Biological and Water Quality Study of the
Raccoon Creek Watershed, 2016
Athens, Gallia, Hocking, Jackson, Meigs, and Vinton Counties

Raccoon Creek, 2016

Ohio EPA Technical Report AMS/2016-RACCO-2

Division of Surface Water
Assessment and Modeling Section
June 2020

TMDL DEVELOPMENT | ●●○○○

Table of Contents

Appendices

Tables

Figures

List of Acronyms

(Glossary of Terms can be found ***here***)

ALU	aquatic life use
AMD	acid mine drainage
CFR	Code of Federal Regulations
cfs	cubic feet per second
cfu	colony forming units
CSO	combined sewer overflow
CWA	Clean Water Act
DELT	deformities, erosions, lesions, tumors
D.O.	dissolved oxygen
EPT	Ephemeroptera, Plecoptera, Trichoptera
ESL	ecological screening level
EWH	exceptional warmwater habitat
GIS	geographic information system
GPS	Global Positioning System
HHEI	Headwater Habitat Evaluation Index
HUC	hydrologic unit code
IBI	Index of Biotic Integrity
ICI	Invertebrate Community Index
IPS	integrated prioritization system
LRAU	large river assessment unit
LRW	limited resource water
MGD	million gallons per day
MIwb	Modified Index of Well-being
NCCW	Noncontact cooling water
NPDES	National Pollutant Discharge Elimination System
NPS	Non-point source
OAC	Ohio Administrative Code
ODNR	Ohio Department of Natural Resources
ORC	Ohio Revised Code
OSM	Office of Surface Mining
PAH	polycyclic aromatic hydrocarbons
PCR	primary contact recreation
PEC	probable effects concentration
QHEI	Qualitative Habitat Evaluation Index
RCP	Raccoon Creek partnership

RM	river mile
SCR	secondary contact recreation
SRV	sediment reference value
SSO	sanitary sewer overflow
TALU	tiered aquatic life use
TDS	total dissolved solids
TEC	threshold effects concentration
TKN	total Kjeldahl nitrogen
TMDL	total maximum daily load
TSS	total suspended solids
UAA	use attainability analysis
VOC	volatile organic compound
WAP	western Allegheny plateau
WAU	watershed assessment unit
WCAP	watershed cooperative agreement program
WQS	water quality standards
WWH	warmwater habitat
WWTP	wastewater treatment plant

Executive Summary

Rivers and streams in Ohio sustain aquatic life populations and support a variety of beneficial uses such as recreation and water supply (public, industrial and agricultural). Ohio EPA evaluates each waterway to determine the appropriate beneficial use designations and determine if the assigned uses are appropriate and are meeting the goals of the federal Clean Water Act. In 2016, Ohio EPA evaluated a total of 83 sampling locations within the Raccoon Creek watershed in Hocking, Vinton, Jackson, Athens, Meigs and Gallia counties for aquatic life or recreation use potential.

The Raccoon Creek mainstem was evaluated in 2016 at eighteen monitoring locations. Seventeen locations met the assigned or recommended aquatic life use (ALU) and one location in the headwaters was in partial attainment of the recommended warmwater habitat (WWH) ALU (Table 2, Figure 2 and Figure 3).

Table 1—Average biological and habit scores from the Raccoon Creek mainstem in 1995 and 2016.

Year Sampled	IBI	MIwb	ICI	QHEI
Upper Raccoon Creek (RM 95.52 to 111.9)				
1995	20.6	4.0	16.6	56.7
2016	44.3	8.2	44.5	63.5
Middle Raccoon Creek (95.52 to 40.3)				
1995	38.8	7.6	40	60.6
2016	49.1	9.2	39	75.4
Lower Raccoon Creek				
1995	42	8.72	42	60.6
2016	50.4	10.14	47.6	78

IBI – Index of biotic integrity
MIwb – Modified index of well being
ICI – Invertebrate community index
QHEI – Qualitative Habitat Evaluation Index
Narrative evaluation:
Exceptional to very good – blue; good – green
Fair – yellow, poor – orange, very poor – Red

The upper section of Raccoon Creek (river mile (RM) 111.9 to RM 95.52) is designated limited resource water (LRW) due to acid mine drainage (AMD) but numerous coal mining reclamation projects in the headwaters has dramatically improved the biological community (Table 1). In 1995, the average biological community scores ranged from very poor to fair and fell below WWH expectations. In 2016, the average scores improved into the good to very good range within WWH expectations. Similar improvements occurred in the middle section of Raccoon Creek (RM 95.52 to RM 40.3) with average scores ranging from fair to good in 1995 and improving in the good to exceptional range. The lower section of Racoon Creek also improved as well ranging from good to very good in 1995 to exceptional in 2016. As a result of these improvements, the upper and middle section of Raccoon Creek are recommended WWH aquatic life use (ALU) and the lower section below the Vinton dam is recommend exceptional warmwater habitat (EWH) ALU. A dam at RM 40.3 is a barrier to fish passage and delineates the EWH boundary. Its removal would have a positive impact on water quality in the watershed and could possibly allow for the extension of the EWH designation upstream an additional 30 river miles.

Forty-two tributaries were also evaluated at 65 locations in the Raccoon Creek survey area in 2016. A total of 23 sites were in full attainment of their existing or recommended aquatic life uses, 21 were in partial attainment, 18 were in non-attainment and three sites remained unassessed (Table 2, Figure 3). The most pervasive cause of aquatic life impairment was excessive sedimentation due to legacy surface disturbances from extensive deforestation and surface mining. Two streams were impaired due to point-source issues, Puncheon Fork and Meadow Run. The McArthur wastewater treatment plant (WWTP) discharges to Puncheon Fork, and a break in a sanitary sewer line contributed to very high levels of ammonia in the stream. The broken sanitary sewer line has since been fixed. Meadow Run has two dischargers contributing high levels of nutrients, General Mills – Wellston, and the Wellston – North WWTP. Two additional sites were impaired due to livestock access to the stream.

The Raccoon Creek Partnership (RCP) is a member based nonprofit 501(c)(3) organization formed in 2007 to improve and protect the water quality in the Raccoon Creek watershed. RCP (and former iterations of the watershed group which began in the 1980s) have completed nineteen projects to treat mine drainage in the upper and middle section of the watershed. RCP continues to maintain and monitor active mine drainage treatment systems and recently removed a low head dam in Big Sandy Run improving the habitat and allowing fish passage to upstream habitats. These projects have continued to improve the water quality of the Raccoon Creek watershed and have also resulted in several tributaries currently designated LRW-AMD to be recommended WWH ALU including East Branch of Raccoon Creek, Hewett Fork, Wolf Run, Indiancamp Run and Dickason Run. Mean IBI scores in the Raccoon Creek tributaries have continued to improve going from a mean of 22.5 in the 1980s, 32 in the 1990s and 2000s, to 36 during the 2016 survey (Figure 1).

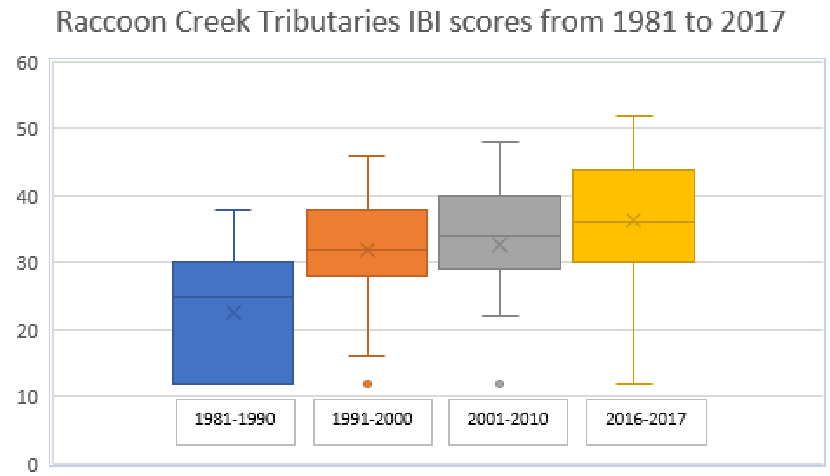


Figure 1 — Box and whisker plots of the IBI scores collected from the Raccoon Creek tributaries from 1981 to 2017.

Twenty-eight locations in the Raccoon Creek watershed study area were sampled for *E. coli* approximately five times apiece, from June – August 2016. Included were 11 sites on Raccoon Creek and 17 sites on tributary streams. Twenty-eight locations, or 97 percent, of the sampling locations in the Raccoon Creek watershed failed to meet both the applicable geometric mean criterion and the statistical threshold value, and thus were in non-attainment of the recreation use. Inadequately functioning home sewage treatment systems (HSTS) in unsewered areas and agricultural activities are the most probable sources of bacteria to streams in the study area.

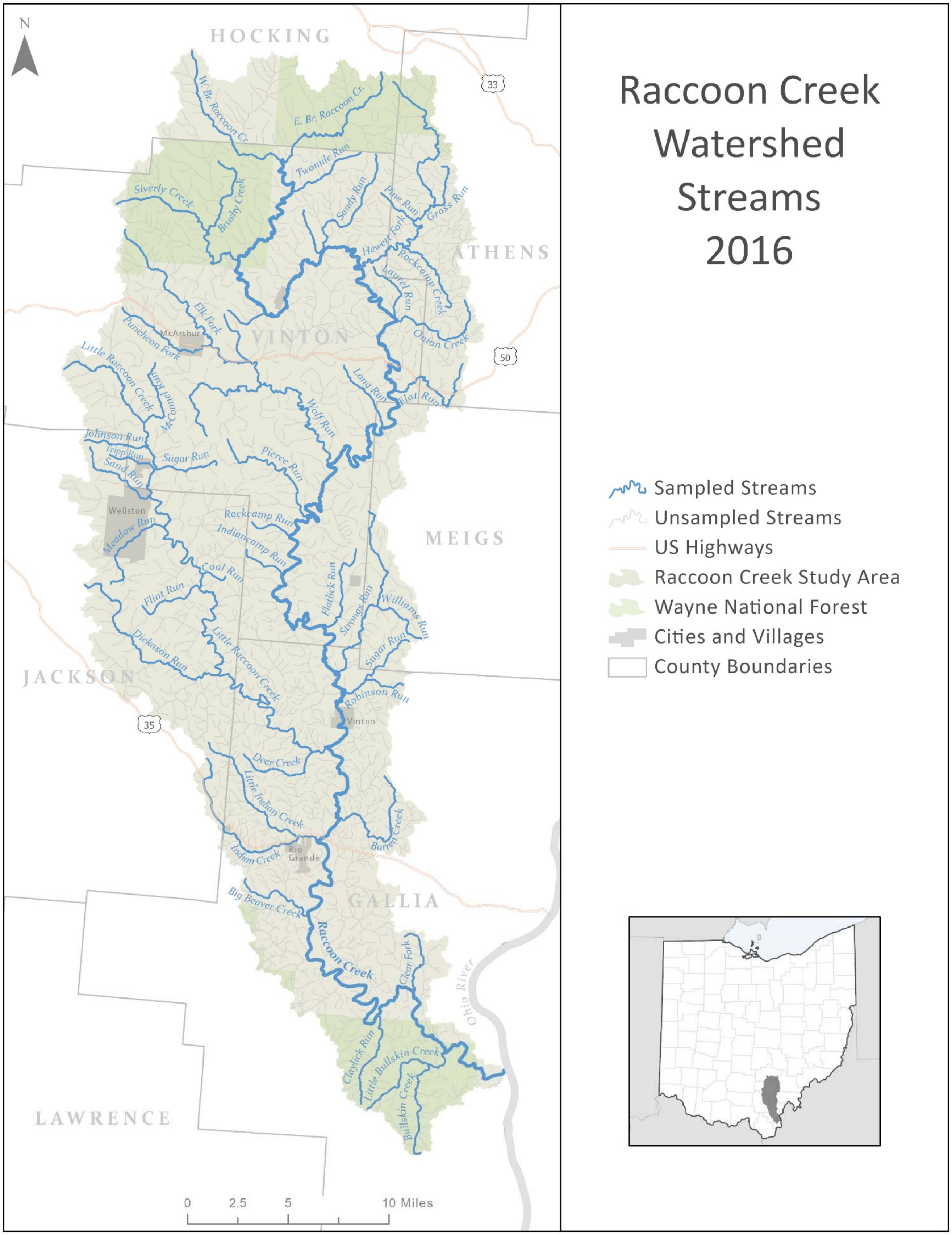


Figure 2 — Raccoon Creek study area and streams sampled in 2016 and 2017.

*Figure 3—**S**ampling locations and ALU attainment status in the Raccoon Creek watershed, based on data collected in 2016 and 2017.*

Table 2 — Aquatic life use (ALU) attainment status for stations sampled in the Raccoon Creek study area based on data collected June - September 2016 and July 2017. ALU is the existing use designation unless noted as a recommended use. The Index of Biotic Integrity (IBI), Modified Index of well-being (MIwb), and Invertebrate Community Index (ICI) are scores based on the performance of the biotic community. The Qualitative Habitat Evaluation Index (QHEI) is a measure of the ability of the physical habitat of the stream to support a biotic community. Raccoon Creek is in the Western Allegheny Plateau (WAP) ecoregion. If biological impairment has occurred, the cause(s) and source(s) of the impairment are noted.

Station	Location	ALU[1]	River Mile[a]	Drain. Area (mi^2)	IBI	MIwb[b]	ICI[c]	QHEI	Attain. Status	Causes	Sources
05090101 02 01 – East Branch Raccoon Creek											
W03W37	E. Br. Raccoon Creek at St. Rt. 328	WWH - Recommended	6.64	3.2[H]	22*	-	P*	75.5	Non	- Aluminum	- Legacy Surface Mining - Mine Drainage
W03K17	E. Br. Raccoon Creek at Laurel Run Rd.	WWH - Recommended	2.10	15.3[H]	28*	-	MG[ns]	71.8	Partial	- Aluminum	-Legacy Surface Mining - Mine Drainage
05090101 02 02 – West Branch Raccoon Creek											
W03W36	W. Br. Raccoon Creek at Ilesboro-Cedar Falls Rd.	WWH	5.68	3.8[H]	20*	-	G	70.5	Non	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
W03W43	W. Br. Raccoon Creek at St. Rt. 328	WWH	0.15	22.7[H]	41[ns]	7.1*	46	63.1	Partial	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
W03P35	Honey Fork at St. Rt. 56, west of New Plymouth	WWH	0.01	10.5[H]	28*	-	G	61.3	Partial	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
05090101 02 03 – Brushy Fork											
W03K40	Brushy Creek at St. Rt. 93	WWH	6.87	8.4[H]	12*	-	G	54.0	Non	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
W03K39	Brushy Creek at St. Rt. 328, north of Creola	WWH	0.36	33.4[H]	38*	6.4*	38	55.0	Partial	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
W03K42	Siverly Creek adj. Siverly Creek Rd.	WWH	0.30	10.1[H]	36*	-	G	67.8	Partial	- Sand Bedload	- Upstream Forestry
05090101 02 04 – Twomile Run-Raccoon Creek											
301747	Raccoon Creek at St. Rt. 328 and Sheets-McCoy Rd.	WWH – Recommended	111.38	43.6[W]	41	7.9[ns]	50	61.8	Full		
301746	Raccoon Creek at St. Rt. 328 and Mitchell Hollow	WWH – Recommended	104.63	56.4[W]	40	7.3*	46	65.1	Partial	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)

Station	Location	ALU[1]	River Mile[a]	Drain. Area (mi^2)	IBI	MIwb[b]	ICI[c]	QHEI	Attain. Status	Causes	Sources
W03W58	Twomile Run at Long Ridge Rd., N. of Zaleski	WWH	0.16	4.9 [H]	26*	-	VG	58.5	Non	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
05090101 02 05 – Town of Zaleski- Raccoon Creek											
W03W32	Raccoon Creek at Creek Rd.	WWH – Recommended	99.60	98.0 [B]	48	9.4	40	58.8	Full		
W03W44	Raccoon Creek at Township Highway F3	WWH – Recommended	98.34	100.0 [W]	48	8.2 [ns]	42	68.5	Full		
W03W33	Raccoon Creek at C.R. 3, dst Sandy Run	WWH	92.30	134.0	-	-	G	-	-		
302520	Raccoon Creek at Hope-Moonville Rd., ust Hewett Fork	WWH	89.98	136.0 [W]	48	8.6	G	87.5	Full		
203928	Trib to Raccoon Creek (RM 98.96) at mouth, SW of Zaleski	WWH	0.10	1.9 [H]	38*	-	P*	36.5	Non	- Natural (Low Flow)	- Natural Sources
203966	Sandy Run at King Hollow Trail, ust Lake Hope	WWH	2.70	5.0 [H]	28*	-	G	65.0	Partial	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
303689	Little Sandy Run at St. Rt. 278, S of Lake Hope	WWH	0.40	1.5 [H]	30*	-	P*	39.0	Non	- Natural (Low Flow and Wetland)	- Natural Sources
05090101 03 01 – Hewett Fork											
W03K37	Hewett Fork adj. Carbondale Rd., NE Carbondale	MWH – Mine Affected – Recommended	13.10	8.3 [H]	30/ 34	-	MG [ns] /MG [ns]	60.0/ 61.25	Full		
303739	Hewett Fork adj. Waterloo Wildlife Area dst bridge	MWH – Mine Affected – Recommended	8.40	16.4 [H]	26/ 34	-	-/ MG [ns]	68.5/ 60.5	Full		
W03P08	Hewett Fork at T.R. 20, SW of Mineral	WWH – Recommended	4.31	28.1 [H]	40/ 36*	7.0*/ 7.3*	44/E	68.1 /70.0	Partial	- Sand Bedload - Riparian Removal	- Legacy Surface Disturbances (Mining/Forestry) - Channelization
W03P32	Hewett Fork at mouth, Hope-Moonville Rail Trail	WWH – Recommended	0.01	40.5 [W]	52/4 8	9.0/ 8.5	G/G	74.5/ 75.5	Full		
W03P41	Grass Run at St. Rt. 356, N of Mineral	WWH	0.04	2.7 [H]	20*	-	F*	73.0	Non	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)

Station	Location	ALU[1]	River Mile[a]	Drain. Area (mi^2)	IBI	MIwb[b]	ICI[c]	QHEI	Attain. Status	Causes	Sources
301579	Pine Run at mouth, near St. Rt. 356	WWH	0.10	2.0 [H]	32*	-	F*	39.5	Non	- Natural (Low Flow)	- Natural Sources
W03W50	Coal Run at St. Rt. 681	WWH	0.05	0.8 [H]	28*	-	F*	41.5	Non	- Natural (Low Flow)	- Natural Sources
W03P33	Rockcamp Creek at St. Rt. 356	WWH	1.53	7.7 [H]	28*	-	MG [ns]	53.3	Partial	- Riparian Removal - Sand Bedload	- Direct Habitat Alterations
05090101 03 02 – Headwaters Elk Fork											
W03W06	Elk Fork at Morgan Rd., ust Puncheon Fork	WWH	13.90	14.4 [H]	42 [ns]	-	VG	76.3	Full		
W03P30	Elk Fork at St. Rt. 50, dst Puncheon Fork	WWH	13.26	24.5 [H]	50	9.2	G	86.3	Full		
W03W09	Austin Powder Tributary to Elk Fork (RM 11.17) at C.R. 7	WWH	0.43	2.4 [H]	28*	-	MG [ns]	45.0	Partial	- Sand Bedload - Total Dissolved Solids	- Legacy Surface Disturbances (Mining/Forestry)
W03K30	Puncheon Fork at T.R. 20, ust McArthur	WWH	2.82	4.7 [H]	28*	-	G	59.0	Partial	- Natural (Low Flow)	- Natural Sources
W03W30	Puncheon Fork at C.R. 25	WWH	1.51	7.2 [H]	40 [ns]	-	-	71.0	(Full)		
W03W07	Puncheon Fork at T.R. 11	WWH	0.28	9.8 [H]	38*	-	VP*	72.8	Non	- Ammonia	- Municipal Point Source Discharges
203947	Wolf Run at C.R. 24, SE of McArthur	WWH – Recommended	3.80	4.7 [H]	32*	-	F*	64.5	Non	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry) - Woodlot Site Clearance
05090101 03 03 – Flat Run-Elk Fork											
W03W14	Elk Fork adj. Stone Quarry Rd at old bridge, dst Wolf Run	WWH	8.55	44.4 [W]	43[ns]/ 42 [ns]	7.7*/ 7.3*	42	66.5/ 74.5	Partial	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
W03P31	Elk Fork at C.R. 43B, NE of Radcliff	WWH	0.01	59.8 [W]	46	7.9 [ns]	G	70.8	Full		
05090101 03 04 – Flat Run-Raccoon Creek											
302519	Raccoon Creek at C.R. 18B, dst Hewett Fork	WWH	89.36	176.0 [A]	46	9.8	MG [ns]	86.0	Full		
W03W34	Raccoon Creek at St. Rt. 356, near Knox	WWH	84.08	183.0 [B]	50	9.4	38	62.5	Full		
W03G50	Raccoon Creek at St. Rt. 50, at Bolins Mills	WWH	80.62	200.0 [B]	51	8.8	40	61.8	Full		

Station	Location	ALU[1]	River Mile[a]	Drain. Area (mi^2)	IBI	MIwb[b]	ICI[c]	QHEI	Attain. Status	Causes	Sources
W03P07	Raccoon Creek at U.S. Rt. 32 W, ust crossing	WWH	72.22	223.0 [B]	50	9.6	38	79.5	Full		
W03W59	Laurel Run at T.R. 18, near Knox	WWH	0.16	2.6 [H]	36*	-	MG [ns]	64.0	Partial	- Natural (Low Flow)	- Natural Sources
W03W45	Onion Creek at C.R. 4, SE of Knox	WWH	1.41	8.3 [H]	38*	-	G	58.0	Partial	- Riparian Removal - Sand Bedload	- Direct Habitat Alterations
W03W51	Flat Run at U.S. Rt. 50, SE Bolins Mills	WWH	1.60	4.8 [H]	40 [ns]	-	VG	60.8	Full		
203960	Long Run adj. C.R. 11K, N Vales Mills	WWH	1.40	2.2 [H]	40 [ns]	-	G	65.0	Full		
05090101 04 01 – Headwaters Little Raccoon Creek											
W03S09	Little Raccoon Creek at Wolf Hill Rd.	WWH	36.67	12.1	-	-	F	-	-		
W03S07	Little Raccoon Creek at Mulga Rd, ust Meadow Run	WWH	27.90	48.0 [B]	42	8.8	40	54.0	Full		
303688	McConnel Run at Lake Rd.	WWH – Recommended	1.98	0.9 [H]	50	-	G	36.0	Full		
W03S10	Meadow Run ust General Mills, on property	WWH	3.10	5.1 [H]	28*	-	F*	61.5	Non	- Sand Bedload - Total Dissolved Solids	- Legacy Surface Disturbances (Mining/Forestry)
W03W27	Meadow Run at St. Rt. 327	WWH	2.16	8.7 [H]	31*	-	F*	61.3	Non	- Ammonia	- Industrial Point Source Discharge
										- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
W03W18	Meadow Run at Cheatwood Rd.	WWH	0.72	9.9 [H]	32*	-	LF*	50.3	Non	- Ammonia	- Industrial Point Source Discharge
										- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
05090101 04 02 – Dickason Run											
W03S48	Dickason Run at Keystone Furnace Rd.	WWH	2.37	17.7 [H]	34*	-	MG [ns]	55.5	Partial	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)

Station	Location	ALU[1]	River Mile[a]	Drain. Area (mi^2)	IBI	MIwb[b]	ICI[c]	QHEI	Attain. Status	Causes	Sources
W03P43	Dickason Run at Orpheus-Keystone Rd.	WWH – Recommended	0.11	26.9 [H]	38*	6.6*	42	64.0	Partial	- Sand Bedload - Total Dissolved Solids	- Legacy Surface Disturbances (Mining/Forestry)
05090101 04 03 – Meadow Run-Little Raccoon Creek											
W03W25	Little Raccoon Creek at St. Rt. 32, ust Mulga Run	WWH	24.55	62.5 [B]	42	9.0	48	52.0	Full		
W03K10	Little Raccoon Creek at Buckeye Furnace Rd.	WWH	18.45	87.0 [W]	48/ 18*	7.1*/ 5.5*	38	68.0	Non	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
W03S06	Little Raccoon Creek at Keystone Rd., ust Dickason Run	WWH	12.71	99.0 [B]	46	9.1	42	57.3	Full		
05090101 04 04 – Deer Creek-Little Raccoon Creek											
W03K09	Little Raccoon Creek at Keystone Furnace Rd. dst Dickason Run	WWH	11.00	129.0 [B]	34*	9.0	44	65.5	Partial	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
W03P04	Little Raccoon Creek at St. Rt. 325	WWH	1.17	154.0 [W]	52	9.1	52	66.8	Full		
W03P15	Deer Creek adj. St. Rt. 325	WWH	0.20	5.9 [H]	30*	-	VP*	51.5	Non	- Sand Bedload	- Livestock (Grazing or Feeding Operations) - Legacy Surface Disturbances (Forestry)
05090101 05 01 – Pierce Run											
W03L08	Pierce Run at St. Rt. 160, near Hamden	LRW	5.47	3.4 [H]	26	-	P	67.5	Full		
W03W47	Pierce Run at Township Hwy 2A	LRW	1.68	9.5 [H]	34	-	F	53.0	Full		
05090101 05 02 – Strongs Run											
W03S36	Strongs Run at Tower Rd.	WWH	5.90	5.9 [H]	36*	-	G	58.8	Partial	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
W03S47	Strongs Run at Adney Rd.	WWH	0.58	16.4 [H]	36*	-	VG	59.8	Partial	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)

Station	Location	ALU[1]	River Mile[a]	Drain. Area (mi^2)	IBI	MIwb[b]	ICI[c]	QHEI	Attain. Status	Causes	Sources
203956	Williams Run at Williams Run Rd.	WWH – Recommended	0.10	3.8^{H}	40^{ns}	-	MG^{ns}	65.5	Full		
05090101 05 03 – Flatlick Run-Raccoon Creek											
W03W35	Raccoon Creek at U.S. Rt. 32W, dst crossing	WWH	63.80	296.0^{B}	50	9.5	40	80.3	Full		
W03P18	Raccoon Creek at St. Rt. 124, S of Clarion	WWH	55.48	322.0^{B}	49	8.6	40	70.4	Full		
W03S34	Raccoon Creek at Covered Bridge Rd.	WWH	50.10	336.0	-	-	40	-	Full		
W03W52	Rockcamp Run at Hawk Station Rd.	LRW	0.11	2.8^{H}	<u>12</u>*	-	F	65.5	Non	- Sand Bedload - Total Dissolved Solids	- Legacy Surface Disturbances (Mining/Forestry)
W03W56	Indiancamp Run at C.R. 26, SW of Clarion	WWH – Recommended	0.30	2.1^{H}	36*		MG^{ns}	77.8	Partial	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
W03S39	Flatlick Run at C.R. 18, S of Wilkesville	WWH	0.60	7.2^{H}	34*	-	F*	63.8	Non	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
05090101 05 04 – Robinson Run-Raccoon Creek											
W03P05	Raccoon Creek at Vinton Park, dst dam, St. Rt. 325	EWH – Recommended	40.01	381.0^{B}	58	10.4	42^{ns}	81.8	Full		
W03S40	Robinson Run at St. Rt. 325	WWH	0.18	9.7^{H}	38*	-	G	69.0	Partial	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
05090101 06 01 – Indian Creek											
W03P36	Indian Creek at St. Rt. 325, ust Rio Grande WWTP	WWH	1.58	10.4^{H}	41^{ns}	-	G	68	Full		
W03W55	Indian Creek at St. Rt. 325, dst Rio Grande WWTP, ust Little Indian Run	WWH	1.45	10.4^{H}	45	-	G	74.9	Full		
W03P14	Little Indian Creek at Buckeye Hills Rd.	WWH	0.17	10.2^{H}	44	-	G	68.3	Full		
05090101 06 02 – Barren Creek-Raccoon Creek											
203953	Barren Creek at OH 554	WWH	0.30	9.1	-	-	G	-	-		
05090101 06 03 – Mud Creek-Raccoon Creek											
303508	Big Beaver Creek at Guthrie Rd.	WWH - Recommended	0.90	7.3^{H}	44	-	G	63.8	Full		

Station	Location	ALU[1]	River Mile[a]	Drain. Area (mi^2)	IBI	MIwb[b]	ICI[c]	QHEI	Attain. Status	Causes	Sources
05090101 06 04 – Bullskin Creek											
W03K21	Bullskin Creek at Williams Hollow Rd.	WWH	0.37	14.4 [H]	48	-	G	78.3	Full		
W03K22	Little Bullskin Creek at Little Bullskin Rd.	WWH	0.01	4.9 [H]	40 [ns]	-	MG [ns]	70.0	Full		
05090101 06 05 – Claylick Run-Raccoon Creek											
203929	Claylick Run at Lincoln Pike	WWH	0.40	7.7 [H]	-	-	G	-	-		
W03K23	Clear Fork at Ingalls Rd.	WWH	0.02	7.7 [H]	50	-	F*	71.0	Partial	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry) - Channel Incision
05090101 90 01 – Raccoon Creek Large River Assessment Units (LRAU)											
W03S44	Raccoon Creek at Glassburn Rd.	EWH – Recommended	35.61	543.0 [B]	51	9.9	48	76.8	Full		
601400	Raccoon Creek at OH 558, Bob Evans camp	EWH – Recommended	29.20	586.0 [B]	49	10.2	E	72.5	Full		
303503	Raccoon Creek at Dan Jones Rd., MacIntyre Park	EWH – Recommended	22.00	615.0 [B]	50	10.3	E	80.5	Full		
W03S24	Raccoon Creek at Ingalls Rd.	EWH – Recommended	10.20	657.0 [B]	44 [ns]	9.9	52	78.3	Full		

a- River Mile (RM) represents the Point of Record (POR) for the station, and may not be the actual sampling RM.
b- MIwb is not applicable to headwater streams with drainage areas ≤ 20 mi^2.
c- A narrative evaluation of the qualitative sample based on attributes such as EPT taxa richness, number of sensitive taxa, and community composition was used when quantitative data was not available or considered unreliable. VP=Very Poor, P=Poor, LF=Low Fair, F=Fair, MG=Marginally Good, G=Good, VG=Very Good, E=Exceptional
ns- Nonsignificant departure from biocriteria (≤4 IBI or ICI units, or ≤0.5 MIwb units).
*- Indicates significant departure from applicable biocriteria (>4 IBI or ICI units, or >0.5 MIwb units). Underlined scores are in the Poor or Very Poor range.
H- Headwater site (draining ≤20 $miles^2$)
W- Wading site (non-boat site draining >20 $miles^2$)
B- Boat site (large or deep waters, necessitating the use of Boat sampling methods)
1- Aquatic Life Use (ALU) designations: Exceptional Warmwater Habitat (EWH), Warmwater Habitat (WWH), Modified Warmwater Habitat (MWH)
2- Biological criteria presented in OAC 3745-1-07, Table 7-1

Biocriteria for the Western Allegheny Plateau (WAP) Ecoregion						
	IBI			MIwb		ICI
ALU	Boat	Wading	Headwater	Boat	Wading	All sizes
EWH	48	50	50	9.6	9.4	46
WWH	40	44	44	8.6	8.4	36
MWH	24	24	24	5.8	6.2	22

Components of an Ohio EPA Biological and Water Quality Survey

What is a Biological and Water Quality Survey?

A biological and water quality survey (biosurvey) estimates the biological, physical and chemical condition of waters within a specified sampling frame. The sampling frame may range from 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.

Ohio EPA employs biological, chemical and physical monitoring to meet three major objectives:

1) determine the extent to which use designations assigned in the Ohio Water Quality Standards (WQS) are either attained or not attained;
2) determine if use designations 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.

The data gathered by a biosurvey is processed, evaluated and synthesized in a biological and water quality report. Each biological and water quality study contains a summary of major findings and recommendations for revisions to WQS, future monitoring needs or other actions that may be needed to resolve existing impairment of designated uses. While the principal focus of a biosurvey is the status of aquatic life uses, the status of other uses such as recreation and water supply, as well as human health concerns are also addressed.

The findings and conclusions of a biological and water quality study may factor into regulatory actions taken by Ohio EPA (for example, NPDES permits, Director's Orders, the Ohio WQS [OAC 3745-1] and Water Quality Permit Support Documents [WQPSDs]), and are eventually incorporated into State Water Quality Management Plans, the Ohio Nonpoint Source Assessment, and the biennial Integrated Water Quality Monitoring and Assessment Report (305[b] and 303[d]).

Hierarchy of Indicators

A carefully conceived ambient monitoring approach, using cost-effective indicators consisting of ecological, chemical and toxicological measures, helps ensure that all relevant pollution sources are judged objectively on the basis of environmental results. Ohio EPA relies on a tiered approach in attempting to link the results of administrative activities with true environmental measures. This integrated approach includes a hierarchical continuum from administrative to true environmental indicators (Figure 4). 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, wasteload allocation); and,
6) changes in health, ecology, or other effects (ecological condition, pathogens).

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). Thus, the aggregate effect of billions of dollars spent on water pollution control since the early 1970s can now be determined with quantifiable measures of environmental condition.

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 Ohio's biological criteria. Other response indicators could include target assemblages (rare, threatened, endangered, special status and declining species) or bacterial levels which 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.

Describing the causes and sources associated with observed impairments revealed by the biological criteria and linking this with pollution sources involves an interpretation of multiple lines of evidence including water chemistry data, sediment data, habitat data, effluent data, biomonitoring results, land use data and patterns within the biological data itself. Thus, the assignment of principal causes and sources of impairment represents the association of impairments (defined by response indicators) with stressor and exposure indicators. The principal reporting venue for this process on a watershed or sub-basin scale is a biological and water quality report. These reports then provide the foundation for aggregated assessments such as the Integrated Report, the Ohio Nonpoint Source Assessment and other technical bulletins.

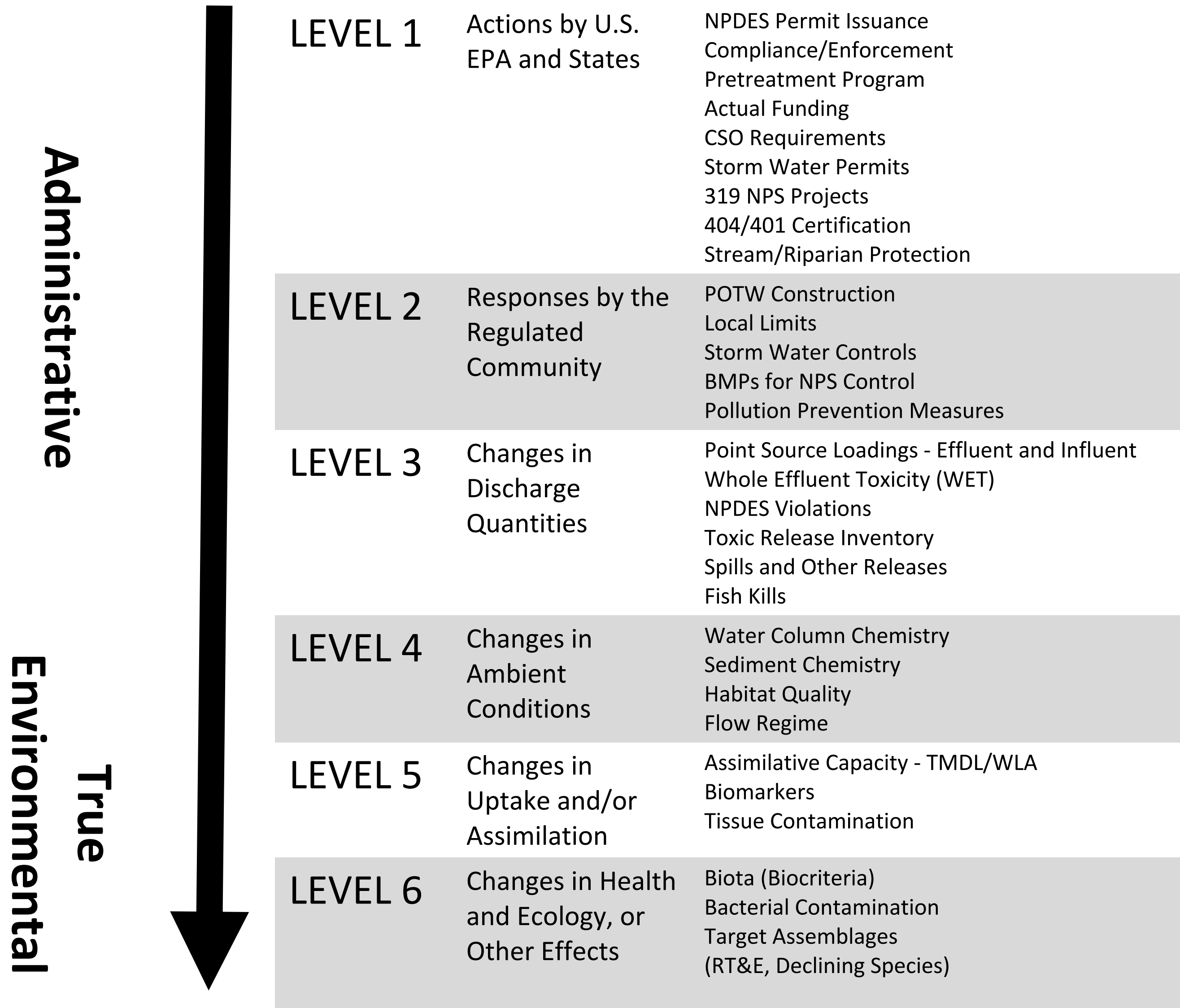


Figure 4 — Hierarchy of administrative and environmental indicators which can be used for water quality management activities such as monitoring and assessment, reporting, and the evaluation of overall program effectiveness. This is patterned after a model developed by U.S. EPA.

Ohio Water Quality Standards: Designated Aquatic Life Use

The Ohio Water Quality Standards (WQS; OAC 3745-1) consist of designated uses and chemical, physical and biological criteria designed to represent measurable properties of the environment that are consistent with the goals specified by each use designation. Use designations consist of two broad groups — aquatic life and non-aquatic life uses. In applications of the Ohio WQS to the management of water resource issues in Ohio's rivers and streams, the aquatic life use criteria frequently result in the most stringent protection and restoration requirements, hence their emphasis in biological and water quality reports. Also, an emphasis on protection for aquatic life generally results in water quality suitable for all uses. The five aquatic life uses currently defined in the Ohio WQS are:

1) **Warmwater Habitat (WWH)** — this use designation defines the typical warmwater assemblage of aquatic organisms for Ohio rivers and streams; this use represents the principal restoration target for the majority of water resource management efforts in Ohio.

2) **Exceptional Warmwater Habitat (EWH)** — this use designation is reserved for waters which support unusual and exceptional assemblages of aquatic organisms which are characterized by a high diversity of species, particularly those which are highly intolerant and/or rare, threatened, endangered or special status (declining species); this designation represents a protection goal for water resource management efforts dealing with Ohio's best water resources.
3) **Coldwater Habitat (CWH)** — this use is intended for waters that support assemblages of coldwater organisms or those which are sanctioned by the Ohio Department of Natural Resources (ODNR), Division of Wildlife and stocked with salmonids with the intent of providing a put-and-take fishery on a year round basis. This use should not be confused with the Seasonal Salmonid Habitat (SSH) use which applies to the Lake Erie tributaries that support periodic runs of salmonids during the spring, summer, and/or fall.
4) **Modified Warmwater Habitat (MWH)** — this use applies to streams and rivers which have been subjected to extensive, maintained and essentially permanent hydromodifications such that the biocriteria for the WWH use are not attainable and where the activities have been sanctioned by state or federal law; the representative aquatic assemblages are generally composed of species which are tolerant to low dissolved oxygen, silt, nutrient enrichment and poor quality habitat.
5) **Limited Resource Water (LRW)** — this use applies to small streams (usually less than three mi^2 drainage area) and other water courses which have been irretrievably altered to the extent that no appreciable assemblage of aquatic life can be supported.

Chemical, physical and/or biological criteria are generally assigned to each use designation in accordance with the broad goals defined by each. As such, the system of use designations employed in the Ohio WQS constitutes a tiered approach in that varying and graduated levels of protection are provided by each. This hierarchy is especially apparent for parameters such as dissolved oxygen, ammonia-nitrogen, temperature and the biological criteria. For other parameters such as heavy metals, the technology to construct an equally graduated set of criteria has been lacking, thus the same water quality criteria may apply to two or three different aquatic life use designations.

Ohio Water Quality Standards: Non-Aquatic Life Uses

In addition to assessing the appropriateness and status of aquatic life uses, each biological and water quality survey also addresses non-aquatic life uses such as recreation, water supply and human health concerns as appropriate. The recreation uses most applicable to rivers and streams are the Primary Contact Recreation (PCR) and Secondary Contact Recreation (SCR) uses. All surface waters of the state are designated as primary contact recreation unless otherwise designated as bathing waters or secondary contact recreation. Primary contact waters are surface waters that, during the recreation season, 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. Secondary contact waters are surface 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 SCR designation applies only to water bodies specifically designated as such in the WQS. Recreational use designations only apply seasonally from May 1 through October 31. Recreational use designation attainment status is determined using bacterial indicators (*E. coli*) and the criteria associated with each recreation use is specified in the

Ohio WQS. The presence of indicator bacteria such as *E. coli* indicates that the water body is contaminated with fecal matter of warm-blooded origin, which could include birds and mammals, including humans.

Attainment of recreation uses are evaluated based on a comparison of measured bacteria levels in the water body to the applicable criterion as reflected in OAC 3745-1-37, which are intended to minimize potential exposure to pathogenic organisms and thereby protect the health of recreational uses of the water.

Water supply uses include Public Water Supply (PWS), Agricultural Water Supply (AWS) and Industrial Water Supply (IWS). The PWS designation applies within 500 yards of a potable (drinking) water supply or food processing industry intake. The Agricultural Water Supply (AWS) and Industrial Water Supply (IWS) use designations are usually applied to all waters unless it can be clearly shown that they are not applicable. A hypothetical example of this might be within an urban area where livestock watering or pasturing does not take place or could not be supported, thus a recommendation may be made that the AWS use not be applied to a particular water body. The limited number of applicable chemical criteria associated with these uses are specified in the Ohio WQS for each use and attainment status is based primarily on chemical-specific indicators. Ohio EPA also measures chemical concentrations in fish tissue to support Ohio's sport fish consumption advisory program and to assess whether water quality is sufficient to support human health water quality goals intended by Ohio's WQS.

Mechanisms for Water Quality Impairment

The following paragraphs present the varied causes of impairment that affect the resource quality of lotic systems in Ohio. While the various issues are presented under separate headings, it is important to remember that they are often interrelated and cumulative in terms of the detrimental impact that can result.

Habitat and Flow Alterations

Habitat alteration, such as channelization, negatively impacts biological communities directly by limiting the complexity of living spaces available to aquatic organisms. Consequently, fish and macroinvertebrate communities are not as diverse compared to unimpacted systems. Indirect impacts may include the removal of riparian trees and field tiling to facilitate drainage. Following a rain event, most of the water is quickly removed from tiled fields rather than filtering through the soil, recharging ground water, and reaching the stream at a lower volume and more sustained rate. As a result, baseflow of small streams can be reduced, causing them to go dry more frequently or to become intermittent. Urbanization impacts include removal of riparian trees, influx of storm water runoff by increasing the area of impervious surfaces, straightening and piping of stream channels and riparian vegetation removal.

Tree shade is important because it limits the energy input from the sun, moderates water temperature and limits evaporation. Removal of the tree canopy further degrades conditions because it eliminates an important source of coarse organic matter essential for a balanced ecosystem. Riparian vegetation aids in nutrient uptake, may decrease runoff rate into streams and helps keep soil in place. Erosion impacts channelized streams more severely due to the lack of a riparian buffer zone to slow runoff, trap sediment and stabilize banks. Additionally, deep trapezoidal channels lack a functioning flood plain and therefore cannot expel sediment as would normally occur during flood events along natural watercourses. The confinement of flow within an artificially deep channel accelerates the movement of water downstream, exacerbating flooding of downstream properties.

Siltation and Sedimentation

Whenever the natural flow regime is altered to facilitate drainage, increased amounts of sediment are likely to enter streams either by overland transport or increased bank erosion. The removal of wooded riparian areas accelerates the erosion process. Channelization excludes all but the highest flow events to confinement within the artificially high banks. As a result, former flood plain areas that allowed for the removal of sediment from the primary stream channel no longer serve this function. As water levels fall following a rain event, interstitial spaces between larger rocks fill with sand and silt and the diversity and quality of available habitat to support fish and macroinvertebrates is reduced. Silt can also clog the gills of both fish and macroinvertebrates, reduce visibility thereby excluding site feeding fish species and smother the nests of lithophilic fishes. Lithophilic spawning fish require clean substrates with interstitial voids in which to deposit eggs. Conversely, pioneering species benefit. They are generalists and best suited for exploiting disturbed and less heterogeneous habitats. The net result is a lower diversity of aquatic species compared with a typical warmwater stream with natural habitats.

Excessive sedimentation can also adversely impact water quality, recreational value, aesthetic quality and drinking water. Nutrients absorbed to soil particles remain trapped in the watercourse. Likewise, bacteria, pathogens and pesticides which also attach to suspended or bedload sediments become concentrated in waterways where the channel is functionally isolated from the landscape. Community drinking water systems must address these issues with more expensive advanced treatment technologies.

Nutrient Enrichment

The assessment of the impact of nutrients on aquatic life uses a weight-of-evidence approach. The objective of the weight-of-evidence approach is to evaluate the trophic state of the stream. Similar to lakes, trophic status in streams can be described by position along the familiar oligotrophic-eutrophic continuum; however, trophic status in streams is additionally described by a continuum defined at one end by heterotrophy, and at the other by autotrophy (Dodds, Trophic State, Eutrophication and Nutrient Criteria in Streams, 2007). In general, oligotrophic systems are described as having low nutrients, low algal biomass and high clarity. Conversely, eutrophic systems are rich in nutrients, have high algal biomass and have large dissolved oxygen (D.O.) swings. Mesotrophic systems have intermediate characteristics between oligotrophic and eutrophic systems. The transition from oligotrophy to eutrophy is often accompanied by a shift from a heterotrophic status to an autotrophic status; and the process is commonly referred to as eutrophication. The amount of dissolved oxygen produced during the day by autotrophs relative to the amount of oxygen consumed at night by the entire microbial community, informs position along both continuums. For the purposes of this evaluation, eutrophication will be defined as the process by which a stream becomes enriched with nutrients, resulting in high chlorophyll-a concentrations or wide diel D.O. swings (USGS 2014). Therefore, the focus for identifying eutrophication requires effective monitoring of the trophic state, which is dictated by primary production and respiration. Ohio EPA considers the performance of the biology relative to the available habitat, diel (24-hour) range of dissolved oxygen, algal biomass and finally nutrient concentrations to perform this assessment.

Ohio and other states have been developing nutrient reduction strategies in recent years to address cultural eutrophication (U.S. EPA, 2015; Ohio EPA, 2014; Miltner, 2010; Heiskary and Markus, 2003). Wide diel D.O. ranges associated with eutrophication are caused by excessive photosynthesis (O_2 production) during daylight hours and respiration at night. The most recent investigations by Ohio EPA have identified a diel D.O. range of 6.5 mg/L as a threshold generally protective of biological and stream quality; diel D.O. ranges greater than 6.5 mg/l are indicative of eutrophication in Ohio streams and are likely over-enriched (Ohio EPA, 2014).

Chlorophyll concentrations from benthic algae (attached to bottom substrates) are measured as a proxy for algal community biomass in wadeable streams and small rivers, while chlorophyll concentrations measured from sestonic algae (suspended in the water column) serve as a proxy for algal abundance in large rivers. Physical factors such as width-depth ratio, time of travel and longitudinal gradient may largely determine whether sestonic or benthic algae drive production and respiration. However, sestonic algae typically dominate streams defined as large rivers, and benthic algae typically dominate small streams. Miltner (2010) identified benthic chlorophyll levels that broadly demarcate enrichment status relative to Ohio. Streams with less than ~90 mg/m^2 can be considered least disturbed for Ohio. Benthic chlorophyll levels between 90 ~ 183 mg/m^2 are typical for Ohio streams with modest amounts of agriculture or wastewater loadings. Levels between 183-320 mg/m^2 are typical of streams draining agricultural landscapes or that are effluent dominated. Chlorophyll levels exceeding 320 mg/m^2 characterize over-enrichment or nuisance conditions. A review of studies on sestonic chlorophyll-a by Dodds (2006), which included some Midwestern streams, suggest that concentrations of 40-100 µg/l sestonic chlorophyll-a identify eutrophic conditions while concentrations >100 µg/l indicate hypertrophic conditions. Miltner (2018) identified essentially identical boundaries based on associations between chlorophyll concentrations and various water quality and biological indicators.

Organic Enrichment and Low Dissolved Oxygen

Relative to atmospheric oxygen, the amount of oxygen soluble in water is low and it decreases as temperature increases. This is one reason why tree shade is so important. The two main sources of oxygen in water are diffusion from the atmosphere and plant photosynthesis. Turbulence at the water surface is critical because it increases surface area and promotes diffusion. Drainage practices such as channelization eliminate turbulence produced by riffles, meanders and debris snags. Although plant photosynthesis produces oxygen by day, it is consumed by the reverse process of respiration at night. Oxygen is also consumed by bacteria that decay organic matter, so it can be easily depleted unless it is replenished from the air. Sources of organic matter include poorly treated wastewater, sewage bypasses and dead plants and algae. Dissolved oxygen criteria are established in the Ohio WQS to protect aquatic life. The minimum and average limits are tiered values related to the applicable aquatic life use designation of the stream (OAC 3745 -1-35, Table 35-1).

Ammonia

Ammonia enters streams as a component of fertilizer and manure run-off and wastewater effluent. Ammonia gas (NH_3) readily dissolves in water to form the compound ammonium hydroxide (NH4OH). In aquatic ecosystems, equilibrium is established as ammonia shifts from a gas to undissociated ammonium hydroxide to the dissociated ammonium ion (NH4+). Under normal conditions (neutral pH 7.0 and temperature 25° C), almost none of the total ammonia is present as gas, only 0.55 percent is present as ammonium hydroxide, and the rest is ammonium ion. Alkaline pH shifts the equation toward gaseous ammonia production, so the amount of ammonium hydroxide increases. This is important because while the ammonium ion is almost harmless to aquatic life, ammonium hydroxide is very toxic and can reduce growth and reproduction or cause mortality.

Ammonia criteria are established in the Ohio WQS to protect aquatic life. The maximum and average limits are tiered values based on sample pH and temperature and vary based upon the aquatic life use designation that applies to the water body (OAC 3745-1-35, Tables 35-2 through 35-8).

Metals

Metals can be toxic to aquatic life and hazardous to human health. Although they are naturally occurring elements, many are extensively used in manufacturing and are byproducts of human activity. Certain metals like copper and zinc are essential in the human diet, but excessive levels are usually detrimental. Lead and mercury are of particular concern because they can trigger fish consumption advisories. Mercury is used in the production of chlorine gas and caustic soda, in the manufacturing of batteries and fluorescent light bulbs and in the burning of fossil fuels. In the environment, it forms inorganic salts, but bacteria convert these to methyl-mercury and this organic form builds up in the tissues of fish. Extended exposure can damage the brain, kidneys and developing fetus. The Ohio Department of Health (ODH) issued a statewide mercury advisory in 1997 primarily for women of child-bearing age and children age 15 and under. They are advised to eat no more than one meal per week of fish (any species) from any Ohio water body unless there is a more or less restrictive advisory. Although the one-meal-per-week advice applies mainly to these sensitive populations, the general advisory recommends that everyone follow that advice. Lead is used in batteries, pipes and paints and is emitted from burning fossil fuels. It can affect the central nervous system and damage the kidneys and reproductive system. Copper is mined extensively and used to manufacture wire, sheet metal and pipes. Ingesting large amounts can cause liver and kidney damage. Zinc is a by-product of mining, steel production and coal burning and used in alloys such as brass and bronze. Ingesting large amounts can cause stomach cramps, nausea and vomiting.

Water quality criteria for various metals are established in the Ohio WQS (Administrative Code 3745-1) to protect human health, wildlife and aquatic life from both acute and chronic exposures. Aquatic life criteria, which are contained in OAC 3745-1-35, vary for some of the metals based on water hardness (OAC 3745-1-35, Table 35-9). Different human health and wildlife criteria apply to the Lake Erie (OAC 3745-1-33, Table 33-2) or Ohio River (OAC 3745-1-34, Table 34-1) drainage basins. The drainage basins also have Tier I criteria and Tier II values for additional metals not established elsewhere that are developed following the procedures outlined in OAC 3745-1-40 and 3745-1-42.

Bacteria

High concentrations of *Escherichia coli* (*E. coli*) in a lake or stream may indicate possible contamination of the water with human pathogens. People can be exposed to contaminated water while wading, swimming, fishing or boating. *E. coli* bacteria are present in large numbers in the feces and intestinal tracts of humans and other warm-blooded animals, such as mammals and birds. While *E. coli* bacteria are harmless in most cases, their presence indicates that the water has been contaminated with fecal material originating from a warm-blooded animal entering the water body either directly or from surface runoff. Indicator bacteria such as *E. coli* can potentially coincide with the presence of pathogenic organisms entering the water through the same pathways but are typically present in the environment in such small amounts that it is impractical to monitor them directly, hence the use of fecal bacteria such as *E. coli* as indicators. While indicator bacteria such as *E. coli* by themselves are usually not pathogenic, some strains of *E. coli* can cause serious illness. Although intestinal organisms eventually perish outside the body, some will remain virulent for a period of time while in the water and may be dangerous sources of infection. This is especially a problem if the fecal material contains pathogens or disease-producing bacteria and viruses. Reactions to exposure can range from an isolated illness such as skin rash, sore throat or ear infection to a more serious wide-spread epidemic. Some types of bacteria that are a concern include *Escherichia*, which cause diarrhea and urinary tract infections, *Salmonella*, which cause typhoid fever and gastroenteritis (food poisoning), and *Shigella*, which cause severe gastroenteritis or bacterial dysentery. Some types of viruses that are a concern include polio, hepatitis A, and encephalitis. Disease-causing microorganisms may also be transmitted through fecal contamination of surface waters and include organisms such as cryptosporidium and giardia.

Since *E. coli* bacteria are associated with warm-blooded animals, there are both human and animal sources. Human sources, including effluent from sewage treatment plants or discharges by on-lot septic systems can present a continuous source. Bacterial contamination from combined sewer overflows are associated with wet weather events. Animal sources are usually more intermittent and are also associated with rainfall, except when domestic livestock have access to the water. Large livestock farms store manure in holding lagoons creating the potential for an accidental spill. Liquid manure applied as fertilizer is a runoff problem if not managed properly and it can seep into field tiles.

Bacteria criteria for the recreational use are established in the Ohio WQS to protect human health during water recreation based upon the quantities of *E. coli* present in the water column. The criteria are seasonal, applying from May 1 through October 31 (OAC 3745-1-37, Table 37-2). The water quality standards also state that streams must be free of any public health nuisance associated with raw or poorly treated sewage during dry weather conditions (OAC 3745-1-04, Part F).

Sediment Contamination

Chemical quality of sediment is relevant because some pollutants can bind strongly to soil particles and are persistent in the environment. Some of these compounds accumulate in the aquatic food chain and may trigger fish consumption advisories, but others are simply a contact hazard because they can cause skin cancer and tumors. The physical and chemical nature of sediment is determined by local geology, land use and contribution from manmade sources. As some materials enter the water column, they are attracted to the surface electrical charges associated with suspended silt and clay particles. Others simply sink to the bottom due to their high specific gravity. Sediment layers form as suspended particles settle, accumulate and combine with other organic and inorganic materials. Sediment is the most physically, chemically and biologically reactive at the water interface because this is where it is affected by sunlight, current, wave action and benthic organisms. Assessment of the chemical nature of this layer can be used to predict ecological impact.

Sediment data are evaluated using Ohio Sediment Reference Values (SRVs; Ohio EPA, 2008), along with guidelines established in *Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems* (MacDonald et.al., 2000), and *Ecological Screening Levels* (ESLs) (U.S. EPA, 2003). Ohio EPA's Sediment Reference Value system was derived from samples collected at ecoregional reference sites. SRVs are site-specific ecoregional-based metals concentrations and are used to identify contaminated stream reaches. The MacDonald guidelines are consensus-based using previously developed values. The system predicts that sediments below the threshold effect concentration (TEC) are absent of toxicity and those greater than the probable effect concentration (PEC) are toxic. ESL values, considered protective benchmarks, were derived by U.S. EPA Region 5 using a variety of sources and methods.

Sediment samples collected by Ohio EPA are measured for a number of physical and chemical properties. Physical attributes analyzed include percent particle size distribution (sand ≥60μ, silt 5-59μ, clay ≤4μ), percent solids and percent organic carbon. Chemical attributes analyzed can include metals, volatile and semi-volatile organic compounds, pesticides and polychlorinated biphenyls (PCBs).

Materials and Methods

All biological, chemical and physical habitat data collection, processing and analysis methods and procedures adhere to those specified in the *Surface Water Field Sampling Manual* for water column chemistry, bacteria and flows (Ohio EPA, 2018), *Biological Criteria for the Protection of Aquatic Life*, Volumes II - III (Ohio EPA, 1987b, 1989a, 1989b, 2015a, 2015b), and the *Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods and Application* (Rankin, 1989).

Determining Use Attainment Status

Use attainment status, also referred to as condition status, is a term describing the degree to which environmental indicators are either above or below criteria specified by the Ohio WQS. Assessing aquatic use attainment status involves a primary reliance on Ohio EPA's biological criteria (OAC 3745-1-07; Table 7-1). These are confined to ambient assessments and apply to rivers and streams outside of mixing zones. Numerical biological criteria are based on multi-metric biological indices including the IBI and MIwb, indices measuring the response of the fish community, and the ICI, which indicates the response of the macroinvertebrate community. Three attainment status results are possible at each sampling location - full, partial or non-attainment. Full attainment means that all of the applicable indices meet the biocriteria. Partial attainment means that one or more of the applicable indices fails to meet the biocriteria. Non-attainment means that none of the applicable indices meet the biocriteria or one of the organism groups reflects poor or very poor performance. An aquatic life use attainment table 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 (full, partial or non), the Qualitative Habitat Evaluation Index (QHEI) and a sampling location description.

Habitat Assessment

Physical habitat is evaluated using the QHEI developed by Ohio EPA for streams and rivers in Ohio (Rankin, 1989 and 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 habitat characteristics 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 the WWH biological criteria. Scores greater than 75 frequently reflect habitat quality sufficient to support exceptional warmwater faunas.

Sediment and Surface Water Assessment

Fine grain sediment samples are collected following the procedures outlined in Ohio EPA's sampling guidance manual, Appendix III (Ohio EPA, 2018). They are shipped to Ohio EPA's Division of Environmental Services for evaluation. Sediment data is reported on a dry weight basis. Sediment evaluations were conducted using guidelines established in MacDonald et al. (2000), U.S. EPA (2003) and Ohio EPA (2008).

Surface water samples are collected according to Ohio EPA's *Surface Water Field Sampling Manual* (Ohio EPA, 2018) and delivered to Ohio EPA's Division of Environmental Services for analysis. Surface water samples are evaluated using comparisons to Ohio WQS criteria, reference conditions or published literature.

Recreation Use Assessment

Recreational use assessments are made at select locations within the study area. Five or more samples are collected within a 90-day period during the recreation season. Most sampling occurs between Memorial Day and Labor Day. Sample locations are generally located toward the downstream end of each HUC-12 watershed. Recreational use assessments are based upon a comparison of the *E. coli* content measured in the surface water against both the applicable geometric mean criteria and statistical threshold values (STV) found in OAC 3745-1-37. Any location where either the geometric mean of the measured values is higher than the applicable geometric mean criterion or where more than 10 percent of the measured values collected at the site are greater than the applicable STV fail to support the recreational use.

Macroinvertebrate Community Assessment

Macroinvertebrates are collected from artificial substrates and from the natural habitats. The artificial substrate collection provides quantitative data and consists of a composite sample of five modified Hester-Dendy multiple-plate samplers colonized for six weeks. At the time of the artificial substrate collection, a qualitative multi-habitat composite sample is also collected. This sampling effort consisted of an inventory of all observed macroinvertebrate taxa from the natural habitats at each site with no attempt to quantify populations other than notations on the predominance of specific taxa or taxa groups within major macrohabitat types (for example, riffle, run, pool, margin). Detailed discussion of macroinvertebrate field and laboratory procedures is contained in *Biological Criteria for the Protection of Aquatic Life*: Volume III, Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities (Ohio EPA, 1989b, 2015b).

Fish Community Assessment

Fish are sampled using pulsed DC electrofishing methods. Fish are processed in the field, and each individual species is identified. Fish are counted, weighed and any external abnormalities are recorded. Discussion of the fish community assessment methodology used in this report is contained in *Biological Criteria for the Protection of Aquatic Life*: Volume III, Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities (Ohio EPA, 1989b, 2015b).

Causal Associations

Using the results, conclusions and recommendations of the biological and water quality report requires an understanding of the methodology used to determine the use attainment status and assignment of probable causes and sources of impairment. The identification of impairment in rivers and streams is straightforward — the numerical biological criteria are used to judge aquatic life use attainment and impairment (partial and non-attainment). The rationale for using the biological criteria, within a weight of evidence framework, has been extensively discussed elsewhere (Karr et al., 1986; Karr, 1991; Ohio EPA, 1987a; Ohio EPA, 1987b; Yoder, 1989; Miner and Borton, 1991; Yoder, 1991; Yoder, 1995). Describing the causes and sources associated with observed impairments relies on an interpretation of multiple lines of evidence including water chemistry data, sediment data, habitat data, effluent data, land use data and biological results (Yoder and Rankin, 1995a, 1995b and 1995c). Thus, the assignment of principal causes and sources of impairment in this report represent the association of impairments (based on response indicators) with stressor and exposure indicators. The reliability of the identification of probable causes and sources is increased where many such prior associations have been identified or have been experimentally or statistically linked together. The ultimate measure of success in water resource management is the restoration of lost or damaged ecosystem attributes including aquatic community structure and function.

Overview: Raccoon Creek Watershed

During 2016 and 2017, Ohio EPA conducted a water resource assessment of 41 streams in the Raccoon Creek study area using standard Ohio EPA protocols, which are described in Appendix A. Included in this study were assessments of the biological, surface water and recreation (bacterial) condition. A total of 83 biological, 83 water chemistry, eight sediment chemistry and 29 bacteria stations were sampled in the study area. The watershed location is shown in Figure 5. Sampling stations are illustrated in Figure 6 and described in Table 3.

Figure 5 — Location of the Raccoon Creek watershed in Ohio.

Please email ***epatmdl@epa.ohio.gov*** to request biological, chemical or bacteria data.

Specific objectives of the evaluation were to:

- ascertain the present biological conditions at the selected sites in the Raccoon Creek study area by evaluating fish and macroinvertebrate communities;
- identify the relative levels of organic, inorganic and nutrient parameters in the sediments and surface water;
- evaluate influences from National Pollutant Discharge Elimination System (NPDES) outfall discharges;
- assess physical habitat influences on stream biotic integrity;
- determine recreational water quality;
- compare present results with historical conditions;
- verify and update fish tissue consumption advisories;
- determine the attainment status of Aquatic Life Uses; and
- recommend beneficial use designations to undesignated streams, verify current designations of designated streams and recommend revisions to designations where appropriate.

The findings of this evaluation may factor into regulatory actions taken by Ohio EPA (for example, NPDES permits, Director's Final Findings and Orders or the Ohio Water Quality Standards – Ohio Administrative Code 3745-1), and may eventually be incorporated into State Water Quality Management Plans, the Ohio Nonpoint Source Assessment, Total Maximum Daily Loads (TMDLs) and the biennial Integrated Water Quality Monitoring and Assessment Report (305[b] and 303[d] reports).

Figure 6 — Sampling locations for the 2016 – 2017 biological survey of the Raccoon Creek watershed.

Table 3 — Sampling locations in the Raccoon Creek watershed.

Station	Location	Assessment Unit (05090101)	River Mile	Sample Type[1]	Drain. Area	Latitude	Longitude
Raccoon Creek (09-500-000)							
301747	Twomile Rd, upstream Twomile Run	02 04	111.38	F2, MQ, C, B, Sn, D, N, Sed	43.6	39.358009	-82.384856
301746	Downstream Mitchell Hollow, at St Rt 328	02 04	104.63	F2, MQ, C, D, N	56.4	39.320336	-82.417968
W03W32	Creek Road (TR18)	02 05	99.60	F, MQ, C, B	98.0	39.29704	-82.43175
W03W44	Township Hwy F3, at ford	02 05	98.34	F2, MQ, C	100.0	39.267093	-82.402485
W03W33	Downstream Sandy Run, Wheelabout Road (C.R. 3)	02 05	92.30	Mq, C	134.0	39.317053	-82.351401
302520	Hope-Moonville Road, upstream Hewett Fork	02 05	89.98	F2, MQ, C, FT	136.0	39.309809	-82.324696
302519	Buck Lane (C.R. 18B), downstream Hewett Fork	03 04	89.36	F, Mq, C, B, Sn, D, N, Sed	176.0	39.302798	-82.325804
W03W34	St Rt 356, near Bunker Hill Rd	03 04	84.08	F2, MQ, C	183.0	39.254812	-82.302918
W03G50	St Rt 50, at Bolins Mills, USGS gage	03 04	80.62	F2, MQ, C, B, Sn, D, N, Sed	200.0	39.230878	-82.286063
W03P07	US 32 W	03 04	72.22	F, MQ, C, FT	223.0	39.167614	-82.313661
W03W35	US 32 W	05 03	63.80	F, MQ, C, D, N, Sed	296.0	39.15752	-82.345777
W03P18	Clarion Road canoe access	05 03	55.48	F2, MQ, C, FT, B, Sn, D, N, Sed	322.0	39.106311	-82.384314
W03S34	Covered Bridge Road (C.R. 4)	05 03	50.10	MQ, C, D, N	336.0	39.047935	-82.376422
W03P05	Vinton Park, downstream dam, St Rt 325	05 04	40.01	F, MQ, C, FT, B, Sn, D, N, Sed	381.0	38.9781	-82.33868
W03S44	Glassburn Road, just off of Woodsmill Road	90 01	35.61	F2, MQ, C, B	543.0	38.934861	-82.334528
601400	Bob Evans Camp, OH 558	90 01	29.20	F2, Mq, C, B, Sn, D, N, Sed, FT	586.0	38.8736	-82.3561
303503	MacIntyre Park, Dan Jones Rd	90 01	22.00	F2, MQ, C, B	615.0	38.803802	-82.370776
W03S24	Ingalls Road, see coordinates	90 01	10.20	F2, MQ, C, B	657.0	38.77136	-82.26819
W03P16	St. Rt. 218	90 01	5.36	B	661.0	38.7367	-82.2453
West Branch Raccoon Creek (09-575-000)							
W03W36	Ilesboro-Cedar Falls Road	02 02	5.68	F, Mq, C	3.8	39.4197	-82.469187
W03W43	St Rt 328, near mouth	02 02	0.15	F2, MQ, C, B, D, N	22.7	39.380293	-82.3978
Honey Fork (09-576-000)							
W03P35	Orlando Flat Road	02 02	0.01	F, Mq, C	10.5	39.382894	-82.418719
East Branch Raccoon Creek (09-574-000)							
W03W37	C.R. 26 (Laurel Run Rd)	02 01	6.64	F, Mq, C	3.2	39.415631	-82.330991
W03K17	Adj. St Rt 56, Wayne National Forest land	02 01	2.10	F, Mq, C, B, D, N	15.3	39.39205	-82.381312
Tributary to Raccoon Creek (RM 98.96) (09-500-011)							
203928	lane off Powder Plant Road	02 05	0.10	F, Mq, C	1.9	39.269274	-82.409886
Twomile Run (09-573-000)							
W03W58	near mouth, Long Ridge Road	02 04	0.16	F, Mq, C	4.9	39.357268	-82.38252
Brushy Creek (09-571-000)							
W03K40	At gravel lane, off St Rt 93	02 03	6.87	F, Mq, C	8.4	39.354422	-82.455758
W03K39	OH 328, near mouth	02 03	0.36	F2, MQ, C, B, Sn, D, N	33.4	39.308551	-82.440039
Siverly Creek (09-571-002)							

Station	Location	Assessment Unit (05090101)	River Mile	Sample Type[1]	Drain. Area	Latitude	Longitude
W03K42	adj. Siverly Creek Road	02 03	0.30	F, Mq, C	10.1	39.329457	-82.465648
Sandy Run (09-568-000)							
203966	King Hollow Road	02 05	2.70	F, Mq, C	5.0	39.333708	-82.331951
Little Sandy Run (09-569-000)							
303689	St Rt 278	02 05	0.40	F, Mq, C	1.5	39.312796	-82.360733
Hewett Fork (09-563-000)							
W03K37	adj. Cabondale Road	03 01	13.10	F, Mq, C	8.3	39.391869	-82.24936
303739	adj. Waterloo Wildlife Area dst bridge	03 01	8.40	F, Mq	16.4	39.347464	-82.253128
W03P08	upstream Rockcamp Creek, Rockcamp Road (T.R. 20)	03 01	4.31	F2, MQ, C, B	28.1	39.317587	-82.278266
W03P32	at mouth	03 01	0.01	F2, MQ, C, D, N	40.5	39.304409	-82.322622
Grass Run (09-567-000)							
W03P41	St Rt 356	03 01	0.04	F, Mq, C, D, N	2.7	39.346021	-82.25475
Pine Run (09-566-000)							
301579	at mouth, 750 ft W OH 356	03 01	0.10	F, Mq, C	2.0	39.336382	-82.273492
Coal Run (09-565-000)							
W03W50	St Rt 681	03 01	0.05	F, Mq, C	0.8	39.297016	-82.249481
Rockcamp Creek (09-564-000)							
W03P33	Rockcamp Road	03 01	1.53	F, Mq, C	7.7	39.316202	-82.280805
Laurel Run (09-562-000)							
W03W59	near Knox, at T.R. 18 (Mulby Road)	03 04	0.16	F, Mq, C	2.6	39.26788	-82.290024
Onion Creek (09-561-000)							
W03W45	C.R. 4 (Worley West Road)	03 04	1.41	F, Mq, C	8.3	39.261058	-82.268151
Flat Run (09-557-000)							
W03W51	Brooks Road, near US 50	03 04	1.60	F, Mq, C	4.8	39.220137	-82.27084
Long Run (09-556-000)							
203960	Adj Long Run Road (C.R. 11)	03 04	1.40	F, Mq, C	2.2	39.205907	-82.30986
Elk Fork (09-530-000)							
W03W06	Morgan Road (C.R. 11), upstream Puncheon Fork	03 02	13.90	F, Mq, C	14.4	39.246783	-82.460101
W03P30	St Rt 50, 1 Mi. E McArthur	03 02	13.26	F2, Mq, C, B, D, N	24.5	39.241393	-82.453426
W03W14	downstream Wolf Run, Adj Stone Quarry Road (C.R. 8)	03 03	8.55	F2, MQ, C	44.4	39.21621	-82.404442
W03P31	C.R. 43B, Northeast of Radcliff	03 03	0.01	F2, Mq, C, B, Sn, D, N, Sed	59.8	39.161494	-82.352306
Austin Powder Tributary to Elk Fork at RM 11.17 (09-530-004)							
W03W09	East of McArthur, at C.R. 7	03 02	0.43	F, Mq, C, D, N	2.4	39.238001	-82.431976
Puncheon Fork (09-534-000)							
W03K30	Bolar Road (T.R. 19)	03 02	2.82	F, Mq, C	4.7	39.261548	-82.52041
W03W30	Upstream McArthur WWTP, C.R. 25	03 02	1.51	F	7.2	39.2433	-82.4844

Station	Location	Assessment Unit (05090101)	River Mile	Sample Type[1]	Drain. Area	Latitude	Longitude
W03W07	St Rt 50	03 02	0.28	F, Mq, C	9.8	39.244646	-82.468306
Wolf Run (09-533-000)							
203947	Vinton Station Road (C.R. 24)	03 02	3.80	F, Mq, C	4.7	39.215793	-82.46127
Pierce Run (09-553-000)							
W03L08	St Rt 160, near Hamden	05 01	5.47	F, Mq, C, D, N	3.4	39.165411	-82.421694
W03W47	Township Hwy 2A	05 01	1.68	F, Mq, C, B, D, N	9.5	39.141186	-82.380155
Rockcamp Run (09-552-000)							
W03W52	Hawk Station Road	05 03	0.11	F, Mq, C	2.8	39.109506	-82.388633
Indiancamp Run (09-551-000)							
W03W56	Adj. Minerton Road (C.R. 26)	05 03	0.30	F, Mq, C	2.1	39.084186	-82.397226
Flatlick Run (09-549-000)							
W03S39	Newsome Road (C.R. 8)	05 03	0.60	F, Mq, C	7.2	39.046791	-82.345344
Strongs Run (09-546-000)							
W03S36	Tower Road (T.R. 24)	05 02	5.90	F, Mq, C	5.9	39.0703	-82.3028
W03S47	Adney Road	05 02	0.58	F, Mq, C, B, D, N	16.4	39.014799	-82.336005
Williams Run (09-547-000)							
203956	Williams Run Road	05 02	0.10	F, Mq, C	3.8	39.055535	-82.300527
Robinson Run (09-544-000)							
W03S40	St Rt 325	05 04	0.18	F, Mq, C	9.7	38.99593	-82.32983
Little Raccoon Creek (09-510-000)							
W03S09	Wolf Hill Road (C.R. 25)	04 01	36.67	Mq, C	12.1	39.208088	-82.541721
W03W38	Lake Rupert discharge (St Rt 93)	04 01	32.95	DW	25.0	39.1722	-82.5203
303474	Wellston Intake	04 01	30.00	DW	36.1	39.138611	-82.51687
W03S07	Mulga Road (C.R. 39), upstream Meadow Run	04 01	27.90	F, MQ, C, B, D	48.0	39.122143	-82.499049
W03W25	St Rt 32, upstream Mulga Run	04 03	24.55	F, MQ, C, D, N	62.5	39.100216	-82.484707
W03K10	Buckeye Furnace Rd, at State Memorial	04 03	18.45	F2, MQ, C	87.0	39.054375	-82.459734
W03S06	Keystone Rd, upstream Dickason Run	04 03	12.71	F, MQ, FT, C, Sn, B, D, N, Sed	99.0	39.01042	-82.452333
W03K09	Keystone Furnace Road, Downstream Dickason Run	04 04	11.00	F2, MQ, C	129.0	39.009439	-82.445003
W03P04	St Rt 325, or Woods Mill Rd	04 04	1.17	F, MQ, C, B, FT, D, N	154.0	38.953265	-82.365672
McConnels Run (09-528-000)							
303688	Lake Road (TR15)	04 01	1.98	F, Mq, C	0.9	39.221381	-82.516539
Johnson Run (09-527-000)							
W03P53	Northwest of Hamden, at Tripp Road	04 01	0.93	DW	2.1	39.1732	-82.5338
Sugar Run (09-510-002)							
W03S11	Carr Ridge Run	04 01	0.17	DW	5	39.1564	-82.5089
Tripp Run (09-526-000)							
W03P45	St Rt 349	04 01	0.33	DW	0.9	39.1567	-82.5122

Station	Location	Assessment Unit (05090101)	River Mile	Sample Type[1]	Drain. Area	Latitude	Longitude
Sand Run (09-525-000)							
W03P10	St Rt 349	04 01	0.33	DW	9.2	39.1356	-82.5211
Meadow Run (09-524-000)							
W03S10	Upstream General Mills, on property	04 01	3.10	F2, Mq, C	5.1	39.095926	-82.546886
W03W27	St Rt 327 (Pennsylvania Road)	04 01	2.16	F2, Mq, C	8.7	39.104613	-82.537206
W03W18	Cheatwood Road	04 01	0.72	F, Mq, C, D, N	9.9	39.115586	-82.515599
Flint Run (09-520-000)							
W03P22	Southeast of Middleton, at mouth	04 03	0.01	C	4	39.0714	-82.4717
Dickason Run (09-514-000)							
W03S48	Keystone Furnace Road, or Ridgeland Road	04 02	2.37	F, Mq, C	17.7	39.016822	-82.503649
W03P43	Orpheus-Keystone Road	04 02	0.11	F2, MQ, C, B, D, N	26.9	39.008732	-82.455195
Deer Creek (09-511-000)							
W03P15	Adj., St Rt 325, near mouth	04 04	0.20	F, Mq, C	5.9	38.952969	-82.366863
Barren Creek (09-542-000)							
203953	OH 554, powerline easement, or upstream at bridge	06 02	0.30	Mq, C, B, D, N	9.1	38.904697	-82.337075
Indian Creek (09-539-000)							
W03P36	upstream Rio Grande WWTP, St Rt 325	06 01	1.58	F2, Mq, C, B	10.4	38.889141	-82.382508
W03W55	Downstream Rio Grande WWTP, St Rt 325, upstream Little Indian Run	06 01	1.45	F2, Mq, C, N, D	10.4	38.890946	-82.38048
Little Indian Creek (09-540-000)							
W03P14	Buckeye Hills Road	06 01	0.17	F, Mq, C	10.2	38.89344	-82.383662
Big Beaver Creek (09-500-012)							
303508	Guthrie Road, off Cora Mill Road	06 03	0.90	F, Mq, C, B	7.3	38.841294	-82.380145
Claylick Run (09-507-000)							
203929	Lincoln Pike	06 05	0.40	Mq, C, B	7.7	38.758631	-82.30476
Clear Fork (09-506-000)							
W03K23	Ingalls Road	06 05	0.02	F, Mq, C	7.7	38.781479	-82.27394
Bullskin Creek (09-502-000)							
W03K21	Williams Hollow Road	06 04	0.37	F2, Mq, C, B, D, N	13.2	38.725654	-82.251873
Little Bullskin Creek (09-503-000)							
W03K22	Little Bullskin Road	06 04	0.01	F, Mq, C	4.9	38.708777	-82.29855

1 C – water chemistry, B – bacteria, D - datasondes, S - Sediment, F2 - two fish pass, F - one fish pass, Mq - qualitative macroinvertebrate, MQ – quantitative macroinvertebrate, N - Nutrient, Sn – Sentinel, R - Reference Site, C3 – Chemistry field parameters only

Study Area Description

The Raccoon Creek watershed drains 683.5 square miles and is located in Athens, Gallia, Hocking, Jackson, Meigs and Vinton counties (Ohio Department of Natural Resources, 2001). The headwaters of Raccoon Creek begin in southern Hocking County with the West and East Branches of Raccoon Creek, dropping from 1,100 feet to 520 feet at the confluence with the Ohio River. The predominant land uses in the watershed

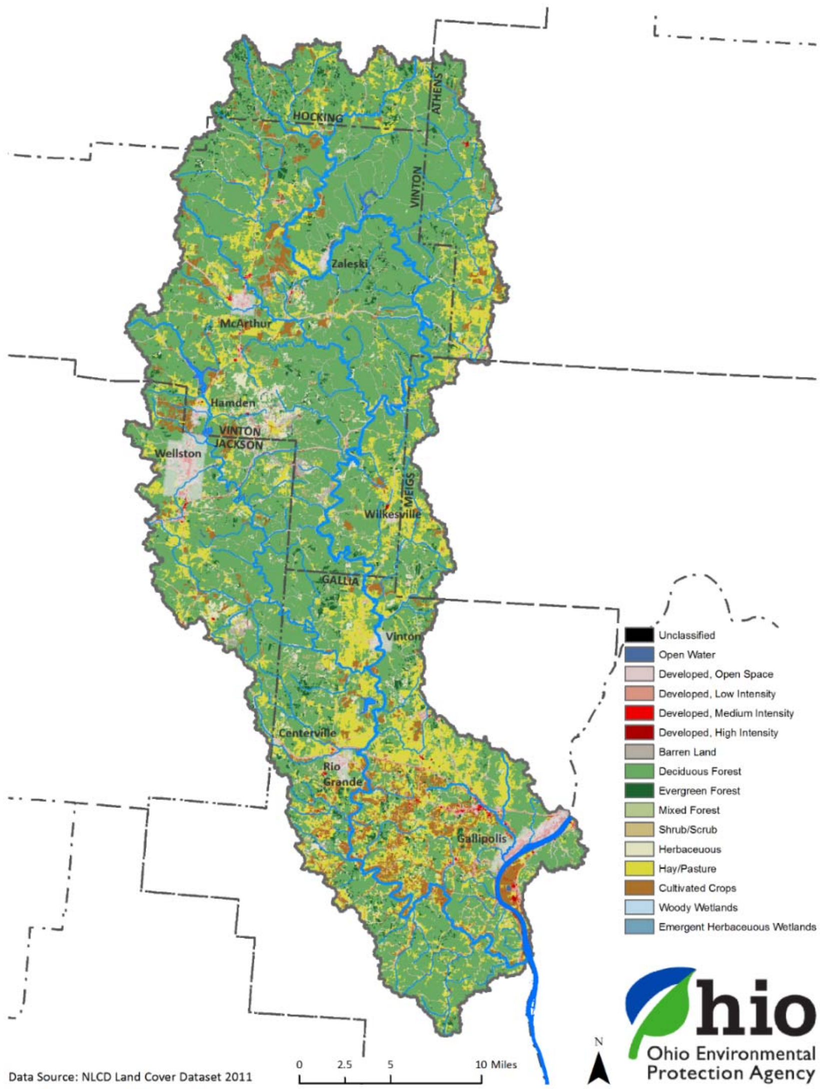


Figure 7 — Raccoon Creek watershed is predominantly forested (66.8 percent) with pasture, grazing, and row crop agriculture at 20.6 percent.

include forest at 66.8 percent, 6.8 percent is developed land, cultivated crops are 5.3 percent and pasture/hay use is 15.3 percent (Figure 7). Approximately 5.2 percent of the land use is barren, grass lands or scrub/shrub lands, 0.46 percent is open water and 0.07 percent is wetland areas (Homer, et al., 2015). Coal, iron, and clay mining have been extensive throughout the upper watershed. The City of Wellston and the villages of Zaleski, Hamden, McArthur, Vinton and Rio Grande are within the watershed. The mainstem flows to the south through the villages of Zaleski and Vinton and enters the Ohio River at river mile (RM) 705.30 in Gallia County. A total of twenty National Pollutant Discharge Elimination System (NPDES) permitted facilities discharge sanitary wastewater, industrial process water, and/or industrial storm water into the Raccoon Creek watershed study area.

Ecoregion, Geology, and Soils

Raccoon Creek watershed is entirely within Ohio's oldest landscape, the Western Allegheny Plateau (WAP) ecoregion. This portion of the WAP consists of Pennsylvanian Age bedrock which is predominately rugged, hilly, wooded terrain that was not glaciated unlike northern and western Ohio (Omernik & Griffith, 2008). Although this area was not glaciated, the south advancing glaciers blocked the major north flowing river draining this area, the Teays River. This blocking of the Teays River caused the valleys of the Teays and its tributaries to fill making a large slack water lake extending into West Virginia and Kentucky. This occurred at least twice in this region of the WAP. These slack water lakes filled with sediments causing major drainage changes and eliminating all-natural lakes (Lafferty, 1979).

The Pennsylvanian Age bedrock is made up of Monongahela, Conemaugh, and Allegheny and Pottsville Group undivided (youngest to oldest) (Figure 8). The Monongahela Group is situated in the most southern portion of the watershed. The Monongahela Group is characterized by shale, siltstone, and mudstone and comprises only 1.8% of the watershed (Ohio Department of Natural Resources, 2013). Siltstone, shale and mudstone are abundant in the Conemaugh Group. Sandstone, limestone, and coal are also found, to a lesser degree, in this group. The coal is mostly thin and impure and lacks the thickness for widespread economic development. The Conemaugh Group makes up the eastern and southern third of the watershed. The Allegheny and Pottsville Group undivided (APGu) comprises the northwestern two-thirds of the watershed and is located in the Ohio's Hanging Rock Iron District. The APGu is characterized by shale and sandstone with lesser amounts of limestone, clay, flint and coal also found in this group. The abundance of these geologic resources had made and continues to make this group an important economic asset. Bituminous coal found in the APGu trends from thin to twelve feet thick. The coal in the APGu was formed in coastal peat swamps where brackish tide water brought in sulfate ions. Dissolved iron in the water and sulfate ions combined to form pyrite (FeS_2) which when later exposed to water and air form acid mine drainage (AMD). The sandstone component of the APGu was utilized in the construction of the Hanging Rock Iron Furnaces and building stones. Some limestones were hard enough to be made into buhrstones for water-powered grist mills, known as the "Raccoon Millstones" while other limestones were used to make Portland cement and as flux in iron furnaces (Camp, 2006). Clays and shale in the group were mined for making pottery and bricks.

Six major soils series make-up over 98 percent of the soils found in Raccoon Creek watershed and hardwood forest dominate the woodland land use (Soil Survey Staff, 2004). The Steinsburg-Rarden-Clymer-Berks soil series comprises 31.5 percent of the soils in the watershed and is found in the middle-west portion of the watershed. These are moderate to well drained soils on ridge tops with moderate to steep slopes. They are formed from shale, sandstone and siltstone. This soil series is typically used for pastures and cropland while the remaining use is woodlands.

The Omulga-Doles soil series comprises 17.3 percent of the soils and is found in abandoned pre-glacial drainage systems throughout the study area. These soils are typically deep, poorly to moderately well drained with little or no slope. Loess, colluvium, and old alluvium are the sources of this soil series and they overlay old lacustrine sediments in most areas and are highly erodible. In most areas, these soils are cultivated with row crops while some areas are used for pastures or woodlands.

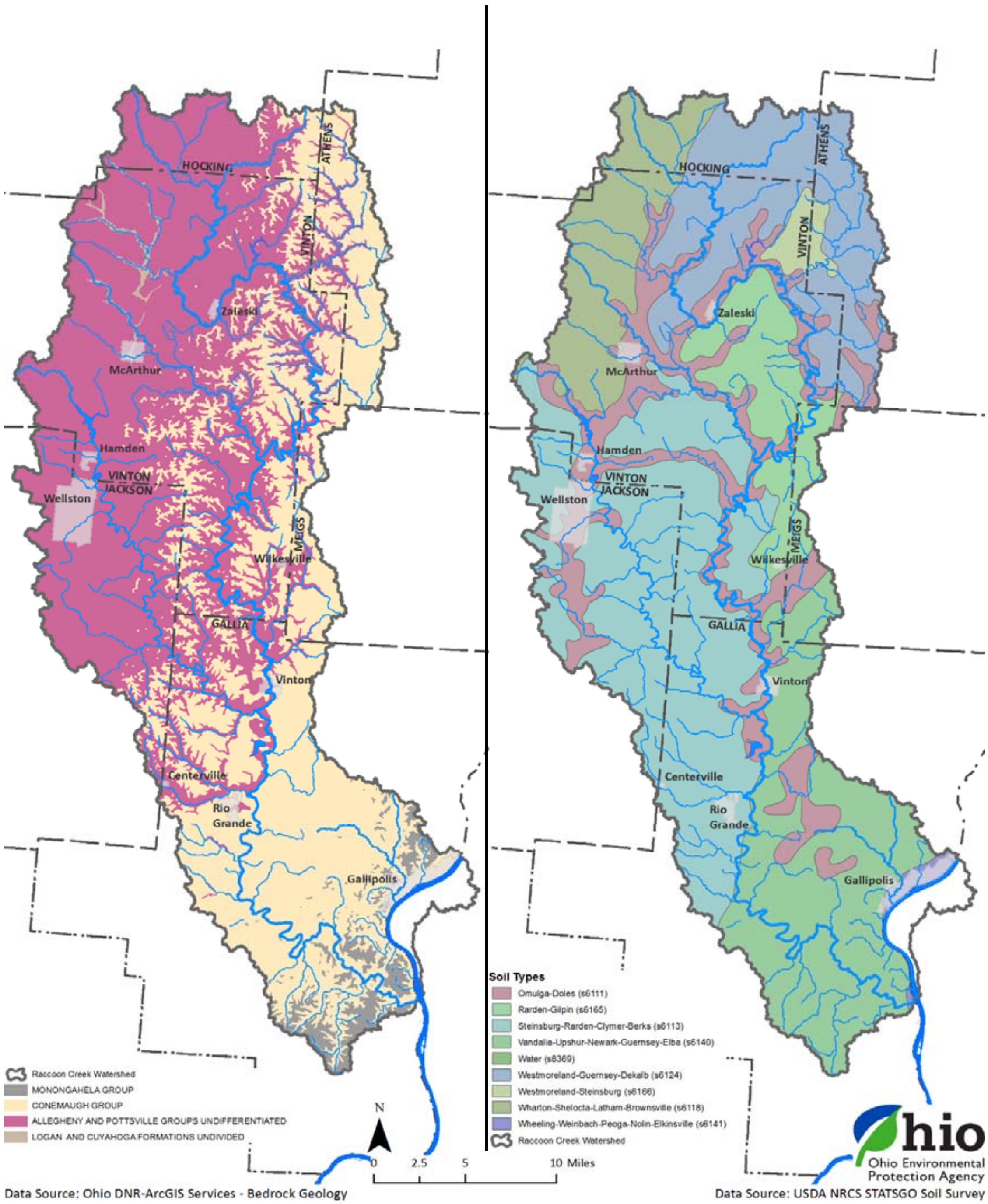


Figure 8 — Raccoon Creek watershed bedrock geologic features and soil types

The Vandalia-Upshur-Newark-Guernsey-Elba soil series comprises 15.6 percent of the watershed and is found in the southeast section of the watershed. These are very deep soils but range from poorly drained to well drained. The origins of this soil series are shale, siltstone, sandstone with some soils originating from limestone and loess. Flat to gently sloping are typical for this series but in some areas have steep slopes. Pasture, cropland and woodland are the dominate land uses. Many areas have been farmed-out and are now used for pasture or have reverted to woodlands.

The Westmoreland-Guernsey-Dekalb soil series comprises 15.4 percent of the watershed and is found in the northeastern section of the watershed. These are deep, well drained soils that originate from siltstone, shale, and limestone. Found on hills, ridgetops and hill slopes, these soils tend from nearly flat on ridgetops to very steep on hills. Woodlands and pastures are the typical land use with some land used for crops.

The Wharton-Shelocta-Latham-Brownsville soils series comprises 10.4 percent of the watershed and is found in the northwestern portion of the watershed. These are deep to very deep, well drained soils that originate from shale, siltstone, and fine-grained sandstone. They are found on gently sloping to very steep upland areas, foot slopes, and summit areas. Woodlands dominate the landscape with some areas in pasture. Very little of this series is used for row crops.

The Rarden-Gilpin soils series comprises 8.2 percent of the watershed and is found along the Vinton-Meigs County line from Wilksville to Zaleski. These are moderately deep, moderately well drained soils that originate from siltstone and shale with some contribution from sandstone. The Rarden-Gilpin series are found on ridgetops and hillslopes with some areas being flat, but most areas have very steep slopes. Most areas are in woodlands or pastures with very little row crop cultivation.

Wastewater Discharge Overview

A total of 20 National Pollutant Discharge Elimination System (NPDES) permitted facilities discharge sanitary wastewater, industrial process water and/or industrial storm water into the Raccoon Creek watershed. Each facility is required to monitor their discharges according to sampling and monitoring conditions specified in their NPDES permit and report results to Ohio EPA in a Discharge Monitoring Report (DMR).

Certain NPDES facilities are considered major dischargers based on the volume (more than one million gallons per day or MGD) and type of waste they discharge. All other individual NPDES permitted facilities are considered minor dischargers. The only major NPDES facility in the Raccoon Creek watershed, as well as minor dischargers that were bracketed with biological monitoring sites, are listed in Table 4. Through our website, Ohio EPA provides an interactive map with NPDES facility locations. Once a facility is selected within the interactive map, the user will have access to basic information about the facility, such as a links to the associated NPDES permit and compliance information through U.S. EPA's website. The interactive map can be found at ***http://oepa.maps.arcgis.com/apps/webappviewer/index.html?id=25cf405adc3444139f4b410e69a2bbc9***.

General NPDES permits are a potential alternative for facilities that have a minimal effect on the environment, have similar operations and meet certain eligibility criteria. There are several different types of general permits, including, but not limited to, small sanitary sewer discharges, petroleum bulk storage and non-contact cooling water. A list of facilities covered under each type may be found at ***epa.ohio.gov/dsw/permits/NonStormgplist.aspx***. There are also several types of general permits specific to storm water, including, but not limited to, small Municipal Separate Storm Systems (MS4s), construction sites, industries and marinas. A list of facilities covered under each type may be found at ***epa.ohio.gov/dsw/permits/gplist.aspx***.

Table 4 — Major NPDES Facilities and Minor Dischargers Bracketed with Biological Monitoring Sites

Ohio EPA Permit Number	Facility Name	Design Discharge (MGD)	Wastewater Type, Treatment System	Stream and River Mile at Discharge	County
WAU 05090101 03 02 – Headwaters Elk Fork					
0PB00080	McArthur WWTP	0.494	Facilitative Lagoons	Elk Fork RM 14.85	Vinton
WAU 05090101 04 01 – Headwaters Little Raccoon Creek					
0PC00013	Wellston North WWTP	1.44	Settling, Filtration, Disinfection and De-chlorination	Meadow Run RM 1.17	Jackson
0IH00046	General Mills Inc. - Wellston Plant	0.360	Biological Lagoons and Settling. NCCW	Meadow Run RM 2.8 and 3.18	Jackson
WAU 05090101 06 01 – Indian Creek					
0PB00035	Village of Rio Grande WWTP	0.160	Oxidation Ditch, Secondary Clarifiers and Disinfection	Indian Creek RM 1.45	Gallia

Mineral Extraction

Underground Coal Mining

There are approximately 25,610 acres of underground mines located in the Raccoon Creek watershed. Mining in the area began in 1840’s and has continued until the present (Crowell, 1995). Large scale coal mining began with the completion of the first railroad in the area in 1856. Coal in this region is typically high in sulfur (especially the No. 6 coal seam which is the most extensive coal seam) resulting in AMD from abandoned mine lands. The most typical underground mines were drift mines. In drift mining, a tunnel is developed into horizontal seams of coal along the hillside. When drift mines were employed “up dip,” the water in the mine would flow out the entrance. As the demand for coal increased, coal seams deeper in the ground or below drainage were developed. This required using vertical shafts entrances to reach the coal. The water that accumulated in the mines would then be pumped to the surface and discharged without treatment. Abandoned underground mines are found in the headwaters of Hewett Fork, East and West Branches of Raccoon Creek and Little Raccoon Creek (Figure 10). There are an estimated 335 coal mines within the Raccoon Creek watershed of which 275 are underground mines with 582 mine openings or entrances (Ohio Department of Natural Resources, 1954). In 1967, it was determined that the underground coal mines discharge significant amounts of AMD into the streams in the Raccoon Creek watershed (U.S. Department of the Interior, 1967). The City of Wellston, in the Little Raccoon Creek watershed, has been extensively under mined which has led to occasional subsidence damage. Approximately 8,000 acres of shaft entry, underground room and pillar mining occur under and around the Wellston city limits. Room and pillar mining is an underground mining method that extracts coal from the “room” leaving behind the “pillar” which supports the roof or overburden. When the pillars become weak, they can buckle and collapse resulting in subsidence of the overburden which fractures and sags into the mine void. Most older underground coal mines used this mining technique. Homes built over mine voids can suffer major damage to walls and foundations when the mine void collapses. The Ohio legislature enacted a law that established the Ohio Mine Subsidence Insurance Fund. All the county residence within the study area are required to purchase the subsidence insurance which has a low annual premium.

Figure 9 — Carbondale calcium oxide doser, courtesy of Amy Mackey, Raccoon Creek Partnership Watershed Coordinator

The Carbondale mine complex, mining the Middle Kittanning No. 6 coal (average thickness 5 feet 5 inches), around Carbondale, Athens County, covers approximately 3,800 acres (approximately six square miles) of underground coal mine. The Carbondale Coal Company began mining in the Hewett Fork watershed as early as 1910. Carbondale Mining continued through the 1950s. The Hocking Valley Mining Company opened the Stadler Mine in 1953. Other large mines in the Hewett Fork watershed include the Coonville No. 2 and Kennard mine (opened in 1951) and the Hocking Moor Del Carlo mine from 1925. One of the largest sources of AMD in the Hewett Fork watershed is the 33-acre Rice Hocking Mine that was abandoned on May 31, 1923 and is most likely connected to other underground mines around Carbondale. There are two drift mine entries from the Rice Hocking Mine that discharged AMD to Hewett Fork at RM 11.01 that essentially eliminated the biological community in Hewett Fork and periodically impacted Raccoon Creek downstream from the mouth of Hewett Fork. Previous reports on Raccoon Creek determined that Hewett Fork was ranked the most AMD impacted stream in the watershed (Ohio Department of Natural Resources, 1982). In 2000, Ohio EPA conducted fish biological monitoring at two locations upstream and downstream from the mine discharge at RM 13.10 and RM 8.30 respectively. The site above the discharge had seven species of fish while the site downstream had no fish. ODNR-DMRM constructed the first AMD wetland treatment on Hewett Fork in 1991 at the Carbondale mine discharge (Farley & Ziemkiewicz, 2005). The anaerobic wetland was constructed to capture the mine discharge at Carbondale, but performance waned over time. The wetland captured large quantities of metals but did not reduce the acidity loading to Hewett Fork. In 2004, the Raccoon Creek Watershed Partnership (RCP) along with ODNR-DMRM installed a water wheel calcium oxide doser (Figure 9) to help raise the pH in the treatment system discharge. Prior to the calcium oxide treatment system being installed, the discharge from the underground mine had a pH of 3 to 4 S.U. After the doser was installed, the pH has risen into the 10 to 11 S.U. range and has effectively treated additional sources (Trace Run and Carbondale Creek) of AMD entering Hewett Fork. At the Waterloo Wildlife Area (formerly the Waterloo Experimental Station), RM 8.40, eighteen species of fish were found in 2017.

A more recent underground coal mining operation, the Southern Ohio Coal Company (SOCCO), operated three mine complexes in the Raccoon Creek and Leading Creek watersheds. SOCCO operated the Raccoon Mine No. 3 from 1974 until 1989, which covered over 2,700 acres of underground mine. The Raccoon No. 3 mine went from Raccoon Creek east and under Flatlick Run. SOCCO operated the Meigs Mine No. 2 from 1972 until 2002 and removed 11,670 acres of coal from the underground mine. Meigs Mine No. 2 mined coal under Brush Fork, North Fork Brush Fork and much of the upper reach of Strongs Run. The Meigs Mine No. 1 operated from 1972 until 2001 and mined 8,755 acres. The Meigs Mine No. 1 mined under Strongs Run, Sugar Run and Williams Run. In 1989, Meigs Mine No. 1 and Raccoon Mine No. 3 Mines were interconnected underground, with the combined mine being named Meigs Mine No. 31. These mines extracted the Clarion No. 4A coal seam which averages about 3¼ feet thick. Room and pillar and longwall mining techniques were employed at these mines with longwall mining being used for most of the coal extraction. In longwall mining, a shaft is constructed down to the coal seam and a longwall miner cuts long sections off the coal face, which falls onto a conveyor for removal. As the longwall miner advances forward, the hydraulic roof supports advance with the miner allowing the ceiling to collapse behind the machine. Longwall mining allows for more coal to be extracted (by not leaving a pillar), but can, sometimes, cause serious subsidence on the surface resulting in damaged roads, buildings, loss of well water and the loss of streams. The shearer or cutting edge of the longwall miner typically cuts five to six feet of coal and rock. In the case of the Clarion No. 4A coal, nearly half of the material removed in this mine complex was waste material or coal refuse and required surface disposal.

On July 11, 1993, Meigs Mine No. 31 suffered a catastrophic mine flooding event. The bulkhead between the expired mine (Raccoon Mine No. 3) and the active mine failed. The bulkhead failure released large quantities of AMD laden water from the old mine into the active mine. This event resulted in the emergency release (pumping) of a substantial volume (approximately 1 billion gallons) of untreated, and partially treated, AMD into the Raccoon Creek and Leading Creek watersheds with substantial environmental impact (U.S. Fish and Wildlife Service, 2006). Beginning on July 30, 1993, flooded mine water was pumped from the mine void into Robinson Run, Sugar Run and Strongs Run in the Raccoon Creek watershed and into Parker Run in Leading Creek. Pumping to Parker Run and Strongs Run ceased on August 25, 1993 and pumping ceased on September 16, 1993 to Robinson Run and Sugar Run. Raccoon Creek and its tributaries received less mine water during the pumping than Leading Creek, but a fish kill was reported on Raccoon Creek between Strongs and Robinson Run. The tributaries were severely impacted from the low pH, high dissolved and suspended solids in the mine water. Strongs Run received mine water with a pH as low as 2.1 S.U. resulting in a complete kill of all aquatic life (Ohio Environmental Protection Agency, 1994). Pumping to Sugar Run resulted in a partial aquatic life kill. The mine pumping event resulted in SOCCO entering a Consent Decree with the US Department of Justice and Director's Finding and Orders with Ohio EPA. The enforcement actions required SOCCO to meet certain ecological endpoints that were stipulated in the *Ecological Recovery Endpoints for Streams Affected by the Meigs Mine #31 Mine Discharge during July and September 1993* (***http://epa.ohio.gov/portals/35/documents/LeadingCreek1994TSD.pdf***) document developed by Ohio EPA. The Consent Decree further required SOCCO to place over 2 million dollars into a trust fund, administrated by the US Department of Fish and Wildlife Service, to be used for restoration project in the Leading Creek watershed. Endpoints or recovery objectives included certain species of fish, macroinvertebrates and unionid mussels that previously occurred in the watershed as well an aquatic salamander (mudpuppy, *Necturus maculosus)*. By 2005, it was determined that the Raccoon Creek watershed streams affected by the 1993 mine flooding and pumping had met the biological endpoints established.

Surface Coal Mining

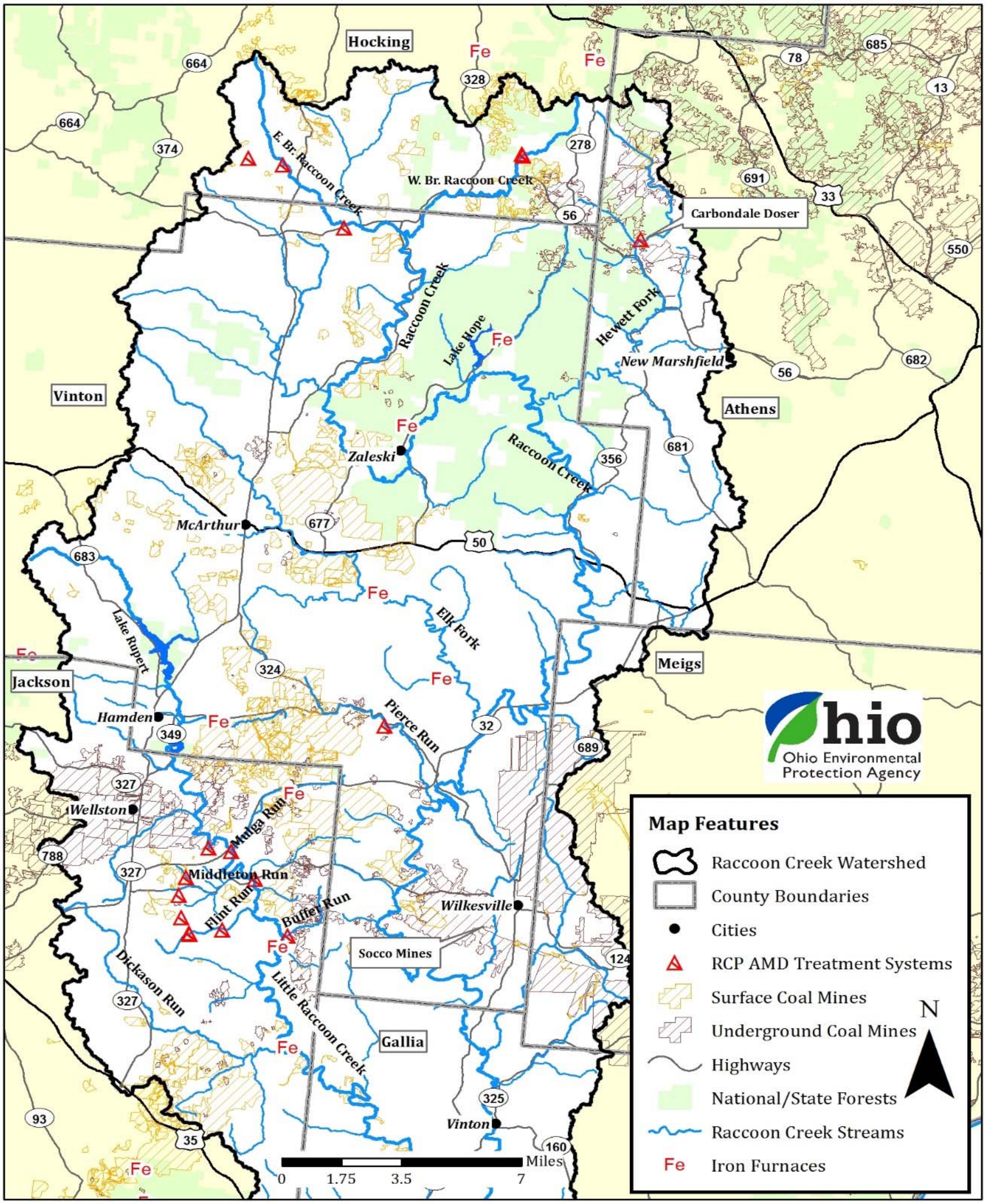


Figure 10 — Upper Raccoon Creek watershed with historic coal mining, iron furnaces and AMD treatment systems.

There are approximately 21,550 acres of surface mines in the Raccoon Creek watershed (Rice, et al., 2002). Surface mining of coal in the watershed began in the 1930s (Laverty, et al., 2000). In Gallia County, near the mouth of Raccoon Creek, many small surface mines of a few acres or less began to operate in the mid-1950s. Large scale surface mining began the 1960s and 1970s in the Raccoon Creek watershed. Prior to 1972, Ohio had few laws regulating surface mining resulting in extensive abandoned and unreclaimed mine lands (Ohio Department of Natural Resources, 2011). In 1972, Ohio passed a revised Strip Coal Mining Act that was the strongest surface mining law in the nation. Under the law, the land had to be returned to approximate pre-mining contours with replacement of topsoil and vegetation. In 1977, a federal law, the Surface Mining Control and Reclamation Act (SMCRA), was enacted to require all surfaces mines in the nation meet certain reclamation standards. Title IV of SMCRA established a federal grant program to fund abandoned mine reclamation.

Abandoned surface coal mines deforested land, filled stream valleys with overburden, eliminated headwater streams, removed hilltops, and often left behind large piles of coal waste (gob and/or refuse), highwalls and slurry impoundments. These abandoned surface mines along with deforestation and stream channelization are the source of vast quantities of sediment found in upper Raccoon Creek (McCament B. M., 2007) and throughout the watershed. In 1967, it was estimated that runoff and seepage from 1,700 acres of unreclaimed or poorly reclaimed surface coal mines contributed a major portion of the AMD in the Raccoon Creek watershed. Before reclamation, abandoned coal refuse piles leached thousands of pounds of sulfuric acid and metals into the creeks daily, significantly degrading the water quality of the streams.

The Little Raccoon Creek watershed was severely impacted by AMD and sedimentation from historic mining with some of the largest surface mines over 1,000 acres (Figure 10). Northeast of Wellston, over 6,500 acres of surface mining occurred from 1960's to the present in the Little Raccoon Creek and Pierce Run watersheds. The Broken Aro Coal Company operated a coal processing facility in the 1950's on 240 acres of land in the headwaters of Flint Run. It is estimated that this plant processed 400,000 tons of coal annually between 1952 and 1956 (Laverty, et al., 2000). The coal processing methods used in the 1950's involved separating marketable coal from waste material that was removed during the surface mining operation. The waste materials, which included rock, shale, pyrite and low-grade coal (coal with layers of sand or shale or clay) was disposed of in stream valleys or in uncovered and unlined impoundments on the property. Exposure to the rain and snow allowed vast quantities of toxic water to drain into Flint Run and Little Raccoon Creek. Prior to reclamation efforts at Broken Aro by ODNR-DMRM and the RCP in 2006 and 2015, Flint Run contributed 42 percent of the acid load and 28 percent of the total metal load to Little Raccoon Creek during high-flow conditions. During low-flow, Flint Run contributed 51 percent of the metals and acid load to Little Raccoon Creek. The drainage just north of Flint Run, locally called Middleton Run, was the next largest AMD contributor to Little Raccoon Creek. Middleton Run has abandoned deep mine discharges, large abandoned unreclaimed or partially reclaimed surface mines and unreclaimed coal refuse and spoil piles throughout this small 2.28 square mile watershed. Abandoned surface mines affect 63 percent of Middleton Run.

Iron

With the discovery of iron ore in the 1840's in the Hanging Rock Iron Region, iron furnaces began to spring-up throughout the Raccoon Creek watershed. The Hanging Rock Iron District extended from northern Kentucky up to Hocking County in southeast Ohio. Eight iron furnaces operated in the Raccoon Creek watershed from 1848 to 1894 (Conway). Iron production at the furnaces was very resource intensive requiring as many as 500 men to gather raw materials, operate the furnace and ship the finished product. The typical furnace required more than 325 acres of virgin timber (or 13,000 cords of wood), for charcoal production, to operate for one year (Ohio Department of Natural Resources, 1954). This meant vast areas within Raccoon Creek were clear cut for charcoal production. Additionally, some areas were logged 3 or 4 times resulting in massive erosion and sedimentation in the surrounding streams. A furnace needed about 5,000 pounds of iron ore which was mined along ridgetop deposits and 300 pounds of limestone for one year of iron production resulting in even more land disturbance and erosion.

Oil and Gas

Natural gas was once an important resource within the Raccoon Creek watershed. In 1862 the first gas well was drilled in the watershed and by the 1920's 450 wells had been drilled. Many of these early wells have been depleted, plugged or abandoned. Due to low pressures in the wells, most of the wells that remain show little profitability (Rice, et al., 2003).

The northern quarter of the watershed overlays the Utica Shale play. There are six producing horizontal wells within Raccoon Creek watershed and several other wells permitted. Many horizontal wells drilled in the lower portion of the watershed have been plugged after drilling. Most wells are vertically drilled wells in the Brushy Fork and West and East Branches of Raccoon Creek. Additionally, there are 13 Underground Injection Control (UIC) wells in Vinton County for the disposal of brine wastewater from well drilling operations. Beginning in 1978, ODNR-Division of Oil and Gas Resources started to regulate brine wastewater from drilling operations. Before these state regulations, drillers would sometimes release the brine water to the surrounding ground and streams killing vegetation and aquatic life. A typical vertical well can generate as many as 100,000 gallons of brine wastewater during drilling and small amounts thereafter during production. Brine that isn't injected back into the drilled well is now taken to an UIC well for disposal.

Beneficial Use Results and Discussion

Aquatic Life Use

Water Chemistry Results

Surface water chemistry samples were collected from the Raccoon Creek study area three to five times at 72 stream locations between May and September 2016 and monthly from nine sentinel locations between January 2016 and January 2017 (Appendix H). Stations were established in free-flowing sections of the streams and samples were collected directly from the stream. Samples were alternatively collected from bridge crossings when high flows or other barriers made for unsafe wading conditions. Surface water samples were collected in appropriate containers, preserved, and delivered to Ohio EPA's Environmental Services laboratory. Collected water was preserved using appropriate methods, as outlined in Ohio EPA's *Surface Water Field Sampling Manual*, July 31, 2015 (Ohio Environmental Protection Agency, 2015).

Data from two USGS gage stations in Raccoon Creek near Bolins Mills (US route 50) and Adamsville and one USGS gage station in Little Raccoon Creek at Keystone Road were used to show flow trends in the Raccoon Creek watershed during the 2016 survey (Figure 11). Dates when water samples and bacteria samples were collected in the study area are noted on the graph as well as historical median flows. Flow conditions in Raccoon Creek and Little Raccoon Creek were often below historic median flows during the 2016 survey but were elevated above historic median flows on several days due to rain events. Samples were typically collected during low flow conditions however a few samples were collected during or after rain events when flows exceeded the historic median flows.

A subset of the sites that were sampled for chemistry were also sampled with water quality sondes that monitor temperature, dissolved oxygen (D.O.), pH and specific conductance (conductivity). Temperature, dissolved oxygen and pH are influenced by diel (24-hour) patterns. These diel patterns have the greatest impact on streams during a critical condition that includes stable, low streamflow. Specific conductance is not influenced by the same diel triggers but is monitored because it is a strong indicator of changes in streamflow. The water quality sondes collect readings hourly to monitor these parameters throughout the diel cycle. Grab readings differ because they only represent one point on the diel cycle. While they are effective at characterizing water quality parameters that change based on hydrologic regime or season, they can miss or not fully characterize parameters that exhibit diel patterns.

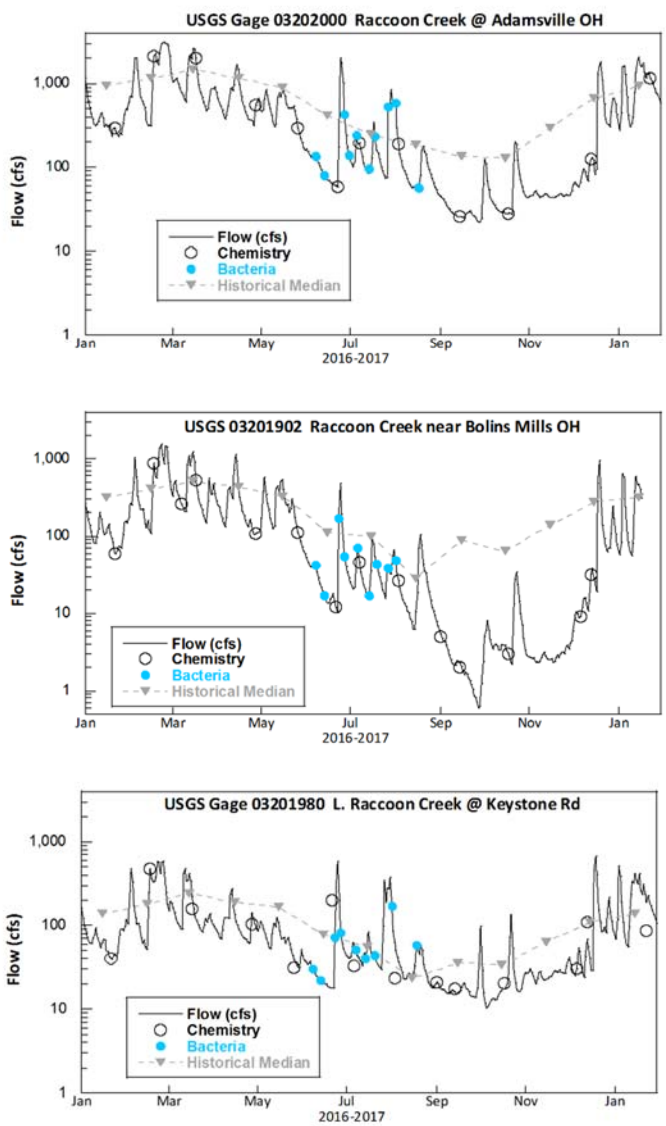


Figure 11 — Flows in Raccoon Creek watershed and sampling dates during the 2016–2017 survey.

Critical conditions for temperature and dissolved oxygen are times when flows are low, temperatures are high, and daylight is long. These are the times that streams are most sensitive to organic and nutrient enrichment. To capture these conditions, sondes are typically deployed during low-flow conditions from June to September. In the Raccoon Creek watershed, sondes were deployed at 26 sites along the mainstem and tributaries from June 21 to June 23, 2016. Summary plots of all data collected are included in Appendix K of this document; the plots are of hourly readings taken for temperature, D.O., pH and specific conductance. Surface water samples were analyzed for metals, nutrients, bromide, total suspended solids (TSS), total dissolved solids (TDS), semi-volatile organic compounds, pH, temperature (°C), specific conductance (µmhos/cm), dissolved oxygen (D.O.) (mg/l), and percent D.O. saturation (Appendix Tables 2 and 5) (Ohio Environmental Protection Agency, 2016). Metals were measured at 81 locations with 17 parameters tested. Parameters which were in exceedance of the Ohio WQS criteria are reported in Table 5.

Mining Parameters

Selected mining parameters on the mainstem of Raccoon Creek were elevated in the headwaters (RM 111.38) then decline significantly until RM 55.48 which is downstream from numerous mine impacted tributaries including Piece Run and Rockcamp Run (Figure 12). Conductivity, manganese, sulfate and TDS were elevated in the headwaters of Raccoon Creek (RM 111.38) downstream from the East Branch and West Branch of Raccoon Creek where numerous unreclaimed surface mines are located. Deep mine and surface mine discharges from Pierce Run and Rockcamp Run increase conductivity, manganese, sulfate, TDS, aluminum, and iron (Figure 12) on the mainstem of Raccoon Creek from RM 55.48 to RM 10.20. Both Rockcamp Run and Pierce Run had TDS exceedances and Piece Run had numerous iron exceedances as well (Table 5).

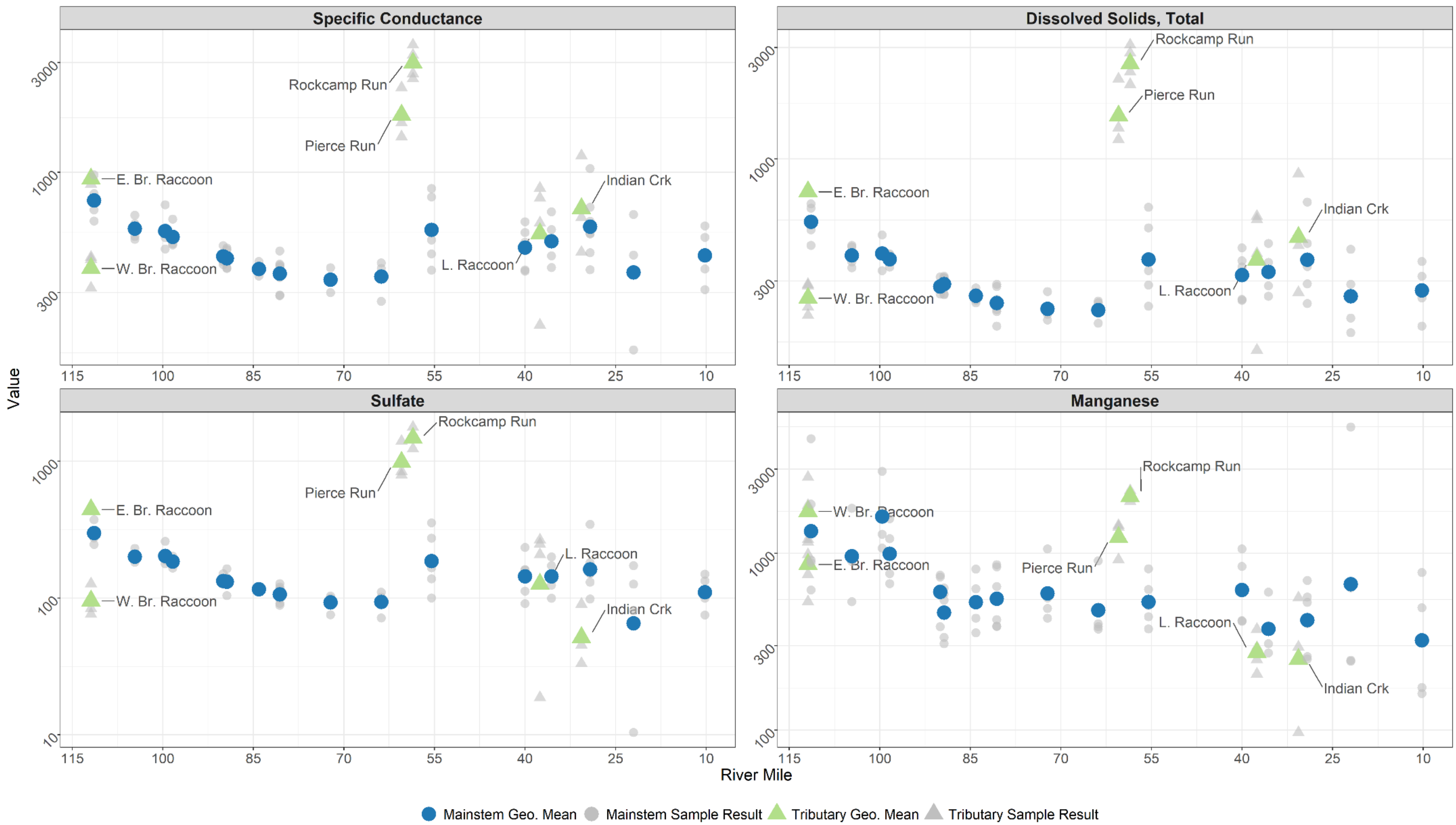


Figure 12 — Selected mining parameter results from Raccoon Creek and selected tributaries during the 2016 survey.

Table 5 — Exceedances of Ohio EPA WQS criteria (OAC 3745-1) (and other chemicals not codified for which toxicity data is available) for chemical/physical water parameters measured in grab samples taken from the Raccoon Creek study area, May-October 2016. Water parameters are assessed based on water quality criteria for the recommended Aquatic Life Use Designations, please refer to *Beneficial Use Designations and Recommendations* within this report for details about use recommendations.

Stream (Stream Code) *use designation* [a]			
Station	12-digit WAU [b]	River Mile	Parameter (value) — (units are µg/l for metals, C° for temperature and mg/L for dissolved oxygen)
Raccoon Creek (09-500-000) WWH – Recommended			
301747	02 04	111.38	None
301746	02 04	104.63	Temperature (28.69 °C) *
W03W32	02 05	99.60	None
W03W44	02 05	98.34	None
Raccoon Creek (09-500-000) WWH			
W03W33	02 05	92.30	None
302520	02 05	89.98	None
302519	03 04	89.36	None
W03W34	03 04	84.08	None
W03G50	03 04	80.62	None
W03P07	03 04	72.22	None
W03W35	05 03	63.80	None
W03P18	05 03	55.48	None
W03S34	05 03	50.10	None
Raccoon Creek (09-500-000) EWH – Recommended			
W03P05	05 04	40.01	None
W03S44	90 01	35.61	None
601400	90 01	29.20	Iron (5200, 5090) ∞
303503	90 01	22.20	D.O. (3.81 mg/l)#
W03S24	90 01	10.20	None
West Branch Raccoon Creek (09-575-000) WWH			
W03W36	02 02	5.68	None
W03W43	02 02	0.15	None
Honey Fork (09-576-000) WWH			
W03P35	02 02	0.01	None
East Branch Raccoon Creek (09-574-000) WWH - Recommended			
W03W37	02 01	6.64	None
W03K17	02 01	2.10	None
Tributary to Raccoon Creek (RM 98.96) (09-500-011) WWH			
203928	02 05	0.10	D.O. (3.25 mg/l) # Ammonia (1.2 mg/l)**
Twomile Run (09-573-000) WWH			
W03W58	02 04	0.16	None
Brushy Creek (09-571-000) WWH			
W03K40	02 03	6.87	None
W03K39	02 03	0.36	None
Siverly Creek (09-571-002) WWH			
W03K42	02 03	0.30	None
Sandy Run (09-568-000) WWH			
203966	02 05	2.70	None
Little Sandy Run (09-569-000) WWH			
303689	02 05	0.40	D.O. (2.21, 1.86, 2.34 mg/l) # Iron (6820, 6370, 7500) ∞
Hewett Fork (09-563-000) MWH – Mine Affected – Recommended			

Stream (Stream Code) *use designation* [a]			
Station	12-digit WAU [b]	River Mile	Parameter (value) — (units are µg/l for metals, C° for temperature and mg/L for dissolved oxygen)
W03K37	03 01	13.10	None
Hewett Fork (09-563-000) WWH – Recommended			
W03P08	03 01	4.31	None
W03P32	03 01	0.01	None
Grass Run (09-567-000) WWH			
W03P41	03 01	0.04	None
Pine Run (09-566-000) WWH			
301579	03 01	0.10	None
Coal Run (09-565-000) WWH			
W03W50	03 01	0.05	None
Rockcamp Creek (09-564-000) WWH			
W03P33	03 01	1.53	None
Laurel Run (09-562-000) WWH			
W03W59	03 04	0.16	None
Onion Creek (09-561-000) WWH			
W03W45	03 04	1.41	None
Flat Run (09-557-000) WWH			
W03W51	03 04	1.60	None
Long Run (09-556-000) WWH			
203960	03 04	1.40	None
Elk Fork (09-530-000) WWH			
W03W06	03 02	13.90	None
W03P30	03 02	13.26	D.O. (3.38 mg/l) [#] Ammonia (4.92 mg/l) [**]
W03W14	03 03	8.55	None
W03P31	03 03	0.01	None
Tributary to Elk Fork (09-530-004) WWH			
W03W09	03 02	0.43	None
Puncheon Fork (09-534-000) WWH			
W03K30	03 02	2.82	None
W03W07	03 02	1.51	D.O. (3.26mg/l) [#] Ammonia (4.77 mg/l) [**] pH (6.4 S.U.) [**]
Wolf Run (09-533-000) WWH – Recommended			
203947	03 02	3.80	None
Pierce Run (09-553-000) LRW			
W03L08	05 01	5.47	Iron (9390, 5070, 6470, 10900)[∞] TDS (1810, 1670, 1940, 2520) [∞]
W03W47	05 01	1.68	TDS (1510, 2200) [∞]
Rockcamp Run (09-552-000) LRW			
W03W52	05 03	0.11	TDS (2860, 3080, 2360, 2080, 2840) [**]
Indiancamp Run (09-551-000) WWH - Recommended			
W03W56	05 03	0.30	None
Flatlick Run (09-549-000) WWH			
W03S39	05 03	0.60	D.O. (2.29 mg/l) [#]
Strongs Run (09-546-000) WWH			
W03S36	05 02	5.90	None
W03S47	05 02	0.58	Iron (5500) [∞]
Williams Run (09-547-000)WWH – Recommended			
203956	05 02	0.10	D.O. (3.93 mg/l) [#]

Stream (Stream Code) *use designation* [a]			
Station	12-digit WAU [b]	River Mile	Parameter (value) — (units are µg/l for metals, C° for temperature and mg/L for dissolved oxygen)
Robinson Run (09-544-000)			WWH
W03S40	05 04	0.18	D.O. (3.98 mg/l) #
Little Raccoon Creek (09-510-000)			WWH
W03S09	04 01	36.67	D.O. (3.44, 2.41 mg/l) #
W03W38	04 01	32.95	None
W03S07	04 01	27.90	Temperature (24.61°C) *
W03W25	04 03	24.55	None
W03K10	04 03	18.45	None
W03S06	04 03	12.71	None
W03K09	04 04	11.00	None
W03P04	04 04	1.17	None
McConnels Run (09-528-000)			WWH – Recommended
303688	04 01	1.98	D.O. (2.49 mg/l) #
Meadow Run (09-524-000)			WWH
W03S10	04 01	3.10	D.O. (3.9 mg/l) #
W03W27	04 01	2.16	None
W03P40	04 01	1.22	None
W03W18	04 01	0.72	Ammonia (4.18 mg/l) **
Dickason Run (09-514-000)			WWH
W03S48	04 02	2.37	Temperature (24.8°C) *
Dickason Run (09-514-000)			WWH – Recommended
W03P43	04 02	0.11	TDS (1830, 1890 mg/l) ∞
Deer Creek (09-511-000) WWH			
W03P15	04 04	0.20	None
Barren Creek (09-542-000)			WWH
203953	06 02	0.30	None
Indian Creek (09-539-000) WWH			
W03P36	06 01	1.58	D.O (3.62 mg/l) #
W03W55	06 01	1.45	Copper (15.7) **
Little Indian Creek (09-540-000)			WWH
W03P14	06 01	0.17	None
Big Beaver Creek (09-500-012)			WWH
303508	06 03	0.90	None
Claylick Run (09-507-000) WWH			
203929	06 05	0.40	None
Clear Fork (09-506-000) WWH			
W03K23	06 05	0.02	D.O. (3.81 mg/l) #
Bullskin Creek (09-502-000)			WWH
W03K21	06 04	0.37	None
Little Bullskin Creek (09-503-000)			WWH
W03K22	06 04	0.01	None

a Use designations:

Aquatic Life Habitat	Water Supply	Recreation
MWH - modified warmwater habitat	IWS - industrial water supply	PCR - primary contact
WWH - warmwater habitat	AWS - agricultural water supply	SCR - secondary contact
LRW – limited resource water	PWS- public water supply	BWR -bathing water

b Watershed Assessment Unit within HUC8 05090101

c Undesignated [WWH criteria apply to 'undesignated' surface waters.]

** Exceedance of OMZM (outside mixing zone maximum) numerical criteria for prevention of acute toxicity.

Exceedance of the applicable minimum D.O. criteria – WWH: 4.0 mg/l, MWH : 3.0 mg/l

∞ Exceedance of agricultural water supply criterion.

* Exceedance of OMZA (outside mixing zone average) numerical criteria for prevention of chronic toxicity.

Table 6 — Exceedances of Ohio Water Quality Standards criteria (OAC 3745-1) for chemical and physical parameters derived from diel monitoring.

Sonde water quality monitors record hourly readings for the duration of the deployment (6/21/17-6/23/17). Consequently, exceedances can be presented as both a measure of magnitude and duration. Rolling 24-hour averages were calculated using the hourly readings for comparison against the average D.O. criteria. The duration is the count of consecutive hours that exceeded the criteria. The magnitude of an exceedance is presented as the most extreme value measured that exceeds the criteria and is presented in parenthesis after the duration. Applicable water quality criteria include: minimum D.O.[c]; average D.O.[d]; maximum temperature[e]; pH[f]; and specific conductance[g].

Stream (Stream Code) *use designation* [a]			
Station	12-digit WAU [b]	River Mile	Parameter (value) — (units are µg/l for metals, C° for temperature and mg/L for dissolved oxygen)
Raccoon Creek (09-500-000)			WWH – Recommended
301747	02 04	111.38	None
301746	02 04	104.63	pH: 5(4.9)
Raccoon Creek (09-500-000)			WWH
302519	03 04	89.36	None
W03G50	03 04	80.62	None
W03P18	05 03	55.48	None
W03S34	05 03	50.10	None
Raccoon Creek (09-500-000)			EWH – Recommended
W03P05	05 04	40.01	None
601400	90 01	29.20	None
West Branch Raccoon Creek (09-575-000) WWH			
W03W43	02 02	0.15	None
East Branch Raccoon Creek (09-574-000) WWH - Recommended			
W03K17	02 01	2.10	None
Brushy Creek (09-571-000)			WWH
W03K39	02 03	0.36	pH: 47(6.1)
Hewett Fork (09-563-000) WWH – Recommended			
W03P32	03 01	0.01	None
Grass Run (09-567-000) WWH			
W03P41	03 01	0.04	D.O. avg: 28(0.8) D.O. min: 42(0.1)
Elk Fork (09-530-000) WWH			
W03P30	03 02	13.26	None
W03P31	03 03	0.01	None
Wolf Run (09-533-000) WWH – Recommended			
203947	03 02	3.80	D.O. avg: 24(0.8) D.O. min: 42(0.0)
Pierce Run (09-553-000) LRW			
W03W47	05 01	1.68	None
Strongs Run (09-546-000) WWH			
W03S47	05 02	0.58	D.O. avg: 8(4.9)
Little Raccoon Creek (09-510-000)			WWH
W03S07	04 01	27.90	None
W03W25	04 03	24.55	None
W03S06	04 03	12.71	None
W03P04	04 04	1.17	None
Meadow Run (09-524-000)			WWH
W03W18	04 01	0.72	None
Dickason Run (09-514-000)			WWH – Recommended
W03P43	04 02	0.11	None

Stream (Stream Code) *use designation* [a]			
Station	12-digit WAU [b]	River Mile	Parameter (value) — (units are µg/l for metals, C° for temperature and mg/L for dissolved oxygen)
Indian Creek (09-539-000) WWH			
W03W55	06 01	1.45	None
Bullskin Creek (09-502-000)			WWH
W03K21	06 04	0.37	None

a Use designations:
Aquatic Life Habitat
MWH - modified warmwater habitat – mine affected
WWH - warmwater habitat
LRW – limited resource water
EWH – exceptional warmwater habitat
b Watershed Assessment Unit within HUC8 05090101
c The General Lake Erie basin daily maximum temperature criteria apply; See OAC 3745-1-35, Table 35-11(G).
d Applicable minimum 24-hour average D.O. criterion - WWH: 5.0 mg/L; MWH: 4.0 mg/L
e Applicable minimum D.O. criterion - WWH: 4.0 mg/L; MWH-HELP: 2.5 mg/L
f The criteria for pH is 6.5-9.0 S.U.
g The criteria for specific conductivity is 2400 µS/cm.

Nutrients and Sonde Results

The data collected during the sonde deployments are sufficient to evaluate exceedances of the standards for the protection of aquatic life for: maximum daily temperature; minimum D.O.; 24-hour average D.O.; pH; and specific conductivity. Absolute minima or maxima exceedances are compared directly to hourly readings reported from the water quality sondes. The 24-hour average for D.O. is calculated as a rolling 24-hour average of the hourly data. A summary of the exceedances is presented in Table 6.

Sites monitored with water quality sondes in the Raccoon Creek watershed were generally well shaded and showed no temperature exceedances, even where flows were very low or interstitial. The presence of riparian shading, along with the limited nutrient sources upstream of many sites, led to a general lack of primary production throughout the system. These conditions were confirmed by very low benthic and sestonic chlorophyll-*a* concentrations. Very few diel swings of D.O. or pH were documented during the survey, although D.O. and pH exceedances were measured. The sites with D.O. minimum or average criteria exceedances were attributed to low flow conditions, where sites exhibited either near-zero surface velocity or interstitial flow. In these cases, D.O. was depressed by limited reaeration and the lack of primary production.

There were two monitored sites with pH exceedances—Raccoon Creek at RM 104.63 and Brushy Fork at RM 0.36. The site on Raccoon Creek only saw a drop in pH after a large storm event, indicating that it was not a chronic condition. The drop can be attributed to a combination of the naturally lower pH of precipitation and acidic surface runoff from the site's direct drainage. Brushy Fork, however, showed the opposite conditions, where low pH persisted during the low flow period. This indicates a continuous AMD source upstream.

Nutrients were measured at each water sampling location and included ammonia, nitrate+nitrite, total Kjeldahl nitrogen (TKN), total phosphorus and orthophosphate. In addition to nutrient monitoring, measurements were taken at a subset of locations to represent the algal biomass and associated dissolved oxygen production and consumption. The purpose of the nutrient monitoring summarized in this report is to consider the effect of nutrients on the biological conditions in the local streams.

Chlorophyll concentrations from benthic algae (attached to bottom substrates) are measured as a proxy for algal community biomass in wadeable streams and small rivers, while chlorophyll concentrations measured from sestonic algae (suspended in the water column) serve as a proxy for algal abundance in large rivers. Physical factors such as width-depth ratio, time of travel and longitudinal gradient may largely determine whether sestonic or benthic algae drive production and respiration. However, sestonic algae typically dominate streams defined as large rivers, and benthic algae typically dominate small streams. Miltner (2010) identified benthic chlorophyll levels that broadly demarcate enrichment status relative to Ohio. Streams with less than 90 mg/m^2 can be considered least disturbed and atypical for Ohio. Benthic chlorophyll levels between 90-183 mg/m^2 are typical for Ohio streams with modest amounts of agriculture or wastewater loadings. Levels between 183-320 mg/m^2 are typical of streams draining agricultural landscapes or that are effluent dominated. Chlorophyll levels exceeding 320 mg/m^2 characterize over-enrichment or nuisance conditions. A review of studies on sestonic chlorophyll-a by Dodds (2006), which included some Midwestern streams, suggest that concentrations of 40-100 µg/l sestonic chlorophyll-a identify eutrophic conditions while concentrations >100 µg/l indicate hyper-eutrophic conditions.

Of the sites sampled for benthic chlorophyll in the study area, one site was above the moderate threshold of 183 mg/m^2. Little Raccoon Creek at RM 12.71 had concentrations of 211 mg/m^2 and had no corresponding swings in D.O.

Ohio and other states have been developing nutrient reduction strategies in recent years to address cultural eutrophication ((U.S. Environmental Protection Agency, 2015), (Ohio Environmental Protection Agency, 2014), (Miltner, 2010), (Heiskary & Markus, 2003)). Wide diel (24-hour) D.O. ranges associated with eutrophication are caused by excessive photosynthesis (O_2 production) during daylight hours and respiration (O_2 consumption) at night. The most recent investigations by Ohio EPA have identified a diel D.O. range of 6.5 mg/L as a threshold generally protective of biological and stream quality; diel D.O. ranges greater than 6.5 mg/L are indicative of eutrophication in Ohio streams and are likely over-enriched (Ohio Environmental Protection Agency, 2014).

One site had a D.O. swing greater than 6.5 mg/L, Grass Run at RM 0.04. D.O. was depressed by limited reaeration and the lack of primary production followed by a rain event, increasing D.O.

Total phosphorus and dissolved inorganic nitrogen (DIN) usually represent the largest portion of these nutrients. The index period for nutrients impacting streams is June 15 – October 15. Ohio EPA assigns a risk category, based on Miltner 2010, using the geometric means of samples collected in the index period. Table 7 presents the risk category for all sites sampled in the study area. Most locations sampled in 2016 were placed in the low-risk category. Seven locations were placed in the moderate-risk category, meaning that especially in the presence of lower quality stream habitat, the threat of nutrient enrichment impacts to biology are elevated. All of the moderate- and high-risk designations were due to total phosphorus concentrations, rather than nitrogen levels.

Average TKN, nitrate+nitrite-N, and total phosphorus were typically below the reference target values on the mainstem of Raccoon Creek. Ammonia was slightly above the target values from RM 104.63 downstream to RM 84.08 which is influenced by mining (Table 7). Several tributaries to Raccoon Creek (Meadow Run, Puncheon Fork and Indian Creek) had extremely elevated levels of nutrients due to point source discharges from NPDES facilities.

Meadow Run receives wastewater from General Mills and the Wellston WWTP. Upstream from General Mills at RM 3.1, nitrate+ nitrite-N was an average of 0.23 mg/l but increased to an average of 6.64 mg/l (maximum value of 13.0 mg/l) downstream from General Mills and 8.34 mg/l (maximum value of 12.1 mg/l) downstream from the Wellston WWTP (Table 7). Ammonia, TKN, and total phosphorus were also elevated in Meadow Run downstream from both facilities. More information about these point sources can be found in the Appendix B of the report.

Indian Creek had the highest average nitrate+nitrite-N and total phosphorus values in the Raccoon Creek watershed downstream from the Rio Grande WWTP (Table 7). Indian Creek also had the highest maximum values for nitrate+nitrite-N (50 mg/l) and total phosphorus (7.45 mg/l). One copper exceedance also occurred on Indian Creek downstream from the WWTP (Table 5).

Puncheon Fork receives wastewater from the McArthur WWTP at RM 0.85. During the summer of 2016, a sanitary sewer line broke and spilled raw sewage to Puncheon Fork. Puncheon Fork had the highest maximum value for ammonia (5.15 mg/l) and TKN (5.73 mg/l) during the 2016 survey downstream from the McArthur WWTP. Total phosphorus is also elevated with a maximum value of 1.32 mg/l and an average value of 0.69 mg/l during the 2016 survey (Table 7) Elk Fork, which is a tributary to Puncheon Fork, also had elevated ammonia values with a maximum of 4.92 mg/l and average of 1.62 mg/l downstream from Puncheon Fork and the McArthur WWTP.

Table 7 — Nutrient sampling results in Raccoon Creek, summer (June 15–October 15) 2016. The seasonal geometric mean for each site was used to assign a site to a risk category based on Miltner, 2010. Please note the risk categories do not directly translate to Cause/Source determinations for Aquatic Life Use impairment. Rather, this data serves as one of many lines of evidence in the Cause/Source determination-process. However, this information does give one a general sense of how individual site-nutrient levels compares to statewide data.

Stream (Stream Code)				Total Phosphorus		Ammonia + (Nitrate + Nitrite)		
Station	AU	River Mile	Drainage Area (mi²)	Samples (#)	Geometric Mean (mg/l)	Samples (#)	Geometric Mean (mg/l)	Risk Category[b]
Raccoon Creek (09-500-000)		WWH – Recommended						
301747	02 04	111.38	43.6	4	0.01	4	0.25	L
301746	02 04	104.63	56.4	4	0.01	4	0.22	L
W03W32	02 05	99.60	98.0	4	0.01	4	0.22	L
W03W44	02 05	98.34	100.0	4	0.01	4	0.23	L
Raccoon Creek (09-500-000)		WWH						
W03W33	02 05	92.30	134.0	4	0.01	4	0.27	L
302520	02 05	89.98	136.0	4	0.01	4	0.25	L
302519	03 04	89.36	176.0	4	0.01	4	0.26	L
W03W34	03 04	84.08	183.0	4	0.01	4	0.26	L
W03G50	03 04	80.62	200.0	6	0.01	6	0.22	L
W03P07	03 04	72.22	223.0	4	0.01	4	0.21	L
W03W35	05 03	63.80	296.0	4	0.01	4	0.23	L
W03P18	05 03	55.48	322.0	4	0.01	4	0.26	L
W03S34	05 03	50.10	336.0	4	0.01	4	0.24	L
Raccoon Creek (09-500-000)		EWH – Recommended						
W03P05	05 04	40.01	381.0	4	0.02	4	0.28	L
W03S44	90 01	35.61	543.0	4	0.02	4	0.37	-
601400	90 01	29.20	586.0	6	0.03	6	0.35	-
303503	90 01	22.00	615.0	4	0.02	4	0.38	-
W03S24	90 01	10.20	657.0	4	0.03	4	0.35	-
West Branch Raccoon Creek (09-575-000) WWH								

Stream (Stream Code)				Total Phosphorus		Ammonia + (Nitrate + Nitrite)		
Station	AU	River Mile	Drainage Area (mi²)	Samples (#)	Geometric Mean (mg/l)	Samples (#)	Geometric Mean (mg/l)	Risk Category[b]
W03W36	02 02	5.68	3.8	4	0.01	4	0.17	L
W03W43	02 02	0.15	22.7	4	0.02	4	0.26	L
Honey Fork (09-576-000) WWH								
W03P35	02 02	0.01	10.5	4	0.02	4	0.18	L
East Branch Raccoon Creek (09-574-000) WWH– Recommended								
W03W37	02 01	6.64	3.2	4	0.01	4	0.22	L
W03K17	02 01	2.10	15.3	4	0.03	4	0.14	L
Tributary to Raccoon Creek (RM 98.96) (09-500-011) WWH								
203928	02 05	0.10	1.9	3	0.09	3	0.24	L
Twomile Run (09-573-000) WWH								
W03W58	02 04	0.16	4.9	4	0.01	4	0.35	L
Brushy Creek (09-571-000) WWH								
W03K40	02 03	6.87	8.4	4	0.02	4	0.13	L
W03K39	02 03	0.36	33.4	4	0.01	4	0.33	L
Siverly Creek (09-571-002) WWH								
W03K42	02 03	0.30	10.1	4	0.05	4	0.18	L
Sandy Run (09-568-000) WWH								
203966	02 05	2.70	5.0	4	0.01	4	0.18	L
Little Sandy Run (09-569-000) WWH								
303689	02 05	0.40	1.5	4	0.07	4	0.15	L
Hewett Fork (09-563-000) MWH – Mine Affected – Recommended								
W03K37	03 01	13.10	8.3	5	0.02	5	0.10	L
Hewett Fork (09-563-000) WWH – Recommended								
W03P08	03 01	4.31	28.1	5	0.02	5	0.25	L
W03P32	03 01	0.01	40.5	5	0.02	5	0.22	L
Grass Run (09-567-000) WWH								
W03P41	03 01	0.04	2.7	5	0.03	5	0.28	L
Pine Run (09-566-000) WWH								
301579	03 01	0.10	2	5	0.03	5	0.16	L
Coal Run (09-565-000) WWH								
W03W50	03 01	0.05	0.8	2	0.02	2	0.08	L
Rockcamp Creek (09-564-000) WWH								
W03P33	03 01	1.53	5.8	5	0.03	5	0.18	L
Laurel Run (09-562-000) WWH								
W03W59	03 04	0.16	2.6	4	0.03	4	0.25	L
Onion Creek (09-561-000) WWH								
W03W45	03 04	1.41	8.3	4	0.03	4	0.28	L
Flat Run (09-557-000) WWH								
W03W51	03 04	1.60	4.8	3	0.05	3	0.38	L
Long Run (09-556-000) WWH								
203960	03 04	1.40	2.2	4	0.03	4	0.10	L
Elk Fork (09-530-000) WWH								
W03W06	03 02	13.90	14.4	4	0.02	4	0.25	L
W03P30	03 02	13.26	24.5	4	0.23	4	1.70	M
W03W14	03 03	8.55	44.4	3	0.02	4	0.56	L
W03P31	03 03	0.01	59.8	6	0.01	6	0.28	L

Stream (Stream Code)				Total Phosphorus		Ammonia + (Nitrate + Nitrite)		
Station	AU	River Mile	Drainage Area (mi²)	Samples (#)	Geometric Mean (mg/l)	Samples (#)	Geometric Mean (mg/l)	Risk Category[b]
Tributary to Elk Fork (09-530-004) WWH								
W03W09	03 02	0.43	2.4	3	0.01	3	0.71	L
Puncheon Fork (09-534-000) WWH								
W03K30	03 02	2.82	4.7	4	0.01	4	0.18	L
W03W07	03 02	0.28	9.8	4	0.64	4	3.00	H
Wolf Run (09-533-000) WWH – Recommended								
203947	03 02	3.80	4.7	5	0.03	5	0.20	L
Pierce Run (09-553-000) LRW								
W03L08	05 01	5.47	3.4	4	0.01	4	0.99	L
W03W47	05 01	1.68	9.5	4	0.02	4	0.68	L
Rockcamp Run (09-552-000) LRW								
W03W52	05 03	0.11	2.8	4	0.02	4	0.57	L
Indiancamp Run (09-551-000) WWH – Recommended								
W03W56	05 03	0.30	2.1	4	0.01	4	0.13	L
Flatlick Run (09-549-000) WWH								
W03S39	05 03	0.60	7.2	4	0.03	4	0.37	L
Strongs Run (09-546-000) WWH								
W03S36	05 02	5.90	5.9	4	0.05	4	0.39	L
W03S47	05 02	0.58	16.4	4	0.04	4	0.46	L
Williams Run (09-547-000)WWH – Recommended								
203956	05 02	0.10	3.8	4	0.07	4	0.52	L
Robinson Run (09-544-000) WWH								
W03S40	05 04	0.18	9.7	4	0.03	4	0.53	L
Little Raccoon Creek (09-510-000) WWH								
W03S09	04 01	36.67	12.1	4	0.02	4	0.30	L
W03W38	04 01	32.95	25.0	1	0.99	1	0.64	H
W03S07	04 01	27.90	48.0	4	0.04	4	0.16	L
W03W25	04 03	24.55	62.5	4	0.04	4	0.75	L
W03K10	04 03	18.45	87.0	4	0.01	4	0.71	L
W03S06	04 03	12.71	99.0	6	0.01	6	0.49	L
W03K09	04 04	11.00	129.0	4	0.01	4	0.51	L
W03P04	04 04	1.2	154.0	4	0.01	4	0.45	L
McConnels Run (09-528-000) WWH – Recommended								
303688	04 01	1.98	0.9	5	0.03	5	0.26	L
Meadow Run (09-524-000) WWH								
W03S10	04 01	3.10	5.1	5	0.05	5	0.32	L
W03W27	04 01	2.16	8.7	4	0.10	5	4.64	H
W03W18	04 01	0.72	9.9	5	0.56	5	8.52	H
Dickason Run (09-514-000) WWH								
W03S48	04 02	2.37	17.7	4	0.02	4	0.27	L
Dickason Run (09-514-000) WWH – Recommended								
W03P43	04 02	0.11	26.9	4	0.02	4	0.45	L
Deer Creek (09-511-000) WWH								
W03P15	04 04	0.20	5.9	3	0.02	3	0.37	L
Barren Creek (09-542-000) WWH								
203953	06 02	0.30	9.1	4	0.07	4	1.15	L

Stream (Stream Code)				Total Phosphorus		Ammonia + (Nitrate + Nitrite)		
Station	AU	River Mile	Drainage Area (mi²)	Samples (#)	Geometric Mean (mg/l)	Samples (#)	Geometric Mean (mg/l)	Risk Category[b]
Indian Creek (09-539-000) WWH								
W03P36	06 01	1.58	10.4	3	0.03	3	0.89	L
W03W55	06 01	1.45	10.4	3	2.41	3	18.12	H
Little Indian Creek (09-540-000) WWH								
W03P14	06 01	0.17	10.2	4	0.03	4	0.45	L
Big Beaver Creek (09-500-012) WWH								
303508	06 03	0.90	7.3	3	0.02	3	0.31	L
Claylick Run (09-507-000) WWH								
203929	06 05	0.40	7.7	3	0.01	3	0.28	L
Clear Fork (09-506-000) WWH								
W03K23	06 05	0.02	7.7	4	0.03	4	0.36	L
Bullskin Creek (09-502-000) WWH								
W03K21	06 04	0.37	13.2	4	0.02	4	0.20	L
Little Bullskin Creek (09-503-000) WWH								
W03K22	06 04	0.01	4.9	2	0.02	4	0.40	L

a AU – HUC-12 Assessment Unit – HUC-8: 05090201
b Risk categories from Miltner (2010).
H – Total Phosphorus ≥0.4 *or* DIN ≥3.6
M – Total phosphorus <0.4 and ≥0.131 *and* DIN<3.6
L – Total Phosphorus <0.131 *and* DIN <3.6

Sediment Quality

Surficial sediment samples were collected at nine locations in the Raccoon Creek study area on August 15, 2016 and August 23, 2016. Sampling locations were co-located with biological sampling sites. Samples were collected following the Sediment Sampling Guide and Methodologies, 3rd Edition (Ohio Environmental Protection Agency, 2012). Samples were analyzed for total analyte list inorganics (metals), phosphorus, ammonia, total organic carbon (TOC), particle size, percent solids, and semi-volatile organic compounds. Specific chemical parameter results are listed in Appendix J. Sediment data were evaluated using Ohio Sediment Reference Values (SRVs) (Ohio Environmental Protection Agency, 2010), along with guidelines established in *Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems* (MacDonald, Ingersoll, & Berger, 2000). The consensus-based sediment guidelines define two levels of ecotoxic effects. A Threshold Effect Concentration (TEC) is a level of sediment chemical quality below which harmful effects are unlikely to be observed. A Probable Effect Concentration (PEC) is a level above which harmful effects are likely to be observed. Ecological Screening Levels (ESL) values, considered protective benchmarks, were derived by US EPA, Region 5 using a variety of sources and methods.

Sediment samples were conservatively sampled by focusing on depositional areas of fine-grain material (silts and clays). These areas typically are represented by higher contaminant levels, compared to coarse sands and gravels. Fine-grained depositional areas were not a predominant substrate type at all sites; however, fine substrates were common along the river margins.

Zinc and nickel were above the TEC for the Raccoon Creek site at State Route 124 (RM 55.48) and the Little Raccoon Creek site at Keystone Furnace Road (RM 12.71). Iron was above the SRV value for the Raccoon

Creek site at State Route 124 (RM 55.48). The Little Raccoon Creek subwatershed was heavily mined and was also the location of several iron furnaces. Iron, zinc, and nickel are commonly associated with mining but could also be remnants from the historic iron furnace activity. Raccoon Creek at State Route 124 is downstream from Rockcamp Run which has numerous abandoned underground mines and prelaw unreclaimed surface mines. All other locations sampled for sediment had no parameters exceeding the target values (Table 8).

Table 8 — Sediment sampling locations collected by Ohio EPA in the Raccoon Creek watershed, August 2016.

Station	Stream	Location	RM	Above Target Values (mg/kg)
301747	Raccoon Creek	At St. Rt. 328 dst East and West Br.	111.4	None
302519	Raccoon Creek	County Road 18B DST Hewett Fork	89.3	None
W03G50	Raccoon Creek	State Route 50 at Bolins Mills	80.6	None
W03P18	Raccoon Creek	State Route 124 Clarion	55.4	TEC – Nickel (27.6) TEC – Zinc (125) SRV – Iron (51800)
W03P05	Raccoon Creek	State Route 160 at Vinton	40.0	None
601400	Raccoon Creek	US Route 35 at Adamsville	29.2	None
W03S06	Little Raccoon Creek	Keystone Furnace Road	12.7	TEC – Nickel (32.8) TEC – Zinc (145)
W03K39	Brushy Creek	At State Route 328 near mouth	0.4	None
W03P31	Elk Fork	At County Road 43B near Radcliff	0.1	None

Physical Habitat

As part of the 2016 fish sampling effort, the quality of near and in-stream macrohabitats of the Raccoon Creek mainstem were evaluated at 18 sampling locations, assessing approximately 100 miles of the mainstem. A matrix of QHEI scores and macrohabitat features are presented in Table 9. Longitudinal performance of the QHEI for Raccoon Creek is presented in Figure 13. Performance of the QHEI at the 71 tributary sites are presented in Figure 14 and Figure 15. A matrix of QHEI scores and macrohabitat features of streams contained within the Raccoon Creek study area can be found in Table 9. QHEI sheet facsimiles can be found in Appendix G.

Instream habitat, as indicated by the QHEI, for the Raccoon Creek mainstem was generally very good ($\bar{X}$ = 72.6 ± 9, range: 58.75 – 87.5) and is not expected to preclude WWH or better fish assemblages. More variation in habitat quality was found in the tributaries to Raccoon Creek but was generally good ($\bar{X}$ = 63.3 ± 10.3, range: 36.0 – 86.25), and in the absence of other stressors should be able to support WWH fish assemblages.

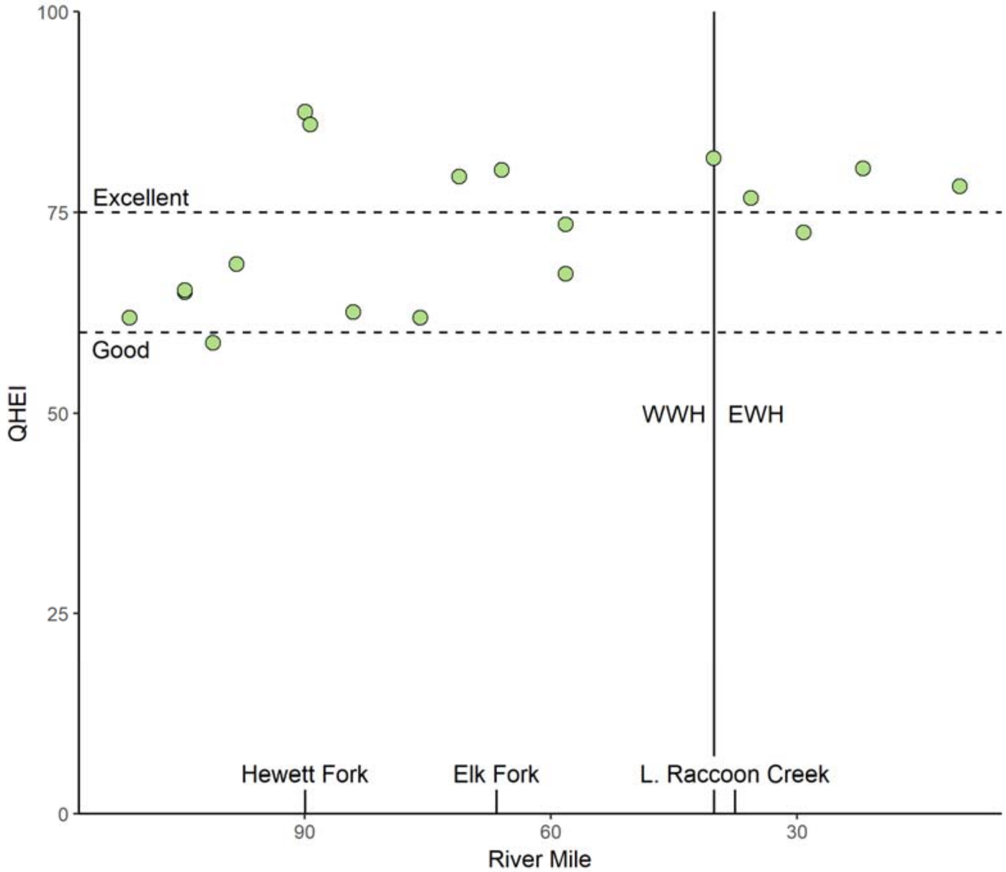


Figure 13 — QHEI scores in Raccoon Creek were generally very good during the 2016 - 2017 survey.

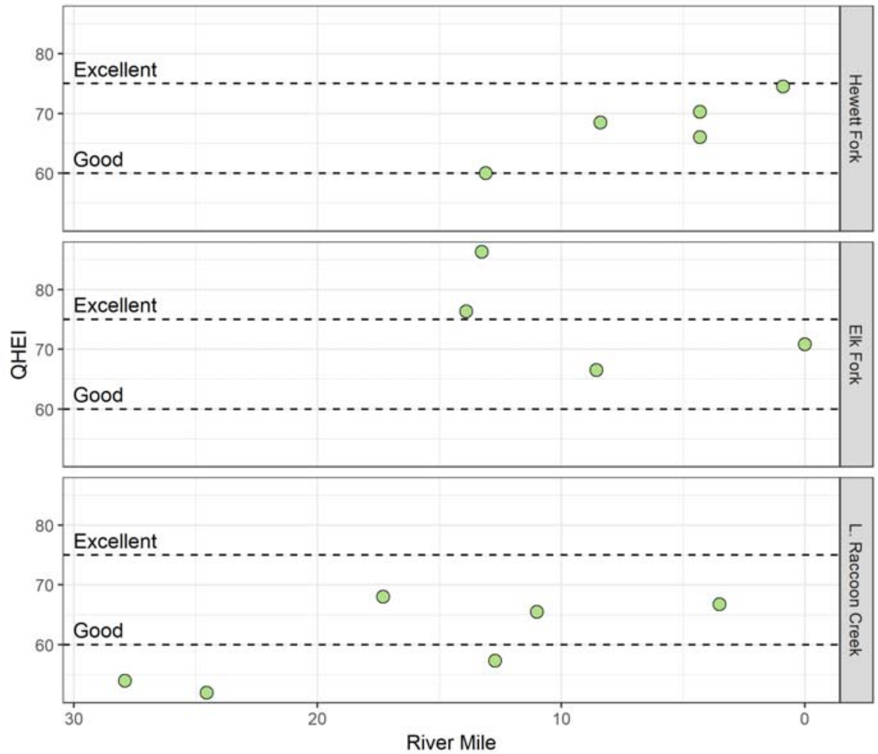


Figure 14 — QHEI scores in selected Raccoon Creek tributaries were generally sufficient to harbor WWH fish communities, barring any external stressors.

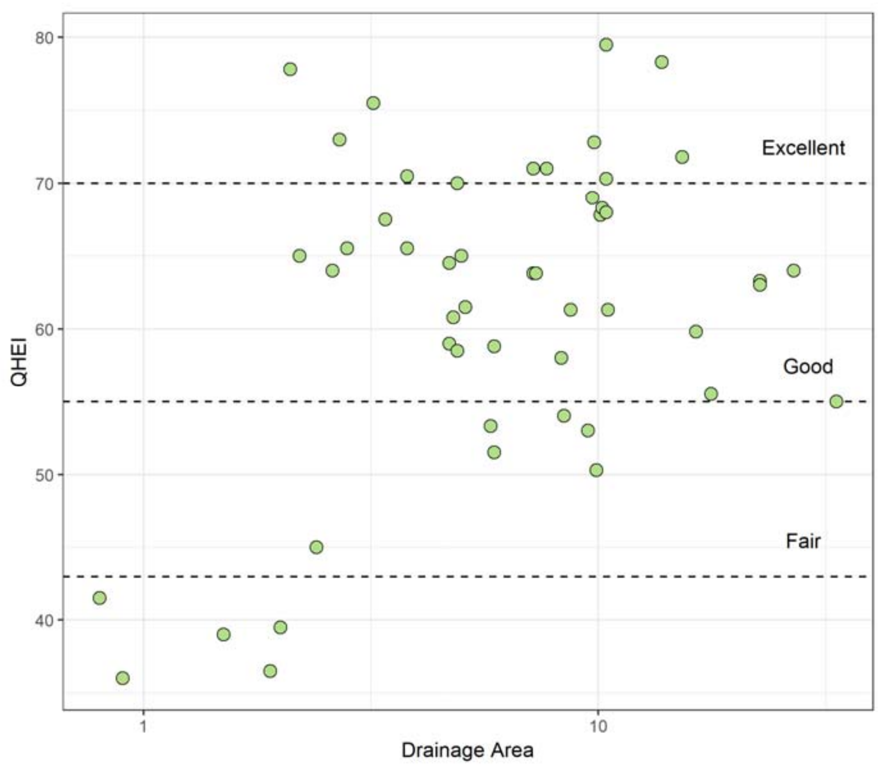


Figure 15 — QHEI scores in Raccoon Creek headwater tributaries were generally sufficient to harbor WWH fish communities, barring any external stressors.

Table 9 — QHEI Results in the Raccoon Creek study area, 2016.

Key QHEI Components				WWH Attributes											MWH Attributes																				
Station	River Mile	QHEI	Grad-ient (ft/mi)	Not Channelized or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrate	Good/Excellent Development	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low/Normal Embeddedness	Max Depth > 40cm	Low/Normal Riffle Embeddedness	**WWH Attributes**	Channelized/No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40cm	**High-Influence Modified Attributes**	Recovering Channel	Heavy/Moderate Substrates	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1 or 2 Cover Types	Intermittent/Poor Pools	No Fast Current	High/Moderate Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	**Mod. Influence Modified Attributes**	MWH H.I.+1 / WWH+1 Ratio	MWH M.I. / WWH Ratio
Honey Fork (09-576-000)																																			
W03P35	0.0	**61.3**	7.46	X			X	X	X			X		5						0					X			X	X	X	X	X	6	0.17	1.33
West Branch Raccoon Creek (09-575-000)																																			
W03W36	5.7	**70.5**	22.22	X	X		X	X	X		X	X	X	8						0		X							X	X	X	X	5	0.11	0.78
W03W43	0.2	**63.0**	10.20	X				X	X			X		4						0				X	X				X	X	X	X	6	0.20	1.60
W03W43	0.2	**63.3**	10.20	X	X			X	X			X		5						0		X		X	X				X	X	X	X	7	0.17	1.50
East Branch Raccoon Creek (09-574-000)																																			
W03W37	6.6	**75.5**	25.97	X	X		X	X	X			X		6						0		X							X	X	X		4	0.14	0.86
W03K17	2.1	**71.8**	8.20	X	X		X	X	X		X	X	X	8						0				X	X	X			X	X	X		6	0.11	0.89
Twomile Run (09-573-000)																																			
W03W58	0.2	**58.5**	10.20	X					X			X		3						0					X	X		X	X	X	X	X	7	0.25	2.25
Siverly Creek (09-571-002)																																			
W03K42	0.3	**67.8**	15.38	X			X	X	X			X		5						0		X		X					X	X	X		5	0.17	1.17
Brushy Fork (09-571-000)																																			
W03K40	6.9	**54.0**	12.58	X				X	X			X		4		X		X		2		X			X				X	X	X	X	6	0.60	1.60
W03K39	0.4	**55.0**	3.10	X					X		X	X		4				X		1					X	X			X	X	X		5	0.40	1.40
Little Sandy Run (09-569-000)																																			
303689	0.4	**39.0**	76.10	X								X		2		X		X		2		X			X	X		X	X	X		X	7	1.00	3.00
Sandy Run (09-568-000)																																			
203966	2.7	**65.0**	5.88	X				X	X			X		4				X		1				X	X				X	X	X		5	0.40	1.40
Grass Run (09-567-000)																																			
W03P41	0.0	**73.0**	21.74	X	X		X	X	X		X	X	X	8						0		X		X	X				X		X	X	6	0.11	0.89
Pine Run (09-566-000)																																			
301579	0.1	**39.5**	85.80	X										1		X		X	X	3		X			X	X			X	X	X	X	7	2.00	4.50
Coal Run (09-565-000)																																			
W03W50	0.1	**41.5**	58.82	X	X			X			X			4				X	X	2					X			X	X			X	4	0.60	1.20
Rockcamp Creek (09-564-000)																																			
W03P33	1.5	**53.3**	14.93	X				X	X			X		4				X		1		X		X	X			X	X	X	X		7	0.40	1.80
Hewett Fork (09-563-000)																																			
W03K37	13.1	**60.0**	6.60	X				X	X			X		4						0		X			X				X	X	X		5	0.20	1.40
303739	8.4	**68.5**	10.00	X			X		X			X		4						0				X	X	X			X	X	X		6	0.20	1.60
W03P08	4.3	**66.0**	5.46		X		X	X	X	X		X		6						0	X	X		X	X					X	X		6	0.29	1.14

Key QHEI Components				WWH Attributes											MWH Attributes																				
Station	River Mile	QHEI	Gradient (ft/mi)	Not Channelized or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrate	Good/Excellent Development	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low/Normal Embeddedness	Max Depth > 40cm	Low/Normal Riffle Embeddedness	**WWH Attributes**	Channelized/No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40cm	**High-Influence Modified Attributes**	Recovering Channel	Heavy/Moderate Substrates	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1 or 2 Cover Types	Intermittent/Poor Pools	No Fast Current	High/Moderate Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	**Mod. Influence Modified Attributes**	MWH H.I.+1 / WWH+1 Ratio	MWH M.I. / WWH Ratio
W03P08	4.3	**70.3**	5.46	X	X		X	X	X		X	X	X	8						0				X					X				2	0.11	0.44
W03P32	0.9	**74.5**	4.10	X			X	X	X			X		5						0		X		X					X	X	X		5	0.17	1.17
W03K37	13.1	**65.3**	6.60	X				X	X			X		4						0		X			X				X	X	X		5	0.20	1.40
303739	8.4	**60.5**	0.00	X					X			X		3						0					X	X			X	X	X		5	0.25	1.75
W03P08	4.3	**70.0**	5.46	X				X	X		X	X	X	6						0					X				X	X		X	4	0.14	0.86
W03P32	0.9	**75.5**	0.00	X			X	X	X		X	X	X	7						0		X							X	X			3	0.13	0.63
Laurel Run (09-562-000)																																			
W03W59	0.2	**64.0**	56.50	X			X	X	X			X		5						0		X		X	X				X	X	X		6	0.17	1.33
Onion Creek (09-561-000)																																			
W03W45	1.4	**58.0**	11.83	X					X		X	X		4						0	X			X	X	X			X		X	X	7	0.40	1.60
Flat Run (09-557-000)																																			
W03W51	1.6	**60.8**	10.64	X				X	X			X		4						0		X			X				X	X	X		5	0.20	1.40
Long Run (09-556-000)																																			
203960	1.4	**65.0**	16.13	X	X			X	X		X	X	X	7				X		1					X			X	X			X	4	0.25	0.75
Pierce Run (09-553-000)																																			
W03L08	5.5	**67.5**	20.02	X	X			X	X			X	X	6				X		1	X				X			X	X	X	X		6	0.43	1.14
W03W47	1.7	**53.0**	9.22	X					X			X		3		X		X		2		X			X	X			X	X	X		6	0.75	2.00
Rockcamp Run (09-552-000)																																			
W03W52	0.1	**65.5**	5.36	X		X			X		X	X	X	6				X		1		X			X	X			X	X			5	0.29	1.00
Indiancamp Run (09-551-000)																																			
W03W56	0.3	**77.8**	24.19	X	X		X	X	X		X	X	X	8						0		X							X		X		3	0.11	0.44
Flatlick Run (09-549-000)																																			
W03S39	0.6	**63.8**	13.89	X			X	X	X			X		5						0		X			X				X	X	X	X	6	0.17	1.33
Williams Run (09-547-000)																																			
203956	0.1	**65.5**	9.57	X	X		X	X	X			X		6						0		X							X	X	X		4	0.14	0.86
Strongs Run (09-546-000)																																			
W03S36	5.9	**58.8**	11.56	X				X	X			X		4				X		1		X			X				X	X	X	X	6	0.40	1.60
W03S47	0.6	**59.8**	7.52	X								X		2				X		1					X	X			X	X	X	X	6	0.67	2.67
Robinson Run (09-544-000)																																			
W03S40	0.2	**69.0**	13.89	X				X	X			X		4						0					X				X	X	X		4	0.20	1.20
Little Indian Creek (09-540-000)																																			
W03P14	0.2	**68.3**	9.22	X			X	X	X			X		5				X		1		X							X	X	X		4	0.33	1.00
Indian Creek (09-539-000)																																			

Key QHEI Components				WWH Attributes											MWH Attributes																				
Station	River Mile	QHEI	Grad-ient (ft/mi)	Not Channelized or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrate	Good/Excellent Development	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low/Normal Embeddedness	Max Depth > 40cm	Low/Normal Riffle Embeddedness	**WWH Attributes**	Channelized/No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40cm	**High-Influence Modified Attributes**	Recovering Channel	Heavy/Moderate Substrates	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1 or 2 Cover Types	Intermittent/Poor Pools	No Fast Current	High/Moderate Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	**Mod. Influence Modified Attributes**	MWH H.I.+1 / WWH+1 Ratio	MWH M.I. / WWH Ratio
W03P36	1.6	**68.0**	9.48	X				X	X			X		4						0		X			X				X	X	X		5	0.20	1.40
W03W55	1.5	**79.5**	9.48	X	X		X	X	X	X	X	X	X	9						0		X								X			2	0.10	0.40
W03W55	1.5	**70.3**	9.48	X	X			X	X			X		5						0		X		X	X				X	X	X		6	0.17	1.33
Puncheon Fork (09-534-000)																																			
W03K30	2.8	**59.0**	46.50	X	X			X	X		X	X	X	7				X		1		X			X			X	X			X	5	0.25	0.75
W03W30	1.5	**71.0**	15.04	X			X	X	X		X	X		6						0		X		X	X				X	X	X		6	0.14	1.14
W03W07	0.3	**72.8**	7.54	X	X		X	X	X		X	X	X	8						0				X	X				X	X	X		5	0.11	0.78
Wolf Run (09-533-000)																																			
203947	3.8	**64.5**	13.51	X				X	X			X		4		X				1		X			X				X	X	X	X	6	0.40	1.60
Trib. To Elk Fork (Rm 11.17) (09-530-004)																																			
W03W09	0.4	**45.0**	35.20		X							X		2			X	X		2	X	X			X			X	X	X	X	X	8	1.33	3.33
Elk Fork (09-530-000)																																			
W03W06	13.9	**76.3**	6.45	X	X			X	X			X	X	6						0		X		X	X				X	X	X	X	7	0.14	1.29
W03P30	13.3	**86.3**	6.45	X	X		X	X	X	X	X	X	X	9						0													0	0.10	0.20
W03W14	8.6	**66.5**	4.06	X					X			X		3						0		X			X	X			X	X	X		6	0.25	2.00
W03P31	0.0	**70.8**	3.94	X			X	X	X	X		X		6						0										X	X		2	0.14	0.57
W03W14	8.6	**74.5**	4.06	X			X	X	X			X	X	6						0		X			X	X			X	X			5	0.14	1.00
Mcconnel Run (09-528-000)																																			
303688	2.0	**36.0**	0.50											0				X	X	2	X	X			X	X			X	X	X	X	8	4.00	10.00
Meadow Run (09-524-000)																																			
W03S10	3.1	**61.5**	12.66		X				X			X		3						0	X	X			X	X			X	X	X	X	8	0.50	2.50
W03W27	2.2	**61.3**	15.63						X			X		2		X				1	X	X			X	X			X	X	X		7	1.00	3.00
W03W18	0.7	**50.3**	2.77	X					X			X		3				X		1		X		X	X	X			X	X		X	7	0.50	2.25
Dickason Run (09-514-000)																																			
W03S48	2.4	**55.5**	5.07	X					X			X		3		X				1		X			X	X			X	X	X		6	0.50	2.00
W03P43	0.1	**64.0**	5.07	X				X	X			X		4						0		X			X				X	X	X		5	0.20	1.40
Deer Creek (09-511-000)																																			
W03P15	0.2	**51.5**	14.20	X				X						2				X	X	2				X	X				X	X	X	X	6	1.00	2.67
Little Raccoon Creek (09-510-000)																																			
W03S07	27.9	**54.0**	2.33	X				X	X			X		4		X				1		X			X				X	X		X	5	0.40	1.40
W03W25	24.6	**52.0**	2.59	X					X			X		3		X				1		X			X	X			X	X		X	6	0.50	1.75
W03K10	17.3	**68.0**	3.71	X			X	X	X			X		5						0		X		X	X				X	X	X		6	0.17	1.33
W03S06	12.7	**57.3**	1.86	X				X	X			X		4				X		1					X				X	X		X	4	0.40	1.20
W03K09	11.0	**65.5**	1.86	X	X			X	X			X		5						0	X				X				X	X	X		5	0.33	1.17

Key QHEI Components				WWH Attributes											MWH Attributes																				
Station	River Mile	QHEI	Grad-ient (ft/mi)	Not Channelized or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrate	Good/Excellent Development	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low/Normal Embeddedness	Max Depth > 40cm	Low/Normal Riffle Embeddedness	**WWH Attributes**	Channelized/No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40cm	**High-Influence Modified Attributes**	Recovering Channel	Heavy/Moderate Substrates	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1 or 2 Cover Types	Intermittent/Poor Pools	No Fast Current	High/Moderate Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	**Mod. Influence Modified Attributes**	MWH H.I.+1 / WWH+1 Ratio	MWH M.I. / WWH Ratio
W03P04	3.5	**66.8**	2.42	X	X		X		X			X		5						0		X		X		X			X	X	X		6	0.17	1.33
W03K10	18.5	**64.0**	3.71	X					X			X		3						0		X			X	X			X	X		X	6	0.25	2.00
Clear Fork (09-506-000)																																			
W03K23	0.1	**71.0**	13.33	X	X		X	X	X			X		6						0		X							X	X	X	X	5	0.14	1.00
Little Bullskin Creek (09-503-000)																																			
W03K22	0.0	**70.0**	43.80	X	X		X	X	X		X	X	X	8						0					X				X	X	X	X	5	0.11	0.67
Bullskin Creek (09-502-000)																																			
W03K21	1.1	**78.3**	11.11	X	X		X	X	X	X	X	X	X	9						0													0	0.10	0.20
Big Beaver Creek (09-500-012)																																			
303508	0.9	**63.8**	40.50	X				X	X			X		4						0		X			X				X	X	X		5	0.20	1.40
Trib. To Raccoon Creek (Rm 98.96) (09-500-011)																																			
203928	0.1	**36.5**	12.90	X										1		X		X	X	3		X			X	X			X	X		X	6	2.00	3.50
Raccoon Creek (09-500-000)																																			
301747	111.4	**61.8**	3.55	X			X		X			X		4						0		X			X	X			X	X	X		6	0.20	1.60
301746	104.6	**65.0**	2.47	X			X	X	X		X	X		6						0				X	X	X			X		X		5	0.14	1.00
301746	104.6	**65.3**	2.47	X	X		X	X	X		X	X	X	8						0		X			X				X	X	X	X	6	0.11	0.89
W03W32	101.2	**58.8**	2.47	X	X				X			X		4						0		X			X	X			X	X		X	6	0.20	1.60
W03W44	98.3	**68.5**	2.47	X			X	X	X			X		5						0		X			X				X	X	X		5	0.17	1.17
302520	90.0	**87.5**	3.54	X	X		X	X	X	X	X	X	X	9						0													0	0.10	0.20
302519	89.4	**86.0**	1.71	X	X		X	X	X	X	X	X	X	9						0													0	0.10	0.20
W03W34	84.1	**62.5**	1.44	X					X			X		3						0		X			X	X			X	X		X	6	0.25	2.00
W03G50	75.9	**61.8**	1.44	X				X	X			X		4						0		X	X		X				X	X		X	6	0.20	1.40
W03P07	71.2	**79.5**	1.88	X	X		X	X	X	X	X	X	X	9						0										X	X		2	0.10	0.40
W03W35	66.0	**80.3**	1.80	X	X				X	X	X	X	X	7						0					X	X				X	X		4	0.13	0.75
W03P18	58.2	**73.5**	1.07	X	X		X		X	X		X		6						0		X				X				X	X		4	0.14	0.86
W03P18	58.2	**67.3**	1.07	X	X				X			X		4						0		X			X	X			X	X	X		6	0.20	1.60
W03P05	40.2	**81.8**	2.12	X	X		X		X	X	X	X	X	8						0						X				X	X		3	0.11	0.56
W03S44	35.6	**76.8**	2.04	X	X		X	X	X	X	X	X	X	9						0		X			X					X	X		4	0.10	0.60
601400	29.2	**72.5**	1.65	X	X				X		X	X		5						0		X			X	X			X	X	X		6	0.17	1.33
303503	22.0	**80.5**	2.19	X	X		X	X	X	X		X		7						0										X	X		2	0.13	0.50
W03S24	10.2	**78.3**	1.54	X	X		X		X	X	X	X		7						0		X			X	X				X	X		5	0.13	0.88

Fish Community Results

A total of 22,292 fish representing 68 species and 2 hybrids were collected from the Raccoon Creek watershed between June and October 2016, and July 2017. The survey effort included 107 sampling events at 78 stations. Sampling locations were evaluated using EWH, WWH, MWH – Mine Affected or LRW biocriteria. Overall, 41 (53%) of the sites sampled achieved their respective aquatic life use biocriteria (Table 11). Relative numbers and species collected per location are presented in Appendix E, and IBI and MIwb scores in Appendix F.

Index of Biological Integrity (IBI) scores for the Raccoon Creek mainstem were generally exceptional ($\bar{X}$ = 48 ± 4, range: 40 – 58) and is not expected to preclude WWH or better fish assemblages. Modified Index of well-being (MIwb) scores in the mainstem were generally very good ($\bar{X}$ = 9.23 ± 0.92, range: 7.32 – 10.4). A dam at RM 40.3 in Vinton delineates a community shift in Raccoon Creek, downstream of the dam fully meets EWH biocriteria, where upstream community performance is diminished (Table 10, Figure 16). Tributaries in the watershed were more variable, but generally indicated that WWH is achievable (Table 10, Figure 17).

Table 10 — Summary statistics of fish biocriteria performance in the Raccoon Creek watershed 2016-2017.

	IBI			MIwb			
	$\bar{X}$	σ	Range	$\bar{X}$	σ	Range	n
Mainstem – EWH	50	5	44-58	10.1	0.2	9.9-10.4	5
Mainstem – WWH	47	4	40-51	8.8	0.8	7.3-9.8	11
Little Raccoon Creek	40	11	18-52	8.2	1.4	5.5-9.1	7
Hewett Fork	38	9	26-52	-	-	-	8
Other Tributaries	35	9	12-50	-	-	-	53

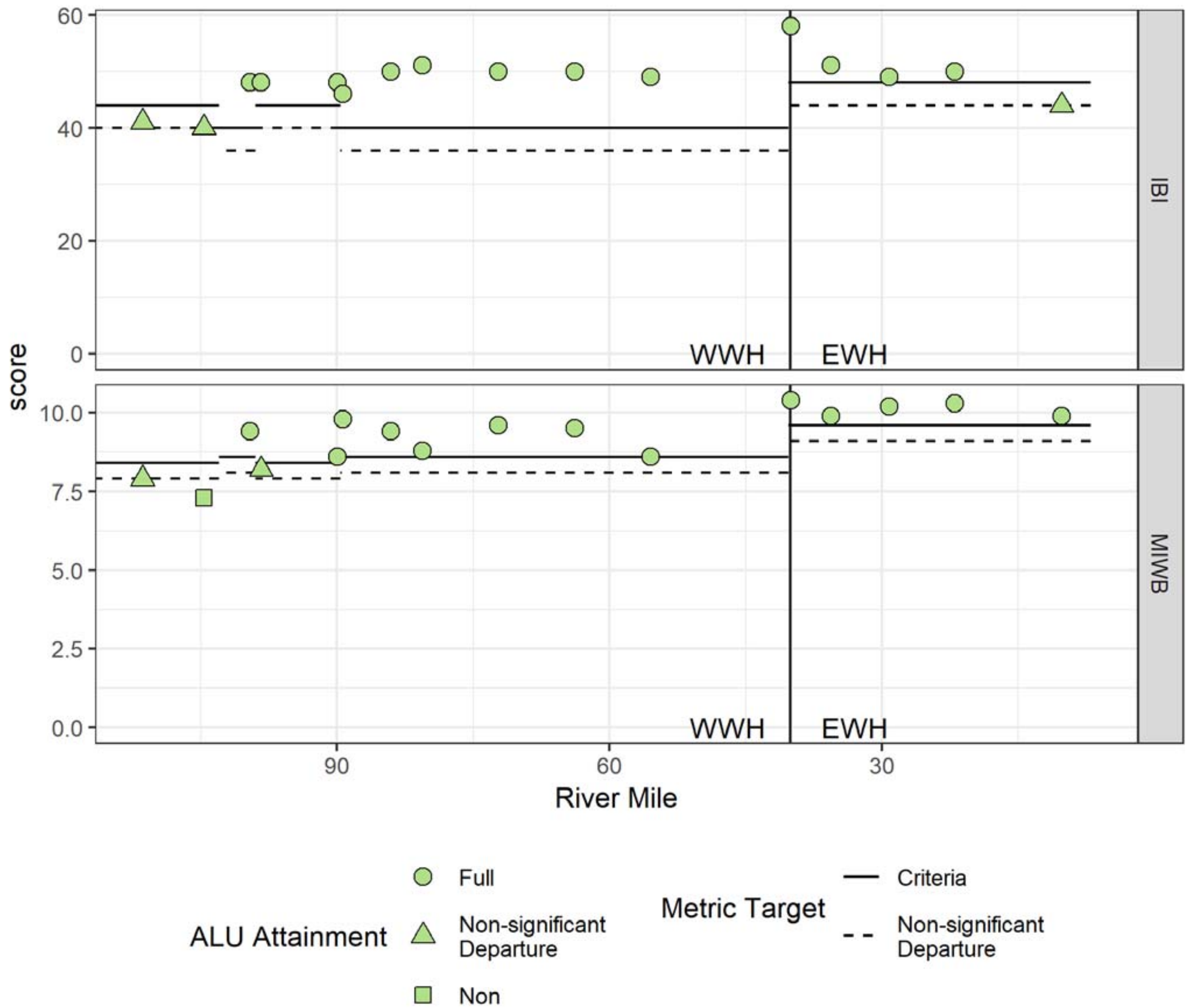


Figure 16 — Fish community performance as expressed by the IBI and MIwb were very good to exceptional in the Raccoon Creek mainstem during the 2016 survey.

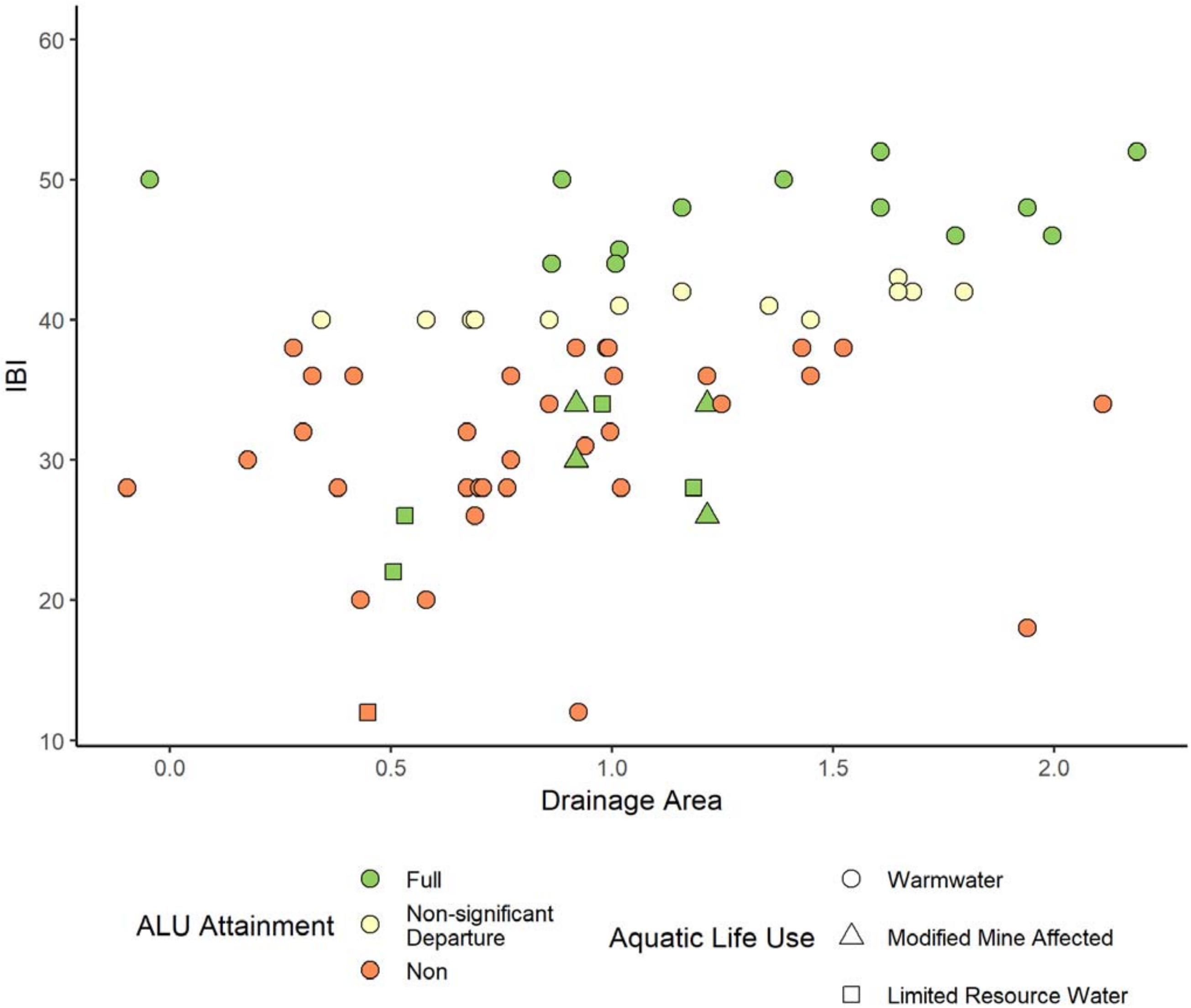


Figure 17 — Fish community performance as expressed by the IBI was variable but generally fair in Raccoon Creek tributaries during the 2016 survey. Drainage area is in log10 units.

Table 11 — Fish community summaries based on pulsed D.C. electrofishing conducted by Ohio EPA in the Raccoon Creek watershed, 2016.

Station	Location	Assessment Unit (04100004)	River Mile	Drain. Area (mi^2)	Avg. Species	Avg. Bio Mass (kg)	Avg. Rel. No.	IBI	MIwb	QHEI	Narrative Evaluation
Raccoon Creek (09-500-000) WWH – Recommended											
301747	Twomile Rd, upstream Twomile Run	02 04	111.38	43.6 ^{W}	19	2.8	318	41	7.9 ^{ns}	61.8	Marginally Good
301746	Downstream Mitchell Hollow, at St Rt 328	02 04	104.63	56.4 ^{W}	17.5	3.6	302.25	40	7.3*	65.1	Fair
W03W32	Creek Road (TR18)	02 05	99.60	95.8 ^{B}	23	13.4	394.29	48	9.4	58.8	Very Good
W03W44	Township Hwy F3, at ford	02 05	98.34	100.0 ^{W}	21	4.6	400.5	48	8.2 ^{ns}	68.5	Marginally Good
Raccoon Creek (09-500-000) WWH											
W03W33	Downstream Sandy Run, Wheelabout Road (CR 3)	02 05	92.30	134.0	-	-	-	-	-	-	-
302520	Hope-Moonville Road, upstream Hewett Fork	02 05	89.98	136.0 ^{W}	22.5	8.4	512.25	48	8.6	87.5	Good
302519	Buck Lane (CR 18B), downstream Hewett Fork	03 04	89.36	176.0 ^{A}	25	10.9	732.5	46	9.8	86	Very Good
W03W34	St Rt 356, near Bunker Hill Rd	03 04	84.08	183.0 ^{B}	25	54.3	399.05	50	9.4	62.5	Very Good
W03G50	St Rt 50, at Bolins Mills, USGS gage	03 04	80.62	2000 ^{B}	21	20.5	400	51	8.8	61.8	Good
W03P07	US 32 W	03 04	72.22	223.0 ^{B}	23	25.1	863.33	50	9.6	79.5	Exceptional
W03W35	US 32 W	05 03	63.80	296.0 ^{B}	27	22.2	674	50	9.5	80.3	Very Good
W03P18	Clarion Road canoe access	05 03	55.48	322.0 ^{B}	22	6.5	265.5	49	8.6	70.4	Good
W03S34	Covered Bridge Road (CR 4)	05 03	50.10	336.0	-	-	-	-	-	-	-
Raccoon Creek (09-500-000) EWH – Recommended											
W03P05	Vinton Park, downstream dam, St Rt 325	05 04	40.01	381.0 ^{B}	35	70.8	565.45	58	10.4	81.8	Exceptional
W03S44	Glassburn Road, just off of Woodsmill Road	90 01	35.61	543.0 ^{B}	30.5	48.7	567	51	9.9	76.8	Exceptional
601400	Bob Evans Camp, OH 558	90 01	29.20	586.0 ^{B}	28.5	54.3	480	49	10.2	72.5	Exceptional
303503	MacIntyre Park, Dan Jones Rd	90 01	22.00	615.0 ^{B}	30.5	32.7	535	50	10.3	80.5	Exceptional
W03S24	Ingalls Road	90 01	10.20	657.0 ^{B}	27.5	37.2	594	44 ^{ns}	9.9	78.3	Very Good
West Branch Raccoon Creek (09-575-000) WWH											
W03W36	Ilesboro-Cedar Falls Road	02 02	5.68	3.8 ^{H}	5	-	380	20*	-	70.5	Poor

Station	Location	Assessment Unit (04100004)	River Mile	Drain. Area (mi²)	Avg. Species	Avg. Bio Mass (kg)	Avg. Rel. No.	IBI	MIwb	QHEI	Narrative Evaluation
W03W43	St Rt 328, near mouth	02 02	0.15	22.7 H	16	3.2	292	41 ns	7.1*	63.1	Fair
Honey Fork (09-576-000) WWH											
W03P35	Orlando Flat Road	02 02	0.01	10.5 H	9	-	196	28*	-	61.3	Fair
East Branch Raccoon Creek (09-574-000) WWH-Recommended											
W03W37	CR 26 (Laurel Run Rd)	02 01	6.64	3.2 H	4	-	92.57	22*	-	75.5	Poor
W03K17	Adj. St Rt 56, Wayne National Forest land	02 01	2.10	15.3 H	13	-	374	28*	-	71.8	Fair
Tributary to Raccoon Creek (RM 98.96) (09-500-011) WWH											
203928	lane off Powder Plant Road	02 05	0.10	0.1 H	11	-	180	38*	-	36.5	Fair
Twomile Run (09-573-000) WWH											
W03W58	near mouth, Long Ridge Road	02 04	0.16	4.9 H	7	-	254	26*	-	58.5	Poor
Brushy Creek (09-571-000) WWH											
W03K40	At gravel lane, off St Rt 93	02 03	6.87	8.4 H	1	-	24	12*	-	54	Very Poor
W03K39	OH 328, near mouth	02 03	0.36	33.4 H	15.5	1.4	261	38*	6.4*	55	Fair
Siverly Creek (09-571-002) WWH											
W03K42	adj. Siverly Creek Road	02 03	0.30	10.1 H	11	-	314.55	36*	-	67.8	Fair
Sandy Run (09-568-000) WWH											
203966	King Hollow Road	02 05	2.70	5.0 H	9	-	504	28*	-	65	Fair
Little Sandy Run (09-569-000) WWH											
303689	St Rt 278	02 05	0.40	1.5 H	11	-	124	30*	-	39	Fair
Hewett Fork (09-563-000) MWH – Mine Affected – Recommended											
W03K37	adj. Carbondale Road	03 01	13.10	8.3 H	9.5	-	157	30/ 34	-	60.0/ 61.25	Fair
303739	adj. Waterloo Wildlife Area dst bridge	03 01	8.40	16.4 H	14	-	121	26/ 34	-	68.5/ 60.5	Fair
Hewett Fork (09-563-000) WWH – Recommended											
W03P08	ust Rockcamp Creek, Rockcamp Road (TR 20)	03 01	4.31	28.1 H	16.5	2.7	230.25	40/ 36*	7.0*/ 7.3*	68.1/ 70.0	Fair
W03P32	at mouth	03 01	0.01	40.5 W	24.5	5.9	345.75	52/48	9.0/8.5	74.5/75.5	Good
Grass Run (09-567-000) WWH											
W03P41	St Rt 356	03 01	0.04	2.7 H	5	-	88.8	20*	-	73	Poor
Pine Run (09-566-000) WWH											
301579	at mouth, 750 ft W OH 356	03 01	0.10	2.0 H	6	-	50.4	32*	-	39.5	Fair
Coal Run (09-565-000) WWH											

Station	Location	Assessment Unit (04100004)	River Mile	Drain. Area (mi^2)	Avg. Species	Avg. Bio Mass (kg)	Avg. Rel. No.	IBI	MIwb	QHEI	Narrative Evaluation
W03W50	St Rt 681	03 01	0.05	0.8^{H}	4	-	201.6	28*	-	41.5	Fair
Rockcamp Creek (09-564-000) WWH											
W03P33	Rockcamp Road	03 01	1.53	7.7^{H}	10	-	184	28*	-	53.3	Fair
Laurel Run (09-562-000) WWH											
W03W59	near Knox, at TR 18 (Mulby Road)	03 04	0.16	2.6^{H}	18	-	355.2	36*	-	64	Fair
Onion Creek (09-561-000) WWH											
W03W45	CR 4 (Worley West Road)	03 04	1.41	8.3^{H}	17	-	262	38*	-	58	Fair
Flat Run (09-557-000) WWH											
W03W51	Brooks Road, near US 50	03 04	1.60	4.8^{H}	18	-	422	40^{ns}	-	60.8	Marginally Good
Long Run (09-556-000) WWH											
203960	Adj Long Run Road (CR 11)	03 04	1.40	2.2^{H}	11	-	292	40^{ns}	-	65	Marginally Good
Elk Fork (09-530-000) WWH											
W03W06	Morgan Road (CR 11), upstream Puncheon Fork	03 02	13.90	14.4^{H}	22	-	877.5	42^{ns}	-	76.3	Marginally Good
W03P30	St Rt 50, 1 Mi. E McArthur	03 02	13.26	24.5^{H}	22.5	14	825	50	9.2	86.3	Very Good
W03W14	downstream Wolf Run, Adj Stone Quarry Road (CR 8)	03 03	8.55	44.4^{W}	18	4.7	215.5	$43^{ns}/42^{ns}$	7.7*/7.3*	66.5/74.5	Fair
W03P31	CR 43B, Northeast of Radcliff	03 03	0.01	60.0^{W}	21	3.5	241.5	46	7.9^{ns}	70.8	Marginally Good
Austin Powder Tributary to Elk Fork at RM 11.17 (09-530-004) WWH											
W03W09	East of McArthur, at CR 7	03 02	0.43	2.4^{H}	12	-	175.2	28*	-	45	Fair
Puncheon Fork (09-534-000) WWH											
W03K30	Bolar Road (TR 19)	03 02	2.82	4.7^{H}	8	-	78	28*	-	59	Fair
W03W30	C.R. 25	03 02	1.51	7.2^{H}	14	-	280	40^{ns}	-	71	Marginally Good
W03W07	St Rt 50	03 02	0.28	9.5^{H}	13	-	418	38*	-	72.8	Fair
Wolf Run (09-533-000) WWH – Recommended											
203947	Vinton Station Road (CR 24)	03 02	3.80	4.7^{H}	10	-	187.2	32*	-	64.5	Fair
Pierce Run (09-553-000) LRW											
W03L08	St Rt 160, near Hamden	05 01	5.47	3.4^{H}	7	-	146	26	-	67.5	Poor
W03W47	Township Hwy 2A	05 01	1.68	9.5^{H}	14	-	182.4	34	-	53	Fair
Rockcamp Run (09-552-000) LRW											
W03W52	Hawk Station Road	05 03	0.11	2.8^{H}	2	-	19.2	12*	-	65.5	Very Poor

Station	Location	Assessment Unit (04100004)	River Mile	Drain. Area (mi^2)	Avg. Species	Avg. Bio Mass (kg)	Avg. Rel. No.	IBI	MIwb	QHEI	Narrative Evaluation
Indiancamp Run (09-551-000) WWH - Recommended											
W03W56	Adj. Minerton Road (CR 26)	05 03	0.30	2.1 ^{H}	9	-	257.78	36*		77.8	Fair
Flatlick Run (09-549-000) WWH											
W03S39	Newsome Road (CR 8)	05 03	0.60	7.2 ^{H}	18	-	638	34*	-	63.8	Fair
Strongs Run (09-546-000) WWH											
W03S36	Tower Road (TR 24)	05 02	5.90	5.9 ^{H}	14	-	1038	36*	-	58.8	Fair
W03S47	Adney Road	05 02	0.58	16.4 ^{H}	16	-	328	36*	-	59.8	Fair
Williams Run (09-547-000) WWH – Recommended											
203956	Williams Run Road	05 02	0.10	3.8 ^{H}	15	-	646	40 ^{ns}	-	65.5	Marginally Good
Robinson Run (09-544-000) WWH											
W03S40	St Rt 325	05 04	0.18	9.7 ^{H}	17	-	301.82	38*	-	69	Fair
Little Raccoon Creek (09-510-000) WWH											
W03S09	Wolf Hill Road (CR 25)	04 01	36.67	12.1	-	-	-	-	-	-	-
W03S07	Mulga Road (CR 39), upstream Meadow Run	04 01	27.90	48.0 ^{B}	19	35.8	630	42	8.8	54	Good
W03W25	St Rt 32, upstream Mulga Run	04 03	24.55	62.5 ^{B}	22	28	500	42	9	52	Good
W03K10	Buckeye Furnace Rd, at State Memorial	04 03	18.45	87.0 ^{W}	15	2.5	45.3	48/18*	7.1*/5.5 *	68	Poor
W03S06	Keystone Rd, ust Dickason Run	04 03	12.71	99.0 ^{B}	23	7.4	417.5	46	9.1	57.3	Very Good
W03K09	Keystone Furnace Road, Downstream Dickason Run	04 04	11.00	129.0 ^{B}	22.5	11.8	380.66 5	34*	9	65.5	Fair
W03P04	St Rt 325, or Woods Mill Rd	04 04	1.17	154.0 ^{W}	26	11.2	420	52	9.1	66.8	Very Good
McConnels Run (09-528-000) WWH – Recommended											
303688	Lake Road (TR15)	04 01	1.98	0.9 ^{H}	10	-	397.67	50	-	36	Exceptional
Meadow Run (09-524-000) WWH											
W03S10	Upstream General Mills, on property	04 01	3.10	5.1 ^{H}	15.5	-	489	28*	-	61.5	Fair
W03W27	St Rt 327 (Pennsylvania Road)	04 01	2.16	8.7 ^{H}	18	-	407.27	31*	-	61.3	Fair
W03W18	Cheatwood Road	04 01	0.72	9.9 ^{H}	16	-	165.45	32*	-	50.3	Fair
Dickason Run (09-514-000) WWH											
W03S48	Keystone Furnace Road, or Ridgeland Road	04 02	2.37	17.7 ^{H}	10	-	112	34*	-	55.5	Fair

Station	Location	Assessment Unit (04100004)	River Mile	Drain. Area (mi^2)	Avg. Species	Avg. Bio Mass (kg)	Avg. Rel. No.	IBI	MIwb	QHEI	Narrative Evaluation
Dickason Run (09-514-000) WWH – Recommended											
W03P43	Orpheus-Keystone Road	04 02	0.11	26.9 H	14.5	1.2	175.5	38*	6.6*	64	Fair
Deer Creek (09-511-000) WWH											
W03P15	Adj., St Rt 325, near mouth	04 04	0.20	5.9 H	10	-	190	30*	-	51.5	Fair
Barren Creek (09-542-000) WWH											
203953	OH 554, powerline easement, or upstream at bridge	06 02	0.30	9.1	-	-	-	-	-	-	-
Indian Creek (09-539-000) WWH											
W03P36	upstream Rio Grande WWTP, St Rt 325	06 01	1.58	10.4 H	21.5	-	781.54 5	41 ns	-	68	Marginally Good
W03W55	Downstream Rio Grande WWTP, St Rt 325, upstream Little Indian Run	06 01	1.45	10.4 H	18	-	935	45	-	74.9	Good
Little Indian Creek (09-540-000) WWH											
W03P14	Buckeye Hills Road	06 01	0.17	10.2 H	18	-	864	44	-	68.3	Good
Big Beaver Creek (09-500-012) WWH											
303508	Guthrie Road, off Cora Mill Road	06 03	0.90	0.9 H	21	-	830	44	-	63.8	Good
Claylick Run (09-507-000) WWH											
203929	Lincoln Pike	06 05	0.40	7.7	-	-	-	-	-	-	-
Clear Fork (09-506-000) WWH											
W03K23	Ingalls Road	06 05	0.02	7.7 H	27	-	601.82	50	-	71	Exceptional
Bullskin Creek (09-502-000) WWH											
W03K21	Williams Hollow Road	06 04	0.37	13.2 H	24.5	-	771	48	-	78.3	Very Good
Little Bullskin Creek (09-503-000) WWH											
W03K22	Little Bullskin Road	06 04	0.01	4.9 H	10	-	1171.2	40 ns	-	70	Marginally Good

a- River Mile (RM) represents the Point of Record (POR) for the station, and may not be the actual sampling RM.

b- MIwb is not applicable to headwater streams with drainage areas $\leq$ 20 mi^2.

c- A narrative evaluation of the qualitative sample based on attributes such as EPT taxa richness, number of sensitive taxa, and community composition was used when quantitative data was not available or considered unreliable. VP=Very Poor, P=Poor, LF=Low Fair, F=Fair, MG=Marginally Good, G=Good, VG=Very Good, E=Exceptional

ns- Nonsignificant departure from biocriteria ($\leq$4 IBI or ICI units, or $\leq$0.5 MIwb units).

*- Indicates significant departure from applicable biocriteria (>4 IBI or ICI units, or >0.5 MIwb units). Underlined scores are in the Poor or Very Poor range.

H- Headwater site (draining ≤20 $miles^2$)

W- Wading site (non-boat site draining >20 $miles^2$)

B- Boat site (large or deep waters, necessitating the use of Boat sampling methods)

1- Aquatic Life Use (ALU) designations: Exceptional Warmwater Habitat (EWH), Warmwater Habitat (WWH), Modified Warmwater Habitat (MWH)

2- Biological criteria presented in OAC 3745-1-07, Table 7-1

Biocriteria for the Western Allegheny Plateau Ecoregion						
	IBI			**MIwb**		**ICI**
ALU	**Boat**	**Wading**	**Headwater**	**Boat**	**Wading**	**All sizes**
EWH	48	50	50	9.6	9.4	46
WWH	40	44	44	8.6	8.4	36
MWH	24	24	24	5.8	6.2	22

Macroinvertebrate Community Results

Macroinvertebrate communities were evaluated at 83 stations in the Raccoon Creek study area in 2016 and 2017. A total of 86 samples were collected, the bulk of which occurred in 2016. Qualitative sampling was conducted from all sampling locations and quantitative Hester-Dendy artificial substrate samples were collected from 24 locations. A summary of the macroinvertebrate data is presented in Table 12 and the site specific data can be found in Appendices C and D. Overall, 71 (83 percent) of the collections met applicable Invertebrate Community Index (ICI) biocriteria or the narrative equivalent. The Raccoon Creek mainstem, although designated as WWH for the entire sampled reach, at least, marginally met the EWH biocriterion at eight of the 18 stations (Figure 18). The longest contiguous reach of EWH attainment began at RM 40.01 then improved and extended to the terminus of the surveyed reach at RM 10.20.

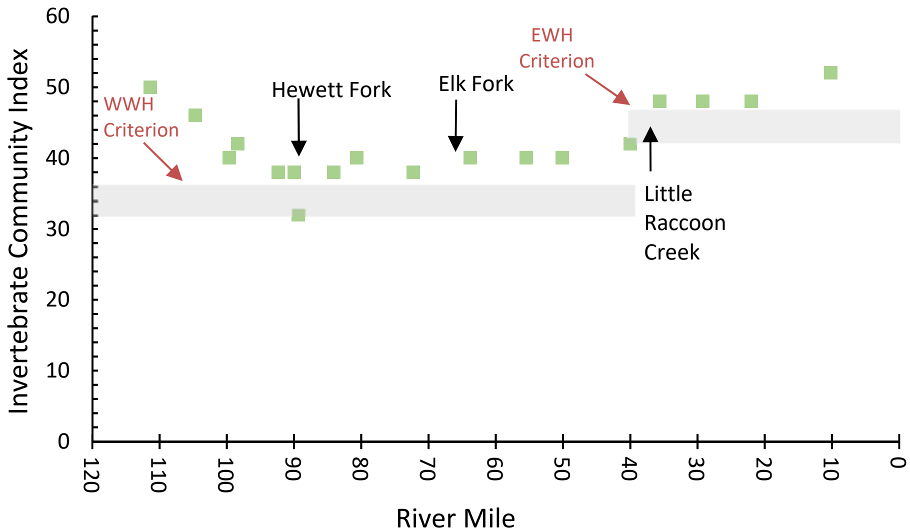


Figure 18 — Longitudinal trend of Invertebrate Community Index (ICI) scores for Raccoon Creek, 2016. Shaded areas represent the range of nonsignificant departure from the WWH and EWH criteria.

Table 12 — Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) in the Raccoon Creek study area, June to September 2016.

Station	River Mile	Drainage Area	Qual Taxa	EPT taxa Qual/Total	Sensitive taxa Qual/Total	Density Qual/Quant	CW Taxa	Predominant Organisms on the Natural Substrates with Tolerance Category(ies)	ICI[a]	Narrative Evaluation
Raccoon Creek (09-500-000)										
301747	111.38	43.6	29	11/15	9/11	80 / L	0	None	50	-
301746	104.63	56.4	39	14/16	11/13	376 / L	0	Caddisflies (F,MI)	46	-
W03W32	99.60	95.8	53	22/22	16/16	11.3 / M	0	Caddisflies (F,MI)	40	-
W03W44	98.34	100.0	34	15/19	10/12	572 / M	0	Hydropsychid caddisflies (F)	42	-
W03W33	92.30	134.0	35	15	8	M	0	Baetid mayflies (MI,F)	-	Good
302520	89.98	136.0	46	18/20	15/16	98 / L	0	Caddisflies (F,MI)	(28)	Good
302519	89.36	176.0	33	12	9	L-M	0	Baetid mayflies (MI)	-	Marg. Good
W03W34	84.08	194.0	43	15/20	13/18	707 / M	0	Hydropsychid caddisflies (F)	38	-
W03G50	80.62	200.0	50	16/20	16/18	690 / L-M	0	Hydropsychid caddisflies (F)	40	-
W03P07	72.22	223.0	52	20/21	17/18	739 / H	0	*Isonychia* mayflies (MI), caddisflies (MI,F)	38	-
W03W35	63.80	291.0	41	20/21	20/20	325 / M-H	0	*Isonychia* mayflies (MI), caddisflies (F,MI)	40	-
W03P18	55.48	322.0	42	17/20	16/18	227 / M	0	Baetid mayflies (F)	40	-
W03S34	50.10	336.0	42	19/21	19/19	376 / H	0	Caddisflies (F,MI), baetid mayflies (F)	40	-
W03P05	40.10	381.0	57	19/21	20/23	1100	0	Baetid mayflies (F), caddisflies (F,MI)	42	-
W03S44	35.61	543.0	43	22/22	18/19	987 / M-H	1	Mayflies (MI,F), hydropsychid caddisflies (F,MI)	48	-
601400	29.20	586.0	47	23	23	H	0	*Isonychia* mayflies (MI), caddisflies (MI,F)	-	Exceptional
303503	22.00	615.0	57	24	21	H	0	Hydropsychid caddisflies (MI,F), mayflies (F,MI)	-	Exceptional
W03S24	10.20	656.0	76	29/31	27/28	902 / M-H	0	Midges (F), hydropsychid caddisflies (F,MI), heptageniid mayflies (MI)	52	-
West Branch Raccoon Creek (09-575-000)										
W03W36	5.68	3.8	36	15	13	M	1	Hydropsychid caddisflies (F,MI)	-	Good
W03W43	0.15	22.7	37	12/17	10/12	104 / L	0	Midges (F)	46	-
Honey Fork (09-576-000)										
W03P35	0.01	10.5	44	15	13	M	0	Odonates (F,MT)	-	Good
East Branch Raccoon Creek (09-574-000)										
W03W37	6.35	3.5	12	2	1	L	0	Midges (T,MT,VT)	-	Poor
W03K17	2.10	15.3	28	11	8	L	1	Hydropsychid caddisflies (F)	-	Marg. Good

Station	River Mile	Drainage Area	Qual Taxa	EPT taxa Qual/Total	Sensitive taxa Qual/Total	Density Qual/Quant	CW Taxa	Predominant Organisms on the Natural Substrates with Tolerance Category(ies)	ICI[a]	Narrative Evaluation
Trib. To Raccoon Creek (Rm 98.96) (09-500-011)										
203928	0.10	1.9	30	2	0	M	0	Odonates (T,F)	-	Poor
Twomile Run (09-573-000)										
W03W58	0.16	4.9	55	18	15	L-M	3	Midges (F), beetles (F)	-	Very Good
Brushy Fork (09-571-000)										
W03K40	6.87	8.4	40	15	14	L	3	Midges (MI,F), heptageniid mayflies (F)	-	Good
W03K39	0.36	33.4	33	15/15	13/14	139 / L	0	Caddisflies (F), Midges (F)	38	-
Siverly Creek (09-571-002)										
W03K42	0.30	10.1	48	15	14	L	2	Midges (F,MI)	-	Good
Sandy Run (09-568-000)										
203966	2.70	5.0	35	13	8	L	2	Hydropsychid caddisflies (F)	-	Good
Little Sandy Run (09-569-000)										
303689	0.40	1.5	27	2	0	H	0	Scuds (F), water mites (F), damselflies (T)	-	Poor
Hewett Fork (09-563-000)										
W03K37	13.10	8.3	34	11	9	M	1	Caddisflies (F,MI)	-	Marg. Good
W03K37	13.10	8.3	29	8	5	L	1	Blackflies (F), baetid mayflies (MI), alderflies (MT)	-	Marg. Good
303739	8.40	16.4	45	12	11	L	3	Caddisflies (F), alderflies (MT) blackflies (F), riffle beetles (F)	-	Marg. Good
W03P08	4.31	28.1	33	18/19	13/14	168 / M	0	Caddisflies (F,MI), midges (F)	44	-
W03P08	4.31	28.1	45	19	16	M	0	Mayflies (MI,F), riffle beetles (F)	-	-
W03P32	0.90	40.3	41	13	11	M	1	Midges (F), riffle beetles (F)	-	Good
W03P32	0.01	40.5	31	13	12	L	0	Heptageniid mayflies (MI), hydropsychid caddisflies (F)	-	Good
Grass Run (09-567-000)										
W03P41	0.10	2.7	33	7	4	L	1	Odonates (F), alder flies (F), midges (F)	-	Fair
Pine Run (09-566-000)										
301579	0.10	2.0	32	8	5	M	0	Hydropsychid caddisflies (F)	-	Fair
Coal Run (09-565-000)										
W03W50	0.10	0.8	14	5	3	L	0	Mayflies (F,MI)	-	Fair
Rockcamp Creek (09-564-000)										
W03P33	1.53	5.8	51	12	7	M	1	Midges (F)	-	Marg. Good

Station	River Mile	Drainage Area	Qual Taxa	EPT taxa Qual/Total	Sensitive taxa Qual/Total	Density Qual/Quant	CW Taxa	Predominant Organisms on the Natural Substrates with Tolerance Category(ies)	ICI[a]	Narrative Evaluation
Laurel Run (09-562-000)										
W03W59	0.16	2.6	38	10	7	L-M	2	Baetid mayflies (MI)	-	Marg. Good
Onion Creek (09-561-000)										
W03W45	1.40	8.3	51	15	7	H	1	Fingernail clams (F), midges (F), scuds (F)	-	Good
Flat Run (09-557-000)										
W03W51	1.60	4.8	45	18	12	M	1	Hydropsychid caddisflies (F), mayflies (MI,F)	-	Very Good
Long Run (09-556-000)										
203960	1.40	2.2	38	14	8	L	2	Baetid mayflies (MI,F)	-	Good
Elk Fork (09-530-000)										
W03W06	13.90	14.4	43	16	11	M	1	Caddisflies (F), riffle beetles (F), fingernail clams (F)	-	Very Good
W03P30	13.26	24.5	38	12	9	H	0	Caddisflies (F,MI), baetid mayflies (F,MT)	-	Good
W03W14	8.55	44.4	43	19/21	14/16	557 / M	0	Caddisflies (F,M)	42	-
W03P31	0.01	59.8	33	14	11	M	0	Baetid mayflies (F), hydropsychid caddisflies (F)	-	Good
Trib. To Elk Fork (Rm 11.17) (09-530-004)										
W03W09	0.43	2.4	45	10	5	M	1	Midges (MT,F)	-	Marg. Good
Puncheon Fork (09-534-000)										
W03K30	4.00	2.9	33	15	10	M-H	2	Hydropsychid caddisflies (F), mayflies (MI,F)	-	Good
W03W07	0.28	9.8	46	6	1	-	1	Midges (F,T), damselflies (F), leeches (MT)	-	Very Poor
Wolf Run (09-533-000)										
203947	3.80	4.7	29	9	3	M	0	Hydropsychid caddisflies (F)	-	Fair
Pierce Run (09-553-000)										
W03L08	5.50	3.4	15	3	2	L	0	Hydropsychid caddisflies (F), alderflies (MT)	-	Poor
W03W47	1.70	9.5	22	6	2	L	0	Hydropsychid caddisflies (F)	-	Fair
Rockcamp Run (09-552-000)										
W03W52	0.11	2.8	26	6	2	L-M	0	Caddisflies (F,MI), blackflies (F)	-	Fair
Indiancamp Run (09-551-000)										
W03W56	0.30	2.1	45	11	9	L-M	1	*Chimarra* caddisflies (MI)	-	Marg. Good
Flatlick Run (09-549-000)										
W03S39	0.60	7.2	26	7	4	M	0	Mayflies (MI,F)	-	Fair

Station	River Mile	Drainage Area	Qual Taxa	EPT taxa Qual/Total	Sensitive taxa Qual/Total	Density Qual/Quant	CW Taxa	Predominant Organisms on the Natural Substrates with Tolerance Category(ies)	ICI[a]	Narrative Evaluation
Strongs Run (09-546-000)										
W03S36	5.90	5.9	31	13	9	L	0	Baetid mayflies (MI)	-	Good
W03S47	0.60	16.4	54	18	14	L-M	1	Midges (F), damselflies (F)	-	Very Good
Williams Run (09-547-000)										
203956	0.45	3.2	29	11	5	M-H	0	Baetid mayflies (MI)	-	Marg. Good
Robinson Run (09-544-000)										
W03S40	0.20	9.7	37	13	8	M	0	Mayflies (F,MI)	-	Good
Little Raccoon Creek (09-510-000)										
W03S09	36.67	12.1	35	8	4	L	0	*Phylocentropus* caddisflies (F), midges (F,MT), dragonflies (F)	-	Fair
W03S07	27.90	48.0	33	9/14	6/8	281 / M	0	Hydropsychid caddisflies (F)	40	-
W03W25	24.60	62.5	26	14/15	10/11	245 / M	0	Baetid mayflies (F), hydropsychid caddisflies (F)	48	-
W03K10	18.45	87.0	24	11/19	8/13	112 / M	0	Baetid mayflies (F), caddisflies (MI,F)	38	-
W03S06	12.71	99.0	40	16/21	14/17	90 / H	0	Baetid mayflies (F)	42	-
W03K09	11.00	129.0	28	14/20	13/17	190 / M	0	Baetid mayflies (F), caddisflies (MI,F)	44	-
W03P04	1.20	148.0	48	22/23	21/21	677 / H	0	Baetid mayflies (F), caddisflies (MI,F)	52	-
Mcconnel Run (09-528-000)										
303688	1.98	0.9	51	15	13	L	6	Midges (F), blackflies (F), other Diptera (F,MI)	-	Good
Meadow Run (09-524-000)										
W03S10	3.10	5.1	31	7	4	L	0	Odonates (F)	-	Fair
W03W27	2.10	8.7	32	9	2	L-M	0	Hydropsychid caddisflies (F), midges (F)	-	Fair
W03W18	0.72	9.9	28	4	1	M	0	Water boatmen (MT), odonates (F)	-	Low Fair
Dickason Run (09-514-000)										
W03S48	2.37	17.7	49	11	6	M-H	0	Scuds (F), midges (T,F), blackflies (F)	-	Marg. Good
W03P43	0.10	27.0	31	14/16	12/15	141 / L	1	Midges (F)	42	-
Deer Creek (09-511-000)										
W03P15	0.20	5.9	10	0	0	-	0	Mosquito larvae (T), dragonflies (MT), beetles (MT)	-	Very Poor
Barren Creek (09-542-000)										
203953	0.30	9.1	36	16	10	M-H	0	Hydropsychid caddisflies (F), baetid mayflies (MI,F), midges (F)	-	Good

Station	River Mile	Drainage Area	Qual Taxa	EPT taxa Qual/Total	Sensitive taxa Qual/Total	Density Qual/Quant	CW Taxa	Predominant Organisms on the Natural Substrates with Tolerance Category(ies)	ICI[a]	Narrative Evaluation
Indian Creek (09-539-000)										
W03P36	1.60	10.4	34	15	10	H	1	Heptageniid mayflies (MI), hydropsychid caddisflies (F)	-	Good
W03W55	1.45	10.4	39	17	12	M-H	0	Hydropsychid caddisflies (F), baetid mayflies (MI,F)	-	Good
Little Indian Creek (09-540-000)										
W03P14	0.25	10.2	30	13	8	L-M	0	Baetid mayflies (MI)	-	Good
Big Beaver Creek (09-500-012)										
303508	0.90	7.3	40	12	10	L	0	Hydropsychid caddisflies (F), mayflies (MI,F)	-	Good
Claylick Run (09-507-000)										
203929	0.40	7.7	31	12	8	M	0	Baetid mayflies (F), hydropsychid caddisflies (F)	-	Good
Clear Fork (09-506-000)										
W03K23	0.10	7.7	29	9	4	L	0	Midges (F,T)	-	Fair
Bullskin Creek (09-502-000)										
W03K21	1.10	13.8	31	15	10	M	0	Hydropsychid caddisflies (F), baetid mayflies (F)	-	Good
Little Bullskin Creek (09-503-000)										
W03K22	2.40	2.6	29	10	7	M	1	Hydropsychid caddisflies (F), baetid mayflies (F), midges (F)	-	Marg. Good

[a] – ICI values in parentheses are invalidated due to insufficient current speed over the artificial substrates or by disturbance. The station evaluation at these sites is based on the qualitative sample narrative evaluation.

RM: River Mile.

Dr. Ar.: Drainage Area

Ql.: Qualitative sample collected from the natural substrates.

Sensitive Taxa: Taxa listed on the Ohio EPA Macroinvertebrate Taxa List as MI (moderately intolerant) or I (intolerant). Qt.: Quantitative sample collected on Hester-Dendy artificial substrates, density is expressed in organisms per square foot.

Qualitative sample relative density: L=Low, M=Moderate, H=High.

CW: Cold Water.

Tolerance Categories: VT=Very Tolerant, T=Tolerant, MT=Moderately Tolerant, F=Facultative, MI=Moderately Intolerant, I=Intolerant

Aquatic Life Use Discussion, Impairment Linkage, and Trends

Table 13 — Aquatic life use attainment status for stations sampled in the Raccoon Creek basin based on data collected June-October 2016. The Index of Biotic Integrity (IBI), Modified Index of well-being (MIwb), and Invertebrate Community Index (ICI) are scores based on the performance of the biotic community. The Qualitative Habitat Evaluation Index (QHEI) is a measure of the ability of the physical habitat to support a biotic community. The table is organized by stream.

Station	Location	Assessment Unit (05090101)	River Mile[a]	Drain. Area (mi^2)	IBI	MIwb[b]	ICI[c]	QHEI	Attain. Status	Causes	Sources
Raccoon Creek (09-500-000) LRW-AMD - Existing/ WWH – Recommended											
301747	Twomile Rd, upstream Twomile Run	02 04	111.38	43.6 [W]	41	7.9 [ns]	50	61.8	Full		
301746	Downstream Mitchell Hollow, at St Rt 328	02 04	104.63	56.4 [W]	40	7.3*	46	65.1	Partial	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
W03W32	Creek Road (TR18)	02 05	99.60	95.8 [B]	48	9.4	40	58.8	Full		
W03W44	Township Hwy F3, at ford	02 05	98.34	100.0 [W]	48	8.2 [ns]	42	68.5	Full		
Raccoon Creek (09-500-000) WWH - Existing											
W03W33	Downstream Sandy Run, Wheelabout Road (CR 3)	02 05	92.30	134.0	-	-	G	-	-		
302520	Hope-Moonville Road, upstream Hewett Fork	02 05	89.98	136.0 [W]	48	8.6	G	87.5	Full		
302519	Buck Lane (CR 18B), downstream Hewett Fork	03 04	89.36	176.0 [A]	46	9.8	MG [ns]	86.0	Full		
W03W34	St Rt 356, near Bunker Hill Rd	03 04	84.08	194.0 [B]	50	9.4	38	62.5	Full		
W03G50	St Rt 50, at Bolins Mills, USGS gage	03 04	80.62	200.0 [B]	51	8.8	40	61.8	Full		
W03P07	US 32 W	03 04	72.22	223.0 [B]	50	9.6	38	79.5	Full		
W03W35	US 32 W	05 03	63.80	296.0 [B]	50	9.5	40	80.3	Full		
W03P18	Clarion Road canoe access	05 03	55.48	318.0 [B]	49	8.6	40	70.4	Full		
W03S34	Covered Bridge Road (CR 4)	05 03	50.10	336.0	-	-	40	-	Full		
Raccoon Creek (09-500-000) WWH –Existing/EWH – Recommended											
W03P05	Vinton Park, downstream dam, St Rt 325	05 04	40.01	381.0 [B]	58	10.4	42 [ns]	81.8	Full		
W03S44	Glassburn Road, just off of Woodsmill Road	90 01	35.61	543.0 [B]	51	9.9	48	76.8	Full		
601400	Bob Evans Camp, OH 558	90 01	29.20	586.0 [B]	49	10.2	E	72.5	Full		
303503	MacIntyre Park, Dan Jones Rd	90 01	22.00	615.0 [B]	50	10.3	E	80.5	Full		

Station	Location	Assessment Unit (05090101)	River Mile[a]	Drain. Area (mi^2)	IBI	MIwb[b]	ICI[c]	QHEI	Attain. Status	Causes	Sources
W03S24	Ingalls Road	90 01	10.20	657.0 [B]	44 [ns]	9.9	52	78.3	Full		
West Branch Raccoon Creek (09-575-000) WWH –Existing											
W03W36	Ilesboro-Cedar Falls Road	02 02	5.68	3.8 [H]	20*	-	G	70.5	Non	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
W03W43	St Rt 328, near mouth	02 02	0.15	22.7 [H]	41 [ns]	7.1*	46	63.1	Partial	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
Honey Fork (09-576-000) WWH –Existing											
W03P35	Orlando Flat Road	02 02	0.01	10.5 [H]	28*	-	G	61.3	Partial	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
East Branch Raccoon Creek (09-574-000) LRW–Existing/WWH-Recommended											
W03W37	CR 26 (Laurel Run Rd)	02 01	6.64	3.2 [H]	22*	-	P*	75.5	Non	-Aluminum	-Legacy Surface Mining -Mine Drainage
W03K17	Adj. St Rt 56, Wayne National Forest land	02 01	2.10	15.3 [H]	28*	-	MG[ns]	71.8	Partial	-Aluminum	-Legacy Surface Mining -Mine Drainage
Tributary to Raccoon Creek (RM 98.96) (09-500-011) WWH–Existing											
203928	lane off Powder Plant Road	02 05	0.10	0.1 [H]	38*	-	P*	36.5	Non	- Natural (Low Flow)	- Natural Sources
Twomile Run (09-573-000) WWH–Existing											
W03W58	near mouth, Long Ridge Road	02 04	0.16	4.9 [H]	26*	-	VG	58.5	Non	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
Brushy Creek (09-571-000) WWH–Existing											
W03K40	At gravel lane, off St Rt 93	02 03	6.87	8.4 [H]	12*	-	G	54.0	Non	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
W03K39	OH 328, near mouth	02 03	0.36	33.4 [H]	38*	6.4*	38	55.0	Partial	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
Siverly Creek (09-571-002) WWH–Existing											
W03K42	adj. Siverly Creek Road	02 03	0.30	10.1 [H]	36*	-	G	67.8	Partial	- Sand Bedload	- Upstream Forestry

Station	Location	Assessment Unit (05090101)	River Mile[a]	Drain. Area (mi²)	IBI	MIwb[b]	ICI[c]	QHEI	Attain. Status	Causes	Sources
Sandy Run (09-568-000) WWH–Existing											
203966	King Hollow Road	02 05	2.70	5.0 [H]	28*	-	G	65.0	Partial	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
Little Sandy Run (09-569-000) WWH–Existing											
303689	St Rt 278	02 05	0.40	1.5 [H]	30*	-	P*	39.0	Non	- Natural (Low Flow and Wetland)	- Natural Sources
Hewett Fork (09-563-000) LRW-AMD –Existing /MWH – Mine Affected – Recommended											
W03K37	adj. Carbondale Road	03 01	13.10	8.3 [H]	30/ 34	-	MG [ns] /MG [ns]	60.0/ 61.25	Full		
303739	adj. Waterloo Wildlife Area dst bridge	03 01	8.40	16.4 [H]	26/ 34	-	- /MG[ns]	68.5/ 60.5	Full		
Hewett Fork (09-563-000) LRW-AMD –Existing /WWH – Recommended											
W03P08	ust Rockcamp Creek, Rockcamp Road (TR 20)	03 01	4.31	28.1 [H]	40/ 36*	7.0*/ 7.3*	44/E	68.1/ 70.0	Partial	- Sand Bedload - Riparian Removal	- Legacy Surface Disturbances (Mining/Forestry) - Channelization
W03P32	at mouth	03 01	0.01	40.5 [W]	52/48	9.0/8.5	G/G	74.5/ 75.5	Full		
Grass Run (09-567-000) WWH–Existing											
W03P41	St Rt 356	03 01	0.04	2.7 [H]	20*	-	F*	73.0	Non	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
Pine Run (09-566-000) WWH–Existing											
301579	at mouth, 750 ft W OH 356	03 01	0.10	2.0 [H]	32*	-	F*	39.5	Non	- Natural (Low Flow)	- Natural Sources
Coal Run (09-565-000) WWH–Existing											
W03W50	St Rt 681	03 01	0.05	0.8 [H]	28*	-	F*	41.5	Non	- Natural (Low Flow)	- Natural Sources
Rockcamp Creek (09-564-000) WWH–Existing											
W03P33	Rockcamp Road	03 01	1.53	7.7 [H]	28*	-	MG [ns]	53.3	Partial	- Riparian Removal - Sand Bedload	- Direct Habitat Alterations
Laurel Run (09-562-000) WWH–Existing											

Station	Location	Assessment Unit (05090101)	River Mile[a]	Drain. Area (mi^2)	IBI	MIwb[b]	ICI[c]	QHEI	Attain. Status	Causes	Sources
W03W59	near Knox, at TR 18 (Mulby Road)	03 04	0.16	2.6 H	36*	-	MG ns	64.0	Partial	- Natural (Low Flow)	- Natural Sources
Onion Creek (09-561-000) WWH–Existing											
W03W45	CR 4 (Worley West Road)	03 04	1.41	8.3 H	38*	-	G	58.0	Partial	- Riparian Removal - Sand Bedload	- Direct Habitat Alterations
Flat Run (09-557-000) WWH–Existing											
W03W51	Brooks Road, near US 50	03 04	1.60	4.8 H	40 ns	-	VG	60.8	Full		
Long Run (09-556-000) WWH–Existing											
203960	Adj Long Run Road (CR 11)	03 04	1.40	2.2 H	40 ns	-	G	65.0	Full		
Elk Fork (09-530-000) WWH–Existing											
W03W06	Morgan Road (CR 11), upstream Puncheon Fork	03 02	13.90	14.4 H	42 ns	-	VG	76.3	Full		
W03P30	St Rt 50, 1 Mi. E McArthur	03 02	13.26	24.5 H	50	9.2	G	86.3	Full		
W03W14	downstream Wolf Run, Adj Stone Quarry Road (CR 8)	03 03	8.55	44.4 W	43 ns/ 42 ns	7.7*/ 7.3*	42	66.5/ 74.5	Partial	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
W03P31	CR 43B, Northeast of Radcliff	03 03	0.01	60.0 W	46	7.9 ns	G	70.8	Full		
Tributary to Elk Fork (09-530-004) WWH–Existing											
W03W09	East of McArthur, at CR 7	03 02	0.43	2.4 H	28*	-	MG ns	45.0	Partial	- Sand Bedload - Total Dissolved Solids	- Legacy Surface Disturbances (Mining/Forestry)
Puncheon Fork (09-534-000) WWH–Existing											
W03K30	Bolar Road (TR 19)	03 02	2.82	4.7 H	28*	-	G	59.0	Partial	- Natural (Low Flow)	- Natural Sources
W03W30	C.R. 25	03 02	1.51	7.2 H	40 ns	-	-	71.0	(Full)		
W03W07	St Rt 50	03 02	0.28	9.5 H	38 *	-	<u>VP</u>*	72.8	Non	- Ammonia	- Municipal Point Source Discharges
Wolf Run (09-533-000) LRW-AMD–Existing /WWH – Recommended											
203947	Vinton Station Road (CR 24)	03 02	3.80	4.7 H	32*	-	F*	64.5	Non	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry) - Woodlot Site Clearance
Pierce Run (09-553-000) LRW–Existing											
W03L08	St Rt 160, near Hamden	05 01	5.47	3.4 H	26	-	P	67.5	Full		

Station	Location	Assessment Unit (05090101)	River Mile[a]	Drain. Area (mi^2)	IBI	MIwb[b]	ICI[c]	QHEI	Attain. Status	Causes	Sources
W03W47	Township Hwy 2A	05 01	1.68	9.5 [H]	34	-	F	53.0	Full		
Rockcamp Run (09-552-000) LRW–Existing											
W03W52	Hawk Station Road	05 03	0.11	2.8 [H]	12*	-	F	65.5	Non	- Sand Bedload - Total Dissolved Solids	- Legacy Surface Disturbances (Mining/Forestry)
Indiancamp Run (09-551-000) LRW-AMD –Existing /WWH - Recommended											
W03W56	Adj. Minerton Road (CR 26)	05 03	0.30	2.1 [H]	36*		MG [ns]	77.8	Partial	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
Flatlick Run (09-549-000) WWH–Existing											
W03S39	Newsome Road (CR 8)	05 03	0.60	7.2 [H]	34*	-	F*	63.8	Non	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
Strongs Run (09-546-000) WWH–Existing											
W03S36	Tower Road (TR 24)	05 02	5.90	5.6 [H]	36*	-	G	58.8	Partial	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
W03S47	Adney Road	05 02	0.58	16.4 [H]	36*	-	VG	59.8	Partial	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
Williams Run (09-547-000) EWH–Existing /WWH – Recommended											
203956	Williams Run Road	05 02	0.10	3.2 [H]	40 [ns]	-	MG [ns]	65.5	Full		
Robinson Run (09-544-000) WWH–Existing											
W03S40	St Rt 325	05 04	0.18	9.2 [H]	38*	-	G	69.0	Partial	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
Little Raccoon Creek (09-510-000) WWH–Existing											
W03S09	Wolf Hill Road (CR 25)	04 01	36.67	12.1	-	-	F	-	-		
W03S07	Mulga Road (CR 39), upstream Meadow Run	04 01	27.90	48 [B]	42	8.8	40	54.0	Full		
W03W25	St Rt 32, upstream Mulga Run	04 03	24.55	62.5 [B]	42	9.0	48	52.0	Full		
W03K10	Buckeye Furnace Rd, at State Memorial	04 03	18.45	87 [W]	48/ 18*	7.1*/ 5.5*	38	68.0	Non	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
W03S06	Keystone Rd, ust Dickason Run	04 03	12.71	99 [B]	46	9.1	42	57.3	Full		

Station	Location	Assessment Unit (05090101)	River Mile[a]	Drain. Area (mi^2)	IBI	MIwb[b]	ICI[c]	QHEI	Attain. Status	Causes	Sources
W03K09	Keystone Furnace Road, Downstream Dickason Run	04 04	11.00	129 [B]	34*	9.0	44	65.5	Partial	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
W03P04	St Rt 325, or Woods Mill Rd	04 04	1.17	154 [W]	52	9.1	52	66.8	Full		
McConnels Run (09-528-000)	EWH–Existing /WWH – Recommended										
303688	Lake Road (TR15)	04 01	1.98	0.9 [H]	50	-	G	36.0	Full		
Meadow Run (09-524-000)	WWH–Existing										
W03S10	Upstream General Mills, on property	04 01	3.10	5.1 [H]	28*	-	F*	61.5	Non	- Sand Bedload - Total Dissolved Solids	- Legacy Surface Disturbances (Mining/Forestry)
W03W27	St Rt 327 (Pennsylvania Road)	04 01	2.16	8.7 [H]	31*	-	F*	61.3	Non	- Ammonia	- Industrial Point Source Discharge
										- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
W03W18	Cheatwood Road	04 01	0.72	9.9 [H]	32*	-	LF*	50.3	Non	- Ammonia	- Industrial Point Source Discharge
										- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
Dickason Run (09-514-000)	WWH–Existing										
W03S48	Keystone Furnace Road, or Ridgeland Road	04 02	2.37	17.7 [H]	34*	-	MG [ns]	55.5	Partial	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry)
Dickason Run (09-514-000)	LRW-AMD–Existing /WWH – Recommended										
W03P43	Orpheus-Keystone Road	04 02	0.11	26.9 [H]	38*	6.6*	42	64.0	Partial	- Sand Bedload - Total Dissolved Solids	- Legacy Surface Disturbances (Mining/Forestry)

Station	Location	Assessment Unit (05090101)	River Mile[a]	Drain. Area (mi^2)	IBI	MIwb[b]	ICI[c]	QHEI	Attain. Status	Causes	Sources
Deer Creek (09-511-000) WWH–Existing											
W03P15	Adj., St Rt 325, near mouth	04 04	0.20	5.9 [H]	30*	-	VP*	51.5	Non	- Sand Bedload	- Livestock (Grazing or Feeding Operations) - Legacy Surface Disturbances (Forestry)
Barren Creek (09-542-000) WWH–Existing											
203953	OH 554, powerline easement, or upstream at bridge	06 02	0.30	9.1	-	-	G	-	-		
Indian Creek (09-539-000) WWH–Existing											
W03P36	upstream Rio Grande WWTP, St Rt 325	06 01	1.58	10.4 [H]	41 [ns]	-	G	68	Full		
W03W55	Downstream Rio Grande WWTP, St Rt 325, upstream Little Indian Run	06 01	1.45	10.4 [H]	45	-	G	74.9	Full		
Little Indian Creek (09-540-000) WWH–Existing											
W03P14	Buckeye Hills Road	06 01	0.17	10.2 [H]	44	-	G	68.3	Full		
Big Beaver Creek (09-500-012) WWH–Recommended											
303508	Guthrie Road, off Cora Mill Road	06 03	0.90	0.9 [H]	44	-	G	63.8	Full		
Claylick Run (09-507-000) WWH–Existing											
203929	Lincoln Pike	06 05	0.40	7.7	-	-	G	-	-		
Clear Fork (09-506-000) WWH–Existing											
W03K23	Ingalls Road	06 05	0.02	7.7 [H]	50	-	F*	71.0	Partial	- Sand Bedload	- Legacy Surface Disturbances (Mining/Forestry) - Channel Incision
Bullskin Creek (09-502-000) WWH–Existing											
W03K21	Williams Hollow Road	06 04	0.37	13.2 [H]	48	-	G	78.3	Full		
Little Bullskin Creek (09-503-000) WWH–Existing											
W03K22	Little Bullskin Road	06 04	0.01	4.9 [H]	40 [ns]	-	MG [ns]	70.0	Full		

a- River Mile (RM) represents the Point of Record (POR) for the station, and may not be the actual sampling RM.
b- MIwb is not applicable to headwater streams with drainage areas ≤ 20 mi^2.
c- A narrative evaluation of the qualitative sample based on attributes such as EPT taxa richness, number of sensitive taxa, and community composition was used when quantitative data was not available or considered unreliable. VP=Very Poor, P=Poor, LF=Low Fair, F=Fair, MG=Marginally Good, G=Good, VG=Very Good, E=Exceptional
ns- Nonsignificant departure from biocriteria (≤4 IBI or ICI units, or ≤0.5 MIwb units).
*- Indicates significant departure from applicable biocriteria (>4 IBI or ICI units, or >0.5 MIwb units). Underlined scores are in the Poor or Very Poor range.
H- Headwater site (draining ≤20 $miles^2$)
W- Wading site (non-boat site draining >20 $miles^2$)
B- Boat site (large or deep waters, necessitating the use of Boat sampling methods)
1- Biological criteria presented in OAC 3745-1-07, Table 7-1

Biocriteria for the Western Allegheny Plateau Ecoregion

	IBI			MIWb		ICI
ALU	Boat	Wading	Headwater	Boat	Wading	All sizes
EWH	48	50	50	9.6	9.4	46
WWH	40	44	44	8.6	8.4	36
MWH	24	24	24	5.8	6.2	22

Habitat and Sediment Impacts

Raccoon Creek

Habitat quality, and thus aquatic life, in the Raccoon Creek watershed is strongly influenced by historic land disturbances which affected sediment transport. Widespread deforestation from the mid-nineteenth century through the early twentieth century and extensive surface mining during the mid-twentieth century contributed to excessive sand sedimentation of streambeds. These activities radically altered the hydrology of the basin and initiated large-scale erosion of the formerly forested uplands, creating a disequilibrium between the process of erosion and sediment transport. Specifically, the rate and volume of sand delivered to the stream channel by erosion and bank wasting overwhelms the hydraulic process by which sediments are either transported by, or purged from, the stream channel. This disequilibrium still exists and is negatively impacting aquatic life potential in the Raccoon Creek watershed, where thirty sampling locations are impaired at least in part due to this issue.

Taxa richness, recruitment, and the performance of other important measures of ecological function, and organization of lotic fish and invertebrate communities are closely linked to the particle size of streambed sediments. The most immediate and consequential effect of excessive sedimentation upon riverine habitat is the smothering or embedding of coarser bed material by sands, clayey silts and related fines, resulting in loss or diminution of substrate interstices. It is through the associated loss or degradation of living space (critical feeding and breeding substrates) that aquatic communities are negatively affected by sediment (Fajen & Layzer, 1993) (Waters, 1995)). Excessive sedimentation also leads to the shallowing and homogenization of streams, and creates an unstable, constantly shifting streambed; a hostile environment for aquatic organisms (Figure 20).

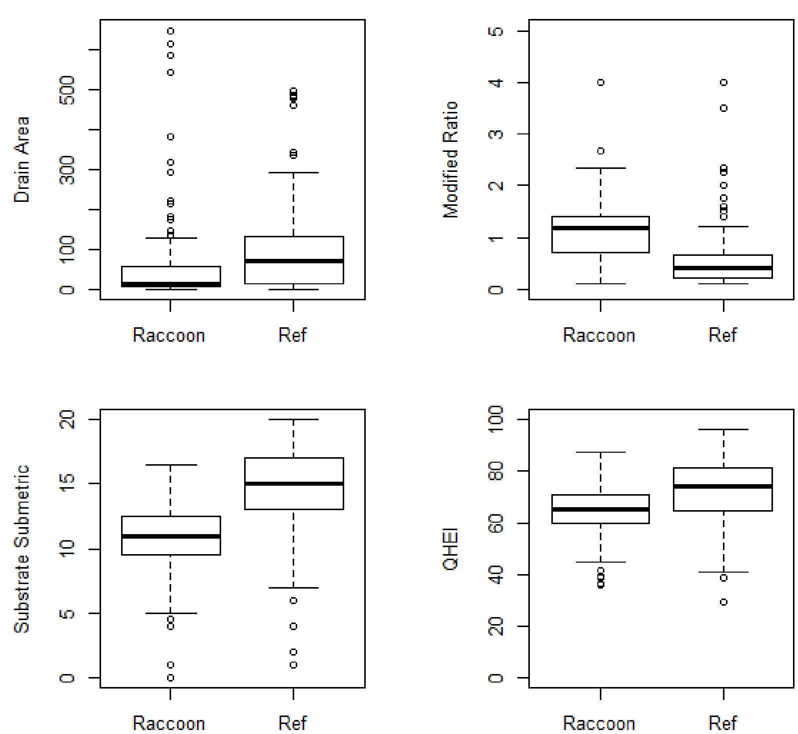


Figure 19 — Box and whisker plots showing distributions of drainage area (mi^2), the ratio of modified to warmwater habitat attributes, substrate submetric scores, and QHEI scores from Western Allegheny Plateau reference sites and the Raccoon Creek study area.

Figure 20 — Prime example of the deleterious effects of the disequilibrium between erosion and sediment transport. This stream, Laurel Run, lacks depth and substrate heterogeneity, creating a hostile environment for aquatic life. The sand dunes seen instream are indicative of a constantly shifting sand bedload.

The net effect of the excessive sand bedload on physical habitat quality is most evident in the frequency with which modified attributes are noted on the QHEI, especially channel embeddedness, lack of fast current, and low channel development. Relative to regional reference sites, the ratio of modified attributes to warmwater attributes is higher in the Raccoon Creek watershed, and QHEI scores average lower[1] (Figure 19). The median ratio of modified attributes to warmwater attributes for sites in the Raccoon system is 1.17, as opposed to 0.38 for reference sites. The mean QHEI score for Raccoon Creek sites is 65.0. This suggests that despite the pervasive effect of sediment bedload, streams in the system generally possess the physical habitat capable of supporting fish assemblages typical of the ecoregion. Because the effect of sand sedimentation is pervasive, the biological expectation (e.g., in terms of the IBI) for a given level of habitat quality would be uniformly lower in the Raccoon Creek system relative to regional reference expectations.

Although the current sediment load appeared to exert a negative influence on macrohabitat quality, observed biological performance and potential, it did not appear sufficient to exclude WWH communities systemwide. Instead effects, as measured by community measures and indices, appeared limited to upper

1 adjusting for differences in drainage area, ANCOVA, $p < 0.001$

headwater streams of Raccoon Creek; the larger streams in the system (Raccoon Creek and Little Raccoon Creek) were largely able to support WWH aquatic communities.

The habitat quality of mainstem Raccoon Creek is generally good to excellent. The habitat downstream RM 72.22, in the absence of other stressors, should be able to sustain an exceptional aquatic community ($\bar{X}$ = 77.5). This is true for fish, but macroinvertebrate performance was more variable. A dam at RM 40.30 in the town of Vinton is a barrier to fish passage, 18 fish species that were observed downstream were not collected upstream of the dam. Raccoon Creek is large enough, and the habitat is available to reasonably expect most of these fish to exist upstream if the dam were removed and fish passage restored. The restoration of flow may also improve the ability of Raccoon Creek to assimilate upstream sediment loads. Altogether, the removal of the dam at RM 40.30 would have a positive effect on water quality in Raccoon Creek, and possibly allow for the extension of the EWH designation upstream an additional 30 river miles.

The habitat upstream of RM 72.22 is notably different, yet still generally able to support a WWH aquatic community ($\bar{X}$ = 69.0). A comparison of the ratio between MWH – Moderate Influence (MWH-MI) and WWH habitat attributes revealed a slightly higher ratio of MWH-MI attributes upstream of RM 72.22. This upstream section of Raccoon Creek was generally sandier, more sluggish, and the channels were less developed than sites downstream. A possible explanation of these differences is that the stream is not as able to assimilate the excessive sand bedload. Factors that could be influencing this is the large contribution of sediment relative to size, and the proximity to areas most affected by historic surface disturbances.

Tributaries

Onion Creek RM 1.41 (W03W45), Hewett Fork RM 4.31 (W03P08) at Rockcamp Rd, Rockcamp Creek RM 1.53 (W03P33), and Siverly Creek RM 0.30 (W03K42) were all affected by riparian removal, and in the instance of Hewett Fork at Rockcamp Road, also previous channelization. The loss of wooded riparian zones negatively impacts a stream by allowing more solar energy to reach a stream, and by inducing excessive bank erosion. Keeping a wide wooded buffer along the streams will have a positive water quality impact in these streams.

Community Stressor Analysis

Methods outlined in Appendix M to describe how biological assemblages relate to environmental and stressor gradients placed Raccoon Creek fish and macroinvertebrate assemblages into groups meaningful to make causal associations.

The ordinations shown in Figure 21 and Figure 22 are from non-metric multidimensional scaling (NMDS)[2] of a distance matrix of assemblage data formed from Bray-Curtis distances. Plot symbols and ellipses were color-coded based on groups suggested by hierarchical cluster analysis[3] of the distance matrix. All analyses were completed using R (R Core Team, 2018). The groups are well clustered in ordination space, indicating that the results from the two methods are in agreement.

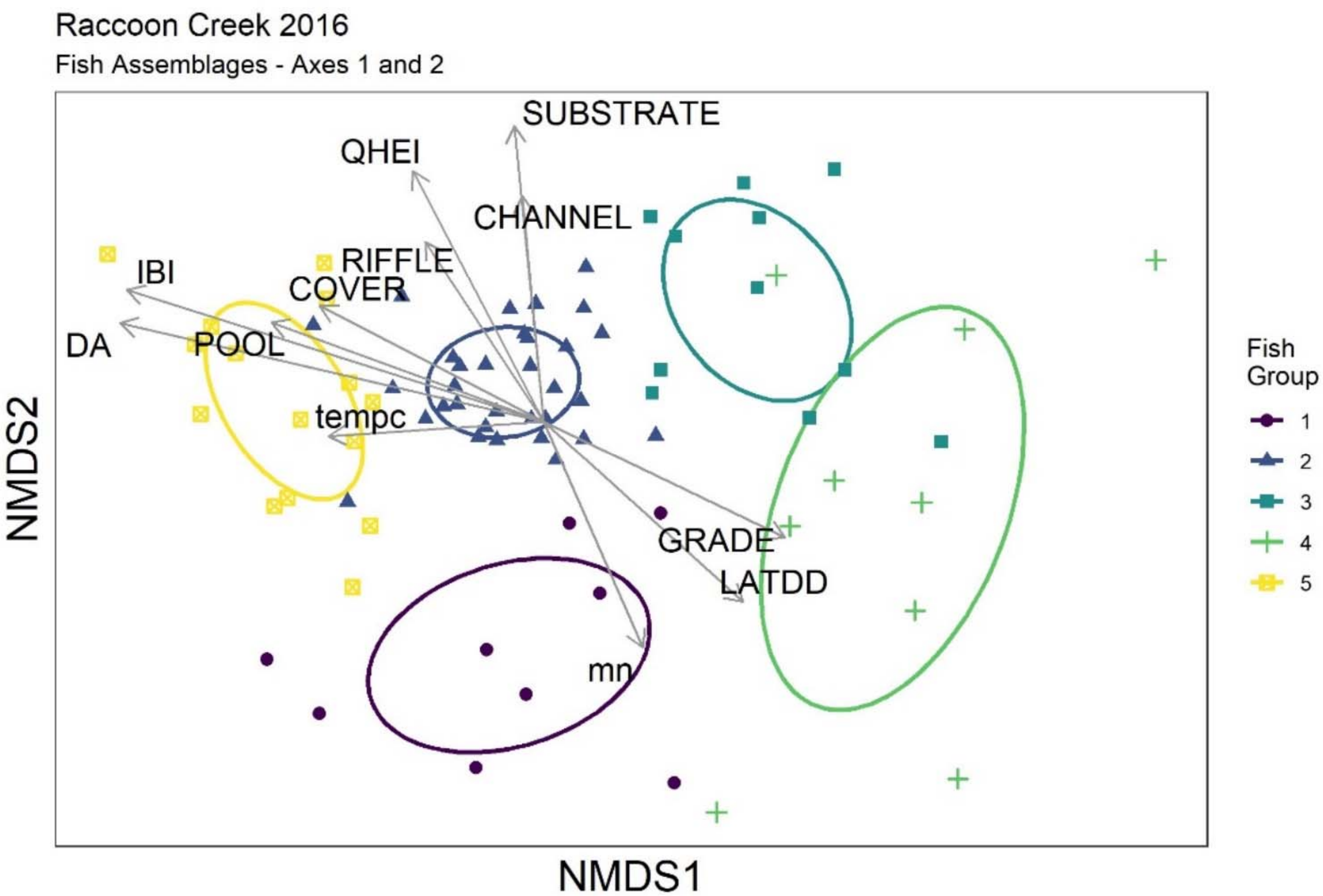


Figure 21 — Fish assemblage groupings are well separated in two-dimensional ordination space. Significant parameter associations (p < 0.005) are indicated by the grey vectors.

2 R development core team, vegan package 2.4-2 (Oksanen, et al., 2017)
3 hclust function in the R base package {stats}; linkage method = ward.D2

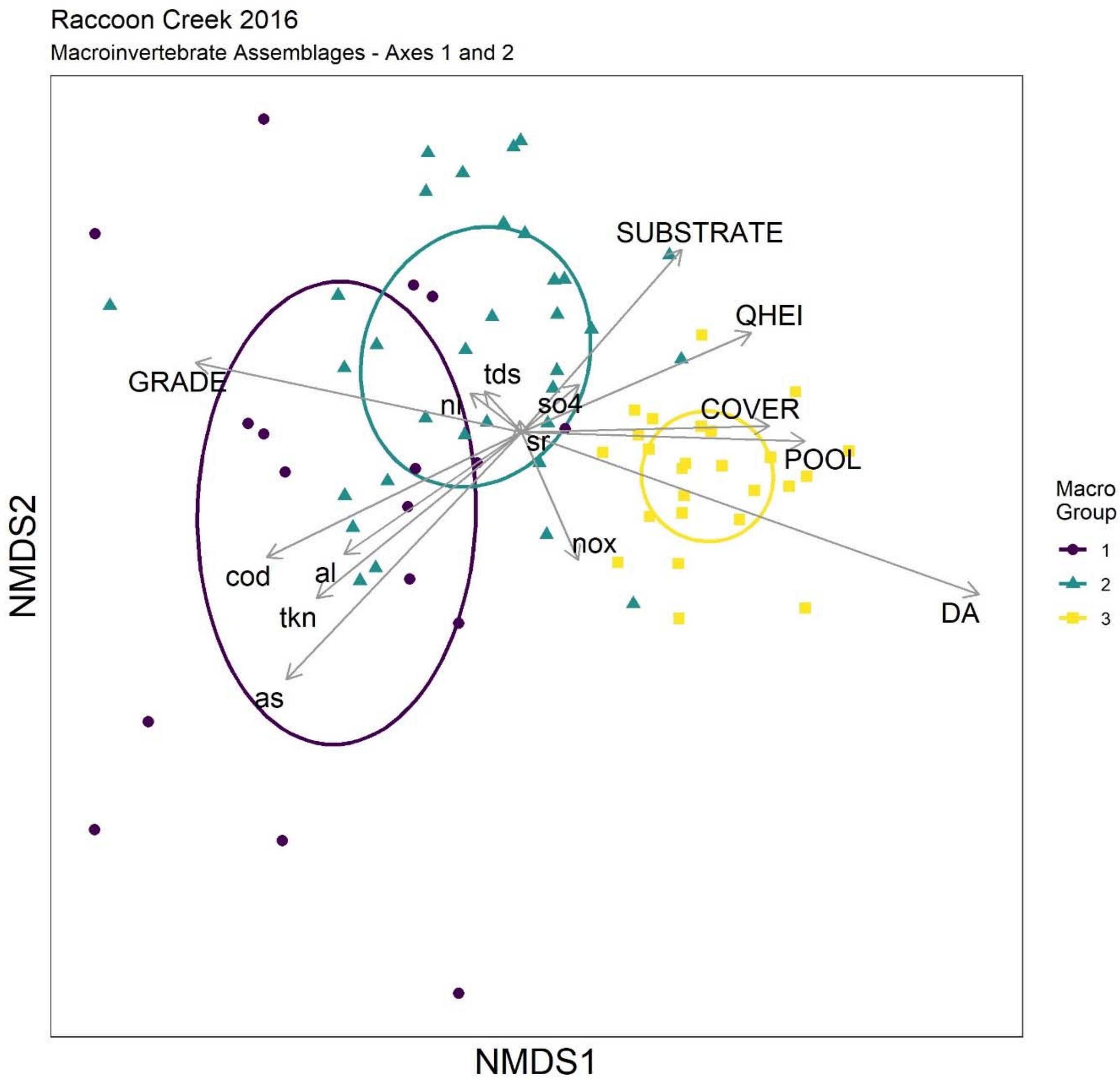


Figure 22 — Aquatic macroinvertebrate assemblage groupings are well separated in three-dimensional ordination space. Significant parameter associations (p <= 0.003) are indicated by the grey vectors. The best-fit ordination was three-dimensional, this figure is only displaying axes 1 and 2.

The macroinvertebrate groups are broadly explained by the drainage area-stream slope gradient, and a range of mine drainage parameters (Table 16). Group three sites are largely Raccoon Creek and Little Raccoon Creek and are the largest sites of the survey and correspond to fish assemblage groups two and five. Sites in macroinvertebrate group one are headwater sites characterized by mine drainage signatures, with higher TDS, sulfate, and nickel, while group two are the more typical headwater sites.

Due to the nature of impairment in the Raccoon Creek survey – largely fish-driven – the fish community stressor analysis provided more resolution to the determination of causes of impairment. The rest of the discussion will be framed by the fish community groups, with discussions of the macroinvertebrate assemblages as appropriate.

Two dominant gradients were observed to explain fish assemblage groupings in Raccoon Creek. The first, and the one with the most apparent influence, is the drainage area-stream slope gradient. This would generally be expected when sampling such a broad range of stream sizes (1–657 mi^2). The second gradient is defined by the QHEI substrate submetric score (Table 15). Stream substrates that are dominated by fines will score lower than coarser material. In the Raccoon Creek basin, these fines were generally sand, and in wetland streams, silt and muck.

Five fish assemblage groups were identified in the watershed and will be discussed more specifically below. Indicator species analysis[4] largely corroborate that five groups are appropriate (Table 14). More on indicator species analysis can be found in appendix M. In short, the analysis identifies species which are predictors of a group (A-value) and species that are highly probable to be found at a site in a group (B-value). A-value is also called the positive predictive value, or specificity, of a species to a group, and B-value is also called the fidelity, or sensitivity, of a species as an indicator of a group.

Group one consisted of wetland headwater streams, group two were upper Raccoon Creek sites and larger tributaries, group three were typical small headwaters, group four were very small headwaters with mine drainage impacts, and group five were largely Raccoon Creek mainstem sites (Figure 23, Figure 24, Table 17).

Table 14 — Species associations based on indicator species analysis for the five fish community groups in the Raccoon Creek watershed. No species were identified as indicators for group 4.

Species	Group	A – Value[a]	B - Value[b]	Indicator Value	*P*
Warmouth Sunfish	1	0.593	0.800	0.689	0.001
Grass Pickerel	1	0.438	1.000	0.662	0.001
Yellow Bullhead	1	0.460	0.900	0.643	0.001
Least Brook Lamprey	2	0.562	0.857	0.694	0.001
Bluntnose Minnow	2	0.434	1.000	0.659	0.001
Blackside Darter	2	0.484	0.857	0.644	0.001
Johnny Darter	2	0.438	0.914	0.633	0.001
Redfin Shiner	2	0.396	1.000	0.630	0.001
Northern Hogsucker	2	0.430	0.914	0.629	0.001
Creek Chub	3	0.344	1.000	0.586	0.001
Southern Redbelly Dace	3	0.695	0.455	0.562	0.003
-	4	-	-	-	-
Silver Redhorse	5	0.950	0.813	0.879	0.001
Smallmouth Redhorse	5	0.967	0.750	0.852	0.001
Channel Catfish	5	0.794	0.750	0.772	0.001
Logperch	5	0.601	0.875	0.725	0.001
Golden Redhorse	5	0.590	0.875	0.719	0.001
Smallmouth Buffalo	5	1.000	0.500	0.707	0.001

a P(Site Group|Species) The probability that the sampled site belongs to the site group given that the species has been found. The specificity, or positive predictive value, of the species as an indicator of the site group.

b P(Species|Site Group) The probability of finding the species in the sites belonging to the group. The fidelity, or sensitivity, of the species as an indicator of the site group.

4 multipatt function from indicspecies R package (De Caceres & Legendre, 2009)

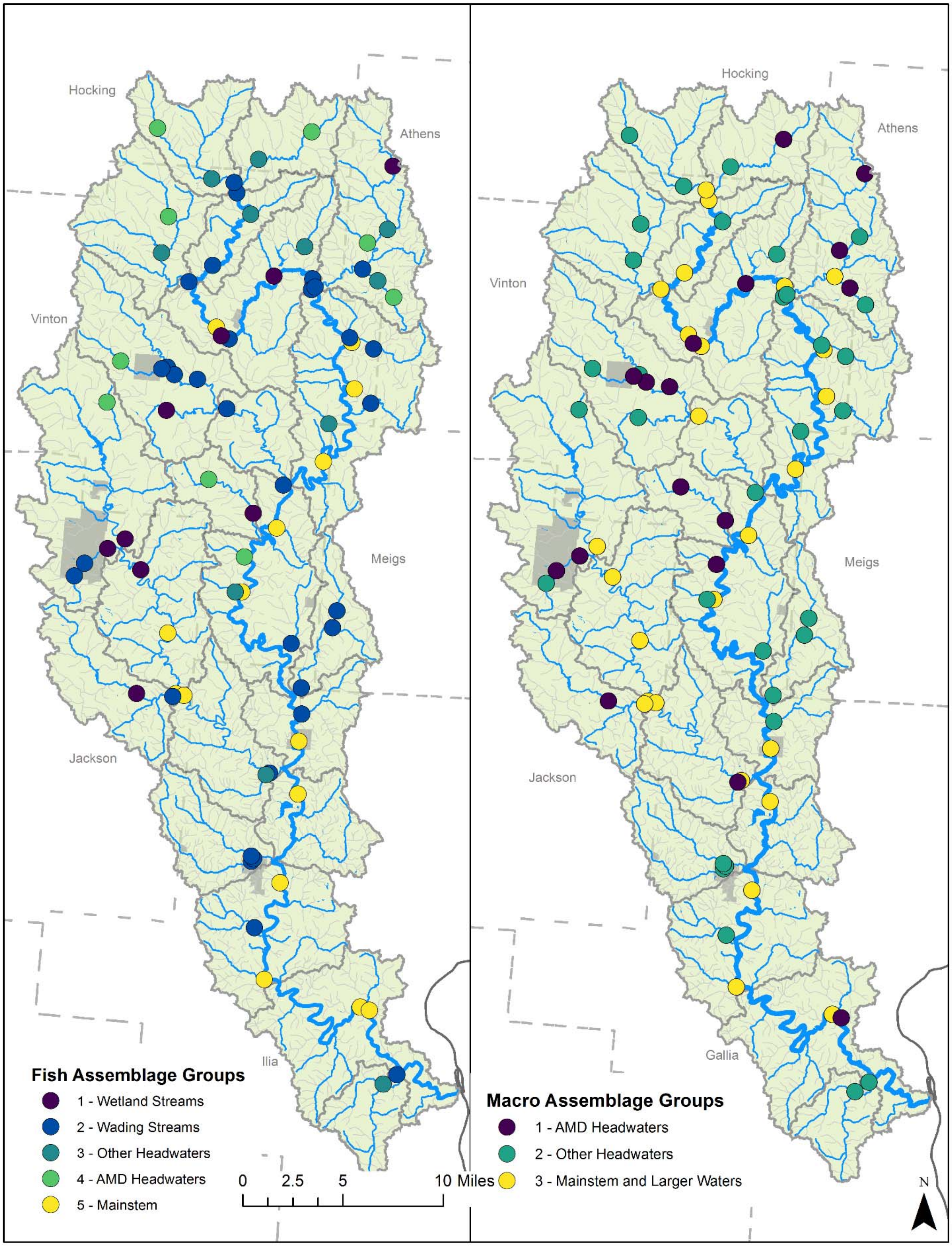


Figure 23 — Fish and macroinvertebrate assemblage groups in the 2016 Raccoon Creek survey identified through clustering analysis (Figure 21 and Figure 22).

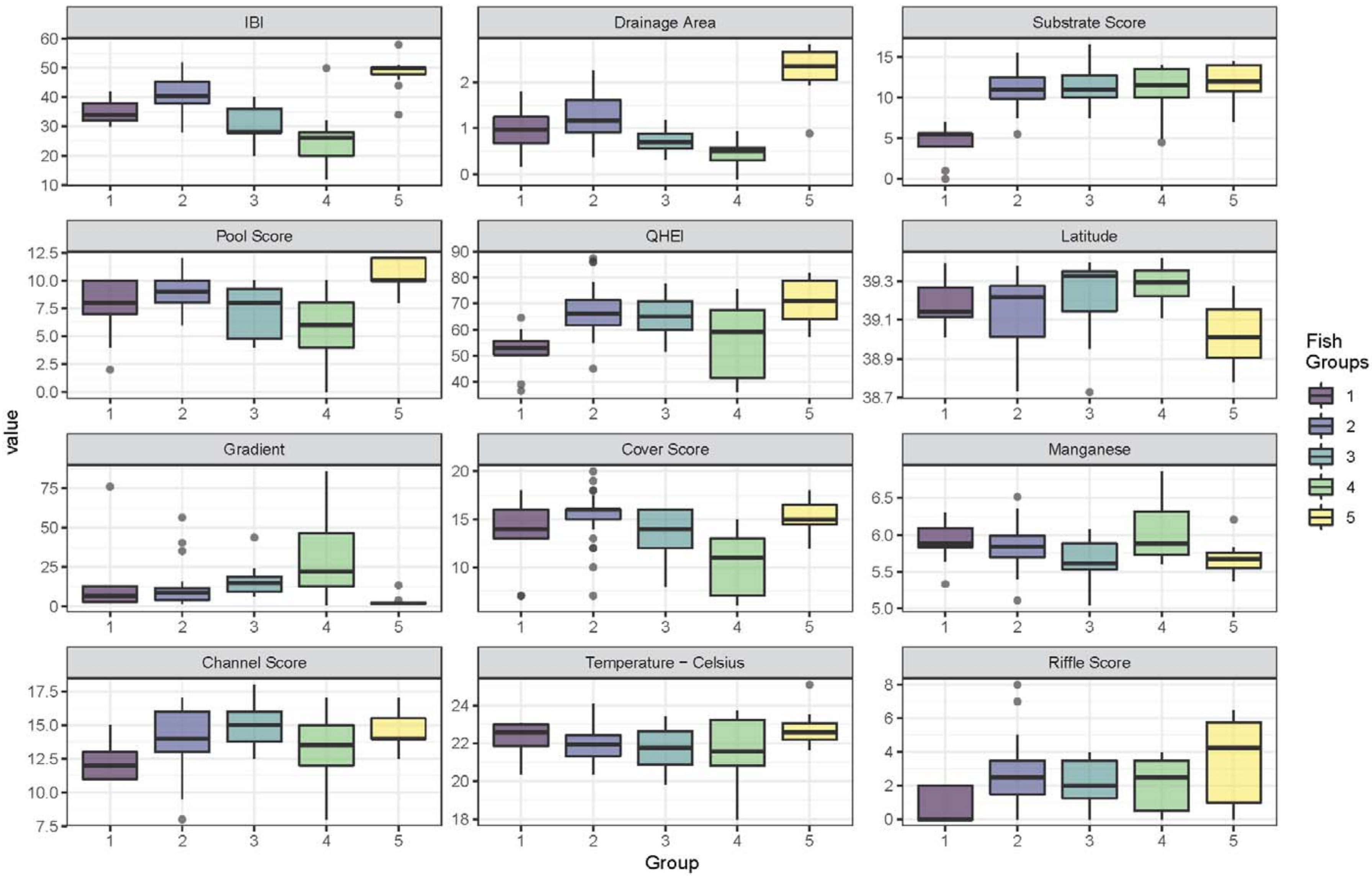


Figure 24 — Selected, significant parameters that were fitted to the fish community ordination. Drainage area values are log10 transformed.

Table 15 — Results from the environmental fitting function to the fish assemblage ordination.

Parameter	NMDS1	NMDS2	R^2	p-value	Parameter	NMDS1	NMDS2	R^2	p-value
IBI	-0.954	0.301	0.696	0.001	**LONGDD**	-0.079	0.997	0.061	0.104
DA	-0.974	0.226	0.688	0.001	**as**	0.110	-0.994	0.058	0.114
SUBSTRATE	-0.099	0.995	0.321	0.001	**mg**	-0.107	-0.994	0.056	0.127
POOL	-0.940	0.342	0.306	0.001	**so4**	-0.403	-0.915	0.049	0.173
QHEI	-0.463	0.886	0.290	0.001	**k**	-0.615	-0.789	0.048	0.157
LATDD	0.741	-0.672	0.264	0.001	**bromide**	-0.900	-0.436	0.042	0.233
GRADE	0.900	-0.435	0.261	0.001	**tds**	-0.045	-0.999	0.038	0.241
COVER	-0.889	0.459	0.231	0.001	**sr**	-0.399	-0.917	0.031	0.331
mn	0.401	-0.916	0.222	0.001	**do2**	0.230	0.973	0.028	0.371
CHANNEL	-0.095	0.996	0.187	0.001	**hard**	-0.118	-0.993	0.027	0.367
tempc	-0.998	-0.069	0.169	0.002	**tss**	-0.513	-0.859	0.023	0.424
RIFFLE	-0.550	0.835	0.168	0.002	**BANK**	-0.765	-0.644	0.023	0.433
ba	-0.400	0.917	0.124	0.018	**dosat**	-0.013	1.000	0.023	0.449
ni	0.056	-0.998	0.115	0.008	**cu**	0.550	-0.835	0.023	0.414
cod	0.433	-0.901	0.110	0.015	**al**	0.198	-0.980	0.021	0.472
spcond	0.365	-0.931	0.105	0.022	**nh3**	0.374	-0.927	0.019	0.494
zn	0.584	-0.812	0.096	0.042	**alk**	-0.758	0.652	0.015	0.596
ph	-0.790	-0.613	0.095	0.021	**ca**	-0.139	-0.990	0.014	0.595
nox	-1.000	0.019	0.072	0.065	**sodium**	-0.475	-0.880	0.011	0.657
TKN	0.062	-0.998	0.068	0.08	**tp**	-0.591	-0.806	0.001	0.969
cl	-0.513	0.858	0.066	0.076	**no2**	-0.860	0.510	0.001	0.978
fe	-0.069	-0.998	0.064	0.087					

Table 16 — Results from the environmental fitting function to the macroinvertebrate assemblage ordination.

Parameter	NMDS1	NMDS2	NMDS3	R^2	p-value	Parameter	NMDS1	NMDS2	NMDS3	R^2	p-value
DA	0.904	-0.320	-0.283	0.751	0.001	**SUBSTRATE**	0.657	0.748	0.095	0.174	0.003
POOL	0.806	-0.026	-0.591	0.363	0.001	**nox**	0.234	-0.527	-0.817	0.172	0.003
as	-0.684	-0.719	-0.126	0.346	0.001	**k**	-0.097	-0.314	-0.944	0.168	0.005
GRADE	-0.958	0.204	0.200	0.339	0.001	**RIFFLE**	0.726	0.374	-0.577	0.166	0.008
TKN	-0.705	-0.570	-0.421	0.247	0.001	**bromide**	0.232	-0.244	-0.941	0.166	0.007
spcond	-0.398	0.169	-0.902	0.241	0.005	**ph**	0.242	-0.885	0.398	0.139	0.012
al	-0.620	-0.427	-0.658	0.240	0.001	**tp**	-0.575	-0.748	-0.330	0.138	0.011
cod	-0.897	-0.441	-0.031	0.236	0.001	**mn**	-0.958	0.183	-0.220	0.134	0.014
COVER	0.881	0.022	-0.472	0.231	0.001	**no2**	-0.319	-0.454	-0.832	0.128	0.033
zn	-0.761	0.268	-0.590	0.229	0.005	**fe**	-0.507	-0.813	-0.286	0.125	0.023
ni	-0.185	0.141	-0.973	0.226	0.003	**nh3**	-0.611	-0.283	-0.740	0.121	0.036
QHEI	0.832	0.360	-0.423	0.224	0.001	**do2**	0.338	0.935	-0.105	0.113	0.046
tds	-0.133	0.148	-0.980	0.224	0.002	**dosat**	0.419	0.869	-0.263	0.108	0.055
sr	-0.006	0.042	-0.999	0.222	0.002	**LATDD**	-0.643	0.685	0.343	0.108	0.038
so4	0.222	0.183	-0.958	0.198	0.003	**ba**	0.262	-0.567	0.781	0.079	0.113
tempc	0.443	-0.420	-0.792	0.191	0.004	**cl**	0.351	-0.308	-0.884	0.063	0.21
mg	-0.022	0.205	-0.978	0.188	0.005	**CHANNEL**	0.640	0.684	0.350	0.061	0.198
hard	-0.105	0.232	-0.967	0.188	0.004	**cu**	-0.708	-0.375	-0.599	0.047	0.301
sodium	-0.070	-0.215	-0.974	0.187	0.006	**alk**	-0.145	-0.988	0.053	0.046	0.339
tss	-0.373	-0.826	-0.423	0.182	0.004	**BANK**	0.655	-0.647	-0.391	0.040	0.413
ca	-0.155	0.248	-0.956	0.182	0.005	**LONGDD**	-0.011	0.358	0.934	0.024	0.624

Table 17 — Site key to the fish and macroinvertebrate assemblage groupings in the Raccoon Creek basin survey, 2016.

STORET	Name	RM	Drainage Area (mi^2)	Fish Groups	Bug Groups
203928	Trib to Raccoon Creek (98.96)	0.10	1.9	1 - Wetland Streams	1 - AMD - Headwaters
203947	Wolf Run	3.80	4.7	1 - Wetland Streams	2 - Other Headwaters
303689	Little Sandy Run	0.40	1.5	1 - Wetland Streams	1 - AMD - Headwaters
W03K37	Hewett Fork	13.10	8.3	1 - Wetland Streams	1 - AMD - Headwaters
W03W25	Little Raccoon Creek	24.55	62.5	1 - Wetland Streams	3 - Mainstem and Larger Waters
W03S07	Little Raccoon Creek	27.90	48	1 - Wetland Streams	3 - Mainstem and Larger Waters
W03S48	Dickason Run	2.37	17.7	1 - Wetland Streams	1 - AMD - Headwaters
W03W18	Meadow Run	0.72	9.9	1 - Wetland Streams	1 - AMD - Headwaters
W03W47	Pierce Run	1.68	9.5	1 - Wetland Streams	1 - AMD - Headwaters
W03W43	West Branch Raccoon Creek	0.15	22.7	2 - Wading Streams	3 - Mainstem and Larger Waters
W03K39	Brushy Creek	0.36	33.4	2 - Wading Streams	3 - Mainstem and Larger Waters
W03P08	Hewett Fork	4.31	28.1	2 - Wading Streams	3 - Mainstem and Larger Waters
W03P32	Hewett Fork	0.01	40.5	2 - Wading Streams	2 - Other Headwaters
W03W59	Laurel Run	0.16	2.6	2 - Wading Streams	2 - Other Headwaters
W03W45	Onion Creek	1.41	8.3	2 - Wading Streams	2 - Other Headwaters
W03W51	Flat Run	1.60	4.8	2 - Wading Streams	2 - Other Headwaters
W03S39	Flatlick Run	0.60	7.2	2 - Wading Streams	2 - Other Headwaters
203956	Williams Run	0.10	3.8	2 - Wading Streams	2 - Other Headwaters
W03S36	Strongs Run	5.90	5.9	2 - Wading Streams	2 - Other Headwaters
W03S47	Strongs Run	0.58	16.4	2 - Wading Streams	2 - Other Headwaters
W03S40	Robinson Run	0.18	9.7	2 - Wading Streams	2 - Other Headwaters
W03P14	Little Indian Creek	0.17	10.2	2 - Wading Streams	2 - Other Headwaters
W03P36	Indian Creek	1.58	10.4	2 - Wading Streams	2 - Other Headwaters
W03W55	Indian Creek	1.45	10.4	2 - Wading Streams	2 - Other Headwaters
W03W07	Puncheon Fork	0.28	9.8	2 - Wading Streams	1 - AMD - Headwaters
W03W09	Trib to Elk Fork	0.43	2.4	2 - Wading Streams	1 - AMD - Headwaters
W03W06	Elk Fork	13.90	14.4	2 - Wading Streams	2 - Other Headwaters
W03P30	Elk Fork	13.26	24.5	2 - Wading Streams	1 - AMD - Headwaters
W03W14	Elk Fork	8.55	44.4	2 - Wading Streams	3 - Mainstem and Larger Waters
W03P31	Elk Fork	0.01	59.8	2 - Wading Streams	2 - Other Headwaters
W03S10	Meadow Run	3.10	5.1	2 - Wading Streams	2 - Other Headwaters
W03W27	Meadow Run	2.16	8.7	2 - Wading Streams	1 - AMD - Headwaters
W03P43	Dickason Run	0.11	26.9	2 - Wading Streams	3 - Mainstem and Larger Waters
W03P04	Little Raccoon Creek	1.17	154	2 - Wading Streams	3 - Mainstem and Larger Waters
W03K21	Bullskin Creek	0.37	14.4	2 - Wading Streams	2 - Other Headwaters
303508	Big Beaver Creek	0.90	7.3	2 - Wading Streams	2 - Other Headwaters
301747	Raccoon Creek	111.38	42.8	2 - Wading Streams	3 - Mainstem and Larger Waters
301746	Raccoon Creek	104.63	56.4	2 - Wading Streams	3 - Mainstem and Larger Waters
W03W44	Raccoon Creek	98.34	100.0	2 - Wading Streams	3 - Mainstem and Larger Waters
302520	Raccoon Creek	89.98	136.0	2 - Wading Streams	3 - Mainstem and Larger Waters
302519	Raccoon Creek	89.36	176.0	2 - Wading Streams	2 - Other Headwaters
W03P35	Honey Fork	0.01	10.5	3 - Other Headwaters	2 - Other Headwaters
W03K17	E. Br. Raccoon Creek	2.10	15.3	3 - Other Headwaters	2 - Other Headwaters
W03W58	Twomile Run	0.16	4.9	3 - Other Headwaters	2 - Other Headwaters
W03K42	Siverly Creek	0.30	10.1	3 - Other Headwaters	2 - Other Headwaters
203966	Sandy Run	2.7	5.0	3 - Other Headwaters	2 - Other Headwaters

STORET	Name	RM	Drainage Area (mi^2)	Fish Groups	Bug Groups
W03P41	Grass Run	0.04	2.7	3 - Other Headwaters	2 - Other Headwaters
W03P33	Rockcamp Creek	1.53	5.8	3 - Other Headwaters	1 - AMD - Headwaters
203960	Long Run	1.4	2.2	3 - Other Headwaters	2 - Other Headwaters
W03W56	Indiancamp Run	0.30	2.1	3 - Other Headwaters	2 - Other Headwaters
W03P15	Deer Creek	0.20	5.9	3 - Other Headwaters	1 - AMD - Headwaters
W03K22	Little Bullskin Creek	0.01	4.9	3 - Other Headwaters	2 - Other Headwaters
301579	Pine Run	0.10	2.0	4 - AMD Headwaters	1 - AMD - Headwaters
303688	McConnel Run	1.98	0.9	4 - AMD Headwaters	2 - Other Headwaters
W03K30	Puncheon Fork	2.82	4.7	4 - AMD Headwaters	2 - Other Headwaters
W03K40	Brushy Creek	6.87	8.4	4 - AMD Headwaters	2 - Other Headwaters
W03L08	Pierce Run	5.47	3.4	4 - AMD Headwaters	1 - AMD - Headwaters
W03W36	West Branch Raccoon Creek	5.68	3.8	4 - AMD Headwaters	2 - Other Headwaters
W03W37	E. Br. Raccoon Creek	6.64	3.2	4 - AMD Headwaters	1 - AMD - Headwaters
W03W50	Coal Run	0.05	0.8	4 - AMD Headwaters	2 - Other Headwaters
W03W52	Rockcamp Run	0.11	2.8	4 - AMD Headwaters	1 - AMD - Headwaters
W03S24	Raccoon Creek	10.20	648.0	5 - Mainstem	3 - Mainstem and Larger Waters
303503	Raccoon Creek	22.00	615.0	5 - Mainstem	3 - Mainstem and Larger Waters
601400	Raccoon Creek	29.20	586.0	5 - Mainstem	3 - Mainstem and Larger Waters
W03S44	Raccoon Creek	35.61	542.0	5 - Mainstem	3 - Mainstem and Larger Waters
W03P05	Raccoon Creek	40.01	381.0	5 - Mainstem	3 - Mainstem and Larger Waters
W03P18	Raccoon Creek	55.48	322.0	5 - Mainstem	3 - Mainstem and Larger Waters
W03W35	Raccoon Creek	63.80	296.0	5 - Mainstem	3 - Mainstem and Larger Waters
W03P07	Raccoon Creek	72.22	223.0	5 - Mainstem	3 - Mainstem and Larger Waters
W03G50	Raccoon Creek	80.62	200.0	5 - Mainstem	3 - Mainstem and Larger Waters
W03W34	Raccoon Creek	84.08	183.0	5 - Mainstem	3 - Mainstem and Larger Waters
W03K09	Little Raccoon Creek	11.00	129.0	5 - Mainstem	3 - Mainstem and Larger Waters
W03S06	Little Raccoon Creek	12.71	99.0	5 - Mainstem	3 - Mainstem and Larger Waters
W03W32	Raccoon Creek	99.60	98.0	5 - Mainstem	3 - Mainstem and Larger Waters
W03K10	Little Raccoon Creek	18.45	87.0	5 - Mainstem	3 - Mainstem and Larger Waters
W03K23	Clear Fork	0.02	7.7	5 - Mainstem	1 - AMD - Headwaters

Fish Group 1 - Wetland Headwater Streams

Group one sites were headwater sites with the lowest substrate metric scores in the survey. Biological communities at these sites reflected the lower gradient, wetland like habitats from which they were collected (Table 14). Warmouth sunfish, grass pickerel, and yellow bullheads were indicators of sites belonging to this group, especially when considered in combination. Together, these three species were highly specific to this group and had high fidelity to the group (A-value: 0.72; B-value: 0.8; indicator value: 0.758). All three species are typically found in slow-moving, clear waters with beds of aquatic vegetation (Rice & Zimmerman, 2019).

The unnamed tributary to Raccoon Creek (RM 98.96) RM 0.10 (203928) and Little Sandy Run RM0.40 (303689) did not meet their respective designated ALUs due to natural conditions related to their wetland character, but the aquatic life surveyed at these sites were not outside the expected.

Other sources of excessive sand and habitat alterations were contributing to aquatic life impairment at several streams in the watershed. Deer Creek RM 0.20 (W03P15) and upper Dickason Run RM 2.37 (W03S48) were flowing through open pasture where livestock had unrestricted access to the stream.

Erosion from livestock stream bank trampling resulted in excessive sand and fines which smothered adjacent and downstream substrates. Limiting livestock access to the stream will have an immediate positive water quality benefit.

Wolf Run (203947) is a wetland stream with good quality habitat expected to support a WWH aquatic community (QHEI = 64.5). It is one of several streams in the watershed where Minford silts are present. Minford silts are lacustrine deposits from the former Lake Tight, a large pre-Illinoian glacial lake. It is believed that Lake Tight formed when the ancestral Teays River system was dammed by receding glaciers between 0.79 and 0.88 million years ago (Bonnett, Noltimier, & Sanderson, 1991). These deposits, where silts are dominant, may naturally limit aquatic life potential, at least when compared to other streams in the ecoregion where coarser colluvial deposits are more common. Exacerbating these natural limitations was the recent clearing of the land draining to Wolf Run (Figure 25 and Figure 26). QHEI sampling conducted in 2008 indicated a well-developed gravel-sand stream flowing through forest. Post-clearing habitat data showed a stream affected by an influx of upland sediment. Silt and muck collected in the pools and margins, and sand was dominant in the runs and riffles, negatively impacting water quality.

Figure 25 — Wolf Run at RM 3.80 where recent clear cutting negatively impacted water quality.

Figure 26 — Satellite imagery showing clear-cut activities in the Wolf Run watershed (clockwise from top left): pre-cut 11/2/2011, recently cut 6/13/2012, and imagery from summer of sampling period 7/23/2015[5].

5 Image credits: 2011 and 2012: Google Earth and USDA Farm Service Agency, 2015: Google Earth and Landsat/ Copernicus

Fish Group 2 – Wading Streams (including Upper Raccoon Creek)

Group two sites were generally meeting WWH expectations with a median IBI of 40 and QHEI of 66. Streams in this group are the upper Raccoon Creek mainstem sites, Hewett Fork, Elk Fork, and the larger headwater streams (Table 17). As a whole, there was nothing remarkable about these sites and no parameters were identified as a causal indicator. Like the other groups, the most prevalent cause and sources of impairment from this group come the from sand bedload issues described in the Habitat and Sediment Impacts section. One site was not attaining due to natural conditions; Laurel Run RM 0.16 (W03W59) was a very small stream flowing through hardpan.

Puncheon Fork

The mouth of Puncheon Fork RM 0.28 (W03W07) was in non-attainment of WWH due to impacts from the McArthur WWTP, which discharges at RM 0.85. Toxicity from high ammonia concentrations was noted at this site. See Appendix B for a detailed description of the ammonia loadings to Puncheon Fork from the McArthur WWTP. During the summer of 2016, a sanitary sewer line broke and spilled raw sewage to Puncheon Fork, this has since been corrected. For the period between 2012 and 2016, the WWTP discharge of ammonia to Puncheon Fork averaged concentrations of 8.47 mg/L and loadings of 8.15 kg/day. As a result, the macroinvertebrate community in Puncheon Fork RM 0.28 was in very poor condition. Twenty-four taxa were collected but no EPT or sensitive taxa were recorded. By comparison, sampling the same location in 1995 produced 9 EPT and 8 pollution sensitive taxa. Inadequately treated effluent had overwhelmed the assimilative capacity of the stream at RM 0.28.

Meadow Run

Two WWTPs discharge to Meadow Run, General Mills Inc. Wellston Plant at RM 2.80 and the Wellston North WWTP at RM 1.17. See Appendix B for a detailed description of these WWTPs. The General Mills WWTP had 6 ammonia violations between February 2015 and September 2015. Throughout the years that Ohio EPA has conducted biological monitoring in Meadow Run, different chemical signatures have kept the fish scores below the WWH aquatic life use biocriterion. Sampling in Meadow Run has shown that nutrients, particularly ammonia, are having a negative effect on the biological community; in addition to the excessive sand bedload. Table 18 shows that ammonia has decreased from past high values, but it remains well above the target value. Poor habitat and flow within the Meadow Run watershed has contributed to the poor biological scores, but nutrient enrichment is also a contributor in the lower reach of Meadow Run. Fish survey scores consistently are under performing at the SR 327 (RM 2.16 W03W27) and Cheatwood Road (RM 0.72 W03W18) sampling sites (Figure 27).

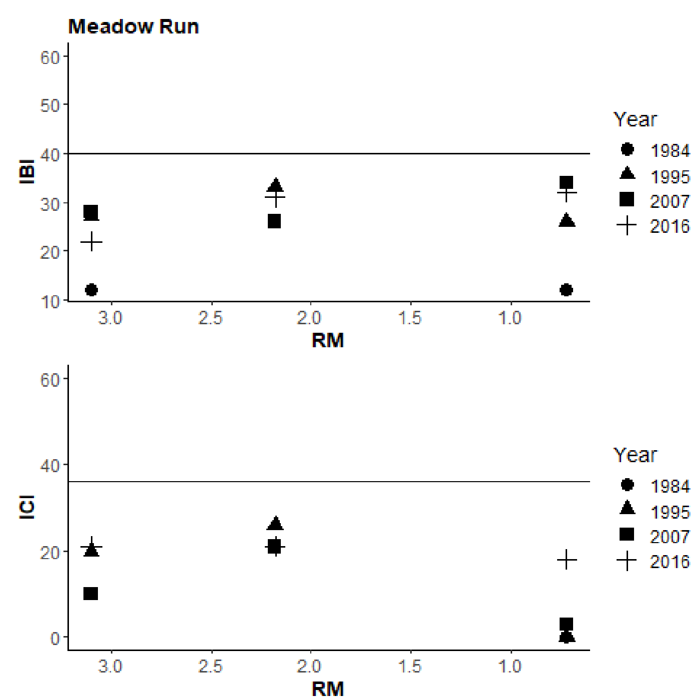


Figure 27 — Biological performance in Meadow Run through time. Solid horizontal lines indicate the WWH biocriterion.

Meadow Run macroinvertebrate assemblages were in fair condition at all three sampled locations beginning at RM 3.10. An excessive sand bedload contributed to the impairment throughout the sub-watershed and was exacerbated by nutrient impacts from treated wastewater discharges and wetland conditions due to a natural impoundment. Fish assemblages were fair–poor in Meadow Run, a typical assemblage had low relative numbers and was dominated by tolerant and omnivorous fishes.

Table 18 — Nutrient sample results from Ohio EPA stream monitoring program. The shaded cells indicate values over the 90th percentile.

Location	RM	Ammonia (mg/L)				N-N (mg/L)				Phosphorus (mg/L)			
		Mean				Mean				Mean			
		1984	1995	2007	2016	1984	1995	2007	2016	1984	1995	2007	2016
Meadow Run													
W03S10	3.10	0.24	0.08	---	0.12	0.08	0.17	---	0.22	0.05	0.03	---	0.06
W03W27	2.16	---	0.29	0.11	0.12	---	0.14	0.22	6.64	---	0.05	7.68	0.15
W03W18	0.72	6.15	5.61	0.12	0.89	0.34	0.32	4.91	8.34	4.70	1.41	3.65	0.72
W03W20	0.01	2.06	---	---	---	20.10	---	---	---	0.76	---	---	---
Reference Values 90th percentile WAP				**0.06**				**0.61**				**0.09**	

Fish Group 3 - Other Headwaters

Group three sites were of a similar size to the sites in group four, however these sites do not appear to have mine drainage impacting biological performance to the same extent. The creek chub and southern redbelly dace were identified as indicator fish species of this group (Table 14). Sites in this group also had marginally more coldwater macroinvertebrate taxa, and more EPT and sensitive macroinvertebrate taxa. Of note, sites in this group were found, where present, downstream of acid mine drainage remediation project areas, while the sites in group four were generally upstream of these project areas. No causal link is reported, but this may be an area for further study.

Two of the 11 sites in this group were meeting their ALU biocriteria, Long Run (203960) and Little Bullskin Run (W03K22). The majority of the impairment from this group comes from sand bedload issues described in the Habitat and Sediment Impacts section. Two sites, Siverly Creek (W03K42) and Rockcamp Creek (W03P33) were impacted by more recent riparian alterations. The landowner adjacent to the Siverly Creek site mentioned an increase in forestry activity in the headwaters of the stream, inspection of aerial imagery confirmed that clear-cutting activities occurred in portion of the watershed between 2006 and 2009. The stream has a narrow riparian area and as a result likely has less potential to deal with increased upstream sediment inputs. Rockcamp Creek, a tributary to Hewett Fork, was impacted by prior channelization and a very narrow wooded riparian area, which exacerbated the sand bedload issues.

Fish Group 4 - Headwaters with Mine Drainage Signatures

Sites in fish group four are small headwaters (< 5 mi^2), the smallest sites in the survey which is likely the primary driver of the grouping. Many of these sites also had mine drainage signatures. While no fish species were indicators of this group, southern redbelly dace and white suckers were highly specific to this group and the other headwater group, group 3. The primary differences separating these groups were differences in species count (5 versus 9) and relative abundance (154/0.3 km vs 348/0.3 km).

Pine Run (301579), Coal Run (W03W50) and Puncheon Fork RM 2.82 (W03K30) were not meeting WWH biocriteria due to size-related natural conditions. These sites supported limited macroinvertebrate diversity and fish assemblages. All had relatively natural channel morphology but were especially small drainages of no more than 2.0 mi^2. Coal Run was nearly intermittent when sampled on 8/22/2016. Substrate in Pine Run consisted of clay/hard pan with occasional bits of woody debris and Little Sandy Run was a deep wetland at the sampled location (RM 0.40 303689). The unnamed tributary to Raccoon Creek drained just 0.1 mi^2 within a narrow silty channel. The macroinvertebrate communities in Coal Run and Pine Run were in fair condition; the tributary to Raccoon Creek (RM 98.96) was rated poor due, in part, to the absence of any pollution sensitive taxa.

Figure 28 — Pierce Run RM 5.5 upstream of St. Rt. 160 showing iron precipitate on 6/29/2016.

Another component of this group were sites where mine drainage was causing impairment to aquatic life. High TDS concentrations or visual evidence of metals precipitate (Figure 28) were the primary indicators that the following streams were impacted by mine drainage: Pierce Run, Rockcamp Run, Brushy Creek, West Branch Raccoon Creek and East Branch Raccoon Creek (Table 13).

Reclamation projects in the East Branch of Raccoon Creek have significantly improved the biological community. In 1995, no fish were found in the East Branch of Raccoon Creek but after reclamation projects began in 2008, a total of nineteen species of fish have been found including least brook lamprey, longear sunfish, spotted bass and three species of darters. The macroinvertebrate community has also improved from 21 taxa in 1995 to 34 taxa in 2016. While the East Branch of Raccoon Creek is not fully meeting the WWH ALU, exceptional habitat scores (QHEI mean = 73), improved biological community and ongoing reclamation projects by the RCP warrant a recommendation from LRW to WWH ALU.

Pierce Run, and Rockcamp Run are still impacted by AMD to such an extent that the LRW use is still supported (Table 13). Pierce Run and Rockcamp Run, supported significantly improved EPT assemblages compared to similar collections in 1995. The narrative evaluation for the two streams improved from poor in 1995 to fair based on the 2016 results. Fish results from these two streams remained in the poor to fair range. Just two species of fish, totaling 8 individuals, were collected in Rockcamp Run, resulting in an IBI of 12.

Fish Group 5 – Mainstem (Lower Raccoon Creek)

Group five sites consist primarily of Raccoon Creek mainstem sites downstream from the currently designated LRW (WWH-Recommended) section (RM 95.52). The middle section of Little Raccoon Creek and Clear Fork are also included in the group (Table 17). These sites were generally the largest in the survey; drainage area was the primary grouping factor. These sites also had very good IBI scores and good to excellent habitat. As a result, excellent fish and macroinvertebrate assemblages were found at these sites.

Silver and smallmouth redhorse and smallmouth buffalo were very good predictors of this group. The previous species as well as, channel catfish, logperch, and golden redhorse had a high fidelity to sites in this group. The redhorse and logperch are species sensitive to pollution, especially siltation, since they are simple lithophilic spawners (fish species which broadcast their eggs over the stream bottom where they can develop in the interstices of sand, gravel, and cobble substrates without parental care). These fish, as well as the smallmouth buffalo, are also specialized insectivores. Specialized insectivores and simple lithophils indicate instream habitat consistent with exceptional water quality. The food base of specialized insectivores is sensitive to stream degradation. As the food base becomes less diverse, generalist feeders, such as omnivores, will replace the specialist insectivores. The traits of the associated fish species of this group is indicative of a high-quality resource. Bug group three largely corresponds to this group. This group had the highest numbers of total taxa, EPT taxa and pollution sensitive taxa in the survey area (Table 19).

Clear Fork (W03K23), at 7 mi^2, would not be expected to group with the mainstem sites. The fish community was reflective of its proximity to Raccoon Creek. Smallmouth buffalo, freshwater drum, silver redhorse and emerald shiners were collected and are more typically expected in much larger waters. While meeting the fish biocriteria, Clear Fork rated fair for macroinvertebrates due to excessive stream bedload (Habitat and Sediment Impacts).

Table 19 — Median values of taxa groupings for the macroinvertebrate groups identified through hierarchical clustering analysis.

Group	Total Taxa (Med.)	Total EPT (Med.)	Coldwater Taxa (Med.)	Sensitive Taxa (Med.)	Tolerant Taxa (Med.)
1	29	6	0	2	7
2	35.5	13	1	9.5	6
3	57	20	0	16.5	6

Aquatic Life Use Changes and Trends

Summary of Water Quality Improvement Projects

In the early 1980's, the Raccoon Creek Improvement Committee (RCIC) citizens group formed to address water quality issue in Raccoon Creek. In the early 1990's, the Raccoon Creek Watershed Partnership (RCP) formed as a partnership between various agencies to address technical AMD issues. In 1999, RCP completed the first reclamation project in the Little Raccoon Creek sub-watershed (SR 124 strip pit and Buckeye Furnace Project). In 2000, an Acid Mine Drainage Abatement and Treatment (AMDAT) plan was completed for Little Raccoon Creek (Laverty B. , 2000) and funding was secured for a watershed coordinator. AMDATs were completed for the headwaters of Raccoon Creek in 2002 (Rice C. , 2002) and for the middle basin in 2003 (Rice C. , 2003). A TMDL was finalized in 2002 for the Upper Raccoon Creek (Ohio Environmental Protection Agency, 2002). In 2014, an updated AMDAT was completed for Little Raccoon Creek (Landers, 2014). Table 20 has all the projects completed by RCP from 1999 to 2015 and includes hyperlinks to the AMD project reports which include pre and post-construction photos, water quality data and estimated acid/metal loading reductions. Funding from the AML program, Office of Surface Mining (OSM) Watershed Cooperative Agreement Program (WCAP) grants, and Ohio EPA's 319 grant program has been used in the Raccoon Creek watershed to implement restoration projects identified in both the AMDATs and TMDL reports. These projects have greatly improved water quality throughout the watershed.

According to the most recent ***2016 NPS Report – Raccoon Creek Watershed***, pH values have improved throughout the watershed from baseline conditions (1994-2001) to 2016. All miles surveyed in 2016 by the Raccoon Creek Partnership (RCP) met the minimum Ohio WQS for pH (6.5 SU) with the exception of the East Branch at the mouth. Ohio EPA saw similar results during the 2016 survey with no instantaneous pH values below the minimum WQS but two pH values below 6.5 SU (water quality sonde data deployed June 21-June 23, 2016) occurred during a rain event at Raccoon Creek at RM 104.63 (301746) and at Brushy Creek at RM 0.36 (W03K39). There are still unreclaimed surface mines in this area. During rain events, AMD is generated and discharged to both Brushy Creek and the headwaters of Raccoon Creek. ***The Abandoned Mine Land (AML) reclamation program*** is administered by ODNR-Division of Mineral Resources Management (DMRM) which can use state or federal funds to reclaim land mined before 1972. Unfortunately, some of the mines in Brushy Fork and the headwaters of Raccoon Creek were disturbed after 1972. These mined areas do not qualify for AML funding even though they are still impacting Raccoon Creek. Reclamation of these surface mines would continue to improve the water quality of Brushy Fork and the headwaters of Raccoon Creek, but alternative funding sources will be required to reclaim these areas.

Table 20 — Completed AMD Remediation Projects in the Raccoon Creek Watershed by the Ohio DNR and RCP (1999-2016) and links to the AMD project report.

Project	Acid Load Reduction (lbs/day)	Metal Load Reduction (lbs/day)	Completion Date
Little Raccoon Creek			
Buckeye Furnace/Buffer Run	2027	456	06/20/1999
State Route 124 Seeps	148	28	06/18/2001
Mulga Run	10	309	08/30/2004
Salem Road/Middleton Run	246	44	11/15/2005
Flint Run East	805	331	08/01/2006
Lake Milton	1072	98	09/05/2006
Flint Run and Lake Milton Maintenance	--	--	06/30/2012
Lake Morrow (Flint Run Trib)	188	17	09/08/2014
Middleton Run Reclamation II	188	22	05/22/2015
Flint Run Wetland Enhancement	1047	145	05/29/2015
Hewett Fork			
Carbondale II Doser	776	174	04/01/2004
Upper Raccoon Creek			
Hope Clay	21.5	4.4	06/01/2005
East Branch Phase I	1674	288	12/31/2007
East Branch Phase II and III	251	--	2010-2011
Orland Gob Pile	102	26	05/14/2012
Harble Griffith	360	54	06/29/2012
East Branch Phase I Maintenance	--	--	05/17/2012
Pierce Run			
Pierce Run - Oreton Seep	16	274	12/05/2012

Water Quality Trends

Numerous water quality surveys have been conducted in the Raccoon Creek watershed by state and federal agencies as well as universities and local groups. The Battelle Memorial Institute published a report in 1954 for ODNR-Division of Wildlife entitled the *Studies of Acid Mine Waters with Particular Reference to the Raccoon Creek Watershed* (Clifford, 1954). In 1967, the US Department of The Interior (USDOI) published a study entitled *Recommendations for Water Pollution Control, Raccoon Creek Basin, Ohio* (US Department of the Interior, 1967). The goal of the studies was to gather baseline data and develop a restoration plan which included costs estimates for reclamation. More recent studies include Acid Mine Drainage Abatement and Treatment (AMDAT) plans (Laverty B. , 2000), (Rice C. , 2002), (Rice C. , 2003), (Landers, 2014), watershed action plans (McCament B. , 2007), (McCament B. , 2003), TMDL reports (Ohio Environmental Protection Agency, 2002), (McCament B. , 2007), Stream Health Reports (Bowman, 2017), Nine Element Plan (Stokes, 2018) and Ohio EPA biological, habitat and water quality reports (Ohio Environmental Protection Agency, 1991), (Ohio Environmental Protection Agency, 1996). These studies helped to guide restoration projects in the watershed and has continued to result in dramatic improvements in reducing acid and metal loads and increasing alkalinity and pH.

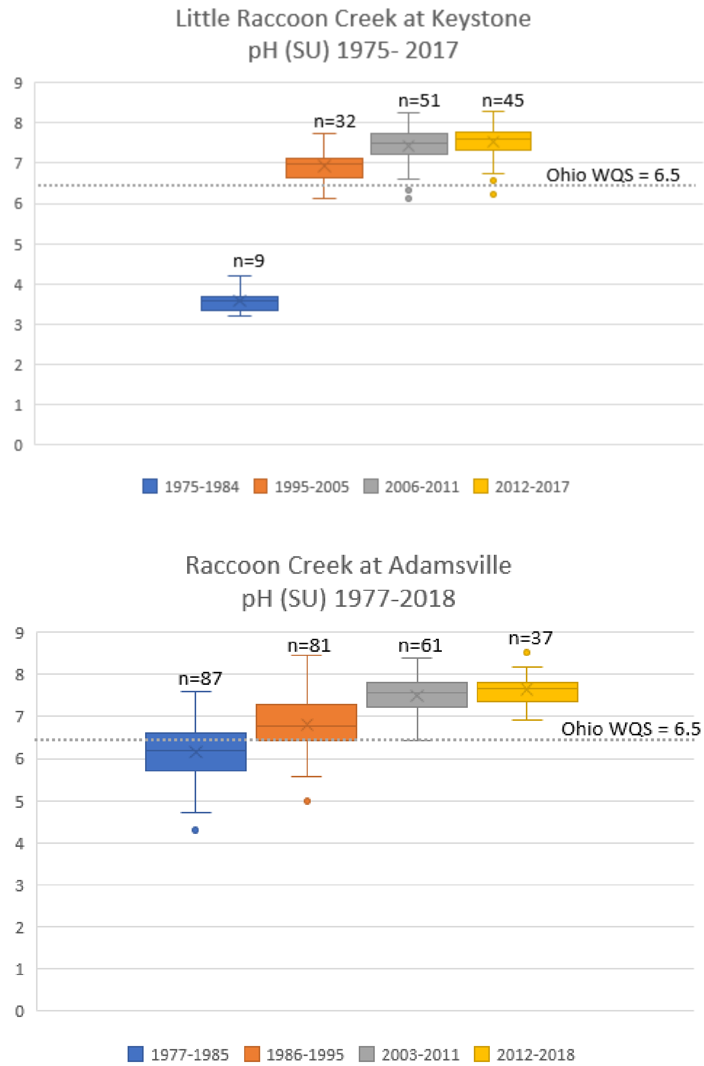


Figure 29 — Field pH trends from Little Raccoon Creek at Keystone Rd (1975-2017) and Raccoon Creek at Adamsville (1977-2018).

Both Raccoon Creek and Little Raccoon Creek has seen significant improvements in pH values because of the mining reclamation projects that have occurred in the watershed (Figure 29). Little Raccoon Creek has seen the most significant improvement with an average pH of 3.6 SU from 1975 to 1984 and steadily improving from 1995 (average of 6.9 SU) to 2017 with an average of 7.4 SU (Figure 29). Only a few outliers were recorded below the WQS from 2012-2017. Average iron, aluminum, sulfate and manganese values in Little Raccoon Creek have declined over time and average alkalinity has increased significantly from 2005 to 2017.

Ohio University compiles a ***Non-point Source (NPS) monitoring report for Acid Mine Drainage (AMD) for Raccoon Creek*** (Ohio University, 2016) which includes reclamation projects, yearly load reduction trends per project and water quality trends in the watershed. In 2001, only 61 percent of the Raccoon Creek stream miles monitored (100 miles) were meeting the pH target WQS of 6.5 but in 2016, 94 percent (116 miles monitored) were meeting the pH target.

Raccoon Creek

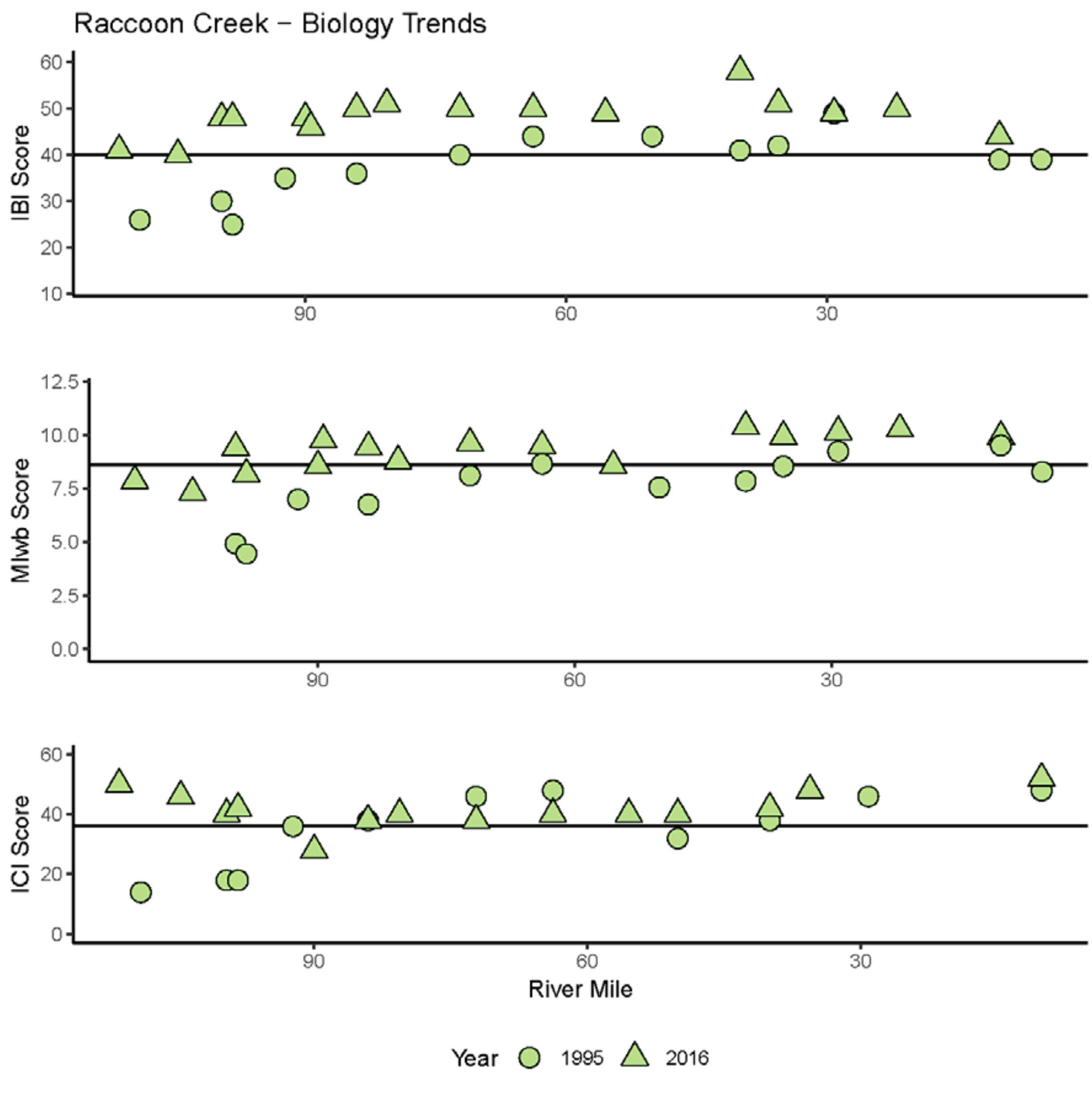


Figure 30 — Biology trends in Raccoon Creek have most notably improved in the upper sections of the stream. The solid horizontal line represents the WWH boating biocriterion.

Major shifts in the aquatic community have occurred between the surveys in 1995 and 2016 (Figure 30). The WWH-Recommended section (upstream RM 95.52) went from a tolerant fish dominated system to one where the majority of the of the fish community was comprised of simple lithophilic spawners. Other notable changes in fish community structure can be found in Table 21. The macroinvertebrate community displayed similar changes with increases in in total taxa, EPT taxa, and pollution sensitive taxa (Table 22, Figure 31). As a result, the currently LRW-designated section upstream of Sandy Run (RM 95.52) is recommended WWH. One site was partially attaining due to a low MIwb score (7.3), which is attributed to sand bedload issues. Otherwise this reach was fully meeting WWH, and there was no biological indication of acid mine drainage impacts.

Similar changes occurred in the rest of the mainstem where there were notable increases in relative biomass and numbers, and the percent pollution sensitive fish species increased from a median of 4.8 percent to 9.8 percent. The per-site median percentage of round-bodied suckers and simple lithophilic spawners also shifted from being a minority component of a site's community to being prevalent (Table 21). The macroinvertebrate community displayed similar changes with increases in in total taxa, EPT taxa, and pollution sensitive taxa (Table 22).

Habitat quality in Raccoon Creek remained stable between 1995 and 2016, a median of 60 in both surveys in the upper section and a median of 70 and 71 in both surveys in the section below RM 95.52. Observing such shifts in the aquatic community, with the habitat remaining stable, can be attributed to the mitigation of acid mine drainage that has happened at the landscape level in the watershed (described in Summary of Water Quality Improvement Projects).

Table 21 — Selected fish assemblage measures showing shifts in the Raccoon Creek mainstem between 1995 and 2016.

Fish Assemblage Component (Median)	WWH – Recommended		WWH Designated or EWH - Recommended	
	1995	2016	1995	2016
Total Taxa	10	20	21	26
Rel. Biomass (kg/km)	0.7	4.1	14.9	28.9
Rel. Number (num/km)	103	356	490	550
Pollution Sensitive Taxa	1	4	5	10
Pollution Tolerant Percent	56%	30%	11%	10%
Simple Lith. Spawners Percent	3%	32%	14%	52%
Round-Body Sucker Percent	0%	7%	15%	52%

Table 22 — Selected aquatic macroinvertebrate assemblage measures showing shifts in the Raccoon Creek mainstem between 1995 and 2016.

Macroinvertebrate Assemblage Component (Median)	WWH – Recommended		WWH Designated or EWH - Recommended	
	1995	2016	1995	2016
Total Taxa Count	36	60	52	57
Total EPT Taxa Count	5	18	16	21
Total Sensitive Taxa Count	4	13	13	19
Total Tolerant Taxa Count	11	6	6	7

A dam in the town of Vinton at RM 40.3 demarks a shift in fish and macroinvertebrate assemblages in Raccoon Creek. Downstream from the dam, the Raccoon Creek is fully meeting EWH biocriteria. The median habitat quality in this stretch is also excellent at 80.5. Notable differences in the fish assemblages were documented comparing the downstream samples from the larger sites in the upstream reach of Raccoon Creek (RM 40.3–89.4). These include more species and relative biomass downstream from the dam (Table 23). Of note is the decrease in sucker species upstream of the dam, going from 8 species to 5. Eighteen fish species found in streams downstream of the dam were not found in the upstream watershed; as well ten species were collected that were not collected by Ohio EPA in the watershed previously, six of which were only collected downstream of the dam (Table 24). Undoubtably some of the 18 species would not be expected to be found upstream due to stream size (e.g., mooneye, river redhorse, river carpsucker), but quite a few of these species would reasonably be expected to be found upstream of the dam. These include the bowfin, quillback carpsucker, bigeye chub, sand shiner and mimic shiner. Removing this barrier to fish passage would have a positive benefit in the Raccoon Creek watershed.

Table 23 — Selected fish assemblage measures showing shifts in the Raccoon Creek mainstem upstream and downstream of the dam in Vinton (RM 40.3).

Fish Assemblage Component (Median)		
	Downstream RM 40.3	RM 40.3 – 89.4
Total Taxa Count	30	24
Rel. Biomass (kg/km)	48.7	21.3
Native Species Count	28	22
Sucker Species Count	8	5
QHEI	80	71

Table 24 — Fish species either only collected in the watershed downstream of the dam in Vinton (RM 40.3) or species newly collected by Ohio EPA in the Raccoon Creek watershed.

Fish Taxa Only Downstream Barrier		
Longnose Gar	Bowfin	Mooneye
Black Buffalo	Quillback Carpsucker	River Carpsucker
River Redhorse	Bigeye Chub	Emerald Shiner
Sand Shiner	Mimic Shiner	Western Mosquitofish
Black Crappie	Smallmouth Bass	Orangespotted Sunfish
Sauger	Saugeye	Gizzard Shad
Newly Collected Fish Taxa		
Bowfin	Black Buffalo	Black Redhorse
River Redhorse	Bigeye Chub	Western Mosquitofish
Orangespotted Sunfish	Eastern Sand Darter	Banded Darter
Rainbow Darter		

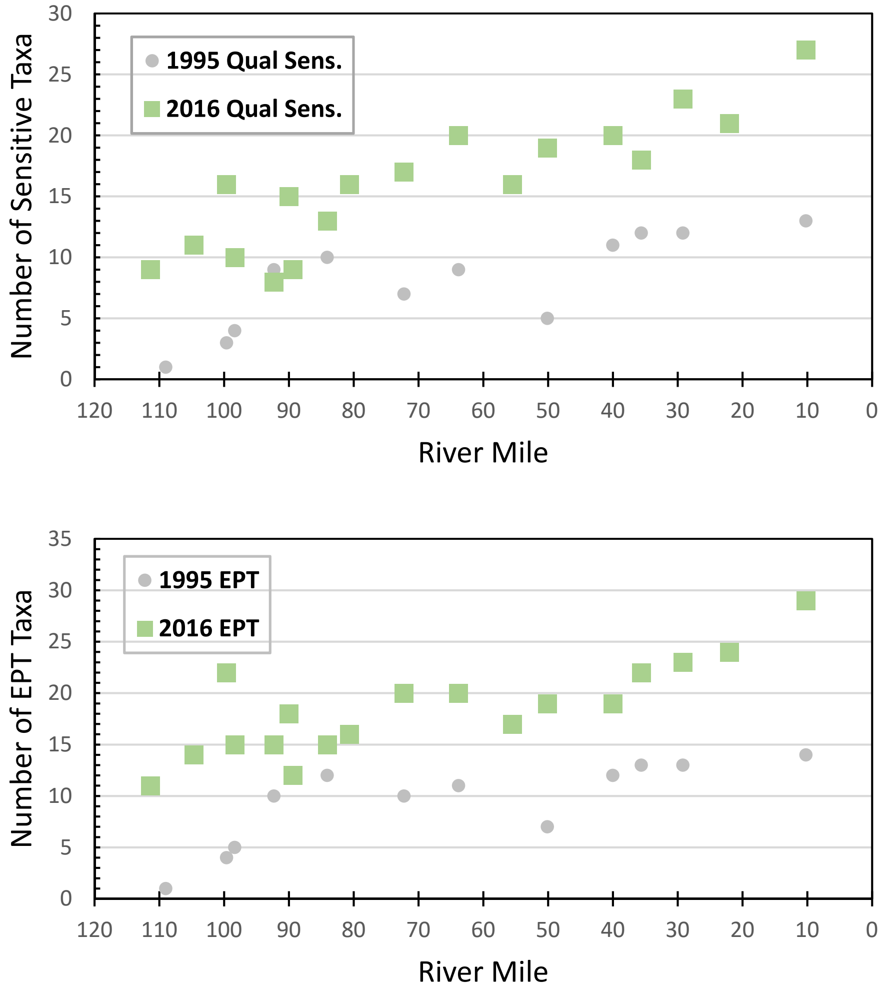


Figure 31 — Longitudinal trend of the number of pollution sensitive and EPT taxa collected from the natural substrates plotted by river mile in the Raccoon Creek, 1995 and 2016.

Hewett Fork

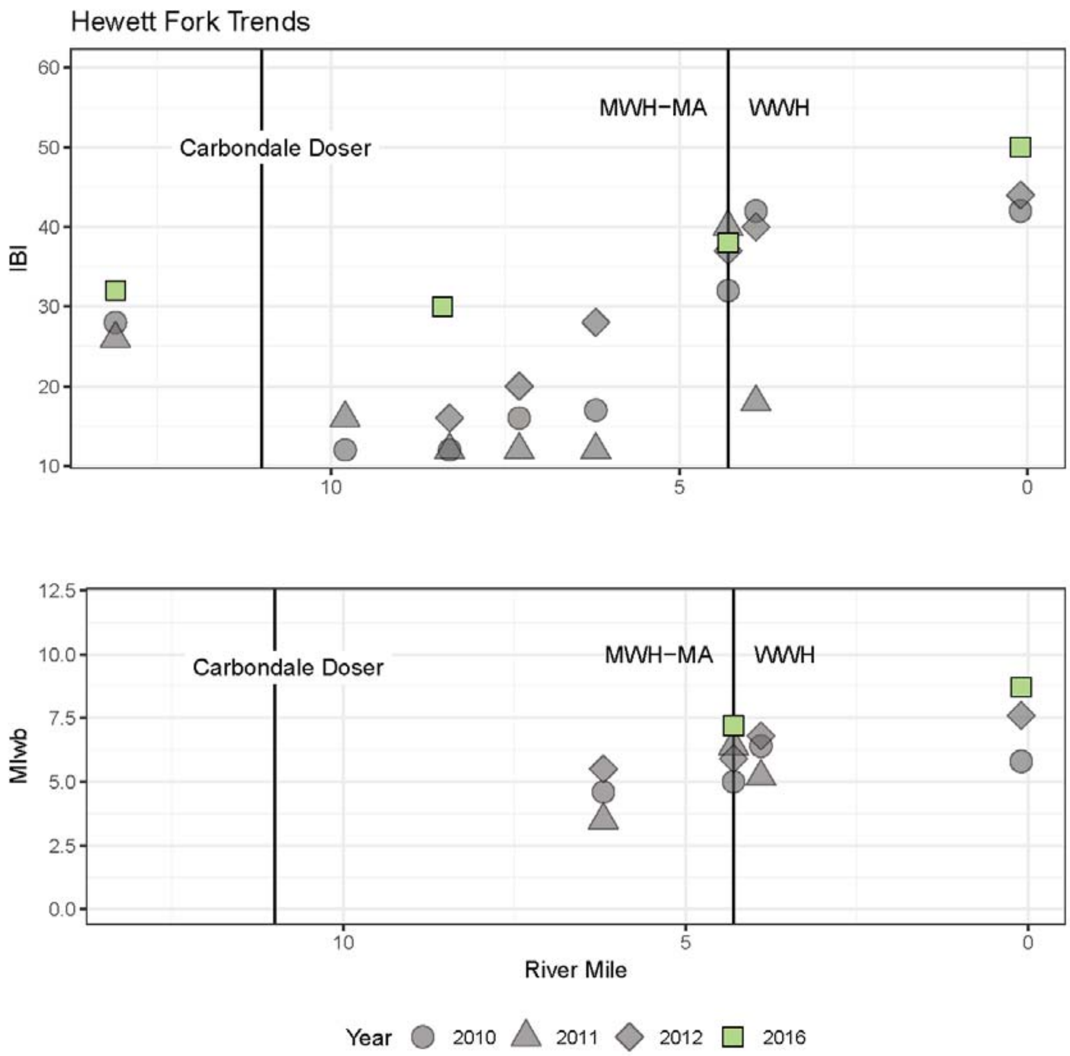


Figure 32 — Hewett Fork fish indices show that the lower four river miles are capable of meeting the WWH biocriteria.

Hewett Fork is a stream impacted by AMD most of which originates from abandoned underground coal mines near Carbondale. Remediation work was completed in 2004 by the Raccoon Creek Partnership; the installed calcium oxide doser has the ability to overtreat the intended AMD and neutralize downstream sources of AMD (Table 20). The alkaline, treated water enters Hewett Fork near RM 11 where the pH spikes and shortly is assimilated and a stable pH near neutral is reached a few river miles downstream.

Hewett Fork is fully capable of meeting WWH in the lower 4.31 river miles and was fully meeting 5 of 6 WWH biocriterion (Figure 32). The MIwb at RM 4.31 was low (7.0 in 2016, 7.3 in 2017) due to sand bedload and incision due to channelization.

Hewett Fork upstream of the doser outfall, while still impacted by mine drainage, is performing at a level well above LRW expectations (fair fish assemblages and marginally good macroinvertebrate assemblages). Data collected by ODNR-DMRM in the early 2010s indicate that the fish community downstream of the doser is consistently performing in the fair-poor range (Figure 32), no macroinvertebrate data was supplied to Ohio EPA. Ohio EPA collected data in the zone impacted by the doser and found fair fish assemblages and marginally good macroinvertebrate assemblages. Water quality in the reach between RM 11 and 4.31 has been permanently modified by the calcium oxide treatment doser, and as such Hewett Fork upstream of RM 4.31 has been recommended MWH-MA. The permanent modification of the stream in this reach has resulted in quantifiable improvements in water quality downstream. One hundred percent of the acid load from the Carbondale mine seeps (776 lbs./day) and 90 – 99 percent of the metal load (174 lbs./day) have been mitigated (Table 20). Details can be found in the project reports found in Summary of Water Quality Improvement Projects.

Other Tributaries

Little Raccoon Creek and Elk Fork, the other two longer tributaries sampled in the Raccoon Creek survey, improved or remained stable through several decades of sampling. Little Raccoon Creek has had several AMD mitigation projects installed (Table 20) resulting in reductions of acid and metal loadings to the stream. Most notably, macroinvertebrate quality has improved to the good-very good range in Little Raccoon Creek. Fish performance has also shown steady improvement (Figure 33). The site at RM 18.45 does show some variability in fish performance, sampling in 2016 indicated a very good- fair fish community, albeit with low abundance (49/0.3 km). In 2017, re-sampling indicated a poor fish community (IBI =18, MIwb = 5.5). The site is downstream from Flint and Buffer Runs, known AMD streams.

Elk Fork has shown improvement in the number of EPT taxa, a positive indicator of water quality, and in IBI performance (Figure 34). The MIwb has stayed relatively stable through time, fish abundance was relatively low in this watershed, likely due to the amount of sand bedload moving through the system (Appendix F).

Figure 35 and Table 25 depict the degree to which EPT and sensitive taxa diversity have changed in the Raccoon Creek tributaries based on qualitative sampling conducted in 1995 or 2000 versus 2016. The number of EPT taxa collected increased at 28 sites and declined at 3 sites. Pollution sensitive taxa diversity increased at 26 sites and declined at 5 sites. Some of the greatest improvement was documented in Elk Fork, Little Raccoon Creek, West Branch Raccoon Creek, Siverly Creek and Brushy Fork. Many of these streams have benefited from projects aimed at reducing acid mine drainage that are detailed in Summary of Water Quality Improvement Projects.

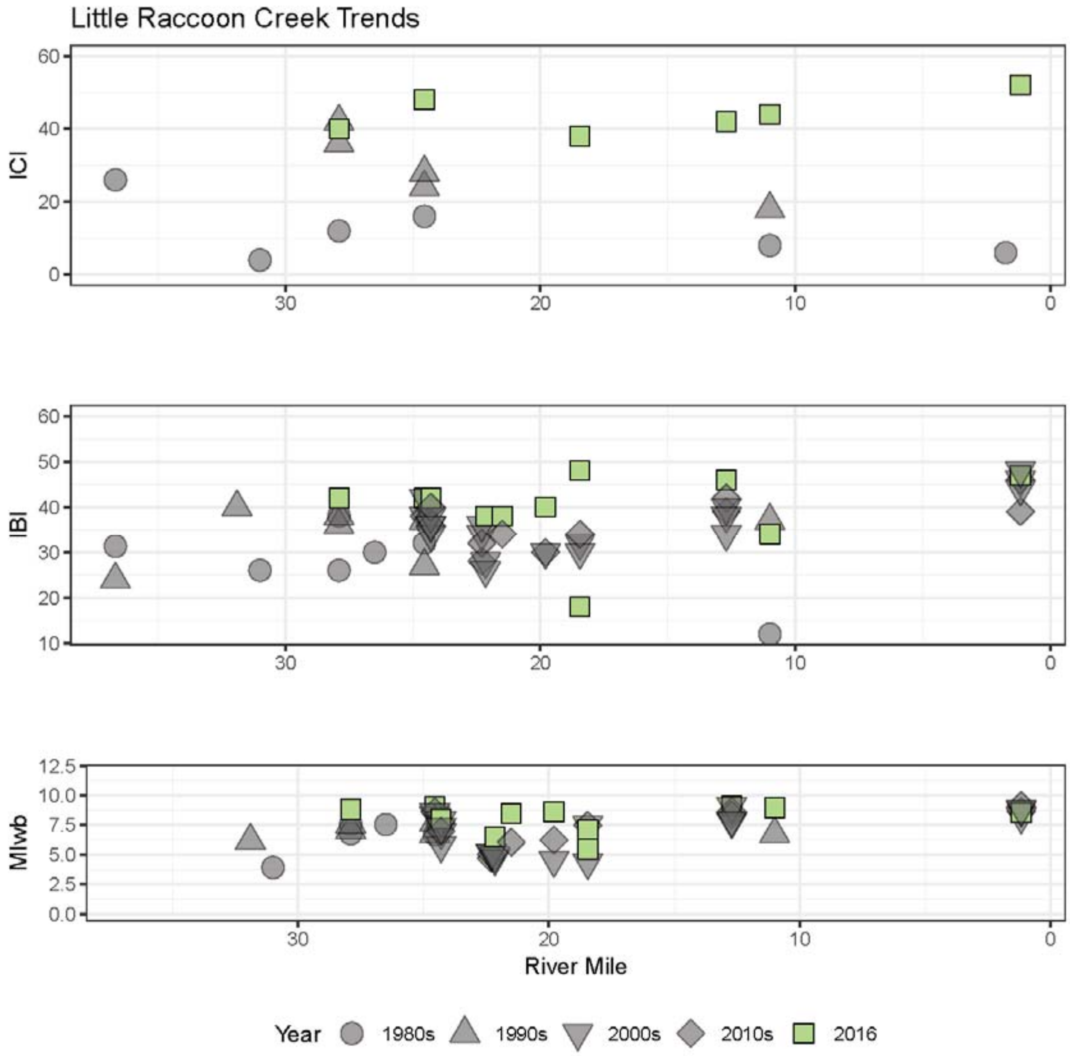


Figure 33 — Little Raccoon Creek biology trends through several decades. Improvement in biological performance is most notable in the macroinvertebrate index.

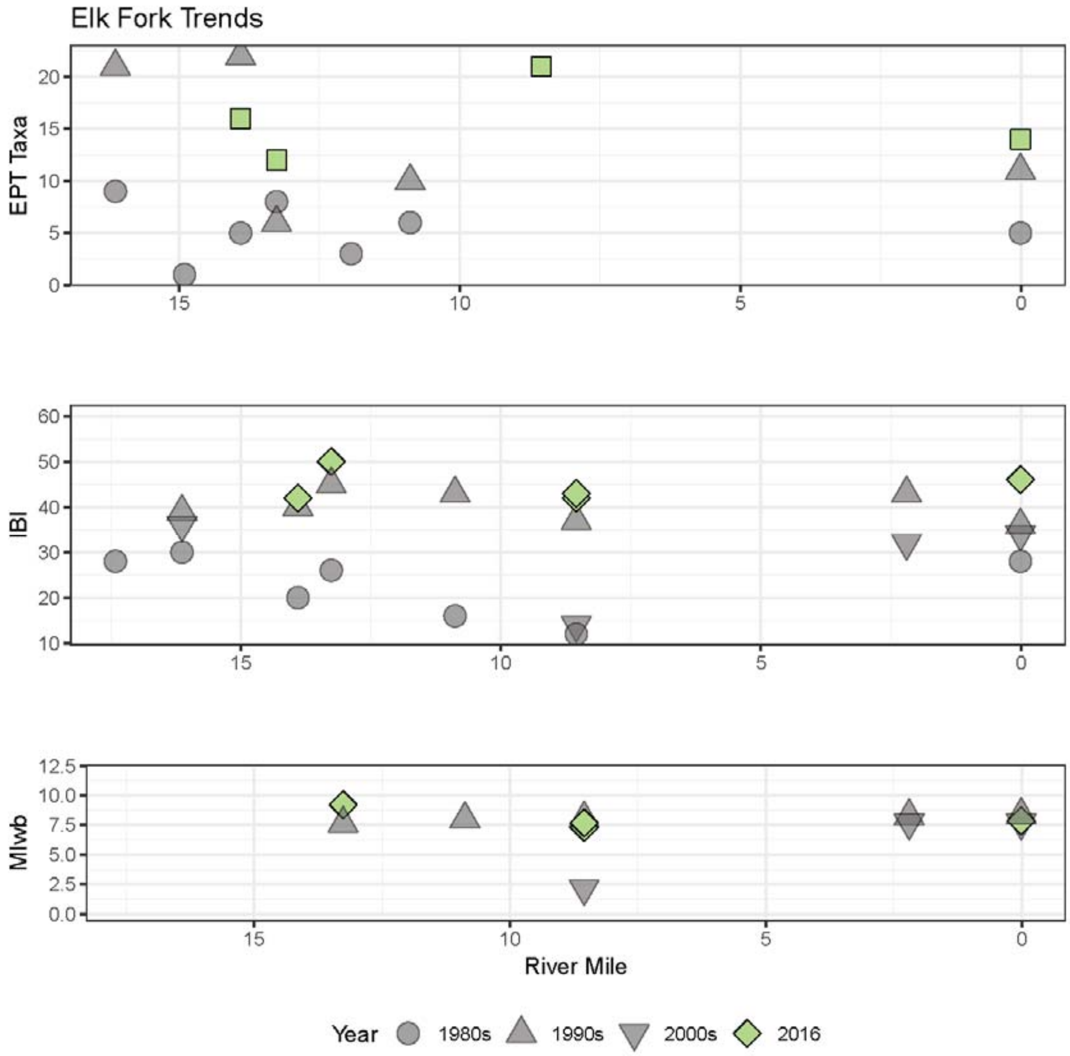
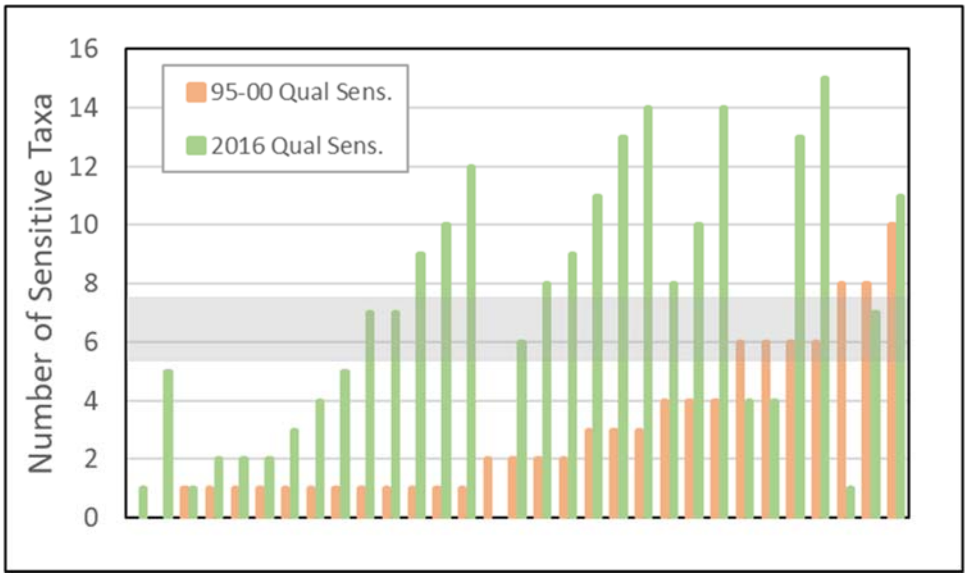


Figure 34 — Elk Fork biology trends through several decades.



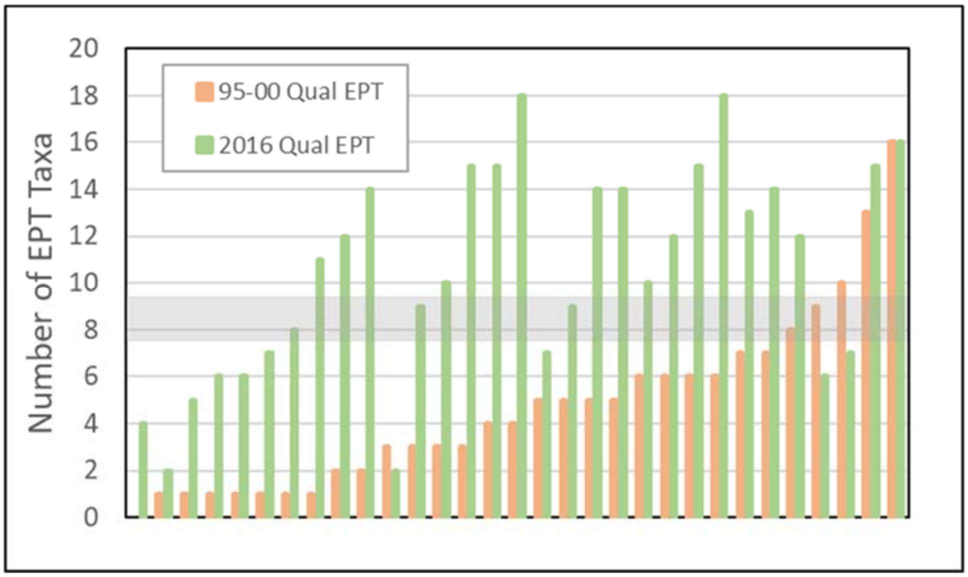


Figure 35 — Number of EPT (Ephemeroptera, Plecoptera and Trichoptera) and pollution sensitive taxa collected from paired Raccoon Creek tributary sites, 1995-2000 and 2016.

Table 25 — Number of EPT (Ephemeroptera, Plecoptera and Trichoptera) and pollution sensitive taxa collected from select Raccoon Creek tributary sites, 1995-2000 and 2016. Shading in 2016 columns is for comparison with earlier years data. Declines in taxa diversity are indicated with pink shading; green represents an increase and darker green identifies instances that also generally meet or exceed WWH aquatic life use expectations.

Stream	River Mile	STORET	1995-2000 EPT	2016 EPT	1995-2000 Sensitive Taxa	2016 Sensitive Taxa
Trib. To Raccoon Creek (RM 98.96)	0.10	203928	3	2	2	0
Little Raccoon Creek	27.90	W03S07	5	9	2	6
Little Raccoon Creek	24.55	W03W25	5	14	1	10
Little Raccoon Creek	11.00	W03K09	7	14	6	13
Meadow Run	3.10	W03S10	1	7	1	4
Meadow Run	2.16	W03W27	3	9	1	2
Meadow Run	0.72	W03W18	0	4	0	1
Elk Fork	13.90	W03W06	16	16	10	11
Elk Fork	13.26	W03P30	6	12	2	9
Elk Fork	0.01	W03P31	5	14	3	11
Trib. To Elk Fork (RM 11.17)	0.43	W03W09	3	10	1	5
Puncheon Fork	0.28	W03W07	9	6	8	1
Robinson Run	0.18	W03S40	7	13	4	8
Flatlick Run	0.60	W03S39	10	7	6	4
Rockcamp Run	0.11	W03W52	1	6	1	2
Pierce Run	1.68	W03W47	1	6	1	2
Long Run	1.40	203960	2	14	2	8
Flat Run	1.60	W03W51	4	18	1	12
Onion Creek	1.41	W03W45	13	15	8	7
Laurel Run	0.16	W03W59	6	10	1	7
Hewett Fork	13.1	W03K37	1	11	1	9
Rockcamp Creek	1.53	W03P33	2	12	1	7
Coal Run	0.05	W03W50	1	5	1	3
Pine Run	0.10	301579	1	8	0	5
Grass Run	0.04	W03P41	5	7	6	4
Brushy Fork	6.87	W03K40	3	15	3	14
Siverly Creek	0.30	W03K42	4	15	4	14
Twomile Run	0.16	W03W58	6	18	6	15
East Branch Raccoon Creek	6.64	W03W37	1	2	1	1
West Branch Raccoon Creek	5.68	W03W36	6	15	3	13
West Branch Raccoon Creek	0.15	W03W43	8	12	4	10
Number of EPT taxa collected increased at 28 sites and declined at 3 sites						
Number of Sensitive taxa collected increased at 26 sites and declined at 5 sites						

Recreation Use

Water quality criteria for determining attainment of recreation uses are established in the Ohio Water Quality Standards (Table 37-2 in OAC 3745-1-37) based upon the presence or absence of bacteria indicators (*Escherichia coli*) in the water column.

Escherichia coli (*E. coli*) bacteria are microscopic organisms that are present in large numbers 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 (Dufor, 1977), but 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 becoming more practicable. 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 these wastes have been deposited.

Pathogenic organisms are typically present in the environment in such small amounts that it is impractical to monitor them directly. 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 indicate the potential presence of pathogenic organisms that enter the environment through the same pathways. When *E. coli* are present in high numbers in a water sample, the water has received fecal matter from one source or another. Swimming or other recreational-based contact with water having a high fecal coliform or *E. coli* count may result in ear, nose, and throat infections, as well as stomach upsets, skin rashes, and diarrhea. Young children, the elderly, and those with depressed immune systems are most susceptible to infection.

The streams of the Raccoon Creek watershed evaluated in this survey are designated with the Primary Contact Recreation (PCR) recreational use in OAC Rule 3745-1-16. Water bodies with a designated recreational use of PCR "...are waters that, during the recreation season, 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)(3)(b)].

Recreation use attainment status is determined by comparing the geomean of samples collected within a 90-day period of the larger recreation season, which extends from May 1 through October 31, to the geometric mean criterion of 126 cfu/100 ml and to the statistical threshold value (STV) of 410 cfu/100 ml, which should not be exceeded by more than 10% of individual samples.

Summarized bacteria results are listed in Table 26, and the complete dataset is reported in Appendix Table L. Twenty-eight locations in the Raccoon Creek watershed study area were sampled for *E. coli* approximately five times apiece, from June – August 2016. Included were 11 sites on Raccoon Creek and 17 sites on tributary streams. Twenty-eight locations, or 97 percent, of the sampling locations in the Raccoon Creek watershed failed to meet both the applicable geometric mean criterion and the statistical threshold value, and thus were in non-attainment of the recreation use.

Strongs Run RM 0.58 had the highest geomean *E. coli* concentration at 2,483 cfu/100 ml and the highest single-sample maximum (76,000 cfu/100 ml) in the Raccoon Creek watershed. Four other sites had *E. coli* geomean concentrations higher than 1,000 cfu/100 ml: West Branch Raccoon Creek RM 0.15 (1,872 cfu), Elk Fork RM 13.26 (1,871 cfu), Barren Creek RM 0.30 (1,433 cfu) and Raccoon Creek RM 22.00 (1,307 cfu). One stream location, Raccoon Creek at RM 89.36, was in full attainment of recreation use with a geomean of 63 cfu/100 ml and 10% of sample exceeding the STV (Table 26). Sources of elevated bacteria concentrations were ubiquitous and most likely due to a variety of inputs and land use conditions in the watershed.

Inadequately functioning home sewage treatment systems (HSTS) in unsewered areas and agricultural activities are the most probable sources of bacteria to streams in the study area. Agricultural activities include land application of manure and biosolids as well as livestock pasture and production.

The highest concentrations of *E. coli* were evident during or shortly following heavy rain events, such as a storm event on 7/5/2016 that coincided with sample collection; however bacterial contamination in most streams was present to some extent during both wet and dry weather events. This indicates that strategies to reduce bacteria levels in streams should include both non-point source and point source measures.

Table 26 — A summary of *E. coli* data for the 28 locations in the Raccoon Creek watershed sampled June through August 2016. Recreation Use Attainment Status is determined by comparing samples collected within a 90-day period during the recreation season to the geometric mean criterion of 126 cfu/100 ml and to the statistical threshold value (STV) of 410 cfu/100 ml (for PCR), or geometric mean of 1,030 cfu/100 ml, and statistical threshold values of 1,030 cfu/100 ml (for SCR). The STV is not be exceeded by more than 10 percent of individual samples. Values in bold exceed the applicable criterion.

Station ID	Location	River Mile	No. Samples	Geometric Mean	Percent > STV	Maximum Value	Attainment Status	Possible Source(s)[1] of Bacteria
05090101 02 01 East Branch Raccoon Creek								
W03K17	Laurel Run Rd.	2.1	5	767	60	26,000	Non	
05090101 02 02 West Branch Raccoon Creek								
W03W43	St. Rte. 328	0.15	5	1,872	100	20,000	Non	
05090101 02 03 Brushy Fork								
W03K39	St. Rte. 328	0.36	10	603	40	42,000	Non	
05090101 02 04 Twomile Run – Raccoon Creek								
301747	Raccoon Creek at St. Rte. 328 and Sheets-McCoy Rd.	111.4	11	486	55	4,800	Non	
05090101 02 05 Town of Zaleski- Raccoon Creek								
W03W32	Raccoon Creek at Creek Rd.	99.6	5	823	60	11,000	Non	
05090101 03 01 – Hewett Fork								
W03P08	Hewett Fork at Twp. Rd. 20, SW of Mineral	4.31	5	544	20	6,900	Non	
05090101 03 02 – Headwaters Elk Fork								
W03P30	Elk Fork at St. Rte. 50, dst Puncheon Fork	13.26	5	1,871	80	28,000	Non	
05090101 03 03 – Flat Run-Elk Fork								
W03P31	Elk Fork at C.R. 43B, NE of Radcliff	0.01	10	287	10	6,200	Non	
05090101 03 04 – Flat Run-Raccoon Creek								
302519	Raccoon Creek at C.R. 18B, dst Hewett Fork	89.36	10	63	10	890	Full	
W03G50	Raccoon Creek at St. Rt. 50, at Bolins Mills	80.62	10	170	10	3,100	Non	
05090101 04 01 – Headwaters Little Raccoon Creek								
W03S07	Little Raccoon Creek at Mulga Rd, ust Meadow Run	27.90	5	256	20	660	Non	
05090101 04 02 – Dickason Run								
W03P43	Dickason Run at Orpheus-Keystone Rd.	0.11	5	338	40	1,100	Non	
05090101 04 03 – Meadow Run-Little Raccoon Creek								
W03S06	Little Raccoon Creek at Keystone Rd., ust Dickason Run	12.71	9	115	11	1,600	Non	
05090101 04 04 – Deer Creek-Little Raccoon Creek								
W03P04	Little Raccoon Creek at St. Rt. 325	1.17	5	316	20	2,300	Non	
05090101 05 01 – Pierce Run								
W03W47	Pierce Run at Township Hwy 2A	1.68	5	362	20	6,200	Non	
05090101 05 03 – Strongs Run								
W03S47	Strongs Run at Adney Rd.	0.58	5	2,483	80	76,000	Non	

Station ID	Location	River Mile	No. Samples	Geometric Mean	Percent > STV	Maximum Value	Attainment Status	Possible Source(s)[1] of Bacteria
05090101 05 03 – Flatlick Run-Raccoon Creek								
W03P18	Raccoon Creek at St. Rt. 124, S of Clarion	55.48	10	143	10	1,300	Non	
05090101 05 04 – Robinson Run-Raccoon Creek								
W03P05	Raccoon Creek at Vinton Park, dst dam, St. Rt. 325	40.01	10	385	30	10,000	Non	
05090101 06 01 – Indian Creek								
W03P36	Indian Creek at St. Rt. 325, ust Rio Grande WWTP	1.58	5	849	80	9,300	Non	
05090101 06 02 – Barren Creek-Raccoon Creek								
203953	Barren Creek at OH 554	0.30	5	1,433	80	44,000	Non	
05090101 06 03 – Mud Creek-Raccoon Creek								
303508	Big Beaver Creek at Guthrie Rd.	0.90	4	762	0	3,600	Non	
05090101 06 04 – Bullskin Creek								
W03K21	Bullskin Creek at Williams Hollow Rd.	0.37	5	602	80	900	Non	
05090101 06 05 – Claylick Run-Raccoon Creek								
203929	Claylick Run at Lincoln Pike	0.40	5	457	60	1,400	Non	
05090101 90 01 – Raccoon Creek LRAU								
W03S44	Raccoon Creek at Glassburn Rd.	35.3	5	286	20	630	Non	
601400	Raccoon Creek at OH 558, Bob Evans camp	29.2	10	743	30	41,000	Non	
303503	Raccoon Creek at Dan Jones Rd., MacIntyre Park	22.0	5	1,307	80	40,000	Non	
W03S24	Raccoon Creek at Ingalls Rd.	10.2	5	356	40	2,000	Non	
W03P16	Raccoon Creek at St. Rt. 218	5.36	5	213	20	1,100	Non	

[1] Possible Sources:
AG – Agriculture
CAFO – Concentrated Animal Feeding Operation
HSTS – Home Sewage Treatment Systems
WWTP – Wastewater Treatment Plants
CSOs – Combined Sewer Overflows
SSOs – Sanitary Sewer Overflows
Urban – Urban runoff

Public Drinking Water Supplies

The public water supply (PWS) beneficial use in the WQS (OAC 3745-1-33) currently applies within 500 yards of drinking water intakes and for all publicly owned lakes. Ohio EPA has developed an assessment methodology for this beneficial use which focuses on source water contaminants not effectively removed through conventional treatment methods. Source water quality is assessed though comparison of water quality data to numeric chemical water quality criteria for three core indicators: nitrate; pesticides (atrazine); and cyanotoxins. The *Integrated Water Quality Monitoring and Assessment Report* (Ohio IR) describes this methodology and is available at ***epa.ohio.gov/dsw/tmdl/OhioIntegratedReport.aspx***. The Ohio IR is updated on a two-year cycle, and the current report at the time of this study was the 2016 Ohio IR.

Impaired source waters may contribute to increased human health risk or treatment costs. When stream water is pumped to a reservoir, the stream and reservoir are evaluated separately. These assessments are designed to determine if the quality of source water meets the standards and criteria of the Clean Water Act. Monitoring of the safety and quality of treated finished drinking water is regulated under the Safe Drinking Water Act and evaluated separately from this assessment. For those cases when the treatment plant processes do not specifically remove a source water contaminant, the finished water quality data may be considered representative of the raw source water directly feeding into the treatment plant.

A community public water system (PWS) is a system that serves at least fifteen service connections available for use by year-round residents or regularly serves at least twenty-five year-round residents. City of Wellston's PWS is directly served by surface water sources within the study area. Wellston's North Water Treatment Plant has an intake on Little Raccoon Creek (RM 30) and intakes on two reservoirs, Lake Alma and Lake Rupert. The source water assessment reports for Wellston Public Water System is available at ***http://wwwapp.epa.ohio.gov/gis/maps/SWAP.html***.

To assess the PWS beneficial use for each indictor, samples were collected at representative sites and analyzed for nitrate, atrazine and cyanotoxins (microcystins, saxitoxins and cylindrospermopsin). Appendices H, I and J contain water quality analytical results. Additionally, all surface water PWSs must conduct routine microcystins monitoring and cyanobacteria screening as specified in OAC 3745-90-03. All cyanotoxin (microcystins, saxitoxins and cylindrospermopsin) results are available on Ohio EPA's website at ***http://wwwapp.epa.ohio.gov/dsw/hab/HAB_Sampling_Results.xlsx***.

City of Wellston

The City of Wellston operates a community PWS with two water treatment plants (North and South) that serves a population of approximately 7,000 people through 2,673 service connections. The North Water Treatment Plant obtains its water from Little Raccoon Creek that is pumped up to the Wellston City Reservoir impoundment. Lake Rupert and Lake Alma are used occasionally as back-up source waters and are located within Raccoon Creek Watershed. The South Water Treatment Plant's source water is ground water from an abandoned coal mine, which is pumped to the plant by three production wells. Because surface water drains directly into the mine via former mine shafts, vents, and drainage wells, this source water is designated "surface water" and is subject to surface water treatment standards.

Ohio EPA collected water quality samples from Little Raccoon Creek (303474) in 2016 and from Lake Alma (L-1), and Lake Rupert (L-1) during 2016 and 2017. The PWS assessment unit is HUC 05090101 04 01 Headwaters Little Raccoon Creek. The results for each impairment indicator are summarized as follows:

- Nitrate Indicator: All results were below the water quality criterion for nitrate (10.0 mg/L).
    - Little Raccoon Creek (303474): Nitrate results ranged from 0.10 to 0.20 mg/L.
    - Lake Alma (L-1): Nitrate results were all below detection limit (BDL), <0.1 mg/L.
    - Lake Rupert (L-1): Nitrates ranged from BDL to 0.27 mg/L.
- Pesticides Indicator: There were no exceedance of the maximum instantaneous value, >12 µg/L, for atrazine. All annual averages for atrazine were below the water quality criteria.
    - Little Raccoon Creek (303474): Atrazine results were all BDL, <0.20 µg/L.
    - Lake Alma (L-1): Atrazine results were all BDL.
    - Lake Rupert (L-1): Atrazine results were all BDL.
- Algae, Cyanotoxins Indicator: There were no exceedances of the water quality criterion for microcystins (1.0 µg/L), saxitoxins (0.2 µg/L) or cylindrospermopsin (1.0 µg/L).
    - Lake Alma (L-1): All results were below the water quality criterion for cyanotoxins.
        - Microcystins ranged from BDL to 0.60 µg/L.
        - Saxitoxins ranged from BDL to 0.18 µg/L.
        - Cylindrospermopsin results were all BDL.
    - Lake Rupert (L-1): All results were below the water quality criterion for cyanotoxins.
        - Microcystins ranged from BDL to 0.50 µg/L.
        - Saxitoxins and cylindrospermopsin results were all BDL.
    - PWS routine monitoring at raw water sampling point occurred June 2016 through November 2018.
        - Microcystin results were all BDL.
        - Saxitoxins ranged from BDL to 0.039 µg/L.
        - Cyanobacteria screening detected microcystin-producing genes in December 2016 and saxitoxin-producing genes during June and October 2018. All results for cylindrospermopsin-producing genes were BDL.

In the 2018 Ohio IR, the drinking water use support for Headwaters Little Raccoon Creek (05090101 04 01) is listed as unknown due to insufficient data for nitrates and atrazine, and watch list for algae due to microcystin and saxitoxin concentrations in Lake Alma.

	PDWS Parameters of Interest				
	Nitrate-Nitrite WQC = 10 mg/L[1]		Atrazine WQC = 3.0 µg/L[2]		
Location(s)	Average (sample count)	Maximum (# samples >WQC)	Average (sample count)	Annual Average (2016)[3]	Maximum Single Detect.
HUC 05090101 04 01 Little Raccoon Creek / Wellston PWS – North Water Treatment Plant					
Little Raccoon Creek (303471)	0.14 mg/L (5)	0.18 mg/L (0)	2.05 µg/L (13)	0.41 µg/L	BDL

1 Nitrate Water Quality Criteria (WQC) evaluated as maximum value not to be exceeded, impaired waters defined as having two or more excursions about the criteria.
2 Atrazine WQC evaluated as annual average based on quarterly averages. Watch List conditions include maximum instantaneous value > 12.0 µg/L.
3 Atrazine data was only collected for two quarters each year. Quarterly average assumes fall and winter quarters are zero.

Human Health

Fish Tissue Contamination

Ohio has been sampling streams annually for sport fish contamination since 1993. Fish are analyzed for contaminants that bioaccumulate in fish and that could pose a threat to human health if consumed in excessive amounts. Contaminants analyzed in Ohio sport fish include mercury, PCBs, DDT, mirex, hexachlorobenzene, lead, selenium and several other metals and pesticides. Other contaminants are sometimes analyzed if indicated by site-specific current or historic sources. For more information about the chemicals analyzed, how fish are collected, or the history of the fish contaminant program, see ***State Of Ohio Cooperative Fish Tissue Monitoring Program Sport Fish Tissue Consumption Advisory Program, Ohio EPA, January 2010***.

Fish contaminant data are primarily used for three purposes: 1) to determine fish advisories; 2) to determine attainment of water quality standards; and 3) to examine trends in fish contaminants over time.

Fish Advisories

Fish contaminant data are used to determine a meal frequency that is safe for people to consume (for example, two meals a week, one meal a month, do not eat). Based on the data, fish advisories are issued for applicable species and locations. Because mercury mostly comes from nonpoint sources, primarily aerial deposition, Ohio has had a statewide one meal a week advisory for most fish since 2001. Most fish are assumed to be safe to eat once a week unless specified otherwise in the fish advisory, which can be viewed at ***epa.ohio.gov/dsw/fishadvisory/index.aspx***.

The minimum data requirement for issuing a fish advisory is three samples of a single species from within the past 10 years. For Raccoon Creek and Little Raccoon Creek, no advisories existed prior to the 2016 sampling.

For all unlisted species, the statewide advisories apply, which are: two meals a week for sunfish (for example, bluegill) and yellow perch; one meal a week for most other fish; and one meal a month for flathead catfish 23" and over, and northern pike 23" and over.

Sufficient data was collected in 2016 to assess several species for advisory updates. The following new advisories were added as the result of this sampling:

Raccoon Creek	State Route 160 in Vinton to mouth (Ohio River) (Vinton, Gallia counties)	Freshwater Drum, Spotted Bass	One/month	Mercury

For a listing of fish tissue data collected from the Raccoon Creek mainstem and tributaries in support of the advisory program, and how the data compare to advisory thresholds, see Appendix O.

Fish Tissue/Human Health Use Attainment

In addition to determining safe meal frequencies, fish contaminant data are also used to determine attainment with the human health water quality criteria pursuant to OAC Rules 3745-1-33 and 3745-1-34. The human health water quality criteria are presented in water column concentrations of µg/L and are then translated into fish tissue concentrations in mg/kg. [See Ohio's 2010 Integrated Report, Section E (***epa.ohio.gov/portals/35/tmdl/2010IntReport/Section%20E.pdf***) for details of this conversion.]

To be considered in attainment of the water quality standards, the sport fish caught within an assessment unit in the Ohio River basin must have a weighted average concentration of the geometric means for all species below 1.0 mg/kg for mercury, and below 0.054 mg/kg for PCBs.

Within the Raccoon Creek study area, fish tissue data were adequate to determine attainment status for seven WAUs and one LRAU. At least two samples from each trophic level three and four are needed, which were available for one WAU and one LRAU assessed as part of the watershed. Table 27 shows the results before and after the 2016 sampling.

Table 27 — Previous and current impairment status for large river assessment units (LRAUs) and watershed assessment units (WAUs) in the Raccoon Creek study area, from the 2016 and 2018 Ohio Integrated reports (IRs), respectively, using fish tissue data from 2005-2014 (2016 IR) and 2007-2016 (2018 IR). Status 1 represents unimpaired watersheds (contaminant levels below impairment thresholds in fish tissue), Status 1h represents unimpaired watersheds based on historic (outdated) data, and Status 3 and 3i represent no or insufficient data to assess the unit, respectively.

Unit	Unit Type	Previous Status (2016)	Current Status (2018)	Assessment Unit Name
50901019001	LRAU	3i	1	Raccoon Creek Mainstem (Little Raccoon Creek to mouth)
50901010204	WAU	3i	3i	Raccoon Creek
50901010205	WAU	1h	1h	Town of Zaleski-Raccoon Creek
50901010304	WAU	3	3i	Flat Run-Raccoon Creek
50901010403	WAU	3	3i	Meadow Run-Little Raccoon Creek
50901010404	WAU	3	3i	Deer Creek-Little Raccoon Creek
50901010503	WAU	3	3i	Flatlick Run-Raccoon Creek
50901010504	WAU	3	1	Robinson Run-Raccoon Creek

Fish Contaminant Trends

Fish contaminant levels can be used as an indicator of pollution in the water column at levels lower than laboratory reporting limits for water concentrations but high enough to pose a threat to human health from eating fish. Most bioaccumulative contaminant concentrations are decreasing in the environment because of bans on certain types of chemicals like PCBs, and because of stricter permitting limits on dischargers for other chemicals.

For this reason, it is useful to compare the results from the survey presented in this TSD with the results of the previous surveys done in the study area. Recent data can be compared against historical data to determine contaminant concentrations trends in fish tissue. However, evaluating trends in contaminant data can be challenging, since many factors beyond time itself—including location and species—can affect the contaminant levels in a particular sample that may vary substantially between sampling events. Therefore, directly comparing contaminant results between years is not always reliable.

When evaluating mercury results, it is often useful to condense samples by trophic level. Because mercury tends to increase with increasing position within the food web (that is, predator fish have higher mercury levels than herbivores and insectivores), all sample results within a trophic level can be calculated as a yearly average and compared between years, making for an informative assessment while remaining concise.

However, this approach does not fare well for PCBs, which are more affected by the fat content of fish species rather than their trophic level. For example, trophic level three fish (insectivores) often include both some of the most-contaminated species for PCBs (such as catfish and carp), as well as some of the least-contaminated species for PCBs (such as bluegill and other panfish). If the same species have been consistently collected across years in a water body, then species PCB concentrations can be evaluated directly, but if different species have been collected across years, then other approaches must be considered. Therefore, PCB contamination trends are often evaluated on a case-by-case basis to ensure the most reliable conclusions.

Mercury

Mercury concentrations in the Raccoon Creek study area were relatively low, with most sampling results below Ohio's 0.220 mg/kg threshold for issuing consumption advisories at the one meal per month level. Mercury concentrations often fluctuate substantially between years, with such normal fluctuations observed in the Raccoon Creek mainstem (Figure 36). Insufficient data was collected from Little Raccoon Creek to conduct a trend analysis.

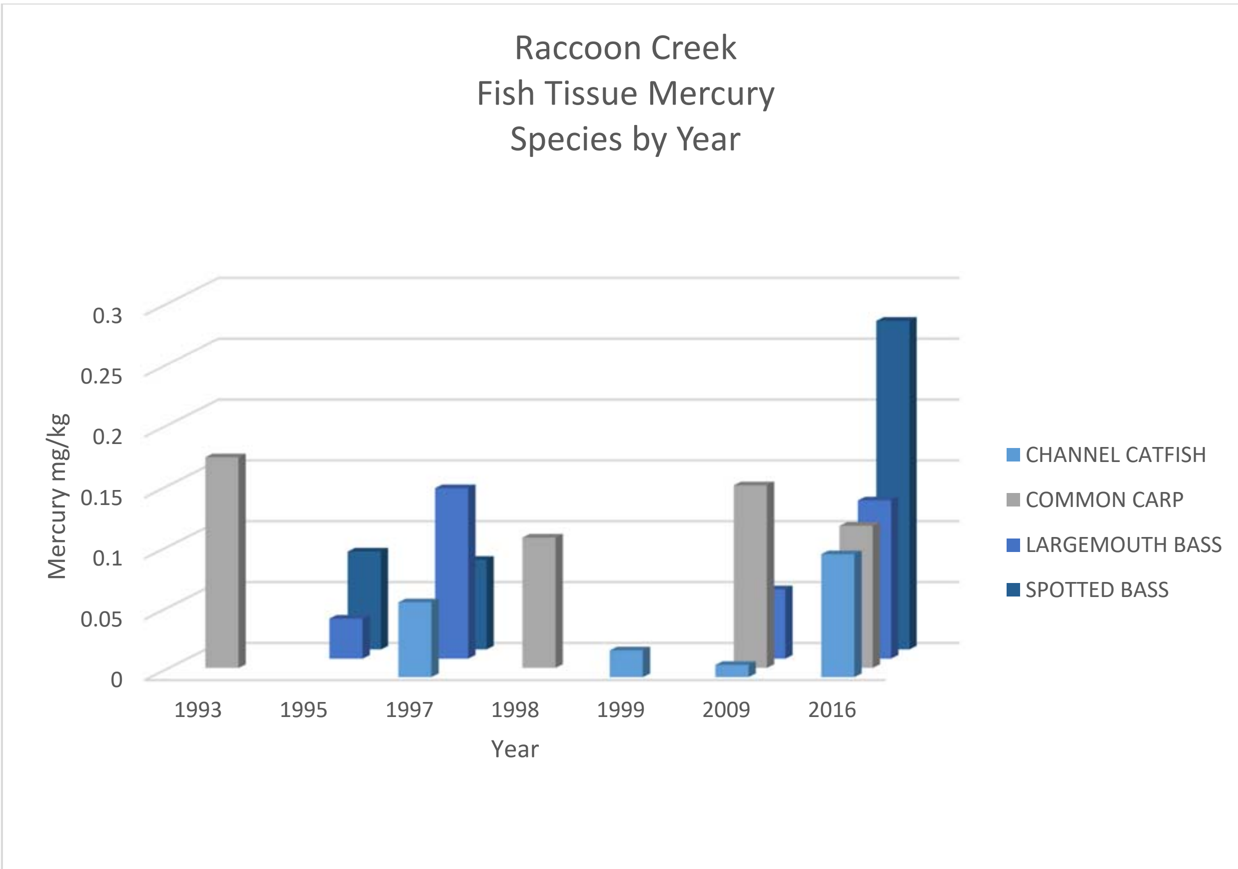


Figure 36 — Average fish tissue mercury concentration by year and trophic level for Raccoon Creek. Mercury concentrations were generally low, with most yearly averages below Ohio's 0.220 mg/kg threshold for issuing consumption advisories at the one meal per month level. Observed inter-annual fluctuations were consistent with expected natural variation. Elevated levels of mercury above Ohio's advisory threshold of 0.220 mg/kg were observed in spotted bass in 2016. Selected data shown based on species with multiple years of data and new samples collected in 2016.

PCBs

PCB concentrations in Raccoon Creek fish were generally low and of minimal concern. No noteworthy trends were observed in the data, although one outlier value was observed in 1998, when a common carp sample had 1.02 mg/kg total PCBs in the fillet sample. This level of contamination just exceeds the threshold for six meals per year consumption level and represents an actual risk level of approximately one meal per month. Other than this single sample, PCB levels in these fish have been consistent and low across all sampling events (Figure 37). Insufficient data was collected from Little Raccoon Creek to conduct a trend analysis.

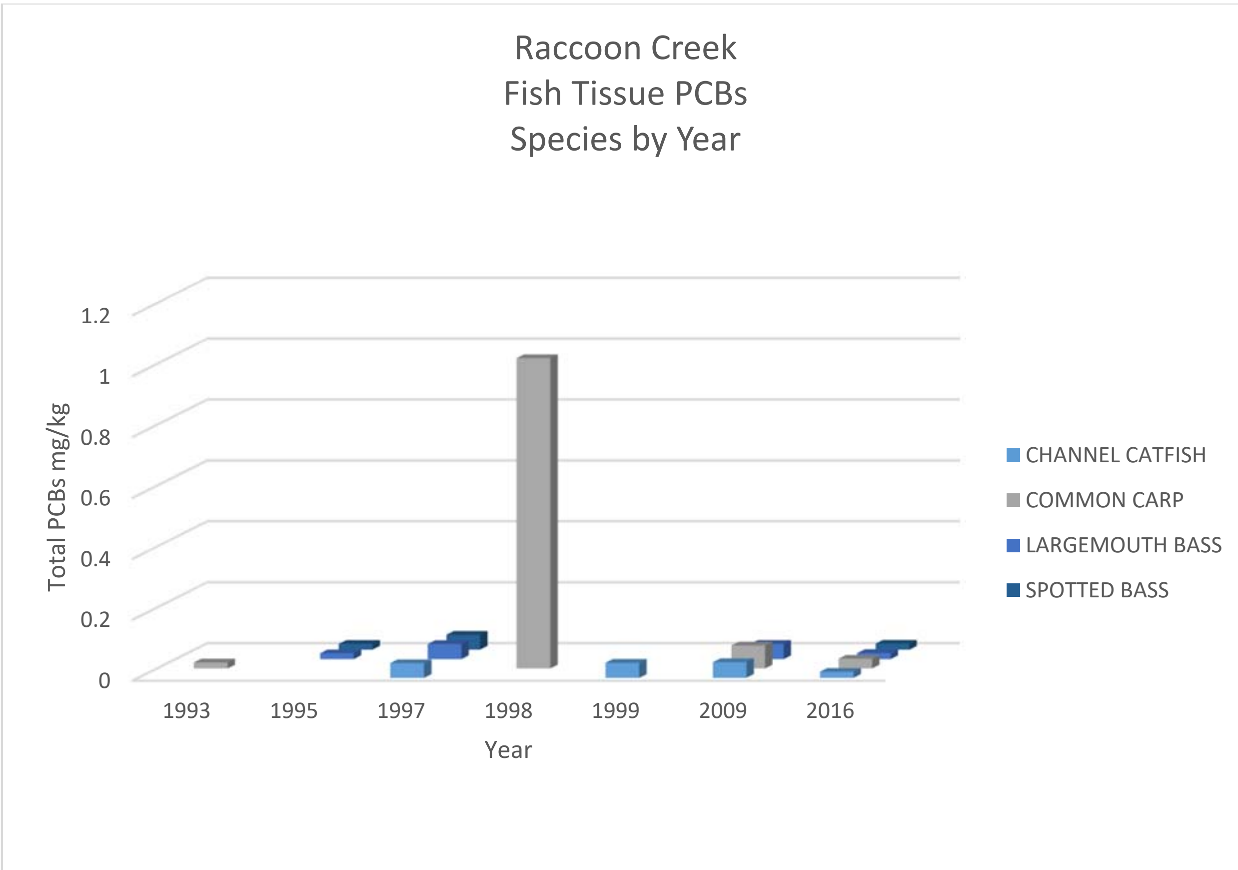


Figure 37 — PCB data from selected species in Raccoon Creek over time, showing generally low PCB concentrations and one outlier value in a single sample of common carp in 1998.

Beneficial Use Designations and Recommendations

Aquatic Life Use Status

Ohio EPA last conducted regular monitoring and assessment in the Raccoon Creek watershed in 1995. The 2016 survey marks the second comprehensive study of the watershed by Ohio EPA. As such, the aquatic life use designations for most of the larger streams within the basin have been verified with biocriteria. However, selected waterbodies have aquatic life use designations which are still based on the original 1978 and 1985 state water quality standards. The techniques in use at that time did not include standardized approaches to the collection of in-stream biological data or numeric biocriteria. There are two such streams in this survey, which constitutes the first application of an objective and robust data-driven process to ascertain the appropriate aquatic life use designation. Any recommended changes to beneficial use designations will go through the Ohio rulemaking process before being finalized.

Existing and recommended aquatic life use(s) resulting from the 2016 intensive survey are summarized in Table 28. Affirmation of existing uses, re-designation of existing, yet unverified uses, or designation of previously unlisted waters and other pertinent information, where needed, are presented below. Forty-one streams were evaluated for aquatic life and recreational use potential in 2016 and 2017 (Table 28). Significant findings of this survey include the following:

- Raccoon Creek from the dam in Vinton (RM 40.3) to the Ohio River backwaters (RM 8.15) is recommended Exceptional Warmwater Habitat. All sites sampled fully attained the applicable EWH biocriteria.
- The previously Limited Resource Water-designated section of Raccoon Creek (from the confluence of the East and West branches (RM 111.0) to Sandy run (RM 95.52)) is recommended the Warmwater Habitat aquatic life use. The designated and previously verified WWH aquatic life use was found to be appropriate for the remaining sections of Raccoon Creek (RM 95.52 to RM 40.3 and RM 8.15 to the mouth).
- Improvements in water quality on the lower 4.31 RMs of Hewett Fork warrants the WWH aquatic life use. These improvements are attributable to an acid mine drainage reclamation project on Hewett Fork that enters at RM 11. Water quality and biological performance on Hewett Fork upstream of RM 4.13 is still impacted by legacy effects of surface mining and the reclamation project, but not to the extent to justify keeping the LRW aquatic life use. This section is recommended the Western Allegheny Plateau – mine affected Modified Warmwater Habitat aquatic life use.
- Twenty-eight streams that were previously verified WWH during the 1995 survey of Raccoon Creek are recommended to remain as such. These streams include Bullskin Creek, Little Bullskin Creek, Clear Fork, Claylick Run, Little Indian Creek, Barren Creek, Little Raccoon Creek, Meadow Run, Robinson Run, Strongs Run, Flatlick Run, Elk Fork, Puncheon Fork, Austin Powder Tributary to Elk Fork (RM 11.17), Long Run, Flat Run, Onion Creek, Laurel Run, Rockcamp Creek, Coal Run, Pine Run, Grass Run, Brushy Fork, Siverly Creek, Tributary to Raccoon Creek (RM 98.96), Twomile Run, West Branch Raccoon Creek, and Honey Fork.
- The WWH aquatic life use designation is recommended for the entire length of Dickason Run. The headwaters of Dickason Run from its origin downstream to Dixon Run (RM 1.3) was previously designated WWH. The remaining section of the stream was previously designated LRW, but biological performance during the 2016 survey supports redesignation to WWH as the survey documented full attainment of the WWH biocriteria.
- The WWH designation currently assigned to four streams was verified. These were Indian Creek, Deer Creek, Sandy Run, and Little Sandy Run.

- McConnel Run and Williams Run were previously unverified EWH and are recommended WWH. The data collected in 2016 represent the first complete biological assessment of these two streams. These assessments did not support the presumed EWH designations that currently apply.
- Big Beaver Creek was not previously designated an aquatic life use. Biological performance supports a WWH recommendation.
- Indiancamp Run and Wolf Run were previously designated LRW. Biological performance from the 2016 survey is indicative of improved water quality and have been recommended WWH.
- Reclamation projects in the East Branch of Raccoon Creek have significantly improved the biological community. No fish were found in the East Branch of Raccoon Creek during the 1995 survey but after reclamation projects began in 2008, a total of nineteen species of fish have been found. The macroinvertebrate community has also improved from 21 taxa in 1995 to 34 taxa in 2016. While the East Branch of Raccoon Creek is not fully meeting the WWH ALU, exceptional habitat scores (QHEI mean = 73), improved biological community and ongoing reclamation and maintenance projects by the Raccoon Creek Partnership warrant a recommendation from LRW to WWH ALU
- Deleterious and pervasive acid mine drainage affects were still found to be preventing improvements to the water quality and biological performance of two streams. The existing LRW designation for these streams, including Rockcamp Run and Pierce Run is recommended to be retained.
- There are fifteen streams listed as unverified WWH in the water quality standards (Table 28) and numerous undesignated streams that were not able to be assessed during the 2016 survey. These streams should be evaluated to determine if there are additional EWH or CWH streams in the basin.

All streams or stream segments in the Raccoon Creek study area should retain or be assigned the Primary Contact Recreation use. In addition, all streams in the study area should retain or be assigned the Agricultural Water Supply and Industrial Water Supply uses.

Little Raccoon Creek, Deer Creek, McConnel Run, Strongs Run, Williams Run, Pierce Run, upper Elk Fork, Sandy Run, Little Sandy Run, and Brushy Fork are all currently listed as a State Resource Water (SRW). The SRW is an outdated antidegradation category being phased out as described in OAC 3745-1-05(A)(25) and replaced with the modern antidegradation categories as described in OAC 3745-1-05. The SRW listing for all the streams listed above are recommended to be removed and replaced with the General High Quality Waters (GHQW). In addition, Wheelabout Creek, which was sampled in 2010, was also found to have habitat and biological characteristics consistent with the GHQW antidegradation category and is therefore also recommended to be listed as such in place of the current SRW listing.

Stream Improvements

Acid mine drainage reclamation projects throughout the watershed have reduced acid and metal loads to Raccoon Creek and Little Raccoon, which are largely attributable to the improvements of biological performance and water quality. These projects should continue and more added as seen fit by ODNR – DMRM and the Raccoon Creek Partnership.

As it exists today, instream habitat of Raccoon Creek downstream RM 72.22, in the absence of other stressors, should be able to sustain an exceptional aquatic community. A dam in the town of Vinton (RM 40.3) is a barrier to fish passage, with 18 species of fish found exclusively downstream of the dam. The size of Raccoon Creek and its instream habitat, up to RM 72.22, should not preclude any of these fish species from residing in this stretch. Removal of the dam would improve upstream habitat and allow for fish passage. See the discussion in the Raccoon Creek section of Aquatic Life Use Changes and Trends. It is recommended that the dam at RM 40.3 on Raccoon Creek be removed.

Recovery from the pervasive excessive sand bedload is through the process of bank erosion that allows for bank widening, the formation of an active floodplain, defined channel features, and eventual aggradation. This condition invites efforts to combat erosion, like rip-rapping and channelization, which are counter-productive to restoring a stable channel geometry. Maintaining or widening the natural riparian area and allowing the stream to move toward a better equilibrium between erosion and deposition will result in generally improved biological conditions.

Sand bedload issues were exacerbated by the loss of riparian habitat on Raccoon Creek at St Rt 328 and Mitchell Hollow Rd, Clear Fork, Rockcamp Creek, Hewett Fork at RM 4.31, and Onion Creek. Clear Fork is severely eroded in the lower reaches. The area surrounding Wolf Run was recently cleared, negatively impacting the stream. The other streams are recovering from previous channelization and have narrow to very narrow riparian areas. It is recommended that a wide riparian area be preserved around these streams.

It is recommended that the acid mine drainage mitigation projects throughout the watershed continue.

Restricting and managing livestock access to Deer Creek and upper Dickason Run would have an immediate positive water quality benefit.

Table 28 — Use designation recommendations for water bodies in the Raccoon Creek basin. Designations based on the 1978 and 1985 water quality standards appear as asterisks (*). A plus sign (+) indicates a confirmation of a current designation and a triangle (▲) denotes a new recommended use based on the findings of this study. Streams evaluated in the 2016–2017 study are in bold.

Water Body Segment	Use Designations													Comments
		Aquatic Life Habitat						Water Supply			Recreation			
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
Raccoon creek - confluence of East and West branches (RM 111.9) to Vinton Dam (RM 40.3)		▲							+	+		+		
- Vinton Dam (RM 40.3) to Ohio River backwaters (RM 8.15)			▲						+	+		+		
- Ohio River backwaters (RM 8.15) to the mouth		+							+	+		+		
Bear run		*							*	*		*		
Bullskin creek		+							+	+		+		
Little Bullskin creek		+							+	+		+		
Burnt run		*							*	*		*		
Rocklick creek		*							*	*		*		
Clear fork		+							+	+		+		
Claylick run		+							+	+		+		
Little Claylick run		*							*	*		*		
Fox branch		*							*	*		*		
Rocky fork		+							+	+		*		
Mud creek		*							*	*		*		
Fork creek		*							*	*		*		
Polecat run		*							*	*		*		

Water Body Segment	Use Designations													Comments
		Aquatic Life Habitat						Water Supply			Recreation			
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
Big Beaver creek		▲							▲	▲		▲		
Little Beaver creek (Big Beaver creek RM 1.63)		+							+	+		+		
Ryan run		+							+	+		+		
Indian creek		*/+							*/+	*/+		*/+		
Little Indian creek		+							+	+		+		
Plum run		+							+	+		*		
Barren creek		+							+	+		+		
Trace run		+							+	+		+		
Little Raccoon creek - Lake Rupert	~~+~~		*					+	*	*		*		Recommend GHQW
- at RM 30	~~+~~	+						+	+	+		*		Recommend GHQW
- all other segments	~~+~~	+							+	+		+		Recommend GHQW
Deer creek	~~*~~	*/+							*/+	*/+		*/+		Recommend GHQW
Keeton run		*							*	*		*		
Spring run		*							*	*		*		
Dickason run - headwaters to Dixon run (RM 1.3)		+							+	+		+		
- Dixon run (RM 1.3) to the mouth		▲							+	+		+		
Kyger run							o		*	*		*		Acid mine drainage
Tarcamp run							+		*	*		*		Acid mine drainage
Goose run							+		+	+			+	Acid mine drainage

Water Body Segment	Use Designations													Comments
		Aquatic Life Habitat						Water Supply			Recreation			
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
Greasy run							+		+	+			+	Acid mine drainage
Buffer run							+		+	+			+	Acid mine drainage
Flint run							+		+	+			+	Acid mine drainage
Coal run		+							+	+			+	
Rich run							+		+	+		+		Acid mine drainage
Mulga run							+		*	*		*		Acid mine drainage
Meadow run		+							+	+		+		
Sand run		+							*	*		*		
Tripp run		*							*	*		*		
Sugar run		+							+	+		+		
Johnson run		*							*	*		*		
McConnel run	~~*~~	▲							*/+	*/+		*/+		Recommend GHQW
Robinson run		+							+	+		+		
Sugar run		*							*	*		*		
Strongs run	~~*~~	+							+	+		+		Recommend GHQW
Williams run	~~*~~	▲							*/+	*/+		*/+		Recommend GHQW
Opossum run		+							+	+		+		
Flatlick run		+							+	+		+		
Karr run							+		+	+			+	Acid mine drainage

Water Body Segment	Use Designations													Comments
		Aquatic Life Habitat						Water Supply			Recreation			
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
Indiancamp run		▲							+	+		+		
Rockcamp run							+		+	+		+		Acid mine drainage
Pierce run	~~*~~						+		+	+		+		Acid mine drainage/ Recommend GHQW
Zinns run		+							+	+		+		
Elk fork - headwaters to Puncheon fork (RM 13.88)	~~+~~	+							+	+		+		Recommend GHQW
- Puncheon fork to the mouth		+							+	+		+		
Alman run		+							+	+		*		
Flat run		+							+	+		*		
Wolf run		▲							+	+		*/+		
Puncheon fork		+							+	+		+		
Austin Powder tributary		+							+	+			+	
Brush fork							o		*	*		*		Acid mine drainage
Long run		+							+	+			+	
Flat run		+							+	+			+	
Russell run		+							+	+			+	
Merrit run		+							+	+			+	
Tedroe run		+							+	+			+	
Onion creek		+							+	+		+		
Laurel run		+							+	+		+		

Water Body Segment	Use Designations													Comments
		Aquatic Life Habitat						Water Supply			Recreation			
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
Hewett fork – headwaters to Rockcamp Rd. (RM 4.3)				▲					+	+		+		WAP ecoregion – mine affected
- Rockcamp Rd. to mouth		▲							▲	▲		▲		
Rockcamp creek		+							+	+		+		
Coal run		+							+	+			+	
Pine run		+							+	+		+		
Grass run		+							+	+			+	
Carbondale creek							+		+	+		+		Acid mine drainage
Sandy run	~~*~~	*/+							*/+	*/+		*/+		Recommend GHQW
Little Sandy run	~~*~~	*/+							*/+	*/+		*/+		Recommend GHQW
Wheelabout creek	~~*~~	+							+	+		+		Recommend GHQW
Brushy fork	~~*~~	+							+	+		+		Recommend GHQW
Dunkle creek		+							+	+		+		
Siverly creek		+							+	+		+		
Unnamed tributary (Raccoon creek RM 98.96)		+							+	+		+		
Rocky branch		*							*	*		*		
Twomile run		+							+	+		+		
East branch		▲							+	+		+		
West branch		+							+	+		+		
Honey fork		+							+	+		+		

<table>
<tr><th rowspan="3">Water Body Segment</th><th colspan="13">Use Designations</th><th rowspan="3">Comments</th></tr>
<tr><th></th><th colspan="6">Aquatic Life Habitat</th><th colspan="3">Water Supply</th><th colspan="3">Recreation</th></tr>
<tr><th>SRW</th><th>WWH</th><th>EWH</th><th>MWH</th><th>SSH</th><th>CWH</th><th>LRW</th><th>PWS</th><th>AWS</th><th>IWS</th><th>BW</th><th>PCR</th><th>SCR</th></tr>
<tr><td>| | | | | | | |
Claylick run</td><td></td><td>*</td><td></td><td></td><td></td><td></td><td></td><td></td><td>*</td><td>*</td><td></td><td>*</td><td></td><td></td></tr>
</table>

SRW = state resource water; WWH = warmwater habitat; EWH = exceptional warmwater habitat; MWH = modified warmwater habitat; SSH = seasonal salmonid habitat; CWH = coldwater habitat; LRW = limited resource water; PWS = public water supply; AWS = agricultural water supply; IWS = industrial water supply; BW = bathing water; PCR = primary contact recreation; SCR = secondary contact recreation.

Acknowledgements

The following Ohio EPA staff provided technical expertise for this project:

Report preparation and analysis	Jordan Jenkins, Chuck McKnight, Kelly Capuzzi, Randy Spencer, Sarah Becker, Gary Klase
Reviewers	Mari Piekutowski, Rachel Taulbee and Chris Skalski
Data Collection	**Water Column and Sediment Chemistry**
	Kelly Capuzzi and Randy Spencer with interns Carson Calhoun, Michael Crowe, and Sarah Maj
	Macroinvertebrate Community
	Laura Hughes with intern Abbie Bowman
	Fish Community
	Jordan Jenkins with interns Ross Stadt and Dylan Schneider
	Water Quality Sonde Monitoring
	Sarah Becker with interns Nick Doarn, Quinn Harnett, Mitch Skinner, Mikaela Tardivo, and Eva Rezek

The Ohio EPA appreciates the cooperation of the property owners who allowed Ohio EPA personnel access to the project area.

References

Alexander, R. B., Elizabeth, B. M., Richard, S. A., Gregory, E. S., & Richard, M. B. (2007). The role of headwater streams in downstream water quality. *Journal of the American Water Resources Association, 43*(1), 41 - 59. doi:10.1111/j.1752-1688.2007.00005.x

Auch, T. (2014, November 17). *The water-energy nexus in Ohio, part II*. Retrieved 2016, from Fractracker Alliance: https://www.fractracker.org/2014/11/water-energy-nexus-ohio-pt2/

Auch, T. (2015, September 29). *The curious case of the shrinking Utica shale play*. Retrieved 2016, from Fractracker Alliance: https://www.fractracker.org/2015/09/shrinking-utica-shale-play/

Becker, G. C. (1983). Muskellunge. In *Fishes of Wisconsin* (pp. 405-414). Madison, Wisconsin: University of WIsconsin Press. Retrieved from http://digital.library.wisc.edu/1711.dl/EcoNatRes.FishesWI

Bonnett, R. B., Noltimier, H. C., & Sanderson, D. D. (1991). A paleomagnetic study of the early Pleistocene Minford Silt Member, Teays Formation, West Virginia. In W. N. Melhorn, & J. P. Kempton, *Geology and hydrogeology of the Teays-Mahomet Bedrock Valley System* (Vol. 258). Geological Society of America. doi:10.1130/SPE258-p9

Bowman, J. (2017). *Stream Health Report.* Athens: Voinovich School of Leadership and Public Affairs. Ohio University.

Camp, M. J. (2006). *Roadside Geology of Ohio.* Missoula, Montana: Mountain Press Publishing.

Clifford, J. E. (1954). *Studies of Acid Mine Waters With Particular Reference to the Raccoon Creek Watershed.* Columbus: Battelle Memorial Institue.

Conway, E. A. (n.d.). *Iron Furnace History in Ohio.* Retrieved from The Olde Forester: http://www.oldeforester.com/ironintr.htm

Crowell, D. L. (1995). *History of the Coal-Mining Industry in Ohio.* Ohio Department of Natural Resources, Division of Geological Survey. Columbus: State of Ohio.

De Caceres, M., & Legendre, P. (2009). Associations between species and groups of sites: indices and statistical inference. *Ecology*. Retrieved from http://sites.google.com/site/miqueldecaceres/

Dodds, W. K. (2006). Eutrophication and Trophic State in Rivers and Streams. *Limnology and Oceanography, 51*(1-2), 671-680.

Dodds, W. K. (2007). Trophic State, Eutrophication and Nutrient Criteria in Streams. *Trends in Ecology and Evolution, 22*(12), 669-676.

Dufor, A. (1977). Escherichia Coli: The Fecal Coliform. In A. W. Hoadley, *Bacterial Indicators/health Hazards Associated with Water* (pp. 48-58). ASTM.

Fajen, A., & Layzer, J. B. (1993). Agricultural Practices. In C. F. Bryan, & D. A. Rutherford (Eds.), *Impacts on warmwater streamsL guidelines for evaluation* (pp. 257-270). Bethesda, Maryland: American Fisheries Society, Southern Division.

Farley, M. E., & Ziemkiewicz, P. (2005). *Selected Abandoned Mined Land Reclamation Projects and Passive Treatments in Ohio.*

Heiskary, S., & Markus, H. (2003). *Establishing Relationships Among In-Stream Nutrient Concentrations, Phytoplankton Abundance and Composition, Fish IBI and Biochemical Oxygen Demand in Minnesota USA*

Rivers Final Report to USEPA Region V. Minnesota Pollution Control Agency, Environmental Outcomes Division.

Homer, C. G., Dewitz, J. A., Yang, L., Jin, S., Danielson, P., Xian, G., . . . Megown, K. (2015). Completion of the 2011 National Land Cover Database for the conterminous United States-Representing a decade of land cover change information. *Photogrammetric Engineering and Remote Sensing, 81*(5), 345-354.

Kennard, M. J., Arthington, A. H., Pusey, B. J., & Harch, B. D. (2005). Are alien fish a reliable indicator of river health? *Freshwater Biology, 50*, 174-193.

Lafferty, M. B. (1979). *Ohio's Natural Heritage.* Columbus, Ohio: The Ohio Academy of Science.

Landers, S. (2014). *Acid Mine Drainage Abatement and Treatement (AMDAT) Plan Update for the Little Raccoon Creek Watershed.* Athens: Ohio Univerisity Voinovich School of Leadership and Public Affairs.

Laverty, B. (2000). *Acid Mine Drainage Abatement and Treatement (AMDAT) Plan for Little Raccoon Creek Watershed, Jackson County, Ohio.* Athens: Ohio University.

Laverty, B., Painter, M., Stoertz, M., Hoy, J. B., Hoy, R., Last, J., . . . Farley, M. (2000). *Acid Mine Drainage Abatement and Treatment (AMDAT) Plan for the Little Raccoon Creek Watershed, Jackson County, Ohio.* Ohio Department of Natural Resources. Ohio University. Retrieved from http://watersheddata.com/AMDATView_Report.aspx

MacDonald, D., Ingersoll, C., & Berger, T. (2000). Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems. *Archives of Environmental Contamination and Toxicology, 39*(1), 20-31.

McCament, B. (2003). *Raccoon Creek Managment Plan. .* Athens: The Institute for Local Government Administration and Rural Development (ILGARD). Ohio University.

McCament, B. (2007). *Watershed Action Plan: Raccoon Creek above Hewett Fork to Below Elk Fork.* Athens: Voinovich School of Leadership and Public Affairs, Ohio University.

McCament, B. M. (2007). *Sediment Total Maximum Daily Load for the Upper Basin of Raccoon Creek.* Ohio University, Voinovich School of Leadership and Public Affairs, Athens.

Miller, W. E. (1943). Petroleum in southeastern Ohio. *The Ohio Journal of Science*, 121-134.

Miltner, R. J. (2010). A Method and Rationale for Deriving Nutrient Criteria for Small Rivers and Streams in Ohio. *Environmental Management, 45*, 842-855.

Ohio Department of Natural Resources. (1954). *Studies of Acid Mine Waters with Particular Reference to the Raccoon Creek Watershed.* Battelle Memorial Institute.

Ohio Department of Natural Resources. (1982). *Raccoon Creek Basin Summary.* Divison of Reclamation. Gwinn, Dobson & Foreman Consulting.

Ohio Department of Natural Resources. (2001). *Gazetteer of Ohio Streams.* Columbus.

Ohio Department of Natural Resources. (2011). *A Citizen'sGuide to Mining and Reclamation in Ohio.* Division of Mineral Resources Management, Columbus.

Ohio Department of Natural Resources. (2013). *Ohio's Geology in Core and Outcrop.* Division of Geological Survey. Columbus: State of Ohio.

Ohio Department of Natural Resources. (2014, June 1). Oil and gas well locations of Ohio. Columbus, Ohio. Retrieved 2016

Ohio Department of Natural Resources. (2015). *Water withdrawal regulations for oil and gas drilling.* Columbus: State of Ohio.

Ohio Environmental Protection Agency. (1991). *Biological and Water Quality Study of the Southeast Ohio River Tributaries.* Columbus: Ecological Assessment Section Division of Water Quality Planning and Assessment.

Ohio Environmental Protection Agency. (1994). *Ecological Recovery Endpoints for Streams Affected by the Meigs #31 Mine Discharges during July-September 1993.* Division of Surface Water - Ecological Assessment Section, Columbus, OH. Retrieved from http://epa.ohio.gov/portals/35/documents/LeadingCreek1994TSD.pdf

Ohio Environmental Protection Agency. (1996). *Biological and Water Quality Study of the Raccoon Creek Basin (1995).* Columbus: Ohio EPA Technical Report Number MAS/1996-12-7.

Ohio Environmental Protection Agency. (2002). *Total Maximum Daily Load (TMDL) for the Upper Raccoon Creek.* Columbus: Division of Surface Water.

Ohio Environmental Protection Agency. (2008). *Sediment reference values.* Columbus: Divison of Environmental Remediation and Response.

Ohio Environmental Protection Agency. (2010). *Guidance on Evaluating Sediment Contaminant Results .* Ohio EPA.

Ohio Environmental Protection Agency. (2012). *Sediment sampling guide and methodologies, 3rd edition.* Division of Surface Water, Columbus.

Ohio Environmental Protection Agency. (2013). *Surface Water Field Sampling Manual for waqter column chemistry, bacteria, and flows.* Columbus.

Ohio Environmental Protection Agency. (2014). *Preamble: Proposed Stream Nutrient Assessment Procedure.* Nutrients Technical Advisory Group - Assessment Procedure Subgroup, Columbus.

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

Ohio Environmental Protection Agency. (2016). *Study Plan for the 2016 Biological and Water Quality Survey of the Raccoon Creek Basin. Vinton, Jackson, Hocking, Athens, Gallia & Meigs Counties.* Columbus: Division of Surface Water.

Ohio University. (2016). *Raccoon Creek Watershed Report.* Athens: Non-Point Source Monitoring System, Ohio University .

Oksanen, J. F., Blanchet, G., Fiendly, M., Kindt, R., Legendre, P., McGlinn, D., & Minchin, P. R. (2017). *vegan: Community Ecology Package. R*. Retrieved from https://CRAN.R-project.org/package=vegan.

Omernik, J., & Griffith, G. (2008, December 11). *Ecoregions of Indiana and Ohio (EPA)*. Retrieved 2015, from The Encyclopedia of Earth: http://www.eoearth.org/view/article/152069

R Core Team. (2018). R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from https://www.R-project.org/

Rice, C. (2002). *Acid Mine Drainage Abatement and Treatment (AMDAT) Plan for the Headwaters of Raccoon Creek Watershed.* Athens: Insitute for Local Government Administration and Rural Development (ILGARD), Ohio University.

Rice, C. (2003). *Acid Mine Drainage Abatement and Treatement (AMDAT) Plan for the Middle Basin of the Raccoon Creek Watershed.* Athens: Institute for the Local Government Administration and Rural Development. Ohio University.

Rice, C., Flemming, L., Hoy, J., Farley, M., Rankin, E., O'Dee, & Minameyer, T. (2003). *Acid Mine Drainage Abatement and Treatment (AMDAT) Plan for the Middle Basin of the Raccoon Creek Watershed.* The Institute for Local Government and Rural Development, Athens. Retrieved from http://watersheddata.com/AMDATView_Report.aspx

Rice, C., Hoy, J., Hoy, R., Last, J., Farley, M., Grow, J., . . . Simon, K. (2002). *Rice, C., Hoy, J, Hoy, R, Last, J, Farley, M., Grow, Acid Mine Drainage Abatement and Treatment (AMDAT) Plan for the Headwaters of the Raccoon Creek Watershed.* Ohio University, The Institute for Local Government and Rural Development, Athens. Retrieved from http://watersheddata.com/AMDATView_Report.aspx

Rice, D., & Zimmerman, B. (2019). *A Naturalist's Guide to the Fishers of Ohio.* Columbus: Ohio Biological Survey.

Soil Survey Staff. (2004, January 20). Soil Survey Geographic Database. Fort Worth, Texas: U.S. Department of Agriculture, Natural Resources Conservation Service.

Stokes, B. (2018). *Nine-Element Nonpoint Source Implementation Strategy (NPS-IS) Town of Zaleski-Raccoon Creek HUC-12(05090101 02 05).* Athens: Voinovich School of Leadership. Ohio University.

Trautman, M. B. (1981). Ohio Lamprey. In *The Fishes of Ohio* (pp. 151-153). Columbus, Ohio: Ohio State University Press.

U.S. Department of the Interior. (1967). *Recommendations for Water Pollution Control, Raccoon Creek Basin, Ohio.* Federal Water Pollution Control Administration, Mine Drainage Unit, Planning and Evaluation Section, Wheeling Field Station, Ohio River Basin Project.

U.S. Environmental Protection Agency. (2012, May 12). Level IV Ecoregions of Ohio. Corvallis, Oregon.

U.S. Environmental Protection Agency. (2015). *State Development of Numeric Criteria for Nitrogen and Phosphrus Pollution.* Nutrient Policy and Data. Retrieved January 2015

U.S. Fish and Wildlife Service. (2006). *Final Natural Resource Restoration Plan and Environmental Assessment for Leading Creek Stream System.* Region 3 Ecological Services, Reynoldsburg, OH.

US Department of the Interior. (1967). *Recommendations for Water Pollution Control Raccoon Creek Basin, Ohio.* Wheeling, West Virginia: Federal Water Pollution Control Administration.

Vengosh, A., Jackson, R. B., Warner, N., Darrah, T. H., & Kondash, A. (2014, March 7). A critical review of the risks to water resources from unconventional shale gas development and hydraulic fracturing in the United States. *Environmental Science & Technology, 48*, 8334 - 8348. doi:dx.doi.org/10.1021/es40511

Waters, T. F. (1995). *Sediment in Streams: Sources, Biological Effects and Control.* Bethesda, Maryland: American Fisheries Society.