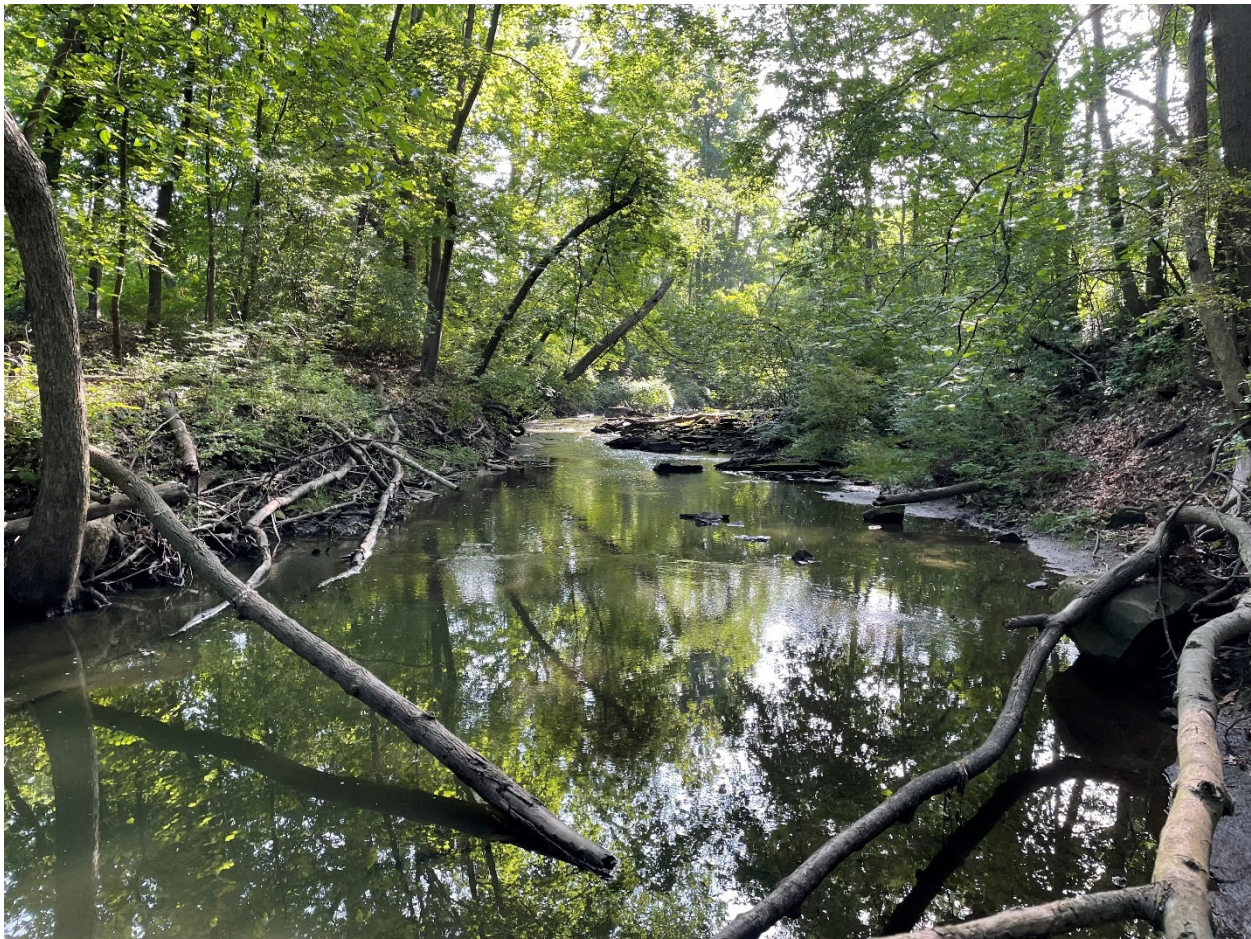




Northeast Ohio Regional Sewer District

2023 Doan Brook

Biological, Water Quality, and Habitat Study



Water Quality and Industrial Surveillance

Environmental Assessment Group

April 2024

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Introduction

In 2023, as part of the Northeast Ohio Regional Sewer District (NEORS) general watershed monitoring program, an ambient water quality assessment study was conducted to determine attainment and appropriateness of existing aquatic life use designations of Doan Brook. Data was also collected at some sites in support of Ohio EPA Permit #3PA00002*JD and to determine any improvements following the completion of the Doan Valley Storage Tunnel (DVT). Finally, data collected was also used to establish pre-construction conditions for the “Doan Brook Restoration near Horseshoe Lake Park” project and the “Lower Shaker Lake Dam Reconstruction” project.

Both the Horseshoe Lake Dam and the Lower Shaker Lake Dam are classified as Class I dams by the Ohio Department of Natural Resources (ODNR). Dam classification is based on height, storage volume, and potential downstream hazards. A Class I dam is classified by being greater than 60 feet in height, having a storage volume greater than 5,000 acre-feet, and in the event of failure, would cause probable loss of life. Both the Horseshoe Lake Dam and the Lower Shaker Lake Dam are classified as Class I dams due to the potential downstream hazards of possible loss of life in the event of dam failure. Regular Dam Safety Inspections performed by ODNR on both the Horseshoe Lake Dam and the Lower Shaker Lake Dam showed several instances of failure to meet multiple Ohio Administrative Codes (OAC) regarding the structural integrity of the dams. The potential for dam failure led to the initial lowering of Horseshoe Lake in June 2018, directed by ODNR. This initial lowering was approximately three feet and resulted in finding additional safety concerns regarding the structural integrity of the dam. A second lowering of Horseshoe Lake, directed by ODNR, was completed in June 2019. This second lowering drained the lake, leading to the current condition of Horseshoe Lake. NEORS has proposed to fund the removal of the Horseshoe Lake Dam and the reconstruction of the Lower Shaker Lake Dam to meet ODNR requirements as part of the NEORS’s Regional Stormwater Management Program. Lower Shaker Lake provides a greater measure of downstream flood control than Horseshoe Lake due to having a greater available storage capacity. NEORS proposes to remove the Horseshoe Lake Dam and restore the north and middle branches of Doan Brook where Horseshoe Lake was located.

Results from this study were compared to data collected by NEORS under the Ohio EPA Credible Data Program during past studies between 2006 and 2016. Doan Brook RMs 0.75 and 6.70 and Doan Brook South Branch RM 1.40 were assessed during these years as part of pre-construction monitoring for the DVT. In 2016, NEORS completed a study at Doan Brook RM 3.00 to collect baseline data prior to a restoration project that was planned at this site. Water chemistry, habitat, and fish and macroinvertebrate communities were evaluated. The restoration project was completed in May 2019. Approximately 1,000-feet of the Doan Brook stream channel was stabilized and restored. The surrounding land was converted into hydraulically connected and functioning floodplains. Stream banks were stabilized to restore eroded areas, streamflow was improved, and the riparian corridor was enhanced. The restoration project also provided flooding relief to the area. Data collected in the 2023 study was used to evaluate the biology and habitat of this site post restoration. This was the first year that NEORS assessed the water chemistry, habitat, and fish and macroinvertebrate communities on Doan Brook at RM 5.45 and Doan Brook

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South Branch at RM 0.50. This was also the first year that NEORSD assessed the habitat and macroinvertebrate community on Doan Brook North Branch at RM 7.05 and Doan Brook Middle Branch at RM 0.10. These two sites are located where Horseshoe Lake once resided. Horseshoe Lake was drained in 2019 and the North and Middle Branches of Doan Brook have been allowed to return to their natural state, creating stream channels where they originally existed.

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 Doan Brook Environmental Monitoring*. The assessments at Doan Brook North Branch RM 7.05 and Doan Brook Middle Branch RM 0.10 were not conducted as part of the Level 3 study but were still completed by Level 3 QDCs. 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 gathered from these assessments were evaluated using the Ohio EPA's Qualitative Habitat Evaluation Index (QHEI), Index of Biotic Integrity (IBI), 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* (2023) and compared to the Ohio Water Quality Standards for their designated use to determine attainment (Ohio EPA, 2023b). An examination of the individual metrics that comprise the IBI and ICI was used in conjunction with the water chemistry data and QHEI scores to assess the health of the stream. A YSI EXO2 data sonde was also installed at Doan Brook RM 5.45 and was used to monitor water quality parameters throughout the year and continued into 2024.

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

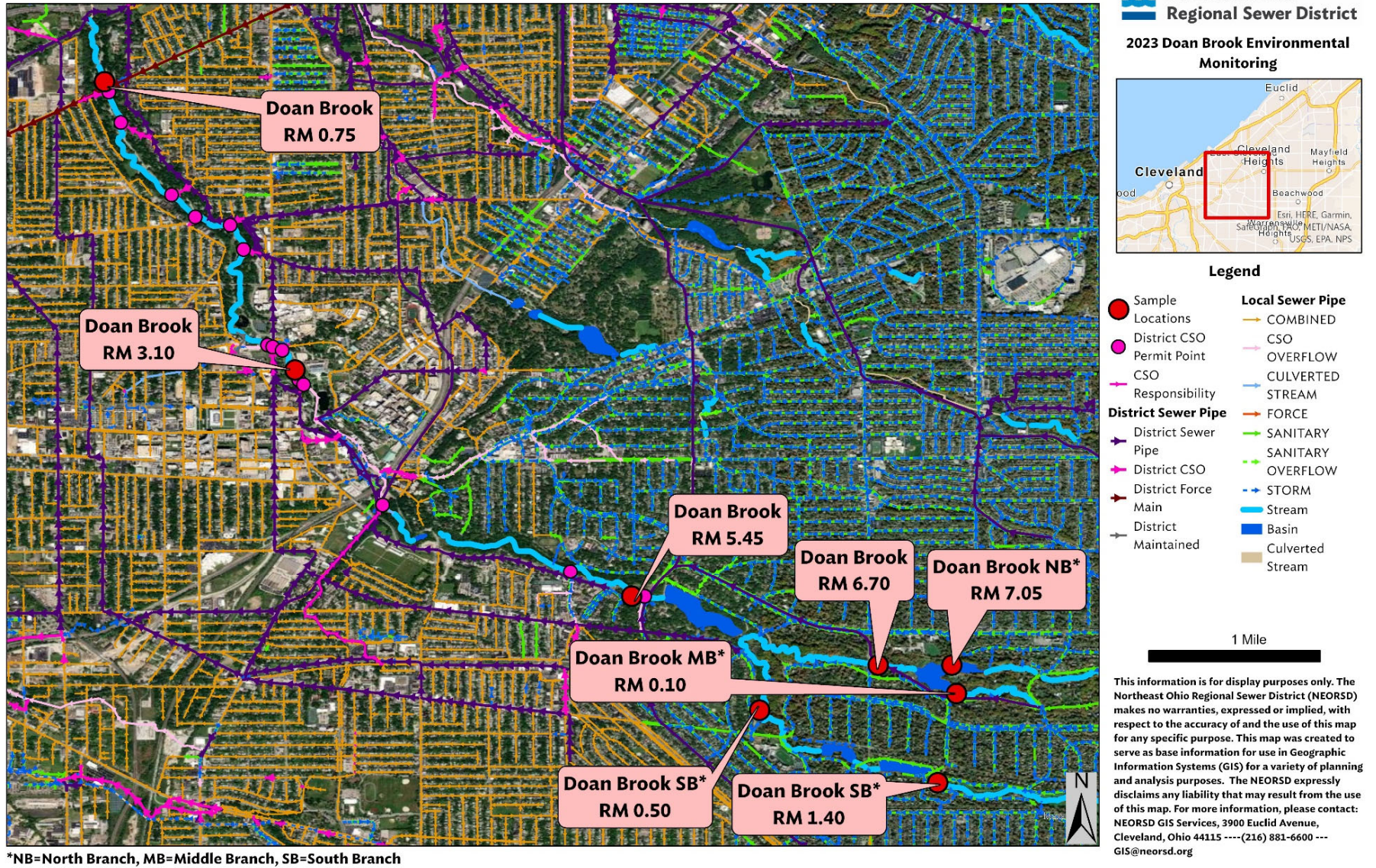


Figure 1. Sampling Locations

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Table 1. 2023 Doan Brook Sampling Locations						
Location	Latitude	Longitude	River Mile	Drainage Area	Station ID	Sampling Conducted
Doan Brook	41.5330	-81.6296	0.75	9.10 mi ²	301428	Habitat, Fish, Macroinvertebrates, and Water Chemistry
Doan Brook	41.5092	-81.6140	3.10	7.35 mi ²	200137	Habitat, Fish, Macroinvertebrates, and Water Chemistry
Doan Brook	41.4900	-81.5856	5.45	4.53 mi ²	301696	Habitat, Fish, Macroinvertebrates, Water Chemistry, and YSI EXO2 Sonde
Doan Brook	41.4838	-81.5643	6.70	1.20 mi ²	F01G52	Habitat, Fish, Macroinvertebrates, and Water Chemistry
Doan Brook, South Branch	41.4800	-81.5742	0.50	2.29	304515	Habitat, Fish, Macroinvertebrates, and Water Chemistry
Doan Brook, South Branch	41.4739	-81.5593	1.40	1.57	301429	Habitat, Fish, Macroinvertebrates, and Water Chemistry
Doan Brook, North Branch	41.4838	-81.5581	7.05	0.69	N/A	Habitat and Macroinvertebrates
Doan Brook, Middle Branch	41.4814	-81.5577	0.10	0.54	N/A	Habitat and Macroinvertebrates

The Ohio EPA assigns designated uses to establish minimum water quality requirements for surface waters. These requirements represent measurable criteria for assessing the chemical, physical, and biological integrity of Ohio’s surface waters consistent with Clean Water Act requirements. The beneficial use designations for Doan Brook are listed below in Table 2.

Table 2. Beneficial Use Designations for Doan Brook													
Stream	Beneficial Use Designation												
	Aquatic Life Habitat (ALU)						Water Supply			Recreation			
	S R W	W W H	E W H	M W H	S S H	C W H	L R W	P W S	A W S	I W S	B W	P C R	S C R
Doan Brook*		+							+	+		+	
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. * Includes the South, North, and Middle Branches of Doan Brook													

Water Chemistry and Bacteriological Sampling

Methods

Water chemistry and bacteriological sampling was conducted five times between July 25, 2023 and August 22, 2023, at the sites listed in Table 1 except for Doan Brook North Branch RM 7.05 and Doan Brook Middle Branch RM 0.10. Water chemistry was not conducted at these two sites in 2023. Five additional bacteriological and total phosphorous samples were collected at Doan Brook RMs 0.75 and 6.70 and Doan Brook South Branch RM 1.40 between September 26, 2023 and October 26, 2023. Techniques used for sampling and analyses followed the Ohio EPA *Surface Water Field Sampling Manual for water quality parameters and flows* (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 sterilized plastic bottles and preserved with sodium thiosulfate. At the time of sampling, measurements for dissolved oxygen, dissolved oxygen percent, pH, temperature, conductivity, and specific conductance were collected using a YSI EXO1 sonde. Duplicate/replicate samples and field blanks 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).

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

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).

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

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 NEORS D WQIS Division. Dates of water chemistry sampling compared to Doan Brook flow data (USGS 4208598) are shown below in Figure 2.

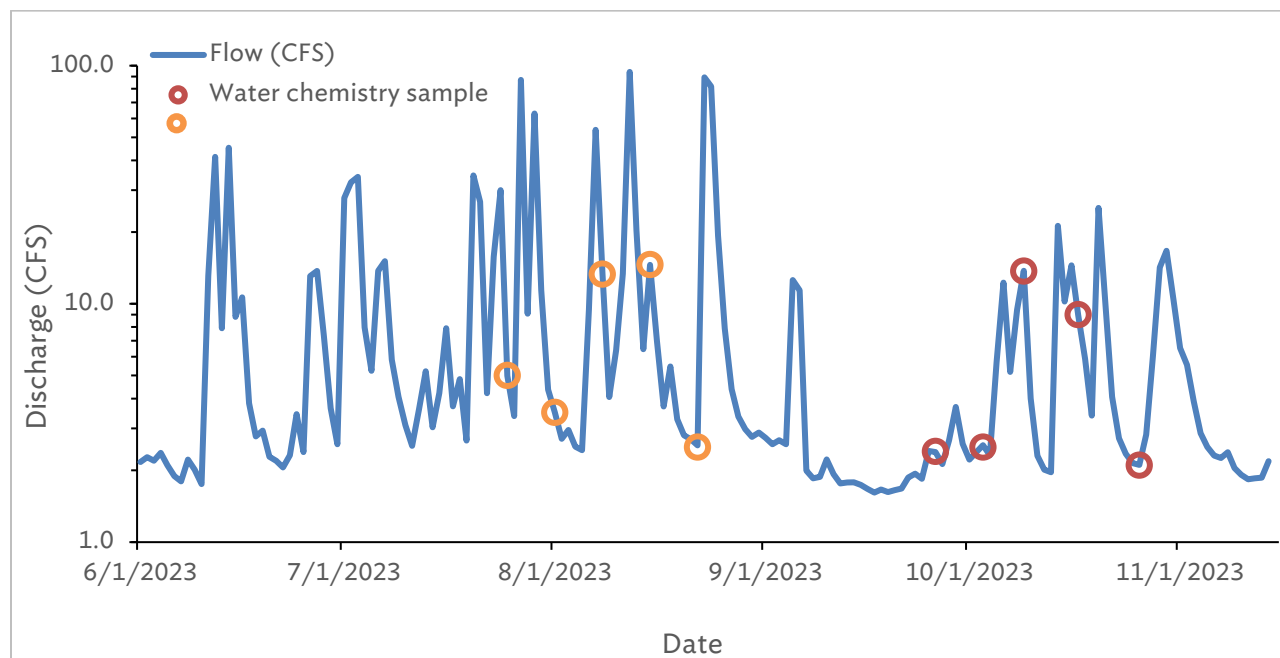


Figure 2. Daily mean discharge in CFS for Doan Brook at USGS Station 4208598. Shown are the daily mean discharge for 2023. Orange circles indicate water chemistry sampling dates. Red circles indicate water quality sampling dates to collect additional bacteriological and total phosphorous samples at Doan Brook RMs 0.75 and 6.70 and Doan Brook South Branch RM 1.40.

Results and Discussion

Quality Assurance / Quality Control

All sites monitored during the 2023 study are designated warmwater habitat, agricultural water supply, industrial water supply, and primary contact recreation (Ohio EPA, 2021). Duplicate/replicate samples, field blanks, and paired parameters were all utilized for QA/QC purposes and the results are as stated below.

Over the course of sampling, three field blanks were collected for QA/QC purposes. One was collected at Doan Brook South Branch RM 1.40 on August 15, 2023, one was collected at Doan Brook RM 0.75 on August 22, 2023, and one was collected at Doan Brook RM 6.70 on October 9, 2023. There were no instances in which the data needed to be qualified due to field blank comparisons.

Three sets of duplicate/replicate samples were collected over the course of sampling for QA/QC purposes. One set of duplicate samples was collected at Doan Brook RM 6.70 on August 1, 2023. A set of replicate samples was collected at Doan Brook South Branch RM 0.50 on August 8, 2023. Another set of replicate samples for *E. coli* and total phosphorous sampling was collected at Doan Brook RM 0.75 on September 26, 2023. The duplicate samples at Doan Brook RM 6.70 on August 1, 2023, revealed multiple parameters that were rejected due to RPDs that were greater than acceptable (Table 3). There may be numerous reasons for the difference between the samples, such as lack of precision and consistency in sample collection and/or analytical procedures, environmental heterogeneity, and/or improper handling of samples.

Site	Date	Parameter	Acceptable RPD	Actual RPD	Qualifier
Doan Brook RM 6.70	8/1/2023	Magnesium	14.7%	16.7%	Rejected
		Sodium	15.1%	17.4%	Rejected
		Strontium	11.0%	16.8%	Rejected

Paired parameters are evaluated in tandem using %RPD because they are interlinked and can be used for QA/QC purposes. There were five instances where the data for the paired parameters had to be qualified due to the sub parameter value being greater than the parent value. On August 15, 2023, five sample results for total dissolved solids were greater than total solids and the results were qualified (Table 4).

Table 4. Paired Parameter Data Qualifications on August 15, 2023					
Site	Total Solids	Total Dissolved Solids	Acceptable RPD	Actual RPD	Qualifier
Doan Brook RM 0.75	234	236	34.0%	0.9%	(J) Estimated
Doan Brook RM 3.10	256	264	33.1%	3.1%	(J) Estimated
Doan Brook RM 5.45	224	430	34.4%	63.0%	Rejected
Doan Brook RM 6.70	264	510	32.8%	63.6%	Rejected
Doan Brook South Branch RM 0.50	172	189	37.2%	9.4%	(J) Estimated

Recreational Use Results and Discussion

Escherichia coli (*E. coli*) is a fecal indicator bacteria commonly found in the intestinal tract and feces of warm-blooded animals and is used to measure the presence of feces (USEPA, 2012). The primary contact recreation (PCR) criteria 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 taken during any 90-day period. The second component is a 90-day geometric mean criterion of 126 MPN/100mL (Ohio EPA, 2022). In accordance with the Ohio EPA procedure and practice to qualify *E. coli* exceedances for the Primary 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 5 lists *E. coli* densities for all samples collected, as well as exceedances of the recreation season geometric mean criterion which occurred for all the sites on Doan Brook. The 90-day period started beginning when the first sample was collected. All sites on Doan Brook were in non-attainment of both criteria in 2023.

E. coli samples were collected at Doan Brook RMs 3.10 and 5.45 and Doan Brook South Branch RM 0.50 five times during the sampling period. *E. coli* samples were collected ten times during the sampling period at Doan Broom RMs 0.75 and 6.70 and Doan Brook South Branch RM 1.40. Additional samples were collected at those locations to help determine if activation of the DVT had resulted in improvements in *E. coli* levels in the brook. Of the ten samples collected, five were collected during dry weather and five were collected during wet-weather events. The wet-weather events may contribute to CSO overflows and stormwater runoff and may contribute to higher *E. coli* densities in the streams. Illicit discharges may also contribute to these exceedances. Out of all the locations sampled this year, Doan Brook RM 0.75 reported the highest geometric mean value of 2,036.9 MPN/100 mL. In 2016, Doan Brook RMs 0.75 and 6.70 also exceeded the 90-day geometric mean. *E. coli* exceedances have consistently occurred on Doan Brook in the

history of NEORSD’s sampling. These exceedances will likely continue to occur until the sources are controlled.

Table 5. 2023 <i>E. coli</i> Densities (MPN/100mL)						
Date	Doan Brook RM 0.75	Doan Brook RM 3.10	Doan Brook RM 5.45	Doan Brook RM 6.70	Doan Brook South Branch RM 0.50	Doan Brook South Branch RM 1.40
7/25/2023*	411	1203	461	2720	579	365
8/1/2023	687	411	411	1091.5	461	214
8/8/2023*	5500	1462	2318	9600	1049	3080
8/15/2023*	6900	2900	517	15,960	9740	4980
8/22/2023	687	210	117	579	1733	76
9/26/2023	55,495	-	-	276	-	53
10/3/2023	308	-	-	1414	-	60
10/9/2023*	3690	-	-	6570	-	1046
10/17/2023*	1300	-	-	<1	-	1300
10/26/2023	488	-	-	461	-	49
90-day Geomean (7/25/2023 – 10/22/2023)	2036.9	848.7	484.0	957.3	1364.3	418.5
<div style="display: flex; align-items: flex-start;"> <div style="width: 20px; height: 15px; background-color: #f4a460; margin-right: 5px;"></div> <div>Exceeds statistical threshold value of 410 MPN/100mL</div> </div> <div style="display: flex; align-items: flex-start; margin-top: 5px;"> <div style="width: 20px; height: 15px; background-color: #ffff00; margin-right: 5px;"></div> <div>Exceeds geometric mean criterion for 90-day period of 126 MPN/100mL</div> </div> <p>*Wet-weather Event: 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.</p>						

Statistical Analysis of the Impact of the Doan Valley Storage Tunnel on the Relationships Between Precipitation Volume with E. coli and Total Phosphorus

The DVT is one of seven large storage tunnels under NEORSD’s Project Clean Lake, a 25-year regional stormwater program to reduce the amount of combined sewer overflow discharging to Lake Erie. Project Clean Lake includes the construction of a combination of large storage tunnels, wastewater treatment plant improvements and expansions, and green infrastructure projects. The DVT was completed and became active in July 2021. By the end of 2021, the DVT, along with the completion of other smaller projects, greatly reduced the combined sewer overflow in the Doan Brook watershed.

It is often difficult to assess the impacts of infrastructure improvement projects on water chemistry and bacteriological parameters in receiving waters. This is primarily due to the complex

relationships between these parameters and multiple environmental factors. These factors may include, but are not limited to, changes in temperature, weather patterns, land use category, precipitation volume, upstream illicit discharges, and other contamination sources. Precipitation volume in particular is known to have a positive correlation with elevated *E. coli* densities due to increases in urban runoff, common trench sewer inflow and infiltration, and combined sewer overflows. Increased rainfall may also contribute to elevated nutrient concentrations depending on land use, particularly in areas where fertilizers are applied such as agricultural fields, golf courses, and heavily landscaped residential lots. It is therefore essential to control for changes in precipitation volume in the time periods leading up to sample collection when comparing results from before and after infrastructure improvement projects.

In order to determine the impact of the DVT on *E. coli* densities and total phosphorus concentrations in Doan Brook, the relationship between precipitation and each parameter before and after DVT installation was compared using analysis of covariates (ANCOVA). The use of ANCOVA controls for the impact from varying rainfall patterns prior to sampling. ANCOVA analysis compares changes in the linear relationship between the parameters and precipitation before and after DVT construction rather than changes in the raw parameter concentrations. Precipitation volumes for the 24-hour periods prior to sample collection between 2012 and 2023 were obtained from the Shaker Heights rain gauge. Data prior to this time period was excluded as there were gaps in the available rain gauge data required for the ANCOVA analysis. All available *E. coli* and total phosphorus data for this time period was used. This included past environmental monitoring studies as well as consent decree sampling, all completed by NEORSD. Table 6 shows the number of observations for *E. coli* and total phosphorus used in the analysis. Results of paired duplicate samples were averaged and counted as a single observation. Sampling results and 24-hour precipitation volumes were log transformed to improve the linear correlation prior to analysis by ANCOVA. A constant value of 0.1 inches was added to the rainfall prior to log transformation in order to allow log transformation of data points with zero rainfall. Statistical analysis was performed using RStudio version 2022.02.3 using the rstatix, tidyverse, and car packages.

Table 6. Number of Available Data Points for <i>E. coli</i> and Total Phosphorus Before and After DVT Completion			
Site	DVT Tunnel Status	Number of <i>E. coli</i> Samples	Number of Total Phosphorus Samples
Doan Brook RM 0.75	Before	109	37
	After	18	10
Doan Brook RM 3.10	Before	5	5
	After	5	5
Doan Brook RM 6.70	Before	17	17
	After	10	10
Doan Brook South Branch RM 1.40	Before	10	10
	After	10	10

Figure 3 shows boxplot distributions of the *E. coli* densities before and after DVT completion. ANCOVA analysis demonstrated that there was no significant change in the relationship between *E. coli* and precipitation at all sites using a p-value cutoff of <0.05. This indicates that the major source of elevated *E. coli* densities during rain events in this watershed was not addressed by the capture of CSO by the DVT. In the upstream portion of the Doan Brook watershed, from approximately RM 5.00 and further upstream, both common trench and separate trench sewers are present. In common trench over/under sewers, the invert plates may become damaged or go missing which results in a direct connection between the storm and sanitary sewers. This, along with deterioration of the local sewer system over time, may be contributing to elevated *E. coli* in the watershed. Downstream in the watershed, mostly combined sewers exist. Median *E. coli* densities were similar before and after DVT completion for all sites except the upstream site, Doan Brook Main Branch RM 6.70. The p-value by ANCOVA at this site was 0.08 which indicates a potential trend of moderate significance. The increase in *E. coli* densities at this site may indicate the presence of upstream illicit discharges or a problem in the local collection system.

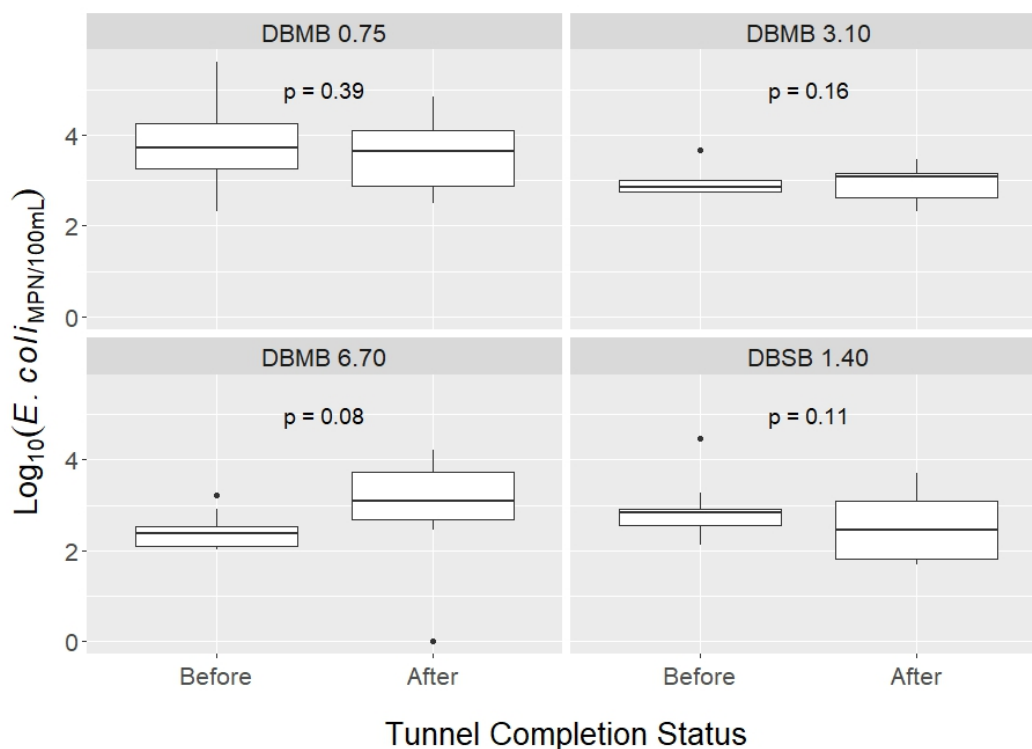


Figure 3. Boxplot distributions of *E. coli* densities before and after DVT completion with p-values from ANCOVA analysis.

Figure 4 shows boxplot distributions of the total phosphorus concentrations before and after DVT completion. ANCOVA analysis demonstrated that there was a significant decrease in total phosphorus concentrations at the sites downstream of NEORSO-operated CSOs (Doan Brook Main Branch RMs 0.75 and 3.10) following the completion of the DVT. No change was observed at the upstream sites before versus after DVT completion. Figure 5 shows the relationships at each site between precipitation and total phosphorus concentrations before and after DVT completion.

Phosphorus concentrations were decreased at both downstream sites during both dry and wet weather. It might be expected that CSO capture would primarily impact phosphorus concentrations during wet-weather events rather than during both dry and wet weather. However, it is possible that CSO discharges may contribute to elevated phosphorus concentrations during dry weather as well by loading the stream with phosphorus-laden solids. Historical phosphorus concentrations prior to completion of the DVT were elevated downstream of NEORSD-operated CSOs during both wet and dry weather compared to the sites upstream of NEORSD-operated CSOs. This would indicate that CSO discharges did contribute to increased phosphorus concentrations during both dry and wet weather. There was also no significant change in total phosphorus concentrations before and after DVT completion at the upstream sites, but significant decreases at the downstream sites. These facts together support the hypothesis that the DVT contributed to the decrease in total phosphorus concentrations in this watershed.

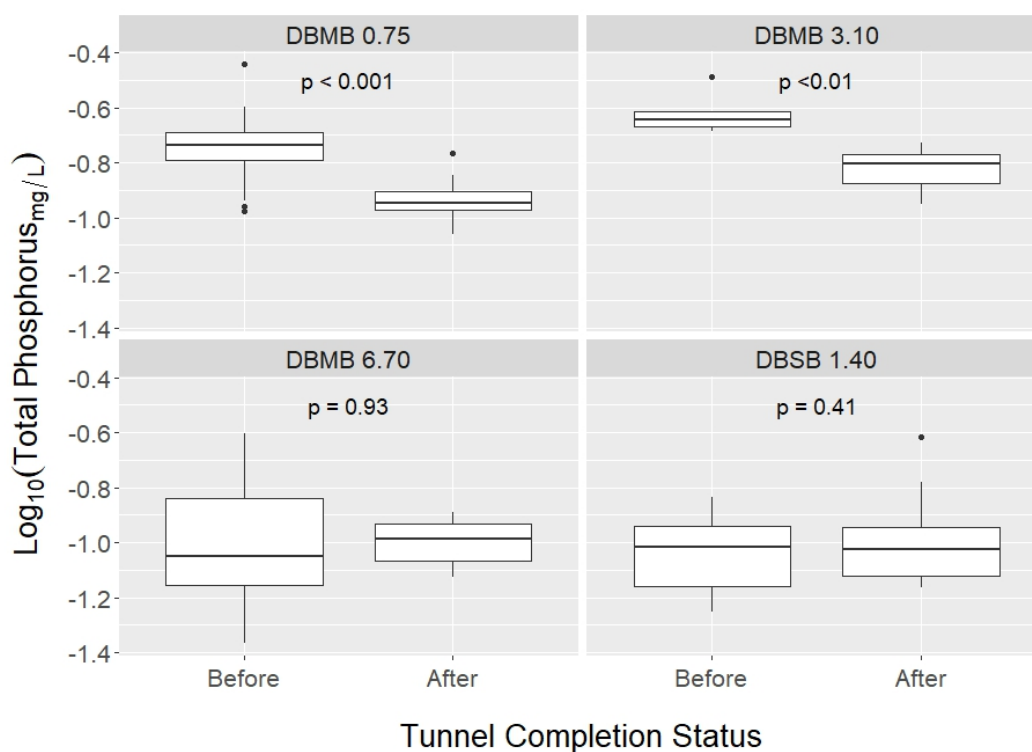


Figure 4. Boxplot distributions of total phosphorus concentrations before and after DVT completion with p-values from ANCOVA analysis.

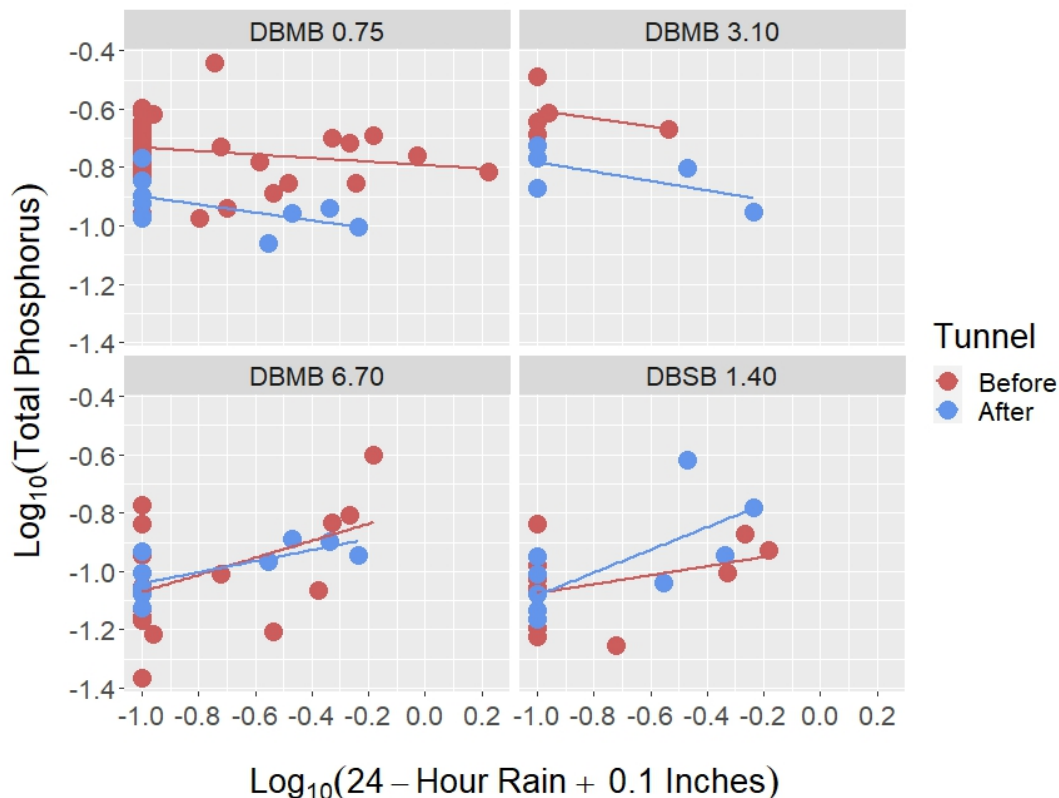


Figure 5. Relationship between precipitation and total phosphorus concentrations before and after DVT completion.

Water Column Chemistry Results and Discussion

Mercury analysis for all the sampling events was done using EPA Method 245.1. Because the detection limit for this method is above the criteria for the Human Health Nondrinking and Protection of Wildlife Outside Mixing Zone Averages (OMZA), it generally cannot be determined if the sites were in attainment of those criteria. Instead, this type of mercury sampling was used as a screening tool to determine whether contamination was present above those levels typically found in the stream. On July 25, 2023, mercury was detected above the analytical method detection limit (MDL), but below the Practical Quantitation Limit (PQL) in the samples from all sites except for Doan Brook RM 0.75 (Table 7). Therefore, the results are considered to be estimated. On August 8, 2023, mercury was detected above the MDL, but below the PQL, in the sample collected at Doan Brook RM 6.70. Therefore, this result is also considered to be an estimate. On August 8, 2023 and August 15, 2023, the samples collected at Doan Brook South Branch RM 1.40 had mercury concentrations of 0.078 ug/L and 0.050 ug/L, respectively, that resulted in exceedances (Table 8).

Table 7. Total Mercury Sample Results Above MDL				
Site	Date	Estimated Result	MDL	PQL
Doan Brook RM 3.10	7/25/2023	0.021 ug/L	0.0199 ug/L	0.05 ug/L
Doan Brook RM 5.45		0.028 ug/L	0.0199 ug/L	0.05 ug/L
Doan Brook RM 6.70		0.027 ug/L	0.0199 ug/L	0.05 ug/L
Doan Brook South Branch RM 0.50		0.027 ug/L	0.0199 ug/L	0.05 ug/L
Doan Brook South Branch RM 1.40		0.035 ug/L	0.0199 ug/L	0.05 ug/L
Doan Brook RM 6.70	8/8/2023	0.026 ug/L	0.0199 ug/L	0.05 ug/L

Table 8. Total Mercury Sample Results Above PQL				
Site	Date	Result	MDL	PQL
Doan Brook South Branch RM 1.40	8/8/2023	0.078 ug/L	0.0199 ug/L	0.05 ug/L
	8/15/2023	0.05 ug/L	0.0199 ug/L	0.05 ug/L

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. The SNAP assigns designations for quality of surface waters based on factors including dissolved oxygen swings, benthic chlorophyll *a*, total phosphorous, and dissolved inorganic nitrogen (Ohio EPA, 2015). NEORSD did not collect benthic chlorophyll *a* in 2023; however, nutrient concentrations were assessed for general watershed monitoring purposes.

The 2023 nutrient concentrations for all sampling sites are shown in Table 9. The results of dissolved inorganic nitrogen (DIN) and total phosphorous (TP) were compared to Table 2 listed in the SNAP document (Figure 6). According to this section of SNAP, Doan Brook RMs 0.75 and 6.70 received an ecological risk narrative level described as “levels typical of working landscapes; low risk of beneficial use if allied responses are within normal ranges.” Doan Brook RM 3.10 and Doan Brook South Branch RM 0.50 received an ecological risk narrative level described as “levels typical of enriched condition; low risk of beneficial use if allied responses are within normal ranges.” Doan Brook RM 5.45 and Doan Brook South Branch RM 1.40 received an ecological risk narrative level described as “levels typical of modestly enriched condition in nitrogen limited systems; low risk to beneficial use if allied responses are within normal ranges.”

Table 9. Nutrient Results for Doan Brook used in 2023 SNAP Analysis

Stream	River Mile	Geomean DIN (mg/L)	Geomean TP (mg/L)	Geomean DRP (mg/L)
Doan Brook	0.75	0.573	0.117**	0.072
	3.10	0.595	0.150	0.094*
	5.45	0.282	0.114	0.026
	6.70	0.715	0.101**	0.045
Doan Brook South Branch	0.50	0.461	0.154	0.094
	1.40	0.104	0.103**	0.063

Data used in Table 2 of SNAP (Ohio EPA, 2015b)
 Geometric means for DIN, TP, and DRP (n=5, unless otherwise noted)
 *n=4 due to rejected data based on QA/QC protocols
 **n=10 due to five dry weather and five wet-weather sampling events

		← DECREASING RISK					
		DIN Concentration (mg/l)					
		<0.44	0.44 < 1.10	1.10 < 3.60	3.60 < 6.70	≥6.70	
DECREASING RISK ↑	TP Conc. (mg/l)	<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 6. Table 2 of the Stream Nutrient Assessment Procedure (Ohio EPA, 2015b).

Dissolved oxygen (DO) diel swings are an indication of nutrient enrichment used in the SNAP protocol. One YSI EXO2 long-term sonde station is operated and maintained by NEORS on Doan Brook at RM 0.40. Another YSI EXO2 data sonde was installed at Doan Brook RM 5.45,

just downstream of Lower Shaker Lake for the 2023 field season. The data sondes collected DO measurements every 15 minutes. The 24-hour DO swings were determined by calculating the difference between the maximum and minimum daily concentrations of DO and compared to the threshold value established in the SNAP recommendation guidance (OEPA, 2015). A low to normal DO swing value is ≤ 6.5 mg/L and a wide DO swing is > 6.5 mg/L. The DO diel swings were analyzed for the time period when the water chemistry samples were collected from July 25, 2023 through August 22, 2023. Table 10 provides minimum and maximum DO concentrations for both sonde locations for the period between July 25 and August 22, 2023. The average DO swings at Doan Brook RM 0.40 and Doan Brook RM 5.45 were 2.46 mg/L and 1.03 mg/L, respectively. These were both in the low to normal range for DO swings of ≤ 6.5 mg/L. The DO swings at both sites never exceeded the 6.5 mg/L threshold during the analyzed period. This indicates that nutrient over enrichment is not a likely cause of impairment on Doan Brook.

Table 10. Daily DO Swings at Doan Brook at RM 0.40 and RM 5.45						
	RM 0.40			RM 5.45		
Date	Maximum DO	Minimum DO	DO Swing	Maximum DO	Minimum DO	DO Swing
7/25/2023	-	-	-	-	-	-
7/26/2023	8.02	5.75	2.27	7.83	6.01	1.82
7/27/2023	8.26	6.54	1.72	8.62	8.07	0.55
7/28/2023	8.04	6.83	1.21	8.16	7.39	0.77
7/29/2023	8.12	6.42	1.70	8.52	7.85	0.67
7/30/2023	8.85	7.36	1.49	8.25	7.71	0.54
7/31/2023	8.60	6.65	1.95	8.02	7.23	0.79
8/1/2023	9.29	6.5	2.79	7.87	6.84	1.03
8/2/2023	9.23	5.67	3.56	7.53	6.40	1.13
8/3/2023	9.53	6.3	3.23	7.35	5.91	1.44
8/4/2023	9.15	6.42	2.73	6.91	5.75	1.16
8/5/2023	9.35	6.23	3.12	7.20	5.81	1.39
8/6/2023	10.41	5.50	4.91	8.09	5.84	2.25
8/7/2023	-	-	-	8.85	7.71	1.14
8/8/2023	-	-	-	-	-	-
8/9/2023	-	-	-	-	-	-
8/10/2023	-	-	-	-	-	-
8/11/2023	-	-	-	-	-	-
8/12/2023	8.67	7.28	1.39	8.99	8.09	0.90
8/13/2023	8.85	7.17	1.68	8.47	8.19	0.28
8/14/2023	8.32	6.84	1.48	8.46	7.96	0.50
8/15/2023	9.03	7.13	1.9	8.98	7.90	1.08
8/16/2023	9.38	7.09	2.29	8.77	8.00	0.77
8/17/2023	8.91	6.77	2.14	8.28	7.28	1.00
8/18/2023	9.94	6.95	2.99	8.72	7.89	0.83
8/19/2023	10.27	7.22	3.05	8.21	7.08	1.13
8/20/2023	9.76	7.21	2.55	7.7	6.27	1.43

Table 10. Daily DO Swings at Doan Brook at RM 0.40 and RM 5.45						
	RM 0.40			RM 5.45		
Date	Maximum DO	Minimum DO	DO Swing	Maximum DO	Minimum DO	DO Swing
8/21/2023	9.74	6.79	2.95	7.23	6.30	0.93
8/22/2023	10.15	6.75	3.40	7.36	6.24	1.12
Average	9.12	6.67	2.46	8.10	7.07	1.03
- Sonde was out for calibration						

Habitat Assessment

Methods

Instream habitat assessments were conducted once at each site listed in Table 1 in 2023 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; however, narrative ratings vary based on the drainage area of the stream (Table 11). All of Doan Brook has a drainage area of less than 20 square miles and is therefore a headwater stream. For headwater streams, a score of 55 and higher suggests that sufficient habitat exists to support a fish community that attains the WWH criterion (Ohio EPA, 2006). Scores greater than 70 frequently demonstrate habitat conditions that have the ability to support exceptional warmwater faunas. 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)* (2006). QHEI field sheets for each site are available upon request from the NEORSWQIS Division.

Table 11. Narrative Ranges Assigned to QHEI Scores		
Narrative Rating	QHEI Range	
	Headwater Stream (Drainage Area ≤ 20 square miles)	Larger Stream (Drainage Area > 20 square miles)
Excellent	≥ 70	≥ 75
Good	55 – 69	60 – 74
Fair	43 – 54	45 – 59
Poor	30 – 42	30 – 44
Very Poor	< 30	< 30

Instream habitat assessments using the Headwater Habitat Evaluation Index (HHEI) were conducted once at two of the sites in the 2023 Doan Brook study, Doan Brook North Branch RM 7.05 and Doan Brook Middle Branch RM 0.10. Primary headwater (PHW) streams are defined as

those that occupy the very uppermost reaches of a watershed and have a total drainage area of approximately 1.0 mi² or less. They also usually have limited pool depth with most pools being less than 40 cm in depth during baseline flow (Ohio EPA, 2020). These two sites have drainage areas less than 1.0 mi² and are considered primary headwater streams.

The HHEI can be used to score physical habitat features that have been found to be statistically important determinants of biological community structure in PHW streams. The index is based on three metrics: stream substrate, maximum pool depth, and bank full width. The HHEI has a maximum score of 100. Biological surveys including fish, macroinvertebrate, and/or salamander surveys can be done in conjunction with the HHEI assessment for more definitive habitat determinations. A more detailed description of the HHEI can be found in Ohio EPA's *Field Methods for Evaluating Primary Headwater Streams in Ohio* (Ohio EPA, 2020). HHEI field sheets for each site are available upon request from the NEORSD WQIS Division. The QHEI and the HHEI were used in conjunction with each other to assess the habitat of these two sites. For this study, a macroinvertebrate qualitative assessment was completed at each site, in conjunction with the HHEI, to determine the stream classification. The macroinvertebrate qualitative assessment will be further discussed in the *Macroinvertebrate Community Biology Assessment* section of this report.

Results and Discussion

Of the eight sites studied in 2023, five received narrative ratings of *Good*, while the other three received narrative ratings of *Fair* (Table 13). The sites that received narrative ratings of *Fair* and did not meet the WWH QHEI target score included Doan Brook RM 0.75, Doan Brook South Branch RM 1.40, and Doan Brook Middle Branch RM 0.10. The other five sites met the WWH QHEI target scores set by the Ohio EPA and should have the ability to support healthy warmwater fish communities. Doan Brook North Branch RM 7.05 and Doan Brook Middle Branch RM 0.10 were also evaluated using the HHEI in conjunction with the QHEI.

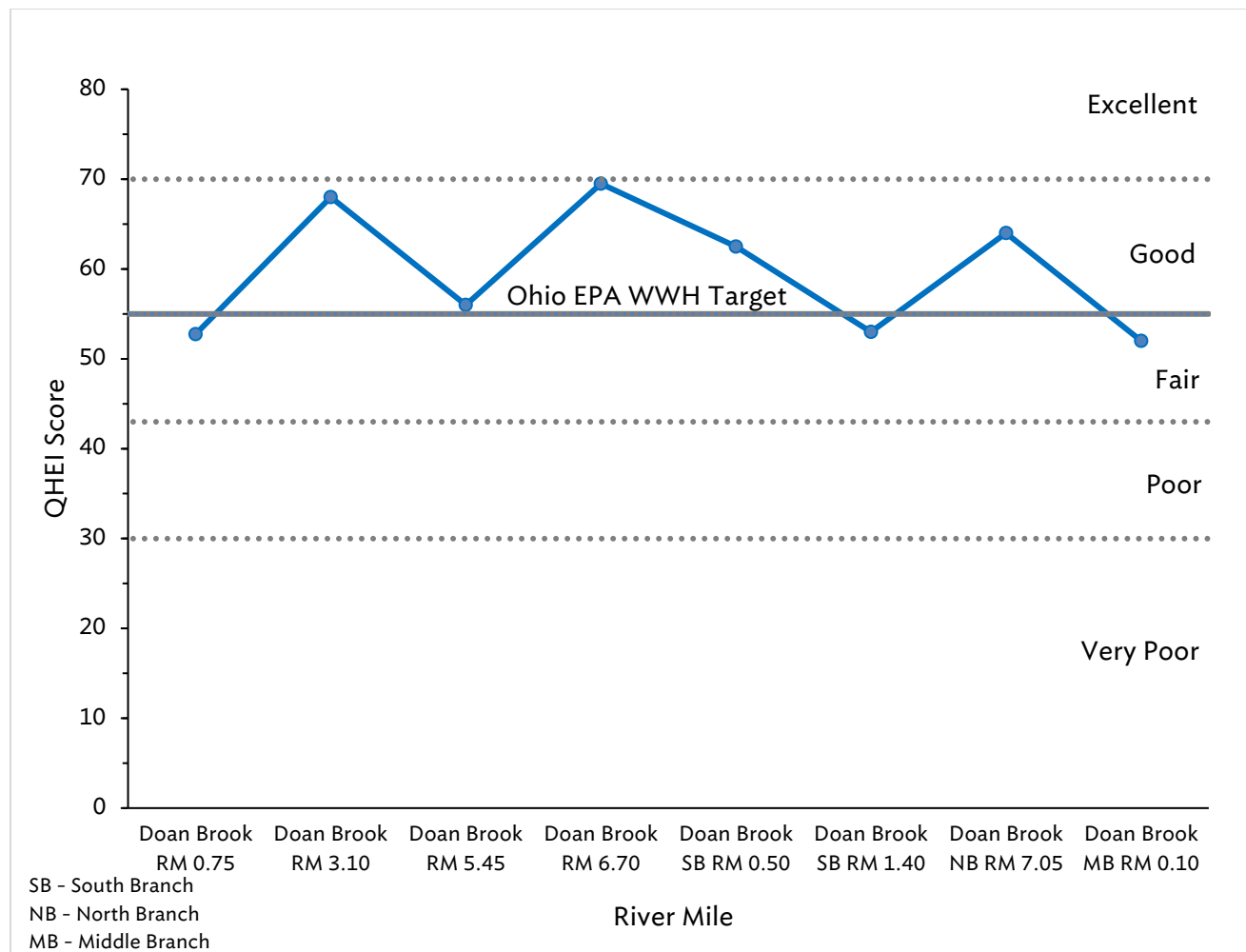


Figure 7. 2023 Doan Brook Watershed Qualitative Habitat Evaluation Index Scores

The QHEI assessment of Doan Brook at RM 0.75 resulted in a score of 52.75 and a narrative rating of *Fair*. This site did not meet the WWH QHEI target score set by the Ohio EPA. The dominant substrate types at this location were gravel and sand. Boulders, slabs, cobble, muck, silt, and artificial substrates were also found throughout the reach. This site had a moderate amount of silt and embeddedness. Instream cover was sparse but consisted of shallows in slow water, pools greater than 70 centimeters in depth, boulders, and woody debris. Channel development was fair to poor, and sinuosity was low. This reach of Doan Brook had pools greater than 70 centimeters deep; however, no riffle was present and runs were limited. This contributed to the lower score at this site. This site has been assessed several times by NEORS since 2007. From 2007 to 2014, this site met the WWH QHEI target criterion; however, the score decreased in 2016 and the target score has not been met since (Table 12). A functional riffle was present up until 2014 and is no longer present. Decreases of the amount of instream cover and the lack of riffle have had the greatest impacts on the QHEI score.

The QHEI assessment of Doan Brook at RM 3.10 resulted in a score of 68.00 and a narrative rating of *Good*. In May 2019, a restoration project was completed at this site which stabilized and

restored approximately 1,000-feet of the Doan Brook stream channel. The surrounding land was converted into hydraulically connected and functioning floodplains. Stream banks were stabilized to restore eroded areas, streamflow was improved, and the riparian corridor was enhanced. In the 2023 assessment, the dominant substrates at this site were boulder and sand. Cobble and gravel were also present throughout the reach. A moderate amount of instream cover was present which consisted of rootmats, boulders, and aquatic macrophytes. This section of Doan Brook is recovering and has good development and moderate to high stability. The maximum pool depth was between 0.7 and 1.0 meters. Deep riffles and runs were present with an average riffle depth greater than 10 centimeters and runs deeper than 50 centimeters. NEORS D studied this site in 2016 to collect baseline evaluations to compare to post-restoration results. In 2016, this site received a QHEI score of 78.5 and a narrative rating of *Excellent*. The 2023 QHEI score has decreased from this assessment; however, the site is recovering and is still meeting the WWH QHEI target score set by the Ohio EPA.

The QHEI assessment of Doan Brook at RM 5.45 resulted in a score of 56.00 and a narrative rating of *Good*. The dominant substrates were boulder slabs and bedrock. Boulders, cobble, gravel, sand, and silt were also present throughout the reach. This section of Doan Brook was moderately embedded and had a normal to moderate amount of silt. Instream cover was sparse but consisted of shallows in slow water, boulders, logs, and woody debris. This section is not channelized and has high stability; however, it has low sinuosity and only fair development. Maximum pool depth is between 0.4 and 0.7 meters. The riffles were shallow, with a maximum depth between 5 and 10 centimeters. The maximum depth of the run was less than 50 centimeters.

The QHEI assessment of Doan Brook at RM 6.70 resulted in a score of 69.50 and a narrative rating of *Good*. The dominant substrates in the pools and riffles were cobble and gravel. Boulders were also present in the riffles and sand was present in the pools. A moderate amount of instream cover was present which consisted of undercut banks, overhanging vegetation, shallows in slow water, rootmats and rootwads, boulders, logs, and woody debris. This section of Doan Brook is not channelized, has good development, and has a moderate amount of sinuosity. Little to no bank erosion is present here. The maximum pool depth is between 0.7 and 1.0 meters. Riffle depth is between 5 and 10 centimeters and maximum run depth is less than 50 centimeters. Overall, this site is moderately stable. This site has been assessed by NEORS D several times since 2007 (Table 12). In 2016, the last time this site was assessed by NEORS D, it also received a QHEI score of 69.50. This site has consistently met the WWH QHEI target score set by the Ohio EPA.

The QHEI assessment of Doan Brook South Branch at RM 0.50 resulted in a score of 62.50 and a narrative rating of *Good*. The dominant substrate was bedrock, but boulders, cobble, and gravel were also present in the riffles. Instream cover consisted of shallows in slow water, rootmats, boulders, aquatic macrophytes, logs, and woody debris. This section of stream is not channelized, has fair to good pool, riffle, run development, and low to moderate sinuosity. Some bank erosion is present. The maximum pool depth was between 0.4 and 0.7 meters. Riffles were deep with depths greater than 10 centimeters. Riffle/run substrates were stable and had low embeddedness.

The QHEI assessment of Doan Brook South Branch at RM 1.40 resulted in a score of 53.00 and a narrative rating of *Fair*. This site did not meet the WWH QHEI target score set by the Ohio

EPA. The dominant substrates were cobble and gravel. Boulder slabs were present throughout the reach and hardpan and artificial substrates were present in the pools. A sparse to moderate amount of instream cover was present and consisted of undercut banks, overhanging vegetation, rootmats, and boulders. This section of the stream is recovering from channelization, though pool, riffle, and run development is poor to fair and sinuosity is low. Little to no erosion is present and the stream is moderately stable. This site has been assessed by NEORS D several times since 2007. In 2013 and 2014, this site received QHEI scores of 60.00 and 61.50, respectively, and met the WWH QHEI target score set by the Ohio EPA (Table 12). The score decreased in 2023 and no longer meets the WWH QHEI target score. A change in the amount and types of instream cover has had the greatest impact on the score.

A QHEI and HHEI assessment were completed at Doan Brook North Branch RM 7.05. The QHEI assessment resulted in a score of 64.00 and a narrative rating of *Good*. This was the first habitat assessment performed following the lowering of Horseshoe Lake in June 2019 which led to the current condition of this section of Doan Brook North Branch. This site has a drainage area of 0.69 mi² classifying it as a PHW stream. The dominant substrates at this site were gravel and hardpan. Boulder, cobble, and sand were also present. A sparse to moderate amount of instream cover was present and consisted of overhanging vegetation, rootmats, pools greater than 70 centimeters, and boulders. Pool, riffle, and run development was fair. This section of the stream has low sinuosity and is low to moderately stable. The average bankfull width was 5 meters. The HHEI assessment resulted in a score of 54. Biological surveys can be completed along with HHEIs to make definitive habitat determinations. The HHEI in conjunction with the macroinvertebrate qualitative assessment resulted in a classification of this stream as a Class II PHW stream. The macroinvertebrate community was comprised of all warmwater species. No coldwater or sensitive taxa were present. A warmwater adapted macroinvertebrate community is typical of a Class II PHW stream. The macroinvertebrate community assessment will further be discussed in the *Macroinvertebrate Community Biology Assessment* section of this report.

A QHEI and HHEI assessment were completed at Doan Brook Middle Branch RM 0.10. The QHEI assessment resulted in a score of 52.00 and a narrative rating of *Fair*. This site did not meet the WWH QHEI target score set by the Ohio EPA; however, this was the first QHEI assessment performed at this site following the lowering of Horseshoe Lake in June 2019 which led to the current condition of Doan Brook, Middle Branch. The dominant substrates throughout this reach were gravel and hardpan. Boulders, cobble, and sand were also present in the pools. Maximum pool depth was 43 cm. Instream cover was sparse and consisted of overhanging vegetation, boulders, and logs and woody debris. This section of stream had moderate sinuosity and fair development of pool, riffle, and run habitat. The riffle/run substrates are unstable and extensive embeddedness occurs throughout the reach. The gradient at this site is 31.25 ft./mi. which classifies it as very high. The average bankfull width was 2.5 meters. The HHEI assessment resulted in a score of 53. A macroinvertebrate qualitative assessment was also completed at this site to support the stream classification. The HHEI assessment, in conjunction with the macroinvertebrate qualitative assessment, resulted in a classification of this stream as a Class II PHW stream. The macroinvertebrate community was mostly comprised of warmwater species, only one coldwater taxa was collected. Only one sensitive taxa (moderately intolerant) was

collected, while all others were facultative to tolerant to pollution. A warmwater-adapted macroinvertebrate community is typical of a Class II PHW stream. The macroinvertebrate community assessment will further be discussed in the *Macroinvertebrate Community Biology Assessment* section of this report.

Doan Brook North Branch RM 7.05 and Doan Brook Middle Branch RM 0.10 are both located where Horseshoe Lake once resided. These two sites have had approximately four years to stabilize and these assessments provide a baseline habitat assessment prior to the future restoration of the stream channels and floodplain.

Table 12. Doan Brook Historic QHEI Scores (2007-2023)								
Year	Doan Brook				Doan Brook, South Branch		Doan Brook, North Branch	Doan Brook, Middle Branch
	RM 0.75	RM 3.10	RM 5.45	RM 6.70	RM 0.50	RM 1.40	RM 7.05	RM 0.10
2007	57.00	-	-	57.50	-	50.75	-	-
2008	51.00	-	-	65.00	-	59.00	-	-
2009	62.00	-	-	-	-	-	-	-
2010	62.50	-	-	-	-	-	-	-
2011	60.00	-	-	-	-	-	-	-
2012	63.50	-	-	-	-	-	-	-
2013	61.00	-	-	67.00	-	60.00	-	-
2014	62.00	-	-	58.75	-	61.50	-	-
2016	51.0	78.5	-	69.5	-	-	-	-
2023	52.75	68.00	56.00	69.50	62.50	53.00	64.00	52.00

Bold = meets WWH target (≥ 55 for headwater sites)

Individual components of the QHEI can also be used to evaluate whether a site is capable of meeting its WWH designated use. 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 or more 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, 1999).

All sites except for Doan Brook RM 3.10 and Doan Brook RM 6.70 had either one high or four or more moderate influence characteristics, or a combination of both. These characteristics indicate that there is a greater number of habitat attributes at these sites that have the potential to have a negative impact on the fish community and prevent them from meeting WWH attainment. Doan Brook RM 3.10 had two moderate influence attributes and no high influence attributes. Doan Brook RM 6.70 had three moderate influence attributes and no high influence

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attributes. These two sites received QHEI narrative ratings of *Good*, indicating that they have the habitat to support a WWH fish community; however, their IBI scores were both *Poor*. This will further be evaluated in the *Fish Community Biology Assessment* section of this report.

Table 13. 2023 Qualitative Habitat Evaluation Index Scores and Physical Attributes.

WWH Attributes														MWH Attributes																		
Stream	River Mile	QHEI Score	Narrative 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	High Influence						Moderate Influence											
															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	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
Doan Brook Main Branch	0.75	52.75	Fair		X						X			2	X			X			X	X			X	X		X	6	1.0	2.3	
	3.10	68.00	Good		X		X	X	X	X	X	X	X	8						0	X			X						2	0.1	0.3
	5.45	56.00	Good	X	X					X		X	X	5				X		X		X				X	X		5	0.3	1.0	
	6.70	69.50	Good	X	X		X	X	X		X			6						0						X	X	X		3	0.1	0.6
Doan Brook South Branch	0.50	62.50	Good	X			X	X	X		X	X	X	7				X				X	X			X	X		4	0.3	0.6	
	1.40	53.00	Fair		X				X		X	X		4				X			X	X			X	X		5	0.4	1.2		
Doan Brook North Branch	7.05	64.00	Good	X	X				X		X	X		5				X			X	X			X	X	X		7	0.3	1.3	
Doan Brook Middle Branch	0.10	52.00	Fair	X	X			X			X			4				X			X	X			X	X	X		5	0.4	1.2	

Fish Community Biology Assessment

Methods

The fish community was assessed at all sites except for Doan Brook North Branch RM 7.05 and Doan Brook Middle Branch RM 0.10. One quantitative electrofishing pass was conducted at Doan Brook RM 5.45, while all other sites had two quantitative electrofishing passes conducted in 2023. A list of the dates when the surveys were completed, along with approved flow measurements from the United States Geological Survey (USGS) gage station in 4208598 (Doan Brook) are shown in Table 14. Sampling was conducted using longline electrofishing techniques and consisted of shocking all habitat types within a sampling zone while moving from downstream to upstream by slowly and steadily wading through the stream while sampling shoreline and submerged habitat. The sampling zone for all sites was 0.15 kilometers and sampling protocols 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, weighed, and examined for the presence of anomalies, including DELTs (deformities, eroded fins, lesions, and tumors). 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.

Date	Sites sampled (RMs)	Daily Mean Flow (CFS)
6/22/2023	Doan Brook RM 3.10	2.1
6/29/2023	Doan Brook RM 0.75	3.6
6/30/2023	Doan Brook RM 5.45, Doan Brook South Branch RM 0.50	2.6
8/10/2023	Doan Brook South Branch RM 1.40	6.4
8/31/2023	Doan Brook RM 3.10, 6.70	2.9
9/1/2023	Doan Brook RM 0.75, Doan Brook South Branch RM 0.50	2.7
9/25/2023	Doan Brook South Branch RM 1.40	2.4
10/10/2023	Doan Brook RM 6.70	4.0

The electrofishing results were compiled and utilized to evaluate fish community health through the application of the Index of Biotic Integrity (IBI). The IBI incorporates twelve community metrics representing structural and functional attributes (Table 15). These metrics vary based on sample site drainage area. 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 IBI was calculated for all sites in this study except for Doan Brook North Branch RM 7.05 and Doan Brook Middle Branch RM 0.10, where the fish community was not assessed.

Table 15. IBI Metrics (Headwater sites)
Number of indigenous fish species
Number of darter species
Number of headwater species
Number of minnow species
Number of sensitive species
Percent tolerant species
Percent omnivore species
Percent insectivore species
Percent pioneering species
Number of individuals (minus tolerants)
Number of simple lithophilic species
Percent DELT anomalies

The Doan Brook drainage area 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 sites. A site is considered to be within non-significant departure if the score falls within 4 IBI units of the criterion (Table 16). 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 NEORSW WQIS Division.

Table 16. Fish Community Biology Scores in the EOLP Ecoregion							
Ohio EPA Narrative	Very Poor	Poor	Fair	Marginally Good	Good	Very Good	Exceptional
IBI Score - Headwater	12-17	18-27	28-35	36-39	40-45	46-49	50-60
Ohio EPA Narrative	Non-Attainment			NSD	Attainment		
NSD – Non-Significant Departure of WWH attainment							

Results and Discussion

For the 2023 sampling event, Doan Brook RM 0.75 received an average IBI score of 26 and a narrative rating of *Poor* (Table 17). The fish community failed to meet the WWH IBI criterion and is in non-attainment. During the two electrofishing passes in 2023, a total of 330 fish were collected which was comprised of 15 species and one hybrid, Bluegill Sunfish x Pumpkinseed

Sunfish. Three of the 16 species were non-native species. In 2016, only six species were collected with one of those species being the Round Goby (*Neogobius melanostomus*), an invasive species. In 2023, 76.6% of the total number of fish collected were tolerant to moderately tolerant and no darter or headwater species were collected. Between the two surveys, the most dominant species was Creek Chub (*Semotilus atromaculatus*), followed by Round Goby, Green Sunfish (*Lepomis cyanellus*), and Common White Sucker (*Catostomus commersonii*). In 2023, ten individual fish were collected that had DELTs, none were collected in the 2016 survey. The 2023 IBI score of 26 (*Poor*) was a decrease from the IBI score of 32 (*Fair*) in 2016; however since 2008, the scores at this site have consistently been in the narrative rating of *Poor* to *Fair* (Table 18). Water quality degradation indicated by exceedances of *E. coli* may have been a contributing factor to the dominant presence of pollution-tolerant and moderately tolerant fish species and the absence of pollution-intolerant species.

Doan Brook RM 3.10 received an average IBI score of 22 with a narrative rating of *Poor* for the 2023 sampling event (Table 17). The fish community failed to meet the WWH IBI criterion and is in non-attainment. Between the two electrofishing passes, a total of 748 fish were collected comprised of eight species with one being a hybrid, Green Sunfish X Pumpkinseed Sunfish. Two of the eight species were non-native and 61% of the total fish collected were tolerant. The most dominant species collected between the two surveys were Green Sunfish, Central Stoneroller Minnow (*Campostoma anomalum*), and Creek Chub. In May 2019, a restoration project was completed at this site which stabilized and restored approximately 1,000-feet of the Doan Brook stream channel. The QHEI score in 2016, prior to the restoration, was 78.5 with a narrative evaluation of *Excellent*. In 2023, approximately four years after the restoration was completed, the site received a QHEI score of 68.00 and a narrative rating of *Good*. The site is recovering and even with the decrease in the QHEI score, it only had two moderate influence attributes and no high influence attributes, indicating that the habitat is present to support a WWH fish community. In 2016, the site received an IBI score of 24 and a narrative rating of *Poor*. The average IBI score decreased to 22 in 2023; however, more species were present in 2023 than 2016, though most were pollution-tolerant species. Exceedances in *E. coli* and urbanization may be contributing factors to the low IBI score.

Only one electrofishing survey was conducted at Doan Brook RM 5.45 in 2023. The site received an IBI score of 24 with a narrative rating of *Poor* (Table 17). The fish community failed to meet the WWH IBI criterion and is in non-attainment. One hundred thirty-one fish were collected in the survey which were comprised of three species, Creek Chub, Central Stoneroller Minnow, and Green Sunfish. All three species are native; however, Creek Chub and Green Sunfish are pollution tolerant. The pollution-tolerant species comprised 92.4% of the total population surveyed. No DELTs were observed; however, this site had a low density and diversity, and overall low IBI score. This site received a QHEI score of 56.00 with a narrative rating of *Good*. The habitat is available to support a healthy WWH fish community; however, exceedances in *E. coli*, culverted downstream sections of Doan Brook, and urbanization may be contributing factors to the low IBI score.

Doan Brook RM 6.70 received an average IBI score of 22 with a narrative rating of *Poor* for the 2023 sampling event (Table 17). The fish community failed to meet the WWH IBI criterion and is in non-attainment. Between the two electrofishing surveys, 2,639 species were collected which were comprised of three native species, Blacknose Dace (*Rhinichthys atratulus*), Creek Chub, and Central Stoneroller Minnow. Creek Chub was the most dominant species collected, comprising 95.9% of the total collected. Blacknose Dace and Creek Chub are both pollution tolerant making the percent tolerant of the total population surveyed at the site 99.2%. NEORSD last surveyed the fish community at this site in 2016. In 2016 the IBI score was 24 with a narrative rating of *Poor*. NEORSD has been surveying the fish community at this site since 2008 and the IBI scores have consistently been in the *Poor* narrative rating range (Table 18). This site received a QHEI score of 69.50 and a narrative rating of *Good*. It only had three moderate-influence attributes and no high-influence attributes, indicating that the habitat is present to support a WWH fish community. Urbanization of Doan Brook, in combination with downstream culverted sections of the stream, fish migration barriers (Lower Shaker Lake), and a lack of a healthy fish community downstream, are some of the greatest factors contributing to the poor fish community and low IBI score. *E. coli* exceedances are also a likely factor contributing to the low IBI score.

Doan Brook South Branch RM 0.50 received an average IBI score of 31 and a narrative rating of *Fair* (Table 17). The fish community failed to meet the WWH IBI criterion and is in non-attainment. During the two electrofishing passes, a total of 2,977 fish were collected. This total was comprised of four native species, Blacknose Dace, Creek Chub, Central Stoneroller Minnow, and Green Sunfish, and one non-native species, Goldfish (*Carassius auratus*). Between the two electrofishing passes, the percent tolerant fish was 43.3%. No darter species were collected and only one headwater species was collected. No DELTs were observed; however, this site had a low diversity and overall low IBI score. This was the first year that NEORSD assessed the fish community at this site. This site received a QHEI score of 62.50 and a narrative rating of *Good*, suggesting that this site should be able to support a healthy fish community based on the warmwater habitat target score. However, *E. coli* exceedances, downstream fish migration barriers, poor fish diversity downstream, and runoff from a nearby golf course are likely factors contributing to the *Fair* IBI score.

Doan Brook South Branch RM 1.40 received an average IBI score between the two electrofishing passes of 22 and a narrative rating of *Poor* (Table 17). The fish community failed to meet the WWH IBI criterion and is in non-attainment. NEORSD last surveyed this site in 2014 and the site received an IBI score of 24 (*Poor*). NEORSD has been surveying this site since 2008 and it has consistently received IBI scores in the *Poor* narrative rating range. In both of the electrofishing passes conducted in 2023, only the native Green Sunfish and the non-native Goldfish were collected, with the majority being Green Sunfish. Between the two electrofishing passes, only five Goldfish were collected out of a total of 351 fish. Both species are pollution tolerant. In all other years that this site was assessed for fish community by NEORSD, only Green Sunfish were collected, except for 2009 when four Goldfish were collected. This site is located just upstream of Green Lake and runs through the Shaker Heights Country Club and golf course. The site received a QHEI score of 53.00 and a narrative rating of *Fair*, therefore not meeting the WWH QHEI target

score set by the Ohio EPA. The lack of habitat features for fish, downstream fish migration barriers, poor fish diversity downstream, runoff from the golf course, and *E. coli* exceedances are all factors contributing to the lack of fish diversity and low IBI score.

Table 17. 2023 Fish Community Assessment Scores				
Waterbody	River Mile	1 st Pass	2 nd Pass	Average
		IBI	IBI	IBI
Doan Brook	0.75	<u>22</u>	30	<u>26</u> (Poor)
Doan Brook	3.10	<u>24</u>	<u>20</u>	<u>22</u> (Poor)
Doan Brook	5.45	<u>24</u>	-	<u>24</u> (Poor)
Doan Brook	6.70	<u>22</u>	<u>22</u>	<u>22</u> (Poor)
Doan Brook South Branch	0.50	30	32	31 (Fair)
Doan Brook South Branch	1.40	<u>20</u>	<u>24</u>	<u>22</u> (Poor)

Underlined scores are in the *Poor* or *Very Poor* narrative range

Table 18. Doan Brook Historic IBI Scores (2007-2023)				
Year	Doan Brook			Doan Brook South Branch
	RM 0.75	RM 3.10	RM 6.70	RM 1.40
2007	<u>26</u> (Poor)	-	<u>26</u> (Poor)	-
2008	<u>22</u> (Poor)	-	<u>20</u> (Poor)	<u>22</u> (Poor)
2009	30 (Fair)	-	<u>24</u> (Poor)	<u>24</u> (Poor)
2010	<u>26</u> (Poor)	-	<u>19</u> (Poor)	<u>23</u> (Poor)
2011	<u>23</u> (Poor)	-	-	-
2012	28 (Fair)	-	-	-
2013	<u>24</u> (Poor)	-	<u>24</u> (Poor)	<u>20</u> (Poor)
2014	28 (Fair)	-	<u>22</u> (Poor)	<u>24</u> (Poor)
2016	32 (Fair)	* <u>24</u> (Poor)	<u>24</u> (Poor)	-
2023	<u>26</u> (Poor)	<u>22</u> (Poor)	<u>22</u> (Poor)	<u>22</u> (Poor)

Underlined scores are in the *Poor* or *Very Poor* narrative range
 *Assessment done at RM 3.00

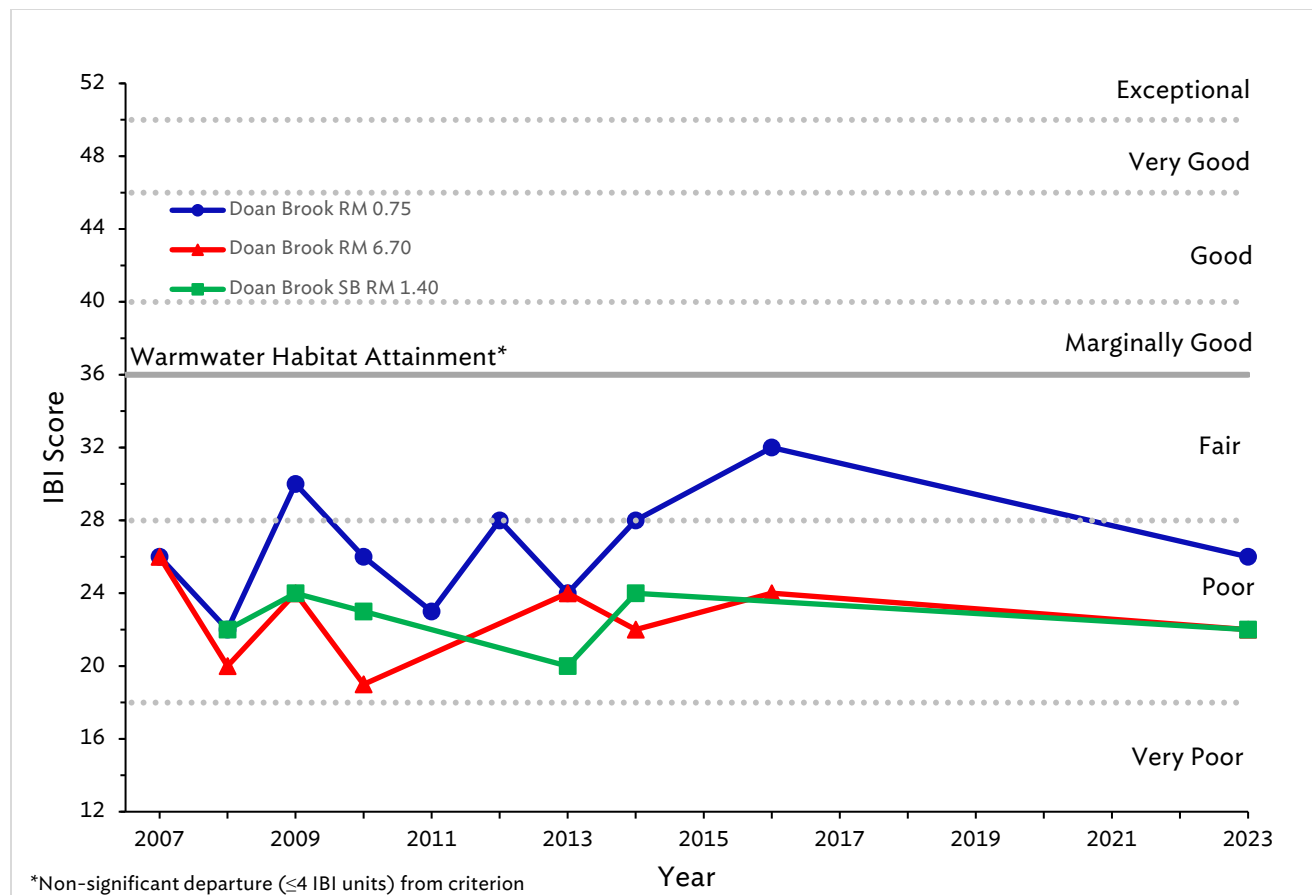


Figure 8. Fish community biology scores for Doan Brook RMs 0.75 and 6.70, and Doan Brook South Branch RM 1.40 from 2007-2023.

Macroinvertebrate Community Biology Assessment

Methods

Macroinvertebrates were sampled quantitatively using modified Hester-Dendy (HD) samplers in conjunction with a qualitative assessment of Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly), also referred to as EPT taxa, inhabiting available habitats at the time of HD retrieval. Both quantitative and qualitative sampling was conducted at all the locations listed in Table 1, except for Doan Brook North Branch RM 7.05 and Doan Brook Middle Branch RM 0.10, where only qualitative sampling was conducted. 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 the NEORSWQIS Division.

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 19), 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 20) and a site is within non-significant departure if the score falls within 4 ICI units of the criterion.

Table 19. 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 20. 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								

Results and Discussion

HDs were installed at all the locations listed in Table 1, except for Doan Brook Middle Branch RM 0.10 and Doan Brook North Branch RM 7.05. HDs were not installed at Doan Brook Middle Branch RM 0.10 and Doan Brook North Branch RM 7.05 due to unsuitable conditions for HD installation. The HDs installed at Doan Brook Main Branch RM 5.45 and Doan Brook South Branch RM 0.50 were unable to be collected and analyzed. Therefore, only qualitative assessments were completed at these sites. All other sites were sampled quantitatively using HDs in conjunction with qualitative sampling. In the Erie-Ontario Lake Plain region, an ICI score of 34 or greater is needed in order for a site to be considered in attainment and a score is within non-significant

departure if the score falls within 4 ICI units of the criterion. Of the four sites sampled quantitatively, only two, Doan Brook RM 3.10 and Doan Brook RM 6.70, met the WWH ICI criterion of non-significant departure of WWH attainment (Table 21).

Table 21. 2023 Macroinvertebrate Results							
Stream RM	Density Qt. (ft ²)/Ql.	Ql./ Total Taxa	Ql. EPT/ sensitive Taxa	Qt. % Tolerant/ Sensitive taxa	Predominant orgs. on natural substrates	ICI	Narrative Evaluation
Doan Brook (19-039-000)							
0.75	266/L	25/32	2/2	12.09/0	Chironomidae, Turbellaria	28	Fair
3.10	409/M-L	24/38	4/3	44.55/0.1	Chironomidae, Simuliidae	30	Marginally Good
5.45	-/M	33/-	4/1	-/-	Turbellaria, Simuliidae	-	Poor
6.70	73/L	20/31	3/0	3.55/0	Turbellaria, Chironomidae	32	Marginally Good
Doan Brook South Branch							
0.50	-/L	24/-	3/-	-/-	Hydropsychidae, Chironomidae, Baetidae, Turbellaria, Gastropoda	-	Low Fair
1.40	334/L	13/22	1/0	28.76/0	Turbellaria	10	Poor
Doan Brook North Branch							
7.05	-/M-L	21/-	2/0	-/-	Chironomidae, Baetidae	-	Low Fair
Doan Brook Middle Branch							
0.10	-/M-L	29/-	4/1	-/-	Baetidae, Chironomidae	-	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 <i>Intolerant</i> or <i>Moderately Intolerant</i> .							

The HD that was installed at Doan Brook Main Branch RM 5.45 was found to be washed out at the time of sample retrieval. The HD that was installed at Doan Brook South Branch RM 0.50 was not collected due to the discovery of an illicit discharge upstream of the HD. On September 8, 2023, the QDCs observed that the stream was heavily contaminated with sanitary sewage. The stream flow was grey in color with visible toilet paper and sanitary debris. This contamination was not occurring at the time of HD installation, nor was it noted during water chemistry sampling collection leading up to HD retrieval. Therefore, it likely began occurring between the last water chemistry sampling collection date on August 22, 2023, and September 8, 2023. The contamination was traced to a nearby upstream storm sewer outfall and was later discovered to be due to a blocked and broken sanitary sewer lateral from Shaker Heights High School that was discharging to the local storm sewer collection system (NEORS D investigation work order number 103393, investigation reports available upon request). As the source of the contamination was determined to be an illicit discharge that began to occur after the HD was installed, it was determined that sampling in the contaminated section of the site would not be representative of typical conditions in this stream. Therefore, qualitative sampling was performed on September 13, 2023, in the section of the site upstream of the contaminated outfall. The lateral responsible for

the sanitary sewage contamination was reported to be repaired on October 20, 2023. This was field verified by WQIS on October 25, 2023.

Narrative rating assessments were performed for these sites 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 22 provides the expectation threshold limits for qualitative total taxa, qualitative EPT taxa, and qualitative sensitive taxa metrics, grouped by drainage area category. Figures 9-11 provide distributions of these metrics grouped by ICI narrative rating category in comparison with the expectation threshold limits provided in Table 22.

Drainage Category	Designation	Qualitative Total Taxa	Qualitative EPT Taxa	Qualitative Sensitive Taxa
Headwater (0-20 miles ²)	EWB	38	12	6
	WWH	27	7	2
	Fair	23	4	1
Wadable (20-200 miles ²)	EWB	51	18	12
	WWH	41	11	6
	Fair	33	8	2
Small River (200-1,000 miles ²)	EWB	44	16	10
	WWH	36	11	7
	Fair	29	9	5

Doan Brook Main Branch RM 5.45 was assigned a narrative rating of *Poor*. This site has a drainage area of 4.53 square miles, placing it near the low end of the headwater drainage area category. A total of 33 taxa were collected in the qualitative sample which meets the *WWH* expectation of 27 for a headwater stream. Four EPT taxa were collected which meets the *Fair* expectation for number of EPT taxa. EPT taxa included one mayfly species, *Baetis flavistriga*, and three caddisfly taxa, *Cheumatopsyche sp.*, *Hydropsyche depravata group*, and *Hydroptila sp.* One sensitive taxa, the moderately intolerant *Cardiocladius obscurus*, was collected, which meets the *Fair* expectation for a headwater stream. Field observations indicated that the site was dominated by *Turbellaria* and *Simuliidae*. The site was assigned a field narrative rating of *Very Poor* at the time of sample collection. Although the numbers of total taxa, EPT taxa, and sensitive taxa met *WWH*, *Fair*, and *Fair* expectations respectively, the observation that the site was dominated by flatworms and blackflies indicates that the percent community composition metrics of the ICI would have scored poorly at this site. Taking this into consideration the site was assigned a narrative rating of *Poor* in 2023.

Doan Brook Middle Branch RM 0.10 was assigned a narrative rating of *Marginally Good*. This site has a drainage area of 0.54 square miles, placing it on the low end of the headwater drainage area category. A total of 29 taxa were collected in the qualitative sample which scores above the *WWH* expectation for a headwater stream. Four EPT taxa were collected which meets the *Fair* expectation for number of EPT taxa. EPT taxa included one mayfly species, *Baetis flavistriga*, and three caddisfly taxa, *Cheumatopsyche sp*, *Hydropsyche depravata group*, and *Hydroptila sp*. One sensitive taxa, the moderately intolerant *Antocha sp*, was collected which also meets the *Fair* expectation. Field observations indicated that the most predominant group was *Baetidae* mayflies, of which only *Baetis flavistriga* was collected. Caddisflies and *Chironomidae* midges were also noted as common. The site was assigned a field narrative rating of *Marginally Good* at the time of sample collection. Taking into consideration the above listed data the site was assigned a narrative rating of *Marginally Good* in 2023.

Doan Brook North Branch RM 7.05 was assigned a narrative rating of *Low Fair*. This site has a drainage area of 0.69 square miles, placing it on the low end of the headwater drainage area category. A total of 21 taxa were collected in the qualitative sample which scores below the *Fair* expectation of 23 for a headwater stream. Two EPT taxa were collected which also falls below the expectation for number of EPT taxa. EPT taxa included one mayfly species, *Baetis flavistriga*, and one caddisfly taxa, *Hydroptila sp*. No sensitive taxa were collected which also falls below the *Fair* expectation for a headwater stream. Field observations indicated that the most predominant groups were *Baetidae* mayflies and *Chironomidae* midges. Caddisflies, *Simuliidae* blackflies, and *Oligochaeta* were also noted as common. The site was assigned a field narrative rating of *Poor* at the time of sample collection. Taking into consideration the above listed data, the site was assigned a narrative rating of *Low Fair* in 2023.

Doan Brook South Branch RM 0.50 was assigned a narrative rating of *Low Fair*. This site has a drainage area of 2.29 square miles, placing it on the low end of the headwater drainage area category. A total of 24 taxa were collected in the qualitative sample which scores between the *Fair* and *WWH* expectation of 23 for a headwater stream. Three EPT taxa were collected which falls below the *Fair* expectation for number of EPT taxa. EPT taxa included one mayfly species, *Baetis flavistriga*, and two caddisfly taxa, *Cheumatopsyche sp*, and *Hydropsyche depravata group*. No sensitive taxa were collected which also falls below the *Fair* expectation for a headwater stream. Field observations indicated that the most predominant groups were *Baetidae* mayflies, *Hydropsychidae* caddisflies, and *Turbellaria*. The site was assigned a field narrative rating of *Low Fair* at the time of sample collection. Taking into consideration the above listed data, the site was assigned a narrative rating of *Low Fair* in 2023.

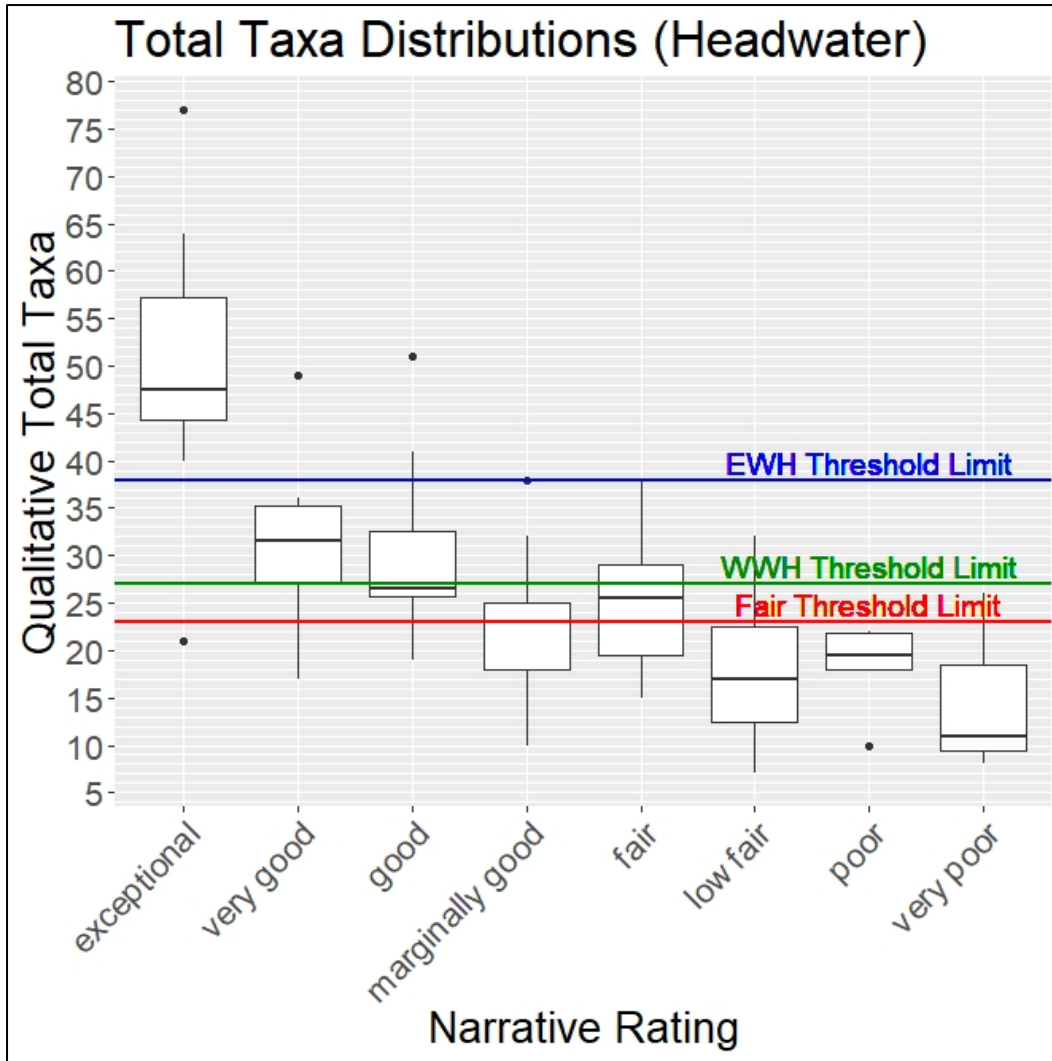


Figure 9. Distribution of the number of qualitative total taxa in EOLP headwater streams grouped by ICI score narrative rating category with EWH, WWH, and Fair expectation threshold limits developed by NEORS.

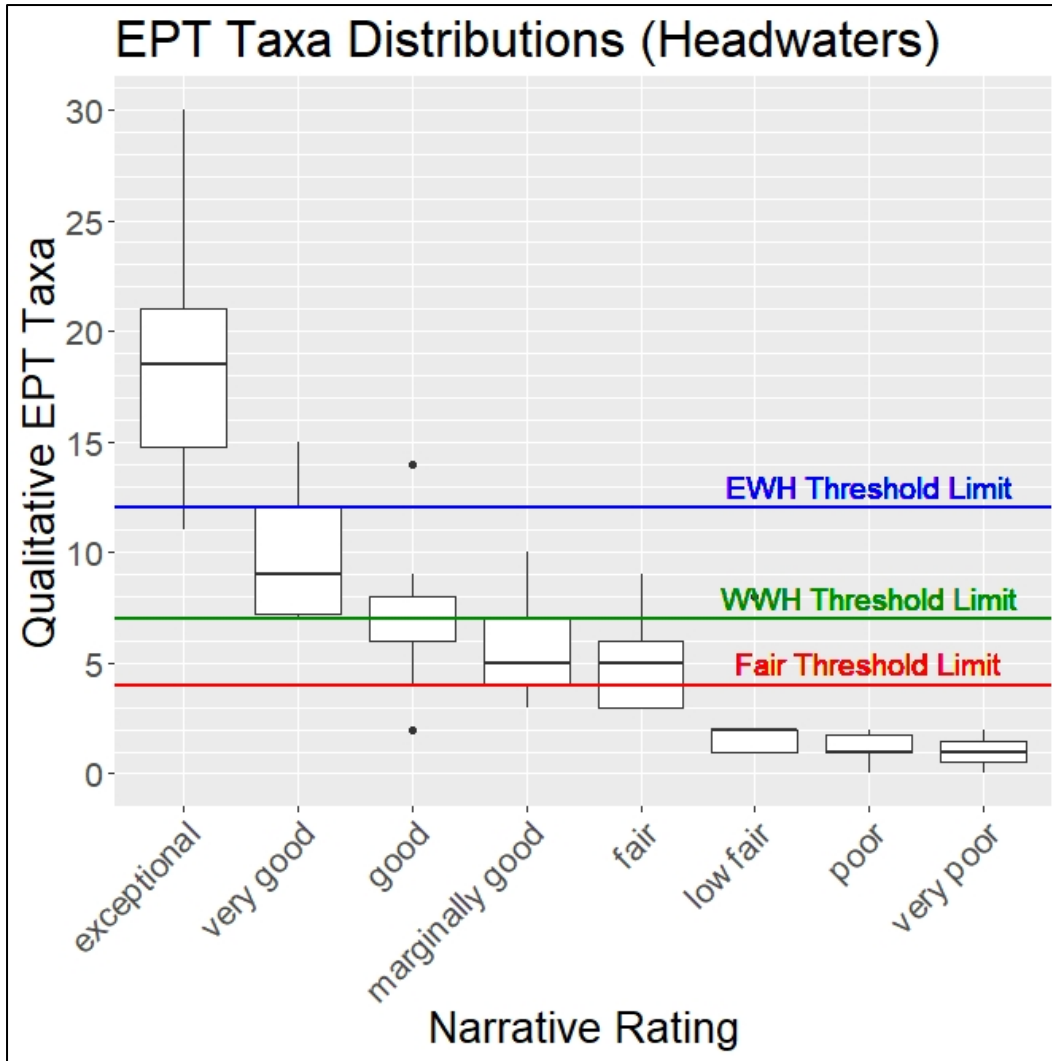


Figure 10. Distribution of the number of qualitative EPT taxa in EOLP headwater streams grouped by ICI score narrative rating category with EWH, WWH, and Fair expectation threshold limits developed by NEORS.

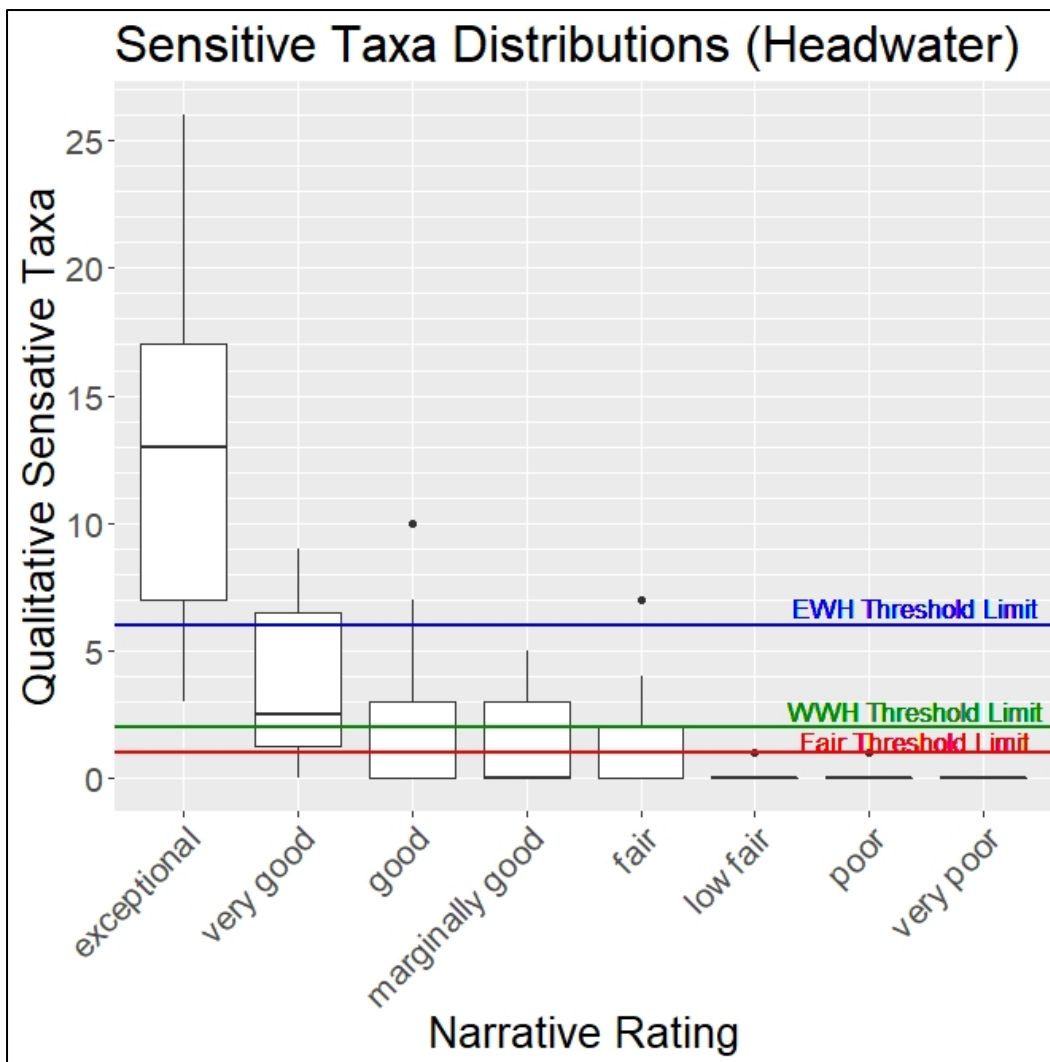


Figure 11. Distribution of the number of qualitative sensitive taxa in EOLP headwater streams grouped by ICI score narrative rating category with EWH, WWH, and Fair expectation threshold limits developed by NEORS.

Doan Brook RM 0.75 had an ICI score of 28 with a narrative rating of *Fair* in 2023. This is an increase from an ICI score of 16 in 2016 and an ICI score of 20 in 2014 (Table 23). In 2023, 32 total taxa were collected between the qualitative and quantitative sample. Only two EPT taxa were collected in the qualitative sample, *Baetis flavistriga* and *Hydropsyche depravata* group. These two, along with one additional EPT taxon, *Cheumatopsyche* sp., were collected on the HD. All three of these taxa are designated as facultative to pollution. Two taxa collected in the qualitative sample are considered sensitive taxa with the designation of moderately intolerant to pollution. All other taxa are facultative to tolerant to pollution. In 2016, only one EPT taxon was collected and no sensitive taxa were collected. This shows slight improvement in the macroinvertebrate community in 2023 compared to 2016.

Doan Brook RM 3.10 received an ICI score of 30 with a narrative rating of *Marginally Good* in 2023. An ICI score of 30 puts the site within non-significant departure of WWH attainment. Thirty-eight total taxa were collected between the quantitative and qualitative assessments. Four EPT taxa were collected in the qualitative assessment and six EPT taxa were collected in the quantitative assessment with a total of seven EPT taxa collected between the two assessments. Five taxa collected in 2023 were considered sensitive taxa with the designation of moderately intolerant to pollution, all other taxa were facultative to tolerant to pollution. NEORSD evaluated the macroinvertebrate community at Doan Brook RM 3.00 in 2016 to collect pre-construction data prior to the stream restoration project that was completed in May 2019. In 2016, the site received an ICI score of 18 and a narrative rating of *Low Fair*. In 2016, the predominant organisms at the site were midges and flatworms which are generally pollution tolerant. This site increased from being in non-attainment in 2016 to being within non-significant departure of WWH attainment. The macroinvertebrate community has proven to improve following the stream restoration at this site.

Doan Brook RM 6.70 received an ICI score of 32 and a narrative rating of *Marginally Good* putting it within non-significant departure of WWH attainment in 2023. This is a significant increase from past years (Table 23). In 2016, the most recent year this site was sampled, it received an ICI score of 4 and a narrative rating of *Very Poor*. Since 2006 when NEORSD started sampling this site under the Ohio EPA Credible Data Program, the ICI scores have consistently been in the *Poor* to *Very Poor* range likely due to poor water quality. In 2016, 17 total taxa were collected between the quantitative and qualitative assessments and only one EPT taxon was collected in the qualitative assessment and none on the HD. The sample collected on the HD was dominated by *Dicrotendipes simpsoni*, a pollution-tolerant species from the Family *Chironomidae* (non-biting midges), accounting for 66.6% of the total organisms collected. In 2023, 31 total taxa were collected between the quantitative and qualitative assessments. Three EPT taxa were collected in both the qualitative assessment and on the HD; however, no sensitive taxa were collected in 2023. All organisms were facultative to tolerant to pollution. The ICI score has significantly increased from 2016 to 2023; however, the macroinvertebrate community is still dominated by taxa that are assigned a pollution tolerance of facultative to tolerant to pollution.

Doan Brook South Branch RM 1.40 received an ICI score of 10 and a narrative rating of *Poor*. This site had 22 total taxa collected and only one EPT taxon, *Baetis flavistriga*, a mayfly in the Baetidae family, collected in both the qualitative and quantitative assessments. No sensitive taxa were collected in 2023. During the qualitative assessment, the predominant organism throughout all habitat types noted by the biologists was the flatworm, which is generally tolerant to pollution. The macroinvertebrate community at this site has been sampled several times by NEORSD since 2006 under the Ohio EPA Credible Data Program (Table 23). The most recent assessment was done in 2014 and the site received an ICI score of 2 and a narrative rating of *Very Poor*. In 2010, this site received an ICI score of 34 and was within attainment. However, in all other years that the macroinvertebrate community at this site has been sampled, it has consistently been in the *Very Poor* to *Low Fair* range and in non-attainment. The 2023 sampling event is consistent with these trends.

Table 23. Doan Brook Historic ICI Scores (2006-2023)				
Year	Doan Brook			Doan Brook South Branch
	RM 0.75	RM 3.10	RM 6.70	RM 1.40
2006	28 [#]	-	<u>4</u> [#]	<u>8</u> [#]
2007	21 [#]	-	<u>4</u> [#]	<u>8.7</u> ^{##}
2008	*Fair/Poor	-	<u>4</u> , *Fair/Poor	<u>8</u> [#]
2009	28	-	<u>12</u>	20
2010	32	-	<u>6</u>	34
2011	24	-	-	-
2012	22	-	-	-
2013	Poor	-	<u>8</u>	16
2014	20	-	-	<u>2</u>
2016	16	18 ¹	<u>4</u>	-
2023	28	30 ^{ns}	32 ^{ns}	<u>10</u>

*Indicates qualitative sample only.
^{ns} non-significant departure from biocriterion
¹Doan Brook RM 3.10 was sampled at RM 3.00 in 2016.
 -No sample collected
[#] Based on 2-sample averaged ICI (early season and late season sample)
^{##} Based on 3-sample averaged ICI
 Underlined scores are in the *Poor* or *Very Poor* narrative range

Figure 12 shows the macroinvertebrate community composition at the four sites on Doan Brook where HDs were collected. Low percentages of mayflies and caddisflies were found at all sites. Low percentages of Tribe *Tanytarsini* were found at Doan Brook RMs 3.10 and 6.70 and Doan Brook South Branch RM 1.40, but a higher percentage was found at Doan Brook RM 0.75. ICI scores at Doan Brook RM 0.75 and Doan Brook South Branch RM 1.40 are generally consistent with historical scores. Doan Brook RM 6.70 significantly increased from past years (Figure 13). The ICI score for Doan Brook RM 3.10 increased from 18 in 2016 to 30 in 2023, following the restoration completed at the site in 2019.

Qualitative sampling conducted at Doan Brook North Branch RM 7.05 and Doan Brook Middle Branch RM 0.10 to collect baseline data on the macroinvertebrate community prior to the restoration of the Horseshoe Lake area resulted in narrative ratings of *Low Fair* and *Marginally Good*, respectively. Qualitative sampling conducted at Doan Brook RM 5.45 and Doan Brook South Branch RM 0.50 received narrative ratings of *Poor* and *Low Fair*, respectively.

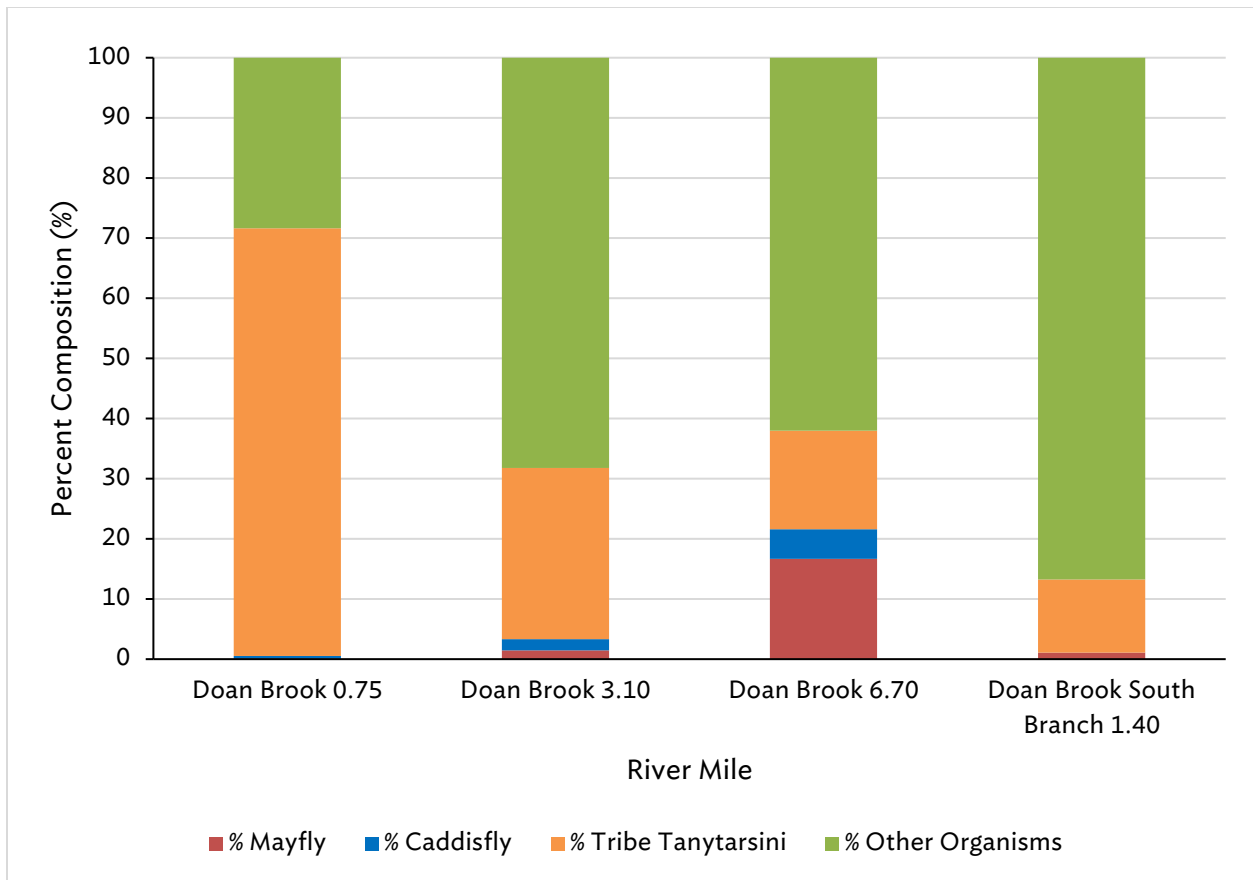


Figure 12. 2023 Macroinvertebrate Community Composition

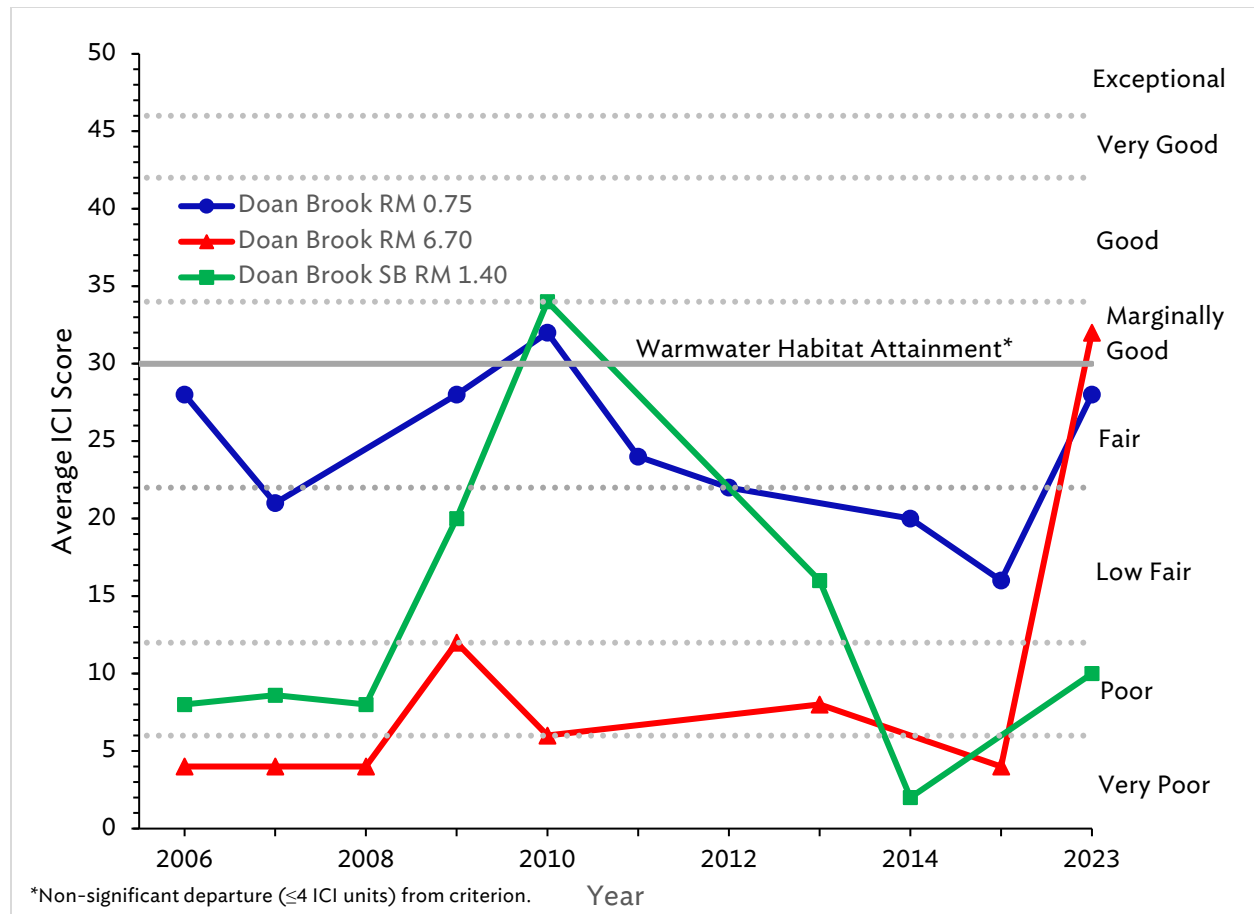


Figure 13. Macroinvertebrate community biology scores of Doan Brook from 2006-2023.

Conclusions

The results of the water chemistry sampling, habitat assessments, and fish and benthic macroinvertebrate community surveys conducted by NEORS D indicate that the Doan Brook watershed may be impacted by a variety of environmental stressors and various aquatic habitat limitations. In 2023, all of the sites assessed in the Doan Brook watershed were in non attainment of WWH criteria (Table 24).

Bacteriological sampling at all six sites in the Doan Brook watershed where water chemistry sampling was completed showed elevated densities of *E. coli*, which is regarded as an indicator of poor water quality conditions. Resulting from these water quality conditions, high proportions of pollution-tolerant fish and macroinvertebrates dominated their respective communities within the stream. Wet-weather flows that originate upstream from combined sewer overflows and stormwater runoff from upstream golf courses and recreational lake areas may contribute to the elevated levels of *E. coli* found within Doan Brook. In addition, illicit discharges may be another contributing factor to the poor water quality conditions in Doan Brook.

The DVT is one of seven large storage tunnels under NEORSD's Project Clean Lake, a 25-year regional stormwater program to reduce the amount of combined sewer overflow discharging to Lake Erie. The DVT was completed and became active in 2021. Statistical analysis of the relationship between precipitation and both *E. coli* and total phosphorous concentrations in Doan Brook were compared before and after completion of the DVT. Statistical analysis showed no significant change in the relationship between *E. coli* and precipitation before and after the completion of the DVT. This indicates that the major source of elevated *E. coli* densities during rain events in this watershed was not addressed by the capture of CSO by the DVT. Total phosphorous concentrations during both wet and dry weather significantly decreased at the sites downstream of NEORSD-operated CSOs after the completion of the DVT. There was no significant change in total phosphorous concentrations before and after DVT completion at the upstream sites. This supports the hypothesis that the DVT contributed to the decrease in total phosphorus concentrations in the Doan Brook watershed.

Several mercury results in the 2023 study were above the Method Detection Limit but below the Practical Quantitation Limit. Because the detection limit for EPA Method 245.1 is above the criteria for the Human Health Non-Drinking and Protection of Wildlife OMZAs, it cannot be determined if the sites were in attainment of those criteria. However, two sampling events at Doan Brook South Branch RM 1.40 resulted in mercury exceedances. Urban runoff may be a cause of the elevated mercury levels in the Doan Brook watershed. No other exceedances were found.

The fish community at Doan Brook appears to be directly impacted by the diminished water quality present in the stream. In 2023, the QHEI analysis at all the sites in this study except for Doan Brook RM 0.75, Doan Brook South Branch RM 1.40, and Doan Brook Middle Branch RM 0.10 met or exceeded the WWH target score of 55. These sites should have the ability to support healthy warmwater fish communities; however, none of the sites where the fish community was assessed met the WWH criterion for fish community. NEORSD has conducted fish community assessments at Doan Brook RMs 0.75 and 6.70 and Doan Brook South Branch RM 1.40 under the Ohio EPA Credible Data Program since 2007. Since 2007, these sites have never met the WWH IBI criterion. While the habitat of Doan Brook can reasonably sustain higher quality and more diverse fish populations based on QHEI scores, overground runoff from lawns and nearby golf courses may be a contributing factor affecting the water quality, in addition to the fish migration barrier challenges and culverted reaches of the stream. These sites will not be able to attain the WWH criterion for IBI unless there is an improvement in the water quality.

The macroinvertebrate community has been sampled at Doan Brook RM 0.75 and 6.70 and Doan Brook South Branch RM 1.40 under the Ohio EPA Credible Data Program since 2006 with the last time prior to this study being in 2016. Since 2006, Doan Brook RM 0.75 has only been within non-significant departure of the WWH criterion for macroinvertebrates in 2006 and 2010, all other years the site failed to meet the WWH ICI criterion. The ICI score increased from 16 in 2016 to 28 in 2023. At RM 6.70, the macroinvertebrate community significantly increased from a score of 4 in 2016 to a score of 32 in 2023, putting the site within non-significant departure of WWH attainment. Prior to this, the macroinvertebrate community had consistently scored in the *Poor* to *Very Poor*

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range. The macroinvertebrate community at RM 1.40 has been assessed eight times since 2006. In 2010, the site received an ICI score of 34 and was in attainment; however, for all other years, the site has been in the *Very Poor* to *Low Fair* range. In 2023, the ICI score was 10 and in non-attainment.

Doan Brook RM 3.10 underwent restoration which was completed in May 2019. The macroinvertebrate community was assessed in 2016 prior to the start of the restoration and received an ICI score of 18. The ICI score increased to 30 in 2023 putting the site within non-significant departure of the WWH criterion for macroinvertebrates. Doan Brook RM 5.45 and Doan Brook South Branch RM 0.50 received narrative ratings of *Poor* and were in non-attainment of WWH ICI criterion.

Qualitative sampling was conducted at Doan Brook North Branch RM 7.05 and Doan Brook Middle Branch RM 0.10 to collect baseline data on the macroinvertebrate community prior to the restoration of the Horseshoe Lake area. The lake was drained in June 2019, leading to its current condition. The North and Middle Branches of Doan Brook have been allowed to return to their natural state, creating stream channels where they originally resided. Restoration is planned for the near future. RM 7.05 received a narrative rating of *Low Fair* and RM 0.10 received a narrative rating of *Marginally Good*. The overall low ICI scores within the Doan Brook watershed may be attributed to poor water quality conditions that continue to compromise Doan Brook. *E. coli* densities above the acceptable levels may be preventing Doan Brook from supporting a healthier and more diverse macroinvertebrate community. Although fish sampling was not conducted at these sites, it was expected that doing so would have resulted in a *Poor* or *Very Poor* fish community. Therefore, the site at Doan Brook Middle Branch RM 0.10 was designated as being in non-attainment, even though the narrative rating for the macroinvertebrate community was in non-significant departure.

Table 24. 2023 Doan Brook Survey Results

RM	DA (mi ²)	Attainment Status	IBI Score	ICI Score	QHEI/HHEI Score	Cause(s)	Source(s)
Doan Brook (WWH Existing)							
0.75 ^H	9.10	Non	<u>26</u> *	28*	52.75	Sewage contamination, pollutants in urban stormwater, Poor habitat	Urbanization and urban runoff, culverted downstream reaches, CSOs
3.10 ^H	7.35	Non	<u>22</u> *	30 ^{ns}	68.00	Sewage contamination, pollutants in urban stormwater, nutrient enrichment	Urbanization and urban runoff, culverted downstream reaches, CSOs

Table 24. 2023 Doan Brook Survey Results							
RM	DA (mi ²)	Attainment Status	IBI Score	ICI Score	QHEI/HHEI Score	Cause(s)	Source(s)
5.45 ^H	4.53	Non	<u>24</u> *	<i>Poor</i> **	56.00	Sewage contamination, pollutants in urban stormwater, nutrient enrichment	Urbanization and urban runoff, culverted downstream reaches, CSOs
6.70 ^H	1.20	Non	<u>22</u> *	32 ^{ns}	69.50	Sewage contamination, pollutants in urban stormwater, physical barrier (dam)	Urbanization and urban runoff, culverted downstream reaches, downstream fish barrier
Doan Brook South Branch (WWH Existing)							
0.50 ^H	2.29	Non	31*	<i>Low Fair</i> **	62.50	Sewage contamination, pollutants in urban stormwater, physical barrier (dam), nutrient enrichment	Urbanization and urban runoff, culverted downstream reaches, downstream fish barrier
1.40 ^H	1.57	Non	<u>22</u> *	<u>10</u> *	53.00	Sewage contamination, mercury exceedances, pollutants in urban stormwater, poor habitat, physical barrier (dam), nutrient enrichment	Urbanization and urban runoff, culverted downstream reaches, downstream fish barrier, golf course runoff
Doan Brook North Branch (WWH Existing)							
7.05 ^H	0.69	Non	-	<i>Low Fair</i> **	64.00/ 54.00	Sewage contamination, Pollutants in urban stormwater, physical barrier (dam)	Urbanization and urban runoff, culverted downstream reaches, downstream fish barrier
Doan Brook Middle Branch (WWH Existing)							
0.10 ^H	0.54	Non***	-	<i>Marginally Good</i> ** ^{ns}	52.00/ 53.00	Sewage contamination, Poor habitat, Pollutants in urban stormwater, physical barrier (dam)	Urbanization and urban runoff, culverted downstream reaches, downstream fish barrier
<p>*Significant departure from WWH biocriterion (> 4ICI; > 4IBI). Underlined scores are in the <i>Poor</i> or <i>Very Poor</i> narrative range ^H Headwater scoring criteria ^{ns} non-significant departure from biocriterion (≤4 ICI; ≤4 IBI; ≤0.5 MIwb units) **Narrative rating assigned due to quantitative sampling not performed ***Based on best professional judgment</p>							

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References

NEORSD. (2023). *An Improved Invertebrate Community Index Narrative Rating Assignment Procedure for the Erie/Ontario Lake Plain Ecoregion*. Cuyahoga Heights, OH: Water Quality and Industrial Surveillance Department.

Ohio Environmental Protection Agency. (1999). *Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams (MAS/1999-1-1)*. Columbus, OH: Division of Surface Water.

Ohio Environmental Protection Agency (2021b). *Beneficial Use Recommendations Summary for the Cuyahoga River drainage basin, Ohio Administrative Code (OAC) Chapter 3745-1-26*. Columbus, OH: Division of Surface Water, Assessment and Modeling Section.

Ohio Environmental Protection Agency. (1987a). *Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters* (Updated January 1988; September 1989; November 2006; August 2008). Columbus, OH: Division of Water Quality Monitoring and Assessment.

Ohio Environmental Protection Agency. (1987b). *Biological criteria for the protection of aquatic life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities* (Updated September 1989; March 2001; November 2006; and August 2008). Columbus, OH: Division of Water Quality Monitoring and Assessment.

Ohio Environmental Protection Agency. (2020). *Field Methods for Evaluating Primary Headwater Streams in Ohio*. Columbus, OH: Division of Surface Water.

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Ohio Environmental Protection Agency. (2006). *Methods for assessing habitat in flowing waters: using the Qualitative Habitat Evaluation Index (QHEI)*. (Ohio EPA Technical Bulletin EAS/2006-06-1). Columbus, OH: Division of Surface Water; Division of Ecological Assessment Section.

Ohio Environmental Protection Agency. 2015. *Proposed Stream Nutrient Assessment Procedure*. Columbus, OH: Division of Surface Water, Ohio EPA Nutrients Technical Advisory Group.

Ohio Environmental Protection Agency. (2022). *State of Ohio Water Quality Standards Ohio Administrative Code Chapter 3745-1*. Columbus, OH: Division of Surface Water, Standards and Technical Support Section.

Ohio Environmental Protection Agency. (2021). *Surface Water Field Sampling Manual*. Columbus, Ohio: Division of Surface Water.

Rankin, E.T. (1995). Habitat indices in water resource quality assessments. In W.S. Davis and T. Simon (eds.). *Biological Assessment and Criteria: Tools for Risk-based Planning and Decision Making* (pp. 181-208). Boca Raton, FL: Lewis Publishers.

United States Environmental Protection Agency. 2012. *NPDES Water-Quality Based Permit Limits for Recreational Water Quality Criteria*. Office of Water. EPA-820-F-12-061.

U.S. Geological Survey (2012). *The StreamStats program for Ohio*, online at <https://water.usgs.gov/osw/streamstats/ohio.html>