NORTHEAST OHIO REGIONAL SEWER DISTRICT

2019 Greater Cleveland Area Lake Erie Nutrient Study

Prepared by
Water Quality and Industrial Surveillance Division

Introduction

Throughout the past decade there has been an increase in toxin producing harmful algal blooms (HAB) in Lake Erie, particularly in the Western Basin. In 2011, a record setting HAB extended beyond the Western Basin, into the Central Basin, along both the United States and Canadian shorelines. The southern portion of the bloom extended well east of Cleveland, where it persisted throughout the month of October (NOAA, 2011). In response to this record setting bloom, the Northeast Ohio Regional Sewer District (NEORSD) began performing nutrient monitoring in Lake Erie near Cleveland in 2012.

Since that time, HABs have continued to be an environmental concern in Lake Erie. In 2014, another HAB fouled the drinking water supply of the City of Toledo, leaving residents without drinking water for three days. In 2015, another record setting bloom occurred in the western basin and was detected by National Oceanic and Atmospheric Administration (NOAA) satellite imagery in the central basin (NOAA, 2015). Although the bloom did not appear to be near Cleveland beaches by NOAA satellite imagery, HABs were observed at Villa Angela and Euclid Beaches in the month of September 2015 during daily sampling as part of the NEORSD's beach monitoring program. HABs in Lake Erie surrounding the Greater Cleveland area have resulted in microcystin toxin concentrations above the Public Advisory Threshold of 6 ug/L during the recreational seasons of 2013, 2015, and 2018. This has resulted in water quality advisories for HABs at Edgewater and Villa Angela Beaches, and presents an ongoing potential threat to local water quality and public health.

The NEORSD continued nutrient monitoring efforts in 2019. This annual Lake Erie Nutrient Study was submitted to the Ohio Environmental Protection Agency's Credible Data Program as a Level 3 study. This study covered eight sites on Lake Erie including six sites within 2 miles of the shoreline distributed west to east from the Rocky River to Euclid Creek confluences (See Table 1 and Figure 1 for sample site locations). The remaining two lake sites included a site near the Cleveland Water Intake Crib, approximately 3.8 miles offshore, and an additional offshore control site located northwest of the Cleveland Water Intake Crib (6.7 miles offshore). Additional sites were added to the study in 2015 to monitor nutrient contributions from Lake Erie tributaries including Rocky River, Cuyahoga River and Euclid Creek. This study plan was approved by the Ohio Environmental Protection Agency (Ohio EPA) on March 22, 2019. Data collected as part of daily NPDES permit required monitoring for the three NEORSD wastewater treatment plants is also included in this report.

All sampling at lake and river sites was completed by NEORSD Level 3 Qualified Data Collectors (QDCs) certified by Ohio EPA in Chemical Water Quality Assessment as explained in the NEORSD study plan *2019 Greater Cleveland Area Lake Erie Nutrient Study*. WWTP samples were collected by wastewater operators using similar methods. Sample analyses were conducted by NEORSD's Analytical Services division, which is accredited by the National Environmental Laboratory Accreditation Program.

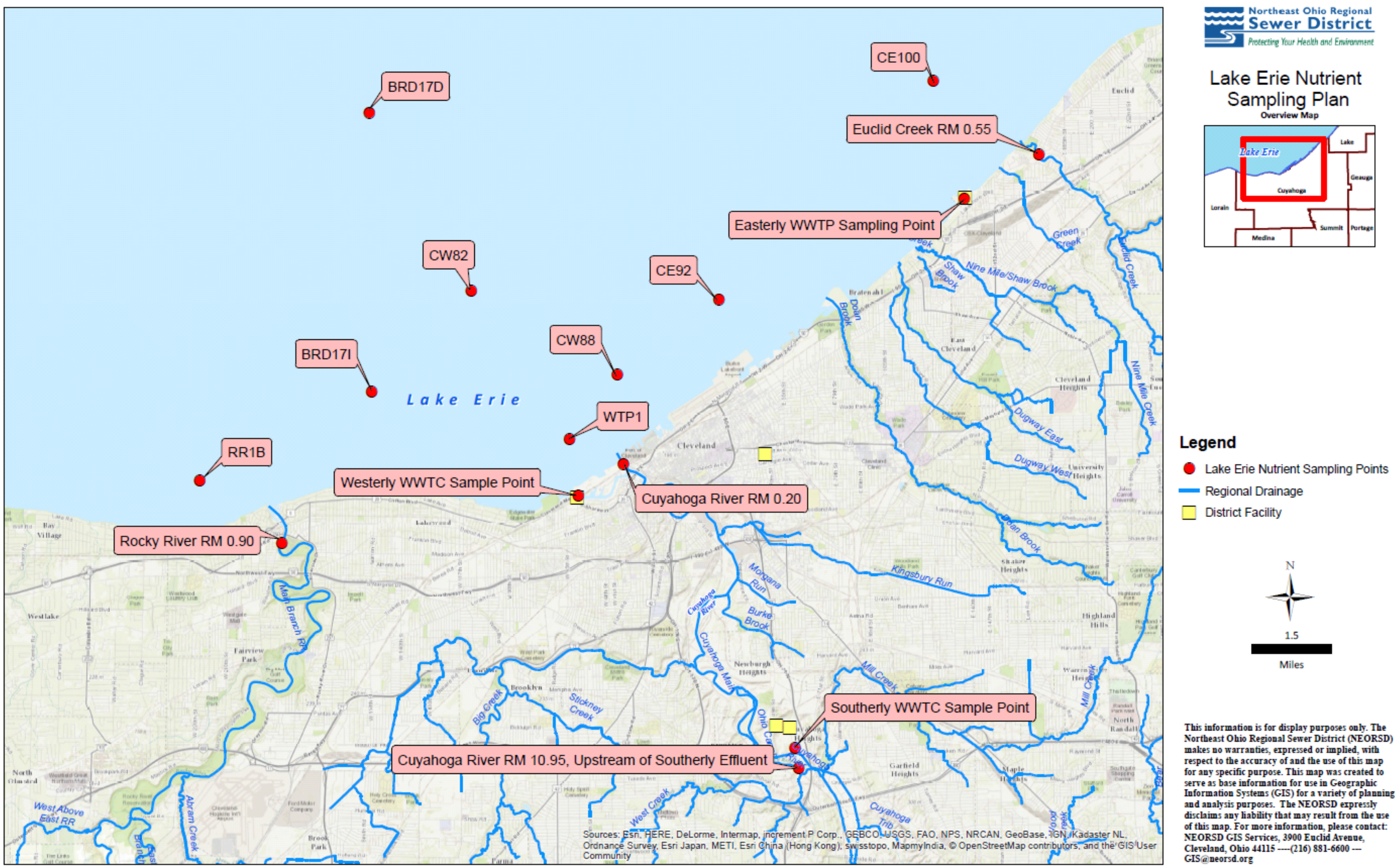

Figure 1. Sampling Locations

Table 1. Lake Erie Nutrient Study Sampling Locations						
Water Body	Latitude	Longitude	Station ID	Location Information	USGS HUC 8 Number -Name	Purpose
Lake Erie	41.49720	-81.86200	RR1B	Near Rocky River	04120200- Lake Erie	Determine trends in algal densities and nutrient concentrations in Lake Erie.
	41.59630	-81.80000	BRD17D	About 7 miles off shore of Lakewood		
	41.52080	-81.80000	BRD17I	Near Lakewood		
	41.54800	-81.76400	CW82	Near Garrett Morgan Water Intake		
	41.50765	-81.72907	WTP1	Near Westerly WWTC Diffusers		
	41.52500	-81.71170	CW88	Outside the City of Cleveland's Breakwall		
	41.54500	-81.67500	CE92	Outside the City of Cleveland's Breakwall		
	41.60333	-81.59717	CE100	2 miles north of Easterly WWTP outfall		
Rocky River	41.4802	-81.8327	RM 0.90	Upstream of Detroit Avenue	04110001 – Black/Rocky	Determine the contribution and effect to receiving waterbody.
Euclid Creek	41.5833	-81.5594	RM 0.55	Downstream of Lake Shore Boulevard	04110003 Ashtabula-Chagrin	
Cuyahoga River	41.5008	-81.7098	RM 0.20	Near mouth of river in navigation channel	04110002 - Cuyahoga	
Cuyahoga River	41.4182	-81.6479	RM 10.95	Chlorine-access railroad bridge, near ash lagoons	04110002 - Cuyahoga	
Easterly WWTP	14021 Lakeshore Blvd, Cleveland, OH 44110			Treated Effluent	Discharges to: 04120200- Lake Erie	
Westerly WWTP	5800 Cleveland Memorial Shoreway, Cleveland, OH 44102			Treated Effluent	Discharges to: 04120200- Lake Erie	
Southerly WWTP	6000 Canal Rd Cuyahoga Heights, OH 44125			Treated Effluent	Discharges to: 04110002- Cuyahoga	
RM = river mile						

Methods

Sample Collection and Handling

Water chemistry sampling was conducted seven times at the lake sites and eleven times at the river sites between May 6th and October 15th. Techniques used for sampling and analyses followed the Ohio EPA *Surface Water Field Sampling Manual* (Ohio EPA, 2018a). These techniques were used for the lake sites and the four river sites. The effluent samples from the NEORSD wastewater treatment plants were collected as grab samples using similar techniques. Chemical water quality samples from each site were collected with one 4-liter disposable polyethylene cubitainer with disposable polypropylene lids and two 473-mL plastic bottles, one which was preserved with sulfuric acid. An additional sample was analyzed for DRP and was filtered in the field using a 0.45-µm PVDF syringe filter and put into a 125-mL plastic bottle. All water quality samples were collected as grab samples at a depth of six to twelve inches below the surface. Samples collected at Westerly, Easterly, and Southerly Wastewater Treatment Plants (WWTP) were collected from the final treated effluent and were analyzed for DRP. Filtering was completed at time of collection using a 0.45-µm PVDF syringe filter and put into a 125-mL plastic bottle.

Duplicate samples and field blanks (FB) were collected at randomly selected sites at a frequency of not less than 5% of the total samples collected for this study. The acceptable relative percent difference (RPD) for field duplicate samples was less than or equal to $[(0.9465x^{-0.344})*100]+5$, where x = sample result/detection limit; results above this range were rejected. Acid preservation of the samples, as specified in the NEORSD laboratory's standard operating procedure for each parameter, also occurred in the field. Field analyses were collected by an EXO1 sonde and measured dissolved oxygen (DO), chlorophyll *a*, phycocyanin, water temperature, conductivity and pH. Turbidity was measured using a Hach 2100Q Portable Turbidimeter.

Water column chlorophyll *a* samples were collected during each sampling event using a 1L amber glass jar. All chlorophyll *a* samples were collected as grab samples at a depth of six to twelve inches below the water's surface. One duplicate chlorophyll *a* sample was collected at randomly selected sites at a frequency of not less than 5% of the total samples collected for this study plan. After returning to the NEORSD Environmental and Maintenance Services Center, each sample was filtered in triplicate using 47 mm glass fiber filters and a vacuum with a pressure not exceeding 6 in. Hg. Filtered samples were stored in a freezer at -37°C for storage prior to analysis.

Statistical Analysis

Data for matching parameter sets between sites were compared using a Kruskal-Wallis test with a 95% confidence interval. If the null hypothesis (data sets between sites have equal distributions) was rejected for a given parameter using the Kruskal-Wallis test, a series of one-tailed Wilcoxon rank-sum tests were performed comparing individual sites with the offshore control site BRD17D. For river sites, since no site was designated as a control site, Wilcoxon rank-sum tests of the individual sites were performed against the data set from the site with the lowest average concentration for that parameter, with the exception of dissolved oxygen for which the site with the highest average concentration was selected for comparison against the other sites.

Results and Discussion

A copy of all analyses is available upon request by contacting the NEORSD's WQIS Division.

Quality Assurance and Quality Control

Seven sets of duplicate samples and five field blanks were collected during the study. Data which did not meet quality control standards set forth in the Ohio EPA *Surface Water Field Sampling Manual* (Ohio EPA 2018a) were qualified as rejected (R), estimated (J), or Trend (downgraded from Level 3 to Level 2 data) based on Ohio EPA data validation protocol.

Seventeen sample results were qualified based on low ratios of sample to field blank results. Table 2 gives the results for parameters that were rejected, estimated, or downgraded from Level 3 to Level 2 (Trend) based on Ohio EPA data validation protocol for field blank comparison. All field blank qualified results were for dissolved reactive phosphorus (DRP) and occurred on the sampling events of June 18, and July 16, 2019. Field blank results on these days were estimated, between the method minimum detection limit (MDL) and practical quantitation limit (PQL). The cause of this minor contamination of the field blanks on these dates is unclear but may have been due to contamination during field sampling, contaminated equipment, contaminated blank water, or analytical error. Eight of these results were rejected as not significantly different from the field blank results. These data points were therefore not included for further statistical analysis. The remaining field blank qualified results were qualified as estimated or trend.

Four pairs of sample results were rejected due to inconsistency between duplicate results. Table 3 gives the results for parameters that were rejected due to RPD values higher than the calculated acceptable RPD. It is unclear what caused the inconsistency between duplicate sample results. Factors that may have contributed include heterogeneity of the source water, inconsistent sample collection technique, or analytical error. These data points were not included for further statistical analysis. All paired parameter data met quality assurance guidelines.

Table 2. Field Blank Data Qualifications

Site	Parameter (Units)	Date	MDL	PQL	Sample Result	Field Blank Result	Sample/Blank Ratio	QA/QC Code	Reason
BRD17D	DRP (ug/L)	6/18/2019	1.11	2.5	4.192	1.939	2.16	R	Sample ≤ 3x Blank
BRD17I	DRP (ug/L)	7/16/2019	1.11	2.5	1.923	1.172	1.64	R	Sample ≤ 3x Blank
CE92	DRP (ug/L)	7/16/2019	1.11	2.5	2.124	1.172	1.81	R	Sample ≤ 3x Blank
CE100	DRP (ug/L)	7/16/2019	1.11	2.5	1.552	1.172	1.32	R	Sample ≤ 3x Blank
CW82	DRP (ug/L)	7/16/2019	1.11	2.5	3.444	1.172	2.94	R	Sample ≤ 3x Blank
CW88	DRP (ug/L)	7/16/2019	1.11	2.5	1.55	1.172	1.32	R	Sample ≤ 3x Blank
RR1B	DRP (ug/L)	7/16/2019	1.11	2.5	3.242	1.172	2.77	R	Sample ≤ 3x Blank
WTP1	DRP (ug/L)	7/16/2019	1.11	2.5	2.046	1.172	1.75	R	Sample ≤ 3x Blank
BRD17D	DRP (ug/L)	7/16/2019	1.11	2.5	4.253	1.172	3.63	Trend (Level 2)	Blank < 3x Sample ≤ 5x Blank
BRD17I	DRP (ug/L)	6/18/2019	1.11	2.5	7.818	1.939	4.03	Trend (Level 2)	Blank < 3x Sample ≤ 5x Blank
CE100	DRP (ug/L)	6/18/2019	1.11	2.5	9.35	1.939	4.82	Trend (Level 2)	Blank < 3x Sample ≤ 5x Blank
CW82	DRP (ug/L)	6/18/2019	1.11	2.5	7.07	1.939	3.65	Trend (Level 2)	Blank < 3x Sample ≤ 5x Blank
CW88	DRP (ug/L)	6/18/2019	1.11	2.5	6.902	1.939	3.56	Trend (Level 2)	Blank < 3x Sample ≤ 5x Blank
BRD17I	DRP (ug/L)	6/18/2019	1.11	2.5	14.9	1.939	7.68	J	Blank < 5x Sample ≤ 10x Blank
CE92	DRP (ug/L)	6/18/2019	1.11	2.5	10.81	1.939	5.58	J	Blank < 5x Sample ≤ 10x Blank
RR1B	DRP (ug/L)	6/18/2019	1.11	2.5	10.16	1.939	5.24	J	Blank < 5x Sample ≤ 10x Blank
WTP1	DRP (ug/L)	6/18/2019	1.11	2.5	13.16	1.939	6.79	J	Blank < 5x Sample ≤ 10x Blank

R - rejected
J- estimated
Level 2 – downgraded from Level 3 to Level 2 data
All units in ug/L

Table 3. Duplicate Data Qualifications						
Site	Parameter (Units)	Date	Result	Acceptable RPD	RPD	QA/QC Code
BRD17I	DRP (ug/L)	6/18/2019	14.9	43.7	62.3	R - rejected
			7.818			
CW82	DRP (ug/L)	7/02/2019	2.092	81.1	88.8	R - rejected
			5.433			
RR1B	Alkalinity (mg/L $CaCO_3$)	8/13/2019	141.3	35.2	40.8	R - rejected
			93.4			
Cuyahoga River RM 10.95	Chlorophyll *a* (ug/L)	6/17/2019	4.855	15.0	19.7	R - rejected
			3.983			

Ohio EPA Water Quality Standards Exceedance

Average water temperature exceeded the limit for the central basin of Lake Erie stated in Ohio Administrative Code Chapter 3745-1-31(B)(2) for the period of October 1-15, 2019. Table 4 gives daily and average temperature results for this period. According to the National Oceanic and Atmospheric Administration (NOAA), October 2019 was the second hottest October to date on record, next to 2015 (NOAA, 2019). The average temperature exceedances observed in October are therefore most likely a result of global climate change. It is worth noting that the period of October 1-15 was the only period during which more than one temperature reading was collected, and that only two temperature readings were collected during this period. Therefore, this was the only period for which an average temperature could be calculated and compared to the average temperature water quality criteria. Also, the limited number of data points collected may not provide an accurate representation of the true average temperature of these sites during this period. One of the two measured temperatures in this period was well below the average temperature criterion for all sites. No other water quality exceedances were observed for the remaining parameters measured throughout the course of this study.

Table 4. Lake Erie Average Temperature Criterion Exceedances

Site	Date	Temperature	Average	Daily Maximum Temperature Criterion	Average Temperature Criterion
BRD17D	10/01/2019	21.0	19.5*	21.7	18.9
	10/15/2019	18.0			
RR1B	10/01/2019	21.5	19.5*		
	10/15/2019	17.5			
BRD17I	10/01/2019	21.5	19.8*		
	10/15/2019	18			
CW82	10/01/2019	21.3	19.6*		
	10/15/2019	17.9			
WTP1	10/01/2019	21.6	19.5*		
	10/15/2019	17.4			
CW88	10/01/2019	21.5	19.5*		
	10/15/2019	17.4			
CE92	10/01/2019	21.4	19.6*		
	10/15/2019	17.7			
CE100	10/01/2019	21.3	19.5*		
	10/15/2019	17.6			

* Indicates an exceedance of the corresponding temperature criteria

Wastewater Treatment Plant Phosphorus Loadings

In 2019, TP was collected daily and DRP was collected twice monthly at Southerly, Easterly, and Westerly WWTPs. Southerly discharges to the Cuyahoga River. Easterly and Westerly discharge to Lake Erie. A monthly average limit of 0.7 mg/L TP is implemented through the Southerly WWTP NPDES permit. A monthly average limit of 1.0 mg/L TP is implemented through the Easterly and Westerly WWTP NPDES permits. No limit for DRP currently exists. However, the NPDES permits require that one grab sample for DRP be collected per month as of April 2016. Phosphorus has many anthropogenic and natural sources. It usually is a limited nutrient in a water body and concentration increases can accelerate growth rates of algae and plants. Tables 4 and 5 show average concentrations and loading values of TP and DRP, respectively. The average TP values for all three WWTPs met the NPDES permit limits of 0.7 mg/L and 1.0 mg/L. The average plant flow volumes in the tables were calculated only from days for which either TP or DRP data was available. The average yearly estimate of TP and DRP in metric tons was calculated using the below formula.

$$P\ Load\ (Annual\ metric\ tons) = \frac{Average\ P\ concentration\left(\frac{mg}{L}\right)\ x\ Average\ flow(MGD)\ x\ 8.345\left(\frac{lbs}{gal}\right) x\ 365\left(\frac{days}{year}\right)}{2205\left(\frac{lbs}{metric\ ton}\right)}$$

The average annual load of TP in the Cuyahoga River for 2013 through 2017 was reported as 308.6 metric tons (Ohio EPA, 2018c). The annual load of TP from the Southerly WWTP was 64.3 metric tons in 2019. Using these numbers, the Southerly WWTP contributed approximately 20.8% of the annual TP load of the Cuyahoga River in 2019. The TP influent load to the Southerly WWTP was elevated in 2019 compared to the previous 3 years (Table 6). Despite this, the Southerly effluent load to the Cuyahoga River was still lower in 2019 than in 2016 and 2017. This is most likely due to improvements in plant processes which have resulted in improved TP removal efficiencies of 91.3% and 91.2% in 2018 and 2019, respectively.

Easterly and Westerly WWTPs contributed 34.8 and 20.0 metric tons of TP, respectively, to Lake Erie. The Lake Erie Phosphorus Task Force has recommended an annual TP loading limit of 6,000 metric tons per year to the central basin (Lake Erie Phosphorus Task Force, 2013). NEORSD WWTP discharges in 2019, including Southerly, accounted for approximately 1.99% of the target TP load to the central basin.

Table 4. NEORSD WWTP TP Loading and Related Values						
Site	Year	Average TP Value (mg/L)	Average Volume * (MGD)	Average Yearly Estimate (metric tons of TP)	n	Highest Collected Value (mg/L)
Southerly	2016	0.488	115.0	77.6	360	1.292, January 5
	2017	0.417	124.3	71.5	358	1.406, February 15
	2018	0.296	132.4	54.1	349	0.837, February 11
	2019	0.373	125.0	64.3	360	0.893, December 28
Easterly	2016	0.456	71.7	45.2	360	1.928, August 25
	2017	0.371	81.9	42.0	359	2.126, August 16
	2018	0.214	93.8	27.7	349	1.977, March 30
	2019	0.282	89.4	34.8	355	2.027, February 2
Westerly	2016	0.530	24.8	18.1	360	1.246, December 18
	2017	0.657	24.1	21.9	359	3.239, November 18
	2018	0.568	26.9	21.1	349	1.484, September 6
	2019	0.563	25.7	20.0	360	1.918, June 16
CSO	2019	0.73	10.7	10.7	-	-
* The average volume calculation only includes flow data from days on which TP data was available.						

Table 5. NEORSD WWTP DRP Loading and Related Values						
Site	Year	Average DRP Value (mg/L)	Average Volume * (MGD)	Average Yearly Estimate (metric tons of DRP)	n	Highest Collected Value (mg/L)
Southerly	2016	0.385	96.7	51.5	29	0.579, June 13
	2017	0.310	129.1	55.4	22	0.561, August15
	2018	0.186	150.5	38.7	24	0.652, December 18
	2019	0.282	115.3	45.0	24	0.762, October 1
Easterly	2016	0.472	58.5	38.1	12	1.093, July 26
	2017	0.322	79.8	35.5	23	1.978, June 15
	2018	0.162	86.1	19.3	23	1.628, August 15
	2019	0.284	77.8	30.5	24	3.508, October 1

Table 5. NEORSD WWTP DRP Loading and Related Values						
Site	Year	Average DRP Value (mg/L)	Average Volume * (MGD)	Average Yearly Estimate (metric tons of DRP)	n	Highest Collected Value (mg/L)
Westerly	2016	0.348	19.4	9.10	12	0.603, August 8
	2017	0.337	21.8	10.1	23	0.893, August 15
	2018	0.232	23.0	7.4	24	0.461, September 5
	2019	0.290	20.4	8.2	24	1.334, June 4
* The average volume calculation only includes flow data from days on which DRP data was available.						

Annual TP removal efficiencies were calculated according to the below formula and are given in Table 6. TP removal efficiencies at the Easterly and Southerly WWTPs improved in 2017 and 2018, and remained high in 2019. This suggests that the decreases in TP loads from these plants over the last two years are due to improvements in plant performance rather than to decreases in influent phosphorus concentrations.

$$TP\ Removal\ Efficiency = 100 \text{ x } \frac{(Average\ Influent\ TP\ \left(\frac{mg}{L}\right) - Average\ Effluent\ TP\ \left(\frac{mg}{L}\right))}{Average\ Influent\ TP\ \left(\frac{mg}{L}\right)}$$

Table 6. TP Removal Efficiency				
Average Influent TP (mg/L)				
	2016	2017	2018	2019
Southerly	2.291	3.817	3.396	4.224
Easterly	2.231	2.288	2.039	2.267
Westerly	2.174	2.327	2.175	2.294
Average Effluent TP (mg/L)				
	2016	2017	2018	2019
Southerly	0.488	0.417	0.296	0.373
Easterly	0.456	0.371	0.214	0.282
Westerly	0.530	0.657	0.568	0.563
TP Removal Efficiency (%)				
	2016	2017	2018	2019
Southerly	78.7	89.1	91.3	91.2
Easterly	79.6	83.8	89.5	87.6
Westerly	75.6	71.8	73.9	75.4

Combined sewer overflow (CSO) discharges also contribute TP to the watersheds in the NEORSD service area. Average TP concentration from CSOs has been estimated at 0.73 mg/L (Ohio EPA, 2018c) and it is estimated, based on model predictions, that approximately 3.893

billion gallons of CSO discharges occurred in the service area in 2019. Using these estimates, CSOs in the NEORSD service area contributed a total of 10.7 metric tons of TP to Lake Erie in 2019. In 2011, the NEORSD entered into a $3 billion, 25-year consent decree program called Project Clean Lake to reduce annual Lake Erie pollution from CSOs by 4 billion gallons by 2036. It is estimated that by 2025, the construction of CSO storage tunnels and other projects will have reduced the volume of CSO discharges to 1.97 billion gallons annually. This would result in the additional treatment of 1.92 billion gallons of wastewater with an average TP loading of 5.3 metric tons annually. Using the average TP removal efficiency for all three NEORSD operated WWTPs from 2016-2019 (82.3%), this would result in an estimated decrease in TP load to Lake Erie of 4.4 metric tons annually. For comparative purposes this reduction in CSO TP would be equal to 1.4% of the annual TP load of the Cuyahoga River and 3.4% of the 2019 NEORSD TP discharge including WWTPs and CSOs.

River Site Analysis

Data for river sites was compared to Ohio EPA Water Quality Standards for the protection of aquatic life, as well as the Ohio EPA proposed Stream Nutrient Assessment Procedure (SNAP) (Ohio EPA, 2015). Applicable data were also compared to the Ohio EPA's proposed Nutrient Water Quality Standards for Ohio's Large Rivers, as well as the proposed summer base-flow target level of total phosphorus of 130 µg/L (Ohio EPA, 2018b) (Miltner, 2017). It should be noted that the Rocky River RM 0.90, Cuyahoga River 0.20, and Euclid Creek RM 0.55 sites are located within the lacustuary zone for these streams. These points therefore do not provide a direct measure of nutrient output from these streams as it is impossible to determine the amount of dilution influence from Lake Erie at the time of sample collection. They instead provide information concerning relative nutrient content upstream of each stream confluence with Lake Erie. Average parameter values for all river sites are given in Table 7. No exceedances of the criteria for the protection of aquatic life were found for all river sites for the parameters in this study.

According to SNAP, concentrations of TP and dissolved inorganic nitrogen (DIN, the sum of nitrate/nitrate and ammonia concentration) for Cuyahoga River RMs 0.20 and 10.95, and Rocky River RM 0.90 were categorized as "levels typical of working landscapes with low risk to beneficial use". Nutrient concentrations for Euclid Creek RM 0.55 were categorized as "Levels typical of developed lands; little to no risk to beneficial use".

Sestonic chlorophyll *a* and total phosphorus concentrations from the river sites were compared to the Ohio EPA's proposed target levels for large rivers, for comparative purposes only. The proposed targets would apply to river sites with a drainage area greater than 500 square miles. Of the four river sites in this study, only the two Cuyahoga River sites would fall into this category. Average sestonic chlorophyll *a* concentrations were below the Ohio EPA's proposed target level of 30 µg/L for all river sites. This indicates that these sites were not in a condition of eutrophication throughout the course of the 2019 sampling season. Average total phosphorus was also below the Ohio EPA's proposed target of 130 µg/L for all river sites, as well as the proposed SNAP target of 400 µg/L for small rivers and streams.

Euclid Creek RM 0.55 had the lowest overall nutrient and chlorophyll *a* average concentrations of the four sites, with the exception of DRP, which was lowest at Cuyahoga River RM 10.95 (Figures 2-6). TP was significantly elevated at the remaining sites compared to Euclid Creek RM 0.55. Despite having the lowest concentration of DRP of all sites, Cuyahoga River RM 10.95 had the most elevated average chlorophyll *a* concentration. However, as stated above, both chlorophyll *a* and total phosphorus concentrations were well below proposed target levels at all sites.

In conclusion, the river sites analyzed as part of this study were found to be typical of working landscapes or developed lands with respect to nutrient concentration. These levels of nutrients pose low risk to beneficial use according to the Ohio EPA's proposed SNAP procedure. In addition, total phosphorus and chlorophyll *a* concentrations were below proposed targets for all river sites in 2019.

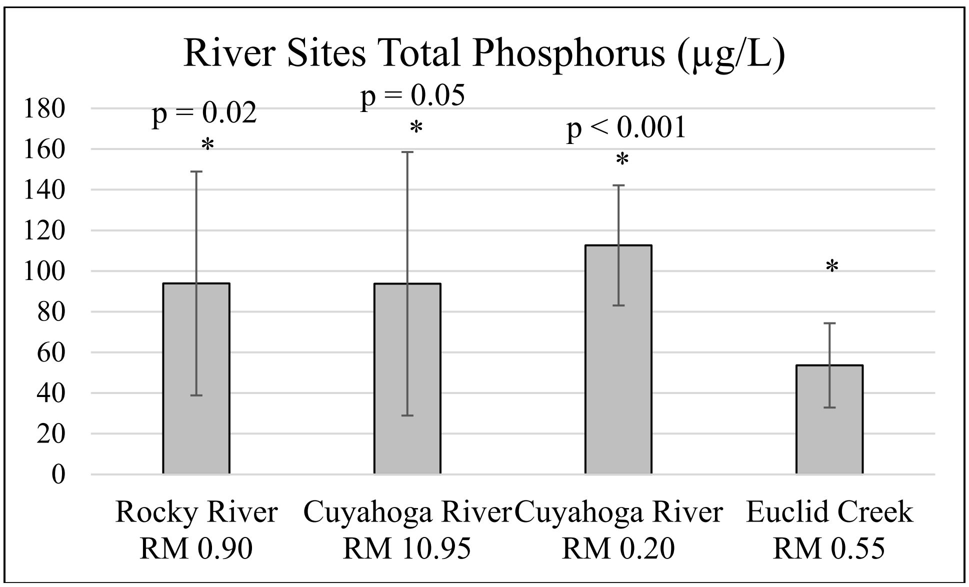

Figure 2. 2019 average TP concentrations at each river site with standard deviation. All other sites were found to have significantly elevated TP concentrations compared to Euclid Creek RM 0.55 according to the Wilcoxon rank-sum test.

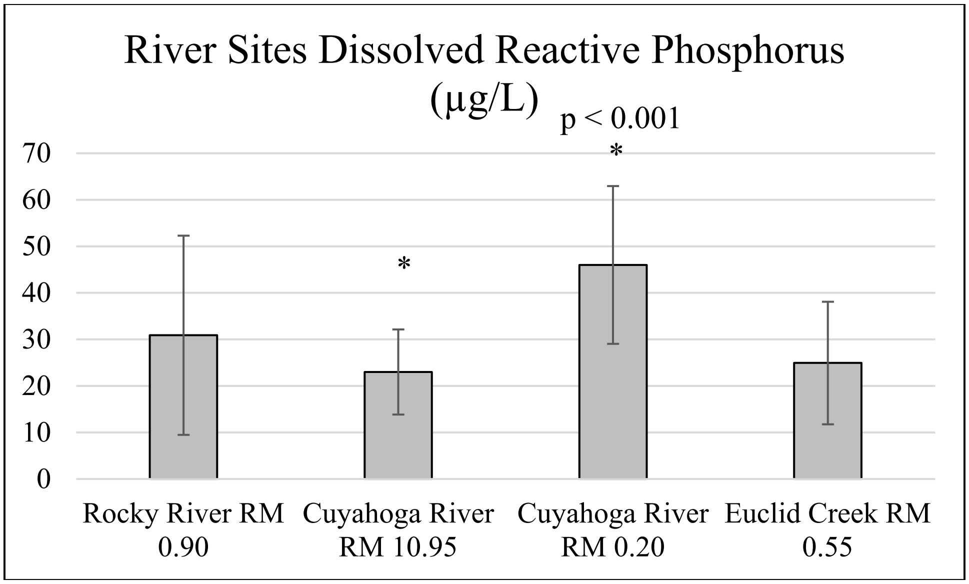

Figure 3. 2019 average DRP concentrations at each river site with standard deviation. Cuyahoga River RM 0.20 was found to have significantly elevated DRP compared to RM 10.95 according to the Wilcoxon rank-sum test.

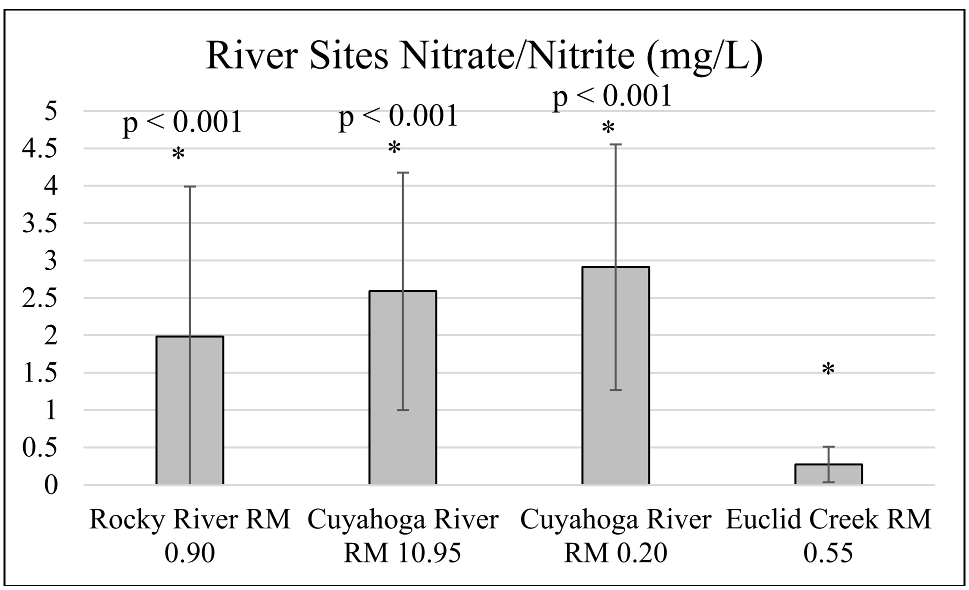

Figure 4. 2019 average nitrate/nitrite concentrations at each river site with standard deviation. All other sites were found to have significantly elevated nitrate/nitrite concentrations compared to Euclid Creek RM 0.55 according to the Wilcoxon rank-sum test.

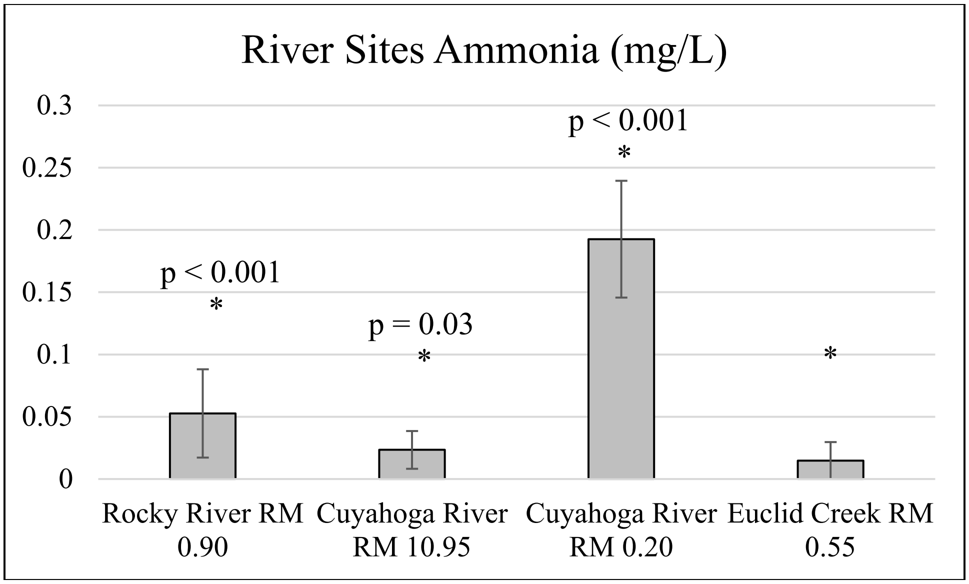

Figure 5. 2019 average ammonia concentrations at each river site with standard deviation. All other sites were found to have significantly elevated ammonia concentrations compared to Euclid Creek RM 0.55 according to the Wilcoxon rank-sum test.

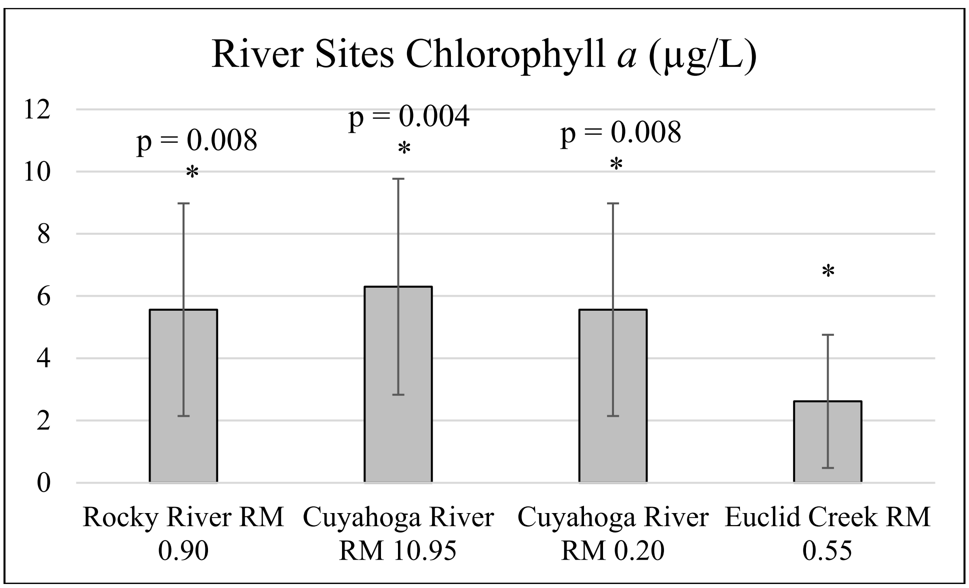

Figure 6. 2018 average chlorophyll *a* concentrations at each river site with standard deviation. All other sites were found to have significantly elevated average chlorophyll *a* concentrations compared to Euclid Creek RM 0.55 according to the Wilcoxon rank-sum test.

Table 7. 2019 River Site Average Values													
	TP	DRP	NO_3-NO_2	NH_3	Chlorophyll *a*	Alkalinity	TSS	pH	Conductivity	DO	Temperature	Turbidity
Site	ug/L	ug/L	mg/L	mg/L	ug/L	mg/L CaCO3	mg/L	S.U.	uS/cm	mg/L	ºC	NTU
Rocky River RM 0.90	94	<31	1.983	<0.053	5.563	122.9	29.9	7.9*	636	8.2	20.2	34.3
Cuyahoga River RM 10.95	94	<23	2.590	<0.023	6.300*	133.4*	41.2*	7.8	695	8.5	20.1	27.9
Cuyahoga River RM 0.20	113*	46*	2.913*	0.193*	5.563	118.2	31.0	7.5	701	6.1*	21.5*	36.6*
Euclid Creek RM 0.55	54	<25	<0.273	<0.015	2.617	123.8	7.4	7.8	762*	8.9	17.8	7.0
Average River Site Values	88	<31	<1.940	<0.071	5.011	124.6	27.4	7.7	699	7.9	19.9	26.5

< - Indicates that one or more samples were found to be below the MDL. The MDL value was used in these cases to calculate the average.
Highlighted – Indicates that the data from this site was significantly elevated (reduced for dissolved oxygen) compared to the data of the site with the lowest average value for this parameter (highest average value for dissolved oxygen) according to a Wilcoxon rank-sum test with 95% confidence.
* - Indicates highest average value for this parameter (lowest for dissolved oxygen). Does not indicate a significant difference from other sites.

Lake Site Analysis

TP for the lake sites was compared to the Interim Substance Objectives for Total Phosphorus Concentration in Open Waters (10 ug/L for Lake Erie Central Basin) as set in the 2012 Great Lakes Water Quality Agreement (GLWQA). Nutrient and chlorophyll *a* data for all lake sites was also compared using the Kruskal-Wallis test. Table 8 gives average parameter results for all lake sites. No significant differences were observed between all sites for all studied parameters. Figures 7-11 show average nutrient and chlorophyll *a* concentrations with standard deviations.

The average TP concentrations for all sites in 2019 were greater than or equal to the 10 µg/L objective set by the GLWQA. BRD17D and CW82 had the lowest average TP concentrations of all sites at 16 µg/L. Average total phosphorus concentrations of the remaining sites ranged from 17 to 22 µg/L, but these differences were not significant according to the Kruskal-Wallis test with a 95% confidence interval. For DRP, no target currently exists, but concentrations above 6 ug/L have been associated with harmful algal blooms (Lake Erie Phosphorus Task Force, 2013). Average DRP was below this concentration at all sites in 2019.

A positive correlation between TP and chlorophyll *a* concentrations was observed and is demonstrated in Figure 12 (R^2=0.6057). However, no positive correlation was observed between DRP, the more bioavailable form of phosphorus, and chlorophyll *a* as demonstrated in Figure 13 (R^2=0.0274). Aside from phosphorus concentrations, factors that may influence algal growth in the Greater Cleveland area include, but are not limited to, weather conditions including sunlight and rain, lake conditions including wave height and currents, lake turbidity, and transportation of HABs from the western basin.

Table 8. 2019 Lake Erie Average Values												
	TP	DRP	NO_3-NO_2	NH_3	Chlorophyll *a*	Alkalinity	TSS	pH	Conductivity	DO	Temperature	Turbidity
Site	ug/L	ug/L	mg/L	mg/L	ug/L	mg/L CaCO3	mg/L	S.U.	uS/cm	mg/L	ºC	NTU
BRD17D	16	<3.679	0.196	<0.009	4.691	91.9	1.3	8.2	267	9.0	21.5	1.72
RR1B	20	3.848	<0.271	<0.016	7.042	94.0	2.1	8.1	279	8.9*	21.8	2.51
BRD17I	19	4.390*	<0.249	<0.013	6.032	92.4	1.6	8.2	273	9.0	21.8	2.34
CW82	16	<3.198	0.199	<0.011	5.411	92.0	1.4	8.2	269	9.1	21.6	1.54
WTP1	22	4.340	<0.330*	<0.015	9.823*	95.2*	3.1*	8.1	295*	9.0	21.7	4.83*
CW88	18	<3.752	<0.259	<0.014	7.027	92.5	1.9	8.2	277	9.1	21.7	2.32
CE92	18	<3.233	<0.229	<0.018*	7.270	94.3	1.8	8.2	275	9.0	21.8	2.59
CE100	17	<3.556	<0.213	<0.016	7.085	93.6	1.6	8.0	271	9.0	21.6	2.04
Average Lake Site Values	18	<3.749	<0.243	<0.014	6.798	93.2	1.8	8.1	276	9.0	21.7	2.49

< - Indicates that one or more samples were found to be below the MDL. The MDL value was used in these cases to calculate the average.
Highlighted – Indicates that the data from this site was significantly different from BRD17D offshore control site by a Wilcoxon rank-sum test with 95% confidence interval.
* - Indicates highest average value for this parameter (lowest for dissolved oxygen). Does not indicate a significant difference from other sites.

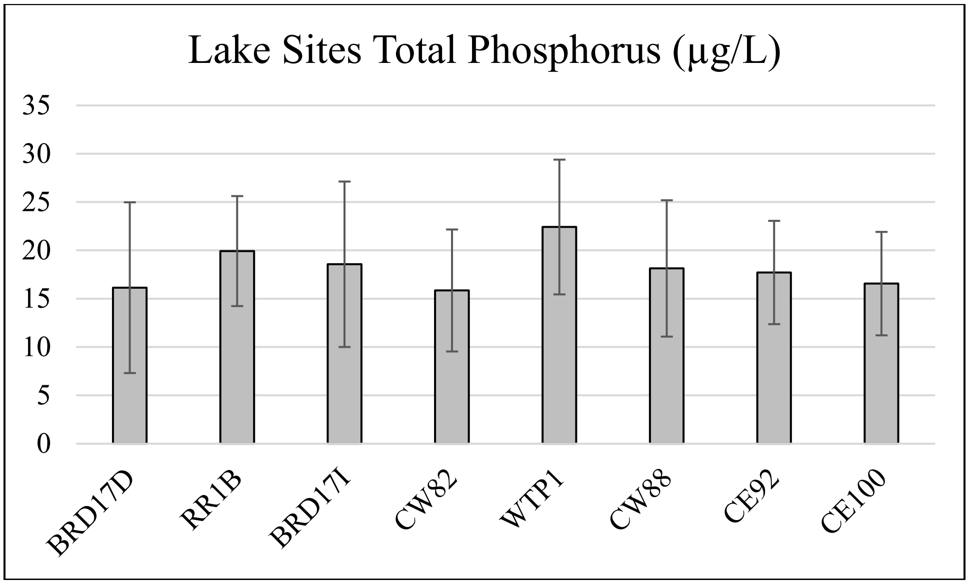

Figure 7. 2019 Average TP concentrations at each lake site with standard deviation. No significant differences among sites with respect to TP were observed according to the Kruskal-Wallis test with a 95% confidence interval.

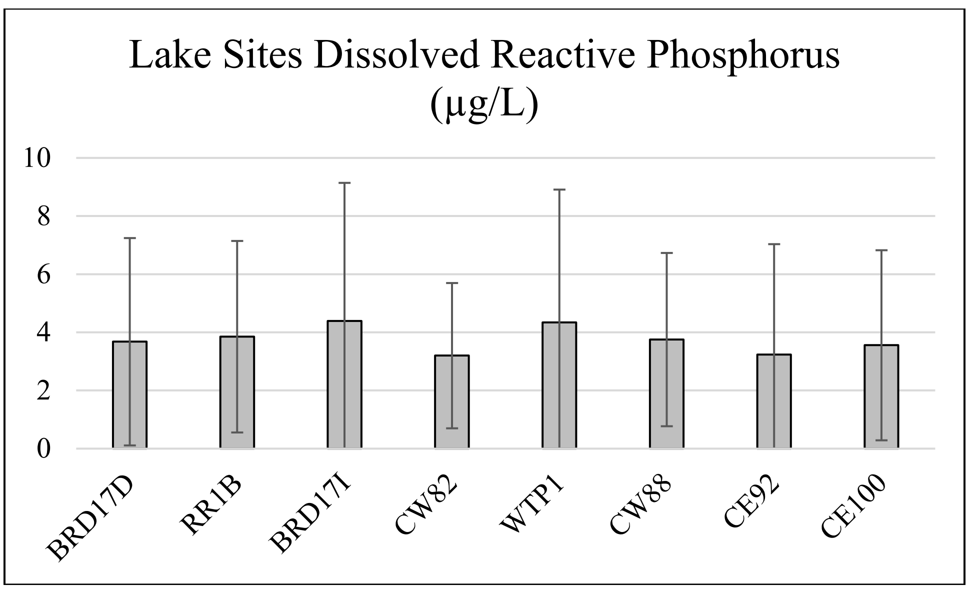

Figure 8. 2019 average DRP concentrations at each lake site with standard deviation. No significant differences among sites with respect to DRP were observed according to the Kruskal-Wallis test with a 95% confidence interval.

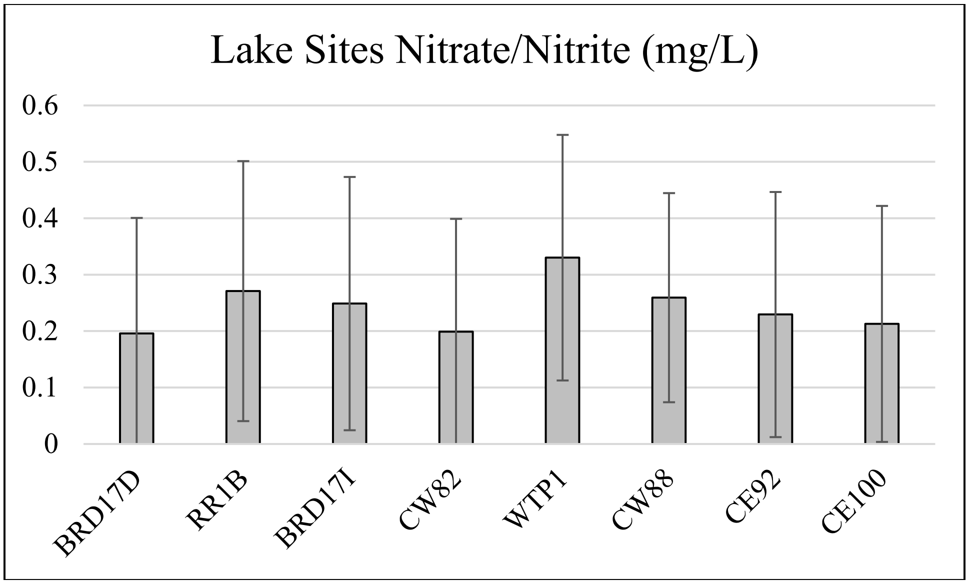

Figure 9. 2019 average nitrate/nitrite concentrations at each lake site with standard deviation. No significant difference among sites was observed with respect to nitrate/nitrite according to the Kruskal-Wallis test with a 95% confidence interval.

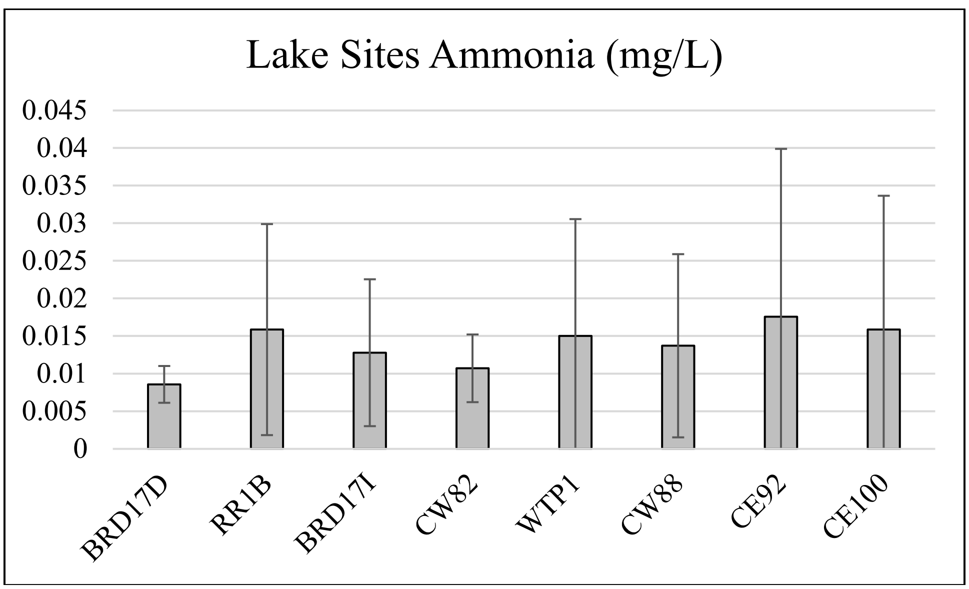

Figure 10. 2019 average ammonia concentrations at each lake site with standard deviation. No significant difference among sites was observed with respect to ammonia according to the Kruskal-Wallis test with a 95% confidence interval.

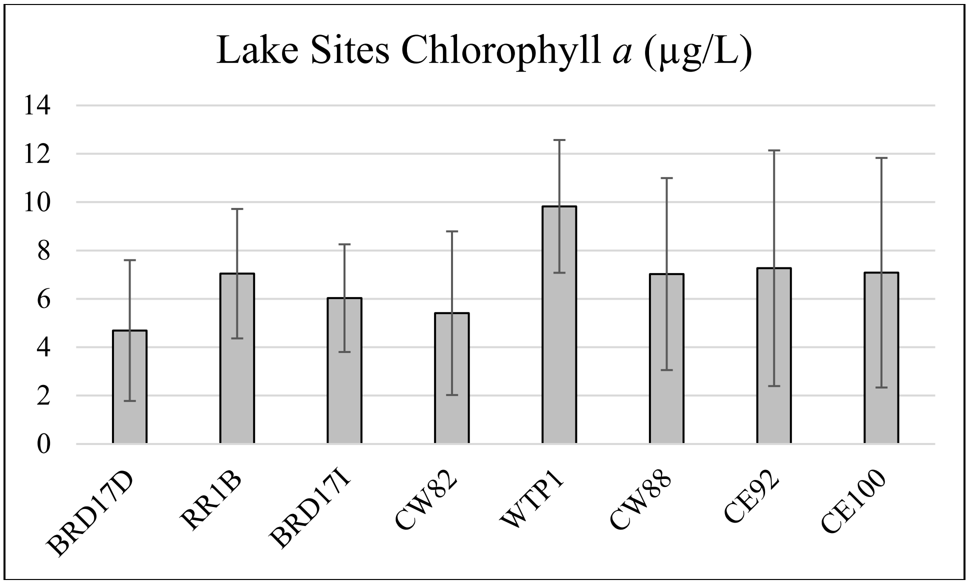

Figure 11. 2019 average chlorophyll *a* concentrations at each lake site with standard deviation. No significant difference among sites was observed with respect to chlorophyll *a* according to the Kruskal-Wallis test with a 95% confidence interval.

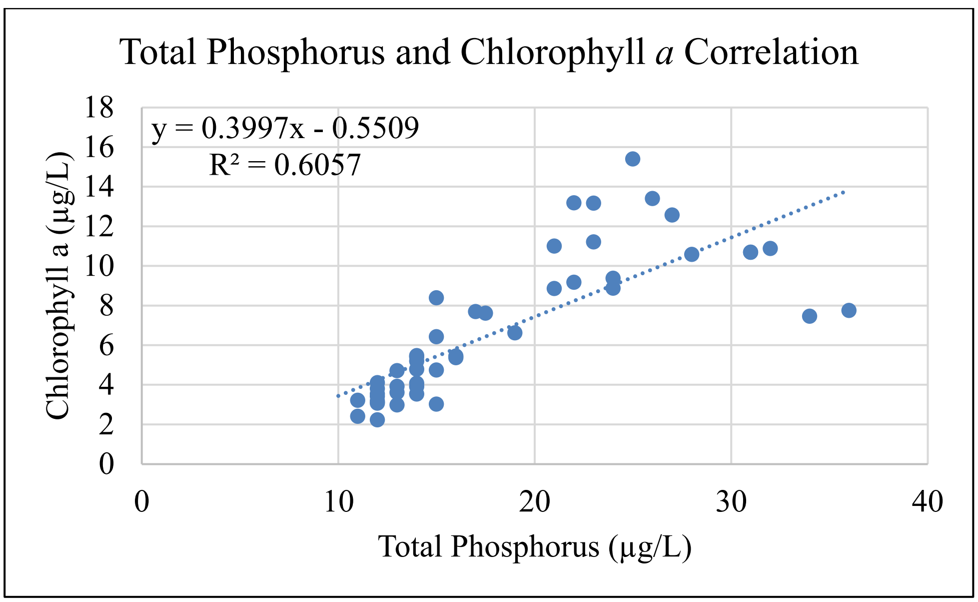

Figure 12. TP and chlorophyll *a* correlation. A positive correlation was observed between TP and chlorophyll *a* in 2019.

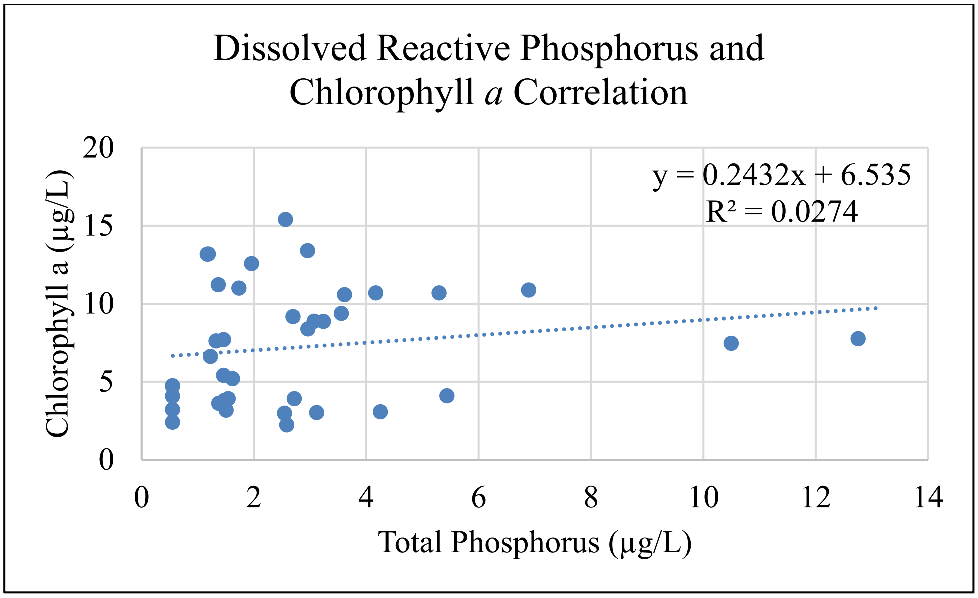

Figure 13. DRP and chlorophyll *a* correlation. No correlation was observed between DRP and chlorophyll *a* in 2019.

Harmful Algal Bloom Occurrence

A single HAB occurred during the 2019 recreational season in the Greater Cleveland Area. On July 10, 2019, NEORSD was notified by Cleveland Metroparks of a potential HAB at Edgewater Beach. NEORSD Water Quality and Industrial Surveillance Investigators were dispatched to both Edgewater and Villa Angela Beaches. No algal bloom was observed at Villa Angela Beach. A visible bloom was apparent at Edgewater Beach and was located on the west side of the swim zone along the shoreline as demonstrated in Figure 14. Water quality samples were collected daily from July 10 through July 17, 2019, from both beaches. Samples were collected from the densest region of the bloom safely approachable by wading if the bloom was visible, or from the daily beach monitoring point if the bloom was not visible. Samples were analyzed for anatoxin-a, cylindrospermopsin, total microcystins, and saxitoxin.

The dominant genera in the Edgewater bloom were identified as Dolichospermum followed by Microcystis. Results of toxin analysis are shown in Table 9. Low concentrations of all measured toxins were observed at Edgewater Beach, and saxitoxin only at Villa Angela Beach on July 10, 2019. These results were found to be below the Recreational Public Health Advisory Cyanotoxin Toxicity Threshold Listed in the *State of Ohio Harmful Algal Bloom Response Strategy for Recreational Waters* (State of Ohio, 2016). All toxin concentrations fell to equal to or below the detection limit the following day and remained below the detection limit for the remainder of the 7-day sampling period. The bloom was short lived and was only visible for one day.

Figure 14. Closeup (Left) and overall (Right) views of the Edgewater HAB that occurred on July 10, 2019.

Table 9. HAB Cyanotoxin Analysis 2019

Date	Beach	Anatoxin-a	Cylindrospermopsin	Total Microcystins	Saxitoxin
7/10/2019	Edgewater	0.185	< 0.013	1.025	0.029
7/11/2019		< 0.008	< 0.026	< 0.13	j 0.004
7/12/2019		< 0.008	< 0.013	< 0.13	< 0.004
7/13/2019		< 0.008	< 0.013	< 0.13	< 0.004
7/14/2019		< 0.008	< 0.013	< 0.13	< 0.004
7/15/2019		< 0.008	< 0.013	< 0.13	< 0.004
7/16/2019		< 0.008	< 0.013	< 0.13	< 0.004
7/17/2019		< 0.008	< 0.013	< 0.13	< 0.004
7/10/2019	Villa Angela	< 0.008	< 0.013	< 0.13	j 0.009
7/11/2019		< 0.008	< 0.026	< 0.13	j 0.004
7/12/2019		< 0.008	< 0.013	< 0.13	< 0.004
7/13/2019		< 0.008	< 0.013	< 0.13	< 0.004
7/14/2019		< 0.008	< 0.013	< 0.13	< 0.004
7/15/2019		< 0.008	< 0.013	< 0.13	< 0.004
7/16/2019		< 0.008	< 0.013	< 0.13	< 0.004
7/17/2019		< 0.008	< 0.013	< 0.13	< 0.004

j – estimated result between MDL and PQL
< – result below detection limit

Comparison to Historical Data

The NEORSD has been conducting the Lake Erie Nutrient Study annually beginning in 2012. Data collected in 2019 was compared to historical data collected since 2012 in order to determine trends over time. (Figures 15-17). Average TP, DRP, and chlorophyll *a* concentrations in the Greater Cleveland area lake sites were similar in 2019 to the overall average values of previous years. No correlation was observed between yearly average chlorophyll *a* trends and yearly average trends of either form of phosphorus. No correlation was observed between the NOAA Western Lake Erie Bloom Severity Index (Figure 18, NOAA, 2019b) and Greater Cleveland Area yearly average chlorophyll *a* concentrations. Although, in previous years including 2013 and 2017, peaks in the Western Lake Erie Bloom Severity Index did correspond with elevated chlorophyll *a* concentrations in the Greater Cleveland Area. This was most likely due to transport of blooms from the western basin to the central basin in these years.

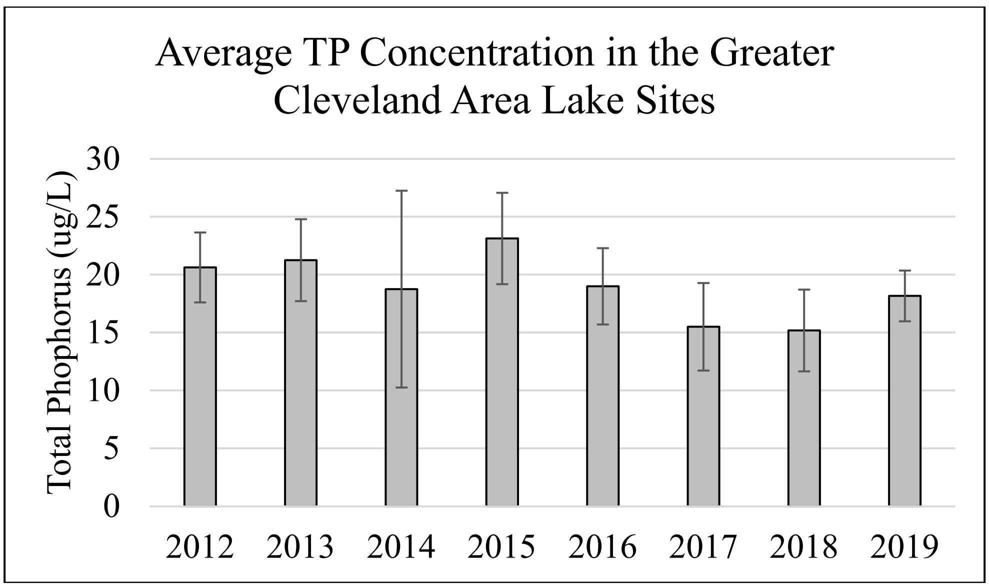

Figure 15. Average TP concentration at all lake sites by year with standard deviation. Average TP concentrations in 2019 were similar to previous years. No clear relationship was observed between TP trends and chlorophyll *a* trends.

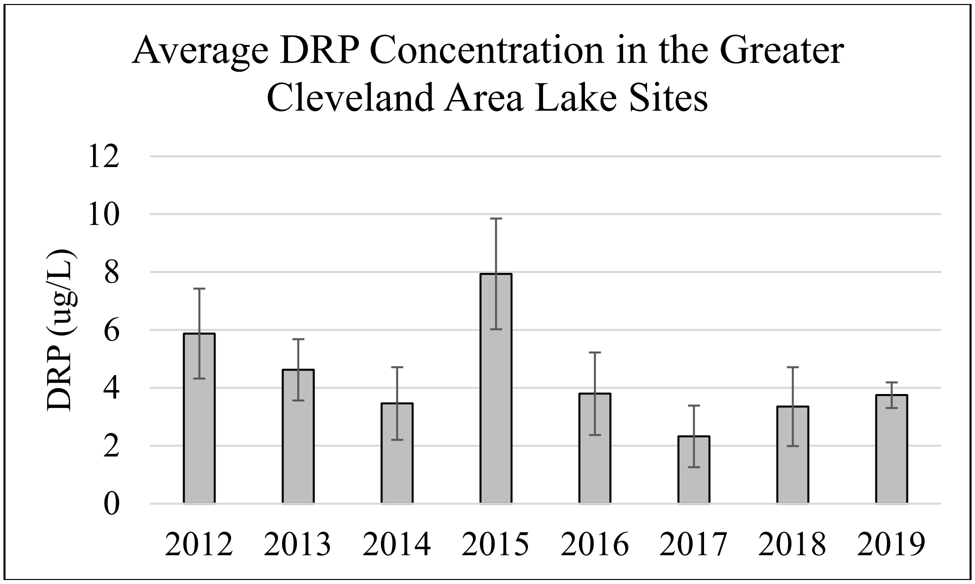

Figure 16. Average DRP concentration at all lake sites by year with standard deviation. No clear relationship was observed between DRP trends and chlorophyll *a* trends.

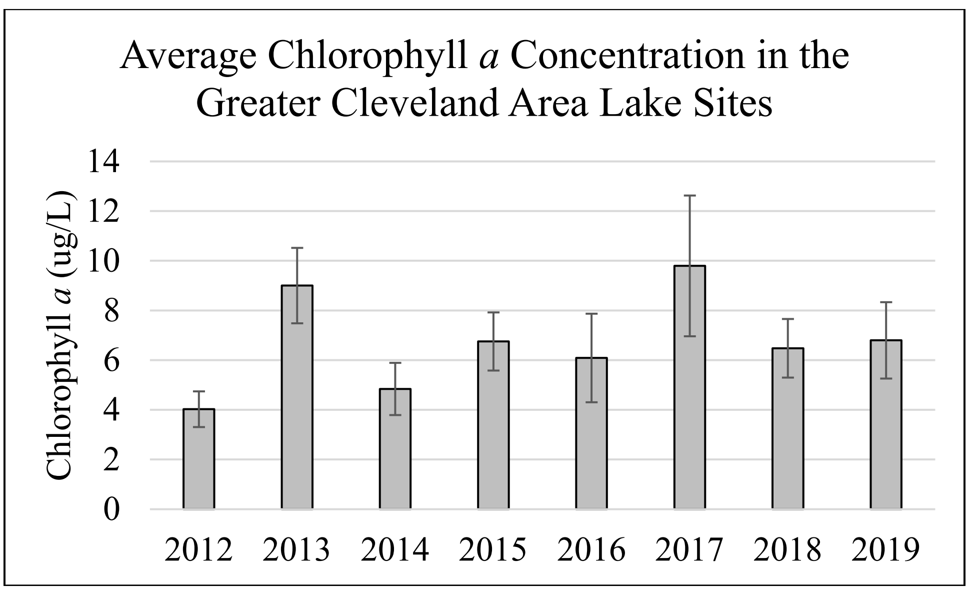

Figure 17. Average chlorophyll *a* concentration at all lake sites by year with standard deviation.

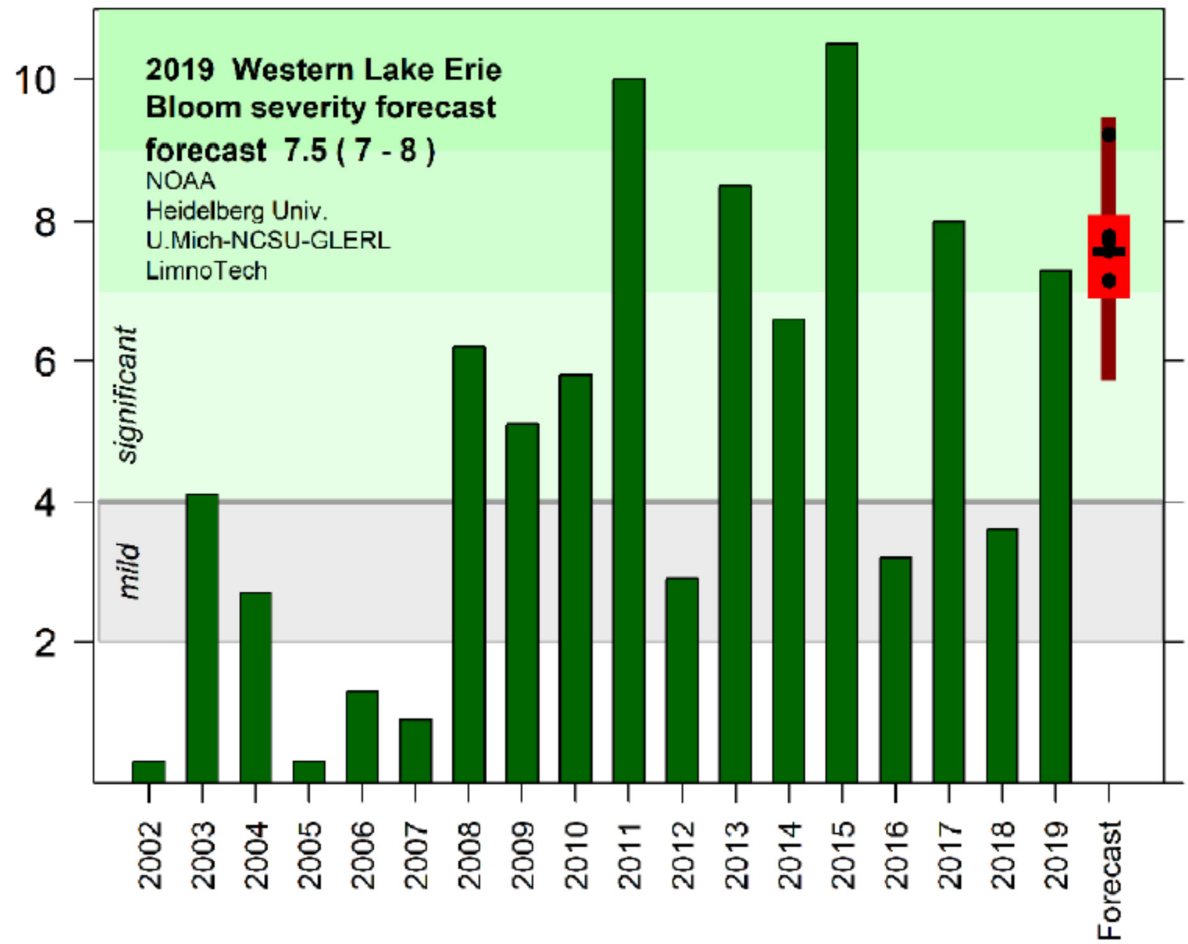

Figure 18. Bloom Severity Index as of October 2019 as published by NOAA (NOAA, 2019).

Conclusion

TP concentrations at all lake sites, including the offshore control site BRD17D, were equal to or above the Interim Substance Objective of 10 µg/L for TP set by the GLWQA. A single HAB was observed in the Greater Cleveland area at Edgewater Beach. This HAB did not produce toxins above the Recreational Public Health Advisory Threshold Limits. Continued reduction of phosphorus concentrations in the Lake Erie watershed will be needed in order to meet the GLWQA objective and prevent future HAB occurrences. Major streams in the NEORSD service area were found to have phosphorus concentrations below Ohio EPA proposed target limits, suggesting that efforts to reduce phosphorus contributions to Lake Erie may provide greater results if directed towards watersheds with more elevated phosphorus concentrations.

The NEORSD continues to invest in improvements to wastewater treatment and collection system infrastructure. These investments have and will continue to reduce phosphorus discharges to surface waters in the NEORSD service area. Phosphorus loading contributions from NEORSD operated sources were decreased in 2019 compared to 2016 and 2017, despite increased influent phosphorus concentrations. This suggests that improvements in plant performance have resulted in increased phosphorus removal efficiency at NEORSD operated facilities. TP loads from NEORSD discharges were increased in 2019 compared to 2018 partially due to increased influent phosphorus concentrations at the Southerly WWTP. Despite this, NEORSD discharges contributed a lower TP load to the environment in 2019 compared to 2016 and 2017, primarily due to improvements in phosphorus removal efficiency at NEORSD WWTPs and NEORSD CSO control projects. Future improvements to NEORSD-operated sewage collection systems as part of Project Clean Lake are expected to result in further reductions of nutrient loads from NEORSD operated sources.

Acknowledgements

Field activities and report review completed by the following, except where otherwise noted:

Kelsey Amidon
Hannah Boesinger
Nya Dreyfuss
Kevin Fitzgibbons
Seth Hothem
Mark Matteson
Denise Phillips
John Rhoades
Eric Soehnlen, Author
Justin Telep

WQIS Interns: Zachary Bayer, Brandon Fitzpatrick, and Matthew Johnson.

Analytical Services Division – Completed analysis for all water chemistry sampling.

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