NORTHEAST OHIO REGIONAL SEWER DISTRICT

2019 Lake Erie Beach Monitoring

Prepared by
Water Quality and Industrial Surveillance Division

Introduction

Since 1992, the Northeast Ohio Regional Sewer District (NEORSD) has conducted bacteriological sampling on Lake Erie at Edgewater Beach, Villa Angela Beach, and Euclid Beach, in an effort to monitor bacteriological densities at the beaches. In 2005, sampling at Euclid Creek was added to determine the impact the creek may have on the water quality at Villa Angela and Euclid Beaches.

In 2019, the NEORSD continued these sampling efforts by monitoring the *Escherichia coli* (*E. coli*) densities at Edgewater, Villa Angela, and Euclid Beaches and Euclid Creek. The purpose of this sampling was to communicate beach conditions to the public and evaluate water quality standards attainment. In this report, an evaluation of water quality standards attainment will be made from the results from each sample site.

The sampling was completed by interns trained by NEORSD Level 3 Qualified Data Collectors (QDCs) certified by Ohio Environmental Protection Agency (Ohio EPA) in Chemical Water Quality Assessment, or by NEORSD Level 3 QDCs, as explained in the NEORSD study plan *2019 Lake Erie Beach Monitoring*, which was approved by Ohio EPA on March 22, 2019. Sample analyses were conducted by NEORSD's Analytical Services division, which is accredited by the National Environmental Laboratory Accreditation Program.

Table 1 indicates the sampling sites with respect to location, site or river mile (RM), latitude/longitude and description. Figure 1 is a map of the sampling locations at Edgewater, Euclid and Villa Angela Beaches and Euclid Creek.

In addition to monitoring for *E. coli*, the NEORSD has also performed limited harmful algal bloom (HAB) monitoring in the past several years, in response to recent increases in HABs in Lake Erie. In response to visual observation of HABs, the NEORSD performed additional sampling for identification of cyanobacterial genera and toxin concentration. No quality assurance, quality control sampling was performed for HAB toxins. Therefore, the presented HAB monitoring data does not qualify for the Ohio EPA QDC Level 3 program. The resulting data from HAB monitoring is only included in this report as supplementary information.

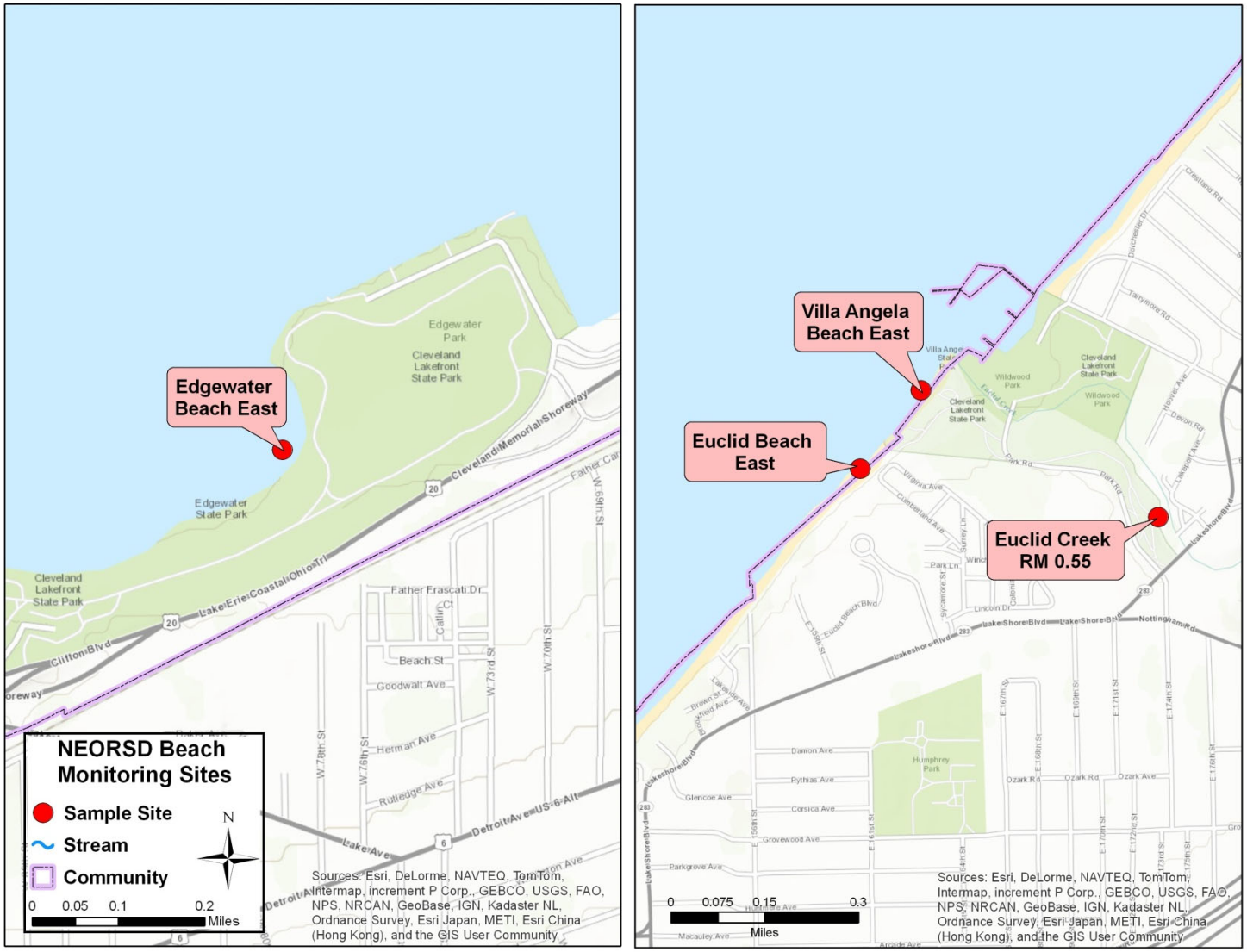


Figure 1. Map of Sampling Sites

Table 1. List of Lake Erie and Euclid Creek Sampling Sites						
Location	Site	Latitude	Longitude	Description	Quadrangle	Purpose
Edgewater Beach	East	41.4893	-81.7392	Eastern half of the beach. In line with the brick stack on the other side of the freeway	Cleveland South	• Public notification of water quality conditions at bathing beaches • Determination of water quality standards attainment • Evaluation of the impact of point and non-point sources
Villa Angela Beach	East	41.5851	-81.5677	Eastern half of beach, mid-distance between the 3rd and 4th break walls	East Cleveland	
Euclid Beach	East	41.5843	-81.5686	Eastern half of beach in line with the East side of the pile of stones on the beach	East Cleveland	
Euclid Creek	RM 0.55	41.5831	-81.5594	Downstream of Lakeshore Boulevard	East Cleveland	

Sampling Schedule and Methods

Bacteriological sampling was conducted from May 1, 2019 to September 30, 2019. From May 1 through May 16, water samples were collected from each beach and Euclid Creek RM 0.55 (further referred to simply as Euclid Creek) four days a week (Monday through Thursday). Beginning May 20, and lasting through September 1, samples were collected at each beach and Euclid Creek seven days a week. From September 2 through September 30, sampling at all sites returned to four days a week (Monday through Thursday). A total of 132 samples were collected at each site. Overall, a total of 555 samples including 27 duplicates were collected throughout the course of this study.

Field analysis included the use of a Hanna HI 98129 meter to measure pH, water temperature, and conductivity. The Hach 2100Q Portable Turbidimeter was additionally used to obtain field turbidity measurements. A long-term EXO2 sonde installed along the eastern break wall collected field measurements of chlorophyll *a* and phycocyanin pigments, pH, conductivity, temperature, and turbidity. The data sonde measurements were primarily used as a predictive tool for HAB monitoring. All water samples, field parameters and analyses were collected as specified in the most current NEORSD Beach Sampling Standard Operating Procedure (*SOP-EA016-18*) and Ohio EPA's *Surface Water Field Sampling Manual for water quality parameters and flows* (Ohio EPA, 2018).

Bacteriological grab samples were collected in a 250-mililiter sterilized polypropylene container. Samples at each location were collected approximately 6-12 inches below the surface, in water that was approximately three-feet deep. At the time of sample collection, field parameters were measured, and field observations and water conditions were documented at each beach site. All data that was collected was recorded on an NEORSD Beach Sampling Field Data Form. All samples were placed in a cooler with ice and stored in a locked NEORSD vehicle until the samples

were transferred to NEORSD's Analytical Services sample receiving with a Chain of Custody. All Beach Sampling Field Data Forms, Chains of Custody and Certificates of Analysis are available upon request from the Water Quality and Industrial Surveillance Division, and the Analytical Services Division.

The quality assurance and quality control of bacteriological water sample collections included field duplicates that were collected at a frequency not less than 5% of the total samples collected. A total of 27 duplicate samples were collected for a final duplicate frequency of 5%. Since field blanks are not required by method SM 9223 or by the National Environmental Laboratory Accreditation Conference (NELAC) for bacteria analysis, no bacteriological field blanks were collected during the study. Analytical Services has procedures in place which are required by NELAC to demonstrate that the sample containers are clean and sterile.

Relative percent difference (RPD) was used to determine the degree of discrepancy between the primary and duplicate sample (Formula 1).

Formula 1:
$$RPD = \left(\frac{|X-Y|}{((X+Y)/2)} \right) * 100$$

X= is the concentration of the parameter in the primary sample
Y= is the concentration of the parameter in the duplicate sample

For bacteriological samples, the acceptable RPD is 133.3%. Those RPDs that are higher than acceptable may indicate potential problems with sample collection and, as a result, the data would not be used for comparison to the water quality standards.

HAB grab samples were collected in accordance with the State of Ohio Harmful Algal Bloom Response Strategy for Recreational Waters (State of Ohio, 2016). Samples were collected at the densest part of the bloom that could be safely reached by wading and therefore represent the worst-case scenario for public exposure to HAB toxins. HAB grab samples were analyzed for toxin-producing genera by microscopic identification, and for total microcystin toxin by ELISA following EPA Method 546.

Results and Discussion

The *E. coli* results from each beach site were compared to the Ohio Water Quality Standards in order to determine recreational use attainment. From May 1st to October 31st, the three beaches are designated as Bathing Waters for the Protection of Recreational Use, while Euclid Creek is designated as a Primary Contact Recreation stream (Ohio EPA, 2018). Both the Bathing Waters and Primary Contact Recreation criteria for *E. coli* include a statistical threshold value (STV) criterion not to exceed 410 colony counts units per 100 milliliters (colony counts/100mL) in more than ten percent of the samples collected during any 90-day period and a 90-day geometric mean criterion of 126 colony counts/100mL. The Bathing Waters criteria also maintain the use of the previous single sample maximum limit of 235 colony counts/100mL as the beach action value for the purpose of posting daily water quality advisories.

Duplicate samples collected at Edgewater Beach and Euclid Creek were outside of the acceptable RPD on May 28, and June 1, and September 4, 2019 (Table 2). Data from these dates were therefore qualified as rejected. Potential reasons for these discrepancies include lack of precision and consistency in sample collection and/or analytical procedures, environmental heterogeneity, and/or improper handling of samples.

Table 2. Rejected Data Due to Unacceptable RPDs.

Site	Date	Result (MPN/100mL)	RPD	Acceptable RPD
Edgewater	5/28/2019	3	199.3	133.3
		1733		
Euclid Creek	6/01/2019	315	140.3	133.3
		1795		
Euclid Creek	9/4/2019	19,600	179.2	133.3
		1076		

Recreational Use Attainment Status

Edgewater Beach

Water Quality Standards attainment status of Edgewater Beach for Bathing Water recreational use criteria is shown in (Figures 2 and 3). Edgewater Beach was in attainment of the recreational use criteria for most of 2019, as the STV criterion was only exceeded at Edgewater Beach for 3.8% of the 90-day periods. The geometric mean criterion was not exceeded for any of the 90-day periods. Single samples exceeded the Beach Action Value of 235 colony counts/100mL for 18 of the 132 sampling events, a frequency of 13.7%. Fourteen of the 18 exceedances of the Beach Action Value (77.7%) occurred within 48 hours of a rain event with a total rainfall greater than 0.10 inches.

Figure 2. 2019 Edgewater Beach East Site - Attainment of Bathing Water STV Criterion

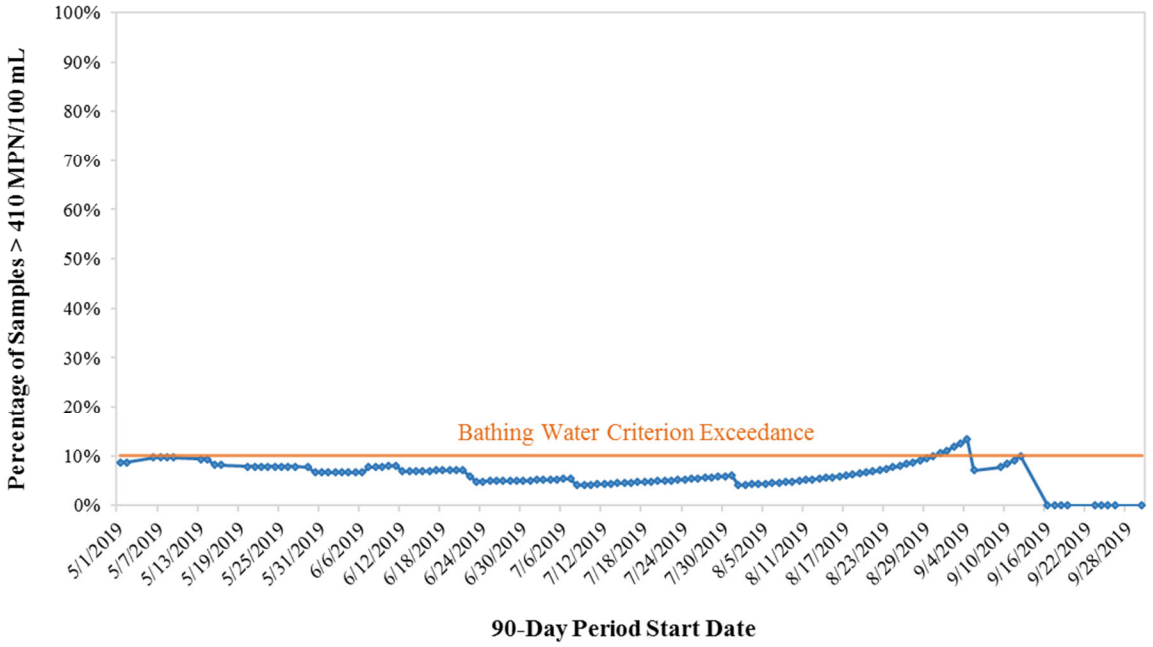
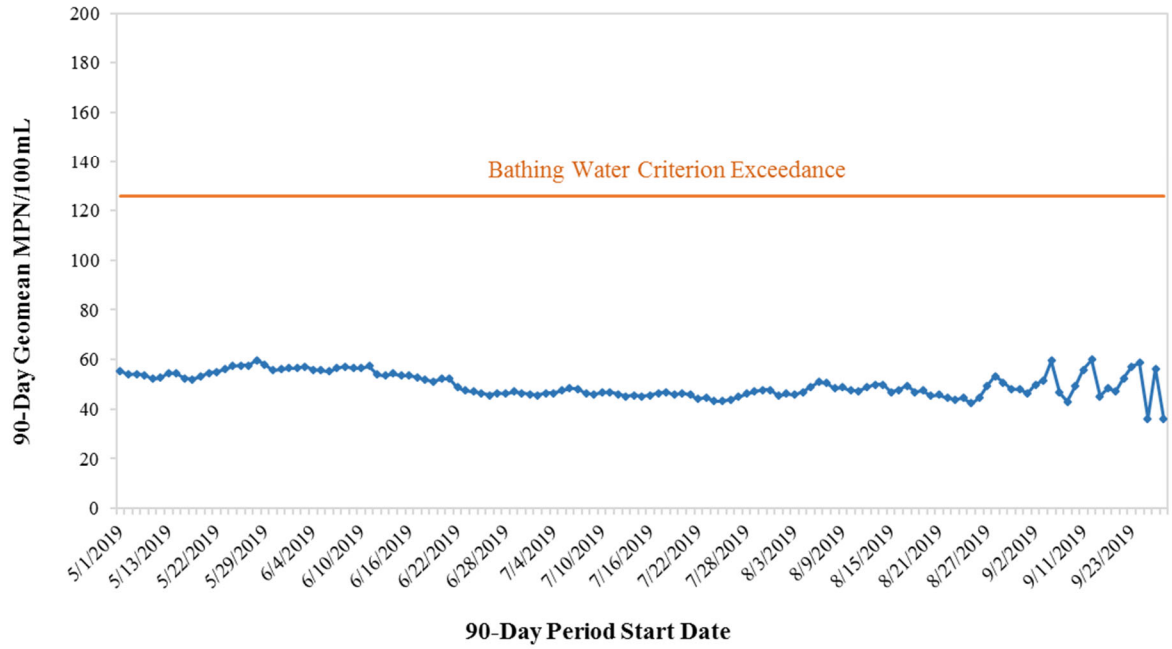


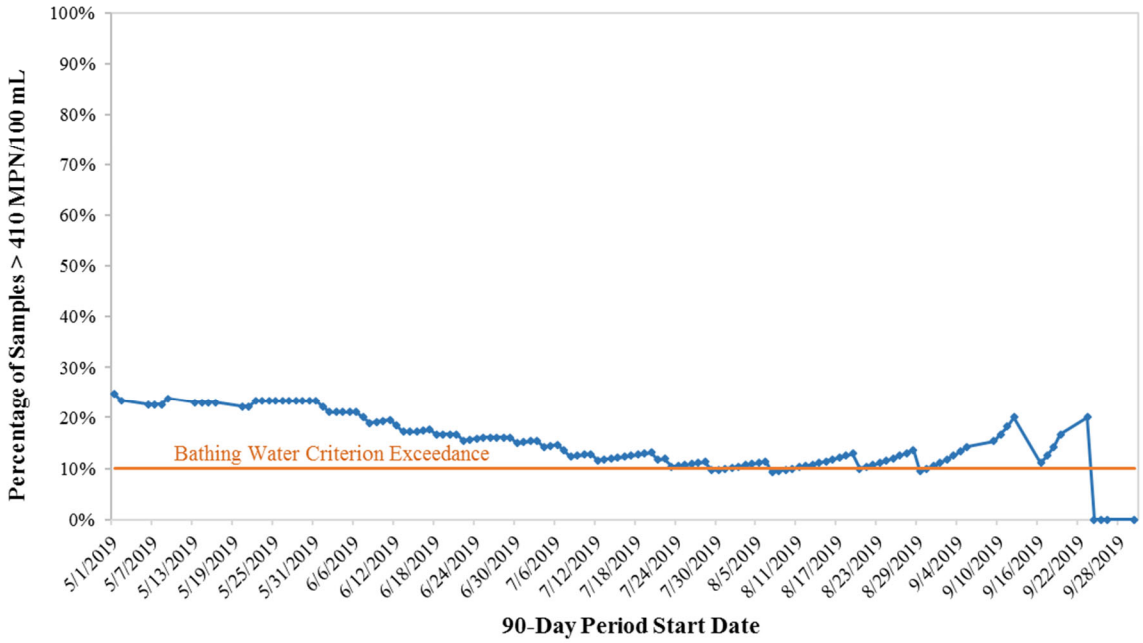
Figure 3. 2019 Edgewater Beach East Site - Attainment of Bathing Water 90-Day Geomean Criterion

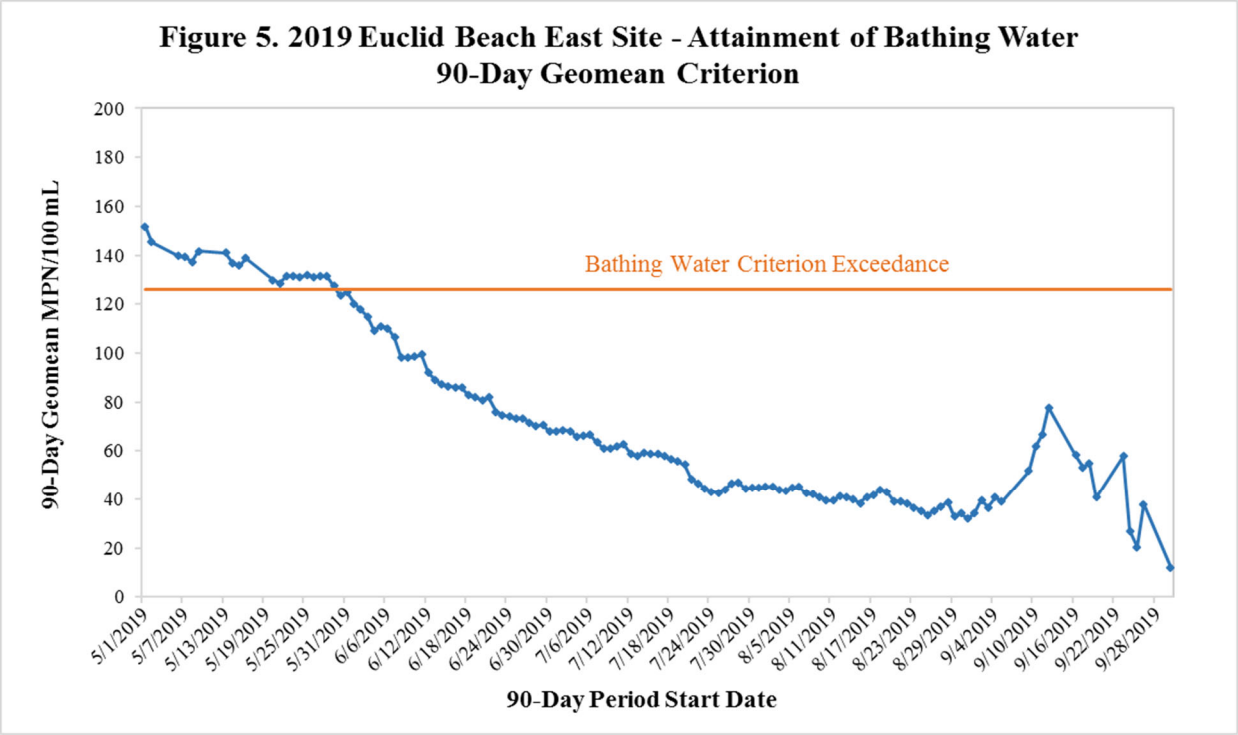


Euclid Beach

Euclid Beach was in non-attainment of the Bathing Water recreational use criteria for most of the recreation season in 2019 (Figures 4 and 5). Euclid Beach was in non-attainment of the STV criterion for 89.4% of the 90-day periods. Euclid Beach was also in non-attainment of the geometric mean criterion for twenty of the 90-day periods, an exceedance frequency of 15.2%. Single samples exceeded the Beach Action Value of 235 colony counts/100mL for 35 of the 132 sampling events, a frequency of 26.5%. Twenty of these 35 exceedances (57.1%) occurred within 48 hours of a rain event with a total rainfall greater than 0.10 inches.

Figure 4. 2019 Euclid Beach East Site - Attainment of Bathing Water STV Criterion





Villa Angela Beach

Villa Angela Beach was also in non-attainment of the Bathing Water recreational use criterion for most of 2019 (Figures 6 and 7). Villa Angela exceeded the STV criterion for 84.1% of the 90-day periods and exceeded the geomean criterion for 20.5% of the 90-day periods in 2019. Single samples exceeded the beach action value of 235 colony counts/100mL for 38 of the 132 sampling events, a frequency of 28.8%. Twenty-four of these 38 exceedances (63.2%) occurred within 48 hours of a rain event with a total rainfall greater than 0.10 inches.

Figure 6. 2019 Villa Angela Beach East Site - Attainment of Bathing Water STV Criterion

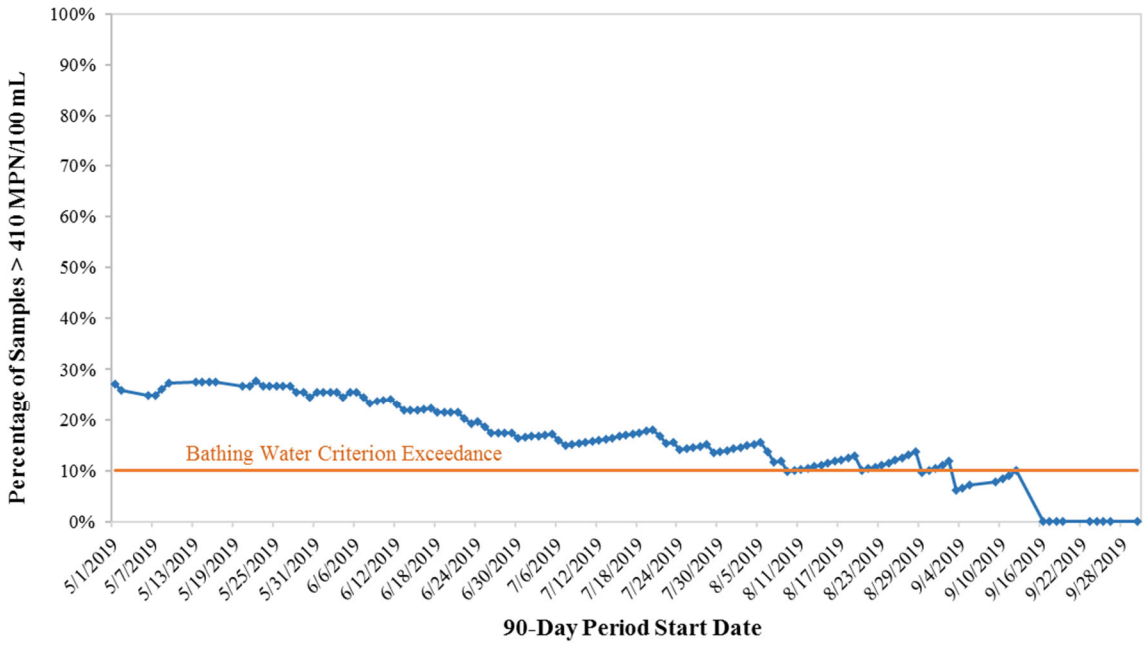
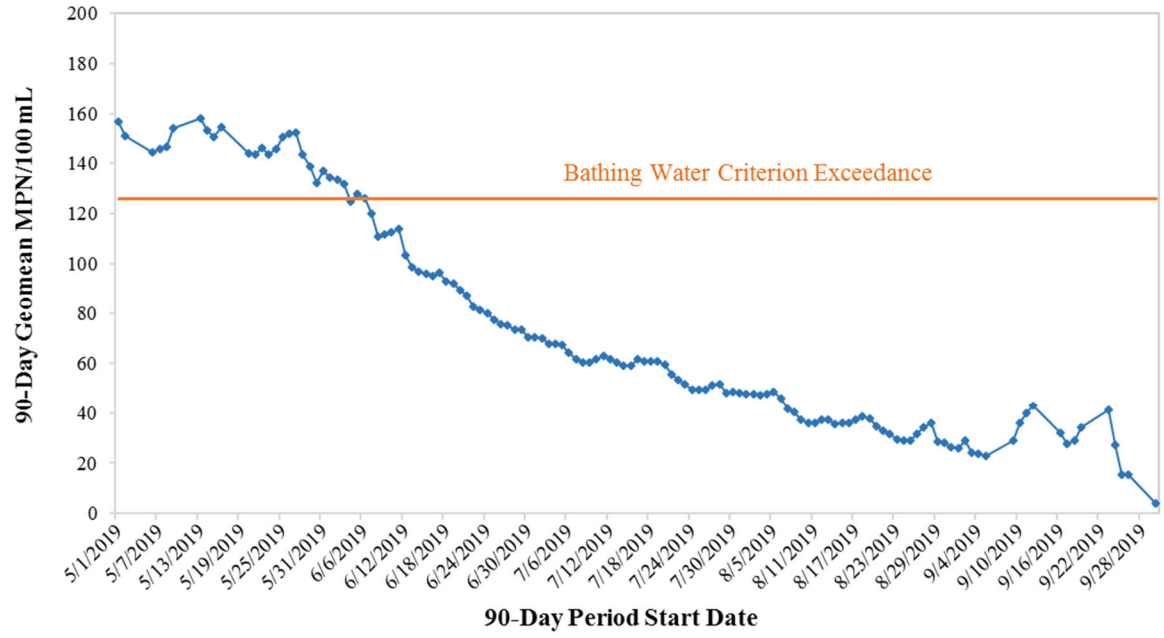


Figure 7. 2019 Villa Angela Beach East Site - Attainment of Bathing Water 90-Day Geomean Criterion



Euclid Creek RM 0.55

Euclid Creek was in non-attainment of both Primary Contact recreational criteria in 2019 (Figures 8 & 9). Euclid Creek exceeded the STV criterion for 98.5% of the 90-day periods and exceeded the geomean criterion for 99% of the 90-day periods. As further discussed below, Euclid Creek RM 0.55 has displayed this degree of exceedance for as long as monitoring has been performed by the NEORSD.

Figure 8. 2019 Euclid Creek RM 0.55 - Attainment of Bathing Water STV Criterion

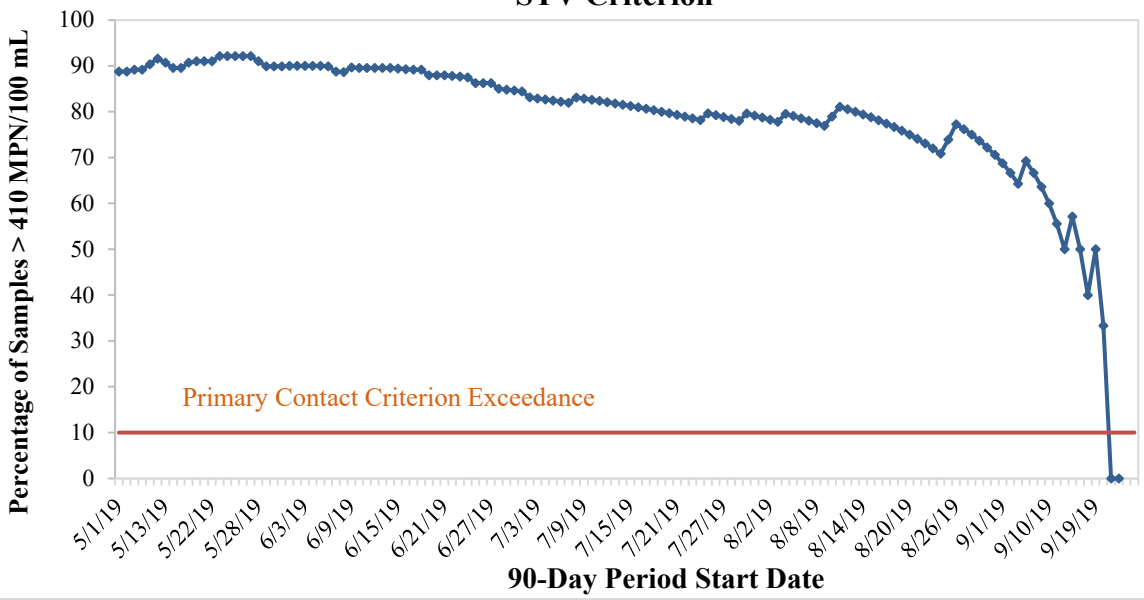
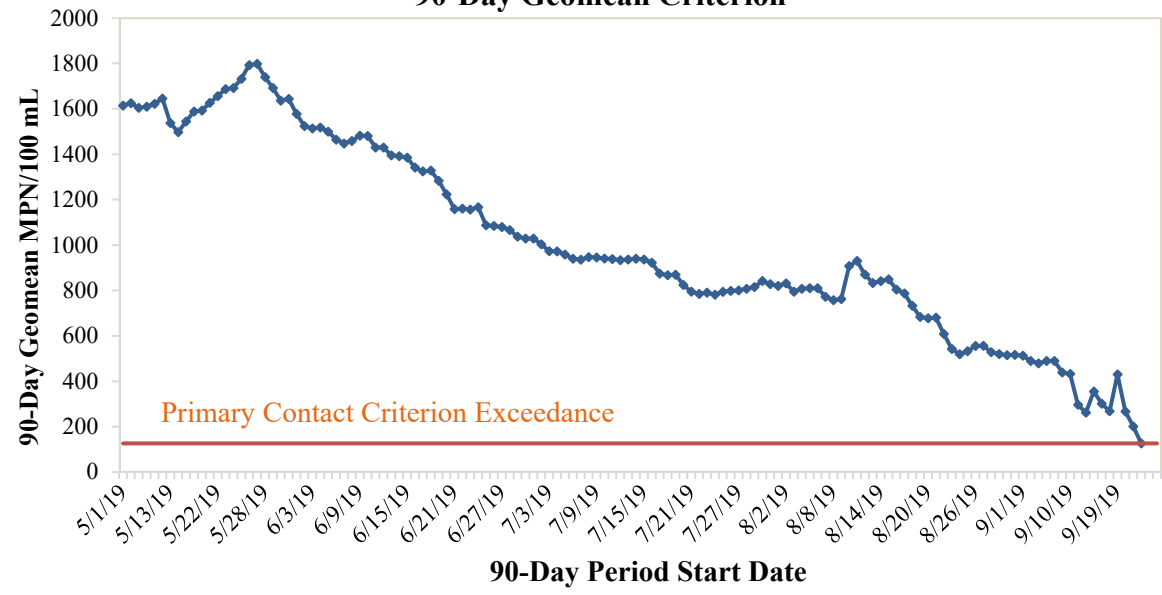


Figure 9. 2019 Euclid Creek RM 0.55 - Attainment of Bathing Water 90-Day Geomean Criterion



Comparison with Historical Data, Rainfall, and CSO Occurrence

Table 3 presents historical data on the recreational use criteria exceedances for all of the sites included in this study. The NEORSD began submitting beach monitoring data to the Ohio EPA Credible Data Program in 2009. Therefore, prior data is not included in this comparison. It should be noted that the recreational use criteria have been modified within the presented timeline. From 2009 to 2014, the applicable Bathing Waters recreational use criteria included an *E. coli* criterion not to exceed a single sample maximum (SSM) of 235 colony counts/100mL in more than ten percent of the samples collected during any 30-day period, and a seasonal geometric mean (SGM) criterion of 126 colony counts/100mL (Ohio EPA, 2010). The current 90-day STV and geometric mean criteria took effect in 2015. The data presented in Table 3 represents exceedances of the criteria that were applicable at the time of sample collection. For comparative purposes only, the SGM *E. coli* density was also calculated from data collected from 2015-2019, even though it does not apply to data collected from these years. Additionally, the beach action value of 235 colony counts/100mL used to post public advisories has remained constant for the entire period of record. The seasonal percent exceedance of the beach action value for each beach site is also presented in Table 3 for historical comparison

The SSM/STV percentages at all three beaches and Euclid Creek were found to be lower compared to the previous year. Villa Angela and Euclid Beaches saw slightly lower Beach Action Value percentages from 2018 as well. Except for Euclid Beach, the SGM was found to be higher at all sites in 2019. The *E. coli* densities at all sites were found to be higher over the past two seasons than in 2016 and 2017, which may be due to the above average amount of precipitation that occurred throughout the 2018 and 2019 recreational seasons. Table 4 presents total rainfall in inches during the past eight years of recreational seasons (May 1st to October 31st) as measured at the Division Avenue (located near Edgewater Beach) and Easterly WWTP rain gauges (located near Euclid and Villa Angela Beaches and Euclid Creek). Wet-weather[1] events have been known to contribute to elevated bacteria levels by causing discharges from CSOs, storm sewer runoff, urban runoff, and runoff from contaminated beach sand to enter Lake Erie. Therefore, the relatively rainy season that occurred in 2019 is most likely the primary factor responsible for the increased number of exceedances of the recreational water quality criteria at Villa Angela Beach, Euclid Beach, and Euclid Creek in comparison to the previous three seasons. The lower *E. coli* densities found at Edgewater Beach in 2019 may be due to the reduction in CSO events from 2018.

[1] 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.

Table 3. Historical Recreational Use Criteria Exceedances.					
Site	Year	SSM/STV % Exceedance	Geometric Mean % Exceedance	Beach Action Value %	SGM
EDGE	2019	3.8	0	13.7	52*
	2018	91.4	1.6	13.6	35*
	2017	0.0	0.0	6.9	30*
	2016	0.0	0.0	8.3	35*
	2015	34.8	0.0	18.8	77*
	2014	93.0	N/A	20.0	60
	2013	66.0	N/A	13.9	53
	2012	58.6	N/A	11.6	41
	2011	92.2	N/A	26.6	98
	2010	73.0	N/A	13.3	56
	2009	90.6	N/A	28.1	107
	Average	60.0	0.4	16.1	59.2
EUBE	2019	89.4	15.2	26.5	63*
	2018	98.6	2.0	29.8	84*
	2017	66.1	1.5	25.4	79*
	2016	89.5	0.0	24.8	71*
	2015	97.8	33.8	37.7	**136***
	2014	98.0	N/A	32.2	126
	2013	97.0	N/A	41.1	**144**
	2012	99.3	N/A	36.9	118
	2011	100	N/A	43.6	**149**
	2010	90.0	N/A	36.3	110
	2009	100	N/A	36.6	112
	Average	93.6	9.3	34.4	113
VABE	2019	84.1	20.5	28.8	100*
	2018	98.6	0.0	30.5	93*
	2017	79.2	8.4	29.2	89*
	2016	91.7	5.3	33.1	99*
	2015	97.8	51.8	46.4	**181***
	2014	96.0	N/A	34.4	**147**
	2013	91.0	N/A	41.7	**141**
	2012	100	N/A	41.5	110
	2011	100	N/A	46.0	**174**
	2010	100	N/A	34.9	**128**
	2009	100	N/A	43.8	**172**
	Average	95.4	16.4	38.2	**133**
EC RM 0.55	2019	98.5	99	N/A	**1241***
	2018	100	100	N/A	**1006***
	2017	100	100	N/A	**1510***
	2016	100	100	N/A	**907***
	2015	100	100	N/A	**1246***
	2014	100	N/A	N/A	**1617**
	2013	100	N/A	N/A	**1092**
	2012	100	N/A	N/A	**973**

Table 3. Historical Recreational Use Criteria Exceedances.					
Site	Year	SSM/STV % Exceedance	Geometric Mean % Exceedance	Beach Action Value %	SGM
	2011	100	N/A	N/A	**1351**
	2010	100	N/A	N/A	**1047**
	2009	99.3	N/A	N/A	**852**
	Average	99.9	100	N/A	**1134**
Exceedances of historical SGM criterion in **Bold (>126 colony counts per 100mL)** *SGM does not apply. Calculated for comparative purposes only.					

Table 4. Total Rainfall (Inches) from May 1st to October 31st.		
Year	Division Ave Rain Gauge	Easterly Rain Gauge
2019	31.80	27.70
2018	27.56	25.32
2017	16.56	20.30
2016	13.87	16.23
2015	23.40	23.41
2014	24.50	25.12
2013	21.35	28.31
2012	26.46	24.80
Average 2012-2019	23.46	23.90

Combined sewer overflow discharges may have contributed to the elevated *E. coli* densities observed at Villa Angela and Euclid Beaches in 2019. Proximity of nearby CSO outfalls to Edgewater, Euclid, and Villa Angela Beaches are shown in Figures 10 and 11. The number of overflow events and total volume of discharge from each of the listed CSOs from May 1 to October 31, is presented in Table 5.

In the proximity of Edgewater Beach, 17 overflow events occurred during the 2019 recreational season. Fifteen of these events occurred from CSO-002, the Westerly Wastewater Treatment Center Overflow. The remaining 2 occurred from CSO-069.

Eighty overflow events occurred in the proximity of Euclid and Villa Angela Beaches in 2019. These events most likely contributed to the elevated *E. coli* densities observed at these beaches. The Euclid Creek Tunnel, a CSO storage tunnel designed to capture CSO discharges, was brought online in September 2018. As a result of, there were zero overflow events at CSO-239 between May 1 and October 31. In total, the Euclid Creek Tunnel captured 54.98 million gallons of sewage and stormwater during that time period.

Elevated *E. coli* densities at Euclid and Villa Angela Beaches are additionally influenced by the proximity of these beaches to Euclid Creek. Euclid Creek was in 100% exceedance of the recreational water quality criteria for nine consecutive years prior to 2019, and in 98.5% exceedance in 2019. Local water current studies have demonstrated that the discharge of Euclid Creek flows to Euclid and Villa Angela Beaches and therefore directly impacts beach water quality (USGS, 2013). The elevated *E. coli* densities present at Euclid Creek are most likely due to a combination of sanitary sewage contamination from illicit discharges and combined sewer overflows, as well as contamination from fecal matter from companion animals. and wildlife from the surrounding urban community. NEORSD projects including illicit discharge remediation efforts, microbial source tracking efforts, and the Euclid Creek Storage Tunnel are expected to lead to improvement of the water quality of Euclid Creek in the coming years. It is therefore expected that these programs will also have a positive impact on the water quality of Euclid and Villa Angela Beaches.

A one-way ANOVA was conducted to compare the annual differences of *E. coli* densities at Euclid Creek from 2013 through 2019. The analysis determined there was not a significant difference in annual *E. coli* densities from 2013 through 2019 ($F(6,745) = 1.317$, $p = 0.247$). *E. coli* densities did not vary significantly in 2019 from the previous years, even with the completion of the Euclid Creek Storage Tunnel. It is possible that the water quality impacts to Euclid Creek from bacteriological contamination will be reduced over time due to the operation of the storage tunnel.

Another explanation for the lack of water quality improvements at Euclid Creek is that *E. coli* is being introduced upstream of CSO-239 and the NEORSD service area. In 2019, Field Biologist Dr. Eric Soehnlen started a study to evaluate the presence of *E. coli* in Euclid Creek. Samples were collected at several locations downstream and upstream of CSO-239 during wet and dry weather events. Initial results from the study show that there is not a significant difference in *E. coli* densities downstream and upstream of CSO-239, and that the elevated *E. coli* densities in Euclid Creek may originate from outside of the service area.

Figure 10. Proximity of CSO Outfalls to Edgewater Beach

Figure 11. Proximity of CSO Outfalls to Euclid and Villa Angela Beaches

		Table 5. CSO Events from May 1 to October 31.									
Outfall ID	Nearest Beach	Number of Overflow Events					Total Overflow Volume (Million Gallons)				
		2019	2018	2017	2016	2015	2019	2018	2017	2016	2015
CSO-002	Edgewater	15	19	8	9	16	155.8	277.7	180.3	125.3	235.2
CSO-069	Edgewater	2	2	0	0	3	0.2	0.1	0.0	0.0	6.5
CSO-071	Edgewater	0	3	0	0	5	0	No Flow Gauge	0.0	0.0	No Flow Gauge
CSO-001	Euclid/Villa Angela	19	23	17	28	31	294.8	670.5	614.6	1,346.7	2301.9
CSO-206	Euclid/Villa Angela	49	18	22	13	13	21.0	65.3	37.4	18.3	50.7
CSO-239	Euclid/Villa Angela	0	27	31	39	46	0	33.5	18.0	26.7	60.0
CSO-242	Euclid/Villa Angela	12	6	5	7	17	21.8	10.5	4.5	9.0	20.7

Harmful Algal Bloom Monitoring

On July 10, 2019, Cleveland Metroparks staff visually observed a harmful algal bloom at Edgewater Beach. A less predominant bloom was also observed at Villa Angela Beach, although the conditions were not indicative of a true harmful algal bloom. At 1230 hours, NEORSD Investigators arrived at Edgewater Beach and confirmed the presence of a potential HAB (Figure 12). Sampling was immediately performed in accordance with the State of Ohio Harmful Algal Bloom Response Strategy for Recreational Waters (State of Ohio, 2016). Investigators also performed sampling from Villa Angela Beach. The cyanobacterial genera Microcystis and Anabaena were confirmed in samples from Edgewater Beach. Cyanotoxin concentrations did not exceed recreational water numeric thresholds at Edgewater Beach, though a public advisory was still issued because of the presence of cyanobacteria. Cyanobacteria was not detected in the sample collected from Villa Angela Beach; therefore, no public advisory was posted.

Figure 12. HAB at Edgewater Beach on July 10, 2019.

Microcystin concentrations were not found to be elevated above the public advisory threshold of 6 µg/L at Edgewater Beach or Villa Angela Beach (Table 6). Additional samples were collected for microcystin analysis on a daily basis from July 11 until July 17, 2019. No

samples collected from either beach from July 10 through July 17, 2019, were found to have toxin concentrations above the public advisory threshold. The public advisory posting was lifted on July 18, 2019, following a full week of consecutively low HAB toxin results at both beaches.

Table 6. Total Microcystin Results (µg/L)		
Date	Edgewater	Villa Angela
7/10/2019	1.025	<0.13
7/11/2019	<0.13	<0.13
7/12/2019	<0.13	<0.13
7/13/2019	<0.13	<0.13
7/14/2019	<0.13	<0.13
7/15/2019	<0.13	<0.13
7/16/2019	<0.13	<0.13
7/17/2019	<0.13	<0.13

Conclusions

In 2019, Euclid and Villa Angela Beaches were found to be in non-attainment of the Bathing Water recreational criteria, while Edgewater Beach was in attainment of the criteria for the majority of the season. The elevated *E. coli* densities at these beaches compared to 2016 and 2017 years is most likely related to the elevated precipitation that occurred in 2019. Potential sources of *E. coli* that lead to elevated densities during wet-weather events include CSOs, storm sewer runoff, urban runoff, and runoff from contaminated beach sand to enter Lake Erie. The Euclid Creek Tunnel eliminated all CSO events from CSO-239 and captured 54.98 million gallons of sewage and storm water between May 1 and October 31, 2019. It is possible that the water quality may improve at Euclid Creek and Euclid and Villa Angela Beaches over time as a result of the storage tunnel, though the improvements may be limited by the introduction of bacteria upstream of the service area. During the 2019 recreation season, one HAB at Edgewater Beach produced cyanobacteria, though there were no exceedances of the public advisory threshold for microcystin toxin at any beach in 2019.

Acknowledgements

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

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

WQIS Paraprofessional Interns: Zachary Bayer, Kevin Fitzgibbons, Brandon Fitzpatrick, and Matthew Johnson
Analytical Services Division – Completed analysis for all bacteriological sampling.

References

Ohio Environmental Protection Agency. (2010). *State of Ohio Water Quality Standards Ohio Administrative Code* Chapters 3745-1-31, 3745-1-26, 3745-1-07. Revision: Adopted December 15, 2009; Effective March 15, 2010. Division of Surface Water, Standards and Technical Support Section. Columbus, Ohio.

Ohio Environmental Protection Agency. (2015). *Surface Water Field Sampling Manual for water quality parameters and flows.* Columbus, OH: Division of Surface Water.

Ohio Environmental Protection Agency. (2018). *State of Ohio Water Quality Standards Ohio Administrative Code* Chapter 3745-1 (Revision: May 1, 2018; Effective: July 30, 2018). Columbus, OH: Division of Surface Water; Standards and Technical Support Section.

State of Ohio. (2016) *State of Ohio Harmful Algal Bloom Response Strategy for Recreational Waters*. Columbus, Ohio: Department of Health, Environmental Protection Agency, and Department of Natural Resources.

USGS. (2013). Circulation, Mixing, and Transport in Nearshore Lake Erie in the Vicinity of Villa Angela Beach and Euclid Creek, Cleveland, Ohio, September 11-12, 2012. U.S. Geological Survey, Reston, Virginia.