NORTHEAST OHIO REGIONAL SEWER DISTRICT

2014 Greater Cleveland Area Lake Erie Nutrient Study

Prepared by
Water Quality and Industrial Surveillance Division

Introduction

Concern about the health of Lake Erie has increased in recent years due to the occurrence of harmful algal blooms within both the western and central basins. A bloom of the blue-green algae microcystis near Toledo in the summer of 2014 resulted in a drinking water ban for the city for several days. Although this bloom did not extend to the Cleveland area, others have in recent years. The increase in algae throughout the lake is thought to be due to increases in dissolved reactive phosphorus (Ohio EPA, 2011) coupled with favorable weather conditions. Northeast Ohio Regional Sewer District (NEORSD) facilities, such as its wastewater treatment plants and the combined sewer overflows (CSOs), could be a potential source of nutrients to the lake and, therefore, contribute to the problem. The extent to which these potential sources, along with other ones within the study area, are doing so is still not well understood.

Studies completed by NEORSD in 2012 and 2013 indicated that nutrient concentrations were not the main factor controlling algal blooms and weather may have had more of an impact. In 2014, monitoring of conditions in the lake continued as a means of determining the degree of algal productivity and developing correlations between chlorophyll *a* and potential contributing factors such as nutrients and weather.

Chlorophyll *a* was measured as a means of determining the total quantity of algae present. Nutrient analyses included both phosphorus and nitrogen. Other water quality parameters that may influence algal production were also measured. Sampling was conducted by NEORSD Level 3 Qualified Data Collectors certified by Ohio Environmental Protection Agency (EPA) in Chemical Water Quality as explained in the NEORSD study plan *2014 Greater Cleveland Area Lake Erie Nutrient Study* approved by the Ohio EPA on April 9, 2014.

Figure 1 is a map of the sampling locations evaluated on Lake Erie during the study, and Table 1 indicates the sampling locations with respect to latitude/longitude and description. A digital photo catalog of the sampling locations is available upon request by contacting the NEORSD's Water Quality and Industrial Surveillance Division (WQIS).

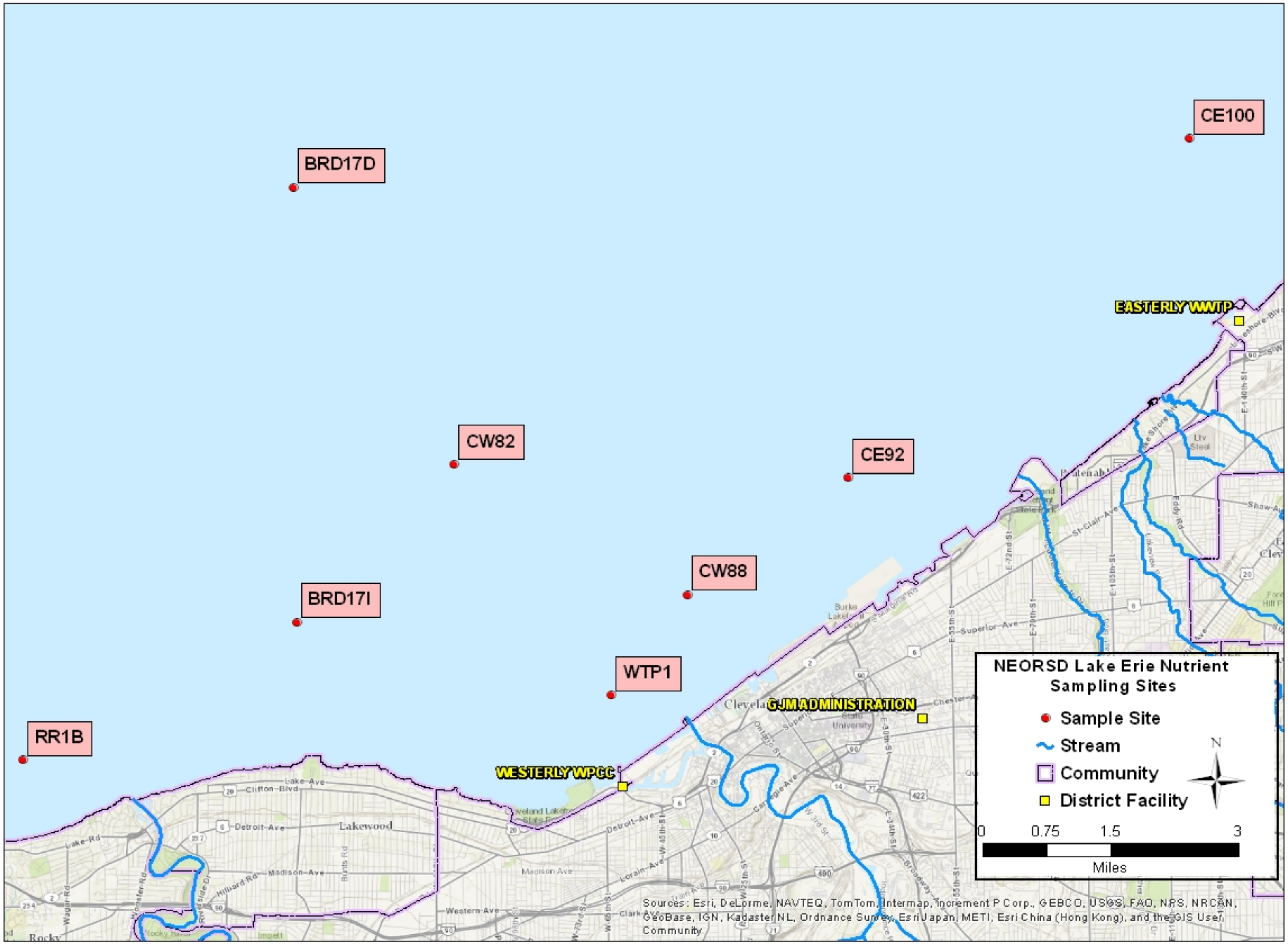


Figure 1. Sampling Locations

Table 1. Sample Locations			
Latitude	Longitude	Station ID	Location Information
41.49720	-81.86200	RR1B	Near Rocky River
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

Water Chemistry Sampling

Methods

Water chemistry sampling was conducted at each of the sites eleven times between May 13th and October 28th. Techniques used for sampling and analyses followed the Ohio EPA *Surface Water Field Sampling Manual* (2013). Chemical water quality samples from each site were collected with one 4-liter disposable polyethylene cubitainer with disposable polypropylene lid, two 473-mL plastic bottles, one 1-liter amber glass jar, and one 100-mL plastic bottle. One of the 473-mL plastic bottles was field preserved with trace sulfuric acid. Filtering of the dissolved reactive phosphorus (DRP) sample was done in the field. All water quality samples were collected as grab samples. At the time of sampling, measurements for dissolved oxygen, pH, temperature, and conductivity were collected using either a YSI 600XL sonde, YSI EXO1 sonde, or Hach 2100Q Turbidimeter. Duplicate samples and field blanks were collected at randomly selected sites at a frequency not less than 5% of the total samples collected. Relative percent difference (RPD) was used to determine the degree of discrepancy between the primary and duplicate sample. 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. Those that are higher may indicate potential problems with sample collection and, as a result, the data was not used for comparison to the water quality standards.

Results and Discussion

Copies of all certificates of analyses are available upon request by contacting the NEORSD's WQIS division.

Six sets of duplicate samples and five field blanks were collected during the study. For the field blanks, there were four parameters that showed possible contamination. It is unclear how the field blanks became contaminated and may be due to inappropriate sample collection, handling, or contaminated blank water. Table 2 lists water quality parameters that were rejected, estimated, or downgraded from Level 3 to Level 2 data based on Ohio EPA data validation protocol for field blanks.

Table 2. Parameters affected by possible blank contamination
DRP
NH_3
NO_2+NO_3
TP

For the duplicate samples that were collected, four instances occurred in which the RPD between duplicate samples was greater than acceptable, with three of them for ammonia (Table 3). The differences between the samples could be due to a variety of reasons such as a lack of precision and consistency in sample collection and/or analytical procedures, improper handling of samples and/or environmental heterogeneity.

Table 3. Duplicate samples with greater than acceptable RPDs

Site	Date	Parameter	Acceptable RPD	Actual RPD
BRD17I	5/13/2014	NH_3	42.6	145.1
BRD17I	5/13/2014	NO_3-NO_2	19.8	25.9
RR1B	10/15/2014	NH_3	99.7	107.7
RR1B	10/28/2014	NH_3	35.1	153.7

The final QA/QC check for the samples that were collected was for paired parameters, or those parameters in which one of them is a subset of the other. For this study, only total phosphorus (TP) and dissolved reactive phosphorus (DRP) fell into this category. During the sampling that was conducted in 2014, there were no instances in which these parameters needed to be qualified due to the subset parameter being greater than the other one.

In 2012 and 2013, the highest nutrient and suspended solids (TSS) concentrations were generally measured at the site near the Westerly Wastewater Treatment Center diffusers (WTP1). For the sampling that was conducted in 2014, however, this was not the case. Instead, the highest TP and TSS concentrations were at the site near Rocky River (RR1B), the highest nitrogen concentrations were at the site outside the City of Cleveland breakwall (CW88), and the highest DRP concentration was at the site two miles north of Easterly WWTP outfall (CE100) (Table 4). The difference between 2014 and previous years may be due to the sampling event on May 13 taking place after a significant rain of over four inches in some areas. The highest concentrations for TP, NO_2+NO_3, and TSS during the study were measured on that date.

Table 4. 2014 Lake Erie Average Values

	TP	DRP	NO_3-NO_2	NH_3	Alkalinity	TSS	pH	Conductivity	DO	Temperature	Turbidity
Site	mg/L	mg/L	mg/L	mg/L	mg/L CaCO3	mg/L	S.U.	uS/cm	mg/L	C	NTU
RR1B	0.034	0.0033	0.25	0.025	84.35	27.06	8.23	262.5	9.21	19.3	35.34
BRD17D	0.012	0.0043	0.22	0.029	89.75	1.14	8.28	254.5	9.59	18.9	1.10
BRD17I	0.013	0.0031	0.18	0.017	89.30	1.67	8.28	258.5	9.46	19.1	1.78
CW82	0.012	0.0022	0.20	0.010	89.85	1.28	8.30	256.3	9.60	19.0	1.35
WTP1	0.018	0.0028	0.33	0.030	89.67	4.42	8.24	285.4	9.07	19.7	4.61
CW88	0.030	0.0028	0.34	0.033	85.65	18.10	8.17	285.7	8.99	19.4	40.36
CE92	0.015	0.0030	0.29	0.026	88.92	3.16	8.19	270.9	9.29	19.2	3.63
CE100	0.016	0.0062	0.27	0.013	88.59	2.95	8.21	261.1	9.51	18.9	3.14

= Highest average value for that parameter

The TP target for the central basin of Lake Erie is currently set at 0.01 mg/L (Lake Erie Nutrient Science Task Group, 2009). The average concentration at all of the sites exceeded this value in 2014, although it was met by many of the sites during at least one sampling event during the study. For DRP, no target currently exists, but concentrations above 0.006mg/L have been associated with harmful algal blooms (Lake Erie Phosphorus Task Force, 2013). CE100 was the only site with an average concentration that exceeded this level, with four of the other sites also having individual measurements above it. Based on these measured phosphorus concentrations, it could be expected that elevated chlorophyll *a* levels may be found in the lake during some dates.

Similar to both 2012 and 2013, the highest average chlorophyll *a* concentrations were at WTP1 in 2014 (Figure 2), but there were no statistically significant differences when comparing the sites as a whole[1]. Overall concentrations in 2014 were lower than those measured in 2013 and about the same as in 2012. All of the average concentrations were greater than the Great Lakes Water Quality Agreement target of 2.6 ug/L (Lake Erie Nutrient Science Task Group, 2009). Some individual samples did meet this target; these were generally found during the first half of the study (Table 5).

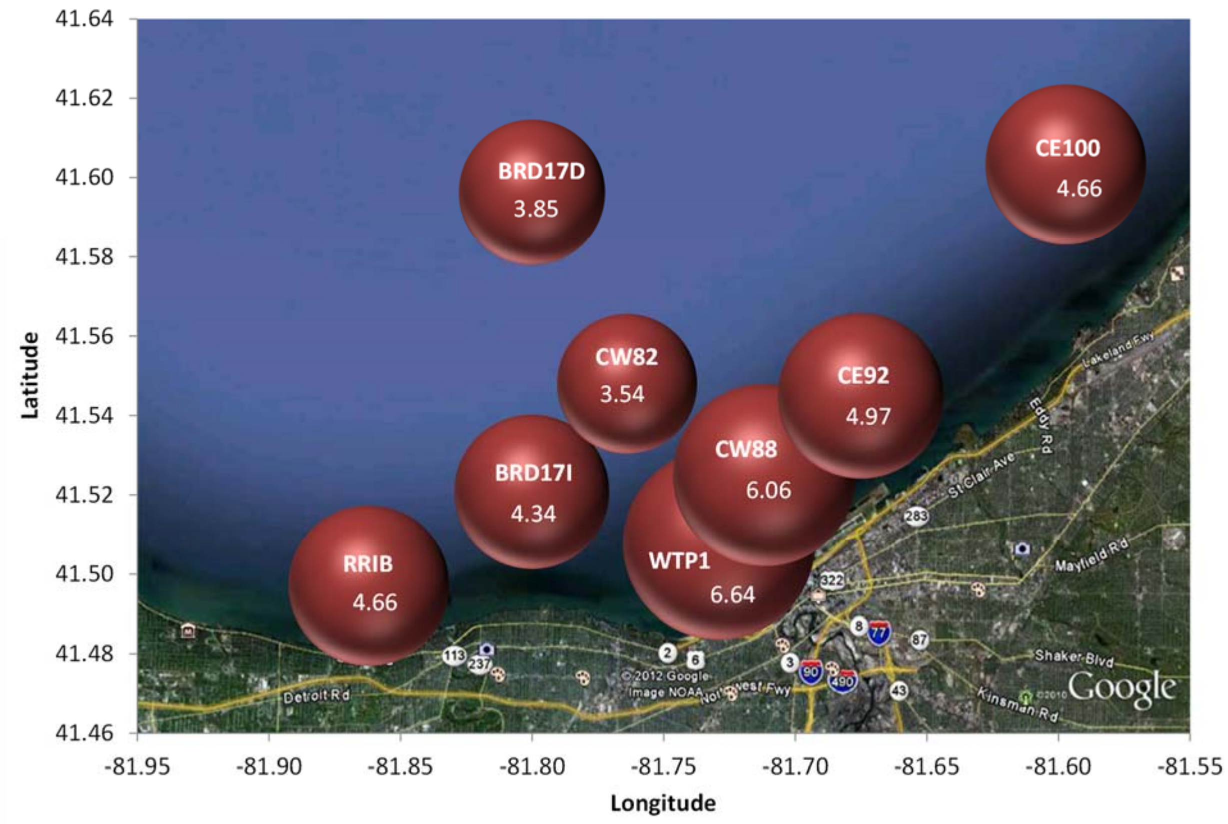


Figure 2. Average Lake Erie Chlorophyll *a* Concentrations (ug/L)

[1] Differences among groups of data were evaluated using the Kruskal-Wallis Test with an alpha of 0.05. Differences between two groups were evaluated using the Mann-Whitney Test, also with an alpha of 0.05.

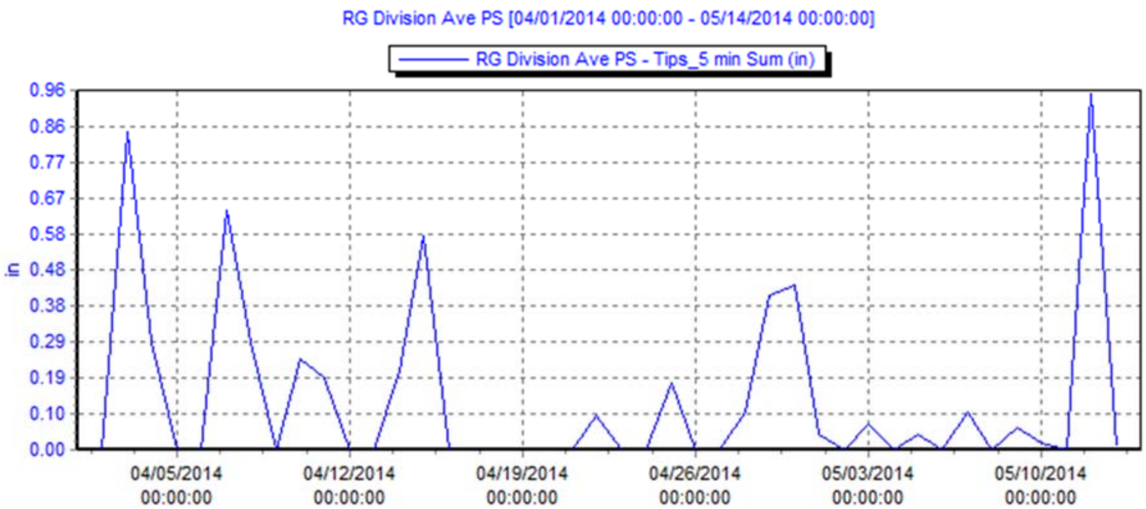
Table 5. 2014 Chlorophyll *a* Concentrations (ug/L)									
	RR1B	BRD17D	BRD17I	CW82	WTP1	CW88	CE92	CE100	Average:
5/13/2014 10:27	7.02	12.02	8.94	6.68	8.24	6.24	5.73	15.13	8.75
5/27/2014 11:22	1.49	1.55	0.75	1.04	0.99	1.71	0.85	1.45	1.23
6/10/2014 9:58	0.88	0.75	0.75	0.50	1.57	1.53	0.96	2.02	1.12
6/24/2014 10:12	1.95	1.45	1.78	2.22	7.46	2.98	---	1.90	2.82
7/9/2014 11:13	2.25	1.47	1.36	1.64	2.85	2.24	1.60	1.93	1.92
7/29/2014 11:15	8.18	1.81	6.50	3.86	8.52	5.26	10.58	7.61	6.54
8/12/2014 9:38	6.90	2.33	3.20	2.91	9.33	12.46	3.89	2.86	5.48
8/26/2014 10:38	3.65	2.69	4.29	2.67	11.13	12.13	4.15	2.20	5.36
9/9/2014 10:38	3.55	2.26	2.53	2.38	5.52	3.61	3.42	2.50	3.22
10/15/2014 11:10	9.51	9.29	11.06	8.93	13.55	12.37	13.11	9.26	10.88
10/28/2014 11:31	5.86	6.77	6.58	6.11	3.89	6.11	5.42	4.43	5.65
Average:	4.66	3.85	4.34	3.54	6.64	6.06	4.97	4.66	4.82

Meets GLWQA Target

As in past years, although there were no significant differences among the sites as a whole, there were some when looking at sample results by date. In general, the chlorophyll *a* concentrations were lower during the first half of the study. The exception to this was the first sampling event, in which the second highest average concentration was measured. During the six weeks prior to this sampling event, there were a series of wet-weather events that may have resulted in an increased nutrient load going to the lake (Figure 3). Increased algal densities have been found to occur in Lake Erie between four and eight weeks after receiving increased nutrients (Bridgeman et al, 2012). In addition, rivers may also serve as a source of algae to the lake. These potential explanations could account for the relatively high chlorophyll *a* measurements that were recorded during the May 13th event.

The highest overall average chlorophyll *a* concentration occurred during mid-October. According to the National Oceanic and Atmospheric Administration (2014), algal blooms were present in Lake Erie around the end of September/beginning of October. These blooms, originating from the western basin, had weakened by the October 15th sampling event, possibly due to mixing. Potentially, elevated algal levels from this were still present in the water column at that time, even though they did not meet the definition of a bloom.

Figure 3. Precipitation preceding May 13th Sampling Event



Relationships between chlorophyll *a* and potential controlling parameters were examined to determine significant correlations[2]. From this analysis, significant relationships were found between chlorophyll *a* and TP, TSS and turbidity; this was the same as was found in 2013. In all three cases, an increase in the parameter was correlated with an increase in chlorophyll *a*. Although statistically significant, the strength of these relationships were generally weak when including all of the data points. One reason for this could be due to the results for the May 13 from the sites near the Rocky River and the City of Cleveland breakwall. As indicated previously, the TP, TSS and turbidity from these sites on that day were extremely elevated due to the significant rain that had fallen in the area the day before. Because of this, the results for total phosphorus were separated into dry and wet weather samples[3] to determine the effect those samples had on the observed relationship with chlorophyll *a*. In doing so, it was found, that although there was still a lot of variability, a much stronger linear regression was found for the dry-weather results (Figure 4). For the wet-weather results, inclusion of the May 13 samples still resulted in a poor correlation coefficient (Figure 5). Exclusion of these samples resulted in a stronger relationship, but not as strong as was seen for dry weather. These results indicate that a direct relationship between TP and chlorophyll *a* may exist, but only to a certain TP concentrations. After a certain concentration is reached, other factors may be more important in determining how much algae is present. Potentially, this could be due to phosphorus no longer being the limiting factor at those concentrations.

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[2] Correlations were evaluated using Kendall's Tau and an alpha level of 0.05.

[3] Wet weather sampling events: greater than 0.10 inches of rain but less than 0.25 inches, samples collected that day and the following day are considered wet weather samples; greater than 0.25 inches, the samples collected that day and the following two days are considered wet weather samples.

Figure 4. Chlorophyll *a* as a Function of Total Phosphorus (Dry Weather)

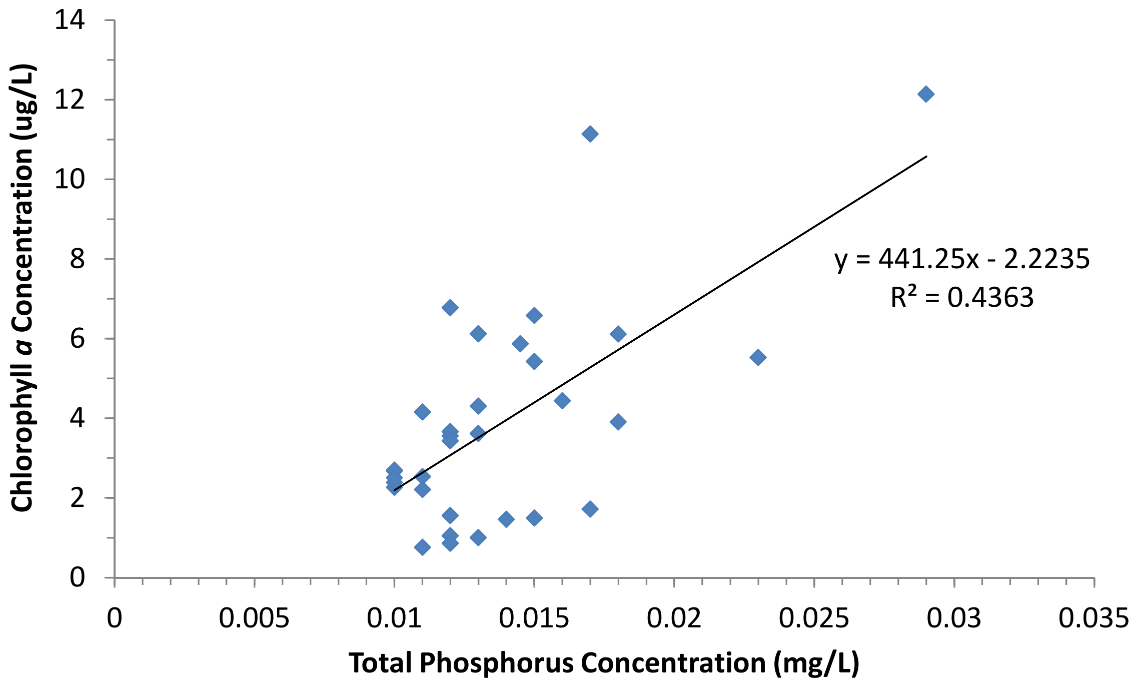
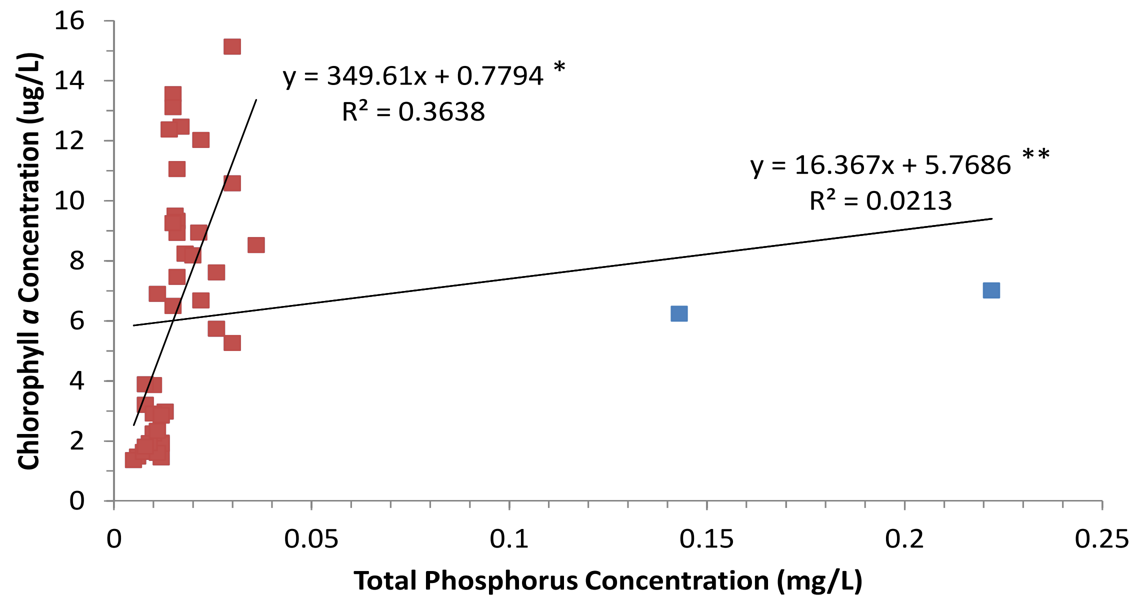


Figure 5. Chlorophyll *a* as a Function of Total Phosphorus (Wet Weather)



* Regression without May 13 samples collected from sites near Rocky and Cuyahoga Rivers
** Regression with May 13 samples collected from sites near Rocky and Cuyahoga Rivers

No significant correlations were found between chlorophyll *a* and DRP, NO_2 + NO_3, and NH_3. For DRP, many of the samples had concentrations below the method detection limit. As was found in previous years, removal of those points did not improve the correlation. Bridgeman et al. (2014) found that during different times of the year in Lake Erie's western basin, other forms of bioavailable phosphorus were also important sources for algal growth. Potentially, this could also be occurring within the central basin and could explain why a direct relationship between DRP and chlorophyll *a* has not been found.

Conclusions

In 2014, for the third consecutive year, Lake Erie was monitored by NEORSD to determine current conditions in terms of algal productivity and nutrient concentrations. For all three years, average chlorophyll *a* concentrations, used as a surrogate for algal densities, were found to be above set targets; the same was true for average TP concentrations. From the sampling that has been conducted, though, the factors most responsible for the observed chlorophyll *a* levels in the lake are still not understood. In 2012, based on a limited dataset, relatively strong positive correlations were found between chlorophyll *a* and TP. For the last two years, however, this relationship was not as clear when including all sample results, but improved when separating out samples collected during dry-weather events. No clear relationships have been found between chlorophyll *a* and NO_2+NO_3, NH_3, and DRP concentrations. One possible explanation for the lack of relationship with the last parameter is that other forms of bioavailable phosphorus are also contributing to algal growth.

Location within the study area has also not been directly linked to measured chlorophyll *a* levels, as no significant differences were found when comparing the sites as a whole. There were some differences, though, when examining some of the other parameters monitored during the study. The highest DRP concentrations were at the site closest to Easterly WWTP and Euclid Creek; the other nutrients measured were found to be highest at the sites most directly affected by flow from the Cuyahoga and Rocky Rivers.

While site location was not significantly linked with chlorophyll *a*, sampling date was found to be. One sampling event with relatively high concentrations occurred following a series of wet-weather events in the spring that may have increased nutrient loads to the lake. The sampling event with the highest average chlorophyll *a* concentration was in October following a period of algal blooms in the western basin of Lake Erie that may have extended to the central basin.

Continued sampling in 2015, following a variety of weather conditions, will potentially help to further refine these relationships and clarify the underlying mechanisms controlling the occurrence of algal blooms within the lake. Because a strong relationship between chlorophyll *a* concentrations and DRP was not found, other forms of phosphorus may also be contributing to the observed algal concentrations. Monitoring of other forms of bioavailable phosphorus may help to determine if this is true. Finally, the occurrence of higher chlorophyll *a* concentrations in the spring may be due to algal loading from tributaries such as the Cuyahoga and Rocky Rivers. Identification of algal species from those rivers and Lake Erie during April and May could be useful in establishing any links between them.

References

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