Evaluating Beneficial Use: Recreation

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set by this proposed method. Frames that show 0% coverage indicates no bloom present the majority of the time. In a few instances, cloud cover or other interferences with the satellite images occurred. 35

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F1. Background (Bacteria)

Prior to the 2002 Integrated Report (IR), the reporting of recreation use (RU) impairment in Ohio was sporadic. Clean Water Act (CWA) Section 305(b) reports (1998 and earlier) may have included an indication of the potential for RU impairment in various streams, but a comprehensive listing of recreational use impairment was not included. The 2002 IR employed a uniform methodology to examine readily available data on fecal coliform counts. This approach was based on counting the number of exceedances of the secondary contact RU maximum criterion [5,000 colony forming units (cfu)/100 mL fecal coliform or 576 cfu/100 mL *Escherichia coli (E. coli)]*. Any assessment unit with five or more samples over the last five years above these values was listed as having an impaired RU.

The 2004 IR adopted a more statistically robust methodology for assessing the RU attainment of the state's surface waters linked more directly to the applicable water quality standards (WQS). The methodology adopted in 2004 continued to be used through the 2008 IR. The 2008 IR also included a preview of changes anticipated at the time for the 2010 report based on the expectation that the watershed assessment unit (WAU) would change from a larger watershed size (11-digit HUC) to a smaller watershed size (12-digit HUC) and on four anticipated revisions to the water quality standards: 1) dropping the fecal coliform criteria; 2) creation of a tiered set of classes of primary contact recreation waters based on RU intensity; 3) revision of the geometric mean averaging period; and 4) extension of the recreation season. Revisions to the water quality standards pertaining to the RU were adopted on Dec. 15, 2009. The RU assessment method employed in the 2010, 2012, 2014 and 2016 IRs was essentially consistent throughout this time.

A more recent revision to Ohio's water quality standards became effective in January 2016. This revision included updates to the recreational water quality standards to make them consistent with U.S. EPA's November 2012 section 304(a) recommendations. These substantial revisions to Ohio's recreation use WQS included changes to the applicable numeric criteria and a change in the geometric mean averaging period from a seasonal basis to a 90-day period. Furthermore, the tiered set of primary contact recreational use classes adopted in 2010 were collapsed back into a single use as part of these revisions. The revised WQS were approved by U.S. EPA in April 2016. A subsequent revision to Ohio's WQS resulted in the movement of the water quality criteria for the protection of recreational uses from OAC 3745-1-07 to OAC 3745-1-37. The revision that reorganized the content of the WQS became effective in February 2017 and was approved by U.S. EPA in June 2017. Methodologies and analyses used in the 2018 IR were carried forward into the 2020 IR with no substantive changes other than the data period used in the analysis. The linkage of the assessment methodology to the Ohio WQS is summarized in Table F-1 and detailed in subsequent text.

Table F-1 — Summary of the RU assessment methods.

Bathing Waters		
Indicator	**Criterion (Table 37-2, OAC 3745-1-37)**	**Assessment Method Summary**
E. coli	Geometric mean *E. coli* content* based on samples collected within a 90-day period during the recreation season within a calendar year is 126 cfu/100 mL; statistical threshold value (STV) is 410 cfu/100 mL.	Applied to the four Lake Erie shoreline assessment units and inland lake beaches, exceedance of the geometric mean bathing water criterion or an exceedance of the STV in more than 10 percent of the samples collected during a 90-day period is considered an impairment of the bathing water use, where sufficient data are available.**
Primary Contact and Secondary Contact		
Indicator	**Criterion (Table 37-2, OAC 3745-1-37)**	**Assessment Method Summary**
E. coli	Geometric mean *E. coli* content* based on samples collected within a 90-day period during the recreation season within a calendar year is as follows: Primary Contact Waters 90-day Geometric Mean: 126 cfu/100 mL STV: 410 cfu/100 mL Secondary Contact Waters 90-day Geometric Mean: 1,030 cfu/100 mL STV: 1,030 cfu/100 mL	Applied to streams and inland lake non-beach sites. Data collected within a 90-day period in the recreation season are assessed on a site-by-site basis and compared to the applicable geometric mean and STV *E. coli* criteria whenever sufficient data** are available for the site. Assessment units (AUs) are in full attainment if all sites assessed within the AU meet both the applicable geometric mean and STV criteria and in non-attainment if one or more sites assessed within the AU exceed the applicable geometric mean or STV criteria.

**E. coli* concentrations are expressed in colony forming units (cfu) per 100 milliliters (mL)
** Five or more samples collected within a 90-day period.

F2. Evaluation Method (*Bacteria*)

Lake Erie (Shoreline)

Attainment of the RU designation for the four shoreline Lake Erie assessment units (LEAUs) as delineated in Section D-1 of this report and depicted in Figure D-3 of this report was based upon examination of *E. coli* data from public bathing beaches provided by the Ohio Department of Health (ODH). Routine bacteria monitoring is performed by local health districts, ODH and the Northeast Ohio Regional Sewer District (NEORSD) to monitor bacteria levels at public bathing beaches. They advise the public when elevated bacteria are present that represent an increased risk of contracting waterborne illness resulting from exposure to pathogens while recreating in the water. This monitoring takes place at 67 public beaches in Ohio's eight coastal counties. The public can access the ODH Beachguard website to view beach advisory postings and bacteria monitoring data from monitored beaches. The website, available at ***http://publicapps.odh.ohio.gov/BeachGuardPublic/Default.aspx***, is updated daily during the summer recreation season.

Since 2006, beach advisory recommendations have been based upon exceedance of the single sample maximum *E. coli* criterion of 235 cfu/100 mL, consistent with provisions of the 2004 federal Beaches Environmental Assessment and Coastal Health (BEACH) Act rule and the *E. coli* criterion applicable for bathing waters in Ohio's water quality standards. Bacteria data collected by local or state health agencies at public beaches during the recreation season from 2015 through 2019 were included in the analysis. Ohio's water quality standards define the recreation season as May 1 through October 31, though Lake Erie beach monitoring typically is focused between the Memorial Day and Labor Day weekends.

Each of the 22 public beaches that have traditionally been sampled as part of the Lake Erie bathing beach monitoring program (Figure F-1) was individually analyzed to evaluate the percentage of recreation days during which the bathing water beach action value (BAV) of 235 cfu/100 mL was exceeded, since this is the

value used by health departments to post a health advisory at a given beach. The frequency of beach advisory postings is a direct measure of RU impairment, since potential users may be discouraged from utilizing a beach on days when a health advisory is posted or to avoid certain beaches altogether that are prone to frequent advisories. The locations of beaches in Erie and Sandusky Counties are depicted in Figure F-2, while those beaches located in Cuyahoga and Lorain Counties are depicted in Figure F-3.

As of September 13, 2017, there were 188 public access locations in the eight coastal counties along Ohio's Lake Erie coastline. These public access points do not all include a swimming beach, as some are for boat access, fishing access, parks, wildlife viewing areas, etc. The Ohio Department of Natural Resources (ODNR) publishes a *Lake Erie Public Access Guide* available at ***coastal.ohiodnr.gov/gocoast***. This report used data collected from 67 different beaches along the coast as depicted in Figure F-1 through Figure F-3.

The total number of recreation days in a recreation season for each beach was determined by adding the number of days beginning with the first day of sampling and ending with Labor Day, or the date the final sample was collected (whichever was later). The total number of days that a beach exceeded the BAV of 235 cfu/100 mL during the recreation season (as defined above) was tallied. A measured exceedance was assumed to continue until a subsequent sample documented that the BAV was not exceeded. Similarly, a beach was presumed to meet the BAV following a measurement that met the BAV until a subsequent sample was found to exceed the BAV. Sampling frequency varied from year-to-year and from beach-to-beach. A sampling frequency of four times per week was typical, though some beaches were sampled daily while the two beaches in the Lake Erie Islands AU were sampled only once per week.

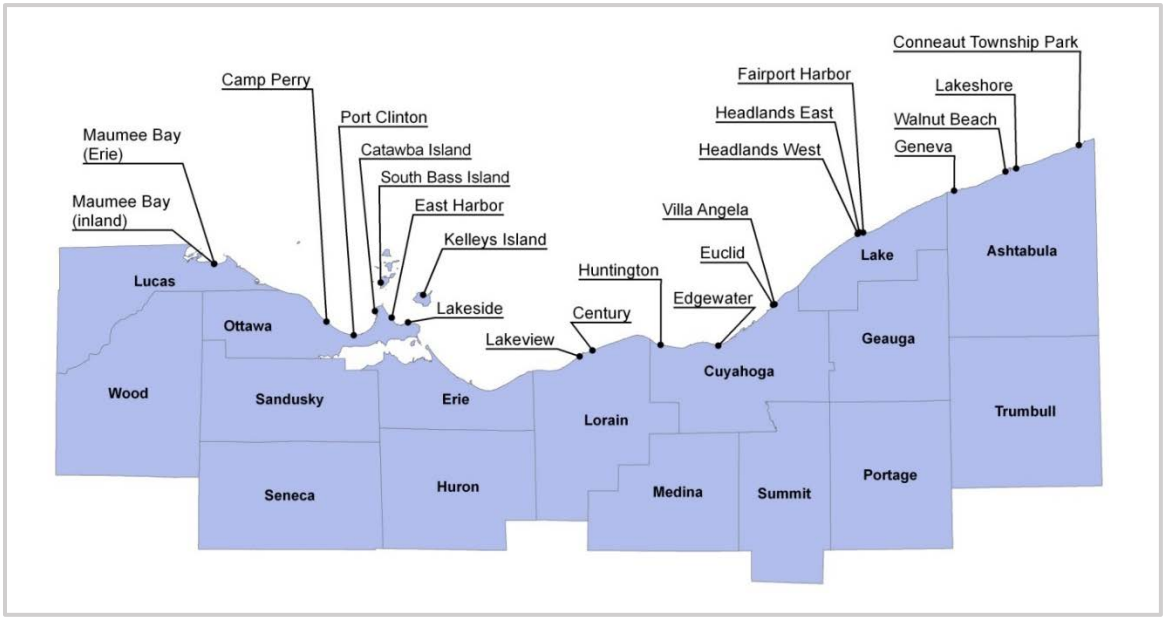

Figure F-1 — Lake Erie public beaches sampled under Ohio's bathing beach monitoring program.

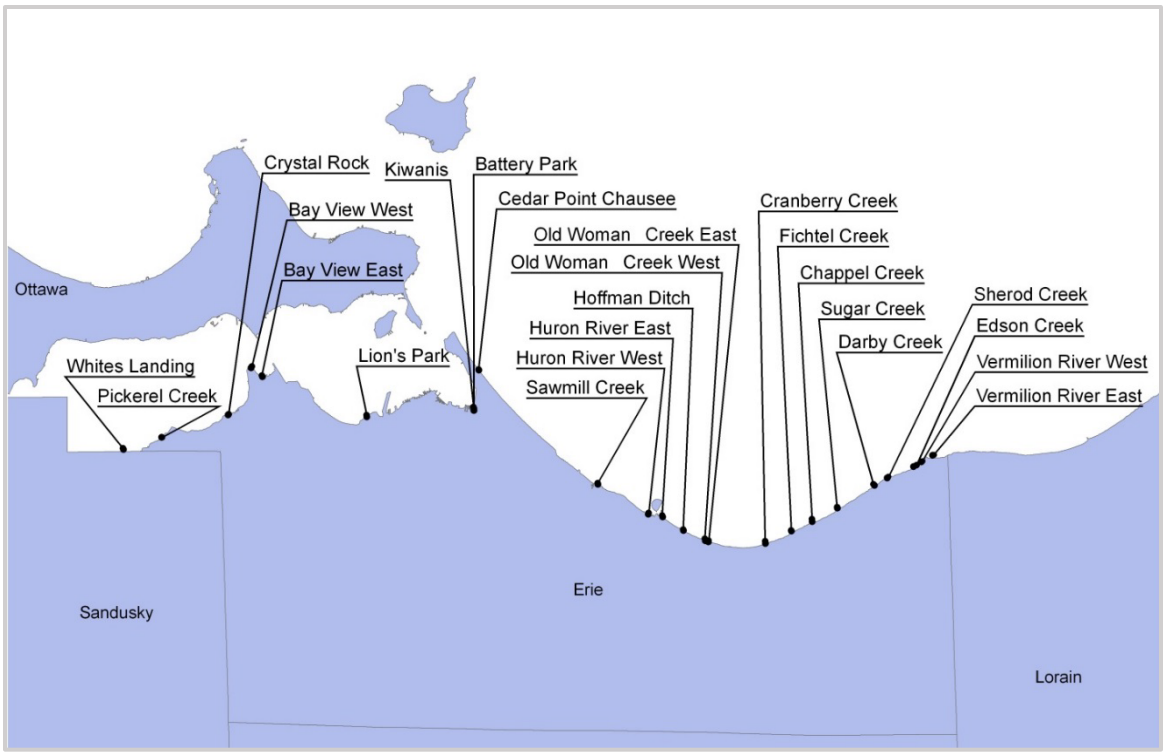

Figure F-2 — Erie and Sandusky County public beaches sampled under Ohio's bathing beach monitoring program.

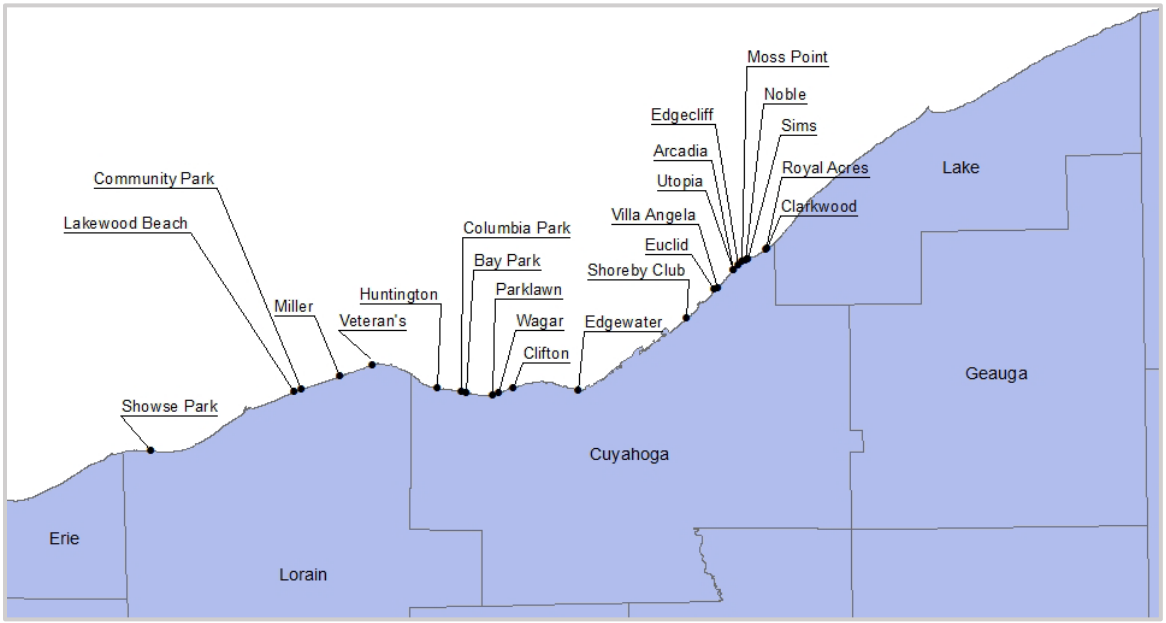

Figure F-3 — Cuyahoga and Lorain County public beaches sampled under Ohio's bathing beach monitoring program.

The exceedance frequency of the bathing water criteria was determined for each beach over a five-year period (2015-2019) on an annual basis. Individual beaches were evaluated for exceedances of both the geometric mean and STV of data collected within 90-day intervals during the recreation season. Results for each individual beach were sorted into the corresponding shoreline LEAU for determining the attainment status of each of the four shoreline LEAUs. The assessment status for each LEAU was based upon whether the frequency of exceedance of the STV was greater than 10 percent for any 90-day period or if the bathing water geometric mean criterion was exceeded within any 90-day period, as described in Table F-2.

Table F-2 — Determining assessment status of Lake Erie shoreline AUs.

LEAU Status	Attainment Status of Individual Beaches
Full	Exceedance frequency of the STV is less than 10 percent and the geometric mean is less than 126 cfu/100 ml based on the samples collected within all 90-day intervals during the recreation season for all the beaches in the AU for all years assessed.
Non	Exceedance frequency of the STV is more than 10 percent or the geometric mean is greater than 126 cfu/100 ml based on the samples collected within all 90-day intervals during the recreation season for one or more of the beaches in the AU for one or more of the years assessed.

A 10 percent exceedance frequency was used as the threshold for attainment determination in the last six assessment cycles and has its origins in the WQS applicable at the time as well as Ohio's 1998 *State of the Lake Report* prepared by the Ohio Lake Erie Commission (Ohio LEC 1998). While the stated goal in the *State of the Lake* report for beaches was to have clean beaches all the time (no days under advisement), the report considered having 10 or fewer days under advisement to be excellent (note that 10 days translates to 10 percent of the season based on a 100-day season). The Ohio Lake Erie Commission last published a *State of the Lake Report* in 2004 (Ohio LEC 2004). That report continued to use these benchmarks in rating the swimmability of Lake Erie beaches along Ohio's 312-mile shoreline. While the 2020 IR continued to track these statistics, which are included in Table F-5 and Table F-6 for individual beaches and further summarized in Table F-7 through Table F-10 and Figure F-5 to provide more detail and allow performance comparisons among individual beaches, the method used to determine the official recreation use status as described above in Table F-2 was revised to reflect the changes to the WQS that became effective in January 2016 (Table F-1).

Rivers and Streams

The 2020 RU impairment list was developed using ambient *E. coli* survey data collected by Ohio EPA from May 2016 through October 2019 by Ohio EPA. These included surveys from the following drainage basins: Conotton Creek, Huron River, Raccoon Creek, Symmes Creek, Southwest Ohio River tributaries, Tuscarawas River, Sugar Creek, Whitewater River, STEM (Swan Creek, Toussaint River and tributaries of the lower Maumee River and direct Lake Erie tributaries), Cuyahoga River, and the upper Auglaize River.

Approximately 2,300 *E. coli* bacteria records were evaluated in this analysis. Data were sorted into their respective 12-digit WAUs and large river assessment units (LRAUs) using a geo-spatial analysis of the latitude/longitude data (and other geographical data if needed) associated with each *E. coli* value. Data within a WAU were further sorted by sampling location and date (calendar year) on which they were collected. Figure F-4 demonstrates the sampling coverage that would be typical for part of a study area. In this case, there are five 12-digit WAUs depicted that drain to one LRAU, the Walhonding River. Each of the five WAUs was sampled in 2010 at one location (depicted by yellow dots) toward the downstream end of the primary tributary in the WAU. Four sampling locations (green dots) are dispersed along the 16-mile stretch of the Walhonding River depicted for an average sampling density of one site per four miles of river length for this LRAU. Sites were sampled on at least five different occasions over the course the 2010 recreation season, though some sites were sampled more frequently. For example, sample collections on some of the LRAU segments such as the Tuscarawas River and Cuyahoga River in 2017 occurred 10 times. Samples were collected within 90-day sample windows during the recreation season to facilitate data evaluation. RU assessment determinations for rivers and streams are based on the following two-step process: site-by-site analysis and assessment unit analysis, as described below.

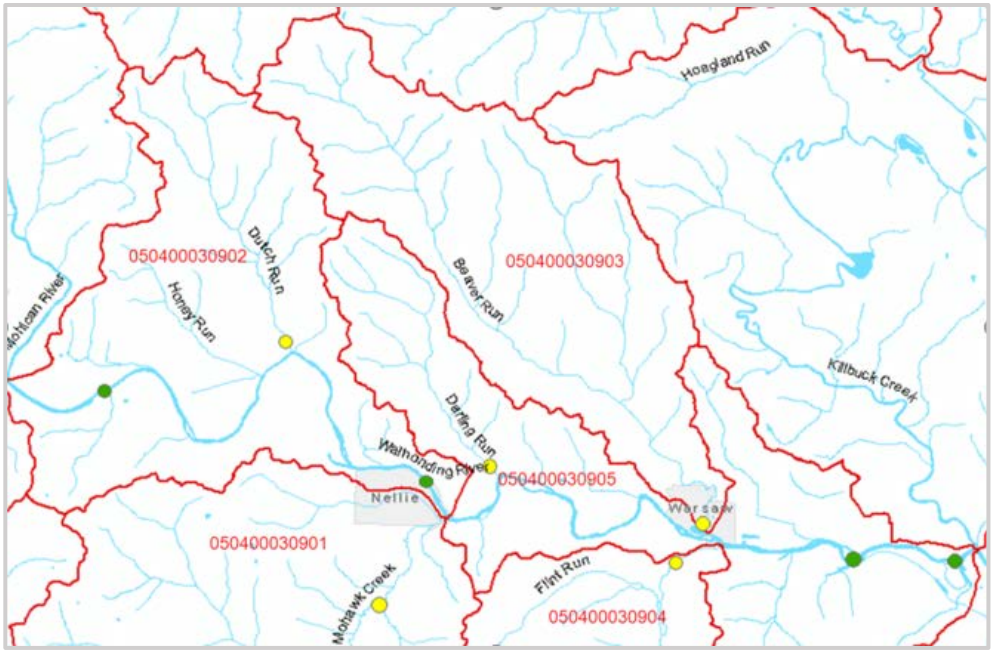

Figure F-4 — Example of bacteria sampling locations, upper Walhonding River study area (2010).

Step One: Site-by-Site Analysis

E. coli data from each site were compared to the geometric mean *E. coli* criterion and STV. The geometric mean was calculated using the "geomean" function in Microsoft Excel 2016® on a site-by-site basis using the pooled dataset of all *E. coli* data (minimum of five data points required) from the site within a 90-day window during a single recreation season. When data were available for multiple recreation seasons, the data from each season were independently analyzed for each recreation season to determine the 90-day geometric mean for each season. Similarly, comparisons were made of the *E. coli* data to the STV to assess sites where the STV was exceeded in more than 10 percent of the samples collected within a 90-day period. Sites in which either the geometric mean or the STV was exceeded did not fully support the recreation use. Further details are listed as follows:

- Data collected outside of the recreation season as defined in Ohio's WQS (May 1 through October 31) were excluded from the analysis.
- Assessments were only made where there were at least five samples within a 90-day period.
- Certain qualified values, such as sample results that exceeded proper holding time or those that have otherwise been indicated to have significant quality assurance deficiencies, were also excluded from the analysis.
- Values reported as too numerous to count (TNTC) were used in the analysis when it was possible to estimate a value based on the dilutions used and/or the maximum reporting limits.
- Values reported as greater than were also used in the analysis. A geometric mean calculated using one or more greater than or TNTC values in the data set was reported as a greater than geometric mean.
- Values reported as less than values of greater than 50 were excluded since acceptable test methods can detect much lower concentrations when appropriate dilutions are used in the analysis. Values reported as 50 or less were used in the analysis. The value used in statistical analysis was one-half the reported less than value. A value of one was substituted for computing the geometric mean in

any case where a value of less than one was reported. Geometric means cannot be calculated using data sets that contain a value of zero.

- Results from duplicate B were used for calculation of the geometric mean in cases where duplicate sample results were reported, except if the E. coli densities of the duplicate samples were more than five times apart from one another, in which case both values were rejected.

Step Two: Assessment Unit Analysis

In the second step of the analysis, the assessment status of the WAU or LRAU was determined based on the attainment status of all the individual sites within the assessment unit and within the assessment period (2016-2019) as described in Table F-3 below.

Table F-3 — Determining assessment status of WAUs and LRAUs.

AU Assessment Status	Attainment Status of Individual Locations
Full (Category 1)	Sufficient data exist to assess at least one location within the WAU (or a minimum of one site for every ~5-7 river miles of a LRAU); the geometric mean criteria and STVs are attained at all assessed sites within the AU
Non (Category 5)	Sufficient data exist to assess at least one location within the WAU (or a minimum of one site for every ~5-7 river miles of a LRAU); the geometric mean or STV is exceeded at one or more assessed sites within the AU
Insufficient Data (Category 3)	No data (category 3) or insufficient data (category 3i) to calculate a geometric mean for any site within the WAU (or for a minimum of one site for every ~5-7 river miles of a LRAU)

Inland Lakes

ODNR, as part of Ohio's Bathing Beach Monitoring Program, monitors *E. coli* levels during the summer at public beaches on lakes located in state parks. While Ohio EPA was unable to establish the level of credibility of these data for use in official listing determinations for this report, a summary of the advisory postings for the 68 beaches monitored in the program is included in Table F-16. Though like the beach monitoring program along Lake Erie, there are several differences. Notably, the sampling frequency is much lower at the inland lake beaches compared to the Lake Erie beaches because of funding disparity. Secondly, because of the large geographic area, beach samples from inland lakes are analyzed by a multitude of consulting laboratories across the state.

F3. Results (Bacteria)

Results for the RU attainment analysis are presented in this section and are based on the methodology outlined in the previous section and available *E. coli* data collected from 67 public beaches along Ohio's Lake Erie 312-mile shoreline (14,848 samples) and at more than 346 locations from Ohio's rivers and streams (2,272 samples) including four of Ohio's largest rivers. Samples used in this analysis were collected from 2015 through 2019 during the recreation season of May 1 through October 31. A summary of the *E. coli* sampling conducted by Ohio EPA in 2016–2019 in presented in Table F-4.

Table F-4 — Summary of Ohio EPA E. coli sampling effort for the 2020 assessment cycle.

Survey	Survey Year	# Sites	# Samples
Raccoon Creek Basin	2016	29	189
Huron River Basin	2016	20	100
Conotton Creek Basin	2016	46	230
Southwest Ohio River Tributaries Basin	2016	18	90
Symmes Creek Basin	2016	19	145
Cuyahoga River Mainstem	2016	16	168
Upper Tuscarawas River Basin	2017	21	208
Lower Tuscarawas River Basin	2017	29	226
Sugar Creek Basin	2017	16	80
Whitewater River Basin	2017	13	65
Swan Creek, Toussaint River, lower Maumee and Western Lake Erie Tributaries Basin	2017	28	140
Cuyahoga River Mainstem	2017	30	171
Cuyahoga River Tributaries Basin	2018	32	315
Upper Auglaize River Basin	2019	29	145

Lake Erie Public Beaches

Information about water quality conditions at Lake Erie public bathing beaches is summarized in Table F-5 through Table F-10 and Figure F-5. The locations of these beaches are shown in Figure F-1 through Figure F-3. The methodology used for assessing the beaches along Ohio's Lake Erie shoreline was consistent in the 2010, 2012, 2014 and 2016 reports. However, as described in section F2, some modifications to the methods for assessing the Lake Erie beach data were made beginning with the 2018 report to accommodate the revisions to the WQS that became effective in January 2016.

Table F-5 contains the seasonal geometric mean *E. coli* levels for 17 public beaches along the coast of Lake Erie's western basin for the past five recreational seasons (2015-2019) while Table F-6 contains the seasonal geometric mean *E. coli* levels for 50 public beaches along the coast of Lake Erie's central basin for the past five recreational seasons (2015-2019).

On a seasonal basis, the geometric mean *E. coli* criterion for bathing waters was exceeded at 16 beaches in 2015; seven beaches in 2016; three beaches in 2017; nine beaches in 2018 and eleven beaches in 2019. The Lakeview beach was the only beach documented to exceed the geometric mean criterion on a seasonal basis each of the past five seasons. Not surprisingly, this beach and others that frequently exceeded the geometric mean criterion on a seasonal basis had among the most days under a swimming advisory during the 2015-2019 reporting period. Highlighted cells in Table F-5 and Table F-6 indicate exceedance of the geometric mean criterion on a seasonal basis or exceedance of the BAV more than 10 percent of season. The table also indicates the number of beach advisories for each beach based upon exceedance of the BAV of 235 cfu/100 mL. This is the threshold that triggers the issuance of beach advisories and has been used since 2006. Use of the BAV to post beach advisories complies with the BEACH Act rule (*Water Quality Standards for Coastal and Great Lakes Recreation Waters*, 69 FR 67217, Nov. 16, 2004), which became effective on Dec. 16, 2004.

In Table F-7 through Table F-10, the beaches are arranged alphabetically according to the LEAU in which they are geographically located. The tables indicate the number of days per recreation season and the total percentage for all years when Ohio's Lake Erie public beaches exceeded the BAV compared to the total number of days in the recreation season sampling period.

As depicted in Figure F-5, the frequency during which individual beaches were under a swimming advisory based on elevated bacteria levels above the advisory level for the entire five-year reporting period (2015-

2019) ranged from near zero at Battery Park, Catawba Island State Park, Conneaut Township Park, East Harbor State Park, Geneva State Park, Lakeside and South Bass Island State Park to more than a third of the season on average at six beaches: Bay View West, Edson Creek, Lakeview, Maumee Bay State Park (Erie and inland) and Villa Angela State Park. Considerable variation in the frequency of advisories was observed between beaches and from season-to-season at many beaches. However, several beaches stand out as consistently good performers over the past several recreation seasons, including Battery Park, Catawba Island, Cedar Point, Conneaut, East Harbor State Park, Geneva State Park, Kelleys Island, Lakeside and South Bass Island State Park, which all had a cumulative exceedance frequency of less than 10 percent on a seasonal basis. These beaches rarely exceeded 10 days per season under advisement. There were also several beaches that consistently performed poorly with three beaches, including Bay View West, Edson Creek and Lakeview under advisement nearly 40 percent of the time or more during the past five recreation seasons on a cumulative basis. High variation in bacteria levels was also seen between seasons for some beaches. For example, Kiwanis beach was under advisement for 44 days in 2015, but under advisement for just seven days in 2016. Crystal Rock beach was under advisement for just two days in 2016, but under advisement for 20 days in 2017. The annual median frequency of advisement for all beaches by calendar year in this reporting cycle was highest in 2015 at 21 days compared to the rest of the reporting years, which had an annual median advisory frequency of 9-12 days per beach. The annual average geometric mean *E. coli* level for all beaches by year within this reporting cycle ranged from a low of 55 in 2017 to a high of 96 in 2015.

In IR cycles prior to 2018, impairment of the bathing water RU was determined by pooling data from beaches in each of the LEAUs and calculating the percentage of days in the recreational season when the *E. coli* criterion was exceeded. A threshold of impairment was set at 10 days per season based on the Ohio Lake Erie Commission's evaluation system (Ohio LEC 1998). This translates to a seasonal exceedance frequency of 10 percent, as the recreation season at Lake Erie's beaches in Ohio typically runs from Memorial Day weekend through Labor Day weekend. Results are shown in Table F-11. As in previous assessment cycles, the 2020 assessment results indicate that the Lake Erie Islands assessment unit would fully support the RU on a seasonal basis while the Western basin, Sandusky basin and Central basin assessment units would not support the RU. The overall total recreation days in exceedance of the bathing waters criterion on a percentage basis was 14.4 percent in the western basin (7 beaches), 16.9 percent (28 beaches) in the Sandusky basin and 15.5 percent in the central basin compared to just 2.8 percent for the Lake Erie Islands (two beaches).

With the revision of Ohio's WQS effective Jan. 4, 2016, the averaging period was revised from a seasonal basis to a 90-day period. Furthermore, the revised WQS specify that the STV is not to be exceeded in more than 10 percent of the samples taken during any 90-day period. As such, the Lake Erie beach data were examined to ensure that all the beaches in each of the Lake Erie shoreline AUs during the reporting cycle of 2015-2019 attained both the geometric mean and STV on a 90-day basis rather than the seasonal basis as has historically been done. As historically observed at numerous beaches in both the Western basin and Central basin on a seasonal basis, numerous beaches also failed to attain the criteria on a 90-day basis as well (Table F-11). In fact, of the 67 total Lake Erie beaches monitored, 23 failed to attain the geometric mean criterion every year during the reporting cycle on a 90-day averaging period basis, while only three beaches attained both the geometric mean and STV criteria every year throughout the monitoring cycle, including East Harbor State Park, Lakeside, and South Bass Island. Both Battery Park beach and Walnut beach experienced no exceedances of the 90-day geometric mean criterion over the 5-year reporting cycle and only experienced an exceedance of the STV during a portion of a single year during the five-year reporting cycle thus falling just short of full attainment at these two beaches.

Table F-5 — Seasonal geometric mean E. coli levels and advisory postings at public Lake Erie shoreline beaches in the western basin (Sandusky Bay and west).

Beach	2015		2016		2017		2018		2019	
	Seasonal geomean	number of days posted	Seasonal geomean	number of days posted	Seasonal geomean	number of days posted	Seasonal geomean	number of days posted	Seasonal geomean	number of days posted
Battery Park	11	4	11	4	7	0	10	0	15	10
Bay View East	94	21	51	18	62	11	89	20	53	5
Bay View West	142	42	542	76	210	50	303	46	77	14
Camp Perry	84	26	125	13	76	19	93	9	107	9
Catawba Island	47	11	20	0	9	2	17	0	29	0
Crystal Rock	43	18	25	2	24	20	39	0	47	3
East Harbor	10	5	6	2	7	3	8	0	13	5
Kelleys Island	36	0	63	0	33	4	46	6	81	8
Kiwanis (Pipe Cr)	141	44	67	7	38	10	63	2	29	3
Lakeside	12	7	8	0	9	4	9	0	26	1
Lion's Park	54	12	65	22	40	10	71	7	94	28
Maumee - Erie	167	45	150	39	122	34	141	31	99	23
Maumee - Inland	92	28	95	29	151	37	259	37	294	41
Pickerel Creek	68	24	33	13	29	13	42	6	61	38
Port Clinton	48	32	21	7	38	13	47	7	NS	NS
South Bass Island	7	2	18	0	15	0	5	0	18	0
Whites Landing	158	45	136	36	71	22	55	6	74	8

Shaded cells indicate exceedance of the geometric mean criterion on a seasonal basis *(seasonal geomean)* or exceedance of the BAV more than 10 percent of the time during a season. The beach season is defined for this analysis as the time *E. coli* monitoring commences, typically in late May though the end of the Labor Day weekend or until the termination of sampling for the season, whichever is later. The number of days posted is determined by counting the number of days the BAV was exceeded. Days for which no monitoring data were collected are presumed to be in exceedance if the preceding day's bacteria level exceeded the BAV. Unmonitored days are presumed to meet the BAV when preceded by a monitored day that was below the BAV. NS = Not Sampled.

Table F-6 — Seasonal geometric mean E. coli levels and advisory postings at public Lake Erie shoreline beaches in the central basin (east of Cedar Point).

Beach	2015		2016		2017		2018		2019	
	Seasonal geomean	number of days posted	Seasonal geomean	number of days posted	Seasonal geomean	number of days posted	Seasonal geomean	number of days posted	Seasonal geomean	number of days posted
Arcadia Beach	279	39	53	4	82	28	124	12	285	35
Bay Park Beach	59	13	45	3	20	4	11	7	35	13
Beulah Beach (Chappel Creek)	110	27	53	26	62	19	76	15	70	19
Cedar Point Chausee	35	8	20	7	35	11	28	7	25	5
Century	110	34	19	10	43	13	106	23	117	29
Clarkwood	117	22	79	4	113	23	176	15	140	8
Clifton	49	22	34	11	44	6	65	23	80	14
Columbia Park	105	20	41	6	67	13	34	4	122	19
Community Park	108	29	23	16	36	9	48	8	86	24
Conneaut	24	3	28	2	17	4	16	2	21	2
Cranberry	39	20	21	4	21	17	23	14	25	10
Darby	86	30	56	16	72	22	94	18	105	27
Edgecliff	288	37	41	8	88	19	171	15	100	19
Edgewater	80	22	36	11	30	7	36	20	57	10
Edson	193	56	151	14	NS	NS	NS	NS	NS	NS
Euclid State Park	152	42	81	27	100	33	87	42	172	27
Fairport Harbor	96	28	44	23	58	20	44	17	31	5
Fichtel Creek (Heidelberg Beach)	34	15	30	4	18	9	49	10	46	18
Geneva State Park	29	3	17	0	17	2	16	2	13	5
Headlands East	53	18	45	16	46	15	45	13	NS	NS
Headlands West	56	18	45	16	46	16	45	15	57	11
Hoffman Ditch	60	25	32	9	39	17	NS	NS	NS	NS
Huntington	68	30	38	15	36	12	48	15	32	6
Huron River East (Nickel Plate Beach)	57	28	64	33	54	16	41	15	41	4
Huron River West (Lake Front Park)	161	28	75	11	106	33	115	27	71	11
Lakeshore Park	228	33	308	38	55	0	88	16	50	2
Lakeview	248	65	264	53	195	38	195	30	139	24
Lakewood Beach Park	84	28	21	13	33	19	71	8	68	23
Miller Beach	82	19	32	10	39	15	49	7	NS	NS
Moss Point	113	21	113	11	27	4	110	8	197	24
Noble	96	25	80	10	45	6	179	13	127	17
Nokomis	NS	NS	NS	NS	44	17	109	24	181	33
Old Woman East (Oberlin Beach)	27	15	14	2	16	3	32	5	33	13

Beach	2015		2016		2017		2018		2019	
	Seasonal geomean	number of days posted	Seasonal geomean	number of days posted	Seasonal geomean	number of days posted	Seasonal geomean	number of days posted	Seasonal geomean	number of days posted
Old Woman West	56	24	18	5	26	3	32	8	17	5
Orchard Beach	NS	NS	NS	NS	NS	NS	52	15	54	16
Parklawn	47	9	55	9	21	0	16	0	51	6
Royal Acres	104	13	69	6	126	24	153	22	146	13
Sawmill Creek	42	11	24	11	26	12	24	0	23	6
Sherod Creek	89	49	49	19	67	12	103	16	95	24
Shoreby Club	90	14	13	0	23	2	64	13	NS	NS
Showse	44	24	22	10	28	13	22	2	55	14
Sims	184	32	227	33	91	21	197	10	196	19
Sugar Creek	60	30	46	12	62	13	NS	NS	NS	NS
Utopia	235	34	43	2	54	10	62	8	124	24
Vermilion East (Lagoons Beach)	65	26	38	16	52	26	49	10	99	24
Vermilion West (Main Street Beach)	143	46	52	9	51	6	87	15	96	23
Veteran's Beach	198	39	53	28	78	27	91	17	118	32
Villa Angela	231	54	122	39	114	39	99	46	158	32
Wagar	65	16	46	9	29	7	48	2	43	8
Walnut	16	14	22	2	10	2	13	2	13	0

Shaded cells indicate exceedance of the geometric mean criterion on a seasonal basis *(seasonal geomean)* or exceedance of the BAV more than 10 percent of the time during a season. The beach season is defined for this analysis as the time *E. coli* monitoring commences, typically in late May, though the end of the Labor Day weekend or until the termination of sampling for the season, whichever is later. The number of days posted is determined by counting the number of days the BAV was exceeded. Days for which no monitoring data were collected are presumed to be in exceedance if the preceding day's bacteria level exceeded the BAV. Unmonitored days are presumed to meet the BAV when preceded by a monitored day that was below the BAV. NS = Not Sampled

Table F-7 — The number of days per season (and the percentage for all years) when Ohio Lake Erie public beaches exceeded the BAV relative to the total number of days in the sampling period, 2015 – 2019, for the central basin shoreline AU.

Beach	2015	2016	2017	2018	2019	All years (%)
Arcadia Beach	39/104	4/97	28/98	12/97	35/97	118/493 (23.9%)
Bay Park Beach	13/105	3/98	4/98	7/98	13/98	40/497 (8.0%)
Century Beach	34/113	10/106	13/106	23/106	29/106	109/537 (20.3%)
Clarkwood Beach	22/104	4/97	23/97	15/97	8/97	72/492 (14.6%)
Clifton Beach	22/105	11/98	6/98	23/98	14/98	76/497 (15.3%)
Columbia Park Beach	20/105	6/98	13/96	4/92	19/98	62/489 (12.7%)
Community Park Beach	29/113	16/106	9/106	8/106	25/106	87/537 (16.2%)
Conneaut Township Park	3/92	2/76	4/92	2/106	2/106	13/472 (2.8%)
Edgecliff Beach	37/104	8/97	19/97	15/97	19/97	98/492 (19.9%)
Edgewater State Park	22/109	11/104	7/102	20/131	10/71	70/517 (13.5%)
Euclid State Park	42/109	27/104	33/109	42/131	27/71	171/524 (32.6%)
Fairport Harbor	28/112	23/102	20/106	17/104	5/98	93/522 (17.8%)
Geneva State Park	3/92	0/76	2/92	2/106	5/106	12/472 (2.5%)
Headlands State Park East	18/112	16/106	15/106	13/104	NS	62/428 (14.5%)
Headlands State Park West	18/113	16/106	16/106	15/104	11/98	76/527 (14.4%)
Huntington Beach	30/113	15/106	12/106	15/106	6/105	78/536 (14.6%)
Lakeshore Park	33/92	38/76	0/92	16/106	2/106	89/472 (18.9%)
Lakewood Beach	28/113	13/99	19/106	9/106	24/106	93/530 (17.5%)
Miller Beach	19/105	10/99	15/106	7/106	NS	51/416 (12.3%)
Moss Point Beach	21/104	11/97	4/97	8/97	24/97	68/492 (13.8%)
Noble Beach	25/104	10/97	6/97	13/97	17/97	71/492 (14.4%)
Parklawn Beach	9/105	9/98	0/98	0/98	6/98	24/497 (4.8%)
Royal Acres Beach	13/104	6/97	24/97	22/97	13/97	78/492 (15.9%)
Shoreby Club Beach	14/104	0/97	2/97	13/97	NS	29/395 (7.3%)
Sims Beach	32/104	33/97	21/97	10/97	19/97	115/492 (23.4%)
Utopia Beach	34/104	2/97	10/98	8/97	24/97	78/493 (15.8%)
Veteran's Beach	39/105	28/99	27/106	17/106	32/106	143/522 (27.4%)
Villa Angela State Park	54/109	39/104	39/110	46/131	32/85	210/539 (40.0%)
Wagar Beach	16/105	9/98	7/92	2/92	8/98	42/485 (8.7%)
Walnut Beach	14/92	2/76	2/92	2/106	0/106	20/472 (4.2%)

Table F-8 — The number of days per season (and the percentage for all years) when Ohio Lake Erie public beaches exceeded the BAV relative to the total number of days in the sampling period, 2015 – 2019, for the western basin shoreline AU.

Beach	2015	2016	2017	2018	2019	All years (%)
Camp Perry	26/113	13/106	19/106	9/106	9/107	76/538 (14.1%)
Catawba Island State Park	11/113	0/106	2/104	0/106	0/106	13/535 (2.4%)
East Harbor State Park	5/113	2/106	3/106	0/106	5/106	15/537 (2.8%)
Lakeside Beach	7/113	0/106	4/106	0/106	1/106	12/535 (2.2%)
Maumee Bay State Park (inland)	28/105	29/103	37/98	37/104	41/98	172/508 (33.9%)
Maumee Bay State Park (Erie)	45/105	39/103	34/98	31/104	23/98	172/508 (33.9%)
Port Clinton	32/113	7/106	13/106	7/106	NS	59/431 (13.7%)

Table F-9 — The number of days per season (and the percentage for all years) when Ohio Lake Erie public beaches exceeded the BAV relative to the total number of days in the sampling period, 2015 – 2019, for the islands shoreline AU.

Beach	2015	2016	2017	2018	2019	All years (%)
Kelleys Island State Park	0/111	10/106	4/106	6/106	8/106	28/535 (5.2%)
South Bass Island State Park	2/113	0/106	0/104	0/106	0/106	2/535 (0.4%)

Table F-10 — The number of days per season (and the percentage for all years) when Ohio Lake Erie public beaches exceeded the BAV relative to the total number of days in the sampling period, 2015 – 2019, for the Sandusky basin shoreline AU.

Beach	2015	2016	2017	2018	2019	All years (%)
Battery Park	4/113	0/106	0/106	0/106	10/106	14/537 (2.6%)
Bay View East	21/113	18/106	11/105	20/106	5/106	75/537 (14.0%)
Bay View West	42/113	76/106	50/106	46/106	14/105	228/537 (42.5%)
Cedar Point Chausee	8/113	7/106	11/106	7/106	5/106	38/537 (7.1%)
Chappel Creek (Beulah Beach)	27/113	26/106	19/106	15/105	19/106	106/536 (19.8%)
Cranberry Creek	20/113	4/106	17/106	14/102	11/107	66/534 (12.4%)
Crystal Rock	18/113	2/106	20/106	0/106	3/106	43/537 (8.0%)
Darby Creek	30/113	16/106	22/106	18/104	27/106	113/535 (21.1%)
Edson Creek	56/113	14/45	NS	NS	NS	70/158 (44.3%)
Heidelberg Beach (Fichtel Creek)	15/113	4/106	9/106	10/105	18/106	56/537 (10.4%)
Hoffman Ditch	25/113	9/106	17/106	NS	NS	51/325 (15.7%)
Huron River East	28/113	33/106	16/106	15/105	4/107	96/537 (17.9%)
Huron River West	28/113	11/82	33/106	27/106	11/106	110/513 (21.4%)
Kiwanis (Pipe Creek)	44/113	7/106	10/106	2/106	3/106	66/537 (12.3%)
Lakeview Beach	65/113	53/106	38/106	30/106	24/106	210/537 (39.1%)
Lion’s Park	12/113	22/106	10/106	7/102	28/101	79/528 (15.0%)
Nokomis	NS	NS	17/78	24/105	35/106	76/289 (26.3%)
Old Woman Cr. East (Oberlin Beach)	15/113	2/106	3/106	5/105	13/106	38/536 (7.1%)
Old Woman Creek West	24/113	5/106	3/106	8/105	5/106	45/536 (8.4%)
Orchard Beach	NS	NS	NS	15/105	16/106	31/211 (14.7%)
Pickerel Creek	24/113	13/106	13/106	6/106	38/106	94/537 (17.5%)
Sawmill Creek	11/113	11/106	12/106	0/106	6/106	40/537 (7.4%)
Sherod Creek	49/113	19/106	12/106	16/105	24/106	120/536 (22.4%)
Showse Park	24/113	10/106	13/105	2/105	15/106	64/535 (12.0%)
Sugar Creek	30/113	12/106	13/106	NS	NS	55/325 (16.9%)
Vermilion River East	26/113	16/106	26/106	10/105	24/106	102/537 (19.0%)
Vermilion River West (Main St Beach)	46/113	9/106	6/106	15/105	23/106	99/536 (18.5%)
Whites Landing	45/113	36/106	22/106	6/106	8/106	117/537 (21.8%)

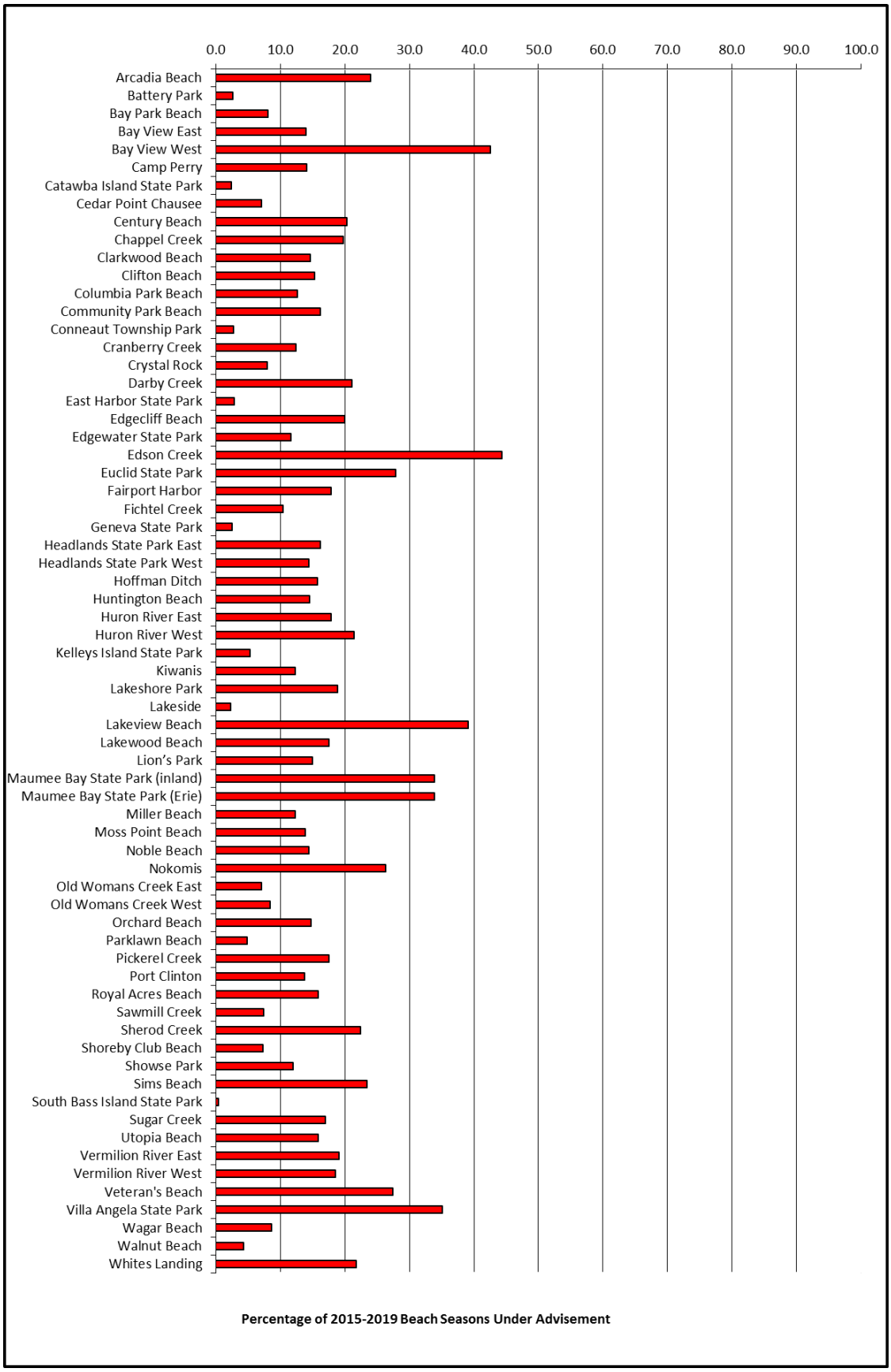

Figure F-5 — Frequency of advisory postings at Ohio's Lake Erie public beaches.

Table F-11 — Aggregated exceedance frequencies at 65 Lake Erie public beaches from 2015-2019 (pooled by Lake Erie shoreline AU to report use support).

	Western Basin	Central Basin	Sandusky Basin	Lake Erie Islands
Number of beaches	7	30	28	2
Total recreation days	3,594	14,821	13,610	1,070
Total days in exceedance	519	2,348	2,302	30
Percentage of days in exceedance	14.4%	15.8%	16.9%	2.8%
Total beach seasons[1]	34	147	128	10
Average # of days *E. coli* BAV exceeded per beach per season[2]	15.3	15.6	18.0	3.0
Number of beaches exceeding 90-d geomean one or more years during reporting cycle[3]	2	13	8	0
Number of beaches exceeding STV within a 90-day period in one or more years during the reporting cycle[3]	5	30	28	1
Attainment status	Does not support	Does not support	Does not Support	Does not Support

[1] The total number of beach seasons in a basin is equal to aggregated sum of the total number of beaches for which monitoring was conducted during each season for the 2015-2019 reporting period.
[2] Calculated by dividing the total days in exceedance in the basin by the total number of beach seasons in the basin.
[3] Used to determine attainment status.

Rivers and Streams

Ohio's RU support analysis is based on an examination of *E. coli* data collected from Ohio's rivers, streams and inland lakes during the recreation season. Approximately 2,300 bacteria measurements were collected and evaluated to support the recreational use assessment of streams and rivers in Ohio as part of this reporting cycle (Table F-4). This is comparable to the number of *E. coli* measurements used in the 2018 assessment cycle (about 2,100 samples). Assessments for this cycle consist of data collected by Ohio EPA in 2016-2019, which are summarized in Table F-4.

Table F-12 provides a summary of Ohio EPA's RU monitoring effort and its translation to use assessment annually for the past nine recreation seasons. Sample collection in the 2016-2017 biennium was down by about one-third compared to the previous biennium and dropped another 25% in the 2018-2019 biennium compared to the 2016-2017 sampling effort.

Table F-12 — Annual Ohio EPA E. coli sampling effort and RU assessment (using Ohio EPA data) in Ohio's surface waters, 2011-2019 recreation seasons.

	2011	2012	2013	2014	2015	2016	2017	2018	2019
Number of samples collected by Ohio EPA	1,674	1,173	1,635	1,423	1,231	922	890	315	145
Number of site geometric means computed	276	219	269	222	219	119	137	32	29
Number of unique WAUs assessed	130	92	131	121	115	85	74	22	15
Number of unique LRAUs assessed	3	5	2	1	0	2	5	0	0

The *E. coli* data used in this report to assess rivers and streams were collected by Ohio EPA staff as part of routine ambient monitoring associated with annual drainage basin surveys conducted around the state. One of the objectives of the annual basin surveys is to collect data to support use assessments needed to fulfill obligations under Section 303 and 305 of the Clean Water Act, which includes the E*. coli* data collected as part of these surveys and used in this report. Using the methodology described in Section F2 and the ambient E. coli data collected by Ohio EPA in 2016-2019, it was possible to determine the RU attainment status of 196 of the 1,538 (13 percent) WAUs in Ohio.

Widespread impairment of the recreation use was documented in Ohio's streams and rivers based on the *E. coli* data collected from 2016-2019. A total of 180 of the 196 WAUs assessed this cycle failed to support the recreational use (Table F-13). This is similar to the widespread and pervasive impairment of the recreation use observed in previous reporting cycles and documented in numerous integrated reports. As can be readily seen in Table F-13, high impairment rates were observed in all the basins sampled and regardless of sample year.

In addition to Ohio's 1,538 WAUs, there are also 23 large rivers in Ohio, eight of which are further divided into two or more subdivisions for a total of 38 large river assessment units. Large river assessment units have drainage areas greater than 500 square miles and comprise, in total, 1,236 river miles in the state. The large river assessment units were analyzed independently of the WAUs through which they flow and LRAU data were not included in WAU assessments. Table F-13 summarizes the results of the analysis of *E. coli* data for the large river assessment units and the resulting RU support determinations. Sufficient data were available to determine the use support status for just six of the 38 LRAUs (16 percent) in the 2020 reporting cycle. No new LRAUs were sampled or assessed in the past two years. However, as part of the new monitoring strategy that is scheduled to be implemented in 2020, all of Ohio's large rivers will be sampled providing a statewide assessment snapshot of these water bodies for the first time.

Table F-13 — Recreational use assessment summary of Ohio's streams and rivers for the 2020 assessment cycle.

				HUC 12s			LRAU Segments	
Survey	Year	Sites	Samples	#	Supporting	Not Supporting	Supporting	Not Supporting
Raccoon Creek Basin	2016	29	189	22	0	22	0	1
Huron River Basin	2016	20	100	17	2	15	N/A	N/A
Conotton Creek Basin	2016	46	230	11	2	9	N/A	N/A
Southwest Ohio River Trib Basin	2016	18	90	17	4	13	N/A	N/A
Symmes Creek Basin	2016	19	145	16	2	14	N/A	N/A
Cuyahoga River Mainstem	2016	16	168	2	0	2	0	1
Upper Tuscarawas River Basin	2017	21	208	15	1	14	0	1
Lower Tuscarawas River Basin	2017	29	226	13	0	13	0	2
Sugar Creek Basin	2017	16	80	15	1	14	N/A	N/A
Whitewater River Basin	2017	13	65	6	0	6	0	1
Swan Creek, Toussaint River, lower Maumee and Western Lake Erie Tributaries Basin	2017	28	140	19	2	17	N/A	N/A
Cuyahoga River Mainstem	2017	30	171	6	0	6	0	1
Cuyahoga River Tributaries Basin	2018	32	315	22	2	20	N/A	N/A
Upper Auglaize River Basin	2019	29	145	15	0	15	N/A	N/A
	Totals	**346**	**2,182**	**196**	**16**	**180**	**0**	**7**

The overall attainment and impairment rates and the changes between reporting years are summarized in Table F-14. Attainment and impairment rates in Table F-14 are based on the total number of watersheds for which sufficient data were available in the respective reporting cycle and not on the total number of assessment units in the state. For the 196 assessment units for which sufficient data were available to determine the RU assessment status in 2020, only eight percent fully supported the recreation use while 92 percent did not support the recreation use. These results are comparable to the results from previous cycles that consistently show only a small proportion of the state's watersheds demonstrate full support of the RU. Only seven percent of the individual stream locations sampled by Ohio EPA in 2017-2018 were found to attain the applicable recreation criteria compared to just 15 percent of the individual sites sampled by Ohio EPA in 2015 and 2016.

Table F-14 — Overall differences in the assessment of RU attainment, 2010-2020.

	2010 Report		2012 Report		2014 Report		2016 Report		2018 Report		2020 Report	
	#	%	#	%	#	%	#	%	#	%	#	%
Total AUs[1]	1,576	100	1,576	100	1,576	100	1,576	100	1,576	100	1,576	100
Assessed	487	31	588	37	680	43	713	45	170	11	203	13
Not Assessed	1,089	69	988	63	896	57	863	55	1,406	89	1,380	87
Supporting Use[2]	65	13	88	15	130	19	73	10	14	8	16	8
Not Supporting Use[2]	422	87	500	85	550	81	640	90	156	92	180	92

[1] Includes LRAUs.

[2] Note: The percentage of AUs reported as supporting the RU and not supporting the RU are based on the total AUs that were assessed that calendar year (e.g., 203 for the 2020 calendar year).

The RU attainment status of Ohio's 1,538 WAUs is summarized in Table F-15. This table differs slightly from the summary presented in Table F-14 as this table accounts for those watersheds for which TMDLs have been completed and placed into category 4 and it also includes historic categorizations carried over from previous reporting cycles. WAUs attaining the recreational WQS appear to have leveled off at around 10 percent. WAUs not supporting the recreation use, and in need of a TMDL, increased to 50 percent. The number of WAUs that have never been assessed for recreational use attainment stands at about 14 percent. To date, Ohio has completed total maximum daily loads (TMDLs) for bacteria in 404 of the 1,538 WAUs in Ohio (26 percent).

Bacteria data collected in support of the past six IR cycles clearly shows that the swimmable goal of the CWA is largely unsupported across Ohio with very little improvement evident over time. Because of the ubiquitous nature of the problem, Ohio EPA is now pursuing a statewide TMDL for bacteria and exploring opportunities for substantial implementation activities in cooperation with state and local partners to identify and address bacteria loading sources. These activities should be coupled with continued monitoring to measure success and trends.

Table F-15 — Summary assessment status of the RU in Ohio's WAUs by Assessment Cycle[1].

Assessment Category	Number of Assessment Units Categorized						Percentage of Assessment Units Categorized					
	2010	2012	2014	2016	2018	2020[2]	2010	2012	2014	2016	2018	2020
1	59	103	141	153	141	159	4%	7%	9%	10%	9%	10%
3	888	673	511	252	182	208	58%	44%	33%	16%	12%	14%
4	266	341	425	449	449	404	17%	22%	28%	29%	29%	26%
5	325	421	461	685	766	769	21%	27%	30%	45%	50%	50%
Total	1,538	1,538	1,538	1,538	1,538	1,538	100%	100%	100%	100%	100%	100%

[1] See Section J for assessment category descriptions.

[2] During the transition of data into U.S. EPA's ATTAINS, refinement was made on the number of WAUs included in TMDL reports, which is why the number of WAUs in category 4 decreased and the number of WAUs in category 3 increased.

Inland Lakes

ODNR's Division of Parks and Recreation also conducts routine bacteria sampling of public bathing beaches at inland state park beaches pursuant to Ohio Revised Code sections 1541.032 and 3701.18. Advisory signs are posted whenever notified by the director of the Ohio Department of Health that the bacteria levels in the waters tested present a possible health risk to swimmers. Advisory postings are recommended whenever the *E. coli* density of a water sample exceeds the bathing water BAV of 235 cfu/100 mL. Sampling frequency at the inland state park beaches is generally once every two weeks. This sampling frequency is much less intense compared to sampling frequency at many of the Lake Erie beaches, which typically occurs at a frequency of four or more days per week.

Table F-16 summarizes the advisory postings from 2015 through 2019 at 50 inland public recreation lakes, primarily located at Ohio's state parks. Some of these lakes had multiple beach locations. Beaches at which more than 10 percent of the samples collected over a recreation season exceeded the BAV of 235 cfu/100 mL are highlighted in blue. The inland lake data from ODNR are presented in the IR for informational purposes and not for official use support determinations since the level of data credibility was indeterminate at the publication of this report. Its inclusion here is intended to notify readers of the existence of this sampling program for these popular recreational resources in Ohio and to provide some information as to the relative amount of data and relative water quality conditions with respect to bacteria indicators. Should Ohio EPA affirm the data as Level 3 credible data in the future, it will be considered in the process for making official use support determinations.

Beaches at inland state park lakes are tested for bacteria less frequently compared to those beaches along Lake Erie. Sampling was most frequent at Seneca Lake (2016-2019), Atwood Lake (2016-2018), Charles Mill Lake, (2017-2018), Pleasant Hill Lake (2017-2018) and Tappan Lake (2016-2019). Even at these beaches, the sampling frequency is roughly only half as intense as that of many Lake Erie beaches (Figure F-5).

The sample results in Table F-16 indicate that at most of the inland lake beaches, the BAV of 235 cfu/100mL is not frequently exceeded, resulting in fewer postings compared to some of the beaches along Lake Erie. There were 39 inland lake beach locations where the overall exceedance frequency was less than 10 percent of the samples collected during the five-year reporting period. Overall, the frequency of exceedances for all the inland lake beaches during the five-year reporting period was 11.9 percent, slightly lower than the 13.8 percent rate reported in the previous cycle and similar to the 12.4 percent rate reported in the 2011-2015 cycle, which in turn was slightly higher than the 10.5 percent reported in the 2008-2012 reporting period. There were 29 inland lake beaches where the aggregated exceedance frequency was more than 10 percent. The highest aggregated exceedance frequency of 42 percent was found at the Dillon Reservoir followed by Madison Lake at 36 percent and Buckeye Lake's Crystal Beach at 32 percent. Twelve beaches exceeded the BAV 20 percent or more of the time over the five-year reporting period total: Alum Creek's main beach, Buckeye Lake's Fairfield and Crystal beaches; Caesar Creek Lake (south beach); Charles Mill Lake; Dillon Reservoir; Jackson Lake; Lake Loramie; Madison Lake; Pike Lake; Seneca Lake; and Tappan Lake.

Sample results at some inland lake beaches indicated a need for posting an advisory much more frequently during certain years. For example, five of 18 (28 percent) of the samples collected at Stonelick Lake exceeded the BAV in 2017 while none of the 15 samples exceeded the BAV in 2016 at Stonelick Lake. More frequent sampling, particularly at beaches where previous sampling data indicates an increased likelihood of exceeding the recreation criteria, should be considered by beach managers so that the public can be adequately informed of actual water quality conditions at the time of their visit. Sampling results at other

lakes appear remarkably consistent, such as Alum Creek Lake's main beach, where from 2013-2017 the annual exceedance rate of the BAV ranged from 20 to 30 percent per year or Findlay Lake, where no exceedances were observed during annual sampling over the past five years.

Table F-16 — Swimming advisory postings at 50 Ohio inland lake public beaches (2015-2019).

Park	Beach	County	2015[1]	2016[1]	2017[1]	2018[1]	2019[1]	Total[1]
Alum Creek	Main	Delaware	2/9	2/10	3/11	2/10	2/8	11/48
	Camp	Delaware	1/8	0/8	0/8	0/7	1/8	2/39
Atwood Lake		Carroll	--	11/44	1/28	1/26	2/12	15/110
Barkcamp		Belmont	0/12	0/9	0/7	0/8	0/8	0/44
Blue Rock		Muskingum	2/10	3/10	0/7	--	1/5	6/32
Buck Creek	Main	Clark	1/9	1/9	0/8	0/8	5/11	7/45
	Camp	Clark	0/8	0/7	0/8	0/8	1/9	1/40
Buckeye Lake	Crystal Beach	Fairfield	3/4	0/1	3/7	--	0/7	6/19
	Fairfield Beach	Fairfield	2/4	--	0/7	4/6	0/6	6/23
Burr Oak	Main	Athens	1/10	0/9	0/8	0/8	0/9	1/44
Caesar Creek	North	Warren	3/11	1/9	0/8	1/9	1/8	6/45
	South	Warren	1/11	2/9	4/10	3/10	0/8	10/48
Charles Mill Lake		Ashland	--	0/1	4/23	6/24	7/15	17/63
Cowan Lake	Main (S)	Clinton	1/10	0/7	0/8	2/10	1/9	4/44
	Camp (N)	Clinton	1/10	0/7	0/8	2/10	0/9	3/44
Deer Creek		Pickaway	0/10	0/7	2/10	0/6	2/9	4/42
Delaware		Delaware	3/9	1/10	2/10	0/8	3/11	9/48
Dillon		Muskingum	6/11	1/9	3/10	6/10	4/8	20/48
East Fork	Main	Clermont	0/16	0/15	2/16	0/14	2/15	4/76
Findlay		Lorain	0/9	0/8	0/5	0/8	0/8	0/38
Forked Run		Meigs	2/12	0/7	0/7	0/8	1/9	3/43
Grand Lake St. Marys	Main East	Auglaize	2/9	2/9	0/9	1/9	0/9	5/45
	Main West	Auglaize	3/11	1/9	0/9	0/8	0/8	4/45
	Camp	Auglaize	1/9	3/11	1/10	2/10	0/8	7/48
	Windy Point	Auglaize	4/10	0/8	0/9	0/8	1/8	5/43
Guilford Lake	Main	Columbiana	0/8	0/6	0/8	1/8	1/7	2/37
	Camp	Columbiana	0/7	0/6	1/8	1/8	0/6	2/35
Harrison Lake		Fulton	1/10	1/9	0/8	2/9	3/10	7/46
Hueston Woods		Preble	1/9	0/8	0/8	0/8	1/10	2/43
Indian Lake	Fox Island	Logan	1/9	2/10	1/9	0/8	1/9	5/45
	Camp	Logan	1/9	0/8	1/9	1/9	1/9	4/44
	Oldfield	Logan	1/9	0/8	0/8	0/8	1/9	2/42
Jackson Lake		Jackson	2/10	1/8	1/8	0/8	7/14	11/48
Jefferson Lake		Jefferson	1/8	0/8	0/8	0/8	1/7	2/39
Kiser Lake		Champaign	2/9	1/9	0/8	1/9	1/7	5/42
Lake Alma	#1-West	Vinton	0/6	0/8	0/8	0/8	0/8	0/38
Lake Hope		Vinton	0/8	0/8	0/8	0/8	0/8	0/40
Lake Logan		Hocking	0/8	0/7	3/11	1/8	0/8	4/42
Lake Loramie		Shelby	5/12	3/11	1/10	1/9	2/10	12/52
Lake Milton		Mahoning	0/8	1/9	0/6	1/9	2/9	4/36
Madison Lake		Madison	6/12	3/11	4/10	4/11	3/11	20/55
Monroe Falls		Summit	--	0/10	--	0/5	0/6	0/21
Mosquito		Trumbull	3/9	1/7	0/8	1/9	0/8	5/40
Paint Creek		Ross	0/8	1/9	1/8	1/9	1/8	4/42
Pike Lake		Pike	2/7	1/9	4/11	2/8	1/6	10/41
Pleasant Hill		Richland	--	0/1	0/24	0/24	0/18	0/67
Portage Lakes	Main	Summit	1/9	2/10	0/8	1/8	1/8	5/43

Park	Beach	County	2015[1]	2016[1]	2017[1]	2018[1]	2019[1]	Total[1]
Punderson		Geauga	0/7	0/8	1/8	1/9	0/8	2/40
Pymatuning	Main	Ashtabula	0/7	0/6	0/9	0/8	1/9	1/39
	Camp	Ashtabula	1/7	0/6	0/9	0/8	0/8	1/38
	Cabins	Ashtabula	0/6	0/6	0/9	0/8	0/8	0/37
Rocky Fork	North Shore	Highland	1/8	1/9	0/8	0/8	0/8	2/41
	South Shore	Highland	1/8	0/9	1/9	2/10	2/10	6/46
Salt Fork	Main	Guernsey	0/8	0/9	1/9	0/6	0/7	1/39
	Camp	Guernsey	0/8	0/9	0/8	0/6	0/8	0/39
Scioto Trail		Ross	1/8	0/7	0/8	0/8	2/9	3/40
Seneca Lake		Noble	--	10/45	3/25	1/26	10/24	24/120
Shawnee	Turkey Cr Lodge	Scioto	1/9	0/7	0/9	1/8	0/3	2/36
	Roosevelt Camp	Scioto	0/6	1/8	0/9	4/8	0/3	5/34
Silver Creek		Summit	--	1/10	--	2/5	1/6	4/21
Stonelick		Clermont	0/16	0/15	4/18	7/18	3/16	14/83
Strouds Run		Athens	2/10	0/8	0/7	2/10	0/8	4/43
Tappan Lake		Harrison	--	12/46	2/25	5/24	11/23	30/118
Tar Hollow	Main	Ross	2/9	0/7	0/8	0/8	0/8	2/40
	Camp	Ross	1/8	1/8	0/8	1/9	0/9	3/42
West Branch	Main	Portage	0/8	0/9	1/9	0/8	2/8	3/43
	Camp	Portage	0/8	0/9	0/8	0/8	1/7	1/40
Wolf Run		Noble	0/8	1/8	0/7	0/8	0/9	1/40
	Total Advisory Postings		**76**	**72**	**55**	**74**	**94**	**371/ 3,121**

[1] Indicates the number of advisories posted, based on a measured E. coli density exceeding 235 cfu/100 mL, followed by the number of samples collected.

F4. Recreation Assessment for Algae in Lake Erie

Background

A healthy Lake Erie is a vital component of Ohio's economic and ecological health. Funding under the Great Lakes Restoration Initiative (GLRI) and other sources has led to the availability of data and opportunities to expand assessment and reporting of water quality conditions in Lake Erie. These combined data sets, along with advances in the use of satellite imagery to detect, quantify and track algal blooms, allow Ohio to include in this report methods to assess Lake Erie for recreation impairment caused by algae.

In 2017, Ohio EPA requested input from representatives from The Ohio State University Sea Grant College Program, University of Toledo, Bowling Green State University and NOAA to identify metrics that would provide a scientifically relevant determination of impairment. The request stated that the metrics needed to provide a reasonable, objective assessment method for the western basin open water using targets that will meet the goals established by the GLWQA Annex 4 committee and provide assurance that the WQS are met. The results of the first phase of this method development have been applied to the western basin. This method is explained below and has been published in the scientific journal *Harmful Algae* (Davis, et al 2019).

In 2019, Ohio EPA received additional input from the same government and university experts to consider recreation use assessment methods for the other Lake Erie AUs. Specific metrics now exist for four assessment units: western open water, Sandusky shoreline, Sandusky open water and central open water. See Figure F-6 for a map of Lake Erie's assessment units.

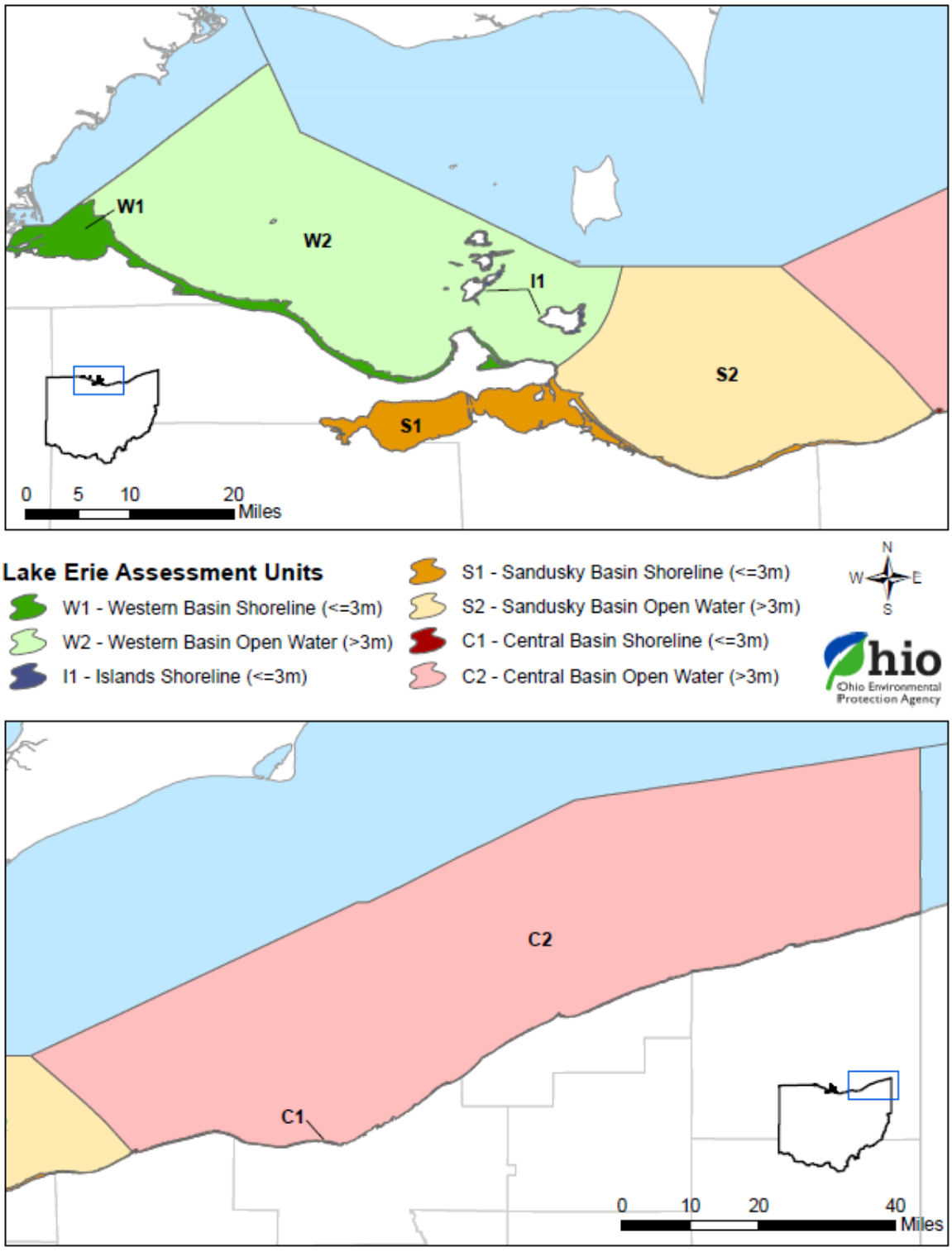

Figure F-6 — Ohio's Lake Erie assessment units – western basin, islands, Sandusky basin, and central basin shorelines and open water areas.

Evaluation Method

Targets for Lake Erie Algal Blooms

A common means to estimate algal productivity and trophic status is to measure the photosynthetic pigment chlorophyll a in a filtered water sample. The importance of phosphorus as the limiting nutrient that feeds algal blooms is also recognized. Ohio does not have numeric criteria for these constituents in Lake Erie and no federal criteria have been established to date. The use of discreet sampling of these parameters to assess a large, dynamic lake would require a great deal of extrapolation. Davis, et al 2019 points out that the this would be problematic in Lake Erie because of the "patchy and temporally variable nature of blooms." Given the great spatial and temporal interpolation assumptions that would be required in using traditional water quality parameters, the researchers explored using remote sensing/satellite data to develop targets for the open water AUs.

Ohio water quality standards (OAC 3745-1-04) do contain narrative requirements that all surface waters be:

> *"(D) Free from substances entering the waters as result of human activity in concentrations that are toxic or harmful to human, animal or aquatic life or are rapidly lethal in the mixing zone.*
> *(E) Free from nutrients entering the water as a result of human activity in concentrations that create nuisance growths of aquatic weeds and algae."*

These narrative criteria provide the basis for the following descriptions of algal bloom targets for the Lake Erie AUs.

Lake Erie Western Basin

The foundation of Ohio's assessment method for algae is an evaluation of the western basin algal bloom pattern over time, such as that conducted by NOAA in 2012 (Stumpf, 2012). Data sets from the MODIS (or Moderate Resolution Imaging Spectroradiometer) satellite (2012 to 2017) were used for this first assessment. For long-term sustainability, Ohio will transition to using the Ocean Land Colour Imager on Sentinel-3 series of satellites. The GLWQA Annex 4 committee set goals for phosphorus loadings to the lake at levels that are expected to produce a bloom no greater than those that occurred in 2004 or 2012. The extent of algal bloom coverage considered acceptable, or attaining the recreation use designation, should be no greater than that in 2004 or 2012.

In addition, the algae (cyanobacteria) cell count level in the bloom as observed via the satellite data sets should be no greater than 20,000 cells/mL. In the western basin of Lake Erie, when cyanobacteria capable of producing cyanotoxins, especially *Microcystis*, exceed concentrations of 20,000 cells/mL, there is a higher likelihood that cyanotoxins will be present at detectable concentrations. The relationship between the presence of *Microcystis* blooms and elevated microcystin concentrations has been well documented in the Lake Erie western basin (Bridgeman, 2013). This density (20,000 cells/mL) corresponds to the nominal floor used by NOAA to analyze satellite images with a comfortable degree of certainty (Wynne and Stumpf, 2015). In Lake Erie's western basin scum formation is likely at this cell density. Potential for skin irritations also may occur at 20,000 cells/mL, but this does not drive the recommended threshold value. The threshold is based on elevated likelihood of scum formations at 20,000 cells and data show that scums consistently have toxin concentration exceeding microcystin concentrations protective of human health recreation exposure.

Furthermore, in large systems like western Lake Erie, blooms can be patchy therefore it is critical to integrate data over large areas. Each pixel from a satellite image represents an average cell count across ~9 hectares (~22 acres). Thus the 20,000 cells/mL that is detected by satellite imagery represents an average cell concentration. Clearly, there will be locations within each pixel that exceed 20,000 cells/mL.

To account for the way that algal blooms shift in time and space in a large water body like the western basin, the method developed is as follows:

- In each 10-day frame, an exceedance means that a bloom with greater than 20,000 cells/mL covers (is present in) more than 30 percent of the western basin open water unit area.
- If three[1] or more 10-day frames have an exceedance in one year (July-Oct.), then that year exceeds the goal (is above the threshold target of the 2004 and 2012 blooms under Annex 4 of the GLWQA).
- Because of the year-to-year variation, if any two or more years in a rolling six-year window exceeds the goal (is above the threshold target of the 2004 and 2012 blooms under Annex 4 of the GLWQA) then the assessment unit is impaired.

Ten-day frames are used as they were determined to be a long enough time period to become a nuisance impeding recreation at a significant level. Within each 10-day frame, an average percent coverage by a bloom at 20,000 cell/mL or greater was calculated for the western basin open water assessment unit (W2 in Figure F-6). In the western basin, blooms typically begin developing by July 22 and peak between August 10 and September 18 (Wynne and Stumpf, 2015). The 10-day time frames used in the assessment method are:

July 1 – July 10	Aug. 10 – Aug. 19	Sept. 19 – Sept. 28
July 11 – July 20	Aug. 20 – Aug. 29	Sept. 29 – Oct. 8
July 21 – July 30	Aug. 30 – Sept. 8	Oct. 9 – Oct. 18
July 31 – Aug 9	Sept. 9 – Sept. 18	Oct. 19 – Oct. 31[2]

The threshold of 30 percent coverage is based on an examination of the bloom coverage in Lake Erie's western basin since 2002 and which blooms were considered to meet the Annex 4 target severity index (the Target Bloom in Figure F-7). Severity Index (SI) is the measure of the peak bloom biomass over a 30-day period (in each year, whichever 30-days captured/represents the most biomass in that year). As illustrated in Figure F-7, bloom severity meets the target in 2004 and very nearly in 2012. In those years the bloom was not considered to significantly impede the recreational use of the water and the extent of coverage did not exceed 30 percent of the western basin open water AU in three or more 10-day frames. Based on this method, it requires five of the last six years to not exceeded the thresholds outlined in order to meet this designated use (or to delist existing impairment). This allows for multiple years of mild or no blooms to be considered without an anomalous occurrence affecting the outcome.

[1] The 2018 Integrated Report mistakenly noted that "more than three" 10-day frames having exceedances is required for a year not to meet its goal. Having three or more exceeding windows however has always been the intent of this method; see Davis, et al. 2019 and Ohio EPA's 2018 Integrated Report public presentation on April 26, 2018 available at ***https://www.youtube.com/watch?v=nlKoBZSQwYU&t=827s***. This clarification does not change the conclusions of the assessments made in the 2016 and 2018 IRs.

[2] Window has 13 days to complete the season.

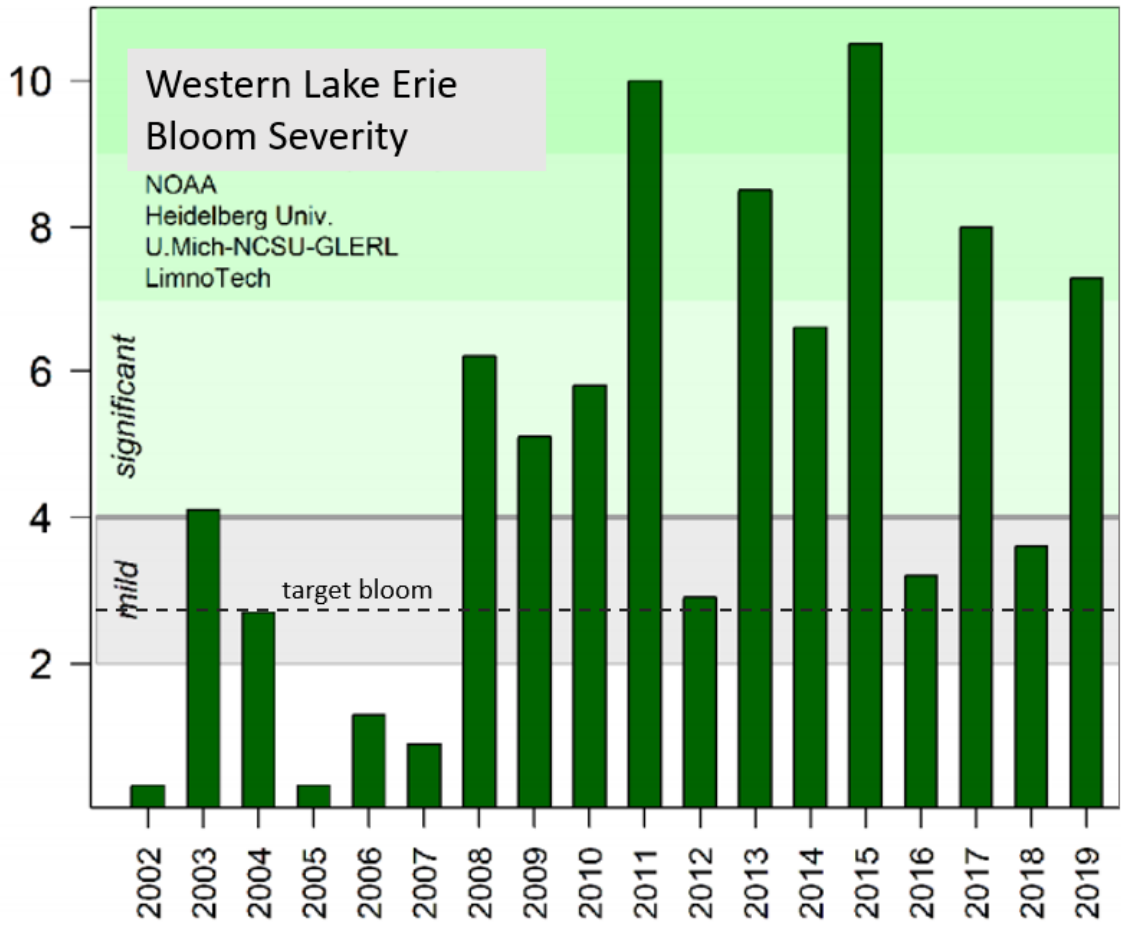

Figure F-7 — Bloom severity observed since 2002. Adapted from figure by Dr. Rick Stumpf, NOAA National Centers for Coastal Ocean Science

Lake Erie Sandusky Shoreline

Each year persistent *Planktothrix* blooms exist in the Sandusky Bay throughout the bloom season (Davis, 2015; Rinta-Kanto, 2006). Unlike the open waters of Lake Erie, the Sandusky Bay bloom is spatially consistent throughout the bay. This results in the bay being a more manageable size for reliable and representable water quality sampling. Therefore, the use of remote sensing was deemed not necessary for the development of an assessment methodology.

Further, although the *Planktothrix* bloom in the bay is persistent, nutrient concentrations change over the course of the bloom season and affect concentration of microcystins. *Planktonthrix* does not typically form scums; rather it is distributed throughout the water column. Because of this we cannot use the rationale applied to the open water assessments that associates *Microcystis* dominated blooms at a certain density with reasonably high microcystins concentrations.

Due to these factors, microcystin data sampled directly from the bay is, therefore, appropriate to be used as the primary attainment determinate. The following outlines the methodology:

- During the June through September Sandusky Bay bloom season, the microcystin value for each 10-day frame, when sampling occurs, will be determined[3].
  - Each microcystin sampling event value will be calculated by the result of a spatial composite sample collected at seven defined locations in the bay. See Table F-17 and Figure F-8 for the defined sampling locations.
    - The average concentration of total microcystins from a subset of four of the defined locations in the bay can be used for a retrospective analysis. These subset of sampling locations are noted in Table F-17.
  - Microcystin will be collected with 1-meter (from the surface) Van Dorn grab samples.
    - Analysis has shown that 0-2 meter (from the surface) vertically integrated samples are equivalent to 1-meter Van Dorn grab samples in the Sandusky Bay and can be used for this impairment determination in retrospect. See Figure F-9.
  - If more than one microcystin sampling event occurs in a 10-day window, the results of the sampling event with the greatest value will be used to represent that 10-day window.
- In order to address seasonable variation of bloom occurrences, if three or more 10-day frames exceed 6 ug/L microcystin in one year, then that year exceeds the goal.
- In order to address year-to-year variation, if any two or more years in a rolling six-year window exceeds the goal then the unit is impaired.
  - When fewer than six years of results are available, if two years exceed the seasonal goal the unit will be considered impaired. However, the five most recent seasons of results not exceeding the goal are required in order to declare the unit in full attainment.

The bloom season assessed for this AU differs from the open water assessments in that it includes June through September for this AU versus July through October for the open water AUs. This timeframe is based on historical occurrence of microcystins observed by Bowling Green State University (BGSU).

The assessment locations (Table F-17 and Figure F-8) were recommended by BGSU. These stations provide coverage over the full length of Sandusky Bay from the mouth of Muddy Creek Bay in the west to the middle of the lower Bay to the east (Salk, 2018). The subset of four sampling locations noted as appropriate for retrospective analysis were selected based on monitoring carried out by BGSU that went into Salk, 2018 and continued efforts. BGSU has determined that these four locations provide a thorough assessment of bloom characteristics as they occur throughout the Sandusky Bay system.

Ten-day frames are used as they were determined to be a long enough time period to become a nuisance impeding recreation at a significant level. The 10-day time frames used in the assessment method are:

June 1 – June 10	July 11 – July 20	Aug. 20 – Aug. 29
June 11 – June 20	July 21– July 30	Aug. 30 – Sep. 8
June 21 – June 30	July 31 – Aug. 9	Sep. 9 – Sep. 18
July 1 – July 10	Aug. 10 – Aug. 19	Sep. 19 – Sep. 30[4]

[3] Microcystin analysis will utilize "Ohio EPA DES method 701.0, Ohio EPA Total (Extracellular and Intracellular) Microcystins - ADDA by ELISA Analytical Methodology" version 2.2 (November 2015) or another method accepted by the director in writing.

[4] Window has 12 days to complete the season.

Table F-17 — Sandusky Bay (S1) Sampling Locations

Station Name	Lat decimal N	Lon decimal W
Environment Canada Station 1163 (or 'EC 1163')	41.469000°	-82.715000°
ODNR 1*	41.477367°	-82.739783°
Sandusky Buoy 2 (or Buoy 2)	41.463222°	-82.769028°
ODNR 2*	41.479817°	-82.782867°
ODNR 6*	41.457300°	-82.898655°
Edison Bridge (or 'Bridge')	41.480156°	-82.834328°
ODNR 4*	41.453333°	-82.960767°

* Denotes the four sites that are appropriate to use for retrospective analysis.

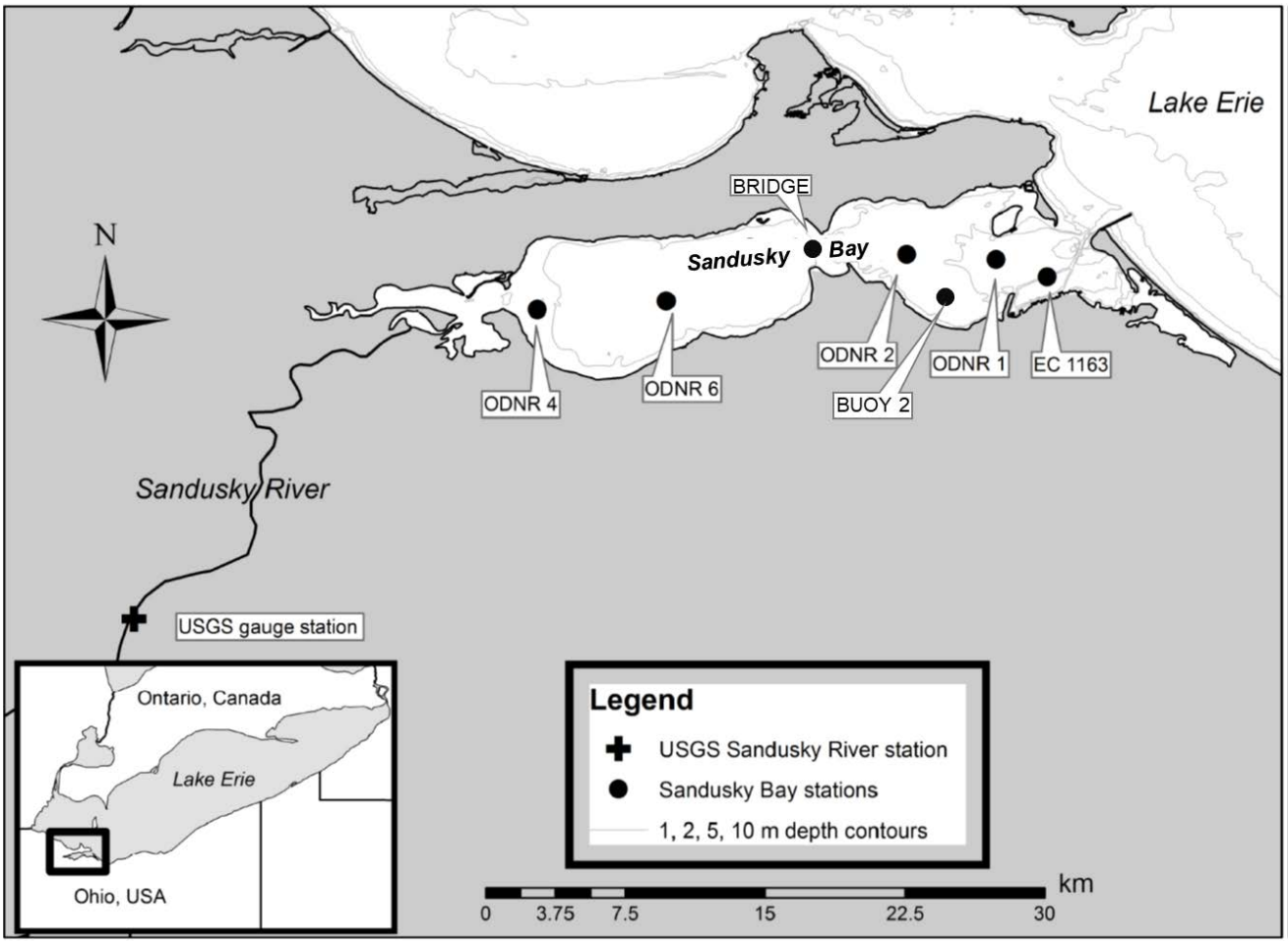

Figure F-8— Sampling locations in the Sandusky Bay; map adapted from Salk, 2018.

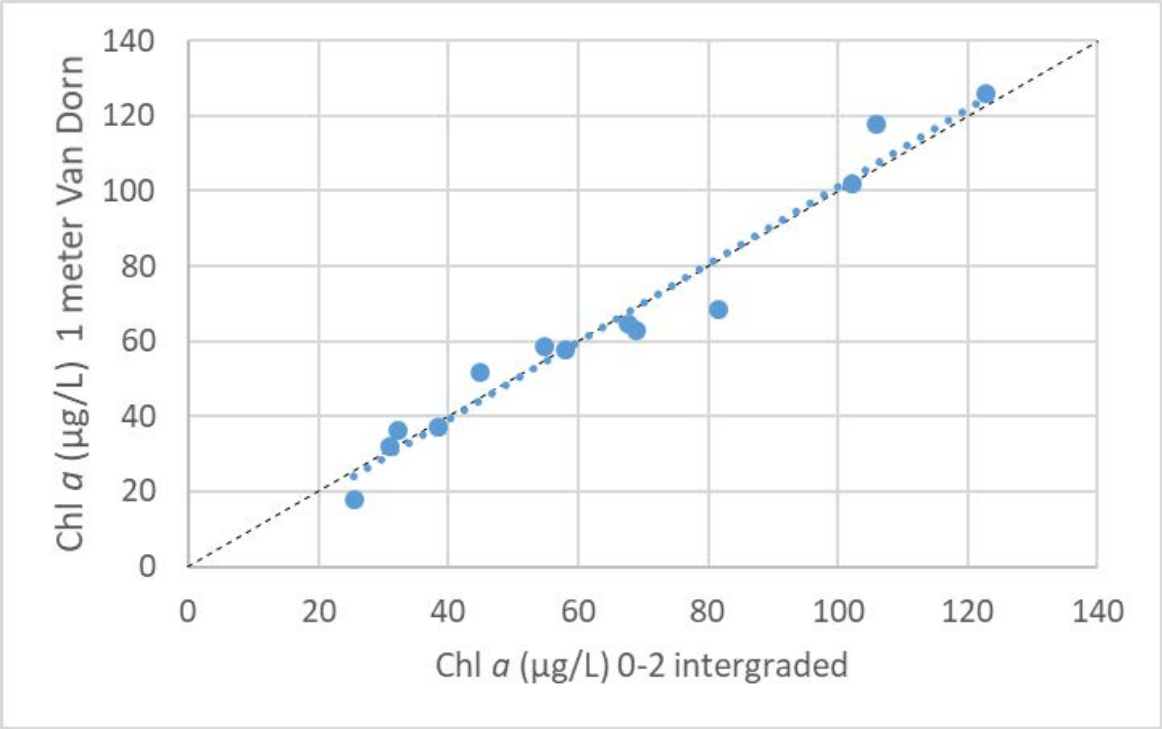

Figure F-9 —A comparison of chlorophyll-a concentration data collected by a 1-meter Van Dorn sampler and a 0-2 meter integrated sample from two Sandusky Bay sites (bay mouth and the center of east/outer bay) by the Ohio State University Stone Laboratory. The dotted blue line is the regression line between the two methods and the thin black dashed line is the 1-to-1 line.

Lake Erie Sandusky Open Water

Algal blooms originating from Sandusky Bay generally do not migrate out of the bay into the Sandusky open water AU (LimnoTech, 2019; Bridgeman, 2020). Because of this, recreation assessment of the Sandusky Basin open water AU will not rely on Sandusky Bay algal bloom occurrences.

Dolichospermum blooms normally associated with Lake Erie's central basin do occasionally form in this AU. However, algal blooms in this AU are most often dominated by *Microcystis* that originate in the western open waters and migrate east. Because of this, the researchers assisting Ohio EPA with assessment methodology development recommended investigating whether assessment of the Sandusky open water AU could be carried out in a similar fashion to the western basin AU method.

Figure F-10 shows 10-day frames of the percent of this AU's area covered by algal bloom greater than 20,000 cyanobacterial count per mL 10-day going back to 2002.

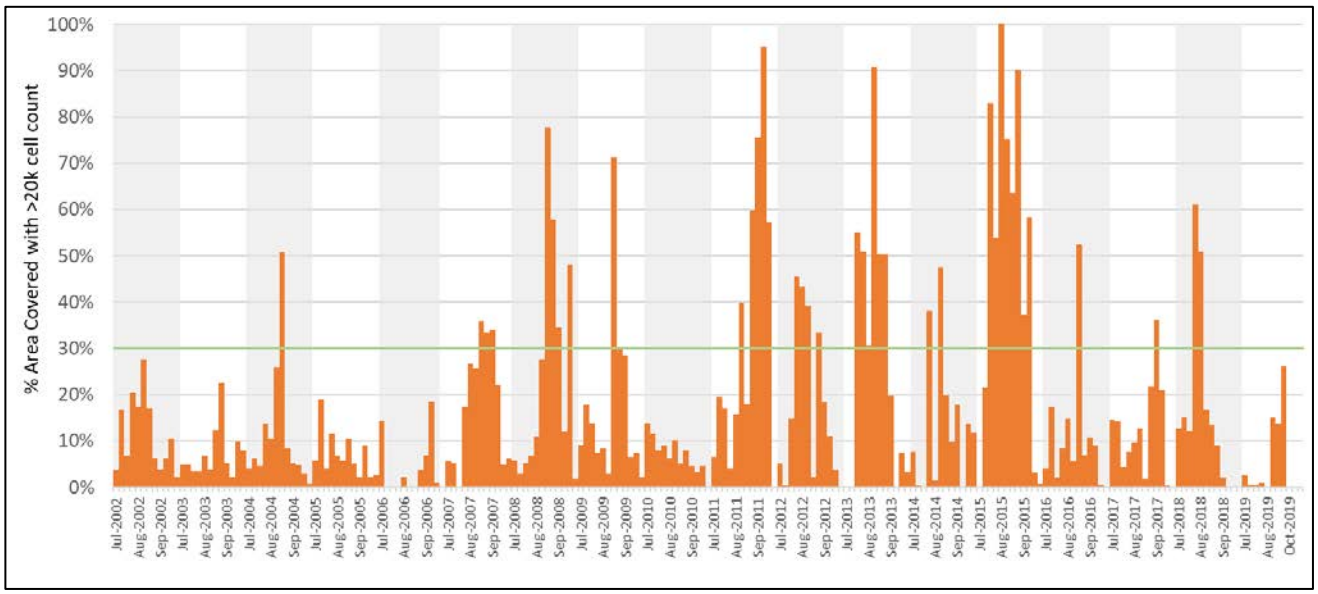

Figure F-10 — Sandusky Open Waters HAB cell densities shown for greater than 20,000 and 100,000 cells per mL by percent of the assessment unit's surface area. Each bar shows a 10-day time frame during the July - October bloom season; this results in 12 10-day frames per year. Frames that show 0% coverage indicates no bloom present the majority of the time. In a few instances, cloud cover or other interferences with the satellite images occurred.

An analysis of the Sandusky open water AU (S2) compared to western basin open water AU (W2) was carried out. Figure F-11 shows the percent of area within each AU covered by algae for the top three 10-day frames of each year. The algae coverage in this analysis uses the same greater than 20,000 (*Microcystis* equivalent) cyanobacteria cell count per mL that is used in the western basin assessment method. On Figure F-11 there is also a black outlined circle that shows the average of these top three for each AU in each year. Focusing on 2008 and more recent data, in most years the blue S2 top three average area coverages are well below the yellow W2 top three average. However, the variance is great. The years 2017, 2014 and 2010 had the large variances (at 52%, 38% and 36%, respectively, based on the averages). In 2015 and 2008 they were much tighter; within 10% of each other. The bloom in 2012 stands out in particular because the average S2 window was greater than W2's.

The Figure F-12 shows the third greatest 10-day frame greater than 20,000 (*Microcystis* equivalent) cyanobacteria cell count per mL coverage for the Sandusky open water and Western basin open water AUs in each year. For the W2, when the yellow dots are above the 30% line that year does not meet the annual western method expectation (see the western open water's AU methodology above). If the same method were to apply to the S2 unit it would exceed the annual expectation in some of the years, but not nearly as many as W2.

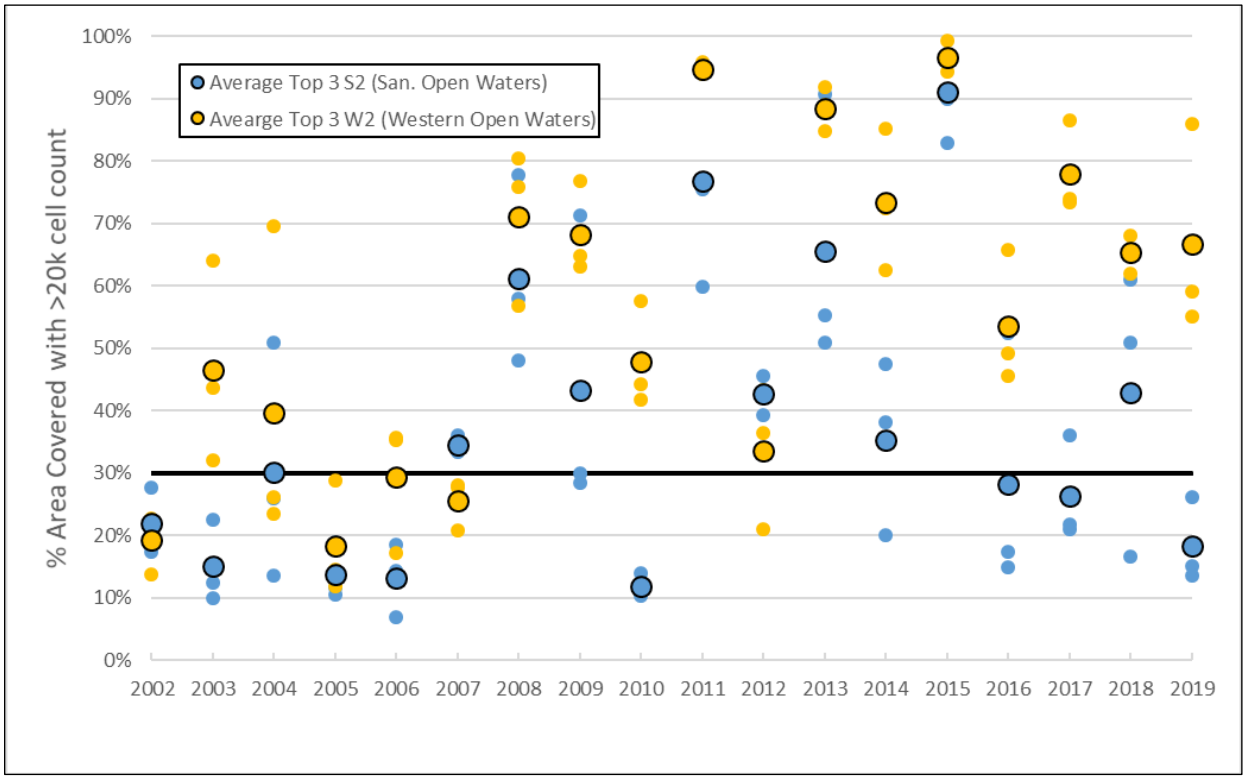

Figure F-11 — Top three 10-day frames with greater than 20,000 cell cyanobacteria count per mL by year for the S2 and W2 assessment units. A black outlined circle for each unit shows the average of each year.

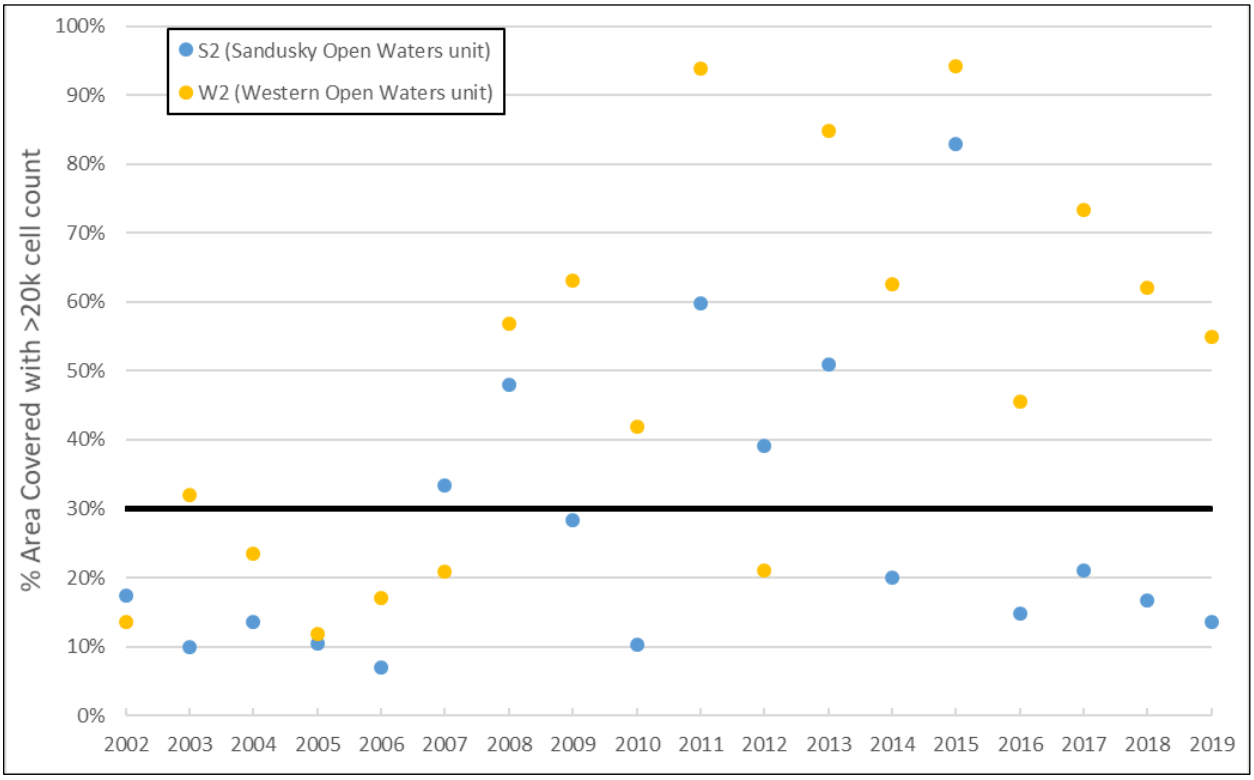

Figure F-12 — The percent of assessment unit area covered by the third greatest 10-day frame with greater than 20,000 cell cyanobacteria count per mL by year for the S2 and W2 assessment units.

Table F-18 shows the number of 10-day frames exceeding 30% of the assessment unit area with >20k cyanobacterial cell density for W2 with S2. In looking at the last six years ending in 2019 the S2 would currently meet its use (since only 2015 exceeds the annual expectation). However, were the six-year window to end in 2018, this use would be impaired as the 2013 bloom would be included.

Using the 30% area coverage breakpoint for assessing 10-day frames in the W2 AU was derived based on benchmarking the actual acceptable bloom sizes in the western basin. Therefore, the same cutoff for S2 is reasonable because much of its blooms mass/aerial extent originates from the west. The fact that western blooms do not always blow over to S2, and also due to occasional sizable *Dolichospermum* blooms, warrants S2 to be analyzed based on its own HABs occurrences.

Table F-18 — The number of 10-day frames exceeding 30% of the assessment unit area with >20k cyanobacterial cell density

Year	Western Open waters	Sandusky Open waters	Year	Western Open waters	Sandusky Open waters
2002	0	0	2011	**8**	**5**
2003	**3**	0	2012	2	**4**
2004	1	1	2013	**10**	**6**
2005	0	0	2014	**6**	2
2006	2	0	2015	**9**	**8**
2007	0	**3**	2016	**5**	1
2008	**4**	**4**	2017	**7**	1
2009	**6**	1	2018	**6**	2
2010	**8**	0	2019	**5**	0

In summary, this comparison of the two assessment units shows that a small annual bloom season in W2 usually means a small bloom in S2. However, large blooms in W2 may or may not lead to large blooms in S2. The researchers mainly attribute the latter to the weather the lake experiences. Since the S2's HAB bloom is directly linked to the W2, using the same Annex 4 of the GLWQA reduction goal is an appropriate benchmark for this AU. Based on this, the same use methodology used in the W2 AU will be applied to the S2 AU using satellite data specific to the S2 AU. The following outlines this method:

To account for the way that algal blooms shift in time and space in a large water body like the Sandusky open water basin, the method developed is as follows:

- In each 10-day frame, an exceedance means that a bloom with greater than 20,000 cells/mL covers (is present in) more than 30 percent of the Sandusky open water unit area.
- If three or more 10-day frames have an exceedance in one year (July-Oct.), then that year exceeds the goal.
- Because of the year-to-year variation, if any two or more years in a rolling six-year window exceeds the goal then the assessment unit is impaired.

Lake Erie Central Basin Open Water

The central basin of Lake Erie experiences HABs dominated by *Dolichospermum* in June and July followed by a community shift to *Microcystis* blooms in August and September. The *Microcystis* generally originate from the western basin. It is understood that these blooms occur independently from one another. Overall however, HAB trends indicate that degrading water quality and resulting eutrophication that has been documented in the western basin is occurring in the central basin (Chaffin, 2019).

The Great Lakes Water Quality Agreement's Annex 4 sub-committee did not set phosphorus loadings goals to address HABs in Lake Erie's central basin similar to the western basin[5]. Due to this, a reference "acceptable" bloom has not been determined for the central basin which could be used as a benchmark for this assessment methodology.

An analysis of the MODIS (or Moderate Resolution Imaging Spectroradiometer) satellite data for this AU was carried out. While these data report *Microcystis* equivalence cell densities, *Dolichospermum* blooms are captured in this analysis. Figure F-13 shows the MODIS HAB results[6] from 2002 through 2018 of how much area of the Ohio's Lake Erie central basin open waters AU was covered at two levels of cell density. Each bar on this figure shows the maximum percentage of area covered for a 10-day frame during the July through October HAB bloom season (this results in 12 frames per year).

Without established benchmark bloom years, analysis focused on the MODIS results from 2011. A measurable *Dolichospermum* bloom occurred early summer 2011 (Chaffin, 2019) and was followed by a large *Microcystis* bloom that spread from the western basin to the to the central basin in late summer (Chaffin, 2013). The 2011 bloom was deemed as unacceptable by the general public (Michalak, 2013; Mangels, 2013). Ohio EPA recognizes that if blooms of this nature were the norm for the central basin that this would result in impairment of the recreation use.

In reviewing the 2011 HAB satellite results on Figure F-13, the peak of the two HAB blooms can be detected. Three 10-day frames met or exceeded an area covering 15 percent of the Central Basin Open Waters AU at the greater than 20,000 cell density level. This bloom year will be used as an assessment method benchmark.

The spatial and temporal nature of HABs are considered in the central basin's method. Therefore, this method will follow a similar structure:

- In each 10-day frame, an exceedance means that a bloom with greater than 20,000 cells/mL covers (is present in) 15 percent or more of the central basin open water unit area.
- If three or more 10-day frames have an exceedance in one year (July-Oct.), then that year exceeds the goal.
- Because of the year-to-year variation, if any two or more years in a rolling six-year window exceeds the goal then the unit is impaired.

Based on this proposed method, the 2011 bloom in the central basin open water exceeds the yearly goal. However due to smaller and less frequent HABs in recent years, this AU is not currently impaired. In fact, since 2011, only one 10-day frame in 2015 exceeded 15 percent area at the greater than 20,000 cells/mL.

[5] Note that the GLWA's Annex 4 has set phosphorus loading goals for the central basin to address seasonal hypoxia. However, using that goal is not appropriate in evaluating loss of recreation use due to HABs.

[6] For long-term sustainability, Ohio will transition to using the Ocean Land Colour Imager on Sentinel-3 series of satellites.

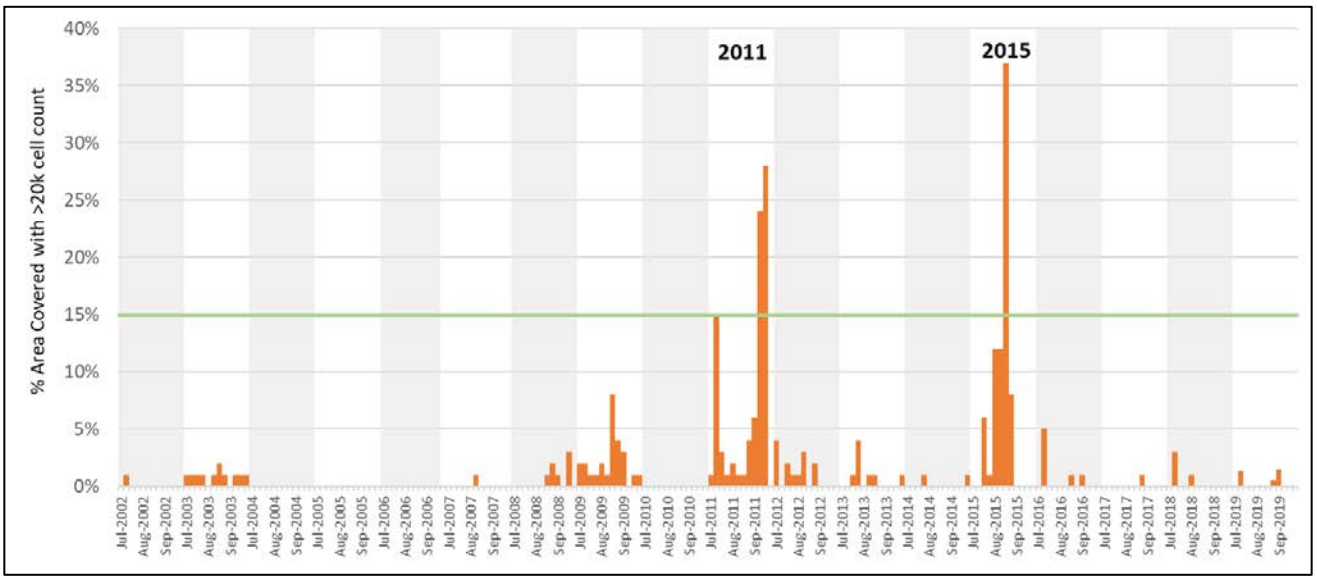

Figure F-13 — Central Basin Open Waters HAB cell densities shown for greater than 20,000 and 100,000 cells per mL by percent of the assessment unit's surface area. Each bar shows a 10-day time frame during the July - October bloom season; this results in 12 10-day frames per year. The green line at 15% area shows the exceedance level set by this proposed method. Frames that show 0% coverage indicates no bloom present the majority of the time. In a few instances, cloud cover or other interferences with the satellite images occurred.

Additional Phases of Method Development for Lake Erie Algal Blooms

The water quality sampling results and available data were discussed with the researchers during the first, western open water AU, method development. The concern then was that amount of sampling locations, sampling frequency and methods need to be evaluated to determine what is appropriate to conclude that, for instance, the microcystin levels are high enough and/or frequent enough to result in a recreation impairment in such a large body of water. During the 2019 efforts to develop methods to address this use in the remainder of the Lake Erie AUs, additional assessments metrics to the western open water AU were again considered. At this time, Ohio EPA finds the existing assessment methods accetapble. Further metrics can be considered in an adaptive management approach in future Integrated Reports if necessary. This will be particularly considered if direct calculations of HAB toxins can be reliably measured via remote sensing.

Results

Lake Erie Western Basin Results

Table F-19 shows the results of the analysis, using satellite data from 2014-2019 for the full six-year window in the assessment. Some years do not include all 12 of the 10-day frames because of extended cloud cover or other interferences with the satellite images. The western basin open waters are considered impaired since all six years exceeded the thresholds outlined above (more than three 10-day frames exceeded within the year).

The 2018 cyanobacterial bloom in the western Lake Erie basin experienced six 10-day frames exceeding 30% coverage of greater than 20,000 cells per mL during the May to October period, with five of these occurring between late July and early September. The 2019 bloom had five 10-day frames exceeding the benchmark. The 2019 bloom started and ended earlier than previous years. However, the windows exceeding 30% coverage occurred from late July through early September. The greatest aerial extent, at 86% of the AU covered, occurred on a frame that centered on September 3, 2019.

Based on the current results, this AU could not attain the recreation use until after the 2024 bloom season. For that to happen there must be fewer than three 10-day frames exceeding the 30% area coverage of algae at the outlined density each year 2020-2024.

Table F-19 — The number of 10-day time frames exceeding the 30 percent coverage threshold

	≥30% coverage at ≥20,000 cell/mL	
Year	10-day frames exceeding	total frames
2014	6	12
2015	9	11
2016	5	10
2017	7	11
2018	6	11
2019	5	12

Since the island shoreline assessment units are contained within the western basin open water unit satellite assessment zone that was used to conduct the analysis, the island shoreline unit is also considered impaired. As people are more likely to come into direct contact with the water and algae along the shoreline than in the open water, Ohio EPA is also including the western basin shoreline unit on the impaired waters list. This is based on proximity to the open waters that are clearly impaired, and the expectation that, reviewing the patterns of blooms over the past six years, the shoreline area would be just as impacted by the blooms as the open water.

Lake Erie Sandusky Shoreline Results

As noted in the methodology explanation above, it is acceptable to use the average microcystin result from four key sites within the Sandusky Bay for analysis of retrospective data prior to when this methodology has been established. Ohio EPA will depend on data collected by credible data collectors from Bowling Green State University for retrospective analysis and future assessment of this AU. Currently two years, 2018 and 2019, have data available to be used for this analysis. Table F-20 shows the number of 10-day frames exceeding the annual benchmark and the number of frames where data was collected. Of the 2018 data collection all frames exceeded the benchmark. However, in 2019 only two of the six frames with data collected exceeded. As noted in the methodology section, while the HAB bloom is regularly dense in the Sandusky Bay, this bloom is Planktothrix dominated. This group of algae does not produce microcystins as consistently as the Microcystis dominated western basin, nor does it form scums like Microcystis.

Because the existing data set does not contain two seasons that exceed the goal and contains fewer than five seasons that do not exceed the goal; this AU is considered to have insufficient information to determine impairment. In the next integrated report, if either 2020 or 2021 exceed the annual goal, this use will be listed as impaired.

Table F-20 — The number of 10-day time frames exceeding the annual threshold for Sandusky Shoreline Assessment unit for each year beginning in 2018.

	Average of four sites >6ug/L microcystin	
Year	10-day frames exceeding	total frames
2018	4	4
2019	2	6

Lake Erie Sandusky Open Water Results

Table F-21 shows the results of the analysis, using satellite data 2014-2019 for the full six-year window in this AU. Some years do not include all 12 of the 10-day frames because of extended cloud cover or other interferences with the satellite images. Based on these results, the Sandusky open water AU meets the recreation use. It is considered attaining since only one of the last six years exceeds the threshold outlined above (more than two 10-day frames exceeding 30% aerial coverage of algae at the outlined density).

Table F-21 — The number of 10-day time frames at or exceeding 30 percent coverage threshold

	≥30% coverage at ≥20,000 cell/mL	
Year	10-day frames exceeding	total frames
2014	2	12
2015	8	11
2016	1	10
2017	1	11
2018	2	11
2019	0	12

Lake Erie Central Open Water Results

Table F-22 shows the results of the analysis, using satellite data from 2014-2019 for the full six-year window in this AU. Some years do not include all 12 of the 10-day frames because of extended cloud cover or other interferences with the satellite images. Based on these results, the central open water AU meets the recreation use. It is considered attaining since there were no exceedances of the threshold outlined above in the last six years (more than two 10-day frames exceeding 15% aerial coverage of algae at the outlined density).

Table F-22 — The number of 10-day time frames at or exceeding 15 percent coverage threshold

	≥15% coverage at ≥20,000 cell/mL	
Year	10-day frames exceeding	total frames
2013	0	12
2014	0	11
2015	1	10
2016	0	11
2017	0	11
2018	0	12