Northeast Ohio
Regional Sewer District

2023 Euclid Creek
Biological, Water Quality, and Habitat Study

Water Quality and Industrial Surveillance

Environmental Assessment Group

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Introduction

In 2023, the Northeast Ohio Regional Sewer District (NEORSD) conducted environmental monitoring of the Euclid Creek watershed. This monitoring was performed as part of the NEORSD general watershed monitoring program. The intent of this program is to periodically assess all major watersheds in the NEORSD service area. Euclid Creek is a Lake Erie direct tributary that drains the communities of South Euclid, Lyndhurst, Willoughby Hills, Richmond Heights, Highland Heights, Euclid, and Cleveland. Additionally, the sites at river miles 1.65 and 0.55 were assessed in support of Ohio EPA Permit #3PA00002*JD.

Previous studies on Euclid Creek have indicated that sanitary sewage contamination is a primary cause of water quality impairments on Euclid Creek. Possible sources of sanitary sewage contamination to this watershed include common trench sewer inflow and infiltration, illicit discharges, combined sewer overflows, and local sanitary sewer overflows. Water quality improvements in Euclid Creek have been a long-term target of the NEORSD "Project Clean Lake" infrastructure investments. These projects utilize large underground storage tunnels to capture combined sewer overflow (CSO) discharges during wet weather for subsequent treatment. The NEORSD completed construction of the Euclid Creek Tunnel (ECT), a massive underground CSO storage tunnel, in 2015. The Tunnel was put fully online following completion of the ECT Dewatering Pump Station in 2019. This has resulted in the total capture of NEORSD-operated CSO discharges to Euclid Creek beginning in the recreational season of 2019.

In 2013 and 2014, prior to the completion of the ECT, the NEORSD performed full fish, macroinvertebrate, habitat, and water chemistry surveys of the Euclid Creek watershed. These studies demonstrated elevated bacterial levels in the stream in exceedance of the recreational criteria. The recreational criteria for *Escherichia coli* (*E. coli*) were exceeded at all sites, both upstream and downstream of NEORSD-operated CSOs, with the exception of Euclid Creek East Branch RM 0.25 in 2013. All sites were in partial or non-attainment of the warmwater habitat (WWH) biological criteria (NEORSD, 2013; NEORSD, 2014). The Euclid Creek Spillway located downstream of St. Clair Avenue and site-specific habitat characteristics were cited as the major limiting factors affecting the biological communities.

The Euclid Creek confluence with Lake Erie is located immediately to the east of Euclid and Villa Angela Beaches. The discharge from Euclid Creek has been demonstrated to negatively impact beach water during and following rain events. In 2018 the NEORSD conducted a joint study with the United States Geological Survey (USGS) to map local currents surrounding the Euclid and Villa Angela Beaches and the confluence of Euclid Creek (NEORSD, 2019). This study demonstrated that the Euclid Creek plume is a primary source of *E. coli* to Villa Angela and Euclid Beaches following major wet-weather events. Numerous additional studies have been conducted in recent years to identify sources of contamination to Euclid Creek and local beaches. In 2018 the NEORSD conducted a pilot microbial source tracking (MST) study on Euclid Creek. Samples were collected upstream and downstream of NEORSD-operated CSOs on Euclid Creek. This study demonstrated that there was no significant difference in *E. coli* downstream of NEORSD CSOs compared to upstream during a CSO discharge. This indicated that CSOs were not the primary

cause of sanitary sewage contamination to Euclid Creek (NEORSD, 2018). In 2019-2022 the NEORSD conducted a more rigorous MST study on Euclid Creek (NEORSD, 2022). This study concluded that human sanitary sewage contamination occurred throughout the entire Euclid Creek watershed, particularly during wet-weather events. This was primarily attributed to inflow and infiltration between common trench separate sanitary and storm sewer collections systems. This study also demonstrated that there was, at the time of the study, no significant improvement in wet-weather *E. coli* densities following the implementation of the ECT despite full capture of NEORSD-operated CSOs. This general watershed study aimed to further assess possible water quality and biological improvements following the completion of the ECT.

Sampling was conducted by NEORSD Level 3 Qualified Data Collectors (QDCs) certified by the Ohio Environmental Protection Agency (EPA) in Fish Community Biology, Benthic Macroinvertebrate Biology, Chemical Water Quality, and Stream Habitat Assessments as explained in the NEORSD study plan *2023 East Side Tributaries Environmental Monitoring*. All sampling and environmental assessments occurred between June 15, 2023, and September 30, 2023 (through October 15 for fish sampling assessments), as required in the Ohio EPA *Biological Criteria for the Protection of Aquatic Life Volume III* (1987b). The results were evaluated using the Ohio EPA's Qualitative Habitat Evaluation Index (QHEI), Index of Biotic Integrity (IBI), Modified Index of Well-Being (MIwb), and the Invertebrate Community Index (ICI). Water chemistry data was validated per methods outlined by the Ohio EPA *Surface Water Field Sampling Manual for water quality parameters and flows* (Ohio EPA, 2023) and compared to the Ohio Water Quality Standards for their designated use to determine attainment (Ohio EPA, 2021). An examination of the individual metrics that comprise the IBI, MIwb, and ICI was used in conjunction with the water chemistry data and QHEI scores to assess the health of the stream.

Figure 1 shows a map of the sampling locations, and Table 1 indicates the sampling locations with respect to stream, river mile (RM), latitude and longitude, and station identification. Table 2 indicates the Beneficial Use Designations with respect to stream. Sites were located on three branches of Euclid Creek. Euclid Creek Main Branch (ECMB), Euclid Creek East Branch (ECEB), and the Un-named Tributary to ECMB at RM 5.50 (UNT). A digital photo catalog of the sampling locations is available upon request by contacting the NEORSD's Water Quality and Industrial Surveillance (WQIS) Division.

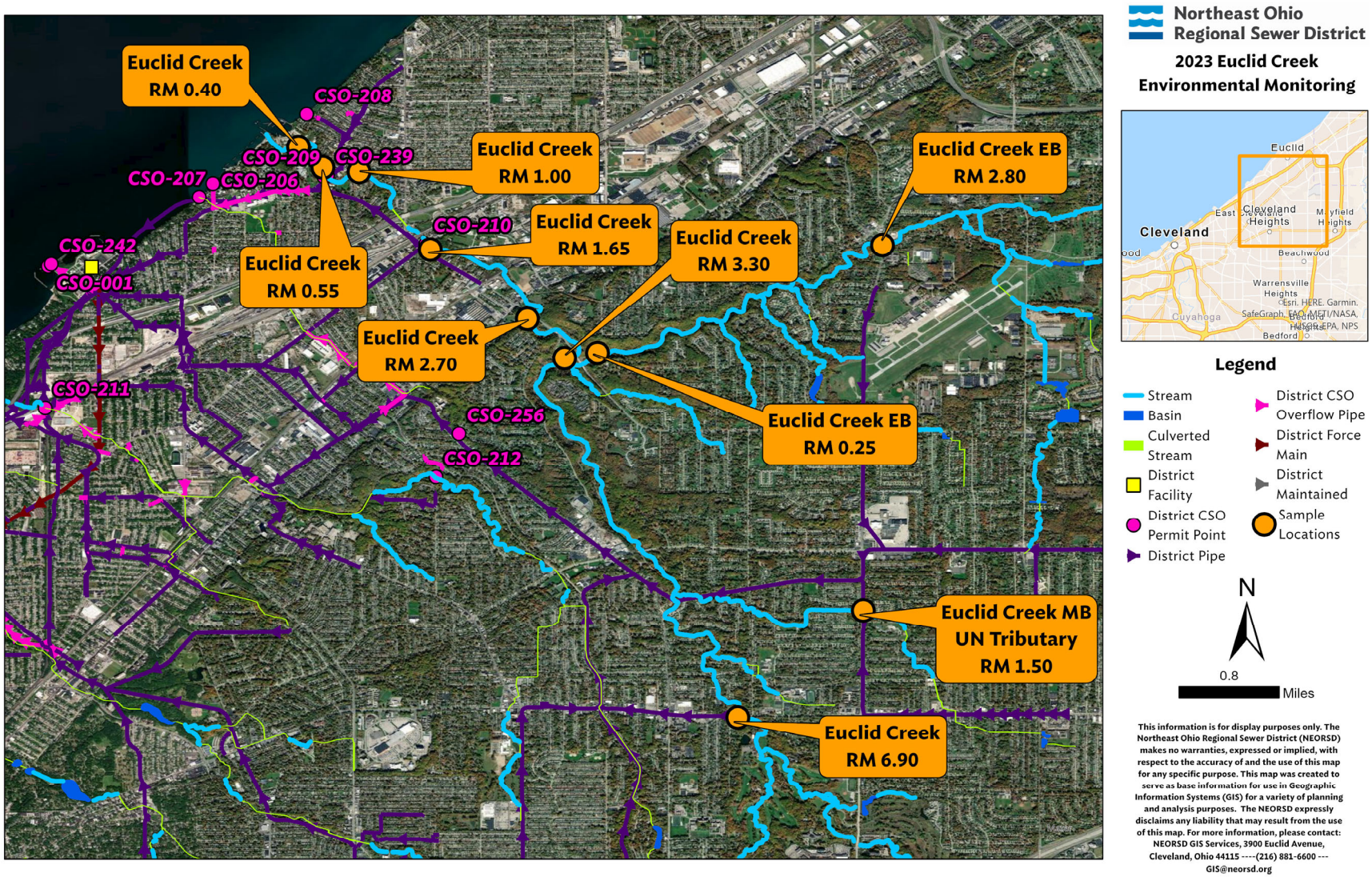

Figure 1. Sampling Locations

Table 1. Sampling Locations

Location	River Mile	Drainage Area	Latitude	Longitude	Station ID	Sampling Conducted
Euclid Creek	6.90	3.90	41.5196	-81.5115	F01G47	Habitat, Fish, Macroinvertebrates, and Water Chemistry
Euclid Creek	3.30	9.10	41.5612	-81.5315	F01G48	Habitat, Fish, Macroinvertebrates, and Water Chemistry
Euclid Creek	2.70	21.9	41.5658	-81.5358	200138	Habitat, Fish, Macroinvertebrates, and Water Chemistry
Euclid Creek	1.65	22.3	41.5738	-81.5470	504250	Habitat, Fish, Macroinvertebrates, and Water Chemistry
Euclid Creek	1.00	23.1	41.5828	-81.5552	F01A48	Habitat, Fish, Macroinvertebrates, and Water Chemistry
Euclid Creek	0.55	23.1	41.5833	-81.5594	F01A47	Habitat, Fish, Macroinvertebrates, and Water Chemistry
Euclid Creek	0.40	23.2	41.5857	-81.5622	F01A46	Habitat, Fish, Macroinvertebrates, and Water Chemistry
Euclid Creek Unnamed Tributary	1.50	1.20	41.5320	-81.4970	302508	Habitat, Fish, Macroinvertebrates, and Water Chemistry
Euclid Creek East Branch	2.80	7.05	41.5743	-81.4948	303283	Habitat, Fish, Macroinvertebrates, and Water Chemistry
Euclid Creek East Branch	0.25	12.5	41.5618	-81.5277	300602	Habitat, Fish, Macroinvertebrates, and Water Chemistry

Table 2. Applicable Beneficial Use Designations for Streams Assessed in 2023

Stream	Beneficial Use Designation												
	Aquatic Life Habitat (ALU)							Water Supply			Recreation		
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR
Euclid Creek-Anderson Road (RM 5.6) to U.S. Rte. 20 (RM 2.4)	*	+							+	+		+	
-all other segments		+							+	+		+	

SRW = state resource water; WWH = warmwater habitat; EWH = exceptional warmwater habitat;
MWH = modified warmwater habitat; SSH = seasonal salmonid habitat; CWH = coldwater habitat;
LRW = limited resource water
PWS = public water supply; AWS = agricultural water supply; IWS = industrial water supply;
BW = bathing water; PCR = primary contact recreation; SCR = secondary contact recreation.
*Designated use based on the 1978 water quality standards.
+Designated use based on the results of a biological field assessment performed by the Ohio Environmental Protection Agency.

Water Chemistry and Bacteriological Sampling

Methods

Water chemistry and bacteriological sampling was conducted at each site five times between June 20 and July 18, 2023, and analyzed for all parameters. Techniques used for sampling and analyses followed the Ohio EPA *Surface Water Field Sampling Manual for water quality parameters and flows* (Ohio EPA, 2023). Chemical water quality samples from each site were collected with a 4-liter disposable polyethylene cubitainer with a disposable polypropylene lid, three 473-mL plastic bottles and one 125-mL plastic bottle. The first 473-mL plastic bottle was field preserved with trace nitric acid, the second was field preserved with trace sulfuric acid and the third bottle received no preservative. The sample collected in the 125-mL plastic bottle (dissolved reactive phosphorus) was filtered using a 0.45-µm PVDF syringe filter. All water quality samples were collected as grab samples. Bacteriological samples were collected in 250 mL sterilized plastic bottles. At the time of sampling, measurements for dissolved oxygen (DO), DO percent, pH, temperature, conductivity, and specific conductance were collected using a YSI EXO1 sonde. Replicate, duplicate, and field blank samples were each 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/replicate 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/replicate sample

The acceptable percent RPD is based on the ratio of the sample concentration and detection limit (Formula 2) (Ohio EPA, 2019).

Formula 2: $$\text{Acceptable \% RPD} = [(0.9465X^{-0.344}) * 100] + 5$$

X = sample/detection limit ratio

Those RPDs that were higher than acceptable may indicate potential problems with sample collection and, as a result, the data was not used for comparison to the water quality standards.

Water chemistry analysis sheets for each site are available upon request from the NEORSD WQIS Division.

Results and Discussion

Data Validation QA/QC Checks

No samples were qualified due to field blank and paired parameter comparisons throughout the course of the study. Samples from three parameters were qualified as rejected due to high RPD between duplicate samples. The duplicate sample collected on June 20, 2023, was qualified for total suspended solids (TSS). The replicate sample collected on July 5, 2023, was qualified for sodium and strontium (Table 3). 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 3. Duplicate and Replicate QA/QC Data Qualifications

Site	Date	Parameter	Result1/ Result2	RPD	Acceptable RPD	Qualifier
UNT 1.50	6/20/2023	TSS	8.5 mg/L 18.2 mg/L	72.7	48.7	R (Rejected)
ECMB 6.90	7/05/2023	Sodium	153 mg/L 132 mg/L	14.7	13.6	R (Rejected)
ECMB 6.90	7/05/2023	Strontium	289 ug/L 254 ug/L	12.9	11.6	R (Rejected)

Bacteriological Exceedances

E. coli is a gram negative, facultative anaerobic bacterium, commonly found in the intestinal tract and feces of warm-blooded animals. *E. coli* is commonly used as a fecal indicator bacteria (FIB) to measure the presence of fecal contamination in surface waters (USEPA, 2012). The primary contact recreation criteria, under which the Euclid Creek watershed is designated, consist of two components. First is an *E. coli* criterion not to exceed a statistical threshold value (STV) of 410 colony counts or most probable number per 100 milliliters (410 MPN/100ml) in more than ten percent of the samples collected during any 90-day period. The second component is a 90-day geometric mean criterion of 126 MPN/100mL (Ohio EPA, 2021). In accordance with the Ohio EPA procedure and practice to qualify *E. coli* exceedances for the primary contact recreation criteria, the geometric mean and STV are only calculated and compared when a minimum of five bacteriological samples have been collected within a rolling 90-day period. Table 4 provides a summary of the recreational criteria comparisons for Euclid Creek. All sites were in exceedance of both recreational criteria in 2023.

Table 4. 2023 Summary of Recreational Use Criteria Exceedances for All Sites

Site	STV % Exceedance	90-Day Geometric Mean
ECMB 6.90	100	1461
ECMB 3.30	100	677
ECMB 2.70	100	682
ECMB 1.65	100	1403
ECMB 1.00	100	1169
ECMB 0.55	100	1219
ECMB 0.40	100	1151
UNT 1.50	100	1208
ECEB 2.80	80	736
ECEB 0.25	40	303
Criterion Limit	10	126

Similar studies were conducted at these sites in 2013 and 2014, prior to the construction of the ECT. Due to the low number of samples collected per year, and the high potential variation in *E. coli* densities from sample to sample due to changes in rainfall and flow conditions, it is difficult to draw comparisons between years. Rainfall and corresponding increases in stream flow have been found to correlate with elevated *E. coli* densities in urban streams including Euclid Creek (NEORSD, 2022). This may be due to a combination of factors that occur during wet weather

including, but not limited to, increases in common trench sewer inflow and infiltration, CSO and sanitary sewer overflow (SSO) discharges, and urban runoff. Figure 2 shows Euclid Creek flow conditions at all sample collection times in 2013, 2014, and 2023 at the Lakeshore Boulevard gauge (USGS gauge number 04208700). There were one and two samples collected during periods of elevated flow in 2013 and 2014, respectively, with the remainder of the samples being collected near baseline levels. Four samples collected during 2023 were collected during baseline flow periods with a single sample being collected during a period of moderate elevation.

Figure 3 provides boxplots of the *E. coli* data at each site by year. ECEB RM 0.25 had the lowest relative *E. coli* densities compared to the remaining sites in the watershed in all years. Elevated *E. coli* densities were ubiquitous throughout the ECMB and the UNT both before and after the completion of the ECT as has been observed in previous studies (NEORSD, 2022). The most likely cause of *E. coli* contamination in this watershed is inflow and infiltration from common trench sewer systems, which are more prevalent in the ECMB watershed than the ECEB watershed (Zgnelic, 2016).

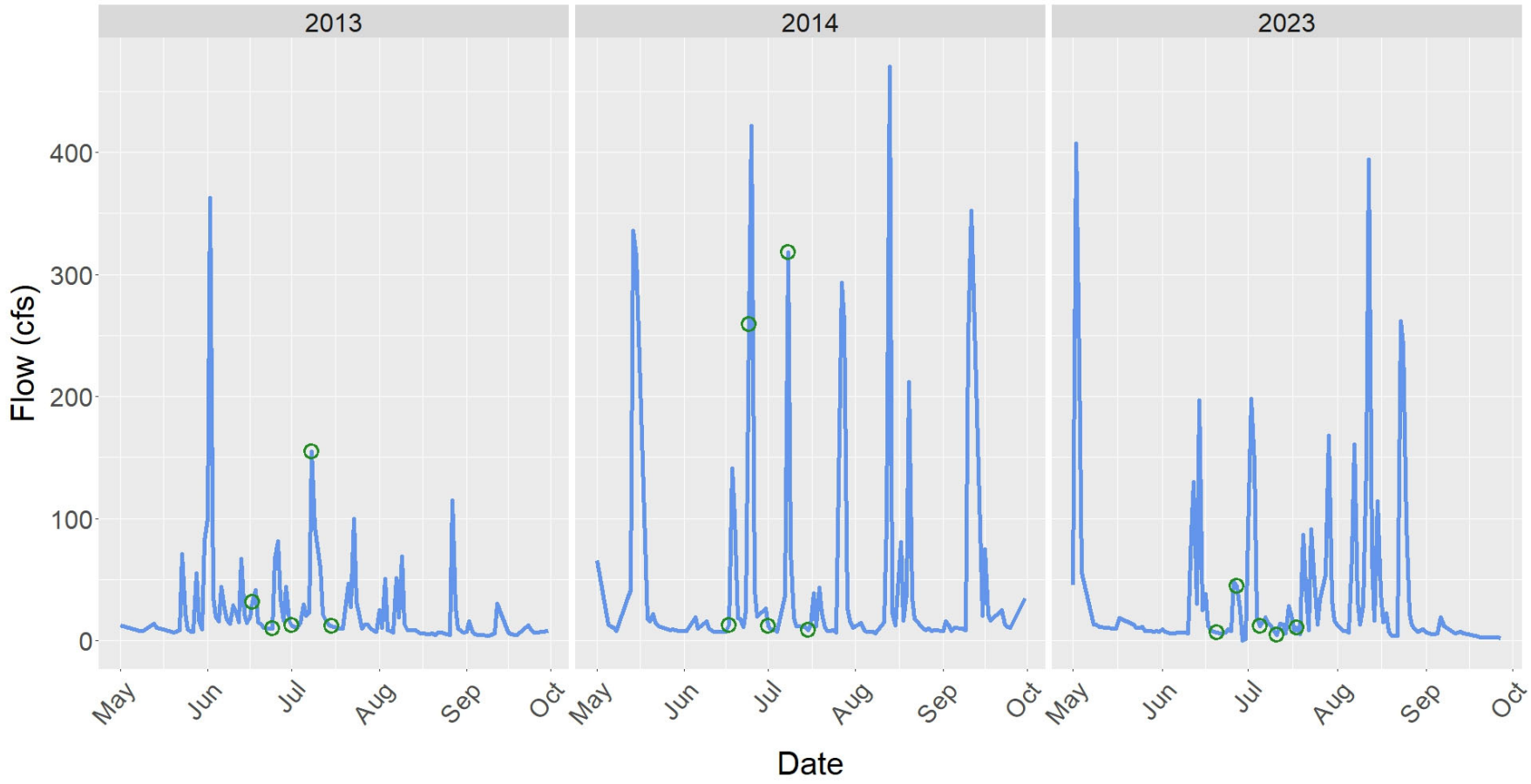

Figure 2. Euclid Creek flow (blue line) at the time of sample collection (green circle) by year.

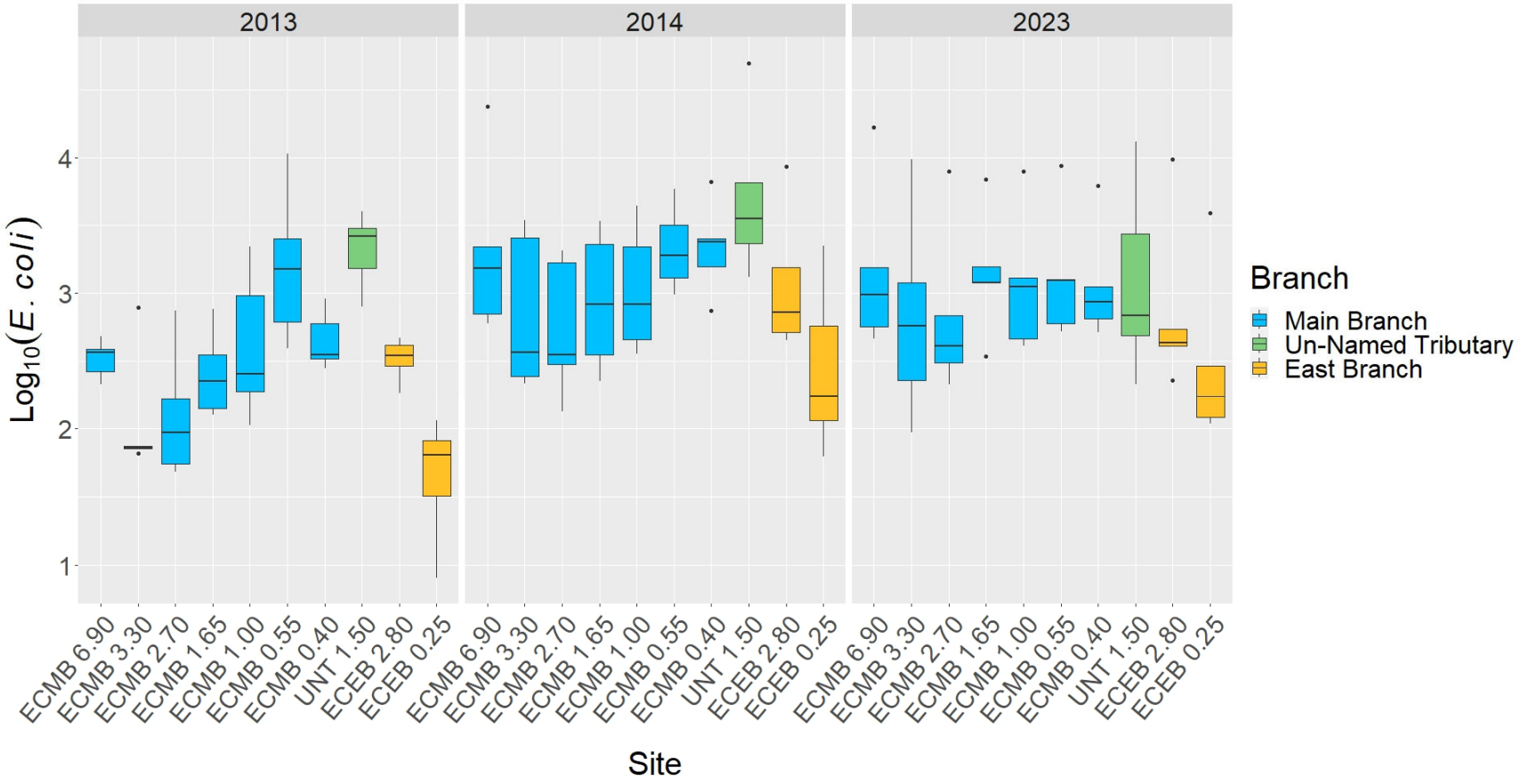

Figure 3. *E. coli* distributions at each site by year.

Mercury Exceedances

Mercury was analyzed using EPA Method 245.1. Because the minimum detection limit (MDL) for this method is above the criteria for the Human Health Nondrinking OMZA (0.0031 ug/L) and Protection of Wildlife OMZA (0.0013 ug/L), it is often difficult to determine whether or not sites are in attainment of those criteria. Mercury results were greater than the MDL at all sites on June 20, 2023, and at all sites except ECMB RM 0.55 and ECEB RM 2.80 on July 11, 2023. For the calculation of the 30-day average, the concentration of all sample results below the MDL is assumed to be half the MDL. Figure 4 shows the water quality criteria comparisons with the 30-day average mercury concentrations for all sites. All sites were in exceedance of the Human Health Nondrinking and Wildlife OMZAs for mercury in 2023. No other exceedances of water quality criteria were observed in this study.

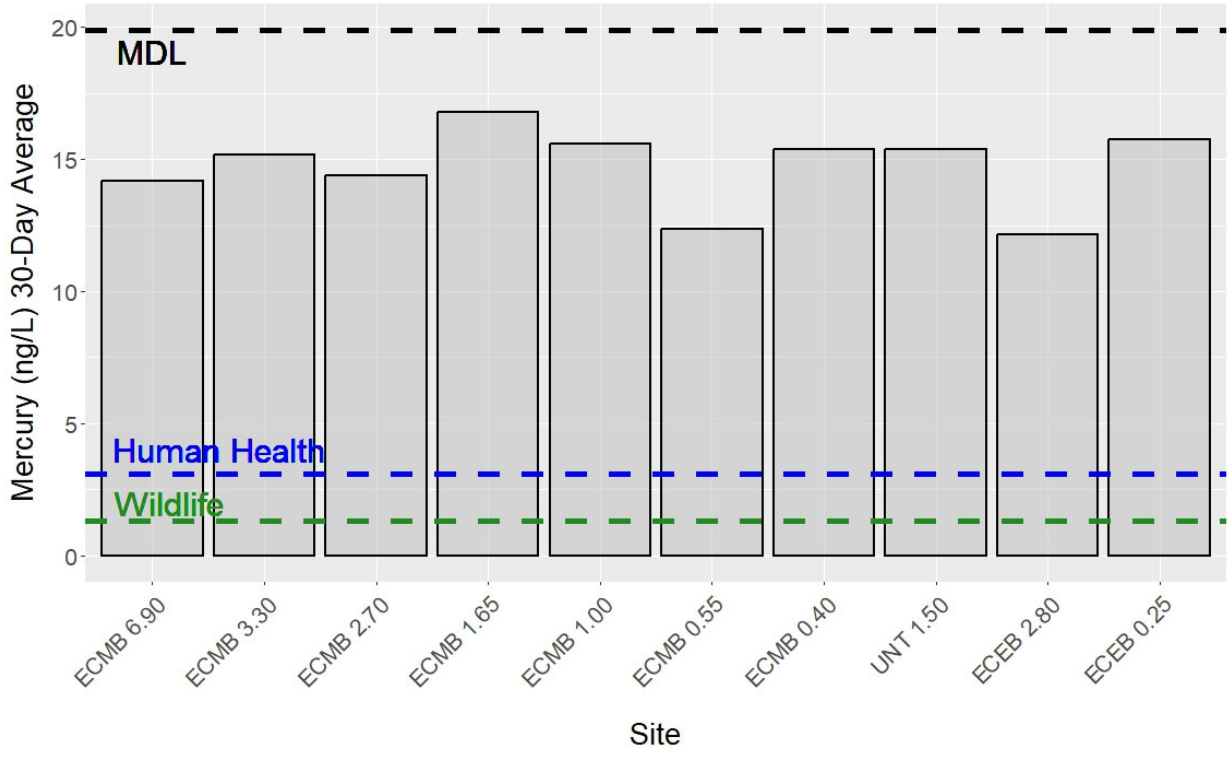

Figure 4. Mercury water quality criteria comparisons.

Nutrient Assessment

In 2015, the Ohio EPA Nutrients Technical Advisory Group released a proposed Stream Nutrient Assessment Procedure (SNAP) designed to determine the degree of impairment in a stream due to nutrient enrichment. SNAP assigns designations for quality of surface waters based on factors including DO diel swings, benthic chlorophyll *a*, total phosphorous, and dissolved inorganic nitrogen (Ohio EPA, 2015).

Maintenance of low levels of nutrients such as nitrogen and phosphorus in Euclid Creek will help limit loading to Lake Erie. An excess of nitrogen and phosphorus can lead to nutrient enrichment in the lake, fueling harmful algal blooms (HABs), which can contribute to hypoxic or anoxic (low or oxygen depleted) zones. Hypoxia degrades water quality, impacting biogeochemical cycling and can be fatal to aquatic life.

Some species of cyanobacteria responsible for HABs can produce toxins like microcystins. Microcystins are potent toxins that are harmful to human and animal health. Exposure can occur through ingestion, inhalation, or dermal contact. Acute effects include vomiting, headache, rashes, fever, diarrhea, and abdominal pain. Additional research is needed to determine long-term health effects and the fate of microcystins in the environment, but the toxin has high potential as a carcinogen.

Table 5 provides the geometric mean nutrient concentrations for all sampling sites in 2023. The results of dissolved inorganic nitrogen (DIN) and total phosphorous (TP) were compared to Table 2 listed in the SNAP document (Figure 5; Ohio EPA, 2015). The following categories were assigned to each site according to this procedure. UNT RM 1.50 was categorized as "levels typical of enriched condition; low risk to beneficial use if allied responses are within normal ranges". ECEB RM 2.80 was categorized as "levels typical of moderately enriched condition in nitrogen limited systems; low risk to beneficial use if allied responses are within normal ranges". All remaining sites were categorized as "levels typical of developed land; little or no risk to beneficial uses".

DO diel swings are an indication of nutrient enrichment used in the SNAP protocol. One long-term sonde station is operated on Euclid Creek by the NEORSD at Lakeshore Boulevard, Cleveland, just upstream of ECMB RM 0.55. Review of the DO data from this sonde station during the sampling period of this study indicated that the probe had not been in the water, likely due to low-flow conditions. Future modification of the sonde housing may be required to ensure proper data collection at this site. Data collected earlier in the year appeared to have been measured with the sonde appropriately placed below the water surface as periodic diel swings for temperature, DO and pH typical of this stream were reflected in the data. The period between May 25 and June 5, 2023, was selected as this represented a complete dataset collected during baseline flow conditions appropriate for measuring DO swing. Table 6 provides maximum and minimum DO concentrations for the period between May 25 and June 5, 2023. The average DO swing was 8.5 mg/L which is above the "Wide Swing" recommended limit of 6.5 mg/L according to SNAP. This indicates that Euclid Creek is impaired, with nutrient overenrichment likely.

Table 5. 2023 Geometric Mean Nutrient Concentrations (n = 5)						
Site	DIN (mg/L)	NO_3-NO_3 (mg/L)	NH_3 (mg/L)	TKN (mg/L)	TP (mg/L)	DRP (mg/L)
ECMB 6.90	0.478	0.360	0.051	0.657	0.045	0.017
ECMB 3.30	0.348	0.323	0.022	0.463	0.047	0.029
ECMB 2.70	0.368	0.337	0.026	0.431	0.063	0.045
ECMB 1.65	0.404	0.321	0.030	0.446	0.056	0.036
ECMB 1.00	0.283	0.246	0.034	0.520	0.055	0.034
ECMB 0.55	0.274	0.237	0.032	0.485	0.054	0.034
ECMB 0.40	0.262	0.228	0.031	0.558	0.053	0.032
UNT 1.50	0.901	0.720	0.057	0.484	0.190	0.149
ECEB 2.80	0.379	0.344	0.034	0.651	0.119	0.081
ECEB 0.25	0.379	0.344	0.029	0.383	0.075	0.057

		← *DECREASING RISK*				
	TP Conc. (mg/l)	**DIN Concentration** (mg/l)				
		<0.44	0.44 < 1.10	1.10 < 3.60	3.60 < 6.70	≥6.70
DECREASING RISK →	<0.040	background levels typical of least disturbed conditions	levels typical of developed lands; little or no risk to beneficial uses	levels typical of modestly enriched condition in phosphorus limited systems; low risk to beneficial use if allied responses are within normal ranges	levels typical of enriched condition in phosphorus limited systems; moderate risk to beneficial use if allied responses are elevated	characteristic of tile-drained lands; otherwise atypical condition with moderate risk to beneficial use if allied responses are elevated (1.1% of observations)
	0.040-<0.080	levels typical of developed lands; little or no risk to beneficial uses	levels typical of developed lands; little or no risk to beneficial uses	levels typical of working landscapes; low risk to beneficial use if allied responses are within normal ranges	levels typical of enriched condition in phosphorus limited systems; moderate risk to beneficial use if allied responses are elevated	characteristic of tile-drained lands; moderate risk to beneficial use if allied responses are elevated (1.1% of observations)
	0.080-<0.131	levels typical of modestly enriched condition in nitrogen limited systems; low risk to beneficial use if allied responses are within normal ranges	levels typical of working landscapes; low risk to beneficial use if allied responses are within normal ranges	levels typical of working landscapes; low risk to beneficial use if allied responses are within normal ranges	characteristic of tile-drained lands; moderate risk to beneficial use if allied responses are elevated; increased risk with poor habitat	characteristic of tile-drained lands; moderate risk to beneficial use if allied responses are elevated (1.0% of observations)
	0.131-<0.400	levels typical of modestly enriched condition in nitrogen limited systems; low risk to beneficial use if allied responses are within normal ranges	levels typical of enriched condition; low risk to beneficial use if allied responses are within normal ranges	levels typical of enriched condition; low risk to beneficial use if allied responses are within normal ranges; increased risk with poor habitat	enriched condition; generally high risk to beneficial uses; often co-occurring with multiple stressors; increased risk with poor habitat	enriched condition; generally high risk to beneficial uses; often co-occurring with multiple stressors
	≥0.400	atypical condition (1.3% of observations)	atypical condition (1% of observations);	enriched condition; generally high risk to beneficial uses; often co-occurring with multiple stressors; increased risk with poor habitat	enriched condition; generally high risk to beneficial uses; often co-occurring with multiple stressors ; increased risk with poor habitat	enriched condition; generally high risk to beneficial uses; often co-occurring with multiple stressors

"allied responses" = allied response indicators (24-hour DO swing, benthic chlorophyll)

Figure 5. Table 2 of the Stream Nutrient Assessment Procedure (Ohio EPA, 2015).

Table 6. Daily DO Swings at Euclid Creek at Lakeshore Boulevard, Cleveland			
Date	Maximum DO	Minimum DO	DO Swing
5/25/2023	14.7	6.7	8.0
5/26/2023	14.9	7.0	7.9
5/27/2023	15.1	6.2	9.0
5/28/2023	15.3	6.0	9.3
5/29/2023	13.9	4.9	9.0
5/30/2023	13.3	5.0	8.3
5/31/2023	12.6	4.4	8.1
6/1/2023	12.0	4.3	7.8
6/2/2023	12.6	4.6	8.0
6/3/2023	12.3	4.7	7.6
6/4/2023	13.0	5.1	7.9
6/5/2023	13.9	5.4	8.5
Average	13.6	5.4	8.3
Standard Deviation	1.2	0.9	0.5

Habitat Assessment

Methods

Instream habitat assessments were conducted at all in-stream sites using the Qualitative Habitat Evaluation Index (QHEI). The QHEI was developed by the Ohio EPA to assess aquatic habitat conditions that may influence the presence or absence of fish species by evaluating the physical attributes of a stream. The index is based on six metrics: stream substrate, instream cover, channel morphology, riparian zone and bank condition, pool and riffle quality, and stream gradient. The QHEI has a maximum score of 100, with slightly different narrative ranges for streams based on total drainage area (Table 7). For headwater streams, a score greater than 55 (and for larger streams a score greater than 60) suggests that sufficient habitat exists to support a fish community that attains the warmwater habitat criterion (Ohio EPA, 2006). Scores greater than 70 for headwaters (and 75 for larger streams) frequently demonstrate habitat conditions that can support exceptional warmwater fauna. A more detailed description of the QHEI can be found in Ohio EPA's *Methods for Assessing Habitat in Flowing Waters: Using the Qualitative Habitat Evaluation Index (QHEI)* (Ohio EPA, 2006). QHEI field sheets for each site are available upon request from the NEORSD WQIS Division.

Table 7. Narrative Ranges Assigned to QHEI Scores		
Narrative Rating	QHEI Range	
	Headwaters (drainage ≤ 20 sq miles)	Larger Streams (drainage > 20 sq miles)
Excellent	≥70	≥75
Good	55-69	60-74
Fair	43-54	45-59
Poor	30-42	30-44
Very Poor	<30	<30

Results and Discussion

All sites with the exceptions of ECMB RMs 1.00 and 0.55 met the WWH QHEI targets for their respective stream sizes and should be of high enough quality to support healthy fish assemblages. (Figure 6). Euclid Creek RM 1.00 received a narrative rating of *Fair*. Lack of good development, low sinuosity, moderate embeddedness, and sparse instream cover all contributed to the low score at this site. This site is located at the downstream end of a concrete flood control channel which is periodically dredged by the Army Corps of Engineers. This structure contributed to the low QHEI score at ECMB 1.00. ECMB RM 0.55 also received a narrative rating of *Fair*. Low sinuosity and poor development due to the lack of riffles contributed to the low score at this site. It should be noted that this site is highly dynamic and influence from Lake Erie regularly modifies the habitat. At the time of the habitat evaluation, the riffle was not present, although a riffle intermittently forms at the site depending on Lake Erie water levels and stream flow. The UNT RM 1.50 received a narrative rating of *Excellent*. All other sites received a narrative rating of *Good*.

Individual components of the QHEI can also be used to evaluate whether a site can meet its WWH designated use (Table 8). This is done by categorizing specific attributes as indicative of either a WWH or modified warmwater habitat (MWH) (Rankin, 1995). Attributes that are considered characteristic of MWH are further classified as being a moderate or high influence on fish communities. The presence of one high or four moderate influence characteristics has been found to result in lower IBI scores, with a greater prevalence of these characteristics usually preventing a site from meeting WWH attainment (Ohio EPA, 2006). All sites in 2023 had a combination of one high and/or four moderate influence characteristics, with the exception of UNT RM 1.50, indicating that there was a greater prevalence of characteristics preventing these sites from meeting the fish WWH attainment criterion.

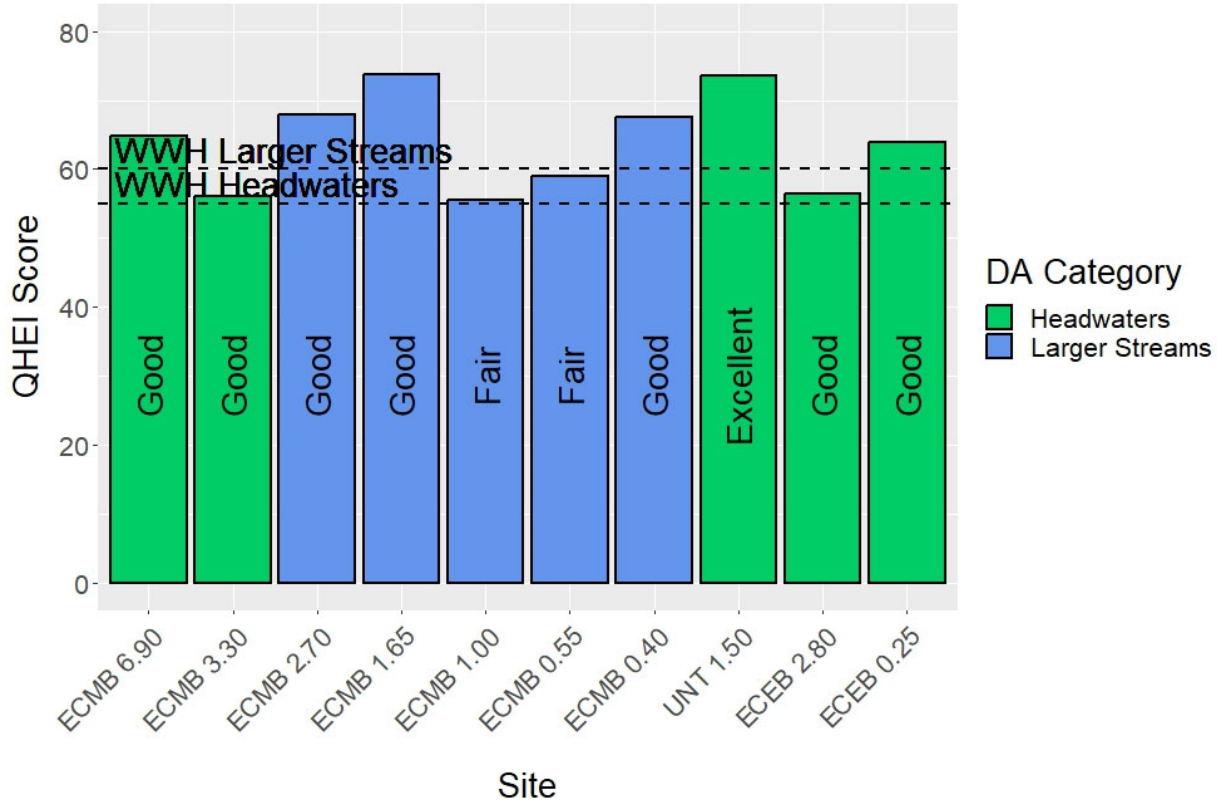

Figure 6. QHEI scores for each site monitored in 2023.

Table 8. QHEI Scores and Physical Attributes

			WWH Attributes											**MWH Attributes**																				
														High Influence						Moderate Influence																
Sampling Location	**QHEI Score**	**Habitat Rating**	No Channelization or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Development	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low-Normal Overall Embeddedness	Max. Depth >40 cm	Low-Normal Riffle Embeddedness	**Total WWH Attributes**	Channelized or no Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40 cm (WD, HW sites)	**Total High Influence Attributes**	Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1-2 Cover Types	Intermittent & Poor Pools	No Fast Current	High/Mod. Overall Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	**Total Moderate Influence Attributes**	**(MWH H.I.+1) / (WWH+1) Ratio**	**(MWH M.I.+1) / (WWH+1) Ratio**
ECMB 6.90	64.75	*Good*	X	X		X	X			X	X		**6**				X		**1**					X				X	X	X		**4**	0.3	0.7
ECMB 3.30	56.00	*Good*					X		X	X	X	X	**5**				X		**1**	X				X								**2**	0.3	0.5
ECMB 2.70	68.00	*Good*	X	X		X	X	X	X	X	X	X	**9**				X		**1**					X	X							**2**	0.2	0.3
ECMB 1.65	73.75	*Good*	X	X		X	X		X	X	X	X	**8**				X		**1**		X				X							**2**	0.2	0.3
ECMB 1.00	55.50	*Fair*		X					X		X		**3**				X		**1**	X				X	X				X	X		**5**	0.5	1.5
ECMB 0.55	59.00	*Fair*	X	X				X			X		**4**						**0**		X			X	X			X	X		X	**6**	0.2	1.4
ECMB 0.40	67.50	*Good*	X	X			X	X			X		**5**						**0**		X			X				X	X		X	**5**	0.2	1.0
UNT 1.50	73.50	*Excellent*		X		X	X	X		X	X	X	**7**						**0**	X					X			X				**3**	0.1	0.5
ECEB 2.80	56.50	*Good*	X		X		X		X	X	X	X	**7**				X		**1**					X								**1**	0.3	0.3
ECEB 0.25	64.00	*Good*	X	X		X			X		X		**5**			X	X		**2**										X	X		**2**	0.5	1.0

Fish Community Biology Assessment

Methods

Two quantitative electrofishing passes were conducted at each site in 2023. A list of the dates when the surveys were completed including stream discharge at the USGS gauge station located at Lakeshore Boulevard (Station ID 04208700) are shown in Table 9. Sampling was conducted using boat (ECMB 0.40) and longline (all other sites) electrofishing techniques and consisted of shocking all habitat types within a sampling zone. ECMB 0.40 was sampled using boat electrofishing methods despite having a relatively low drainage area due to the presence of deep channels that were un-wadable at this lacustuary site. Sites were sampled by slowly and steadily wading or boating through the stream while sampling shoreline and submerged habitat. The sampling zone was 0.15 kilometers for the headwater sites, 0.20 kilometers for the wading sites, and 0.50 kilometers for the boat site. All sampling followed the Ohio EPA methods as detailed in *Biological Criteria for the Protection of Aquatic Life, Volumes II* (1987a) and *III* (1987b). Fish collected during the surveys were identified and examined for the presence of anomalies, including DELTs (deformities, eroded fins, lesions, and tumors). Fish collected at streams with a drainage area greater than twenty square miles were weighed and counted, while sites with a drainage area less than twenty square miles were counted only. All fish were then released to the waters from which they were collected, except for vouchers and those that could not be easily identified in the field.

Table 9. Electrofishing Dates

Site	Date	Stream Discharge at USGS Gauge Station 04208700 (cfs)
ECMB 6.90	7/10/2023	7.18
	9/5/2023	5.79
ECMB 3.30	8/3/2023	8.25
	9/5/2023	5.79
ECMB 2.70	8/29/2023	7.37
	9/27/2023	2.29
ECMB 1.65	8/3/2023	8.25
	9/27/2023	2.29
ECMB 1.00	7/14/2023	6.07
	9/20/2023	2.37
ECMB 0.55	7/14/2023	6.07
	9/20/2023	2.37
ECMB 0.40	6/23/2023	6.64
	9/8/2023	5.48
UNT 1.50	8/28/2023	9.24
	10/11/2023	4.50
ECEB 2.80	8/28/2023	9.24

Table 9. Electrofishing Dates		
Site	Date	Stream Discharge at USGS Gauge Station 04208700 (cfs)
	10/11/2023	4.50
ECEB 0.25	8/29/2023	7.37
	10/10/2023	7.19

The electrofishing results were compiled and utilized to evaluate fish community health through the application of three Ohio EPA indices. The first index, the Index of Biotic Integrity (IBI), incorporates twelve community metrics representing structural and functional attributes (Table 10). The structural attributes are based upon fish community aspects such as fish abundance and diversity. The functional attributes are based upon fish community aspects such as feeding strategies, environmental tolerances, and disease symptoms. These metrics are individually scored by comparing the data collected at the survey site with values expected at reference sites located in a similar geographical region. The maximum possible IBI score is 60 and the minimum possible score is 12. The summation of the 12 individual metrics scores provides a single-value IBI score, which corresponds to a narrative rating of *Exceptional, Good, Marginally Good, Fair, Poor* or *Very Poor*.

The second fish index used by the Ohio EPA is the Modified Index of Well-being (MIwb). The MIwb (calculated using Formula 1 below) incorporates four fish community measures: numbers of individuals, biomass, the Shannon Diversity Index ($\overline{H}$) (Formula 2 below) based on sample numbers, and the Shannon Diversity Index ($\overline{H}$) based on sample weights.

Formula 1: $$MIwb = 0.5\,lnN + 0.5\,lnB + \overline{H}(No.) + \overline{H}(Wt.)$$

N = Relative numbers of all species excluding species designated as highly tolerant, hybrids, or exotics

B = Relative weights of all species excluding species designated as highly tolerant, hybrids, or exotics

$\overline{H}(No.)$ = Shannon Diversity Index based on numbers

$\overline{H}(Wt.)$ = Shannon Diversity Index based on weight

Formula 2: $$\overline{H} = -\sum\left[\left(\frac{n_i}{N}\right)log_e\left(\frac{n_i}{N}\right)\right]$$

n_i = Relative numbers or weight of species

N = Total number or weight of the sample

ECMB 0.40 is located in the lacustuary zone of Euclid Creek and is heavily influenced by Lake Erie. Therefore, the Ohio EPA Lacustuary Index of Biotic Integrity (LIBI) was also applied to ECMB 0.40. The LIBI is described in the *Biological Criteria for the Protection of Aquatic Life: Volume*

IV: Fish and Macroinvertebrate Indices for Ohio's Lake Erie Nearshore Waters, Harbors and Lacustuaries (Ohio EPA, 1994). This volume was only published in draft form and is not used for regulatory purposes. The LIBI analysis is therefore used for comparative purposes only. The LIBI is composed of 12 community metrics shown in Table 10.

Table 10. IBI Metrics

Boat Sites	Wading Sites	Headwater Sites (<20 sq. miles)	Lacustuary Sites
Number of Indigenous Fish Species	Number of Indigenous Fish Species	Number of Indigenous Fish Species	Number of Native Species
Percent Round-bodied Suckers	Number of Darter Species	Number of Darter Species	Number of Benthic Species
Number of Sunfish Species	Number of Sunfish Species	Number of Headwater Species	Number of Sunfish Species
Number of Sucker Species	Number of Sucker Species	Number of Minnow Species	Number of Cyprinid Species
Number of Intolerant Species	Number of Intolerant Species	Number of Sensitive Species	Number of Intolerant Species
Percent Tolerant Species	Percent Tolerant Species	Percent Tolerant Species	Percent Tolerant Species
Percent Omnivore Species	Percent Omnivore Species	Percent Omnivore Species	Percent Omnivore Species
Percent Insectivore Species	Percent Insectivore Species	Percent Insectivore Species	Percent Phytophilic Species
Percent of Top Carnivore Species	Percent of Top Carnivore Species	Percent Pioneering Species	Percent of Top Carnivore Species
Number of Individuals (minus tolerants)	Number of Individuals (minus tolerants)	Number of Individuals (minus tolerants)	Number of Individuals (minus Gizzard Shad)
Percent of Simple Lithophilic Spawners	Percent of Simple Lithophilic Spawners	Number of Simple Lithophilic Species	Percent Non-Indigenous Species
Percent of Individuals with DELTs	Percent of Individuals with DELTs	Percent of Individuals with DELTs	Percent of Individuals with DELTs

Euclid Creek is located completely within the Erie-Ontario Lake Plains (EOLP) ecoregion and follows the EOLP IBI metric scoring. The WWH IBI scoring criterion in the EOLP ecoregion is 40 for headwater and boat sites and 38 for wading sites. A site is within non-significant departure if the score falls within 4 IBI units or 0.5 MIwb units of the criterion (Table 11). Lists of the species diversity, abundance, pollution tolerances, and incidence of DELT anomalies for fish collected during the electrofishing passes at each site are available upon request from the NEORSD WQIS Division.

Table 11. Fish Community Biology Scores in the EOLP Ecoregion							
Ohio EPA Narrative	Very Poor	Poor	Fair	Marginally Good	Good	Very Good	Exceptional
Boat							
IBI Score	12-15	16-25	26-35	36-39	40-43	44-47	48-60
MIwb Score	0-4.9	5.0-6.3	6.4-8.1	8.2-8.6	8.7-9.0	9.1-9.5	≥ 9.6
LIBI	0-16	17-30	31-41	NA	42-49	NA	50-60
Wading							
IBI Score	12-17	18-27	28-33	34-37	38-45	46-49	50-60
MIwb Score	0-4.4	4.5-5.8	5.9-7.3	7.4-7.8	7.9-8.8	8.9-9.3	≥9.4
LIBI	0-16	17-30	31-41	NA	42-49	NA	50-60
Headwaters							
IBI Score	12-17	18-27	28-35	36-39	40-45	46-49	50-60
Ohio EPA Status	Non-Attainment			NSD	Attainment		
NSD – Non-Significant Departure of WWH attainment							

Results and Discussion

All sites failed to meet the WWH IBI scoring criteria in 2023. Figure 7 shows the average IBI results between the two passes for all sites. Average IBI scores ranged from 19 (*Poor*) to 32 (*Fair*). For headwater sites (ECMB 6.90, ECMB 3.30, UNT 1.50, ECEB 2.80, and ECEB 0.25), metrics that consistently performed poorly included numbers of darter, headwater, sensitive, and lithophilic species; and percent of tolerant and insectivore species. Wading sites (ECMB 2.70, ECMB 1.65, and ECMB 1.00) consistently performed poorly for metrics including number of darter, sunfish, sucker, and intolerant species; and percent of insectivore and carnivore species. The boat site (ECMB 0.40) performed poorly for number of sucker species and percent round-bodied suckers, intolerant species, and tolerant species. Fish communities at all sites were primarily composed of pollution-tolerant species. The majority of sites were dominated by Blacknose Dace, Creek Chubs, and Central Stoneroller Minnows. Bluntnose Minnows and/or Common White Suckers were also prevalent at most of the sites.

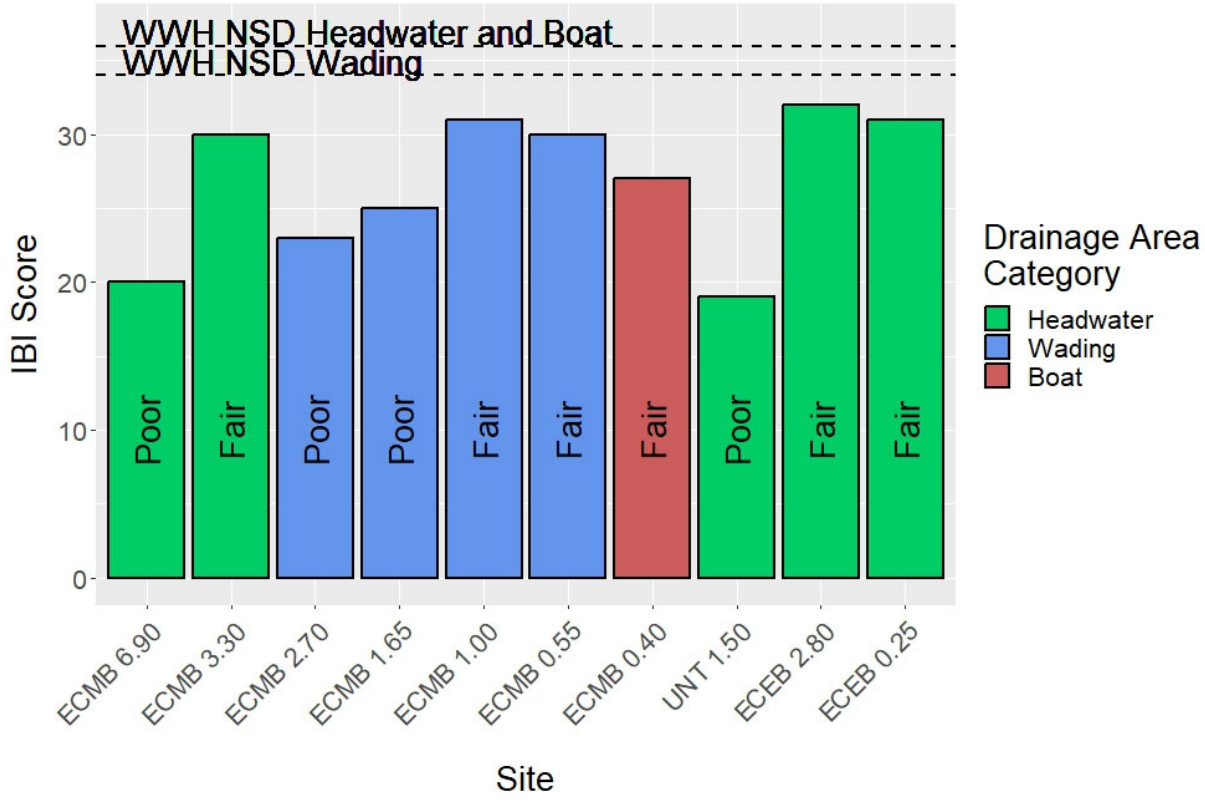

Figure 7. Average IBI scores between the two passes performed at each site in 2023 with narrative rating and WWH criterion comparisons.

Comparisons to historical IBI data for headwater, wading, and boat sites are shown in Figures 8, 9 and 10, respectively. Fewer observations were available for comparison at the headwater sites. Improvement was seen at ECEB 2.80, which moved from the narrative rating of *Poor* to *Fair*, although the number of electrofishing passes is too low to indicate a trend. The remaining headwater sites performed similarly to previous years. The wading sites and boat site continued to perform in the *Poor* to *Fair* range as has been observed for most historical fish assessments. No apparent change in fish community biology outside of typical annual variation was observed.

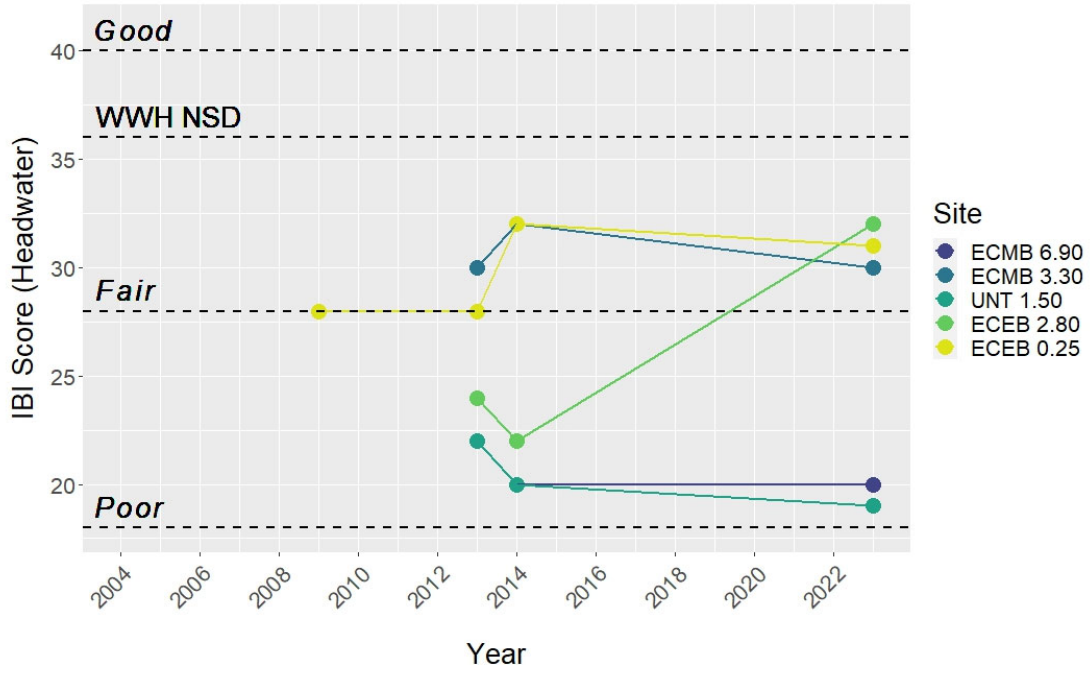

Figure 8. IBI scores for headwater sites over time.

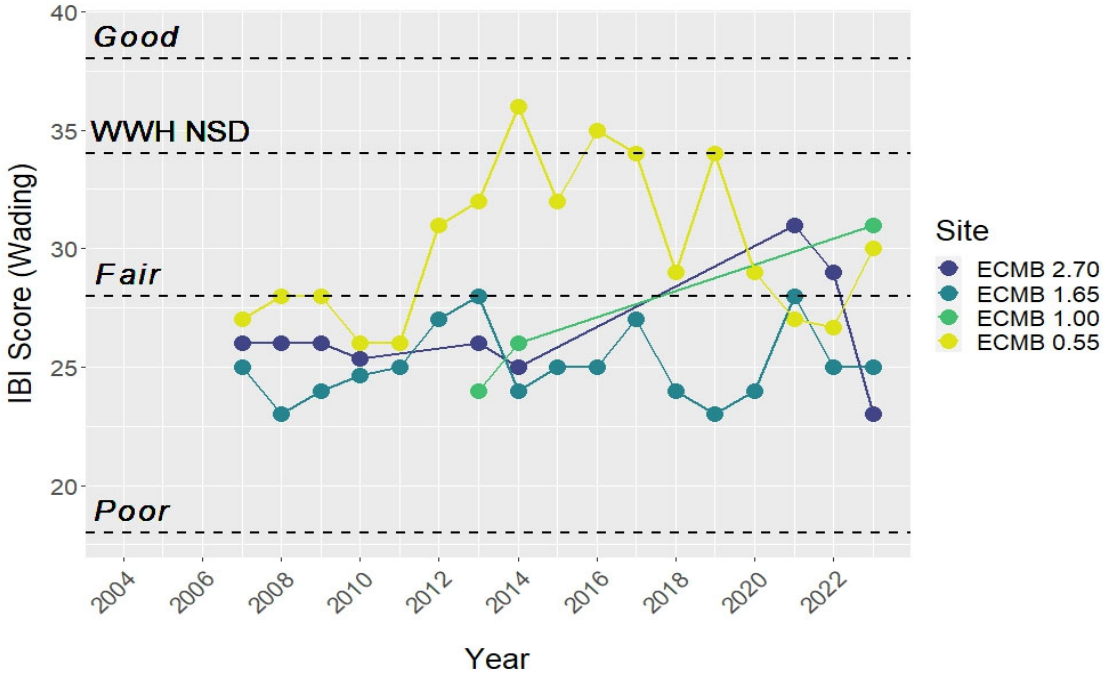

Figure 9. IBI scores for wading sites over time.

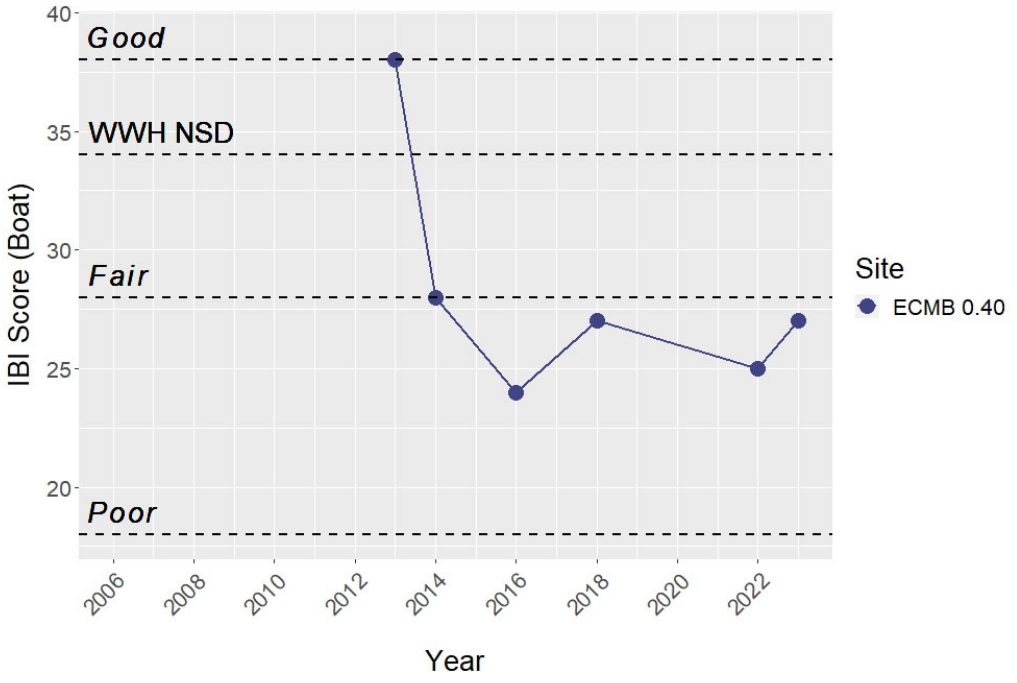

Figure 10. IBI scores for the boat site over time.

The WWH MIwb criterion only applies to the wading sites and boat site. Figure 11 shows the average MIwb results between the two passes for all applicable sites. Of these five sites, ECMB 0.40 and ECMB 1.00 were within non-significant departure of the WWH criteria. The remaining sites failed to meet attainment. Average MIwb scores ranged from 6.0 (*Fair*) to 8.5 (*Good*). Figures 12 and 13 compare historical MIwb scores over time for all wading and boat sites, respectively. Annual variation was found to be high at all sites with no apparent trends or patterns over time. The majority of historical scores fall within the *Poor* to *Fair* narrative categories. ECMB 1.00, 0.55, and 0.40 remain the only sites with historical scores in the *Marginally Good* (WWH NSD) to *Good* narrative ranges. These sites are located downstream of the fish barrier caused by the Euclid Creek Spillway located downstream of St. Clair Avenue. While fish migration from Lake Erie may occur at the downstream sites, ECMB 2.70 and 1.65 are located upstream of this barrier. This results in decreased fish community index scores at the upstream sites.

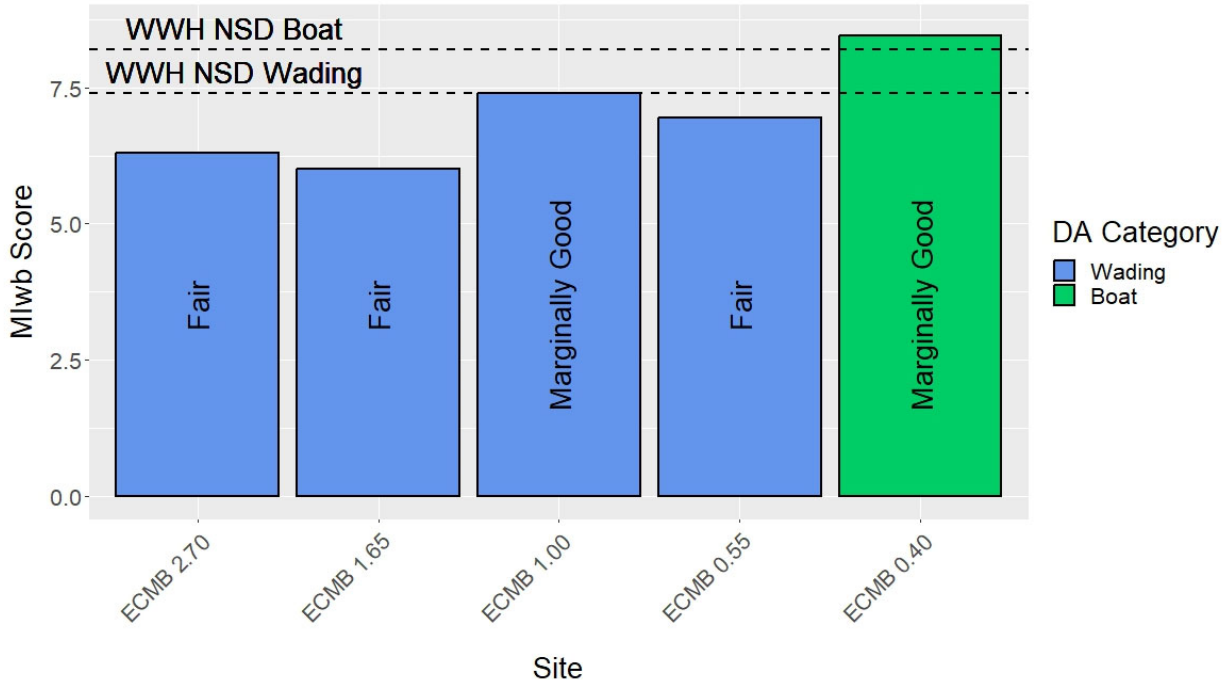

Figure 11. Average MIwb scores between the two passes performed at each site in 2023 with narrative rating and WWH criterion comparisons.

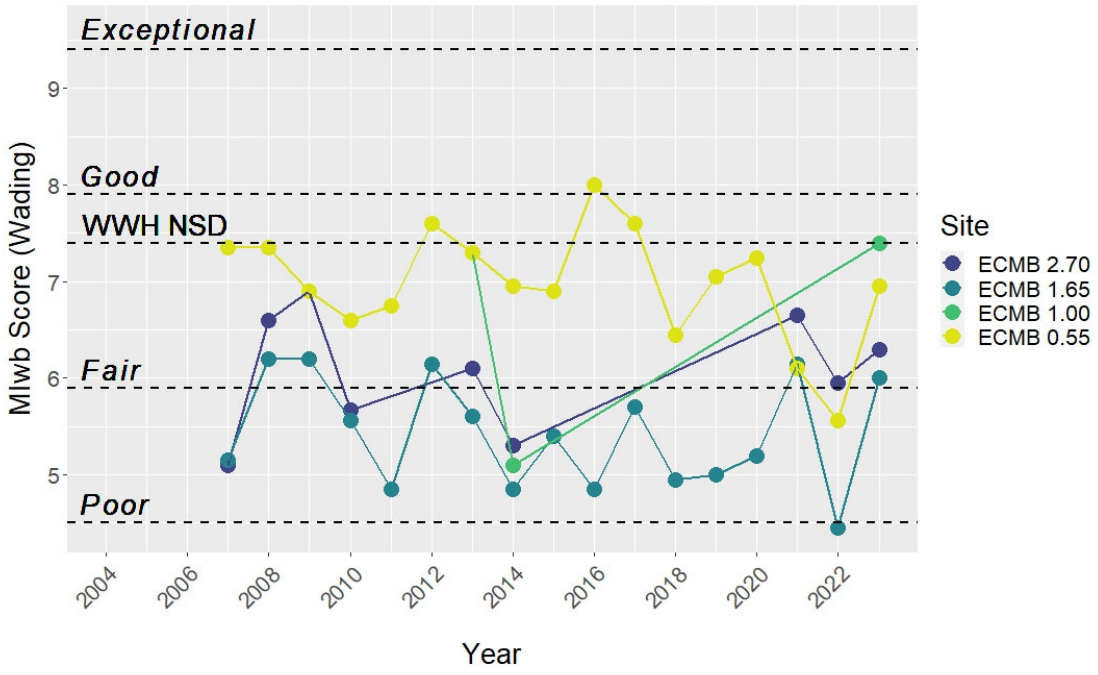

Figure 12. MIwb scores for wading sites over time.

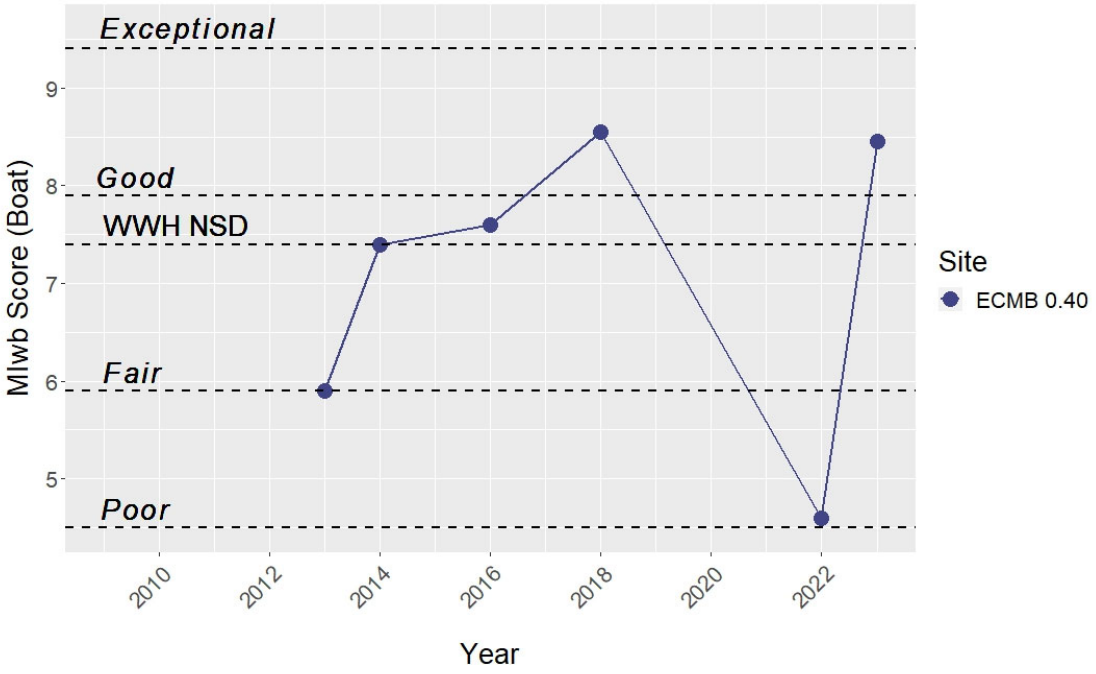

Figure 13. MIwb scores for the boat site over time.

Macroinvertebrate Community Biology Assessment

Methods

Macroinvertebrates were sampled quantitatively using modified Hester-Dendy (HD) samplers and/or with a qualitative assessment of macroinvertebrates inhabiting available habitats at the time of HD retrieval. Sampling was conducted at all locations listed in Table 12. The recommended period for HDs to be installed is six weeks. The macroinvertebrate samples were sent to Third Rock Consultants, LLC for identification and enumeration. Specimens were identified to the lowest practical taxonomic level as defined by the Ohio EPA (1987b). Lists of the species collected during the quantitative and qualitative sampling at each site are available upon request from NEORSD WQIS Division.

Table 12. HD Locations and Installation/Collection Dates

Site	HD Installation Date(s)	HD Retrieval and Qualitative Sample Date	Comments
ECMB 6.90	6/20/2023	8/3/2023	--
ECMB 3.30	6/20/2023* 7/5/2023* 8/1/2023*	9/13/2023	Qualitative sample only. HD repeatedly blown out in heavy rains.

Table 12. HD Locations and Installation/Collection Dates			
Site	HD Installation Date(s)	HD Retrieval and Qualitative Sample Date	Comments
ECMB 2.70	6/20/2023	8/1/2023	HD partially buried. Approximately 20% exposed.
ECMB 1.65	6/20/2023* 7/5/2023	8/23/2023	HD partially buried. Approximately 60% exposed.
ECMB 1.00	6/20/2023	8/1/2023	Sediment runoff present from upstream construction.
ECMB 0.55	6/20/2023	8/1/2023	--
ECMB 0.40	6/20/2023	8/1/2023	HD partially buried. Approximately 20% exposed.
UNT 1.50	6/20/2023	8/3/2023	HD partially buried. Approximately 50% exposed.
ECEB 2.80	6/20/2023	8/1/2023	--
ECEB 0.25	6/20/2023	8/1/2023	--
**HD was found missing, most likely due to being blown out or buried from siltation by elevated stream flows following significant wet-weather events.*			

The macroinvertebrate sampling methods followed Ohio EPA protocols as detailed in *Biological Criteria for the Protection of Aquatic Life, Volumes II* (1987a) and *III* (1987b). The overall aquatic macroinvertebrate community in the stream was evaluated using Ohio EPA's Invertebrate Community Index (ICI). The ICI consists of ten community metrics (Table 13), each with four scoring categories. Metrics 1-9 are based on the quantitative sample, while metric 10 is based on the qualitative EPT taxa collected. The sum of the individual metric scores results in the overall ICI score. This scoring evaluates the macroinvertebrate community against Ohio EPA's reference sites for each specific eco-region. The WWH ICI criterion in the EOLP ecoregion is 34 (Table 14) and a site is within non-significant departure if the score falls within 4 ICI units of the criterion.

Table 13. ICI Metrics
Total Number of Taxa
Number of Mayfly taxa
Number of Caddisfly taxa
Number of Dipteran taxa
Percent Mayflies
Percent Caddisflies
Percent Tanytarsini Midges
Percent Other Diptera and Non-Insects
Percent Tolerant Organisms (as defined)
Number of Qualitative EPT Taxa

Table 14. Invertebrate Community Index (ICI) Range for EOLP Ecoregion								
Ohio EPA Narrative	Very Poor	Poor	Low Fair	Fair	Marginally Good	Good	Very Good	Exceptional
ICI Score	0-6	8-12	14-20	22-28	30-32	34-40	42-44	46-60
Ohio EPA Status	Non-Attainment				NSD	Attainment		
NSD – Non-Significant Departure of WWH attainment								

Macroinvertebrate Narrative Rating Assessment

Multiple HDs installed at Euclid Creek Main Branch RM 3.30 were repeatedly missing throughout the sampling season. Therefore, a narrative rating assessment was performed for this site based on the results of qualitative sampling. The qualitative sample data was compared to expectations developed by NEORSD using threshold limit models (NEORSD, 2023). These models were developed using QDC Level 3 macroinvertebrate data provided by the Ohio EPA from the Erie Ontario Lake Plain ecoregion (EOLP) from the ten-year period between 2005 and 2014 (threshold limit model analysis available upon request). Table 15 provides the expectation threshold limits for qualitative total taxa, qualitative EPT taxa, and qualitative sensitive taxa metrics, grouped by drainage area category.

Table 15. NEORSD Recommended Expectation Threshold Limits for Narrative Rating Assignments in the EOLP				
Drainage Category	Designation	Qualitative Total Taxa	Qualitative EPT Taxa	Qualitative Sensitive Taxa
Headwater (0-20 miles^2)	EWH	38	12	6
	WWH	27	7	2
	Fair	23	4	1
Wadable (20-200 miles^2)	EWH	51	18	12
	WWH	41	11	6
	Fair	33	8	2
Small River (200-1,000 miles^2)	EWH	44	16	10
	WWH	36	11	7
	Fair	29	9	5

ECMB 3.30 has a drainage area of 9.1 square miles, placing it in the headwater drainage area category. A total of 38 taxa were collected in the qualitative sample which meets the *EWH* expectation for a headwater stream. Ten EPT taxa were collected which scores between the *WWH* and *EWH* expectations for number of EPT taxa. EPT taxa included three mayfly taxa and seven caddisfly taxa. Four sensitive taxa were collected at this site which scores between the *WWH* and

EWH expectations for a headwater stream. Field observations indicated that Baetidae were the most abundant group at the site followed by Hydropsychidae and Chironomidae. The site was assigned a field narrative rating of *Good* at the time of sample collection. Taking the above data into consideration the site was assigned a narrative rating of *Good* in 2023.

Results and Discussion

Table 16 provides a summary analysis of the macroinvertebrate sampling results in 2023. Figure 14 compares ICI scores and/or narrative rating results to the WWH criterion for macroinvertebrates. ECMB 1.00, ECMB 0.40 and UNT 1.50 were in non-attainment of the WWH macroinvertebrate criterion. The remaining sites were in attainment or within non-significant departure from the criterion. Macroinvertebrate community composition by site in 2023 is shown in Figure 15. There were distinct shifts in the community compositions at the sites that scored poorly. The percentage of specimens made up of good water quality indicators including mayflies and caddisflies were greatly diminished at these sites.

Table 16. 2023 Macroinvertebrate Results

Site	Density Qt. (ft^2) /Ql.	Ql./ Total Taxa	Ql. EPT/ sensitive Taxa	Qt. % Tolerant/ Sensitive taxa	Predominant orgs. on natural substrates	ICI	Narrative Evaluation
ECMB 6.90	720/L-M	37/48	8/3	4.03/2.03	Turbellaria, Polycentropodidae, Chironomidae, Amphipoda, Coenagrionidae	42	*Very Good*
ECMB 3.30	--/L-M	38/--	10/5	--	Baetidae, Hydropsychidae, Chironomidae	--	*Good*
ECMB 2.70	72/L-M	35/38	9/4	6.94/0.55	Baetidae, Elmidae, Isopoda, Amphipoda	30	*Marginally Good*
ECMB 1.65	125/L-M	28/42	10/8	6.42/8.19	Baetidae, Hydropsychidae, Turbellaria	40	*Good*
ECMB 1.00	602/L-M	43/49	10/6	1.83/1.13	Turbellaria, Hirudinea, Oligochaeta, Isopoda, Amphipoda, Elmidae	26	*Fair*
ECMB 0.55	171/L-M	36/50	7/5	8.56/2.46	Turbellaria, Hirudinea, Oligochaeta, Isopoda, Amphipoda, Baetidae	32	*Marginally Good*

Table 16. 2023 Macroinvertebrate Results

Site	Density Qt. (ft^2) /Ql.	Ql./ Total Taxa	Ql. EPT/ sensitive Taxa	Qt. % Tolerant/ Sensitive taxa	Predominant orgs. on natural substrates	ICI	Narrative Evaluation
ECMB 0.40	164/L	30/33	6/1	56.36/0.00	Turbellaria, Isopoda, Amphipoda	8	*Poor*
UNT 1.50	164/L-M	31/36	4/0	20.07/0.00	Simuliidae, Chironomidae, Turbellaria, Amphipoda	22	*Fair*
ECEB 2.80	64/L-M	34/44	9/3	11.60/9.40	Baetidae, Isopoda, Turbellaria	36	*Good*
ECEB 0.25	141/L-M	34/45	10/5	4.41/8.25	Baetidae, Hydropsychidae, Chironomidae,	32	*Marginally Good*

Qt. Quantitative sample collected on Hester-Dendy artificial substrates.
Ql. Qualitative sample collected from natural stream substrates.
Qualitative sample relative density: L=Low, M=Moderate, H=High
Sensitive Taxa: Taxa listed on the Ohio EPA Macroinvertebrate Taxa List (2019) as *Moderately Intolerant* or *Intolerant*.

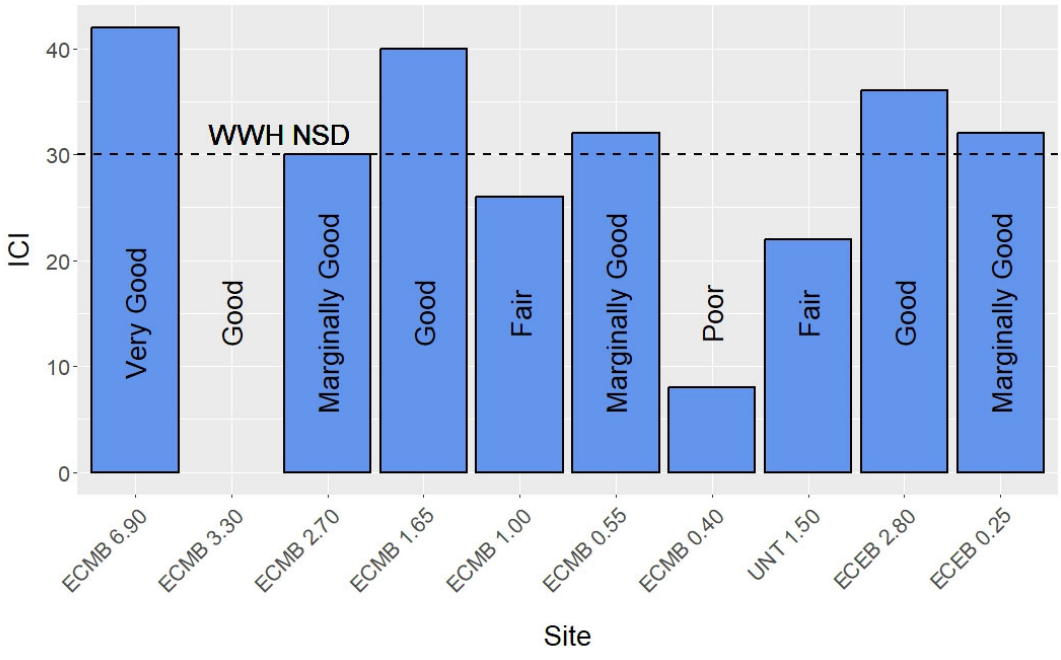

Figure 14. ICI scores and narrative ratings from 2023 compared to the WWH criterion. No ICI score could be calculated for ECMB 3.30. This site was assigned a narrative rating of *Good*, which meets the WWH criterion.

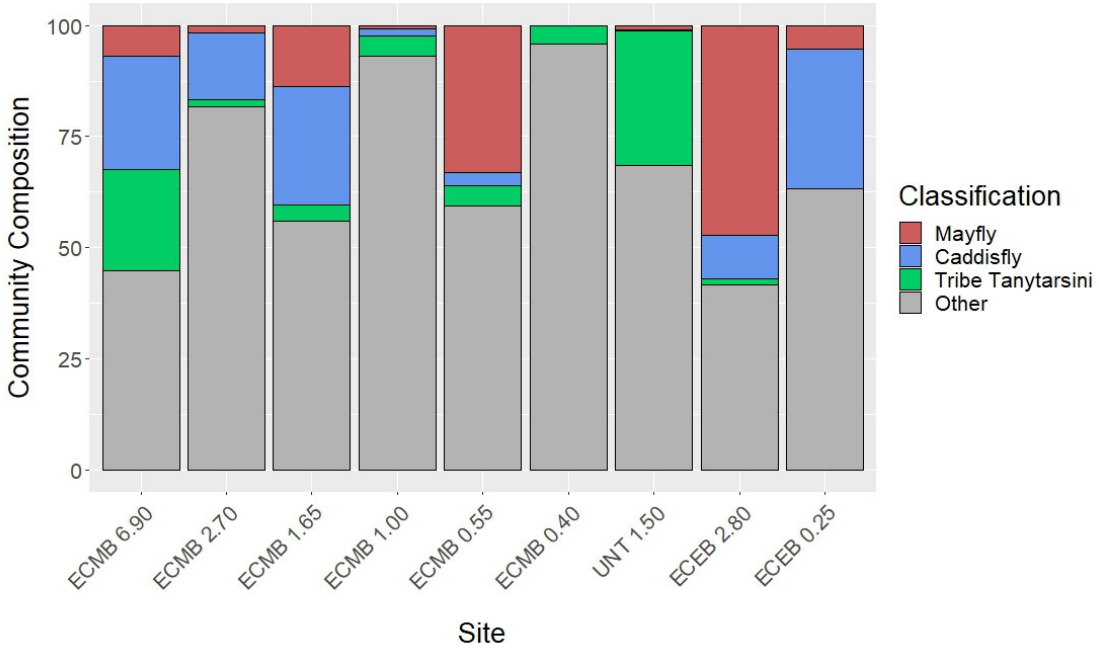

Figure 15. Macroinvertebrate community composition by site in 2023.

ECMB 1.00 had an ICI score of 26 (*Fair*). The HD at ECMB 1.00 was highly dominated by Turbellaria (flatworms) which made up 80% of the total organisms on the HD. The lead biologist noted at the time of HD collection that upstream construction of a residence was leading to runoff of construction soil and sediment. This may have negatively impacted the HD at this site resulting in the high proportion of Turbellaria. This site scored similarly to the most recent historical assessment in 2014 with a score of 28 (*Fair*). In 2014, pollution-tolerant Oligochaeta rather than Turbellaria dominated the HD, comprising 36% of the sample.

ECMB 0.40 had an ICI score of 8 (*Poor*) in 2023. The HD at ECMB 0.40 was negatively impacted by low flows and deposition of sediment as this site was located within the lacustuary zone near the confluence with Euclid Creek. The flow over the HD was 0.12 feet per second (fps) at the time of installation and 0.24 fps at the time of collection. These flows fell below the minimum recommended flow rate for HD installation (0.3 fps) and well below the optimal rate (0.7-1.5 fps). This was unavoidable due to the low-flow rates throughout the site. Additionally, 80% of the HD was found to be buried in sediment at the time of collection. These low-flow rates and heavy sediment cover over the HD contributed substantially to the reduced ICI score at this site.

The LICI score was also applied to this site for comparative purposes only. Figure 16 shows LICI scores over time at ECMB 0.40. This site had an LICI score of 26 (*Poor*) in 2023 with historical LICI scores ranging from 34 (*Fair*) to 52 (*Exceptional*). The reason for the variation in LICI scores over time at this site is due to annual variations in streamflow. 2014 was the only year in which flow over the HD was measured to be greater than the minimum recommended flow of 0.30 fps at

the time of sample collection resulting in the LICI score of 52 (*Exceptional*). A similar pattern is observed for the historical ICI scores at this site as shown in Figure 17 as further discussed below.

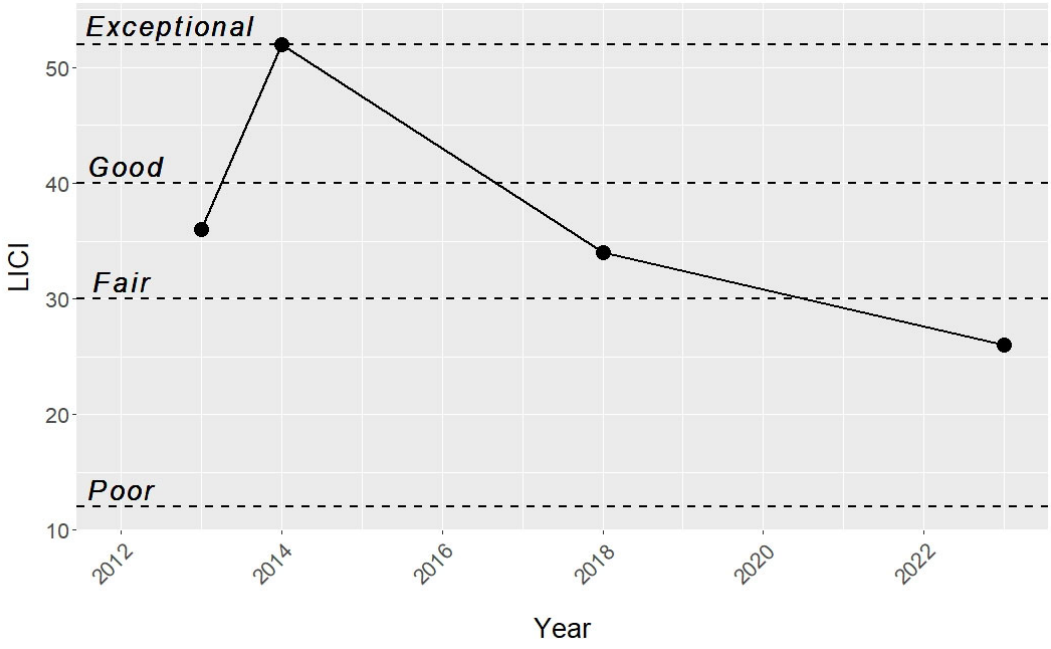

Figure 16. LICI scores over time at ECMB 0.40.

UNT 1.50 had an ICI score of 22 (*Fair*) in 2023. The HD at UNT 1.50 was dominated by facultative Chironomidae taxa including *Rheotanytarsus sp* and *Thenemannimyia sp*, which made up 23.1% and 22.2% of the macroinvertebrate community, respectively. Pollution-tolerant oligochaetes were the third most dominant organism at this site comprising 20.1% of the sample. This site had the lowest numbers of qualitative EPT and sensitive taxa in this study with four EPT and zero sensitive taxa collected. The number of qualitative EPT and sensitive taxa ranged from six to ten and three to eight, respectively, at the remaining sites. While the QHEI score is more tailored to fish than macroinvertebrate habitats, the *Excellent* QHEI score at this site would still indicate that suitable macroinvertebrate habitat was present. The lack of EPT and sensitive taxa at this site despite the presence of good habitat and the close proximity to sites with increased EPT and sensitive taxa numbers indicates that poor water quality has contributed to the degradation of the macroinvertebrate community at this site.

Figures 17 and 18 show ICI scores over time for the Main Branch and the tributaries (East Branch and Un-named Tributary), respectively. ICI scores at ECMB 1.00 and upstream sites remained fairly consistent over time. The majority of historical ICI scores at ECMB 1.65 and upstream sites met or were within non-significant departure of the WWH criterion. ICI scores at ECMB 0.55 and ECMB 0.40 varied significantly over time, likely due to annual changes in the degree

of lacustuary influence at these sites. The number of observations was much lower for the East Branch sites and UNT 1.50. Results at these sites remained relatively consistent over time.

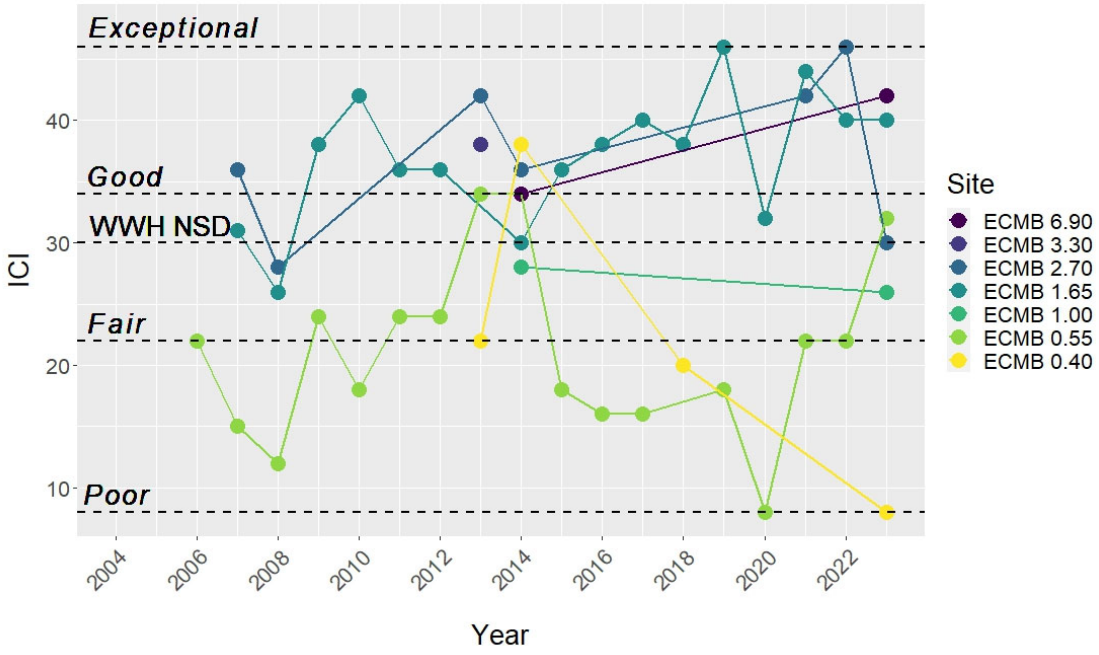

Figure 17. ICI scores over time at Main Branch sites.

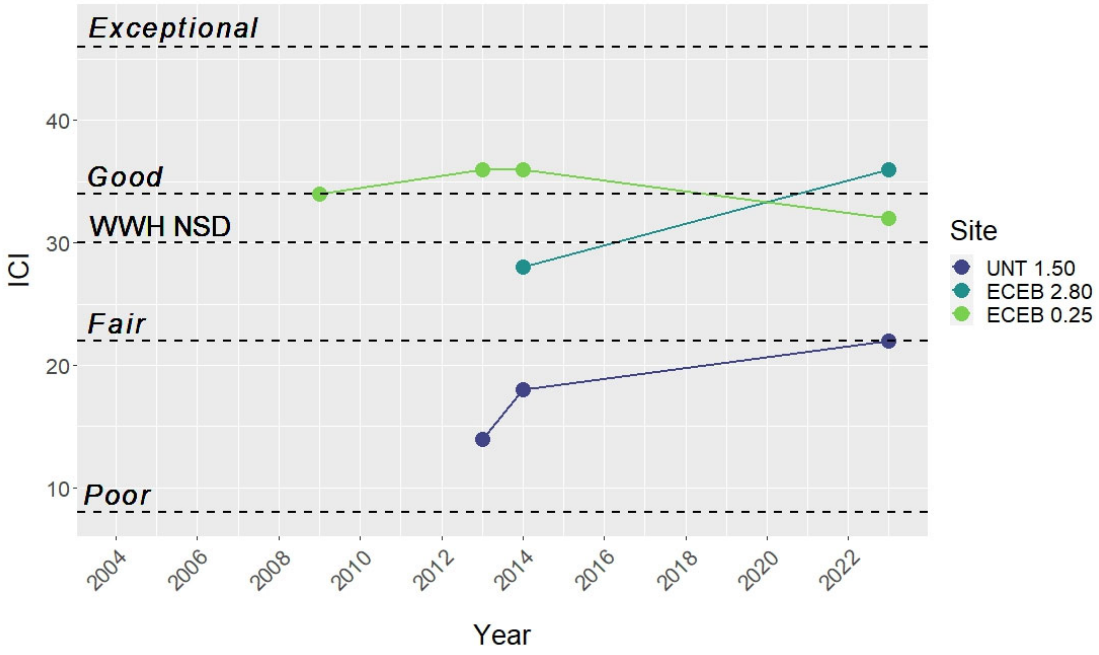

Figure 18. ICI scores over time at East Branch and Un-named Tributary sites.

Impact of CSO Control by the Euclid Creek Tunnel on Biological Community Metrics

Additional statistical analysis was performed to compare the habitat, fish, and macroinvertebrate metrics upstream and downstream of NEORSD-operated CSOs before and after completion of the ECT. ECMB 1.65 and 0.55 serve as the upstream and downstream monitoring points for the NEORSD CSO permit. Annual data has been collected at these sites beginning in 2007. The ECT went fully online in 2019. In 2018, the ECT was partially online. Data from 2018 was therefore not used in the comparison between the habitat and biological community metrics before and after ECT completion. The Wilcoxon Ranked Sum Test was used to determine whether there was a significant change in metric scores at each site before and after ECT completion. The Wilcoxon Signed Rank Test was also used to determine if there was a significant difference in scores between the two sites over time pairing the data by year.

It is not expected that CSO control would have an impact on habitat quality, but additional factors may have impacted habitat at these sites over time. This analysis was performed as a control, to determine whether changes in habitat that may influence biological communities occurred between the time periods before and after completion of the ECT. Boxplot diagrams showing the distribution of QHEI scores at these two sites for the time periods from 2007 to 2017 (before ECT completion) and 2019 to 2023 (after ECT completion) are shown in Figure 19. There was no statistically significant difference between QHEI score distributions before and after ECT completion at either site. Therefore, habitat is not expected to influence any changes in biological community indexes observed between these two time periods. Overall, ECMB 1.65 had significantly higher QHEI scores than ECMB 0.55 ($p = 5.5x10^{-4}$). This is likely due to the lacustuary nature of the site at ECMB 0.55 which is heavily influenced by Lake Erie. QHEI scoring parameters that are improved at ECMB 1.65 compared to 0.55 include Riffle/Run/Pool complex development, sinuosity, fast currents, and low substrate embeddedness. Annual variations in the lake levels of Lake Erie also result in the absence of functional riffles at ECMB 0.55 in some years. This contributes to decreased QHEI scores at this site.

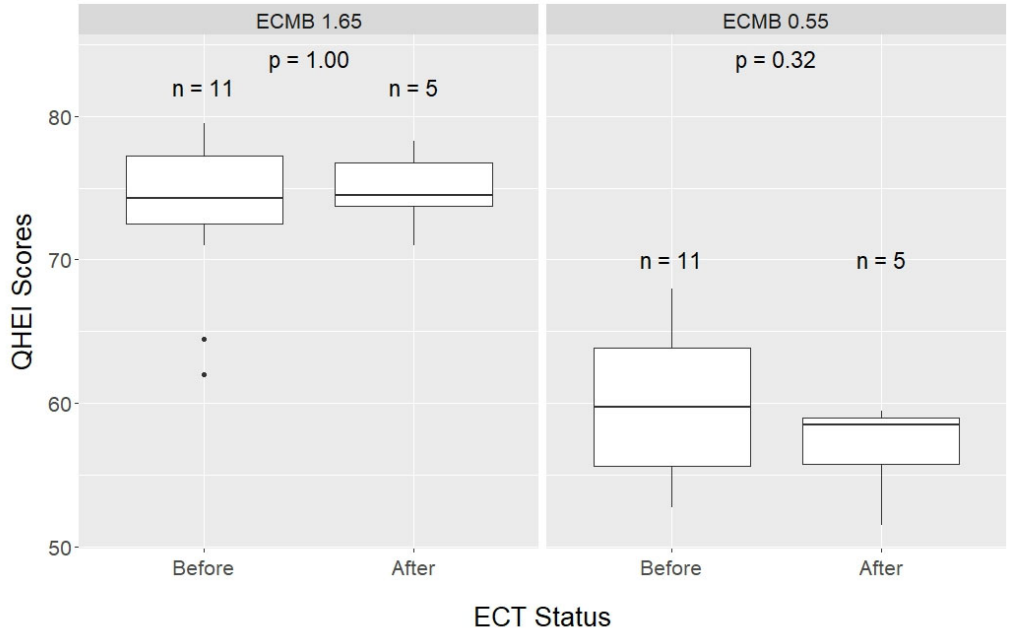

Figure 19. Distributions of QHEI scores before and after ECT installation at ECMB 1.65 and 0.55 with p-values from Wilcoxon Rank Sum Test.

Boxplot diagrams of historical IBI scores before and after ECT completion for ECMB 1.65 and 0.55 are shown in Figure 20. Overall IBI and MIwb scores were significantly elevated at the downstream site, ECMB 0.55, compared to ECMB 1.65 ($p = 4.1x10^{-4}$ and $3.1x10^{-5}$, respectively). This is most likely due to the presence of the fish barrier downstream of St. Clair Avenue as previously discussed. Median IBI scores remained unchanged at each site before and after ECT completion. There was no significant difference in the overall distribution of IBI scores before versus after ECT completion at either site.

Figure 21 shows the same comparison for historical MIwb scores. The median MIwb score at ECMB 1.65 was the same before and after ECT completion with no significant change in the distribution of scores. The median MIwb score at ECMB 0.55 was unexpectedly lower after ECT completion. This difference was not significant but was close to significance ($p = 0.06$) according to the Wilcoxon Ranked Sum Test, possibly indicating a trend. As previously discussed, no significant differences in QHEI scores at RM 0.55 were observed before versus after ECT completion to explain this potential trend. However, Lake Erie water levels were found to be significantly elevated at the USGS lake level station number 9063063 located at the East 72nd Marina in Cleveland after ECT completion (Figure 22, $p = 0.003$). The average lake level was approximately 1.5 feet higher in the years following ECT completion compared to the years before. This indicates that there would have been a greater lacustuary influence at ECMB 0.55 after ECT completion which may have negatively impacted the MIwb scores.

Figure 23 shows the same comparison for historical ICI scores. The upstream site ECMB 1.65 had significantly higher ICI scores both before and after Euclid Creek Tunnel installation (p =

$7.6x10^{-6}$). This is likely due to the lacustuary influence and lack of high-quality riffle habitat at the downstream site ECMB 0.55. There was an upward trend in the median ICI score at ECMB 1.65 following ECT completion although this was not significant (p = 0.07). This trend is likely unrelated to the ECT completion as it was observed at the upstream site. ICI score distributions remained unchanged at ECMB 0.55 before and after completion of the Euclid Creek Tunnel.

These data taken together demonstrate no improvement in the composition of the biological communities on Euclid Creek following CSO control by the ECT. This is likely due to continued human sewage contamination from local storm and sanitary collection systems. These local systems include a mixture of common trench, combined, and separate sewer systems. Together these systems have been demonstrated to have a higher contribution to elevated *E. coli* densities than historical NEORSD-operated CSO discharges during wet-weather events through both sampling and modeling studies (NEORSD, 2018; NEORSD, 2022; Zgnilec, 2016). Improvements in the recreational criteria and biological community metrics in the Euclid Creek watershed are unlikely to occur until contamination from local collection systems is addressed.

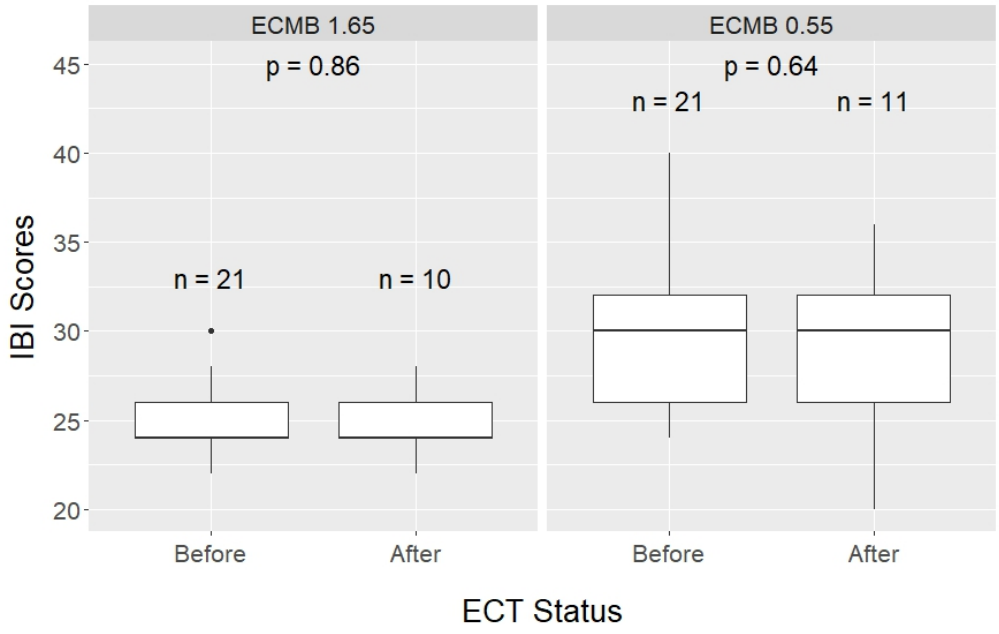

Figure 20. Distributions of IBI scores before and after ECT installation at ECMB 1.65 and 0.55 with p-values from Wilcoxon Rank Sum Test.

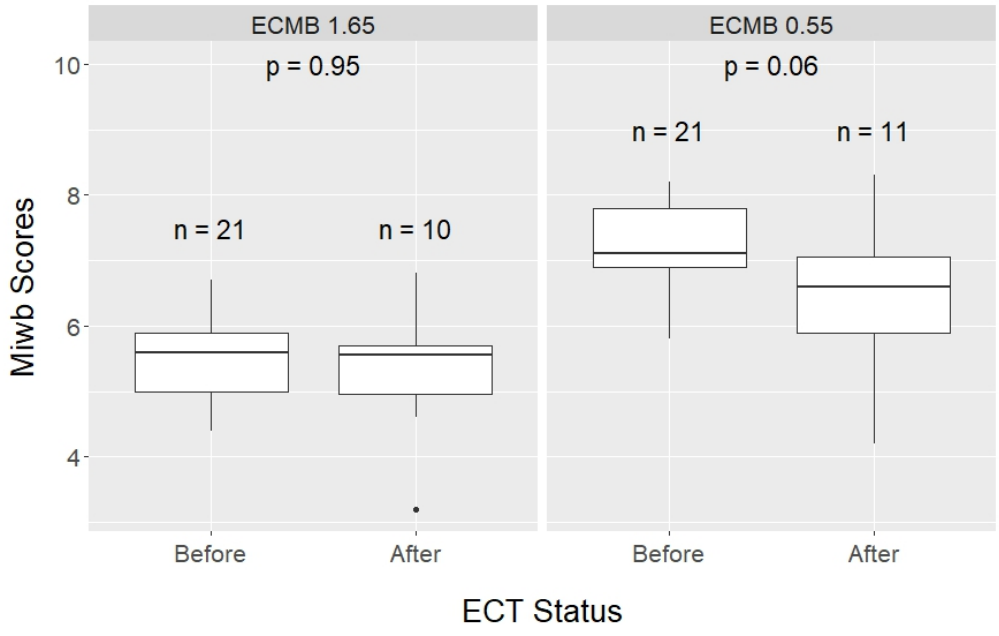

Figure 21. Distributions of MIwb scores before and after ECT installation at ECMB 1.65 and 0.55 with p-values from Wilcoxon Rank Sum Test.

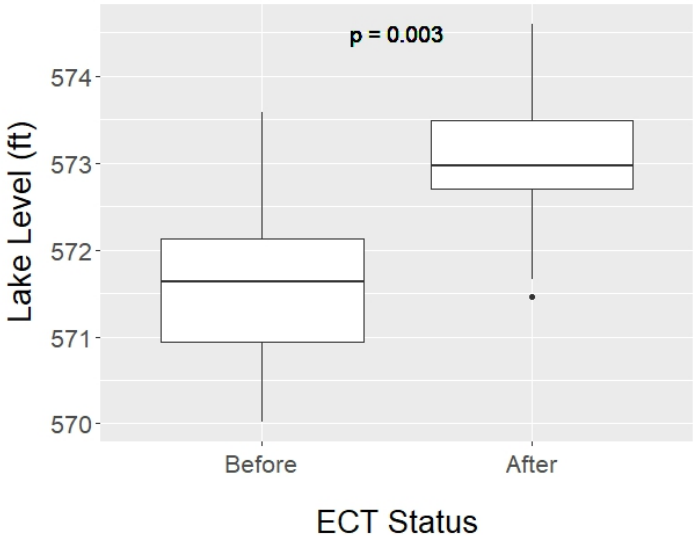

Figure 22. Distributions of annual average lake level at USGS station.

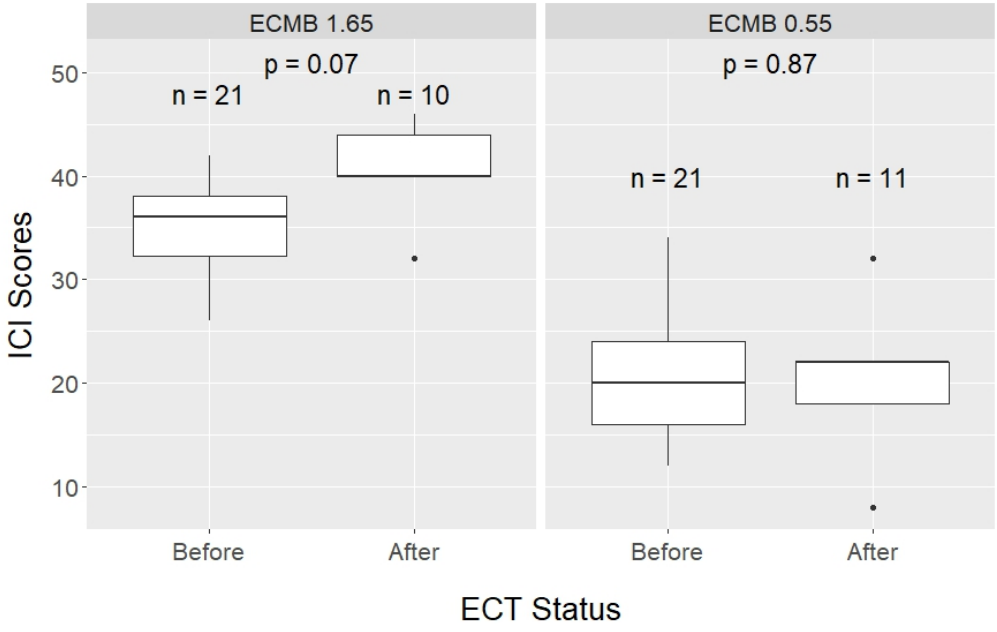

Figure 23. Distributions of ICI scores before and after ECT installation at ECMB 1.65 and 0.55 with p-values from Wilcoxon Rank Sum Test.

Conclusions

A summary of the 2023 Euclid Creek survey results is provided in Table 17. Euclid Creek was in exceedance of both the STV and geomean recreational criteria for *E. coli* at all sites. All sites were also in exceedance of the Human Health Non-Drinking, and Wildlife OMZA criteria for mercury. Nutrient concentrations at UNT 1.50 and ECEB 2.80 were categorized as enriched and moderately enriched, respectively, according to the proposed SNAP. Nutrients at the remaining sites were categorized as typical of developed lands. Wide DO diel swings at the sonde station located near the confluence with Lake Erie at ECMB 0.55 indicate a state of nutrient enrichment at this site according to the proposed SNAP. The elevated levels of sanitary sewage contamination in this watershed, in combination with urban runoff, are most likely the greatest contributors to elevated nutrient concentrations and wide DO diel swings in this watershed.

Habitat scores met WWH expectations at all sites with the exceptions of ECMB 1.00 and 0.55, which scored in the *Fair* narrative rating category. Poor riffle/run/pool sequence development, low sinuosity, and high substrate embeddedness contributed to the low QHEI score at these two sites. Five sites were in non-attainment of the WWH biological criteria including ECMB 6.90, 2.70, 1.65, 0.40, and UNT 1.50. The remaining five sites were in partial attainment of the WWH criteria. All sites were in non-attainment of the fish IBI scoring criterion with scores ranging from 19 (*Poor*) to 32 (*Fair*). ECMB 1.00 and 0.40 were within non-significant departure of the fish MIwb scoring criterion. Seven of the ten sites were in attainment or within non-significant

departure of the macroinvertebrate ICI scoring criterion with ECMB 1.00 and 0.40, and UNT 1.50 not meeting the criteria.

Analysis of historical sampling results before and after the construction of the ECT was performed using annual data from ECMB 1.65 (upstream of NEORSD-operated CSOs) and ECMB 0.55 (downstream of NEORSD-operated CSOs). Previous studies have concluded that there was no statistically significant improvement in *E. coli* densities downstream of NEORD-operated CSOs on Euclid Creek following the ECT installation despite complete CSO capture (NEORSD, 2018; NEORSD, 2022). These studies were supported by previous modeling results which indicated that only 27% of the *E. coli* loading to Euclid Creek was due to NEORSD-operated CSO discharges. The remaining 73% of the *E. coli* load was modeled to come from divider wall (28%), dual manhole (26%) and separate trench sewers (18%) (Zgnilec, 2016). These studies indicated that, while CSO capture is an essential step towards correcting recreational criteria exceedances in Euclid Creek, CSO was not the major source of sanitary sewage contamination in Euclid Creek. Bacteriological results from the 2023 survey support these previous findings. No improvement in *E. coli* densities downstream of NEORSD-operated CSOs was observed following construction of the ECT. Additional work to address recreational criteria exceedances in this watershed should focus on correcting inflow and infiltration in the aging local separate sewer collection systems. Much of the collection system in this region consists of common trench sewers which are known to be particularly problematic in terms of mixing of sanitary sewage with stormwater.

Additional statistical analysis to determine the impact of the ECT on macroinvertebrate and fish community index scores was conducted in this study. No significant improvements in macroinvertebrate or fish community scores were observed at either ECMB 1.65 or 0.55 following the installation of the ECT. Overall historical ICI scores were significantly higher at ECMB 1.65 compared to ECMB 0.55 ($p = 7.6 \times 10^{-6}$). This is most likely due to improved macroinvertebrate habitat and higher streamflow velocities which support a healthy macroinvertebrate community at the upstream site compared to the lacustuary-influenced downstream monitoring site. The opposite pattern was observed for fish community index scores. ECMB 0.55 outperformed ECMB 1.65 for both IBI and MIwb indexes ($p = 4.1 \times 10^{-4}$ and 3.1×10^{-5}, respectively). This has been historically attributed to the presence of the fish barrier located downstream of St. Clair Avenue. Fish from Lake Erie may colonize the creek downstream of this barrier, resulting in elevated fish metric scores downstream compared to upstream.

Removal of this barrier is considered a key step to improving biological criteria scores in this watershed, which is a target area for the Cuyahoga River Area of Concern. The NEORSD and the United States Army Corps of Engineers have partnered to reconstruct the spillway and install a fishway passage structure to allow for fish migration upstream of the spillway. Funding for this project has been obtained through the Great Lakes Restoration Initiative grant program. Construction of this project is expected to take place in 2026. It is expected that construction of the fishway will improve upstream fish community index scores. This will likely assist in the delisting of the Cuyahoga River Area of Concern Beneficial Use Impairment 3a: Fish Populations by restoring fish migration patterns throughout this watershed.

Table 17. 2023 Survey Results								
RM	DA (mi^2)	Attainment Status	IBI Score	MIwb Score	ICI Score	QHEI Score	Cause(s)	Source(s)
Euclid Creek East Branch (WWH Existing)								
6.90 [H]	3.9	Non	20*[P]	--	42	64.75	Nutrient enrichment. Toxic metals. Sewage contamination. Fish migration barrier.	Urbanization and urban runoff. Common trench sewer inflow and infiltration. Culverted stream reaches. Atmospheric deposition.
3.30 [H]	9.1	Partial	30*[F]	--	*Good*	56.0	Nutrient enrichment. Toxic metals. Sewage contamination. Fish migration barrier.	Urbanization and urban runoff. Common trench sewer inflow and infiltration. Culverted stream reaches. Atmospheric deposition.
2.70	21.9	Non	23*[P]	6.30[F]	30[MG]	68.0	Nutrient enrichment. Toxic metals. Sewage contamination. Fish migration barrier.	Urbanization and urban runoff. Common trench sewer inflow and infiltration. Culverted stream reaches. Atmospheric deposition.
1.65	22.3	Non	25*[P]	6.00[F]	40	73.75	Nutrient enrichment. Toxic metals. Sewage contamination. Fish migration barrier.	Urbanization and urban runoff. Common trench sewer inflow and infiltration. Culverted stream reaches. Atmospheric deposition.
1.00	23.1	Partial	31*[F]	7.40[MG]	26*[F]	55.5[F]	Sedimentation. Nutrient enrichment. Toxic metals. Sewage contamination. Poor habitat development.	Urbanization and urban runoff. Common trench sewer inflow and infiltration. Culverted stream reaches. Atmospheric deposition.
0.55	23.1	Partial	30*[F]	6.95[F]	32[MG]	59.0[F]	Sedimentation. Nutrient enrichment. Toxic metals. Poor habitat development.	Urbanization and urban runoff. Common trench sewer inflow and infiltration. Culverted stream reaches. Atmospheric deposition.
0.40	23.2	Non	27*[P]	8.45[MG]	8*[P]	67.5	Sedimentation. Nutrient enrichment. Toxic metals. Poor habitat development. Lacustuary influence.	Urbanization and urban runoff. Common trench sewer inflow and infiltration. Culverted stream reaches. Atmospheric deposition.

Table 17. 2023 Survey Results								
RM	DA (mi^2)	Attainment Status	IBI Score	MIwb Score	ICI Score	QHEI Score	Cause(s)	Source(s)
Un-named Tributary at Euclid Creek Main Branch RM 5.50 (WWH Existing)								
1.50 [H]	1.2	Non	19*[P]	--	22*[F]	73.5	Nutrient enrichment. Toxic metals. Sewage contamination. Fish migration barrier.	Urbanization and urban runoff. Common trench sewer inflow and infiltration. Culverted stream reaches. Atmospheric deposition.
Euclid Creek East Branch (WWH Existing)								
2.80 [H]	7.05	Partial	32*[F]	--	36	56.5	Nutrient enrichment. Toxic metals. Sewage contamination. Fish migration barrier.	Urbanization and urban runoff. Common trench sewer inflow and infiltration. Culverted stream reaches. Atmospheric deposition.
0.25 [H]	12.5	Partial	31*[F]	--	32	64.0	Nutrient enrichment. Toxic metals. Sewage contamination. Fish migration barrier.	Urbanization and urban runoff. Common trench sewer inflow and infiltration. Culverted stream reaches. Atmospheric deposition.

*Significant departure from biocriterion (>4 ICI; >4 IBI; >0.5 MIwb units). Underlined scores are in the *Poor* or *Very Poor* narrative range.
[H] Headwater scoring criteria
[MG] *Marginally Good* narrative rating
[F] *Fair* narrative rating
[P] *Poor* narrative rating
[VP] *Very Poor* narrative rating

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