Biological and Water Quality Study of the Ohio River Direct Tributaries 2018

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)

Peter A. Precario, Executive Director
James Lane, Board President

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Biological and Water Quality Study of the Ohio River Direct Tributaries 2018

Hamilton County, Ohio

Technical Report MBI/2019-6-4

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ACKNOWLEDGEMENTS

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Glossary of Terms

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.

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. 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

	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.

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

	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

	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.

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.

	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

ALU	Aquatic Life Use
BCG	Biological Condition Gradient
CSO	Combined Sewer Overflow
CWA	Clean Water Act
EPT	Ephemeroptera, Plecoptera, Trichoptera
HSTS	Home Sewage Treatment System
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. The latter is the case as all or parts of four subwatersheds with a mix of numerous overlapping stressors and sources in a highly urbanized landscape. The 2018 assessment is a follow-up to a baseline survey of these subwatersheds performed by MBI in 2014 (MBI 2015a).

Scope of the 2018 Ohio River Direct Tributaries Biological and Water Quality Assessment

The scope of the MSDGC 2018 Ohio River Direct Tributaries biological and water quality assessment was limited to three direct tributaries to the Ohio River and the upper tributaries of Taylor Creek compared to the fuller scope of the 2014 survey (MBI 2015a). In addition to supporting the instream monitoring requirement of the CSO NPDES permit the overall objectives remained the same:

1. Determine the extent to which biological assemblages are impaired (using Ohio EPA methods and criteria);
2. Determine the categorical stressors and sources that are associated with those impairments; and,
3. Add to the broader databases for the study area to track and understand changes through 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 by MBI such that trends in status can be examined, and causes and sources of impairment can be confirmed, appended, or removed. The 2018 study included an assessment of chemical and physical stressors related to the biological assemblages and an assessment of recreational uses. It is not the purpose of this study to identify specific remedial actions on a site specific or watershed basis. However, the data produced by this study contributes to the maintenance and use of the Integrated Prioritization System (IPS; MBI 2015b) that was developed to determine and prioritize remedial projects for the MSDGC service area in addition to its other functions such as serving as a data warehouse and data exploration platform.

EXECUTIVE SUMMARY

Scope and Purpose

In 2010 MSDGC and MBI developed a four-year 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 of Project Groundwork to further improve water quality. The 2018 bioassessment of the Ohio River Direct Tributaries study area is Year Three of the follow-up sampling and analysis conducted 2016-18 and completes the second cycle of monitoring that is required by the current CSO NPDES permit. The sampling and analysis in 2018 was performed by Level 3 Qualified Data Collectors and under a biological Project Study Plan 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 existing aquatic life and recreational use designations, assign uses to unlisted streams, 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 that employed by Ohio EPA. 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 stressors by relating them to the chemical, physical, and biological data generated by the surveys to ancillary data available in GIS coverages.

Highlighted Findings

Aquatic Life Use Attainability and Attainment Status

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 2018 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 prior assessments. The 2014 baseline biological and water quality assessment by MBI is the only prior survey that provides a consistent basis for comparison in terms of spatial coverage and between indicators and parameters for the 2018 study area.

Of the 34 sites that were assessed in the 2018 Ohio River Direct Tributaries bioassessment 22 sites were evaluated against the Warmwater Habitat (WWH) use, 5 sites against the Limited Resource Waters (LRW) use, and 7 for the Primary Headwater Habitat (PHWH) classification. Recommendations for aquatic life use changes were originally made as part of the 2014 bioassessment (MBI 2015a) and these were likewise used to gauge attainment status in 2018. All of the 2014 use recommendations were verified in 2018 for 30 in common sites.

Table 1. *Summary of recommended aquatic life use (AQLU) changes based on use attainability analyses from the 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 Designation	Sites Affected	Rulemaking Status
Recommended Uses 2018			
Undesignated	WWH	2	Recommended
Undesignated	PHW3A	2	Recommended
WWH (2014)	WWH (verified)	4	Pending
WWH (Existing[1])	WWH (verified)	16	Pending
PHW3A	PHW3A (verified)	4	Recommended
PHW2	PHW2 (verified)	1	Recommended
LRW (Existing[1])	Deferred	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.

Four (4) new sites were added in 2018 to coincide with the water quality model calibration and recommendations for the aquatic life use were made and used to assess attainment status which is depicted in Table 2 and Figure 1.

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. The determinations are in

***Table 2**. Aquatic life use attainment status at sites in Ohio River Direct Tributaries and upper Taylor Creek in 2018. Index of Biotic Integrity (IBI) and Invertebrate Community Index (ICI) scores and narratives are based on the biological assemblages. The Qualitative Habitat Evaluation Index (QHEI) measures physical habitat quality. Causes and sources are listed at sites that did not fully attain the recommended or verified use – sites in full attainment of WWH are green shaded; PHW are blue (3A) and green (2) shaded. Sampling locations are arranged by HUC 12 subwatershed Watershed Assessment Units (WAUs). Changes in biological condition since 2014 are denoted as improving (⇧), unchanged (⊙), or declining (⇩); sites with two status arrows indicate differing changes between fish and macroinvertebrates; sites with no trend arrow are new in 2018. Causes and sources are listed in order of importance – see glossary of acronyms for names of each.*

Site ID	River Mile[1]	Drainage Area (mi.[2])	Aquatic Life Use (AQLU)	IBI	ICI or Narrative[a]	Status	QHEI/HHEI	Causes	Sources
Muddy Creek (WWH Existing/WWH Verified)									
MU05	6.35/6.35	5.4	WWH	12*	VP*	Non⊙	48.0	Habitat alter.,Low D.O.,Nutrients, Chloride, Org. Enrich., PAH	CSO/SSO,Urban, Sewer Constr.
MU04.5	5.62/5.60	7.7	WWH	12*	VP*	Non	48.5	Habitat alter.,Low D.O.,Nutrients, Org. Enrich., PAH	CSO/SSO, Urban,Sew. Const.
MU04	5.45/5.40	7.8	WWH	24*	VP*	Non⇧⊙	55.5	Low D.O., Org. Enrich., PAH	CSO/SSO,Urban
MU03	2.80/2.72	10.4	WWH	30*	12*	Non⊙⇩	60.0	Low D.O., Org. Enrich.,Chloride	CSO/SSO/NEO,Urban,HSTS
MU02	2.25/2.25	12.1	WWH	30*	30	Partial⇩	52.0	Low D.O., Chloride, PAH	CSO/SSO/NEO,Urban,HSTS
MU01	0.17/0.17	13.6	WWH	26	-	Non⊙	56.0	Low D.O., Org. Enrich, PAH	CSO/SSO/NEO,Urban
Unnamed Tributary to Muddy Creek @RM 0.3 (PHW3A in 2014/PHW3A Verified)									
MU08	1.72/1.80	0.74	PHW3A	20	SW[2]	PHW3A⊙	53.5/95.0		
Unnamed Tributary to Muddy Creek @RM 0.3 (Undesignated/WWH Recommended)									
MU07.5	0.80/0.90	2.6	WWH	34*	F*	Non	52.5/84.0	Chloride	Urban
MU07	0.40/0.60	2.8	WWH	34*	G	Partial⊙	58.0	Low D.O., Chloride	CSO/SSO,Urban
Unnamed Tributary to Unnamed Tributary to Muddy Creek @RM 0.30 (PHW3A in 2014/PHW3A Verified)									
MU09	0.10/0.60	1.3	PHW3A	14	SW	PHW3A⊙	50.0/89.0		
Unnamed Tributary to Muddy Creek @RM 2.37 (WWH Recommended in 2014/WWH Verified)									
MU10	0.50/0.60	0.71	WWH	12	VP*	Non⊙	56.0/95.0	Habitat alter., Chloride	Urban
Unnamed Tributary to Muddy Creek @RM 5.97 (WWH Recommended in 2014/WWH Verified)									
MU12	0.55/0.65	1.0	WWH	36[ns]	VP*	Non⇧⊙	50.0/75.0	Low D.O., Org. Enrich, metals	CSO/SSO,Urban
Unnamed Tributary to Muddy Creek @RM 6.53 (WWH Recommended in 2014/WWH Verified)									
MU13	0.60/0.60	2.3	WWH	--[3]	VP*	Non⊙	--/93.0	Low D.O., Org. Enrich, Unk. Tox., Flow	CSO/SSO,Urban
Unnamed Tributary to Unnamed Tributary to Muddy Creek @RM 5.97 (PHW2 Recommended in 2014/PHW2 Verified)									
MU14	0.20/0.20	0.1	PWH2	--[3]	P2	PHW2⊙	-		
Rapid Run (LRW Existing/Use Change Recommendation Deferred)									
RR03	2.70/2.70	2.3	LRW	--[3]	VP*	Non⊙	--/88.0	PAH, Organic Enrich., Flow	Urban, Sewer Constr.,HSTS

***Table 2**. Aquatic life use attainment status at sites in Ohio River Direct Tributaries and upper Taylor Creek in 2018. Index of Biotic Integrity (IBI) and Invertebrate Community Index (ICI) scores and narratives are based on the biological assemblages. The Qualitative Habitat Evaluation Index (QHEI) measures physical habitat quality. Causes and sources are listed at sites that did not fully attain the recommended or verified use – sites in full attainment of WWH are green shaded; PHW are blue (3A) and green (2) shaded. Sampling locations are arranged by HUC 12 subwatershed Watershed Assessment Units (WAUs). Changes in biological condition since 2014 are denoted as improving (⇧), unchanged (⊙), or declining (⇩); sites with two status arrows indicate differing changes between fish and macroinvertebrates; sites with no trend arrow are new in 2018. Causes and sources are listed in order of importance – see glossary of acronyms for names of each.*

Site ID	River Mile[1]	Drainage Area (mi.[2])	Aquatic Life Use (AQLU)	IBI	ICI or Narrative[a]	Status	QHEI/HHEI	Causes	Sources
RR02	1.05/1.20	5.9	LRW	30	F	Full⇧⊙	45.5	PAH, Chloride	Urban, Sewer Constr.
RR01	0.10/0.10	6.6	LRW	--[3]	MG	[Full]⊙	-	Chloride, Unk. Toxicity, Flow	Urban, Sewer Constr.,HSTS
Wulff Run (LRW Existing/Use Change Recommendation Deferred)									
RR05	0.70/0.68	1.3	WWH	--[2]	VP*	Non⊙	--/101.0	Low D.O., Chloride, Flow	CSO/SSO,Urban,Sew. Const.
RR04	0.45/0.55	2.2	WWH	20	P	Full⊙	48.8/95.0	Habitat alter.,Org. Enrich., Chlor.	CSO/SSO,Urban
Unnamed Tributary to Wulff Run @ RM 0.77 (Undesignated/PHW3A Recommended)									
RR05.5	1.20/1.20	0.33	PHW3A	12	SW	PHW3A	57.0/81.0		
RR04.5	1.10/1.10	0.33	PHW3A	12	SW	PHW3A	51.0/77.0		
Indian Creek (WWH Existing/WWH Verified)									
IC06	2.30/2.43	0.58	WWH	28*	G	Partial⇧	55.0/87.0	Chloride, Organic Enrich., PAH	Urban, HSTS
IC05	2.08/2.08	1.1	WWH	38[ns]	F*	Partial⊙⇩	54.5/91.0	Nutrients, Chloride, Organic Enrich.	Urban
IC02	1.15/1.22	1.4	WWH	22*	G	Partial⊙⇧	51.5/75.0	Chloride, Organic Enrich.	Urban
IC01	0.30/0.30	2.3	WWH	26*	G	Partial⊙⇧	43.5/73.0	Organic enrich.	Urban
Unnamed Tributary to Indian Creek @RM1.02 (Undesignated/PHW3A Recommended)									
IC07	0.10/0.13	0.39	PHW3A	12	SW	PHW3A⊙	57.0/76.0		
Taylor Creek (WWH Existing/WWH Verified)									
GM86	6.40/6.30	0.5	WWH	32*	MG	Partial⇧	46.5/80.0	Habitat alter., Chlorides, Organic Enrich.	Urban, HSTS
GM85	5.30/4.98	2.2	WWH	34*	F*	Non⇧	46.0/90.0	Nutrients, Chloride, PAH	Urban, HSTS
Unnamed Tributary to Taylor Creek @RM4.90 (WWH Recommended in 2014/WWH Verified)									
GM106	0.20/0.28	0.92	WWH	42	F*	Partial⊙	58.0/90.0	Chloride	Urban
Briarly Creek (PHW3A in 2014/PHW3A Verified)									
GM91	3.90/3.90	0.34	PHW3A	24	SW	PHW3A⊙	56.5		
Briarly Creek (WWH Existing/WWH Verified)									
GM90	2.45/2.45	1.3	WWH	26*	MG	Partial⇩⇧	54.8/97.0	Chloride, PAH, Organic Enrich.	Urban, HSTS

***Table 2**. Aquatic life use attainment status at sites in Ohio River Direct Tributaries and upper Taylor Creek in 2018. Index of Biotic Integrity (IBI) and Invertebrate Community Index (ICI) scores and narratives are based on the biological assemblages. The Qualitative Habitat Evaluation Index (QHEI) measures physical habitat quality. Causes and sources are listed at sites that did not fully attain the recommended or verified use – sites in full attainment of WWH are green shaded; PHW are blue (3A) and green (2) shaded. Sampling locations are arranged by HUC 12 subwatershed Watershed Assessment Units (WAUs). Changes in biological condition since 2014 are denoted as improving (⇧), unchanged (⊙), or declining (⇩); sites with two status arrows indicate differing changes between fish and macroinvertebrates; sites with no trend arrow are new in 2018. Causes and sources are listed in order of importance – see glossary of acronyms for names of each.*

Site ID	River Mile[1]	Drainage Area (mi.[2])	Aquatic Life Use (AQLU)	IBI	ICI or Narrative[a]	Status	QHEI/HHEI	Causes	Sources
GM89	1.80/1.70	2.1	WWH	30*	MG	Partial⊙	57.5/88.0	Metals, PAH	Urban, HSTS
Wesselman Creek (WWH Existing/WWH Verified)									
GM94	4.70/4.72	1.1	WWH	22*	F	Non⊙	53.0/87.0	Chloride, PAH, Organic enrich.	Urban, HSTS
Unnamed Tributary to Wesselman Creek @RM 2.59 (PHW3A in 2014/PHW3A Verified)									
GM100	1.05/1.21	0.91	PHW3A	24	SW	PHW3A⊙	48.5/91.0		

[1] – Fish/Macroinvertebrate site river miles.
[2]- Macroinvertebrate assessment for PHWH: SW – Spring Water Type 2; P2 – Small Drainage Warmwater Stream.
[3]- Insufficient water to sample fish.
[a] - VP=Very Poor; P=Poor; MF=Marginally Fair; F=Fair; MG=Marginally Good; G=Good; VG=Very Good; E=Exceptional.
[ns] - Non-significant departure from the biocriteria (<4 IBI or ICI units or <0.5 MIwb units).
* - Significant departure from the biocriteria (>4 IBI or ICI units or >0.5 MIwb units); poor or very poor conditions are underlined.

Biological Criteria – Interior Plateau Ecoregion			
Index	**WWH**	**EWH**	**MWH-C**
IBI – Boat	38	48	24
IBI – Wading	40	50	24
IBI - Headwater	40	50	24
MIwb - Boat	8.7	9.6	5.8
MIwb – Wading	8.1	9.4	6.2
ICI	30	46	22
ICI Narrative	G	E	F

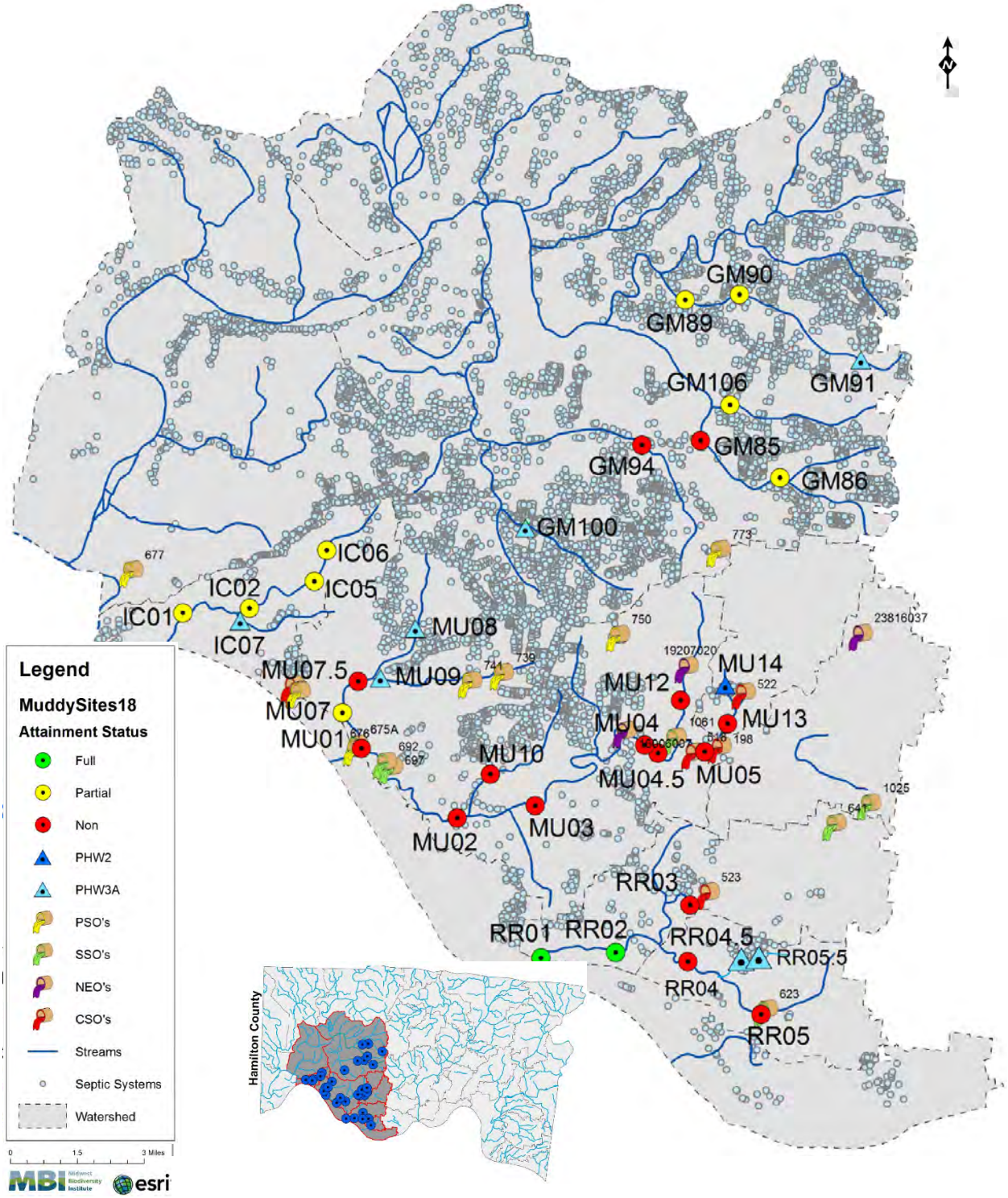

Figure 1. *Aquatic life use attainment status in the Ohio River Direct Tributaries study area during 2018 (green circles – full attainment; yellow – partial attainment; red – non-attainment; outfall type – CSO, SSO, NEO, PSO, HSTS). Site descriptions and site codes appear in Table 5. Sites evaluated as Primary Headwater Habitat (PHWH) sites appear as triangles with their classification results (green – PHW Class III; orange – PHWH Class II).*

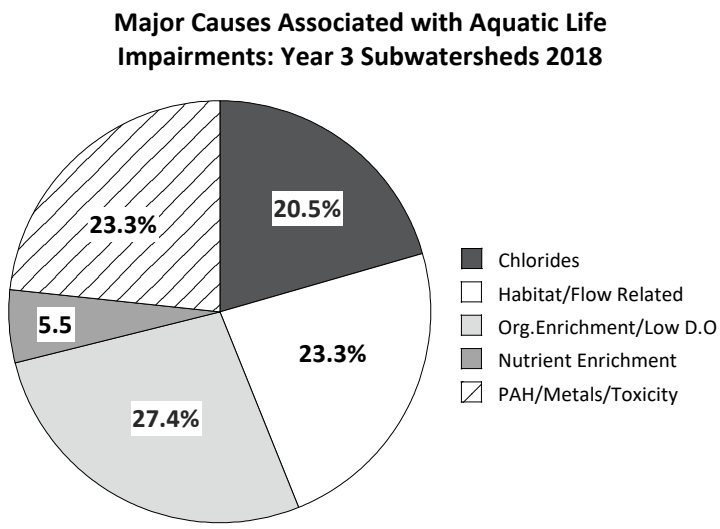

Figure 2. *Major causes associated with aquatic life impairments in the Ohio River Direct Tributaries subwatersheds, 2018.*

some cases categorical (e.g., habitat alterations, organic enrichment, toxicity) which can include multiple parameters and may also include multiple specific types of effects and mechanisms. Some determinations can be parameter specific (e.g., dissolved oxygen, chlorides). In addition, some stressors are proxies for a wider range of specific causes or can mask causes that can emerge only with changing conditions. Sources are also 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 along with the biological impairments appear in the determination of aquatic life use attainment status (Table 2) and are summarized on a study area basis in Figure 2. Categories of cause and source are proportionally depicted by the number of sites each was assigned in 2018. Habitat alteration, low D.O., chlorides, organic enrichment, PAH compounds were the most frequently assigned with less frequent assignments of flow alteration, nutrient enrichment, metals, and unknown toxicity in 2018. The chloride assignments were similar to 2014. Organic enrichment and low D.O. increased in 2018 and were associated with wet weather sources such as CSOs, SSOs, and NEOs and HSTS discharges.

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

Muddy Creek

- The 2018 results showed non-attainment of the Warmwater Habitat (WWH) AQLU at all six mainstem sites. Full attainment observed at RM 2.25 in 2014 was partial in 2018 due the failure of the IBI to meet the WWH biocriterion. The macroinvertebrate ICI met the WWH biocriterion, but was 18 units lower than in 2014. Releases of raw sewage from NEO 160006007 occurred just upstream and may related to the decline in biological performance since 2014. However, several other CSOs and SSOs and a pocket of HSTS discharges also occur upstream. The predominant causes included low D.O., organic enrichment, chlorides, and PAH compounds.
- Biological performance as measured by the fish IBI and the macroinvertebrate ICI or narrative improved at one site (RM 5.45/5.40), but declined at the next two sites downstream.
- Eight (8) sites were sampled in seven (7) unnamed tributaries to Muddy Creek in 2018 of which two sites in one tributary are new sites. Two were recommended for the PHW3A

and one for the PHW2 classification in 2014 and verified in 2018. Of the remaining four tributaries, three were recommended as WWH in 2014 and verified as WWH in 2018 and the other recommended for WWH in 2018. Four sites were in non-attainment of WWH and one (MU07) was in partial attainment with the fish IBI just missing the WWH biocriterion. The fish IBI at MU12 improved since 2014 to meet the WWH biocriterion, but the very poor macroinvertebrate narrative resulted in non-attainment.

Rapid Run

- Seven sites were sampled in the Rapid Run subwatershed in 2018 with 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 three of the five sites so designated and non-attainment at the remaining two sites. The fish IBI of 30 at RR02 was an improvement from 2014 and coupled with incremental improvements observed in 2014 resulted in deferring any recommendations about revising the current LRW use designation. Three sites (RR03, RR01, and RR05) were not sampled for fish due to insufficient water being present at those sites which is the 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 only slowly receding at certain locations. HSTS discharges are also comparatively dense at certain locations.
- Predominant causes of impairment included flow alteration, organic enrichment, chlorides, and PAH compounds.
- Two new 2018 sites in an unnamed tributary to Wulff Run (RR 05.5 and RR 04.5) had a non-fish biota sufficient to recommend the PHW3A classification.

Indian Creek

- Five sites were sampled in the Indian Creek subwatershed in 2018 with four sites in the mainstem and one in an unnamed tributary (IC07). The results showed partial attainment of WWH at all four mainstem sites. Biological performance showed an incremental improvement from 2014 at three sites and a decline at one site.
- Predominant causes of impairment included organic enrichment and chlorides.
- The macroinvertebrate narrative was good at three sites which meets the WWH biocriteria narrative. The fish IBI met the WWH biocriterion at only one site (IC05), but showed an incremental improvement over 2014 at the remaining three mainstem sites.

Taylor Creek

- Eight sites were sampled in the upper Taylor Creek subwatershed in 2018 with two sites in the mainstem, three in Briarly Creek, one in Wesselman Creek, and two in unnamed tributaries to Taylor Creek and Wesselman Creek. The results showed partial and non-attainment of the WWH use with incremental improvements in biological performance at the two upper mainstem sites. The unnamed tributary to Taylor Creek (GM106) was also in partial attainment with the macroinvertebrate narrative if fair being the limiting result.
- Three sites were sampled in upper Briarly Creek with two in partial attainment of WWH and a mix of decline and improvement in biological performance over 2014. The

upstream most site was classified as PHW3A in 2014 and verified in 2018.

- The single site in Wesselman Creek was in non-attainment of WWH with no change from 2014. The unnamed tributary (GM100) was classified as PHW3A in 2014 and verified in 2018.
- Predominant causes of impairment included flow alteration, organic enrichment, chlorides, and PAH compounds.

Recreational Use Status

Impairment of the Primary Contact Recreation (PCR) recreational use in the 2018 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. *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.

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, but these could potentially be reviewed and revised to PCR by Ohio EPA at any time. Any new SCR recommendations would need to document that human contact is precluded by physical restrictions for accessing a surface water. As a result the evaluation of the recreational uses in the 2018 Ohio River Direct Tributaries study area were done in accordance with PCR only.

Rivers and streams in the 2018 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.

Widespread impairment of the Primary Contact (PCR) and Secondary Contact Recreation (SCR) based on *E. coli* results persisted in all of the subwatersheds in 2018. However, direct comparisons of changes in attainment status between 2014 and 2018 are complicated by changes to the recreation uses and criteria in 2016. Recreational use attainment for each of the 34 sites sampled in 2018 appears in Table 4 and in Figure 3. A narrative summary of the major portions of the 2018 study area follows:

Table 3. *E. coli criteria for Ohio streams and rivers (OAC 3745-1-07).*

	***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

- Only two (MU 07.5 and MU09) of the 14 sites that were evaluated fully attained the PCR use (Table 4; Figure 3). The geometric mean was met at two sites where the STV was exceeded (MU02 and MU12) and the STV was met at one site where the geometric mean was exceeded (MU03).
- Extremely high geometric mean and/or STVs 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). Such elevated values indicate the sustained or intermittent presence of raw or partially treated sewage from wet weather sources and a cluster of HSTS discharges.

Rapid Run Subwatershed

- The entirety of the Rapid Run subwatershed including Wulff Run is currently designated as SCR. However, because human contact is not precluded by any physical barriers all seven sites in the Rapid Run subwatershed were assessed with the PCR criteria.
- Two sites in lower Rapid Run (RR01 and RR02) each met the PCR geometric mean and STV

***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 2018. 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) recreation use; values exceeding the geometric mean criterion are highlighted in blue and exceeding the STV in red.*

Site ID	River Mile	Drainage Area (sq. mi.)	Samples	Minimum	Geometric Mean	Maximum STV
Muddy Creek						
MU05	6.25	5.39	5	161	3128.8	41060
MU04.5	5.6	7.71	5	241	1179.9	198630
MU04	5.4	7.8	5	86	413.4	884
MU03	3.1	10.4	5	52	131.0	364
MU02	2.25	12.1	5	10	96.5	663
MU01	0.2	13.6	5	41	292.8	8164
Unnamed Trib to Muddy Creek @RM 0.3						
MU08	1.72	0.74	4	305	637.0	1236
MU07.5	0.8	2.6	4	74	100.2	131
MU07	0.4	2.8	4	109	398.7	880
UT RM 0.95 to UT to Muddy Creek @RM 0.3						
MU09	0.1	1.33	4	10	48.8	189
Unnamed Trib to Muddy Creek @RM 2.37						
MU10	0.5	0.71	4	173	354.2	644
Unnamed Trib to Muddy Creek @RM 5.97						
MU12	0.55	1.01	4	10	122.3	12997
Unnamed Trib to Muddy Creek @RM 6.53						
MU13	0.6	2.25	4	393	1548.8	24196
Unnamed Trib to Unnamed Trib to Muddy Creek @RM 5.97						
MU14	0.2	2.7	4	20	1227.1	43520
Rapid Run						
RR03	2.58	2.32	5	146	488.2	2909
RR02	1.1	5.9	4	10	39.4	279
RR01	0.35	5.99	4	10	78.3	199
Wulff Run						
RR05	0.68	1.33	3	50	496.0	1726
RR04	0.55	2.18	4	52	524.9	8164
Unnamed Trib to Wulff Run @RM 0.77						
RR05.5	1.2	1	3	266	1174.4	4106
RR04.5	1.1	0.34	3	565	902.4	1624
Indian Creek						
IC06	2.25	0.58	3	97	139.9	288
IC05	2.08	1.07	4	98	698.4	6867
IC02	1.15	1.38	4	98	375.4	1860
IC01	0.2	2.3	4	1019	2858.0	5172
Trib to Indian Creek @RM 1.02						
IC07	0.19	0.39	4	241	329.8	529

***Table 4**. Continued.*

Site ID	River Mile	Drainage Area (sq. mi.)	Samples	Minimum	Geometric Mean	Maximum STV
Taylor Creek						
GM86	6.5	0.49	5	211	816.3	17329
GM85	5.3	2.22	5	437	876.4	1515
Unnamed Trib to Taylor Creek @RM 4.9						
GM106	0.28	0.92	4	31	128.5	318
Briarly Creek						
GM91	3.9	0.34	5	1187	2675.7	10462
GM90	2.55	1.3	5	341	1025.0	2282
GM89	1.98	2.1	5	292	639.7	1054
Wesselman Creek						
GM94	4.75	1.1	5	583	1516.7	8160
Unnamed Trib to Wesselman Creek @RM 2.95						
GM100	1.28	0.91	4	538	685.1	959

E.coli values (cfu/100 ml) for samples collected in the Year 3 subwatersheds study area during May-October 2018. Blue shaded cells exceed the Ohio EPA (2016) 90-day geometric mean (126 cfu/100 mL) and red shaded cells exceed the maximun STV (410 cfu/100 mL) Primary Contact Recreation (PCR) use criteria.

criteria for PCR (Table 4). The remaining five sites failed to meet either PCR criterion.

- 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). Again, such elevated values indicate the sustained or intermittent presence of raw sewage from two wet weather sources and a comparatively high density of HSTS discharges.

Indian Creek Subwatershed

- Of the five sites assessed in the Indian Creek subwatershed none fully met the PCR use criteria and only one STV (IC06) met PCR. Extremely elevated geometric mean and/or STVs occurred in Indian Creek at IC05 (6,867 cfu/100 ml STV) and IC01 (2,858 cfu/100 ml and 5,172 cfu/100 ml). Again, such elevated values indicate the sustained or intermittent presence of raw sewage most likely from HSTS discharges in the headwaters.

Upper Taylor Creek Subwatershed

- Of the eight sites assessed in the upper Taylor Creek subwatershed, none fully attained the PCR use criteria with only one site in an unnamed tributary (GM106) meeting the STV. Extremely elevated geometric mean and/or STVs 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). Again, such elevated values indicate the sustained or intermittent presence of raw sewage most likely from HSTS discharges.

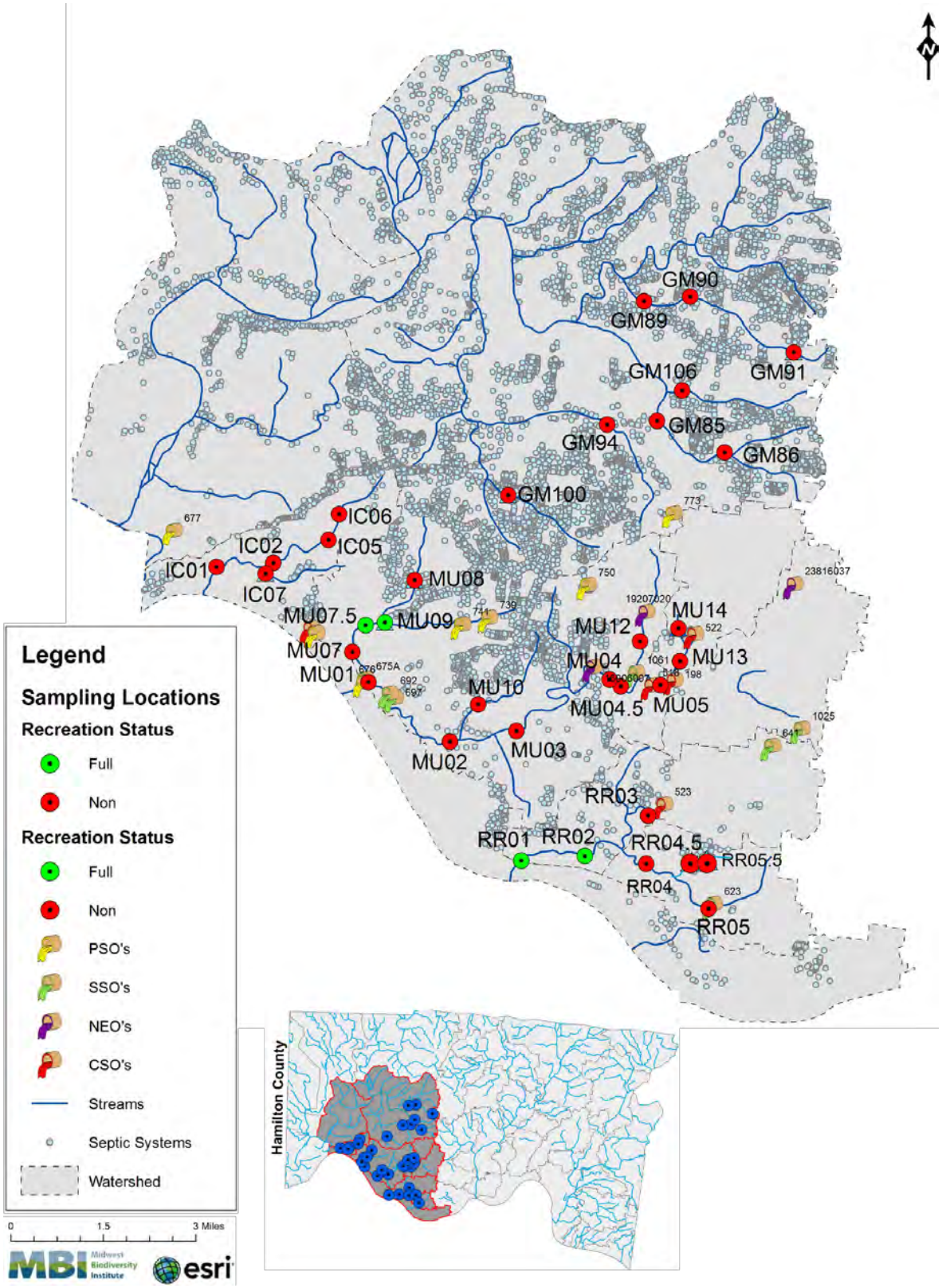

***Figure 3**. Map of recreational use attainment status for the Primary Contact Recreational and Secondary Contact uses in the 2018 Ohio River Direct Tributaries study area expressed as attainment (green) or non-attainment (red) based on E. coli values. Various pollution sources are denoted by symbols 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. It is for these reasons that 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 survey was designed to provide results that could 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 2018 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) and 2018 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 quantification of the "quantity" 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 which is taking place through time.

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 and 2018 MSDGC surveys of the Muddy Creek mainstem. Incremental improvements in both the fish and macroinvertebrate assemblages since 1991 were evident in reduced ADVs and detectable AAVs in 2014 and the incremental reduction in miles of very poor condition through 2018. However, while the ADVs were similar in 2018 the AAVs were reduced to zero reflecting the loss of full WWH attainment between 2014 and 2018 (Figure 4). These results still reflect a recovering system in terms of incremental improvements in biological performance, but with fluctuations in aquatic life use attainment between monitoring cycles.

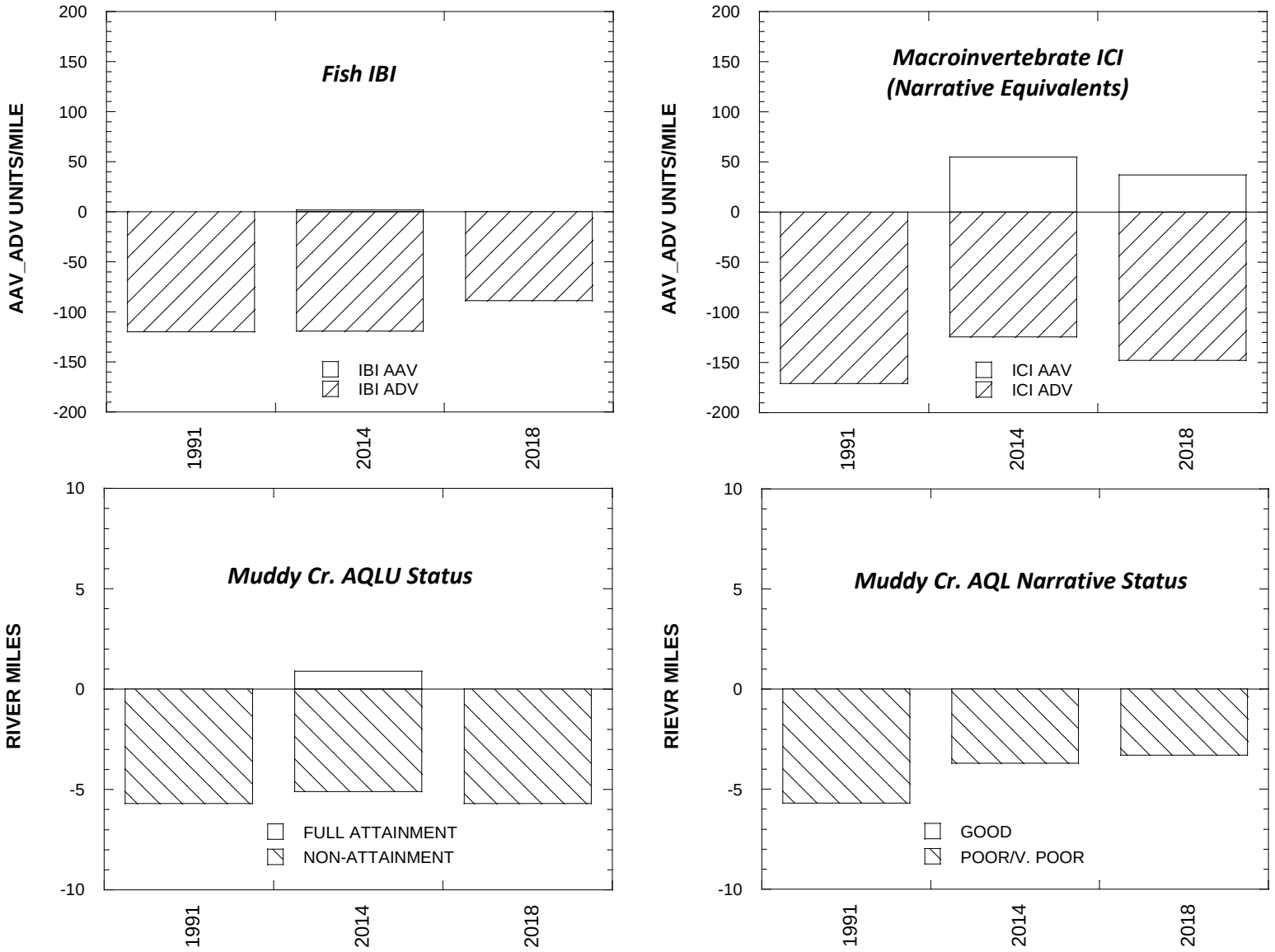

***Figure 4**. Area of Degradation (ADV) and Area of Attainment (AAV) values for the IBI (upper left), ICI (upper right), Aquatic Life Use (AQLU) status (lower left), and Aquatic Life (AQL) narrative status (Lower right) in Muddy Creek between 1991 and 2018.*

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 2015). 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]. As such, that objective has been largely satisfied, but the same recommendations are repeated herein for resampled stream and river sites. The MSDGC instream monitoring has since shifted to a more focused approach to document status, trends, and causes/sources of impairments related to pollution control efforts by Project Groundwork and related pollution source abatement efforts by MSDGC. A continued focus on documenting status and trends will inform decisions on Project Groundwork 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 2018 Ohio River Direct Tributaries and Selected Tributaries assessment represents the first follow-up survey four years after the 2014 baseline survey.

No recommendations are being made for recreational uses given the strict adherence to the single set of Primary Contact Recreational (PCR) use E. coli criteria by Ohio EPA that was initiated in December 2016. While the Secondary Contact Recreation (SCR) use was adopted for Rapid Run in the 1990s by Ohio EPA, that designation could be subject to 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.

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 singular in importance in the Muddy Creek subwatershed. HSTS discharges present in large numbers in portions of the 2018 study area need to be better assessed to quantify their role in observed impairments. At present we were only able to generally assign this as a source of impairment based on GIS coverage provided by MSDGC 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 E. coli, organic enrichment, and nutrient related impairments Other more widespread sources include generalized urban runoff and the established relationship with chloride and PAH exceedances which can be dealt with via various best management practices. Lastly, the legacy impacts of instream sewer line construction are showing instances of incremental abatement, but little can be done at present to actively restore these alterations except to abandon the practice altogether.

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

BIOLOGICAL AND WATER QUALITY STUDY OF THE OHIO RIVER DIRECT TRIBUTARIES 2018

Introduction

The 2018 Ohio River Direct Tributaries and upper Taylor Creek biological and water quality assessment covered four subwatersheds with 13 CSOs and SSOs, one minor discharge, and numerous 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). 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 eleven 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 septic treatment systems are scattered throughout the MSDGC service area, but are especially dense in the 2018 study area especially in portions of Muddy Creek, Rapid Run, Indian Creek, and the upper Tayler Creek subwatersheds.

2018 Ohio River Direct Tributaries Assessment Scope and Purpose

The 2018 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 2018 include a high density of CSO and SSO outfalls and other pollution sources including home sewage treatment systems, 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 2018 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 Project Groundwork, 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 2018 Ohio River Direct Tributaries bioassessment is a continuation of that process.

The 2018 monitoring also fulfills the MSDGC National Pollution Discharge Elimination System (NPDES) CSO permit reporting requirements.

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 2018. 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 6 and Figure 5.

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 2018 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
Unnamed Tributary RM 0.95 to Unnamed Tributary 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 2018 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).

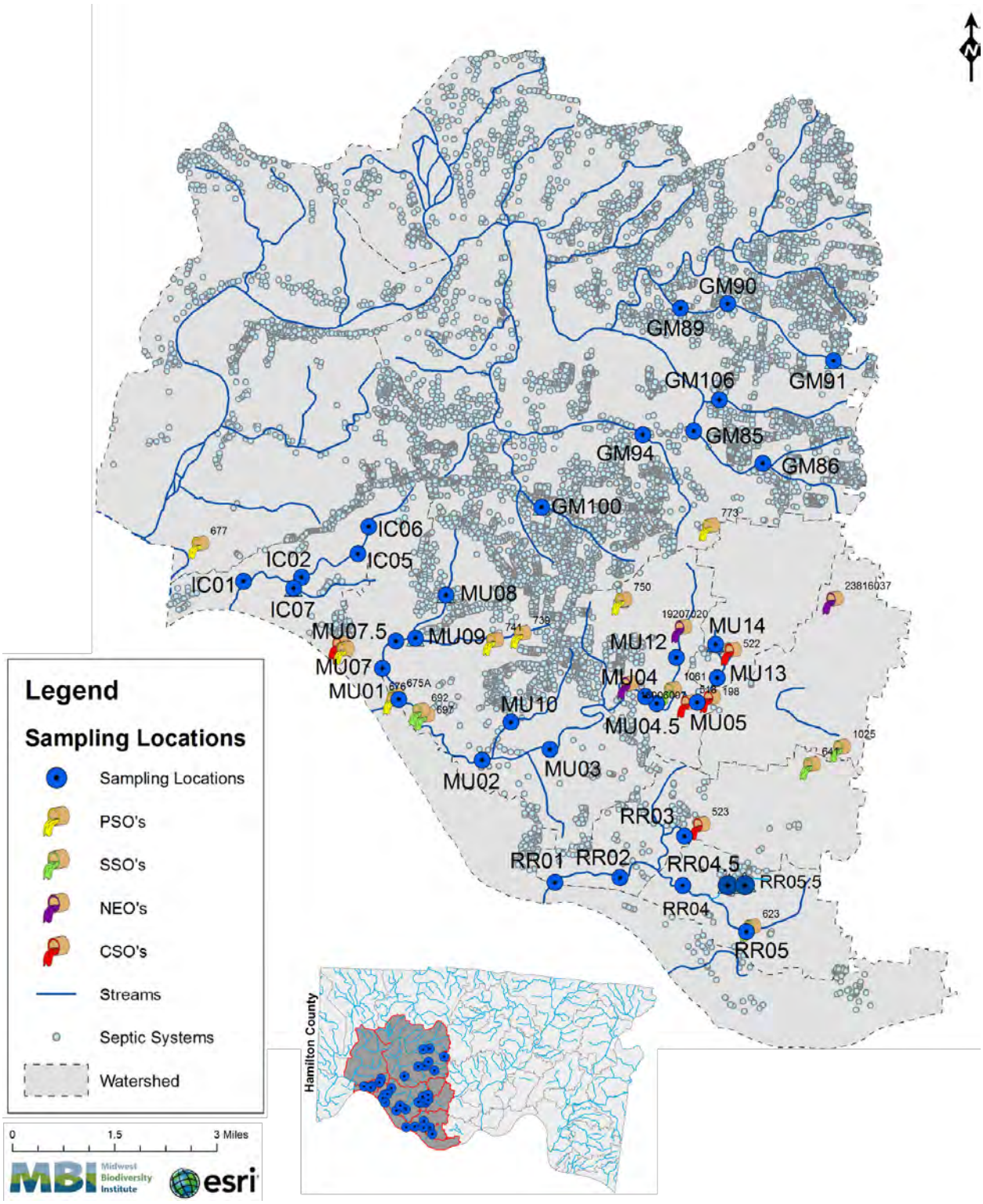

Figure 5*. The 2018 Ohio River Direct Tributaries study area showing sampling locations by site code (see Table 5) and the occurrence of CSO, SSO, NEO, PSO, and HSTS discharge locations in the Ohio River Direct Tributaries study area streams and subwatersheds.*

- ***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 2018 results to the 2014 baseline assessment.

Biological Methods

All biological sampling methods are defined by the applicable protocols published by the Ohio EPA (1987a,b; 1989a,b; 2006, 2015a,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 was performed using a tow-barge or long-line pulsed D.C. electrofishing equipment based on a T&J 1736 DCV electrofishing unit described by Ohio EPA (1989a). A Wisconsin DNR battery powered backpack electrofishing unit was used as an alternative to the long line in the smallest streams and in accordance with the restrictions described by Ohio EPA (1989a). 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. Non-wadeable mainstem sites were sampled with a raft-mounted pulsed D.C. electrofishing device. A Smith-Root 5.0 GPP unit was mounted on a 15.5' Wing raft with an electrode array in keeping with Ohio EPA (1989a) electrofishing design specifications. Sampling effort for this method was 500 meters and was conducted during a June 16-October 15 seasonal index period once or twice at all sites. Variably high flows in September and October precluded a second pass at several mainstem sites. 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 between July 12 and September 14 and placed to ensure adequate stream flow over the substrates, but in general samplers should be set where flow is 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 then transferred to the laboratory, disassembled, sieved (standard no. 30 and 40), and transferred to 70% ethyl alcohol. 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, 2015a). 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 an Invertebrate Community Index (ICI; Ohio EPA 1987b; DeShon 1995) score for the quantitative samples and a narrative assessment for the standalone qualitative samples. 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 designation. Stream sites that were completely dry during any of the sampling visits were evaluated with the 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 2018). Salamander collections were made in two 30 feet subsections of the 200 feet stream 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 a biocriterion it is expressed as an Area of Attainment Value (AAV) that quantifies the extent to which minimum attainment criteria are surpassed is. 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:

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

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 includes 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 (2015b) and MSDGC (2011c). Sediment chemical sampling followed that described by Ohio EPA (2015c). All laboratory analysis was performed and/or 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 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 MBI sampling crews. Samples were collected from the upper 12-24” of the surface and then transferred to sample containers in accordance with MSDGC procedures (MSDGC 2011c) and delivered to 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” levels. The frequency of sampling ranged from five times per season at most sites to two times per season at primary headwater

sites. Water samples were collected provided there was sufficient water depth to collect a sample without disturbing the substrates. Instantaneous values for temperature (°C), conductivity (µS/cm2), 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. 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 18 sites during August 4-11, 12-28, and August 27-September 4, 2018, which represented periods of maximum summer temperatures and normal summer flows, with readings taken at 15 minute intervals. Datasonde data was downloaded to a YSI Model 650 Instrument with high memory capacity and then transferred to a PC for storage and later analysis.

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 2015c).

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 (to maintain 4°C) in a cooler, and delivered to MSDGC Mill Creek Lab. Sediment data is reported on a dry weight basis. Sediment samples were analyzed for total analyte list inorganics (metals), nutrients, 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 2018 Ohio River Direct Tributaries and 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 7-15). 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 Water Quality Standards (OAC 3745-1-07; Table 7-13) based upon the quantities of bacterial indicators *(Escherichia coli)* present in the water column. *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 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. This action also 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 physical restrictions to access a surface water. As a result the evaluation of the recreational uses in the 2018 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 2018 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 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 necessary, were a major product of the series of 2011-14 watershed assessments conducted throughout the MSDGC service area. Since the 2018 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

[2] These criteria shall not be exceeded in more than ten per cent of the samples taken during any ninety-day period.

watershed assessment report3. 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 subsequent revision 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 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 2015a) were also used to support causal assignments. 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

[3] http://www.msdgc.org/initiatives/water_quality/index.html.
[4] OAC 3745-1-07(A)(6)(a) for full attainment and (A)(6)(b) for non-attainment.

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).

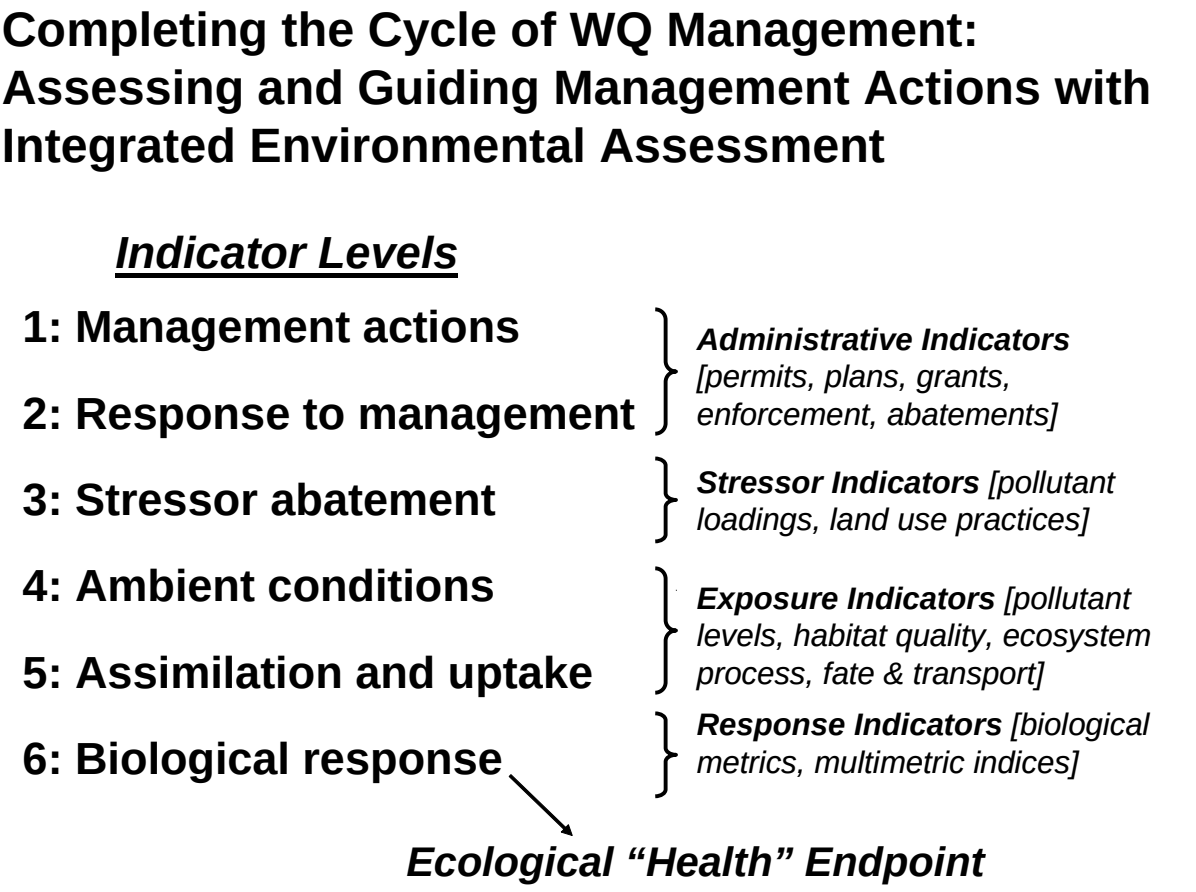

***Figure 6**. Hierarchy of administrative and environmental indicators which can be used for water quality management activities such as monitoring and assessment, reporting, and the evaluation of overall program effectiveness. This is patterned after a model developed by U.S. EPA (1995a,b) and further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

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 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).

STUDY AREA DESCRIPTION

General Setting

The 2018 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, urban runoff, and the physical effects of instream sewer line construction. The tributaries are suburban to urban in nature being the most developed in the upper portions of each watershed. Taylor Creek is not impacted by CSOs and largely avoided the impacts of instream sewer line construction when interceptor sewers for the Taylor Creek Regional WWTP were installed in the mid to late 1990s.

Subecoregion Characteristics

The 2018 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 2018 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 2018 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 2018 study area (Table 7). HSTS discharges (not permitted) are numerous in portions of the 2018 study area (Figure 5). The 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 a higher rate of 51% in 1994 that is credited to increased inspections.

Wet Weather Sources

CSOs and SSOs are the major permitted sources of wet weather discharges in the 2018 study area (Table 7; Figure 4). Most discharge to the Muddy Creek subwatershed and a single CSO and a single SSO occur in the Rapid Run subwatershed. No CSOs or SSOs discharge to Indian

***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

Creek or Taylor Creek. 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. Six PSOs occur in the Muddy Creek subwatershed as well.

Table 7. *Major pollution sources in and adjacent to the 2018 Ohio River Direct Tributaries study area.*

MSDGC CSO#	MSDGC SSO#	MSDGC PSO#	MSDGC NEO#	First Dst. Site Code	Facility Name/ Description	NPDES Permit No.
Muddy Creek						
			19207020	MU12	Cincinnati Galbraith Road MSD Site	1PX00022
518		773		MU0.45	Cincinnati Galbraith Road MSD Site	1PX00022
			16000667	MU03	Cincinnati Galbraith Road MSD Site	1PX00022
	692/697			MU01	Cincinnati Galbraith Road MSD Site	1PX00022
	676	675A		MU01	Cincinnati Galbraith Road MSD Site	1PX00022
Unnamed Tributary to Muddy Creek @RM 6.53						
522				MU13	Cincinnati Galbraith Road MSD Site	1PX00022
198				MU05	Cincinnati Galbraith Road MSD Site	1PX00022
Unnamed Tributary @RM 0.95 to Unnamed Tributary to Muddy Creek @RM 0.30						
		739/741		MU09	Cincinnati Galbraith Road MSD Site	1PX00022
					Cincinnati Galbraith Road MSD Site	1PX00022
Rapid Run						
	623			RR05		
Unnamed Tributary to Wulff Run @RM 0.77						
523				RR03	Cincinnati Galbraith Road MSD Site	1PX00022
Wesselman Creek						
				GM94	Home City Ice	1PX00035

CSO - Combined Sewer Overflow; SSO - Sanitary Sewer Overflow; PSO - Pump Station Overflow; Non-Enumerated Overflow

RESULTS – CHEMICAL PHYSICAL WATER QUALITY

Chemical/physical water quality in the 2018 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 4-11, 12-28, and August 27-September 4, 2018. Sediment chemistry was determined from samples collected at all mainstem and selected tributaries in mid-October. Heavy metal and volatile organic chemical results in water and sediment are reported in Appendix E. Some results were detections that did not exceed any water quality criteria or biological effect thresholds.

The results were evaluated by assessing exceedances of criteria in the Ohio WQS, regionally derived biological effect thresholds (IPS Thresholds; MBI 2015a), 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. This focused on chronic and acute criteria for the protection of aquatic life. Compared to other study areas in the MSDGC monitoring rotation, exceedances of water quality criteria in the Ohio WQS were more frequent. Multiple exceedances of dissolved oxygen (D.O.) and less frequent exceedances of ammonia and copper occurred at 11 of the 34 sites in 2018 (Table 8). The D.O. exceedances occurred in daytime grab samples in the Muddy Creek subwatershed including values well below the 4.0 mg/l WWH minimum at the two upstream most sites MU05 (RM 6.35) and MU04.5 (RM 5.62) and then declining in frequency downstream with no exceedances at MU01 (RM 0.17). Sites with low D.O. values included MU07, MU12, and MU13 located on unnamed tributaries that receive CSO, NEO, SSO, and HSTS discharges. Only one other site outside of the Muddy Creek subwatershed had a D.O. exceedance, an unnamed tributary to Wulff Run (RR05) that receives SSO and HSTS discharges. No other exceedances were measured with the exception of a high copper value at GM89 at the downstream site in Briarly Creek (RM 1.82).

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

***Table 8**. Exceedances of water quality criteria for aquatic life based on grab sampling in the 2018 Ohio River Direct Tributaries study area.*

Site ID	River Mile	Aquatic Life Use	Parameters (Values in mg/L) Exceeding Ohio Aquatic Life Criteria[1]
Muddy Creek			
MU05	6.35	WWH	D.O. (2.60), (0.75), (1.42), (1.94), (0.80), (0.80);T. Amm (5.67),(3.10),(3.77)
MU04.5	5.62	WWH	D.O. (3.60), (3.66), (3.66)
MU04	5.4	WWH	D.O. (2.39), (0.50)
MU03	2.72	WWH	D.O. (3.34)
MU02	2.25	WWH	D.O. (1.53)
MU01	0.17	WWH	
Unnamed Tributary to Muddy Creek @RM 0.30			
MU08	1.8	PHW3A	
MU07.5	0.8	WWH	
MU07	0.6	WWH	D.O. (1.86), (1.99)
Unnamed Tributary @RM 0.95 to Unnamed Tributary to Muddy Creek @RM 0.30			
MU09	0.6	PHW3A	
Unnamed Tributary to Muddy Creek @RM 2.37			
MU10	0.6	WWH	
Unnamed Tributary to Muddy Creek @RM 5.97			
MU12	0.65	WWH	D.O. (0.89), (1.85); Cu (0.032),
Unnamed Tributary to Muddy Creek @RM 6.53			
MU13	0.6	WWH	D.O. (0.65), (1.13), (0.68)
Unnamed Tributary to Unnamed Tributary to Muddy Creek @RM 5.97			
MU14	0.2	PHW2	Cu (0.012)
Rapid Run			
RR03	2.7	PHW3A	
RR02	1.2	WWH	
RR01	0.1	WWH	
Wulff Run			
RR05.5	1.2	PHW3A	
RR04.5	1.1	PHW3A	
RR04	0.55	WWH	
Unnamed Tributary to Wulff Run @RM 0.77			
RR05	0.68	WWH	D.O. (1.92)
Indian Creek			
IC06	2.43	WWH	
IC05	2.08	WWH	
IC02	1.22	WWH	
IC01	0.3	WWH	

***Table 8**. Exceedances of water quality criteria for aquatic life based on grab sampling in the 2018 Ohio River Direct Tributaries study area.*

Site ID	River Mile	Aquatic Life Use	Parameters (Values in mg/L) Exceeding Ohio Aquatic Life Criteria[1]
Unnamed Tributary to Indian Creek @RM 1.02			
IC07	0.13	PHW3A	
Taylor Creek			
GM86	6.3	WWH	
GM85	4.98	WWH	
Unnamed Tributary to Taylor Creek @RM 4.9			
GM106	0.28	WWH	
Briarly Creek			
GM91	3.9	PHW3A	
GM90	2.45	WWH	
GM89	1.82	WWH	Cu (0.268),
Wesselman Creek			
GM94	4.72	PHW3A	
Unnamed Tributary to Wesselman Creek @RM 2.95			
GM100	1.21	PHW3A	

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 2015a) 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 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 2018. Nutrient enrichment effects were assessed using the draft Stream Nutrient Assessment Procedure (SNAP; Ohio EPA 2015e) which is a "combined criteria" consisting of the fish and macroinvertebrate biological criteria, the diel D.O. flux,

[5] OAC 3745-1-07(A)(6)(a) describe the options for a finding of full attainment and (A)(6)(b) for a finding of non-attainment.

benthic chlorophyll α, total nitrate, and phosphorus. 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 4-11, 12-28, and August 27-September 4, 2018.

As just described water quality exceedances based on daytime D.O. values were both severe and frequent in the Muddy Creek subwatershed and in proximity to wet weather releases of sewage from CSOs, SSOs, and NEOs. The continuous results confirmed these observations and added information about diel fluxes that were most pronounced at MU04.5 (Figure 7). Maximum values exceeded the 12 mg/L maximum D.O. screening value for signaling the effects of excessive nutrient enrichment at four of the six sampled locations. Minimum values paralleled the grab sample results with very low values pf near zero improving in a downstream direction to the mouth. Still, minimum values were less than the 4.0 mg/L minimum water quality criterion at all sites. Only two other sites had minimum values below the 4 mg/L minimum, the headwaters of Briarly Creek (GM91) and the upstream most site in Rapid Run (RR03). The site with the highest diel flux and the highest maximum value was IC05 in the headwaters of Indian Creek (Figure 6) and along with two other sites (IC01 and GM 85) were the only maximums that exceeded 12 mg/L outside of Muddy Creek subwatershed.

Values for pH were all within the 6.5-9.0 S.U. range of the water quality criterion, but fluxes in pH can be indicative of nutrient enrichment effects as well. The diel swings in pH were among the highest in the 2018 study area and were the highest at MU03 nearing 9.0 S.U. (Figure 7).

Temperature results revealed only a few exceedances of the maximum of 29.4°C at the Ohio River influenced mouth of Muddy Creek (MU01) and a single value at the mouth of Indian Creek (IC01). No exceedances of the 27.8°C average were recorded and the range of most sites was between 22-25°C (Figure 8).

Conductivity results showed a wide range of variability both within and between sites (Figure 7). 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 increasing chloride values over time in the 2014 assessment (MBI 2015a). The upstream most site in Briarly Creek showed the highest sustained values exceeding 1100 µS/cm over a 3 day period in August. Rapid Run also had frequent exceedances along with the upstream most site in Indian Creek (IC05). In contrast conductivity values in Muddy Creek were mostly 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 threshold.

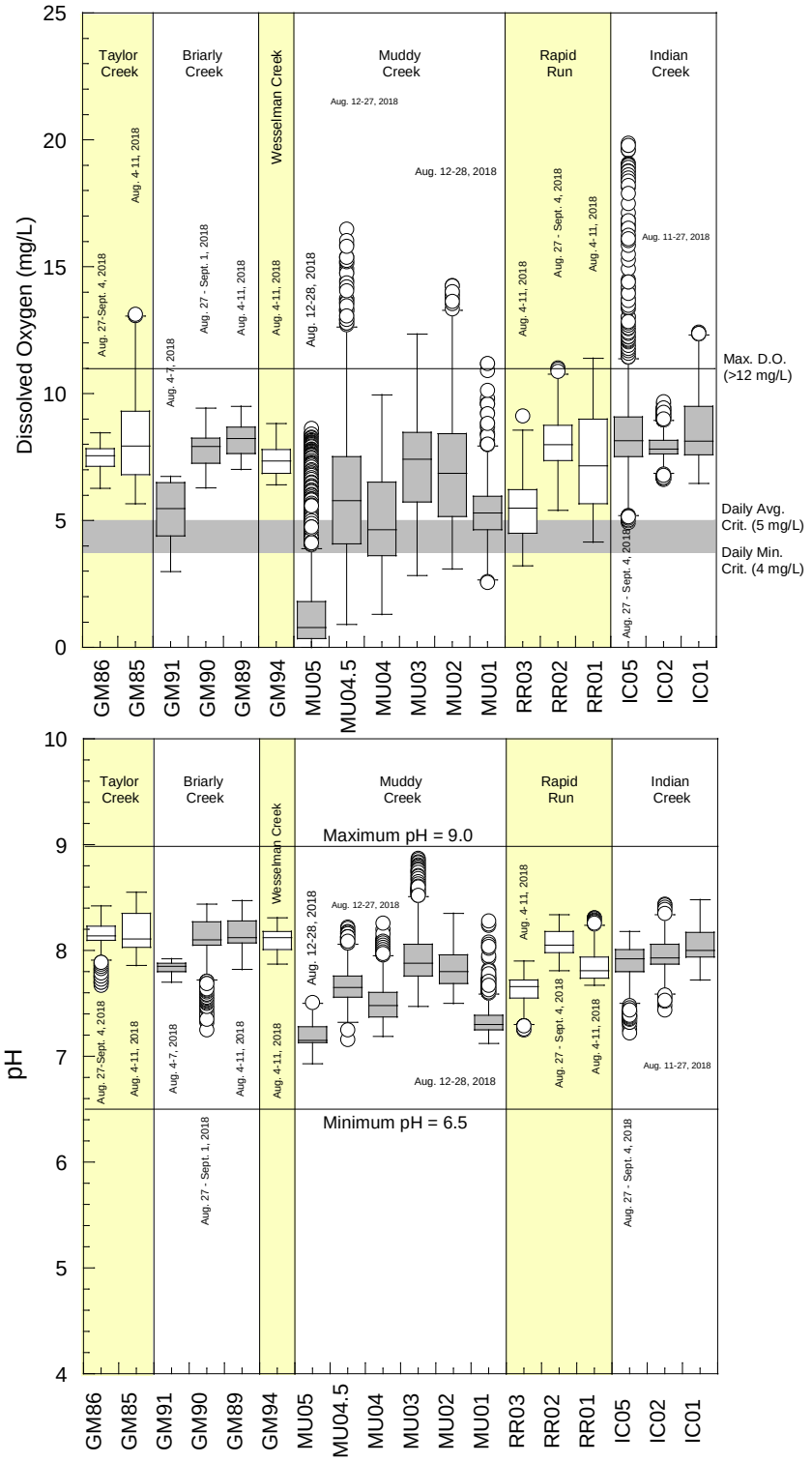

Figure 7. *Box-and-whisker plots of continuous D.O. (mg/L) and pH(S.U.) from Datasonde continuous recorders at 18 sites in the Ohio River Direct Tributaries study area during August 4-September 4, 2018. The WWH daily average and minimum D.O. criteria are indicated by gray shaded bars and the maximum D.O. indicative of excessive diel swings is indicated by a black dashed line (upper panel). The maximum and minimum pH criteria are indicated by solid lines (lower panel).*

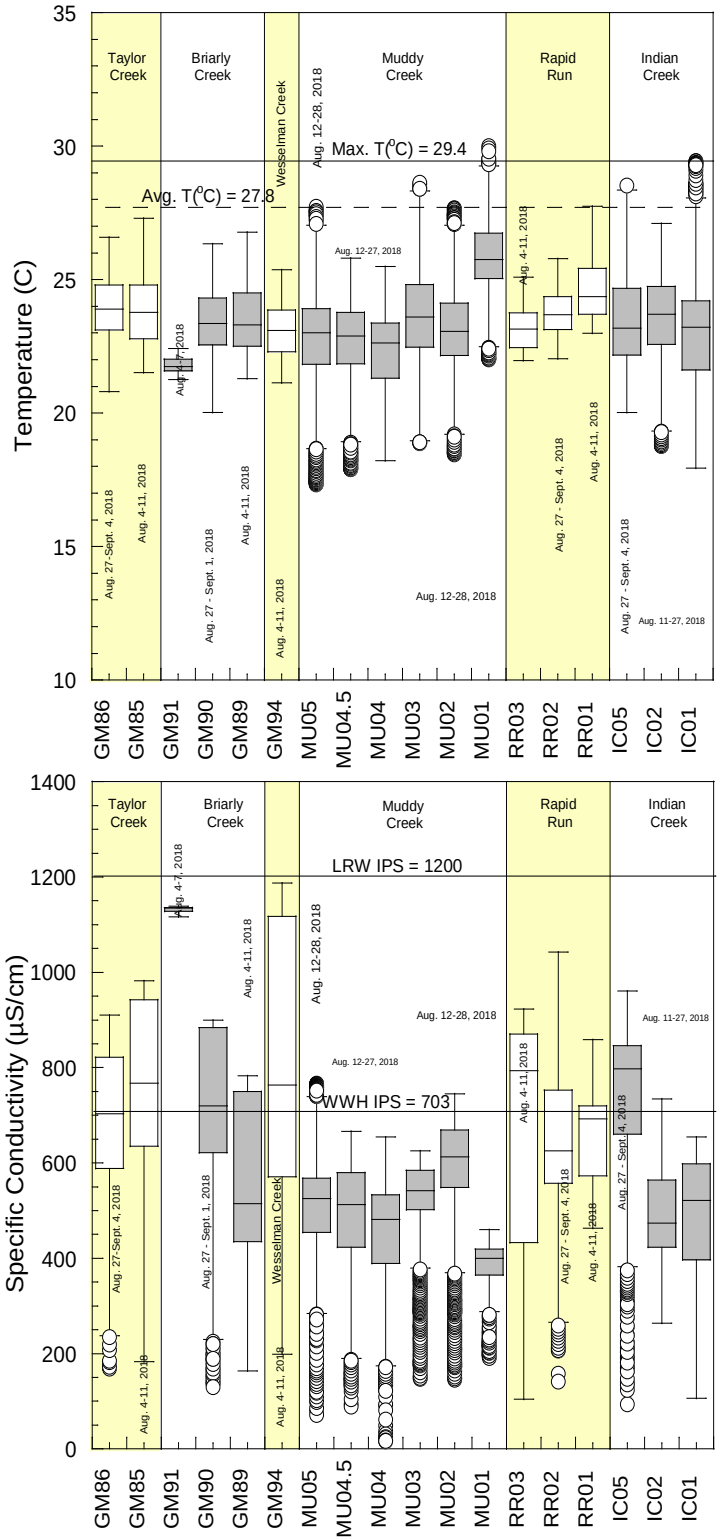

***Figure 8**. Box-and-whisker plots of continuous temperature (°C) and specific conductance (µS/Cm) from Datasonde continuous recorders at 18 sites in the Ohio River Direct Tributaries study area during August 4-September 4, 2018. The WWH daily maximum and average temperature criteria are indicated by solid and dashed lines (upper panel). The WWH IPS specific conductance thresholds are indicated by solid lines (lower panel).*

Nutrient Related Parameters

This category includes ammonia-N, total phosphorus, total nitrate, total Kjeldahl nitrogen, benthic chlorophyll a, and sestonic chlorophyll a, all from grab samples collected under normal summer-fall flows (Table 9). Ammonia-N exceeded the WWH IPS threshold at three sites all in the Muddy Creek subwatershed. The highest value of 3.10 mg/L at the upstream most site (MU05) in Muddy Creek even exceeded the LRW IPS threshold of 1.43 mg/L. The other two sites in unnamed tributaries (MU13 and MU14) had mush lower values only just above the WWH IPS threshold of 0.31 mg/L. Ammonia-N was below detection at 10 of the 34 sites.

Total Kjeldahl Nitrogen (TKN) flowed a similar patter to ammonia-N with the highest value at MU05 that exceeded both the WWH and LRW IPS thresholds (Table 9). Other values elevated above the WWH threshold occurred in the Muddy Creek subwatershed at MU04, MU10, MU12, MU13, and MU14 and indicator of organic enrichment from the multiple CSO, SSO, NEO, and HSTS discharges.

Nitrate-N was elevated above the WWH IPS threshold in Briarly Creek at all 3 sampling locations (Table 9). There were no other such exceedances in the remainder of the 2018 study area. Total phosphorus (P) was elevated above the WWH IPS threshold at 23 of the 34 sampling locations (Table 9). The highest value occurred at MU05 and was more than two times the values observed at most other sites. Total P showed an overall declining pattern with distance downstream in the mainstem of Muddy Creek.

Nutrient Assessment Using SNAP

Benthic chlorophyll a values along with aquatic life use attainment status, the diel D.O. swing, nitrate-N, and total P were assessed using the draft Ohio EPA SNAP procedure (Ohio EPA 2015e) in the 2018 study area. The SNAP was used to assess the overall effects of nutrient enrichment at 18 sites in the Muddy Creek, Rapid Run, Indian Creek, and Taylor Creek subwatersheds. SNAP requires data for fish, macroinvertebrates, total P, nitrate-N, benthic chlorophyll α, and the diel D.O. flux which was provided by the Datasonde results (Figure 7). SNAP utilizes the IBI, MIwb (where applicable), and ICI (or narrative), the aquatic life use attainment status (impaired or attaining), the total P and nitrate-N results, the maximum and minimum D.O., the width of the diel D.O. swing, and benthic chlorophyll α to arrive at trophic status determination for sites that are impaired for the biocriteria (Table 9). The biologically impaired sites are assessed for the likelihood that nutrient enrichment is a primary cause of the observed impairment.

Only four of the 18 impaired sites assessed with SNAP were determined to be likely associated with a nutrient enrichment related cause (Table 9) which included the two upstream most sites in Muddy Creek (MU05 and MU04.5), the upstream most site in Indian Creek (IC05), and the downstream site in upper Taylor Creek (GM85). The most important SNAP factors in making the likelihood of nutrients as a cause of the impairment were the benthic chlorophyll a and the diel D.O. swing. Only two sites (MU05 and GM85) had elevated benthic chlorophyll a values that were in the low-moderate range and a very wide diel D.O. swing. Two of the four sites

Table 9. *Nutrient parameter results in the Ohio River Direct Tributaries study area in 2018. Values >stressor benchmarks are shaded in yellow.*

Site ID	River Mile	Drainage Area (sq. mi.)	Ammonia-N (mg/L)	Nitrate-N (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Total Phosphorus (mg/L)	Chlorophyll a, Benthic (mg/m^3)	Chlorophyll a, Sestonic (µg/L)
Muddy Creek								
MU05	6.25	5.4	3.10	0.01	3.71	0.70	238.0	5.34
MU04.5	5.60	7.7	0.10	0.17	0.49	0.27	150.0	2.14
MU04	5.40	7.8	0.22	0.18	0.71	0.31	123.0	1.00
MU03	3.10	10.4	0.01	0.09	0.22	0.10	98.2	1.00
MU02	2.25	12.1	AA	0.11	0.16	0.11	112.0	1.00
MU01	0.20	13.6	0.18	0.36	0.93	0.19	46.7	20.8
Unnamed Tributary to Muddy Creek @RM 0.3								
MU08	1.72	0.74	AA	0.58	0.40	0.30	-	1.00
MU07.5	0.80	2.6	AA	0.37	0.26	0.23	-	2.94
MU07	0.40	2.8	0.04	0.36	0.32	0.22	-	1.57
Unnamed Tributary @RM 0.95 to Unnamed Tributary to Muddy Creek @RM 0.3								
MU09	0.10	1.3	AA	0.42	0.23	0.23	-	1.87
Unnamed Tributary to Muddy Creek @RM 2.37								
MU10	0.50	0.71	AA	0.41	0.35	0.40	-	1.00
Unnamed Tributary to Muddy Creek @RM 5.97								
MU12	0.55	1.0	0.02	0.19	0.69	0.20	-	2.64
Unnamed Tributary to Muddy Creek @RM 6.53								
MU13	0.60	2.3	0.60	0.12	1.31	0.26	-	1.87
Unnamed Tributary to Unnamed Tributary to Muddy Creek @RM 5.97								
MU14	0.20	2.7	0.48	0.59	1.18	0.26	-	1.84
Rapid Run (23-008)								
RR03	2.58	2.32	0.03	0.20	0.35	0.17	81.4	1.00
RR02	1.10	5.9	AA	0.45	0.27	0.10	133.0	1.30
RR01	0.35	6.0	AA	0.27	0.18	0.09	147.0	1.30
Wulff Run (23-012)								
RR05	0.68	1.3	AA	0.21	0.32	0.13	-	1.00
RR04	0.55	2.2	0.004	0.32	0.17	0.18	-	1.30
Unnamed Tributary to Wulff Run @RM 0.77								
RR05.5	1.20	1	AA	1.76	0.45	0.30	-	1.00
RR04.5	1.10	0.34	AA	2.24	0.44	0.40	-	1.00
IPS threshold (headwater sites) - WWH			0.31	0.96	0.51	0.17		
IPS threshold (headwater sites) - LRW			1.43	1.51	2.15	2.60		
AA - below method detection limit (MDL)								

***Table 10**. Results for parameters and indicators used in the Stream Nutrient Assessment Procedure (SNAP) to determine the role of the effect of nutrients on aquatic life use attainment in the 2018 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	AQLU Status	Total Phosphorus (mg/L)	Nitrate-N (mg/L)	Max. D.O.	Min. D.O.	Max. Diel D.O. Swing	D.O. Swing Narrative	Chlorophyll a, Benthic (mg/m^3)	Benthic Chlorophyll Narrative	Trophic Status
Muddy Creek															
MU05	6.25	WWH	5.39	12*	VP*	Non	0.70	0.01	8.6	0.0	8.6	Wide	238.0	Low-Moderate	Likely Nutrients
MU04.5	5.6	WWH	7.71	12*	VP*	Non	0.27	0.17	16.5	0.9	13.6	Wide	150.0	Low	Likely Nutrients
MU04	5.4	WWH	7.8	24*	VP*	Non	0.31	0.18	10.0	1.3	6.3	Normal-Low	123.0	Low	Not Nutrients
MU03	3.1	WWH	10.4	30*	12*	Non	0.10	0.09	12.3	2.8	7.3	Wide	98.2	Low	Not Nutrients
MU02	2.25	WWH	12.1	30*	40	Partial	0.11	0.11	14.3	3.1	9.8	Wide	112.0	Low	Not Nutrients
MU01	0.2	WWH	13.6	26*	na	Non	0.19	0.36	11.2	2.6	7.5	Wide	46.7	Low	Not Nutrients
Rapid Run															
RR03	2.58	PHW3A	2.32	12*	VP*	Non	0.17	0.20	9.1	3.2	5.4	Normal-Low	81.4	Low	Not Nutrients
RR02	1.1	LRW	5.9	30	F	Full	0.10	0.45	11.0	5.4	5.6*	Normal-Low	133.0	Low	Not Nutrients
RR01	0.35	LRW	5.99	12*	MG	Partial	0.09	0.27	11.4	4.2	6.2	Normal-Low	147.0	Low	Not Nutrients
Indian Creek															
IC05	2.08	WWH	1.07	38^{ns}	F*	Partial	0.14	0.21	19.9	4.9	15.0*	Wide	66.4	Low	Likely Nutrients
IC02	1.15	WWH	1.38	22*	G	Non	0.16	0.32	9.7	6.6	2.5	Normal-Low	57.5	Low	Not Nutrients
IC01	0.2	WWH	2.3	26*	G	Non	0.11	0.21	12.4	6.5	5.9	Normal-Low	40.7	Low	Not Nutrients
Taylor Creek															
GM86	6.5	WWH	0.49	32*	MG^{ns}	Partial	0.26	0.55	8.5	6.3	1.8	Normal-Low	125.0	Low	Not Nutrients
GM85	5.3	WWH	2.22	34*	F*	Non	0.30	0.53	13.1	5.7	7.3*	Wide	240.0	Low-Moderate	Likely Nutrients
Briarly Creek															
GM91	3.9	PHW3A	0.34	24	SW	PHW3A	0.20	1.01	6.7	3.0	3.5	Normal-Low	93.6	Low	Not Nutrients
GM90	2.55	WWH	1.3	26*	MG^{ns}	Non	0.36	1.13	9.4	6.3	2.6*	Normal-Low	67.8	Low	Not Nutrients
GM89	1.98	WWH	2.1	30*	MG^{ns}	Partial	0.32	1.03	9.5	7.0	2.3	Normal-Low	150.0	Low	Not Nutrients
Wesselman Creek															
GM94	4.75	WWH	1.1	22*	F*	Non	0.37	0.84	8.8	6.4	2.4	Normal-Low	21.9	Low	Not Nutrients

ICI Narratives: G - good; MG - marginally good; F - fair; P - poor; VP - very poor; SW - Spring Water.

(MU04.5) and IC05) were included on the basis of a wide diel D.O. swing and a very high maximum D.O. alone. Three sites in Muddy Creek (MU01, MU02, MU03) had wide diel swings, but lacked the other indicators of excessive nutrient enrichment. Total P was elevated above the WWH IPS threshold at 10 of the 18 sites, but lacked other signals of nutrient enrichment. Nitrate-N was elevated above the WWH IPS threshold at the three Briarly Creek sites, but well below at all other sites. Only the Muddy Creek and Rapid Run sites are impacted by CSOs/SSOs, but all are impacted by HSTS discharges which are especially dense in Rapid Run, upper Taylor Creek, and upper Indian Creek.

Urban Parameters

Urban parameters include ionic strength measures such as conductivity, total chlorides, and total sulfates, suspended sediment, and selected heavy metals such as 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).

IPS thresholds for conductivity and chlorides were the most frequently exceeded in the study area in 2018 (Table 11). The WWH IPS threshold for conductivity was exceeded at 22 of the 34 sites which parallels the Datasonde results discussed earlier. The Muddy Creek mainstem had no exceedances which is unusual given the number of sewage discharges and the urban character of that subwatershed. The unnamed tributaries all had values exceeding the WWH IPS threshold, however. Some the highest values tracked well with sources of sewage including high densities of HSTS discharges in upper Taylor Creek and upper Indian Creek.

Chlorides exceeded the WWH IPS threshold at 30 of the 34 sites in the 2018 study area with exceedances of the LRW threshold at six sites (Table 11). The highest chloride values all occurred in the upper Taylor Creek subwatershed. The increasing trend of elevated chlorides in this subwatershed was highlighted in the 2014 assessment (MBI 2015a).

Only two exceedances of the respective IPS thresholds for any of the metals parameters included in Table 11 were observed. Copper was just at the WWH IPS threshold in the unnamed tributary to Muddy Creek at RM 5.97 (MU12) and zinc only slightly exceeded the same in the unnamed tributary to Muddy Creek at RM 2.37 (MU10).

Sediment Chemistry

Sediment samples were collected from 21 sites in the 2018 study area in October 2018 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

***Table 11**. Urban parameter results in the Ohio River Direct Tributaries study area in 2018. Values exceeding the applicable IPS thresholds (MBI 2015b) are highlighted in yellow.*

Site ID	River Mile	Drainage Area (sq. mi.)	Specific Conductance (µS/cm)	SSC (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Copper (mg/L)	Copper by ICP-MS (µg/L)	Zinc (mg/L)
Muddy Creek									
MU05	6.25	5.39	645	8.2	59	18	AA	0.65	0.0133
MU04.5	5.6	7.71	604	2.5	54	18	0.0052	1.39	0.0328
MU04	5.4	7.8	577	1.3	50	16	0.0041	1.40	0.0036
MU03	3.1	10.4	670	1.6	59	59	0.0049	1.95	0.0048
MU02	2.25	12.1	718	1.2	64	49	0.0045	1.95	0.0099
MU01	0.2	13.6	406	41	26	46	0.0045	3.07	0.0145
Unnamed Tributary to Muddy Creek @RM 0.30									
MU08	1.72	0.74	801	3.4	59	97	0.0063	1.75	0.0101
MU07.5	0.8	2.6	796	2.9	68	78	0.0047	1.75	0.0074
MU07	0.4	2.8	785	2.3	66	74	0.0041	1.70	0.0115
Unnamed Tributary @RM 0.95 to Unnamed Tributary to Muddy Creek @RM 0.30									
MU09	0.1	1.33	834	3.7	79	87	0.0052	1.75	0.0108
Unnamed Tributary to Muddy Creek @RM 2.37									
MU10	0.5	0.71	744	35	64	59	0.0071	4.65	0.0194
Unnamed Tributary to Muddy Creek @RM 5.97									
MU12	0.55	1.01	359	4.1	36	15	0.0089	7.25	0.0099
Unnamed Tributary to Muddy Creek @RM 6.53									
MU13	0.6	2.25	587	4.0	48	28	0.0069	1.15	0.0073
Unnamed Tributary to Unnamed Tributary to Muddy Creek @RM 5.97									
MU14	0.2	2.7	781	12	114	20	0.0047	2.30	0.0099
Rapid Run (23-008)									
RR03	2.58	2.32	653	3.4	40	32	0.0060	1.25	0.0094
RR02	1.1	5.9	1021	2.8	130	65	0.0061	2.90	0.0041
RR01	0.35	5.99	770	4.1	76	74	0.0051	2.30	0.0083
Wulff Run									
RR05	0.68	1.33	645	1.6	76	36	0.0063	1.85	0.0075
RR04	0.55	2.18	1085	2.4	175	55	0.0079	2.70	0.0083
Unnamed Tributary to Wulff Run @RM 0.77									
RR05.5	1.2	1	865	5.9	71	52	0.0049	2.20	0.0087
RR04.5	1.1	0.34	812	6.0	73	54	0.0058	2.80	0.0082
Indian Creek (23-019)									
IC06	2.25	0.58	913	2.5	77	69	0.0055	1.10	0.0053
IC05	2.08	1.07	868	1.6	74	66	0.0067	1.07	0.0113
IC02	1.15	1.38	665	6.8	82	48	0.0046	1.20	0.0050
IC01	0.2	2.3	766	6.1	58	97	0.0049	1.40	0.0083
Unnamed Tributary to Indian Creek @RM 1.02									
IC07	0.19	0.39	839	7.8	80	51	0.0062	1.20	0.0094
IPS threshold (headwater sites) - WWH			703	65	53	119	0.0089	8.9	0.0164
IPS threshold (headwater sites) - LRW			1240	203	106		0.0141	14.1	0.7944

***Table 11**. (continued)*

Site ID	River Mile	Drainage Area (sq. mi.)	Specific Conductance (µS/cm)	SSC (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Copper (mg/L)	Copper by ICP-MS (µg/L)	Zinc (mg/L)
Taylor Creek									
GM86	6.5	0.49	842	1.75	96	73	0.0040	2.08	0.0124
GM85	5.3	2.22	894	15.85	100	76	0.0064	2.85	0.0145
Unnamed Tributary to Taylor Creek @RM 4.9									
GM106	0.28	0.92	898	2.6	120	78.5	0.0069	1.34	0.0078
Briarly Creek									
GM91	3.9	0.34	1012	2.9	130	65	0.0050	2.55	0.0157
GM90	2.55	1.3	790	3.2	76	56	0.0050	2.30	0.0115
GM89	1.98	2.1	759	3.4	65	52	0.0040	2.24	0.0326
Wesselman Creek									
GM94	4.75	1.1	939	12	120	69	0.0047	2.32	0.0079
Unnamed Trib to Wesselman Creek @RM 2.95									
GM100	1.28	0.91	829	8.05	84	64.5	0.0053	2.25	0.0069
IPS threshold (headwater sites) - WWH			703	65	53		0.0089	8.9	0.0164
IPS threshold (headwater sites) - LRW			1240	203	106		0.0141	14.1	0.7944

effects for most species and taxa. IPS thresholds have not yet been developed for sediment chemicals.

Metals in Sediment

Multiple exceedances of cadmium were the only metal recorded with values exceeding only the TEC at 15 sites (Table 12). Cadmium values also exceeded the Ohio Sediment Reference Values (SRV). No other measured metals values exceeded their respective TEC or SRV thresholds.

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 also 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-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.

TEC levels were frequently exceeded for all 15 PAH compounds throughout the 2018 study area (Table 13). Twelve (12) of the 15 PAH compounds detected occurred in the Muddy Creek subwatershed with 19 exceedances of the PEC threshold among eight (8) compounds. A similar level and magnitude of TEC and PEC exceedances occurred in the Rapid Run subwatershed. However, no exceedances or detections of PAH compounds were observed at the downstream most site in Rapid Run (RR01). The site in the unnamed tributary to Indian Creek (IC07) had exceedances of all 15 PAH compounds of which 13 were exceedances of the PEC.

***Table 12**. Sediment metals concentrations (mg/kg) for parameters with values >detection in the Ohio River Direct Tributaries study area in October 2018. 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 color-code key at bottom.*

Site ID	River Mile	Drainage Area (sq. mi.)	Arsenic (mg/kg)	Cadmium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Magnesium (mg/kg)	Zinc (mg/kg)
Muddy Creek								
MU05	6.25	5.39	2	AA	14	12	10000	54
MU04.5	5.60	7.71	16	3.5	15	24	3400	48
MU04	5.40	7.8	3.2	1.8	13	13	3300	50
MU03	3.10	10.4	2.2	1.1	8.8	6.7	2700	29
MU02	2.25	12.1	3.4	1.7	21	20	3800	52
MU01	0.20	13.6	8.1	1.6	15	15	4500	44
Rapid Run								
RR03	2.58	2.32	AW	AA	9.8	6.7	2500	29
RR02	1.1	5.9	AW	AA	12	5.7	2500	29
RR01	0.35	5.99	AW	AA	4.9	2.7	1400	15
Wulff Run								
RR04	0.55	2.18	1.8	0.62	8	8.7	1300	26
Indian Creek								
IC06	2.25	0.58	2.9	1.2	8.4	7.6	1800	24
IC05	2.08	1.07	3.8	1.4	8.9	9.5	1900	29
IC02	1.15	1.38	3.4	1.6	10	7.9	2800	3200
IC01	0.2	2.3	4.7	1.8	14	9.8	2700	33
Unnamed Tributary to Indian Creek @RM 1.02								
IC07	0.19	0.39	2.6	1.5	11	7.8	2600	32
Taylor Creek								
GM86	6.5	0.49	5.7	1.6	15	26	3700	53
GM85	5.3	2.22	3.8	1.8	17	12	4700	46
Briarly Creek								
GM91	3.9	0.34	5	1.7	13	23	3300	66
GM90	2.55	1.3	5.5	1.7	14	20	2900	41
GM89	1.98	2.1	8.2	2.1	13	23	3200	41
Wesselman Creek								
GM94	4.75	1.1	6.6	2	14	21	3300	48
MacDonald et al.(2000) TEC			9.75	0.99	31.6	35.8		121
MacDonald et al.(2000) PEC			33	4.98	149	128		459
Ohio EPA Sediment Refrence Values			25	0.79	32	47		160

***Table 13**. Sediment PAH concentrations (µg/kg) for parameters with values >detection in the Ohio River Direct Tributaries study area in October 2018. Values above the MacDonald et al. (2000) TEC and PEC thresholds are shaded in accordance with the color-code 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)	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																	
MU05	6.25	5.39	0.100	0.036	0.410	1.500	1.500	2.500	1.100	0.890	0.250	3.800	0.130	1.100	0.012	2.100	2.900
MU04.5	5.6	7.71	AA	0.015	0.120	0.510	0.480	0.700	0.350	0.300	0.077	1.400	0.041	0.350	AA	0.650	1.100
MU04	5.4	7.8	0.013	0.007	0.037	0.260	0.310	0.560	AA	0.170	0.061	0.730	0.013	0.270	AA	0.300	0.580
MU03	3.1	10.4	AA	AA	0.005	0.023	0.021	0.018	0.017	0.024	AA	0.034	AA	0.017	AA	0.017	0.028
MU02	2.25	12.1	0.082	0.021	0.180	0.530	0.540	0.810	0.370	0.290	0.087	1.500	0.088	0.390	0.016	1.000	1.100
MU01	0.2	13.6	0.033	0.011	0.140	0.550	0.540	0.830	0.320	0.280	0.082	1.400	0.043	0.340	0.009	0.710	1.100
Rapid Run																	
RR03	2.58	2.32	0.093	0.041	0.300	1.100	1.100	1.500	0.820	0.420	0.190	2.500	0.100	0.075	AA	1.700	2.100
RR02	1.1	5.9	0.038	AA	0.110	0.460	0.450	0.660	0.340	0.240	0.079	1.000	0.039	0.330	AA	0.560	0.770
RR01	0.35	5.99	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA
Wulff Run																	
RR04	0.55	2.18	0.016	0.082	0.068	0.310	0.350	0.570	0.260	0.170	0.052	0.800	0.017	0.260	AA	0.320	0.630
Indian Creek																	
IC06	2.25	0.58	0.004	0.005	0.033	AA	AA	AA	AA	AA	0.026	0.440	0.009	0.120	AA	0.160	0.340
IC05	2.08	1.07	AA	AA	0.005	0.041	0.043	0.075	0.034	0.027	0.003	0.110	AA	0.037	AA	0.045	0.083
IC02	1.15	1.38	AA	0.003	AA	0.023	0.025	0.025	0.020	0.013	0.007	0.048	AA	0.021	AA	0.021	0.039
IC01	0.2	2.3	AA	0.007	AA	0.047	0.050	0.086	0.041	0.018	0.011	0.100	0.005	0.034	AA	0.044	0.081
Unnamed Tributary to Indian Creek @RM 1.02																	
IC07	0.19	0.39	1.500	0.310	4.800	6.300	5.600	7.300	3.000	2.700	1.100	16.000	2.700	3.100	0.200	18.000	12.000
Taylor Creek																	
GM86	6.5	0.49	0.010	0.012	0.044	0.160	0.170	0.260	0.120	0.071	0.028	0.370	0.015	0.120	0.005	0.190	0.300
GM85	5.3	2.22	0.004	0.004	0.013	0.082	0.100	0.160	0.083	0.063	0.021	0.230	0.005	0.087	AA	0.090	0.190
Briarly Creek																	
GM91	3.9	0.34	0.025	0.013	0.110	0.900	1.000	1.700	0.710	0.570	0.160	2.200	0.029	0.710	0.005	AA	1.800
GM90	2.55	1.3	0.006	0.005	0.043	0.200	0.210	0.330	0.140	0.110	0.038	0.440	0.011	0.140	AA	AA	0.360
GM89	1.98	2.1	AA	0.006	0.021	0.097	0.110	0.170	0.077	0.061	0.007	0.230	AA	0.080	AA	0.077	0.190
Wesselman Creek																	
GM94	4.75	1.1	0.016	0.019	0.057	0.320	0.370	0.590	0.280	0.190	0.067	0.810	0.019	0.270	0.007	0.330	0.660
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
AA - below method detection limit																	

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.

QHEI scores ranged mostly from poor to good throughout the 2018 study area, although most 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 very high (>4.00) at MU05 and MU04.5, reflecting prior alterations due to instream sewer line construction, and in the unnamed tributary at RM 0.30 (MU09). All other sites had fair to good habitat and five sites had modified:good attribute ratios of >2.00. 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 form 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 (Table 14) 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 alternation layers of softer blue-grey shales that are more erodible. Destruction of the limestone bedrock layers by trenching for installation of sewer lines destabilized the substrate and created “debris torrents”

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

Year	IBI	Species	ICI	Qual. EPT Taxa	QHEI	Habitat Attributes		Modified: 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

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

***Figure 9**. Qualitative Habitat Evaluation Index (QHEI) scores showing good and modified habitat attributes at sites in the Ohio River Direct Tributaries study area in 2018. Modified:good ratios are color coded as follows: <2.00 (yellow); >2.00,<4.00 (orange); >5.99 (red).*

			Good Habitat Attributes											High Influence Modified Attributes						Moderate Influence Modified Attributes													Ratios	
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	No Riffle	Poor Habitat Attributes	Ratio of Poor (High) to Good	Ratio of Poor (All) to Good
Muddy Creek																																		
MU05	6.35	**48.0**		■				■					2					●	1	●	●			●	●	●	●	●	●		●	9	0.50	5.00
MU04.5	5.62	**48.5**		■				■					2				●	●	2	●	●			●	●			●	●		●	7	1.00	4.50
MU04	5.45	**55.5**		■				■		■	■		4	●					1					●	●	●		●			●	5	0.25	1.50
MU03	2.80	**60.0**		■			■	■		■	■		5						0	●				●				●			●	4	0,00	0.80
MU02	2.25	**52.0**		■				■		■			3					●	1	●				●	●			●			●	5	0.33	2.00
MU01	0.17	**56.0**		■			■	■			■		4						0	●	●			●	●			●	●		●	7	0.00	1.75
Unnamed Tributary to Muddy Creek @RM 2.37																																		
MU10	0.50	**56.0**		■			■	■					3					●	1	●	●			●				●	●		●	6	0.33	2.33
Unnamed Tributary to Muddy Creek @RM 5.97																																		
MU12	0.55	**50.0**		■			■	■			■		4						0	●	●			●				●	●		●	6	0.00	1.50
Unnamed Tributary to Muddy Creek @RM 0.30																																		
MU08	1.72	**53.5**		■				■			■		3				●		1	●	●			●	●			●	●		●	7	0.33	2.67
MU07.5	0.80	**52.5**		■				■		■			3					●	1	●				●	●			●			●	5	0.33	2.00
MU04	0.40	**58.0**		■				■		■	■		4						0	●				●	●			●			●	5	0.00	1.25
Unnamed Tributary @0.95 to Unnamed Tributary to Muddy Creek @RM 0.30																																		
MU09	0.10	**50.0**		■				■					2					●	1	●	●			●	●	●		●	●		●	8	0.50	4.50

***Figure 9**. Qualitative Habitat Evaluation Index (QHEI) scores showing good and modified habitat attributes at sites in the Ohio River Direct Tributaries study area in 2018. Modified:good ratios are color coded as follows: <2.00 (yellow); >2.00,<4.00 (orange); >5.99 (red).*

			Good Habitat Attributes											High Influence Modified Attributes						Moderate Influence Modified Attributes														Ratios	
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	No Riffle	Poor Habitat Attributes	Ratio of Poor (High) to Good	Ratio of Poor (All) to Good
Rapid Run																																			
RR02	1.05	**45.5**		■	■					■			3				●	●	2	●				●	●	●		●			●	6	0.67	2.67
Wulff Run																																			
RR04	0.45	**48.8**		■				■					2					●	1	●	●			●	●	●		●	●		●	7	0.50	4.00
Unnamed Tributary to Wulff Run @RM 0.77																																			
RR05.5	1.20	**57.0**	■	■			■	■					4					●	1		●			●				●	●		●	5	0.25	1.50
RR04.5	1.10	**51.0**		■			■	■					3					●	1	●	●			●				●	●		●	6	0.33	2.33
Indian Creek																																			
IC06	2.30	**55.0**		■		■	■	■			■		5						0	●	●			●				●	●		●	6	0.00	1.20
IC05	2.08	**54.5**		■			■	■		■			4	●			●	●	3					●				●			●	3	0.75	1.50
IC02	1.15	**51.5**		■		■	■	■					4					●	1	●	●			●				●	●		●	6	0.25	1.75
IC01	0.30	**43.5**		■				■			■		3				●		1	●	●			●	●			●	●		●	7	0.33	2.67
Unnamed Tributary to Indian Creek @RM 1.02																																			
IC07	0.10	**57.0**		■			■	■		■			4					●	1	●				●				●			●	4	0.25	1.25
Taylor Creek																																			
GM86	6.40	**46.5**		■						■			2				●	●	2	●				●	●			●		●		5	1.00	3.50
GM85	5.30	**46.0**		■				■					2					●	1	●	●			●	●	●		●	●		●	8	0.50	4.50

***Figure 9**. Qualitative Habitat Evaluation Index (QHEI) scores showing good and modified habitat attributes at sites in the Ohio River Direct Tributaries study area in 2018. Modified:good ratios are color coded as follows: <2.00 (yellow); >2.00,<4.00 (orange); >5.99 (red).*

			Good Habitat Attributes											High Influence Modified Attributes						Moderate Influence Modified Attributes													Ratios	
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	No Riffle	Poor Habitat Attributes	Ratio of Poor (High) to Good	Ratio of Poor (All) to Good
Briarly Creek																																		
GM91	3.90	**56.5**	■	■			■	■			■		5						0		●			●				●	●		●	5	0.00	1.00
GM90	2.45	**54.8**		■		■		■		■			4					●	1	●				●	●			●		●		5	0.25	1.50
GM89	1.80	**57.5**		■				■		■		■	4				●	●	2	●				●	●			●		●		5	0.50	1.75
Wesselman Creek																																		
GM94	4.70	**53.0**		■				■					2				●	●	2	●	●			●	●			●	●		●	7	1.00	4.50
Unnamed Tributary to Wesselman Creek @RM 2.59																																		
GM100	1.05	**48.5**		■				■		■	■		4						0	●				●	●	●		●		●		6	0.00	1.50
GM106	0.20	**58.0**		■				■			■	■	4						0	●	●			●	●	●		●	●			7	0.00	1.75

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). The biological scores were similar 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. 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 2022. Stream habitat in the upper Taylor Creek and Indian Creek subwatersheds ranged from fair to good which was largely unchanged from 2014.

Biological Assemblages

Fish and macroinvertebrates were sampled at all 34 sites in 2018 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, thus 26 sites were evaluated against the fish and macroinvertebrate biological criteria for the WWH suite of uses.

Fish Assemblage Results

There were 35 species and one hybrid collected in the Muddy Creek subwatershed in 2018. The predominant fish species were Central Stoneroller, Blacknose Dace, Creek Chub, and Bluntnose Minnow. Rapid Run was the least diverse subwatershed with only seven 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 2018 subwatersheds are portrayed as box-and-whisker plots for all sites in 2014 and 2018 (Figure 10). The results between 2014 and 2018 were similar with some improvement at some sites between 2014 and 2018. Only 3 sites met the WWH biocriterion and 18 sites did not (not including the eight PHWH classified sites). Five sites were not sampleable for fish due to a lack of sufficient water or being completely dry. Muddy Creek had a single site in full attainment of WWH in 2014 (MU02), but the IBI declined in 2018 such the site was rated in partial attainment of WWH (Figure 11). Despite this setback, IBI values incrementally improved at other Muddy Creek sites including MU03 and MU04.

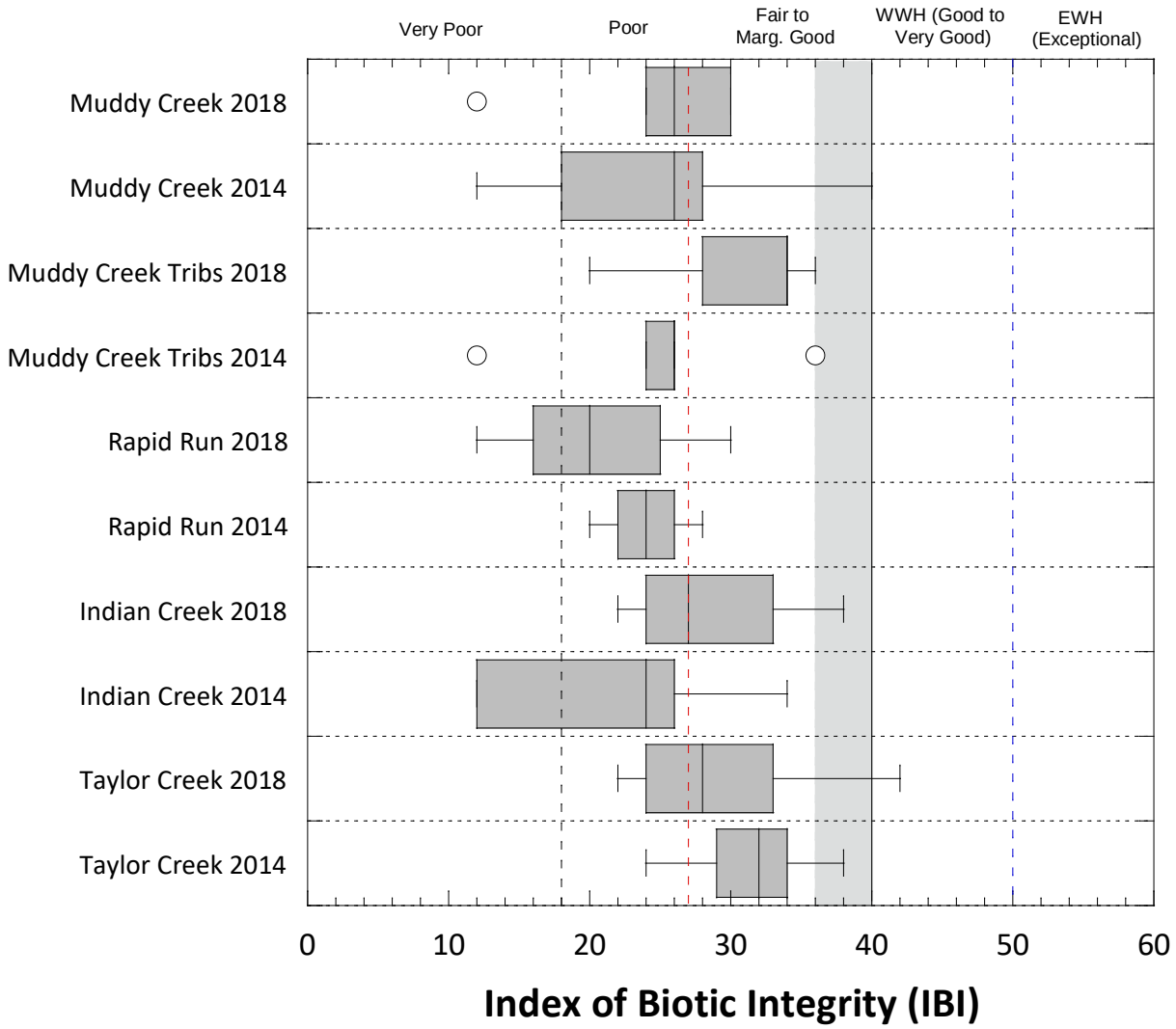

***Figure 10**. IBI scores for Direct Ohio River Tributaries subwatersheds in 2014 and 2018 shown as box-and-whisker plots of all IBI values in each year. The WWH biocriteria and Ohio EPA thresholds for narrative categories (excellent, good, fair, poor, and very poor) are indicated by dashed lines.*

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 six sites and tolerant species exceeded the toxic response threshold of >70% at eight sites. However, %DELT anomalies were zero at all except one site ruling out a response to acutely toxic conditions. All of the responses instead point to organic enrichment and habitat limitations.

Macroinvertebrate Assemblage Results

Macroinvertebrates were judged by the WWH suite if uses at 26 sites, the remainder in one of the PHWH classes. Of the WWH sites eight met the WWH narrative or the ICI. The remainder ranged from very poor to fair. Of the eight PHWH sites, all except one were in the new Spring Water category (Ohio EPA 2018). Key macroinvertebrate assemblage indices and attributes

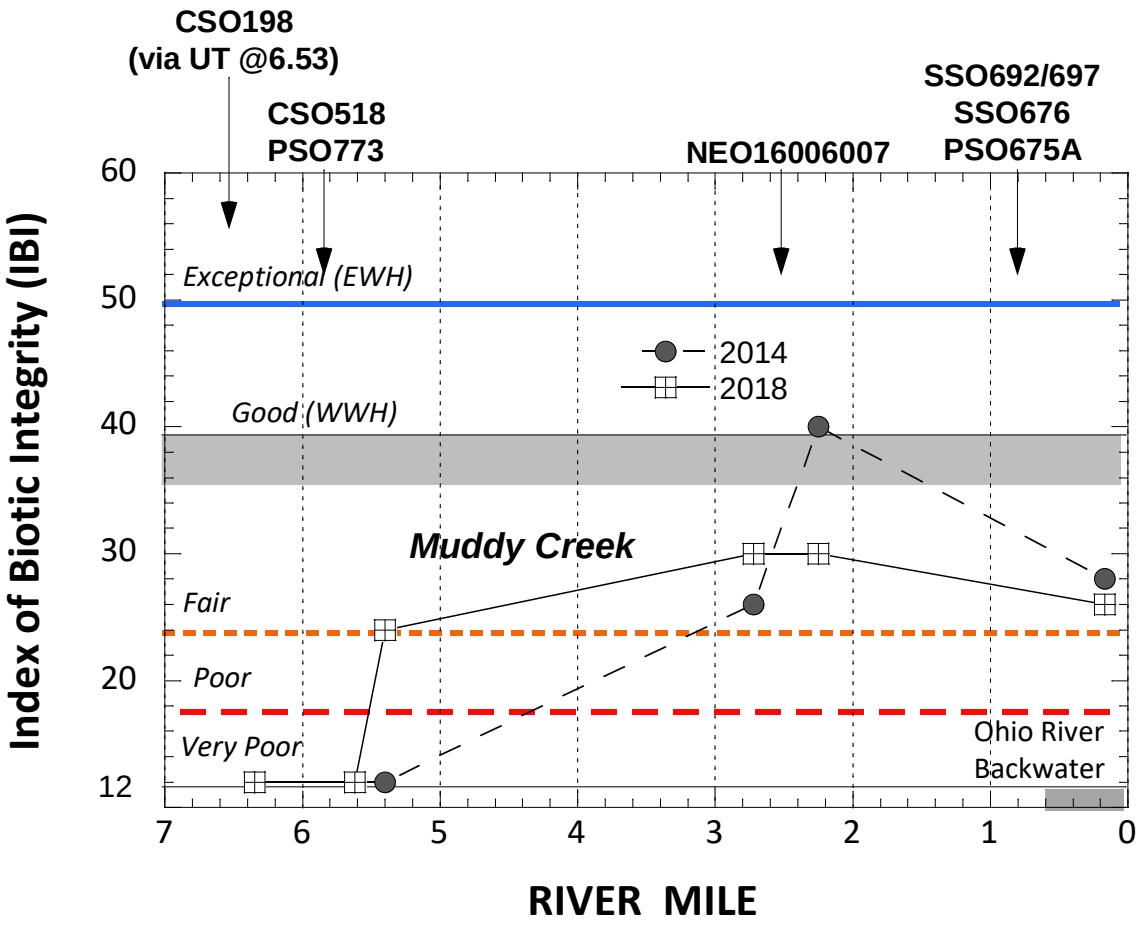

Figure 11*.Index of Biotic Integrity (IBI) in 2014 and 2018 at sites sampled in the mainstem of Muddy Creek. Major pollution sources are indicated along the x2 axis. The Ohio biocriteria and narrative quality classes are depicted by horizontal lines.*

depicted in Table 14. Of the 26 sites designated for one of the WWH suite of uses, only one failed to attain the WWH ICI biocriteria threshold and another two failed LRW. The remaining 30 sites met their applicable biocriterion including all of the EWH designated sites on the Ohio River Direct Tributaries mainstem. 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. The proportion of tolerant taxa was <10% at all other sites. No toxic responses were observed, but two sites (MU13 and RR01) had toxic tolerant taxa >10%.

SYNTHESIS

The baseline 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

Table 15.. *Selected fish and macroinvertebrate assemblage attributes and response signatures at 34 sites sampled in the 2018 Taylor Creek and Ohio River tributaries study area. 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.*

Site ID	River Miles	DA (mi^2)	IBI	Nat. Spec.	% DELT	Sens. Spec.	%Simp. Lith.	%Toler-ants	ICI/Narra-tive	Total Taxa	Sens. Taxa	%Toler-ant[1]	Qual. EPT	Toxic Tol. Taxa[1]	Organic Enrich-ment Taxa[1]
Muddy Creek															
MU05	6.35/6.35	5.39	12	0	0	0	0	0	VP	11	0	63.6	0	9.1	35.4
MU04.5	5.62/5.60	7.71	12	2	0	0	0	25.0	VP	17	1	29.4	1	5.9	17.6
MU04	5.45/5.40	7.80	24	2	0	0	0	86.1	VP	13	0	38.5	0	7.7	30.8
MU03	2.80/3.10	10.4	30	7	0	1	22.7	43.1	12	38	2	41.5	4	2.4	74.0
MU02	2.25/2.25	12.1	30	8	0	2	15.9	43.7	40	38	3	3.1	10	8.7	14.8
MU01	0.17/0.00	13.6	26	25	0	4	4.8	2.7	--	--	--	--	--	--	--
Unnamed Tributary RM 0.95 to Unnamed Tributary to Muddy Creek @RM 0.3															
MU09	0.10/0.60	1.33	14	1.5	0	0	32.6	40.9	SW	17	2	0.0	6	0	11.8
Unnamed Tributary to Muddy Creek @ RM 2.37															
MU10	0.50/0.50	0.71	12	0	0	0	0	0	VP	10	1	0.0	2	0	10.0
Unnamed Tributary to Muddy Creek @ RM 5.97															
MU12	0.55/0.59	1.01	36	2	0	0	0	27.6	VP	16	0	25.0	3	0	12.5
Unnamed Tributary to Muddy Creek @ RM 6.53															
MU13	0.60/0.30	2.25	12	1	0	0	0	0	VP	17	1	41.2	1	11.8	35.3
Unnamed Tributary to Unnamed Tributary to Muddy Cr. @RM 5.97															
MU14	0.00/0.20	0.09	-	-	-	-	-	-	P2	12	0	25.0	1	0	16.7
Unnamed Tributary to Muddy Creek @RM 0.3															
MU08	1.72/1.50	0.74	20	1	0	0	0	100	SW	19	1	0.0	6	0	5.3
MU07.5	0.80/0.90	2.60	34	7	0	1	63.1	72.3	F	17	1	0.0	6	0	5.9
MU07	0.40/0.45	2.80	34	6	0	1	14.7	48.3	G	26	4	7.7	10	0	11.5
Rapid Run															
RR03	2.70/2.58	2.32	--	--	--	--	--	--	VP	8	0	50.0	0	0	37.5
RR02	1.05/1.10	5.90	30	4	0	0	34.8	54.6	F	40	1	12.5	7	7.5	7.5
RR01	0.10/0.35	6.56	--	--	--	--	--	--	MG	30	3	13.3	8	10.0	10.0
Unnamed Tributary to Wulff Run @0.77															
RR05.5	1.20/1.20	0.33	--	--	--	--	--	--	SW	15	0	13.4	1	0	26.7
RR04.5	1.10/1.10	0.33	--	0	0	0	0	0	SW	14	1	14.3	4	0	28.6
Wulff Run															
RR05	0.70/0.68	1.33	--	--	--	--	--	--	VP	18	0	16.7	1	5.6	16.7
RR04	0.45/0.55	2.18	20	1	0	0	0	100	P	20	1	10.0	3	0	15.0
Indian Creek															
IC06	2.30/2.25	0.58	28	4	0	0	46.1	98.9	G	24	4	12.5	10	0	12.5
IC05	2.08/2.08	1.07	38	5	0	0	12.6	34.7	F	21	3	14.3	7	0	9.5
IC02	1.15/1.15	1.38	22	3	0	0	1.1	99.4	G	27	7	7.4	12	0	7.4
IC01	0.30/0.20	2.30	26	9	0	1	3.2	83.7	G	23	5	4.3	13	0	4.3

***Table 15**.. Selected fish and macroinvertebrate assemblage attributes and response signatures at 34 sites sampled in the 2018 Taylor Creek and Ohio River tributaries study area. 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.*

Site ID	River Miles	DA (mi^2)	IBI	Nat. Spec.	% DELT	Sens. Spec.	%Simp. Lith.	%Toler-ants	ICI/Narra-tive	Total Taxa	Sens. Taxa	%Toler-ant[1]	Qual. EPT	Toxic Tol. Taxa[1]	Organic Enrich-ment Taxa[1]
Unnamed Tributary to Indian Creek @RM 0.97															
IC07	0.10/0.19	0.39	12	0	0	0	0	0	SW	20	2	10.0	6	0	15.0
Taylor Creek															
GM86	6.40/6.40	1.20	32	4	0	0	0	45.1	MG	24	3	16.8	8	4.2	12.5
GM85	5.30/5.30	2.22	34	5	0	0	0.7	27.8	F	16	3	6.8	7	0	6.3
Briarly Creek															
GM91	3.90/3.90	0.34	24	2	0	0	0	85.3	SW	12	0	0.0	4	0	8.3
GM90	2.45/2.45	1.30	26	2	0.21	0	0	63.5	MG	23	2	8.6	8	0	4.3
GM89	1.80/1.80	2.10	30	4	0	0	1.2	39.9	MG	20	3	10.0	9	0	5.0
Wesselman Creek															
GM94	4.70/4.70	1.10	22	3	0	0	0	89.7	SW	21	2	4.8	6	0	9.5
Unnamed Tributary to Wesselman Creek @RM 2.59															
GM100	1.05/1.28	0.91	24	2	0	0	0	100	SW	24	2	8.4	7	0	4.2
Unnamed Tributary to Taylor Creek @RM 4.9															
GM106	0.20/0.28	0.92	42	9	0	0	1.5	66.8	SW	15	2	0.0	6	0	6.7

[1] - % of numbers for HD samples; % of taxa for qualitative samples.
Screening criteria for fish IBI: ≤18 (Very Poor); 19-26 (Poor)
Screening criteria for macroinvertebrate ICI or narrative rating: ≤8 (Very Poor); and 16 (Poor)
Screening criteria for percent organic enrichment taxa: >35%: (Yoder and DeShon 2003)
Screening criteria for percent toxic-tolerant taxa: >35%: (Yoder and DeShon 2003)
Screening criteria for percent -tolerant fish individuals: >70% (Yoder and DeShon 2003)
Screening criteria for number of intolerant or sensitive fish species: <1 (Yoder and DeShon 2003)

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 2018 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 2018. 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 2018 are included in Table 15 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. The rationale for listing a particular cause follows:

- Organic enrichment (20 of 34 sites) – any organic enrichment *Biological Response* in Table 15, a TKN value >IPS thresholds in Table 6, or an extremely elevated *E. coli* value in Table 4.
- Chloride (15 of 34 sites) – any chloride value >IPS threshold in Table 7.
- Habitat modification (13 of 34 sites) – any modified:good QHEI attributes >2.00 (Figure 8).
- PAH (12 of 21 sites) – any sediment PEC exceedance in Table 13.
- Low D.O. (10 of 34 sites) – any instantaneous value <4.0 mg/L or average <5 mg/L in Table 8 or Figure 7; values <2 mg/L are considered nuisance levels.
- Flow alteration – any site with no or insufficient water at the time of sampling (4 sites of 34 sites).
- Nutrient Enrichment (4 of 18 sites) - nutrient enrichment status of *Likely Nutrients* as described in Table 10.

***Table 16**. Key chemical, physical, and biological response indicators of impairment observed at each site in the Ohio River Direct Tributaries subwatersheds study area in 2018. Proximate 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	River Mile	AQLU	Drainage Area (sq. mi.)	IBI	ICI	AQLU Status	QHEI/ HHEI	QHEI Modified: Good Ratio	Min. D.O. (Grab) <WQC	Min. D.O. (Sonde) <WQC	D.O. Swing Narrative	Nutrient Enrichment Effect Status	Chemical Threshold Exceedances	Sediment Threshold Exceedances	%Organic Enrichment Indicators	%Toxic Tolerant Indicators	Proximate Causes	Sources
Muddy Creek																		
MU05	6.25	WWH	5.4	12*	VP*	Non	48.0	5.00	0.75	0.0	Wide	Likley Nutr.	Chloride,TKN	PAH(8)	M(35.4)		Habitat alter.,Low D.O.,Nutrients, Chloride, Org. Enrich., PAH	CSO/SSO.Urban, Sewer Constr.
MU04.5	5.60	WWH	7.7	12*	VP*	Non	48.5	4.50	3.60	0.9	Wide	Likley Nutr.	Chloride	PAH(4)			Habitat alter.,Low D.O.,Nutrients, Org. Enrich., PAH	CSO/SSO.Urban, Sewer Constr.
MU04	5.40	WWH	7.8	24*	VP*	Non	55.5	1.50	0.50	1.3	Normal-Low	Not Nutr.	TKN	PAH(1)	F(86.1)		Low D.O., Org. Enrich., PAH	CSO/SSO,Urban
MU03	3.10	WWH	10.4	30*	12*	Non	60.0	0.80	3.34	2.8	Wide	Not Nutr.	Chloride		M(74.0)		Low D.O., Org. Enrich.,Chloride	CSO/SSO/NEO,Urban,HSTS
MU02	2.25	WWH	12.1	30*	30	Partial	52.0	2.00	1.53	3.1	Wide	Not Nutr.	Chloride	PAH(3)			Low D.O., Chloride, PAH	CSO/SSO/NEO,Urban,HSTS
MU01	0.20	WWH	13.6	26	ns	Non	56.0	1.75	ne	2.6	Wide	Not Nutr.	TKN	PAH(3)			Low D.O., Org. Enrich, PAH	CSO/SSO/NEO,Urban
Unnamed Tributary to Muddy Creek @RM 0.3																		
MU08	1.72	PHW3A	0.74	20	SW	PHW3A	53.5/95.0	2.67	ne	ns	ns	ns	Chloride	ns				
MU07.5	0.80	WWH	2.6	34*	F*	Non	52.4/84.0	2.00	ne	ns	ns	ns	Chloride	ns			Chloride	Urban
MU07	0.40	WWH	2.8	34*	G	Partial	58.0	1.00	1.86	ns	ns	ns	Chloride	ns			Low D.O..,Chloride	CSO/SSO,Urban
Unnamed Tributary @RM 0.95 to Unnamed Tributary to Muddy Creek @RM 0.3																		
MU09	0.10	PHW3A	1.3	14	SW	PHW3A	50.0/89.0	4.50	ne	ns	ns	ns	Chloride	ns				
Unnamed Tributary to Muddy Creek @RM 2.37																		
MU10	0.50	WWH	0.71	12*	VP*	Non	56.0/95.0	2.33	ne	ns	ns	ns	Chloride	ns			Habitat alter.,Chloride	Urban
Unnamed Tributary to Muddy Creek @RM 5.97																		
MU12	0.55	WWH	1.0	36ns	VP*	Non	50.0/75.0	1.50	0.89	ns	ns	ns	Cu, TKN	ns			Low D.O., Org. Enrich, metals	CSO/SSO,Urban
Unnamed Tributary to Muddy Creek @RM 6.53																		
MU13	0.60	WWH	2.3	ns	VP*	Non	ns /93.0	ns	0.68	ns	ns	ns	TKN	ns	M(41.2)	M(11.8)	Low D.O., Org. Enrich, Unk.tox.,Flow	CSO/SSO,Urban
Unnamed Tributary to Unnamed Tributary to Muddy Creek @RM 5.97																		
MU14	0.20	PHW2	2.7	ns	P2	PHW2	ns	ns	ne	ns	ns	ns	Cu, Chlor.,TKN	ns				
Rapid Run (23-008)																		
RR03	2.58	LRW	2.32	ns	VP*	Non	ns/88.0	ns	ne	3.20	Normal-Low	Not Nutr.		PAH(6)			PAH, Org. Enrich., Flow	Urban, Sewer Constr.,HSTS
RR02	1.10	LRW	5.9	30	F*	Full	45.50	2.67	ne	5.40	Normal-Low	Not Nutr.	Chloride	PAH(2)			PAH, Chloride	Urban, Sewer Constr.
RR01	0.35	LRW	6.0	ns	MGns	Full	ns	ns	ne	4.20	Normal-Low	Not Nutr.	Chloride			M(10.0)	Chloride, Unk. Toxicity, Flow	Urban, Sewer Constr.,HSTS
Wulff Run (23-012)																		
RR05	0.68	WWH	1.3	ns	VP*	Non	ns/101.0	ns	1.92	ns	ns	ns	Chloride	ns			Low D.O., Chloride, Flow	CSO/SSO, Urban,Sew. Constr.
RR04	0.55	WWH	2.2	20	P2	Full	48.8/95.0	4.00	ne	ns	ns	ns	Chloride	ns	F(100)		Habitat alter.,Org. Enrich., Chlor.	CSO/SSO, Urban
Unnamed Tributary to Wulff Run @RM 0.77																		
RR05.5	1.20	PHW3A	1	12	SW	PHW3A	57.0/81.0	1.50	ne	ns	ns	ns	Chloride	ns				
RR04.5	1.10	PHW3A	0.34	12	SW	PHW3A	51.0/77.0	2.33	ne	ns	ns	ns	Chloride	ns				
Indian Creek																		
IC06	2.25	WWH	0.58	28*	G	Partial	55.0/87.0	1.20	ne	ns	ns	ns	Chloride	PAH(1)	F(98.9)		Chloride, Organic enrich., PAH	Urban, HSTS
IC05	2.08	WWH	1.1	38ns	F*	Partial	54.5/91.0	1.50	ne	4.90	Wide	Likley Nutr.	Chloride				Nutrients, Chloride, Org. enrich.	Urban
IC02	1.15	WWH	1.4	22*	G	Partial	51.5/75.0	1.75	ne	6.60	Normal-Low	Not Nutr.	Chloride		F(99.4)		Chloride, Organic enrich.	Urban
IC01	0.20	WWH	2.3	26*	G	Partial	43.5/73.0	2.67	ne	6.50	Normal-Low	Not Nutr.			F(83.7)		Organic enrich.	Urban
Unnamed Tributary to Indian Creek @RM 1.02																		
IC07	0.19	PHW3A	0.39	12	SW	PHW3A	57.0/76.0	1.25	ne	ns	ns	ns	Chloride	PAH(13)				

ne - no exceedances measure

ne - no exceedances measure

***Table 16**. (continued)*

Site ID	River Mile	AQLU	Drainage Area (sq. mi.)	IBI	ICI	AQLU Status	QHEI/ HHEI	QHEI Modified: Good Ratio	Min. D.O. (Grab) <WQC	Min. D.O. (Sonde) <WQC	D.O. Swing Narrative	Nutrient Enrichment Effect Status	Chemical Threshold Exceedances	Sediment Threshold Exceedances	%Organic Enrichment Indicators	%Toxic Tolerant Indicators	Proximate Causes	Sources
Taylor Creek																		
GM86	6.50	WWH	0.49	32*	MG^{ns}	Partial	46.5/80.0	3.50	ne	6.30	Normal-Low	Not Nutr.	Chloride	PAH(1)			Habitat alter., Chlor.,Org. Enrich.	Urban, HSTS
GM85	5.30	WWH	2.2	34*	F*	Non	46.0/90.0	4.50	ne	5.70	Wide	Likley Nutr.	Chloride	PAH(1)			Nutrients, Chloride, PAH	Urban, HSTS
Unnamed Tributary to Taylor Creek @RM 4.9																		
GM106	0.28	WWH	0.92	42	F*	Partial	58.0/90.0	1.75	ne	ns	ns	ns	Chloride	ns			Chloride	Urban
Briarly Creek																		
GM91	3.90	PHW3A	0.34	24	SW	PHW3A	56.50	1.00	ne	3.0	Normal-Low	Not Nutr.	Chloride	PAH(5)	F(85.3)			
GM90	2.55	WWH	1.3	26*	MG^{ns}	Partial	54.8/97.0	1.50	ne	6.3	Normal-Low	Not Nutr.	Chloride	PAH(1)			Chloride, PAH, Org. Enrich.	Urban, HSTS
GM89	1.98	WWH	2.1	30*	MG^{ns}	Partial	57.5/88.0	1.75	ne	7.0	Normal-Low	Not Nutr.	Cu	PAH(1)			Metals PAH	Urban, HSTS
Wesselman Creek																		
GM94	4.75	WWH	1.1	22*	F*	Non	53.0/87.0	4.50	ne	6.4	Normal-Low	Not Nutr.	Chloride	PAH(1)	F(89.7)		Chloride, PAH, Organic enrich.	Urban, HSTS
Unnamed Tributary to Wesselman Creek @RM 2.95																		
GM100	1.28	PHW3A	0.91	24*	SW	PHW3A	48.5/91.0	1.50	ne	ns	ns	ns	Chloride		F(100)			

ne - no exceedances measure

ne - no exceedances measure

- Toxicity (2 of 34 sites) – any toxic biological response in Table 15.
- Metals (1 of 34 sites) – any acute exceedance in Table 5 or sediment PEC exceedance in Table 12.

Organic enrichment (12 sites) was the most pervasive cause followed by exceedances of the chloride threshold at 15 sites. These were followed habitat alteration (13 sites), PAH exceedances (12 sites), low D.O. (10 sites), nutrient enrichment (4 sites), toxicity (2 sites), and metals (1 site). Four sources were assigned including urban runoff (26 of 34 sites), CSO/SSO (11 sites; NEO at 3 sites), HSTS (10 sites), and legacy impacts from sewer line construction (6 sites).

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Appendix A

Ohio River Direct Tributaries 2018 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 Muddy Creek and Taylor Creek study areas in 2018..

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
(23-007) - Muddy Creek																	
Year: 2018																	
MU05	6.35	F	07/11/2018	5.4	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
MU04.5	5.62	E	07/11/2018	7.7	2(1)	0(1)	0(1)	0(1)	0(1)	0(1)	25(1)	0(1)	25(1)	100(1)	0.0(1)	7(1) * *	12
MU04	5.45	E	07/11/2018	7.8	2(1)	0(1)	0(1)	0(1)	0(1)	0(1)	86(1)	0(5)	86(1)	100(5)	0.0(5)	10(1) *	24
MU03	2.80	F	07/11/2018	10.4	7(1)	4(3)	1(1)	1(1)	1(1)	2(1)	43(3)	6(5)	21(5)	3(1)	0.0(5)	462(3)	30
MU02	2.25	F	07/11/2018	12.1	8(3)	5(3)	1(1)	2(1)	1(1)	3(1)	44(3)	27(3)	31(3)	3(1)	0.0(5)	1156(5)	30
MU01	0.17	P	07/09/2018	16.6	25(5)	5(3)	0(1)	4(3)	0(1)	3(1)	3(5)	41(1)	2(5)	45(3)	0.0(5)	732(3)	26
(23-008) - Rapid Run																	
Year: 2018																	
RR03	2.70	F	07/12/2018	2.2	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) * *	12
RR02	1.05	F	07/12/2018	5.9	4(1)	3(3)	1(1)	0(1)	0(1)	1(1)	55(3)	0(5)	20(5)	1(1)	0.0(5)	333(3)	30
RR01	0.10	F	07/11/2018	9.0	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) * *	12
(23-012) - Unnamed Trib to Wulff Run @																	
Year: 2018																	
RR05.5	1.20	F	07/12/2018	0.3	1(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	100(1)	0.0(1)	4(1) * *	12
RR04.5	1.10	F	07/12/2018	0.3	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	0.45	F	07/12/2018	2.2	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: 2018																	
IC06	2.30	F	07/10/2018	0.6	4(3)	2(3)	1(1)	0(1)	0(1)	1(3)	99(1)	0(5)	53(3)	1(1)	0.0(5)	10(1)	28
IC05	2.08	F	07/10/2018	1.1	5(3)	3(3)	1(1)	0(1)	0(1)	1(1)	35(3)	0(5)	22(5)	64(5)	0.0(5)	1058(5)	38
IC02	1.15	F	07/10/2018	1.4	3(1)	3(3)	1(1)	0(1)	0(1)	1(1)	99(1)	0(5)	98(1)	0(1)	0.0(5)	2(1)	22
IC01	0.30	F	07/10/2018	2.3	9(3)	4(3)	1(1)	1(1)	1(1)	3(3)	84(1)	64(1)	81(1)	6(1)	0.0(5)	238(5)	26

♦ - 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 Muddy Creek and Taylor Creek study areas in 2018..

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
(23-020) - Trib to Indian Creek @RM1.02 RM0.97																	
Year: 2018																	
IC07	0.10	F	07/10/2018	0.4	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
(23-066) - UT RM 0.95 to UT to Muddy Creek @RM0.3																	
Year: 2018																	
MU09	0.10	F	07/10/2018	0.0	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0.0(0)	0(0) * *	0
(23-067) - Unnamed Trib to Wulff Run @ RM0.77																	
Year: 2018																	
RR05	0.70	F	07/12/2018	1.3	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) * *	12
(23-071) - Unnamed Trib to Muddy Creek @ RM2.37																	
Year: 2018																	
MU10	0.50	F	07/12/2018	0.7	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: 2018																	
MU12	0.55	F	07/12/2018	1.0	2(1)	0(1)	0(1)	0(1)	0(1)	0(1)	28(5)	0(5)	28(5)	94(5)	0.0(5)	178(5)	36
(23-073) - Unnamed Trib to Muddy Creek @ RM6.53																	
Year: 2018																	
MU13	0.60	F	07/12/2018	1.9	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) * *	12
(23-075) - Unnamed Trib to Muddy Creek @RM0.3																	
Year: 2018																	
MU08	1.72	F	07/10/2018	0.7	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
MU07.5	0.80	F	07/10/2018	2.6	7(3)	4(3)	1(1)	1(1)	1(1)	3(3)	72(1)	0(5)	10(5)	1(1)	0.0(5)	832(5)	34
MU07	0.40	F	07/11/2018	2.8	6(3)	4(3)	1(1)	1(1)	1(1)	3(3)	48(3)	7(5)	35(3)	1(1)	0.0(5)	514(5)	34
(23-076) - UT @ 0.95 to UT to Muddy Creek @ RM0.3																	
Year: 2018																	

♦ - 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 Muddy Creek and Taylor Creek study areas in 2018..

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
MU09	0.10	F	07/10/2018	1.3	3(1)	3(3)	1(1)	0(1)	0(1)	1(1)	82(1)	0(5)	17(5)	0(1)	0.0(5)	63(3)	28

♦ - 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: *Muddy Creek; Unnamed Trib to Muddy Creek @ RM2.37; Unnamed Trib to Muddy Creek @ RM5.97; Unnamed Trib to Muddy Creek @ RM6.53; Unnamed Trib to Muddy Creek @ RM0.3; UT RM0.95 to UT to Muddy Creek @ RM0.3*

Years: 2018

Number of Samples: 13 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.
43-044	CENTRAL STONEROLLER	H		N	N	1456	198.0	34.61	0	0.00	0.0
43-011	WESTERN BLACKNOSE DACE	G	T	S	N	1242	168.9	29.52	0	0.00	0.0
43-013	CREEK CHUB	G	T	N	N	557	75.8	13.24	0	0.00	0.0
43-043	BLUNTNOSE MINNOW	O	T	C	N	268	121.1	6.37	0	0.00	0.0
77-009	BLUEGILL SUNFISH	I	P	C	S	147	66.4	3.49	418	3.94	6.2
20-003	GIZZARD SHAD	O		M		137	61.9	3.26	131	1.23	2.1
77-008	GREEN SUNFISH	I	T	C	S	87	39.3	2.07	22	0.21	0.5
40-016	WHITE SUCKER	O	T	S	W	80	10.9	1.90	0	0.00	0.0
80-022	RAINBOW DARTER	I	M	S	D	44	6.0	1.05	0	0.00	0.0
40-004	SMALLMOUTH BUFFALO	I		M	C	42	19.0	1.00	2915	27.46	153.5
47-002	CHANNEL CATFISH			C	F	19	8.6	0.45	3164	29.80	368.4
77-011	LONGEAR SUNFISH	I	M	C	S	16	7.2	0.38	135	1.28	18.7
43-063	CHANNEL SHINER	I	I	M	N	15	2.0	0.36	2	0.06	1.0
40-010	GOLDEN REDHORSE	I	M	S	R	13	5.9	0.31	533	5.02	90.7
77-006	LARGEMOUTH BASS	C		C	F	13	5.9	0.31	452	4.26	76.9
77-010	ORANGESPOTTED SUNFISH	I		C	S	10	4.5	0.24	4	0.04	1.0
77-015	GREEN SF X BLUEGILL SF					10	4.5	0.24	9	0.09	2.0
40-006	RIVER CARPSUCKER	O		M	C	8	3.6	0.19	578	5.45	160.0
43-020	EMERALD SHINER	I		M	N	7	3.2	0.17	3	0.03	1.1
85-001	FRESHWATER DRUM		P	M		6	2.7	0.14	244	2.30	90.0
77-001	WHITE CRAPPIE	I		C	S	5	2.3	0.12	140	1.32	62.0
80-001	SAUGER	P		S	F	4	1.8	0.10	271	2.55	150.0
20-001	SKIPJACK HERRING	P		M		3	1.4	0.07	1	0.01	1.0
40-005	QUILLBACK CARPSUCKER	O		M	C	3	1.4	0.07	90	0.85	66.6
43-001	COMMON CARP	O	T	M	G	3	1.4	0.07	1243	11.71	916.6
77-007	WARMOUTH SUNFISH	C		C	S	3	1.4	0.07	22	0.21	16.6
77-002	BLACK CRAPPIE	I		C	S	2	0.9	0.05	81	0.77	90.0
77-005	SPOTTED BASS	C		C	F	2	0.9	0.05	49	0.47	55.0
43-027	RIVER SHINER	I		S	N	1	0.5	0.02	0	0.01	2.0
43-041	BULLHEAD MINNOW	O		C	N	1	0.5	0.02	0	0.01	2.0
74-001	WHITE BASS	P		M	F	1	0.5	0.02	31	0.30	70.0
77-004	SMALLMOUTH BASS	C	M	C	F	1	0.5	0.02	0	0.01	2.0
77-012	REDEAR SUNFISH	I		C	E	1	0.5	0.02	63	0.60	140.0
99-997	Dry Site					0	0.0	0.00	0	0.00	*****.*
99-999	NO FISH					0	0.0	0.00	0	0.00	*****.*

No Species: 35 **Nat. Species:** 32 **Hybrids:** 1 **Total Counted:** 4207 **Total Rel. Wt. :** 10611

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

Rivers: *Rapid Run; Wulff Run;*

Years: 2018

Number of Samples: 7 Data Sources: 99 Data Types: F

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	149	46.0	38.40	0	***.**	0.0
43-044	CENTRAL STONEROLLER	H		N	N	133	41.1	34.28	0	***.**	0.0
43-011	WESTERN BLACKNOSE DACE	G	T	S	N	102	31.5	26.29	0	***.**	0.0
77-008	GREEN SUNFISH	I	T	C	S	2	0.6	0.52	0	***.**	0.0
77-009	BLUEGILL SUNFISH	I	P	C	S	2	0.6	0.52	0	***.**	0.0
99-997	Dry Site					0	0.0	0.00	0	***.**	*****.*
99-999	NO FISH					0	0.0	0.00	0	***.**	*****.*

No Species: 7 **Nat. Species:** 7 **Hybrids:** 0 **Total Counted:** 388 **Total Rel. Wt. :** 0

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

Rivers: *Indian Creek; Trib. to Indian Creek (RM 1.02)*

Years: 2018

Number of Samples: 5 Data Sources: 99 Data Types: F

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	704	281.6	32.44	0	***.**	0.0
77-009	BLUEGILL SUNFISH	I	P	C	S	523	209.2	24.10	0	***.**	0.0
43-043	BLUNTNOSE MINNOW	O	T	C	N	453	181.2	20.88	0	***.**	0.0
43-011	WESTERN BLACKNOSE DACE	G	T	S	N	313	125.2	14.42	0	***.**	0.0
43-044	CENTRAL STONEROLLER	H		N	N	107	42.8	4.93	0	***.**	0.0
77-008	GREEN SUNFISH	I	T	C	S	30	12.0	1.38	0	***.**	0.0
77-006	LARGEMOUTH BASS	C		C	F	17	6.8	0.78	0	***.**	0.0
40-016	WHITE SUCKER	O	T	S	W	16	6.4	0.74	0	***.**	0.0
80-022	RAINBOW DARTER	I	M	S	D	6	2.4	0.28	0	***.**	0.0
57-001	WESTERN MOSQUITOFISH	I		N	E	1	0.4	0.05	0	***.**	0.0
99-999	NO FISH					0	0.0	0.00	0	***.**	*****.*

No Species: 11 **Nat. Species:** 10 **Hybrids:** 0 **Total Counted:** 2170 **Total Rel. Wt. :** 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*

Years: 2018

Number of Samples: 8 Data Sources: 99 Data Types: E; F

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	1336	348.7	50.23	0	***.**	0.0
43-044	CENTRAL STONEROLLER	H		N	N	1191	310.9	44.77	0	***.**	0.0
77-006	LARGEMOUTH BASS	C		C	F	63	16.4	2.37	0	***.**	0.0
80-024	FANTAIL DARTER	I		C	D	26	6.8	0.98	0	***.**	0.0
77-008	GREEN SUNFISH	I	T	C	S	21	5.5	0.79	0	***.**	0.0
43-011	WESTERN BLACKNOSE DACE	G	T	S	N	9	2.4	0.34	0	***.**	0.0
40-016	WHITE SUCKER	O	T	S	W	4	1.0	0.15	0	***.**	0.0
43-042	FATHEAD MINNOW	O	T	C	N	4	1.0	0.15	0	***.**	0.0
43-025	STRIPED SHINER	I		S	N	3	0.8	0.11	0	***.**	0.0
77-009	BLUEGILL SUNFISH	I	P	C	S	3	0.8	0.11	0	***.**	0.0

No Species: 10 **Nat. Species:** 10 **Hybrids:** 0 **Total Counted:** 2660 **Total Rel. Wt. :** 0

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

Site ID: GM85 River: 14-004 Taylor Creek RM: 5.30 Date: 07/12/2018

Time Fished: 701 Distance: 0.150 Drainge (sq mi): 2.2 Depth: 0

Location: Ust. Johnson Rd. Lat: 39.18112 Long: -84.64101

Species Code:	Species Name:	Feed Guild	Toler-ance	Breed Guild	IBI Group	No. Fish	Rel. No.	% by No.	Rel. Wt.	% by Wt.	Av. Wt.
43-044	CENTRAL STONEROLLER	H		N	N	400	800.0	70.30	0	0.00	0.0
43-013	CREEK CHUB	G	T	N	N	154	308.0	27.07	0	0.00	0.0
77-006	LARGEMOUTH BASS	C		C	F	8	16.0	1.41	0	0.00	0.0
40-016	WHITE SUCKER	O	T	S	W	4	8.0	0.70	0	0.00	0.0
80-024	FANTAIL DARTER	I		C	D	3	6.0	0.53	0	0.00	0.0

No Species: 5 **Nat. Species:** 5 **Hybrids:** 0 **Total Counted:** 569 **Total Rel. Wt. :** 0

IBI: 34.0 **Mlwb:** N/A

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

Site ID: GM86 River: 14-004 Taylor Creek RM: 6.40 Date: 07/09/2018

Time Fished: 772 Distance: 0.150 Drainge (sq mi): 1.2 Depth: 0

Location: Reemelin Rd. Lat: 39.17574 Long: -84.62520

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	144	288.0	45.14	0	0.00	0.0
43-044	CENTRAL STONEROLLER	H		N	N	126	252.0	39.50	0	0.00	0.0
77-006	LARGEMOUTH BASS	C		C	F	48	96.0	15.05	0	0.00	0.0
77-009	BLUEGILL SUNFISH	I	P	C	S	1	2.0	0.31	0	0.00	0.0

No Species: 4 **Nat. Species:** 4 **Hybrids:** 0 **Total Counted:** 319 **Total Rel. Wt. :** 0

IBI: 32.0 **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: 06/29/2018

Time Fished: 837 Distance: 0.150 Drainge (sq mi): 2.1 Depth: 0

Location: Adj. Briarly Creek Lat: 39.20264 Long: -84.64467

Species Code:	Species Name:	Feed Guild	Toler-ance	Breed Guild	IBI Group	No. Fish	Rel. No.	% by No.	Rel. Wt.	% by Wt.	Av. Wt.
43-044	CENTRAL STONEROLLER	H		N	N	394	788.0	60.06	0	0.00	0.0
43-013	CREEK CHUB	G	T	N	N	246	492.0	37.50	0	0.00	0.0
43-011	WESTERN BLACKNOSE DACE	G	T	S	N	8	16.0	1.22	0	0.00	0.0
77-008	GREEN SUNFISH	I	T	C	S	8	16.0	1.22	0	0.00	0.0

No Species: 4 **Nat. Species:** 4 **Hybrids:** 0 **Total Counted:** 656 **Total Rel. Wt. :** 0

IBI: 30.0 **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: 06/29/2018

Time Fished: 977 Distance: 0.130 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	297	685.5	63.46	0	0.00	0.0
43-044	CENTRAL STONEROLLER	H		N	N	171	394.7	36.54	0	0.00	0.0

No Species: 2 **Nat. Species:** 2 **Hybrids:** 0 **Total Counted:** 468 **Total Rel. Wt. :** 0

IBI: 26.0 **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: 07/09/2018

Time Fished: 912 Distance: 0.130 Drainge (sq mi): 0.3 Depth: 0

Location: Ust. private drive Lat: 39.19405 Long: -84.60977

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	191	440.8	85.27	0	0.00	0.0
43-044	CENTRAL STONEROLLER	H		N	N	33	76.2	14.73	0	0.00	0.0

No Species: 2 **Nat. Species:** 2 **Hybrids:** 0 **Total Counted:** 224 **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: 06/29/2018

Time Fished: 561 Distance: 0.150 Drainge (sq mi): 1.1 Depth: 0

Location: Ust. Wesselman Rd. Lat: 39.18024 Long: -84.65250

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	102	204.0	87.18	0	0.00	0.0
43-044	CENTRAL STONEROLLER	H		N	N	12	24.0	10.26	0	0.00	0.0
43-042	FATHEAD MINNOW	O	T	C	N	3	6.0	2.56	0	0.00	0.0

No Species: 3 **Nat. Species:** 3 **Hybrids:** 0 **Total Counted:** 117 **Total Rel. Wt. :** 0

IBI: 22.0 **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: 06/29/2018 RM2.95

Time Fished: 644 Distance: 0.150 Drainge (sq mi): 0.9 Depth: 0

Location: Ust. Rockview Rd. Lat: 39.10680 Long: -84.67772

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	69.44	0	0.00	0.0
77-008	GREEN SUNFISH	I	T	C	S	11	22.0	30.56	0	0.00	0.0

No Species: 2 **Nat. Species:** 2 **Hybrids:** 0 **Total Counted:** 36 **Total Rel. Wt. :** 0

IBI: 24.0 **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: 07/09/2018

Time Fished: 1159 Distance: 0.150 Drainge (sq mi): 0.9 Depth: 0

Location: Adj. to private drive Lat: 39.18669 Long: -84.63535

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	177	354.0	65.31	0	0.00	0.0
43-044	CENTRAL STONEROLLER	H		N	N	55	110.0	20.30	0	0.00	0.0
80-024	FANTAIL DARTER	I		C	D	23	46.0	8.49	0	0.00	0.0
77-006	LARGEMOUTH BASS	C		C	F	7	14.0	2.58	0	0.00	0.0
43-025	STRIPED SHINER	I		S	N	3	6.0	1.11	0	0.00	0.0
77-008	GREEN SUNFISH	I	T	C	S	2	4.0	0.74	0	0.00	0.0
77-009	BLUEGILL SUNFISH	I	P	C	S	2	4.0	0.74	0	0.00	0.0
43-011	WESTERN BLACKNOSE DACE	G	T	S	N	1	2.0	0.37	0	0.00	0.0
43-042	FATHEAD MINNOW	O	T	C	N	1	2.0	0.37	0	0.00	0.0

No Species: 9 **Nat. Species:** 9 **Hybrids:** 0 **Total Counted:** 271 **Total Rel. Wt. :** 0

IBI: 42.0 **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: 07/09/2018

Time Fished: 2029 Distance: 0.500 Drainge (sq mi): 13.6 Depth: 0

Location: Route 50-Ohio River backwater Lat: 39.13276 Long: -84.70625

Species Code:	Species Name:	Feed Guild	Toler-ance	Breed Guild	IBI Group	No. Fish	Rel. No.	% by No.	Rel. Wt.	% by Wt.	Av. Wt.
20-003	GIZZARD SHAD	O		M		137	274.0	36.44	13150	12.83	47.9
77-009	BLUEGILL SUNFISH	I	P	C	S	53	106.0	14.10	2454	2.39	23.1
40-004	SMALLMOUTH BUFFALO	I		M	C	42	84.0	11.17	38800	37.86	461.9
47-002	CHANNEL CATFISH			C	F	19	38.0	5.05	22180	21.64	583.6
77-011	LONGEAR SUNFISH	I	M	C	S	16	32.0	4.26	700	0.68	21.8
43-063	CHANNEL SHINER	I	I	M	N	14	28.0	3.72	30	0.03	1.0
40-010	GOLDEN REDHORSE	I	M	S	R	13	26.0	3.46	2360	2.30	90.7
77-006	LARGEMOUTH BASS	C		C	F	13	26.0	3.46	3250	3.17	125.0
77-010	ORANGESPOTTED SUNFISH	I		C	S	10	20.0	2.66	120	0.12	6.0
40-006	RIVER CARPSUCKER	O		M	C	8	16.0	2.13	2560	2.50	160.0
43-020	EMERALD SHINER	I		M	N	7	14.0	1.86	16	0.02	1.1
77-008	GREEN SUNFISH	I	T	C	S	6	12.0	1.60	100	0.10	8.3
85-001	FRESHWATER DRUM		P	M		6	12.0	1.60	1080	1.05	90.0
77-001	WHITE CRAPPIE	I		C	S	5	10.0	1.33	620	0.60	62.0
80-001	SAUGER	P		S	F	4	8.0	1.06	1210	1.18	151.2
20-001	SKIPJACK HERRING	P		M		3	6.0	0.80	6	0.01	1.0
40-005	QUILLBACK CARPSUCKER	O		M	C	3	6.0	0.80	400	0.39	66.6
43-001	COMMON CARP	O	T	M	G	3	6.0	0.80	12300	12.00	2050.0
77-007	WARMOUTH SUNFISH	C		C	S	3	6.0	0.80	100	0.10	16.6
77-002	BLACK CRAPPIE	I		C	S	2	4.0	0.53	360	0.35	90.0
77-005	SPOTTED BASS	C		C	F	2	4.0	0.53	220	0.21	55.0
43-027	RIVER SHINER	I		S	N	1	2.0	0.27	4	0.00	2.0
43-041	BULLHEAD MINNOW	O		C	N	1	2.0	0.27	4	0.00	2.0
43-043	BLUNTNOSE MINNOW	O	T	C	N	1	2.0	0.27	2	0.00	1.0
74-001	WHITE BASS	P		M	F	1	2.0	0.27	140	0.14	70.0
77-004	SMALLMOUTH BASS	C	M	C	F	1	2.0	0.27	4	0.00	2.0
77-012	REDEAR SUNFISH	I		C	E	1	2.0	0.27	280	0.27	140.0
77-015	GREEN SF X BLUEGILL SF					1	2.0	0.27	40	0.04	20.0

No Species: 27 **Nat. Species:** 25 **Hybrids:** 1 **Total Counted:** 376 **Total Rel. Wt. :** 102490

IBI: 26.0 **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: 07/11/2018

Time Fished: 823 Distance: 0.150 Drainge (sq mi): 12.1 Depth: 0

Location: Hillside Ave. Lat: 39.12250 Long: -84.68710

Species Code:	Species Name:	Feed Guild	Toler-ance	Breed Guild	IBI Group	No. Fish	Rel. No.	% by No.	Rel. Wt.	% by Wt.	Av. Wt.
43-044	CENTRAL STONEROLLER	H		N	N	548	1096.0	53.36	0	0.00	0.0
43-043	BLUNTNOSE MINNOW	O	T	C	N	220	440.0	21.42	0	0.00	0.0
43-013	CREEK CHUB	G	T	N	N	93	186.0	9.06	0	0.00	0.0
43-011	WESTERN BLACKNOSE DACE	G	T	S	N	73	146.0	7.11	0	0.00	0.0
40-016	WHITE SUCKER	O	T	S	W	61	122.0	5.94	0	0.00	0.0
80-022	RAINBOW DARTER	I	M	S	D	29	58.0	2.82	0	0.00	0.0
77-008	GREEN SUNFISH	I	T	C	S	2	4.0	0.19	0	0.00	0.0
43-063	CHANNEL SHINER	I	I	M	N	1	2.0	0.10	0	0.00	0.0

No Species: 8 **Nat. Species:** 8 **Hybrids:** 0 **Total Counted:** 1027 **Total Rel. Wt. :** 0

IBI: 30.0 **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: 07/11/2018

Time Fished: 912 Distance: 0.150 Drainge (sq mi): 10.4 Depth: 0

Location: Cleves-Warsaw Pike Lat: 0.00000 Long: 0.00000

Species Code:	Species Name:	Feed Guild	Toler-ance	Breed Guild	IBI Group	No. Fish	Rel. No.	% by No.	Rel. Wt.	% by Wt.	Av. Wt.
43-044	CENTRAL STONEROLLER	H		N	N	221	442.0	54.43	0	0.00	0.0
43-011	WESTERN BLACKNOSE DACE	G	T	S	N	88	176.0	21.67	0	0.00	0.0
43-013	CREEK CHUB	G	T	N	N	60	120.0	14.78	0	0.00	0.0
43-043	BLUNTNOSE MINNOW	O	T	C	N	24	48.0	5.91	0	0.00	0.0
77-009	BLUEGILL SUNFISH	I	P	C	S	5	10.0	1.23	0	0.00	0.0
80-022	RAINBOW DARTER	I	M	S	D	4	8.0	0.99	0	0.00	0.0
77-008	GREEN SUNFISH	I	T	C	S	3	6.0	0.74	0	0.00	0.0
77-015	GREEN SF X BLUEGILL SF					1	2.0	0.25	0	0.00	0.0

No Species: 7 **Nat. Species:** 7 **Hybrids:** 1 **Total Counted:** 406 **Total Rel. Wt. :** 0

IBI: 30.0 **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: 07/11/2018

Time Fished: 606 Distance: 0.150 Drainge (sq mi): 7.8 Depth: 0

Location: Ebenezer Rd. Lat: 39.13433 Long: -84.65057

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	31	62.0	86.11	0	0.00	0.0
77-009	BLUEGILL SUNFISH	I	P	C	S	5	10.0	13.89	0	0.00	0.0

No Species: 2 **Nat. Species:** 2 **Hybrids:** 0 **Total Counted:** 36 **Total Rel. Wt. :** 0

IBI: 24.0 **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: 07/11/2018

Time Fished: 729 Distance: 0.140 Drainge (sq mi): 7.7 Depth: 0

Location: Beech Creek Lane Lat: 39.13314 Long: -84.64796

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	3	6.4	75.00	0	0.00	0.0
77-008	GREEN SUNFISH	I	T	C	S	1	2.1	25.00	0	0.00	0.0

No Species: 2 **Nat. Species:** 2 **Hybrids:** 0 **Total Counted:** 4 **Total Rel. Wt. :** 0

IBI: 12.0 **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: 07/11/2018

Time Fished: 253 Distance: 0.100 Drainge (sq mi): 5.3 Depth: 0

Location: Sidney Ave/ Beech Grove Lat: 39.13355 Long: -84.63875

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 **Mlwb:** N/A

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

Site ID: RR01 River: 23-008 Rapid Run RM: 0.10 Date: 07/11/2018

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

Location: US 50 Overpass Lat: 39.10140 Long: -84.66993

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: RR02 River: 23-008 Rapid Run RM: 1.05 Date: 07/12/2018

Time Fished: 458 Distance: 0.120 Drainge (sq mi): 5.9 Depth: 0

Location: US Rt. 50 Lat: 39.10249 Long: -84.65532

Species Code:	Species Name:	Feed Guild	Toler-ance	Breed Guild	IBI Group	No. Fish	Rel. No.	% by No.	Rel. Wt.	% by Wt.	Av. Wt.
43-044	CENTRAL STONEROLLER	H		N	N	133	332.5	45.39	0	0.00	0.0
43-011	WESTERN BLACKNOSE DACE	G	T	S	N	102	255.0	34.81	0	0.00	0.0
43-013	CREEK CHUB	G	T	N	N	56	140.0	19.11	0	0.00	0.0
77-008	GREEN SUNFISH	I	T	C	S	2	5.0	0.68	0	0.00	0.0

No Species: 4 **Nat. Species:** 4 **Hybrids:** 0 **Total Counted:** 293 **Total Rel. Wt. :** 0

IBI: 30.0 **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: 07/12/2018

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

Location: Rapid Run Rd. Lat: 39.11000 Long: -84.64091

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: RR04 River: 23-012 Wulff Run RM: 0.45 Date: 07/12/2018

Time Fished: 398 Distance: 0.100 Drainge (sq mi): 2.1 Depth: 0

Location: Wulff Run Rd. Lat: 39.10133 Long: -84.64112

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	93	279.0	100.00	0	0.00	0.0

No Species: 1 **Nat. Species:** 1 **Hybrids:** 0 **Total Counted:** 93 **Total Rel. Wt. :** 0

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

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

Site ID: RR04.5 River: 23-012 Wulff Run RM: 1.10 Date: 07/12/2018

Time Fished: 162 Distance: 0.150 Drainge (sq mi): 0.3 Depth: 0

Location: Overhill Lane (Limnotech RR04) Lat: 39.10202 Long: -84.63076

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 **Mlwb:** N/A

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

Site ID: RR05.5 River: 23-012 Wulff Run RM: 1.20 Date: 07/12/2018

Time Fished: 210 Distance: 0.150 Drainge (sq mi): 0.3 Depth: 0

Location: Foley Rd. @ Mitchell Way Court Lat: 39.10200 Long: -84.63080

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	2	4.0	100.00	0	0.00	0.0

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

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

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

Site ID: IC01 River: 23-019 Indian Creek RM: 0.30 Date: 07/10/2018

Time Fished: 729 Distance: 0.150 Drainge (sq mi): 2.3 Depth: 0

Location: Near TISCH Environmental Parking Lot Lat: 39.15282 Long: -84.74200

Species Code:	Species Name:	Feed Guild	Toler-ance	Breed Guild	IBI Group	No. Fish	Rel. No.	% by No.	Rel. Wt.	% by Wt.	Av. Wt.
43-043	BLUNTNOSE MINNOW	O	T	C	N	453	906.0	61.97	0	0.00	0.0
43-013	CREEK CHUB	G	T	N	N	112	224.0	15.32	0	0.00	0.0
43-044	CENTRAL STONEROLLER	H		N	N	101	202.0	13.82	0	0.00	0.0
77-008	GREEN SUNFISH	I	T	C	S	30	60.0	4.10	0	0.00	0.0
40-016	WHITE SUCKER	O	T	S	W	16	32.0	2.19	0	0.00	0.0
77-009	BLUEGILL SUNFISH	I	P	C	S	7	14.0	0.96	0	0.00	0.0
80-022	RAINBOW DARTER	I	M	S	D	6	12.0	0.82	0	0.00	0.0
77-006	LARGEMOUTH BASS	C		C	F	5	10.0	0.68	0	0.00	0.0
43-011	WESTERN BLACKNOSE DACE	G	T	S	N	1	2.0	0.14	0	0.00	0.0

No Species: 9 **Nat. Species:** 9 **Hybrids:** 0 **Total Counted:** 731 **Total Rel. Wt. :** 0

IBI: 26.0 **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: 07/10/2018

Time Fished: 552 Distance: 0.150 Drainge (sq mi): 1.3 Depth: 0

Location: Aston Oaks Golf Club Lat: 39.15384 Long: -84.72888

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	175	350.0	98.31	0	0.00	0.0
43-011	WESTERN BLACKNOSE DACE	G	T	S	N	2	4.0	1.12	0	0.00	0.0
43-044	CENTRAL STONEROLLER	H		N	N	1	2.0	0.56	0	0.00	0.0

No Species: 3 **Nat. Species:** 3 **Hybrids:** 0 **Total Counted:** 178 **Total Rel. Wt. :** 0

IBI: 22.0 **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: 07/10/2018

Time Fished: 489 Distance: 0.150 Drainge (sq mi): 1.0 Depth: 0

Location: Golf course hole #8 Lat: 39.15817 Long: -84.71631

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	513	1026.0	63.33	0	0.00	0.0
43-013	CREEK CHUB	G	T	N	N	179	358.0	22.10	0	0.00	0.0
43-011	WESTERN BLACKNOSE DACE	G	T	S	N	102	204.0	12.59	0	0.00	0.0
77-006	LARGEMOUTH BASS	C		C	F	10	20.0	1.23	0	0.00	0.0
43-044	CENTRAL STONEROLLER	H		N	N	5	10.0	0.62	0	0.00	0.0
57-001	WESTERN MOSQUITOFISH	I		N	E	1	2.0	0.12	0	0.00	0.0

No Species: 6 **Nat. Species:** 5 **Hybrids:** 0 **Total Counted:** 810 **Total Rel. Wt. :** 0

IBI: 38.0 **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: 07/10/2018

Time Fished: 661 Distance: 0.150 Drainge (sq mi): 0.5 Depth: 0

Location: Hampshire Rd. crossing Lat: 39.16016 Long: -84.75480

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	238	476.0	52.77	0	0.00	0.0
43-011	WESTERN BLACKNOSE DACE	G	T	S	N	208	416.0	46.12	0	0.00	0.0
77-009	BLUEGILL SUNFISH	I	P	C	S	3	6.0	0.67	0	0.00	0.0
77-006	LARGEMOUTH BASS	C		C	F	2	4.0	0.44	0	0.00	0.0

No Species: 4 **Nat. Species:** 4 **Hybrids:** 0 **Total Counted:** 451 **Total Rel. Wt. :** 0

IBI: 28.0 **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: 07/10/2018

Time Fished: 373 Distance: 0.150 Drainge (sq mi): 0.3 Depth: 0

Location: at dead end of Stonehaven Dr. Lat: 39.15182 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 **Mlwb:** N/A

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

Site ID: RR05 River: 23-067 RM: 0.70 Date: 07/12/2018

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

Location: Near intersection of Oakwood and Delhi Lat: 39.09353 Long: -84.62643

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: MU10 River: 23-071 Unnamed Trib to Muddy Creek @ RM2.37 RM: 0.50 Date: 07/12/2018

Time Fished: 108 Distance: 0.150 Drainge (sq mi): 0.7 Depth: 0

Location: Van Blaricum Rd. Lat: 39.12927 Long: -84.68078

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: 07/12/2018

Time Fished: 317 Distance: 0.150 Drainge (sq mi): 1.0 Depth: 0

Location: Werk and Qualhill Lat: 39.14131 Long: -84.64374

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	81	162.0	65.85	0	0.00	0.0
77-008	GREEN SUNFISH	I	T	C	S	34	68.0	27.64	0	0.00	0.0
77-015	GREEN SF X BLUEGILL SF					8	16.0	6.50	0	0.00	0.0

No Species: 2 **Nat. Species:** 2 **Hybrids:** 1 **Total Counted:** 123 **Total Rel. Wt. :** 0

IBI: 36.0 **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: 07/12/2018

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

Location: Werk Rd. and Westbourne Dr. Lat: 39.13789 Long: -84.63441

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 River: 23-075 Unnamed Trib to Muddy Creek @ RM0.3 RM: 0.40 Date: 07/11/2018

Time Fished: 240 Distance: 0.150 Drainge (sq mi): 2.8 Depth: 0

Location: VFW Post 6428 on Main Street Lat: 39.13817 Long: -84.71011

Species Code:	Species Name:	Feed Guild	Toler-ance	Breed Guild	IBI Group	No. Fish	Rel. No.	% by No.	Rel. Wt.	% by Wt.	Av. Wt.
43-044	CENTRAL STONEROLLER	H		N	N	251	502.0	50.50	0	0.00	0.0
43-013	CREEK CHUB	G	T	N	N	155	310.0	31.19	0	0.00	0.0
43-011	WESTERN BLACKNOSE DACE	G	T	S	N	49	98.0	9.86	0	0.00	0.0
40-016	WHITE SUCKER	O	T	S	W	18	36.0	3.62	0	0.00	0.0
43-043	BLUNTNOSE MINNOW	O	T	C	N	18	36.0	3.62	0	0.00	0.0
80-022	RAINBOW DARTER	I	M	S	D	6	12.0	1.21	0	0.00	0.0

No Species: 6 **Nat. Species:** 6 **Hybrids:** 0 **Total Counted:** 497 **Total Rel. Wt. :** 0

IBI: 34.0 **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: 07/10/2018

Time Fished: 500 Distance: 0.150 Drainge (sq mi): 2.6 Depth: 0

Location: First Str. Turns into Fiddles Green, Dst. Confluence Lat: 39.14305 Long: -84.70718

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	942	1884.0	62.72	0	0.00	0.0
43-044	CENTRAL STONEROLLER	H		N	N	411	822.0	27.36	0	0.00	0.0
43-013	CREEK CHUB	G	T	N	N	128	256.0	8.52	0	0.00	0.0
77-008	GREEN SUNFISH	I	T	C	S	10	20.0	0.67	0	0.00	0.0
43-043	BLUNTNOSE MINNOW	O	T	C	N	5	10.0	0.33	0	0.00	0.0
80-022	RAINBOW DARTER	I	M	S	D	5	10.0	0.33	0	0.00	0.0
40-016	WHITE SUCKER	O	T	S	W	1	2.0	0.07	0	0.00	0.0

No Species: 7 **Nat. Species:** 7 **Hybrids:** 0 **Total Counted:** 1502 **Total Rel. Wt. :** 0

IBI: 34.0 **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: 07/10/2018

Time Fished: 425 Distance: 0.150 Drainge (sq mi): 0.7 Depth: 0

Location: Aston Golf Club, access at 51 Oaks Dr. Lat: 39.15133 Long: -84.69617

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	98	196.0	100.00	0	0.00	0.0

No Species: 1 **Nat. Species:** 1 **Hybrids:** 0 **Total Counted:** 98 **Total Rel. Wt. :** 0

IBI: 20.0 **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: 07/10/2018

Time Fished: 527 Distance: 0.120 Drainge (sq mi): 1.3 Depth: 0

Location: Fiddler Green Rd. Lat: 39.14360 Long: -84.70280

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	90	225.0	65.22	0	0.00	0.0
43-044	CENTRAL STONEROLLER	H		N	N	25	62.5	18.12	0	0.00	0.0
43-013	CREEK CHUB	G	T	N	N	23	57.5	16.67	0	0.00	0.0

No Species: 3 **Nat. Species:** 3 **Hybrids:** 0 **Total Counted:** 138 **Total Rel. Wt. :** 0

IBI: 28.0 **MIwb:** N/A

Appendix B

Ohio River Direct Tributaries 2018 Macroinvertebrate Assemblage Data
B-1: ICI Metrics & Narratives
B-2: Macroinvertebrate Taxa by Site

Appendix Table B-1. ICI metrics and values for the Taylor Creek and Ohio River trib study areas in 2018.

Site_ID	River Mile	Drainage Area (sq mi)	Number of				Percent:						ICI or Narrative
			Total Taxa	Mayfly Taxa	Caddisfly Taxa	Dipteran Taxa	Mayflies	Caddis-flies	Tany-tarsini	Other Dipt/NI	Tolerant Organisms	Qual. EPT	
Taylor Creek (14-004)													
Year: 2018													
GM86	6.40	0.5										8	MG
GM85	5.30	2.2										7	F
Briarly Creek (14-148)													
Year: 2018													
GM91	3.90	0.3										4	SW
GM90	2.45	1.3										8	MG
GM89	1.80	2.1										9	MG
Wesselman Creek (14-149)													
Year: 2018													
GM94	4.70	1.1										6	SW
Unnamed Trib to Wesselman Creek @ RM 2.59 (14-275)													
Year: 2018													
GM100	1.28	1.4										7	SW
Unnamed Trib to Taylor Creek @ RM4.9 (14-277)													
Year: 2018													
GM106	0.28	0.9										6	SW
Muddy Creek (23-007)													
Year: 2018													
MU05	6.35	5.4										0	VP
MU04.5	5.60	7.7										1	VP
MU04	5.40	5.4										0	
MU03	3.10	10.3	24(2)	0(0)	0(0)	18(4)	0.0(0)	0.0(0)	12.8(4)	87.1(0)	41.5(0)	4(2)	12
MU02	2.25	12.1	26(4)	4(2)	5(6)	12(2)	7.2(2)	3.6(6)	32.3(6)	56.9(2)	3.1(6)	10(4)	40
Rapid Run (23-008)													
Year: 2018													
RR03	2.58	2.3										0	VP
RR02	1.10	5.8										7	F
RR01	0.35	6.5										8	MG
Unnamed Trib to Wulff Run @ (23-012)													
Year: 2018													
RR05.5	1.20	0.3										1	SW
RR04.5	1.10	0.3										4	SW
RR04	0.55	2.2										3	P

Narrative Codes, VP - Very Poor, P - Poor, F - Fair, MG - Marginally Good, G - Good, E - Excellent, SW - Spring Water Type A, P2 - Small Drainage Warm Water Stream

Appendix Table B-1. ICI metrics and values for the Taylor Creek and Ohio River trib study areas in 2018.

Site_ID	River Mile	Drainage Area (sq mi)	Number of				Percent:						ICI or Narrative
			Total Taxa	Mayfly Taxa	Caddisfly Taxa	Dipteran Taxa	Mayflies	Caddis-flies	Tany-tarsini	Other Dipt/NI	Tolerant Organisms	Qual. EPT	
Indian Creek (23-019)													
Year: 2018													
IC06	2.25	0.6										10	G
IC05	2.08	1.1										7	F
IC02	1.15	1.4										12	G
IC01	0.20	2.4										13	G
Trib to Indian Creek @RM1.02 RM0.97 (23-020)													
Year: 2018													
IC07	0.19	0.4										6	SW
UT @ 0.95 to UT to Muddy Creek @ RM0.3 (23-066)													
Year: 2018													
MU09	0.60											6	SW
Unnamed Trib to Wulff Run @ RM0.77 (23-067)													
Year: 2018													
RR05	0.68	1.4										1	VP
Unnamed Trib to Muddy Creek @ RM2.37 (23-071)													
Year: 2018													
MU10	0.50	0.7										2	VP
Unnamed Trib to Muddy Creek @ RM5.97 (23-072)													
Year: 2018													
MU12	0.59	1.0										3	VP
Unnamed Trib to Muddy Creek @ RM 6.53 (23-073)													
Year: 2018													
MU13	0.30	2.3										1	VP
Unnamed Trib to Unnamed Trib to Muddy Creek @ RM5. (23-074)													
Year: 2018													
MU14	0.20	0.1										1	P2
Unnamed Trib to Muddy Creek @ RM 0.3 (23-075)													
Year: 2018													
MU08	1.50											6	SW
MU07.5	0.90	2.5										6	F
MU07	0.45	2.8										10	G

Narrative Codes, VP - Very Poor, P - Poor, F - Fair, MG - Marginally Good, G - Good, E - Excellent, SW - Spring Water Type A, P2 - Small Drainage Warm Water Stream

Table B-2. Macroinvertebrate data from the Taylor Creek and Ohio River tributaries in 2018.

River Code: **14-004** River: ***Taylor Creek*** Coll. Date: *09/12/2018* RM: **5.30**

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

Taxa Code	Taxa	CWH Taxa	Tol.	Qt./Ql.
01801	Turbellaria		**F**	+
05900	Lirceus sp		**MT**	+
11120	Baetis flavistriga		**F**	+
11130	Baetis intercalaris		**F**	+
13400	Stenacron sp		**F**	+
13521	Stenonema femoratum		**F**	+
17200	Caenis sp		**F**	+
22001	Coenagrionidae		**T**	+
50301	Chimarra aterrima		**MI**	+
50315	Chimarra obscura		**MI**	+
68025	Ectopria sp		**F**	+
68075	Psephenus herricki		**MI**	+
69400	Stenelmis sp		**F**	+
74100	Simulium sp		**F**	+
77500	Conchapelopia sp		**F**	+
84450	Polypedilum (Uresipedilum) flavum		**F**	+

No. Quantitative Taxa:	0	Total Taxa;	16
No. Qualitative Taxa:	16	ICI:	F
Number of Organisms:	0	Qual EPT:	7

Table B-2. Macroinvertebrate data from the Taylor Creek and Ohio River tributaries in 2018.

River Code: **14-004** River: ***Taylor Creek*** Coll. Date: *09/21/2018* 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**	+
11120	Baetis flavistriga		**F**	+
11130	Baetis intercalaris		**F**	+
13400	Stenacron sp		**F**	+
17200	Caenis sp		**F**	+
21200	Calopteryx sp		**F**	+
22001	Coenagrionidae		**T**	+
50301	Chimarra aterrima		**MI**	+
50315	Chimarra obscura		**MI**	+
52200	Cheumatopsyche sp		**F**	+
52530	Hydropsyche depravata group		**F**	+
68075	Psephenus herricki		**MI**	+
69400	Stenelmis sp		**F**	+
71900	Tipula sp		**F**	+
74100	Simulium sp		**F**	+
77500	Conchapelopia sp		**F**	+
77800	Helopelopia sp		**F**	+
80001	Orthocladiinae			+
84470	Polypedilum (P.) illinoense		**T**	+
84540	Polypedilum (Tripodura) scalaenum group		**F**	+
95100	Physella sp		**T**	+
96264	Planorbella (Pierosoma) pilsbryi		**T**	+

No. Quantitative Taxa:	0	Total Taxa;	24
No. Qualitative Taxa:	24	ICI:	MG
Number of Organisms:	0	Qual EPT:	8

Table B-2. Macroinvertebrate data from the Taylor Creek and Ohio River tributaries in 2018.

River Code: **14-148** River: ***Briarly Creek*** Coll. Date: *09/20/2018* RM: **1.80**

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

Taxa Code	Taxa	CWH Taxa	Tol.	Qt./Ql.
01801	Turbellaria		**F**	+
03600	Oligochaeta		**T**	+
05900	Lirceus sp		**MT**	+
08601	Hydrachnidia		**F**	+
11120	Baetis flavistriga		**F**	+
11130	Baetis intercalaris		**F**	+
13400	Stenacron sp		**F**	+
13521	Stenonema femoratum		**F**	+
17200	Caenis sp		**F**	+
21200	Calopteryx sp		**F**	+
22001	Coenagrionidae		**T**	+
22300	Argia sp		**F**	+
50301	Chimarra aterrima		**MI**	+
51100	poss. Cernotina sp or Polycentropus sp		**MI**	+
52200	Cheumatopsyche sp		**F**	+
52530	Hydropsyche depravata group		**F**	+
68025	Ectopria sp		**F**	+
68075	Psephenus herricki		**MI**	+
69400	Stenelmis sp		**F**	+
74100	Simulium sp		**F**	+

No. Quantitative Taxa:	0	Total Taxa;	20
No. Qualitative Taxa:	20	ICI:	MG
Number of Organisms:	0	Qual EPT:	9

Table B-2. Macroinvertebrate data from the Taylor Creek and Ohio River tributaries in 2018.

River Code: **14-148** River: ***Briarly Creek*** Coll. Date: *09/20/2018* RM: **2.45**

Site ID: **GM90** Location: *Ust. bridge* 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**	+
11130	Baetis intercalaris		**F**	+
13400	Stenacron sp		**F**	+
13521	Stenonema femoratum		**F**	+
17200	Caenis sp		**F**	+
21200	Calopteryx sp		**F**	+
22001	Coenagrionidae		**T**	+
22300	Argia 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**	+
74100	Simulium sp		**F**	+
77500	Conchapelopia sp		**F**	+
84210	Paratendipes albimanus or P. duplicatus		**F**	+
84450	Polypedilum (Uresipedilum) flavum		**F**	+

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

Table B-2. Macroinvertebrate data from the Taylor Creek and Ohio River tributaries in 2018.

River Code: **14-148** River: ***Briarly Creek*** Coll. Date: *09/20/2018* RM: **3.90**

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

Taxa Code	Taxa	CWH Taxa	Tol.	Qt./Ql.
01801	Turbellaria		**F**	+
05900	Lirceus sp		**MT**	+
07800	Cambarus sp			+
11120	Baetis flavistriga		**F**	+
17200	Caenis sp		**F**	+
21200	Calopteryx sp		**F**	+
52200	Cheumatopsyche sp		**F**	+
52400	Hydropsyche sp or Ceratopsyche sp			+
68025	Ectopria sp		**F**	+
71900	Tipula sp		**F**	+
79100	Thienemannimyia group		**F**	+
84210	Paratendipes albimanus or P. duplicatus		**F**	+

No. Quantitative Taxa:	0	Total Taxa;	12
No. Qualitative Taxa:	12	ICI:	SW
Number of Organisms:	0	Qual EPT:	4

Table B-2. Macroinvertebrate data from the Taylor Creek and Ohio River tributaries in 2018.

River Code: **14-149** River: ***Wesselman Creek*** Coll. Date: *09/12/2018* 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**	+
05900	Lirceus sp		**MT**	+
06700	Crangonyx sp		**MT**	+
08601	Hydrachnidia		**F**	+
11120	Baetis flavistriga		**F**	+
13400	Stenacron sp		**F**	+
13521	Stenonema femoratum		**F**	+
21200	Calopteryx 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**	+
74100	Simulium sp		**F**	+
77500	Conchapelopia sp		**F**	+
80001	Orthocladiinae			+
84450	Polypedilum (Uresipedilum) flavum		**F**	+
84540	Polypedilum (Tripodura) scalaenum group		**F**	+
84750	Stictochironomus sp		**F**	+

No. Quantitative Taxa:	0	Total Taxa;	21
No. Qualitative Taxa:	21	ICI:	SW
Number of Organisms:	0	Qual EPT:	6

Table B-2. Macroinvertebrate data from the Taylor Creek and Ohio River tributaries in 2018.

River Code: **14-275** River: ***Unnamed Trib to Wesselman Creek @ RM 2.59*** Coll. Date: *09/21/2018* RM: **1.28**

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

Taxa Code	Taxa	CWH Taxa	Tol.	Qt./Ql.
01801	Turbellaria		**F**	+
03600	Oligochaeta		**T**	+
04664	Helobdella stagnalis		**T**	+
05900	Lirceus sp		**MT**	+
06904	Synurella dentata		**MT**	+
07800	Cambarus sp			+
08601	Hydrachnidia		**F**	+
11120	Baetis flavistriga		**F**	+
11130	Baetis intercalaris		**F**	+
13400	Stenacron sp		**F**	+
17200	Caenis sp		**F**	+
21200	Calopteryx sp		**F**	+
51600	Polycentropus sp		**MI**	+
52200	Cheumatopsyche sp		**F**	+
52530	Hydropsyche depravata group		**F**	+
68025	Ectopria sp		**F**	+
68075	Psephenus herricki		**MI**	+
69400	Stenelmis sp		**F**	+
72700	Anopheles sp		**F**	+
74100	Simulium sp		**F**	+
77500	Conchapelopia sp		**F**	+
79100	Thienemannimyia group		**F**	+
82141	Thienemanniella xena		**F**	+
84450	Polypedilum (Uresipedilum) flavum		**F**	+

No. Quantitative Taxa:	0	Total Taxa;	24
No. Qualitative Taxa:	24	ICI:	SW
Number of Organisms:	0	Qual EPT:	7

Table B-2. Macroinvertebrate data from the Taylor Creek and Ohio River tributaries in 2018.

River Code: **14-277** River: ***Unnamed Trib to Taylor Creek @ RM4.9*** Coll. Date: *09/12/2018* RM: **0.28**

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

Taxa Code	Taxa	CWH Taxa	Tol.	Qt./Ql.
01801	Turbellaria		**F**	+
05900	Lirceus sp		**MT**	+
08601	Hydrachnidia		**F**	+
11120	Baetis flavistriga		**F**	+
11130	Baetis intercalaris		**F**	+
17200	Caenis sp		**F**	+
21200	Calopteryx sp		**F**	+
50301	Chimarra aterrima		**MI**	+
52315	Diplectrona modesta	**X**	**F**	+
52530	Hydropsyche depravata group		**F**	+
68025	Ectopria sp		**F**	+
68075	Psephenus herricki		**MI**	+
77800	Helopelopia sp		**F**	+
84210	Paratendipes albimanus or P. duplicatus		**F**	+
85500	Paratanytarsus sp		**F**	+

No. Quantitative Taxa:	0	Total Taxa;	15
No. Qualitative Taxa:	15	ICI:	SW
Number of Organisms:	0	Qual EPT:	6

Table B-2. Macroinvertebrate data from the Taylor Creek and Ohio River tributaries in 2018.

River Code: **23-007** River: ***Muddy Creek*** Coll. Date: *08/28/2018* RM: **2.25**

Site ID: **MU02** Location: *Hillside Ave.* Sample:

Taxa Code	Taxa	CWH Taxa	Tol.	Qt./Ql.	
01801	Turbellaria		**F**	45	+
01900	Nemertea		**F**	8	
03600	Oligochaeta		**T**	80	+
04964	Erpobdella microstoma		**MT**		+
05900	Lirceus sp		**MT**	3	+
11120	Baetis flavistriga		**F**	31	+
11130	Baetis intercalaris		**F**	83	+
11200	Callibaetis sp		**MT**		+
13521	Stenonema femoratum		**F**	66	+
17200	Caenis sp		**F**	8	+
27001	Corduliidae				+
50301	Chimarra aterrima		**MI**		+
50315	Chimarra obscura		**MI**	3	+
52200	Cheumatopsyche sp		**F**	1	+
52430	Ceratopsyche morosa group		**MI**	1	
52530	Hydropsyche depravata group		**F**	1	+
53800	Hydroptila sp		**F**	88	+
65800	Berosus sp		**MT**	2	+
67500	Laccobius sp		**F**		+
68075	Psephenus herricki		**MI**		+
68130	Helichus sp		**F**		+
69400	Stenelmis sp		**F**		+
77120	Ablabesmyia mallochi		**F**	19	
77500	Conchapelopia sp		**F**	75	
77800	Helopelopia sp		**F**		+
80370	Corynoneura lobata		**F**	19	
80410	Cricotopus (C.) sp		**F**	131	+
80411	Cricotopus (Isocladius) sp nr. absurdus		**MT**	19	+
80420	Cricotopus (C.) bicinctus		**T**		+
80430	Cricotopus (C.) tremulus group		**MT**	75	
80480	Cricotopus (Isocladius) sp		**MT**		+
83040	Dicrotendipes neomodestus		**F**	187	+
84450	Polypedilum (Uresipedilum) flavum		**F**	506	
84540	Polypedilum (Tripodura) scalaenum group		**F**	75	+
84960	Pseudochironomus sp		**F**	243	+
85625	Rheotanytarsus sp		**F**	693	
85800	Tanytarsus sp		**F**		+
85821	Tanytarsus glabrescens group sp 7		**F**	150	

No. Quantitative Taxa:	26	Total Taxa;	38
No. Qualitative Taxa:	29	ICI:	40
Number of Organisms:	2612	Qual EPT:	10

Table B-2. Macroinvertebrate data from the Taylor Creek and Ohio River tributaries in 2018.

River Code: **23-007** River: ***Muddy Creek*** Coll. Date: *08/28/2018* RM: **3.10**

Site ID: **MU03** Location: Sample:

Taxa Code	Taxa	CWH Taxa	Tol.	Qt./Ql.	
01320	Hydra sp		F	4	
01801	Turbellaria		F	167	+
03600	Oligochaeta		T	393	+
04666	Helobdella papillata		MT		+
05900	Lirceus sp		MT	2	+
06700	Crangonyx sp		MT		+
11120	Baetis flavistriga		F		+
13521	Stenonema femoratum		F		+
21200	Calopteryx sp		F		+
22001	Coenagrionidae		T		+
22300	Argia sp		F		+
27000	Corduliidae or Libellulidae				+
50315	Chimarra obscura		MI		+
52530	Hydropsyche depravata group		F		+
68075	Psephenus herricki		MI	1	+
68708	Dubiraphia vittata group		F		+
69400	Stenelmis sp		F		+
74650	Atrichopogon sp		F	1	
77500	Conchapelopia sp		F	14	+
77800	Helopelopia sp		F	19	+
78140	Labrundinia pilosella		F	5	
78350	Meropelopia sp	X	F		+
78601	Pentaneura inyoensis		F	5	+
80001	Orthocladiinae			5	
82730	Chironomus (C.) decorus group		T	5	
83040	Dicrotendipes neomodestus		F	48	+
83051	Dicrotendipes simpsoni		T	5	
83300	Glyptotendipes (G.) sp		MT	5	
84210	Paratendipes albimanus or P. duplicatus		F		+
84450	Polypedilum (Uresipedilum) flavum		F	24	
84470	Polypedilum (P.) illinoense		T	19	
84540	Polypedilum (Tripodura) scalaenum group		F	135	+
84960	Pseudochironomus sp		F	29	
85500	Paratanytarsus sp		F	5	
85625	Rheotanytarsus sp		F	14	
85800	Tanytarsus sp		F	5	
85821	Tanytarsus glabrescens group sp 7		F	106	
96120	Menetus (Micromenetus) dilatatus		MT	2	

No. Quantitative Taxa:	24	Total Taxa;	38
No. Qualitative Taxa:	23	ICI:	12
Number of Organisms:	1018	Qual EPT:	4

Table B-2. Macroinvertebrate data from the Taylor Creek and Ohio River tributaries in 2018.

River Code: **23-007** River: ***Muddy Creek*** Coll. Date: *08/29/2018* RM: **5.40**

Site ID: **MU04** Location: *Ebenezer Rd.* Sample:

Taxa Code	Taxa	CWH Taxa	Tol.	Qt./Ql.
01801	Turbellaria		**F**	+
03600	Oligochaeta		**T**	+
04664	Helobdella stagnalis		**T**	+
04964	Erpobdella microstoma		**MT**	+
77500	Conchapelopia sp		**F**	+
80420	Cricotopus (C.) bicinctus		**T**	+
82770	Chironomus (C.) riparius group		**T**	+
83000	Dicrotendipes sp		**F**	+
83003	Dicrotendipes fumidus		**F**	+
83040	Dicrotendipes neomodestus		**F**	+
84450	Polypedilum (Uresipedilum) flavum		**F**	+
84470	Polypedilum (P.) illinoense		**T**	+
84960	Pseudochironomus sp		**F**	+

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

Table B-2. Macroinvertebrate data from the Taylor Creek and Ohio River tributaries in 2018.

River Code: **23-007** River: ***Muddy Creek*** Coll. Date: *08/29/2018* RM: **5.60**

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

Taxa Code	Taxa	CWH Taxa	Tol.	Qt./Ql.
01801	Turbellaria		**F**	+
03600	Oligochaeta		**T**	+
04964	Erpobdella microstoma		**MT**	+
22001	Coenagrionidae		**T**	+
28208	Erythemis simplicicollis		**MT**	+
51100	poss. Cernotina sp or Polycentropus sp		**MI**	+
69400	Stenelmis sp		**F**	+
71900	Tipula sp		**F**	+
74501	Ceratopogonidae		**T**	+
77120	Ablabesmyia mallochi		**F**	+
82730	Chironomus (C.) decorus group		**T**	+
83003	Dicrotendipes fumidus		**F**	+
83040	Dicrotendipes neomodestus		**F**	+
84450	Polypedilum (Uresipedilum) flavum		**F**	+
84470	Polypedilum (P.) illinoense		**T**	+
84960	Pseudochironomus sp		**F**	+
85800	Tanytarsus sp		**F**	+

No. Quantitative Taxa:	0	Total Taxa;	17
No. Qualitative Taxa:	17	ICI:	VP
Number of Organisms:	0	Qual EPT:	1

Table B-2. Macroinvertebrate data from the Taylor Creek and Ohio River tributaries in 2018.

River Code: **23-007** River: ***Muddy Creek*** Coll. Date: *08/29/2018* 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**	+
63900	Laccophilus sp		**T**	+
72700	Anopheles sp		**F**	+
72900	Culex sp		**T**	+
78702	Psectrotanypus dyari		**VT**	+
82730	Chironomus (C.) decorus group		**T**	+
82770	Chironomus (C.) riparius group		**T**	+
83003	Dicrotendipes fumidus		**F**	+
84470	Polypedilum (P.) illinoense		**T**	+
95100	Physella sp		**T**	+

No. Quantitative Taxa:	0	Total Taxa;	11
No. Qualitative Taxa:	11	ICI:	VP
Number of Organisms:	0	Qual EPT:	0

Table B-2. Macroinvertebrate data from the Taylor Creek and Ohio River tributaries in 2018.

River Code: **23-008** River: ***Rapid Run*** Coll. Date: *08/09/2018* RM: **0.35**

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

Taxa Code	Taxa	CWH Taxa	Tol.	Qt./Ql.
01801	Turbellaria		**F**	+
03600	Oligochaeta		**T**	+
05900	Lirceus sp		**MT**	+
08601	Hydrachnidia		**F**	+
11120	Baetis flavistriga		**F**	+
11130	Baetis intercalaris		**F**	+
11200	Callibaetis sp		**MT**	+
13521	Stenonema femoratum		**F**	+
17200	Caenis sp		**F**	+
28001	Libellulidae		**MT**	+
50301	Chimarra aterrima		**MI**	+
51600	Polycentropus sp		**MI**	+
52200	Cheumatopsyche sp		**F**	+
66500	Enochrus sp		**MT**	+
66901	Helocombus bifidus		**MT**	+
68075	Psephenus herricki		**MI**	+
68201	Scirtidae		**F**	+
69400	Stenelmis sp		**F**	+
74100	Simulium sp		**F**	+
74501	Ceratopogonidae		**T**	+
77120	Ablabesmyia mallochi		**F**	+
77750	Hayesomyia senata or Thienemannimyia norena		**F**	+
78601	Pentaneura inyoensis		**F**	+
80410	Cricotopus (C.) sp		**F**	+
80420	Cricotopus (C.) bicinctus		**T**	+
83003	Dicrotendipes fumidus		**F**	+
83040	Dicrotendipes neomodestus		**F**	+
84450	Polypedilum (Uresipedilum) flavum		**F**	+
84470	Polypedilum (P.) illinoense		**T**	+
84960	Pseudochironomus sp		**F**	+

No. Quantitative Taxa:	0	Total Taxa;	30
No. Qualitative Taxa:	30	ICI:	MG
Number of Organisms:	0	Qual EPT:	8

Table B-2. Macroinvertebrate data from the Taylor Creek and Ohio River tributaries in 2018.

River Code: **23-008** River: ***Rapid Run*** Coll. Date: *08/09/2018* RM: **1.10**

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

Taxa Code	Taxa	CWH Taxa	Tol.	Qt./Ql.
01801	Turbellaria		**F**	+
01900	Nemertea		**F**	+
03600	Oligochaeta		**T**	+
05900	Lirceus sp		**MT**	+
08601	Hydrachnidia		**F**	+
11120	Baetis flavistriga		**F**	+
11130	Baetis intercalaris		**F**	+
11200	Callibaetis sp		**MT**	+
13521	Stenonema femoratum		**F**	+
44501	Corixidae		**F**	+
52200	Cheumatopsyche sp		**F**	+
52530	Hydropsyche depravata group		**F**	+
53800	Hydroptila sp		**F**	+
65800	Berosus sp		**MT**	+
66500	Enochrus sp		**MT**	+
67400	Hydrophilus sp			+
67700	Paracymus sp		**MT**	+
68075	Psephenus herricki		**MI**	+
72700	Anopheles sp		**F**	+
72900	Culex sp		**T**	+
77120	Ablabesmyia mallochi		**F**	+
77750	Hayesomyia senata or Thienemannimyia norena		**F**	+
78601	Pentaneura inyoensis		**F**	+
80410	Cricotopus (C.) sp		**F**	+
80413				+
80420	Cricotopus (C.) bicinctus		**T**	+
83000	Dicrotendipes sp		**F**	+
83003	Dicrotendipes fumidus		**F**	+
83040	Dicrotendipes neomodestus		**F**	+
84210	Paratendipes albimanus or P. duplicatus		**F**	+
84470	Polypedilum (P.) illinoense		**T**	+
84960	Pseudochironomus sp		**F**	+
85200	Cladotanytarsus sp			+
85500	Paratanytarsus sp		**F**	+
85800	Tanytarsus sp		**F**	+
85821	Tanytarsus glabrescens group sp 7		**F**	+
86501	Stratiomyidae			+
87250	Odontomyia (Odontomyiina) sp		**MT**	+
94400	Fossaria sp		**MT**	+
95100	Physella sp		**T**	+

No. Quantitative Taxa:	0	Total Taxa;	40
No. Qualitative Taxa:	40	ICI:	F
Number of Organisms:	0	Qual EPT:	7

Table B-2. Macroinvertebrate data from the Taylor Creek and Ohio River tributaries in 2018.

River Code: **23-008** River: ***Rapid Run*** Coll. Date: *08/09/2018* RM: **2.58**

Site ID: **RR03** Location: Sample:

Taxa Code	Taxa	CWH Taxa	Tol.	Qt./Ql.
01801	Turbellaria		**F**	+
03600	Oligochaeta		**T**	+
45900	Notonecta sp		**T**	+
72150	Pericoma sp		**MT**	+
72600	Aedes sp		**T**	+
72700	Anopheles sp		**F**	+
82710	Chironomus (C.) sp		**MT**	+
95100	Physella sp		**T**	+

No. Quantitative Taxa:	0	Total Taxa;	8
No. Qualitative Taxa:	8	ICI:	VP
Number of Organisms:	0	Qual EPT:	0

Table B-2. Macroinvertebrate data from the Taylor Creek and Ohio River tributaries in 2018.

River Code: **23-012** River: ***Wulff Run*** Coll. Date: *08/10/2018* RM: **0.55**

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

Taxa Code	Taxa	CWH Taxa	Tol.	Qt./Ql.
01801	Turbellaria		**F**	+
03600	Oligochaeta		**T**	+
04901	Erpobdellidae		**MT**	+
05900	Lirceus sp		**MT**	+
08601	Hydrachnidia		**F**	+
11120	Baetis flavistriga		**F**	+
21200	Calopteryx sp		**F**	+
22001	Coenagrionidae		**T**	+
28001	Libellulidae		**MT**	+
50301	Chimarra aterrima		**MI**	+
53501	Hydroptilidae		**F**	+
67811	Staphylinidae		**F**	+
69400	Stenelmis sp		**F**	+
71900	Tipula sp		**F**	+
77800	Helopelopia sp		**F**	+
79100	Thienemannimyia group		**F**	+
79701	Diamesinae			+
83003	Dicrotendipes fumidus		**F**	+
83040	Dicrotendipes neomodestus		**F**	+
84210	Paratendipes albimanus or P. duplicatus		**F**	+

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

No. Quantitative Taxa:	0	Total Taxa;	20
No. Qualitative Taxa:	20	ICI:	P
Number of Organisms:	0	Qual EPT:	3

Table B-2. Macroinvertebrate data from the Taylor Creek and Ohio River tributaries in 2018.

River Code: **23-012** River: ***Unnamed Trib to Wulff Run*** @ Coll. Date: *08/10/2018* RM: **1.10**

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

Taxa Code	Taxa	CWH Taxa	Tol.	Qt./Ql.
01801	Turbellaria		**F**	+
03600	Oligochaeta		**T**	+
05900	Lirceus sp		**MT**	+
06904	Synurella dentata		**MT**	+
07800	Cambarus sp			+
11120	Baetis flavistriga		**F**	+
21200	Calopteryx sp		**F**	+
50301	Chimarra aterrima		**MI**	+
52200	Cheumatopsyche sp		**F**	+
52530	Hydropsyche depravata group		**F**	+
77800	Helopelopia sp		**F**	+
84210	Paratendipes albimanus or P. duplicatus		**F**	+
84540	Polypedilum (Tripodura) scalaenum group		**F**	+
95100	Physella sp		**T**	+

No. Quantitative Taxa:	0	Total Taxa;	14
No. Qualitative Taxa:	14	ICI:	SW
Number of Organisms:	0	Qual EPT:	4

Table B-2. Macroinvertebrate data from the Taylor Creek and Ohio River tributaries in 2018.

River Code: **23-012** River: ***Unnamed Trib to Wulff Run*** @ Coll. Date: *08/28/2018* RM: **1.20**

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**	+
04901	Erpobdellidae		**MT**	+
05900	Lirceus sp		**MT**	+
07800	Cambarus sp			+
11120	Baetis flavistriga		**F**	+
21200	Calopteryx sp		**F**	+
21700	Lestes sp			+
67811	Staphylinidae		**F**	+
68025	Ectopria sp		**F**	+
79400	Zavrelimyia sp	**X**	**F**	+
83040	Dicrotendipes neomodestus		**F**	+
84210	Paratendipes albimanus or P. duplicatus		**F**	+
85800	Tanytarsus sp		**F**	+
95100	Physella sp		**T**	+

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

Table B-2. Macroinvertebrate data from the Taylor Creek and Ohio River tributaries in 2018.

River Code: **23-019** River: ***Indian Creek*** Coll. Date: *09/14/2018* RM: **0.20**

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

Taxa Code	Taxa	CWH Taxa	Tol.	Qt./Ql.
01801	Turbellaria		**F**	+
05900	Lirceus sp		**MT**	+
06904	Synurella dentata		**MT**	+
11120	Baetis flavistriga		**F**	+
11130	Baetis intercalaris		**F**	+
11650	Procloeon sp (w/ hindwing pads)		**MI**	+
13400	Stenacron sp		**F**	+
13521	Stenonema femoratum		**F**	+
15000	Paraleptophlebia sp		**F**	+
17200	Caenis sp		**F**	+
22001	Coenagrionidae		**T**	+
50301	Chimarra aterrima		**MI**	+
50315	Chimarra obscura		**MI**	+
51600	Polycentropus sp		**MI**	+
52200	Cheumatopsyche sp		**F**	+
52315	Diplectrona modesta	**X**	**F**	+
52530	Hydropsyche depravata group		**F**	+
68025	Ectopria sp		**F**	+
68075	Psephenus herricki		**MI**	+
69400	Stenelmis sp		**F**	+
71900	Tipula sp		**F**	+
74100	Simulium sp		**F**	+
76001	Chironomidae			+

No. Quantitative Taxa:	0	Total Taxa;	23
No. Qualitative Taxa:	23	ICI:	G
Number of Organisms:	0	Qual EPT:	13

Table B-2. Macroinvertebrate data from the Taylor Creek and Ohio River tributaries in 2018.

River Code: **23-019** River: ***Indian Creek*** Coll. Date: *09/13/2018* RM: **1.15**

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

Taxa Code	Taxa	CWH Taxa	Tol.	Qt./Ql.
01801	Turbellaria		**F**	+
03360	Plumatella sp		**F**	+
03600	Oligochaeta		**T**	+
05900	Lirceus sp		**MT**	+
06904	Synurella dentata		**MT**	+
07800	Cambarus sp			+
08250	Orconectes (Procericambarus) rusticus		**F**	+
08601	Hydrachnidia		**F**	+
11120	Baetis flavistriga		**F**	+
11430	Diphetor hageni		**MI**	+
11651	Procloeon sp (w/o hindwing pads)		**MI**	+
13400	Stenacron sp		**F**	+
13521	Stenonema femoratum		**F**	+
17200	Caenis sp		**F**	+
21200	Calopteryx sp		**F**	+
22001	Coenagrionidae		**T**	+
22300	Argia sp		**F**	+
50301	Chimarra aterrima		**MI**	+
50315	Chimarra obscura		**MI**	+
51600	Polycentropus sp		**MI**	+
52200	Cheumatopsyche sp		**F**	+
52530	Hydropsyche depravata group		**F**	+
57400	Neophylax sp		**MI**	+
68025	Ectopria sp		**F**	+
68075	Psephenus herricki		**MI**	+
69400	Stenelmis sp		**F**	+
77500	Conchapelopia sp		**F**	+

No. Quantitative Taxa:	0	Total Taxa;	27
No. Qualitative Taxa:	27	ICI:	G
Number of Organisms:	0	Qual EPT:	12

Table B-2. Macroinvertebrate data from the Taylor Creek and Ohio River tributaries in 2018.

River Code: **23-019** River: ***Indian Creek*** Coll. Date: *09/13/2018* RM: **2.08**

Site ID: **IC05** Location: *Golf course hole #8* Sample:

Taxa Code	Taxa	CWH Taxa	Tol.	Qt./Ql.
01801	Turbellaria		**F**	+
03600	Oligochaeta		**T**	+
05900	Lirceus sp		**MT**	+
06700	Crangonyx sp		**MT**	+
06904	Synurella dentata		**MT**	+
11120	Baetis flavistriga		**F**	+
11130	Baetis intercalaris		**F**	+
13521	Stenonema femoratum		**F**	+
17200	Caenis sp		**F**	+
21200	Calopteryx sp		**F**	+
22001	Coenagrionidae		**T**	+
22300	Argia sp		**F**	+
28955	Plathemis lydia		**T**	+
50301	Chimarra aterrima		**MI**	+
50315	Chimarra obscura		**MI**	+
52530	Hydropsyche depravata group		**F**	+
60900	Peltodytes sp		**MT**	+
68025	Ectopria sp		**F**	+
68075	Psephenus herricki		**MI**	+
69400	Stenelmis sp		**F**	+
74100	Simulium sp		**F**	+

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

Table B-2. Macroinvertebrate data from the Taylor Creek and Ohio River tributaries in 2018.

River Code: **23-019** River: ***Indian Creek*** Coll. Date: *09/13/2018* RM: **2.25**

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**	+
06904	Synurella dentata		**MT**	+
11120	Baetis flavistriga		**F**	+
11130	Baetis intercalaris		**F**	+
11651	Procloeon sp (w/o hindwing pads)		**MI**	+
13400	Stenacron sp		**F**	+
17200	Caenis sp		**F**	+
21200	Calopteryx sp		**F**	+
22001	Coenagrionidae		**T**	+
50301	Chimarra aterrima		**MI**	+
52200	Cheumatopsyche sp		**F**	+
52315	Diplectrona modesta	**X**	**F**	+
52530	Hydropsyche depravata group		**F**	+
53501	Hydroptilidae		**F**	+
68025	Ectopria sp		**F**	+
68075	Psephenus herricki		**MI**	+
69400	Stenelmis sp		**F**	+
77800	Helopelopia sp		**F**	+
83820	Microtendipes "caelum" (sensu Simpson & Bode, 1980)		**MI**	+
84210	Paratendipes albimanus or P. duplicatus		**F**	+
84315	Phaenopsectra flavipes		**MT**	+
95100	Physella sp		**T**	+

No. Quantitative Taxa:	0	Total Taxa;	24
No. Qualitative Taxa:	24	ICI:	G
Number of Organisms:	0	Qual EPT:	10

Table B-2. Macroinvertebrate data from the Taylor Creek and Ohio River tributaries in 2018.

River Code: **23-020** River: ***Trib to Indian Creek @RM1.02 RM0.97*** Coll. Date: *09/14/2018* RM: **0.19**

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

Taxa Code	Taxa	CWH Taxa	Tol.	Qt./Ql.
03600	Oligochaeta		**T**	+
05900	Lirceus sp		**MT**	+
06904	Synurella dentata		**MT**	+
07800	Cambarus sp			+
11120	Baetis flavistriga		**F**	+
21200	Calopteryx sp		**F**	+
50301	Chimarra aterrima		**MI**	+
52200	Cheumatopsyche sp		**F**	+
52315	Diplectrona modesta	**X**	**F**	+
52530	Hydropsyche depravata group		**F**	+
57400	Neophylax sp		**MI**	+
68025	Ectopria sp		**F**	+
69400	Stenelmis sp		**F**	+
77750	Hayesomyia senata or Thienemannimyia norena		**F**	+
77800	Helopelopia sp		**F**	+
79400	Zavrelimyia sp	**X**	**F**	+
84210	Paratendipes albimanus or P. duplicatus		**F**	+
84450	Polypedilum (Uresipedilum) flavum		**F**	+
84540	Polypedilum (Tripodura) scalaenum group		**F**	+
95100	Physella sp		**T**	+

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

Table B-2. Macroinvertebrate data from the Taylor Creek and Ohio River tributaries in 2018.

River Code: **23-066** River: ***UT @ 0.95 to UT to Muddy Creek @ RM0.3*** Coll. Date: *09/05/2018* RM: **0.60**

Site ID: **MU09** Location: Sample:

Taxa Code	Taxa	CWH Taxa	Tol.	Qt./Ql.
01801	Turbellaria		**F**	+
05900	Lirceus sp		**MT**	+
06904	Synurella dentata		**MT**	+
11120	Baetis flavistriga		**F**	+
15000	Paraleptophlebia sp		**F**	+
21200	Calopteryx sp		**F**	+
50301	Chimarra aterrima		**MI**	+
52200	Cheumatopsyche sp		**F**	+
52315	Diplectrona modesta	**X**	**F**	+
52530	Hydropsyche depravata group		**F**	+
68025	Ectopria sp		**F**	+
68075	Psephenus herricki		**MI**	+
69400	Stenelmis sp		**F**	+
74100	Simulium sp		**F**	+
83040	Dicrotendipes neomodestus		**F**	+
83840	Microtendipes pedellus group		**F**	+
84210	Paratendipes albimanus or P. duplicatus		**F**	+

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

No. Quantitative Taxa:	0	Total Taxa;	17
No. Qualitative Taxa:	17	ICI:	SW
Number of Organisms:	0	Qual EPT:	6

Table B-2. Macroinvertebrate data from the Taylor Creek and Ohio River tributaries in 2018.

River Code: **23-067** River: ***Unnamed Trib to Wulff Run @ RM0.77*** Coll. Date: *08/28/2018* RM: **0.68**

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**	+
05900	Lirceus sp		**MT**	+
07800	Cambarus sp			+
08601	Hydrachnidia		**F**	+
53800	Hydroptila sp		**F**	+
72700	Anopheles sp		**F**	+
77120	Ablabesmyia mallochi		**F**	+
80490	Cricotopus (Isocladius) intersectus group		**MT**	+
82501	Chironomini			+
82710	Chironomus (C.) sp		**MT**	+
83003	Dicrotendipes fumidus		**F**	+
84210	Paratendipes albimanus or P. duplicatus		**F**	+
84470	Polypedilum (P.) illinoense		**T**	+
84960	Pseudochironomus sp		**F**	+
85800	Tanytarsus sp		**F**	+
95100	Physella sp		**T**	+
98001	Pisidiidae			+

No. Quantitative Taxa:	0	Total Taxa;	18
No. Qualitative Taxa:	18	ICI:	VP
Number of Organisms:	0	Qual EPT:	1

Table B-2. Macroinvertebrate data from the Taylor Creek and Ohio River tributaries in 2018.

River Code: **23-071** River: ***Unnamed Trib to Muddy Creek @ RM2.37*** Coll. Date: *10/01/2018* RM: **0.50**

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

Taxa Code	Taxa	CWH Taxa	Tol.	Qt./Ql.
01801	Turbellaria		**F**	+
05900	Lirceus sp		**MT**	+
06904	Synurella dentata		**MT**	+
07800	Cambarus sp			+
11120	Baetis flavistriga		**F**	+
52315	Diplectrona modesta	**X**	**F**	+
68025	Ectopria sp		**F**	+
68075	Psephenus herricki		**MI**	+
69400	Stenelmis sp		**F**	+
71900	Tipula sp		**F**	+

No. Quantitative Taxa:	0	Total Taxa;	10
No. Qualitative Taxa:	10	ICI:	VP
Number of Organisms:	0	Qual EPT:	2

Table B-2. Macroinvertebrate data from the Taylor Creek and Ohio River tributaries in 2018.

River Code: **23-072** River: ***Unnamed Trib to Muddy Creek @ RM5.97*** Coll. Date: *08/31/2018* RM: **0.59**

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

Taxa Code	Taxa	CWH Taxa	Tol.	Qt./Ql.
01801	Turbellaria		**F**	+
03600	Oligochaeta		**T**	+
05900	Lirceus sp		**MT**	+
08601	Hydrachnidia		**F**	+
11200	Callibaetis sp		**MT**	+
17200	Caenis sp		**F**	+
22001	Coenagrionidae		**T**	+
27600	Epitheca (Tetragoneuria) sp		**MT**	+
28208	Erythemis simplicicollis		**MT**	+
28500	Libellula sp		**MT**	+
28705	Pachydiplax longipennis		**T**	+
45900	Notonecta sp		**T**	+
54200	Orthotrichia sp		**F**	+
69400	Stenelmis sp		**F**	+
77100	Ablabesmyia sp			+
84450	Polypedilum (Uresipedilum) flavum		**F**	+

No. Quantitative Taxa:	0	Total Taxa;	16
No. Qualitative Taxa:	16	ICI:	VP
Number of Organisms:	0	Qual EPT:	3

Table B-2. Macroinvertebrate data from the Taylor Creek and Ohio River tributaries in 2018.

River Code: **23-073** River: ***Unnamed Trib to Muddy Creek @ RM 6.53*** Coll. Date: *09/30/2018* RM: **0.30**

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

Taxa Code	Taxa	CWH Taxa	Tol.	Qt./Ql.
01801	Turbellaria		**F**	+
03600	Oligochaeta		**T**	+
51600	Polycentropus sp		**MI**	+
70800	Erioptera sp		**MT**	+
77250	Alotanypus venustus		**VT**	+
77355	Clinotanypus pinguis		**MT**	+
78350	Meropelopia sp	**X**	**F**	+
78401	Natarsia species A (sensu Roback, 1978)		**T**	+
80510	Cricotopus (Isocladius) sylvestris group		**T**	+
82730	Chironomus (C.) decorus group		**T**	+
82770	Chironomus (C.) riparius group		**T**	+
83003	Dicrotendipes fumidus		**F**	+
83040	Dicrotendipes neomodestus		**F**	+
84470	Polypedilum (P.) illinoense		**T**	+
85500	Paratanytarsus sp		**F**	+
85800	Tanytarsus sp		**F**	+
95100	Physella sp		**T**	+

No. Quantitative Taxa:	0	Total Taxa;	17
No. Qualitative Taxa:	17	ICI:	VP
Number of Organisms:	0	Qual EPT:	1

Table B-2. Macroinvertebrate data from the Taylor Creek and Ohio River tributaries in 2018.

River Code: **23-074** River: ***Unnamed Trib to Unnamed Trib to Muddy Creek*** @ Coll. Date: *08/31/2018* RM: **0.20**

Site ID: **MU14** Location: *Andres Ln. crossing* Sample:

Taxa Code	Taxa	CWH Taxa	Tol.	Qt./Ql.
01801	Turbellaria		**F**	+
07830	Cambarus (Cambarus) ortmanni			+
52200	Cheumatopsyche sp		**F**	+
71700	Pilaria sp		**F**	+
72900	Culex sp		**T**	+
77250	Alotanypus venustus		**VT**	+
78350	Meropelopia sp	**X**	**F**	+
78401	Natarsia species A (sensu Roback, 1978)		**T**	+
84210	Paratendipes albimanus or P. duplicatus		**F**	+
84450	Polypedilum (Uresipedilum) flavum		**F**	+
95100	Physella sp		**T**	+
98200	Pisidium sp		**MT**	+

No. Quantitative Taxa:	0	Total Taxa;	12
No. Qualitative Taxa:	12	ICI:	P2
Number of Organisms:	0	Qual EPT:	1

Table B-2. Macroinvertebrate data from the Taylor Creek and Ohio River tributaries in 2018.

River Code: **23-075** River: ***Unnamed Trib to Muddy Creek @RM0.3*** Coll. Date: *09/05/2018* RM: **0.45**

Site ID: **MU07** Location: *VFW Post 6428 on Main Street* Sample:

Taxa Code	Taxa	CWH Taxa	Tol.	Qt./Ql.
01801	Turbellaria		**F**	+
03600	Oligochaeta		**T**	+
05900	Lirceus sp		**MT**	+
06904	Synurella dentata		**MT**	+
08601	Hydrachnidia		**F**	+
11120	Baetis flavistriga		**F**	+
11645	Procloeon sp		**MI**	+
13521	Stenonema femoratum		**F**	+
15000	Paraleptophlebia sp		**F**	+
17200	Caenis sp		**F**	+
21200	Calopteryx sp		**F**	+
51100	poss. Cernotina sp or Polycentropus sp		**MI**	+
52200	Cheumatopsyche sp		**F**	+
52315	Diplectrona modesta	**X**	**F**	+
52430	Ceratopsyche morosa group		**MI**	+
52530	Hydropsyche depravata group		**F**	+
68075	Psephenus herricki		**MI**	+
69400	Stenelmis sp		**F**	+
74100	Simulium sp		**F**	+
77750	Hayesomyia senata or Thienemannimyia norena		**F**	+
77800	Helopelopia sp		**F**	+
83840	Microtendipes pedellus group		**F**	+
84210	Paratendipes albimanus or P. duplicatus		**F**	+
84450	Polypedilum (Uresipedilum) flavum		**F**	+
87400	Stratiomys sp		**MT**	+
95100	Physella sp		**T**	+

No. Quantitative Taxa:	0	Total Taxa;	26
No. Qualitative Taxa:	26	ICI:	G
Number of Organisms:	0	Qual EPT:	10

Table B-2. Macroinvertebrate data from the Taylor Creek and Ohio River tributaries in 2018.

River Code: **23-075** River: ***Unnamed Trib to Muddy Creek @RM0.3*** Coll. Date: *09/05/2018* RM: **0.90**

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

Taxa Code	Taxa	CWH Taxa	Tol.	Qt./Ql.	Taxa Code	Taxa	CWH Taxa	Tol.	Qt./Ql.
01801	Turbellaria		F	+					
05900	Lirceus sp		MT	+					
06904	Synurella dentata		MT	+					
11120	Baetis flavistriga		F	+					
11130	Baetis intercalaris		F	+					
13521	Stenonema femoratum		F	+					
52200	Cheumatopsyche sp		F	+					
52315	Diplectrona modesta	X	F	+					
52530	Hydropsyche depravata group		F	+					
68075	Psephenus herricki		MI	+					
69400	Stenelmis sp		F	+					
71900	Tipula sp		F	+					
74100	Simulium sp		F	+					
77500	Conchapelopia sp		F	+					
79400	Zavrelimyia sp	X	F	+					
79720	Diamesa sp	X	F	+					
87601	Dolichopodidae		MT	+					

No. Quantitative Taxa:	0	Total Taxa;	17
No. Qualitative Taxa:	17	ICI:	F
Number of Organisms:	0	Qual EPT:	6

Table B-2. Macroinvertebrate data from the Taylor Creek and Ohio River tributaries in 2018.

River Code: **23-075** River: ***Unnamed Trib to Muddy Creek @ RM 0.3*** Coll. Date: *10/01/2018* RM: **1.50**

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

Taxa Code	Taxa	CWH Taxa	Tol.	Qt./Ql.
01801	Turbellaria		F	+
05900	Lirceus sp		MT	+
06904	Synurella dentata		MT	+
07830	Cambarus (Cambarus) ortmanni			+
08601	Hydrachnidia		F	+
11120	Baetis flavistriga		F	+
13400	Stenacron sp		F	+
17200	Caenis sp		F	+
21200	Calopteryx sp		F	+
52200	Cheumatopsyche sp		F	+
52315	Diplectrona modesta	X	F	+
52530	Hydropsyche depravata group		F	+
68025	Ectopria sp		F	+
68075	Psephenus herricki		MI	+
69400	Stenelmis sp		F	+
71900	Tipula sp		F	+
83840	Microtendipes pedellus group		F	+
84200	Paratendipes sp		F	+
85800	Tanytarsus sp		F	+

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

Appendix C

Ohio River Direct Tributaries 2018 Habitat Data
C-1: QHEI Metrics & Scores

Appendix C-1. QHEI metric scores for sites in Taylor Creek and Muddy Creek study areas during 2018.

River Mile	QHEI	QHEI Metrics: Substrate	Cover	Channel	Riparian	Pool	Riffle	Gradient & Score	Narrative
(14004) Taylor Creek									
Year: 2018									
6.40	**46.50**	15.0	6.0	10.0	5.00	4.0	2.5	62.50 - (4)	**Fair**
5.30	**46.00**	13.0	9.0	11.0	5.00	4.0	0.0	111.0 - (4)	**Fair**
(14148) Briarly Creek									
Year: 2018									
3.90	**56.50**	16.0	13.0	13.0	5.50	5.0	0.0	100.0 - (4)	**Fair**
2.45	**54.75**	15.0	10.0	12.0	5.25	5.0	3.5	50.00 - (4)	**Fair**
1.80	**57.50**	21.0	8.0	11.0	5.00	5.0	4.5	66.70 - (4)	**Fair**
(14149) Wesselman Creek									
Year: 2018									
4.70	**53.00**	16.0	10.0	10.0	5.00	4.0	0.0	33.30 - (8)	**Fair**
(14275) Unnamed Trib to Wesselman Creek @ RM2.95									
Year: 2018									
1.05	**48.50**	11.0	9.0	11.0	4.50	5.0	4.0	66.70 - (4)	**Fair**
(14277) Unnamed Trib to Taylor Creek @ RM4.9									
Year: 2018									
0.20	**58.00**	19.0	9.0	11.0	5.00	5.0	5.0	93.70 - (4)	**Fair**
(23007) Muddy Creek									
Year: 2018									
5.62	**48.50**	12.0	9.0	11.0	4.50	4.0	0.0	40.00 - (8)	**Fair**
5.45	**55.50**	18.0	10.0	9.0	5.50	5.0	0.0	33.00 - (8)	**Fair**
2.80	**60.00**	18.0	12.0	12.0	7.00	7.0	0.0	52.50 - (4)	**Good**
(23008) Rapid Run									
Year: 2018									
1.05	**45.50**	17.0	5.0	9.0	7.50	3.0	0.0	100.0 - (4)	**Fair**
(23012) Wulff Run									
Year: 2018									
1.20	**57.00**	16.0	14.0	13.0	6.00	4.0	0.0	100.0 - (4)	**Fair**
1.10	**51.00**	16.0	13.0	10.0	5.00	3.0	0.0	100.0 - (4)	**Fair**
0.45	**48.75**	16.0	10.0	9.0	5.75	4.0	0.0	58.50 - (4)	**Fair**
(23019) Indian Creek									
Year: 2018									
2.30	**55.00**	14.0	15.0	13.0	5.00	4.0	0.0	153.0 - (4)	**Fair**
1.15	**51.50**	16.0	11.0	13.0	4.50	3.0	0.0	121.0 - (4)	**Fair**

Appendix C-1. QHEI metric scores for sites in Taylor Creek and Muddy Creek study areas during 2018.

River Mile	QHEI	QHEI Metrics: Substrate	Cover	Channel	Riparian	Pool	Riffle	Gradient & Score	Narrative
(23020) Trib. to Indian Creek (RM 1.02)									
Year: 2018									
0.10	**57.00**	18.0	12.0	12.0	7.00	4.0	0.0	188.0 - (4)	**Fair**
(23071) Unnamed Trib to Muddy Creek @ RM2.37									
Year: 2018									
0.50	**56.00**	19.0	10.0	12.0	8.00	3.0	0.0	200.0 - (4)	**Fair**
(23072) Unnamed Trib to Muddy Creek @ RM5.97									
Year: 2018									
0.55	**50.00**	14.0	10.0	11.0	6.00	5.0	0.0	100.0 - (4)	**Fair**
(23075) Unnamed Trib to Muddy Creek @ RM0.3									
Year: 2018									
1.72	**53.50**	16.0	11.0	11.0	6.50	5.0	0.0	125.0 - (4)	**Fair**
0.80	**52.50**	18.0	11.0	11.0	4.50	4.0	0.0	100.0 - (4)	**Fair**
0.40	**58.00**	18.0	12.0	11.0	4.00	5.0	0.0	40.00 - (8)	**Fair**
(23076) UT RM0.95 to UT to Muddy Creek @ RM0.3									
Year: 2018									
0.10	**50.00**	19.0	9.0	11.0	4.00	3.0	0.0	125.0 - (4)	**Fair**

Appendix D

Ohio River Direct Tributaries 2018 Primary Headwater Habitat Data
D-1: PHWH Evaluation & HHEI Metrics & Scores

Appendix D1. Primary Headwater Aquatic Life Use information for the Taylor Creek and Muddy Creek study area.

Site ID	RM	Year	River	Location:
IC02	**1.15**	**2018**	Indian Creek	Aston Oaks Golf Club

HHEI Info: HHEI Score: ***75.0*** Substrate: **35.0** Pool: **20.0** Bankfull **20.0** Channel: ***Natural*** Flow: ***Flowing***

QHEI Info: QHEI Score: ***51.5*** Substrate: **16.0** Pool: **3.0** Max Z.: **< 20 cm** Channel **13.0** Flow: ***Flowing***

Drainage Size: **1.40** Riffle: **0.0** Ripar: **4.5** Cover: **11.0** PHW Class: **WWH**

FISH Info: IBI Score: **22.0** Species: **3.0** Sensitive Sp.: **0.0** % Pioneer: **98.3** Headwater Sp. **1.00**

MACRO Info: ICI Score: QUAL EPT: **12** Coldwater Taxa.: **0** Intols: Sens. **7** Toler: V. Tol.

Salamanders: **X** Adults: Larvae: **5** *Eurycea cirrigera*

IC05	**2.08**	**2018**	Indian Creek	

HHEI Info: HHEI Score: ***91.0*** Substrate: **41.0** Pool: **20.0** Bankfull **30.0** Channel: ***Natural*** Flow: ***Flowing***

QHEI Info: QHEI Score: ***54.5*** Substrate: **16.0** Pool: **5.0** Max Z.: **20-40 cm** Channel **9.5** Flow: ***Flowing***

Drainage Size: **1.07** Riffle: **0.0** Ripar: **8.0** Cover: **12.0** PHW Class: **WWH**

FISH Info: IBI Score: **38.0** Species: **6.0** Sensitive Sp.: **0.0** % Pioneer: **22.1** Headwater Sp. **1.00**

MACRO Info: ICI Score: QUAL EPT: **7** Coldwater Taxa.: **0** Intols: Sens. **3** Toler: V. Tol.

Salamanders: **X** Adults: Larvae: **3** *Eurycea cirrigera*

IC06	**2.25**	**2018**	Indian Creek	Hampshire Rd. crossing

HHEI Info: HHEI Score: ***87.0*** Substrate: **42.0** Pool: **20.0** Bankfull **25.0** Channel: ***Natural*** Flow: ***Flowing***

QHEI Info: QHEI Score: ***55.0*** Substrate: **14.0** Pool: **4.0** Max Z.: **40-70 cm** Channel **13.0** Flow: ***Flowing***

Drainage Size: **0.62** Riffle: **0.0** Ripar: **5.0** Cover: **15.0** PHW Class: **WWH**

FISH Info: IBI Score: **28.0** Species: **4.0** Sensitive Sp.: **0.0** % Pioneer: **52.8** Headwater Sp. **1.00**

MACRO Info: ICI Score: QUAL EPT: **10** Coldwater Taxa.: **1** Intols: Sens. **4** Toler: V. Tol.

Salamanders: **X** Adults: Larvae: **6** *Eurycea cirrigera*

IC07	**0.10**	**2018**	Trib to Indian Creek @RM1.02 RM0.97	at dead end of Stonehaven Dr.

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

QHEI Info: QHEI Score: ***57.0*** Substrate: **18.0** Pool: **4.0** Max Z.: **20-40 cm** Channel **12.0** Flow: ***Flowing***

Drainage Size: **0.39** Riffle: **0.0** Ripar: **7.0** Cover: **12.0** PHW Class: **PHW3A**

FISH Info: IBI Score: **12.0** Species: **0.0** Sensitive Sp.: **0.0** % Pioneer: **0.00** Headwater Sp. **0.00**

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

Salamanders: **X** Adults: Larvae: **1** *Eurycea cirrigera*

Appendix D1. Primary Headwater Aquatic Life Use information for the Taylor Creek and Muddy Creek study area.

Site ID	RM	Year	River	Location:
IC01	**0.20**	**2018**	Indian Creek	Near TISCH Environmental Parking Lot

HHEI Info: HHEI Score: ***73.0*** Substrate: **23.0** Pool: **20.0** Bankfull **30.0** Channel: ***Natural*** Flow: ***Flowing***

QHEI Info: QHEI Score: ***43.5*** Substrate: **10.0** Pool: **5.0** Max Z.: **40-70 cm** Channel **9.5** Flow: ***Flowing***

Drainage Size: **2.35** Riffle: **0.0** Ripar: **5.0** Cover: **10.0** PHW Class: **WWH**

FISH Info: IBI Score: **26.0** Species: **9.0** Sensitive Sp.: **1.0** % Pioneer: **81.4** Headwater Sp. **1.00**

MACRO Info: ICI Score: QUAL EPT: **13** Coldwater Taxa.: **1** Intols: Sens. **5** Toler: V. Tol.

Salamanders: **X** Adults: Larvae: **1** *Eurycea cirrigera*

GM85	**5.30**	**2018**	Taylor Creek	Ust. Johnson Rd.

HHEI Info: HHEI Score: ***90.0*** Substrate: **40.0** Pool: **20.0** Bankfull **30.0** Channel: ***Natural*** Flow: ***Flowing***

QHEI Info: QHEI Score: ***46.0*** Substrate: **13.0** Pool: **4.0** Max Z.: **20-40 cm** Channel **11.0** Flow: ***Flowing***

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

FISH Info: IBI Score: **34.0** Species: **5.0** Sensitive Sp.: **0.0** % Pioneer: **27.1** Headwater Sp. **1.00**

MACRO Info: ICI Score: QUAL EPT: **7** Coldwater Taxa.: **0** Intols: Sens. **3** Toler: V. Tol.

Salamanders: **X** Adults: Larvae: **1** *Eurycea cirrigera*

GM106	**0.20**	**2018**	Unnamed Trib to Taylor Creek @ RM4.9	Adj. to private drive

HHEI Info: HHEI Score: ***90.0*** Substrate: **40.0** Pool: **20.0** Bankfull **30.0** Channel: ***Natural*** Flow: ***Flowing***

QHEI Info: QHEI Score: ***58.0*** Substrate: **19.0** Pool: **5.0** Max Z.: **40-70 cm** Channel **11.0** Flow: ***Flowing***

Drainage Size: **0.92** Riffle: **5.0** Ripar: **5.0** Cover: **9.0** PHW Class: **WWH**

FISH Info: IBI Score: **42.0** Species: **9.0** Sensitive Sp.: **0.0** % Pioneer: **66.4** Headwater Sp. **2.00**

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

Salamanders: **X** Adults: Larvae: **2** *Eurycea cirrigera*

GM94	**4.70**	**2018**	Wesselman Creek	Ust. Wesselman Rd.

HHEI Info: HHEI Score: ***87.0*** Substrate: **37.0** Pool: **20.0** Bankfull **30.0** Channel: ***Natural*** Flow: ***Flowing***

QHEI Info: QHEI Score: ***53.0*** Substrate: **16.0** Pool: **4.0** Max Z.: **20-40 cm** Channel **10.0** Flow: ***Flowing***

Drainage Size: **1.10** Riffle: **0.0** Ripar: **5.0** Cover: **10.0** PHW Class: **PHW3A**

FISH Info: IBI Score: **22.0** Species: **3.0** Sensitive Sp.: **0.0** % Pioneer: **89.7** Headwater Sp. **0.00**

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

Salamanders: **X** Adults: Larvae: **2** *Eurycea cirrigera*

Appendix D1. Primary Headwater Aquatic Life Use information for the Taylor Creek and Muddy Creek study area.

Site ID	RM	Year	River	Location:
GM91	**3.90**	**2018**	Briarly Creek	Ust. private drive

HHEI Info: HHEI Score: ***70.0*** Substrate: **30.0** Pool: **20.0** Bankfull **20.0** Channel: ***Natural*** Flow: ***Flowing***

QHEI Info: QHEI Score: ***56.5*** Substrate: **16.0** Pool: **5.0** Max Z.: **40-70 cm** Channel **13.0** Flow: ***Flowing***

Drainage Size: **0.34** Riffle: **0.0** Ripar: **5.5** Cover: **13.0** PHW Class: **PHW3A**

FISH Info: IBI Score: **24.0** Species: **2.0** Sensitive Sp.: **0.0** % Pioneer: **85.3** Headwater Sp. **0.00**

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

Salamanders: **X** Adults: Larvae: **8** *Eurycea cirrigera*

GM89	**1.80**	**2018**	Briarly Creek	Adj. Briarly Creek

HHEI Info: HHEI Score: ***88.0*** Substrate: **38.0** Pool: **20.0** Bankfull **30.0** Channel: ***Natural*** Flow: ***Flowing***

QHEI Info: QHEI Score: ***57.5*** Substrate: **21.0** Pool: **5.0** Max Z.: **20-40 cm** Channel **11.0** Flow: ***Flowing***

Drainage Size: **2.10** Riffle: **4.5** Ripar: **5.0** Cover: **8.0** PHW Class: **WWH**

FISH Info: IBI Score: **30.0** Species: **4.0** Sensitive Sp.: **0.0** % Pioneer: **38.7** Headwater Sp. **1.00**

MACRO Info: ICI Score: QUAL EPT: **9** Coldwater Taxa.: **0** Intols: Sens. **3** Toler: V. Tol.

Salamanders: **X** Adults: Larvae: **8** *Eurycea cirrigera*

GM90	**2.45**	**2018**	Briarly Creek	Ust. bridge

HHEI Info: HHEI Score: ***97.0*** Substrate: **37.0** Pool: **30.0** Bankfull **30.0** Channel: ***Natural*** Flow: ***Flowing***

QHEI Info: QHEI Score: ***54.7*** Substrate: **15.0** Pool: **5.0** Max Z.: **20-40 cm** Channel **12.0** Flow: ***Flowing***

Drainage Size: **1.30** Riffle: **3.5** Ripar: **5.2** Cover: **10.0** PHW Class: **WWH**

FISH Info: IBI Score: **26.0** Species: **2.0** Sensitive Sp.: **0.0** % Pioneer: **63.5** Headwater Sp. **0.00**

MACRO Info: ICI Score: QUAL EPT: **8** Coldwater Taxa.: **0** Intols: Sens. **2** Toler: V. Tol.

Salamanders: **X** Adults: Larvae: **8** *Eurycea cirrigera*

GM100	**1.05**	**2018**	Unnamed Trib to Wesselman Creek @ RM2.59	Ust. Rockview Rd.

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

QHEI Info: QHEI Score: ***48.5*** Substrate: **11.0** Pool: **5.0** Max Z.: **40-70 cm** Channel **11.0** Flow: ***Flowing***

Drainage Size: **0.91** Riffle: **4.0** Ripar: **4.5** Cover: **9.0** PHW Class: **PHW3A**

FISH Info: IBI Score: **24.0** Species: **2.0** Sensitive Sp.: **0.0** % Pioneer: **100** Headwater Sp. **0.00**

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

Salamanders: **X** Adults: Larvae: **8** *Eurycea cirrigera*

Appendix D1. Primary Headwater Aquatic Life Use information for the Taylor Creek and Muddy Creek study area.

Site ID	RM	Year	River	Location:
GM86	**6.40**	**2018**	Taylor Creek	Reemelin Rd.

HHEI Info: HHEI Score: ***80.0*** Substrate: **30.0** Pool: **20.0** Bankfull **30.0** Channel: ***Natural*** Flow: ***Flowing***

QHEI Info: QHEI Score: ***46.5*** Substrate: **15.0** Pool: **4.0** Max Z.: **20-40 cm** Channel **10.0** Flow: ***Flowing***

Drainage Size: **1.20** Riffle: **2.5** Ripar: **5.0** Cover: **6.0** PHW Class: **WWH**

FISH Info: IBI Score: **32.0** Species: **4.0** Sensitive Sp.: **0.0** % Pioneer: **45.1** Headwater Sp. **0.00**

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

Salamanders: **X** Adults: Larvae: **7** *Eurycea cirrigera*

RR03 **2.58** **2018** Rapid Run

HHEI Info: HHEI Score: ***88.0*** Substrate: **38.0** Pool: **20.0** Bankfull **30.0** Channel: ***Natural*** Flow: ***Flowing***

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

Drainage Size: **2.32** Riffle: Ripar: Cover: PHW Class: **PHW3A**

FISH Info: IBI Score: **12.0** Species: **1.0** 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: V. Tol.

Salamanders: Adults: Larvae:

RR04 **0.45** **2018** Wulff Run Wulff Run Rd.

HHEI Info: HHEI Score: ***95.0*** Substrate: **35.0** Pool: **30.0** Bankfull **30.0** Channel: ***Natural*** Flow: ***Flowing***

QHEI Info: QHEI Score: ***48.7*** Substrate: **16.0** Pool: **4.0** Max Z.: **20-40 cm** Channel **9.0** Flow: ***Flowing***

Drainage Size: **2.18** Riffle: **0.0** Ripar: **5.7** Cover: **10.0** PHW Class: **WWH**

FISH Info: IBI Score: **20.0** Species: **1.0** Sensitive Sp.: **0.0** % Pioneer: **100** Headwater Sp. **0.00**

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

Salamanders: **X** Adults: Larvae: **2** *Eurycea cirrigera*

RR04.5 **1.10** **2018** Unnamed Trib to Wulff Run @ Overhill Lane (Limnotech RR04)

HHEI Info: HHEI Score: ***77.0*** Substrate: **37.0** Pool: **20.0** Bankfull **20.0** Channel: ***Natural*** Flow: ***Flowing***

QHEI Info: QHEI Score: ***51.0*** Substrate: **16.0** Pool: **3.0** Max Z.: **< 20 cm** Channel **10.0** Flow: ***Flowing***

Drainage Size: **0.33** Riffle: **0.0** Ripar: **5.0** Cover: **13.0** PHW Class: **PHW3A**

FISH Info: IBI Score: **12.0** Species: **0.0** Sensitive Sp.: **0.0** % Pioneer: **0.00** Headwater Sp. **0.00**

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

Salamanders: **X** Adults: Larvae: **3** *Eurycea cirrigera*

Appendix D1. Primary Headwater Aquatic Life Use information for the Taylor Creek and Muddy Creek study area.

Site ID	RM	Year	River	Location:
RR05.5	**1.20**	**2018**	Unnamed Trib to Wulff Run @	Foley Rd. @ Mitchell Way Court

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

QHEI Info: QHEI Score: ***57.0*** Substrate: **16.0** Pool: **4.0** Max Z.: **20-40 cm** Channel **13.0** Flow: ***Flowing***

Drainage Size: **0.33** Riffle: **0.0** Ripar: **6.0** Cover: **14.0** PHW Class: **PHW3A**

FISH Info: IBI Score: **12.0** Species: **1.0** Sensitive Sp.: **0.0** % Pioneer: **0.00** Headwater Sp. **0.00**

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

Salamanders: **X** Adults: Larvae: **1** *Eurycea cirrigera*

RR05 **0.68** **2018** Unnamed Trib to Wulff Run @ RM0.77 Near intersection of Oakwood and Delhi

HHEI Info: HHEI Score: ***101.0*** Substrate: **41.0** Pool: **30.0** Bankfull **30.0** Channel: ***Recovering*** Flow: ***Flowing***

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

Drainage Size: **1.38** Riffle: Ripar: Cover: PHW Class: **WWH**

FISH Info: IBI Score: **12.0** Species: **1.0** Sensitive Sp.: **0.0** % Pioneer: **0.00** Headwater Sp. **0.00**

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

Salamanders: Adults: Larvae:

MU12 **0.55** **2018** Unnamed Trib to Muddy Creek @ RM5.97 Werk and Qualhill

HHEI Info: HHEI Score: ***78.0*** Substrate: **28.0** Pool: **20.0** Bankfull **30.0** Channel: ***Natural*** Flow: ***Flowing***

QHEI Info: QHEI Score: ***50.0*** Substrate: **14.0** Pool: **5.0** Max Z.: **40-70 cm** Channel **11.0** Flow: ***Flowing***

Drainage Size: **1.01** Riffle: **0.0** Ripar: **6.0** Cover: **10.0** PHW Class: **WWH**

FISH Info: IBI Score: **36.0** Species: **2.0** Sensitive Sp.: **0.0** % Pioneer: **27.6** Headwater Sp. **0.00**

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

Salamanders: **X** Adults: Larvae: **1** *Eurycea cirrigera*

MU13 **0.30** **2018** Unnamed Trib to Muddy Creek @ RM6.53

HHEI Info: HHEI Score: ***90.0*** Substrate: **35.0** Pool: **25.0** Bankfull **30.0** Channel: ***Natural*** Flow: ***Flowing***

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

Drainage Size: **2.25** Riffle: Ripar: Cover: PHW Class: **WWH**

FISH Info: IBI Score: **12.0** Species: **1.0** Sensitive Sp.: **0.0** % Pioneer: **0.00** Headwater Sp. **0.00**

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

Salamanders: Adults: Larvae:

Appendix D1. Primary Headwater Aquatic Life Use information for the Taylor Creek and Muddy Creek study area.

Site ID	RM	Year	River	Location:
MU09	**0.10**	**2018**	UT RM 0.95 to UT to Muddy Creek @RM0.3	

HHEI Info: HHEI Score: ***89.0*** Substrate: **34.0** Pool: **30.0** Bankfull **25.0** Channel: ***Natural*** Flow: ***Flowing***

QHEI Info: QHEI Score: ***50.0*** Substrate: **19.0** Pool: **3.0** Max Z.: **< 20 cm** Channel **11.0** Flow: ***Flowing***

Drainage Size: **1.33** Riffle: **0.0** Ripar: **4.0** Cover: **9.0** PHW Class:**PHW3A**

FISH Info: IBI Score: **28.0** Species: **3.0** Sensitive Sp.: **0.0** % Pioneer: **16.7** Headwater Sp. **1.00**

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

Salamanders:**X** Adults: Larvae: **7** *Eurycea cirrigera*

MU07.5	**0.80**	**2018**	Unnamed Trib to Muddy Creek @RM0.3	First Str. Turns into Fiddles Green, Dst. Confluence

HHEI Info: HHEI Score: ***84.0*** Substrate: **34.0** Pool: **20.0** Bankfull **30.0** Channel: ***Natural*** Flow: ***Flowing***

QHEI Info: QHEI Score: ***52.5*** Substrate: **18.0** Pool: **4.0** Max Z.: **20-40 cm** Channel **11.0** Flow: ***Flowing***

Drainage Size: **2.60** Riffle: **0.0** Ripar: **4.5** Cover: **11.0** PHW Class:**WWH**

FISH Info: IBI Score: **34.0** Species: **7.0** Sensitive Sp.: **1.0** % Pioneer: **9.52** Headwater Sp. **1.00**

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

Salamanders:**X** Adults: Larvae: **4** *Eurycea cirrigera*

MU10	**0.50**	**2018**	Unnamed Trib to Muddy Creek @ RM2.37	Van Blaricum Rd.

HHEI Info: HHEI Score: ***95.0*** Substrate: **35.0** Pool: **30.0** Bankfull **30.0** Channel: ***Natural*** Flow: ***Flowing***

QHEI Info: QHEI Score: ***56.0*** Substrate: **19.0** Pool: **3.0** Max Z.: **< 20 cm** Channel **12.0** Flow: ***Flowing***

Drainage Size: **0.71** Riffle: **0.0** Ripar: **8.0** Cover: **10.0** PHW Class:**WWH**

FISH Info: IBI Score: **12.0** 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: Adults: Larvae:

MU08	**1.50**	**2018**	Unnamed Trib to Muddy Creek @ RM 0.3	Aston Golf Club, access at 51 Oaks Dr.

HHEI Info: HHEI Score: ***95.0*** Substrate: **37.0** Pool: **25.0** Bankfull **30.0** Channel: ***Natural*** Flow: ***Flowing***

QHEI Info: QHEI Score: ***53.5*** Substrate: **16.0** Pool: **5.0** Max Z.: **40-70 cm** Channel **11.0** Flow: ***Flowing***

Drainage Size: **1.21** Riffle: **0.0** Ripar: **6.5** Cover: **11.0** PHW Class:**PHW3A**

FISH Info: IBI Score: **20.0** Species: **1.0** Sensitive Sp.: **0.0** % Pioneer: **100** Headwater Sp. **0.00**

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

Salamanders:**X** Adults: Larvae: **5** *Eurycea cirrigera*

Appendix E

Ohio River Direct Tributaries 2018 Chemical Water Quality Data

E-1: 2018 Sampling Sites
E-2: Heavy Metal Detections in Water
E-3: Volatile Organic Compounds in Water and Sediment
E-4: Raw Chemical Data

(Contact Chris Hall, MSDGC at Chris.Hall@cincinnati-oh.gov for Excel files)

Appendix Table E-1. *Master list of 2018 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				

Site ID	River Mile	Drainage Area (sq. mi.)	Al (mg/L)	Arsenic by ICP-MS (ppb)	Arsenic (mg/L)	Ca (mg/L)	Cadmium by ICP-MS (ppb)	Copper (mg/kg)	Copper by ICP-MS (ppb)	Fe (mg/L)	Lead by ICP-MS (ppb)	Lead (mg/L)	Magnesium (mg/L)	Selenium (mg/L)	Strontium (mg/L)	Thallium (mg/L)	Titanium (mg/L)	Vanadium (mg/L)	Zinc (mg/L)
Muddy Creek (23-007)																			
MU05	6.25	5.39	-	2.90	AA	52.50	AA	AA	0.65	1.50	0.37	AA	8.14	AA	0.18	AA	0.04	0.01	0.01
MU04.5	5.60	7.71	-	2.15	AA	63.50	AA	0.01	1.39	1.00	0.62	AA	10.93	AA	0.24	AA	AA	AA	0.03
MU04	5.40	7.80	-	2.80	AA	67.50	AA	0.00	1.40	1.00	AA	AA	12.07	AA	0.24	AA	AA	AA	0.00
MU03	3.10	10.40	-	0.90	AA	76.00	0.07	0.00	1.95	AA	0.14	AA	13.27	AA	0.33	AA	AA	AA	0.00
MU02	2.25	12.10	-	0.81	AA	95.50	AA	0.00	1.95	AA	0.15	AA	13.90	AA	0.37	AA	AA	AA	0.01
MU01	0.20	13.60	-	2.00	AA	41.50	AA	0.00	3.07	2.00	1.94	0.01	10.47	AA	0.24	AA	0.01	AA	0.01
Unnamed Tributary to Muddy Creek @ RM 0.3 (23-075)																			
MU08	1.72	0.74	-	2.00	AA	118.50	0.06	0.01	1.75	AA	0.15	AA	22.03	AA	0.40	AA	AA	AA	0.01
MU07.5	0.80	2.60	-	1.35	0.03	112.00	0.08	0.00	1.75	AA	0.13	AA	17.80	AA	0.42	AA	AA	AA	0.01
MU07	0.40	2.80	-	1.30	AA	104.50	0.09	0.00	1.70	AA	0.17	AA	16.75	AA	0.40	AA	AA	AA	0.01
UT RM 0.95 to UT to Muddy Creek @ RM 0.3 (95-066)																			
MU09	0.10	1.33	-	1.15	0.03	110.50	0.05	0.01	1.75	AA	0.09	AA	18.72	0.03	0.43	AA	0.00	AA	0.01
Unnamed Tributary to Muddy Creek @ RM 2.37 (23-071)																			
MU10	0.50	0.71	-	1.60	0.03	98.50	0.07	0.01	4.65	1.00	1.40	AA	16.24	AA	0.35	AA	0.01	AA	0.02
Unnamed Tributary to Muddy Creek @ RM 5.97 (23-072)																			
MU12	0.55	1.01	-	2.15	AA	44.50	0.13	0.01	7.25	1.00	0.31	AA	7.10	AA	0.15	AA	0.01	AA	0.01
Unnamed Tributary to Muddy Creek @ RM 6.53 (23-073)																			
MU13	0.60	2.25	-	2.45	AA	70.50	0.12	0.01	1.15	1.00	0.42	AA	10.26	AA	0.26	AA	AA	AA	0.01
Unnamed Tributary to Unnamed Tributary to Muddy Creek @ RM 5.97 (23-074)																			
MU14	0.20	2.70	-	3.75	0.02	73.00	AA	0.00	2.30	2.00	0.47	AA	11.96	AA	0.25	AA	0.00	AA	0.01
Rapid Run (23-008)																			
RR03	2.58	2.32	-	1.55	0.02	92.00	AA	0.01	1.25	1.00	0.22	AA	14.87	AA	0.43	AA	AA	AA	0.01
RR02	1.10	5.90	-	0.57	0.02	103.00	AA	0.01	2.90	AA	0.25	AA	17.13	AA	0.54	AA	0.00	AA	0.00
RR01	0.35	5.99	-	0.61	0.02	89.00	AA	0.01	2.30	AA	0.11	AA	15.86	AA	0.42	AA	0.00	AA	0.01
Wulff Run (23-012)																			
RR05	0.68	1.33	0.01	1.40	0.02	80.50	AA	0.01	1.85	AA	0.19	AA	13.36	AA	0.26	0.02	0.00	AA	0.01
RR04	0.55	2.18	-	1.10	0.03	106.00	AA	0.01	2.70	AA	0.23	AA	17.19	AA	0.35	AA	AA	AA	0.01
Unnamed Tributary to Wulff Run @ RM 0.77 (23-067)																			
RR05.5	1.20	1.00	-	1.30	AA	110.00	0.09	0.00	2.20	AA	0.24	AA	20.44	AA	0.35	AA	0.00	AA	0.01
RR04.5	1.10	0.34	-	1.80	AA	107.00	0.08	0.01	2.80	AA	0.26	AA	19.30	AA	0.34	AA	0.00	AA	0.01
Indian Creek (23-019)																			
IC06	2.25	0.58	-	1.30	0.03	136.50	0.10	0.01	1.10	AA	0.19	AA	21.48	AA	0.48	AA	AA	AA	0.01
IC05	2.08	1.07	-	1.15	0.03	132.50	AA	0.01	1.07	AA	0.45	AA	20.60	AA	0.49	AA	AA	AA	0.01
IC02	1.15	1.38	-	1.40	AA	96.50	AA	0.00	1.20	AA	0.12	AA	15.91	AA	0.40	AA	0.01	AA	0.00
IC01	0.20	2.30	-	1.35	AA	117.00	0.10	0.00	1.40	AA	0.16	AA	19.48	AA	0.57	AA	0.00	AA	0.01
Unnamed Tributary to Indian Creek @RM 1.02 (23-020)																			
IC07	0.19	0.39	-	0.97	0.03	124.00	AA	0.01	1.20	1.00	0.19	0.01	18.57	AA	0.45	AA	0.01	AA	0.01
Taylor Creek (14-004)																			
GM86	6.50	0.49	-	1.79	0.02	102.50	AA	0.00	2.08	AA	0.13	AA	19.62	AA	0.39	AA	AA	AA	0.01
GM85	5.30	2.22	-	1.92	0.03	108.50	0.06	0.01	2.85	3.50	1.00	AA	20.21	AA	0.42	AA	0.02	0.01	0.01
Unnamed Tributary to Taylor Creek @ RM4.9 (14-277)																			
GM106	0.28	0.92	-	1.40	0.03	99.50	AA	0.01	1.34	AA	0.36	AA	17.79	AA	0.40	AA	AA	AA	0.01
Briarly Creek (14-148)																			
GM91	3.90	0.34	-	1.30	0.02	108.50	0.05	0.01	2.55	AA	0.20	AA	20.71	AA	0.42	AA	0.00	AA	0.02
GM90	2.55	1.30	-	1.35	0.02	104.00	AA	0.01	2.30	AA	0.41	AA	18.96	AA	0.38	AA	**0.00**	AA	0.01
GM89	1.98	2.10	-	1.35	0.02	94.50	0.06	0.00	2.24	AA	0.18	0.02	19.00	AA	0.36	AA	AA	AA	0.03
Wesselman Creek (14-149)																			
GM94	4.75	1.10	-	1.53	0.02	125.00	0.05	0.00	2.32	1.00	0.29	AA	20.32	AA	0.47	AA	0.00	AA	0.01
Unnamed Tributary to Wesselman Creek @ RM2.95 (14-275)																			
GM100	1.28	0.91	-	1.88	0.02	106.50	0.05	0.01	2.25	AA	0.29	0.01	15.94	0.03	0.40	AA	0.00	AA	0.01

AA - below method detection limit

Appendix Table E-2. *Heavy metal compounds detected in water samples in the 2018 Ohio River Direct Tributaries study area, 2018.*

Site ID	River Mile	Drainage Area (sq. mi.)	Water column							Sediment							
			1,4-Difluorobenzene (ug/L)	2,4,6-Tribromophenol (ug/L)	2-Butanone (ug/L)	2-Fluorophenol (ug/L)	Bromofluorobenzene (ug/L)	Di-n-butyl phthalate (ug/L)	Di-n-octyl phthalate (ug/L)	Bis(2-ethylhexyl)phthalate (mg/kg)	Butyl benzyl phthalate (mg/kg)	carbazole (mg/kg)	Di-n-butyl phthalate (mg/kg)	Di-n-octyl phthalate (mg/kg)	n-nitrosodi-n-propylamine (mg/kg)	Phenol (mg/kg)	pyridine (mg/kg)
Muddy Creek (23-007)																	
MU05	6.25	5.39	50	73	AA	20	41	AA	AA	0.22	AA	0.28	0.035	AA	AA	AA	AA
MU04.5	5.6	7.71	50	76	AA	36	40	AA	AA	0.08	AA	0.077	0.021	AA	AA	AA	AA
MU04	5.4	7.8	50	85	AA	41	40	AA	AA	0.11	AA	0.063	0.036	AA	AA	0.03	AA
MU03	3.1	10.4	50	87	AA	34	40	AA	AA	0.037	AA	AA	AA	0.033	AA	AA	AA
MU02	2.25	12.1	50	88	AA	30	41	AA	AA	0.089	AA	0.11	AA	AA	AA	AA	0.016
MU01	0.2	13.6	50	74.5	AA	32	41	AA	1.3	0.051	AA	0.079	0.035	0.030	AA	AA	AA
Rapid Run (23-008)																	
RR03	2.58	2.32	50	62	AA	30	40	AA	AA	0.056	AA	0.13	AA	AA	AA	AA	AA
RR02	1.1	5.9	50	84	AA	38	43.5	AA	AA	0.045	AA	0.054	AA	AA	AA	AA	AA
RR01	0.35	5.99	50	72	AA	28	41	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA
Wulff Run (23-012)																	
RR04	0.55	2.18	50	68	AA	36	41	AA	AA	0.049	AA	0.05	0.021	AA	0.054	AA	AA
Indian Creek (23-019)																	
IC06	2.25	0.58	50	82.5	AA	33	42	AA	AA	AA	AA	0.022	AA	AA	AA	AA	AA
IC05	2.08	1.07	50	72.5	AA	26.5	42	AA	AA	0.031	AA	AA	AA	AA	AA	AA	AA
IC02	1.15	1.38	50	91	AA	37.5	41	AA	AA	AA	AA	AA	AA	AA	AA	AA	0.015
IC01	0.2	2.3	50	70.5	AA	28	42	AA	AA	0.033	AA	AA	AA	0.027	AA	AA	AA
Unnamed Tributary to Indian Creek @RM 1.02 (23-020)																	
IC07	0.19	0.39	50	80.5	AA	45	40	AA	AA	AA	AA	1.2	0.029	AA	AA	AA	AA
Taylor Creek (14-004)																	
GM86	6.5	0.49	50	66.5	AA	49	43	13.2	1.4	0.035	AA	0.027	AA	AA	AA	AA	AA
GM85	5.3	2.22	50	85	12.89	32	42	AA	AA	0.033	AA	0.017	0.021	AA	AA	AA	AA
Briarly Creek (14-148)																	
GM91	3.9	0.34	50	66	AA	40	41	AA	AA	0.21	0.033	0.13	AA	0.035	AA	AA	AA
GM90	2.55	1.3	50	65	AA	27	42	AA	AA	0.074	AA	0.025	0.026	AA	AA	AA	AA
GM89	1.98	2.1	50	56	AA	36	41	AA	1.7	0.049	AA	AA	AA	0.033	AA	AA	AA
Wesselman Creek (14-149)																	
GM94	4.75	1.1	50	88	AA	30	41	AA	AA	AA	AA	0.055	0.021	AA	AA	AA	AA

AA - below method detection limit.

Appendix Table E-3. *Volatile organic chemical compounds detected in water and sediment samples in the 2018 Ohio River Direct Tributaries study area, 2018.*