-36). Small plumes from the minor tributaries are readily apparent during this timeframe, since they discharge at considerably larger concentrations (0.08 to 0.16 mg/L).

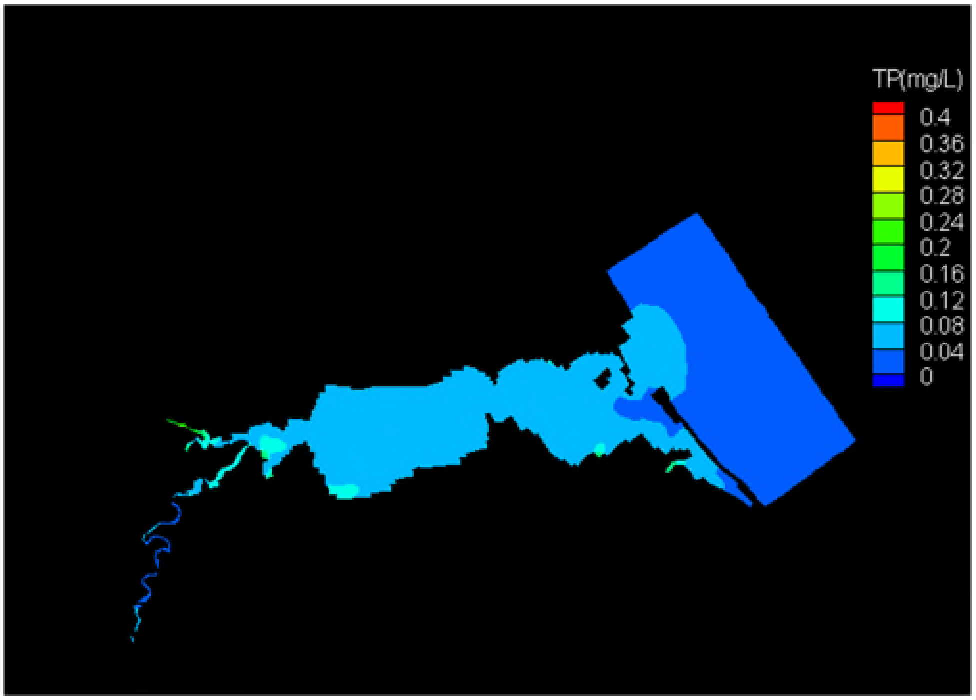


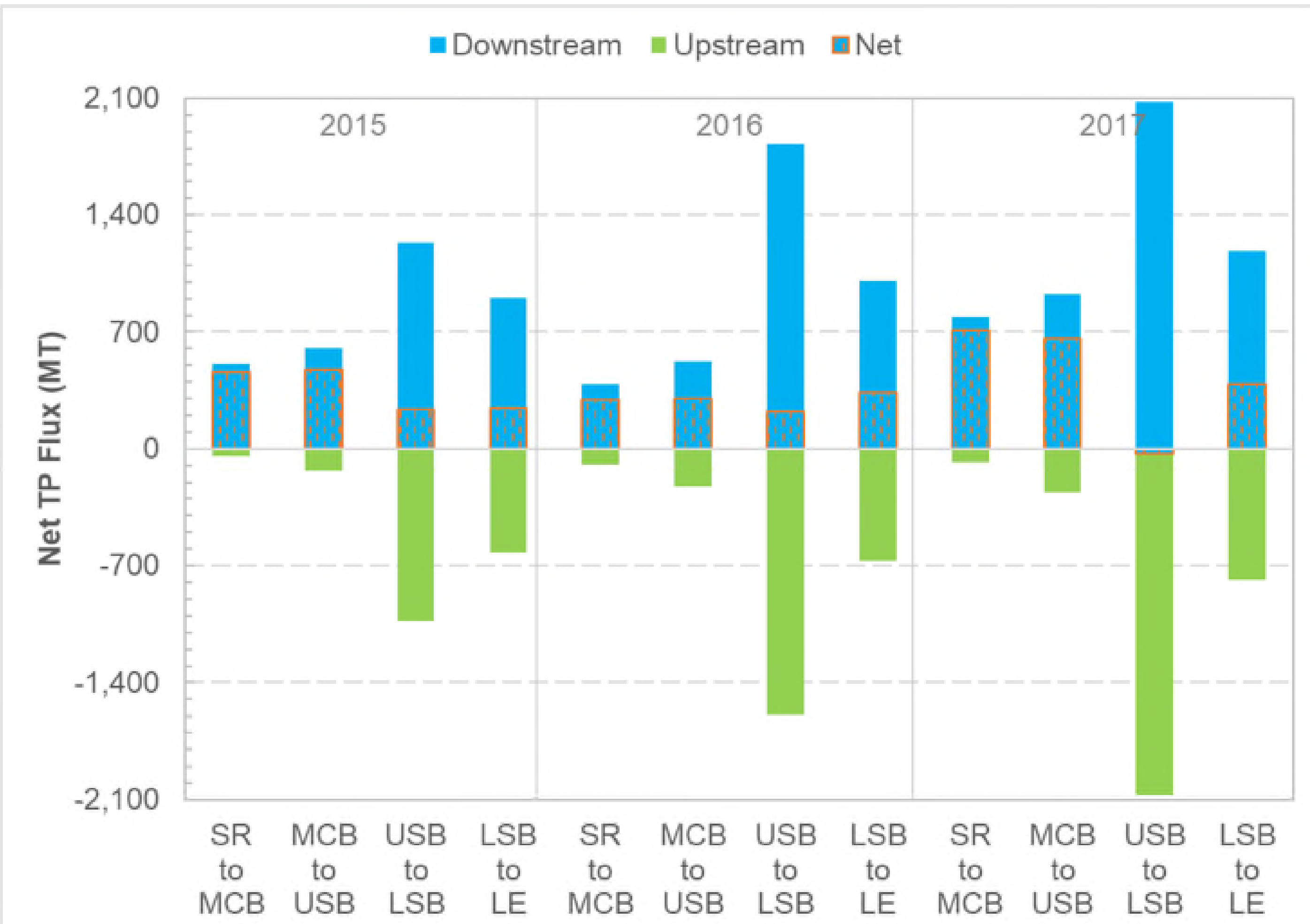

Figure 19. Visual representation of EFDC model results on November 28, 2015.

### 2.5.2.2 Total Phosphorus Flux

EFDC model results indicate that flux between waterbodies in the Sandusky system is complex, with considerable upstream flux during certain conditions (e.g., seiches). TP flux was in the downstream direction during a majority of days:

- Sandusky River to Muddy Creek Bay: 66 to 68 percent of days
- Muddy Creek Bay to Upper Sandusky Bay: 59 to 63 percent of days
- Upper Sandusky Bay to Lower Sandusky Bay: 50 to 55 percent of days
- Lower Sandusky Bay to Lake Erie: 50 to 54 percent of days

Evaluation of annual and seasonal net TP flux indicated that the most flux occurred in 2017. Net spring flux exceeded net non-spring flux in 2015 and at most locations in 2016 and 2017 (Figure 20). Significant daily flux is simulated in an upstream direction (e.g., Muddy Creek Bay upstream to the Sandusky River); however, net flux is generally in the downstream direction (Figure 20).




*Notes*

LE = Lake Erie; LSB = Lower Sandusky Bay; MCB = Muddy Creek Bay; SR = Sandusky River; USB = Upper Sandusky Bay.

Negative net seasonal fluxes represent loading moving in an upstream direction.

Figure 20. Daily net flux between the bays in 2015 through 2017.

### 2.5.2.3 Sources of Total Phosphorus Loading

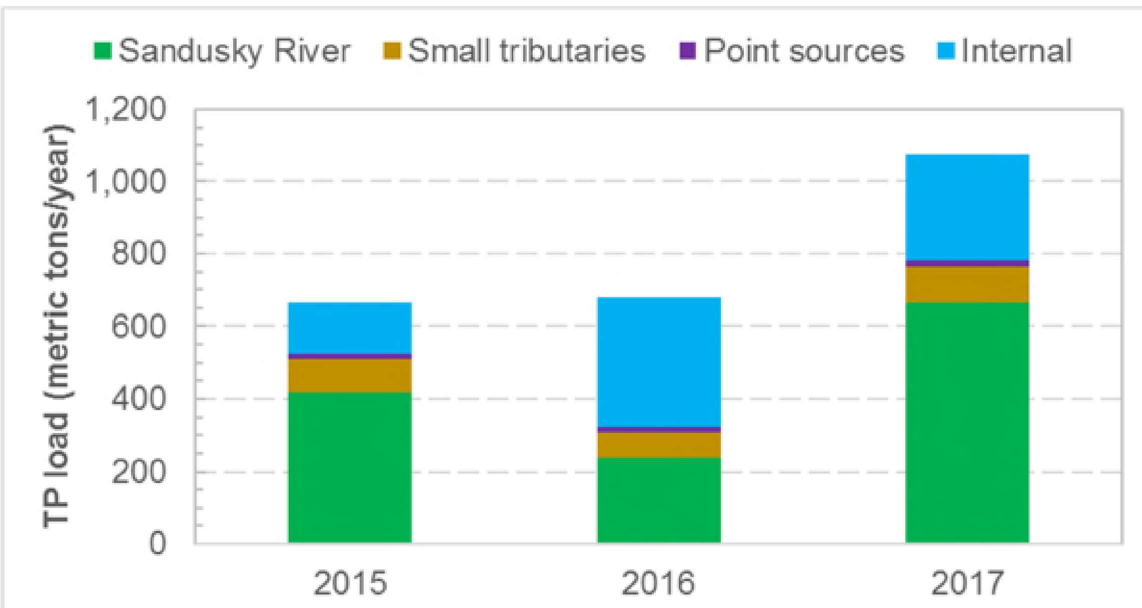
EFDC simulates phosphorus release from or deposition to (or settling to) bottom sediment in each grid cell for each time-interval. Net internal loading per bay was calculated by summing all the grid cells per bay on a seasonal and annual basis. Internal loading varied spatially; thus, bay-wide net internal loading patterns presented below may not be reflective of short-term loading patterns at finer scales at certain locations within the bays.

A net release of TP into the water column occurred in each year in each bay (Table 4). The most internal loading occurred in 2016, which is the year with the lowest total flow from the Sandusky River. Similarly, the most runoff-derived loading from the Sandusky River occurred in 2017 (Figure 21), which is the year with the highest total flow in the Sandusky River. Much of the net internal loading each year occurs outside of the spring (March 1 through July 31).

Table 4. Internal loading in Sandusky Bay in 2015 and 2016.

| | Muddy Creek Bay | | | Upper Sandusky Bay | | | Lower Sandusky Bay | | |
|---|---|---|---|---|---|---|---|---|---|
| | **2015** | **2016** | **2017** | **2015** | **2016** | **2017** | **2015** | **2016** | **2017** |
| Settling | (0.5) | (<0.1) | (<0.1) | (5.4) | (0.3) | (0.1) | (4.5) | (0.3) | (<0.1) |
| Release | 6.6 | 18.9 | 16.0 | 70.6 | 175.7 | 151.0 | 71.0 | 163.1 | 128.7 |
| **Net** | **6.1** | **18.9** | **16.0** | **65.2** | **175.4** | **150.9** | **66.4** | **162.8** | **128.7** |

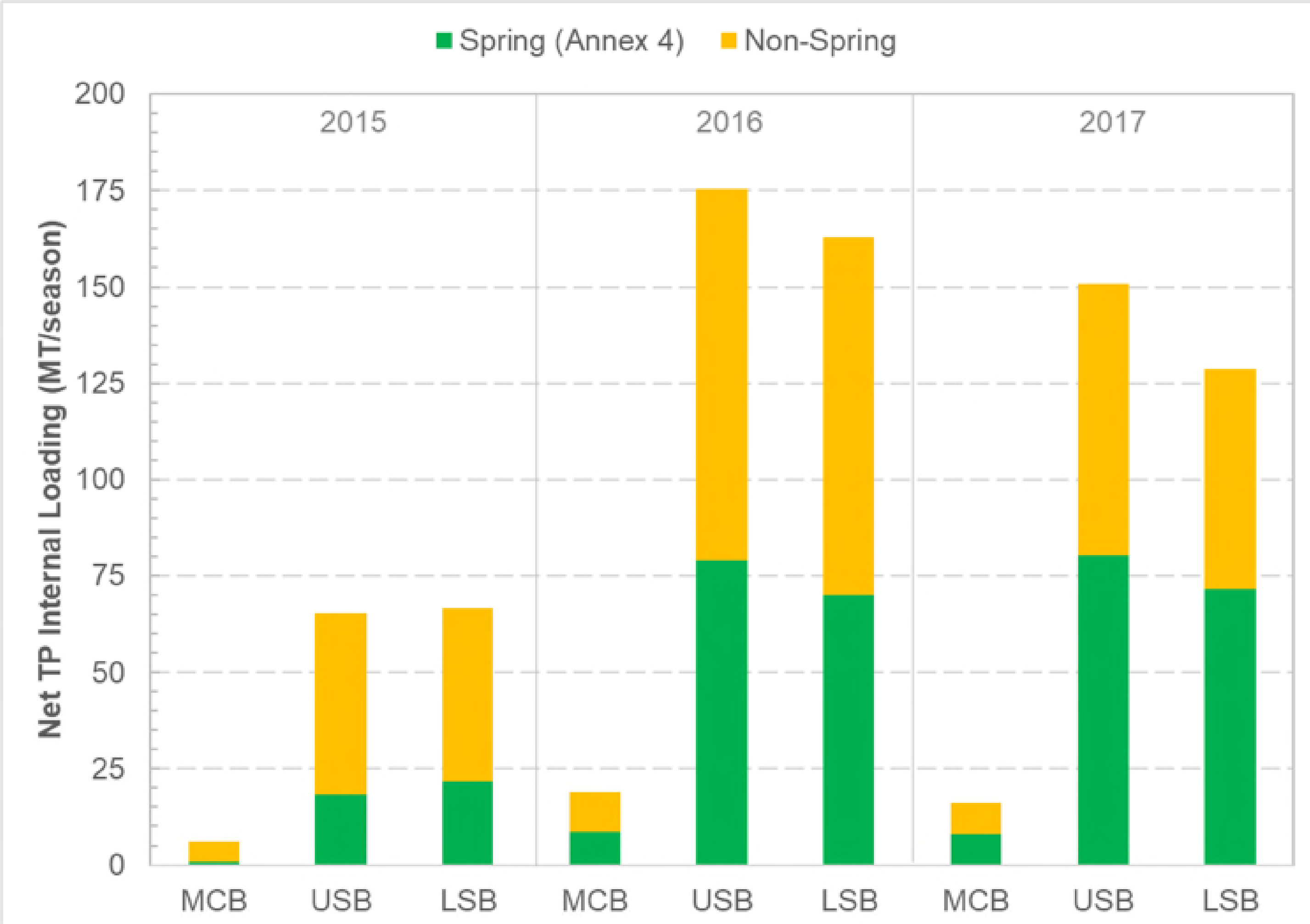
*Note:* Loads are in metric tons per year, rounded to the nearest one-tenth metric ton per year. Net may not sum exactly due to rounding.




*Note:* Internal loading in this figure represents the summation of net internal loading across all three bays. Refer to Section 3.3 for a discussion of modeling tributary loads.

Figure 21. Annual loading to Sandusky Bay in 2015 through 2017.

In 2015 and 2016, most internal loading occurred in August through February (i.e., non-spring; Figure 22). Significantly more phosphorus was released into the water column in Upper Sandusky Bay and Lower Sandusky Bay, which is expected given their relative sizes compared with Muddy Creek Bay.

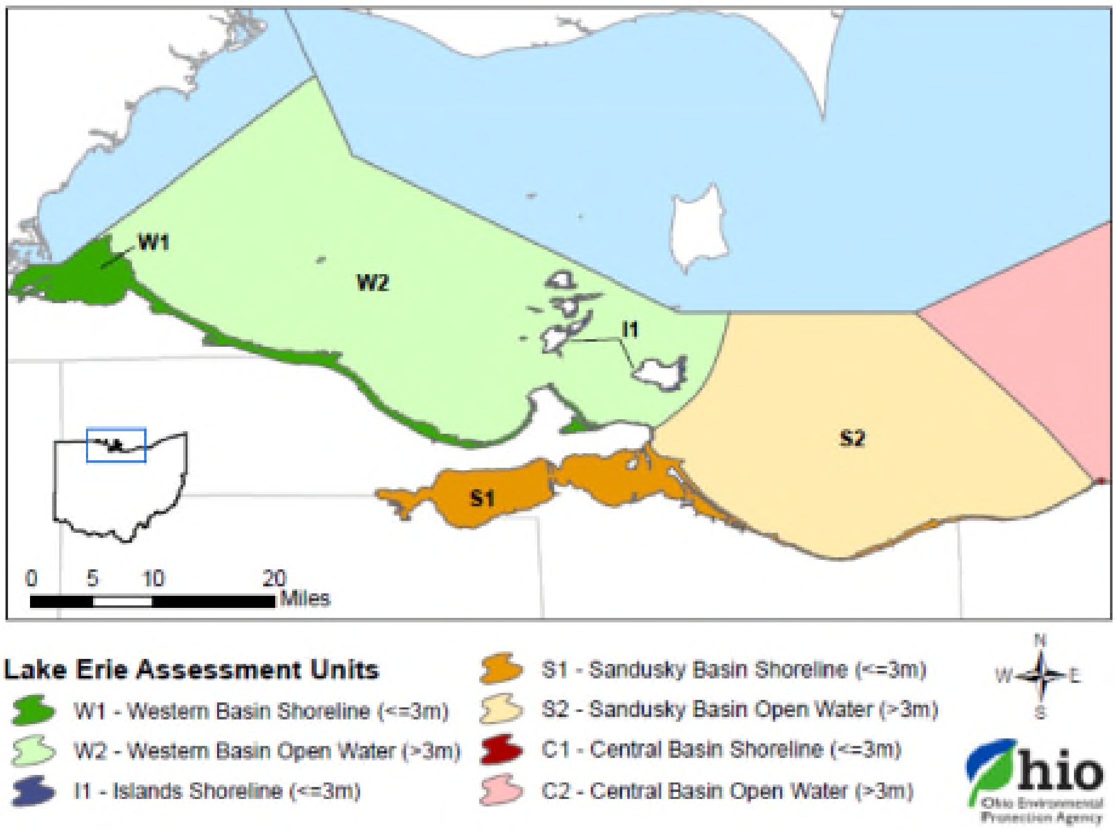



*Note:* LSB = Lower Sandusky Bay; MCB = Muddy Creek Bay; USB = Upper Sandusky Bay.

Figure 22. Net internal loading in Sandusky Bay in 2015 through 2017.

## 2.6 SUMMARY OF POLLUTION CAUSES AND ASSOCIATED SOURCES

Ohio EPA redefined the LEAUs in 2018. Sandusky Bay is included within the *Sandusky Basin Shoreline* LEAU (i.e., S1 and LEAU 04120200 02 02; Ohio EPA 2018a, Section D3; Figure 23).




*Source:* Ohio EPA 2018a

Figure 23. Lake Erie Assessment Units.

The 68-square mile *Sandusky Basin Shoreline* LEAU is impaired for its aquatic life (Table 5), human health, public drinking water supply, and recreation uses (Ohio EPA 2018a). The LEAU was evaluated each year from 2011 through 2016. Of the 14 monitoring sites, 5 sites were in full attainment, 5 sites were in partial attainment, and 4 sites were in non-attainment of the exceptional warmwater habitat ALU (Ohio EPA 2018b).

Table 5. Causes and sources of ALU impairment to *Sandusky Basin Shoreline* LEAU

| Causes | Sources |
|---|---|
| ▪ Habitat alterations | ▪ Active combined sewer overflows [a] |
| ▪ Non-native fish/shellfish/zooplankton | ▪ Combined sewer overflows [a] |
| ▪ Nutrients | ▪ Habitat modifications other than hydromodification |
| ▪ Organic enrichment | ▪ Municipal point sources [a] |
| ▪ Sedimentation/siltation | ▪ Non-irrigated crop production |
| | ▪ Other |
| | ▪ Streambank modification/destabilization |
| | ▪ Urban runoff/storm sewers |

*Source:* Ohio EPA 2018b

*Note a:* Permitted point sources (including combined sewer overflows) are beyond the scope of this NRIP that addresses phosphorus loads from NPS.

# 3 WATERSHED CHARACTERIZATION AND ASSESSMENT

The Sandusky watershed drains to Sandusky Bay and ultimately Lake Erie. The watershed is part of the Western Basin of Lake Erie[7].

## 3.1 SUMMARY OF WATERSHED CHARACTERIZATION

The Sandusky watershed encompasses approximately 1,827 square miles and is delineated as one 8-digit hydrologic unit (04100011). The Sandusky watershed was subdivided by the Ohio EPA into three areas—the Sandusky River (upper) watershed, Sandusky River (lower) watershed, and Sandusky Bay tributaries.[8] Ohio EPA developed technical support documents (TSDs; Ohio EPA 2003, 2010, and 2011) and TMDLs (Ohio EPA 2004, 2014b) for all three areas. Watershed action plans were developed by the National Center for Water Quality Research at Heidelberg University (Loftus et al. 2006) and the Sandusky River Watershed Coalition (Riddle 2006); a TMDL implementation plan (Tetra Tech 2016) and an Integrated Water Quantity Management Plan were developed (U.S. EPA 2017). Several SWAT models were developed for the Sandusky watershed, including a SWAT model to evaluate TP, nitrate + nitrite, and TSS as part of the TMDL effort (Ohio EPA 2014b), and an EFDC model for Sandusky Bay was developed as part of this study.

Land cover, soil hydrologic groups, level III ecoregions, hydrology, and weather are summarized for the entire Sandusky watershed *Total Maximum Daily Loads for the Sandusky River (Lower) and Bay Tributaries Watershed* (Ohio EPA 2014b, Chapter 3 and Appendix B). Similar information for the tributaries is presented in the TSDs (Ohio EPA 2010, 2011). Land cover, soils, and development information are also provided in the *Ohio Coastal Atlas* (ODNR 2007a).

### 3.1.1 Physical and Natural Features

#### 3.1.1.1 Sandusky River and Tributaries

The largest tributary to Sandusky Bay is the Sandusky River, which discharges to Muddy Creek Bay. The Sandusky River is unique, with respect to Lake Erie tributaries, because most other tributaries discharge directly to Lake Erie (e.g., Black River, Rocky River) instead of through a bay first, and the Maumee River discharges to Maumee Bay, which is not enclosed (Richards 1985). River-bay-lake dynamics control hydrology and pollutant loading. The river typically contributes its highest annual runoff to the bay in the spring, while low flows dominate in the summer and early fall (Richards 1985). During large runoff events, river water and bay water can be pushed into Lake Erie, and such water brings phosphorus (including sediment-bound phosphorus) into the lake (Richards 1985). However, during lower flow conditions, pollutants are assimilated and thus “pollutant load to the lake is substantially less than it would be if the bay were not there” (Richards 1985, p. 153).

To the west of the Sandusky River, Muddy Creek and Little Muddy Creek also drain to Muddy Creek Bay. To the east of the Sandusky River, several tributaries discharge to Upper Sandusky Bay, including South Creek, Raccoon Creek, Pickerel Creek, and Little Pickerel Creek. Farther east, tributaries to Lower Sandusky Bay include Cold Creek, Mills Creek, and Pipe Creek. These tributaries are further described in the TSDs (Ohio EPA 2010 and 2011).

The lower segments of many of the tributaries to Sandusky Bay are lacustrine, which means that waters from the streams and Sandusky Bay mix within a freshwater estuary. These lacustuaries are slack water that can ebb and flow as bay and lake seiches affect water levels. The lacustuaries are generally located between the farthest downstream riffle of the tributary and Sandusky Bay proper.

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[7] By rule, Ohio considers the Sandusky watershed to be in the Western Basin of Lake Erie: Ohio Revised Code 905.326(E)(4). U.S. EPA and other organizations consider the Sandusky watershed to be part of the Central Basin of Lake Erie.

[8] 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 in a study in eastern Sandusky County.

### 3.1.1.2 The Great Black Swamp

The lower Sandusky River watershed and tributary subwatersheds draining directly to Sandusky Bay were part of the historic Great Black Swamp. Much of northwest Ohio was covered by the Great Black Swamp that is described as “a wetland ecosystem composed of 60-foot-tall ash, elm, maple and oak forest cover, coastal marshes, poorly-drained soils, pristine spawning areas, lush habitat and an overabundance of flies and mosquitoes” (ODNR 2007a, p. 117). Today, little of the Great Black Swamp remains (about 15,000 acres); it was formerly about 90,000 acres spanning parts of 13 present-day counties (ODNR 2007a). Prior to settlement, an “extensive barrier beach-wetland system originally comprised the shoreline westward from Sandusky to Toledo and northward to Detroit” and the loss of wetlands “is primarily attributed to drainage practices associated with agriculture, filling and dredging” (ODNR 2007b, p. 2-3). Many of the wetlands that remain along the shoreline are diked to allow property owners to raise or lower water levels (Mitsch & Wang 2000).

Wetland restoration in the Great Black Swamp is an objective of several local environmental groups because wetlands can significantly impact watershed nutrient loading. Mitsch & Wang (2000) estimated that converting 1 percent of the Sandusky River watershed to wetlands could remove up to 23 percent of watershed phosphorus loading. A recent study funded by U.S. EPA Region 5 (2014a) evaluated 11 wetland functions in the Sandusky River watershed for existing wetlands (identified in the National Wetland Inventory) and for an estimation of wetlands present before European settlement. Analysis using the landscape-level wetland function analysis (LLWFA) and wetland function method (W-PAWF) showed that wetland function for existing and pre-settlement wetlands was typically similar. However, wetland area has decreased significantly since settlement began (e.g., 90 percent loss of forested wetlands). The study indicated that the most effective candidate wetlands to reduce nutrient loads from the Sandusky River watershed are vegetated palustrine and lacustrine, open-water wetlands from the lowlands that flood occasionally or frequently (U.S. EPA 2014a, p. 74).

## 3.1.2 Land Use and Protection

The Sandusky watershed, like other watersheds in north-central and northwestern Ohio, is dominated by agricultural land use (Table 6; Figure 25), including both cultivated row crops (Figure 24) and pastureland for livestock grazing. Urban development and wetlands are slightly more prevalent in the subwatersheds that drain directly to Sandusky Bay (Table 6) than the upland subwatersheds. The city of Sandusky is the largest urban center along the Sandusky Bay shoreline.

Table 6. Land cover in the Sandusky watershed

| | Sandusky watershed (HUC 04100011) | | Subwatersheds directly discharging to Sandusky Bay | |
|---|---|---|---|---|
| **Land cover** | **Area (acres)** | **Area (%)** | **Area (acres)** | **Area (%)** |
| Open water | 8,892 | 1% | 4,681 | 2% |
| Developed, open | 70,452 | 6% | 18,560 | 7% |
| Developed, low intensity | 32,826 | 3% | 13,663 | 5% |
| Developed, medium intensity | 11,572 | 1% | 5,768 | 2% |
| Developed, high intensity | 4,737 | <1% | 2,855 | 1% |
| Barren land | 5,790 | <1% | 2,833 | 1% |
| Deciduous forest | 91,713 | 8% | 16,112 | 6% |
| Evergreen forest | 510 | <1% | 105 | <1% |
| Mixed forest | 1,133 | <1% | 9 | <1% |
| Shrub/scrub | 171 | <1% | 64 | <1% |
| Grassland / herbaceous | 13,132 | 1% | 3,072 | 1% |
| Pasture/hay | 28,100 | 2% | 2,020 | 1% |
| Cultivated crops | 877,181 | 75% | 172,366 | 67% |
| Woody wetlands | 1,347 | <1% | 312 | <1% |
| Emergent herbaceous wetlands | 17,364 | 1% | 15,827 | 6% |
| **Total [a]** | **1,164,919** | **100%** | **258,245** | **100%** |

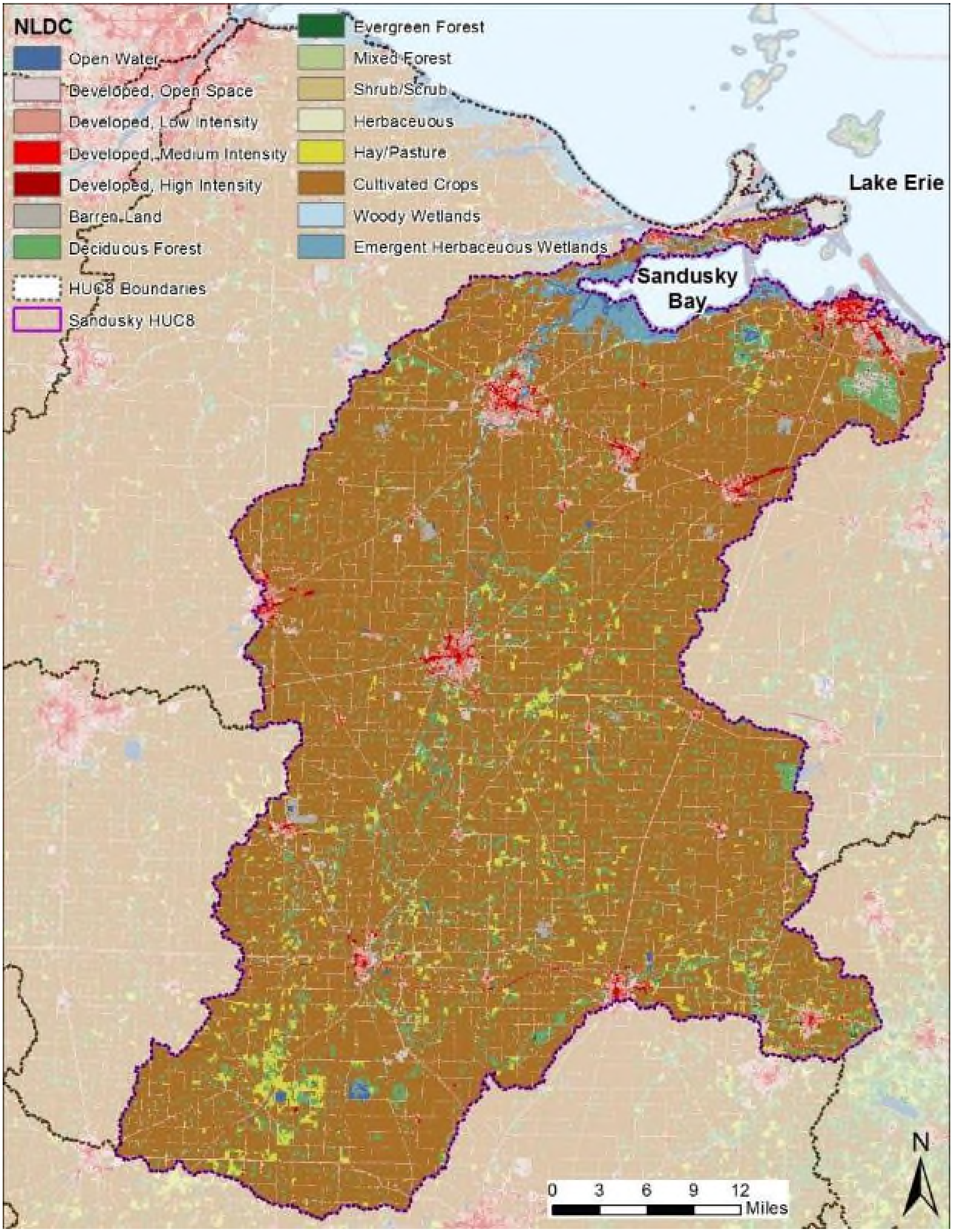
*Source of spatial data:* Jin et al. 2013.

*Notes*

Areas rounded to the nearest acre or percentage point.

a. Totals do not sum exactly due to rounding.

Figure 24. Crop fields in the lower Sandusky watershed.




*Source of spatial data:* Jin et al. 2013.

Figure 25. Land cover in the Sandusky watershed.

Cropland in the Sandusky watershed typically consists of a two-crop rotation of soybean and corn (Figure 26). Winter wheat is also grown in the Sandusky watershed. Generally, between a tenth and a quarter of farmers include winter wheat in a 3-crop rotation with corn and soybeans. Hay is grown throughout the Sandusky watershed but in very small amounts as compared to corn and soybeans.

Phosphorus and nitrogen starter fertilizers are applied during corn planting, and broadcast and planter applications are the most common application methods (Ohio EPA 2014b). Corn fields are typically fertilized with nitrogen again about a month after planting. Some farmers broadcast-apply phosphorus and nitrogen fertilizers to winter wheat in the fall; a spring nitrogen application to winter wheat is common for those farmers who do fertilize winter wheat.

Manure application is limited across the Sandusky basin with most permitted operations applying manure to their own land (Ohio EPA 2014b). However, manure is distributed throughout the county and a limited number of farmers do apply manure to corn fields, typically in early spring before planting.

Cropland throughout the Sandusky watershed is served by drainage ditches and drain tiles (Figure 27); drain tiling is ubiquitous in row crop fields in northwest Ohio. Typically, drain tiles are installed in row crop fields in the lake plain areas along Sandusky Bay to manage water levels (Ohio EPA 2010).

Figure 26. Corn field in the Sandusky watershed.

Figure 27. Tile drain along Pipe Creek.

Modern agricultural drainage programs began in Ohio in 1957 following the passage of the Ohio Drainage Laws (Loftus et al. 2006). 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 2013, p. 42).

Ditches in the Sandusky watershed include both county maintained ditches and privately owned and maintained ditches (Ohio EPA 2014b). 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).

Figure 28. Cattle in South Creek.

Many agricultural and rural properties have small numbers of livestock which do not require a concentrated animal feeding operation[9] or confined animal feeding facility[10] permit. Some small operations with livestock do not restrict access to streams (Figure 28). Watershed-specific data are not available for livestock populations in the Sandusky watershed; county-level data are available in the Censuses of Agriculture.

Land throughout the Sandusky watershed is protected by public and private organizations; for example, ODNR manages 39 properties in the watershed[11], including along the Sandusky River like the Howard Collier State Nature Preserve. Six organizations manage protected lands in the tributaries that discharge directly to Sandusky Bay (Figure 30); lands managed by the Erie MetroParks, ODNR, and Sandusky County Park District are accessible to the public:

- **Erie MetroParks:** Castalia Quarry MetroPark (153 acres), East Sandusky Bay MetroPark (1,293 acres)[12], James McBride Arboretum (104 acres), Osborn MetroPark (138 acres), and Pelton Park (20 acres)
- **ODNR:** 13 properties
    - **Fish Hatchery:** Castalia Fish Hatchery (117 acres)

[9] Concentrated animal feeding operations are regulated under the Clean Water Act by U.S. EPA and the states through the NPDES program. Three such operations are in the Sandusky watershed.

[10] Confined animal feeding facilities are regulated by the Ohio Department of Agriculture, through the Livestock Environmental Permit Program. Four such facilities are in the Sandusky watershed.

[11] Several divisions at ODNR manage 39 properties across the Sandusky watershed and ODNR designated a 65-mile segment of the Sandusky River from Upper Sandusky to Fremont as a *scenic river*. The Division of Forestry manages one nursery; the Division of Natural Areas and Preserves manages six designated nature preserves; the Division of Watercraft manages four scenic river areas and one scenic river public access; and the Division of Wildlife manages one conservation area, one fishing access area, one hatchery, and 24 wildlife areas.

[12] The East Sandusky Bay MetroPark is composed of Eagle Point (87 acres), Joseph Steinen Wildlife Area (57 acres), Putnam Marsh (993 acres; includes a portion of the Lower Sandusky Bay, i.e., east back bay), and Wyandot Wetland and Barnes Addition (156 acres).

- **Nature Preserves:** Erie Sand Barrens (30 acres; Figure 29) and Sheldon Marsh (461 acres)
- **Wildlife Areas:** Dempseys Sandusky Bay (68 acres), Joseph Steinen (157 acres), Millers Blue Hole (13 acres), Moxley (192 acres), Pickerel Creek (3,151 acres), Pipe Creek (111 acres), Resthaven (2,219 acres), Willow Point (433 acres) and wildlife production areas 30 (56 acres) and 63 (40 acres).

- **Sandusky County Park District:** Blue Heron Reserve (164 acres) and Decoy Marsh (67 acres)

Figure 29. Sheldon Marsh (left) and Erie Sand Barrens (right) state nature preserves.

NASA's Plum Brook Station is not open to the public. Black Swamp Conservancy and the Western Reserve Land Conservancy are non-profit organizations that operate land trusts to protect natural areas through conservation easements. Conservation easements are typically not open to the public either. Black Swamp Conservancy also owns and manages properties in the Sandusky watershed but none of these properties are in the subwatersheds directly discharging to Sandusky Bay.

Several private hunting and fishing clubs also protect land along Sandusky Bay (Figure 30). The Ottawa Shooting Club (2,406 acres) and Winous Point Shooting Club (2,754 acres) are the clubs with the largest land holdings in the area. [13] Several private organizations manage about 1,200 acres of marshes near Bay View; for example, Standing Rush (333 acres) is managed by a private conservation organization. A private organization also manages a private barrier beach system along Bay Point on the Marblehead Peninsula.

[13] The Ottawa Point Shooting Club and Winous Point Shooting Club include wetlands, lacustuaries, and nearshore that are classified as lake (i.e., Muddy Creek Bay) in the National Hydrography Dataset.

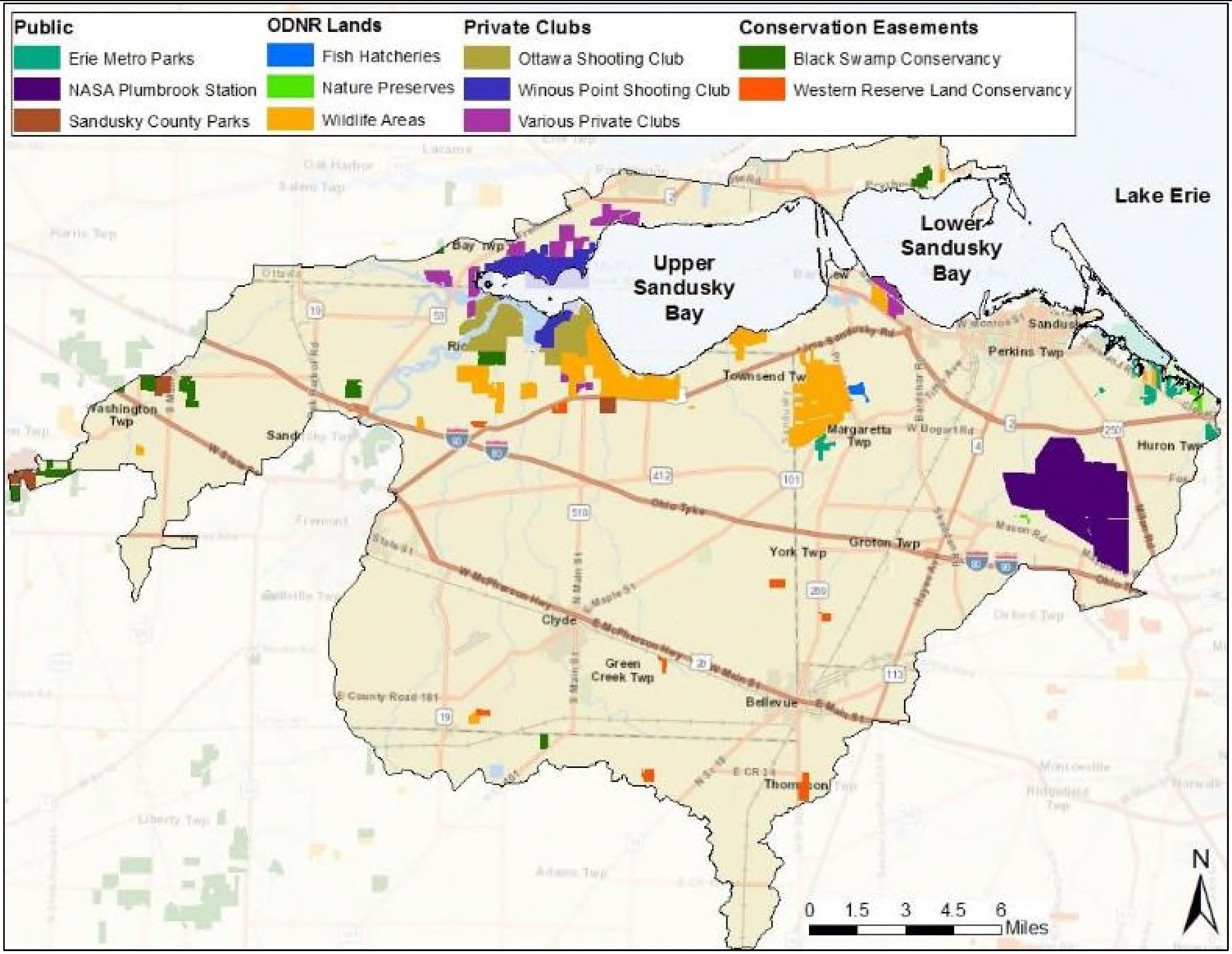



Figure 30. Protected lands in the subwatersheds draining directly to Sandusky Bay.

## 3.2 SUMMARY OF BIOLOGICAL TRENDS

Biological and habitat data and evaluations are published in several recent[14] TSDs for the Sandusky watershed (Ohio EPA 2003, 2010, 2011). Sites across the Sandusky watershed do not meet biological criteria (biocriteria) and do not meet targets for fish habitat. Many such sites were addressed through TMDLs (Ohio EPA 2014b) to address the impairments due to agricultural production (Figure 31). Attainment across the project area is shown at the end of this section in Figure 32.

Figure 31. Little Pickerel Creek.

Only those tributaries discharging to Sandusky Bay are relevant to this study. The designated ALU of such streams is warmwater habitat (WWH). IBI, MIwb, and Invertebrate Community Index (ICI) vary by stream size and sampling method, as does the targets for the Qualitative Habitat Evaluation Index (QHEI).

Streams in the *Mills Creek-Frontal Sandusky Bay* watershed (Table 7) are tributary to the Lower Bay. Only Sawmill Creek met the biocriteria. Most sites on Pipe Creek and Mills Creek either met biocriteria for fish community health or for macroinvertebrate community health but not both. The lowest sites on these two streams (U05K15 and U05P05) did not meet biocriteria for all three indices and did not meet the target for QHEI. In-stream fish habitat was typically degraded.

Table 7. Overall biological indices scores in *Mills Creek-Frontal Sandusky Bay* (HUC 04100011 03)

| HUC 12 | Stream | River mile (Area) | IBI | MIwb | ICI | Status | QHEI | Site ID |
|---|---|---|---|---|---|---|---|---|
| 01 01 | Sawmill Creek | 1.10 (13.5) H | 44 | --a | MG* | Full | 50.5 | K01K21 |
| 01 02 | Pipe Creek | 10.81 (9.4) H | -- | --a | Fair | -- | -- | U05K18 |
| | | 8.18 (14.7) H | 20 | --a | Good | Partial | 46.5 | U05K17 |
| | | 6.70 (18.4) H | 24* | --a | Fair | Partial | 30 | U05K16 |
| | | 2.32 (22.8) W | 23 | 4.6 | 22 | NON | 41.5 | U05K15 |
| 01 03 | Mills Creek | 10.40 (21) W | 26* | 5.3 | LF | NON | 28.5 | U05S07 |
| | | 6.03 (29) W | 21 | 4.9 | 28 | NON | 49 | U05S06 |
| | | 5.20 (29) W | 23 | 5.7 | 38 | NON | 61.5 | U05P07 |
| | | 3.70 (35) W | 25* | 6.9* | 30* | Full | 42.5 | U05S18 |
| | | 1.35 (41) W | 19 | 4.9 | 18 | NON | 46.5 | U05P05 |
| | Caswell Ditch | 0.85 (3.9) H | 22 | --a | 30* | Partial | 34.5 | U05W37 |

*Source:* Ohio EPA 2010

*Notes*

* = non-significant departure; H = headwaters site; LF = low-fair (non-attainment); MG = marginally good (attainment); P = poor (non-attainment); W = wading site.

a. The MIwb is not applicable to headwaters streams, which are less than 20 square miles.

[14] Ohio EPA also published TSDs for waterbodies in the Sandusky watershed in 1991, 1996, and 2000.

Streams in the *Pickerel Creek-Frontal Sandusky Bay* watershed (Table 8) are tributary to the Upper Bay, and these mostly headwaters-sized streams typically met the biocriteria for fish community health but did not meet biocriteria for macroinvertebrate community health. In-stream fish habitat was typically degraded.

Table 8. Overall biological indices scores in *Pickerel Creek-Frontal Sandusky Bay* (HUC 04100011 02)

| HUC 12 | Stream | River mile (Area) | IBI | MIwb | ICI | Status | QHEI | Site ID |
|---|---|---|---|---|---|---|---|---|
| 01 | Little Pickerel Creek | 2.00 (5.5) H | 26* | --[a] | LF | Partial | 50.5 | 201385 |
| | Cold Creek | 0.36 (2.9) H | 34 | --[a] | F | Partial | 47.0 | 300670 |
| 03 | Pickerel Creek | 6.26 (9.5) H | 32 | --[a] | MG* | Full | 48 | U05K10 |
| | | 3.35 (43.7) W | 27* | --[a] | LF | Partial | 45 | U05S04 |
| 04 | Raccoon Creek | 13.26 (9.9) H | 28 | --[a] | MG* | Full | 49.5 | U05S01 |
| | | 11.32 (12.7) H | 32 | --[a] | P | NON | 42.0 | U05P04 |
| | | 10.18 (13.8) H | 34 | --[a] | P | NON | 51.5 | U05W10 |
| | | 5.45 (23.6) W | 29* | 5.5 | 34 | Partial | 66.0 | U05W17 |
| | Buck Creek | 0.20 (4.5) H | 30 | --[a] | LF | Partial | 45.5 | U05S03 |
| 05 | South Creek | 7.92 (7.1) H | 20 | --[a] | LF | NON | 48.5 | U05G01 |
| | | 4.04 (18.1) H | 24* | --[a] | LF | Partial | 33.5 | U05K05 |

*Source:* Ohio EPA 2010

*Notes*

* = non-significant departure; H = headwaters site; LF = low-fair (non-attainment); MG = marginally good (attainment); P = poor (non-attainment); W = wading site.

a. The MIwb is not applicable to headwaters streams, which are less than 20 square miles.

Streams in the *Muskellunge Creek-Sandusky River* watershed (Table 9) are tributary to the Sandusky River, which discharges to Muddy Creek Bay. Lower Muskellunge Creek is in nonattainment due to very poor macroinvertebrate community health, while Bark Creek is in nonattainment due to fair fish and macroinvertebrate community health.

Table 9. Overall biological indices scores in *Muskellunge Creek-Sandusky River* (HUC 04100011 13)

| HUC 12 | Stream | River mile (Area) | IBI | MIwb | ICI | Status | QHEI | Site ID |
|---|---|---|---|---|---|---|---|---|
| 01 | Muskellunge Creek | 24.44 (2.3) H | NS | NS | Poor | -- | NS | 300675 |
| | | 16.70 (17.7) H | 44 | --[a] | Good | Full | 38.5 | 300674 |
| | | 5.40 (37) W | 37 | 6.9* | Good | Full | 58.5 | 201332 |
| | | 1.23 (44) W | 37* [b] | 9.1 [b] | 10 [b] | NON | 69.0 | U04P08 |
| 03 | Bark Creek | 3.20 (10) H | 20 | --[a] | Fair | NON | 32.0 | 300671 |

*Source:* Ohio EPA 2010

*Notes*

* = non-significant departure; H = headwaters site; NS = no sample; W = wading site.

a. The MIwb is not applicable to headwaters streams, which are less than 20 square miles.

b. Monitoring site is lacustrine and biological criteria do not apply. Data were assessed with lacustrine benchmarks

Streams in the *Muddy Creek-Frontal Sandusky Bay* watershed (Table 10) are tributary to Muddy Creek Bay. These streams are west of the Sandusky River. Muddy Creek and Little Muddy Creek each span two HUC12s. The lower segments of Muddy Creek and Little Muddy Creek do not meet biocriteria for fish or macroinvertebrate community health and are characterized by poor in-stream habitat.

Table 10. Overall biological indices scores in *Muddy Creek-Frontal Sandusky Bay* (HUC 04100011 14)

| HUC 12 | Stream | River mile (Area) | IBI | MIwb | ICI | Status | QHEI | Site ID |
|---|---|---|---|---|---|---|---|---|
| 03 | Little Muddy Creek | 2.5 (25) [W] | 20 [a] | 6.9 [a] | 20 [a] | NON | 47.5 | 300676 |
| | Fishing Creek | 0.20 (7.0) [H] | 32 | --[b] | P | NON | 21.5 | 300678 |
| 04 | Muddy Creek | 1.23 (110) [B] | 21 [a] | 6.7 [a] | 12 [a] | NON | 50.5 | U04Q13 |

*Source:* Ohio EPA 2010

*Notes*

* = non-significant departure; B= boating site; H = headwaters site; P = poor (non-attainment); W = wading site.

QHEI scores were rounded to the nearest one-tenth.

a. Monitoring site is lacustrine and biological criteria do not apply. Data were assessed with lacustrine benchmarks

b. The MIwb is not applicable to headwaters streams, which are less than 20 square miles.

The Sandusky River "is home to 85 species of fish, 29 species of mussels, and 228 species of invertebrates" (ODNR 2007a, p. 43). The river is delineated into two large river assessment units and only the lower unit downstream of Fremont is relevant to this study. Along the *Sandusky River from Wolf Creek to Sandusky Bay* (Table 11), the riverine segments often meet all the biocriteria while the lacustrine segments to not meet many biocriteria. Habitat is ubiquitously good along this large river assessment unit. TMDLs were developed for the Sandusky River in Fremont for the riverine segments of the *Sandusky River from Wolf Creek to Sandusky Bay* (Ohio EPA 2014b).

Table 11. Overall biological indices scores in *Sandusky River from Wolf Creek to Sandusky Bay* (large river assessment unit 04100011 90 02)

| River mile (Area) | IBI | MIwb | ICI | Status | QHEI | Site ID |
|---|---|---|---|---|---|---|
| 23.00 (1,073) [B] | 55 | 10.2 | 52 | Full | 83.5 | U04Q06 |
| 21.30 (1,238) [B] | 54 | 9.7 | 58 | Full | 76.0 | U04Q05 |
| 19.00 (1,255) [B] | 44 | 8.0 | no sample | Partial | 59.0 | 300830 |
| 18.05 (1,255) [B] | 35* | 7.2 | P | NON | 52.0 | U04T02 |
| 17.70 (1,256) [B] | 41 | 9.9 | 34 | Full | 93.0 | U04S23 |
| 15.40 (1,260) [B] | 38 | 9.7 | G | Full | 67.0 | U04W11 |
| 12.96 (1,264) [B] | 26 [a] | 9.2 [a] | no sample | NON | 67.0 | 500890 |
| 4.70 (1,330) [B] | 32 [a] | 8.7 [a] | 14 [a] | NON | 60.0 | U04S17 |
| 1.00 (1,335) [B] | 31 [a] | 7.5 [a] | no sample | NON | 64.5 | 201314 |

*Source:* Ohio EPA 2011

*Notes*

* = non-significant departure; B = boating site; DA = drainage area, in square miles; G = good (attainment); IBI = Index of Biotic Integrity; ICI = Invertebrate Community Index; MIwb = Modified Index of well-being; P = poor (non-attainment); QHEI = Qualitative Habitat Evaluation Index; RM = river mile.

QHEI scores were rounded to the nearest one-tenth.

a. Monitoring site is lacustrine and biological criteria do not apply. Data were assessed with lacustrine benchmarks

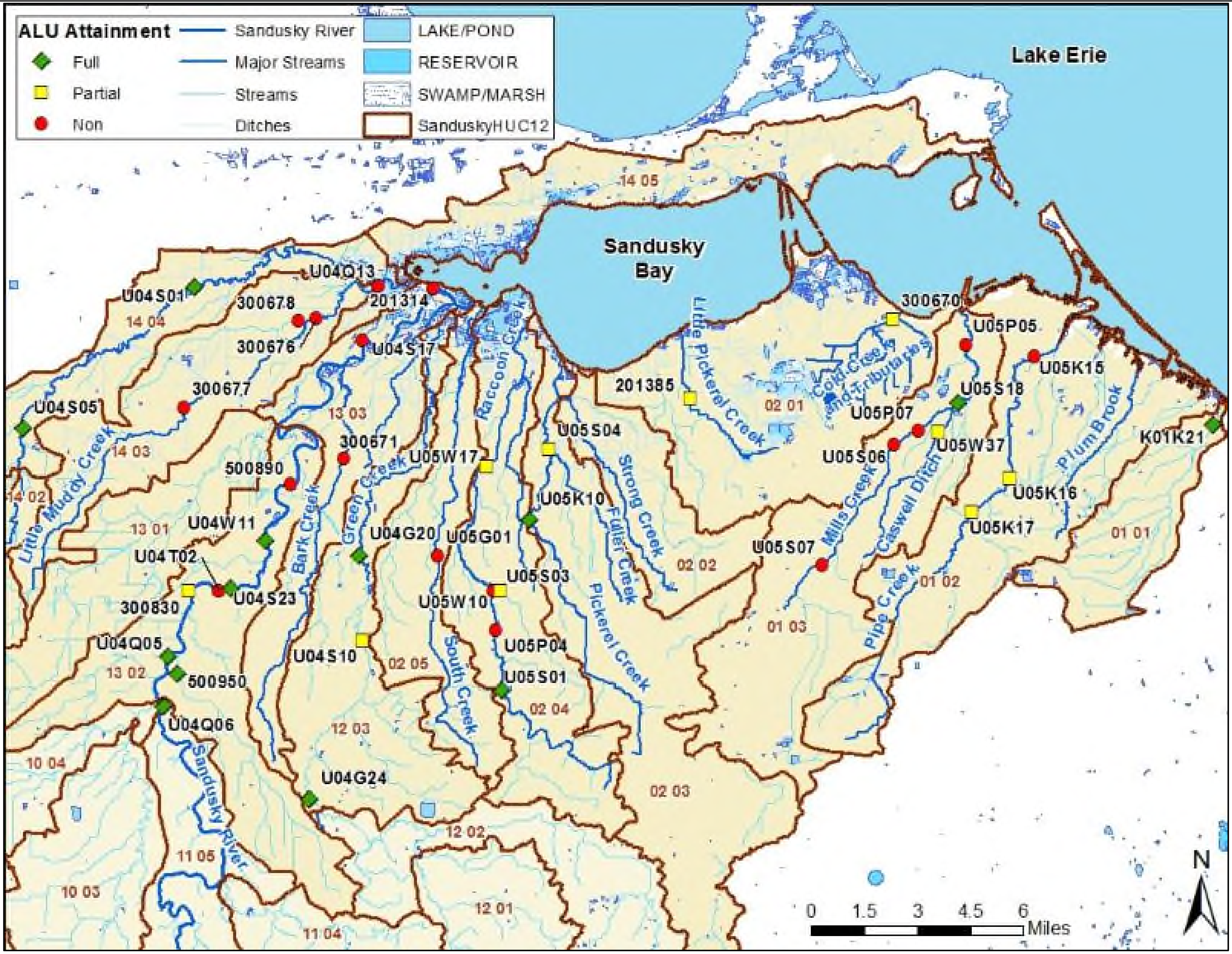



Figure 32. ALU attainment in the subwatersheds draining directly to Sandusky Bay.

## 3.3 SUMMARY OF PHOSPHORUS TRENDS

Several SWAT models have been developed for the Sandusky watershed, including a model that was built to support TMDL development (Ohio EPA 2014b). This SWAT model was built using the 2006 NLCD and the 2010 and 2011 Cropland Data Layers (Ohio EPA 2014b, Appendix D). Cropland was simulated as tile-drained two-year rotations of either corn-soybean or corn-soybean-winter wheat. The model simulated water years 2000 to 2010 and was calibrated using five flow gages (U.S. Geological Survey) and three water quality stations (Ohio EPA and National Center for Water Quality Research). Model results are available for TP, SRP, total Kjeldahl nitrogen, nitrate + nitrite, and TSS (Ohio EPA 2014b, Appendices D, E, and F).

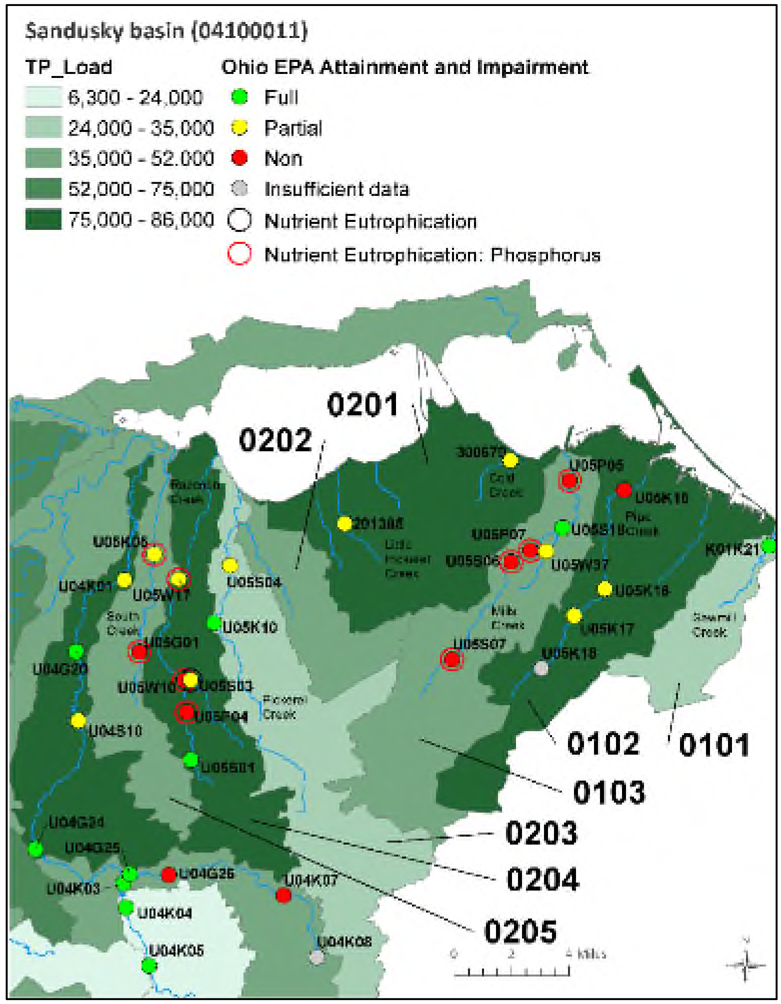



Figure 33. SWAT-simulated TP loads and Ohio EPA assessment sites in the eastern tributaries of Sandusky Bay.

Annual average TP loads were typically larger in the tributaries to Sandusky Bay, frontal Lake Erie, and Sandusky River (lower) versus the Sandusky River (upper) tributaries. However, more of the TP load was derived from agriculture in the Sandusky River (upper) tributaries than elsewhere; though, a majority of the TP load in all subwatersheds was derived from agriculture. Nutrient eutrophication (Figure 33) and sedimentation/siltation often impaired the eastern tributaries of Sandusky Bay.

Annual average SRP loads were typically larger in the Sandusky River tributaries versus the Sandusky Bay tributaries. The dominant sources of SRP were always agriculture or developed land, with the percentage of average annual load derived from agriculture ranging from 61 to 100 percent.

The TMDL SWAT model was reconfigured for a study of drainage water management (U.S. EPA 2014), and then extended through water year 2017 and re-calibrated for this study. As expected, model results indicate that the vast majority of springtime tributary loading to Sandusky Bay came from the Sandusky River (Figure 34). The majority (55 to 80 percent) of springtime TP loading from the Sandusky River was organic phosphorus. However, organic phosphorus was a smaller portion of TP loading in the bay tributaries (e.g., Muddy Creek [28 to 71 percent]).

Model results indicate that the Sandusky River typically discharged springs loads one or two orders of magnitude larger than the other bay tributaries. Muddy Creek contributed the largest loads of the bay tributaries, followed by Green Creek, Pickerel Creek, and Mills Creek.

In an evaluation of targets to reduce Central Basin hypoxia, Scavia et al. (2014) evaluated research, including several SWAT models that simulated TP and DRP loading. The authors found that anthropogenic phosphorus loading in the Sandusky River watershed was dominated by fertilizers and that “high-yield subwatershed for both DRP and TP were dispersed throughout the Sandusky River watershed” (Scavia et al. 2014 p. 236). These results are consistent with the SWAT modeling for this study.

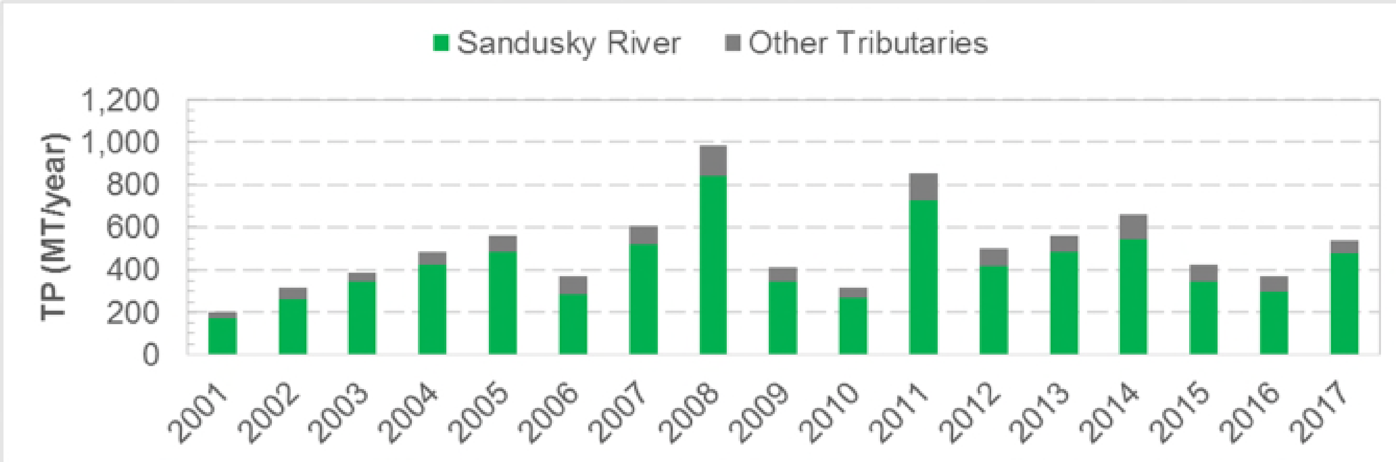



Figure 34: SWAT-simulated TP load from the tributaries to Sandusky Bay.

## 3.4 SUMMARY OF POLLUTION CAUSES AND ASSOCIATED SOURCES

Causes and sources of impairments to the Sandusky River (Ohio EPA 2011) and its tributaries (Ohio EPA 2010) are presented in the TSDs and summarized across the entire Sandusky watershed in the TMDL report (Ohio EPA 2014b, Section 2.5). Causes and sources to impaired sites on the Sandusky River and direct tributaries to Sandusky Bay are summarized in Table 12.

Table 12. Causes and sources of ALU impairment to the uplands in the Sandusky watershed

| Causes | Sources |
|---|---|
| ▪ Direct habitat alterations<br>▪ Embedded substrates<br>▪ Habitat alteration<br>▪ Natural [a]<br>▪ Nutrient eutrophication<br>▪ Organic enrichment (sewage)<br>▪ Other flow regime alterations<br>▪ Phosphorus (total)<br>▪ Siltation | ▪ Active combined sewer overflows [a]<br>▪ Channelization<br>▪ Crop production with subsurface drainage<br>▪ Clyde WWTP [a]<br>▪ Livestock<br>▪ Natural [a]<br>▪ On-site treatment systems [b]<br>▪ Urban runoff [a] |

*Source:* Ohio EPA 2010, 2011.

a. Natural causes, natural sources, and permitted point sources (including combined sewer overflows and regulated stormwater) are beyond the scope of this NRIP that addresses phosphorus loads from NPS.

b. On-site treatment systems are septic systems and similar decentralized systems.

Crop production with subsurface drainage is the most common NPS of impairment throughout the lower Sandusky River, tributaries of the lower Sandusky River, and direct tributaries of Sandusky Bay (Ohio EPA 2010, 2011). Such crop production increases sedimentation/siltation, nutrient enrichment, and channel erosion/incisions (Ohio EPA 2011). Nutrient enrichment is primarily caused by crop production; however, at isolated locations, nutrient enrichment is due to inadequate treatment of residential sanitary wastewater (Ohio EPA 2011). The lower segments of the tributaries to Sandusky Bay act as conduits that transport sediment and nutrients from upstream/upland areas to Sandusky Bay. Additionally, channelization and crop production with subsurface drainage within the tributaries' lower subwatersheds contribute to excessive siltation, sedimentation, and nutrient enrichment in the lacustuaries of these tributaries (Ohio EPA 2011).

# 4 CONDITIONS & RESTORATION STRATEGIES FOR THE CRITICAL AREAS

## 4.1 OVERVIEW OF CRITICAL AREAS

Three critical areas were identified: *Western Uplands*, *Muddy Creek Bay and Upper Sandusky Bay*, and *Lower Sandusky Bay* (Figure 35). The *Western Uplands* critical area is the only critical area completely composed of land area with streams; as such, this is the only critical area that Ohio EPA (2010, 2011) assessed in-stream attainment of designated ALUs. Phosphorus loading from this critical area typically discharges to the *Muddy Creek Bay and Upper Sandusky Bay*, which is impaired by HABs due to upstream phosphorus loading from the Sandusky River watershed and direct tributaries to Muddy Creek Bay and Upper Sandusky Bay. Phosphorus loading from the *Muddy Creek Bay and Upper Sandusky Bay* critical area typically discharges to the *Lower Sandusky Bay* critical area, which is also impaired by HABs due to upstream phosphorus loading from Upper Sandusky Bay and direct tributaries to Lower Sandusky Bay. During seiches, phosphorus loading from Lake Erie flows into Sandusky Bay and can flow up into the Sandusky River and the other bay tributaries.

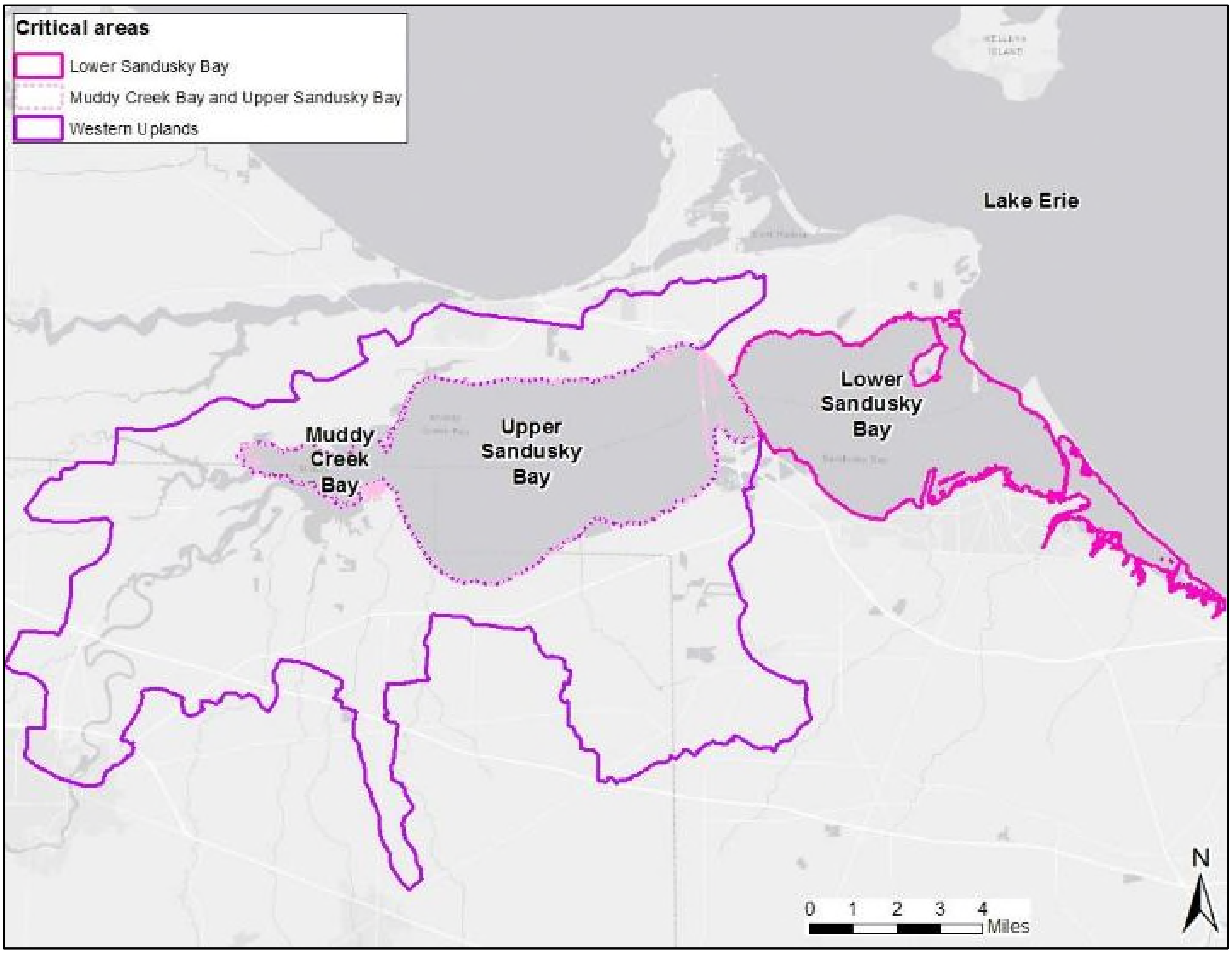



Figure 35. Critical areas.

## 4.2 CRITICAL AREA #1: CONDITIONS, GOALS, & OBJECTIVES

### 4.2.1 Detailed Characterization

The *Western Uplands* critical area is composed of the lower portions of several subwatersheds that discharge directly to Muddy Creek Bay and Upper Sandusky Bay (Figure 36). The upstream boundaries across several subwatersheds are described below:

- **Muddy Creek (*14 04):** Muddy Creek at South Bolsinger Road (CR-168; RM 5.3), which is the upstream lacustrine boundary and where a TP TMDL was developed
- **Little Muddy Creek (*14 03):** Little Muddy Creek at Weickert Road (CR-174; RM 3.5), which is the upstream lacustrine boundary and where TP and TSS TMDLs were developed, and Fish Creek at Weickert Road (RM 0.20; 300678), where a TP TMDL was developed
- **Muskellunge Creek (*13 01):** Muskellunge Creek at Oak Harbor Road (OH-19), which is the upstream lacustrine boundary and where TP and TSS TMDLs were developed
- **Indian Creek-Sandusky River (*13 02):** Sandusky River at RM 15.2, which is the upstream lacustrine boundary, just downstream of State Street (RM 15.4; U04W11).
- **Mouth Sandusky River (*13 03):** Bark Creek at Kelley Road (CR-245; RM 3.2;300671)
- **Green Creek (*12 03):** Green Creek at TR-239 (RM 5.06; U04K21), which is where a TSS TMDL was developed
- **South Creek (*02 05):** South Creek at Whitmore Road (TR-247; RM 4.04; U04K25), which is where TP and TSS TMDLs were developed
- **Raccoon Creek (*02 04):** Raccoon Creek at TR-244 (RM 5.45; U05W17), which is where TP and TSS TMDLs were developed
- **Pickerel Creek (*02 03):** Pickerel Creek at TR-247 (RM 3.35; U05S04), which is where a TSS TMDL was developed. Excludes Strong Creek (*02 01) that was not assessed (Ohio EPA 2010, 2011).

The *Western Uplands* critical area includes two frontal Sandusky Bay watersheds that are composed of many small drainages that discharge directly to Muddy Creek Bay and Upper Sandusky Bay. Frontal drainages that discharge directly to the Lower Sandusky Bay are excluded from the *Western Uplands* critical area. The eastern boundaries of these two frontal Sandusky Bay subwatersheds are described below:

- **North Side Sandusky Bay Frontal (*14 05):** The eastern boundary runs along unnamed ditches that discharge directly east of the OH-2 immediately south of the OH-2/OH-269 interchange.
- **Frontal South Side of Sandusky Bay (*02 01):** The eastern boundary runs along the upstream boundary of the Cold Creek subwatershed and the Resthaven Wildlife Area.

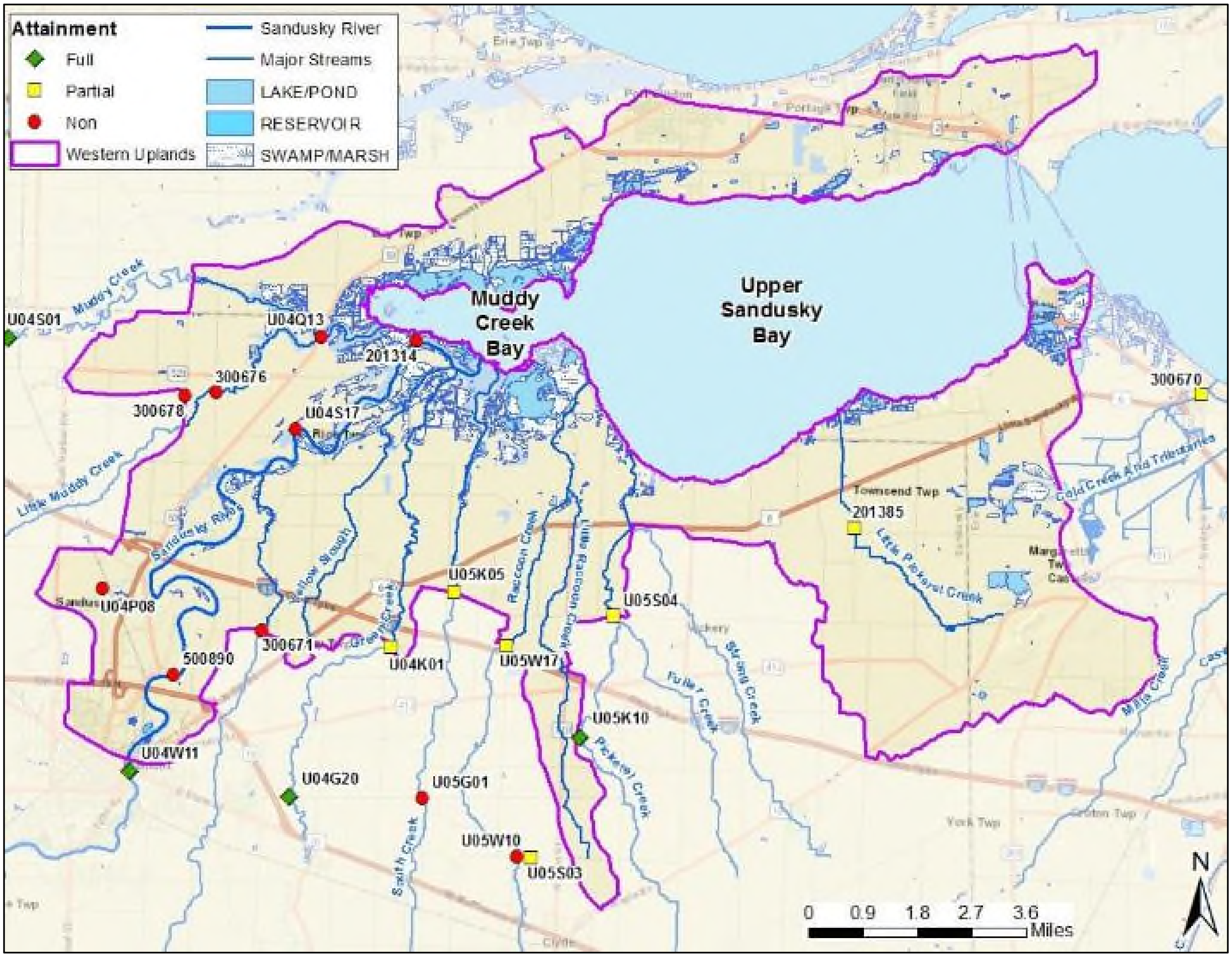



Figure 36. *Western Uplands* (critical area #1).

The *Western Uplands* critical area is 59,134 acres dominated by cropland (51 percent), wetlands (22 percent), and development (15 percent; Table 13). Wetlands are most prevalent around Muddy Creek Bay and its tributaries (e.g., lower Muddy Creek, lower Sandusky River). Large areas of wetlands are protected in the Pickerel Creek, Resthaven, and Willow Point wildlife areas; forested lands are also prevalent in the Resthaven Wildlife Area. Only two incorporated municipalities are in the *Western Uplands* critical area: the city of Port Clinton[15] and the village of Bay View. The unincorporated communities of Crystal Rock, Danbury, Gypsum, and White's Landing are each along the shores of Upper Sandusky Bay. Rural residences dominate in the agricultural portions of the critical area.

The lower Sandusky River and low Muddy Creek are lacustuaries and their mouths are drowned within Muddy Creek Bay. Land adjacent to the lower segments of most of the larger, named streams is dominated by wetlands (e.g., Muddy Creek, Sandusky River, South Creek, and Raccoon Creek). However, the unnamed ditches in the southeastern portion of the *Western Uplands* critical area are predominantly row crop fields, including along their lower segments.

[15] A portion of Port Clinton drains northward directly to Lake Erie, while the other portion drains southward to Upper Sandusky Bay.

Table 13. Land cover in the *Western Uplands* critical area

| Land cover | Area (acres) | Area (%) |
|---|---|---|
| Open water | 3,189 | 5% |
| Developed, open | 4,059 | 6% |
| Developed, low intensity | 3,593 | 6% |
| Developed, medium intensity | 1,105 | 2% |
| Developed, high intensity | 328 | 1% |
| Barren land | 400 | 1% |
| Deciduous forest | 3,364 | 5% |
| Evergreen forest | 10 | <1% |
| Mixed forest | 4 | <1% |
| Shrub/scrub | 62 | <1% |
| Grassland / herbaceous | 1,312 | 2% |
| Pasture/hay | 505 | 1% |
| Cultivated crops | 32,826 | 51% |
| Woody wetlands | 117 | <1% |
| Emergent herbaceous wetlands | 14,118 | 22% |
| **Total** | **64,991** | **100%** |

*Source of spatial data:* 2011 National Land Cover Database (Jin et al. 2013).

*Note:* Areas rounded to the nearest acre or percentage point. Totals do not sum exactly due to rounding.

Figure 37. Sandusky River in Fremont at the State Street Bridge (U.S. Route 20; looking downstream).

## 4.2.2 Detailed Tributary Phosphorus Loading

Spring loads from March 1 through July 31 were evaluated for the years 2000 through 2017 to determine which tributaries in the *Western Uplands* critical area (#1) contributed the largest loads to the *Muddy Creek Bay and Upper Sandusky Bay* critical area (#2). The Sandusky River contributed 92 percent of the TP load and 87 percent of the SRP load, while Muddy Creek contributed 2 percent and 6 percent, respectively. Figure 38 presents box-and-whisker plots of spring TP and SRP loads for the tributaries to the *Western Uplands* critical area.

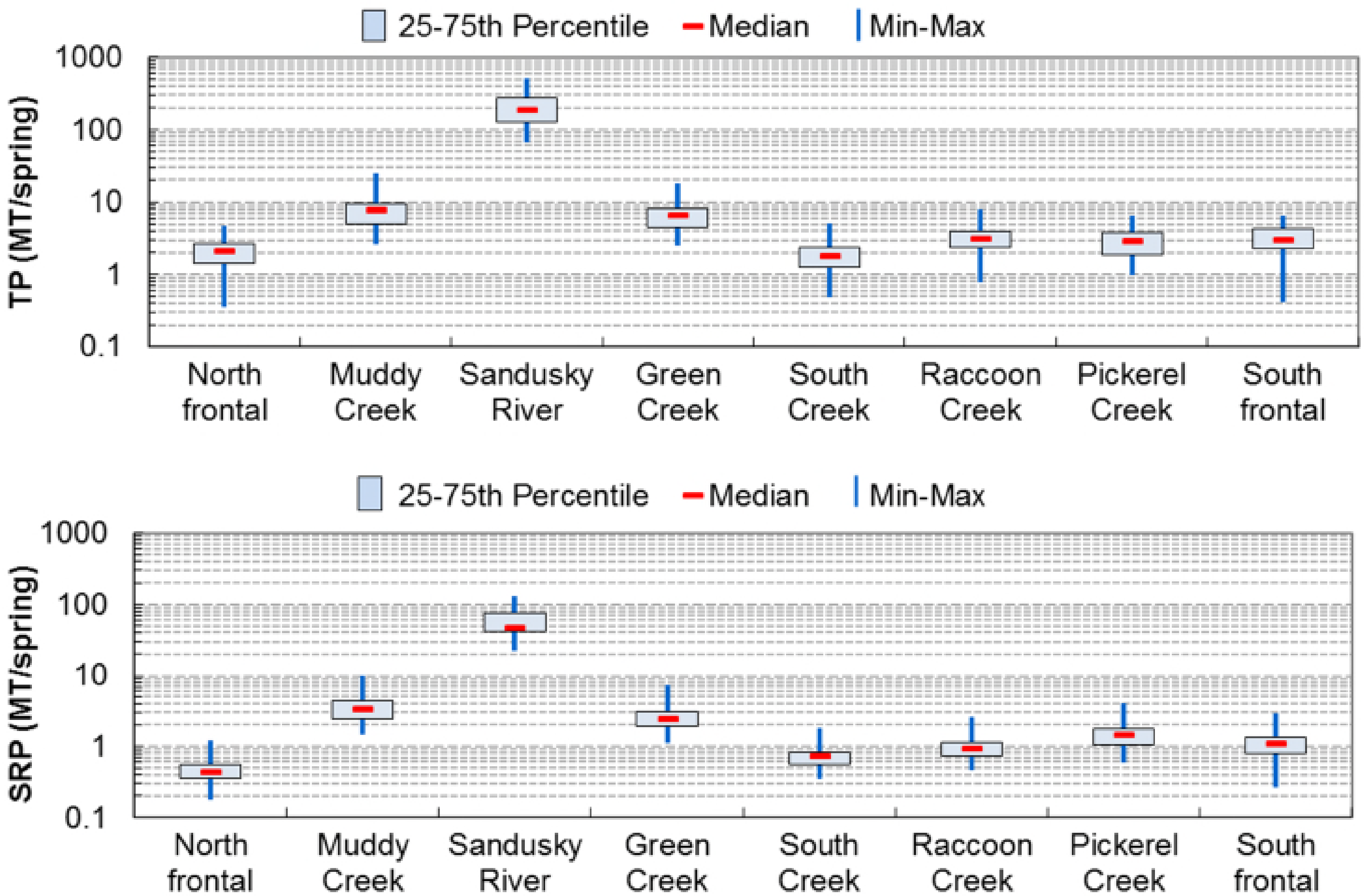



Figure 38. Springtime phosphorus loading in the *Western Uplands* critical area.

## 4.2.3 Detailed Biological Condition

Discussions of aquatic community health and aquatic habitat are presented in the TSDs for the lower Sandusky River watershed (Ohio EPA 2011) and tributaries to Sandusky Bay (Ohio EPA 2010). The biological and habitat indices scores for Ohio EPA monitoring sites within the *Western Uplands* are summarized herein:

- **Fish Community Health:** The Sandusky River, Muddy Creek, and Little Muddy Creek did not meet the lacustrine benchmarks (except for the Sandusky River L-MIwb of 8.7 at site U04S17). The remaining tributaries mostly met their IBI biocriteria but did not meet the MIwb biocriteria.

- **Macroinvertebrate Community Health:** The Sandusky River, Muddy Creek, and Little Muddy Creek did not meet the lacustrine benchmarks. With one exception (U05W17 on Raccoon Creek), the bay tributaries did not meet the ICI biocriteria.

- **Fish Habitat:** The Sandusky River and Raccoon Creek are the only waterbodies that met their habitat targets.

## 4.2.4 Detailed Causes and Associated Sources

The lower segments of tributaries to Muddy Creek Bay and the Upper Bay are typically impaired by elevated nutrients and siltation derived from local or upstream agricultural production (Table 14).

Table 14. Causes and sources of impairment in the *Western Uplands* critical area

| HUC (04100011) | Stream | RM | Site | Status | Cause(s) | Sources |
|---|---|---|---|---|---|---|
| 14 04 | Muddy Creek | 1.23 | U04Q13 | NON | Direct habitat alteration<br>Other flow regime alterations<br>Phosphorus(total) | Channelization (including extensive levees and armored banks) |
| 14 03 | Fishing Creek | 0.20 | 300678 | NON | Nutrient enrichment<br>Phosphorus (total) | Upstream crop production with subsurface drainage |
| | Little Muddy Creek | 2.50 | 300676 | NON | Nutrient enrichment<br>Phosphorus (total)<br>Siltation | Upstream crop production with subsurface drainage |
| 13 01 | Muskellunge Creek | 1.23 | U04P08 | NON | Nutrient eutrophication<br>Phosphorus (total)<br>Sedimentation/siltation | Crop production with subsurface drainage |
| 13 02 | Sandusky River | 13.0 | 500890 | NON | Nutrient eutrophication<br>Sedimentation/siltation | Crop production with subsurface drainage<br>Municipal point sources |
| 13 03<br><br>large river assess. unit<br>90 02 | Sandusky River | 5.5 | U04S17 | NON | Embedded substrates<br>Nutrient eutrophication<br>Siltation | Upstream crop production with subsurface drainage |
| | | 1.3 | 201314 | NON | Embedded substrates<br>Siltation | Upstream crop production with subsurface drainage |
| | Bark Creek | 3.2 | 300671 | NON | Direct habitat alteration<br>Organic enrichment<br>Nutrient eutrophication<br>Particle distribution<br>Phosphorus (total)<br>Sedimentation/siltation | Channelization<br>Crop production with subsurface drainage<br>Sewage discharge in unsewered areas |
| 12 03 | Green Creek | 5.06 | U04K01 | Partial | Sedimentation/siltation | Channel erosion/incision [a]<br>Crop production with subsurface drainage |
| 02 05 | South Creek | 4.04 | U05K05 | Partial | Embedded substrates<br>Nutrient eutrophication<br>Phosphorus (total)<br>Siltation | Channelization<br>Livestock |
| 02 04 | Raccoon Creek | 5.45 | U05W17 | Partial | Nutrient eutrophication<br>Organic enrichment<br>Phosphorus (total) | Clyde WWTP<br>Crop production with subsurface drainage |

| HUC (04100011) | Stream | RM | Site | Status | Cause(s) | Sources |
|---|---|---|---|---|---|---|
| 02 03 | Pickerel Creek | 3.35 | U05S04 | Partial | Embedded substrates<br>Siltation | Channel erosion/incision [a]<br>Crop production with subsurface drainage |
| 02 01 | Little Pickerel Creek | 2.00 | 201385 | Partial | Embedded substrates<br>Siltation | Crop production with subsurface drainage |

*Source:* Ohio EPA 2010, 2011.

*Notes*

Streams are sorted from top to bottom as west to east along the southern coastline of Muddy Creek Bay and Upper Sandusky Bay.

a. Channel erosion/incision from upstream hydromodifications. For Pickerel Creek, this includes bank destabilization.

## 4.2.5 Goals and Objectives for Critical Area #1

As explained in detail above, *Critical Area #1* is primarily impaired by embedded substrates, nutrient enrichment/eutrophication, phosphorus, sedimentation/siltation, and siltation. The landscape and hydrology of the *Western Uplands* critical area has been modified to accommodate agricultural development. Agricultural BMPs (e.g., saturated buffers, drainage mater management), in-stream and riparian habitat restoration, and floodplain reconnection will be needed to improve aquatic community health.

Phosphorus loading from these impaired streams directly contributes to the persistent HABs in Sandusky Bay and hypoxia in Lake Erie. While some impaired sites are not listed[16] for nutrient enrichment/eutrophication or phosphorus, at least a few water quality samples collected from such sites resulted in TP concentrations in excess of targets from the *Associations* document (Ohio EPA 1999). EFDC model results indicate that the Sandusky River is the largest source of TP loading to Sandusky Bay; however, smaller tributaries (e.g., Muddy Creek, Pickerel Creek) also generate localized TP plumes. A few large, sustained runoff events per year result in large pulses of TP migrating down the Sandusky River and across Sandusky Bay to Lake Erie. The plumes from most runoff events from the Sandusky River are limited to Muddy Creek Bay and Upper Sandusky Bay. To reduce HABs, tributary phosphorus loads must be reduced or captured.

The overarching goals of the Clean Water Act are to make all waters of the United States fishable and swimmable. To this end, states established WQS and must develop plans to achieve WQS when waters of the United States do not attain such WQS. In Ohio, attainment in impaired watersheds will be achieved through the efforts of multiple state programs, including Ohio EPA's TMDL program. In the *Western Uplands* critical area, Ohio EPA (2014b) developed TMDLs for TP, total suspended solids, and nitrate + nitrite at several locations. While attainment of WQS and achievement of these TMDLs are important goals of Ohio EPA, they are beyond the scope of this NRIP. Thus, WQS and TMDLs for each and every impaired subwatershed and monitoring site are not included as goals in this NRIP.

### 4.2.5.1 Goals

The overall NPS restoration goals for the *Western Uplands* critical area are twofold: (1) bring the waterbodies into full attainment of the designated ALUs to meet Ohio's WQS and (2) reduce phosphorus loads by 40 percent to meet Annex 4

[16] Ohio EPA identifies the causes and sources of impairment to each assessment site that does not meet WQS. Impairment can be due to several causes and sources. Ohio EPA (2010, 2011) reports the main causes and sources but may not specifically identify every cause and source that contributes to an impairment.

recommendations (GLWQA 2015). These overall goals were specifically applied to the Sandusky River (goals 1 and 2) and key tributaries[17] to Muddy Creek Bay and Upper Sandusky Bay (goals 3, 4, 5, and 6).

**Goal 1.** A 40 percent reduction in spring (March-July) TP and SRP loads and annual TP loads in the Sandusky River. [18]

- Not Achieved: The Sandusky River has a 2017 spring TP load of 276 MT that is a 28 percent reduction from the 2008 baseline load (386 MT)
- Not Achieved: The Sandusky River has a 2017 spring SRP load of 80 MT that is larger than the 2008 baseline load (78 MT).
- Achieved: The Sandusky River has a WY 2017 annual TP load of 476 MT that is a 43 percent reduction from the WY 2008 baseline load (841 MT).

**Goal 2.** Achieve L-IBI (42), L-MIwb (8.6), L-ICI (42), and L-QHEI (55) benchmarks at site 201314 on the Sandusky River.

- Not Achieved: The L-IBI (31) does not meet the lacustuary benchmark.
- Not Achieved: The L-MIwb (7.5) do not meet the lacustuary benchmark.
- Not Achieved: No ICI data were collected.
- Achieved: The L-QHEI (64.5) meets the lacustuary benchmark.

**Goal 3.** A 40 percent reduction in spring (March-July) TP and SRP load and annual TP load from north and south side frontal bay tributaries, Green Creek, Muddy Creek, Pickerel Creek, Raccoon Creek, and South Creek. [19]

- Not Achieved: North and south side frontal bay tributaries, Muddy Creek, Pickerel Creek, Raccoon Creek, and South Creek have a combined 2017 spring TP load of 31 MT that is a 34 percent reduction from the combined 2008 baseline load (46 MT).
- Not Achieved: The tributaries have a combined 2017 spring SRP load of 15 MT that is larger than the 2008 baseline load (13 MT).
- Achieved: The tributaries have a combined WY 2017 TP load of 48 MT that is a 55 percent reduction from the combined 2008 baseline load (106 MT).

**Goal 4.** Achieve L-IBI (42), L-MIwb (8.6), L-ICI (42), and L-QHEI (55) benchmarks at site U04Q13 on Muddy Creek.

- Not Achieved: The L-IBI (21) does not meet the lacustuary benchmark.
- Not Achieved: The L-MIwb (6.7) does not meet the lacustuary benchmark.
- Not Achieved: The L-ICI (12) does not meet the lacustuary benchmark.
- Not Achieved: The L-QHEI (50.5) does not meet the lacustuary benchmark.

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[17] For setting NPS restoration goals for this NRIP, the key tributaries are Muddy Creek, Raccoon Creek, and South Creek. Each of these streams is impaired for its WWH use by TP derived from crop production.

[18] Loads were calculated using SWAT model results for the Sandusky River.

[19] Loads were calculated using SWAT model results for the following subwatersheds: *South Side Frontal Sandusky Bay* (*02 01), *Strong Creek* (*02 02), *Pickerel Creek* (*02 03), *Raccoon Creek* (*02 04), *South Creek* (*02 05), *Green Creek* (*12 03), *Muskellunge Creek-Sandusky River* (*13 03), *Town of Lindsey-Muddy Creek* (*14 04), and *North Side Sandusky Bay Frontal* (*14 05). Loads are cumulative of all upstream subwatersheds and in-stream processes. About 69 percent of *Frontal South Side of Sandusky Bay* and about 73 percent of *North Side Sandusky Bay Frontal* are in the *Western Uplands* critical area; thus, only 69 and 73 percent (respectively) of the subwatersheds' simulated loads are included in these load calculations.

**Goal 5.** Achieve IBI (32), MIwb (7.3), and ICI (34) wading WWH biocriteria and the QHEI WWH target (60) at site U05W17 on Raccoon Creek.

- Achieved: The IBI (29)[20] meets the biocriterion.
- Not Achieved: The MIwb (5.5) does not meet the biocriterion.
- Achieved: The ICI (34) meets the biocriterion.
- Achieved: The QHEI (66) meets the target.

**Goal 6.** Achieve IBI (28) and ICI (34) headwaters WWH biocriteria and the QHEI headwaters WWH target (55) at site U05K05 on South Creek.

- Achieved: The IBI (24)[21] meets the biocriterion.
- Not Achieved: The ICI (low-fair) does not meet biocriterion.
- Not Achieved: The QHEI (33.5) does not meet the target.

### 4.2.5.2 Objectives

To achieve the overall NPS restoration goals of achieving water quality standards and 40 percent phosphorus load reductions, the following objectives need to be achieved within *Critical Area #1*; practices throughout the Sandusky watershed will be necessary to achieve these goals. In the *Western Uplands* critical area, the following objectives need to be met.

**Drainage water management**

Perhaps the single most important action that can be taken to reduce nutrient loadings and impacts on Ohio streams is to reduce the rate and amount of runoff from agricultural production areas.

(Ohio EPA 2013a, p. 38, Goal 3.03.01)

**Objective 1** Reduce nutrient- and sediment-loads from 3,300 acres[22] of cropland using drainage water management practices to treat runoff such that the runoff is like that of the native landscape.

- *Reduce erosion and nutrient- and sediment-loss to surface waters* (Ohio EPA 2013a, Goal 3.01.02)
- *Reduce the rate and amount of runoff* (Ohio EPA 2013a, Goal 3.03.01)
- *Increase treatment of field runoff* (Ohio EPA 2013a, Goal 3.03.02)

Cropland throughout the *Western Uplands* critical area is tiled. Runoff from tiled cropland contains high nutrient- and sediment loads that are quickly transported downstream through straightened, channelized ditches.

- o Installation of drainage control structures and saturated buffers will prevent nutrient- and sediment loads from discharging directly to streams.
- o Installation of retention structures (e.g., wetlands, basins) will capture and retain nutrient- and sediment-loads from agricultural runoff.

[20] The IBI score of 29 is in nonsignificant departure from the biocriteria (32).

[21] The IBI score of 24 is in nonsignificant departure from the biocriteria (28).

[22] To achieve a 40 percent reduction of annual TP load from the Sandusky watershed (381 MT), using the annual wetland retention rate of 1.44 grams TP per square meter per year (Mitsch & Wang 2000), about 65,000 acres of wetlands would need to be installed in the Sandusky watershed, which would be 5.6 percent of the watershed. This 5.6 percent was applied to the total acreage of the *Western Uplands* to estimate the 3,300 acres of land that must be converted to wetlands or modified to treat nutrient- and sediment-loads like a wetland.

- o Removal of marginal cropland from production will eliminate nutrient- and sediment-loads. If drainage water management is installed on the former cropland, nutrient- and sediment-loads from valuable cropland can then be treated.
- o Removal of cropland from production and restoration to native landscape will eliminate anthropogenic nutrient loads.

**Objective 2** Improve stream channel morphology and implement riparian management strategies in at least 5 miles of stream channel along the bay tributaries (excluding the Sandusky River mainstem).

- *Restore streams impaired aquatic habitat* (Ohio EPA 2013a, Goal 2.01.01)
- *Restore and protect riparian habitat* (Ohio EPA 2013a, Goal 2.03.01)
- *Increase riparian wetland areas* (Ohio EPA 2013a, Goal 3.04.01)
- *Protect and restore riparian forested acres* (Ohio EPA 2013a, Goal 3.04.02)

Streams throughout the *Western Uplands* critical area have been straightened and channelized to quickly remove runoff from crop fields. The result is low-quality in-stream habitat that cannot support healthy, diverse fish or macroinvertebrate communities.

- o Improvement of stream channel morphology, including streambank restoration, will provide high-quality habitat that can support healthy aquatic communities.
- o Improvement of stream channel morphology may also reduce flashiness and slowdown in-stream velocities, which can overwhelm aquatic life.

Straightened, channelized streams throughout the *Western Uplands* critical have limited riparian vegetation and lack trees. The result is low-quality shoreline habitat that cannot support healthy, diverse wildlife communities.

- o Forested riparian corridors will provide high-quality wildlife habitat and will shade in-stream habitat.
- o Vegetated riparian corridors are more stable (i.e., less sediment erosion) and can reduce overland runoff that contains nutrients and sediment (e.g., saturated buffers).

**Objective 3** Install 160 acres[23] of off-line wetland/detention stormwater treatment systems, potentially with alum injection, at publicly managed lands adjacent to the bay shoreline. Potential locations include along small tributaries to the bay (e.g., ODNR's Pickerel Creek Wildlife Area) as well as the Sandusky River. A feasibility study should be performed to determine which locations are most feasible and beneficial.

As these objectives are implemented, water quality monitoring (both project-related and regularly scheduled monitoring) will be conducted to determine progress toward meeting the identified goals (i.e., water quality standards). These objectives will be reevaluated and modified, as necessary. When reevaluating, the Ohio's *Nonpoint Source Management Plan Update* (Ohio EPA 2013a) will be referenced, which has a complete listing of all eligible NPS management strategies.

[23] The 160-acres is based on four new wetland/detention stormwater treatment systems, each at least 40-acres in size.

# 4.3 CRITICAL AREA #2: CONDITIONS, GOALS, & OBJECTIVES

## 4.3.1 Detailed Characterization

The *Muddy Creek Bay and Upper Sandusky Bay* critical area is composed of the nearshore and open waters of Muddy Creek Bay and Upper Sandusky Bay (Figure 39); the critical area is 32.2 square miles (Lee 1986). The *Western Uplands* critical area drains directly to the *Muddy Creek Bay and Upper Sandusky Bay* critical area. This critical area then drains to the *Lower Sandusky Bay* critical area. The Thomas A. Edison Memorial Bridge, fishing piers (former Sandusky Bay Bridge), and Norfolk Southern railroad bridge are the divide between the upper and lower bays.

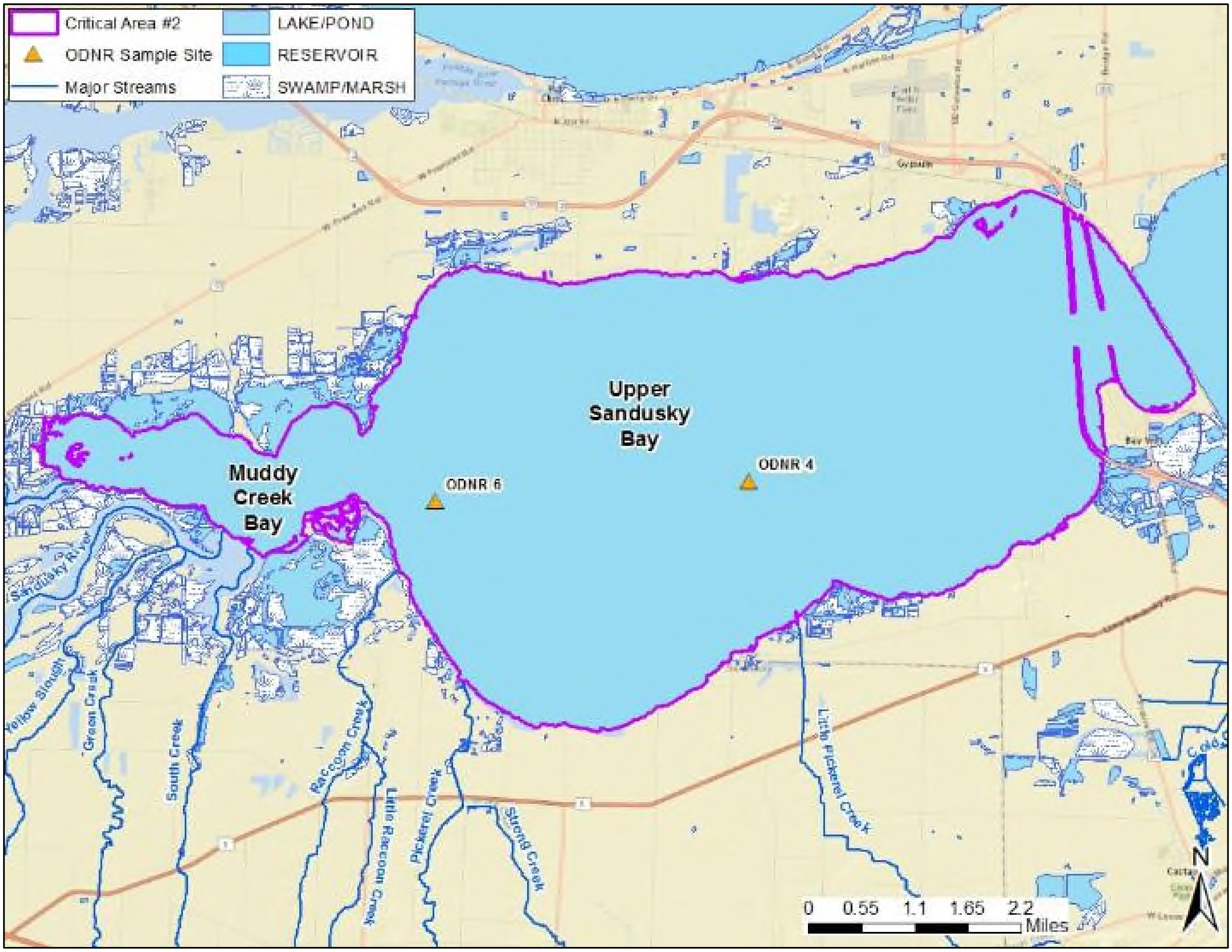



Figure 39. *Muddy Creek Bay and Upper Sandusky Bay* (critical area #2).

## 4.3.2 Detailed Biological Condition

In 2012, fish were captured from Upper Sandusky Bay in June and August. Two pairs of sites were sampled on the same day or adjacent days: (1) 301570 and 301572 and (2) 302436 and 302437. In each pair, one site was near the north shore and one site was near the south shore of Upper Sandusky Bay. No fish data were collected in Muddy Creek Bay.

Predominant species were often white perch, bluegill sunfish, gizzard shad, and freshwater drum (Table 15). The narrative N-IBI scores were poor. Only site 301570 was in full attainment in Upper Sandusky Bay. Poor fish community health in Upper Sandusky Bay is the result of turbid waters and lack of submerged aquatic vegetation[24]; additionally, such vegetation cannot survive in such turbid waters.

Table 15. Fish community health data - Critical Area #2

| Site | Total species | N-IBI | N-MIwb | Predominant species (percent of catch) | | Narrative evaluation |
|---|---|---|---|---|---|---|
| | | | | June 6th, 7th or 28th | August 2nd or 3rd | |
| ***North Shore*** | | | | | | |
| 302436 | 23 / 13 | 28 | 7.7 | White perch (28%), common carp (14%), bluegill sunfish (10%) | White perch (21%), freshwater drum (17%), common carp (16%) | Poor |
| 301570 | 18 / 20 | 31 | 8.7 | Bluegill sunfish (46%), ghost shiner (14%), channel catfish (7%) | Gizzard shad (23%), bluegill sunfish (23%), freshwater drum (18%) | Poor |
| ***South Shore*** | | | | | | |
| 302437 | 14 / 19 | 30 | 7.5 | White perch (74%), common carp (7%), gizzard shad (5%) | White perch (40%), freshwater drum (18%), bluegill sunfish (16%) | Poor |
| 301572 | 21 / 17 | 28 | 7.7 | Bluegill sunfish (22%), emerald shiner (14%), spotfin shiner (10%) | White perch (22%), gizzard shad (22%), bluegill sunfish (20%) | Poor |

*Source:* Ohio EPA 2016d. Data collected in 2012.

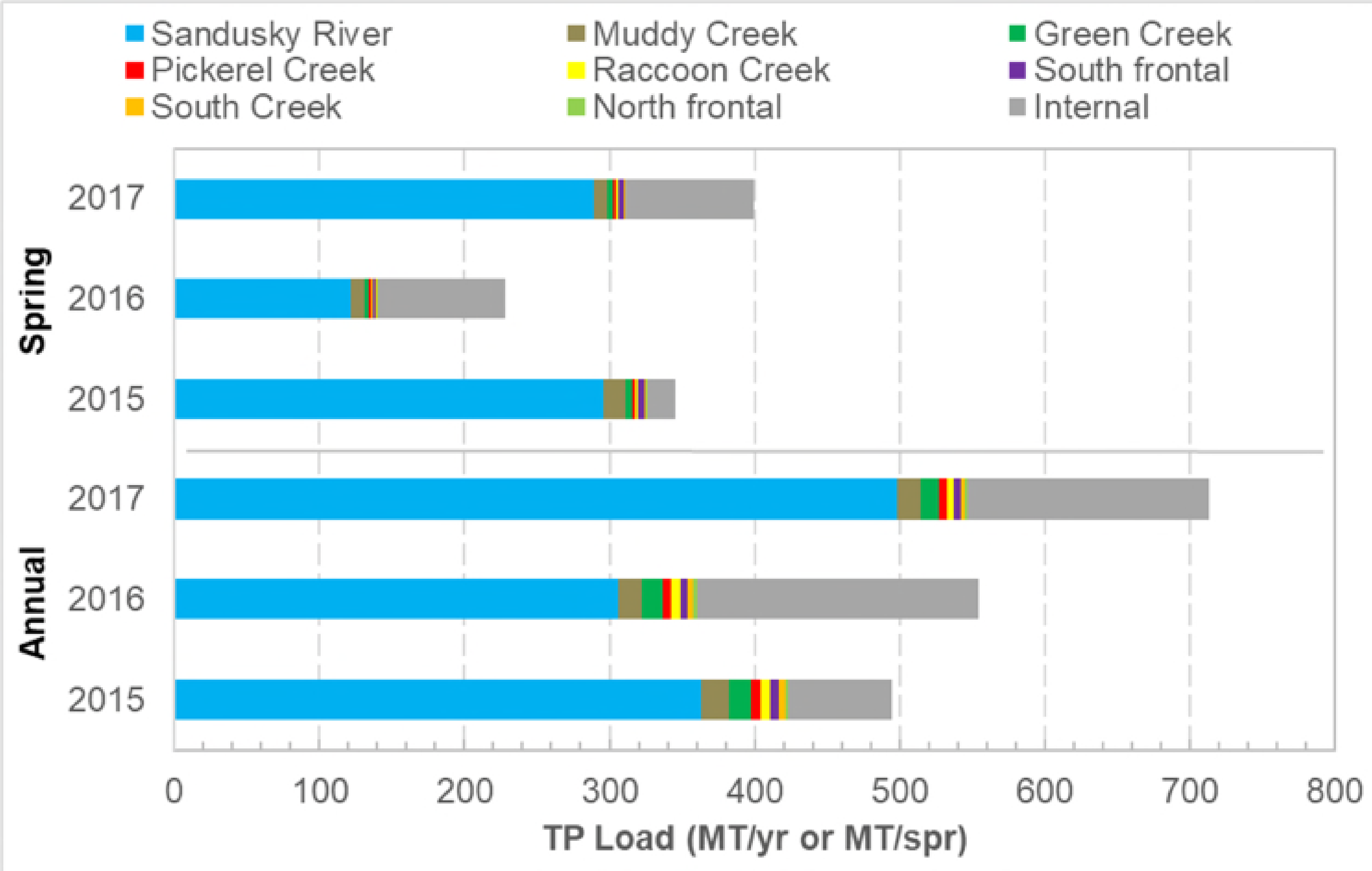
*Note a:* The soft, nearshore benchmarks are N-IBI score of 31 and N-MIwb score of 7.2 (Ohio EPA 2016a). Green scores met the benchmarks, while red scores did not meet the thresholds.

## 4.3.3 Detailed Bay Phosphorus Loading

The majority of TP loading to the *Muddy Creek Bay and Upper Sandusky Bay* critical area is from the Sandusky River. Loading from the Sandusky River and internal loading were the largest sources of loading, with more internal loading in 2016 (Figure 40).

Due to seiches in Lake Erie and Sandusky Bay, considerable TP flux was in the upstream direction (e.g., from Muddy Creek Bay upstream into the lacustuary of the Sandusky River). In 2015 and 2016, net TP flux was from the critical area to Lower Sandusky Bay.

[24] Scott Winkler, Ohio EPA, electronic communication, January 24, 2018.




*Note*: This analysis does not consider TP flux into Upper Sandusky Bay from Lower Sandusky Bay. This analysis also does not consider flux out of Muddy Creek Bay to the Sandusky River or out of Upper Sandusky Bay into Lower Sandusky Bay.

Figure 40. TP loading into the *Muddy Creek Bay and Upper Sandusky Bay* critical area.

## 4.3.4 Detailed Causes and Associated Sources

The shorelines of Muddy Creek Bay and Upper Sandusky Bay are within the *Sandusky Basin Shoreline* (LEAU 04120200 02 02) that is impaired for its designated ALU (Ohio EPA 2018a). Fish community health is impaired by high turbidity and lack of submerged aquatic vegetation (also the result of high turbidity). As discussed in Section 2.6, impairment of this LEAU is due to several point sources and NPS. This NRIP addresses the impairment caused by nutrients from non-irrigated crop production

Elevated phosphorus loads from NPS agricultural operations in the Sandusky watershed are discharged to Sandusky Bay, and eventually Lake Erie, and these high phosphorus loads contribute to HABs in Sandusky Bay and to hypoxia in the Central Basin of Lake Erie (Lake Erie LaMP 2009, 2011; Ohio EPA 2013b, 2016b). The Sandusky watershed contributed the highest NPS phosphorus yield of Ohio's seven major watersheds[25] in water years 2013 and 2014 (Ohio EPA 2016b, p. 15). The Sandusky watershed also has the highest relative NPS phosphorus load with about 94 percent of the TP load from NPS (Ohio EPA 2016b, p. 27).

[25] The seven major watersheds are the Cuyahoga, Great Miami, Maumee, Muskingum, Portage, Sandusky, and Scioto rivers

## 4.3.5 Goals and Objectives for Critical Area #2

As explained in detail above, the shoreline of *Critical Area #2* is impaired by phosphorus and sediment loading from agricultural operations in the Sandusky watershed. Nearshore and open waters are afflicted by HABs that are derived from the same NPS loading. The *Western Uplands* critical area, and specifically the Sandusky River, contribute large phosphorus loads to the *Muddy Creek and Upper Sandusky Bay* critical area. EFDC model results indicate that most runoff-derived loads from the Sandusky River yield TP plumes that become trapped in Upper Sandusky Bay, with few plumes migrating to Lower Sandusky Bay and Lake Erie. Some plumes that are stopped upon entering Upper Sandusky Bay are pushed to shorelines in the northwest and southwest corners of Upper Sandusky Bay.

In *Critical Area #2*, restoration of wetlands and submerged aquatic vegetation are needed along the shoreline and nearshore to assimilate upland phosphorus loads before they are transported into open waters. To maximize nutrient reduction, Mitsch & Wang (2000) found that wetland restoration should be designed to receive upstream runoff and may need to consider breaching dikes to restore a more natural hydrology.

Additionally, living shorelines and coastal wetland can assimilate phosphorus plumes and trap sediment from the Sandusky River when plumes from the river are stopped in Upper Sandusky Bay and pushed to the shorelines. Such projects should focus on the western half or Upper Sandusky Bay because the hydrodynamics associated with the constriction between Upper Sandusky Bay and Lower Sandusky Bay typically tend to prevent phosphorus plumes from being forced to the northeast and southeast corners of Upper Sandusky Bay.

### 4.3.5.1 Goals

The NPS restoration goals for the *Muddy Creek Bay and Upper Sandusky Bay* critical area are to meet the biological and habitat benchmarks for soft-bottom nearshore (Ohio EPA 2016a) and the *Sandusky Basin Shoreline* TP concentration target (Ohio EPA 2014a, Table I5-4, p. I-36).

**Goal 1.** Achieve N-IBI-soft (31), N-MIwb-soft (7.2), and N-QHEI (50) nearshore benchmarks.

- Not Achieved: The N-IBI-soft at sites 302436 (28), 302437 (30), and 301572 (28) did not achieve the nearshore benchmark. Site 301570 (31) did achieve the nearshore benchmark.
- Achieved: The N-MIwb-soft at sites 302436 (7.7), 301570 (8.7), 302437 (7.5), and 301572 (7.7) achieved the nearshore benchmark.
- Not Achieved: Appropriate N-QHEI data have not been collected.

**Goal 2.** An average shoreline[26] TP concentration of 0.03 mg/L during the ice-free period.

- Not Achieved: The summer 2016 average concentration at sampling site ODNR 4 was 0.19 mg/L.
- Not Achieved: The summer 2016 average concentration at sampling site ODNR 6 was 0.17 mg/L

### 4.3.5.2 Objectives

To achieve the overall NPS restoration goals of achieving water quality standards and 40 percent phosphorus load reductions, the following objectives need to be achieved within *Critical Area #2*:

**Objective 1** Restoration of at least 500 acres of coastal and lacustrine wetlands in Muddy Creek Bay (about one-fifth of the bay's area), focusing on the mouth of the Sandusky River.

[26]"This target applies to Sandusky Bay (Ohio EPA 2014a, Table I5-3, p. I-32).

**Objective 2** Restoration of at least 5 miles of coastline along the shores of Upper Sandusky Bay, focusing on the southwest lobe and northwest lobe of the bay. The coastline should be restored to a natural morphology with native vegetation, including creation/restoration of coastal wetlands and lacustrine wetlands and re-establishment of submerged aquatic vegetation.

**Objective 3** Conduct feasibility studies to evaluate the creation of islands in the open waters of Upper Sandusky Bay, focusing on the western portion of the bay closest to Muddy Creek Bay. The islands should include coastal wetlands with living shorelines and be established with native vegetation, including submerged aquatic vegetation. Key factors to address during the feasibility studies include impacts to the hydrodynamics of the bay and the ability of the wetlands to be a long-term sink of phosphorus.

**Objective 4** Conduct a feasibility study to evaluate potential modifications of the Thomas A. Edison Memorial Bridge, the former Sandusky Bay bridge, and the Norfolk Southern railroad bridge to alter the hydrodynamics of the constriction between Upper Sandusky Bay and Lower Sandusky Bay, with the objective of increasing nutrient and sediment load transport through the constriction. Key factors to address during the feasibility study include determining whether the benefit to Upper Sandusky Bay water quality would justify the expected high cost, and evaluating potential negative impacts on Lower Sandusky Bay and Lake Erie. The existing EFDC model could be used to inform these analyses.

As these objectives are implemented, water quality monitoring (both project-related and regularly scheduled monitoring) will be conducted to determine progress toward meeting the identified goals (i.e., water quality standards). These objectives will be reevaluated and modified, as necessary. When reevaluating, the Ohio's *Nonpoint Source Management Plan Update* (Ohio EPA 2013a) will be referenced, which has a complete listing of all eligible NPS management strategies

# 4.4 CRITICAL AREA #3: CONDITIONS, GOALS, & OBJECTIVES

## 4.4.1 Detailed Characterization

The *Lower Sandusky Bay* critical area is composed of the nearshore and open waters of Lower Sandusky Bay (Figure 41); the critical area is 24.5 square miles (Lee 1986). The *Muddy Creek Bay and Upper Sandusky Bay* critical area drains directly to the *Lower Sandusky Bay* critical area through the narrow constriction that separates the upper and lower bays. A portion of the Marblehead Peninsula to the north of Lower Sandusky Bay and several watersheds to the south of Lower Sandusky Bay also drain to this critical area[27]. The largest outlet of Lower Sandusky Bay is the channel between the Marblehead and Cedar Point peninsulas. A second, smaller outlet is near the northwest tip of the Sheldon Marsh nature preserve and the Cedar Point Road bridge.

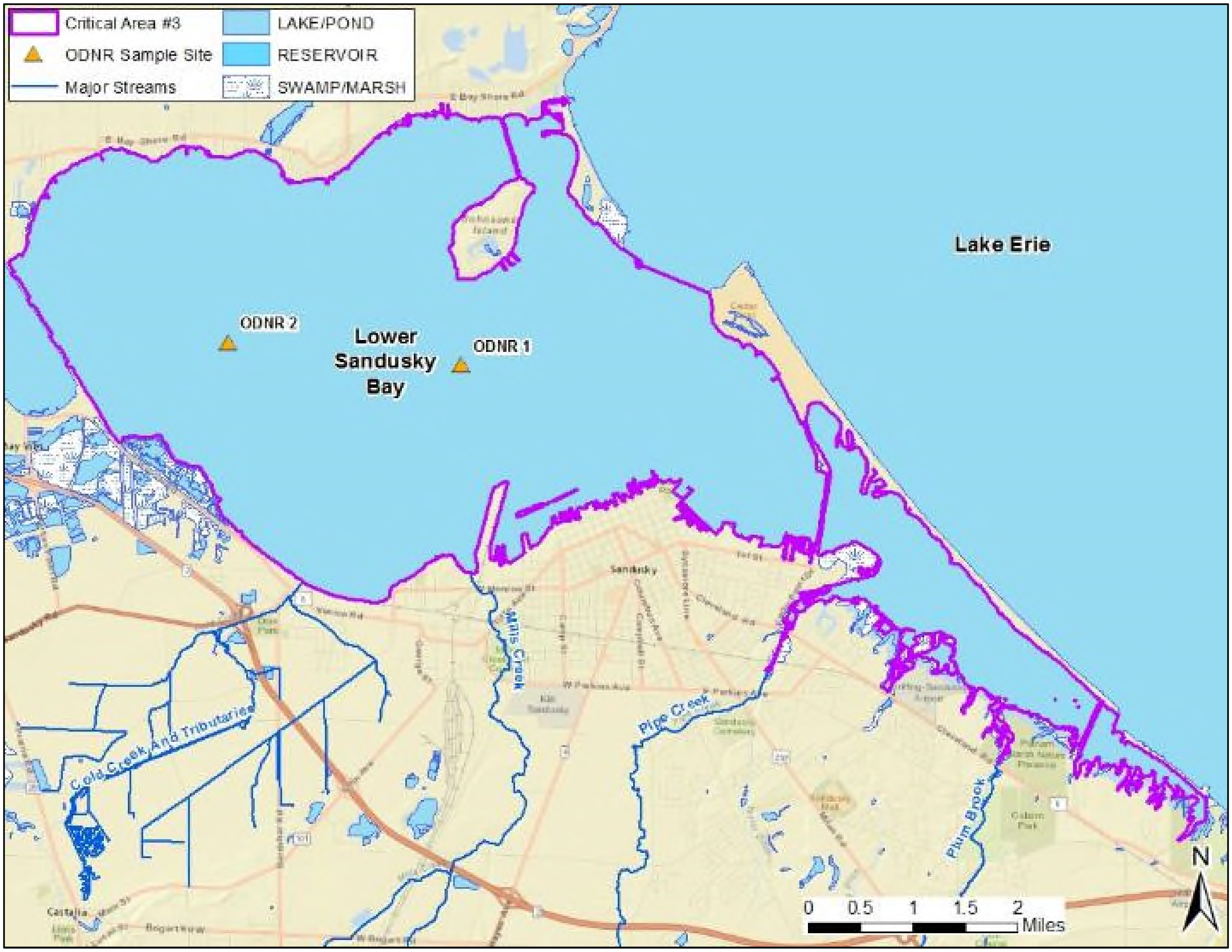



Figure 41. *Lower Sandusky Bay* (critical area #3).

[27] The following subwatersheds drain to the Lower Sandusky Bay: the eastern half of *North Side Sandusky Bay Frontal* (*15 05), the eastern half of *Frontal South Side Sandusky Bay* (*02 01), *Mills Creek* (*01 03), and *Pipe Creek-Frontal Sandusky Bay* (*01 02).

## 4.4.2 Detailed Biological Condition

Fish were captured from Lower Sandusky Bay at six sites in recent years. Three sites were in the portion of Lower Sandusky Bay between the Thomas A. Edison Memorial Bridge and outlet between the Marblehead and Cedar Point peninsulas. Three additional sites are in the East Sandusky Bay, to the east of the Cedar Point Causeway.

Predominant species were often white perch and emerald shiner (Table 16). The narrative N-IBI scores were mostly poor. Only sites 302434 and 302435 was in full attainment in Lower Sandusky Bay. Poor fish community health in Lower Sandusky Bay is the result of turbid waters. Lack of submerged aquatic vegetation more common in Lower Sandusky Bay (than Upper Sandusky Bay) especially in areas that receive flow from Lake Erie. Such vegetation is more often abundant in East Sandusky Bay. [28]

Table 16. Fish community health data - Critical Area #3

| Site | Total species | N-IBI | N-MIwb | Predominant species | | Narrative evaluation |
|---|---|---|---|---|---|---|
| | | | | Date | Predominant species (percent of catch) | |
| ***Lower Sandusky Bay*** | | | | | | |
| 302446 | 14 | 18 | 8.8 | July 13, 2012 | Gizzard shad (35%), emerald shiner (16%), smallmouth buffalo (16%) | Poor |
| 301568 | 17 | 30 | 8.8 | June 25, 2014 | White perch (33%), spotfin shiner (16%), emerald shiner (14%) | Poor |
| 302435 | 19 | 34 | 9.1 | June 19, 2014 | Spottail shiner (21%), white perch (18%), emerald shiner (15%), mimic shiner (12%) | Fair |
| ***East Sandusky Bay*** | | | | | | |
| 302434 [a] | 14 | 31 | 8.4 | June 4, 2012 | White perch (26%), bluegill sunfish (23%), goldfish (13%), common carp (12%) | Poor |
| 302432 | 20 | 29 | 8.8 | June 26, 2014 | Emerald shiner (64%), bluntnose minnow (17%), pumpkinseed sunfish (9%) | Poor |
| 302433 | 6 | 18 | 5.5 | June 26, 2014 | White perch (51%), emerald shiner (45%), gizzard shad (2%) | Poor |

*Source:* Ohio EPA 2016d. Data collected in 2012.

*Notes*

The soft, nearshore benchmarks are N-IBI score of 31 and N-MIwb score of 7.2 (Ohio EPA 2016a). Green scores met the benchmarks, while red scores did not meet the thresholds.

a. Ohio EPA (2016d) assessed attainment using 2011 data; total species and predominant species are from 2012 data.

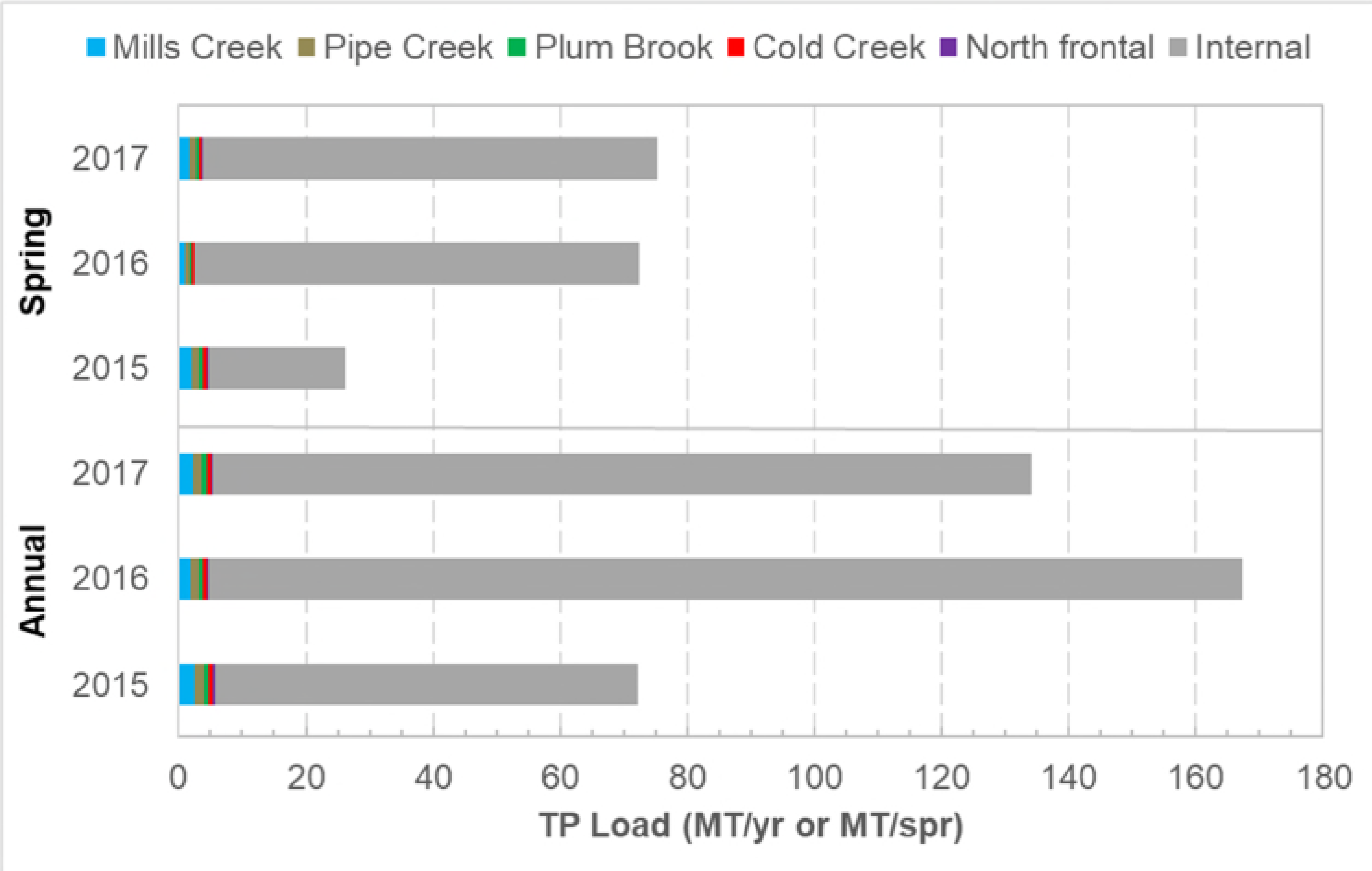
## 4.4.3 Detailed Bay Phosphorus Loading

The majority of TP loading to the *Lower Sandusky Bay* critical area is from internal loading (Figure 42), and internal loading was over ten times as large as tributary loading. However, in East Sandusky Bay and within individual small coves, tributary loads may be the largest sources of TP loading. Much of the internal loading in Lower Sandusky Bay occurs west of the Cedar Point Causeway.

Due to seiches in Lake Erie and Sandusky Bay, considerable TP flux was in the upstream direction (e.g., from Lake Erie upstream into Lower Sandusky Bay). While flux into and out of Lower Sandusky Bay between the Marblehead and Cedar

[28] Scott Winkler, Ohio EPA, electronic communication, January 24, 2018.

Point peninsulas occurred equally often, flux from Upper Sandusky Bay into Lower Sandusky Bay occurred more often than in the opposite direction.




*Note*: This analysis does not consider TP flux into Lower Sandusky Bay from Upper Sandusky Bay or from Lake Erie. This analysis also does not consider flux out of Lower Sandusky Bay to Upper Sandusky Bay or to Lake Erie.

Figure 42. TP loading into the *Lower Sandusky Bay* critical area.

## 4.4.4 Detailed Causes and Associated Sources

The shoreline of Lower Sandusky Bay is within the *Sandusky Basin Shoreline* (LEAU 04120200 02 02) that is impaired for its designated ALU (Ohio EPA 2018a). As discussed in Section 2.6, impairment of this LEAU is due to several point sources and nonpoint sources. This NRIP addresses the impairment caused by nutrients from non-irrigated crop production

Elevated phosphorus loads from NPS agricultural operations in the Sandusky watershed are discharged to Sandusky Bay, and eventually Lake Erie, and these high phosphorus loads contribute to HABs in Sandusky Bay and to hypoxia in the Central Basin of Lake Erie (Lake Erie LaMP 2009, 2011; Ohio EPA 2013b, 2016b). The Sandusky watershed contributed the highest NPS phosphorus yield of Ohio's seven major watersheds[29] in water years 2013 and 2014 (Ohio

[29] The seven major watersheds are the Cuyahoga, Great Miami, Maumee, Muskingum, Portage, Sandusky, and Scioto rivers

EPA 2016b, p. 15). The Sandusky watershed also has the highest relative NPS phosphorus load with about 94 percent of the TP load from NPS (Ohio EPA 2016b, p. 27).

## 4.4.5 Goals and Objectives for Critical Area #3

As explained in detail above, the shoreline of *Critical Area #3* is impaired by phosphorus loading from agricultural operations in the Sandusky watershed. Nearshore and open waters are afflicted by HABs that are derived from the same NPS phosphorus loading. EFDC model results indicate that only a few large storm events per year yield TP plumes that traverse the constriction between Upper Sandusky Bay and Lower Sandusky Bay. These large plumes did not migrate very far eastward into East Sandusky Bay beyond the Cedar Point Causeway. Except for large storm events, internal loading is the dominant source of phosphorus to Lower Sandusky Bay. EFDC TP flux results indicate that Lower Sandusky Bay discharged to Lake Erie during only half of the days in 2015 and 2016, while TP load from Lake Erie was discharged into Lower Sandusky Bay the other half of days. Mills Creek, Pipe Creek, and Plum Brook yielded small, localized TP plumes in Lower Sandusky Bay throughout 2015 and 2016.

Agricultural and urban BMPs are needed to reduce phosphorus loads transported from uplands (*Critical Area #1*), while restoration of coastal wetlands and submerged aquatic vegetation are needed along the shoreline and nearshore in Lower Sandusky Bay (*Critical Area #3*) to assimilate upstream phosphorus and sediment loads before they are transported into open waters.

Especially in East Sandusky Bay, living shorelines and coastal wetland can assimilate phosphorus plumes from Pipe Creek and Plum Brook that are pushed to the shorelines when they are stopped and dissipate. Such projects should focus on the lacustuaries and coastline adjacent to the lacustuaries because the hydrodynamics associated with the numerous bays of East Sandusky Bay typically tend to prevent phosphorus plumes from being forced westward to open waters of Lower Sandusky Bay.

### 4.4.5.1 Goals

The overall NPS restoration goals for the *Lower Sandusky Bay* critical area are twofold: (1) bring the waterbodies into full attainment of the designated ALUs to meet Ohio's WQS and (2) reduce phosphorus loads by 40 percent to meet Annex 4 recommendations (GLWQA 2015). The attainment goals are set using nearshore, soft-substrate benchmarks, while the phosphorus load reduction goals are set using the Annex 4 (GLWQA 2015) load target to address Central Basin hypoxia and the *Sandusky Basin Shoreline* TP concentration target (Ohio EPA 2014a, Table I5-4, p. I-36).

**Goal 1.** Achieve N-IBI-soft (31), N-MIwb-soft (7.2), and N-QHEI (50) nearshore benchmarks.

- Not Achieved: The N-IBI-soft at sites 302446 (18), 301568 (30), 302432 (29), and 302433 (18) did not achieve the nearshore benchmark. Sites 302435 (34) and 302434 (31) did achieve the nearshore benchmark.
- Not Achieved: The N-MIwb-soft at site 302433 (5.5) did not achieve the nearshore benchmark. Sites 302446 (8.8), 301568 (8.8), 302435 (9.1), 302434 (8.4), and 302432 (8.8) achieved the nearshore benchmark.
- Not Achieved: Appropriate N-QHEI data have not been collected.

**Goal 2.** A 40 percent reduction in annual TP loads from Lower Sandusky Bay to Lake Erie.

- Not Achieved: A baseline load needs to be established to evaluate the 40 percent reduction. The EFDC model simulation of only two years (2015-2016)[30] is insufficient to develop a representative baseline; an additional year or two of wetter years would need to be simulated to develop a better baseline.

**Goal 3.** An average shoreline[31] TP concentration of 0.03 mg/L during the ice-free period.

- Not Achieved: The summer 2016 average concentration at sampling site ODNR 1 was 0.09 mg/L.
- Not Achieved: The summer 2016 average concentration at sampling site ODNR 2 was 0.14 mg/L.

### 4.4.5.2 Objectives

To achieve the overall NPS restoration goals of achieving water quality standards and 40 percent phosphorus load reductions, the following objectives need to be achieved within *Critical Area #3*:

**Objective 1** Restoration of at least 5 miles of coastline along the shores of Lower Sandusky Bay, including Johnson's Island and the bayside shores of the Marblehead and Cedar Point peninsulas but excluding East Sandusky Bay. The coastline should be restored to a natural morphology with native vegetation, including creation/restoration of coastal wetlands and re-establishment of submerged aquatic vegetation. The EFDC model indicates that plumes of water with high phosphorus concentrations impact both the north and south shorelines of Lower Sandusky Bay.

**Objective 2** Restoration of at least 2 miles of coastline along the shores of East Sandusky Bay, including the bayside shore of the Cedar Point Peninsula. Coastal and lacustrine wetlands and nearshore submerged aquatic vegetation should be enhanced and expanded.

As these objectives are implemented, water quality monitoring (both project-related and regularly scheduled monitoring) will be conducted to determine progress toward meeting the identified goals (i.e., water quality standards). These objectives will be reevaluated and modified, as necessary. When reevaluating, the Ohio's *Nonpoint Source Management Plan Update* (Ohio EPA 2013a) will be referenced, which has a complete listing of all eligible NPS management strategies

**Upland Loads**

The nutrient and sediment loads delivered to Sandusky Bay originate from nonpoint sources throughout the Sandusky watershed.

Upland agricultural BMPs (e.g., saturated buffers, drainage water management) will need to be implemented throughout the watershed to reduce loads delivered to the bay, and ultimately, Lake Erie.

[30] When ranking total annual flows in the Sandusky River monitored at Fremont from the years 2002 through 2017, total annual flow in 2015 was ranked 12th and in 2016 was ranked 16th (the lowest). The year 2008 was ranked 1st (highest) and is the baseline year for Annex 4.

[31] "This target applies to Sandusky Bay (Ohio EPA 2014a, Table I5-3, p. I-32).

# 5 PROJECTS AND IMPLEMENTATION STRATEGY

Projects and evaluations believed to be necessary to address the causes and sources of impairments to the Sandusky watershed are presented by critical area in this section. As Ohio assesses attainment using numeric biological criteria, periodic re-evaluation of biological condition will be necessary to determine if the implemented projects restore the critical areas.

Time is an important factor to consider when measuring project success and overall status. Biological systems in some cases can show response quickly (e.g., one season); others system may take longer (e.g., several seasons, years) to show recovery. There may also be reasons other than nonpoint source pollution for the impairment. Those issues will need to be addressed under different initiatives, authorities or programs which may or may not be accomplished by the same implementers addressing the nonpoint source pollution issues.

The Sandusky project area was delineated into three critical areas to address causes and sources of impairment. An overview table is presented for each critical area in the following subsections (5.1.1, 5.2.1, and □). Projects in each of the three critical areas were prioritized using the following process:

| | |
|---|---|
| **Highest priority** | Directly addresses one or more of the critical area’s objectives |
| | Directly or indirectly reduces nutrient or sediment loads delivered to Sandusky Bay |
| | Directly or indirectly increases water clarity in Sandusky Bay |
| | Directly or indirectly increases submerged aquatic vegetation in Sandusky Bay |
| | Land owner support |
| | Provides additional benefits to the community |
| **Higher priority** | Directly addresses one or more of the critical area’s objectives |
| | Directly or indirectly reduces nutrient or sediment loads delivered to Sandusky Bay |
| | Land owner support |
| **Lower priority** | Indirectly addresses one or more of the critical area’s objectives |
| | Indirectly reduces nutrient or sediment loads delivered to Sandusky Bay |
| | Land owner support |
| **Lowest priority** | Indirectly addresses one or more of the critical area’s objectives |

If additional NPS impairments are identified for an existing critical area, the critical area’s overview table will be updated. If a new impairment is determined that is not within an existing critical area, then a new critical area will be delineated and a new summary table will be created.

Project Summary Sheets (PSS) are in Sections 5.1.2, 5.2.1, and 5.3.2. These PSS provide the essential nine elements for short-term and/or next step projects that are in development and/or in need of funding. As projects are implemented and new projects developed these sheets will be updated. Any new PSS created will be submitted to the state of Ohio for funding eligibility verification (i.e., all nine elements are included).

## 5.1 CRITICAL AREA #1: OVERVIEW TABLE AND PROJECT SHEETS

The information included in Table 17 is a condensed overview of all identified projects needed for nonpoint source restoration of the *Western Uplands* critical area. PSSs are included for short term projects or any project that is considering seeking funding in the near future. Only those projects with complete PSS will be considered for state and federal nonpoint source program funding.

Since phosphorus loading to Sandusky Bay and the Western and Central basins is dominated by NPS, substantial NPS reductions will be necessary to significantly reduce phosphorus loading to Sandusky Bay and Lake Erie. For the *Western Uplands* critical area, source[32] and transport[33] BMPs should be the focus because such BMPs will reduce the amount of phosphorus that is eventually discharged to Sandusky Bay.

Scavia et al. (2014, p. 236) found that targeting BMPs to high source locations decreased nutrient yields more than siting the BMPs randomly throughout a subwatershed. Thus, BMPs in the *Western Uplands* should be targeted to areas with high nutrient yields. To this end, higher priority subwatersheds for agricultural BMP opportunities were identified in several U.S. EPA Region 5 studies that evaluated nutrient loading in the Sandusky watershed. Organizations and stakeholders in the Sandusky watershed can use these studies to help determine suitability and site locations for certain agricultural BMPs throughout the Sandusky watershed.

- **Drainage Water Management** (U.S. EPA 2014b): This study evaluated four drainage water management (DWM) practices for tiled crop fields: drainage control structures, pretreatment wetlands, saturated buffers, and bioreactors. A GIS methodology was developed to determine tile drained areas, potential tile outlet locations, and suitable locations for DWM practices. A DWM Options Matrix was developed that allows users to select the optimum DWM practice or combination of practices. Section 3.4 presents the high priority tile drained areas for the Sandusky watershed. Many high priority areas are in subwatersheds that drain directly to Sandusky Bay, with drainage control structures and bioreactors ranked high and pretreatment wetlands and saturated buffers ranked low.

- **Integrated Water Management** (U.S. EPA 2017): This study evaluated six practices: the four DWM for tiled crop fields (U.S. EPA 2014b), wetland management, and two-staged ditches. The SWAT model from the TMDL (Ohio EPA 2014b) was enhanced and re-calibrated and re-validated; the model was then used to assess the effects of these agricultural BMPs upon nutrient loads. The modeling results showed (1) decreased nutrient loads for saturated buffers, two-stage ditches, and wetlands and (2) that controlled drainage simulated the largest reduction in soluble phosphorus load but also simulated a large increase in sediment-bound phosphorus due to increased runoff. Model scenarios were also simulated to identify optimum combinations of DWM practices. For the Sandusky watershed, the optimum combination was controlled drainage, bioreactors, wetlands, and two-stage ditches.

### 5.1.1 Critical Area #1: Project Implementation Strategy Overview Table

The *Western Uplands* critical area is based in part upon non-attainment and partial attainment of Ohio's biocriteria and lacustrine benchmarks at several monitoring sites in the lower reaches of the following waterbodies: Fishing Creek, Green Creek, Little Muddy Creek, Muddy Creek, Pickerel Creek, Raccoon Creek, the Sandusky River, and South Creek. The critical area is also based upon phosphorus-loading from the aforementioned waterbodies and other frontal Sandusky Bay tributaries. The overview table (Table 17) provides a quick summary of what needs to be done, where and what problem (cause/source) will be addressed. The table includes projects at all levels of development (e.g., concept, in progress), and the table is intended to show a prioritized path toward restoration of the *Western Uplands* critical area.

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[32] Source BMPs limit the discharge of pollutant loads at the source (e.g. "4R" fertilizer management).

[33] Transport BMPs reduce pollutant runoff (e.g., conservation tillage, buffers, drainage water management).

Table 17. Critical Area #1: Overview table for the *Western Uplands*

| Goal | Objective | Project | Project title | Lead organization (criteria d) | Timeframe (criteria f) | Estimated cost (criteria d) | Potential/actual funding sources (criteria d) |
|---|---|---|---|---|---|---|---|
| ***Urban sediment and nutrient reduction strategies*** | | | | | | | |
| *none identified at this time* | | | | | | | |
| ***Altered stream and habitat restoration strategies*** | | | | | | | |
| 1, 2 | 1 | 1 | Restoring Sandusky River Floodplain at Redhorse Bend | Black Swamp Conservancy | Short | $850,000 | Ohio EPA §319, SWIF, SOGL |
| ***Agricultural nonpoint source reduction strategies*** | | | | | | | |
| TBD | 1, 2 | 2 | Sandusky River watershed nutrient and sediment reduction | TNC | Long | TBD | Ohio EPA §319, GLRI |
| ***High quality waters protection strategies*** | | | | | | | |
| *none identified at this time* | | | | | | | |
| ***Other NPS causes and associates sources of impairment*** | | | | | | | |
| *none identified at this time* | | | | | | | |

*Note:* GLRI = Great Lakes Restoration Initiative; SOGL = Sustain our Great Lakes; SWIF = Surface Water Improvement Fund (Ohio EPA); TBD = to be determined; TNC = The Nature Conservancy.

## 5.1.2 Critical Area #1: Project Summary Sheets

The PSSs provided below were developed based on the actions or activities needed to restore sampling site 500890 to attainment of the ALU designation. These projects are considered next step or priority/short term projects. Medium and long-term projects are not presented in PSSs since they are not yet ready for implementation.

| Critical Area 1: Project 1 | | |
|---|---|---|
| **Nine Element Criteria** | **Information Needed** | **Explanation** |
| ***n/a*** | Title | Restoring Sandusky River Floodplain at Redhorse Bend |
| ***criterion d*** | Project Lead Organization and Partners | Black Swamp Conservancy |
| ***criterion c*** | HUC-12 & Critical Area | *Indian Creek-Sandusky River* (HUC 04100011 13 02)<br>*Western Uplands* (critical area #1) |
| ***criterion c*** | Project Location | Redhorse Bend, the former Sachs Farm, on the right (east) bank of the Sandusky River, from about RM 13.9 downstream to about RM 12.9. The project site is about 78 acres of crop fields immediately north and south of US-6/US-20/OH-19. See Figure 43. |
| ***n/a*** | Which strategy is being addressed by this project? | Manage invasive species (Goal 2.01.02)<br>Restore and protect riparian habitat (Goal 2.03.01)<br>Increase native shrub and tree plantings in riparian areas (Goal 2.03.04)<br>Restore and protect natural flow conditions (Goal 2.04.01) |
| ***criterion f*** | Time Frame | Short-term<br>Planning & Securing Funds: 2018. Implementation: 2019-2020. |
| ***criterion g*** | Short Description | Restoration of former crop fields to natural areas with native vegetation, including installation of wetlands and riparian woods. |
| ***criterion g*** | Project Narrative | The property lies along 4,410 linear feet of the Sandusky River and contains 48 acres of farmland, 10 acres of woods, 10 acres of shrub/scrub habitat, and 2.5 acres of mature, Category 2, forested wetlands. Much of the agricultural lands are conducive to wetland restoration having hydric soils. The project scope is to restore approximately 25 acres of floodplain wetlands through breaking of field tile and re-contouring of the field topography (excess soil can be deposited on the upland portions of the agricultural fields so that no aquatic resources or vegetation would be damaged). Approximately 1,300 linear feet of an unnamed tributary to the Sandusky River will also be restored throughout the southern portion of the property (referred to as “Ditch 1”) – this tributary is currently ditched adjacent to and on the south side of State Route 20. This ditch likely used to meander throughout the southern portion of this property before it was relocated to maximize tillable land. Approximately 3,650 feet of the 4,410 feet long Sandusky River riparian corridor will be treated for invasive species and have extensive re-vegetation activities conducted in to improve and expand the river’s riparian corridor. The bottomland areas and the terraces overlooking the floodplain will all be reforested as a native hardwood forest. |
| ***criterion d*** | Estimated Total Cost | $850,000 |
| ***criterion d*** | Possible Funding Source | Ohio EPA §319; SWIF; SOGL |
| ***criterion a*** | Identified Causes and Sources | Causes: Sedimentation/siltation and nutrient eutrophication.<br>Source: Crop production with subsurface drainage. |

| | | |
|---|---|---|
| **criteria b & h** | Part 1: How much improvement is needed to remove the NPS impairment associated with this Critical Area? | Significant improvement is necessary for the L-IBI score of 26 to be increased to 42 to meet the lacustrine benchmark. |
| | Part 2: How much of the needed improvement for the whole Critical Area is estimated to be accomplished by this project? | Removal of 81.2 pounds TP per year is less than 1 percent of Goal #1 (154 MT spring TP reduction for the Sandusky River)<br>Removal of 48 acres of farmland is about 1 percent of Objective #1 (drainage water management of 3,000 acres). |
| | Part 3: Load reduced? | Nitrogen: 319.5 pounds per year.<br>Phosphorus: 81.2 pounds per year<br>Sediment: 31.6 tons per year. |
| ***criterion i*** | How will the effectiveness of this project in addressing the NPS impairment be measured? | If this project is funded through §319, Ohio EPA will perform monitoring and IBI, ICI, and QHEI will be assessed before and after project implementation. Water chemistry samples can also be collected and evaluated for nutrient and sediment content. |
| ***criterion e*** | Information and Education | Black Swamp Conservancy will discuss the project in its newsletters and post about the project on its website and social media. |


*Note:* Approximate boundary of the project is indicated in red.

Figure 43. Restoring Sandusky River Floodplain at Redhorse Bend.

## 5.2 CRITICAL AREA #2: OVERVIEW TABLE AND PROJECT SHEETS

The information included in Table 18 is a condensed overview of all identified projects needed for nonpoint source restoration of the *Muddy Creek Bay and Upper Sandusky Bay* critical area. PSSs are included for short term projects or any project that is considering seeking funding in the near future. Only those projects with complete PSS will be considered for state and federal nonpoint source program funding.

Several efforts are identifying projects that can be designed to reduce HABs and reduce nutrient loading to Lower Sandusky Bay. The resulting projects from such efforts would need to be assessed and potentially incorporated into this NRIP if Ohio EPA and U.S. EPA NPS funding is sought.

- **Sandusky Bay Integrated Monitoring and Data Assessment**: Monitoring data are being collected from Sandusky Bay by Bowling Green State University, Heidelberg University, and Kent State University. This effort was funded by ODNR-OCM and is being coordinated by the Ohio State University's Ohio Sea Grant.
- **Sandusky Bay Strategic Restoration Initiative** (Biohabitats 2019): This Initiative assembled a portfolio of in-water and nearshore projects that seek to reduce nutrient loading, beneficially reuse dredge materials, and restore coastal wetlands. The city of Sandusky, with its consultant Biohabitats Inc., developed the Initiative through funding from ODNR-OCM.

### 5.2.1 Critical Area #2: Project Implementation Strategy Overview Table

The *Muddy Creek Bay and Upper Sandusky Bay* critical area is based upon impairment of the Western Basin Shoreline and HABs in the open waters of Muddy Creek Bay and Upper Sandusky Bay. The overview table (Table 18) provides a quick summary of what needs to be done, where and what problem (cause/source) will be addressed. The table includes projects at all levels of development (e.g., concept, in progress), and the table is intended to show a prioritized path toward restoration of the *Muddy Creek Bay and Upper Sandusky Bay* critical area. Many of the projects in this table were also identified during the development of *State of Ohio Domestic Action Plan* (Ohio Lake Erie Commission 2018).

Table 18. Critical Area #2: Overview table for the *Muddy Creek Bay and Upper Sandusky Bay*

| Goal | Objective | Project | Project title | Lead organization (criteria d) | Timeframe (criteria f) | Estimated cost (criteria d) | Potential/actual funding sources (criteria d) |
|---|---|---|---|---|---|---|---|
| ***Urban sediment and nutrient reduction strategies*** | | | | | | | |
| *not applicable* | | | | | | | |
| ***Altered stream and habitat restoration strategies*** | | | | | | | |
| 1, 2 | 1 | 1 | Sandusky River Delta Restoration (feasibility study) | TNC | *Completed* | -- | TNC |
| 1, 2 | 1 | 2 | Muddy Creek Bay Restoration | TNC | Short | $5.5M | GLRI, HLEF, H2Ohio |
| 1, 2 | 2 | 3 | Western Sandusky Bay coastal marsh and marsh terrace installation | ODNR-DW, City of Sandusky | Medium-Long | TBD | GLRI, HLEF |
| 1 | 2 | 4 | Willow Point Wildlife Area nearshore enhancement and restoration (multiple phases; installation of living shoreline along dikes, creation of emergent wetlands) | ODNR-DW | Long | TBD | GLRI, HLEF, H2Ohio |
| 1, 2 | 2 | 5 | Standing Rush Phase I: Wetland Restoration/Reconnection | Erie SWCD, Standing Rush LLC | *Completed* | -- | ODNR-OCM from U.S. EPA GLRI |
| 1, 2 | 2 | 6 | Standing Rush Wetland Phase II: Coastal wetlands to capture nutrient runoff | Erie SWCD, Standing Rush LLC | Short | TBD | GLRI |
| 1, 2 | 2 | 7 | Standing Rush Phase III: Restoration of Hydrological Connectivity, Installation of Living Shorelines, and Enhancement of Coastal Wetlands | Erie SWCD, Standing Rush LLC | Short | $2.8M - $3.6M | GLRI, HLEF, H2Ohio |
| 1 | 2 | 8 | Pickerel Creek Wildlife Area nearshore enhancement and restoration (multiple phases; installation of living shoreline along dikes, creation of emergent wetlands) | ODNR-DW | Long | TBD | GLRI, HLEF, H2Ohio |
| 1 | 1, 2 | 9 | Raccoon Creek Mouth Restoration (installation of off shore headland sills; installation of living shoreline along dikes; creation of emergent wetlands) | ODNR-OCM, ODNR-DW | Long | TBD | GLRI, HLEF, H2Ohio |
| 1,2 | 3 | 10 | Creation of Islands in Upper Sandusky Bay | ODNR-OCM | Long | TBD | GLRI, HLEF, H2Ohio |
| ***Agricultural nonpoint source reduction strategies*** | | | | | | | |
| *not applicable* | | | | | | | |

| |
|---|
| ***High quality waters protection strategies*** |
| *none identified at this time* |
| ***Other NPS causes and associates sources of impairment*** |
| *none identified at this time* |

*Sources:* Ohio Lake Erie Commission (2018) and Biohabitats (2019).

*Note:* Erie SWCD = Eric County Soil and Water Conservation District; GLRI = Great Lakes Restoration Initiative; HLEF = Help Lake Erie Fund; M = million; ODNR-DW = Ohio Department of Natural Resources, Division of Wildlife; ODNR-OCM = Ohio Department of Natural Resources, Office of Coastal Management; TBD = to be determined; TNC = The Nature Conservancy.

## 5.2.2 Critical Area #2: Project Summary Sheets

The PSSs provided below were developed based on the actions or activities needed to restore sampling sites to attainment of the ALU designation. These projects are considered next step or priority/short term projects. Medium and long-term projects are not presented in PSSs since they are not yet ready for implementation.

| Critical Area 2: Project 2 | | |
|---|---|---|
| **Nine Element Criteria** | **Information Needed** | **Explanation** |
| ***n/a*** | Title | Muddy Creek Bay Restoration |
| ***criterion d*** | Project Lead Organization and Partners | The Nature Conservancy |
| ***criterion c*** | HUC-12 & Critical Area | *Sandusky Basin Shoreline* (S1 and LEAU 04120200 02 02<br>*Muddy Creek Bay and Upper Sandusky Bay* (critical area #2) |
| ***criterion c*** | Project Location | Mouth of Muddy Creek Bay<br>(41.46°, -82.98°) |
| ***n/a*** | Which strategy is being addressed by this project? | Nature-based living shoreline |
| ***criterion f*** | Time Frame | Short |
| ***criterion g*** | Short Description | Extension of existing dikes, potentially using Wave Attenuating Devices, to calm the energy in Muddy Creek Bay. Reduced wave energy (and potentially reduced turbidity) will allow for revegetation. |
| ***criterion g*** | Project Narrative | In Area 2, at the mouth of Muddy Creek Bay, the dikes will be extended out into the bay. This could involve the extension of the southern dike by approximately 500-feet and extension of the northern dike by 1,000-feet through the use of Wave Attenuating Devices (WADS). Such a construction would have a net calming effect of energy within the bay.<br><br>Area 3 is located in the center of the bay, around an island remnant where wetland vegetation could be reestablished because of the shallow bottom (approximately 570). At this location, a 2,400-linear foot stone dike is proposed that will buffer not only the island, but also the portions of the bay west of the island.<br><br>The dike would be constructed of 24-30-inch stone, with a 1:1 slope on the east side and a 2.5:1 slope on the west side. It may be possible to establish American lotus on the site once it enjoys protection from wave energy. If turbidity can also be reduced, this location could become suitable for the establishment of additional species. |
| ***criterion d*** | Estimated Total Cost | Area #2: $1.9M<br>Area #3: $3.6M<br>Total: $5.5M |
| ***criterion d*** | Possible Funding Source | GLRI, HLEF, H2Ohio |
| ***criterion a*** | Identified Causes and Sources | The *Sandusky Basin Shoreline* LEAU is impaired by habitat alteration and sedimentation/siltation from habitat modifications other than hydromodification and from non-irrigated crop production.<br><br>Fish community health is impaired by high turbidity and lack of submerged aquatic vegetation (also the result of high turbidity). |

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| **criteria b & h** | Part 1: How much improvement is needed to remove the NPS impairment associated with this Critical Area? | Small improvement is needed for fish community health to meet biological criteria. N-IBI-soft scores at Ohio EPA monitoring sites 302436 (28), 302437 (30), and 301572 (28) need to improve 1 to 3-points to achieve the target N-IBI-soft score of 31-points.<br><br>N-QHEI data have never been collected.<br><br>Significant improvement is needed to reduce TP concentrations. Reductions of between 0.14 and 0.16 mg/L are necessary to achieve the target TP concentration of 0.03 mg/L. |
| | Part 2: How much of the needed improvement for the whole Critical Area is estimated to be accomplished by this project? | This project will locally improve water clarity that directly affects fish populations. Increased water clarity will allow for local submerged aquatic vegetation growth, which will also benefit fish community health. Finally, the project will create new local fish habitat.<br><br>The implementation of several projects, including this one, may improve the N-IBI-soft by 1 to 3 points; however, this project alone would not likely result in significant improvement. Due to the combined size of Muddy Creek Bay and Upper Sandusky Bay, many projects in Muddy Creek Bay and Upper Sandusky Bay and along their shorelines are needed to improve fish community health. |
| | Part 3: Load reduced? | Total phosphorus: 726 lb/y<br>Total nitrogen: 220 – 1,815 lb/y |
| ***criterion i*** | How will the effectiveness of this project in addressing the NPS impairment be measured? | Bowling Green State University (under ODNR contract) collects biweekly water chemistry data and will continue to be contracted to do so for the foreseeable future.<br><br>ODNR Division of Wildlife collects fish on a regular basis. Ohio EPA collect fish on a rotating basin approach and evaluates fish community health.<br><br>Effectiveness will be measured by evaluating regular water chemistry and fish community health data collected before and after project implementation. |
| ***criterion e*** | Information and Education | ODNR will manage public outreach and education, likely through the publication of educational materials and information on ODNR's website. ODNR may also facilitate guided tours. ODNR will work with the Sandusky and Ottawa SWCDs to distribute publications. |

*Note*: The *Project Narrative*, *Estimated Total Costs*, and *Load Reduced* were provide by Biohabitats (2019).

| Critical Area 2: Project 7 | | |
|---|---|---|
| **Nine Element Criteria** | **Information Needed** | **Explanation** |
| ***n/a*** | Title | Standing Rush Phase III |
| ***criterion d*** | Project Lead Organization and Partners | Erie SWCD<br>Standing Rush LLC |
| ***criterion c*** | HUC-12 & Critical Area | *Sandusky Basin Shoreline* (S1 and LEAU 04120200 02 02<br>*Muddy Creek Bay and Upper Sandusky Bay* (critical area #2) |
| ***criterion c*** | Project Location | Standing Rush property<br>South of the village of Bay View, Sandusky County<br>(41.46°, -82.82°) |
| ***n/a*** | Which strategy is being addressed by this project? | Nature-based living shoreline |
| ***criterion f*** | Time Frame | Short |
| ***criterion g*** | Short Description | Restoration of hydrological connectivity of coastal wetlands to Upper Sandusky Bay, creation of living coastline, and enhancement of coastal wetlands to improve wildlife habitat and reduce nutrient-loading from upland sources. |
| ***criterion g*** | Project Narrative | Installation of two screw gates to connect a drainage ditch to an existing wetland cell berm, which will allow filtration of water and add some fish passage. The filtered water would be released back into the ditch closer to Lake Erie.<br><br>Installation of 2,850-lineal feet (option #1) to 3,135-lineal feet (option #2) of living berm. The living berm system will create nearshore habitat and repair the function on the southern side by re-establishing wetland and submerged aquatic vegetation habitat. The primary function of placing this living berm is to reduce the near shore exposure of the areas behind the proposed berms, allowing reestablishment of SAV and emergent vegetation. |
| ***criterion d*** | Estimated Total Cost | $2.8M - $3.6M |
| ***criterion d*** | Possible Funding Source | GLRI, HLEF, H2Ohio |
| ***criterion a*** | Identified Causes and Sources | The *Sandusky Basin Shoreline* LEAU is impaired by habitat alteration and sedimentation/siltation from habitat modifications other than hydromodification and from non-irrigated crop production.<br><br>Fish community health is impaired by high turbidity and lack of submerged aquatic vegetation (also the result of high turbidity). |
| ***criteria b & h*** | Part 1: How much improvement is needed to remove the NPS impairment associated with this Critical Area? | Small improvement is needed for fish community health to meet biological criteria. N-IBI-soft scores at Ohio EPA monitoring sites 302436 (28), 302437 (30), and 301572 (28) need to improve 1 to 3-points to achieve the target N-IBI-soft score of 31-points.<br><br>N-QHEI data have never been collected.<br><br>Significant improvement is needed to reduce TP concentrations. Reductions of between 0.14 and 0.16 mg/L are necessary to achieve the target TP concentration of 0.03 mg/L. |
| | Part 2: How much of the needed improvement for the whole Critical Area is estimated to be accomplished by this project? | Installation of 2,850 to 3,135-lineal feet of living shoreline will achieve 5 to 6 percent of Objective #2.<br><br>The implementation of several projects, including this one, may improve the N-IBI-soft by 1 to 3 points; however, this project alone |

| | | |
|---|---|---|
| | | would not likely result in significant improvement. Due to the size of Upper Sandusky Bay, many projects in Upper Sandusky Bay and along its shorelines are needed to improve fish community health. |
| | Part 3: Load reduced? | Option #1: Total phosphorus: 1,961 – 3,915 lb/y<br>Total nitrogen: 1,862 – 29,650 lb/y<br><br>Option #2: Total phosphorus: 209 – 1,447 lb/y<br>Total nitrogen: 724 – 7,044 lb/y |
| ***criterion i*** | How will the effectiveness of this project in addressing the NPS impairment be measured? | Bowling Green State University (under ODNR contract) collects biweekly water chemistry data and will continue to be contracted to do so for the foreseeable future.<br><br>ODNR Division of Wildlife collects fish on a regular basis. Ohio EPA collect fish on a rotating basin approach and evaluates fish community health.<br><br>Effectiveness will be measured by evaluating regular water chemistry and fish community health data collected before and after project implementation. |
| ***criterion e*** | Information and Education | Erie SWCD will facilitate public outreach and education through the publication of newsletters and information on their website. Erie SWCD and Standing Rush LLC may host guided tours and distribute educational publications. |

*Note*: The *Project Narrative*, *Estimated Total Costs*, and *Load Reduced* were provide by Biohabitats (2019).

## 5.3 CRITICAL AREA #3: OVERVIEW TABLE AND PROJECT SHEETS

The information included in Table 19 is a condensed overview of all identified projects needed for nonpoint source restoration of the *Lower Sandusky Bay* critical area. PSSs are included for short term projects or any project that is considering seeking funding in the near future. Only those projects with complete PSS will be considered for state and federal NPS program funding.

### 5.3.1 Critical Area #3: Project Implementation Strategy Overview Table

Several efforts are identifying projects that can be designed to reduce HABs and reduce nutrient loading to Lower Sandusky Bay. The resulting projects from such efforts would need to be assessed and potentially incorporated into this NRIP if Ohio EPA and U.S. EPA NPS funding is sought.

- **Sandusky Bay Integrated Monitoring and Data Assessment**: Monitoring data are being collected from Sandusky Bay by Bowling Green State University, Heidelberg University, and Kent State University. This effort was funded by ODNR-OCM and is being coordinated by the Ohio State University's Ohio Sea Grant.
- **Sandusky Bay Initiative** (Biohabitats 2019): This Initiative assembled a portfolio of in-water and nearshore projects that seek to reduce nutrient loading, beneficially reuse dredge materials, and restore coastal wetlands. The city of Sandusky, with its consultant Biohabitats Inc., developed the Initiative through funding from ODNR-OCM. Critical Area #3: Project Implementation Strategy Overview Table

The *Lower Sandusky Bay* critical area (Figure 44) is based upon impairment of the Western Basin Shoreline and HABs in the open waters of Lower Sandusky Bay. The overview table (Table 19) provides a quick summary of what needs to be done, where and what problem (cause/source) will be addressed. The table includes projects at all levels of development (e.g., concept, in progress), and the table is intended to show a prioritized path toward restoration of the *Lower Sandusky Bay* critical area.

Figure 44. East Sandusky Bay near Pipe Creek.

Table 19. Critical Area #3: Overview table for the *Lower Sandusky Bay*

| Goal | Objective | Project | Project title | Lead organization (criteria d) | Timeframe (criteria f) | Estimated cost (criteria d) | Potential/actual funding sources (criteria d) |
|---|---|---|---|---|---|---|---|
| ***Urban sediment and nutrient reduction strategies*** | | | | | | | |
| *not applicable* | | | | | | | |
| ***Altered stream and habitat restoration strategies*** | | | | | | | |
| 1, 2 | 1, 2 | 1 | E&D for habitat restoration at four nearshore sites | city of Sandusky [a] | *Completed* | -- | ODNR-OCM |
| 1, 2 | 1 | 2 | Eastern Sandusky Bay Nearshore Wetland Creation (Project #1) | city of Sandusky | Medium | TBD | GLRI, HLEF |
| 1, 2 | 1 | 3 | Cedar Point Causeway and Inland Areas Living Shoreline and Wetland Enhancement (Project #2) Phase I | city of Sandusky, Cedar Fair LP | Short | $8.2M | GLRI, HLEF, H2Ohio |
| 1, 2 | 2 | 4 | East Sandusky Bay Marsh Restoration/Recreation (Project #3) | city of Sandusky | Short | $7.8M | GLRI, HLEF, H2Ohio |
| 1, 2 | 2 | 5 | Sheldon Marsh Wetland Beach Nourishment and Nature-Based Shoreline (Project #4) | ODNR, city of Sandusky | Medium | TBD | GLRI, HLEF |
| 1, 2 | 2 | 6 | Pipe Creek Outlet to East Sandusky Bay | Erie SWCD, Cedar Fair LP | Short | *funded* | ODNR-OCM from U.S. EPA GLRI |
| ***Agricultural nonpoint source reduction strategies*** | | | | | | | |
| *not applicable* | | | | | | | |
| ***High quality waters protection strategies*** | | | | | | | |
| *none identified at this time* | | | | | | | |
| ***Other NPS causes and associates sources of impairment*** | | | | | | | |
| *none identified at this time* | | | | | | | |

*Notes*

E&D = engineering and design; GLRI = Great Lakes Restoration Initiative; HLEF = Help Lake Erie Fund; M = million; *TBD* = to be determined.

a. Two consultant teams were contracted by the city of Sandusky: Biohabitats Inc. and Baird Inc. and KS, AES, and Limnotech.

## 5.3.2 Critical Area #3: Project Summary Sheets

The PSSs provided below were developed based on the actions or activities needed to restore sampling sites to attainment of the ALU designation. These projects are considered next step or priority/short term projects. Medium and long-term projects are not presented in PSSs since they are not yet ready for implementation.

**Critical Area 3: Project 3**

| Nine Element Criteria | Information Needed | Explanation |
|---|---|---|
| ***n/a*** | Title | Cedar Point Causeway and Inland Areas Living Shoreline and Wetland Enhancement (Project #2) Phase I |
| ***criterion d*** | Project Lead Organization and Partners | city of Sandusky<br>Cedar Fair LP |
| ***criterion c*** | HUC-12 & Critical Area | *Sandusky Basin Shoreline* (S1 and LEAU 04120200 02 02<br>*Lower Sandusky Bay* (critical area #3) |
| ***criterion c*** | Project Location | Cedar Point Drive causeway<br>(41.469°, -82.677°) |
| ***n/a*** | Which strategy is being addressed by this project? | Nature-based living shoreline |
| ***criterion f*** | Time Frame | Short |
| ***criterion g*** | Short Description | First phase of the creation of wetland cells and living shoreline along the Cedar Point Drive causeway to create wildlife habitat. |
| ***criterion g*** | Project Narrative | On the western side of the Cedar Point causeway, roughly centered between the northern two culverts passing under the causeway, this project forces water from the northerly underpass through created wetland cells. The selected approach includes two wetland cells. The northerly cell consists of an outer breakwater of varying heights that protects interior backwater coves, yet still allows waves to wash over the breakwater at select locations depending on wave height and lake water levels. The interior of the cell consists of a created channel parallel to the shore that conveys water south from the underpass to its outlet just north of the middle underpass. The channel is linked to a chain of backwater lagoons. The primary design intent is to maximize the residence time of water flowing between the two bays for water quality benefits; and to create a variety of habitats ranging from backwater lagoons to higher energy zones more favorable to fish that spawn on coarse material. The southerly cell consists of a series of detached breakwaters that allow waves to wash into and through the wetland complex to mimic a dynamic shoreline. The outer breakwaters wrap toward the middle underpass to create a larger open water backwater lagoon.<br><br>The plan is designed to facilitate the circulation of water and associated movement of aquatic wildlife through the created wetland cells. The interior cells are intended to provide backwater emergent and aquatic habitat for largemouth bass, bluegill and northern pike. The outer breakwater and interior channel of the northern cell may provide favorable habitat for smallmouth bath and other aquatic wildlife that prefer coarser material for spawning, and a higher energy environment. The shrub scrub zone will provide habitat for passerines particularly during migration. |
| ***criterion d*** | Estimated Total Cost | $8.2M |

| | | |
|---|---|---|
| ***criterion d*** | Possible Funding Source | GLRI, HLEF, H2Ohio |
| ***criterion a*** | Identified Causes and Sources | The *Sandusky Basin Shoreline* LEAU is impaired by habitat alteration and sedimentation/siltation from habitat modifications other than hydromodification and from non-irrigated crop production.<br><br>Fish community health is impaired by high turbidity and lack of submerged aquatic vegetation (also the result of high turbidity). |
| **criteria b & h** | Part 1: How much improvement is needed to remove the NPS impairment associated with this Critical Area? | Significant improvement is needed for fish community health to meet biological criteria. N-IBI-soft scores at Ohio EPA monitoring sites 302446 (18), 301568 (30), 302432 (29), and 302433 (18) need to improve 1 to 13-points to achieve the target N-IBI-soft score of 31-points. The N-MIwb-soft score at Ohio EPA monitoring site 302433 (5.5) needs to improve 1.7-points to achieve the target N-MIwb-soft score of 7.2-points.<br><br>N-QHEI data have never been collected.<br><br>Significant improvement is needed to reduce TP concentrations. Reductions of between 0.06 and 0.11 mg/L are necessary to achieve the target TP concentration of 0.03 mg/L. |
| | Part 2: How much of the needed improvement for the whole Critical Area is estimated to be accomplished by this project? | Installation of 3,100-feet of living shoreline will achieve 12 percent of Objective #2.<br><br>The implementation of several projects, including this one, may improve the N-IBI-soft by 1 to 3 points; however, this project alone would not likely result in significant improvement. Due to the combined size of Lower Sandusky Bay and East Sandusky Bay, many projects in Muddy Creek Bay and Upper Sandusky Bay and along their shorelines are needed to improve fish community health. |
| | Part 3: Load reduced? | Total phosphorus: 2,318 – 8,923 lb/y<br>Total nitrogen: 4,989 – 89,476 lb/y |
| ***criterion i*** | How will the effectiveness of this project in addressing the NPS impairment be measured? | Bowling Green State University (under ODNR contract) collects biweekly water chemistry data and will continue to be contracted to do so for the foreseeable future.<br><br>ODNR Division of Wildlife collects fish on a regular basis. Ohio EPA collect fish on a rotating basin approach and evaluates fish community health.<br><br>Effectiveness will be measured by evaluating regular water chemistry and fish community health data collected before and after project implementation. |
| ***criterion e*** | Information and Education | The city of Sandusky will manage public outreach and education, likely through the publication of educational materials and information on city's website. Signage may be installed at Cedar Point and educational publications can be provided for visitors. |

*Note*: The *Project Narrative*, *Estimated Total Costs*, and *Load Reduced* were provide by Biohabitats (2019).

| Critical Area 3: Project 4 | | |
|---|---|---|
| **Nine Element Criteria** | **Information Needed** | **Explanation** |
| ***n/a*** | Title | East Sandusky Bay Marsh Restoration/Recreation (Project #3) |
| ***criterion d*** | Project Lead Organization and Partners | city of Sandusky |
| ***criterion c*** | HUC-12 & Critical Area | *Sandusky Basin Shoreline* (S1 and LEAU 04120200 02 02<br>*Lower Sandusky Bay* (critical area #3) |
| ***criterion c*** | Project Location | East Sandusky Bay at the Plum Brook estuary<br>(41.44°, -82.66°) |
| ***n/a*** | Which strategy is being addressed by this project? | Nature-based living shoreline |
| ***criterion f*** | Time Frame | Short |
| ***criterion g*** | Short Description | Nature-based shoreline restoration and improvement |
| ***criterion g*** | Project Narrative | Excavation and regrading the shoreline to recreate a buffer on the lakeward edge without adjusting the shoreline position (which could drive erosion or accretion on adjacent shoreline). The proposed design uses an 18-inch layer of shot rock from local quarries to serve as a foundation for 4.5-feet of large woody debris (LWD). The final edge will be overtopped at times due to lake level variations. During lower lake levels, water will exchange through two fish channels through a fence to deter carp.<br><br>Installation of LWD about 300 to 500-feet offshore in a “zig-zag” pattern to both create habitat and support/protect the nature based shoreline (by reducing the energy of water or ice as it approaches the shore). In addition to creating fish and plant habitat at and shoreward of the construction site, installing LWD will attenuate the wave energy of water traveling to shore, creating swath of low-energy, deep water zones parallel to the fetch. Taken together, these create conditions for passive restoration in the area protected by the wood aggradation structures. |
| ***criterion d*** | Estimated Total Cost | $7.8M |
| ***criterion d*** | Possible Funding Source | GLRI, HLEF, H2Ohio |
| ***criterion a*** | Identified Causes and Sources | The *Sandusky Basin Shoreline* LEAU is impaired by habitat alteration and sedimentation/siltation from habitat modifications other than hydromodification and from non-irrigated crop production.<br><br>Fish community health is impaired by high turbidity and lack of submerged aquatic vegetation (also the result of high turbidity). |
| **criteria b & h** | Part 1: How much improvement is needed to remove the NPS impairment associated with this Critical Area? | Significant improvement is needed for fish community health to meet biological criteria. N-IBI-soft scores at Ohio EPA monitoring sites 302446 (18), 301568 (30), 302432 (29), and 302433 (18) need to improve 1 to 13-points to achieve the target N-IBI-soft score of 31-points. The N-MIwb-soft score at Ohio EPA monitoring site 302433 (5.5) needs to improve 1.7-points to achieve the target N-MIwb-soft score of 7.2-points.<br><br>N-QHEI data have never been collected.<br><br>Significant improvement is needed to reduce TP concentrations. Reductions of between 0.06 and 0.11 mg/L are necessary to achieve the target TP concentration of 0.03 mg/L. |

| | | |
|---|---|---|
| | Part 2: How much of the needed improvement for the whole Critical Area is estimated to be accomplished by this project? | Installation of 2,100-feet of living shoreline will achieve 8 percent of Objective #2.<br><br>The implementation of several projects, including this one, may improve the N-IBI-soft by 1 to 3 points; however, this project alone would not likely result in significant improvement. Due to the size of East Sandusky Bay, many projects in East Sandusky Bay and along its shorelines are needed to improve fish community health. |
| | Part 3: Load reduced? | Total phosphorus: 1,475 – 3,634 lb/y<br>Total nitrogen: 1,848 – 31,038 lb/y |
| ***criterion i*** | How will the effectiveness of this project in addressing the NPS impairment be measured? | Bowling Green State University (under ODNR contract) collects biweekly water chemistry data and will continue to be contracted to do so for the foreseeable future.<br><br>ODNR Division of Wildlife collects fish on a regular basis. Ohio EPA collect fish on a rotating basin approach and evaluates fish community health.<br><br>Effectiveness will be measured by evaluating regular water chemistry and fish community health data collected before and after project implementation. |
| ***criterion e*** | Information and Education | The city of Sandusky will manage public outreach and education, likely through the publication of educational materials and information on city's website. |

*Note*: The *Project Narrative*, *Estimated Total Costs*, and *Load Reduced* were provide by Biohabitats (2019).

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