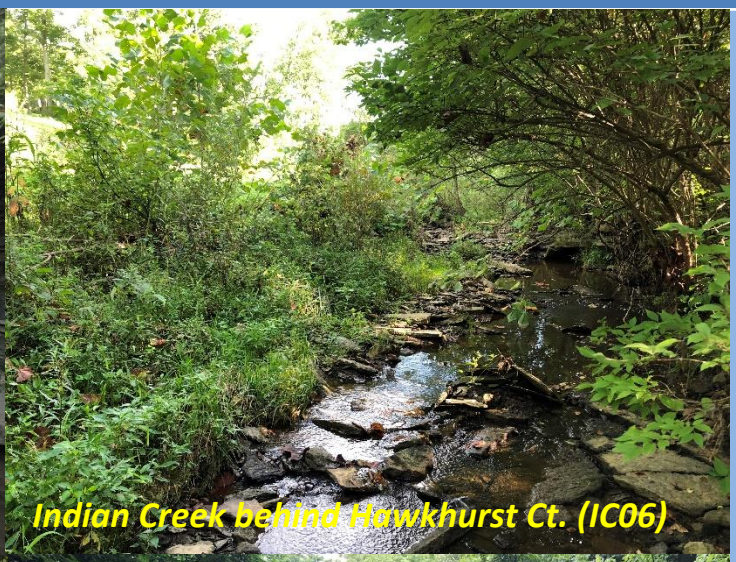
# Biological and Water Quality Study of the Ohio River Direct Tributaries 2023

*Taylor Cr. at Johnson Rd. (GM85)*


*Indian Creek behind Hawkhurst Ct. (IC06)*


*Rapid Run at Rapid Run Rd. (RR03)*


*Muddy Cr. at Beechcreek Ln. (MU04.5)*

**Trent A. Dougherty, Executive Director**
**James Lane, Board President**

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# Biological and Water Quality Study of the Ohio River Direct Tributaries 2024

**Hamilton County, Ohio**

Technical Report MBI/2024-6-6

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## TABLE OF CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

## ACKNOWLEDGEMENTS

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## Glossary of Terms

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| **Ambient Monitoring** | Sampling and evaluation of receiving waters not necessarily associated with episodic perturbations. |
| **Aquatic Assemblage** | An association of interacting populations of organisms in a given waterbody, for example, the fish assemblage or the benthic macroinvertebrate assemblage. |
| **Aquatic Community** | An association of interacting assemblages in a given waterbody, the biotic component of an ecosystem. |
| **Aquatic Life Use (ALU)** | A beneficial use designation in which the waterbody provides suitable habitat for survival and reproduction of desirable fish, shellfish, and other aquatic organisms; classifications specified in State water quality standards relating to the level of protection afforded to the resident biological community by the custodial State agency. |
| **Assemblage** | Refers to all of the various species of a particular taxonomic grouping (e.g., fish, macroinvertebrates, algae, submergent aquatic plants, etc.) that exist in a particular habitat. Operationally this term is useful for defining biological assessment methods and their attendant assessment mechanisms, i.e., indices of biotic integrity (IBI), O/E models, or fuzzy set models. |
| **Attainment Status** | The state of condition of a waterbody as measured by chemical, physical, and biological indicators. Full attainment is the point at which measured indicators signify that a water quality standard has been met and it signifies that the designated use is both attained and protected. Non-attainment is when the designated use is not attained based on one or more of these indicators being below the required condition or state for that measure or parameter. |
| **Attribute** | A measurable part or process of a biological system. |
| **Beneficial Uses** | Desirable uses that acceptable water quality should support. Examples are drinking water supply, primary contact recreation (such as swimming), and aquatic life support. |

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| **Benthic Macroinvertebrates** | Animals without backbones, living in or on the substrates, of a size large enough to be seen by the unaided eye, and which can be retained by a U.S. Standard No. 30 sieve (0.595 mm openings). Also referred to as benthos, infauna, or macrobenthos. |
| **Best Management Practice** | An engineered structure or management activity, or combination of these that eliminates or reduces an adverse environmental effect of a pollutant, pollution, or stressor effect. |
| **Biological Assessment** | An evaluation of the biological condition of a waterbody using surveys of the structure and function of a community of resident biota; also known as bioassessment. It also includes the interdisciplinary process of determining condition and relating that condition to chemical, physical, and biological factors that are measured along with the biological sampling. |
| **Biological Criteria (Biocriteria)** | Scientific meaning: quantified values representing the biological condition of a waterbody as measured by structure and function of the aquatic communities typically at reference condition; also known as biocriteria.<br><br>Regulatory meaning: narrative descriptions or numerical values of the structure and function of aquatic communities in a waterbody necessary to protect a designated aquatic life use, implemented in, or through state water quality standards. |
| **Biological Condition Gradient** | A scientific model that describes the biological responses within an aquatic ecosystem to the increasing effects of stressors. |
| **Biological Diversity** | Refers to the variety and variability among living organisms and the ecological complexes in which they occur. Diversity can be defined as the number of different taxa and their relative frequencies. For biological diversity, these taxa are organized at many levels, ranging from complete ecosystems to the biochemical structures that are the molecular basis of heredity. Thus, the term encompasses different |

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| | ecosystems, species, and genes; also known as biodiversity. |
| **Biological Indicator** | An organism, species, assemblage, or community characteristic of a particular habitat, or indicative of a particular set of environmental conditions; also known as a bioindicator. |
| **Biological Integrity** | The ability of an aquatic ecosystem to support and maintain a balanced, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats within a region (after Karr and Dudley 1981). |
| **Biological Monitoring** | The use of a biological entity (taxon, species, assemblage) as a detector and its response as a measure of response to determine environmental conditions. Ambient biological surveys and toxicity tests are common biological monitoring methods; also known as biomonitoring. |
| **Biological Survey** | The collection, processing, and analysis of a representative portion of the resident aquatic community to determine its structural and/or functional characteristics and hence its condition using standardized methods. |
| **Clean Water Act (CWA)** | An act passed by the U.S. Congress to control water pollution (formally referred to as the Federal Water Pollution Control Act of 1972). Public Law 92-500, as amended. 33 U.S.C. 1251 et seq.; referred to herein as the CWA. |
| **CWA Section 303(d)** | This section of the Act requires States, territories, and authorized Tribes to develop lists of impaired waters for which applicable water quality standards are not being met, even after point sources of pollution have installed the minimum required levels of pollution control technology. The law requires that these jurisdictions establish priority rankings for waters on the lists and develop TMDLs for these waters. States, territories, and authorized Tribes are to submit their list of waters on April 1 in every even-numbered year. |

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| **CWA Section 305(b)** | Biennial reporting required by the Act to describe the quality of the Nation's surface waters, to serve as an evaluation of progress made in maintaining and restoring water quality, and describe the extent of remaining problems. |
| **Criteria** | Limits on a particular pollutant or condition of a waterbody presumed to support or protect the designated use or uses of a waterbody. Criteria may be narrative or numeric and are commonly expressed as a chemical concentration, a physical parameter, or a biological assemblage endpoint. |
| **DELT Anomalies** | The percentage of Deformities, Erosions (e.g., fins, barbels), Lesions and Tumors on fish assemblages (DELT). An important fish assemblage attribute that is a commonly employed metric in fish IBIs. |
| **Designated Uses** | Those uses specified in state water quality standards for each waterbody or segment whether or not they are being attained. |
| **Disturbance** | Any activity of natural or human causes that alters the natural state of the environment and its attributes and which can occur at or across many spatial and temporal scales. |
| **Ecological integrity** | The summation of chemical, physical, and biological integrity capable of supporting and maintaining a balanced, integrated adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats in the region. |
| **Ecoregion** | A relatively homogeneous geographical area defined by a similarity of climate, landform, soil, potential natural vegetation, hydrology, or other ecologically relevant variables; ecoregions are portioned at increasing levels of spatial detail from level I to level IV. |
| **Existing Use** | A use that was actually attained in a waterbody on or after November 28, 1975, whether or not they are included in the state water quality standards (November 28, 1975 is the date on which U.S. EPA |

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| | promulgated its first water quality standards regulation in 40CFR Part 131). Existing uses must be maintained and cannot be removed. |
| **Index of Biotic Integrity (IBI)** | An integrative expression of site condition across multiple metrics comprised of attributes of a biological assemblage. It refers to the index developed by Karr (1981) and explained by Karr et al. (1986). It has been used to express the condition of fish, macroinvertebrate, algal, and terrestrial assemblages throughout the U.S. and in each of five major continents. |
| **MIwb** | The Modified Index of Well-Being (MIwb) is based on fish assemblage measures including numbers, biomass, and two diversity indices (Shannon Index) based on numbers and biomass. The numbers and biomass metrics exclude highly tolerant species. It reflects the overall productivity and diversity of the fish assemblage and it frequently responds before the IBI to improvements in water quality and habitat. |
| **Metric** | A calculated term or enumeration representing an attribute of a biological assemblage, usually a structural aspect, that changes in a predictable manner with an increased effect of human disturbance. |
| **Monitoring and Assessment** | The entire process of collecting data from the aquatic environment using standardized methods and protocols, managing that data, analyzing that data to make assessments in support of multiple program objectives, and disseminating the assessments to stakeholders and the public. |
| **Multimetric Index** | An index that combines assemblage attributes, or metrics, into a single index value. Each metric is tested and calibrated to a scale and transformed into a unitless score prior to being aggregated into a multimetric index. Both the index and metrics are useful in assessing and diagnosing ecological condition. |
| **Narrative Biocriteria** | Written statements describing the narrative attributes of the structure and function of aquatic communities |

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| | in a waterbody necessary to protect a designated aquatic life use. |
| **Natural Condition** | This includes the multiplicity of factors that determine the physical, chemical, or biological conditions that would exist in a waterbody in the absence of measurable impacts from human activity or influence. |
| **Numeric Biocriteria** | Specific quantitative and numeric measures of the structure and function of aquatic communities in a waterbody necessary to protect a designated aquatic life use. |
| **Qualitative Habitat Evaluation Index** | A qualitative habitat evaluation assessment tool that is applied to streams and rivers in Ohio and which is used to identify habitat variables that are important to attainment of the Ohio biological criteria. |
| **Reference Condition** | The condition that approximates natural, unimpacted to best attainable conditions (biological, chemical, physical, etc.) for a waterbody. Reference condition is best determined by collecting measurements at a number of sites in a similar waterbody class or region under minimally or least disturbed conditions (by human activity), if they exist. Since undisturbed or minimally disturbed conditions may be difficult or impossible to find in some states, least disturbed conditions, combined with historical information, models or other methods may be used to approximate reference condition as long as the departure from natural or ideal is comprehended. Reference condition is used as a benchmark to establish numeric biocriteria. |
| **Reference Site** | A site selected to represent an approximation of reference condition and by comparison to other sites being assessed. For the purpose of assessing the ecological condition of other sites, a reference site is a specific locality on a waterbody that is minimally or least disturbed and is representative of the expected ecological condition of other localities on the same waterbody or nearby waterbodies. |

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| **Regional Reference Condition** | A description of the chemical, physical, or biological condition based on an aggregation of data from reference sites that are representative of a waterbody type in an ecoregion, subregion, bioregion, or major drainage unit. |
| **Stressors** | Physical, chemical, and biological factors that can adversely affect aquatic organisms. The effect of stressors is apparent in the biological responses. |
| **Use Attainability Analysis (UAA)** | A structured scientific assessment of the physical, chemical, biological or economic factors affecting attainment of the uses of waterbodies. |
| **Use Classes** | A broad capture of a designated use for general purposes such as recreation, water supply, and aquatic life. |
| **Use Subclasses** | A subcategorization of use classes into discrete and meaningful descriptions. For aquatic life this would include a hierarchy of warmwater and cold water uses and additional stratification provided by different levels of warmwater uses and further stratification by waterbody types. |
| **TALU Based Approach** | This approach includes tiered aquatic life uses (TALU) based on numeric biological criteria and implementation via an adequate monitoring and assessment program that includes biological, chemical, and physical measures, parameters, indicators and a process for stressor identification. |
| **Tiered Aquatic Life Uses (TALUs)** | As defined: The structure of designated aquatic life uses that incorporates a hierarchy of use subclasses and stratification by natural divisions that pertain to geographical and waterbody class strata. TALUs are based on representative ecological attributes and these should be reflected in the narrative description of each TALU tier and be embodied in the measurements that extend to expressions of that narrative through numeric biocriteria and by extension to chemical and physical indictors and criteria. |

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| | As used: TALUs are assigned to water bodies based on the protection and restoration of ecological potential. This means that the assignment of a TALU tier to a specific waterbody is done with regard to reasonable restoration or protection expectations and attainability. Hence knowledge of the current condition of a waterbody and an accompanying and adequate assessment of stressors affecting that waterbody are needed to make these assignments. |
| **Total Maximum Daily Load (TMDL)** | The maximum amount of a pollutant that a body of water can receive while still meeting water quality standards. Alternatively, a TMDL is an allocation of a water pollutant deemed acceptable to attain the designated use assigned to the receiving water. |
| **Water Quality Standards (WQS)** | A law or regulation that consists of the designated use or uses of a waterbody, the narrative or numerical water quality criteria (including biocriteria) that are necessary to protect the use or uses of that particular waterbody, and an antidegradation policy. |
| **Water Quality Management** | A collection of management programs relevant to a water resource protection that includes problem identification, the need for and placement of best management practices, pollution abatement actions, and measuring the effectiveness of management actions. |

## List of Acronyms

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| **ALU** | Aquatic Life Use |
| **CSO** | Combined Sewer Overflow |
| **CWA** | Clean Water Act |
| **EPT** | Ephemeroptera, Plecoptera, Trichoptera |
| **HSTS** | Home Sewage Treatment System |
| **HRTF** | High-Rate Treatment Facility |
| **IBI** | Index of Biotic Integrity for fish assemblages |
| **ICI** | Invertebrate Community Index |
| **M&A** | Monitoring and Assessment |
| **NEO** | Non-enumerated Overflow |
| **NPDES** | National Pollutant Discharge Elimination System |
| **OEPA** | Ohio Environmental Protection Agency |
| **PSO** | Pump Station Overflow |
| **QHEI** | Qualitative Habitat Evaluation Index |
| **SSO** | Sanitary Sewer Overflow |
| **TALU** | Tiered Aquatic Life Use |
| **TMDL** | Total Maximum Daily Load |
| **UAA** | Use Attainability Analysis |
| **WLA** | Waste Load Allocation |
| **WQS** | Water Quality Standards |
| **WWTP** | Wastewater Treatment Plant |

# FOREWORD

## What is a Biological and Water Quality Survey?

A biological and water quality survey, or "biosurvey", is an interdisciplinary monitoring effort coordinated on a waterbody specific or watershed scale. This may involve a relatively simple setting focusing on one or two small streams, one or two principal stressors, and a handful of sampling sites or a much more complex effort including entire drainage basins, multiple and overlapping stressors, and tens of sites. In this case, the latter is true as this assessment includes four subwatersheds with a mix of numerous overlapping stressors and sources in a highly urbanized landscape. The 2023 assessment is a second follow-up to a baseline survey of these same subwatersheds performed by MBI in 2014 (MBI 2015a) and the first follow-up survey in 2018 (MBI 2019).

## Scope of the 2023 Ohio River Direct Tributaries Biological and Water Quality Assessment

The scope of the MSDGC 2023 Ohio River Direct Tributaries biological and water quality assessment included three direct tributaries to the Ohio River and the upper portions of Taylor Creek compared to the fuller scope of the 2014 baseline survey of the entire Taylor Creek subbasin and the Ohio River mainstem (MBI 2015a). In addition to supporting the instream monitoring requirement of the MSDGC CSO NPDES permit, the overall objectives remained the same:

1. Assess the attainability of the existing aquatic life use designations codified in the Ohio Water Quality Standards (WQS) and make recommendations for any changes as revealed by the survey data and analysis;
2. Determine the extent to which biological assemblages are impaired (using Ohio EPA methods and criteria);
3. Determine the extent of recreational use impairments using *E. coli* as the sole indicator and criteria in the Ohio WQS;
4. Determine the categorical stressors and sources that are associated with those impairments; and,
5. Add to the broader databases for the Direct Ohio River Tributaries study area to track and understand changes over time that occur as the result of MSDGC abatement actions or other factors.

The data presented herein were processed, evaluated, and synthesized as a biological and water quality assessment of aquatic life and recreational use support status. The assessment of the tributaries is directly comparable to that accomplished previously in 2014 and 2018 by MBI such that trends in status can be examined, and causes and sources of impairment can be confirmed, appended, or removed. The 2023 study included an assessment of chemical and physical stressors related to the biological assemblages and an assessment of recreational uses. It is the purpose of this study to identify specific impairments and their causes and threats to full attainment upon which both remedial and protective actions can be developed by MSDGC

or stakeholders on a site specific or watershed basis. The data produced by this study also contributes to the maintenance and use of the Southwestern Ohio Integrated Prioritization System (IPS; MBI 2015b) that provides weighted stressor thresholds and serves as a data warehouse and data exploration platform. The IPS thresholds for chemical, habitat, and land use parameters were used to assign causes of impairment and their severity and threats to attaining sites and reaches.

# EXECUTIVE SUMMARY

## Scope and Purpose

In 2010 MSDGC and MBI developed a rotational watershed assessment approach that is documented in the *Watershed Monitoring and Bioassessment Plan for the MSD Greater Cincinnati Service Area, Hamilton County, Ohio; Technical Report MBI/5-11-3* (MBI 2011). Initiated in 2011 it has provided biological and water quality monitoring data that has assisted MSDGC in better understanding current water quality, trends through time, and considerations for its capital planning and implementation as part of their Wet Weather Improvement Plan (WWIP). The 2023 bioassessment of the Ohio River Direct Tributaries study area is Year Three (2021-23) of the follow-up assessments and completes the third cycle of monitoring required by the current CSO NPDES permit. The sampling and analysis in 2023 were performed by Level 3 Qualified Data Collectors under a Biological and Water Quality Project Study Plan (MBI 2023) approved by Ohio EPA under the specifications of the Ohio Credible Data Law.

An intensive pollution survey design that employed a high density of sampling sites and biological, chemical, and physical indicators and parameters was followed. The principal objectives of biological assessments are to assess current conditions, verify current aquatic life use designations, assign uses to undesignated streams (if any are encountered), make recommendations for changes to use designations, report attainment status following Ohio EPA practices, determine associated causes and sources of impairment, and evaluate changes over time. The determination of associated causes and sources of impairments to aquatic life and recreational uses followed practices similar to those employed by Ohio EPA and as enhanced by the thresholds available in the SW Ohio IPS (MBI 2015a). As such, these determinations are typically categorical, but can include the identification of specific pollutants. The results of this study will be incorporated in the Integrated Prioritization System (IPS; MBI 2015b) as part of an ongoing assessment of stressors and their root causes and sources throughout the MSDGC service area. The IPS includes more detailed analyses of regional patterns in stressor thresholds by relating them to the chemical, physical, and biological data generated by the aggregation of all MSDGC surveys to ancillary data available in GIS coverages.

## Highlighted Findings

### *Aquatic Life Use Attainability 2023*

The key indicator of overall condition in terms of aquatic life is the status of the attainment of aquatic life use designations based on attainment of the Ohio biological criteria. The status of use attainment is portrayed as full, partial, or non-attainment at each site. The 2023 assessment of the Ohio River Direct Tributaries provided an opportunity to update use attainment status and to gauge the effectiveness of prior and ongoing attempts to improve water quality and overall conditions by comparing the results to the prior assessments. The 2014 baseline and 2018 follow-up biological and water quality assessments by MBI are the only prior surveys that provide a consistent basis for comparison in terms of spatial coverage and indicators and parameters for the 2023 study area.

Of the 34 sites that were assessed in the 2023 Ohio River Direct Tributaries bioassessment, 19 sites were evaluated against the Warmwater Habitat (WWH) use, 5 sites against the Limited Resource Waters (LRW) use, and 10 for the Primary Headwater Habitat (PHWH) classification. Recommendations for aquatic life use changes were originally made as part of the 2014 and 2018 bioassessments (MBI 2015a; MBI 2019). The 2023 recommended uses were used to gauge attainment status in 2023. All of the original 2014 use recommendations were verified in 2018 and again in 2023. The four (4) new sites added in 2018 to coincide with the water quality model calibration were likewise sampled in 2023 and used to assess attainment status, which is depicted in Table 2 and Figure 1. The 2023 use attainability analysis resulted in a reduction of three (3) WWH and an increase of three (3) in PHWH recommended uses (Table 1). The LRW designation for the Rapid run subwatershed was left intact pending the outcome of the next round of monitoring scheduled for 2028. The incremental improvements at selected sites in Rapid Run justify this deferment.

***Table 1**. Summary of recommended aquatic life use (AQLU) changes based on use attainability analyses from the 2023, 2018, and 2014 Ohio River Direct Tributaries and Taylor Creek biological and water quality assessments by AQLU and sampling sites and the current status of an Ohio EPA rulemaking to act on recommended changes.*

| Current Aquatic Life Use (AQLU) | Recommended AQLU/Existing Use | Sites Affected | Ohio EPA Rulemaking Status |
|---|---|---|---|
| ***Recommended Uses 2023*** | | | |
| WWH (2018) | WWH (verified) | 5 | Pending |
| WWH (Existing[1]) | WWH (verified) | 14 | Pending |
| Undesignated | PHW3A (verified) | 9 | Recommended |
| Undesignated | PHW2 (verified) | 1 | Recommended |
| LRW (Existing[1]) | TBD | 5 | None |
| TOTAL | 7 | 34 | |
| ***Recommended Uses 2018*** | | | |
| Undesignated | WWH | 2 | Recommended |
| Undesignated | PHW3A | 2 | Recommended |
| WWH (2014) | WWH (verified) | 4 | Pending |
| WWH (Existing[1]) | WWH (verified) | 16 | Pending |
| Undesignated | PHW3A (verified) | 4 | Recommended |
| Undesignated | PHW2 (verified) | 1 | Recommended |
| LRW (Existing[1]) | TBD | 5 | None |
| TOTAL | 7 | 34 | |
| ***Recommended Uses 2014*** | | | |
| Undesignated | WWH | 12 | Pending |
| Undesignated | PHW3A | 7 | Pending |
| Undesignated | PHW2 | 3 | Pending |
| WWH | WWH (verified) | 25 | Pending |
| WWH | PHW3A | 1 | Pending |
| LRW | Deferred | 3 | None |
| TOTAL | 5 | 49 | |

WWH – Warmwater Habitat; LRW – Limited Resource Waters; PHWH – Primary Headwater Habitat; TBD – deferred to next monitoring cycle. 1 – Originally adopted in 1978 or 1985 WQS.

***Aquatic Life Use Attainment Status***

A summary of aquatic life use attainment status, impairment, and threats to attainment for each of the Ohio River Direct Tributaries subwatersheds follows:

*Muddy Creek*

- The 2023 results showed non-attainment of the Warmwater Habitat (WWH) AQLU at four (4) of the six (6) mainstem sites (Table 2). Full attainment of WWH occurred at MU03 (RM 2.80/2.72) and partial attainment occurred at MU02 (RM 2.25) and only because the IBI missed meeting the biocriterion by two (2) points. This is an overall improvement from the 2018 results that showed non-attainment of WWH at all six mainstem sites. Full attainment was observed at MU02 in 2014, but declined to partial in 2018 due the failure of the IBI to meet the WWH biocriterion. The macroinvertebrate ICI met the WWH biocriterion in 2018, but was 18 units lower than in 2014. Raw sewage from NEO 160006007 entered just upstream and was likely related to the decline in biological performance in 2018. There was a slight improvement at MU02 in 2023, but the site remained in partial attainment. Other CSOs and SSOs and a pocket of HSTS discharges are also located upstream. The predominant causes included high urban land use in the 500-meter buffer, chlorides, and conductivity. The absence of the low D.O. and organic enrichment causes in 2018 are likely due to reduced CSO/SSO inputs in 2023. This would include the installation and operation of the Werk and Westbourne Enhanced High-Rate Treatment Facility in late July 2018 and an upgrade to the Muddy and Westbourne facility in 2019-20.
- Biological performance as measured by the fish IBI and the macroinvertebrate ICI or narrative improved at a single site in Muddy Creek at MU03 (RM 2.80/2.72) in 2023 compared to 2018.
- Eight (8) sites were sampled in seven (7) unnamed tributaries to Muddy Creek in 2023 of which two sites in one tributary were new sites in 2018. Four (4) sites were recommended for the PHW3A and one for the PHW2 classification in 2023, replacing WWH at two of those sites. Of the remaining four tributaries, all were recommended as WWH in 2018 and verified in 2023 and were in non-attainment of WWH which is an overall decline from 2018.
- Macroinvertebrates improved at MU12 in 2023, but this was offset by a decline in the fish IBI to poor and non-attainment as a result. Three sites (MU07, MU08, and MU14) were dry and could not be sampled for fish in 2023. Causes of impairment included very poor values for TKN, $BOD_5$, Total Ammonia, and High Urban Land Use in the 500-meter Buffer at MU12 and very poor and poor values for TKN, Chloride, High Urban Land Use in the 500-meter Buffer, $BOD_5$, and Specific Conductance at MU13. The moat upstream sites at MU04 and MU04.5 were impaired for nutrients and the next site downstream was attaining, but threatened by nutrient enrichment. These causes are from a mix of sewage via wet weather discharges and urban runoff sources.
- The causes at other sites were habitat related with very poor QHEI, Substrate, and Channel attributes at MU07 with fair exceedances of habitat at MU07.5, MU12, and MU13. Threats include a mix of fair exceedances of habitat and ionic strength parameters at MU03 and MU10 with the addition of organic enrichment indicators at MU14.

***Table 2.*** *Aquatic life use attainment status at sites in the Ohio River Direct Tributaries and upper Taylor Creek in 2023. Weighted causes and sources (see glossary at bottom) are listed at sites that did not fully attain the recommended or verified use. Sites in non-attainment are red, orange, or yellow shaded and site in full attainment of WWH are green shaded; PHW are blue (3A) and green (2) shaded. Changes in biological condition since 2014 are denoted as improving (↑), unchanged (ʘ), or declining (↓).*

| Site ID | Fish/Macro. River Mile | Drainage Area (sq. mi.) | Aquatic Life Use Designation | IBI | ICI/QL Narra-tive | Aq Life Use Status | QHEI/ HHEI | Causes of Impairment | | | Threats | Sources |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Very Poor | Poor | Fair | | |
| ***Muddy Creek*** | | | | | | | | | | | | |
| **MU05** | 6.35/6.35 | 5.39 | WWH | 12*ʘ | VP*ʘ | **NON** ʘ | 39.50 | H. Urb (Buff) | BOD | QHEI; Channel; TKN | | CSO/SSO,Urban, Sewer Constr. |
| **MU04.5** | 5.62/5.60 | 7.71 | WWH | 12*ʘ | VP*ʘ | **NON** ʘ | 61.50 | BOD | | Channel; TKN; pH | | CSO/SSO, Urban,Sew. Const. |
| **MU04** | 5.45/5.40 | 7.80 | WWH | 24*ʘ | VP*ʘ | **NON** ʘ | 64.30 | H. Urb (Buff) | | TKN | | CSO/SSO,Urban |
| **MU03** | 2.80/2.72 | 10.40 | WWH | $36^{ns}$ ↑ | $28^{ns}$ ↑ | **FULL** ↑ | 56.30 | | | | H. Urb (Buff); QHEI; Channel; Chloride | CSO/SSO/NEO,Urban,HSTS |
| **MU02** | 2.25/2.25 | | WWH | 34*ʘ | 36 ʘ | **Partial** ʘ | 63.50 | H. Urb (Buff) | Chloride | Cond. | | CSO/SSO/NEO,Urban,HSTS |
| **MU01** | 0.17/0.17 | 13.60 | WWH | 12*ʘ | NS | **NON** ʘ | 49.00 | H. Urb (Buff) | BOD | QHEI; Substr; TKN; Temperature | | CSO/SSO/NEO,Urban |
| ***Unnamed Tributary to Muddy Creek @RM 2.37*** | | | | | | | | | | | | |
| **MU10** | 0.50/0.60 | 0.71 | PHW3A | 12 ʘ | ʘ | **PHW3A** | 96.00 | | | | Chloride; QHEI; Channel; Cond. | Urban |
| ***Unnamed Tributary to Muddy Creek @RM 5.97*** | | | | | | | | | | | | |
| **MU12** | 0.55/0.65 | 1.01 | WWH | 24*↓ | F*↑ | **NON** ʘ | 47.50 | TKN; BOD; TAmm; H. Urb (Buff) | | QHEI; Channel | | CSO/SSO,Urban |
| ***Unnamed Tributary to Muddy Creek @RM 6.53*** | | | | | | | | | | | | |
| **MU13** | 0.60/0.60 | 2.25 | WWH | 12*ʘ | VP*ʘ | **NON** ʘ | 41.00 | TKN; Chloride; H. Urb (Buff) | BOD; Cond. | QHEI; Channel | | CSO/SSO,Urban |
| ***Unnamed Tributary to Unnamed Tributary to Muddy Creek @RM 5.9*** | | | | | | | | | | | | |
| **MU14** | 0.20/0.20 | 0.09 | PHW2 | Dry ʘ | NS | **PHW2** ʘ | NS | | | | QHEI; Substr; Channel; Chloride; H. Urb; BOD; Cond; TKN; TAmm; Nitrate | CSO/SSO,Urban |
| ***Unnamed Tributary to Muddy Creek @RM 0.3*** | | | | | | | | | | | | |
| **MU08** | 1.72/1.80 | 0.74 | PHW3A | Dry↓ | ʘ | **PHW3A** | 91.00 | | | | QHEI; Substr; Channel; Nitrate; BOD | Urban |
| **MU07.5** | 0.80/0.90 | 2.60 | WWH | 32*ʘ | F*ʘ | **NON** ʘ | 56.00 | | | QHEI; Channel; Chloride; BOD; Cond. | | Urban |
| **MU07** | 0.40/0.60 | 2.80 | WWH | Dry↓ | ND | **NON**↓ | | QHEI; Substr; Channel | | | | CSO/SSO,Urban |
| ***Fiddlers Creek RM 0.95 to W. Branch Muddy Creek to Muddy Creek @RM 0.3*** | | | | | | | | | | | | |
| **MU09** | 0.10/0.60 | 1.31 | PHW3A | 24 ʘ | ʘ | **PHW3** A | 86.00 | | | | QHEI; Channel; Chloride; Cond | CSO/SSO,Urban |
| ***Rapid Run*** | | | | | | | | | | | | |
| **RR03** | 2.70/2.70 | 2.32 | LRW | Dry ʘ | $MG^{ns}$ ↑ | NS | NS | QHEI; Substr; Channel; H. Urb (Buff) | | | | Urban, Sewer Constr.,HSTS |
| **RR02** | 1.05/1.20 | 5.90 | LRW | 24↓ | $MG^{ns}$ ↑ | **FULL** ʘ | 51.00 | Chloride; H. Urb (Buff) | Cond. | QHEI; Channel | | Urban, Sewer Constr. |
| **RR01** | 0.10/0.10 | 6.56 | LRW | Dry ʘ | VP*↓ | NS | NS | QHEI; Substr; Channel; Chloride; Cond. | | | | Urban, Sewer Constr.,HSTS |
| ***Wulff Run*** | | | | | | | | | | | | |
| **RR05** | 1.45/0.68 | 1.33 | LRW | Dry ʘ | VP*ʘ | NS | NS | QHEI; Substr; Channel;H. Urb (Buff) | | | | CSO/SSO,Urban,Sew. Const. |
| **RR04** | 0.45/0.55 | 2.18 | LRW | 20 ʘ | F↑ | **FULL** ʘ | 73.00 | Chloride; H. Urb (Buff) | Cond. | QHEI; Channel | | CSO/SSO,Urban |
| ***Unnamed Tributary to Wulff Run @RM 0.77*** | | | | | | | | | | | | |
| **RR05.5** | 0.40/1.20 | 0.33 | PHW3A | 12 ʘ | ʘ | **PHW3A** | 73.00 | | | | Nitrate; Chloride; QHEI; Channel; TKN; Cond. | CSO/SSO,Urban |
| **RR04.5** | 0.35/1.10 | 0.33 | PHW3A | 12 ʘ | ʘ | **PHW3A** | 69.00 | | | | Nitrate; QHEI; Channel; Cond. | CSO/SSO,Urban |

| Narrative Threshold Rankings | | IBI | ICI | QHEI |
|---|---|---|---|---|
| | **Exceptional** | 48-60 | ≥46/E | FULL >75 |
| | **Good** | 38-43 | ≥32/G | FULL 60-74 |
| | **Fair** | 26-37 | >14/F | PARTIAL 46-59 |
| | **Poor** | 19-25 | >8/P | NON-POOR 30-45 |
| | **Very Poor** | 12-18 | ≤6/VP | NON-V.POOR <30 |

**Footnotes:** [a] - as codified in OAC 3745-1-07, Table 7-1; [b] - Nonsignificant departure of 4 units for IBI and ICI or marginal for narrative ratings; [c] - FULL - all biocriteria attain; PARTIAL - one or two biocriteria fail to attain; NON - no biocriteria attain or one assemblage with poor or very poor narrative. Qualitative (QL) narratine ratings: E - exceptional (EWH); G - good (WWH); F - fair; P - poor; VP - very poor. NS - no sample due to dry streambed.

***Table 2**. continued.*

| Site ID | Fish/Macro. River Mile | Drainage Area (sq. mi.) | Aquatic Life Use Designation | IBI | ICI/QL Narra-tive | Aq Life Use Status | QHEI/ HHEI | Causes of Impairment | | | Threats | Sources |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Very Poor | Poor | Fair | | |
| ***Indian Creek*** | | | | | | | | | | | | |
| **IC06** | 2.30/2.43 | 0.58 | WWH | 24*Θ | $MG^{ns}$ ↓ | **NON** ↓ | 53.50 | Lead; H. Urb (Buff); | Chloride; Cond. | QHEI; Channel | | Urban, HSTS |
| **IC05** | 2.08/2.08 | 1.07 | WWH | $38^{ns}$Θ | F*Θ | **Partial** Θ | 55.00 | H. Urb (Buff); | Cond. | QHEI; Channel; Chloride | | Urban |
| **IC02** | 1.15/1.22 | 1.38 | WWH | $36^{ns}$ ↑ | F*↓ | **Partial** Θ | 48.00 | Chloride;H. Urb (Buff); | Cond. | QHEI; Channel | | Urban |
| **IC01** | 0.30/0.30 | 2.30 | WWH | 24*Θ | F*↓ | **NON** ↓ | 50.00 | H. Urb (Buff); | Chloride; BOD; Cond. | QHEI; Channel; TKN | | Urban |
| ***Tributary to Indian Creek @RM1.02*** | | | | | | | | | | | | |
| **IC07** | 0.10/0.13 | 0.39 | PHW3A | 12 Θ | Θ | **PHW3A** Θ | 91.00 | | | | BOD; H. Urb (Buff);Chloride; TAmm; QHEI; Channel; TKN; Cond. | Urban |
| ***Taylor Creek*** | | | | | | | | | | | | |
| **GM86** | 6.40/6.30 | 0.49 | WWH | 22*↓ | VP↓ | **NON** ↓ | 40.30 | H. Urb (Buff) | Chloride | QHEI; Substr; Channel; TKN; Cond. | | Urban, HSTS |
| **GM85** | 5.30/4.98 | 2.22 | WWH | 20*↓ | FΘ | **NON** Θ | 44.00 | Chloride; Nitrate; H. Urb (Buff) | Cond. | QHEI; Channel | | Urban, HSTS |
| ***Briarly Creek*** | | | | | | | | | | | | |
| **GM91** | 3.90/3.90 | 0.34 | PHW3A | 24 Θ | | **PHW3A** Θ | 76.00 | | | | H. Urb (Buff); Chloride; QHEI; Cond. | Urban, HSTS |
| **GM90** | 2.45/2.45 | 1.30 | WWH | 22*Θ | F↓ | **NON** ↓ | 49.50 | | | QHEI; Channel; TKN; Chloride | | Urban, HSTS |
| **GM89** | 1.80/1.70 | 2.10 | WWH | 24*↓ | $MG^{ns}$Θ | **NON** ↓ | 53.50 | H. Urb (Buff) | Chloride | QHEI; Channel | | Urban, HSTS |
| ***Wesselman Creek*** | | | | | | | | | | | | |
| **GM94** | 4.70/4.72 | 1.10 | PHW3A | 26 ↑ | Θ | **PHW3A** Θ | 96.00 | | | | Chloride; H. Urb (Buff); Cond; QHEI; Channel; TKN | Urban, HSTS |
| ***Unnamed Tributary to Wesselman Creek @RM 2.59*** | | | | | | | | | | | | |
| **GM100** | 1.05/1.21 | 0.91 | PHW3A | 20Θ | Θ | **PHW3A** Θ | 84.00 | | | | H. Urb (Buff); Chloride; QHEI; Substr; Channel; TKN; Cond. | Urban, HSTS |
| ***Unnamed Tributary to Taylor Creek @RM 4.9*** | | | | | | | | | | | | |
| **GM106** | 0.20/0.28 | 0.92 | WWH | 30*↓ | PΘ | **NON** Θ | 57.00 | Chloride; H. Urb (Buff); | | QHEI; Cond; | | Urban, HSTS |

| **Criteria and Narrative Thresholds** | | | | | |
|---|---|---|---|---|---|
| **Exceptional** | >50 | E | FULL | >75 |
| **Good** | >40 | G | FULL | >60 |
| **Fair** | >26 | F | PARTIAL | >45 |
| **Poor** | >18 | P | NON-POOR | >30 |
| **Very Poor** | ≤12 | VP | NON-V.POOR | ≤30 |

**Footnotes:** [a] - as codified in OAC 3745-1-07, Table 7-1; [b] - Nonsignificant departure of 4 units for IBI and ICI or marginal for narrative ratings; [c] - FULL - all biocriteria attain; PARTIAL - one or two biocriteria fail to attain; NON - no biocriteria attain or one assemblage with poor or very poor narrative. Qualitative (QL) narratine ratings: E - exceptional (EWH); G - good (WWH); F - fair; P - poor; VP - very poor. NS - no sample due to dry streambed.

***Glossary of terms used in Table 2***

| Acronym | Description | Acronym | Description | Acronym | Description |
|---|---|---|---|---|---|
| H. Urb. (Buff.) | Hign urban land use in 500 m buffer | Chloride | Chloride concentration in mg/L | TKN | Total Kjeldahl nitrogen |
| QHEI | Qualitative Habitat Evaluation Index (QHEI) | Low D.O. | Minium Dissolved Oxygen in mg/L | TP | Total phosphorus |
| QHEI Ratio | Ratio of Modified:Good QHEI attributes | Max. D.O. | Maximum Dissolved Oxygen in mg/L | Nitrate | Nitrate as N |
| Chan | Channel condition from QHEI | D.O. Swing | Width of Diel D.O. Variation in 24 Hrs. | Tamm | Total Ammonia |
| Substr | Substrate condition from QHEI | Conduct | Specific conductivity | CSO | Combined Sewer Overflow |
| High Mod. Attr. | NumberHigh Influence Modified QHEI Attributes | Toxicity | Exceedance of Toxic Biological Signature | SSO | Sanitary Sewer Overflow |
| Good QHEI Attr. | Number of Good Habitat Attributes | Org. Enrich. | Exceedance of Organic Enrichment Biological Signature | NEO | Non-enumerated Overflow |
| Poor QHEI Attr. | Number if Modified Habitat Attributes | TSS | Total suspended solids | HSTS | Home Sewager Treatment System |

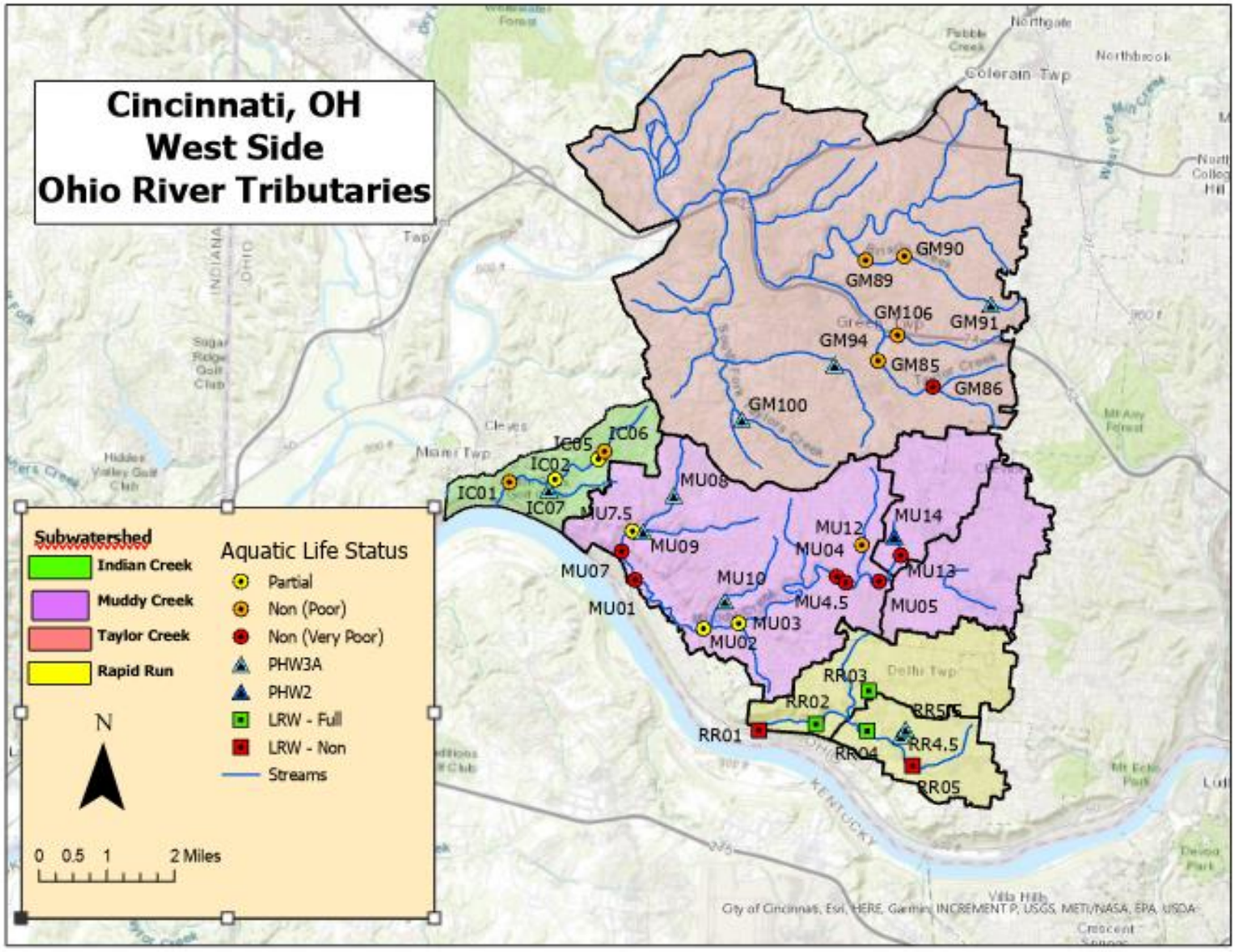


***Figure 1***. *Aquatic life use attainment status in the Ohio River Direct Tributaries study area during 2023 (green circles – full attainment; yellow – partial attainment; red – non-attainment; outfall type – CSO, SSO, NEO, PSO, HSTS). Site descriptions and site codes appear in Table 5. Sites evaluated as Primary Headwater Habitat (PHWH) sites appear as triangles with their classification results (green – PHW Class III; orange – PHWH Class II).*

*Rapid Run*

- Seven (7) sites were sampled in the Rapid Run subwatershed in 2023 with three (3) sites in the mainstem, two in Wulff Run, and two in an unnamed tributary to Wulff Run. The results showed full attainment of the Limited Resource Water (LRW) AQLU at two of the seven sites (RR02 and RR04), PHW3A at two sites (RR04.5 and RR05.5), and no determination at the remaining three (3) sites that could not be sampled due to dry conditions at the time of fish sampling, a repeat of 2018. This is the continuing result of flow alterations due to the infiltration of stream water at low flows into previous sewer line excavations which constitute a legacy impact that has recently showed signs of slowly receding at certain locations (RR02).
- There was sufficient water to sample macroinvertebrates which were Marginally Good at RR02 and RR03, but Very Poor at RR01 in the Rapid Run mainstem.
- The fish IBI of 24 at RR02 was a decline from 2018 which halted the incremental improvements observed since 2014. Still, the incremental improvement above the LRW biocriteria and the consistent improvement of the macroinvertebrates to Marginally Good in 2023 resulted in deferring any recommendations about revising the current LRW use designation. The habitat attributes were largely fair-very poor with certain locations showing incremental improvement. Overall the habitat remains impacted by legacy modifications to the stream channel that affected the flow regime as a result.
- The predominant causes of impairment included very poor and poor flow alteration, QHEI, Substrate modification, Channel modification, High Urban Land Use in the 500-meter Buffer, Chloride, and Specific Conductance. Besides the single CSO and two SSOs, HSTS discharges are also comparatively dense at certain locations in the Rapid Run subwatershed. These causes are predominantly via urban land use and runoff sources.
- Threats to the two PHW3A sites included Nitrate-N, Chloride, QHEI, Channel condition, TKN, and Specific Conductance.

*Indian Creek*

- Five (5) sites were sampled in the Indian Creek subwatershed in 2023 with four (4) sites in the mainstem and one (1) in an unnamed tributary (IC07). The results showed partial attainment of WWH at two middle mainstem sites and non-attainment at the upstream and downstream sites in Indian Creek due to poor fish IBIs. The macroinvertebrate assemblage showed consistent declines at all sites in 2023. This contrasts with the incremental improvement from 2014 to 2018 at three sites and a decline at one (1) site. Site IC07 in the unnamed tributary was classified PHW3A.
- Causes of impairment included very poor and poor exceedances of Lead, High Urban Land Use in the 500-meter Buffer, Chloride; Specific Conductance, and $BOD_5$. Fair exceedances occurred for QHEI, Channel condition, Chloride, and TKN. These causes are from a mix of sewage via HSTS or unknown sources and urban land use and runoff sources. Indian Creek lacks the wet weather sewer system discharges that are numerous in Muddy Creek and Rapid Run.
- Threats the single PHW3A site included Nitrate-N, Chloride, QHEI, Channel condition, TKN, and Specific Conductance.

*Taylor Creek*

- Eight (8) sites were sampled in the upper Taylor Creek subwatershed in 2023 with two (2) sites in the mainstem, three in Briarly Creek, one (1) in Wesselman Creek, and two (2) in unnamed tributaries to Taylor Creek and Wesselman Creek. The results showed consistent non-attainment of the WWH use with significant declines in fish and/or macroinvertebrate performance at five sites. The non-attainment was due to poor and one very poor biological index result.
- Three (3) sites, GM 91 in Briarly Creek, GM 94 in Wesselman Creek, and GM 100 in an unnamed tributary to Wesselman Creek were classified PHW3A which is considered to be equivalent to receiving WWH protections and is the highest PHWH classification possible.
- Weighted causes of impairment included very poor and poor High Urban Land Use in the 500-meter Buffer, Chloride, Nitrate-N, Specific Conductance at the five (5) impaired sites. These are clearly indicative of urban land use and runoff sources particularly the predominance of the ionic strength parameters
- Fair exceedances included QHEI, Substrate condition, Channel condition, TKN, and Specific Conductance.
- Threats to the PHW3A sites included a wider array of stressors including High Urban Land Use in the 500-meter Buffer, Chloride, QHEI, Substrate condition, Channel condition, TKN, and Specific Conductance.

***Causes and Sources of Non-attainment***

The determination of causes and sources of aquatic life use impairment was accomplished by associating the occurrence of sampling results that exceeded various chemical and physical thresholds that are known to adversely affect aquatic organisms, which in this case are the SW Ohio IPS thresholds (MBI 2015b). This includes parameter specific chemical (e.g., dissolved oxygen, chlorides), attributes of habitat, and watershed and stream buffer land use thresholds that are weighted by their severity, i.e., exceptional to very poor condition. Sources are necessarily categorical and some are broader in their inclusion of specific activities than others (e.g., urban runoff vs. CSO/SSO). The causes and sources that are listed with the biological impairments in the determination of aquatic life use attainment status (Table 2) were derived by compiling the exceedances of IPS thresholds with corresponding biological impairments in the Synthesis table at the end of the report. Weighted causes were extracted and summarized on a subwatershed basis in Figure 2. This included combining the Muddy Creek and Rapid Run subwatersheds as being affected by wet weather sewage sources in addition to urban land use, urban runoff, and HSTS related impacts. The Taylor Creek and Indian Creek subwatersheds were combined as they lack the wet weather sewer system overflows, but have the urban land use and urban runoff impacts plus a more dense clustering of HSTS sources. Categories of cause and source are proportionally depicted by the number of sites each was assigned in 2023 in Figure 2. Urban Related (31.7%) and Habitat Related (30.7%) weighted causes were the most frequently observed followed by Organic_Nutrient Enrichment Related (19.6%) weighted causes and D.O. Related (13.1%) weighted causes in the Muddy Creek-Rapid Run subwatersheds. A higher proportion of Urban Related (56.1%) weighted causes dominated the Taylor Creek-Indian Creek subwatersheds followed by Habitat Related (19.3%) and

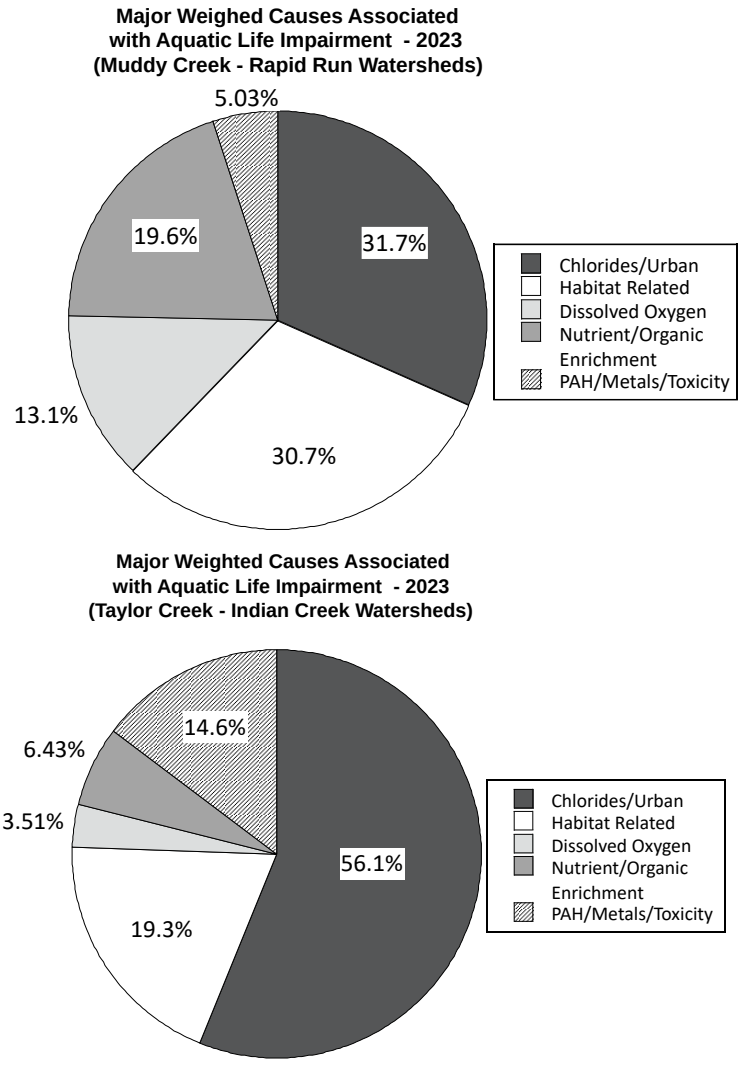


***Figure 2.*** *Major causes associated with aquatic life impairments in the Muddy Creek/Rapid Run (upper) and Taylor Creek/Indian Creek (lower) subwatersheds, 2023. Causes are weighted by severity in accordance with SW Ohio IPS stressor effect thresholds.*

comparatively lower Organic_Nutrient Related (6.4%) and D.O. Related (3.5%) weighted causes. The differences reflect the absence of sewer system wet weather sources in the latter subwatersheds that lack those sources. The much higher proportion of Urban Related impacts including urban land uses and highly elevated ionic strength indicators such as Chlorides and Specific Conductance are typical for urbanized watersheds.

***Recreational Use Status***

Impairment of the Primary Contact Recreation (PCR) recreational use in the 2023 Ohio River Direct Tributaries study area was judged by the *Escherichia coli (E. coli)* bacterial criteria in the Ohio WQS (OAC 3745-1-07; Table 7-13). *E. coli* bacteria are normally present in the feces and intestinal tracts of humans and other warm-blooded animals typically comprising 97 percent of the fecal coliform bacteria in humans (Dufour 1977). There is currently no practical way to differentiate between human and animal sources of coliform bacteria in surface waters, although methodologies for this type of analysis have been developed including previous research supported by MSDGC in 2010-11. *E. coli* enters surface waters via direct discharges of human and animal wastes, and in runoff from land surfaces where such wastes have been deposited. Pathogenic (disease-causing) organisms are typically present in the environment in such small amounts that it is impractical to directly monitor them. Fecal indicator bacteria by themselves, including *E. coli,* are generally not pathogenic. However, some strains of *E. coli* can be pathogenic, capable of causing serious human illness. Although not necessarily agents of disease, fecal indicator bacteria such as *E. coli* may signal the *potential* presence of pathogenic organisms that enter the environment via the same pathways.

When *E. coli* are present in extremely high numbers in a water sample, it usually means the water has received a dose of fecal matter from one or more sources including human sewage.

The Ohio WQS for recreational uses were revised in 2016 to reflect a more rigid adherence to equalizing all forms of human contact with surface waters as ensuing the same level of risk. This replaced the former framework that was stratified to account for the degree of contact with three levels of the Primary Contact Recreational (PCR) use as PCR-A, PCR-B, and PCR-C. Those subcategories are now merged into a single use. This action also obviated the recommendations made in the 2011-14 MSDGC watershed assessments for the redesignation of certain streams to one of the three former subcategories. The application of the Secondary Contact Recreational (SCR) use was also changed by Ohio EPA to a more restrictive interpretation of the potential for human contact with surface waters. Existing SCR designations made prior to 2011 remain for some MSDGC service area streams including the Rapid Run subbasin, but these could potentially be reviewed and revised to PCR by Ohio EPA at any time. Any new SCR recommendations will need to document that human contact is precluded by legal or physical restrictions for accessing a surface water. The recreational uses in the 2023 Ohio River Direct Tributaries study area were done in accordance with the currently assigned uses including PCR and SCR where it still applies.

Rivers and streams in the 2023 study area are designated as primary contact recreation (PCR) and/or secondary contact recreation (SCR) in the Ohio WQS (OAC 3745-1-07). Water bodies with a designated recreation use of PCR *". . . these are waters that, during the recreation season, are suitable or one or more full body contact recreation activities such as, but not limited to, wading, swimming, boating, water skiing, canoeing, kayaking, and scuba diving. All surface waters of the state are designated as primary contact recreation unless otherwise designated as bathing waters or secondary contact recreation"* (OAC 3745-1- 07(B)(3)(b)). Secondary Contact includes waters that *". . . result in minimal exposure potential to water borne pathogens because the waters are: rarely used for water based recreation such as, but not limited to, wading; situated in remote, sparsely populated areas; have restricted access points; and have insufficient depth to provide full body immersion, thereby greatly limiting the potential for water based recreation activities"* (OAC 3745-1- 07(B)(3)(c)). The *E. coli* criterion that applies to PCR is expressed as a 90-day geometric mean of ≤126 colony forming units (cfu)/100 ml with a Statistical Threshold Value of 410 cfu/100 ml (Table 3). The criterion that applies to SCR streams is ≤1,030 cfu/100 ml for both the 90-day geometric mean and the STV. The geometric mean is based on two or more samples and is used as the basis for determining the attainment status of the PCR use. Samples were collected under summer normal flows and not immediately after elevated flow and runoff events.

Impairment of the Primary Contact (PCR) and Secondary Contact Recreation (SCR) uses based on *E. coli* results persisted throughout the Ohio River Direct Tributaries study area in 2023. While the criteria are expressed in terms of a geometric mean and statistical threshold value, the reality is that the number of samples limits the assessment to a geometric mean calculated on and a maximum value. Hence these endpoints are used as surrogates for the two criteria values. Based on this approach, recreational use attainment for each of the 34 sites sampled in

2023 appears in Table 4 and in Figure 3. A narrative summary of the major portions of the 2023 study area follows:

***Table 3****. E. coli criteria for Ohio streams and rivers (OAC 3745-1-37) that apply during the May 1-October 31 recreation season.*

| ***E. coli*** **Counts (cfu/100 mL** | | |
|---|---|---|
| **Recreation Use** | **Seasonal Geometric Mean** | **Statistical Threshold Value[1]** |
| **PCR** | 126 | 410 |
| **SCR** | 1,030 | 1,030 |

[1]These criteria shall not be exceeded in more than 10 percent of the samples taken during any 90-day period.

*Muddy Creek Subwatershed*

- Three (MU02, MU03, and MU059) of the 14 sites that were evaluated met the PCR geometric mean and one site (MU09 met the STV (Table 4; Figure 3). No sites met the geometric mean and the STV at the same site. The STV was exceeded at 13 of 14 sites and exceeded the SCR value of 1030 cfu/mL at eight (8) sites.
- MU08 was the only site with an extremely elevated geometric mean of 4552 cfu/100 mL and the highest maximum of 27,230 cfu/100 mL indicating sustained high values throughout the sampling index period. Extremely high values were observed at MU05 (3,129 and 41,060 cfu/100 ml), MU 04.5 (1,179 and 198,630 cfu/100 ml), MU01 (8,164 cfu/100 ml STV), MU12 (12,997 cfu/100 ml STV), MU13 (24,196 cfu/100 ml STV), and MU 13 (1,549 and 43,520 cfu/100 ml) in 2018.

*Rapid Run Subwatershed*

- The entirety of the Rapid Run subwatershed including Wulff Run is currently designated as SCR and were assessed against the 1030 cfu/100 mL criterion.
- Four (4) of the seven (7) sites met the SCR criterion (Table 4) while three (3) did not. The highest maximum values of 9,590 and 11,190 cfu/100 mL were recorded in Rapid Run at RC03 and RC02, respectively.
- Extremely elevated geometric mean and/or STVs occurred in Wulff Run at RR04 (8,164 cfu/100 ml STV) and the unnamed tributary to Wulff Run at RR05.5 (1,174 and 4,106 cfu/100 ml) in 2018. However, *E. coli* levels at RR04 in 2023 were much reduced enough to meet both the PCR mean and STV criteria. The levels at RR05.5 remained elevated with a mean of 1,003 cfu/100 mL and a maximum of 3,830 cfu/100 mL.

*Indian Creek Subwatershed*

- Of the five (5) sites assessed in the Indian Creek subwatershed, the upstream site (IC06) fully met both the mean and STV PCR criteria. The other four sites all exceeded the mean and STV criteria.
- The remaining exceedances in 2023 were lower than the extremely elevated geometric mean and/or STVs at IC05 (6,867 cfu/100 ml STV) and IC01 (2,858 cfu/100 ml and 5,172 cfu/100 ml) in 2018.

*Upper Taylor Creek Subwatershed*

- Of the eight (8) sites assessed in the upper Taylor Creek subwatershed, three attained the PCR geometric mean criterion, but all sites exceeded the STV criterion. Of these exceedances only one was below the SCR criterion of 1,030 mg/L.
- The exceedances in 2023 were lower than the extremely elevated geometric mean and maximums that occurred in Taylor Creek at GM86 (17,329 cfu/100 ml STV) and Briarly Creek at GM91 (2,676 cfu/100 ml and 10,462 cfu/100 ml) in 2018.

***Table 4**. Bacteriological (E. coli) sampling results during summer-fall normal flows in the Ohio River Direct Tributaries and upper Taylor Creek study area during 2023. All values are expressed as colony forming units (cfu) per 100 ml of water. Geometric mean and statistical threshold (STV) values were used to determine attainment of the Primary Contact Recreation (PCR) and Secondary Contact Recreation (SCR) use; values exceeding the geometric mean criterion are highlighted in yellow, exceeding the STV in orange, and the SCR maximum in red.*

| Site ID | River Mile | Drainage Area (sq. mi.) | Samples | Minimum | Geometric Mean | Maximum |
|---|---|---|---|---|---|---|
| ***Muddy Creek (PCR)*** | | | | | | |
| MU05 | 6.25 | 5.39 | 5 | 8 | 110 | 411 |
| MU04.5 | 5.60 | 7.71 | 6 | 37 | 220 | 2420 |
| MU04 | 5.40 | 7.80 | 6 | 91 | 261 | 687 |
| MU03 | 3.10 | 10.40 | 6 | 15 | 49 | 1203 |
| MU02 | 2.25 | 12.10 | 6 | 27 | 107 | 411 |
| MU01 | 0.20 | 13.60 | 6 | 57 | 169 | 579 |
| ***Unnamed Trib to Muddy Creek @RM 0.3 (PCR)*** | | | | | | |
| MU08 | 1.72 | 0.74 | 3 | 1553 | 4552 | 27230 |
| MU07.5 | 0.80 | 2.60 | 5 | 45 | 319 | 1986 |
| MU07 | 0.40 | 2.80 | 1 | 488 | 488 | 488 |
| ***Fiddlers Creek RM 0.95 to W. Branch Muddy Creek to Muddy Creek @RM 0.3 (PCR)*** | | | | | | |
| MU09 | 0.10 | 1.33 | 5 | 62 | 143 | 345 |
| ***Unnamed Trib to Muddy Creek @RM 2.37 (PCR)*** | | | | | | |
| MU10 | 0.50 | 0.71 | 5 | 140 | 556 | 1553 |
| ***Unnamed Trib to Muddy Creek @RM 5.97 (PCR)*** | | | | | | |
| MU12 | 0.55 | 1.01 | 4 | 326 | 1164 | 7060 |
| ***Unnamed Trib to Muddy Creek @RM 6.53 (PCR)*** | | | | | | |
| MU13 | 0.60 | 2.25 | 5 | 18 | 432 | 1986 |
| ***Unnamed Trib to Unnamed Trib to Muddy Creek @RM 5.97 (PCR)*** | | | | | | |
| MU14 | 0.20 | 2.70 | 4 | 12 | 197 | 6370 |
| ***Rapid Run (SCR)*** | | | | | | |
| RR03 | 2.58 | 2.32 | 2 | 1414 | 3682 | 9590 |
| RR02 | 1.10 | 5.90 | 6 | 7 | 94 | 11190 |
| RR01 | 0.35 | 5.99 | 2 | 40 | 157 | 613 |
| ***Wulff Run (SCR)*** | | | | | | |
| RR05 | 0.68 | 1.33 | 4 | 140 | 242 | 387 |
| RR04 | 0.55 | 2.18 | 5 | 40 | 114 | 291 |
| ***Unnamed Trib to Wulff Run @RM 0.77 (SCR)*** | | | | | | |
| RR05.5 | 1.20 | 1.00 | 5 | 248 | 1003 | 3830 |
| RR04.5 | 1.10 | 0.34 | 5 | 91 | 497 | 1414 |

| | |
|---|---|
| | exceeds Primary Contact Recreation (PCR) geometric mean (126 cfu/100 mL). |
| | exceeds Primary Contact Recreation (PCR) statistical threshold value (STV; 410 cfu/100 mL). |
| | exceeds Secondary Contact Recreation (SCR) maximum (1030 cfu/100 mL. |

***Table 4**. continued.*

| Site ID | River Mile | Drainage Area (sq. mi.) | Samples | Minimum | Geometric Mean | Maximum |
|---|---|---|---|---|---|---|
| ***Indian Creek (PCR)*** | | | | | | |
| IC06 | 2.25 | 0.58 | 5 | 37 | 92 | 179 |
| IC05 | 2.08 | 1.07 | 6 | 249 | 904 | 2420 |
| IC02 | 1.15 | 1.38 | 6 | 117 | 374 | 1553 |
| IC01 | 0.20 | 2.30 | 6 | 261 | 627 | 1203 |
| ***Trib to Indian Creek @RM 1.02 (PCR)*** | | | | | | |
| IC07 | 0.19 | 0.39 | 5 | 93 | 663 | 14550 |
| ***Taylor Creek (PCR)*** | | | | | | |
| GM86 | 6.50 | 0.49 | 6 | 152 | 734 | 2420 |
| GM85 | 5.30 | 2.22 | 6 | 30 | 105 | 488 |
| ***Unnamed Trib to Taylor Creek @RM 4.9 (PCR)*** | | | | | | |
| GM106 | 0.28 | 0.92 | 6 | 5 | 106 | 10540 |
| ***Briarly Creek*** | | | | | | |
| GM91 | 3.90 | 0.34 | 7 | 185 | 612 | 5460 |
| GM90 | 2.55 | 1.30 | 7 | 17 | 95 | 1986 |
| GM89 | 1.98 | 2.10 | 6 | 76 | 329 | 1986 |
| ***Wesselman Creek (PCR)*** | | | | | | |
| GM94 | 4.75 | 1.10 | 7 | 135 | 370 | 1320 |
| ***Unnamed Trib to Wesselman Creek @RM 2.95 (PCR)*** | | | | | | |
| GM100 | 1.28 | 0.91 | 5 | 411 | 824 | 1733 |

| | |
|---|---|
| | exceeds Primary Contact Recreation (PCR) geometric mean (126 cfu/100 mL). |
| | exceeds Primary Contact Recreation (PCR) statistical threshold value (STV; 410 cfu/100 mL). |
| | exceeds Secondary Contact Recreation (SCR) maximum (1030 cfu/100 mL. |

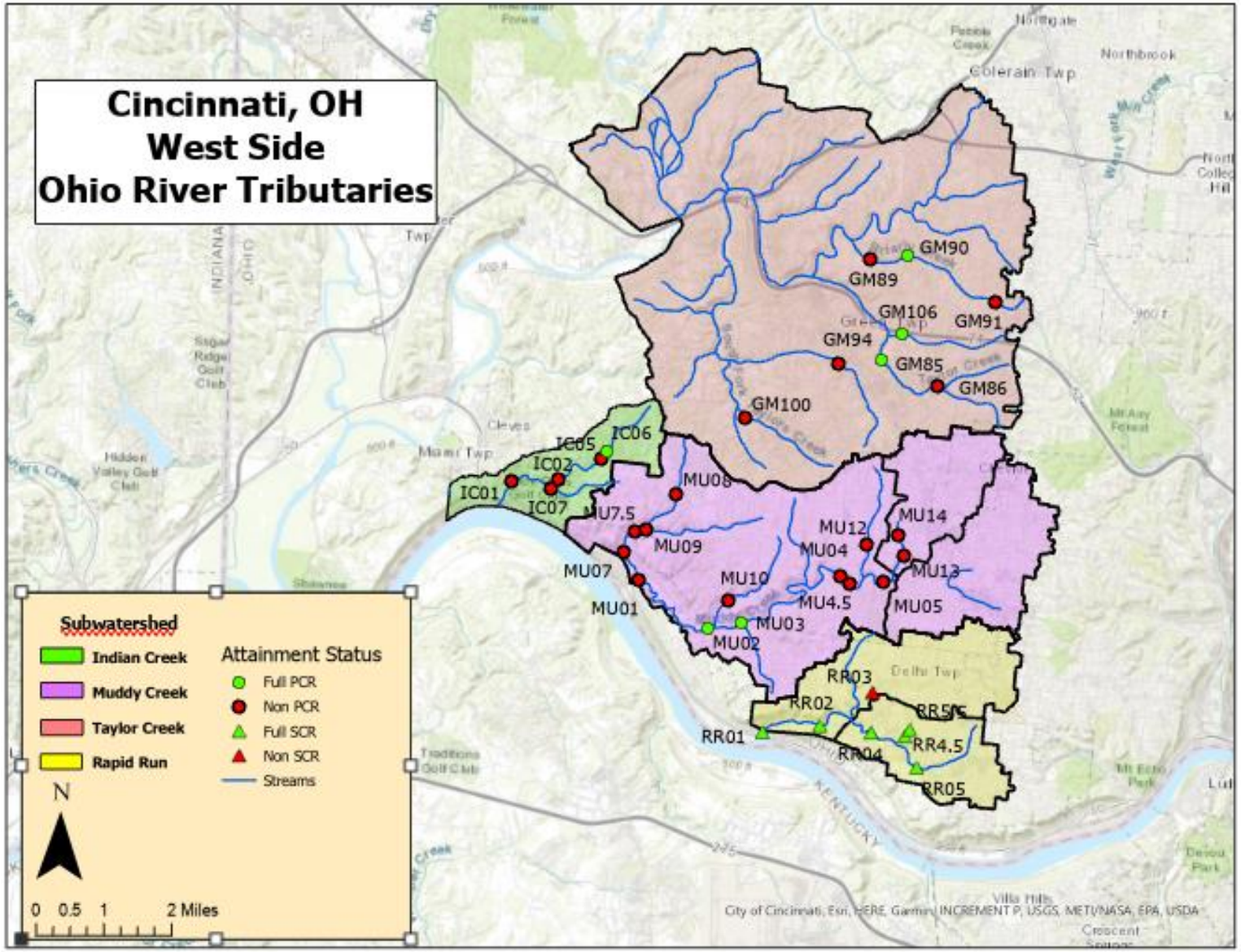


***Figure 3**. Map of recreational use attainment status for the Primary Contact Recreation (PCR) and Secondary Contact Recreation (SCR) uses in the 2023 Ohio River Direct Tributaries study area expressed as attainment (green) or non-attainment (red) based on E. coli values. Various pollution sources are denoted by symbols in the legend.*

## Trajectories in Key Indicators

The temporal trajectory of the indicators and parameters that are provided by a spatially adequate monitoring design can provide important feedback to MSDGC, Ohio EPA, and stakeholders in the Ohio River Direct Tributaries study area. The study area has a mosaic of watershed level and site-specific impacts the complexity of which makes being able to understand and then develop management responses to impairments contingent on tracking quantitative changes through time. The documentation of incremental improvements as opposed to a singular focus on the full restoration of aquatic life use impairments allows program effectiveness to receive credit short of achieving full restoration. Furthermore, failing to recognize that conditions are improving and on a positive trajectory can lead to erroneous conclusions about the attainability of Clean Water Act (CWA) goals and the viability of current and future restoration efforts. Simply put, a selective focus on full use attainment is simply insufficient in a complex setting like the Ohio River Direct Tributaries study area. For these reasons being able to detect, measure, and express incremental improvements in key indicators is vital. Showing incremental progress not only provides confirmation that restoration efforts are working, it also provides important feedback for those programs which, because of uncertainties in their control, must be adaptive in order to succeed. As such, the type of monitoring and assessment that was employed in this and prior surveys is designed to produce results that can be used to demonstrate the degree and direction of incremental change.

The results of the bioassessment using the primary indices that comprise the Ohio biocriteria were used to quantify the degree to which overall aquatic life conditions have improved through time up to and including the 2023 survey. The Area of Degradation (ADV) and Attainment (AAV) methodology (Yoder et al. 2005) was used to illustrate the degree of change between the Ohio EPA surveys of 1991 (Ohio EPA 1992) and the 2014 (MBI 2015a), 2018 (MBI 2019), and 2023 MBI surveys of the mainstem of Muddy Creek. The ADV/AAV term is an expression of the degree to which one of the biological index values is either above or below the WWH biocriterion and the distance of the mainstem over which it occurs. As such it is a multidimensional quantification of biological attainment and impairment. When normalized to a standard distance (e.g., per mile) it can be an effective indicator of the degree of change that is taking place through time or between stream and river reaches.

### *Muddy Creek Mainstem*

ADV/AAV results for the fish Index of Biotic Integrity (IBI) and the macroinvertebrate Invertebrate Community Index (ICI) were available from an Ohio EPA survey in 1991 and the 2014, 2018, and 2023 MSDGC surveys of the Muddy Creek mainstem. Incremental improvements in both the fish and macroinvertebrate assemblages since 1991 were first evident in reduced ADVs and detectable AAVs in 2014 in both the fish IBI and macroinvertebrate ICI narrative equivalents (Figure 4). In 2018 the ADVs were similar to 1991 for the macroinvertebrate ICI narrative equivalents and slightly lower for the fish IBI. Fish IBI AAVs have been zero in each year which does not reflect the marginal WWH attainment in 2014, 2018 and 2023 (Figure 4). However, the fish IBI ADVs declined across the 2014-2023 span, which is an indication of incremental improvement through time that corresponds to

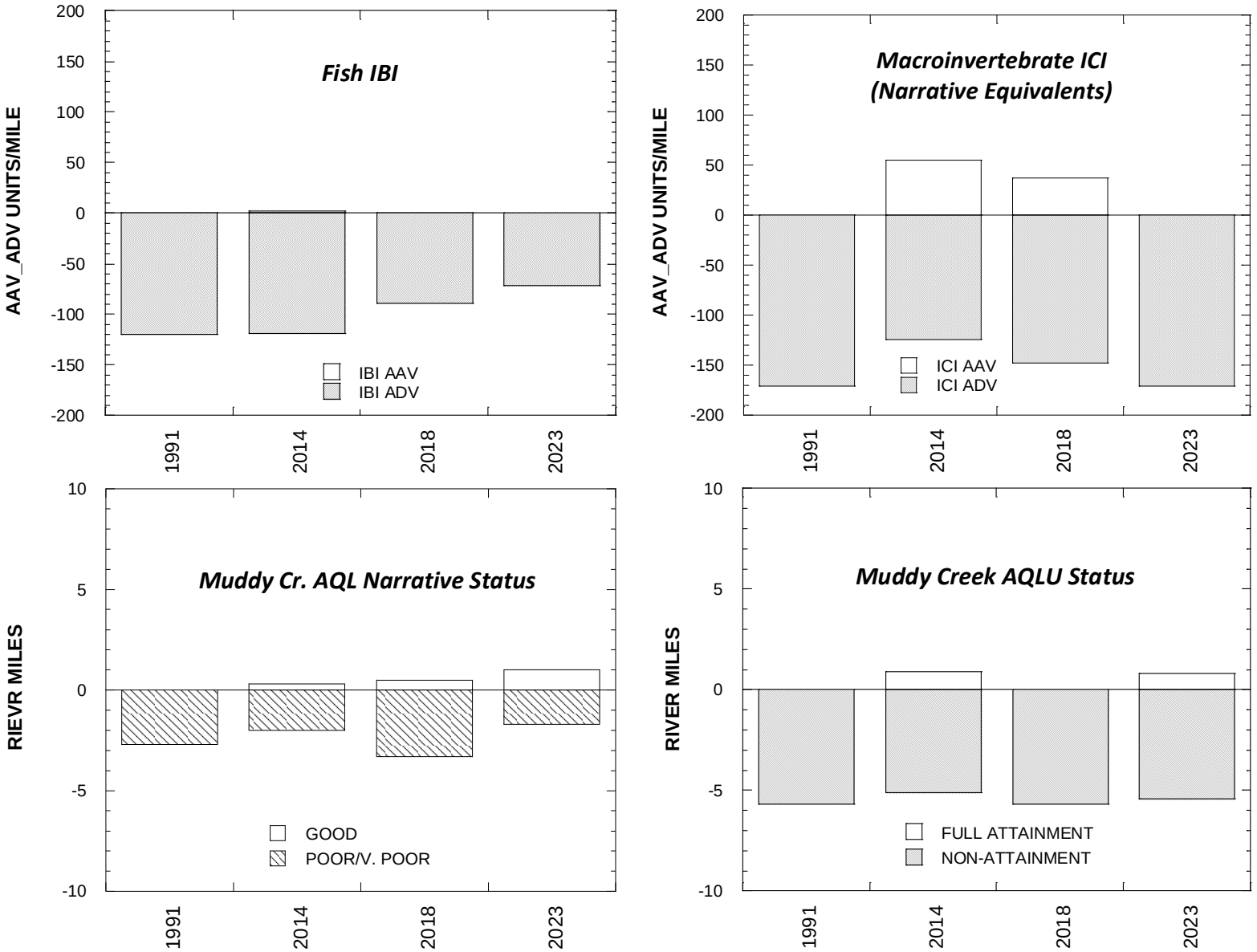


***Figure 4**. Area of Degradation (ADV) and Area of Attainment (AAV) values for the IBI (upper left), ICI Narrative Equivalents (upper right), Aquatic Life (AQL) narrative status (lower left), and Aquatic Life (AQLU) status (lower right) in Muddy Creek between 1991 and 2023.*

improvements made by MSDGC via the WWIP. The macroinvertebrate ICI equivalents maintained the AAVs first observed in 2014 and extending into 2023. This improvement was accompanied by an increase in the ADV signaling a minor, but detectable overall decline in that assemblage. The miles of attainment and non-attainment were similar in 2014 and 2023 which are the only years with any instances of full attainment. The overall narrative condition has improved with the highest number of miles above the WWH goal of good. These results continue to reflect urban subwatersheds that are in various states of recovery as evidenced by incremental improvements in biological performance, but with some fluctuations in aquatic life use attainment between monitoring cycles. The improvements are no doubt related to improvements made by MSDGC to better treat wet weather flows and reduce their volume and pollutant loadings.

## Recommendations

### *Designated Uses*

An original objective of the MSDGC service area watershed bioassessment plan was to evaluate existing aquatic life and recreational use designations and to recommend new uses for undesignated/unverified streams and changes to existing uses as a result of the series of 2011-14 baseline watershed assessments. Ohio EPA had last reviewed the aquatic life and recreational designations in the Ohio River Direct Tributaries study area in 2014 (Ohio EPA 2015a). Now, Ohio EPA has either adopted or is in the process of adopting the use designation recommendations from the series of 2011-2014 MSDGC surveys[1], except for Muddy Creek and Rapid Run. Part of the reason is that Muddy Creek and Rapid Run are part of the Mill Creek basin use designations at 3745-1-30 and are apparently out-of-sequence with the Ohio EPA rulemaking schedule. As a result the same recommendations made in 2014 and 2018 are repeated herein for resampled stream and river sites. The MSDGC instream monitoring since 2011-14 shifted to a more focused approach to document status, trends, and causes/sources of impairments related to pollution control efforts by WWIP and related pollution source abatement efforts by MSDGC. A continued focus on documenting status and trends will inform decisions on WWIP and document post-abatement improvements. The methodology can identify and track causes and sources of impairment allowing informed decisions about the allocation of pollution abatement resources by MSDGC. The 2023 Ohio River Direct Tributaries and Selected Tributaries assessment is the second follow-up survey since the 2014 baseline survey.

No recommendations are being made for recreational uses given the strict adherence to the Primary Contact Recreational (PCR) use by Ohio EPA that was formalized in December 2016. While the Secondary Contact Recreation (SCR) use was first adopted for Rapid Run in the 1990s by Ohio EPA, that designation could be subject to a future review by Ohio EPA. This also negates the recommendations made in the 2014 Ohio River Direct Tributaries assessment (MBI 2015a) under the prior set of tiered PCR criteria.

[1] Find the 2011-2014 MSDGC bioassessments at: http://www.msdgc.org/initiatives/water_quality/index.html.

***Impairment Sources***

Recommendations for directing attention to impairment sources include the current strategy of MSDGC for eliminating CSO, SSO, and NEO sources which were the most pronounced and in some cases of singular in importance in the upper Muddy Creek subwatershed. The addition of the Werk and Westbourne EHRTS and the elimination of SSO 633 are but two examples of the continuing effort to better control wet weather discharges. HSTS discharges are present in large numbers in portions of the 2023 study area need to be better characterized to quantify their role in observed impairments. At present we are able to generally assign this as a source of impairment based on the updated GIS coverage provided by MSDGC in 2023 and the documentation provided by the Hamilton Co. Public Health (HCPH) 2012 assessment that indicated one in five systems (20%) as "failing". These are undoubtedly related in part to the documented *E. coli,* organic enrichment, and nutrient related impairments in all four subwatersheds including Taylor Creek and Indian Creek. Other sources include generalized urban runoff and the established relationship with dissolved ions such as chloride and PAH exceedances which could be dealt with via various best management practices. Lastly, the legacy impacts of instream sewer line construction in Rapid Run are showing instances of incremental improvement, but still contribute to stream desiccation as evidenced by multiple sites not being sampled due to dry stream beds. However, little can be done at present to actively restore these alterations except to await natural recovery processes and, more importantly, abandoning that practice elsewhere.

# BIOLOGICAL AND WATER QUALITY STUDY OF THE OHIO RIVER DIRECT TRIBUTARIES 2023

## Introduction

The 2023 Ohio River Direct Tributaries and upper Taylor Creek biological and water quality assessment covered four (4) subwatersheds with four (4) CSOs, seven (7) SSOs, five (5) PSOs, and three (3) NEOs, an Enhanced HRTF, another HRTF, one (1) minor discharge, and hundreds of HSTS discharges providing the basis for documenting incremental changes against previous surveys including Ohio EPA in 1991 (Ohio EPA 1992) and MSDGC in 2014 (MBI 2015a) and 2018 (MBI 2019). The spatial and temporal sampling design and the biological, chemical, and physical indicators and parameters that were collected at each sampling site are described in the *Watershed Monitoring and Bioassessment Plan for the MSD Greater Cincinnati Service Area, Hamilton County, Ohio; Technical Report MBI/5-11-3* (MBI 2011). Biological sampling methods for fish and macroinvertebrate assemblages and habitat assessment are supported by chemical and physical measures and ancillary information about pollution sources and other stressors for the overall biological assessment. The assessment employed a targeted-intensive pollution survey design which documents changes in a longitudinal manner as the effects of multiple pollution sources accumulate in a downstream direction.

MSDGC intends to use the results and analysis of the monitoring and bioassessment program to accomplish the following:

1. Determine the status of service area rivers and streams in quantitative terms, i.e., not only if the waterbody is impaired but the spatial extent and severity of the impairment;
2. Determine the proximate stressors that contribute to the observed impairments for the purpose of targeting management actions to those stressors;
3. Evaluate the appropriateness of existing aquatic life and recreational use designations and make recommendations for any changes to those designations; and,
4. Continue the development of the Integrated Prioritization System (IPS) for a variety of purposes. Among its many uses, the IPS will assist MSDGC in making decisions about how to prioritize and design pollution abatement projects and measure their effectiveness.

To meet these objectives all data was generated by methods and implementation in conformance with the provisions of the Ohio Credible Data Law (ORC 6111.51). Under the regulations that govern the Credible Data program at Ohio EPA, data collection and analyses must be collected and performed under the direction of Level 3 Qualified Data Collectors (OAC 3745-4). MSDGC has used the data to evaluate the attainability of aquatic life and recreational uses and determine the status of service area rivers and streams since 2011. As such, the sampling and analysis of the biological and physical condition conducted herein conforms to these provisions by the development and submittal of annual Level 3 Project Study Plans (PSP).

## MSDGC Watershed Bioassessment Scope and Purpose

The MSDGC watershed bioassessment project domain consists of 11 subwatersheds, three mainstem rivers, and the Ohio River mainstem within Hamilton County and parts of adjoining counties. These watersheds are impacted by a variety of stressors including municipal and industrial point source discharges of wastewater, habitat modifications in the form of modified stream channels, run-of-river low head dams, riparian encroachment, and channelization, and nonpoint source runoff from widely differing degrees of landscape modifications from rural to suburban to intensive urban development. The urban impact gradient is the strongest in the lower and middle Mill Creek lessening somewhat across the Little Miami and Great Miami River subwatersheds. Combined sewer overflows (CSOs) are the most numerous in Duck Creek and the adjacent Little Miami and some have subsumed historical streams. Home Sewage Treatment Systems (HSTS) are scattered throughout the MSDGC service area, but are especially dense in the 2023 study area especially in portions of Muddy Creek, Rapid Run, Indian Creek, and the upper Taylor Creek subwatersheds.

## 2023 Ohio River Direct Tributaries Assessment Scope and Purpose

The 2023 Ohio River Direct Tributaries assessment included the Muddy Creek, Rapid Run, Indian Creek, and upper Taylor Creek subwatersheds that are within the scope of the MSDGC service area watershed monitoring plan (MBI 2011). In addition to the baseline purposes of the MSDGC monitoring plan, specific assessment issues in 2023 include a high density of CSO/SSO/ PSO/NEO outfalls and other pollution sources including a new enhanced HRTF, HSTSs, urban stormwater runoff, and legacy habitat and flow modifications.

Cincinnati has the fifth highest volume of CSOs in the U.S. (MSDGC 2011a). As a result, water quality has been significantly impacted in the 2023 subwatersheds that have such discharges. MSDGC is working to remediate these issues under a Consent Decree with the U.S. Dept. of Justice and U.S. EPA to reduce CSO volume by 2 billion gallons by 2019. To resolve the public health and water quality issues, MSDGC has implemented a Wet Weather Improvement plan (WWIP), a multi-year and multi-billion-dollar initiative that includes hundreds of sewer improvements and stormwater control projects (MSDGC 2011b). The role of the watershed monitoring program is to support these initiatives by providing current information about baseline conditions, provide feedback about the effectiveness of new and past remediation efforts via trend assessment, and to assure that restoration resources are targeted to the actions and places that have the greatest return on investment. As such the 2023 Ohio River Direct Tributaries bioassessment is a continuation of that process. The 2023 monitoring also fulfills the MSDGC National Pollution Discharge Elimination System (NPDES) CSO permit reporting requirements specifically the biomonitoring provision.

# METHODS

## Monitoring Design

An intensive pollution survey design that employs a high density of sampling sites and biological, chemical, and physical indicators and parameters was followed in 2023. The principal objectives of the biological assessment are to report aquatic life and recreational use attainment status, following the Ohio WQS and Ohio EPA practices, and determine associated causes and sources of impairment. To accomplish this sites were positioned upstream and downstream from major discharges, sources of potential releases and contamination, and major physical modifications to provide a "pollution profile" along the Ohio River Direct Tributaries mainstems and tributaries. The result was a design that included chemical, physical, and biological sampling at a total of 34 sites. Each site was assigned a unique site code as depicted in Table 5 and Figure 6.

### *Biological and Water Quality Surveys*

A biological and water quality survey, or "biosurvey", is an interdisciplinary monitoring effort coordinated on a water body specific or watershed scale. Biological, chemical, and physical monitoring and assessment techniques are employed in biosurveys to meet three major objectives:

1. Determine the extent to which use designations assigned in the state Water Quality Standards (WQS) or equivalent policies or procedures are either attained or not attained;
2. Determine if use designations and/or goals set for or assigned to a given water body are appropriate and attainable; and,
3. Determine if any changes in key ambient biological, chemical, or physical indicators have taken place over time, particularly before and after the implementation of point source pollution controls or best management practices.

### *Measuring Incremental Changes*

Incremental change is defined here to represent a measurable and technically defensible, change in the condition of a water body within which it has been measured. Most commonly this is termed "incremental improvement" in which the condition of a water body that does not yet fully meet all applicable water quality standards (WQS) can be tracked as to the direction of any changes. The general principles of incremental change are defined as follows (after Yoder and Rankin 2008):

- ***measurement of incremental change*** can be accomplished in different ways, provided the measurement method is scientifically sound, appropriately used, and sufficiently sensitive enough to generate data from which signal can be discerned from noise;

***Table 5**. List of sampling locations in the 2023 Ohio River Direct Tributaries study area with site code, stream name, the biological, habitat, and chemical parameters (see footnotes) collected at each site, location description, and USGS Quadrangle (Ust. – upstream; Dst. – downstream).*

| Site ID | River Mile | Drainage Area (mi.$^2$) | Biological/Habitat Sample Type | Chemical Sampling Type | Latitude | Longitude | Location Description | USGS QUAD |
|---|---|---|---|---|---|---|---|---|
| ***Muddy Creek (23-007)*** | | | | | | | | |
| MU05 | 6.35 | 5.4 | FHW,QL,QHEI | C, B, N, H, S | 39.1335 | -84.6387 | Ust. Beech Grove Dr. | Addyston |
| MU04.5 | 5.62 | 7.7 | FHW,QL,QHEI | C, B, N, H, S | 39.1331 | -84.6479 | Ust. Beechcreek Ln. | Addyston |
| MU04 | 5.45 | 7.8 | FHW,QL,QHEI | C, B, N, H, S | 39.1343 | -84.6505 | Adj. Muddy Creek Rd. | Addyston |
| MU03 | 2.80 | 10.4 | FHW,HD,QHEI | C, B, N, H, S | 39.1237 | -84.6772 | Ust. Cleves-Warsaw Pike | Burlington |
| MU02 | 2.25 | 12.1 | FHW,HD,QHEI | C, B, N, H, S | 39.1225 | -84.6869 | Ust. Hillsdale Ave. | Burlington |
| MU01 | 0.17 | 16.6 | FB,QHEI | C, B, N, H, S | 39.1327 | -84.7062 | Ust. Confluence w/Ohio R. | Addyston |
| ***Unnamed Tributary to Muddy Creek @RM 0.3 (23-075)*** | | | | | | | | |
| MU08 | 1.72 | 0.7 | FHW,QL,QHEI,PHW | C, B, N, H, S | 39.1513 | -84.6961 | 3309 Cherryridge Dr. | Addyston |
| MU07.5 | 0.80 | 2.6 | FHW,QL,QHEI,PHW | C, B, N, H, S | 39.1430 | -84.7071 | Adj. 1st St. | Addyston |
| MU07 | 0.40 | 2.8 | FHW,QL,QHEI,PHW | C, B, N, H, S | 39.1381 | -84.7101 | Ust. Cleves Warsaw Pike | Addyston |
| ***Fiddlers Creek RM 0.95 to W. Branch Muddy Creek to Muddy Creek @RM 0.3 (95-076)*** | | | | | | | | |
| MU09 | 0.10 | 1.3 | FHW,QL,QHEI,PHW | C,B, N, H, S | 39.1433 | -84.7043 | Adj. Fiddlers Green Rd. | Addyston |
| ***Unnamed Tributary to Muddy Creek @RM 2.37 (23-071)*** | | | | | | | | |
| MU10 | 0.50 | 0.71 | FHW,QL,QHEI,PHW | C, B, N, H, S | 39.1288 | -84.6812 | Adj. Van Blaricum Rd. | Addyston |
| ***Unnamed Tributary to Muddy Creek @RM 5.97 (23-072)*** | | | | | | | | |
| MU12 | 0.55 | 1.0 | FHW,QL,QHEI,PHW | C, B, N, H, S | 39.1413 | -84.6437 | Dst. Werk Rd. | Addyston |
| ***Unnamed Tributary to Muddy Creek @RM 6.53 (23-073)*** | | | | | | | | |
| MU13 | 0.60 | 1.9 | QL,QHEI,PHW | C, N, H, S | 39.1378 | -84.6344 | Adj. Westbourne Rd. | Addyston |
| ***Unnamed Tributary to Unnamed Tributary to Muddy Creek @RM 5.97 (23-074)*** | | | | | | | | |
| MU14 | 0.50 | 0.1 | QL,QHEI,PHW | C, B, N, H, S | 39.1440 | -84.6349 | Behind 3161 Anders Ln. | Addyston |
| ***Rapid Run (23-008)*** | | | | | | | | |
| RR03 | 2.70 | 2.2 | QL,QHEI,PHW | C, N, H, S | 39.1100 | -84.6410 | Ust. Rapid Run Rd. | Burlington |
| RR02 | 1.05 | 5.9 | FHW,QL,QHEI | C, N, H, S | 39.1024 | -84.6553 | Dst. Bender Rd. | Burlington |
| RR01 | 0.10 | 9.0 | QL | C, N, H, S | 39.1014 | -84.6699 | Ust. Hillsdale Ave. | Burlington |
| ***Wulff Run (23-012)*** | | | | | | | | |
| RR05 | 0.70 | 1.3 | QL,QHEI,PHW | C, N, H, S | 39.0935 | -84.6264 | Ust Dehli Ave. | Burlington |

***Table 5**. List of sampling locations in the 2023 Ohio River Direct Tributaries study area with site code, stream name, the biological, habitat, and chemical parameters (see footnotes) collected at each site, location description, and USGS Quadrangle (Ust. – upstream; Dst. – downstream).*

| Site ID | River Mile | Drainage Area (mi.$^2$) | Biological/Habitat Sample Type | Chemical Sampling Type | Latitude | Longitude | Location Description | USGS QUAD |
|---|---|---|---|---|---|---|---|---|
| RR04 | 0.45 | 2.2 | FHW,QL,QHEI,PHW | C, B, N, H, S | 39.1013 | -84.6411 | Adj. Wulff Run Rd. | Burlington |
| ***Unnamed Tributary to Wulff Run @ RM 0.77 (23-067)*** | | | | | | | | |
| RR05.5 | 1.20 | 0.33 | FHW,QL,QHEI,PHW | C, B, N, H, S | 39.0935 | -84.6264 | Ust. Overhill Ln. | Burlington |
| RR04.5 | 1.10 | 0.33 | FHW,QL,QHEI,PHW | C, B, N, H, S | 39.1009 | -84.6315 | Dst. Overhill Ln. | Burlington |
| ***Indian Creek (23-019)*** | | | | | | | | |
| IC06 | 2.30 | 0.58 | FHW,QL,QHEI,PHW | C, B, N, H, S | 39.1601 | -84.7548 | Behind 7953 Hawkhurst Ct. | Addyston |
| IC05 | 2.08 | 1.1 | FHW,QL,QHEI,PHW | C, B, N, H, S | 39.1583 | -84.7171 | Ust. Aston Oaks GC Pond | Addyston |
| IC02 | 1.15 | 1.4 | FHW,QL,QHEI,PHW | C, B, N, H, S | 39.1538 | -84.7289 | Adj. St. Annes Ct. | Addyston |
| IC01 | 0.30 | 2.3 | FHW,QL,QHEI,PHW | C, B, N, H, S | 39.1528 | -84.7420 | Dst. site @Aston Oaks GC | Addyston |
| ***Tributary to Indian Creek @RM 1.02 (23-020)*** | | | | | | | | |
| IC07 | 0.10 | 0.39 | FHW,QL,QHEI,PHW | C, B, N, H, S | 39.1518 | -84.7306 | Dst. Aston Oaks Dr. | Addyston |
| ***Taylor Creek (14-004)*** | | | | | | | | |
| GM86 | 6.40 | 0.5 | FHW,QL,QHEI,PHW | C, B, N, H, S | 39.1757 | -84.6252 | Adj. Reemelin Rd. | Addyston |
| GM85 | 5.30 | 2.2 | FHW,QL,QHEI,PHW | C, B, N, H, S | 39.1810 | -84.6405 | Ust. Johnson Rd. | Addyston |
| ***Unnamed Tributary to Taylor Creek @ RM 4.9 (14-277)*** | | | | | | | | |
| GM106 | 0.20 | 0.92 | FHW,QL,QHEI,PHW | C, B, N, H, S | 39.1866 | -84.6353 | Adj. 5308 Half Rd. | Addyston |
| ***Briarly Creek (14-148)*** | | | | | | | | |
| GM91 | 3.90 | 0.34 | FHW,QL,QHEI,PHW | C, N, H, S | 39.1941 | -84.6098 | Ust. Private Dr. Bridge | Addyston |
| GM90 | 2.45 | 1.3 | FHW,QL,QHEI,PHW | C, N, H, S | 39.2036 | -84.6340 | Ust. Private Dr. Bridge | Addyston |
| GM89 | 1.80 | 2.1 | FHW,QL,QHEI,PHW | C, N, H, S | 39.2026 | -84.6446 | Adj. Briery Creek Rd. | Addyston |
| ***Wesselman Creek (14-149)*** | | | | | | | | |
| GM94 | 4.70 | 1.1 | FHW,QL,QHEI,PHW | C, B, N, S | 39.1802 | -84.6525 | Ust. Wesselman Rd. | Addyston |
| ***Unnamed Tributary to Wesselman Creek @RM 2.95 (14-275)*** | | | | | | | | |
| GM100 | 1.05 | 0.91 | FHW,QL,QHEI,PHW | C, B, N, S | 39.1680 | -84.6777 | Ust. Rockview Rd. | Addyston |

Sampling types: FB – fish boat site type; FHW – fish headwater site type; HD – macroinvertebrate artificial substrate & qualitative sample; QL – macroinvertebrate qualitative sample only; PHW – salamander and Headwater Habitat Evaluation Index (HHEI); QHEI – Qualitative Habitat Evaluation Index (QHEI).

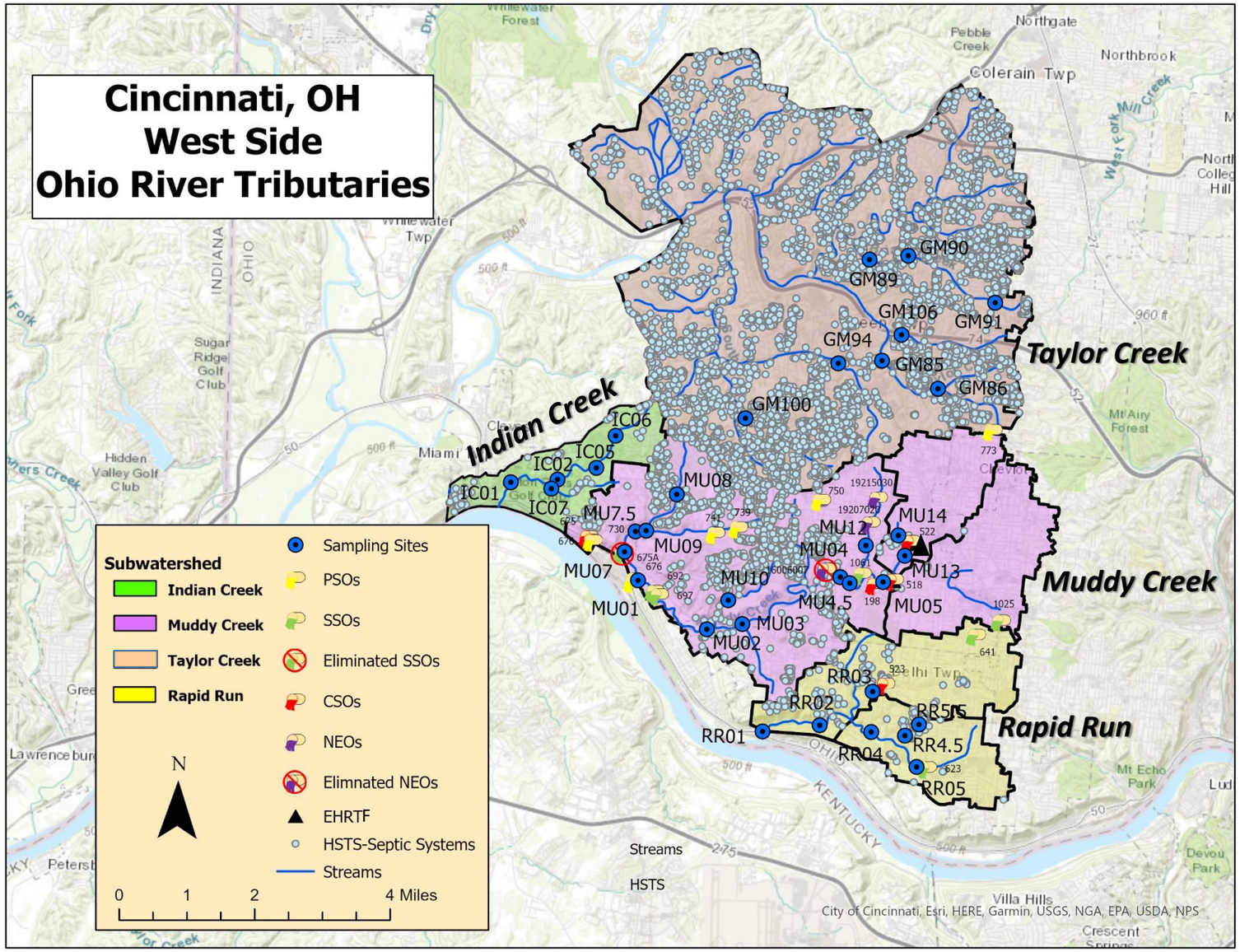


***Figure 5**. The 2023 Ohio River Direct Tributaries study area showing sampling locations by site code (see Table 5) and the locations of CSO, SSO, NEO, PSO, HSTS, and EHRTF discharge locations relative to the study area streams and subwatersheds.*

- ***measurable parameters and indicators*** of incremental change include biological, chemical, and physical properties or attributes of an aquatic ecosystem that can be used to reliably indicate a change in condition; and,
- ***a positive change in condition*** means a measurable improvement that is related to a reduction in a specific pollutant load, a reduction in the number of impairment causes, a reduction in an accepted non-pollutant measure of degradation, or an increase in an accepted measure of waterbody condition relevant to designated use support.

This was accomplished for this study by comparing the 2023 results to the 2014 baseline and 2018 follow-up assessment.

## Biological Methods

All biological sampling methods are defined by the applicable protocols published by the Ohio EPA (1987a,b; 1989a,b; 2006, 2015a; 2019 a,b). These meet the specifications of the Ohio WQS and are used to assess aquatic life and recreational use designations, to determine the extent and severity of impairments, and to document incremental changes that result from pollution abatement actions.

### *Fish Assemblage Methods*

Methods for the collection of fish at wadeable sites were performed using a tow-barge or long-line pulsed D.C. electrofishing equipment based on a Smith-Root 2.5 GPP electrofishing unit described by Ohio EPA (1989a). A Wisconsin DNR battery powered backpack electrofishing unit was used as an alternative to the long line apparatus in the smallest streams and in accordance with the restrictions described by Ohio EPA (1989a; 2015a). A three-person crew carried out the sampling protocol for each type of wading equipment. Sampling effort was indexed to lineal distance and ranged from 150-200 meters in length and was conducted once during a June 16-October 15 index period. A single non-wadeable site at the mouth of Muddy Creek was sampled with a raft-mounted pulsed D.C. electrofishing device consisting of a Smith-Root 5.0 GPP unit mounted on a 15.5' Wing raft with an electrode array in keeping with Ohio EPA (1989a; 2015a) electrofishing design specifications. Sampling effort for this method is 500-meters and was conducted during a June 16-October 15 seasonal index period twice. A more detailed summary of the key aspects of each method appears in the *Watershed Monitoring and Bioassessment Plan for the MSD Greater Cincinnati Service Area, Hamilton County, Ohio; Technical Report MBI/5-11-3* (MBI 2011).

### *Macroinvertebrate Assemblage Methods*

Macroinvertebrates were sampled using modified Hester-Dendy artificial substrate samplers (quantitative sample) and a qualitative dip net/hand pick method in accordance with Ohio EPA macroinvertebrate assessment procedures (Ohio EPA 1989a, 2015a). The artificial substrates were exposed for a colonization period of six weeks and placed to ensure adequate flow velocities (generally $\geq$0.3 feet/second) over the plates. A qualitative sample using a triangular frame dip net and hand picking was collected at the time of substrate retrieval. All samples

were initially preserved in a 10% solution of formaldehyde. Substrates were transferred to the laboratory, disassembled, sieved (standard no. 30 and 40), and transferred to 70% ethyl alcohol.

Qualitative samples were collected at each site either at the time of artificial substrate retrieval or as a standalone assessment of sites <10 mi.$^2$. These samples were collected using a triangular frame 30-mesh dip net and by hand picking. All available habitats were sampled at a given site for a total time of at least 30 minutes and thereafter until no new taxa were observed based on visual examination. These samples were preserved in 70% ethanol and included representatives of each taxon and an estimate of relative abundance using narrative descriptors (Ohio EPA 1989a). Qualitative sample data are used to supplement the quantitative samples in the case of artificial substrate sets, but also function as standalone assessment for sites where the artificial substrates were either not retrieved or otherwise rendered unusable.

Laboratory sample processing of both the quantitative and qualitative samples included an initial scan and pre-pick for large and rare taxa followed by subsampling procedures in accordance with Ohio EPA (1989a). Identifications were performed to the lowest taxonomic resolution possible for the commonly encountered orders and families, which is genus/species for most organisms. From these results, the density of macroinvertebrates per square foot is determined as well as a taxonomic richness and the Invertebrate Community Index (ICI; Ohio EPA 1987; DeShon 1995) score for the quantitative samples and a narrative assessment for the standalone qualitative samples (Ohio EPA 2015a). A more detailed summary of the key aspects of the methods appears in the *Watershed Monitoring and Bioassessment Plan for the MSD Greater Cincinnati Service Area, Hamilton County, Ohio; Technical Report MBI/5-11-3* (MBI 2011).

***Primary Headwater Habitat (PHWH) Methods***

PHWH methods were simultaneously applied to all sites draining <2.5 mi.$^2$ to allow for a data driven determination of the existing use. Stream sites that were completely dry during any of the sampling visits were evaluated with the Headwater Habitat Evaluation Index (HHEI) at a minimum. Methods for the collection of macroinvertebrates and salamanders at PHWH candidate sites followed the qualitative macroinvertebrate collection techniques used by the Ohio EPA for all stream types (Ohio EPA 1989a, 2015a) and in accordance with the most recent PHWH manual (Ohio EPA 2020). Salamander collections were made in two 30 feet long subsections of the 200 feet of reach assessed for a PHWH evaluation. Each subsection was chosen where an optimal number and size of cobble type microhabitat substrates are present. A minimum of 30 minutes was spent searching for salamanders. At least five larvae and two juvenile-adults of each species type were preserved. Adult and juvenile salamanders were placed into plastic bags with moist leaf litter. The larva were transported in stream water and placed in a cooler and returned to the lab for preparation of voucher specimens and verifications.

***Area of Degradation and Attainment Values***

The ADV (Yoder and Rankin 1995; Yoder et al. 2005) was originally developed to quantify the extent and severity of departures from biocriterion within a defined river reach. For reaches that exceed the applicable biocriterion it is expressed as an Area of Attainment Value (AAV) that quantifies the extent to which minimum attainment criteria are surpassed. The ADV/AAV correspond to the area of the polygon formed by the longitudinal profile of IBI scores and the straight line boundary formed by a criterion, the ADV below and the AAV above. The computational formula (after Yoder et al. 2005) is:

$$ADV/AAV = \sum [(aIBIa + aIBIb) – (pIBIa + pIBIb)] * (RMa – RMb), \text{ for } a = 1 \text{ to } n, \text{ where;}$$

aIBIa = actual IBI at river mile a,
aIBIb = actual IBI at river mile b,
pIBIa = IBI biocriterion at river mile a,
pIBIb = IBI biocriterion at river mile b,
RMa = upstream most river mile,
RMb = downstream most river mile, and
n = number of samples.

The average of two contiguous sampling sites is assumed to integrate biological assemblage status for the distance between the points. The intensive pollution survey design typically positions sites in close enough proximity to sources of stress and along probable zones of impact and recovery so that meaningful changes are adequately captured. We have observed biological assemblages as portrayed by their respective indices to change predictably in proximity to major sources and types of pollution in numerous instances (Ohio EPA1987a; Yoder and Rankin 1995; Yoder and Smith 1999; Yoder et al. 2005). Thus, the longitudinal connection of contiguous sampling points produces a reasonably accurate portrayal of the extent and severity of impairment in a specified river reach as reflected by the indices (Yoder and Rankin 1995). The total ADV/AAV for a specified river segment is normalized to ADV/AAV units/mile for making comparisons between years and rivers. The ADV is calculated as a negative (below the biocriterion) expression; the AAV is calculated as a positive (above the biocriterion) expression. Each depicts the extent and degree of impairment (ADV) and attainment (AAV) of a biological criterion, which provides a more quantitative depiction of quality than do pass/fail descriptions. It also allows the visualization of incremental changes in condition that may not alter the pass/fail status, but are nonetheless meaningful in terms of incremental change over space and time. In these analyses, the Warmwater Habitat (WWH) biocriterion for the fish and macroinvertebrate indices were used as the threshold for calculating the ADV and AAV for the Muddy Creek mainstem as it represents the minimum goal required by the Clean Water Act (CWA) for the protection and propagation of aquatic life.

## Habitat Assessment

Physical habitat was evaluated using the Qualitative Habitat Evaluation Index (QHEI) developed by the Ohio EPA for streams and rivers in Ohio (Rankin 1989, 1995; Ohio EPA 2006). Various

attributes of the habitat are scored based on the overall importance of each to the maintenance of viable, diverse, and functional aquatic faunas. The type(s) and quality of substrates, amount and quality of instream cover, channel morphology, extent and quality of riparian vegetation, pool, run, and riffle development and quality, and gradient are some of the metrics used to determine the QHEI score which generally ranges from 20 to less than 100. The QHEI is used to evaluate the characteristics of a stream segment, as opposed to the characteristics of a single sampling site. As such, individual sites may have poorer physical habitat due to a localized disturbance yet still support aquatic communities closely resembling those sampled at adjacent sites with better habitat, provided water quality conditions are similar. QHEI scores from hundreds of segments around the state have indicated that values greater than 60 are generally conducive to the existence of warmwater faunas whereas scores less than 45 generally cannot support a warmwater assemblage consistent with baseline Clean Water Act goal expectations (e.g., the WWH in the Ohio WQS).

Physical habitat was simultaneously evaluated at sites draining <2.5 mi.$^2$ using the Headwater Habitat Evaluation Index (HHEI) developed by Ohio EPA (2013). The HHEI scores various attributes of the physical habitat that have been found to be statistically important determinants of biological community structure in primary headwater streams. Statistical analysis of a large number of physical habitat measurements showed that three QHEI habitat variables (channel substrate composition, bank full width, and maximum pool depth) are sufficient in distinguishing the physical habitat of primary headwater streams using the HHEI. The characterization of the channel substrate includes a visual assessment of a 200 feet stream reach using a reasonably detailed evaluation of both the dominant types of substrate and the total number of substrate types. Bank full width is a morphological characteristic of streams that is determined by the energy dynamics related to flow and has been found to be a strong discriminator of the three classes of primary headwater streams in Ohio. The bank full width is the average of 3-4 separate bank full measurements along the stream reach. The maximum pool depth within the stream reach is important since it is a key indicator of whether the stream can support a WWH fish assemblage. Streams with pools less than 20 cm in depth during the low flow periods of the year are less likely to have WWH fish assemblages and thus more likely to have viable populations of lungless salamanders, which replace fish as the key vertebrate indicator in Primary Headwater streams.

## Chemical/Physical Methods

Chemical/physical assessment for the MSDGC service area included the collection and analysis of water samples for chemical/physical and bacterial analysis and sediment samples for determining sediment chemical quality. Methods for the collection of water column chemical/physical and bacterial samples followed the procedures of Ohio EPA (2019a,b) and MSDGC (2011c). Sediment chemical sampling followed that described by Ohio EPA (2019c). All laboratory analysis was performed by MSDGC or contract laboratories overseen by MSDGC.

***Water Column Chemical Quality***

Water column chemical quality was determined by the collection and analysis of grab water samples, instantaneous measurements recorded with a water quality meter, and continuous measurements recorded over 4-5 day periods in the subwatershed mainstems and selected tributary sites.

*Grab Sampling*

Grab samples of water were collected with a stainless steel bucket from a location as close to the center point of the stream channel as possible by an MBI sampling crew. Samples were transferred to sample containers in accordance with MSDGC procedures (MSDGC 2011c) and delivered to the MSDGC Mill Creek Lab for analysis. Sampling was conducted between mid-June and mid-October and under "normal" summer-fall low flows. Highly elevated flows following precipitation events were avoided and sampling was delayed until flows subsided to "normal" conditions. The frequency of sampling ranged from six times per season at most sites to 2-4 times per season at smaller headwater and primary headwater sites. Water samples were collected provided there was sufficient water depth to collect a sample without disturbing the substrate. Instantaneous values for temperature (°C), conductivity (µS/cm), pH (S.U.), and dissolved oxygen (D.O.; mg/L) were recorded with a YSI Model 664 meter at the time of grab sample collection.

*Continuous Recordings*

Continuous readings of temperature (°C), conductivity (µS/cm2), pH (S.U.), and dissolved oxygen (D.O.; mg/L) were recorded with a YSI 6920 V2 Sonde ("Datasonde") instrument at subwatershed mainstem and tributary locations in accordance with Ohio EPA (2019b). The Datasondes were set as close as possible to the Thalweg (i.e., deepest part of the stream channel) in a PVC enclosure that protected each unit. The Datasondes were positioned vertically where depth allowed by driving steel fence posts into the bottom and positioning the PVC enclosure in an upright position. Where the depth was too shallow the PVC enclosure was secured in a horizontal position in an area of the stream channel with continuous flow. The Datasondes were secured against theft or vandalism as much as possible. Datasondes were deployed over consecutive day periods at eight sites during August 18-21 and 22-25, 2023, which represented periods of maximum summer temperatures and normal summer flows, with readings taken at 15 minute intervals. Data was downloaded to a YSI Model 650 Instrument with high memory capacity and then transferred to a PC for storage and later analysis at MBI.

***Sediment Chemical Quality***

Fine grain sediment samples were collected in the upper 4 inches of bottom material at each sampling location using decontaminated stainless steel spoons and excavated using nitrile gloves. Decontamination of sediment sampling equipment followed the procedures outlined in the Ohio EPA sediment sampling guidance manual (Ohio EPA 2019c). Sediment grab samples were homogenized in stainless steel pans (material for VOC analysis was not homogenized), transferred into glass jars with Teflon® lined lids, placed on ice in a cooler (to maintain 4°C), and delivered to the MSDGC Mill Creek Lab. Sediment data is reported on a dry weight basis.

Sediment samples were analyzed for an analyte list consisting of inorganics (metals), volatile organic compounds, semivolatile organic compounds, PCBs, total petroleum hydrocarbons, and cyanide.

## Determining Use Attainment Status

Use attainment status is a term which describes the degree to which environmental parameters or indicators are either above or below criteria specified by the Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1). For the 2023 Ohio River Direct Tributaries assessment two use designations were evaluated, aquatic life and recreation in and on the water by humans. Hence the process herein is referred to as the determination of aquatic life and recreational status for each sampling site. The process is applied to data collected by ambient assessments and applies to rivers and streams outside of point source discharge mixing zones.

### *Aquatic Life*

Aquatic life use attainment status is determined by the Ohio EPA biological criteria (OAC 3745-1-07; Table 7-1). Numerical biological criteria are based on multimetric biological indices which include the Index of Biotic Integrity (IBI) and modified Index of Well-Being (MIwb), which indicate the response of the fish assemblage, and the Invertebrate Community Index (ICI), which indicates the response of the macroinvertebrate assemblage. The IBI and ICI are multimetric indices patterned after an original IBI described by Karr (1981) and Fausch *et al.* (1984) and subsequently modified by Ohio EPA (1987b) for application to Ohio rivers and streams. The ICI was developed by Ohio EPA (1987b) and is further described by DeShon (1995). The MIwb is a measure of fish community abundance and diversity using numbers and weight information and is a modification of the original Index of Well-Being originally applied to fish community information (Gammon 1976; Gammon *et al.* 1981). Numerical biocriteria are stratified by ecoregion, use designation, and stream or river size. Three attainment status results are possible at each sampling location - full, partial, or non-attainment. Full attainment means that all of the indices meet the applicable biocriteria. Partial attainment means that one or more of the indices fails to meet the applicable biocriteria. Non-attainment means that none of the indices meet the applicable biocriteria or one of the organism groups reflects poor or very poor quality. An aquatic life use attainment table (see Table 2) is constructed based on the sampling results and is arranged from upstream to downstream and includes the sampling locations indicated by river mile, the applicable biological indices, the use attainment status (*i.e.,* full, partial, or non), the Qualitative Habitat Evaluation Index (QHEI), and comments and observations for each sampling location. The use attainment table is further organized by Ohio EPA Waterbody Assessment Unit so that the results can be used by Ohio EPA for assessment purposes.

### *Recreation*

Water quality criteria for determining attainment of recreational uses are established in the Ohio WQS (OAC 3745-1-37) based upon colony forming units (cfu) of bacterial indicators *(Escherichia coli)* present in the water column during the May 1-October 31 recreation season.

*Escherichia coli (E. coli)* bacteria are microscopic organisms that are normally present in the feces and intestinal tracts of humans and other warm-blooded animals. *E. coli* typically comprises approximately 97 percent of the organisms found in the fecal coliform bacteria of human feces (Dufour 1977). There is currently no simple way to differentiate between human and animal sources of coliform bacteria in surface waters, although methodologies for this type of analysis are being developed including recent research supported by MSDGC. These microorganisms can enter water bodies where there is a direct discharge of human and animal wastes, or may enter water bodies along with runoff from soils where wastes have been deposited. Pathogenic (disease-causing) organisms are typically present in the environment in such small amounts that it is impractical to directly monitor each type of pathogen. Fecal indicator bacteria by themselves, including *E. coli,* are usually not pathogenic. However, some strains of *E. coli* can be pathogenic, capable of causing serious illness. Although not necessarily agents of disease, fecal indicator bacteria such as *E. coli* may signal the potential presence of pathogenic organisms that enter the environment via the same pathways. When *E. coli* are present in extremely high numbers in a water sample, it invariably means the water has received fecal matter from one or more sources.

The Ohio WQS for recreational uses were revised in early 2016 to reflect a more rigid adherence to any form of human contact with surface waters as ensuing the same level of risk. This replaced the former framework that was stratified to account for the degree of bodily contact with three subcategories of the Primary Contact Recreational (PCR) use as PCR-A, PCR-B, and PCR-C. Those subcategories were essentially merged into a single use category in 2016. This action obviated the recommendations made in the 2011-14 watershed assessments for assignment certain streams to one of the three former subcategories. The application of the Secondary Contact Recreational (SCR) use was also changed to a more restrictive interpretation of the potential for human contact with surface waters. Existing SCR designations remain, but could potentially be reviewed and revised to PCR by Ohio EPA. Any new SCR recommendations would need to document that there is no human contact possible due to legal or physical restrictions to access a surface water. As a result the evaluation of the recreational uses in the 2023 Ohio River Direct Tributaries study were done in accordance with the existing designations of PCR and SCR where the latter remains applicable.

Streams in the 2023 study area are designated as primary contact recreation (PCR) and/or secondary contact recreation (SCR) use in the Ohio WQS (OAC 3745-1- 30). Water bodies with a designated recreation use of PCR *". . . are suitable for one or more full-body contact recreation activities such as, but not limited to, wading, swimming, boating, water skiing, canoeing, kayaking, and scuba diving"* (OAC 3745-1- 07(B)(4)(b)). Secondary Contact includes waters that *". . . result in minimal exposure potential to water borne pathogens because the waters are: rarely used for water based recreation such as, but not limited to, wading; situated in remote, sparsely populated areas; have restricted access points; and have insufficient depth to provide full body immersion, thereby greatly limiting the potential for water based recreation activities."*

The *E. coli* criterion that applies to PCR is expressed as a 90-day geometric mean of ≤126 colony forming units (cfu)/100 ml with a Statistical Threshold Value of 410 cfu/100 ml[2]. The criterion that applies to SCR streams is ≤1,030 cfu/100 ml for both the 90 day geometric mean and the STV. The geometric mean is based on two or more samples and along with the maximum value is used as the basis for determining the attainment status of the PCR use.

## Determining Use Attainability

Use designation reviews and recommendations for revisions, when appropriate, were a major product of the series of 2011-14 watershed assessments conducted throughout the MSDGC service area. Since the 2023 Ohio River Direct Tributaries and Tributaries survey is a reassessment of a portion of the 2014 study area we did not expect to have many use change recommendations. The details of the 2011-14 use recommendations are available in each watershed assessment report[3]. Given the status of the 2011-14 data as Level 3 credible data it is eligible to be used by Ohio EPA to revise aquatic life use designations. All of the use recommendations made for the Warmwater Habitat suite of uses were either adopted or are in the process of being adopted by Ohio EPA into the Ohio WQS. None of the recreational use recommendations were accepted because of the 2016 revisions to the recreational uses and criteria and how these are assigned to individual stream segments. None of the Primary Headwater Habitat (PHWH) use recommendations were adopted because Ohio EPA has not yet adopted PHWH as a distinct use tier. For the interim, MSDGC is assuming such streams will receive protections equivalent to WWH.

## Determining Causal Associations

Using the results, conclusions, and recommendations of this report requires an understanding of the methodology used to determine biological status (i.e., unimpaired or impaired, narrative ratings of quality) and assigning associated causes and sources of impairment utilizing the accompanying chemical/physical data and source information (e.g., point source loadings, land use). The identification of impairment in rivers and streams is straightforward - the numerical biological indices are the principal arbiter of aquatic life use attainment and impairment following the guidelines of Ohio EPA (1987). The rationale for using the biological results in the role as the principal arbiter within a weight of evidence framework has been extensively discussed elsewhere (Karr *et al.* 1986; Karr 1991; Ohio EPA 1987a,b; Yoder 1991; Yoder 1995).

Describing the causes and sources associated with observed biological impairments relies on an interpretation of multiple lines of evidence including the water chemistry data, sediment chemistry data, habitat data, effluent data, land use data, and biological response signatures (Yoder and Rankin 1995; Yoder and DeShon 2003). Thus the assignment of associated causes and sources of biological impairment in this report represents the association of impairments (based on response indicators) with stressor and exposure indicators using linkages to the

[2] These criteria shall not be exceeded in more than ten per cent of the samples taken during any ninety-day period.
[3] http://www.msdgc.org/initiatives/water_quality/index.html.

bioassessment data based on previous experiences within the strata of analogous situations and impacts. For example, exceedances of established chemical thresholds such as chronic and acute water quality criteria or sediment effect thresholds are grounds for listing such categories of parameters to include individual pollutants provided that they co-occur with a biological impairment. Biological effect thresholds in the recently completed *Integrated Prioritization System (IPS) Documentation and Atlas of Biological Stressor Relationships for Southwest Ohio* (Technical Report MBI/2015-12-15, MBI 2015b) were also used to support weighted causal assignments. The weighting was done in accordance of the severity of a threshold exceedance with very poor being weighted five (5) times a fair exceedance and poor in between. These were used either as primary or supplemental screenings for the interpretation of biological impairments consistent with the application of biological criteria in Ohio[4].

***Hierarchy of Water Indicators***

A carefully conceived ambient monitoring approach, using cost-effective indicators comprised of ecological, chemical, and toxicological measures, can ensure that all pollution sources are judged objectively on the basis of environmental results. A tiered approach that links the results of administrative actions with true environmental measures (U.S. EPA 1995a,b) was employed in our analyses and within the limitations of the data that is currently available for certain sources. This integrated approach is outlined in Figure 6 and includes a hierarchical continuum from administrative to true environmental indicators. The six "levels" of indicators include:

1. Actions taken by regulatory agencies (permitting, enforcement, grants);
2. Responses by the regulated community (treatment works, pollution prevention);
3. Changes in discharged quantities (pollutant loadings);
4. Changes in ambient conditions (water quality, habitat);
5. Changes in uptake and/or assimilation (tissue contamination, biomarkers, assimilative capacity); and, changes in health, ecology, or other effects (ecological condition, pathogens).

In this process the results of administrative activities (levels 1 and 2) can be linked to efforts to improve water quality (levels 3, 4, and 5) which should translate into the environmental "results" (level 6). An example is the aggregate effect of billions of dollars spent on water pollution control since the early 1970s that have been determined with quantifiable measures of environmental condition (Yoder et al. 2005). Superimposed on this hierarchy is the concept of stressor, exposure, and response indicators. *Stressor* indicators generally include activities which have the potential to degrade the aquatic environment such as pollutant discharges (permitted and unpermitted), land use effects, and habitat modifications. *Exposure* indicators are those which measure the effects of stressors and can include whole effluent toxicity tests, tissue residues, and biomarkers, each of which provides evidence of biological exposure to a stressor or bioaccumulative agent. *Response* indicators are generally composite measures of the cumulative effects of stress and exposure and include the more direct measures of

[4] OAC 3745-1-07(A)(6)(a) for full attainment and (A)(6)(b) for non-attainment.

community and population response that are represented here by the biological indices which comprise the Ohio EPA biological endpoints. Other response indicators can include target

assemblages, *i.e.,* rare, threatened, endangered, special status, and declining species or bacterial levels that serve as surrogates for the recreational uses. These indicators represent the essential technical elements for watershed-based management approaches. The key, however, is to use the different indicators *within* the roles which are most appropriate for each (Yoder and Rankin 1998).

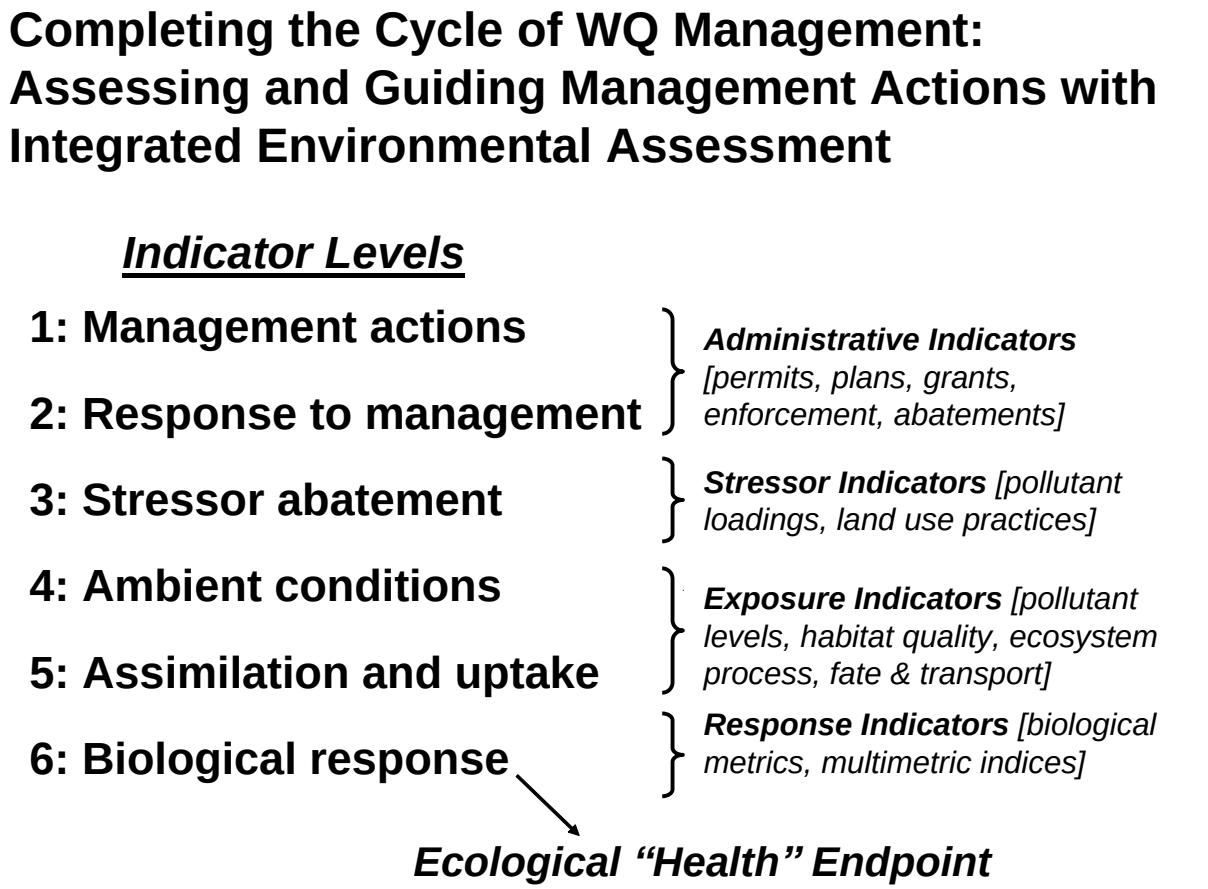


***Figure 6****. Hierarchy of administrative and environmental indicators which can be used for water quality management activities such as monitoring and assessment, reporting, and the evaluation of overall program effectiveness. This is patterned after a model developed by U.S. EPA (1995a,b) and further enhanced by Karr and Yoder (2004).*

## STUDY AREA DESCRIPTION

### General Setting

The 2023 study area lies in southwest Ohio and is bounded by Mill Creek to the east, the Great Miami River to the west and northwest, and the Ohio River mainstem to the south. Major streams included Muddy Creek, Indian Creek, Rapid Run, and the upper portions of Taylor Creek and tributaries. The Muddy Creek and Rapid Run subwatersheds are impacted by CSOs, SSOs, PSOs, NEOs, urban runoff, and the legacy impacts of instream sewer line construction. The tributaries are dominated by urban land uses being the most developed in the upper portions of each watershed. Taylor Creek is not impacted by CSOs or SSOs and has largely avoided the impacts of instream sewer line construction when sewers for the Taylor Creek Regional WWTP were installed in the mid to late 1990s.

#### *Subecoregion Characteristics*

The 2023 study area lies within two different level III ecoregions, the Interior Plateau (IP) and the Eastern Corn Belt Plains (ECBP; Omernik 1987). More recent delineations of Level IV subregions provide additional detail for the four components of ecoregions - surficial geology, soils, potential natural vegetation, and land use (Woods et al. 1995). The 2023 study area lies almost entirely within the Northern Bluegrass subregion (71d) of the Interior Plateau. The characteristics of this subregion appear in Table 6.

### Description of Pollution Sources and Other Stressors

Pollution sources and general stressors in the 2023 study area include permitted discharges of municipal wastewater, one minor industrial point source, urban runoff and its associated chemical pollution, home septic treatment system (HSTS) discharges, and hydrological alterations, and direct and indirect flow and habitat alterations from the past. These are described in the following discussions and permitted sources are included in Table 7.

#### *Point Sources*

One minor NPDES permitted discharge to the headwaters of Wesselman Creek is listed for the 2023 study area (Table 7). HSTS discharges (not NPDES permitted) are quite numerous in portions of the 2023 study area (Figure 5). Upper Taylor Creek and portions of the Indian Creek, Rapid Run, and Muddy Creek subwatersheds have the highest density of HSTS discharges. The Hamilton Co. Public Health (HCPH) department *Sewage Treatment System (STS) Management Plan* (HCPH 2012) lists 18,637 privately owned onsite sewage treatment systems within the HCPH jurisdiction of which 18,112 are HSTS. HSTS failures as defined by HCPH (2012) were about 20% in 2012 a decline from 51% in 1994 that is credited to increased inspections.

#### *Wet Weather Sources*

An enhanced HRTF, HRTF, and CSOs are the major permitted sources of wet weather discharges in the study area (Table 7; Figure 6) with most discharging to the Muddy Creek and Rapid Run subwatersheds. Non-permitted SSOs, PSOs, and NEOs also occur in the Muddy Creek and Rapid

***Table 6**. Level IV subregions of the Ohio River Direct Tributaries watersheds watershed and their key attributes (from Woods et al. 1995).*

| Level IV Subregion | Physiography | Geology | Soils | Potential Natural Vegetation | Land Use/Land Cover |
|---|---|---|---|---|---|
| **Loamy, High Lime Till Plains (55b)** | Glaciated; level to rolling glacial till plain with low gradient streams; also end moraines and glacial outwash landforms. | Loamy, high lime, late-Wisconsinan glacial till and also glacial outwash and scattered loess overlie Paleozoic carbonates and shale. | Alfisols (Hapludalfs, Epiaqualfs, Endoaqualfs), Mollisols (Argiaquolls, Endoaquolls, Argiudolls), Entisols (Fluvaquents) | Mostly beech forest; also, oak-sugar maple forest, elm-ash swamp forest on poorly-drained valley bottoms and ground moraines. | Extensive corn, soybean, and livestock farming; also scattered beech-maple, pin oak-swamp, white oak woodlands. Urban-industrial activity in municipal areas. |
| **Pre-Wisconsinan Drift Plains (55d)** | Glaciated. Dissected glacial till plain with low to medium gradient streams. | Deeply leached, acidic pre-Wisconsinan clay-loam glacial till and thin loess overlie Paleozoic carbonates. | Alfisols (Fragiudalfs, Hapludalfs, Fragiaqualfs, Glossaqualfs), Entisols (Fluvaquents) | Mostly beech forest, elm-ash swamp forest; also oak-sugar maple forest. | Soybean, livestock, corn, general, and tobacco farming; where poorly-drained or rugged, pin oak-swamp, white oak flatwoods, and beech-maple woodlands. |
| **Northern Bluegrass (71d)** | Unglaciated and glaciated; dissected plains and hills with medium gradient, gravel bottom streams. Steep slopes, high relief near Ohio River. | Discontinuous loess and leached pre-Wisconsinan glacial till deposits. Ordovician limestone and shale. | Alfisols (Hapludalfs, Fragiudalfs), Mollisols (Hapludolls) | Mixed meso-phytic forest, mixed oak forest, oak-sugar maple forest; along Ohio River, bottomland hardwoods. | Mosaic of forest, agriculture, and urban-industrial activity near Cincinnati and elsewhere along Ohio River. Wooded where steep |

Run subwatersheds (Table 7). Other wet weather sources include non-enumerated overflows (NEOs) and pump station overflows (PSOs). NEOs consist of manhole covers through which sewage can discharge during rainfall events and there are three (3) located in the Muddy Creek subwatershed. Five (5) PSOs are located in the Muddy Creek subwatershed as well. No CSOs or SSOs discharge to Indian Creek. One (1) PSO is located in the Taylor Creek subwatershed discharging to Wesselman Creek.

***Table 7**. Major pollution sources in and adjacent to the Ohio River Direct Tributaries study area in 2023. Eliminated sources are shown with strikethrough.*

| MSDGC CSO | MSDGC SSO | MSDGC PSO | MSDGC NEO | First Dst. Site | Facility Name/description | NPDES Permit No. |
|---|---|---|---|---|---|---|
| ***Muddy Creek*** | | | | | | |
| | 1025 | | | MU05 | Sanitary Sewer Oveflow | 1PX00022 |
| 198 | | | | MU05 | Muddy & Westbourne HRTF | 1PX00022 |
| 518 | | | | MU4.5 | Combined Sewer Overflow | 1PX00022 |
| | | | 16006007 | MU03 | Non-enumerated Overflow | 1PX00022 |
| | 697 | | | MU01 | Sanitary Sewer Oveflow | 1PX00022 |
| | 692 | | | MU01 | Sanitary Sewer Oveflow | 1PX00022 |
| | 675A | | | No Site Dst. | Sanitary Sewer Oveflow | 1PX00022 |
| | | 676 | | No Site Dst. | Pump Station Overflow | 1PX00022 |
| ***Unnamed Tributary (0.47) to Unnamed Tributary (6.53) to Muddy Creek*** | | | | | | |
| 522 | | | | MU13 | Werk & Westbourne EHRTF | 1PX00022 |
| ***Unnamed Tributary (RM 5.97) to Muddy Creek*** | | | | | | |
| | | | 19215030 | MU4.5 | Non-enumerated Overflow | 1PX00022 |
| | | | 19207020 | MU4.5 | Non-enumerated Overflow | 1PX00022 |
| | 1061 | | | MU4.5 | Sanitary Sewer Oveflow | 1PX00022 |
| ***Unnamed Tributary (RM 4.58) to Muddy Creek*** | | | | | | |
| | | 750 | | MU03 | Pump Station Overflow | 1PX00022 |
| ***Unnamed Tributary (RM 0.3) to Muddy Creek*** | | | | | | |
| | ~~633~~ | | | ~~MU07~~ | Eliminated SSO | 1PX00022 |
| ***Fiddlers Creek RM 0.95 to W. Branch Muddy Creek to Muddy Creek @RM 0.3*** | | | | | | |
| | | 739 | | MU09 | Pump Station Overflow | 1PX00022 |
| | | 741 | | MU09 | Pump Station Overflow | 1PX00022 |
| ***Rapid Run*** | | | | | | |
| 523 | | | | RR03 | Combined Sewer Overflow | 1PX00022 |
| ***Unnamed Tributary (RM 4.60) to Rapid Run*** | | | | | | |
| | 641 | | | RR03 | Sanitary Sewer Oveflow | 1PX00022 |
| ***Wulf Run*** | | | | | | |
| | 623 | | | RR05 | Sanitary Sewer Oveflow | 1PX00022 |
| ***Wesselman Creek*** | | | | | | |
| | | | | GM94 | Home City Ice | 1PX00035 |
| | | 773 | | GM86 | Pump Station Overflow | 1PX00022 |

## RESULTS – CHEMICAL PHYSICAL WATER QUALITY

Chemical/physical water quality in the 2023 Ohio River Direct Tributaries study area was characterized by grab sample data collected from the water column two to five times at each site during base flows and within a June 16-October 15 seasonal index period. Chemical parameter groupings included field, demand, ionic strength, nutrients, heavy metals, and organic compounds. Continuous measurements over consecutive day periods were made at all mainstem sites for D.O. (mg/l), pH (S.U.), conductivity (µS/cm), and temperature (°C) using YSI Datasonde continuous recorders at 18 sites during August 18-21 and 22-25, 2023. Sediment chemistry was determined from samples collected at all mainstem and selected tributaries in mid-October. Heavy metal and volatile organic chemical results in the water column were not detected at levels of concern and are reported in Appendix E.

The results were evaluated by assessing exceedances of criteria in the Ohio WQS, regionally derived biological effect thresholds (IPS Thresholds; MBI 2015b), and by exceedances of probable and threshold effect levels for sediment chemistry (MacDonald et al. 2000). The chemical/physical results also served as indicators of exposure and stress in support of using the biological data for assessing attainment of aquatic life uses and assigning associated causes and sources of impairments.

### Water Quality Criteria Exceedances

#### *Aquatic Life Criteria Exceedances*

Assessing exceedances of water quality criteria was done for parameters that have formal criteria codified in the Ohio WQS and focused on chronic and acute criteria for the protection of aquatic life. Exceedances of water quality criteria in the Ohio WQS were infrequent and occurred for dissolved oxygen (D.O.) at 10 of 31 sites and a single exceedances of pH in 2023 (Table 8). The D.O. exceedances occurred in daytime grab samples in the upper Muddy Creek mainstem and tributaries including values well below the 4.0 mg/l WWH minimum at the three upstream most sites MU05 (RM 6.35), MU04.5 (RM 5.62), and MU04 (RM 5.45) and then declining in frequency downstream with two lesser exceedances at MU01 (RM 0.17). Sites with low D.O. values also included MU12 and MU13 located on unnamed tributaries. Only two sites outside of the Muddy Creek subwatershed had a single D.O. exceedance, Rapid Run site RR01 (RM 0.10) an unnamed tributary to Indian Creek (IC07; RM 0.10).

### Exceedances of Biological Effect Thresholds

Biological effect thresholds were employed for parameters that do and do not have formal criteria codified in the Ohio WQS to determine the risks of any exceedances to the attainment of aquatic life uses. Biological effect thresholds developed as part of the *Integrated Prioritization System (IPS) Documentation and Atlas of Biological Stressor Relationships for Southwest Ohio* (Technical Report MBI/2015-12-15, MBI 2015b) were used to assess conventional, ionic strength, and nutrient parameters. These “IPS thresholds” were used in lieu of the thresholds in Ohio EPA (1999) *Appendices to Association Between Nutrients and the*

***Table 8**. Exceedances of water quality criteria for aquatic life based on grab sampling in the 2023 Ohio River Direct Tributaries study area.*

| Site ID | River Mile | Aq Life Use | Parameters (mg/L) Exceeding Ohio Aquatic Life Criteria[1] |
|---|---|---|---|
| ***Muddy Creek*** | | | |
| MU05 | 6.35 | WWH | Grab D.O. (2.41) |
| MU04.5 | 5.62 | WWH | Grab D.O. (3.70) |
| MU04 | 5.45 | WWH | Grab D.O. (4.27); Sonde D.O. (0.80) |
| MU03 | 2.80 | WWH | |
| MU02 | 2.25 | WWH | |
| MU01 | 0.17 | WWH | Grab D.O. (4.81); Sonde D.O. (3.70) |
| ***Unnamed Tributary to Muddy Creek @ RM 2.37*** | | | |
| MU10 | 0.50 | PHW3A | |
| ***Unnamed Tributary to Muddy Creek @ RM 5.97*** | | | |
| MU12 | 0.55 | WWH | Grab D.O. (1.29) |
| ***Unnamed Tributary to Muddy Creek @ RM 6.53*** | | | |
| MU13 | 0.60 | WWH | pH (9.26); Grab D.O. (3.22) |
| ***Unnamed Tributary to Unnamed Tributary to Muddy Creek @ RM 5.9*** | | | |
| MU14 | 0.20 | PHW2 | |
| ***Unnamed Tributary to Muddy Creek @RM 0.3*** | | | |
| MU08 | 1.72 | PHW3A | |
| MU07.5 | 0.80 | WWH | |
| MU07 | 0.40 | WWH | |
| ***Fiddlers Creek RM 0.95 to W. Branch Muddy Creek to Muddy Creek @RM 0.3*** | | | |
| MU09 | 0.10 | PHW3A | |
| ***Rapid Run*** | | | |
| RR03 | 2.70 | LRW | |
| RR02 | 1.05 | LRW | |
| RR01 | 0.10 | LRW | Grab D.O. (1.75) |
| ***Wulff Run*** | | | |
| RR05 | 1.45 | LRW | |
| RR04 | 0.45 | LRW | |
| ***Unnamed Tributary to Wulff Run @ RM 0.77*** | | | |
| RR05.5 | 0.40 | PHW3A | |
| RR04.5 | 0.35 | PHW3A | |
| ***Indian Creek*** | | | |
| IC06 | 2.30 | WWH | |
| IC05 | 2.08 | WWH | |
| IC02 | 1.15 | WWH | |
| IC01 | 0.30 | WWH | |
| ***Tributary to Indian Creek @RM 1.02 RM 0.97*** | | | |
| IC07 | 0.10 | PHW3A | Grab D.O. (1.75) |

***Table 8**. continued.*

| Site ID | River Mile | Aq Life Use | Parameters (mg/L) Exceeding Ohio Aquatic Life Criteria[1] |
|---|---|---|---|
| ***Taylor Creek*** | | | |
| GM86 | 6.40 | WWH | D.O. (2.43); Sonde D.O. (2.21) |
| GM85 | 5.30 | WWH | |
| ***Briarly Creek*** | | | |
| GM91 | 3.90 | PHW3A | Sonde D.O. (2.91) |
| GM90 | 2.45 | WWH | |
| GM89 | 1.80 | WWH | |
| ***Wesselman Creek*** | | | |
| GM94 | 4.70 | PHW3A | |
| ***Unnamed Tributary to Wesselman Creek @ RM 2.59*** | | | |
| GM100 | 1.05 | PHW3A | |
| ***Unnamed Tributary to Taylor Creek @ RM 4.9*** | | | |
| GM106 | 0.20 | WWH | |

*Aquatic Biota of Ohio River and Streams* that were employed in a similar fashion in the 2011-14 MSDGC service area watershed assessments. The IPS thresholds were derived from a more robust and regionally relevant analysis of biological stressor thresholds and especially in light of the Ohio EPA (1999) dataset being somewhat sparse in the Interior Plateau ecoregion. The newer IPS thresholds also offer discrete goals that are directly linked to the codified biological criteria and their application in the determination of aquatic life use attainment and the options for responding to a finding of attainment or a finding of non-attainment[5]. The results for selected parameters were then compared to the IPS thresholds that align with the applicable aquatic life use tier and stream size categories and are color coded in keeping with the hierarchy of the Ohio tiered aquatic life uses and corresponding narrative condition ratings. The results are organized in tabular form within each of the Ohio River Direct Tributaries subwatersheds as mean values in 2023. Nutrient enrichment effects were assessed using a modification of the Stream Nutrient Assessment Procedure (SNAP; Ohio EPA 2015b) which is a "combined criteria" consisting of the fish and macroinvertebrate biological criteria, the diel D.O. flux, benthic chlorophyll a, total nitrate, phosphorus, TKN, and SSC. Lastly, sediment chemical data was assessed using the threshold and probable effect levels of MacDonald et al. (2000).

***Continuously Monitored Parameters***

Continuous measurements of D.O., temperature, pH, and conductivity were recorded using Datasondes deployed over consecutive day periods at 18 sites during August 18-21 and 22-25, 2023.

As just described, water quality exceedances based on daytime D.O. values were infrequent in

[5] OAC 3745-1-07(C) and OAC 3745-2-03 describe the options for a finding of full attainment and non-attainment.

the Muddy Creek subwatershed which is an improvement from 2018. The continuous results confirmed these observations and added information about diel fluxes that were most pronounced at MU03 and MU04.5 (Figure 8). Maximum values exceeded the 12 mg/L maximum D.O. screening value for signaling the effects of excessive nutrient enrichment at two of the eight continuous monitoring locations. Minimum values were very low only at MU04 (RM 5.45) which is likely a "sag" effect from the organic enrichment inputs from sources located upstream. Minimum values of lesser magnitude at MU01 in the Ohio River backwater affected portion of the Muddy Creek mainstem. Two other sites had minimum values below the 4 mg/L minimum, in Briarly Creek (GM91) and the upstream most site in Taylor Creek (GM86).

Values for pH were all within the 6.5-9.0 S.U. range of the water quality criterion excepting site MU4.5 in upper Muddy Creek that had exceedances of the 9.0 maximum criterion (Figure 8). High pH values can also be indicative of excessive nutrient enrichment.

Temperature results revealed no exceedances of the maximum of 29.4°C, but the median value at the Ohio River influenced mouth of Muddy Creek (MU01) exceeded the 27.8°C average. The range of most sites was between 18-23°C (Figure 8).

Specific conductance results showed a wide range of variability both within and between sites (Figure 8). Exceedances of the WWH IPS threshold of 703 µS/cm were the highest and most frequent in the Taylor Creek subwatershed, which parallels the finding of increased chloride values over time in the 2014 assessment (MBI 2015a). All other sites had values below the WWH IPS threshold with a very wide range in values and very low minimum values. No sites had values that exceeded the LRW IPS or poor threshold.

***Nutrient and Demand Related Parameters***

This category includes ammonia-N, total phosphorus, total nitrate-N, total nitrite-N, total Kjeldahl nitrogen, 5-day biochemical oxygen demand, and sestonic chlorophyll a, all from grab samples collected under normal summer-fall flows (Table 9). Very poor and poor exceedances of IPS thresholds occurred for ammonia-N, Total Kjeldahl Nitrogen (TKN), total P, and BOD5 at only a few selected sites in the 2023 study area (Table 9). Fair exceedances were more frequent for TKN, total P, and BOD5 and at more sites throughout the study area. Ammonia-N had a single fair exceedance and was below detection at 12 sites. Nitrate-N, nitrite-N, and sestonic chlorophyll a had no exceedances and were within either the exceptional or good IPS ranges.

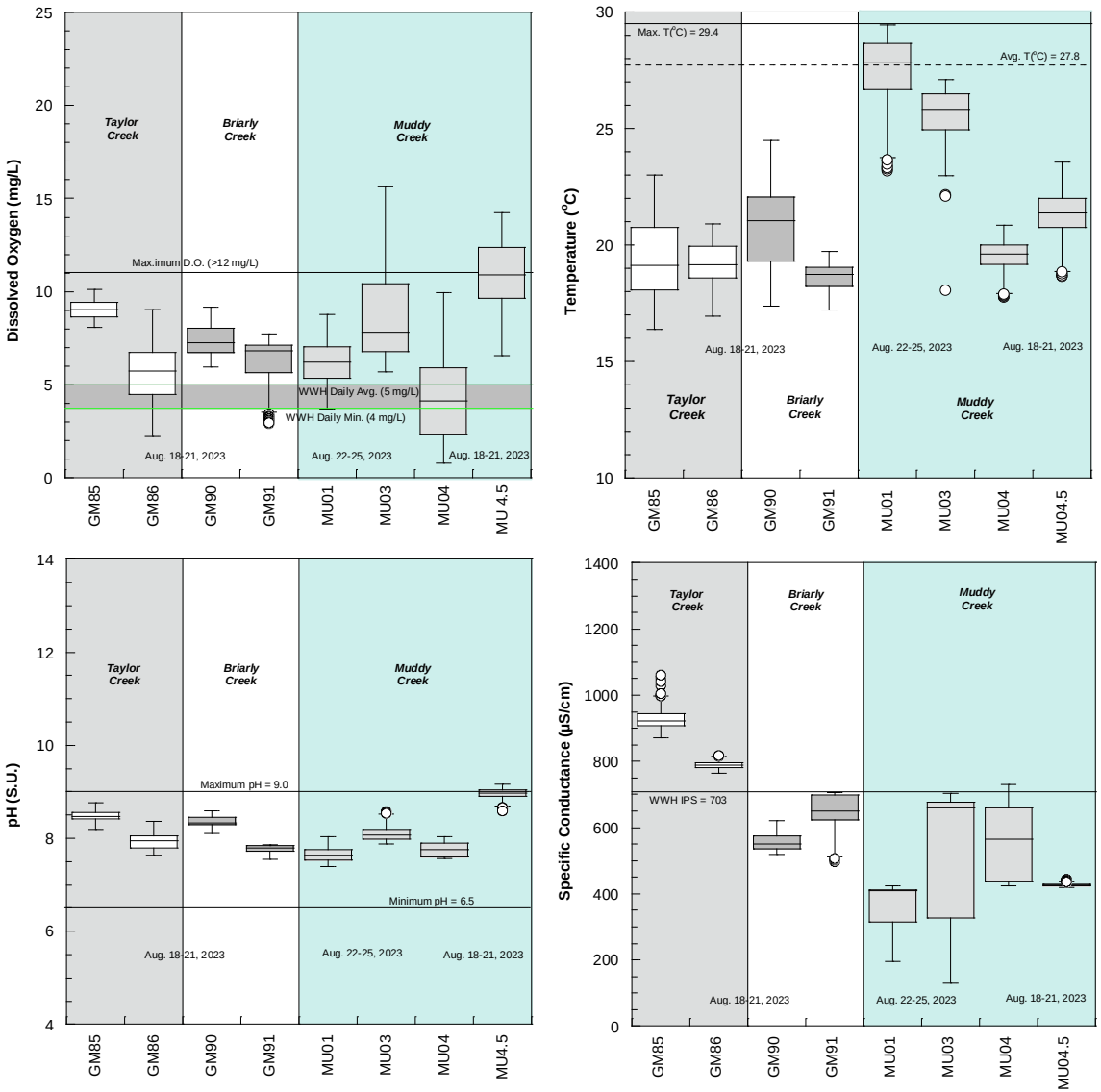


***Figure 7***. *Box-and-whisker plots of continuous D.O. (mg/L; upper left), pH(S.U.; lower left), temperature (℃; upper right), and specific conductance (µS/cm; lower right) from Datasonde continuous recorders at eight (8) sites in the Ohio River Direct Tributaries study area during August 18-21 and August 22-24, 2023. The WWH daily average and minimum D.O. criteria are indicated by gray shaded bars and the maximum D.O. indicative of excessive diel swings is indicated by a black dashed line (upper left). The maximum and minimum pH criteria are indicated by solid lines (lower left). The WWH daily maximum and average temperature criteria are indicated by solid and dashed lines (upper right). The WWH IPS specific conductance threshold is indicated by a solid line (lower right).*

***Table 9**. Nutrient and demand parameter results in the Ohio River Direct Tributaries study area in 2023. Values >SW Ohio IPS stressor thresholds are shaded in accordance with the legend at the bottom of the table.*

| Site ID | River Mile | Drainage Area (sq. mi.) | Ammonia-N (mg/L) | | Nitrate-N (mg/L) | | Nitrite - N (mg/L) | | Total Kjeldahl Nitrogen (mg/L) | | Total Phosphorus (mg/L) | | Biochemical Oxygen Demand (mg/L) | | Sestonic Chlorophyll a (µg/L) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Median | Mean | Median | Mean | Median | Mean | Median | Mean | Median | Mean | Median | Mean | Median | Mean |
| ***Muddy Creek*** | | | | | | | | | | | | | | | | |
| **MU05** | 6.25 | 5.4 | 0.18 | 0.20 | 0.0178 | 0.0352 | 0.0178 | 0.0352 | 0.71 | 0.77 | 0.22 | 0.22 | 2.00 | 3.17 | 1.0 | 1.6 |
| **MU04.5** | 5.60 | 7.7 | 0.00 | 0.05 | 0.0039 | 0.0146 | 0.0039 | 0.0146 | 0.55 | 0.57 | 0.19 | 0.19 | 3.00 | 3.43 | 1.0 | 1.7 |
| **MU04** | 5.40 | 7.8 | 0.01 | 0.02 | 0.0052 | 0.0136 | 0.0052 | 0.0136 | 0.46 | 0.52 | 0.25 | 0.23 | 2.00 | 2.00 | 1.0 | 1.2 |
| **MU03** | 3.10 | 10.4 | 0.00 | 0.01 | 0.0013 | 0.0013 | 0.0013 | 0.0013 | 0.28 | 0.24 | 0.10 | 0.09 | 2.00 | 2.00 | 1.0 | 1.5 |
| **MU02** | 2.25 | 12.1 | 0.00 | 0.01 | 0.0004 | 0.0009 | 0.0004 | 0.0009 | 0.18 | 0.18 | 0.09 | 0.08 | 2.00 | 2.00 | 1.0 | 1.3 |
| **MU01** | 0.20 | 13.6 | 0.05 | 0.04 | 0.0367 | 0.0374 | 0.0367 | 0.0374 | 0.71 | 0.69 | 0.15 | 0.16 | 2.50 | 3.00 | 17.8 | 18.5 |
| ***Unnamed Tributary to Muddy Creek @RM 0.3*** | | | | | | | | | | | | | | | | |
| **MU08** | 1.72 | 0.74 | 0.00 | 0.01 | 0.0424 | 0.0437 | 0.0424 | 0.0437 | 0.00 | 0.30 | 3.34 | 2.41 | 3.00 | 3.00 | 1.0 | 1.2 |
| **MU07.5** | 0.80 | 2.6 | BD | BD | 0.0009 | 0.0008 | 0.0009 | 0.0008 | 0.42 | 0.35 | 0.24 | 0.84 | 2.00 | 2.60 | 1.0 | 1.5 |
| **MU07** | 0.40 | 2.8 | BD | BD | 0.0023 | 0.0023 | 0.0023 | 0.0023 | 0.30 | 0.30 | 0.25 | 0.25 | 2.00 | 2.00 | 1.0 | 1.0 |
| ***Fiddlers Creek RM 0.95 to W. Branch Muddy Creek to Muddy Creek @RM 0.3 (95-076)*** | | | | | | | | | | | | | | | | |
| **MU09** | 0.10 | 1.3 | BD | BD | 0.0002 | 0.0006 | 0.0002 | 0.0006 | 0.28 | 0.27 | 0.22 | 0.21 | 2.00 | 2.20 | 1.0 | 1.0 |
| ***Unnamed Tributary to Muddy Creek @RM 2.37*** | | | | | | | | | | | | | | | | |
| **MU10** | 0.50 | 0.71 | BD | BD | 0.0007 | 0.0007 | 0.0007 | 0.0007 | 0.31 | 0.33 | 0.41 | 0.41 | 2.00 | 2.00 | 1.0 | 1.9 |
| ***Unnamed Tributary to Muddy Creek @RM 5.97*** | | | | | | | | | | | | | | | | |
| **MU12** | 0.55 | 1.0 | 0.88 | 2.29 | 0.0225 | 0.0191 | 0.0225 | 0.0191 | 1.58 | 3.76 | 0.32 | 0.58 | 4.00 | 7.00 | 1.0 | 5.8 |
| ***Unnamed Tributary to Muddy Creek @RM 6.53*** | | | | | | | | | | | | | | | | |
| **MU13** | 0.60 | 2.3 | 0.02 | 0.06 | 0.0024 | 0.0047 | 0.0024 | 0.0047 | 1.01 | 4.49 | 0.19 | 0.16 | 3.00 | 2.80 | 1.6 | 1.7 |
| ***Unnamed Tributary to Unnamed Tributary to Muddy Creek @RM 5.97*** | | | | | | | | | | | | | | | | |
| **MU14** | 0.20 | 2.7 | 0.46 | 0.38 | 0.0637 | 0.0912 | 0.0637 | 0.0912 | 1.20 | 1.25 | 0.15 | 0.17 | 3.00 | 3.25 | 5.9 | 9.9 |
| ***Rapid Run*** | | | | | | | | | | | | | | | | |
| **RR03** | 2.58 | 2.32 | BD | BD | 0.0102 | 0.0102 | 0.0102 | 0.0102 | 0.36 | 0.36 | 0.24 | 0.24 | 2.00 | 2.00 | 1.0 | 1.0 |
| **RR02** | 1.10 | 5.9 | BD | BD | 0.0013 | 0.0028 | 0.0013 | 0.0028 | 0.19 | 0.24 | 0.08 | 0.08 | 2.00 | 2.00 | 1.0 | 1.5 |
| **RR01** | 0.35 | 6.0 | 0.01 | 0.01 | 0.0023 | 0.0023 | 0.0023 | 0.0023 | 0.24 | 0.24 | 0.10 | 0.10 | 2.00 | 2.00 | 1.0 | 1.0 |
| ***Wulff Run*** | | | | | | | | | | | | | | | | |
| **RR05** | 0.68 | 1.3 | 0.01 | 0.05 | 0.0042 | 0.0089 | 0.0042 | 0.0089 | 0.39 | 0.43 | 0.13 | 0.14 | 2.00 | 2.00 | 1.0 | 1.3 |
| **RR04** | 0.55 | 2.2 | BD | BD | 0.0021 | 0.0026 | 0.0021 | 0.0026 | 0.44 | 0.44 | 0.16 | 0.17 | 2.00 | 2.00 | 1.6 | 5.4 |
| ***Unnamed Tributary to Wulff Run @RM 0.77*** | | | | | | | | | | | | | | | | |
| **RR05.5** | 1.20 | 1 | BD | BD | 0.0044 | 0.0057 | 0.0044 | 0.0057 | 0.51 | 1.14 | 0.44 | 0.44 | 2.00 | 2.00 | 1.0 | 1.0 |
| **RR04.5** | 1.10 | 0.34 | BD | BD | 0.0038 | 0.0046 | 0.0038 | 0.0046 | 0.48 | 0.44 | 0.59 | 0.58 | 2.00 | 2.00 | 1.0 | 1.0 |

| Headwater Sites IPS Threshold | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Exceptional | <0.09 | | <0.65 | | <0.200 | | <0.38 | | <0.03 | | <1.96 | | | |
| | Good | <0.31 | | <0.96 | | <0.040 | | <0.51 | | <0.17 | | <2.48 | | <30 | |
| | Fair | <0.63 | | <1.12 | | <1.060 | | <1.70 | | <1.03 | | >2.48 | | 30-100 | |
| | Poor | <1.43 | | <1.51 | | <0.255 | | <2.15 | | <2.60 | | <2.74 | | >100 | |
| | Very Poor | ≥1.43 | | ≥1.51 | | ≥0.533 | | ≥2.15 | | ≥2.60 | | ≥3.38 | | | |

***Table 9**. continued.*

| Site ID | River Mile | Drainage Area (sq. mi.) | Ammonia-N (mg/L) | | Nitrate-N (mg/L) | | Nitrite - N (mg/L) | | Total Kjeldahl Nitrogen (mg/L) | | Total Phosphorus (mg/L) | | Biochemical Oxygen Demand (mg/L) | | Sestonic Chlorophyll a (µg/L) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Median | Mean | Median | Mean | Median | Mean | Median | Mean | Median | Mean | Median | Mean | Median | Mean |
| ***Indian Creek*** | | | | | | | | | | | | | | | | |
| **IC06** | 2.25 | 0.58 | 0.00 | 0.01 | 0.0003 | 0.0004 | 0.0003 | 0.0004 | 0.28 | 0.29 | 0.12 | 0.12 | 2.00 | 2.00 | 1.0 | 1.7 |
| **IC05** | 2.08 | 1.1 | 0.00 | 0.02 | 0.0008 | 0.0009 | 0.0008 | 0.0009 | 0.31 | 0.33 | 0.15 | 0.14 | 2.00 | 2.00 | 1.0 | 1.5 |
| **IC02** | 1.15 | 1.4 | 0.00 | 0.01 | 0.0018 | 0.0017 | 0.0018 | 0.0017 | 0.31 | 0.34 | 0.13 | 0.13 | 2.00 | 2.00 | 1.3 | 1.5 |
| **IC01** | 0.20 | 2.3 | 0.06 | 0.08 | 0.0090 | 0.0080 | 0.0090 | 0.0080 | 0.56 | 0.55 | 0.12 | 0.12 | 2.00 | 2.83 | 2.3 | 3.1 |
| ***Unnamed Tributary to Indian Creek @RM 1.02*** | | | | | | | | | | | | | | | | |
| **IC07** | 0.19 | 0.39 | 0.09 | 0.69 | 0.0015 | 0.0018 | 0.0015 | 0.0018 | 0.32 | 1.42 | 0.12 | 0.20 | 2.00 | 4.20 | 1.0 | 5.2 |
| ***Taylor Creek*** | | | | | | | | | | | | | | | | |
| **GM86** | 6.50 | 0.49 | 0.03 | 0.05 | 0.0059 | 0.0090 | 0.0059 | 0.0090 | 0.45 | 0.54 | 0.40 | 0.39 | 2.00 | 2.17 | 1.0 | 1.0 |
| **GM85** | 5.30 | 2.2 | BD | BD | 0.0131 | 0.0121 | 0.0131 | 0.0121 | 0.00 | 0.01 | 1.30 | 1.41 | 2.00 | 2.00 | 1.0 | 1.0 |
| ***Unnamed Tributary to Taylor Creek @RM 4.9*** | | | | | | | | | | | | | | | | |
| **GM106** | 0.28 | 0.92 | 0.00 | 0.02 | 0.0015 | 0.0051 | 0.0015 | 0.0051 | 0.33 | 0.40 | 0.25 | 0.25 | 2.00 | 2.00 | 1.0 | 1.0 |
| ***Briarly Creek*** | | | | | | | | | | | | | | | | |
| **GM91** | 3.90 | 0.34 | 0.00 | 0.01 | 0.0016 | 0.0021 | 0.0016 | 0.0021 | 0.24 | 0.29 | 0.20 | 0.19 | 2.00 | 2.14 | 1.0 | 3.1 |
| **GM90** | 2.55 | 1.3 | 0.05 | 0.05 | 0.0178 | 0.0270 | 0.0178 | 0.0270 | 0.46 | 0.58 | 0.33 | 0.34 | 2.00 | 2.00 | 1.0 | 1.2 |
| **GM89** | 1.98 | 2.1 | 0.00 | 0.06 | 0.0027 | 0.0027 | 0.0027 | 0.0027 | 0.40 | 0.39 | 0.34 | 0.35 | 2.00 | 2.00 | 2.7 | 2.6 |
| ***Wesselman Creek*** | | | | | | | | | | | | | | | | |
| **GM94** | 4.75 | 1.1 | 0.00 | 0.01 | 0.0029 | 0.0026 | 0.0029 | 0.0026 | 0.52 | 0.62 | 0.34 | 0.33 | 2.00 | 2.14 | 2.7 | 10.5 |
| ***Unnamed Tributary to Wesselman Creek @RM 2.95*** | | | | | | | | | | | | | | | | |
| **GM100** | 1.28 | 0.91 | 0.00 | 0.02 | 0.0061 | 0.0076 | 0.0061 | 0.0076 | 0.52 | 0.61 | 0.54 | 0.54 | 2.00 | 2.20 | 1.0 | 1.7 |

| Headwater Sites IPS Threshold | | | | | | |
|---|---|---|---|---|---|---|
| **Exceptional** | <0.09 | <0.65 | <0.200 | <0.38 | <0.03 | <1.96 | |
| **Good** | <0.31 | <0.96 | <0.040 | <0.51 | <0.17 | <2.48 | <30 |
| **Fair** | <0.63 | <1.12 | <1.060 | <1.70 | <1.03 | >2.48 | 30-100 |
| **Poor** | <1.43 | <1.51 | <0.255 | <2.15 | <2.60 | <2.74 | >100 |
| **Very Poor** | ≥1.43 | ≥1.51 | ≥0.533 | ≥2.15 | ≥2.60 | ≥3.38 | |

*Nutrient Assessment Using SNAP*

Benthic chlorophyll a values along with aquatic life use attainment status, the diel D.O. swing, nitrate-N, total P, TKN, and SSC were assessed using a modification of the Ohio EPA SNAP procedure (Ohio EPA 2015b; Appendix F) in the 2023 study area. The SNAP was used to assess the overall effects of nutrient enrichment at the eight (8) continuous monitoring four sites in Muddy Creek and two (2) sites each in Briarly Creek and Taylor Creek. SNAP requires data for fish, macroinvertebrates, QHEI, continuous D.O., total P, nitrate-N, benthic chlorophyll a. Continuous data is required to derive the diel D.O. flux which limits this analysis to continuous monitoring locations. SNAP utilizes the aforementioned parameters to arrive at trophic status determination for sites that are impaired for the biocriteria (Table 10). MBI utilized the IPS thresholds for the chemical parameters that had less stratified thresholds in Ohio EPA (2015b). Biologically impaired sites are assessed for the likelihood that nutrient enrichment is a primary cause of an observed impairment or a threat to an attaining site.

Two (2) of the (8) eight sites assessed with SNAP were determined to be likely associated with a nutrient enrichment related cause (Table 10) which included the two upstream most sites in Muddy Creek (MU05 and MU04.5). One site in Muddy Creek, MU03 (RM 2.80) was attaining, but threatened. Four (4) sites were impaired due to non-nutrient causes and one (1) site was attaining and not threatened. All of these sites were located in Briarly Creek and Taylor Creek. The most important SNAP factors in making the likelihood of nutrients as a cause of the impairment were the maximum D.O. and the diel D.O. swing. A $BOD_5$ value in the poor range was a factor at the upstream most site in Muddy Creek. All of benthic chlorophyll a values were in the very low risk range, but the two (2) of the highest values occurred at the two (2) Muddy Creek sites (MU04.5 and MU04) with nutrients as a likely cause of impairment.

***Table 10**. Results for parameters and indicators used in the modified Stream Nutrient Assessment Procedure (SNAP) to determine the role of the effect of nutrients on aquatic life use attainment in the 2023 Direct Ohio River Tributaries study area. SNAP produces a trophic status that is the likelihood of nutrients as a cause of non-attainment.*

| Site ID | River Mile | AQLU | Drainage Area (sq. mi.) | IBI | ICI/ Narra-tive | AQLU Status | Total Phosporus (mg/L) | | Nitrate-N (mg/L) | | Grab D.O. | | Continuous D.O. | | | | Benthic Chloro-phyll a | Total Kjeldahl Nitrogen (TKN) | | $BOD_5$ (mg/L) | | Suspended Sediment Conc. (mg/L) | | Sestonic Chloro-phyll a | Trophic Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Mean | Median | Mean | Median | Max. | Min. | Max. | Min. | Diel Swing | Diel Swing Narrative | $mg/m^2$ | Mean | Median | Mean | Median | Mean | Median | µg/L | |
| ***Muddy Creek*** | | | | | | | | | | | | | | | | | | | | | | | | | |
| **MU04.5** | 5.62 | WWH | 7.71 | 12*Θ | VP Θ | Non Θ | 0.19 | 0.19 | 0.16 | 0.15 | 10.52 | 3.70 | 14.25 | 6.55 | 7.05 | Wide | 69.8 | 0.57 | 0.55 | 3.43 | 3.00 | 3.16 | 2.10 | 1.7 | Impaired Nutrients Likely |
| **MU04** | 5.45 | WWH | 7.80 | 24*Θ | VP Θ | Non Θ | 0.23 | 0.25 | 0.36 | 0.15 | 8.43 | 4.27 | 9.93 | 0.80 | 7.15 | Wide | 102.0 | 0.52 | 0.46 | 2.00 | 2.00 | 2.83 | 1.55 | 1.2 | Impaired Nutrients Likely |
| **MU03** | 2.80 | WWH | 10.40 | $36^{ns}$ ↑ | $28^{ns}$ ↑ | Full ↑ | 0.09 | 0.10 | 0.28 | 0.12 | 12.52 | 6.79 | 15.62 | 5.70 | 9.38 | Wide | 32.3 | 0.24 | 0.28 | 2.00 | 2.00 | 3.77 | 4.40 | 1.5 | Attaining Threatened |
| **MU01** | 0.17 | WWH | 13.60 | 12*Θ | 12*Θ | Non Θ | 0.16 | 0.15 | 0.52 | 0.52 | 8.14 | 4.81 | 8.78 | 3.70 | 3.99 | Low | 37.8 | 0.69 | 0.71 | 3.00 | 2.50 | 30.67 | 24.50 | 18.5 | Impaired Other Cause(s) |
| ***Taylor Creek*** | | | | | | | | | | | | | | | | | | | | | | | | | |
| **GM86** | 6.40 | WWH | 0.49 | 22*↓ | VP ↓ | Non ↓ | 0.39 | 0.40 | 0.30 | 0.22 | 9.63 | 2.43 | 9.02 | 2.21 | 2.12 | Low | 53.3 | 0.54 | 0.45 | 2.17 | 2.00 | 7.42 | 5.15 | 1.0 | Impaired Other Cause(s) |
| **GM85** | 5.30 | WWH | 2.22 | 20*↓ | F Θ | Non Θ | 1.41 | 1.30 | 12.72 | 9.96 | 10.18 | 6.79 | 10.11 | 8.08 | 1.83 | Low | 24.7 | 0.12 | 0.18 | 2.00 | 2.00 | 2.27 | 2.05 | 1.0 | Impaired Other Cause(s) |
| ***Briarly Creek*** | | | | | | | | | | | | | | | | | | | | | | | | | |
| **GM91** | 3.90 | PHW3A | 0.34 | 24Θ | | PHW3A Θ | 0.19 | 0.20 | 0.48 | 0.42 | 9.65 | 6.50 | 7.71 | 2.92 | 2.24 | Low | 72.3 | 0.29 | 0.24 | 2.14 | 2.00 | 7.29 | 2.30 | 3.1 | Attaining Not Threatened |
| **GM90** | 2.45 | WWH | 1.30 | 22*Θ | F ↓ | Non ↓ | 0.34 | 0.33 | 0.88 | 0.85 | 9.91 | 6.21 | 9.15 | 5.94 | 2.74 | Low | 40.0 | 0.58 | 0.46 | 2.00 | 2.00 | 7.99 | 4.30 | 1.2 | Impaired Other Cause(s) |
| **SNAP Thresholds** | | | | **Refrence** | | | < 0.031 | | <0.65 | | <10 | >6.0 | <10 | >6.0 | | | | <0.38 | | <1.96 | | <17.0 | | | Attaining Not Threatened |
| | | | | **Very Low Risk** | | | <0.173 | | <0.96 | | <12 | >5.0 | <12 | >5.0 | ≤6.5 | Low | ≤182 | <0.51 | | <2.48 | | <64.7 | | <5 | Attaining Not Threatened |
| | | | | **Low Risk** | | | <1.032 | | <1.12 | | >12 | >3.0 | >12 | >3.0 | | | <320 | <1.70 | | <2.74 | | <165.3 | | <30 | Attaining Threatened |
| | | | | **Moderate Risk** | | | <2.620 | | <1.51 | | >15 | >2.0 | >15 | >2.0 | >6.5 | Wide | >320 | <2.15 | | <3.38 | | <215.0 | | <100 | Impaired Nutrients Likely |
| | | | | **High Risk** | | | ≥2.620 | | >1.51 | | >18 | <2.0 | >18 | <2.0 | | | | >2.15 | | >3.38 | | >215.0 | | >100 | Impaired Nutrients |
| | | | | **SNAP** | | | **SW OH IPS** | | **SNAP** | | **MBI** | **OH WQC** | **MBI** | **OH WQC** | | | **SNAP** | **SW OH IPS** | | **SW OH IPS** | | **SW OH IPS** | | **OHEPA** | **SNAP** |

Only the Muddy Creek sites are impacted by CSOs/SSOs, but all are impacted by HSTS discharges which are especially dense in the Taylor Creek subwatershed where low D.O. values below the 4 mg/L WWH minimum occurred without excessive diel D.O. swings.

***Urban Parameters***

Urban parameters include ionic strength measures such as conductivity, total chlorides, and total dissolved solids (TDS), suspended sediment (SSC) and selected heavy metals such as lead, copper, and zinc. These parameters are commonly elevated in urban areas and are the result of stormwater runoff, but can also be indicative of other sources of pollution. The IPS biological effect thresholds (MBI 2015b) were used to assess all of the urban parameters similar to the preceding analyses of nutrient and demand parameters (Table 11).

Very poor and poor IPS threshold exceedance were limited to the ionic strength parameters, TDS, conductivity, and chlorides in 2023 (Table 11). TDS had the most exceedances followed by chloride and conductivity. No exceedances occurred for the three heavy metals or SSC. The most severe exceedances occurred in the unnamed tributaries in Muddy Creek, the Rapid Run mainstem, upper Taylor Creek, Indian Creek, and Wesselman Creek. Some the highest values tracked well with sources of urban runoff and sewage including the high densities of HSTS discharges in upper Taylor Creek and upper Indian Creek.

***Sediment Chemistry***

Sediment samples were collected from 19 sites in the 2023 study area in October 2023 and analyzed for heavy metals and organic compounds. The results were screened with the MacDonald et al. (2000) consensus-based levels for potential adverse effects to aquatic life and Ohio Sediment Reference Values (SRVs). MacDonald et al. (2000) described two levels of contamination - a Threshold Effects Concentration (TEC) and a Probable Effects Concentration (PEC). The TEC indicates exceedances for sensitive species and taxa while the PEC indicates effects for most species and taxa. IPS thresholds have not yet been developed for sediment chemicals.

*Metals in Sediment*

Three exceedances of lead in upper Muddy Creek at MU04, MU04.5, and MU05 were the only parameter with values exceeding the PEC or TEC (Table 12). No other measured metals values exceeded their respective TEC or SRV thresholds. The lead exceedances are at the same locations as other exceedances related to both wet weather sewage and urban runoff sources.

*Polycyclic Aromatic Hydrocarbon Compounds (PAH) in Sediment*

Most of the common PAH compounds such as benzo(a)pyrene, benzo(ghi)perylene, chrysene, fluoranthene, phenanthrene, and pyrene originate from oil-based and coal tar-based compounds (e.g., asphalt sealants, tars, gasoline, car exhaust, tire residues, motor oil, etc.). Acenaphthylene, anthracene, benzo(a)pyrene, naphthalene, phenanthrene, and pyrene are manufactured and used in various industrial processes. The remaining PAH compounds are not commercially produced and are solely the result of the incomplete combustion of coal or oil-

***Table 11**. Urban parameter results in the Ohio River Direct Tributaries study area in 2023. Values exceeding the applicable IPS thresholds (MBI 2015b) are highlighted in accordance with the legend at the bottom of the table (* - chronic WQC).*

| Site ID | River Mile | Drainage Area (sq. mi.) | Specific Conductance (µS/cm) | | Suspended Sediment Concentration (mg/L) | | Total Dissolved Solids (mg/L) | | Chloride (mg/L) | | Lead (µg/L) | | Copper (µg/L) | | Zinc (µg/L) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Median | Mean | Median | Mean | Median | Mean | Median | Mean | Median | Mean | Median | Mean | Median | Mean |
| ***Muddy Creek*** | | | | | | | | | | | | | | | | |
| **MU05** | 6.25 | 5.39 | 445 | 395 | 2 | 2 | 202.0 | 188.7 | 37 | 34 | BD | BD | 1.7 | 1.7 | 6.8 | 6.4 |
| **MU04.5** | 5.6 | 7.71 | 520 | 490 | 2 | 3 | 240.0 | 227.4 | 46 | 48 | 0.0 | 0.2 | 2.4 | 2.5 | 6.5 | 7.2 |
| **MU04** | 5.4 | 7.8 | 485 | 452 | 2 | 3 | 230.0 | 205.7 | 44 | 44 | 0.0 | 0.1 | 2.0 | 2.3 | 5.0 | 4.8 |
| **MU03** | 3.1 | 10.4 | 675 | 678 | 4 | 4 | 370.0 | 354.0 | 67 | 68 | 0.1 | 0.2 | 2.1 | 2.4 | 6.3 | 6.6 |
| **MU02** | 2.25 | 12.1 | 725 | 713 | 0 | 2 | 404.0 | 394.0 | 69 | 70 | BD | BD | 1.5 | 1.5 | 4.0 | 4.2 |
| **MU01** | 0.2 | 13.6 | 430 | 430 | 25 | 31 | 204.0 | 212.0 | 32 | 32 | 1.7 | 1.7 | 3.1 | 3.7 | 10.8 | 11.4 |
| ***Unnamed Tributary to Muddy Creek @RM 0.30*** | | | | | | | | | | | | | | | | |
| **MU08** | 1.72 | 0.74 | 750 | 753 | 24 | 24 | 408.0 | 418.7 | 50 | 51 | 0.4 | 0.4 | 3.7 | 3.6 | 12.6 | 15.7 |
| **MU07.5** | 0.8 | 2.6 | 820 | 792 | 9 | 9 | 496.0 | 451.2 | 68 | 66 | 0.2 | 0.1 | 1.8 | 1.8 | 9.4 | 10.1 |
| **MU07** | 0.4 | 2.8 | 600 | 600 | 1 | 1 | 308.0 | 308.0 | 43 | 43 | BD | BD | 1.7 | 1.7 | BD | BD |
| ***Fiddlers Creek RM 0.95 to W. Branch Muddy Creek to Muddy Creek @RM 0.3*** | | | | | | | | | | | | | | | | |
| **MU09** | 0.1 | 1.33 | 830 | 794 | 10 | 8 | 524.0 | 457.6 | 69 | 66 | 0.2 | 0.2 | 1.8 | 1.6 | 6.1 | 7.5 |
| ***Unnamed Tributary to Muddy Creek @RM 2.37*** | | | | | | | | | | | | | | | | |
| **MU10** | 0.5 | 0.71 | 820 | 790 | 14 | 14 | 468.0 | 423.2 | 74 | 69 | 0.6 | 0.6 | 5.1 | 5.1 | 6.7 | 7.6 |
| ***Unnamed Tributary to Muddy Creek @RM 5.97*** | | | | | | | | | | | | | | | | |
| **MU12** | 0.55 | 1.01 | 460 | 438 | 12 | 9 | 220.0 | 201.2 | 47 | 47 | 0.3 | 0.3 | 6.2 | 7.4 | 5.1 | 6.7 |
| ***Unnamed Tributary to Muddy Creek @RM 6.53*** | | | | | | | | | | | | | | | | |
| **MU13** | 0.6 | 2.25 | 850 | 942 | 4 | 4 | 428.0 | 496.0 | 110 | 183 | 0.4 | 0.3 | 2.6 | 2.8 | 5.0 | 6.5 |
| ***Unnamed Tributary to Unnamed Tributary to Muddy Creek @RM 5.97*** | | | | | | | | | | | | | | | | |
| **MU14** | 0.2 | 2.7 | 1200 | 1170 | 18 | 20 | 638.0 | 629.0 | 145 | 181 | 0.3 | 0.4 | 2.1 | 2.2 | 9.0 | 10.0 |
| ***Rapid Run*** | | | | | | | | | | | | | | | | |
| **RR03** | 2.58 | 2.32 | 350 | 350 | 2 | 2 | 150.0 | 150.0 | 13 | 13 | 0.1 | 0.1 | 4.2 | 4.2 | 4.8 | 4.8 |
| **RR02** | 1.1 | 5.9 | 960 | 935 | 3 | 6 | 554.0 | 550.7 | 165 | 150 | BD | BD | 2.4 | 2.8 | 4.7 | 4.0 |
| **RR01** | 0.35 | 5.99 | 1800 | 1800 | 1 | 1 | 926.0 | 926.0 | 415 | 415 | BD | BD | 2.9 | 2.9 | 4.5 | 4.5 |
| ***Wulff Run*** | | | | | | | | | | | | | | | | |
| **RR05** | 0.68 | 1.33 | 500 | 503 | 3 | 4 | 228.0 | 228.0 | 48 | 48 | 0.0 | 0.1 | 2.0 | 2.0 | 6.8 | 8.2 |
| **RR04** | 0.55 | 2.18 | 900 | 890 | 3 | 3 | 480.0 | 446.4 | 140 | 128 | 0.0 | 0.1 | 4.4 | 4.0 | 10.7 | 11.2 |
| ***Unnamed Tributary to Wulff Run @RM 0.77*** | | | | | | | | | | | | | | | | |
| **RR05.5** | 1.2 | 1 | 890 | 802 | 7 | 8 | 472.0 | 421.6 | 81 | 77 | 0.0 | 0.3 | 2.4 | 2.6 | 8.0 | 6.7 |
| **RR04.5** | 1.1 | 0.34 | 690 | 690 | 15 | 15 | 344.0 | 358.4 | 50 | 48 | 0.2 | 0.2 | 2.5 | 2.5 | 4.7 | 5.2 |
| **Headwater Sites IPS Thresholds** | Excellent | | <397 | | <17.0 | | <284 | | <21.9 | | <2.7 | | <5.9 | | <16.4 | |
| | Good | | <703 | | <65.7 | | <364 | | <52.6 | | <17.4 | | <8.9/24.0* | | <39.3/300* | |
| | Fair | | <856 | | <165.3 | | <403 | | <68.0 | | <26.8 | | <10.4 | | <50.8 | |
| | Poor | | <1240 | | <203 | | <503 | | <106.5 | | <50.3 | | <14.1 | | <79.4 | |
| | Very Poor | | ≥1240 | | ≥203 | | ≥503 | | ≥106.4 | | >50.3 | | ≥14.1 | | ≥79.4 | |

***Table 11**. continued.*

| Site ID | River Mile | Drainage Area (sq. mi.) | Specific Conductance (µS/cm) | | Suspended Sediment Concentration (mg/L) | | Total Dissolved Solids (mg/L) | | Chloride (mg/L) | | Lead (µg/L) | | Copper (µg/L) | | Zinc (µg/L) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Median | Mean | Median | Mean | Median | Mean | Median | Mean | Median | Mean | Median | Mean | Median | Mean |
| ***Indian Creek*** | | | | | | | | | | | | | | | | |
| **IC06** | 2.25 | 0.58 | 920 | 900 | 6 | 5 | 528.0 | 520.0 | 71 | 70 | 0.0 | 0.0 | 0.0 | 0.2 | 8.5 | 6.1 |
| **IC05** | 2.08 | 1.07 | 870 | 873 | 8 | 11 | 504.0 | 516.0 | 67 | 68 | BD | BD | 1.2 | 1.1 | 5.4 | 8.2 |
| **IC02** | 1.15 | 1.38 | 995 | 1007 | 11 | 11 | 560.0 | 562.7 | 140 | 142 | 0.0 | 0.1 | 1.2 | 1.2 | 4.2 | 5.1 |
| **IC01** | 0.2 | 2.3 | 950 | 975 | 19 | 23 | 598.0 | 608.7 | 73 | 74 | 0.7 | 1.2 | 2.1 | 2.1 | 11.1 | 9.9 |
| ***Unnamed Tributary to Indian Creek @RM 1.02*** | | | | | | | | | | | | | | | | |
| **IC07** | 0.19 | 0.39 | 850 | 882 | 8 | 9 | 464.0 | 489.6 | 80 | 99 | 0.0 | 0.1 | 1.2 | 1.3 | 3.7 | 4.7 |
| ***Taylor Creek*** | | | | | | | | | | | | | | | | |
| **GM86** | 6.5 | 0.49 | 820 | 820 | 5 | 7 | 434.0 | 427.3 | 97 | 92 | 0.1 | 0.3 | 2.3 | 2.6 | 4.5 | 6.0 |
| **GM85** | 5.3 | 2.22 | 980 | 968 | 2 | 2 | 518.0 | 524.0 | 130 | 130 | 0.1 | 0.1 | 2.6 | 2.9 | 7.3 | 11.0 |
| ***Unnamed Tributary to Taylor Creek @RM 4.9*** | | | | | | | | | | | | | | | | |
| **GM106** | 0.28 | 0.92 | 870 | 805 | 1 | 2 | 470.0 | 421.3 | 120 | 107 | 0.0 | 0.0 | 2.1 | 1.9 | 8.3 | 12.0 |
| ***Briarly Creek*** | | | | | | | | | | | | | | | | |
| **GM91** | 3.9 | 0.34 | 710 | 729 | 2 | 7 | 388.0 | 372.0 | 85 | 91 | 0.1 | 1.1 | 2.0 | 2.2 | 5.3 | 6.6 |
| **GM90** | 2.55 | 1.3 | 600 | 583 | 4 | 8 | 272.0 | 269.7 | 67 | 64 | 0.3 | 0.2 | 2.1 | 2.1 | 5.3 | 7.3 |
| **GM89** | 1.98 | 2.1 | 670 | 632 | 13 | 14 | 364.0 | 344.7 | 73 | 69 | 0.4 | 0.4 | 2.2 | 2.1 | 7.6 | 6.9 |
| ***Wesselman Creek*** | | | | | | | | | | | | | | | | |
| **GM94** | 4.75 | 1.1 | 1200 | 1114 | 7 | 7 | 632.0 | 611.4 | 180 | 183 | 0.3 | 0.3 | 1.8 | 2.1 | 8.3 | 8.6 |
| ***Unnamed Trib to Wesselman Creek @RM 2.95*** | | | | | | | | | | | | | | | | |
| **GM100** | 1.28 | 0.91 | 860 | 838 | 6 | 12 | 452.0 | 444.0 | 89 | 90 | 0.3 | 0.3 | 2.3 | 2.3 | 3.0 | 4.1 |
| **Headwater Sites IPS Thresholds** | Excellent | | <397 | | <17.0 | | <284 | | <21.9 | | <2.7 | | <5.9 | | <16.4 | |
| | Good | | <703 | | <65.7 | | <364 | | <52.6 | | <17.4 | | <8.9/24.0* | | <39.3/300* | |
| | Fair | | <856 | | <165.3 | | <403 | | <68.0 | | <26.8 | | <10.4 | | <50.8 | |
| | Poor | | <1240 | | <203 | | <503 | | <106.5 | | <50.3 | | <14.1 | | <79.4 | |
| | Very Poor | | ≥1240 | | ≥203 | | ≥503 | | ≥106.4 | | >50.3 | | ≥14.1 | | ≥79.4 | |

***Table 12**. Sediment metals concentrations (mg/kg) for parameters with values >detection in the Ohio River Direct Tributaries study area in October 2023 (BD – below detection). Values above the MacDonald et al. (2000) Threshold Effect Concentration (TEL) and Probable Effect Concentration (PEC) thresholds or above Ohio Sediment Reference Values (SRVs) are shaded in accordance with the key at bottom.*

| Site ID | River Mile | Drainage Area (sq. mi.) | Arsenic (mg/kg) | Cadmium (mg/kg) | Calcium (mg/kg) | Copper (mg/kg) | Iron (mg/kg) | Lead (mg/kg) | Magnesium (mg/kg) | Zinc (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Muddy Creek*** | | | | | | | | | | |
| **MU05** | 6.25 | 5.39 | 1.70 | BD | 120000 | 13 | 8700 | 130 | 13000 | 44 |
| **MU04.5** | 5.60 | 7.71 | 6.50 | BD | 44000 | 20 | 26000 | 36 | 5700 | 66 |
| **MU04** | 5.40 | 7.8 | BD | BD | 39000 | 21 | 9600 | 38 | 3000 | 51 |
| **MU03** | 3.10 | 10.4 | BD | BD | 12000 | 9 | 9500 | 3.3 | 2500 | 26 |
| **MU02** | 2.25 | 12.1 | 1.30 | BD | 40000 | 13 | 9300 | 13 | 3400 | 35 |
| **MU01** | 0.20 | 13.6 | 1.80 | BD | 11000 | 10 | 8600 | 12 | 2200 | 35 |
| ***Rapid Run*** | | | | | | | | | | |
| **RR02** | 1.1 | 5.9 | BD | BD | 15000 | 16 | 15000 | 6 | 4700 | 35 |
| ***Wulff Run*** | | | | | | | | | | |
| **RR04** | 0.55 | 2.18 | BD | BD | 10000 | 13 | 7700 | 14 | 2300 | 46 |
| ***Indian Creek*** | | | | | | | | | | |
| **IC06** | 2.25 | 0.58 | 0.78 | BD | 6500 | 2.4 | 2900 | BD | 670 | 7.9 |
| **IC05** | 2.08 | 1.07 | 1.10 | BD | 17000 | 6.9 | 7100 | 5.5 | 1900 | 18 |
| **IC02** | 1.15 | 1.38 | BD | BD | 34000 | 4.9 | 6500 | BD | 2000 | 16 |
| **IC01** | 0.2 | 2.3 | 3.70 | BD | 8800 | 9.4 | 9100 | 7.4 | 1600 | 23 |
| ***Unnamed Tributary to Indian Creek @RM 1.02*** | | | | | | | | | | |
| **IC07** | 0.19 | 0.39 | 4.80 | BD | 66000 | 4.9 | 21000 | 8.1 | 3000 | 15 |
| ***Taylor Creek*** | | | | | | | | | | |
| **GM86** | 6.5 | 0.49 | BD | BD | 9400 | 7.7 | 6100 | 7.8 | 1400 | 23 |
| **GM85** | 5.3 | 2.22 | BD | BD | 20000 | 5.9 | 6100 | 11 | 4200 | 25 |
| ***Briarly Creek*** | | | | | | | | | | |
| **GM91** | 3.9 | 0.34 | 1.60 | BD | 25000 | 9.1 | 10000 | 17 | 1800 | 38 |
| **GM90** | 2.55 | 1.3 | BD | BD | 21000 | 11 | 11000 | 11 | 2500 | 31 |
| **GM89** | 1.98 | 2.1 | BD | BD | 20000 | 8 | 8300 | 9.9 | 1700 | 24 |
| ***Wesselman Creek*** | | | | | | | | | | |
| **GM94** | 4.75 | 1.1 | BD | BD | 11000 | 6 | 5600 | 6.8 | 1300 | 19 |
| MacDonald et al.(2000) TEC | | | 9.75 | 0.99 | | 31.6 | | 35.8 | | 121 |
| MacDonald et al.(2000) PEC | | | 33.00 | 4.98 | | 149 | | 128 | | 459 |
| Ohio EPA Sediment Refrence Values | | | 25.00 | 0.79 | | 32 | | 47 | | 160 |

based products. As such, multiple PAH compounds are commonly found in urbanized watersheds with a high density of asphalt paved surfaces and heavy automobile traffic and enter streams via runoff from highways and other paved surfaces.

For the 2023 assessment, sediment PAH results were valid at only 11 sites, the remainder being invalidated by laboratory errors. PEC levels were the most frequently exceeded for eight of the 16 PAH compounds that were analyzed for in the 2023 study area (Table 13). Similar to 2018, most exceedances occurred in Muddy Creek with eight (8) exceedances of the PEC threshold and four (4) exceedances of the TEC threshold among 13 of the 16 compounds. TEC and PEC exceedances also occurred in the Indian Creek and Taylor Creek subwatersheds, but at much lesser frequencies than Muddy Creek.

***Table 13**. Sediment PAH concentrations (µg/kg) for parameters with values >detection in the Ohio River Direct Tributaries study area in October 2023 (BD – below detection). Values above the MacDonald et al. (2000) TEC and PEC thresholds are shaded in accordance with the key at the bottom of the table.*

| Site ID | River Mile | Drainage Area (sq. mi.) | Acenaphthene (mg/kg) | Acenaphthylene (mg/kg) | Anthracene (mg/kg) | Benzo(a)anthracene (mg/kg) | Benzo(a)pyrene (mg/kg) | Benzo(b)fluoranthene (mg/kg) | Benzo(ghi)perylene (mg/kg) | Benzo(k)fluoranthene (mg/kg) | Chrysene (mg/kg) | Dibenzo(a,h)anthracene (mg/kg) | Fluoranthene (mg/kg) | Fluorene (mg/kg) | Indeno(1,2,3-cd)pyrene (mg/kg) | Naphthalene (mg/kg) | Phenanthrene (mg/kg) | Pyrene (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Muddy Creek*** | | | | | | | | | | | | | | | | | | |
| **MU04.5** | 5.6 | 7.71 | 0.240 | 0.093 | 0.810 | 4.000 | 5.400 | 7.500 | 3.800 | 2.400 | 5.400 | 0.840 | 13.000 | 0.370 | 4.100 | BD | 7.300 | 10.000 |
| **MU04** | 5.4 | 7.8 | 0.058 | 0.047 | 0.220 | 1.700 | 2.400 | 3.500 | 1.900 | 1.100 | 2.300 | 0.380 | 4.800 | 0.084 | 1.900 | BD | 1.700 | 3.800 |
| **MU03** | 3.1 | 10.4 | 0.018 | BD | 0.046 | 0.200 | 0.240 | 0.320 | 0.160 | 0.120 | 0.240 | 0.039 | 0.580 | 0.025 | 0.160 | BD | 0.310 | 0.450 |
| ***Indian Creek*** | | | | | | | | | | | | | | | | | | |
| **IC06** | 2.25 | 0.58 | BD | BD | BD | 0.045 | 0.071 | 0.100 | 0.047 | 0.041 | 0.069 | 0.012 | 0.130 | BD | 0.049 | BD | 0.051 | 0.110 |
| **IC05** | 2.08 | 1.07 | BD | 0.012 | 0.044 | 0.490 | 0.760 | 1.100 | 0.540 | 0.410 | 0.820 | 0.110 | 1.700 | 0.023 | 0.590 | BD | 0.560 | 1.400 |
| **IC02** | 1.15 | 1.38 | BD | BD | BD | 0.094 | 0.160 | 0.230 | 0.110 | 0.081 | 0.160 | 0.023 | 0.300 | BD | 0.120 | BD | 0.087 | 0.250 |
| **IC01** | 0.2 | 2.3 | BD | BD | 0.012 | 0.030 | 0.036 | 0.040 | 0.018 | 0.015 | 0.028 | BD | 0.068 | BD | 0.019 | 0.031 | 0.035 | 0.057 |
| ***Unnamed Tributary to Indian Creek @RM 1.02*** | | | | | | | | | | | | | | | | | | |
| **IC07** | 0.19 | 0.39 | 0.011 | 0.011 | 0.083 | 0.430 | 0.560 | 0.860 | 0.380 | 0.260 | 0.620 | 0.079 | 1.400 | 0.027 | 0.400 | BD | 0.540 | 1.200 |
| ***Taylor Creek*** | | | | | | | | | | | | | | | | | | |
| **GM85** | 5.3 | 2.22 | BD | 0.016 | 0.049 | 0.240 | 0.290 | 0.410 | 0.220 | 0.130 | 0.310 | 0.044 | 0.620 | 0.015 | 0.230 | BD | 0.220 | 0.570 |
| ***Briarly Creek*** | | | | | | | | | | | | | | | | | | |
| **GM90** | 2.55 | 1.3 | BD | 0.012 | 0.045 | 0.260 | 0.400 | 0.610 | 0.300 | 0.200 | 0.390 | 0.059 | 0.750 | 0.015 | 0.290 | BD | 0.220 | 0.590 |
| **GM89** | 1.98 | 2.1 | 0.057 | 0.080 | 0.230 | 0.790 | 0.950 | 1.200 | 0.540 | 0.420 | 0.910 | 0.120 | 2.200 | 0.120 | 0.550 | 0.021 | 1.200 | 1.700 |
| MacDonald et al.(2000) TEC/TEL | | | 0.067 | 0.059 | 0.057 | 0.108 | 0.150 | 0.240 | 0.170 | 0.240 | | 0.067 | 0.033 | 0.423 | 0.077 | 0.200 | 0.176 | 0.204 |
| MacDonald et al.(2000) PEC/PEL | | | 0.889 | 0.128 | 0.845 | 1.050 | 1.450 | 13.400 | 0.320 | 13.400 | | 0.135 | 0.135 | 2.230 | 0.534 | 3.700 | 0.561 | 1.170 |

## Stream Habitat

The assessment of stream and river habitat is based on the QHEI and its metrics, submetrics, and individual attributes (Figure 9). Habitat quality is an important determinant of biological potential, and it factors into the determination of causes of impairment and use attainability analyses, the latter of which were mostly accomplished in 2014 and verified in 2018 and 2023.

QHEI scores ranged mostly from poor to good throughout the 2023 study area, although seven of the 10 good sites barely eclipsed the good QHEI of 55 for headwater sites (Figure 9). Two sites in Muddy Creek (MU01, MU03) and an unnamed tributary (MU14) showed evidence of prior channel disturbances and the site at the mouth of Muddy Creek (MU01) is a modified backwater of the impounded Ohio River. The ratio of modified:good attributes was elevated (>4.00) at MU05, reflecting prior alterations due to instream sewer line construction, and in upper Taylor Creek at GM86 (RM 6.50) with a very poor ratio of 10.00, a substantial departure from 2018. Other sites with elevated ratios included IC02 in Indian Creek, and GM85 in Taylor Creek. All other sites had fair to good habitat and 15 sites had modified:good attribute ratios of >2.00, a result similar to 2018. Sites with modified:good ratios >2.00 had high influence modified attributes such as recent channelization, sparse or no cover, and/or pool depths <40 cm. Other modified attributes that frequently occurred included recovering from channelization, moderate-high siltation, low sinuosity, no fast current types, moderate-extensive embeddedness, and no riffles.

Portions of Rapid Run and Wulff Run have been altered by prior, extreme habitat disturbances related to the placement of sewer lines directly in the stream channel (Ohio EPA 1992). In 1992 these streams were recommended to be assigned the LRW aquatic life use because the initial alterations resulted in a near dewatering of the stream channel resulting in very poor fish and macroinvertebrate assemblages (Ohio EPA 1992) and little prospect for natural recovery. Most small streams in Hamilton Co. are susceptible to this type of damage because the stream beds are perched on limestone bedrock layers above an alternation of layers of softer, blue-grey shales that are erodible. Destruction of the limestone bedrock layers by trenching for the installation of sewer lines destabilized the substrate and created “debris torrents” consisting of large limestone slabs and unconsolidated shale materials. Because of the size and volume of this material and the small size of the streams it was concluded in 1992 that recovery would be unlikely and LRW would be the attainable near-term condition. Indeed, the streams were not able to readily move or export this unconsolidated material. However, in the intervening 23 years between 1991 and the 2014 assessments these streams responded in an unanticipated manner that resulted in incremental physical and biological improvements (Table 14). Over time the interstitial gaps in the debris torrent have become filled by sand, gravel, and other fines (MBI 2015a). In essence, the wetted channel is now perched on these materials such that pools and riffles have regained some positive functions to offer more suitable habitat. However, the channel still is not close to approximating the pre-disturbance conditions when QHEI scores would have been good to excellent. The permanent destruction of the limestone bedrock stream bed precludes this. The incrementally improved habitat resulted in fair quality biological index scores in 2014 compared to the very poor and poor results in 1991 (Table 14).

***Figure 8**. Qualitative Habitat Evaluation Index (QHEI) scores showing good and modified habitat attributes at sites in the Ohio River Direct Tributaries study area in 2023. Modified:good ratios are color coded in accordance with the legend at the bottom of the table.*

| | | | Good Habitat Attributes | | | | | | | | | | | High Influence Modified Attributes | | | | | | Moderate Influence Modified Attributes | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Site ID | River Mile | QHEI | No Channelization | Boulder, Cobble, Gravel | Silt Free | Good-Excellent Development | Moderate-High Sinuosity | Moderate-Extensive Cover | Fast Flow w Eddies | Little to No Embeddedness | Max Depth > 40 cm | No Riffle Embeddedness | Good Habitat Attributes | Channelized or No Recovery | Silt/Muck Substrates | No Sinuosity | Sparse No Cover | Max Depths <40 cm | High Influence Poor Attributes | Recovering from Channelization | Mod-High Silt Cover | Sand Substrates (Boatable sites) | Hardpan Origin | Fair- Poor Development | Low Sinuosity | < 2 Cover Types | Intermittent Flow or Pools <20 cm | No Fast Current Types | Mod-Extensive Embeddedness | Mod-Extensive Riffle Embeddedness | No Riffle | Poor Habitat Attributes | Ratio of Modified (High) to Good | Ratio of Modified (All) to Good |
| ***Muddy Creek*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| MU05 | 6.35 | 39.50 | | ■ | | | | | | | ■ | | 2 | ● | | | ● | | 2 | | ● | | | ● | ● | ● | | ● | ● | | ● | 7 | 1.00 | 4.50 |
| MU04.5 | 5.62 | 61.50 | | ■ | ■ | | | ■ | | ■ | | ■ | 5 | | | | ● | ● | 2 | ● | | | | ● | ● | | | ● | | | | 4 | 0.40 | 1.20 |
| MU04 | 5.45 | 64.30 | | ■ | ■ | ■ | | ■ | | ■ | ■ | ■ | 7 | | | | | | 0 | ● | | | | ● | ● | | | ● | | | | 4 | 0.00 | 0.57 |
| MU03 | 2.80 | 56.30 | | ■ | ■ | | ■ | | | | ■ | ■ | 5 | | | | ● | | 1 | ● | | | | ● | | | | ● | ● | | | 4 | 0.20 | 1.00 |
| MU02 | 2.25 | 63.50 | ■ | ■ | | | | ■ | | ■ | ■ | ■ | 6 | | | | | | 0 | | ● | | | ● | ● | | | ● | ● | ● | | 6 | 0.00 | 1.00 |
| MU01 | 0.17 | 49.00 | ■ | | | | ■ | ■ | | | ■ | | 4 | | ● | | | | 1 | | ● | | | ● | | | | ● | ● | | ● | 5 | 0.25 | 1.50 |
| ***Unnamed Tributary to Muddy Creek @RM 2.37*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| MU10 | 0.50 | 53.30 | | ■ | | | ■ | ■ | | | | | 3 | | | | | ● | 1 | ● | ● | | | ● | ● | | | ● | ● | | ● | 7 | 0.33 | 2.67 |
| ***Unnamed Tributary to Muddy Creek @RM 5.97*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| MU12 | 0.55 | 47.50 | | ■ | | | | ■ | | ■ | ■ | | 4 | | | ● | ● | | 2 | ● | ● | | | ● | ● | | | ● | ● | | ● | 7 | 0.50 | 2.25 |
| ***Unnamed Tributary to Muddy Creek @RM 6.53*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| MU13 | 0.60 | 41.00 | | ■ | | | | | | ■ | ■ | | 3 | | | | ● | | 1 | ● | ● | | | ● | ● | | | ● | ● | | ● | 7 | 0.33 | 2.67 |
| ***Unnamed Tributary to Muddy Creek @RM 0.30*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| MU07.5 | 0.80 | 56.00 | | ■ | | | | ■ | | ■ | | ■ | 4 | | | | | ● | 1 | ● | ● | | | ● | ● | | | ● | ● | | | 6 | 0.25 | 1.75 |
| ***Fiddlers Creek RM 0.95 to W. Branch Muddy Creek to Muddy Creek @RM 0.3*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| MU09 | 0.10 | 55.50 | | ■ | | | ■ | ■ | | | | ■ | 4 | | | | ● | ● | 2 | ● | ● | | | ● | ● | | | ● | ● | | | 6 | 0.50 | 2.00 |
| ***Rapid Run*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| RR02 | 1.05 | 51.00 | | ■ | | | | ■ | | ■ | | | 3 | | | | ● | ● | 2 | ● | | | | ● | ● | | | ● | | | ● | 5 | 0.67 | 2.33 |
| ***Wulff Run*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| RR04 | 0.45 | 50.00 | | ■ | | | | ■ | | ■ | | | 3 | | | | ● | ● | 2 | ● | ● | | | ● | ● | | | ● | ● | | ● | 7 | 0.67 | 3.00 |
| ***Unnamed Tributary to Wulff Run @RM 0.77*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| RR05.5 | 0.40 | 49.50 | | ■ | | | ■ | ■ | | | | | 3 | | | | ● | ● | 2 | ● | ● | | | ● | | | | ● | ● | | ● | 6 | 0.67 | 2.67 |
| RR04.5 | 0.35 | 54.00 | | ■ | | | | ■ | | ■ | | | 3 | | | | | ● | 1 | ● | ● | | | ● | ● | | | ● | ● | | ● | 7 | 0.33 | 2.67 |
| QHEI Narra-tive | Excellent | ≥70 | | | | | | | | | | | ≥8 | | | | | | 0 | | | | | | | | | | | | | ≤1 | <0.20 | ≤0.50 |
| | Good | ≥55 | | | | | | | | | | | ≥6 | | | | | | 0 | | | | | | | | | | | | | ≤4 | <0.50 | ≤2.00 |
| | Fair | ≥43 | | | | | | | | | | | ≥3 | | | | | | 1 | | | | | | | | | | | | | ≤5 | ≥0.51 | >2.00 |
| | Poor | ≥30 | | | | | | | | | | | ≥2 | | | | | | 2 | | | | | | | | | | | | | ≥6 | >2.00 | >6.00 |
| | Very Poor | <30 | | | | | | | | | | | ≤1 | | | | | | 3 | | | | | | | | | | | | | ≥7 | >4.00 | >10.00 |

***Figure 8**. continued.*

| | | | Good Habitat Attributes | | | | | | | | | | | High Influence Modified Attributes | | | | | | Moderate Influence Modified Attributes | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Site ID | River Mile | QHEI | No Channelization | Boulder, Cobble, Gravel | Silt Free | Good-Excellent Development | Moderate-High Sinuosity | Moderate-Extensive Cover | Fast Flow w Eddies | Little to No Embeddedness | Max Depth > 40 cm | No Riffle Embeddedness | Good Habitat Attributes | Channelized or No Recovery | Silt/Muck Substrates | No Sinuosity | Sparse No Cover | Max Depths <40 cm | High Influence Poor Attributes | Recovering from Channelization | Mod-High Silt Cover | Sand Substrates (Boatable sites) | Hardpan Origin | Fair- Poor Development | Low Sinuosity | < 2 Cover Types | Intermittent Flow or Pools <20 cm | No Fast Current Types | Mod-Extensive Embeddedness | Mod-Extensive Riffle Embeddedness | No Riffle | Poor Habitat Attributes | Ratio of Modified (High) to Good | Ratio of Modified (All) to Good |
| ***Indian Creek*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **IC06** | 2.30 | **53.50** | | ■ | | | | ■ | | ■ | | | 3 | | | | ● | ● | 1 | ● | ● | | | ● | ● | | | ● | ● | | ● | 7 | 0.33 | 2.67 |
| **IC05** | 2.08 | **55.00** | | ■ | | | | ■ | | | ■ | | 3 | | | | ● | | 1 | ● | ● | | | ● | ● | | | ● | ● | | ● | 7 | 0.33 | 2.67 |
| **IC02** | 1.15 | **48.00** | | ■ | | | | ■ | | | | | 2 | | | | ● | ● | 2 | ● | ● | | | ● | ● | | | ● | ● | | ● | 7 | 1.00 | 4.50 |
| **IC01** | 0.30 | **50.00** | | ■ | | | | ■ | | | ■ | | 3 | | | | | | 0 | ● | ● | | | ● | ● | | | ● | ● | | ● | 7 | 0.00 | 2.33 |
| **IC07** | 0.10 | **50.00** | ■ | ■ | | | | ■ | | | | | 3 | | | | ● | ● | 2 | | ● | | | ● | ● | | | ● | ● | | ● | 6 | 0.67 | 2.67 |
| ***Taylor Creek*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **GM86** | 6.40 | **40.30** | | | | | | | | | | | 0 | | | | ● | ● | 2 | ● | ● | | | ● | ● | | | ● | ● | | ● | 7 | 3.00 | 10.00 |
| **GM85** | 5.30 | **44.00** | | ■ | | | | | | ■ | | | 2 | | | ● | ● | ● | 3 | ● | ● | | | ● | ● | | | ● | ● | | ● | 7 | 1.50 | 5.00 |
| ***Briarly Creek*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **GM91** | 3.90 | **58.50** | ■ | ■ | | | ■ | ■ | | ■ | ■ | | 6 | | | | | | 0 | ● | ● | | | ● | | | | ● | | | ● | 5 | 0.00 | 0.83 |
| **GM90** | 2.45 | **49.50** | | | | | | ■ | | ■ | | ■ | 3 | | | | ● | ● | 2 | ● | ● | | | ● | ● | | | ● | ● | | | 6 | 0.67 | 2.67 |
| **GM89** | 1.80 | **53.50** | | ■ | | | | ■ | | ■ | | ■ | 4 | | | | ● | ● | 2 | ● | ● | | | ● | ● | | | ● | | | | 5 | 0.50 | 1.75 |
| ***Wesselman Creek*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **GM94** | 4.70 | **55.00** | | ■ | | | | | | ■ | | | 2 | | | | ● | ● | 2 | ● | ● | | | ● | ● | | | ● | | ● | | 6 | 1.00 | 4.00 |
| ***Unnamed Tributary to Wesselman Creek @RM 2.5*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **GM100** | 1.05 | **46.50** | | ■ | | | | ■ | | ■ | ■ | ■ | 5 | | | | ● | | 1 | ● | ● | | | ● | ● | | | ● | ● | | | 6 | 0.20 | 1.40 |
| ***Unnamed Tributary to Taylor Creek @RM 4.9*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **GM106** | 0.20 | **57.00** | ■ | ■ | | | | ■ | | ■ | ■ | ■ | 6 | | | | | | 0 | | ● | | | ● | ● | | | ● | ● | | | 5 | 0.00 | 0.83 |
| **QHEI Narra-tive** | **Excellent** | ≥70 | | | | | | | | | | | ≥8 | | | | | | 0 | | | | | | | | | | | | | ≤1 | <0.20 | <0.50 |
| | **Good** | ≥55 | | | | | | | | | | | ≥6 | | | | | | 0 | | | | | | | | | | | | | ≤4 | <0.50 | ≤2.00 |
| | **Fair** | ≥43 | | | | | | | | | | | ≥3 | | | | | | 1 | | | | | | | | | | | | | ≤5 | ≥0.51 | >2.00 |
| | **Poor** | ≥30 | | | | | | | | | | | ≥2 | | | | | | 2 | | | | | | | | | | | | | ≥6 | >2.00 | >6.00 |
| | **Very Poor** | <30 | | | | | | | | | | | ≤1 | | | | | | 3 | | | | | | | | | | | | | ≥7 | >4.00 | >10.00 |

***Table 14**. Summary of biological and habitat trends at station RR02 (RM 1.2) in Rapid Run in 1991, 2014, 2018, and 2023.*

| Year | IBI | Fish Species | ICI Narrative | Qual. EPT Taxa | QHEI | Habitat Attributes | | Poor:Good Ratio |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Good | Poor | |
| 1991 | 12* | 2 | P* | 4 | 36.5 | 2 | 10 | 3.67 |
| 2014 | 24 | 6 | F | 7 | 56.5 | 7 | 2 | 0.28 |
| 2018 | 30 | 4 | F | 6 | 45.5 | 3 | 8 | 2.67 |
| 2024 | 24 | 5 | MG | 8 | 51.0 | 3 | 7 | 2.33 |
| Narrative Thresholds | >50 | >25 | E | >16 | ≥70 | ≥8 | 0 | <0.50 |
| | >40 | >14 | G | >11 | ≥55 | ≥6 | 0 | <2.00 |
| | >26 | >10 | F | >6 | ≥43 | ≤3 | 1 | >2.00 |
| | >18 | >7 | P | >2 | ≥30 | ≥2 | 2 | >6.00 |
| | <18 | ≤7 | VP | <2 | <30 | 0 | 3 | >10.00 |

The biological scores were incrementally improved at this site in 2018 with the fish IBI showing the most improvement. However, habitat quality was reduced to fair compared to 2014 with modified attributes outnumbering good attributes. In addition, stream dewatering was evident in Rapid Run in 2018 as two sites (RR01 and RR03) could not be sampled for fish. In 2023 the fish IBI declined to poor, the same as 2014. However, the macroinvertebrate narrative increased to Marginally Good and the QHEI improved slightly to fair. Despite this incremental improvement we recommend that the LRW use designation be retained and that any consideration of upgrading to WWH be deferred until the next cycle of bioassessment in 2028. Stream habitat in the upper Taylor Creek and Indian Creek subwatersheds ranged from poor to mostly fair with four good sites which is a slight decline in habitat quality compared to 2018.

## Biological Assemblages

Fish and macroinvertebrates were sampled at all 34 sites in 2023 following standardized procedures specified by the 2011 Plan (MBI 2011) and consistent with Level 3 specifications and the Ohio WQS. Eight (8) of these sites were either verified or recommended for the Primary Headwater Habitat (PHWH) classification in 2018 and 2023, thus 26 sites were evaluated against the fish and macroinvertebrate biological criteria for the WWH suite of uses.

### *Fish Assemblage Results*

There were 36 species and two hybrids collected in the 2023 study area. The predominant fish species were Central Stoneroller, Blacknose Dace, Creek Chub, and Bluntnose Minnow. Rapid Run was the least diverse subwatershed with only five species predominated by Creek Chub, Central Stoneroller, and Blacknose Dace. Indian Creek had 11 species predominated by Creek Chub, Bluegill, Central Stoneroller, and Blacknose Dace. Upper Taylor Creek had 11 species predominated by Creek Chub and Central Stoneroller. These associations are typical of headwater streams in urbanized settings.

IBI results for each of the subwatersheds are portrayed as box-and-whisker plots for all sites in 2014, 2018, and 2023 (Figure 11). The results between subwatersheds were variable with

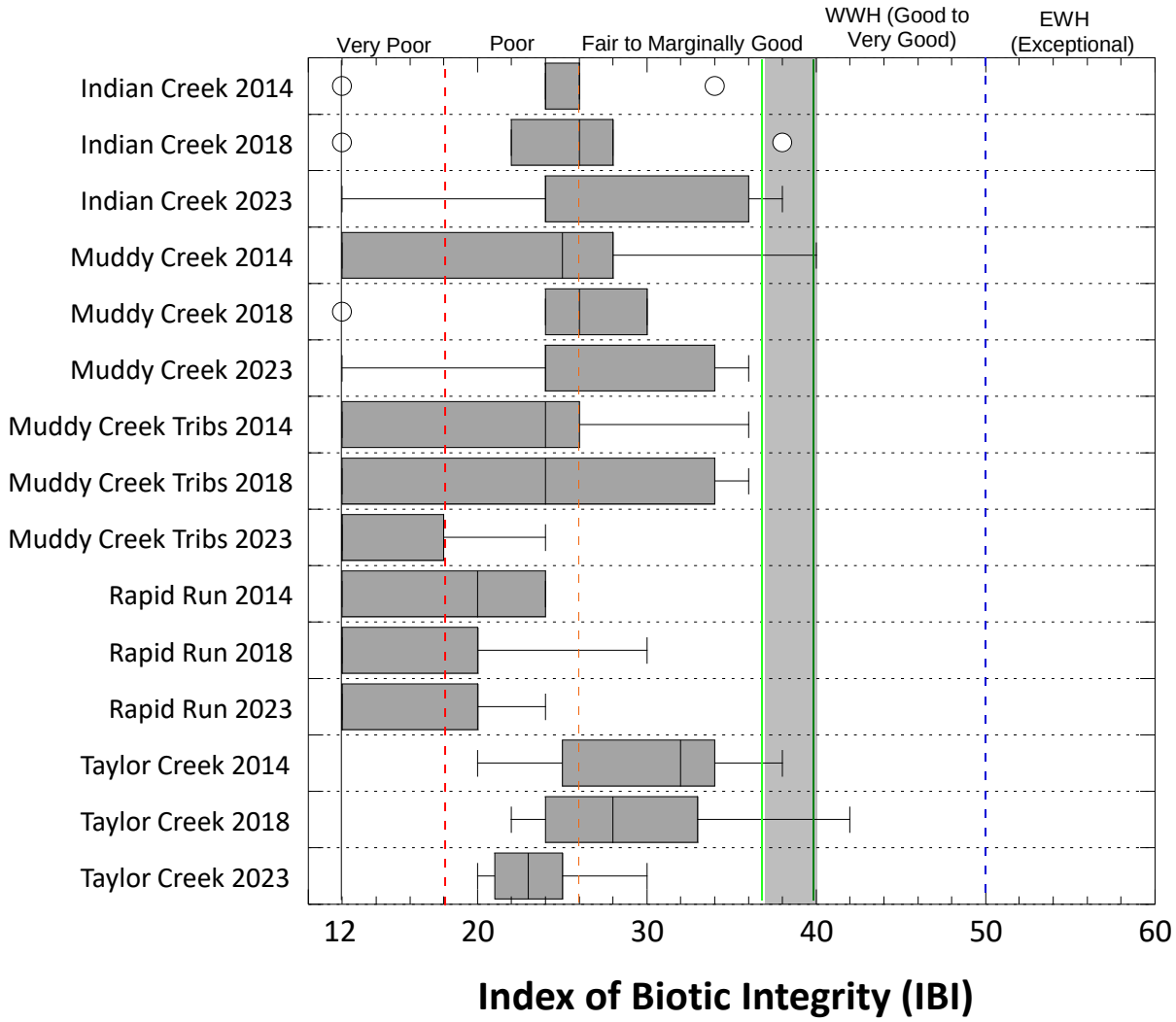


***Figure 9**. IBI scores for Direct Ohio River Tributaries subwatersheds in 2014, 2018, and 2023 shown as box-and-whisker plots of all IBI values by subwatershed in each year. The WWH biocriteria and Ohio EPA thresholds for narrative categories (exceptional, very good-good, marginally good, fair, poor, and very poor) are indicated by dashed lines.*

trends of increase in selected subwatersheds between 2014-2023. Only a few sites have met the WWH IBI biocriterion in all three survey years. General improvements occurred in Indian Creek and Muddy Creek, but declines were evident in the Muddy Creek tributaries, Rapid Run, and Taylor Creek the latter the most significant and concerning of all. Key fish assemblage indices and attributes such as %DELT, sensitive species, and %tolerant species are depicted in Table 15. Sensitive species were absent at all except five sites and tolerant species exceeded the toxic response threshold of >70% at 13 sites up from eight sites in 2018. However, %DELT anomalies were zero at all sites ruling out a response to acutely toxic conditions. All of the responses instead point to organic enrichment and habitat limitations as they did in 2018.

The longitudinal profile of IBI results in the mainstem of Muddy Creek showed a repetitive

longitudinal trend of minimum values in the very poor range at the two upstream sites that are closest to the wet weather sewage sources with a relatively rapid recovery to fair at MU04 increasing to marginal attainment of WWH in 2023 and full attainment in 2014 with a decline at the habitat modified Ohio River backwater site (Figure 11). This demonstrates incremental improvement at best with still serious impairments from sources in upper Muddy Creek.

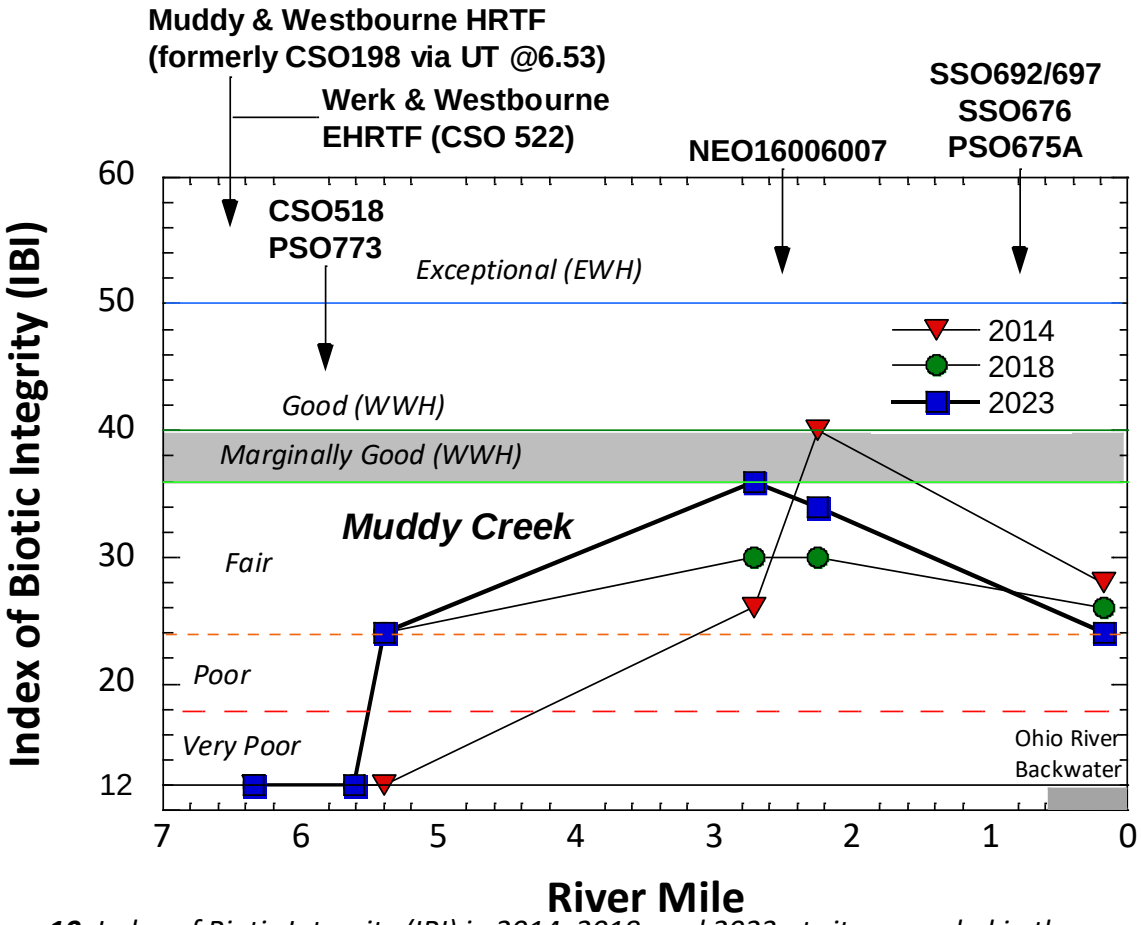


***Figure 10**. Index of Biotic Integrity (IBI) in 2014, 2018, and 2023 at sites sampled in the mainstem of Muddy Creek. Major pollution sources are indicated along the x2 axis. The Ohio biocriteria and narrative quality classes are depicted by horizontal lines.*

***Macroinvertebrate Assemblage Results***

Macroinvertebrates were judged by the WWH suite of uses at 26 sites, the remaining eight as PHW3A (7 sites) and PHW2 (1 site). Of the WWH designated sites, six (down from 8 in 2018) met the WWH narrative or the ICI. The remainder ranged from very poor to fair. Key macroinvertebrate assemblage indices and attributes are depicted in Table 16. Sites with a high proportion of tolerant taxa and organic enrichment taxa indicative of that response signature occurred in the Muddy Creek mainstem, the unnamed tributary to Muddy Creek at RM 6.53, and the upstream most site in Rapid Run, all of which are directly impacted by CSOs, SSOs, or NEOs. Toxic responses were observed at low levels and all in Muddy Creek. Organic tolerant taxa were the most prevalent in Muddy Creek as well.

***Table 15**. Selected fish assemblage attributes and response signatures at 34 sites sampled in the Ohio River Direct Tributaries study area in 2023. Color shaded cells indicate the degree of exceedance of a poor, very poor, or organic enrichment or toxic response signature threshold for an index, metric, or attribute value in accordance with the key at the bottom of the table.*

| Site ID | River Mile | Drainage Area (mi.$^2$) | IBI | Native Species | % DELT Anomalies | Sensitive Species | % Simple Lithophils | % Tolerant |
|---|---|---|---|---|---|---|---|---|
| ***Muddy Creek*** | | | | | | | | |
| MU05 | 6.35 | 5.39 | 12*Θ | 2 | 0 | 0 | 0.0 | 80.0 |
| MU04.5 | 5.62 | 7.71 | 12*Θ | 1 | 0 | 0 | 0.0 | 90.0 |
| MU04 | 5.45 | 7.80 | 24*Θ | 2 | 0 | 0 | 0.0 | 95.5 |
| MU03 | 2.80 | 10.40 | 36$^{ns}$↑ | 9 | 0 | 2 | 13.1 | 19.6 |
| MU02 | 2.25 | 12.10 | 34*Θ | 11 | 0 | 3 | 25.0 | 37.1 |
| MU01 | 0.17 | 13.60 | 12*Θ | 21 | 0 | 3 | 2.8 | 3.7 |
| ***Unnamed Tributary to Muddy Creek @ RM2.37*** | | | | | | | | |
| MU10 | 0.50 | 0.71 | 12$^a$Θ | 0 | 0 | 0 | 0.0 | 0.0 |
| ***Unnamed Tributary to Muddy Creek @ RM 5.97*** | | | | | | | | |
| MU12 | 0.55 | 1.01 | 24*↓ | 2 | 0 | 0 | 0.0 | 94.4 |
| ***Unnamed Tributary to Muddy Creek @ RM 6.53*** | | | | | | | | |
| MU13 | 0.60 | 2.25 | 12*$^a$Θ | 0 | 0 | 0 | 0.0 | 0.0 |
| ***Unnamed Tributary to Unnamed Tributary to Muddy Creek @ RM 5.97*** | | | | | | | | |
| MU14 | 0.20 | 0.09 | DryΘ | **Not sampled** | | | | |
| ***Unnamed Tributary to Muddy Creek @RM 0.3*** | | | | | | | | |
| MU08 | 1.72 | 0.74 | Dry↓ | **Not sampled** | | | | |
| MU07.5 | 0.80 | 2.60 | 32*Θ | 7 | 0 | 1 | 44.5 | 57.8 |
| MU07 | 0.40 | 2.80 | Dry↓ | **Not sampled** | | | | |
| ***Fiddlers Creek RM 0.95 to W. Branch Muddy Creek to Muddy Creek @RM 0.3*** | | | | | | | | |
| MU09 | 0.10 | 1.31 | 24Θ | 3 | 0 | 0 | 55.9 | 100.0 |
| ***Rapid Run*** | | | | | | | | |
| RR03 | 2.70 | 2.32 | DryΘ | **Not sampled** | | | | |
| RR02 | 1.05 | 5.90 | 24↓ | 5 | 0 | 0 | 35.5 | 69.7 |
| RR01 | 0.10 | 6.56 | DryΘ | **Not sampled** | | | | |
| ***Wulff run*** | | | | | | | | |
| RR05 | 1.45 | 1.33 | DryΘ | **Not sampled** | | | | |
| RR04 | 0.45 | 2.18 | 20Θ | 1 | 0 | 0 | 0.0 | 100.0 |
| ***Unnamed Tributary to Wulff Run @ RM 0.77*** | | | | | | | | |
| RR05.5 | 0.40 | 0.33 | 12$^a$Θ | 0 | 0 | 0 | 0.0 | 0.0 |
| RR04.5 | 0.35 | 0.33 | 12Θ | 1 | 0 | 0 | 0.0 | 0.0 |
| **Narrative Thresholds** | | | >50 | >25 | 0 | >15 | >30 | ≤15 |
| | | | >40 | >14 | <1.3 | 11-15 | >20-30 | >15-30 |
| | | | >26 | >10 | 1.3-3 | 3-10 | >10-20 | >30-50 |
| | | | >18 | >7 | 3-10 | 1-2 | >5-10 | >50-70 |
| | | | <18 | ≤7 | >10 | 0 | ≤5 | ≥70 |

***Table 15**. continued.*

| Site ID | River Mile | Drainage Area (mi.$^2$) | IBI | Native Species | % DELT Anomalies | Sensitive Species | % Simple Lithophils | % Tolerant |
|---|---|---|---|---|---|---|---|---|
| ***Indian Creek*** | | | | | | | | |
| IC06 | 2.30 | 0.58 | 24*Θ | 3 | 0 | 0 | 32.4 | 99.3 |
| IC05 | 2.08 | 1.07 | 38$^{ns}$Θ | 3 | 0 | 0 | 8.7 | 27.2 |
| IC02 | 1.15 | 1.38 | 36$^{ns}$↑ | 5 | 0 | 0 | 9.5 | 43.3 |
| IC01 | 0.30 | 2.30 | 24*Θ | 9 | 0 | 1 | 16.1 | 75.3 |
| ***Tributary to Indian Creek @RM 1.02 at RM 0.97*** | | | | | | | | |
| IC07 | 0.10 | 0.39 | 12$^{a}$Θ | 0 | 0 | 0 | 0.0 | 0.0 |
| ***Taylor Creek*** | | | | | | | | |
| GM86 | 6.40 | 0.49 | 22*↓ | 2 | 0 | 0 | 0.0 | 68.4 |
| GM85 | 5.30 | 2.22 | 20*↓ | 4 | 0 | 0 | 1.4 | 62.5 |
| ***Briarly Creek*** | | | | | | | | |
| GM91 | 3.90 | 0.34 | 24Θ | 3 | 0 | 0 | 0.0 | 84.6 |
| GM90 | 2.45 | 1.30 | 22*Θ | 3 | 0 | 0 | 0.0 | 96.8 |
| GM89 | 1.80 | 2.10 | 24*↓ | 3 | 0 | 0 | 8.9 | 66.7 |
| ***Wesselman Creek*** | | | | | | | | |
| GM94 | 4.70 | 1.10 | 26↑ | 4 | 0 | 0 | 0.0 | 91.9 |
| ***Unnamed Tributary to Wesselman Creek @ RM 2.59*** | | | | | | | | |
| GM100 | 1.05 | 0.91 | 20Θ | 1 | 0 | 0 | 0.0 | 100.0 |
| ***Unnamed Tributary to Taylor Creek @ RM 4.9*** | | | | | | | | |
| GM106 | 0.20 | 0.92 | 30*↓ | 5 | 0 | 0 | 0.8 | 71.5 |
| **Narrative Thresholds** | | | >50 | >25 | 0 | >15 | >30 | ≤15 |
| | | | >40 | >14 | <1.3 | 11-15 | >20-30 | >15-30 |
| | | | >26 | >10 | 1.3-3 | 3-10 | >10-20 | >30-50 |
| | | | >18 | >7 | 3-10 | 1-2 | >5-10 | >50-70 |
| | | | <18 | ≤7 | >10 | 0 | ≤5 | ≥70 |

***Table 16**. Selected macroinvertebrate assemblage attributes and response signatures at 34 sites sampled in the Ohio River Direct Tributaries study area in 2023. Color shaded cells indicate the degree of exceedance of a poor, very poor, or organic enrichment or toxic response signature threshold for an index, metric, or attribute value in accordance with the key at the bottom of the table.*

| Site ID | River Mile | Drainage Area (mi.$^2$) | ICI or Narrative | Total Taxa | Sensitive Taxa | Qual. EPT Taxa | #Toxic Tolerant Taxa | #Organic Enrich-ment Taxa |
|---|---|---|---|---|---|---|---|---|
| ***Muddy Creek*** | | | | | | | | |
| **MU05** | 6.35 | 5.39 | a | 12 | 0 | 0 | 1 | 3 |
| **MU04.5** | 5.62 | 7.71 | VPΘ | 15 | 1 | 0 | 2 | 4 |
| **MU04** | 5.45 | 7.80 | VPΘ | 16 | 0 | 1 | 1 | 4 |
| **MU03** | 2.80 | 10.40 | $28^{ns}$↑ | 36 | 4 | 9 | 1 | 6 |
| **MU02** | 2.25 | 12.10 | 36Θ | 44 | 3 | 8 | 2 | 6 |
| **MU01** | 0.17 | 13.60 | No Data | | | | | |
| ***Unnamed Tributary to Muddy Creek @ RM 2.37*** | | | | | | | | |
| **MU10** | 0.50 | 0.71 | Θ | 32 | 4 | 10 | 0 | 1 |
| ***Unnamed Tributary to Muddy Creek @ RM 5.97*** | | | | | | | | |
| **MU12** | 0.55 | 1.01 | F*↑ | 19 | 3 | 6 | 0 | 1 |
| ***Unnamed Tributary to Muddy Creek @ RM 6.53*** | | | | | | | | |
| **MU13** | 0.60 | 2.25 | VP*Θ | 10 | 0 | 0 | 0 | 4 |
| ***Unnamed Tributary to Unnamed Tributary to Muddy Creek @ RM 5.9*** | | | | | | | | |
| **MU14** | 0.20 | 0.09 | No Data | | | | | |
| ***Unnamed Tributary to Muddy Creek @RM 0.3*** | | | | | | | | |
| **MU08** | 1.72 | 0.74 | Θ | 25 | 4 | 9 | 0 | 2 |
| **MU07.5** | 0.80 | 2.60 | F*Θ | 23 | 2 | 5 | 0 | 5 |
| **MU07** | 0.40 | 2.60 | No Data | | | | | |
| ***Fiddlers Creek RM 0.95 to W. Branch Muddy Creek to Muddy Creek @RM 0.3*** | | | | | | | | |
| **MU09** | 0.10 | 1.31 | Θ | 29 | 3 | 8 | 0 | 2 |
| ***Rapid Run*** | | | | | | | | |
| **RR03** | 2.70 | 2.32 | MG↑ | 25 | 4 | 7 | 0 | 4 |
| **RR02** | 1.05 | 5.90 | MG↑ | 27 | 3 | 8 | 0 | 5 |
| **RR01** | 0.10 | 6.56 | VP*↓ | 9 | 1 | 1 | 0 | 4 |
| ***Wulff Run*** | | | | | | | | |
| **RR05** | 1.45 | 1.33 | VP*Θ | 13 | 1 | 0 | 1 | 4 |
| **RR04** | 0.45 | 2.18 | F↑ | 29 | 2 | 6 | 1 | 3 |
| ***Unnamed Tributary to Wulff Run @ RM 0.77*** | | | | | | | | |
| **RR05.5** | 0.40 | 0.33 | Θ | 20 | 1 | 2 | 1 | 2 |
| **RR04.5** | 0.35 | 0.33 | Θ | 20 | 1 | 4 | 0 | 3 |
| **Narrative Thresholds** | | | E | >60 | >16 | >16 | 0 | 0 |
| | | | G | >40 | >11 | >11 | 1 | <3 |
| | | | F | >20 | >6 | >6 | ≥2 | <5 |
| | | | P | >10 | >2 | >2 | ≥3 | <8 |
| | | | VP | ≤10 | <2 | <2 | ≥4 | >9 |

***Table 16**. continued.*

| Site ID | River Mile | Drainage Area (mi.$^2$) | ICI or Narrative | Total Taxa | Sensitive Taxa | Qual. EPT Taxa | #Toxic Tolerant Taxa | #Organic Enrich-ment Taxa |
|---|---|---|---|---|---|---|---|---|
| ***Indian Creek*** | | | | | | | | |
| **IC06** | 2.30 | 0.58 | MG$^{ns}$↓ | 16 | 5 | 8 | 0 | 2 |
| **IC05** | 2.08 | 1.07 | F*Θ | 23 | 2 | 6 | 0 | 2 |
| **IC02** | 1.15 | 1.38 | F*↓ | 14 | 3 | 8 | 0 | 1 |
| **IC01** | 0.30 | 2.30 | F*↓ | 23 | 3 | 8 | 0 | 2 |
| ***Tributary to Indian Creek @RM 1.02 RM 0.97*** | | | | | | | | |
| **IC07** | 0.10 | 0.39 | Θ | 15 | 2 | 1 | 0 | 2 |
| ***Taylor Creek*** | | | | | | | | |
| **GM86** | 6.40 | 0.49 | VP↓ | 12 | 1 | 1 | 0 | 1 |
| **GM85** | 5.30 | 2.22 | FΘ | 21 | 2 | 7 | 0 | 3 |
| ***Briarly Creek*** | | | | | | | | |
| **GM91** | 3.90 | 0.34 | | 22 | 2 | 4 | 0 | 4 |
| **GM90** | 2.45 | 1.30 | F↓ | 20 | 3 | 6 | 0 | 4 |
| **GM89** | 1.80 | 2.10 | MGΘ | 17 | 4 | 9 | 0 | 1 |
| ***Wesselman Creek*** | | | | | | | | |
| **GM94** | 4.70 | 1.10 | Θ | 16 | 1 | 4 | 0 | 2 |
| ***Unnamed Tributary to Wesselman Creek @ RM 2.59*** | | | | | | | | |
| **GM100** | 1.05 | 0.91 | Θ | 22 | 2 | 7 | 0 | 1 |
| ***Unnamed Tributary to Taylor Creek @ RM 4.9*** | | | | | | | | |
| **GM106** | 0.20 | 0.92 | PΘ | 20 | 3 | 4 | 0 | 2 |
| **Narrative Thresholds** | | | E | >60 | >16 | >16 | 0 | 0 |
| | | | G | >40 | >11 | >11 | 1 | <3 |
| | | | F | >20 | >6 | >6 | ≥2 | <5 |
| | | | P | >10 | >2 | >2 | ≥3 | <8 |
| | | | VP | ≤10 | <2 | <2 | ≥4 | >9 |

## SYNTHESIS

The current biological condition of the Ohio River Direct Tributaries subwatersheds has been shaped by the legacy of urbanization and associated development of more than a century. The current condition of the biological assemblages reflects influences that have altered the former natural features mostly via the introduction of raw and partially diluted municipal wastewater, stormwater runoff that transports urban pollutants, and by hydrological and physical alterations resulting from sewer line placement and urban development. The influence of altered hydrology, increased pollutant delivery, and past habitat alterations were evident in the 2018 bioassessment results. Indicators of organic enrichment in response to sewage wastes discharged from CSOs, SSOs, NEOs, and HSTS discharges were acute in certain subwatersheds.

Tools applied in the 2023 subwatershed assessments included a multiparameter analysis of the *effect* of nutrient enrichment along with continuous monitoring to yield a more comprehensive characterization of the D.O. regime including diel fluxes. Coupled with the chemical/physical assessment and the habitat and biological measures, all were used in an integrated manner to assign associated causes to the biological impairments observed in 2023. The biological criteria for fish and macroinvertebrates in the Ohio WQS establish the thresholds by which impaired sites and reaches are delineated. The assignment of causes in this analysis generally followed the intent of Ohio EPA practices, but was supplemented by more recent and robust biological effect thresholds derived by the MSDGC Integrated Prioritization System (IPS) for southwestern Ohio (MBI 2015b) and from the scientific literature (e.g., consensus-based sediment quality guidelines of MacDonald et al. 2000).

The delineation of causes and sources was based on integrating and synthesizing the preceding analyses of categorical and parameter-specific stressor threshold exceedances and biological response indicators and signatures. The most influential of these in 2023 are included in Table 17 along with the fish and macroinvertebrate IBI scores. Habitat alteration is represented by the QHEI and the QHEI modified:good attributes ratio, D.O. includes the minimum measured by grab sampling and Datasondes, the effect of nutrient enrichment portrayed by the maximum D.O., diel D.O. swing narrative, and the nutrient enrichment effect status, IPS chemical threshold exceedances for water and sediment, and two biological response signatures, organic enrichment and toxic tolerant indicators.

New in 2023 was splitting the compilations of weighted causes between the Muddy Creek and Rapid Run subwatersheds and the Taylor Creek and Indian Run subwatersheds. This was done to determine if there were differences in the proportion of weighted causes between subwatersheds impacted by wet weather sewage sources (Muddy Creek, Rapid Run) and those lacking such sources Taylor Creek, Indian Creek).

The weighted results for listing causes follows:

***Table 17**. Synthesis of key chemical, physical, and biological response indicators of impairment and threat observed at each site in the Ohio River Direct Tributaries subwatersheds study area in 2023. IPS weighted causes associated with biological impairments are drawn from exceedance and other analyses of habitat, nutrient effects, chemical threshold exceedances, sediment chemical exceedances, and biological response signatures.*

| Site ID | Fish/Macro River Mile | Drainage Area (sq. mi.) | Designated AQL Use | IBI | ICI/Narrative | AQLU Status | QHEI/ HHEI | QHEI Modified: Good Ratio | Min. D.O. (Grab) <WQC | Min. D.O. (Sonde) <WQC | D.O. Swing Narrative | Nutrient Enrichment SNAP Status | Water Column Poor/VP Exceedances | Sediment Threshold Exceedances | %Toxic Tolerant Indicators | %Organic Enrichment Indicators | Very Poor | Poor | Fair | Threats to Attainment | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Muddy Creek*** | | | | | | | | | | | | | | | | | | | | | |
| **MU05** | 6.35/6.35 | 5.39 | WWH | 12*Θ | VP Θ | Non Θ | 39.50 | 4.50 | 2.41 | | | | 2 | | 1 | 3 | H. Urb (Buff); | BOD; D.O.; | QHEI; Channel; TKN; | | CSO/SSO,Urban, Sewer Constr. |
| **MU04.5** | 5.62/5.60 | 7.71 | WWH | 12*Θ | VP Θ | Non Θ | 61.50 | 1.20 | 3.70 | 6.55 | Wide | Impaired Nutrients Likely | 2 | 13 PAH | 2 | 4 | BOD; | D.O. Swing; | Channel; TKN; | | CSO/SSO, Urban,Sew. Const. |
| **MU04** | 5.45/5.40 | 7.80 | WWH | 24*Θ | VP Θ | Non Θ | 64.30 | 0.57 | 4.27 | 0.80 | Wide | Impaired Nutrients Likely | 2 | 12 PAH | 1 | 4 | H. Urb (Buff); D.O. | D.O. Swing; | TKN; | | CSO/SSO,Urban |
| **MU03** | 2.80/2.72 | 10.40 | WWH | 36$^{ns}$ ↑ | 28$^{ns}$ | Full ↑ | 56.30 | 1.00 | 6.79 | 5.70 | Wide | Attaining Threatened | 0 | 6 PAH | 1 | 6 | | | | H. Urb (Buff); QHEI; Channel; Chloride; D.O. Swing | CSO/SSO/NEO,Urban,HSTS |
| **MU02** | 2.25/2.25 | | WWH | 34*Θ | 36Θ | Partial Θ | | | | | | | 1 | | 2 | 6 | | | | H. Urb (Buff); Chloride; Cond; | CSO/SSO/NEO,Urban,HSTS |
| **MU01** | 0.17/0.17 | 13.60 | WWH | 12*Θ | ND | Non Θ | 49.00 | 1.50 | 4.81 | 3.70 | Low | Impaired Other Cause(s) | 1 | | | | H. Urb (Buff); | BOD; | QHEI; Substr; TKN; D.O.; | | CSO/SSO/NEO,Urban |
| ***Unnamed Tributary to Muddy Creek @RM 2.37*** | | | | | | | | | | | | | | | | | | | | | |
| **MU10** | 0.50/0.60 | 0.71 | PHW3A | 12Θ | Θ | PHW3A Θ | 96.00 | 2.67 | 5.19 | | | | | | 0 | 1 | | | | Chloride; QHEI; Channel; Cond; | Urban |
| ***Unnamed Tributary to Muddy Creek @RM 5.97*** | | | | | | | | | | | | | | | | | | | | | |
| **MU12** | 0.55/0.65 | 1.01 | WWH | 24*↓ | F*↑ | Non Θ | 47.50 | 2.25 | 0.42 | | | | 4 | | 0 | 1 | TKN; BOD; TAmm; H. Urb (Buff); D.O.; | | QHEI; Channel; | | CSO/SSO,Urban |
| ***Unnamed Tributary to Muddy Creek @RM 6.53*** | | | | | | | | | | | | | | | | | | | | | |
| **MU13** | 0.60/0.60 | 2.25 | WWH | 12*Θ | VP*Θ | Non Θ | 41.00 | 2.67 | 3.22 | | | | 4 | | 0 | 4 | TKN; Chloride; H. Urb (Buff); | BOD; Cond; | QHEI; Channel; D.O.; | | CSO/SSO,Urban |
| ***Unnamed Tributary to Unnamed Tributary to Muddy Creek @RM 5.9*** | | | | | | | | | | | | | | | | | | | | | |
| **MU14** | 0.20/0.20 | 0.09 | PHW2 | Dry | | PHW2 | | | 2.44 | | | | 0 | | | | | | | QHEI; Substr; Channel; Chloride; H. Urb; BOD; Cond; TKN; TAmm; Nitrate; D.O.; | CSO/SSO,Urban |
| ***Unnamed Tributary to Muddy Creek @RM 0.3*** | | | | | | | | | | | | | | | | | | | | | |
| **MU08** | 1.72/1.80 | 0.74 | PHW3A | Dry↓ | Θ | PHW3A Θ | 91.00 | | 6.51 | | | | 0 | | 0 | 2 | | | | QHEI; Substr; Channel; Nitrate; BOD; | Urban |
| **MU07.5** | 0.80/0.90 | 2.60 | WWH | 32*Θ | F*Θ | Non Θ | 56.00 | 1.75 | 5.07 | | | | 0 | | 0 | 5 | | | QHEI; Channel; Chloride; BOD; Cond; | | Urban |
| **MU07** | 0.40/0.60 | 2.80 | WWH | Dry↓ | ND | Non↓ | | | 7.04 | | | | 0 | | | | QHEI; Substr; Channel | | | | CSO/SSO,Urban |
| ***Fiddlers Creek RM 0.95 to W. Branch Muddy Creek to Muddy Creek @RM 0.3*** | | | | | | | | | | | | | | | | | | | | | |
| **MU09** | 0.10/0.60 | 1.31 | PHW3A | 24Θ | Θ | PHW3A Θ | 86.00 | 2.00 | 6.06 | | | | | | 0 | 2 | | | | QHEI; Channel; Chloride; Cond | CSO/SSO,Urban |
| ***Rapid Run*** | | | | | | | | | | | | | | | | | | | | | |
| **RR03** | 2.70/2.70 | 2.32 | LRW | Dry Θ | MG ↑ | NA | | | 2.58 | | | | 0 | | 0 | 4 | QHEI; Substr; Channel; H. Urb (Buff); | | | | Urban, Sewer Constr.,HSTS |
| **RR02** | 1.05/1.20 | 5.90 | LRW | 24↓ | MG ↑ | Full Θ | 51.00 | 2.33 | 3.94 | | | | 2 | | 0 | 5 | | | | Chloride; H. Urb (Buff); Cond; QHEI; Channel; | Urban, Sewer Constr. |
| **RR01** | 0.10/0.10 | 6.56 | LRW | Dry Θ | VP*↓ | NA | | | 1.75 | | | | 2 | | 0 | 4 | QHEI; Substr; Channel; Chloride; Cond; | | | | Urban, Sewer Constr.,HSTS |
| ***Wulff Run*** | | | | | | | | | | | | | | | | | | | | | |
| **RR05** | 1.45/0.68 | 1.33 | LRW | Dry Θ | VP*Θ | NA | | | 3.84 | | | | 0 | | 1 | 4 | QHEI; Substr; Channel;H. Urb (Buff); | | | | CSO/SSO,Urban,Sew. Const. |
| **RR04** | 0.45/0.55 | 2.18 | LRW | 20Θ | F ↑ | Full Θ | 50.00 | 3.00 | 3.37 | | | | 2 | | 1 | 3 | Chloride; H. Urb (Buff); | Cond; | QHEI; Channel; | | CSO/SSO,Urban |
| ***Unnamed Tributary to Wulff Run @RM 0.77*** | | | | | | | | | | | | | | | | | | | | | |
| **RR05.5** | 0.40/1.20 | 0.33 | PHW3A | 12Θ | Θ | PHW3A Θ | 73.00 | 2.67 | 4.88 | | | | 0 | | 1 | 2 | | | | Nitrate; Chloride; QHEI; Channel; TKN; Cond; | CSO/SSO,Urban |
| **RR04.5** | 0.35/1.10 | 0.33 | PHW3A | 12Θ | Θ | PHW3A Θ | 69.00 | 2.67 | 5.26 | | | | 0 | | 0 | 3 | | | | Nitrate; QHEI; Channel; Cond; | CSO/SSO,Urban |

| Criteria and Narrative Thresholds | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Exceptional** | >50 | E | FULL | >75 | <0.50 | >6.0 | Attaining Not Threatened | 0 | 0 | 0 | <5 |
| | **Good** | >40 | G | FULL | >60 | <2.00 | >5.0 | Low | Attaining Not Threatened | 1 | <4 | <5 | <15 |
| | **Fair** | >26 | F | PARTIAL | >45 | >2.00 | >3.0 | | Attaining Threatened | 2 | <7 | <20 | ≥15 |
| | **Poor** | >18 | P | NON-POOR | >30 | >6.00 | >2.0 | Wide | Impaired Nutrients Likely | 3 | <10 | ≥35 | ≥35 |
| | **Very Poor** | ≤12 | VP | NON-V.POOR | ≤30 | >10.00 | <2.0 | | Impaired Nutrients | >3 | ≥10 | <60 | >60 |
| | | **OHEPA** | | | | | **OH WQC** | **SNAP** | **SNAP** | **MBI** | | **OH EPA** | |

**Footnotes:** [a] - as codified in OAC 3745-1-07, Table 7-1; [b] - Nonsignificant departure of 4 units for IBI and ICI or marginal for narrative ratings; [c] - FULL - all biocriteria attain; PARTIAL - one or two biocriteria fail to attain; NON - no biocriteria attain or one assemblage with poor or very poor narrative.

***Table 17**. (continued)*

| Site ID | Fish/Macro River Mile | Drainage Area (sq. mi.) | Designated AQL Use | IBI | ICI/Narrative | AQLU Status | QHEI/ HHEI | QHEI Modified: Good Ratio | Min. D.O. (Grab) <WQC | Min. D.O. (Sonde) <WQC | D.O. Swing Narrative | Nutrient Enrichment SNAP Status | Water Column Poor/VP Exceedances | Sediment Threshold Exceedances | %Toxic Tolerant Indicators | %Organic Enrichment Indicators | Very Poor | Poor | Fair | Threats to Attainment | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Indian Creek*** | | | | | | | | | | | | | | | | | | | | | |
| **IC06** | 2.30/2.43 | 0.58 | WWH | 24*Θ | MG$^{ns}$↓ | Non↓ | 53.50 | 2.67 | 6.14 | | | | 3 | 0 PAH | 0 | 2 | Lead; H. Urb (Buff); | Chloride; Cond; | QHEI; Channel; | | Urban, HSTS |
| **IC05** | 2.08/2.08 | 1.07 | WWH | 38$^{ns}$Θ | F*Θ | PartialΘ | 55.00 | 2.67 | 5.55 | | | | 1 | 11 PAH | 0 | 2 | H. Urb (Buff); | Cond; | QHEI; Channel; Chloride; | | Urban |
| **IC02** | 1.15/1.22 | 1.38 | WWH | 36$^{ns}$↑ | F*↓ | PartialΘ | 48.00 | 4.50 | 4.72 | | | | 2 | 4 PAH | 0 | 1 | Chloride;H. Urb (Buff); | Cond; | QHEI; Channel; | | Urban |
| **IC01** | 0.30/0.30 | 2.30 | WWH | 24*Θ | F*↓ | Non↓ | 50.00 | 2.33 | 4.43 | | | | 3 | 1 PAH | 0 | 2 | H. Urb (Buff); | Chloride; BOD; Cond; | QHEI; Channel; TKN; | | Urban |
| ***Tributary to Indian Creek @RM1.02 RM0.97*** | | | | | | | | | | | | | | | | | | | | | |
| **IC07** | 0.10/0.13 | 0.39 | PHW3A | 12Θ | Θ | PHW3AΘ | 91.00 | 2.67 | 1.75 | | | | 0 | 12 PAH | 0 | 2 | | | | BOD; H. Urb (Buff);Chloride; TAmm; QHEI; Channel; TKN; Cond; D.O. | Urban |
| ***Taylor Creek*** | | | | | | | | | | | | | | | | | | | | | |
| **GM86** | 6.40/6.30 | 0.49 | WWH | 22*↓ | VP↓ | Non↓ | 40.30 | 10.00 | 2.43 | 2.21 | Low | Impaired Other Cause(s) | 2 | | 0 | 1 | H. Urb (Buff); D.O. | Chloride; | QHEI; Substr; Channel; TKN; Cond; | | Urban, HSTS |
| **GM85** | 5.30/4.98 | 2.22 | WWH | 20*↓ | FΘ | NonΘ | 44.00 | 5.00 | 6.79 | 8.08 | Low | Impaired Other Cause(s) | 3 | 7 PAH | 0 | 3 | Chloride; Nitrate; H. Urb (Buff); | Cond; | QHEI; Channel; | | Urban, HSTS |
| ***Briarly Creek*** | | | | | | | | | | | | | | | | | | | | | |
| **GM91** | 3.90/3.90 | 0.34 | PHW3A | 24Θ | | PHW3AΘ | 76.00 | 0.83 | 6.50 | 2.92 | Low | Attaining Not Threatened | 0 | | 0 | 4 | | | | H. Urb (Buff); Chloride; QHEI; Cond; D.O.; | |
| **GM90** | 2.45/2.45 | 1.30 | WWH | 22*Θ | F↓ | Non↓ | 49.50 | 2.67 | 6.21 | 5.94 | Low | Impaired Other Cause(s) | 0 | 9 PAH | 0 | 4 | | | QHEI; Channel; TKN; Chloride; | | Urban, HSTS |
| **GM89** | 1.80/1.70 | 2.10 | WWH | 24*↓ | MGΘ | Non↓ | 53.50 | 1.75 | 6.95 | | | | 1 | 13 PAH | 0 | 1 | H. Urb (Buff); | Chloride; | QHEI; Channel; | | Urban, HSTS |
| ***Wesselman Creek*** | | | | | | | | | | | | | | | | | | | | | |
| **GM94** | 4.70/4.72 | 1.10 | PHW3A | 26↑ | Θ | PHW3AΘ | 96.00 | 4.00 | 8.24 | | | | 0 | | 0 | 2 | | | | Chloride; H. Urb (Buff); Cond; QHEI; Channel; TKN; | Urban, HSTS |
| ***Unnamed Tributary to Wesselman Creek @RM 2.59*** | | | | | | | | | | | | | | | | | | | | | |
| **GM100** | 1.05/1.21 | 0.91 | PHW3A | 20Θ | Θ | PHW3AΘ | 84.00 | 1.40 | 3.75 | | | | 0 | | 0 | 1 | | | | H. Urb (Buff); Chloride; QHEI; Substr; Channel; TKN; Cond; | Urban, HSTS |
| ***Unnamed Tributary to Taylor Creek @RM 4.9*** | | | | | | | | | | | | | | | | | | | | | |
| **GM106** | 0.20/0.28 | 0.92 | WWH | 30*↓ | PΘ | NonΘ | 57.00 | 0.83 | 4.85 | | | | 1 | | 0 | 2 | Chloride; H. Urb (Buff); | | QHEI; Cond; D.O. | | Urban, HSTS |

| Criteria and Narrative Thresholds | | OHEPA | | | | OH WQC | SNAP | SNAP | MBI | OH EPA | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Exceptional | >50 | E | FULL | >75 | <0.50 | >6.0 | | Attaining Not Threatened | 0 | 0 | 0 | <5 |
| | Good | >40 | G | FULL | >60 | <2.00 | >5.0 | Low | Attaining Not Threatened | 1 | <4 | <5 | <15 |
| | Fair | >26 | F | PARTIAL | >45 | >2.00 | >3.0 | | Attaining Threatened | 2 | <7 | <20 | >15 |
| | Poor | >18 | P | NON-POOR | >30 | >6.00 | >2.0 | Wide | Impaired Nutrients Likely | 3 | <10 | >35 | >35 |
| | Very Poor | <12 | VP | NON-V.POOR | <30 | >10.00 | <2.0 | | Impaired Nutrients | >3 | >10 | <60 | >60 |

Footnotes: [a] - as codified in OAC 3745-1-07, Table 7-1; [b] - Nonsignificant departure of 4 units for IBI and ICI or marginal for narrative ratings; [c] - FULL - all biocriteria attain; PARTIAL - one or two biocriteria fail to attain; NON - no biocriteria attain or one assemblage with poor or very poor narrative.

| Acronym | Description | Acronym | Description | Acronym | Description |
|---|---|---|---|---|---|
| H. Urb. (Buff.) | Hign urban land use in 500 m buffer | Chloride | Chloride concentration in mg/L | TKN | Total Kjeldahl nitrogen |
| QHEI | Qualitative Habitat Evaluation Index (QHEI) | Low D.O. | Minium Dissolved Oxygen in mg/L | TP | Total phosphorus |
| QHEI Ratio | Ratio of Modified:Good QHEI attributes | Max. D.O. | Maximum Dissolved Oxygen in mg/L | Nitrate | Nitrate as N |
| Chan | Channel condition from QHEI | D.O. Swing | Width of Diel D.O. Variation in 24 Hrs. | Tamm | Total Ammonia |
| Substr | Substrate condition from QHEI | Conduct | Specific conductivity | CSO | Combined Sewer Overflow |
| High Mod. Attr. | NumberHigh Influence Modified QHEI Attributes | Toxicity | Exceedance of Toxic Biological Signature | SSO | Sanitary Sewer Overflow |
| Good QHEI Attr. | Number of Good Habitat Attributes | Org. Enrich. | Exceedance of Organic Enrichment Biological Signature | NEO | Non-enumerated Overflow |
| Poor QHEI Attr. | Number if Modified Habitat Attributes | TSS | Total suspended solids | HSTS | Home Sewager Treatment System |

***Muddy Creek-Rapid Run Subwatersheds***

- **Urban Related** (63 of 199 weighted observations; 31.7%) – ionic strength exceedances, SSC exceedances, and urban land use exceedances; land use exceedances mostly urban land uses in the 500-meter buffer.
- **Macrohabitat Related** (61 of 199 weighted observations; 30.7%) - QHEI Score, QHEI Ratios, Substrate, #Poor Attributes, #Good Attributes, Channel Condition.
- **Organic/Nutrient_Enrichment Related** (39 of 199 weighted observations; 19.6%) – TKN, Ammonia-N, Total P, Nitrate-N, Biological indicators of organic enrichment.
- **D.O. Related** (26 of 199 weighted observations; 13.1%) - Minimum D.O., Maximum D.O., Diel D.O.
- **Toxics Related** (10 of 99 observations; 5.0%) – Metals, PAH compounds, Biological signatures of toxicity.

***Taylor Creek-Indian Creek subwatersheds***

- **Urban Related** (83 of 155 weighted observations; 56.1%) – Chlorides, Conductivity, SSC, Urban Land Use in the 500-meter Buffer.
- **Macrohabitat Related** (31 of 155 weighted observations; 19.3%) - QHEI Score, QHEI Ratios, Substrate, #Poor Attributes, #Good Attributes, Channel Condition.
- **Toxics Related** (25 of 155 observations; 14.6%) – Metals, PAH compounds, Biological signatures of toxicity.
- **Organic/Nutrient_Enrichment Related** (10 of 155 weighted observations; 6.5%) – TKN, Ammonia-N, Total P, Nitrate-N, Biological indicators of organic enrichment.
- **D.O. Related** (6 of 155 weighted observations; 3.9%) - Minimum D.O., Maximum D.O., Diel D.O.

The contrast between watersheds is the most evident in the higher predominance of urban related and toxic related causes in the non-CSO/SSO Taylor Creek and Indian Creek subwatersheds compared to the higher proportion of organic enrichment and D.O. related causes in the Muddy Creek And Rapid Run watersheds. These results distinguish the wet weather sewage related sources in Muddy Creek and Rapid Run compared to their absence in Taylor Creek and Indian Creek subwatersheds.

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# Appendix A

## Ohio River Direct Tributaries 2023 Fish Assemblage Data
## A-1: IBI Metrics & Scores, MIwb
## A-2: Fish Species Grand Reports
## A-3: Fish Species by Date

**Appendix Table A-1. Headwater IBI scores and metrics for sites sampled in the Ohio River tributaries during 2023.**

| Site ID | River Mile | Type | Date | Drainage area (sq mi) | Number of: Total species | Minnow species | Headwater species | Sensitive species | Darter & Sculpin species | Simple Lithophils | Percent of Individuals: Tolerant fishes | Omni-vores | Pioneering fishes | Insect-ivores | DELT anomalies | Rel.No. minus tolerants /(0.3km) | IBI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *(14-004) - Taylor Creek* | | | | | | | | | | | | | | | | | |
| Year: 2023 | | | | | | | | | | | | | | | | | |
| GM86 | 6.40 | F | 06/28/2023 | 0.49 | 2(1) | 2(3) | 0(1) | 0(1) | 0(1) | 0(1) | 68(1) | 0(5) | 68(1) | 0(1) | 0.0(5) | 12(1) * * | 22 |
| GM85 | 5.30 | F | 06/26/2023 | 2.22 | 4(1) | 2(1) | 1(1) | 0(1) | 1(1) | 1(1) | 63(1) | 1(5) | 61(1) | 4(1) | 0.0(5) | 54(1) * | 20 |
| *(14-148) - Briarly Creek* | | | | | | | | | | | | | | | | | |
| Year: 2023 | | | | | | | | | | | | | | | | | |
| GM91 | 3.90 | F | 06/26/2023 | 0.34 | 3(1) | 3(3) | 0(1) | 0(1) | 0(1) | 0(1) | 85(1) | 1(5) | 85(1) | 0(1) | 0.0(5) | 46(3) | 24 |
| GM90 | 2.45 | F | 06/26/2023 | 1.30 | 3(1) | 3(3) | 0(1) | 0(1) | 0(1) | 0(1) | 97(1) | 2(5) | 97(1) | 0(1) | 0.0(5) | 4(1) * | 22 |
| GM89 | 1.80 | F | 06/23/2023 | 2.10 | 3(1) | 3(3) | 1(1) | 0(1) | 0(1) | 1(1) | 67(1) | 0(5) | 58(1) | 0(1) | 0.0(5) | 180(3) | 24 |
| *(14-149) - Wesselman Creek* | | | | | | | | | | | | | | | | | |
| Year: 2023 | | | | | | | | | | | | | | | | | |
| GM94 | 4.70 | F | 06/26/2023 | 1.10 | 4(3) | 3(3) | 0(1) | 0(1) | 0(1) | 0(1) | 92(1) | 6(5) | 92(1) | 1(1) | 0.0(5) | 28(3) | 26 |
| *(14-275) - Unnamed Trib to Wesselman Creek @ RM 2.59* | | | | | | | | | | | | | | | | | |
| Year: 2023 | | | | | | | | | | | | | | | | | |
| GM100 | 1.05 | F | 06/26/2023 | 0.91 | 1(1) | 1(1) | 0(1) | 0(1) | 0(1) | 0(1) | 100(1) | 0(5) | 100(1) | 0(1) | 0.0(5) | 0(1) * * | 20 |
| *(14-277) - Unnamed Trib to Taylor Creek @ RM4.9* | | | | | | | | | | | | | | | | | |
| Year: 2023 | | | | | | | | | | | | | | | | | |
| GM106 | 0.20 | F | 06/28/2023 | 0.92 | 5(3) | 2(3) | 1(1) | 0(1) | 1(3) | 1(3) | 72(1) | 1(5) | 71(1) | 10(1) | 0.0(5) | 74(3) | 30 |
| *(23-007) - Muddy Creek* | | | | | | | | | | | | | | | | | |
| Year: 2023 | | | | | | | | | | | | | | | | | |
| MU05 | 6.35 | F | 08/21/2023 | 5.39 | 2(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 80(1) | 0(1) | 80(1) | 80(1) | 0.0(1) | 3(1) * * | 12 |
| MU04.5 | 5.62 | E | 08/21/2023 | 7.71 | 1(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 90(1) | 10(1) | 80(1) | 80(1) | 0.0(1) | 2(1) * * | 12 |
| MU04 | 5.45 | F | 08/21/2023 | 7.80 | 2(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 95(1) | 0(5) | 96(1) | 97(5) | 0.0(5) | 6(1) * | 24 |
| MU03 | 2.80 | F | 08/21/2023 | 10.40 | 9(3) | 4(3) | 0(1) | 2(1) | 1(1) | 2(1) | 20(5) | 9(5) | 12(5) | 6(1) | 0.0(5) | 1300(5) | 36 |
| MU02 | 2.25 | E | 08/23/2023 | 12.10 | 11(3) | 6(3) | 1(1) | 3(3) | 1(1) | 3(1) | 37(3) | 18(3) | 19(5) | 9(1) | 0.0(5) | 936(5) | 34 |

♦ - IBI is low end adjusted.

* - < 200 Total individuals in sample

** - < 50 Total individuals in sample

● - One or more species excluded from IBI calculation.

**Appendix Table A-1. Headwater IBI scores and metrics for sites sampled in the Ohio River tributaries during 2023.**

| Site ID | River Mile | Type | Date | Drainage area (sq mi) | Number of: Total species | Minnow species | Headwater species | Sensitive species | Darter & Sculpin species | Simple Lithophils | Percent of Individuals: Tolerant fishes | Omni-vores | Pioneering fishes | Insect-ivores | DELT anomalies | Rel.No. minus tolerants /(0.3km) | IBI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MU01 | 0.17 | P | 08/23/2023 | 13.60 | 21(5) | 1(1) | 0(1) | 3(1) | 1(1) | 3(1) | 4(5) | 54(1) | 1(5) | 28(3) | 0.0(5) | 418(3) | 24 |
| *(23-008) - Rapid Run* | | | | | | | | | | | | | | | | | |
| Year: 2023 | | | | | | | | | | | | | | | | | |
| RR03 | 2.70 | F | 06/27/2023 | 2.32 | 1(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0.0(1) | 0(1) * * | Dry |
| RR02 | 1.05 | F | 06/27/2023 | 5.90 | 5(1) | 4(3) | 1(1) | 0(1) | 0(1) | 1(1) | 70(1) | 1(5) | 34(3) | 1(1) | 0.0(5) | 46(1) * | 24 |
| RR01 | 0.10 | F | 06/27/2023 | 6.56 | 1(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0.0(1) | 0(1) * * | Dry |
| *(23-012) - Wulff Run* | | | | | | | | | | | | | | | | | |
| Year: 2023 | | | | | | | | | | | | | | | | | |
| RR05 | 1.45 | F | 06/27/2023 | 1.33 | 1(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0.0(1) | 0(1) * * | Dry |
| RR04 | 0.45 | F | 06/27/2023 | 2.18 | 1(1) | 1(1) | 0(1) | 0(1) | 0(1) | 0(1) | 100(1) | 0(5) | 100(1) | 0(1) | 0.0(5) | 0(1) * * | 20 |
| *(23-019) - Indian Creek* | | | | | | | | | | | | | | | | | |
| Year: 2023 | | | | | | | | | | | | | | | | | |
| IC06 | 2.30 | F | 06/29/2023 | 0.58 | 3(1) | 2(3) | 1(1) | 0(1) | 0(1) | 1(3) | 99(1) | 0(5) | 67(1) | 1(1) | 0.0(5) | 2(1) | 24 |
| IC05 | 2.08 | F | 06/29/2023 | 1.07 | 3(1) | 2(3) | 1(1) | 0(1) | 0(1) | 1(1) | 27(5) | 0(5) | 19(5) | 73(5) | 0.0(5) | 284(5) | 38 |
| IC02 | 1.15 | F | 06/29/2023 | 1.38 | 5(3) | 3(3) | 1(1) | 0(1) | 0(1) | 1(1) | 43(3) | 0(5) | 34(3) | 26(5) | 0.0(5) | 262(5) | 36 |
| IC01 | 0.30 | F | 06/29/2023 | 2.30 | 9(3) | 4(3) | 1(1) | 1(1) | 1(1) | 3(3) | 75(1) | 41(1) | 62(1) | 11(1) | 0.0(5) | 220(3) | 24 |
| *(23-020) - Trib to Indian Creek @RM1.02 RM0.97* | | | | | | | | | | | | | | | | | |
| Year: 2023 | | | | | | | | | | | | | | | | | |
| IC07 | 0.10 | F | 06/29/2023 | 0.39 | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0.0(1) | 0(1) * * | 12 |
| *(23-071) - Unnamed Trib to Muddy Creek @ RM2.37* | | | | | | | | | | | | | | | | | |
| Year: 2023 | | | | | | | | | | | | | | | | | |
| MU10 | 0.50 | F | 06/28/2023 | 0.71 | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0.0(1) | 0(1) * * | 12 |
| *(23-072) - Unnamed Trib to Muddy Creek @ RM5.97* | | | | | | | | | | | | | | | | | |
| Year: 2023 | | | | | | | | | | | | | | | | | |
| MU12 | 0.55 | F | 06/28/2023 | 1.01 | 2(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 94(1) | 0(5) | 94(1) | 98(5) | 0.0(5) | 14(1) | 24 |

♦ - IBI is low end adjusted.

* - < 200 Total individuals in sample

** - < 50 Total individuals in sample

● - One or more species excluded from IBI calculation.

**Appendix Table A-1. Headwater IBI scores and metrics for sites sampled in the Ohio River tributaries during 2023.**

| Site ID | River Mile | Type | Date | Drainage area (sq mi) | Number of: Total species | Minnow species | Headwater species | Sensitive species | Darter & Sculpin species | Simple Lithophils | Percent of Individuals: Tolerant fishes | Omni-vores | Pioneering fishes | Insect-ivores | DELT anomalies | Rel.No. minus tolerants /(0.3km) | IBI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *(23-073) - Unnamed Trib to Muddy Creek @ RM6.53* | | | | | | | | | | | | | | | | | |
| Year: 2023 | | | | | | | | | | | | | | | | | |
| MU13 | 0.60 | F | 06/28/2023 | 2.25 | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0.0(1) | 0(1) * * | 12 |
| *(23-074) - Unnamed Trib to Unnamed Trib to Muddy Creek @ RM5.* | | | | | | | | | | | | | | | | | |
| Year: 2023 | | | | | | | | | | | | | | | | | |
| MU14 | 0.20 | F | 06/29/2023 | 0.09 | 1(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0.0(1) | 0(1) * * | Dry |
| *(23-075) - Unnamed Trib to Muddy Creek @RM0.3* | | | | | | | | | | | | | | | | | |
| Year: 2023 | | | | | | | | | | | | | | | | | |
| MU08 | 1.72 | F | 06/27/2023 | 0.74 | 1(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0.0(1) | 0(1) * * | Dry |
| MU07.5 | 0.80 | F | 06/28/2023 | 2.60 | 7(3) | 4(3) | 1(1) | 1(1) | 1(1) | 3(3) | 58(1) | 2(5) | 14(5) | 2(1) | 0.0(5) | 254(3) | 32 |
| MU07 | 0.40 | F | 06/28/2023 | 2.80 | 1(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0.0(1) | 0(1) * * | Dry |
| *(23-076) - UT @ 0.95 to UT to Muddy Creek @ RM0.3* | | | | | | | | | | | | | | | | | |
| Year: 2023 | | | | | | | | | | | | | | | | | |
| MU09 | 0.10 | F | 06/28/2023 | 1.31 | 3(1) | 2(3) | 1(1) | 0(1) | 0(1) | 1(1) | 100(1) | 0(5) | 44(3) | 1(1) | 0.0(5) | 0(1) | 24 |
| *(23-077) - Unnamed Trib to Wulff Run @ RM 0.77* | | | | | | | | | | | | | | | | | |
| Year: 2023 | | | | | | | | | | | | | | | | | |
| RR05.5 | 0.40 | F | 06/27/2023 | 0.33 | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0.0(1) | 0(1) * * | 12 |
| RR04.5 | 0.35 | F | 06/27/2023 | 0.33 | 1(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 0(1) | 100(1) | 0.0(1) | 2(1) * * | 12 |

♦ - IBI is low end adjusted.

* - < 200 Total individuals in sample

** - < 50 Total individuals in sample

● - One or more species excluded from IBI calculation.

# Appendix A-2: Midwest Biodiversity Institute
# Fish Species List - Grand Totals

Rivers: *Taylor Creek; Briarly Creek; Wesselman Creek; Unnamed Trib to Wesselman Creek @ RM2.95; Unnamed Trib to Taylor Creek @ RM4.9; Muddy Creek; Rapid Run; Wulff Run; Indian Creek; Trib. to Indian Creek (RM 1.02)*

Years: 2023

Number of Samples: 34 Data Sources: 99 Data Types: E; F; P

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10-004 | Longnose Gar | P | | M | | 1 | 0.2 | 0.02 | 0 | ***.** | 0.0 |
| 20-001 | Skipjack Herring | P | | M | | 6 | 1.1 | 0.14 | 0 | ***.** | 0.0 |
| 20-003 | Gizzard Shad | O | | M | | 106 | 19.7 | 2.41 | 0 | ***.** | 0.0 |
| 40-002 | Bigmnouth Buffalo | I | | M | C | 1 | 0.2 | 0.02 | 0 | ***.** | 0.0 |
| 40-004 | Smallmouth Buffalo | I | | M | C | 6 | 1.1 | 0.14 | 0 | ***.** | 0.0 |
| 40-005 | Quillback Carpsucker | O | | M | C | 2 | 0.4 | 0.05 | 0 | ***.** | 0.0 |
| 40-006 | River Carpsucker | O | | M | C | 2 | 0.4 | 0.05 | 0 | ***.** | 0.0 |
| 40-010 | Golden Redhorse | I | M | S | R | 2 | 0.4 | 0.05 | 0 | ***.** | 0.0 |
| 40-016 | White Sucker | O | T | S | W | 153 | 8.6 | 3.48 | 0 | ***.** | 0.0 |
| 43-001 | Common Carp | O | T | M | G | 7 | 1.3 | 0.16 | 0 | ***.** | 0.0 |
| 43-002 | Goldfish | O | T | M | G | 1 | 0.1 | 0.02 | 0 | ***.** | 0.0 |
| 43-006 | Silver Chub | I | | M | N | 1 | 0.2 | 0.02 | 0 | ***.** | 0.0 |
| 43-011 | Western Blacknose Dace | G | T | S | N | 428 | 24.0 | 9.75 | 0 | ***.** | 0.0 |
| 43-013 | Creek Chub | G | T | N | N | 1264 | 70.8 | 28.79 | 0 | ***.** | 0.0 |
| 43-020 | Emerald Shiner | I | | M | N | 5 | 0.3 | 0.11 | 0 | ***.** | 0.0 |
| 43-034 | Sand Shiner | I | M | M | N | 2 | 0.1 | 0.05 | 0 | ***.** | 0.0 |
| 43-042 | Fathead Minnow | O | T | C | N | 13 | 0.7 | 0.30 | 0 | ***.** | 0.0 |
| 43-043 | Bluntnose Minnow | O | T | C | N | 245 | 13.7 | 5.58 | 0 | ***.** | 0.0 |
| 43-044 | Central Stoneroller | H | | N | N | 1377 | 77.1 | 31.36 | 0 | ***.** | 0.0 |
| 43-086 | Eastern Blacknose Dace | | | | N | 90 | 5.0 | 2.05 | 0 | ***.** | 0.0 |
| 57-001 | Western Mosquitofish | I | | N | E | 2 | 0.1 | 0.05 | 0 | ***.** | 0.0 |
| 77-001 | White Crappie | I | | C | S | 5 | 0.9 | 0.11 | 0 | ***.** | 0.0 |
| 77-002 | Black Crappie | I | | C | S | 1 | 0.2 | 0.02 | 0 | ***.** | 0.0 |
| 77-005 | Spotted Bass | C | | C | F | 3 | 0.6 | 0.07 | 0 | ***.** | 0.0 |
| 77-006 | Largemouth Bass | C | | C | F | 16 | 3.0 | 0.36 | 0 | ***.** | 0.0 |
| 77-007 | Warmouth Sunfish | C | | C | S | 4 | 0.7 | 0.09 | 0 | ***.** | 0.0 |
| 77-008 | Green Sunfish | I | T | C | S | 207 | 11.6 | 4.71 | 0 | ***.** | 0.0 |
| 77-009 | Bluegill Sunfish | I | P | C | S | 260 | 48.4 | 5.92 | 0 | ***.** | 0.0 |
| 77-010 | Orangespotted Sunfish | I | | C | S | 2 | 0.4 | 0.05 | 0 | ***.** | 0.0 |
| 77-011 | Longear Sunfish | I | M | C | S | 24 | 4.5 | 0.55 | 0 | ***.** | 0.0 |
| 77-012 | Redear Sunfish | I | | C | E | 1 | 0.2 | 0.02 | 0 | ***.** | 0.0 |
| 77-015 | Green X Bluegill Sunfish | | | | | 7 | 0.4 | 0.16 | 0 | ***.** | 0.0 |
| 80-001 | Sauger | P | | S | F | 3 | 0.6 | 0.07 | 0 | ***.** | 0.0 |
| 80-011 | Logperch | I | M | S | D | 1 | 0.2 | 0.02 | 0 | ***.** | 0.0 |
| 80-022 | Rainbow Darter | I | M | S | D | 116 | 6.5 | 2.64 | 0 | ***.** | 0.0 |
| 80-024 | Fantail Darter | I | | C | D | 15 | 0.8 | 0.34 | 0 | ***.** | 0.0 |
| 80-026 | Sauger X Walleye | P | | | E | 9 | 1.7 | 0.20 | 0 | ***.** | 0.0 |
| 85-001 | Freshwater Drum | | P | M | | 3 | 0.6 | 0.07 | 0 | ***.** | 0.0 |
| 99-997 | Dry Site | | | | | 0 | 0.0 | 0.00 | 0 | ***.** | *****.* |

# Appendix A-2: Midwest Biodiversity Institute
# Fish Species List - Grand Totals

Rivers: *Taylor Creek; Briarly Creek; Wesselman Creek; Unnamed Trib to Wesselman Creek @ RM2.95; Unnamed Trib to Taylor Creek @ RM4.9; Muddy Creek; Rapid Run; Wulff Run; Indian Creek; Trib. to Indian Creek (RM 1.02)*

Years: 2023

Number of Samples: 34 Data Sources: 99 Data Types: E; F; P

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 99-999 | No Fish | | | | | 0 | 0.0 | 0.00 | 0 | ***.** | *****.* |

**No Species:** 40 **Nat. Species:** 34 **Hybrids:** 2 **Total Counted:** 4391 **Total Rel. Wt. :** 0

# Appendix Table A-3. Midwest Biodiversity Institute
# Fish Species List

Site ID: GM86 River: 14-004 Taylor Creek RM: 6.40 Date: 06/28/2023

Time Fished: 449 Distance: 0.150 Drainge (sq mi): 0.4 Depth: 0

Location: Reemelin Rd. Lat: 39.17573 Long: -84.62518

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 43-013 | Creek Chub | G | T | N | N | 13 | 26.0 | 68.42 | 0 | 0.00 | 0.0 |
| 43-044 | Central Stoneroller | H | | N | N | 6 | 12.0 | 31.58 | 0 | 0.00 | 0.0 |

**No Species:** 2 **Nat. Species:** 2 **Hybrids:** 0 **Total Counted:** 19 **Total Rel. Wt. :** 0

**IBI:** 22.0 **MIwb:** N/A

# Appendix Table A-3. Midwest Biodiversity Institute
# Fish Species List

Site ID: GM85 River: 14-004 Taylor Creek RM: 5.30 Date: 06/26/2023

Time Fished: 969 Distance: 0.150 Drainge (sq mi): 2.2 Depth: 0

Location: Ust. Johnson Rd. Lat: 39.18103 Long: -84.64057

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 40-016 | White Sucker | O | T | S | W | 1 | 2.0 | 1.39 | 0 | 0.00 | 0.0 |
| 43-013 | Creek Chub | G | T | N | N | 44 | 88.0 | 61.11 | 0 | 0.00 | 0.0 |
| 43-044 | Central Stoneroller | H | | N | N | 24 | 48.0 | 33.33 | 0 | 0.00 | 0.0 |
| 80-024 | Fantail Darter | I | | C | D | 3 | 6.0 | 4.17 | 0 | 0.00 | 0.0 |

**No Species:** 4 **Nat. Species:** 4 **Hybrids:** 0 **Total Counted:** 72 **Total Rel. Wt. :** 0

**IBI:** 20.0 **MIwb:** N/A

# Appendix Table A-3. Midwest Biodiversity Institute
# Fish Species List

Site ID: GM91 River: 14-148 Briarly Creek RM: 3.90 Date: 06/26/2023

Time Fished: 1002 Distance: 0.150 Drainge (sq mi): 0.3 Depth: 0

Location: Ust. private drive Lat: 39.19402 Long: -84.60981

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 43-013 | Creek Chub | G | T | N | N | 125 | 250.0 | 83.89 | 0 | 0.00 | 0.0 |
| 43-042 | Fathead Minnow | O | T | C | N | 1 | 2.0 | 0.67 | 0 | 0.00 | 0.0 |
| 43-044 | Central Stoneroller | H | | N | N | 23 | 46.0 | 15.44 | 0 | 0.00 | 0.0 |

**No Species:** 3 **Nat. Species:** 3 **Hybrids:** 0 **Total Counted:** 149 **Total Rel. Wt. :** 0

**IBI:** 24.0 **MIwb:** N/A

# Appendix Table A-3. Midwest Biodiversity Institute
# Fish Species List

Site ID: GM90 River: 14-148 Briarly Creek RM: 2.45 Date: 06/26/2023

Time Fished: 771 Distance: 0.150 Drainge (sq mi): 1.3 Depth: 0

Location: Ust. bridge Lat: 39.20367 Long: -84.63400

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 43-013 | Creek Chub | G | T | N | N | 59 | 118.0 | 95.16 | 0 | 0.00 | 0.0 |
| 43-042 | Fathead Minnow | O | T | C | N | 1 | 2.0 | 1.61 | 0 | 0.00 | 0.0 |
| 43-044 | Central Stoneroller | H | | N | N | 2 | 4.0 | 3.23 | 0 | 0.00 | 0.0 |

**No Species:** 3 **Nat. Species:** 3 **Hybrids:** 0 **Total Counted:** 62 **Total Rel. Wt. :** 0

**IBI:** 22.0 **MIwb:** N/A

# Appendix Table A-3. Midwest Biodiversity Institute
## Fish Species List

Site ID: GM89 River: 14-148 Briarly Creek RM: 1.80 Date: 06/23/2023

Time Fished: 1335 Distance: 0.150 Drainge (sq mi): 2.1 Depth: 0

Location: Adj. Briarly Creek Lat: 39.20263 Long: -84.64465

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 43-011 | Western Blacknose Dace | G | T | S | N | 24 | 48.0 | 8.89 | 0 | 0.00 | 0.0 |
| 43-013 | Creek Chub | G | T | N | N | 156 | 312.0 | 57.78 | 0 | 0.00 | 0.0 |
| 43-044 | Central Stoneroller | H | | N | N | 90 | 180.0 | 33.33 | 0 | 0.00 | 0.0 |

**No Species:** 3 **Nat. Species:** 3 **Hybrids:** 0 **Total Counted:** 270 **Total Rel. Wt. :** 0

**IBI:** 24.0 **MIwb:** N/A

# Appendix Table A-3. Midwest Biodiversity Institute
## Fish Species List

Site ID: GM94 River: 14-149 Wesselman Creek RM: 4.70 Date: 06/26/2023

Time Fished: 739 Distance: 0.150 Drainge (sq mi): 1.1 Depth: 0

Location: Ust. Wesselman Rd. Lat: 39.18023 Long: -84.65256

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 43-013 | Creek Chub | G | T | N | N | 145 | 290.0 | 84.30 | 0 | 0.00 | 0.0 |
| 43-042 | Fathead Minnow | O | T | C | N | 11 | 22.0 | 6.40 | 0 | 0.00 | 0.0 |
| 43-044 | Central Stoneroller | H | | N | N | 14 | 28.0 | 8.14 | 0 | 0.00 | 0.0 |
| 77-008 | Green Sunfish | I | T | C | S | 2 | 4.0 | 1.16 | 0 | 0.00 | 0.0 |

**No Species:** 4 **Nat. Species:** 4 **Hybrids:** 0 **Total Counted:** 172 **Total Rel. Wt. :** 0

**IBI:** 26.0 **MIwb:** N/A

# Appendix Table A-3. Midwest Biodiversity Institute
## Fish Species List

Site ID: GM100 River: 14-275 Unnamed Trib to Wesselman Creek @ RM: 1.05 Date: 06/26/2023

Time Fished: 520 Distance: 0.150 RM2.95 Drainge (sq mi): 0.9 Depth: 0

Location: Ust. Rockview Rd. Lat: 39.16798 Long: -84.67773

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 43-013 | Creek Chub | G | T | N | N | 18 | 36.0 | 100.00 | 0 | 0.00 | 0.0 |

**No Species:** 1 **Nat. Species:** 1 **Hybrids:** 0 **Total Counted:** 18 **Total Rel. Wt. :** 0

**IBI:** 20.0 **MIwb:** N/A

# Appendix Table A-3. Midwest Biodiversity Institute
## Fish Species List

Site ID: GM106 River: 14-277 Unnamed Trib to Taylor Creek @ RM4.9 RM: 0.20 Date: 06/28/2023

Time Fished: 984 Distance: 0.150 Drainge (sq mi): 0.9 Depth: 0

Location: Adj. to private drive Lat: 39.18667 Long: -84.63537

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 40-016 | White Sucker | O | T | S | W | 1 | 2.0 | 0.77 | 0 | 0.00 | 0.0 |
| 43-013 | Creek Chub | G | T | N | N | 91 | 182.0 | 70.00 | 0 | 0.00 | 0.0 |
| 43-044 | Central Stoneroller | H | | N | N | 25 | 50.0 | 19.23 | 0 | 0.00 | 0.0 |
| 77-008 | Green Sunfish | I | T | C | S | 1 | 2.0 | 0.77 | 0 | 0.00 | 0.0 |
| 80-024 | Fantail Darter | I | | C | D | 12 | 24.0 | 9.23 | 0 | 0.00 | 0.0 |

**No Species:** 5 **Nat. Species:** 5 **Hybrids:** 0 **Total Counted:** 130 **Total Rel. Wt. :** 0

**IBI:** 30.0 **MIwb:** N/A

# Appendix Table A-3. Midwest Biodiversity Institute
## Fish Species List

Site ID: MU05 River: 23-007 Muddy Creek RM: 6.35 Date: 08/21/2023

Time Fished: 187 Distance: 0.100 Drainge (sq mi): 5.3 Depth: 0

Location: Sidney Ave/ Beech Grove Lat: 39.13356 Long: -84.63882

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 77-006 | Largemouth Bass | C | | C | F | 1 | 3.0 | 20.00 | 0 | 0.00 | 0.0 |
| 77-008 | Green Sunfish | I | T | C | S | 4 | 12.0 | 80.00 | 0 | 0.00 | 0.0 |

**No Species:** 2 **Nat. Species:** 2 **Hybrids:** 0 **Total Counted:** 5 **Total Rel. Wt. :** 0

**IBI:** 12.0 **MIwb:** N/A

# Appendix Table A-3. Midwest Biodiversity Institute
## Fish Species List

Site ID: MU04.5 River: 23-007 Muddy Creek RM: 5.62 Date: 08/21/2023

Time Fished: 349 Distance: 0.140 Drainge (sq mi): 7.7 Depth: 0

Location: Beech Creek Lane Lat: 39.13314 Long: -84.64798

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 43-002 | Goldfish | O | T | M | G | 1 | 2.1 | 10.00 | 0 | 0.00 | 0.0 |
| 77-008 | Green Sunfish | I | T | C | S | 8 | 17.1 | 80.00 | 0 | 0.00 | 0.0 |
| 77-015 | Green X Bluegill Sunfish | | | | | 1 | 2.1 | 10.00 | 0 | 0.00 | 0.0 |

**No Species:** 2 **Nat. Species:** 1 **Hybrids:** 1 **Total Counted:** 10 **Total Rel. Wt. :** 0

**IBI:** 12.0 **MIwb:** N/A

# Appendix Table A-3. Midwest Biodiversity Institute
## Fish Species List

Site ID: MU04 River: 23-007 Muddy Creek RM: 5.45 Date: 08/21/2023

Time Fished: 848 Distance: 0.150 Drainge (sq mi): 7.8 Depth: 0

Location: Ust. Muddy Creek Rd. Lat: 39.13439 Long: -84.65060

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 77-008 | Green Sunfish | I | T | C | S | 63 | 126.0 | 95.45 | 0 | 0.00 | 0.0 |
| 77-009 | Bluegill Sunfish | I | P | C | S | 1 | 2.0 | 1.52 | 0 | 0.00 | 0.0 |
| 77-015 | Green X Bluegill Sunfish | | | | | 2 | 4.0 | 3.03 | 0 | 0.00 | 0.0 |

**No Species:** 2 **Nat. Species:** 2 **Hybrids:** 1 **Total Counted:** 66 **Total Rel. Wt. :** 0

**IBI:** 24.0 **MIwb:** N/A

# Appendix Table A-3. Midwest Biodiversity Institute
## Fish Species List

Site ID: MU03 River: 23-007 Muddy Creek RM: 2.80 Date: 08/21/2023

Time Fished: 949 Distance: 0.150 Drainge (sq mi): 10.4 Depth: 0

Location: Cleves-Warsaw Pike Lat: 39.12383 Long: -84.67723

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 40-016 | White Sucker | O | T | S | W | 59 | 118.0 | 7.30 | 0 | 0.00 | 0.0 |
| 43-013 | Creek Chub | G | T | N | N | 83 | 166.0 | 10.27 | 0 | 0.00 | 0.0 |
| 43-020 | Emerald Shiner | I | | M | N | 2 | 4.0 | 0.25 | 0 | 0.00 | 0.0 |
| 43-043 | Bluntnose Minnow | O | T | C | N | 15 | 30.0 | 1.86 | 0 | 0.00 | 0.0 |
| 43-044 | Central Stoneroller | H | | N | N | 509 | 1018.0 | 63.00 | 0 | 0.00 | 0.0 |
| 43-086 | Eastern Blacknose Dace | | | | N | 90 | 180.0 | 11.14 | 0 | 0.00 | 0.0 |
| 77-008 | Green Sunfish | I | T | C | S | 1 | 2.0 | 0.12 | 0 | 0.00 | 0.0 |
| 77-011 | Longear Sunfish | I | M | C | S | 2 | 4.0 | 0.25 | 0 | 0.00 | 0.0 |
| 80-022 | Rainbow Darter | I | M | S | D | 47 | 94.0 | 5.82 | 0 | 0.00 | 0.0 |

**No Species:** 9 **Nat. Species:** 9 **Hybrids:** 0 **Total Counted:** 808 **Total Rel. Wt. :** 0

**IBI:** 36.0 **MIwb:** N/A

# Appendix Table A-3. Midwest Biodiversity Institute
# Fish Species List

Site ID: MU02 River: 23-007 Muddy Creek RM: 2.25 Date: 08/23/2023

Time Fished: 1852 Distance: 0.150 Drainge (sq mi): 12.1 Depth: 0

Location: ust. Hillside Rd. Lat: 39.12251 Long: -84.68694

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 40-016 | White Sucker | O | T | S | W | 61 | 122.0 | 8.20 | 0 | 0.00 | 0.0 |
| 43-011 | Western Blacknose Dace | G | T | S | N | 71 | 142.0 | 9.54 | 0 | 0.00 | 0.0 |
| 43-013 | Creek Chub | G | T | N | N | 72 | 144.0 | 9.68 | 0 | 0.00 | 0.0 |
| 43-020 | Emerald Shiner | I | | M | N | 3 | 6.0 | 0.40 | 0 | 0.00 | 0.0 |
| 43-034 | Sand Shiner | I | M | M | N | 2 | 4.0 | 0.27 | 0 | 0.00 | 0.0 |
| 43-043 | Bluntnose Minnow | O | T | C | N | 70 | 140.0 | 9.41 | 0 | 0.00 | 0.0 |
| 43-044 | Central Stoneroller | H | | N | N | 400 | 800.0 | 53.76 | 0 | 0.00 | 0.0 |
| 77-006 | Largemouth Bass | C | | C | F | 3 | 6.0 | 0.40 | 0 | 0.00 | 0.0 |
| 77-008 | Green Sunfish | I | T | C | S | 2 | 4.0 | 0.27 | 0 | 0.00 | 0.0 |
| 77-011 | Longear Sunfish | I | M | C | S | 5 | 10.0 | 0.67 | 0 | 0.00 | 0.0 |
| 77-015 | Green X Bluegill Sunfish | | | | | 1 | 2.0 | 0.13 | 0 | 0.00 | 0.0 |
| 80-022 | Rainbow Darter | I | M | S | D | 54 | 108.0 | 7.26 | 0 | 0.00 | 0.0 |

**No Species:** 11 **Nat. Species:** 11 **Hybrids:** 1 **Total Counted:** 744 **Total Rel. Wt. :** 0

**IBI:** 34.0 **MIwb:** N/A

# Appendix Table A-3. Midwest Biodiversity Institute
# Fish Species List

Site ID: MU01 River: 23-007 Muddy Creek RM: 0.17 Date: 08/23/2023

Time Fished: 2033 Distance: 0.500 Drainge (sq mi): 13.6 Depth: 0

Location: at the confluence with Ohio River Lat: 39.13266 Long: -84.70617

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10-004 | Longnose Gar | P | | M | | 1 | 2.0 | 0.46 | 0 | 0.00 | 0.0 |
| 20-001 | Skipjack Herring | P | | M | | 6 | 12.0 | 2.76 | 0 | 0.00 | 0.0 |
| 20-003 | Gizzard Shad | O | | M | | 106 | 212.0 | 48.85 | 0 | 0.00 | 0.0 |
| 40-002 | Bigmnouth Buffalo | I | | M | C | 1 | 2.0 | 0.46 | 0 | 0.00 | 0.0 |
| 40-004 | Smallmouth Buffalo | I | | M | C | 6 | 12.0 | 2.76 | 0 | 0.00 | 0.0 |
| 40-005 | Quillback Carpsucker | O | | M | C | 2 | 4.0 | 0.92 | 0 | 0.00 | 0.0 |
| 40-006 | River Carpsucker | O | | M | C | 2 | 4.0 | 0.92 | 0 | 0.00 | 0.0 |
| 40-010 | Golden Redhorse | I | M | S | R | 2 | 4.0 | 0.92 | 0 | 0.00 | 0.0 |
| 43-001 | Common Carp | O | T | M | G | 7 | 14.0 | 3.23 | 0 | 0.00 | 0.0 |
| 43-006 | Silver Chub | I | | M | N | 1 | 2.0 | 0.46 | 0 | 0.00 | 0.0 |
| 77-001 | White Crappie | I | | C | S | 5 | 10.0 | 2.30 | 0 | 0.00 | 0.0 |
| 77-002 | Black Crappie | I | | C | S | 1 | 2.0 | 0.46 | 0 | 0.00 | 0.0 |
| 77-005 | Spotted Bass | C | | C | F | 3 | 6.0 | 1.38 | 0 | 0.00 | 0.0 |
| 77-006 | Largemouth Bass | C | | C | F | 10 | 20.0 | 4.61 | 0 | 0.00 | 0.0 |
| 77-007 | Warmouth Sunfish | C | | C | S | 4 | 8.0 | 1.84 | 0 | 0.00 | 0.0 |
| 77-008 | Green Sunfish | I | T | C | S | 1 | 2.0 | 0.46 | 0 | 0.00 | 0.0 |
| 77-009 | Bluegill Sunfish | I | P | C | S | 23 | 46.0 | 10.60 | 0 | 0.00 | 0.0 |
| 77-010 | Orangespotted Sunfish | I | | C | S | 2 | 4.0 | 0.92 | 0 | 0.00 | 0.0 |
| 77-011 | Longear Sunfish | I | M | C | S | 17 | 34.0 | 7.83 | 0 | 0.00 | 0.0 |
| 77-012 | Redear Sunfish | I | | C | E | 1 | 2.0 | 0.46 | 0 | 0.00 | 0.0 |
| 80-001 | Sauger | P | | S | F | 3 | 6.0 | 1.38 | 0 | 0.00 | 0.0 |
| 80-011 | Logperch | I | M | S | D | 1 | 2.0 | 0.46 | 0 | 0.00 | 0.0 |
| 80-026 | Sauger X Walleye | P | | | E | 9 | 18.0 | 4.15 | 0 | 0.00 | 0.0 |
| 85-001 | Freshwater Drum | | P | M | | 3 | 6.0 | 1.38 | 0 | 0.00 | 0.0 |

**No Species:** 23 **Nat. Species:** 21 **Hybrids:** 1 **Total Counted:** 217 **Total Rel. Wt. :** 0

**IBI:** 24.0 **MIwb:** N/A

# Appendix Table A-3. Midwest Biodiversity Institute
## Fish Species List

Site ID: RR03 River: 23-008 Rapid Run RM: 2.70 Date: 06/27/2023

Time Fished: 0 Distance: 0.150 Drainge (sq mi): 2.3 Depth: 0

Location: Rapid Run Rd. Lat: 39.11000 Long: -84.64098

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 99-997 | Dry Site | | | | | 0 | 0.0 | ***.** | 0 | 0.00 | *****.* |

**No Species:** 1 **Nat. Species:** 1 **Hybrids:** 0 **Total Counted:** 0 **Total Rel. Wt. :** 0

**IBI:** 12.0 **MIwb:** N/A

# Appendix Table A-3. Midwest Biodiversity Institute
# Fish Species List

Site ID: RR02 River: 23-008 Rapid Run RM: 1.05 Date: 06/27/2023

Time Fished: 959 Distance: 0.150 Drainge (sq mi): 5.9 Depth: 0

Location: US Rt. 50 Lat: 39.10252 Long: -84.65530

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 43-011 | Western Blacknose Dace | G | T | S | N | 27 | 54.0 | 35.53 | 0 | 0.00 | 0.0 |
| 43-013 | Creek Chub | G | T | N | N | 24 | 48.0 | 31.58 | 0 | 0.00 | 0.0 |
| 43-043 | Bluntnose Minnow | O | T | C | N | 1 | 2.0 | 1.32 | 0 | 0.00 | 0.0 |
| 43-044 | Central Stoneroller | H | | N | N | 23 | 46.0 | 30.26 | 0 | 0.00 | 0.0 |
| 77-008 | Green Sunfish | I | T | C | S | 1 | 2.0 | 1.32 | 0 | 0.00 | 0.0 |

**No Species:** 5 **Nat. Species:** 5 **Hybrids:** 0 **Total Counted:** 76 **Total Rel. Wt. :** 0

**IBI:** 24.0 **MIwb:** N/A

# Appendix Table A-3. Midwest Biodiversity Institute
## Fish Species List

Site ID: RR01 River: 23-008 Rapid Run RM: 0.10 Date: 06/27/2023

Time Fished: 0 Distance: 0.150 Drainge (sq mi): 6.5 Depth: 0

Location: US 50 Overpass Lat: 39.10090 Long: -84.67096

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 99-997 | Dry Site | | | | | 0 | 0.0 | ***.** | 0 | 0.00 | *****.* |

**No Species:** 1 **Nat. Species:** 1 **Hybrids:** 0 **Total Counted:** 0 **Total Rel. Wt. :** 0

**IBI:** 12.0 **Mlwb:** N/A

# Appendix Table A-3. Midwest Biodiversity Institute
## Fish Species List

Site ID: RR05 River: 23-012 Wulff Run RM: 1.45 Date: 06/27/2023

Time Fished: 0 Distance: 0.150 Drainge (sq mi): 1.3 Depth: 0

Location: Near intersection of Oakwood and Delhi Lat: 39.09407 Long: -84.62842

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 99-997 | Dry Site | | | | | 0 | 0.0 | ***.** | 0 | 0.00 | *****.* |

**No Species:** 1 **Nat. Species:** 1 **Hybrids:** 0 **Total Counted:** 0 **Total Rel. Wt. :** 0

**IBI:** 12.0 **MIwb:** N/A

# Appendix Table A-3. Midwest Biodiversity Institute
## Fish Species List

Site ID: RR04 River: 23-012 Wulff Run RM: 0.45 Date: 06/27/2023

Time Fished: 596 Distance: 0.150 Drainge (sq mi): 2.1 Depth: 0

Location: Wulff Run Rd. Lat: 39.10133 Long: -84.64111

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 43-013 | Creek Chub | G | T | N | N | 25 | 50.0 | 100.00 | 0 | 0.00 | 0.0 |

**No Species:** 1 **Nat. Species:** 1 **Hybrids:** 0 **Total Counted:** 25 **Total Rel. Wt. :** 0

**IBI:** 20.0 **MIwb:** N/A

# Appendix Table A-3. Midwest Biodiversity Institute
## Fish Species List

Site ID: IC06 River: 23-019 Indian Creek RM: 2.30 Date: 06/29/2023

Time Fished: 832 Distance: 0.150 Drainge (sq mi): 0.5 Depth: 0

Location: Hampshire Rd. crossing Lat: 39.16014 Long: -84.71545

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 43-011 | Western Blacknose Dace | G | T | S | N | 45 | 90.0 | 32.37 | 0 | 0.00 | 0.0 |
| 43-013 | Creek Chub | G | T | N | N | 93 | 186.0 | 66.91 | 0 | 0.00 | 0.0 |
| 77-009 | Bluegill Sunfish | I | P | C | S | 1 | 2.0 | 0.72 | 0 | 0.00 | 0.0 |

**No Species:** 3 **Nat. Species:** 3 **Hybrids:** 0 **Total Counted:** 139 **Total Rel. Wt. :** 0

**IBI:** 24.0 **MIwb:** N/A

# Appendix Table A-3. Midwest Biodiversity Institute
## Fish Species List

Site ID: IC05 River: 23-019 Indian Creek RM: 2.08 Date: 06/29/2023

Time Fished: 978 Distance: 0.150 Drainge (sq mi): 1.0 Depth: 0

Location: Golf course pond Lat: 39.15841 Long: -84.71713

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 43-011 | Western Blacknose Dace | G | T | S | N | 17 | 34.0 | 8.72 | 0 | 0.00 | 0.0 |
| 43-013 | Creek Chub | G | T | N | N | 36 | 72.0 | 18.46 | 0 | 0.00 | 0.0 |
| 57-001 | Western Mosquitofish | I | | N | E | 2 | 4.0 | 1.03 | 0 | 0.00 | 0.0 |
| 77-009 | Bluegill Sunfish | I | P | C | S | 140 | 280.0 | 71.79 | 0 | 0.00 | 0.0 |

**No Species:** 4 **Nat. Species:** 3 **Hybrids:** 0 **Total Counted:** 195 **Total Rel. Wt. :** 0

**IBI:** 38.0 **MIwb:** N/A

# Appendix Table A-3. Midwest Biodiversity Institute
# Fish Species List

Site ID: IC02 River: 23-019 Indian Creek RM: 1.15 Date: 06/29/2023

Time Fished: 974 Distance: 0.150 Drainge (sq mi): 1.3 Depth: 0

Location: Aston Oaks Golf Club Lat: 39.15385 Long: -84.72897

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 43-011 | Western Blacknose Dace | G | T | S | N | 22 | 44.0 | 9.52 | 0 | 0.00 | 0.0 |
| 43-013 | Creek Chub | G | T | N | N | 78 | 156.0 | 33.77 | 0 | 0.00 | 0.0 |
| 43-044 | Central Stoneroller | H | | N | N | 71 | 142.0 | 30.74 | 0 | 0.00 | 0.0 |
| 77-006 | Largemouth Bass | C | | C | F | 1 | 2.0 | 0.43 | 0 | 0.00 | 0.0 |
| 77-009 | Bluegill Sunfish | I | P | C | S | 59 | 118.0 | 25.54 | 0 | 0.00 | 0.0 |

**No Species:** 5 **Nat. Species:** 5 **Hybrids:** 0 **Total Counted:** 231 **Total Rel. Wt. :** 0

**IBI:** 36.0 **MIwb:** N/A

# Appendix Table A-3. Midwest Biodiversity Institute
## Fish Species List

Site ID: IC01 River: 23-019 Indian Creek RM: 0.30 Date: 06/29/2023

Time Fished: 1201 Distance: 0.150 Drainge (sq mi): 2.3 Depth: 0

Location: Near TISCH Environmental Parking Lot Lat: 39.15303 Long: -84.74149

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 40-016 | White Sucker | O | T | S | W | 29 | 58.0 | 6.50 | 0 | 0.00 | 0.0 |
| 43-011 | Western Blacknose Dace | G | T | S | N | 29 | 58.0 | 6.50 | 0 | 0.00 | 0.0 |
| 43-013 | Creek Chub | G | T | N | N | 121 | 242.0 | 27.13 | 0 | 0.00 | 0.0 |
| 43-043 | Bluntnose Minnow | O | T | C | N | 155 | 310.0 | 34.75 | 0 | 0.00 | 0.0 |
| 43-044 | Central Stoneroller | H | | N | N | 64 | 128.0 | 14.35 | 0 | 0.00 | 0.0 |
| 77-006 | Largemouth Bass | C | | C | F | 1 | 2.0 | 0.22 | 0 | 0.00 | 0.0 |
| 77-008 | Green Sunfish | I | T | C | S | 2 | 4.0 | 0.45 | 0 | 0.00 | 0.0 |
| 77-009 | Bluegill Sunfish | I | P | C | S | 31 | 62.0 | 6.95 | 0 | 0.00 | 0.0 |
| 80-022 | Rainbow Darter | I | M | S | D | 14 | 28.0 | 3.14 | 0 | 0.00 | 0.0 |

**No Species:** 9 **Nat. Species:** 9 **Hybrids:** 0 **Total Counted:** 446 **Total Rel. Wt. :** 0

**IBI:** 24.0 **MIwb:** N/A

# Appendix Table A-3. Midwest Biodiversity Institute
## Fish Species List

Site ID: IC07 River: 23-020 Trib. to Indian Creek (RM 1.02) RM: 0.10 Date: 06/29/2023

Time Fished: 164 Distance: 0.150 Drainge (sq mi): 0.3 Depth: 0

Location: at dead end of Stonehaven Dr. Lat: 39.15186 Long: -84.73061

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 99-999 | No Fish | | | | | 0 | 0.0 | ***.** | 0 | 0.00 | *****.* |

**No Species:** 0 **Nat. Species:** 1 **Hybrids:** 0 **Total Counted:** 0 **Total Rel. Wt. :** 0

**IBI:** 12.0 **MIwb:** N/A

# Appendix Table A-3. Midwest Biodiversity Institute
## Fish Species List

Site ID: MU10 River: 23-071 Unnamed Trib to Muddy Creek @ RM2.37 RM: 0.50 Date: 06/28/2023

Time Fished: 122 Distance: 0.150 Drainge (sq mi): 0.7 Depth: 0

Location: Van Blaricum Rd. Lat: 39.12887 Long: -84.68124

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 99-999 | No Fish | | | | | 0 | 0.0 | ***.** | 0 | 0.00 | *****.* |

**No Species:** 0 **Nat. Species:** 1 **Hybrids:** 0 **Total Counted:** 0 **Total Rel. Wt. :** 0

**IBI:** 12.0 **MIwb:** N/A

# Appendix Table A-3. Midwest Biodiversity Institute
## Fish Species List

Site ID: MU12 River: 23-072 Unnamed Trib to Muddy Creek @ RM5.97 RM: 0.55 Date: 06/28/2023

Time Fished: 572 Distance: 0.150 Drainge (sq mi): 1.0 Depth: 0

Location: Werk and Qualhill Lat: 39.14132 Long: -84.64380

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 77-008 | Green Sunfish | I | T | C | S | 117 | 234.0 | 94.35 | 0 | 0.00 | 0.0 |
| 77-009 | Bluegill Sunfish | I | P | C | S | 4 | 8.0 | 3.23 | 0 | 0.00 | 0.0 |
| 77-015 | Green X Bluegill Sunfish | | | | | 3 | 6.0 | 2.42 | 0 | 0.00 | 0.0 |

**No Species:** 2 **Nat. Species:** 2 **Hybrids:** 1 **Total Counted:** 124 **Total Rel. Wt. :** 0

**IBI:** 24.0 **MIwb:** N/A

# Appendix Table A-3. Midwest Biodiversity Institute
## Fish Species List

Site ID: MU13 River: 23-073 Unnamed Trib to Muddy Creek @ RM6.53 RM: 0.60 Date: 06/28/2023

Time Fished: 270 Distance: 0.150 Drainge (sq mi): 2.2 Depth: 0

Location: Werk Rd. and Westbourne Dr. Lat: 39.13931 Long: -84.63304

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 99-999 | No Fish | | | | | 0 | 0.0 | ***.** | 0 | 0.00 | *****.* |

**No Species:** 0 **Nat. Species:** 1 **Hybrids:** 0 **Total Counted:** 0 **Total Rel. Wt. :** 0

**IBI:** 12.0 **MIwb:** N/A

# Appendix Table A-3. Midwest Biodiversity Institute
## Fish Species List

Site ID: MU14 River: 23-074 UT RM0.45 to UT to Muddy Cr @ RM5.97 RM: 0.20 Date: 06/29/2023

Time Fished: 0 Distance: 0.150 Drainge (sq mi): 0.0 Depth: 0

Location: Andres Ln. crossing Lat: 39.14363 Long: -84.63493

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 99-997 | Dry Site | | | | | 0 | 0.0 | ***.** | 0 | 0.00 | *****.* |

**No Species:** 1 **Nat. Species:** 1 **Hybrids:** 0 **Total Counted:** 0 **Total Rel. Wt. :** 0

**IBI:** 12.0 **MIwb:** N/A

# Appendix Table A-3. Midwest Biodiversity Institute
# Fish Species List

Site ID: MU08 River: 23-075 Unnamed Trib to Muddy Creek @ RM0.3 RM: 1.72 Date: 06/27/2023

Time Fished: 0 Distance: 0.150 Drainge (sq mi): 0.7 Depth: 0

Location: Aston Golf Club, access at 51 Oaks Dr. Lat: 39.15130 Long: -84.69610

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 99-997 | Dry Site | | | | | 0 | 0.0 | ***.** | 0 | 0.00 | *****.* |

**No Species:** 1 **Nat. Species:** 1 **Hybrids:** 0 **Total Counted:** 0 **Total Rel. Wt. :** 0

**IBI:** 12.0 **MIwb:** N/A

# Appendix Table A-3. Midwest Biodiversity Institute
## Fish Species List

Site ID: MU07.5 River: 23-075 Unnamed Trib to Muddy Creek @ RM0.3 RM: 0.80 Date: 06/28/2023

Time Fished: 1059 Distance: 0.150 Drainge (sq mi): 2.6 Depth: 0

Location: First Str. Turns into Fiddles Green, Dst. Confluence Lat: 39.14312 Long: -84.70720

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 40-016 | White Sucker | O | T | S | W | 2 | 4.0 | 0.66 | 0 | 0.00 | 0.0 |
| 43-011 | Western Blacknose Dace | G | T | S | N | 131 | 262.0 | 43.52 | 0 | 0.00 | 0.0 |
| 43-013 | Creek Chub | G | T | N | N | 33 | 66.0 | 10.96 | 0 | 0.00 | 0.0 |
| 43-043 | Bluntnose Minnow | O | T | C | N | 4 | 8.0 | 1.33 | 0 | 0.00 | 0.0 |
| 43-044 | Central Stoneroller | H | | N | N | 126 | 252.0 | 41.86 | 0 | 0.00 | 0.0 |
| 77-008 | Green Sunfish | I | T | C | S | 4 | 8.0 | 1.33 | 0 | 0.00 | 0.0 |
| 80-022 | Rainbow Darter | I | M | S | D | 1 | 2.0 | 0.33 | 0 | 0.00 | 0.0 |

**No Species:** 7 **Nat. Species:** 7 **Hybrids:** 0 **Total Counted:** 301 **Total Rel. Wt. :** 0

**IBI:** 32.0 **MIwb:** N/A

# Appendix Table A-3. Midwest Biodiversity Institute
## Fish Species List

Site ID: MU07 River: 23-075 Unnamed Trib to Muddy Creek @ RM0.3 RM: 0.40 Date: 06/28/2023

Time Fished: 0 Distance: 0.150 Drainge (sq mi): 2.8 Depth: 0

Location: VFW Post 6428 on Main Street Lat: 39.13871 Long: -84.71006

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 99-997 | Dry Site | | | | | 0 | 0.0 | ***.** | 0 | 0.00 | *****.* |

**No Species:** 1 **Nat. Species:** 1 **Hybrids:** 0 **Total Counted:** 0 **Total Rel. Wt. :** 0

**IBI:** 12.0 **MIwb:** N/A

# Appendix Table A-3. Midwest Biodiversity Institute
## Fish Species List

Site ID: MU09 River: 23-076 UT RM0.95 to UT to Muddy Creek @ RM0.3 RM: 0.10 Date: 06/28/2023

Time Fished: 664 Distance: 0.150 Drainge (sq mi): 1.3 Depth: 0

Location: pull-off near Addyston Town Sign Lat: 39.14336 Long: -84.70426

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 43-011 | Western Blacknose Dace | G | T | S | N | 62 | 124.0 | 55.86 | 0 | 0.00 | 0.0 |
| 43-013 | Creek Chub | G | T | N | N | 48 | 96.0 | 43.24 | 0 | 0.00 | 0.0 |
| 77-008 | Green Sunfish | I | T | C | S | 1 | 2.0 | 0.90 | 0 | 0.00 | 0.0 |

**No Species:** 3 **Nat. Species:** 3 **Hybrids:** 0 **Total Counted:** 111 **Total Rel. Wt. :** 0

**IBI:** 24.0 **MIwb:** N/A

# Appendix Table A-3. Midwest Biodiversity Institute
## Fish Species List

Site ID: RR05.5 River: 23-077 Unnamed Trib to Wulff Run @ RM0.77 RM: 0.40 Date: 06/27/2023

Time Fished: 430 Distance: 0.150 Drainge (sq mi): 0.3 Depth: 0

Location: Foley Rd. @ Mitchell Way Court Lat: 39.10217 Long: -84.63055

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 99-999 | No Fish | | | | | 0 | 0.0 | ***.** | 0 | 0.00 | *****.* |

**No Species:** 0 **Nat. Species:** 1 **Hybrids:** 0 **Total Counted:** 0 **Total Rel. Wt. :** 0

**IBI:** 12.0 **MIwb:** N/A

# Appendix Table A-3. Midwest Biodiversity Institute
## Fish Species List

Site ID: RR04.5 River: 23-077 Unnamed Trib to Wulff Run @ RM0.77 RM: 0.35 Date: 06/27/2023

Time Fished: 419 Distance: 0.150 Drainge (sq mi): 0.3 Depth: 0

Location: Overhill Lane (Limnotech RR04) Lat: 39.10072 Long: -84.63182

| Species Code: | Species Name: | Feed Guild | Toler-ance | Breed Guild | IBI Group | No. Fish | Rel. No. | % by No. | Rel. Wt. | % by Wt. | Av. Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 77-009 | Bluegill Sunfish | I | P | C | S | 1 | 2.0 | 100.00 | 0 | 0.00 | 0.0 |

**No Species:** 1 **Nat. Species:** 1 **Hybrids:** 0 **Total Counted:** 1 **Total Rel. Wt. :** 0

**IBI:** 12.0 **MIwb:** N/A

# Appendix B

## Ohio River Direct Tributaries 2023 Macroinvertebrate Assemblage Data
## B-1: ICI Metrics & Narratives
## B-2: Macroinvertebrate Taxa by Site

**Appendix Table B-1. ICI metrics and narrative for sites in the Ohio River Tributary study area sampled by MBI in 2023.**

| Site ID | River Mile | Drainage Area (sq mi) | Number of | | | | Percent: | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Total Taxa[a] | Mayfly Taxa | Caddisfly Taxa | Dipteran Taxa | Mayflies | Caddis-flies | Tany-tarsini | Other Dipt/NI | Tolerant Organisms | Qual. EPT | ICI or Narrative |
| **Taylor Creek (14-004)** | | | | | | | | | | | | | |
| **Year:2023** | | | | | | | | | | | | | |
| GM86 | 6.40 | 0.49 | 12 | | | | | | | | | 1 | VP |
| GM85 | 5.30 | 2.22 | 21 | | | | | | | | | 7 | F |
| **Briarly Creek (14-148)** | | | | | | | | | | | | | |
| **Year:2023** | | | | | | | | | | | | | |
| GM91 | 3.90 | 0.34 | 22 | | | | | | | | | 4 | HW |
| GM90 | 2.45 | 1.30 | 20 | | | | | | | | | 6 | F |
| GM89 | 1.80 | 2.10 | 17 | | | | | | | | | 9 | MG |
| **Wesselman Creek (14-149)** | | | | | | | | | | | | | |
| **Year:2023** | | | | | | | | | | | | | |
| GM94 | 4.70 | 1.10 | 16 | | | | | | | | | 4 | P |
| **Unnamed Trib to Wesselman Creek @ RM 2.59 (14-275)** | | | | | | | | | | | | | |
| **Year:2023** | | | | | | | | | | | | | |
| GM100 | 1.05 | 0.91 | 22 | | | | | | | | | 7 | HW |
| **Unnamed Trib to Taylor Creek @ RM4.9 (14-277)** | | | | | | | | | | | | | |
| **Year:2023** | | | | | | | | | | | | | |
| GM106 | 0.20 | 0.92 | 20 | | | | | | | | | 4 | P |
| **Muddy Creek (23-007)** | | | | | | | | | | | | | |
| **Year:2023** | | | | | | | | | | | | | |
| MU05 | 6.35 | 5.39 | 12 | | | | | | | | | 0 | VP |
| MU04.5 | 5.62 | 7.71 | 15 | | | | | | | | | 0 | VP |
| MU04 | 5.45 | 7.80 | 16 | | | | | | | | | 1 | VP |
| MU03 | 2.80 | 10.40 | 24(2) | 2(0) | 5(6) | 12(2) | 2.7(2) | 15.3(6) | 4.5(2) | 77.2(0) | 9.9(4) | 9(4) | 28 |
| MU02 | 2.25 | 12.10 | 25(4) | 1(0) | 4(6) | 15(4) | 7.2(2) | 3.5(6) | 17.1(4) | 71.4(0) | 4.3(6) | 8(4) | 36 |
| **Rapid Run (23-008)** | | | | | | | | | | | | | |
| **Year:2023** | | | | | | | | | | | | | |
| RR03 | 2.70 | 2.32 | 25 | | | | | | | | | 7 | MG |
| RR02 | 1.05 | 5.90 | 27 | | | | | | | | | 8 | MG |
| RR01 | 0.10 | 6.56 | 9 | | | | | | | | | 1 | VP |
| **Wulff Run (23-012)** | | | | | | | | | | | | | |
| **Year:2023** | | | | | | | | | | | | | |
| RR05 | 1.45 | 1.33 | 13 | | | | | | | | | 0 | VP |
| RR04 | 0.45 | 2.18 | 29 | | | | | | | | | 6 | F |
| **Indian Creek (23-019)** | | | | | | | | | | | | | |
| **Year:2023** | | | | | | | | | | | | | |
| IC06 | 2.30 | 0.58 | 16 | | | | | | | | | 8 | MG |

[a] For HD samples represents total QUANT taxa, but for QUAL samples represents QUAL taxa.

**Appendix Table B-1. ICI metrics and narrative for sites in the Ohio River Tributary study area sampled by MBI in 2023.**

| Site ID | River Mile | Drainage Area (sq mi) | Number of | | | | Percent: | | | | | Qual. EPT | ICI or Narrative |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Total Taxa[a] | Mayfly Taxa | Caddisfly Taxa | Dipteran Taxa | Mayflies | Caddis-flies | Tany-tarsini | Other Dipt/NI | Tolerant Organisms | | |
| IC05 | 2.08 | 1.07 | 23 | | | | | | | | | 6 | F |
| IC02 | 1.15 | 1.38 | 14 | | | | | | | | | 8 | F |
| IC01 | 0.30 | 2.30 | 23 | | | | | | | | | 8 | F |
| **Trib to Indian Creek @RM1.02 RM0.97 (23-020)** | | | | | | | | | | | | | |
| **Year:2023** | | | | | | | | | | | | | |
| IC07 | 0.10 | 0.39 | 15 | | | | | | | | | 1 | HW |
| **Unnamed Trib to Muddy Creek @ RM2.37 (23-071)** | | | | | | | | | | | | | |
| **Year:2023** | | | | | | | | | | | | | |
| MU10 | 0.50 | 0.71 | 32 | | | | | | | | | 10 | HW |
| **Unnamed Trib to Muddy Creek @ RM5.97 (23-072)** | | | | | | | | | | | | | |
| **Year:2023** | | | | | | | | | | | | | |
| MU12 | 0.55 | 1.01 | 19 | | | | | | | | | 6 | F |
| **Unnamed Trib to Muddy Creek @ RM6.53 (23-073)** | | | | | | | | | | | | | |
| **Year:2023** | | | | | | | | | | | | | |
| MU13 | 0.60 | 2.25 | 10 | | | | | | | | | 0 | VP |
| **Unnamed Trib to Muddy Creek @RM0.3 (23-075)** | | | | | | | | | | | | | |
| **Year:2023** | | | | | | | | | | | | | |
| MU08 | 1.72 | 0.74 | 25 | | | | | | | | | 9 | HW |
| MU07.5 | 0.80 | 2.60 | 23 | | | | | | | | | 5 | F |
| **UT @ 0.95 to UT to Muddy Creek @ RM0.3 (23-076)** | | | | | | | | | | | | | |
| **Year:2023** | | | | | | | | | | | | | |
| MU09 | 0.10 | 1.31 | 29 | | | | | | | | | 8 | HW |
| **Unnamed Trib to Wulff Run @ RM 0.77 (23-077)** | | | | | | | | | | | | | |
| **Year:2023** | | | | | | | | | | | | | |
| RR05.5 | 0.40 | 0.33 | 20 | | | | | | | | | 2 | HW |
| RR04.5 | 0.35 | 0.33 | 20 | | | | | | | | | 4 | HW |

[a] For HD samples represents total QUANT taxa, but for QUAL samples represents QUAL taxa.

**Appendix Table B-2. Macroinvertebrate taxa list for sites sampled in the Ohio River Tributaries study area in 2023.**

River Code: **14-004** River: ***Taylor Creek*** Coll. Date: *09/11/2023* RM: **6.40**

Site ID: **GM86** Location: *Reemelin Rd.* Sample:

| Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. |
|---|---|---|---|---|
| 01801 | Turbellaria | | **F** | + |
| 05900 | Lirceus sp | | **MT** | + |
| 06700 | Crangonyx sp | | **MT** | + |
| 08250 | Orconectes (Procericambarus) rusticus | | **F** | + |
| 28001 | Libellulidae | | **MT** | + |
| 51610 | Polycentropus sp | | **MI** | + |
| 68025 | Ectopria sp | | **F** | + |
| 69400 | Stenelmis sp | | **F** | + |
| 71900 | Tipula sp | | **F** | + |
| 84210 | Paratendipes albimanus or P. duplicatus | | **F** | + |
| 84450 | Polypedilum (Uresipedilum) flavum | | **F** | + |
| 98600 | Sphaerium sp | | **F** | + |

| | | | |
|---|---|---|---|
| No. Quantitative Taxa: | 0 | Total Taxa; | 12 |
| No. Qualitative Taxa: | 12 | ICI: | VP |
| Number of Organisms: | 0 | Qual EPT: | 1 |

**Appendix Table B-2. Macroinvertebrate taxa list for sites sampled in the Ohio River Tributaries study area in 2023.**

River Code: **14-004** River: ***Taylor Creek*** Coll. Date: *09/11/2023* RM: **5.30**

Site ID: **GM85** Location: *Ust. Johnson Rd.* Sample:

| Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. |
|---|---|---|---|---|
| 01801 | Turbellaria | | **F** | + |
| 03600 | Oligochaeta | | **T** | + |
| 05900 | Lirceus sp | | **MT** | + |
| 06700 | Crangonyx sp | | **MT** | + |
| 08250 | Orconectes (Procericambarus) rusticus | | **F** | + |
| 11120 | Baetis flavistriga | | **F** | + |
| 13400 | Stenacron sp | | **F** | + |
| 13521 | Stenonema femoratum | | **F** | + |
| 17200 | Caenis sp | | **F** | + |
| 50301 | Chimarra aterrima | | **MI** | + |
| 52200 | Cheumatopsyche sp | | **F** | + |
| 52530 | Hydropsyche depravata group | | **F** | + |
| 68025 | Ectopria sp | | **F** | + |
| 68075 | Psephenus herricki | | **MI** | + |
| 69400 | Stenelmis sp | | **F** | + |
| 71900 | Tipula sp | | **F** | + |
| 74501 | Ceratopogonidae | | **T** | + |
| 79720 | Diamesa sp | **X** | **F** | + |
| 81650 | Parametriocnemus sp | **X** | **F** | + |
| 84210 | Paratendipes albimanus or P. duplicatus | | **F** | + |
| 84540 | Polypedilum (Tripodura) scalaenum group | | **F** | + |

| | | | |
|---|---|---|---|
| No. Quantitative Taxa: | 0 | Total Taxa; | 21 |
| No. Qualitative Taxa: | 21 | ICI: | F |
| Number of Organisms: | 0 | Qual EPT: | 7 |

**Appendix Table B-2. Macroinvertebrate taxa list for sites sampled in the Ohio River Tributaries study area in 2023.**

River Code: **14-148** River: ***Briarly Creek*** Coll. Date: *09/18/2023* RM: **3.90**

Site ID: **GM91** Location: *Ust. private drive* Sample:

| Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. |
|---|---|---|---|---|
| 01801 | Turbellaria | | **F** | + |
| 03600 | Oligochaeta | | **T** | + |
| 05800 | Caecidotea sp | | **T** | + |
| 05900 | Lirceus sp | | **MT** | + |
| 08601 | Hydrachnidia | | **F** | + |
| 11120 | Baetis flavistriga | | **F** | + |
| 21200 | Calopteryx sp | | **F** | + |
| 21300 | Hetaerina sp | | **F** | + |
| 50301 | Chimarra aterrima | | **MI** | + |
| 52530 | Hydropsyche depravata group | | **F** | + |
| 53800 | Hydroptila sp | | **F** | + |
| 68025 | Ectopria sp | | **F** | + |
| 68075 | Psephenus herricki | | **MI** | + |
| 72700 | Anopheles sp | | **F** | + |
| 74100 | Simulium sp | | **F** | + |
| 77120 | Ablabesmyia mallochi | | **F** | + |
| 77800 | Helopelopia sp | | **F** | + |
| 78655 | Procladius (Holotanypus) sp | | **MT** | + |
| 79760 | Pagastia sp | | **F** | + |
| 81650 | Parametriocnemus sp | **X** | **F** | + |
| 83040 | Dicrotendipes neomodestus | | **F** | + |
| 84210 | Paratendipes albimanus or P. duplicatus | | **F** | + |

| | | | |
|---|---|---|---|
| No. Quantitative Taxa: | 0 | Total Taxa; | 22 |
| No. Qualitative Taxa: | 22 | ICI: | HW |
| Number of Organisms: | 0 | Qual EPT: | 4 |

**Appendix Table B-2. Macroinvertebrate taxa list for sites sampled in the Ohio River Tributaries study area in 2023.**

River Code: **14-148** River: ***Briarly Creek*** Coll. Date: *09/18/2023* RM: **2.45**

Site ID: **GM90** Location: *Ust. bridge* Sample:

| Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. |
|---|---|---|---|---|
| 01801 | Turbellaria | | **F** | + |
| 03600 | Oligochaeta | | **T** | + |
| 04664 | Helobdella stagnalis | | **T** | + |
| 05900 | Lirceus sp | | **MT** | + |
| 07800 | Cambarus sp | | | + |
| 13400 | Stenacron sp | | **F** | + |
| 13521 | Stenonema femoratum | | **F** | + |
| 17200 | Caenis sp | | **F** | + |
| 50301 | Chimarra aterrima | | **MI** | + |
| 52200 | Cheumatopsyche sp | | **F** | + |
| 58505 | Helicopsyche borealis | | **MI** | + |
| 68025 | Ectopria sp | | **F** | + |
| 68075 | Psephenus herricki | | **MI** | + |
| 77800 | Helopelopia sp | | **F** | + |
| 79760 | Pagastia sp | | **F** | + |
| 81650 | Parametriocnemus sp | **X** | **F** | + |
| 83040 | Dicrotendipes neomodestus | | **F** | + |
| 84300 | Phaenopsectra obediens group | | **F** | + |
| 85800 | Tanytarsus sp | | **F** | + |
| 95100 | Physella sp | | **T** | + |

| | | | |
|---|---|---|---|
| No. Quantitative Taxa: | 0 | Total Taxa; | 20 |
| No. Qualitative Taxa: | 20 | ICI: | F |
| Number of Organisms: | 0 | Qual EPT: | 6 |

**Appendix Table B-2. Macroinvertebrate taxa list for sites sampled in the Ohio River Tributaries study area in 2023.**

River Code: **14-148** River: ***Briarly Creek*** Coll. Date: *09/18/2023* RM: **1.80**

Site ID: **GM89** Location: *Adj. Briarly Creek* Sample:

| Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. |
|---|---|---|---|---|
| 03600 | Oligochaeta | | **T** | + |
| 05900 | Lirceus sp | | **MT** | + |
| 08200 | Orconectes sp | | **F** | + |
| 11120 | Baetis flavistriga | | **F** | + |
| 13400 | Stenacron sp | | **F** | + |
| 13521 | Stenonema femoratum | | **F** | + |
| 17200 | Caenis sp | | **F** | + |
| 50301 | Chimarra aterrima | | **MI** | + |
| 52200 | Cheumatopsyche sp | | **F** | + |
| 52530 | Hydropsyche depravata group | | **F** | + |
| 57400 | Neophylax sp | | **MI** | + |
| 58505 | Helicopsyche borealis | | **MI** | + |
| 68075 | Psephenus herricki | | **MI** | + |
| 77500 | Conchapelopia sp | | **F** | + |
| 80420 | Cricotopus (C.) bicinctus | | **T** | + |
| 81825 | Rheocricotopus (Psilocricotopus) robacki | | **F** | + |
| 84450 | Polypedilum (Uresipedilum) flavum | | **F** | + |

| | | | |
|---|---|---|---|
| No. Quantitative Taxa: | 0 | Total Taxa; | 17 |
| No. Qualitative Taxa: | 17 | ICI: | MG |
| Number of Organisms: | 0 | Qual EPT: | 9 |

**Appendix Table B-2. Macroinvertebrate taxa list for sites sampled in the Ohio River Tributaries study area in 2023.**

River Code: **14-149** River: ***Wesselman Creek*** Coll. Date: *09/19/2023* RM: **4.70**

Site ID: **GM94** Location: *Ust. Wesselman Rd.* Sample:

| Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. |
|---|---|---|---|---|
| 01801 | Turbellaria | | **F** | + |
| 03600 | Oligochaeta | | **T** | + |
| 04935 | Erpobdella punctata punctata | | **MT** | + |
| 05800 | Caecidotea sp | | **T** | + |
| 05900 | Lirceus sp | | **MT** | + |
| 08200 | Orconectes sp | | **F** | + |
| 11120 | Baetis flavistriga | | **F** | + |
| 13521 | Stenonema femoratum | | **F** | + |
| 52200 | Cheumatopsyche sp | | **F** | + |
| 52530 | Hydropsyche depravata group | | **F** | + |
| 68025 | Ectopria sp | | **F** | + |
| 68075 | Psephenus herricki | | **MI** | + |
| 72700 | Anopheles sp | | **F** | + |
| 77100 | Ablabesmyia sp | | | + |
| 84210 | Paratendipes albimanus or P. duplicatus | | **F** | + |
| 84450 | Polypedilum (Uresipedilum) flavum | | **F** | + |

| | | | |
|---|---|---|---|
| No. Quantitative Taxa: | 0 | Total Taxa; | 16 |
| No. Qualitative Taxa: | 16 | ICI: | P |
| Number of Organisms: | 0 | Qual EPT: | 4 |

**Appendix Table B-2. Macroinvertebrate taxa list for sites sampled in the Ohio River Tributaries study area in 2023.**

River Code: **14-275** River: ***Unnamed Trib to Wesselman Creek @ RM 2.59*** Coll. Date: *09/11/2023* RM: **1.05**

Site ID: **GM100** Location: *Ust. Rockview Rd.* Sample:

| Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. |
|---|---|---|---|---|
| 03600 | Oligochaeta | | **T** | + |
| 04664 | Helobdella stagnalis | | **T** | + |
| 04901 | Erpobdellidae | | **MT** | + |
| 05900 | Lirceus sp | | **MT** | + |
| 06700 | Crangonyx sp | | **MT** | + |
| 08250 | Orconectes (Procericambarus) rusticus | | **F** | + |
| 11120 | Baetis flavistriga | | **F** | + |
| 13400 | Stenacron sp | | **F** | + |
| 13521 | Stenonema femoratum | | **F** | + |
| 17200 | Caenis sp | | **F** | + |
| 21200 | Calopteryx sp | | **F** | + |
| 22001 | Coenagrionidae | | **T** | + |
| 22300 | Argia sp | | **F** | + |
| 45300 | Sigara sp | | **MT** | + |
| 50301 | Chimarra aterrima | | **MI** | + |
| 52200 | Cheumatopsyche sp | | **F** | + |
| 52530 | Hydropsyche depravata group | | **F** | + |
| 68025 | Ectopria sp | | **F** | + |
| 68075 | Psephenus herricki | | **MI** | + |
| 71900 | Tipula sp | | **F** | + |
| 72700 | Anopheles sp | | **F** | + |
| 84450 | Polypedilum (Uresipedilum) flavum | | **F** | + |

| | | | |
|---|---|---|---|
| No. Quantitative Taxa: | 0 | Total Taxa; | 22 |
| No. Qualitative Taxa: | 22 | ICI: | HW |
| Number of Organisms: | 0 | Qual EPT: | 7 |

**Appendix Table B-2. Macroinvertebrate taxa list for sites sampled in the Ohio River Tributaries study area in 2023.**

River Code: **14-277** River: ***Unnamed Trib to Taylor Creek @ RM4.9*** Coll. Date: *09/18/2023* RM: **0.20**

Site ID: **GM106** Location: *Adj. to private drive* Sample:

| Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. |
|---|---|---|---|---|
| 01801 | Turbellaria | | **F** | + |
| 03600 | Oligochaeta | | **T** | + |
| 04664 | Helobdella stagnalis | | **T** | + |
| 05900 | Lirceus sp | | **MT** | + |
| 06700 | Crangonyx sp | | **MT** | + |
| 08601 | Hydrachnidia | | **F** | + |
| 11120 | Baetis flavistriga | | **F** | + |
| 13400 | Stenacron sp | | **F** | + |
| 21200 | Calopteryx sp | | **F** | + |
| 44501 | Corixidae | | **F** | + |
| 50301 | Chimarra aterrima | | **MI** | + |
| 57400 | Neophylax sp | | **MI** | + |
| 68025 | Ectopria sp | | **F** | + |
| 68075 | Psephenus herricki | | **MI** | + |
| 71900 | Tipula sp | | **F** | + |
| 77800 | Helopelopia sp | | **F** | + |
| 78655 | Procladius (Holotanypus) sp | | **MT** | + |
| 81650 | Parametriocnemus sp | **X** | **F** | + |
| 84315 | Phaenopsectra flavipes | | **MT** | + |
| 84450 | Polypedilum (Uresipedilum) flavum | | **F** | + |

| | | | |
|---|---|---|---|
| No. Quantitative Taxa: | 0 | Total Taxa; | 20 |
| No. Qualitative Taxa: | 20 | ICI: | P |
| Number of Organisms: | 0 | Qual EPT: | 4 |

**Appendix Table B-2. Macroinvertebrate taxa list for sites sampled in the Ohio River Tributaries study area in 2023.**

River Code: **23-007** River: ***Muddy Creek*** Coll. Date: *09/19/2023* RM: **6.35**

Site ID: **MU05** Location: *Sidney Ave/ Beech Grove* Sample:

| Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. |
|---|---|---|---|---|
| 01801 | Turbellaria | | **F** | + |
| 03600 | Oligochaeta | | **T** | + |
| 04901 | Erpobdellidae | | **MT** | + |
| 71900 | Tipula sp | | **F** | + |
| 72700 | Anopheles sp | | **F** | + |
| 77500 | Conchapelopia sp | | **F** | + |
| 82710 | Chironomus (C.) sp | | **MT** | + |
| 83000 | Dicrotendipes sp | | **F** | + |
| 84450 | Polypedilum (Uresipedilum) flavum | | **F** | + |
| 84470 | Polypedilum (P.) illinoense | | **T** | + |
| 95100 | Physella sp | | **T** | + |
| 96120 | Menetus (Micromenetus) dilatatus | | **MT** | + |

| | | | |
|---|---|---|---|
| No. Quantitative Taxa: | 0 | Total Taxa; | 12 |
| No. Qualitative Taxa: | 12 | ICI: | VP |
| Number of Organisms: | 0 | Qual EPT: | 0 |

**Appendix Table B-2. Macroinvertebrate taxa list for sites sampled in the Ohio River Tributaries study area in 2023.**

River Code: **23-007** River: ***Muddy Creek*** Coll. Date: *08/31/2023* RM: **5.62**

Site ID: **MU04.5** Location: *Beech Creek Lane* Sample:

| Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. |
|---|---|---|---|---|
| 01801 | Turbellaria | | **F** | + |
| 03600 | Oligochaeta | | **T** | + |
| 04664 | Helobdella stagnalis | | **T** | + |
| 04901 | Erpobdellidae | | **MT** | + |
| 05900 | Lirceus sp | | **MT** | + |
| 28500 | Libellula sp | | **MT** | + |
| 71900 | Tipula sp | | **F** | + |
| 74100 | Simulium sp | | **F** | + |
| 77120 | Ablabesmyia mallochi | | **F** | + |
| 81600 | Parachaetocladius sp | **X** | **MI** | + |
| 83040 | Dicrotendipes neomodestus | | **F** | + |
| 83051 | Dicrotendipes simpsoni | | **T** | + |
| 84450 | Polypedilum (Uresipedilum) flavum | | **F** | + |
| 84470 | Polypedilum (P.) illinoense | | **T** | + |
| 84960 | Pseudochironomus sp | | **F** | + |

| Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. |
|---|---|---|---|---|

| | | | |
|---|---|---|---|
| No. Quantitative Taxa: | 0 | Total Taxa; | 15 |
| No. Qualitative Taxa: | 15 | ICI: | VP |
| Number of Organisms: | 0 | Qual EPT: | 0 |

**Appendix Table B-2. Macroinvertebrate taxa list for sites sampled in the Ohio River Tributaries study area in 2023.**

River Code: **23-007** River: ***Muddy Creek*** Coll. Date: *08/31/2023* RM: **5.45**

Site ID: **MU04** Location: *Ust. Muddy Creek Rd.* Sample:

| Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. |
|---|---|---|---|---|
| 01801 | Turbellaria | | **F** | + |
| 03600 | Oligochaeta | | **T** | + |
| 04664 | Helobdella stagnalis | | **T** | + |
| 04901 | Erpobdellidae | | **MT** | + |
| 11200 | Callibaetis sp | | **MT** | + |
| 22001 | Coenagrionidae | | **T** | + |
| 68025 | Ectopria sp | | **F** | + |
| 71900 | Tipula sp | | **F** | + |
| 77120 | Ablabesmyia mallochi | | **F** | + |
| 78600 | Pentaneura inconspicua | | **F** | + |
| 81650 | Parametriocnemus sp | **X** | **F** | + |
| 82730 | Chironomus (C.) decorus group | | **T** | + |
| 83040 | Dicrotendipes neomodestus | | **F** | + |
| 84450 | Polypedilum (Uresipedilum) flavum | | **F** | + |
| 84470 | Polypedilum (P.) illinoense | | **T** | + |
| 84960 | Pseudochironomus sp | | **F** | + |

| | | | |
|---|---|---|---|
| No. Quantitative Taxa: | 0 | Total Taxa; | 16 |
| No. Qualitative Taxa: | 16 | ICI: | VP |
| Number of Organisms: | 0 | Qual EPT: | 1 |

**Appendix Table B-2. Macroinvertebrate taxa list for sites sampled in the Ohio River Tributaries study area in 2023.**

River Code: **23-007** River: ***Muddy Creek*** Coll. Date: *08/29/2023* RM: **2.80**

Site ID: **MU03** Location: *Cleves-Warsaw Pike* Sample:

| Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. | | Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. |
|---|---|---|---|---|---|---|---|---|---|---|
| 01801 | Turbellaria | | **F** | 15 | + | | | | | |
| 03000 | Ectoprocta | | **F** | 1 | | | | | | |
| 03600 | Oligochaeta | | **T** | 26 | + | | | | | |
| 04901 | Erpobdellidae | | **MT** | | + | | | | | |
| 05900 | Lirceus sp | | **MT** | 1 | + | | | | | |
| 11120 | Baetis flavistriga | | **F** | | + | | | | | |
| 11130 | Baetis intercalaris | | **F** | | + | | | | | |
| 13521 | Stenonema femoratum | | **F** | 7 | + | | | | | |
| 17200 | Caenis sp | | **F** | 2 | | | | | | |
| 50315 | Chimarra obscura | | **MI** | | + | | | | | |
| 51550 | Plectrocnemia sp | | **MI** | | + | | | | | |
| 51550 | Plectrocnemia sp | | **MI** | 25 | | | | | | |
| 52200 | Cheumatopsyche sp | | **F** | 18 | + | | | | | |
| 52430 | Ceratopsyche morosa group | | **MI** | 3 | + | | | | | |
| 52530 | Hydropsyche depravata group | | **F** | 1 | + | | | | | |
| 53800 | Hydroptila sp | | **F** | 4 | + | | | | | |
| 65800 | Berosus sp | | **MT** | | + | | | | | |
| 68075 | Psephenus herricki | | **MI** | | + | | | | | |
| 69400 | Stenelmis sp | | **F** | | + | | | | | |
| 72900 | Culex sp | | **T** | | + | | | | | |
| 77120 | Ablabesmyia mallochi | | **F** | | + | | | | | |
| 77500 | Conchapelopia sp | | **F** | 15 | + | | | | | |
| 77750 | Hayesomyia senata or Thienemannimyia norena | | **F** | 15 | | | | | | |
| 77800 | Helopelopia sp | | **F** | 3 | + | | | | | |
| 80410 | Cricotopus (C.) sp | | **F** | | + | | | | | |
| 82730 | Chironomus (C.) decorus group | | **T** | 6 | + | | | | | |
| 83040 | Dicrotendipes neomodestus | | **F** | 124 | | | | | | |
| 83300 | Glyptotendipes (G.) sp | | **MT** | 3 | | | | | | |
| 83840 | Microtendipes pedellus group | | **F** | 3 | | | | | | |
| 84300 | Phaenopsectra obediens group | | **F** | 15 | | | | | | |
| 84450 | Polypedilum (Uresipedilum) flavum | | **F** | 6 | + | | | | | |
| 84470 | Polypedilum (P.) illinoense | | **T** | | + | | | | | |
| 84540 | Polypedilum (Tripodura) scalaenum group | | **F** | 25 | + | | | | | |
| 85200 | Cladotanytarsus sp | | | 3 | | | | | | |
| 85625 | Rheotanytarsus sp | | **F** | 12 | | | | | | |
| 96900 | Ferrissia sp | | **F** | 1 | | | | | | |

| | | | |
|---|---|---|---|
| No. Quantitative Taxa: | 24 | Total Taxa; | 36 |
| No. Qualitative Taxa: | 25 | ICI: | 28 |
| Number of Organisms: | 334 | Qual EPT: | 9 |

**Appendix Table B-2. Macroinvertebrate taxa list for sites sampled in the Ohio River Tributaries study area in 2023.**

River Code: **23-007** River: ***Muddy Creek*** Coll. Date: *08/29/2023* RM: **2.25**

Site ID: **MU02** Location: *ust. Hillside Rd.* Sample:

| Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. |
|---|---|---|---|---|
| 01801 | Turbellaria | | **F** | 6 + |
| 03000 | Ectoprocta | | **F** | 5 |
| 03600 | Oligochaeta | | **T** | 5 |
| 04664 | Helobdella stagnalis | | **T** | + |
| 04935 | Erpobdella punctata punctata | | **MT** | + |
| 05900 | Lirceus sp | | **MT** | 27 + |
| 11130 | Baetis intercalaris | | **F** | + |
| 13521 | Stenonema femoratum | | **F** | 80 + |
| 17200 | Caenis sp | | **F** | + |
| 22001 | Coenagrionidae | | **T** | + |
| 22300 | Argia sp | | **F** | + |
| 27307 | Epitheca (Epicordulia) princeps | | **MT** | + |
| 50315 | Chimarra obscura | | **MI** | 3 + |
| 51550 | Plectrocnemia sp | | **MI** | + |
| 52200 | Cheumatopsyche sp | | **F** | 28 + |
| 52530 | Hydropsyche depravata group | | **F** | 6 + |
| 53800 | Hydroptila sp | | **F** | 2 + |
| 60900 | Peltodytes sp | | **MT** | + |
| 65800 | Berosus sp | | **MT** | 3 + |
| 68075 | Psephenus herricki | | **MI** | + |
| 68708 | Dubiraphia vittata group | | **F** | + |
| 69400 | Stenelmis sp | | **F** | + |
| 71900 | Tipula sp | | **F** | 1 + |
| 77120 | Ablabesmyia mallochi | | **F** | + |
| 77500 | Conchapelopia sp | | **F** | 42 |
| 77800 | Helopelopia sp | | **F** | + |
| 78599 | Pentaneura sp | | **F** | + |
| 80420 | Cricotopus (C.) bicinctus | | **T** | 32 |
| 82730 | Chironomus (C.) decorus group | | **T** | + |
| 83040 | Dicrotendipes neomodestus | | **F** | 307 + |
| 83051 | Dicrotendipes simpsoni | | **T** | 11 |
| 83310 | Glyptotendipes (Heynotendipes) chelonia | | **MI** | 11 |
| 83820 | Microtendipes "caelum" (sensu Simpson & Bode, 1980) | | **MI** | 11 |
| 83840 | Microtendipes pedellus group | | **F** | 21 |
| 83900 | Nilothauma sp | | **F** | 21 |
| 84300 | Phaenopsectra obediens group | | **F** | + |
| 84450 | Polypedilum (Uresipedilum) flavum | | **F** | 138 + |
| 84470 | Polypedilum (P.) illinoense | | **T** | + |
| 84540 | Polypedilum (Tripodura) scalaenum group | | **F** | 53 + |
| 84960 | Pseudochironomus sp | | **F** | 106 + |
| 85500 | Paratanytarsus sp | | **F** | 21 |
| 85800 | Tanytarsus sp | | **F** | 21 |
| 85821 | Tanytarsus glabrescens group sp 7 | | **F** | 148 + |
| 95100 | Physella sp | | **T** | + |

| | | | |
|---|---|---|---|
| No. Quantitative Taxa: | 25 | Total Taxa; | 44 |
| No. Qualitative Taxa: | 33 | ICI: | 36 |
| Number of Organisms: | 1109 | Qual EPT: | 8 |

**Appendix Table B-2. Macroinvertebrate taxa list for sites sampled in the Ohio River Tributaries study area in 2023.**

River Code: **23-008** River: ***Rapid Run*** Coll. Date: *08/02/2023* RM: **2.70**

Site ID: **RR03** Location: *Rapid Run Rd.* Sample:

| Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. |
|---|---|---|---|---|
| 03600 | Oligochaeta | | **T** | + |
| 05900 | Lirceus sp | | **MT** | + |
| 08601 | Hydrachnidia | | **F** | + |
| 11120 | Baetis flavistriga | | **F** | + |
| 13521 | Stenonema femoratum | | **F** | + |
| 22001 | Coenagrionidae | | **T** | + |
| 50301 | Chimarra aterrima | | **MI** | + |
| 50315 | Chimarra obscura | | **MI** | + |
| 51550 | Plectrocnemia sp | | **MI** | + |
| 52200 | Cheumatopsyche sp | | **F** | + |
| 52530 | Hydropsyche depravata group | | **F** | + |
| 60900 | Peltodytes sp | | **MT** | + |
| 68025 | Ectopria sp | | **F** | + |
| 68075 | Psephenus herricki | | **MI** | + |
| 69400 | Stenelmis sp | | **F** | + |
| 77100 | Ablabesmyia sp | | | + |
| 77500 | Conchapelopia sp | | **F** | + |
| 80413 | Cricotopus (Isocladius) sp "Ozarks" | | **MT** | + |
| 82730 | Chironomus (C.) decorus group | | **T** | + |
| 83040 | Dicrotendipes neomodestus | | **F** | + |
| 84210 | Paratendipes albimanus or P. duplicatus | | **F** | + |
| 84450 | Polypedilum (Uresipedilum) flavum | | **F** | + |
| 85500 | Paratanytarsus sp | | **F** | + |
| 94800 | Stagnicola sp | | **T** | + |
| 95100 | Physella sp | | **T** | + |

| | | | |
|---|---|---|---|
| No. Quantitative Taxa: | 0 | Total Taxa; | 25 |
| No. Qualitative Taxa: | 25 | ICI: | MG |
| Number of Organisms: | 0 | Qual EPT: | 7 |

**Appendix Table B-2. Macroinvertebrate taxa list for sites sampled in the Ohio River Tributaries study area in 2023.**

River Code: **23-008** River: ***Rapid Run*** Coll. Date: *08/03/2023* RM: **1.05**

Site ID: **RR02** Location: *US Rt. 50* Sample:

| Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. |
|---|---|---|---|---|
| 01801 | Turbellaria | | **F** | + |
| 03600 | Oligochaeta | | **T** | + |
| 04935 | Erpobdella punctata punctata | | **MT** | + |
| 05900 | Lirceus sp | | **MT** | + |
| 07800 | Cambarus sp | | | + |
| 08601 | Hydrachnidia | | **F** | + |
| 11120 | Baetis flavistriga | | **F** | + |
| 11130 | Baetis intercalaris | | **F** | + |
| 13521 | Stenonema femoratum | | **F** | + |
| 23700 | Anax sp | | **MT** | + |
| 50315 | Chimarra obscura | | **MI** | + |
| 51050 | Cernotina sp | | **MI** | + |
| 52200 | Cheumatopsyche sp | | **F** | + |
| 52530 | Hydropsyche depravata group | | **F** | + |
| 53800 | Hydroptila sp | | **F** | + |
| 60900 | Peltodytes sp | | **MT** | + |
| 68075 | Psephenus herricki | | **MI** | + |
| 69400 | Stenelmis sp | | **F** | + |
| 74100 | Simulium sp | | **F** | + |
| 77140 | Ablabesmyia peleensis | | | + |
| 77800 | Helopelopia sp | | **F** | + |
| 80420 | Cricotopus (C.) bicinctus | | **T** | + |
| 82820 | Cryptochironomus sp | | **F** | + |
| 83040 | Dicrotendipes neomodestus | | **F** | + |
| 84450 | Polypedilum (Uresipedilum) flavum | | **F** | + |
| 85821 | Tanytarsus glabrescens group sp 7 | | **F** | + |
| 95100 | Physella sp | | **T** | + |

| | | | |
|---|---|---|---|
| No. Quantitative Taxa: | 0 | Total Taxa; | 27 |
| No. Qualitative Taxa: | 27 | ICI: | MG |
| Number of Organisms: | 0 | Qual EPT: | 8 |

**Appendix Table B-2. Macroinvertebrate taxa list for sites sampled in the Ohio River Tributaries study area in 2023.**

River Code: **23-008** River: ***Rapid Run*** Coll. Date: *09/19/2023* RM: **0.10**

Site ID: **RR01** Location: *US 50 Overpass* Sample:

| Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. |
|---|---|---|---|---|
| 01801 | Turbellaria | | **F** | + |
| 03600 | Oligochaeta | | **T** | + |
| 04901 | Erpobdellidae | | **MT** | + |
| 05900 | Lirceus sp | | **MT** | + |
| 13521 | Stenonema femoratum | | **F** | + |
| 68075 | Psephenus herricki | | **MI** | + |
| 78400 | Natarsia sp | | **F** | + |
| 82730 | Chironomus (C.) decorus group | | **T** | + |
| 83040 | Dicrotendipes neomodestus | | **F** | + |

| | | | |
|---|---|---|---|
| No. Quantitative Taxa: | 0 | Total Taxa; | 9 |
| No. Qualitative Taxa: | 9 | ICI: | VP |
| Number of Organisms: | 0 | Qual EPT: | 1 |

**Appendix Table B-2. Macroinvertebrate taxa list for sites sampled in the Ohio River Tributaries study area in 2023.**

River Code: **23-012** River: ***Wulff Run*** Coll. Date: *08/02/2023* RM: **1.45**

Site ID: **RR05** Location: *Near intersection of Oakwood and Delhi* Sample:

| Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. |
|---|---|---|---|---|
| 01801 | Turbellaria | | **F** | + |
| 03600 | Oligochaeta | | **T** | + |
| 04660 | Helobdella sp | | **MT** | + |
| 05900 | Lirceus sp | | **MT** | + |
| 08601 | Hydrachnidia | | **F** | + |
| 77260 | Apsectrotanypus johnsoni | **X** | **MI** | + |
| 78401 | Natarsia species A (sensu Roback, 1978) | | **T** | + |
| 78600 | Pentaneura inconspicua | | **F** | + |
| 83040 | Dicrotendipes neomodestus | | **F** | + |
| 84210 | Paratendipes albimanus or P. duplicatus | | **F** | + |
| 84470 | Polypedilum (P.) illinoense | | **T** | + |
| 95100 | Physella sp | | **T** | + |
| 98600 | Sphaerium sp | | **F** | + |

| Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. |
|---|---|---|---|---|

| | | | |
|---|---|---|---|
| No. Quantitative Taxa: | 0 | Total Taxa; | 13 |
| No. Qualitative Taxa: | 13 | ICI: | VP |
| Number of Organisms: | 0 | Qual EPT: | 0 |

**Appendix Table B-2. Macroinvertebrate taxa list for sites sampled in the Ohio River Tributaries study area in 2023.**

River Code: **23-012** River: ***Wulff Run*** Coll. Date: *08/03/2023* RM: **0.45**

Site ID: **RR04** Location: *Wulff Run Rd.* Sample:

| Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. |
|---|---|---|---|---|
| 01801 | Turbellaria | | **F** | + |
| 03600 | Oligochaeta | | **T** | + |
| 04664 | Helobdella stagnalis | | **T** | + |
| 05900 | Lirceus sp | | **MT** | + |
| 06700 | Crangonyx sp | | **MT** | + |
| 08200 | Orconectes sp | | **F** | + |
| 08601 | Hydrachnidia | | **F** | + |
| 11120 | Baetis flavistriga | | **F** | + |
| 17200 | Caenis sp | | **F** | + |
| 21001 | Calopterygidae | | **F** | + |
| 23700 | Anax sp | | **MT** | + |
| 50301 | Chimarra aterrima | | **MI** | + |
| 51550 | Plectrocnemia sp | | **MI** | + |
| 52200 | Cheumatopsyche sp | | **F** | + |
| 52530 | Hydropsyche depravata group | | **F** | + |
| 60900 | Peltodytes sp | | **MT** | + |
| 68025 | Ectopria sp | | **F** | + |
| 68201 | Scirtidae | | **F** | + |
| 69400 | Stenelmis sp | | **F** | + |
| 71900 | Tipula sp | | **F** | + |
| 72900 | Culex sp | | **T** | + |
| 77500 | Conchapelopia sp | | **F** | + |
| 81650 | Parametriocnemus sp | **X** | **F** | + |
| 83040 | Dicrotendipes neomodestus | | **F** | + |
| 84210 | Paratendipes albimanus or P. duplicatus | | **F** | + |
| 84450 | Polypedilum (Uresipedilum) flavum | | **F** | + |
| 84470 | Polypedilum (P.) illinoense | | **T** | + |
| 85821 | Tanytarsus glabrescens group sp 7 | | **F** | + |
| 98600 | Sphaerium sp | | **F** | + |

| | | | |
|---|---|---|---|
| No. Quantitative Taxa: | 0 | Total Taxa; | 29 |
| No. Qualitative Taxa: | 29 | ICI: | F |
| Number of Organisms: | 0 | Qual EPT: | 6 |

**Appendix Table B-2. Macroinvertebrate taxa list for sites sampled in the Ohio River Tributaries study area in 2023.**

River Code: **23-019** River: ***Indian Creek*** Coll. Date: *09/20/2023* RM: **2.30**

Site ID: **IC06** Location: *Hampshire Rd. crossing* Sample:

| Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. |
|---|---|---|---|---|
| 01801 | Turbellaria | | **F** | + |
| 03600 | Oligochaeta | | **T** | + |
| 05900 | Lirceus sp | | **MT** | + |
| 06700 | Crangonyx sp | | **MT** | + |
| 08200 | Orconectes sp | | **F** | + |
| 13400 | Stenacron sp | | **F** | + |
| 13521 | Stenonema femoratum | | **F** | + |
| 17200 | Caenis sp | | **F** | + |
| 22300 | Argia sp | | **F** | + |
| 50301 | Chimarra aterrima | | **MI** | + |
| 50315 | Chimarra obscura | | **MI** | + |
| 51550 | Plectrocnemia sp | | **MI** | + |
| 52200 | Cheumatopsyche sp | | **F** | + |
| 57400 | Neophylax sp | | **MI** | + |
| 68075 | Psephenus herricki | | **MI** | + |
| 69400 | Stenelmis sp | | **F** | + |

| | | | |
|---|---|---|---|
| No. Quantitative Taxa: | 0 | Total Taxa; | 16 |
| No. Qualitative Taxa: | 16 | ICI: | MG |
| Number of Organisms: | 0 | Qual EPT: | 8 |

**Appendix Table B-2. Macroinvertebrate taxa list for sites sampled in the Ohio River Tributaries study area in 2023.**

River Code: **23-019** River: ***Indian Creek*** Coll. Date: *09/20/2023* RM: **2.08**

Site ID: **IC05** Location: *Golf course pond* Sample:

| Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. |
|---|---|---|---|---|
| 01801 | Turbellaria | | **F** | + |
| 03600 | Oligochaeta | | **T** | + |
| 05900 | Lirceus sp | | **MT** | + |
| 06700 | Crangonyx sp | | **MT** | + |
| 11120 | Baetis flavistriga | | **F** | + |
| 13400 | Stenacron sp | | **F** | + |
| 13521 | Stenonema femoratum | | **F** | + |
| 17200 | Caenis sp | | **F** | + |
| 21001 | Calopterygidae | | **F** | + |
| 22001 | Coenagrionidae | | **T** | + |
| 22300 | Argia sp | | **F** | + |
| 50301 | Chimarra aterrima | | **MI** | + |
| 52530 | Hydropsyche depravata group | | **F** | + |
| 60900 | Peltodytes sp | | **MT** | + |
| 67800 | Tropisternus sp | | **T** | + |
| 68025 | Ectopria sp | | **F** | + |
| 68075 | Psephenus herricki | | **MI** | + |
| 69400 | Stenelmis sp | | **F** | + |
| 77800 | Helopelopia sp | | **F** | + |
| 82710 | Chironomus (C.) sp | | **MT** | + |
| 83840 | Microtendipes pedellus group | | **F** | + |
| 84210 | Paratendipes albimanus or P. duplicatus | | **F** | + |
| 85821 | Tanytarsus glabrescens group sp 7 | | **F** | + |

| | | | |
|---|---|---|---|
| No. Quantitative Taxa: | 0 | Total Taxa; | 23 |
| No. Qualitative Taxa: | 23 | ICI: | F |
| Number of Organisms: | 0 | Qual EPT: | 6 |

**Appendix Table B-2. Macroinvertebrate taxa list for sites sampled in the Ohio River Tributaries study area in 2023.**

River Code: **23-019** River: ***Indian Creek*** Coll. Date: *09/20/2023* RM: **1.15**

Site ID: **IC02** Location: *Aston Oaks Golf Club* Sample:

| Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. |
|---|---|---|---|---|
| 05900 | Lirceus sp | | **MT** | + |
| 08200 | Orconectes sp | | **F** | + |
| 11120 | Baetis flavistriga | | **F** | + |
| 11200 | Callibaetis sp | | **MT** | + |
| 13400 | Stenacron sp | | **F** | + |
| 13521 | Stenonema femoratum | | **F** | + |
| 17200 | Caenis sp | | **F** | + |
| 50315 | Chimarra obscura | | **MI** | + |
| 52200 | Cheumatopsyche sp | | **F** | + |
| 58505 | Helicopsyche borealis | | **MI** | + |
| 68075 | Psephenus herricki | | **MI** | + |
| 82730 | Chironomus (C.) decorus group | | **T** | + |
| 84210 | Paratendipes albimanus or P. duplicatus | | **F** | + |
| 84750 | Stictochironomus sp | | **F** | + |

| | | | |
|---|---|---|---|
| No. Quantitative Taxa: | 0 | Total Taxa; | 14 |
| No. Qualitative Taxa: | 14 | ICI: | F |
| Number of Organisms: | 0 | Qual EPT: | 8 |

**Appendix Table B-2. Macroinvertebrate taxa list for sites sampled in the Ohio River Tributaries study area in 2023.**

River Code: **23-019** River: ***Indian Creek*** Coll. Date: *09/19/2023* RM: **0.30**

Site ID: **IC01** Location: *Near TISCH Environmental Parking Lot* Sample:

| Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. |
|---|---|---|---|---|
| 01801 | Turbellaria | | **F** | + |
| 03600 | Oligochaeta | | **T** | + |
| 04935 | Erpobdella punctata punctata | | **MT** | + |
| 05900 | Lirceus sp | | **MT** | + |
| 06700 | Crangonyx sp | | **MT** | + |
| 08200 | Orconectes sp | | **F** | + |
| 11130 | Baetis intercalaris | | **F** | + |
| 13400 | Stenacron sp | | **F** | + |
| 13521 | Stenonema femoratum | | **F** | + |
| 17200 | Caenis sp | | **F** | + |
| 21200 | Calopteryx sp | | **F** | + |
| 50301 | Chimarra aterrima | | **MI** | + |
| 52200 | Cheumatopsyche sp | | **F** | + |
| 52530 | Hydropsyche depravata group | | **F** | + |
| 58505 | Helicopsyche borealis | | **MI** | + |
| 68075 | Psephenus herricki | | **MI** | + |
| 69400 | Stenelmis sp | | **F** | + |
| 72900 | Culex sp | | **T** | + |
| 77500 | Conchapelopia sp | | **F** | + |
| 77800 | Helopelopia sp | | **F** | + |
| 84210 | Paratendipes albimanus or P. duplicatus | | **F** | + |
| 84315 | Phaenopsectra flavipes | | **MT** | + |
| 98200 | Pisidium sp | | **MT** | + |

| | | | |
|---|---|---|---|
| No. Quantitative Taxa: | 0 | Total Taxa; | 23 |
| No. Qualitative Taxa: | 23 | ICI: | F |
| Number of Organisms: | 0 | Qual EPT: | 8 |

**Appendix Table B-2. Macroinvertebrate taxa list for sites sampled in the Ohio River Tributaries study area in 2023.**

River Code: **23-020** River: ***Trib to Indian Creek @RM1.02 RM0.97*** Coll. Date: *09/20/2023* RM: **0.10**

Site ID: **IC07** Location: *at dead end of Stonehaven Dr.* Sample:

| Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. |
|---|---|---|---|---|
| 01801 | Turbellaria | | **F** | + |
| 05900 | Lirceus sp | | **MT** | + |
| 08200 | Orconectes sp | | **F** | + |
| 44501 | Corixidae | | **F** | + |
| 57400 | Neophylax sp | | **MI** | + |
| 68025 | Ectopria sp | | **F** | + |
| 68075 | Psephenus herricki | | **MI** | + |
| 72700 | Anopheles sp | | **F** | + |
| 78401 | Natarsia species A (sensu Roback, 1978) | | **T** | + |
| 83840 | Microtendipes pedellus group | | **F** | + |
| 84210 | Paratendipes albimanus or P. duplicatus | | **F** | + |
| 84300 | Phaenopsectra obediens group | | **F** | + |
| 84315 | Phaenopsectra flavipes | | **MT** | + |
| 84750 | Stictochironomus sp | | **F** | + |
| 95100 | Physella sp | | **T** | + |

| | | | |
|---|---|---|---|
| No. Quantitative Taxa: | 0 | Total Taxa; | 15 |
| No. Qualitative Taxa: | 15 | ICI: | HW |
| Number of Organisms: | 0 | Qual EPT: | 1 |

**Appendix Table B-2. Macroinvertebrate taxa list for sites sampled in the Ohio River Tributaries study area in 2023.**

River Code: **23-071** River: ***Unnamed Trib to Muddy Creek @ RM2.37*** Coll. Date: *08/03/2023* RM: **0.50**

Site ID: **MU10** Location: *Van Blaricum Rd.* Sample:

| Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. |
|---|---|---|---|---|
| 03600 | Oligochaeta | | **T** | + |
| 05900 | Lirceus sp | | **MT** | + |
| 11120 | Baetis flavistriga | | **F** | + |
| 11430 | Diphetor hageni | | **MI** | + |
| 13400 | Stenacron sp | | **F** | + |
| 13521 | Stenonema femoratum | | **F** | + |
| 15000 | Paraleptophlebia sp | | **F** | + |
| 17200 | Caenis sp | | **F** | + |
| 21700 | Lestes sp | | | + |
| 22300 | Argia sp | | **F** | + |
| 45300 | Sigara sp | | **MT** | + |
| 52200 | Cheumatopsyche sp | | **F** | + |
| 52315 | Diplectrona modesta | **X** | **F** | + |
| 52530 | Hydropsyche depravata group | | **F** | + |
| 57400 | Neophylax sp | | **MI** | + |
| 68025 | Ectopria sp | | **F** | + |
| 68075 | Psephenus herricki | | **MI** | + |
| 68708 | Dubiraphia vittata group | | **F** | + |
| 69400 | Stenelmis sp | | **F** | + |
| 70000 | Diptera | | | + |
| 71900 | Tipula sp | | **F** | + |
| 77500 | Conchapelopia sp | | **F** | + |
| 77800 | Helopelopia sp | | **F** | + |
| 78200 | Larsia sp | | **MT** | + |
| 79720 | Diamesa sp | **X** | **F** | + |
| 83840 | Microtendipes pedellus group | | **F** | + |
| 83860 | Microtendipes rydalensis | | **MI** | + |
| 84210 | Paratendipes albimanus or P. duplicatus | | **F** | + |
| 84450 | Polypedilum (Uresipedilum) flavum | | **F** | + |
| 84750 | Stictochironomus sp | | **F** | + |
| 85800 | Tanytarsus sp | | **F** | + |
| 87400 | Stratiomys sp | | **MT** | + |

| | | | |
|---|---|---|---|
| No. Quantitative Taxa: | 0 | Total Taxa; | 32 |
| No. Qualitative Taxa: | 32 | ICI: | HW |
| Number of Organisms: | 0 | Qual EPT: | 10 |

**Appendix Table B-2. Macroinvertebrate taxa list for sites sampled in the Ohio River Tributaries study area in 2023.**

River Code: **23-072** River: ***Unnamed Trib to Muddy Creek @ RM5.97*** Coll. Date: *07/06/2023* RM: **0.55**

Site ID: **MU12** Location: *Werk and Qualhill* Sample:

| Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. |
|---|---|---|---|---|
| 01801 | Turbellaria | | **F** | + |
| 04664 | Helobdella stagnalis | | **T** | + |
| 04964 | Erpobdella microstoma | | **MT** | + |
| 05900 | Lirceus sp | | **MT** | + |
| 08200 | Orconectes sp | | **F** | + |
| 08601 | Hydrachnidia | | **F** | + |
| 11200 | Callibaetis sp | | **MT** | + |
| 16324 | Teloganopsis deficiens | | **I** | + |
| 17200 | Caenis sp | | **F** | + |
| 22001 | Coenagrionidae | | **T** | + |
| 45300 | Sigara sp | | **MT** | + |
| 50301 | Chimarra aterrima | | **MI** | + |
| 51250 | Holocentropus sp | | **F** | + |
| 54160 | Ochrotrichia sp | | **MI** | + |
| 71900 | Tipula sp | | **F** | + |
| 77800 | Helopelopia sp | | **F** | + |
| 84500 | Polypedilum (P.) trigonus | | | + |
| 96264 | Planorbella (Pierosoma) pilsbryi | | **T** | + |
| 98001 | Pisidiidae | | | + |

| | | | |
|---|---|---|---|
| No. Quantitative Taxa: | 0 | Total Taxa; | 19 |
| No. Qualitative Taxa: | 19 | ICI: | F |
| Number of Organisms: | 0 | Qual EPT: | 6 |

**Appendix Table B-2. Macroinvertebrate taxa list for sites sampled in the Ohio River Tributaries study area in 2023.**

River Code: **23-073** River: ***Unnamed Trib to Muddy Creek @ RM6.53*** Coll. Date: *07/06/2023* RM: **0.60**

Site ID: **MU13** Location: *Werk Rd. and Westbourne Dr.* Sample:

| Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. |
|---|---|---|---|---|
| 01801 | Turbellaria | | **F** | + |
| 03600 | Oligochaeta | | **T** | + |
| 04935 | Erpobdella punctata punctata | | **MT** | + |
| 78200 | Larsia sp | | **MT** | + |
| 78650 | Procladius sp | | **MT** | + |
| 78702 | Psectrotanypus dyari | | **VT** | + |
| 82710 | Chironomus (C.) sp | | **MT** | + |
| 83040 | Dicrotendipes neomodestus | | **F** | + |
| 89001 | Sciomyzidae | | **MT** | + |
| 95100 | Physella sp | | **T** | + |

| Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. |
|---|---|---|---|---|

| | | | |
|---|---|---|---|
| No. Quantitative Taxa: | 0 | Total Taxa; | 10 |
| No. Qualitative Taxa: | 10 | ICI: | VP |
| Number of Organisms: | 0 | Qual EPT: | 0 |

**Appendix Table B-2. Macroinvertebrate taxa list for sites sampled in the Ohio River Tributaries study area in 2023.**

River Code: **23-075** River: ***Unnamed Trib to Muddy Creek @RM0.3*** Coll. Date: *08/04/2023* RM: **1.72**

Site ID: **MU08** Location: *Aston Golf Club, access at 51 Oaks Dr.* Sample:

| Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. |
|---|---|---|---|---|
| 03600 | Oligochaeta | | T | + |
| 05800 | Caecidotea sp | | T | + |
| 05900 | Lirceus sp | | MT | + |
| 06700 | Crangonyx sp | | MT | + |
| 11120 | Baetis flavistriga | | F | + |
| 11430 | Diphetor hageni | | MI | + |
| 13400 | Stenacron sp | | F | + |
| 15000 | Paraleptophlebia sp | | F | + |
| 21200 | Calopteryx sp | | F | + |
| 45300 | Sigara sp | | MT | + |
| 51550 | Plectrocnemia sp | | MI | + |
| 52200 | Cheumatopsyche sp | | F | + |
| 52315 | Diplectrona modesta | X | F | + |
| 52530 | Hydropsyche depravata group | | F | + |
| 57400 | Neophylax sp | | MI | + |
| 68025 | Ectopria sp | | F | + |
| 68075 | Psephenus herricki | | MI | + |
| 69400 | Stenelmis sp | | F | + |
| 77120 | Ablabesmyia mallochi | | F | + |
| 77500 | Conchapelopia sp | | F | + |
| 78599 | Pentaneura sp | | F | + |
| 83840 | Microtendipes pedellus group | | F | + |
| 84210 | Paratendipes albimanus or P. duplicatus | | F | + |
| 94800 | Stagnicola sp | | T | + |
| 95100 | Physella sp | | T | + |

| | | | |
|---|---|---|---|
| No. Quantitative Taxa: | 0 | Total Taxa; | 25 |
| No. Qualitative Taxa: | 25 | ICI: | HW |
| Number of Organisms: | 0 | Qual EPT: | 9 |

**Appendix Table B-2. Macroinvertebrate taxa list for sites sampled in the Ohio River Tributaries study area in 2023.**

River Code: **23-075** River: ***Unnamed Trib to Muddy Creek @RM0.3*** Coll. Date: *08/04/2023* RM: **0.80**

Site ID: **MU07.5** Location: *First Str. Turns into Fiddles Green, Dst. Confluence* Sample:

| Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. |
|---|---|---|---|---|
| 01801 | Turbellaria | | **F** | + |
| 03600 | Oligochaeta | | **T** | + |
| 05900 | Lirceus sp | | **MT** | + |
| 06700 | Crangonyx sp | | **MT** | + |
| 08601 | Hydrachnidia | | **F** | + |
| 11120 | Baetis flavistriga | | **F** | + |
| 13521 | Stenonema femoratum | | **F** | + |
| 52200 | Cheumatopsyche sp | | **F** | + |
| 52530 | Hydropsyche depravata group | | **F** | + |
| 58505 | Helicopsyche borealis | | **MI** | + |
| 65501 | Hydrophilidae | | **F** | + |
| 68075 | Psephenus herricki | | **MI** | + |
| 68700 | Dubiraphia sp | | **F** | + |
| 69400 | Stenelmis sp | | **F** | + |
| 72900 | Culex sp | | **T** | + |
| 74100 | Simulium sp | | **F** | + |
| 77120 | Ablabesmyia mallochi | | **F** | + |
| 77800 | Helopelopia sp | | **F** | + |
| 82820 | Cryptochironomus sp | | **F** | + |
| 83840 | Microtendipes pedellus group | | **F** | + |
| 84210 | Paratendipes albimanus or P. duplicatus | | **F** | + |
| 84540 | Polypedilum (Tripodura) scalaenum group | | **F** | + |
| 95100 | Physella sp | | **T** | + |

| | | | |
|---|---|---|---|
| No. Quantitative Taxa: | 0 | Total Taxa; | 23 |
| No. Qualitative Taxa: | 23 | ICI: | F |
| Number of Organisms: | 0 | Qual EPT: | 5 |

**Appendix Table B-2. Macroinvertebrate taxa list for sites sampled in the Ohio River Tributaries study area in 2023.**

River Code: **23-076** River: ***UT @ 0.95 to UT to Muddy Creek @ RM0.3*** Coll. Date: *08/04/2023* RM: **0.10**

Site ID: **MU09** Location: *pull-off near Addyston Town Sign* Sample:

| Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. |
|---|---|---|---|---|
| 01801 | Turbellaria | | **F** | + |
| 03600 | Oligochaeta | | **T** | + |
| 04664 | Helobdella stagnalis | | **T** | + |
| 05900 | Lirceus sp | | **MT** | + |
| 06700 | Crangonyx sp | | **MT** | + |
| 08601 | Hydrachnidia | | **F** | + |
| 11120 | Baetis flavistriga | | **F** | + |
| 13521 | Stenonema femoratum | | **F** | + |
| 17200 | Caenis sp | | **F** | + |
| 21300 | Hetaerina sp | | **F** | + |
| 51250 | Holocentropus sp | | **F** | + |
| 52200 | Cheumatopsyche sp | | **F** | + |
| 52530 | Hydropsyche depravata group | | **F** | + |
| 57400 | Neophylax sp | | **MI** | + |
| 58505 | Helicopsyche borealis | | **MI** | + |
| 68025 | Ectopria sp | | **F** | + |
| 68075 | Psephenus herricki | | **MI** | + |
| 68708 | Dubiraphia vittata group | | **F** | + |
| 69400 | Stenelmis sp | | **F** | + |
| 71900 | Tipula sp | | **F** | + |
| 71910 | Tipula abdominalis | | **F** | + |
| 77800 | Helopelopia sp | | **F** | + |
| 78200 | Larsia sp | | **MT** | + |
| 82820 | Cryptochironomus sp | | **F** | + |
| 84210 | Paratendipes albimanus or P. duplicatus | | **F** | + |
| 84450 | Polypedilum (Uresipedilum) flavum | | **F** | + |
| 85818 | Tanytarsus glabrescens group sp 4 | | **F** | + |
| 85821 | Tanytarsus glabrescens group sp 7 | | **F** | + |
| 86501 | Stratiomyidae | | | + |

| | | | |
|---|---|---|---|
| No. Quantitative Taxa: | 0 | Total Taxa; | 29 |
| No. Qualitative Taxa: | 29 | ICI: | HW |
| Number of Organisms: | 0 | Qual EPT: | 8 |

**Appendix Table B-2. Macroinvertebrate taxa list for sites sampled in the Ohio River Tributaries study area in 2023.**

River Code: **23-077** River: ***Unnamed Trib to Wulff Run @ RM 0.77*** Coll. Date: *08/02/2023* RM: **0.40**

Site ID: **RR05.5** Location: *Foley Rd. @ Mitchell Way Court* Sample:

| Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. |
|---|---|---|---|---|
| 01801 | Turbellaria | | **F** | + |
| 03600 | Oligochaeta | | **T** | + |
| 04964 | Erpobdella microstoma | | **MT** | + |
| 05900 | Lirceus sp | | **MT** | + |
| 06700 | Crangonyx sp | | **MT** | + |
| 07800 | Cambarus sp | | | + |
| 50301 | Chimarra aterrima | | **MI** | + |
| 52200 | Cheumatopsyche sp | | **F** | + |
| 68025 | Ectopria sp | | **F** | + |
| 70000 | Diptera | | | + |
| 71700 | Pilaria sp | | **F** | + |
| 72501 | Culicidae | | **MT** | + |
| 77800 | Helopelopia sp | | **F** | + |
| 78401 | Natarsia species A (sensu Roback, 1978) | | **T** | + |
| 78600 | Pentaneura inconspicua | | **F** | + |
| 81650 | Parametriocnemus sp | **X** | **F** | + |
| 84210 | Paratendipes albimanus or P. duplicatus | | **F** | + |
| 84470 | Polypedilum (P.) illinoense | | **T** | + |
| 87601 | Dolichopodidae | | **MT** | + |
| 96801 | Ancylidae | | **F** | + |

| | | | |
|---|---|---|---|
| No. Quantitative Taxa: | 0 | Total Taxa; | 20 |
| No. Qualitative Taxa: | 20 | ICI: | HW |
| Number of Organisms: | 0 | Qual EPT: | 2 |

**Appendix Table B-2. Macroinvertebrate taxa list for sites sampled in the Ohio River Tributaries study area in 2023.**

River Code: **23-077** River: ***Unnamed Trib to Wulff Run @ RM 0.77*** Coll. Date: *08/02/2023* RM: **0.35**

Site ID: **RR04.5** Location: *Overhill Lane (Limnotech RR04)* Sample:

| Taxa Code | Taxa | CWH Taxa | Tol. | Qt./Ql. |
|---|---|---|---|---|
| 01801 | Turbellaria | | **F** | + |
| 03600 | Oligochaeta | | **T** | + |
| 04664 | Helobdella stagnalis | | **T** | + |
| 05900 | Lirceus sp | | **MT** | + |
| 06700 | Crangonyx sp | | **MT** | + |
| 08601 | Hydrachnidia | | **F** | + |
| 21001 | Calopterygidae | | **F** | + |
| 23600 | Aeshna sp | | **MT** | + |
| 50301 | Chimarra aterrima | | **MI** | + |
| 51250 | Holocentropus sp | | **F** | + |
| 52200 | Cheumatopsyche sp | | **F** | + |
| 52530 | Hydropsyche depravata group | | **F** | + |
| 71900 | Tipula sp | | **F** | + |
| 74100 | Simulium sp | | **F** | + |
| 77800 | Helopelopia sp | | **F** | + |
| 78350 | Meropelopia sp | **X** | **F** | + |
| 81650 | Parametriocnemus sp | **X** | **F** | + |
| 84210 | Paratendipes albimanus or P. duplicatus | | **F** | + |
| 84302 | Phaenopsectra punctipes | | **F** | + |
| 98001 | Pisidiidae | | | + |

| | | | |
|---|---|---|---|
| No. Quantitative Taxa: | 0 | Total Taxa; | 20 |
| No. Qualitative Taxa: | 20 | ICI: | HW |
| Number of Organisms: | 0 | Qual EPT: | 4 |

# Appendix C

## Ohio River Direct Tributaries 2023 Habitat Data
## C-1: QHEI Metrics & Scores

***Appendix Table C-1**. QHEI and metric scores in the Ohio River Tributaries study area in 2023.*

| Site ID | River Mile | QHEI | Substrate Score | Cover Score | Channel Score | Riparian Score | Pool Score | Riffle Score | Gradient Value | Gradient Score |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Muddy Creek*** | | | | | | | | | | |
| **MU05** | 6.35 | 39.50 | 14.0 | 5.0 | 7.0 | 5.5 | 0.0 | 0.0 | 33.30 | 8 |
| **MU04.5** | 5.62 | 61.50 | 18.0 | 10.0 | 11.0 | 5.0 | 4.0 | 5.5 | 40.00 | 8 |
| **MU04** | 5.45 | 64.25 | 17.0 | 12.0 | 12.0 | 5.3 | 5.0 | 5.0 | 33.00 | 8 |
| **MU03** | 2.80 | 56.25 | 18.0 | 6.0 | 11.0 | 7.3 | 5.0 | 5.0 | 52.50 | 4 |
| **MU02** | 2.25 | 63.50 | 17.0 | 11.0 | 14.0 | 7.5 | 6.0 | 4.0 | 54.20 | 4 |
| **MU01** | 0.17 | 49.00 | 4.0 | 16.0 | 12.0 | 4.0 | 7.0 | 0.0 | 3.70 | 6 |
| ***Rapid Run*** | | | | | | | | | | |
| **RR02** | 1.05 | 51.00 | 16.0 | 8.0 | 10.0 | 9.0 | 4.0 | 0.0 | 100.00 | 4 |
| ***Wulff Run*** | | | | | | | | | | |
| **RR04** | 0.45 | 50.00 | 16.5 | 8.0 | 10.0 | 7.5 | 4.0 | 0.0 | 58.50 | 4 |
| ***Indian Creek*** | | | | | | | | | | |
| **IC06** | 2.30 | 53.50 | 14.5 | 15.0 | 10.0 | 6.0 | 4.0 | 0.0 | 153.00 | 4 |
| **IC05** | 2.08 | 55.00 | 16.0 | 13.0 | 10.0 | 7.0 | 5.0 | 0.0 | 123.00 | 4 |
| **IC02** | 1.15 | 48.00 | 16.0 | 11.0 | 10.0 | 5.0 | 2.0 | 0.0 | 121.00 | 4 |
| **IC01** | 0.30 | 50.00 | 13.5 | 12.0 | 8.5 | 7.0 | 5.0 | 0.0 | 50.00 | 4 |
| **IC07** | 0.10 | 50.00 | 16.0 | 9.0 | 10.0 | 8.0 | 3.0 | 0.0 | 188.00 | 4 |
| ***Unnamed Tributary to Muddy Creek @RM 2.37*** | | | | | | | | | | |
| **MU10** | 0.50 | 53.25 | 17.0 | 13.0 | 9.5 | 6.8 | 3.0 | 0.0 | 200.00 | 4 |
| ***Unnamed Tributary to Muddy Creek @RM 5.97*** | | | | | | | | | | |
| **MU12** | 0.55 | 47.50 | 18.5 | 10.0 | 8.5 | 5.5 | 1.0 | 0.0 | 100.00 | 4 |
| ***Unnamed Tributary to Muddy Creek @RM 6.53*** | | | | | | | | | | |
| **MU13** | 0.60 | 41.00 | 16.5 | 6.0 | 9.0 | 5.5 | 0.0 | 0.0 | 118.76 | 4 |
| ***Unnamed Tributary to Muddy Creek @RM 0.30*** | | | | | | | | | | |
| **MU07.5** | 0.80 | 56.00 | 14.5 | 11.0 | 11.0 | 7.0 | 3.0 | 5.5 | 100.00 | 4 |
| ***Unnamed Tributary @0.95 to Unnamed Tributary to Muddy Creek @RM 0.30*** | | | | | | | | | | |
| **MU09** | 0.10 | 55.50 | 16.0 | 11.0 | 10.5 | 6.0 | 3.0 | 5.0 | 125.00 | 4 |
| ***Unnamed Tributary to Wulff Run @RM 0.77*** | | | | | | | | | | |
| **RR05.5** | 0.40 | 49.50 | 14.0 | 11.0 | 11.5 | 5.0 | 4.0 | 0.0 | 100.00 | 4 |
| **RR04.5** | 0.35 | 54.00 | 16.5 | 14.0 | 10.0 | 6.5 | 3.0 | 0.0 | 100.00 | 4 |
| ***Taylor Creek*** | | | | | | | | | | |
| **GM86** | 6.40 | 40.25 | 9.5 | 9.0 | 9.0 | 5.8 | 3.0 | 0.0 | 62.50 | 4 |
| **GM85** | 5.30 | 44.00 | 14.5 | 9.0 | 9.5 | 5.0 | 2.0 | 0.0 | 111.00 | 4 |
| ***Briarly Creek*** | | | | | | | | | | |
| **GM91** | 3.90 | 58.50 | 17.5 | 14.0 | 13.0 | 5.0 | 5.0 | 0.0 | 100.00 | 4 |
| **GM90** | 2.45 | 49.50 | 12.0 | 10.0 | 10.0 | 6.0 | 3.0 | 4.5 | 50.00 | 4 |
| **GM89** | 1.80 | 53.50 | 17.5 | 8.0 | 11.0 | 5.0 | 3.0 | 5.0 | 66.70 | 4 |
| **Wesselman Creek** | | | | | | | | | | |
| **GM94** | 4.70 | 55.00 | 17.0 | 7.0 | 10.0 | 6.0 | 3.0 | 4.0 | 33.30 | 8 |
| ***Unnamed Tributary to Wesselman Creek @RM 2.5*** | | | | | | | | | | |
| **GM100** | 1.05 | 46.50 | 9.5 | 8.0 | 10.0 | 5.0 | 5.0 | 5.0 | 66.70 | 4 |
| ***Unnamed Tributary to Taylor Creek @RM 4.9*** | | | | | | | | | | |
| **GM106** | 0.20 | 57.00 | 14.5 | 11.0 | 12.0 | 5.0 | 5.0 | 5.5 | 93.70 | 4 |

| QHEI Narrative | |
|---|---|
| Excellent | ≥70 |
| Good | ≥55 |
| Fair | ≥43 |
| Poor | ≥30 |
| Very Poor | <30 |

# Appendix D

## Ohio River Direct Tributaries 2023 Primary Headwater Habitat Data
## D-1: PHWH Evaluation & HHEI Metrics & Scores

Appendix D1. Primary Headwater Aquatic Life Use information for the small Ohio River tributaries during 2023.

| Site ID | RM | Year | River | Location: |
|---|---|---|---|---|
| **GM86** | **6.40** | **2023** | (14004) Taylor Creek | Reemelin Rd. |

HHEI Info: HHEI Score: ***91.0*** Substrate: **36.0** Pool: **30.0** Bankfull **25.0** Channel: ***Recovering*** Flow: ***Flowing***

QHEI Info: QHEI Score: ***40.2*** Substrate: **9.5** Pool: **3.0** Max Z.: **20-40 cm** Channel **9.0** Flow: ***Flowing***

***Drainage Size:*** **0.49** Riffle: **0.0** Ripar: **5.7** Cover: **9.0** PHW Class: **WWH**

FISH Info: IBI Score: **22** Species: **2.0** Sensitive Sp.: **0.0** % Pioneer: **68.42** Headwater Sp. **0.00**

MACRO Info: ICI Score: QUAL EPT: **1** Coldwater Taxa.: **0** Intols: Sens. **1** Toler: V. Tol.

Salamanders: **X** Adults: **4** Larvae: **6** *Eurycea cirrigera* Alternate Site ID:

| | | | | |
|---|---|---|---|---|
| **GM85** | **5.30** | **2023** | (14004) Taylor Creek | Ust. Johnson Rd. |

HHEI Info: HHEI Score: ***96.0*** Substrate: **36.0** Pool: **30.0** Bankfull **30.0** Channel: ***Recent*** Flow: ***Flowing***

QHEI Info: QHEI Score: ***44.0*** Substrate: **14.5** Pool: **2.0** Max Z.: **< 20 cm** Channel **9.5** Flow: ***Flowing***

***Drainage Size:*** **2.22** Riffle: **0.0** Ripar: **5.0** Cover: **9.0** PHW Class: **WWH**

FISH Info: IBI Score: **20** Species: **4.0** Sensitive Sp.: **0.0** % Pioneer: **61.11** Headwater Sp. **1.00**

MACRO Info: ICI Score: QUAL EPT: **7** Coldwater Taxa.: **2** Intols: Sens. **2** Toler: V. Tol.

Salamanders: Adults: Larvae: Alternate Site ID:

| | | | | |
|---|---|---|---|---|
| **GM91** | **3.90** | **2023** | (14148) Briarly Creek | Ust. private drive |

HHEI Info: HHEI Score: ***76.0*** Substrate: **36.0** Pool: **20.0** Bankfull **20.0** Channel: ***Recent*** Flow: ***Flowing***

QHEI Info: QHEI Score: ***58.5*** Substrate: **17.5** Pool: **5.0** Max Z.: **40-70 cm** Channel **13.0** Flow: ***Flowing***

***Drainage Size:*** **0.34** Riffle: **0.0** Ripar: **5.0** Cover: **14.0** PHW Class: **PHW3A**

FISH Info: IBI Score: **24** Species: **3.0** Sensitive Sp.: **0.0** % Pioneer: **84.56** Headwater Sp. **0.00**

MACRO Info: ICI Score: QUAL EPT: **4** Coldwater Taxa.: **1** Intols: Sens. **2** Toler: V. Tol.

Salamanders: **X** Adults: **20** Larvae: **20** *Eurycea cirrigera* Alternate Site ID:

| | | | | |
|---|---|---|---|---|
| **GM90** | **2.45** | **2023** | (14148) Briarly Creek | Ust. bridge |

HHEI Info: HHEI Score: ***91.0*** Substrate: **36.0** Pool: **25.0** Bankfull **30.0** Channel: ***Recent*** Flow: ***Flowing***

QHEI Info: QHEI Score: ***49.5*** Substrate: **12.0** Pool: **3.0** Max Z.: **< 20 cm** Channel **10.0** Flow: ***Flowing***

***Drainage Size:*** **1.30** Riffle: **4.5** Ripar: **6.0** Cover: **10.0** PHW Class: **WWH**

FISH Info: IBI Score: **22** Species: **3.0** Sensitive Sp.: **0.0** % Pioneer: **96.77** Headwater Sp. **0.00**

MACRO Info: ICI Score: QUAL EPT: **6** Coldwater Taxa.: **1** Intols: Sens. **3** Toler: V. Tol.

Salamanders: **X** Adults: **13** Larvae: **21** *Eurycea cirrigera* Alternate Site ID:

Appendix D1. Primary Headwater Aquatic Life Use information for the small Ohio River tributaries during 2023.

| Site ID | RM | Year | River | Location: |
|---|---|---|---|---|
| **GM89** | **1.80** | **2023** | (14148) Briarly Creek | Adj. Briarly Creek |

HHEI Info: HHEI Score: ***96.0*** Substrate: **36.0** Pool: **30.0** Bankfull **30.0** Channel: ***Recent*** Flow: ***Flowing***

QHEI Info: QHEI Score: ***53.5*** Substrate: **17.5** Pool: **3.0** Max Z.: **< 20 cm** Channel **11.0** Flow: ***Flowing***

***Drainage Size:*** **2.10** Riffle: **5.0** Ripar: **5.0** Cover: **8.0** PHW Class: **WWH**

FISH Info: IBI Score: **24** Species: **3.0** Sensitive Sp.: **0.0** % Pioneer: **57.78** Headwater Sp. **1.00**

MACRO Info: ICI Score: QUAL EPT: **9** Coldwater Taxa.: **0** Intols: Sens. **4** Toler: V. Tol.

Salamanders: **X** Adults: Larvae: **20** *Eurycea cirrigera* Alternate Site ID:

| | | | | |
|---|---|---|---|---|
| **GM94** | **4.70** | **2023** | (14149) Wesselman Creek | Ust. Wesselman Rd. |

HHEI Info: HHEI Score: ***96.0*** Substrate: **36.0** Pool: **30.0** Bankfull **30.0** Channel: ***Recent*** Flow: ***Flowing***

QHEI Info: QHEI Score: ***55.0*** Substrate: **17.0** Pool: **3.0** Max Z.: **< 20 cm** Channel **10.0** Flow: ***Flowing***

***Drainage Size:*** **1.10** Riffle: **4.0** Ripar: **6.0** Cover: **7.0** PHW Class: **PHW3A**

FISH Info: IBI Score: **26** Species: **4.0** Sensitive Sp.: **0.0** % Pioneer: **91.86** Headwater Sp. **0.00**

MACRO Info: ICI Score: QUAL EPT: **4** Coldwater Taxa.: **0** Intols: Sens. **1** Toler: V. Tol.

Salamanders: **X** Adults: **21** Larvae: **15** *Eurycea cirrigera* Alternate Site ID:

| | | | | |
|---|---|---|---|---|
| **GM100** | **1.05** | **2023** | (14275) Unnamed Trib to Wesselman Creek @ RM 2.5 | Ust. Rockview Rd. |

HHEI Info: HHEI Score: ***84.0*** Substrate: **29.0** Pool: **25.0** Bankfull **30.0** Channel: ***Recovering*** Flow: ***Flowing***

QHEI Info: QHEI Score: ***46.5*** Substrate: **9.5** Pool: **5.0** Max Z.: **40-70 cm** Channel **10.0** Flow: ***Flowing***

***Drainage Size:*** **0.91** Riffle: **5.0** Ripar: **5.0** Cover: **8.0** PHW Class: **PHW3A**

FISH Info: IBI Score: **20** Species: **1.0** Sensitive Sp.: **0.0** % Pioneer: **100.0** Headwater Sp. **0.00**

MACRO Info: ICI Score: QUAL EPT: **7** Coldwater Taxa.: **0** Intols: Sens. **2** Toler: V. Tol.

Salamanders: **X** Adults: **5** Larvae: **16** *Eurycea cirrigera* Alternate Site ID:

| | | | | |
|---|---|---|---|---|
| **GM106** | **0.20** | **2023** | (14277) Unnamed Trib to Taylor Creek @ RM4.9 | Adj. to private drive |

HHEI Info: HHEI Score: ***86.0*** Substrate: **36.0** Pool: **20.0** Bankfull **30.0** Channel: ***Recent*** Flow: ***Flowing***

QHEI Info: QHEI Score: ***57.0*** Substrate: **14.5** Pool: **5.0** Max Z.: **40-70 cm** Channel **12.0** Flow: ***Flowing***

***Drainage Size:*** **0.92** Riffle: **5.5** Ripar: **5.0** Cover: **11.0** PHW Class: **WWH**

FISH Info: IBI Score: **30** Species: **5.0** Sensitive Sp.: **0.0** % Pioneer: **70.77** Headwater Sp. **1.00**

MACRO Info: ICI Score: QUAL EPT: **4** Coldwater Taxa.: **1** Intols: Sens. **3** Toler: V. Tol.

Salamanders: **X** Adults: **8** Larvae: **4** *Eurycea cirrigera* Alternate Site ID:

Appendix D1. Primary Headwater Aquatic Life Use information for the small Ohio River tributaries during 2023.

| Site ID | RM | Year | River | Location: |
|---|---|---|---|---|
| **RR05** | **1.45** | **2023** | (23012) Wulff Run | Near intersection of Oakwood and Delhi |

HHEI Info: HHEI Score: ***95.0*** Substrate: **40.0** Pool: **25.0** Bankfull **30.0** Channel: ***Recent*** Flow: ***Flowing***

QHEI Info: QHEI Score: Substrate: Pool: Max Z.: Channel Flow:

***Drainage Size:*** **1.33** Riffle: Ripar: Cover: PHW Class: **WWH**

FISH Info: IBI Score: **Dry** Species: **1.0** Sensitive Sp.: **0.0** % Pioneer: **0.00** Headwater Sp. **0.00**

MACRO Info: ICI Score: QUAL EPT: **0** Coldwater Taxa.: **1** Intols: Sens. **1** Toler: V. Tol.

Salamanders: **X** Adults: Larvae: **3** *Eurycea cirrigera* Alternate Site ID:

| | | | | |
|---|---|---|---|---|
| **RR04** | **0.45** | **2023** | (23012) Wulff Run | Wulff Run Rd. |

HHEI Info: HHEI Score: ***86.0*** Substrate: **36.0** Pool: **20.0** Bankfull **30.0** Channel: ***Recent*** Flow: ***Flowing***

QHEI Info: QHEI Score: ***50.0*** Substrate: **16.5** Pool: **4.0** Max Z.: **20-40 cm** Channel **10.0** Flow: ***Flowing***

***Drainage Size:*** **2.18** Riffle: **0.0** Ripar: **7.5** Cover: **8.0** PHW Class: **WWH**

FISH Info: IBI Score: **20** Species: **1.0** Sensitive Sp.: **0.0** % Pioneer: **100.0** Headwater Sp. **0.00**

MACRO Info: ICI Score: QUAL EPT: **6** Coldwater Taxa.: **1** Intols: Sens. **2** Toler: V. Tol.

Salamanders: **X** Adults: **2** Larvae: **10** *Eurycea cirrigera* Alternate Site ID:

| | | | | |
|---|---|---|---|---|
| **IC06** | **2.30** | **2023** | (23019) Indian Creek | Hampshire Rd. crossing |

HHEI Info: HHEI Score: ***86.0*** Substrate: **36.0** Pool: **25.0** Bankfull **25.0** Channel: ***Recent*** Flow: ***Flowing***

QHEI Info: QHEI Score: ***53.5*** Substrate: **14.5** Pool: **4.0** Max Z.: **20-40 cm** Channel **10.0** Flow: ***Flowing***

***Drainage Size:*** **0.58** Riffle: **0.0** Ripar: **6.0** Cover: **15.0** PHW Class: **WWH**

FISH Info: IBI Score: **24** Species: **3.0** Sensitive Sp.: **0.0** % Pioneer: **66.91** Headwater Sp. **1.00**

MACRO Info: ICI Score: QUAL EPT: **8** Coldwater Taxa.: **0** Intols: Sens. **5** Toler: V. Tol.

Salamanders: **X** Adults: **5** Larvae: **4** *Eurycea cirrigera* Alternate Site ID:

| | | | | |
|---|---|---|---|---|
| **IC05** | **2.08** | **2023** | (23019) Indian Creek | Golf course pond |

HHEI Info: HHEI Score: ***95.0*** Substrate: **40.0** Pool: **30.0** Bankfull **25.0** Channel: ***Recovering*** Flow: ***Flowing***

QHEI Info: QHEI Score: ***55.0*** Substrate: **16.0** Pool: **5.0** Max Z.: **40-70 cm** Channel **10.0** Flow: ***Flowing***

***Drainage Size:*** **1.07** Riffle: **0.0** Ripar: **7.0** Cover: **13.0** PHW Class: **WWH**

FISH Info: IBI Score: **38** Species: **4.0** Sensitive Sp.: **0.0** % Pioneer: **18.46** Headwater Sp. **1.00**

MACRO Info: ICI Score: QUAL EPT: **6** Coldwater Taxa.: **0** Intols: Sens. **2** Toler: V. Tol.

Salamanders: **X** Adults: **1** Larvae: **9** *Eurycea cirrigera* Alternate Site ID:

Appendix D1. Primary Headwater Aquatic Life Use information for the small Ohio River tributaries during 2023.

| Site ID | RM | Year | River | Location: |
|---|---|---|---|---|
| **IC02** | **1.15** | **2023** | (23019) Indian Creek | Aston Oaks Golf Club |

HHEI Info: HHEI Score: ***91.0*** Substrate: **36.0** Pool: **30.0** Bankfull **25.0** Channel: ***Recovered*** Flow: ***Flowing***

QHEI Info: QHEI Score: ***48.0*** Substrate: **16.0** Pool: **2.0** Max Z.: **< 20 cm** Channel **10.0** Flow: ***Flowing***

***Drainage Size:*** **1.38** Riffle: **0.0** Ripar: **5.0** Cover: **11.0** PHW Class: **WWH**

FISH Info: IBI Score: **36** Species: **5.0** Sensitive Sp.: **0.0** % Pioneer: **33.77** Headwater Sp. **1.00**

MACRO Info: ICI Score: QUAL EPT: **8** Coldwater Taxa.: **0** Intols: Sens. **3** Toler: V. Tol.

Salamanders: **X** Adults: Larvae: **10** *Eurycea cirrigera* Alternate Site ID:

| | | | | |
|---|---|---|---|---|
| **IC01** | **0.30** | **2023** | (23019) Indian Creek | Near TISCH Environmental Parking Lot |

HHEI Info: HHEI Score: ***89.0*** Substrate: **29.0** Pool: **30.0** Bankfull **30.0** Channel: ***Recent*** Flow: ***Flowing***

QHEI Info: QHEI Score: ***50.0*** Substrate: **13.5** Pool: **5.0** Max Z.: **40-70 cm** Channel **8.5** Flow: ***Flowing***

***Drainage Size:*** **2.30** Riffle: **0.0** Ripar: **7.0** Cover: **12.0** PHW Class: **WWH**

FISH Info: IBI Score: **24** Species: **9.0** Sensitive Sp.: **1.0** % Pioneer: **62.33** Headwater Sp. **1.00**

MACRO Info: ICI Score: QUAL EPT: **8** Coldwater Taxa.: **0** Intols: Sens. **3** Toler: V. Tol.

Salamanders: **X** Adults: Larvae: **20** *Eurycea cirrigera* Alternate Site ID:

| | | | | |
|---|---|---|---|---|
| **IC07** | **0.10** | **2023** | (23020) Trib to Indian Creek @RM1.02 RM0.97 | at dead end of Stonehaven Dr. |

HHEI Info: HHEI Score: ***91.0*** Substrate: **36.0** Pool: **25.0** Bankfull **30.0** Channel: ***Recent*** Flow: ***Interm.***

QHEI Info: QHEI Score: ***50.0*** Substrate: **16.0** Pool: **3.0** Max Z.: **< 20 cm** Channel **10.0** Flow: ***Flowing***

***Drainage Size:*** **0.39** Riffle: **0.0** Ripar: **8.0** Cover: **9.0** PHW Class: **PHW3A**

FISH Info: IBI Score: **No Fish** Species: **0.0** Sensitive Sp.: **0.0** % Pioneer: **0.00** Headwater Sp. **0.00**

MACRO Info: ICI Score: QUAL EPT: **1** Coldwater Taxa.: **0** Intols: Sens. **2** Toler: V. Tol.

Salamanders: **X** Adults: **7** Larvae: **48** *Eurycea cirrigera* Alternate Site ID:

| | | | | |
|---|---|---|---|---|
| **MU10** | **0.50** | **2023** | (23071) Unnamed Trib to Muddy Creek @ RM2.37 | Van Blaricum Rd. |

HHEI Info: HHEI Score: ***96.0*** Substrate: **36.0** Pool: **30.0** Bankfull **30.0** Channel: ***Recent*** Flow: ***Flowing***

QHEI Info: QHEI Score: ***53.2*** Substrate: **17.0** Pool: **3.0** Max Z.: **< 20 cm** Channel **9.5** Flow: ***Flowing***

***Drainage Size:*** **0.71** Riffle: **0.0** Ripar: **6.7** Cover: **13.0** PHW Class: **PHW3A**

FISH Info: IBI Score: **No Fish** Species: **0.0** Sensitive Sp.: **0.0** % Pioneer: **0.00** Headwater Sp. **0.00**

MACRO Info: ICI Score: QUAL EPT: **10** Coldwater Taxa.: **2** Intols: Sens. **4** Toler: V. Tol.

Salamanders: **X** Adults: **1** Larvae: **4** *Eurycea cirrigera* Alternate Site ID:

Appendix D1. Primary Headwater Aquatic Life Use information for the small Ohio River tributaries during 2023.

| Site ID | RM | Year | River | Location: |
|---|---|---|---|---|
| **MU12** | **0.55** | **2023** | (23072) Unnamed Trib to Muddy Creek @ RM5.97 | Werk and Qualhill |

HHEI Info: HHEI Score: ***81.0*** Substrate: **36.0** Pool: **20.0** Bankfull **25.0** Channel: ***Recovering*** Flow: ***Flowing***

QHEI Info: QHEI Score: ***47.5*** Substrate: **18.5** Pool: **1.0** Max Z.: **40-70 cm** Channel **8.5** Flow: ***Interst.***

***Drainage Size:*** **1.01** Riffle: **0.0** Ripar: **5.5** Cover: **10.0** PHW Class: **WWH**

FISH Info: IBI Score: **24** Species: **2.0** Sensitive Sp.: **0.0** % Pioneer: **94.35** Headwater Sp. **0.00**

MACRO Info: ICI Score: QUAL EPT: **6** Coldwater Taxa.: **0** Intols: **1** Sens. **3** Toler: V. Tol.

Salamanders: **X** Adults: Larvae: **18** *Eurycea cirrigera* Alternate Site ID:

| | | | | |
|---|---|---|---|---|
| **MU13** | **0.60** | **2023** | (23073) Unnamed Trib to Muddy Creek @ RM6.53 | Werk Rd. and Westbourne Dr. |

HHEI Info: HHEI Score: ***100.0*** Substrate: **40.0** Pool: **30.0** Bankfull **30.0** Channel: ***Recovered*** Flow: ***Interm.***

QHEI Info: QHEI Score: ***41.0*** Substrate: **16.5** Pool: **0.0** Max Z.: **40-70 cm** Channel **9.0** Flow: ***Interm.***

***Drainage Size:*** **2.25** Riffle: **0.0** Ripar: **5.5** Cover: **6.0** PHW Class: **WWH**

FISH Info: IBI Score: **No Fish** Species: **0.0** Sensitive Sp.: **0.0** % Pioneer: **0.00** Headwater Sp. **0.00**

MACRO Info: ICI Score: QUAL EPT: **0** Coldwater Taxa.: **0** Intols: Sens. **0** Toler: **1** V. Tol. **1.0**

Salamanders: Adults: Larvae: Alternate Site ID:

| | | | | |
|---|---|---|---|---|
| **MU08** | **1.72** | **2023** | (23075) Unnamed Trib to Muddy Creek @RM0.3 | Aston Golf Club, access at 51 Oaks Dr. |

HHEI Info: HHEI Score: ***91.0*** Substrate: **36.0** Pool: **25.0** Bankfull **30.0** Channel: ***Recent*** Flow: ***Flowing***

QHEI Info: QHEI Score: Substrate: Pool: Max Z.: Channel Flow:

***Drainage Size:*** **0.74** Riffle: Ripar: Cover: PHW Class: **PHW3A**

FISH Info: IBI Score: **Dry** Species: **1.0** Sensitive Sp.: **0.0** % Pioneer: **0.00** Headwater Sp. **0.00**

MACRO Info: ICI Score: QUAL EPT: **9** Coldwater Taxa.: **1** Intols: Sens. **4** Toler: V. Tol.

Salamanders: **X** Adults: Larvae: **20** *Eurycea cirrigera* Alternate Site ID:

| | | | | |
|---|---|---|---|---|
| **MU09** | **0.10** | **2023** | (23076) UT @ 0.95 to UT to Muddy Creek @ RM0.3 | pull-off near Addyston Town Sign |

HHEI Info: HHEI Score: ***86.0*** Substrate: **36.0** Pool: **20.0** Bankfull **30.0** Channel: ***Recent*** Flow: ***Flowing***

QHEI Info: QHEI Score: ***55.5*** Substrate: **16.0** Pool: **3.0** Max Z.: **< 20 cm** Channel **10.5** Flow: ***Flowing***

***Drainage Size:*** **1.31** Riffle: **5.0** Ripar: **6.0** Cover: **11.0** PHW Class: **PHW3A**

FISH Info: IBI Score: **24** Species: **3.0** Sensitive Sp.: **0.0** % Pioneer: **44.14** Headwater Sp. **1.00**

MACRO Info: ICI Score: QUAL EPT: **8** Coldwater Taxa.: **0** Intols: Sens. **3** Toler: V. Tol.

Salamanders: **X** Adults: **1** Larvae: **10** *Eurycea cirrigera* Alternate Site ID:

Appendix D1. Primary Headwater Aquatic Life Use information for the small Ohio River tributaries during 2023.

| Site ID | RM | Year | River | Location: |
|---|---|---|---|---|
| **RR05.5** | **0.40** | **2023** | (23077) Unnamed Trib to Wulff Run @ RM 0.77 | Foley Rd. @ Mitchell Way Court |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HHEI Info: | HHEI Score: | ***73.0*** | Substrate: | **28.0** | Pool: | **25.0** | Bankfull | **20.0** | Channel: | ***Recent*** | Flow: | ***Flowing*** |
| QHEI Info: | QHEI Score: | ***49.5*** | Substrate: | **14.0** | Pool: | **4.0** | Max Z.: | **20-40 cm** | Channel | **11.5** | Flow: | ***Flowing*** |
| ***Drainage Size:*** | **0.33** | | Riffle: | **0.0** | Ripar: | **5.0** | Cover: | **11.0** | PHW Class: | **PHW3A** | | |
| FISH Info: | IBI Score: | **No Fish** | Species: | **0.0** | Sensitive Sp.: | **0.0** | % Pioneer: | **0.00** | Headwater Sp. | **0.00** | | |
| MACRO Info: | ICI Score: | | QUAL EPT: | **2** | Coldwater Taxa.: | **1** | Intols: | | Sens. | **1** | Toler: | V. Tol. |
| Salamanders: | **X** | Adults: **3** | Larvae: **3** | *Eurycea cirrigera* | | | | | | | Alternate Site ID: | |

| Site ID | RM | Year | River | Location: |
|---|---|---|---|---|
| **RR04.5** | **0.35** | **2023** | (23077) Unnamed Trib to Wulff Run @ RM 0.77 | Overhill Lane (Limnotech RR04) |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HHEI Info: | HHEI Score: | ***69.0*** | Substrate: | **29.0** | Pool: | **20.0** | Bankfull | **20.0** | Channel: | ***Recovering*** | Flow: | ***Flowing*** |
| QHEI Info: | QHEI Score: | ***54.0*** | Substrate: | **16.5** | Pool: | **3.0** | Max Z.: | **< 20 cm** | Channel | **10.0** | Flow: | ***Flowing*** |
| ***Drainage Size:*** | **0.33** | | Riffle: | **0.0** | Ripar: | **6.5** | Cover: | **14.0** | PHW Class: | **PHW3A** | | |
| FISH Info: | IBI Score: | **12** | Species: | **1.0** | Sensitive Sp.: | **0.0** | % Pioneer: | **0.00** | Headwater Sp. | **0.00** | | |
| MACRO Info: | ICI Score: | | QUAL EPT: | **4** | Coldwater Taxa.: | **2** | Intols: | | Sens. | **1** | Toler: | V. Tol. |
| Salamanders: | **X** | Adults: **1** | Larvae: **18** | *Eurycea cirrigera* | | | | | | | Alternate Site ID: | |

# Appendix E

## Ohio River Direct Tributaries 2023 Chemical Water Quality Data

### F-1: 2023 Sampling Sites
### F-2: Raw Chemical Data

(Contact Laura Boyd, MSDGC at Laura.Boyd@cincinnati-oh.gov for Excel files)

***Appendix Table E-1***. *Master list of 2023 Ohio River Direct Tributary sampling sites with location data and biological, habitat, and chemical indicators and parameters and frequencies.*

| Site ID | Basin | Stream | River_Stream Name | Latitude | Longitude | RM | SubType | Bio Site | Chem Site | Location-Description | Drain. Area | Geo. Level | Fish | Macroinvert | Habitat | Field Chem | Demand | Nutrients | Sonde* | Metals | Organics | Supplemental | Sed. Metals | Sed. Organics |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ohio River Direct Tributaries** | | | | | | | | | | | | | | | | | | | | | | | | |
| IC01 | 23 | 019 | Indian Creek | 39.1517 | -84.7439 | 0.30 | Added | X | X | Near TISCH Environmental Parking Lot | 2.30 | 8 | F | QL/PH | QHEI/HHEI | 5X | 4X | 4X | | 4X | 2X | Bact (4X) | X | X |
| IC02 | 23 | 019 | Indian Creek | 39.1538 | -84.7290 | 1.22 | OH EPA | X | X | Aston Oaks Golf Club | 1.38 | 8 | F | QL/PH | QHEI/HHEI | 6X | 5X | 5X | 1X | 5X | 2X | Bact (5X) | X | X |
| IC05 | 23 | 019 | Indian Creek | 39.1583 | -84.7173 | 2.08 | OH EPA | X | X | Golf course hole #8 | 1.07 | 8 | F | QL/PH | QHEI/HHEI | 6X | 5X | 5X | 1X | 5X | 2X | Bact (5X) | X | X |
| IC06 | 23 | 019 | Indian Creek | 39.1608 | -84.7147 | 2.43 | OH EPA | X | X | Hampshire Rd. Crossing | 0.58 | 9 | F | QL/PH | QHEI/HHEI | 6X | 5X | 5X | 1X | 5X | 2X | Bact (5X) | X | X |
| IC07 | 23 | 020 | Trib to Indian Creek @RM1.02 | 39.1514 | -84.7294 | 0.13 | OH EPA | X | X | At dead end of Stonhaven Dr. | 0.40 | 9 | F | QL/PH | QHEI/HHEI | 5X | 4X | 4X | | | | Bact (4X) | | |
| MU01 | 23 | 007 | Muddy Creek | 39.1319 | -84.7081 | 0.17 | MSDGC | X | X | Route 50 - Ohio R. backwater | 16.60 | 5 | A | HD | QHEI | 6X | 5X | 5X | 1X | 5X | 2X | Bact (5X) | X | X |
| MU02 | 23 | 007 | Muddy Creek | 39.1225 | -84.6871 | 2.25 | MSDGC | X | X | Hillside Ave. | 12.10 | 5 | E | HD | QHEI | 6X | 5X | 5X | 1X | 5X | 2X | Bact (5X) | X | X |
| MU03 | 23 | 007 | Muddy Creek | 39.1237 | -84.6773 | 2.72 | OH EPA | X | X | Cleves-Warsaw Pike | 10.40 | 5 | E | HD | QHEI | 6X | 5X | 5X | 1X | 5X | 2X | Bact (5X) | X | X |
| MU04 | 23 | 007 | Muddy Creek | 39.1348 | -84.6512 | 5.40 | OH EPA | X | X | Ebenezer Road | 7.80 | 6 | E | QL | QHEI | 6X | 5X | 5X | 1X | 5X | 2X | Bact (5X) | X | X |
| MU04.5 | 23 | 007 | Muddy Creek | 39.1332 | -84.6481 | 5.60 | Modeling | X | X | Beech Creek Lane | 7.50 | 6 | E | QL | QHEI | 6X | 5X | 5X | 1X | 5X | 2X | Bact (5X) | X | X |
| MU05 | 23 | 007 | Muddy Creek | 39.1334 | -84.6393 | 6.35 | MSDGC | X | X | Sidney Ave/Beech Grove | 5.41 | 6 | E | QL | QHEI | 6X | 5X | 5X | 1X | 5X | 2X | Bact (5X) | X | X |
| MU07 | 23 | 075 | Unnamed Trib to Muddy Creek @RM 0.3 | 39.1388 | -84.7101 | 0.60 | Geometric | X | X | VFW Post 6428 on Main Street | 2.80 | 8 | F | QL/PH | QHEI/HHEI | 5X | 4X | 4X | | | | Bact (4X) | | |
| MU07.5 | 23 | 075 | Unnamed Trib to Muddy Creek @RM 0.3 | 39.1433 | -84.7054 | 0.90 | Modeling | X | X | First Str. Turns into Fiddlers Green dst, confluence | 2.47 | 8 | F | QL/PH | QHEI/HHEI | 5X | 4X | 4X | | | | Bact (4X) | | |
| MU08 | 23 | 075 | Unnamed Trib to Muddy Creek @RM 0.3 | 39.1513 | -84.6961 | 1.50 | Geometric | X | X | Aston Golf Club, access at 51 Oaks Dr | 1.21 | 8 | F | QL/PH | QHEI/HHEI | 5X | 4X | 4X | | | | Bact (4X) | | |
| MU09 | 23 | 066 | UT RM 0.95 to UT to Muddy Creek @RM 0.3 | 39.1436 | -84.7028 | 0.60 | Geometric | X | X | Fiddlers Green Rd. | 1.09 | 9 | F | QL/PH | QHEI/HHEI | 5X | 4X | 4X | | | | Bact (4X) | | |
| MU10 | 23 | 071 | Unnamed Trib to Muddy Creek @RM 2.37 | 39.1297 | -84.6800 | 0.60 | Geometric | X | X | Van Blaricum Rd. | 0.69 | 9 | F | QL/PH | QHEI/HHEI | 5X | 4X | 4X | | | | Bact (4X) | | |
| MU12 | 23 | 072 | Unnamed Trib to Muddy Creek @RM 5.97 | 39.1429 | -84.6436 | 0.65 | Geometric | X | X | Werk and Qualhill | 0.98 | 9 | F | QL/PH | QHEI/HHEI | 5X | 4X | 4X | | | | Bact (4X) | | |
| MU13 | 23 | 073 | Unnamed Trib to Muddy Creek @RM 6.53 | 39.1413 | -84.6318 | 0.60 | Geometric | X | X | Werk Rd and Westbourne Dr. | 1.94 | 9 | F | QL/PH | QHEI/HHEI | 5X | 4X | 4X | | | | Bact (4X) | | |
| MU14 | 23 | 074 | Unnamed Trib to Unnamed Trib to Muddy Creek @RM 5.97 | 39.1438 | -84.6349 | 0.20 | Geometric | X | X | Andres Ln. Crossing | 2.70 | 7 | E,F | QL | QHEI | 6X | 5X | 5X | | | | Bact (5X) | | |
| RR01 | 23 | 008 | Rapid Run | 39.1009 | -84.6707 | 0.10 | Geometric | X | X | US 50 overpass | 5.99 | 6 | E | QL | QHEI | 6X | 5X | 5X | 1X | 5X | 2X | Bact (5X) | X | X |
| RR02 | 23 | 008 | Rapid Run | 39.1022 | -84.6544 | 1.20 | OH EPA | X | X | U.S. Rt. 50 | 5.80 | 6 | E | QL | QHEI | 6X | 5X | 5X | 1X | 5X | 2X | Bact (5X) | X | X |
| RR03 | 23 | 008 | Rapid Run | 39.1100 | -84.6410 | 2.70 | Geometric | X | X | Rapid Run Rd. | 0.18 | 9 | F | QL/PH | QHEI/HHEI | 5X | 4X | 4X | 1X | 5X | 2X | Bact (5X) | X | X |
| RR05 | 23 | 067 | Wulff Run | 39.0941 | -84.6284 | 0.68 | Geometric | X | X | Near intersection of Oakwood and Delhi | 1.37 | 8 | F | QL/PH | QHEI/HHEI | 5X | 4X | 4X | | | | Bact (4X) | | |
| RR04 | 23 | 012 | Wulff Run | 39.1009 | -84.6401 | 0.55 | OH EPA | X | X | Wulff Run Road | 2.20 | 8 | E,F | QL/PH | QHEI/HHEI | 5X | 4X | 4X | | 4X | 2X | Bact (5X) | X | X |
| RR04.5 | 23 | 012 | Unnamed Trib to Wulff Run @RM 0.77 | 39.1020 | -84.6308 | 0.90 | Modeling | X | X | Overhill Lane (Limnotech RR04) | 0.90 | 9 | F | QL/PH | QHEI/HHEI | 5X | 4X | 4X | | | | Bact (4X) | | |
| RR05.5 | 23 | 012 | Unnamed Trib to Wulff Run @RM 0.77 | 39.1033 | -84.6302 | 0.70 | Modeling | X | X | Foley Rd. @Mitchell Way Court | 1.00 | 9 | F | QL/PH | QHEI/HHEI | 5X | 4X | 4X | | | | Bact (4X) | | |
| | | | | | | | | 26 | 26 | | | | | | | 26 | 26 | 26 | 12 | 14 | 14 | 26 | 14 | 14 |
| **Taylor Creek Tributaries** | | | | | | | | | | | | | | | | | | | | | | | | |
| GM85 | 14 | 004 | Taylor Creek | 39.1811 | -84.6410 | 4.89 | Geometric | X | X | Intersection of Johnson & Reemelin Rds. | 2.47 | 8 | F | QL/PH | QHEI/HHEI | 6X | 5X | 5X | 1X | 5X | 2X | Bact (5X) | X | X |
| GM86 | 14 | 004 | Taylor Creek | 39.1755 | -84.6255 | 6.30 | Geometric | X | X | near 4540 Reemelin Road | 1.21 | 8 | F | QL/PH | QHEI/HHEI | 6X | 5X | 5X | 1X | 5X | 2X | Bact (5X) | X | X |
| GM100 | 14 | 275 | Unnamed Trib to Wesselman Creek @ RM2.59 | 39.1671 | -84.6750 | 1.21 | Geometric | X | X | Between Taylor & Old Taylor Rd. | 0.91 | 9 | F | QL/PH | QHEI/HHEI | 5X | 4X | 4X | | | | Bact (4X) | | |
| GM106 | 14 | 277 | Unnamed Trib to Taylor Creek @ RM4.9 | 39.1864 | -84.6340 | 0.28 | Geometric | X | X | Residence 5310 Haft Rd. near I-74 | 0.92 | 9 | F | QL/PH | QHEI/HHEI | 5X | 4X | 4X | | | | Bact (4X) | | |
| GM89 | 14 | 148 | Briarly Creek | 39.2025 | -84.6450 | 1.80 | OH EPA | X | X | Adj. to Briarly Creek Rd. | 2.10 | 8 | F | QL/PH | QHEI/HHEI | 6X | 5X | 5X | 1X | 5X | 2X | Bact (5X) | X | X |
| GM90 | 14 | 148 | Briarly Creek | 39.2040 | -84.6340 | 2.45 | Added | X | X | Bridge crossing near 5994 Gaines Rd. | 1.3 | 8 | F | QL/PH | QHEI/HHEI | 6X | 5X | 5X | 1X | 5X | 2X | Bact (5X) | X | X |
| GM91 | 14 | 148 | Briarly Creek | 39.1940 | -84.6100 | 3.90 | Geometric | X | X | Near bridge at 3852 Ridgedale Dr. | 0.3 | 9 | F | QL/PH | QHEI/HHEI | 6X | 5X | 5X | 1X | 5X | 2X | Bact (5X) | X | X |
| GM94 | 14 | 149 | Wesselman Creek | 39.1800 | -84.6520 | 4.70 | Added | X | X | Road crossing near 6250 Wesselman Rd. | 1.1 | 8 | F | QL/PH | QHEI/HHEI | 6X | 5X | 5X | 1X | 5X | 2X | Bact (5X) | X | X |
| | | | | | | | | 8 | 8 | | | | | | | 8 | 8 | 8 | 6 | 6 | 6 | 8 | 6 | 6 |
| | - sites added in 2018 to assess HSTS areas. | | | | | | | | | | | | | | | | | | * | Benthic chlorphyll a collected at all Datasonde sites | | | | |

**Appendix F**: Ohio EPA Stream Nutrient Assessment Procedure (SNAP) Matrix and Flow Chart

<table>
<tr><th colspan="5">Proposed Stream Nutrient Assessment Procedure (SNAP; Ohio EPA 2015b)</th></tr>
<tr><th>STEP 1</th><th>STEP 2</th><th>STEP 3</th><th colspan="2">STEP 4</th></tr>
<tr><th>Biological Criteria</th><th>Diel D.O. Swing [2]</th><th>Benthic Chlorophyll [3]</th><th colspan="2">Preliminary Assessment: Trophic Condition Status of Evaluated Segment or Waterbody</th></tr>
<tr><td rowspan="4">All indices attaining or in non-significant departure[1]</td><td rowspan="2">Normal or low swings (≤6.5 mg/l)</td><td>Low to moderate (≤320 mg/m$^2$)</td><td colspan="2">Attaining use / Not threatened</td></tr>
<tr><td>High (>320 mg/m$^2$)</td><td rowspan="2">Attaining use, but may be threatened</td><td rowspan="2">See Flow Chart A</td></tr>
<tr><td rowspan="2">Wide swings (>6.5 mg/l)</td><td>Low (≤182 mg/m$^2$)</td></tr>
<tr><td>Moderate to high (>182 mg/m$^2$)</td></tr>
<tr><td rowspan="4">Non-attaining (one or more indices below nonsignificant departure)</td><td rowspan="2">Normal or low swings (≤6.5 mg/l)</td><td>Low to moderate (≤320 mg/m$^2$)</td><td>Impaired, but cause(s) other than nutrients</td><td>See Flow Chart B</td></tr>
<tr><td>High (>320 mg/m$^2$)</td><td rowspan="2">Impaired; likely nutrients over-enrichment</td><td rowspan="3">See Flow Chart C</td></tr>
<tr><td rowspan="2">Wide swings (>6.5 mg/l)</td><td>Low (≤182 mg/m$^2$)</td></tr>
<tr><td>Moderate to high (>182 mg/m$^2$)</td><td>Impaired; Nutrients over-enrichment</td></tr>
</table>

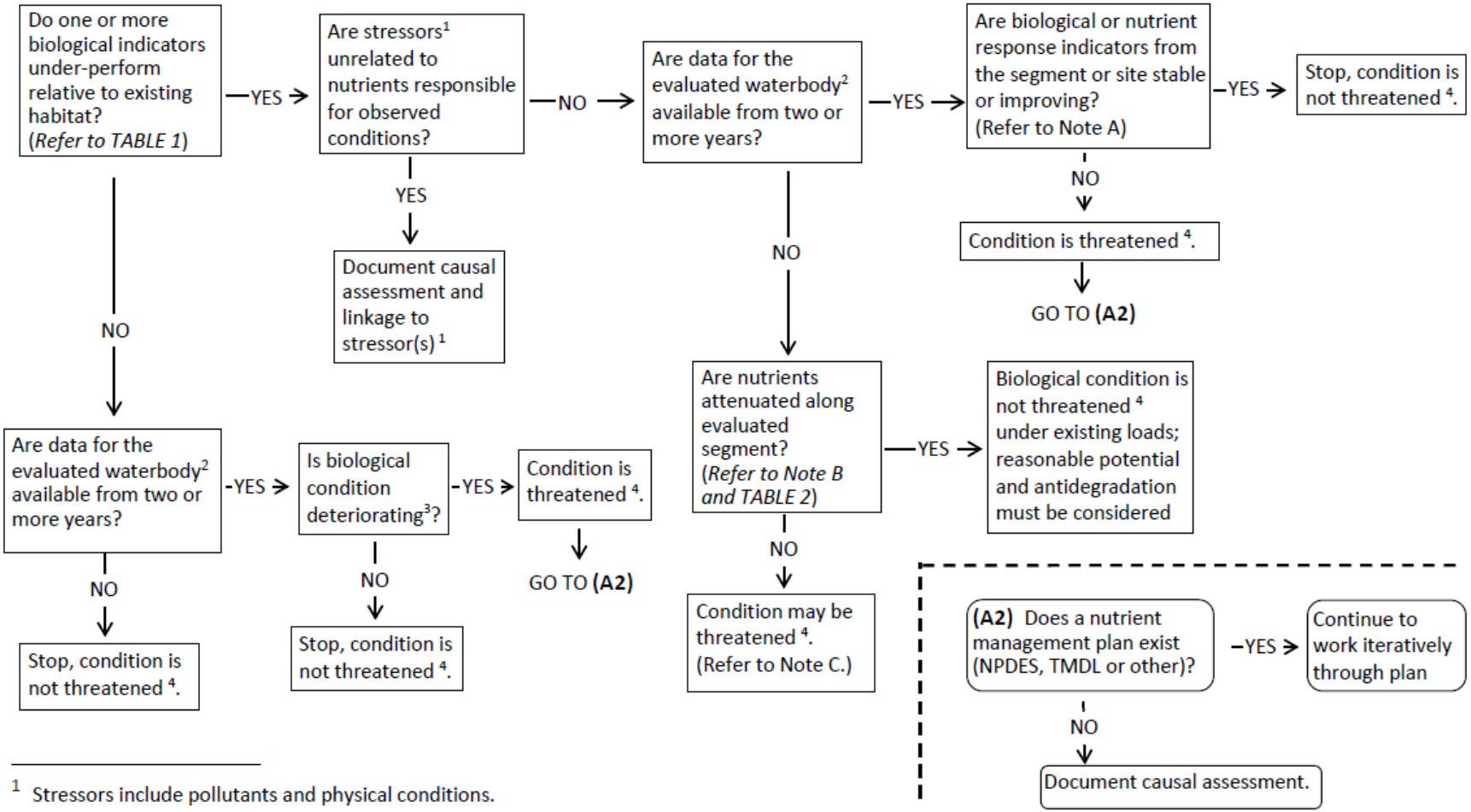
[1] Non-significant departure from biocriteria values accounts for background variability in measurements for biological indices. In accordance with "Biological Criteria for the Protection of Aquatic Life: Volume II: Users Manual for Biological Field Assessment of Ohio Surface Waters", Ohio EPA (1987, updated 2015b), non-significant departure is 4 points for IBI and ICI, and 0.5 point for MIwb.

[2] Threshold value for 24-hour DO swing based upon a change point of 6.5 mg/l between DO swing and minimum DO. "Low to normal" DO swing is ≤6.5 mg/l. "Wide" DO swing is >6.5 mg/l. Data used for analysis from Technical Support Document for Nutrient Water Quality Standards for Ohio Rivers and Streams, Ohio EPA (2011).

[3] Threshold values for benthic chlorophyll a are based upon change points between benthic chlorophyll a and DO swings or Invertebrate Community Index (ICI). "Low" chlorophyll a is ≤182 mg/m2. "Moderate" chlorophyll a is >182 and ≤320 mg/m2. "High" chlorophyll a is >320 mg/m2. Data used for analysis from Technical Support Document for Nutrient Water Quality Standards for Ohio Rivers and Streams, Ohio EPA (2011).

**FLOW CHART A. – DECISION TREE FOR DETERMINING WHEN BIOLOGICALLY ATTAINING CONDITION STATUS IS THREATENED BY NUTRIENTS**

*For application when biological criteria are attaining, but one or both nutrient response indicators (DO swing or benthic chlorophyll) are elevated.*




[1] Stressors include pollutants and physical conditions.

[2] The geographic scope or length of evaluated stream segments are defined in approved study plans.

[3] For a given location, a decrease of 5 or more IBI or ICI points, or 0.6 or more MIWb points between sampling years represents a significant change. Trends for waterbodies are formally evaluated in Biological and Water Quality Technical Support Documents.

[4] As recommended by US EPA in its integrated reporting guidance (*Guidance for 2006 Assessment, Listing and Reporting Requirements Pursuant to Sections 303(d), 305(b) and 314 of the Clean Water Act*), "threatened" waters are currently attaining WQSs but are expected to not meet WQSs by the next listing cycle (every two years). For example, a declining trend may indicate threatened status, whereas a stable or improving trend would not.