Biological and Water Quality Study of the Upper Little Miami River, 2011

Clark, Clinton, Greene, Madison, Montgomery,and Warren Counties

OHIO EPA Technical Report EAS/2013-05-06

Division of Surface Water
Ecological Assessment Section
February 20, 2014

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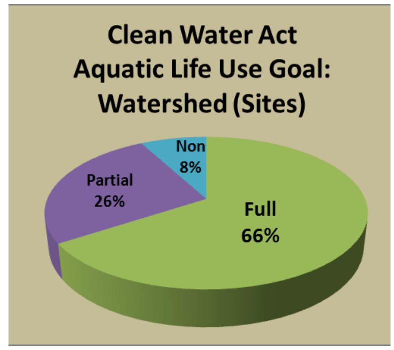
EXECUTIVE SUMMARY

Rivers and streams in Ohio support a variety of uses such as recreation, water supply, and aquatic life. Ohio EPA evaluates each stream to determine the appropriate use designation and to also determine if the use is meeting the goals of the federal Clean Water Act (CWA). Thirty-five streams in the upper Little Miami River watershed, located in Clark, Clinton, Greene, Montgomery, and Warren counties, were evaluated for aquatic life and recreation use potential in 2011 (Table 1, Figure 1).



Of the 76 biological samples collected and assessed throughout the watershed, 50 (66%) were fully meeting the designated or recommended aquatic life use, 20 (26%) were in partial attainment, and 6 (8%) were in non-attainment (Table 2, Figure 2). The majority of sites not meeting CWA goals were located in tributaries to the Little Miami River. The upper Little Miami River mainstem, sampled at 22 locations, was meeting biological goals at 21 sites, accounting for 53.23 stream miles of continuous full attainment. Only the most upstream sampling location at river mile (RM) 104.88 was in non-attainment due to habitat alterations and discharges from an upstream agribusiness.

Partial and non-attainment in the tributaries was due to a variety of influences (Table 2). Habitat alterations, namely channelization, were responsible for impairments in Little Miami River headwater tributaries and in the Anderson Fork subwatershed. A small dam located in Port William affected biological communities immediately upstream and downstream from its location on Anderson Fork. Urban runoff and municipal wastewater treatment plant (WWTP) discharges impacted the Beaver Creek and Little Beaver Creek subwatersheds, while urban runoff affected biological communities in Glady Run. Agricultural land use practices contributed to organic enrichment in Grog Run and Flat Fork, and also to sedimentation in South Branch Caesar Creek downstream from Jamestown. Low to intermittent stream flows impacted the small streams draining into Caesar Creek Lake and those emptying into the Little Miami River near Waynesville.

Evaluation of *E. coli* results revealed that 42 of the 46 locations (91%) failed to attain the applicable geometric mean criterion, indicating an impairment of the recreation use at these locations. Agriculture, accounting for 67% of the total land use in the upper Little Miami River watershed, was a potential source of contamination at many of the impaired sites. However, exacerbated by above normal precipitation and higher stream flow, the preponderance of elevated bacteria counts may also be attributed to ubiquitous background contamination.

Water chemistry was collected at 91 sites in the watershed, including 23 on the upper Little Miami River mainstem. Sampling results generally reflected good to very good water quality across the watershed, with only a handful of Water Quality Standards (WQS) criteria exceedances. On the mainstem, dissolved oxygen (DO) fell below critical levels in the headwaters due to a lack of riparian buffer and interstitial stream flows. In the tributaries, low DO concentrations were frequently documented in smaller streams (<10mi^2), particularly those draining into Caesar Creek Lake and in the Anderson Fork subwatershed, due to intermittent flows. Lack of riparian cover was responsible for temperature exceedances in the headwaters of Anderson Fork, Grassy Run, and in Little Beaver Creek upstream from the Montgomery Eastern Regional WWTP. One exceedance for ammonia was noted in Lisbon Fork due to the over-application of manure to surrounding fields. Wide diel DO and pH swings and high chlorophyll-a and nutrient levels were particularly evident in the mainstem at Dolly Varden Road (RM 98.98), Little Beaver Creek, and North Fork Massies Creek.

The upper Little Miami River watershed was last sampled in 1998, and the corresponding TMDL was approved by USEPA in 2002. One of the primary recommendations of the TMDL was to reduce phosphorus loadings to the watershed and to the Little Miami River mainstem in particular (Ohio EPA 2002). In the Little Miami River mainstem, total phosphorus levels were markedly lower in 2011, with an overall median of 0.100mg/l compared to 0.235 mg/l in 1998. With respect to the TMDL target values, 70% of 2011 individual total phosphorus values were below the target, compared to only 29% of the 1998 concentrations.

These reductions, owing in large part to phosphorus removal at six of the major WWTPs in the watershed, have aided in the full attainment of biological criteria at 53.23 miles of the upper Little Miami River mainstem. Only 19.89 miles were in full attainment in 1998. Most of the improvement to biological communities was realized in the fish assemblages, which were significantly improved in the mainstem in 2011, especially for the reach downstream from Clifton where the Index of Biotic Integrity (IBI) scores improved by 7 points and the Modified Index of Well-Being (MIwb) scores improved by 0.7 points. However, upstream from Clifton, where the mainstem had been historically and recently channelized and the aquatic life use designation is Warmwater Habitat (WWH), the condition of the fish assemblage was essentially unchanged.

For the upper Little Miami River watershed exclusive of the mainstem downstream from Clifton, the trends in phosphorus concentrations and IBI scores mirror that for headwater and wadeable streams in the Eastern Corn Belt Plains (ECBP). Mean phosphorus concentrations in the upper Little Miami River watershed decreased from 0.170 to 0.066 mg/l, between the 1990s and the 2000s, and mean IBI scores increased from 39 to 45. For the ECBP, phosphorus concentrations decreased from 0.109 to 0.076 mg/l, and IBI scores increased from 38 to 41.

Table 1. Upper Little Miami River watershed sampling locations sampled and assessed by Ohio EPA, 2011-13. Drainage areas are not applicable for WWTP effluents, as the discharge is evaluated from the discharge pipe and not in the receiving stream.

Site #	Station	Stream	Location	River Mile	Drain. Area	Latitude	Longitude
1	M01W62	Little Miami River	Ust Paygro and ust Huntington Road	106.95	1.40	39.820755	-83.590255
2	M01S27	Little Miami River	@ SR 41 SE of South Charleston	104.88	4.60	39.811305	-83.620997
3	M01W64	Little Miami River	@ Jamestown Road	103.13	6.40	39.804812	-83.647115
4	M01P02	Little Miami River	@ Dolly Varden Road near South Charleston	98.98	33.00	39.832435	-83.694644
5	M01P06	Little Miami River	@ Pitchin Road near Clifton	92.27	53.00	39.805788	-83.781185
6	M01W67	Little Miami River	Ust sharp bend, adj N. River Road, ½ mile E of SR 72	89.77	94.00	39.795124	-83.814646
7	M01P12	Little Miami River	@ Grinnel Road near Yellow Springs	85.38	104.00	39.782562	-83.875683
8	M01S09	Little Miami River	Dst Yellow Springs WWTP @ Jacoby Road	83.14	118.00	39.764008	-83.901941
9	600570	Little Miami River	@ US 68	80.63	129.00	39.747738	-83.931180
10	M01S25	Little Miami River	NW Xenia @ Fairgrounds Road	77.70	217.00	39.724134	-83.964143
11	M01W22	Little Miami River	Xenia Ford Rd WWTP effluent	77.03	-	39.716341	-83.969821
12	M01W30	Little Miami River	@ Trebein Road	75.38	238.00	39.707663	-83.991326
13	M01W32	Little Miami River	0.42 mi ust Beaver Creek at Alpha	73.16	241.00	39.698660	-84.019646
14	M01P13	Little Miami River	@ Indian Ripple Road near Kettering	72.30	295.00	39.691208	-84.028840
15	610550	Little Miami River	@ Upper Bellbrook Road near Bellbrook	69.84	302.00	39.661862	-84.040483
16	M01W39	Little Miami River	@ Washington Mills Road	68.54	307.00	39.644936	-84.043080
17	M01W40	Little Miami River	Ust Greene Co.-Sugar Creek WWTP	64.44	345.00	39.616214	-84.029807
18	M01W41	Little Miami River	Sugarcreek WWTP effluent	64.43	-	39.615673	-84.028600
19	M01S30	Little Miami River	Dst Greene Co.-Sugar Creek WWTP	64.28	345.00	39.615734	-84.026943
20	M01W45	Little Miami River	@ Spring Valley Roadside Park	63.28	361.00	39.605425	-84.014169
21	600600	Little Miami River	@ Roxanna-N. Burlington Rd at USGS gage	60.84	367.00	39.583358	-84.030708
22	M01W75	Little Miami River	Just dst Sandy Run, ¾ mi SW Spring Valley Lake	58.30	378.00	39.554934	-84.031342
23	M01P29	Little Miami River	SR 73	53.84	398.00	39.524969	-84.087822
24	M01W54	Little Miami River	Waynesville WWTP effluent	53.79	-	39.524415	-84.089089
25	M01S29	Little Miami River	Adj Corwin Rd, Dst Waynesville WWTP, upstream Newman Run	53.2	402.00	39.523816	-84.090621

Site #	Station	Stream	Location	River Mile	Drain. Area	Latitude	Longitude
26	M01W55	Little Miami River	S of Waynesville; 0.1 miles ust Middletown Road	51.65	413.00	39.498488	-84.100785
27	M01W08	Gilroy Ditch	South Charleston WWTP effluent	1.40	-	39.829301	-83.644333
28	M01W09	Gilroy Ditch	Near ford, 0.9 mi dst South Charleston WWTP	0.50	7.50	39.830208	-83.658161
29	200567	Lisbon Fork	N of South Charleston @ SR 41	2.80	7.00	39.855109	-83.635242
30	M01W10	Lisbon Fork	@ Old Springfield Road	0.40	11.8	39.841238	-83.672803
31	200564	North Fork Little Miami River	At Thorps @ SR 41	9.10	11.50	39.881460	-83.708346
32	M01P04	North Fork Little Miami River	@ North River Road	0.37	35.80	39.807886	-83.790549
33	200562	UT to North Fork Little Miami River (5.60)	S of Springfield @ Crabill Road	0.80	7.40	39.875753	-83.757149
34	200565	UT to Little Miami River (96.26)	SE of Pitchin @ Buffenbarger Road	0.60	6.00	39.831633	-83.734607
35	M01W79	Conner Branch	@ US 68 near mouth	0.17	2.30	39.754936	-83.926780
36	M01W78	Jacoby Branch	@ US 68 SW of Yellow Springs	0.50	5.10	39.767310	-83.915878
37	M01W13	Yellow Springs Creek	Yellow Springs WWTP effluent	0.43	-	39.790368	-83.879261
38	M01P09	Yellow Springs Creek	@ Grinnel Road near mouth	0.10	11.30	39.786162	-83.877883
39	M01W19	Massies Creek	Cedarville WWTP final effluent	8.98	-	39.739026	-83.817436
40	M01S11	Massies Creek	@ Tarbox Cemetery Road dst Cedarville	7.70	55.00	39.736883	-83.839138
41	M01P17	Massies Creek	@ Wilberforce-Clifton Road NR Wilberforce	4.38	63.20	39.722632	-83.882366
42	M01W83	Massies Creek	@ Fawcett Drive N of Xenia	1.20	73.00	39.739934	-83.920543
43	200555	North Fork Massies Creek	Near Selma @ Old Route 42	5.90	18.60	39.781425	-83.725020
44	301220	North Fork Massies Creek	@ US 42, Dst tributary	5.73	17.90	39.781496	-83.727932
45	200554	North Fork Massies Creek	NE of Cedarville @ McMillan Road	2.80	20.90	39.769686	-83.770213
46	M01P19	South Fork Massies Creek	@ Weimer Road near Cedarville	2.15	17.10	39.738288	-83.765385
47	M01P20	South Fork Massies Creek	@ RR at Cedarville	0.14	19.90	39.742257	-83.801671
48	M01W87	Clark Run	@ Stevenson Road NW of Wilberforce	0.44	6.20	39.740862	-83.893983
49	M01S13	Oldtown Creek	@ Mouth near US 68	0.4	10.55	39.735514	-83.934250
50	M01S53	Beaver Creek	@ Fairgrounds Road N of Alpha	3.86	14.80	39.738197	-84.010693
51	M01S37	Beaver Creek	@ Dayton-Xenia Road	1.57	20.90	39.713706	-84.021503
52	M01W56	Beaver Creek	@ US 35 dst Little Beaver Creek	1.04	48.10	39.708840	-84.028075
53	M01W33	Beaver Creek	Beavercreek WWTP effluent	0.4	-	39.700373	-84.027724

Site #	Station	Stream	Location	River Mile	Drain. Area	Latitude	Longitude
54	M01S35	Beaver Creek	Adj Factory Road dst Beaver Creek WWTP	0.20	49.40	39.698168	-84.026494
55	M01S04	Little Beaver Creek	@ Vale Road N of Kettering	6.20	3.60	39.707398	-84.116430
56	M01W01	Little Beaver Creek	Ust Montgomery Co Eastern Regional WWTP	4.76	10.00	39.724546	-84.103634
57	M01S05	Little Beaver Creek	Eastern Regional WWTP effluent	4.75	-	39.725014	-84.103645
58	M01S44	Little Beaver Creek	Ust Grange Hall Rd near Dayton	3.54	16.50	39.726968	-84.085631
59	M01W06	Little Beaver Creek	@ Valleywood	2.83	17.10	39.72658	-84.072577
60	600630	Little Beaver Creek	@ Factory Road near Alpha	0.05	26.40	39.710075	-84.028901
61	M01W84	Ludlow Creek	@ Hilltop Road NW Of Xenia	0.25	6.90	39.715023	-83.975571
62	M01P23	Shawnee Creek	@ Hawkins Road near Xenia	0.65	11.60	39.703623	-83.966371
63	301482	Caesar Creek	@ US 35 W of Jamestown	30.76	8.89	39.662854	-83.754318
64	M02S08	Caesar Creek	@ Paintersville Road at New Jasper	26.50	12.90	39.642569	-83.819672
65	M02S07	Caesar Creek	@ Stone Road SE of Xenia	23.10	64.60	39.633169	-83.869672
66	M02P13	Caesar Creek	@ Paintersville Road	16.52	88.00	39.599179	-83.964552
67	600550	Caesar Creek	@ Corwin Road near Oregonia	0.15	242.00	39.492824	-84.101794
68	M02S12	Anderson Fork	@ Haley Road SE of Port William	18.80	30.00	39.515986	-83.752227
69	M02S02	Anderson Fork	@ Port William Road W of Port William	13.87	50.00	39.553279	-83.795593
70	301480	Anderson Fork	@ McKay Road	7.90	60.32	39.554316	-83.865006
71	M02S01	Anderson Fork	@ Old Winchester Trail	4.90	78.00	39.566376	-83.902888
72	M02P12	Anderson Fork	@ Engle Mill Road	3.27	88.00	39.581720	-83.922407
73	301481	UT to Anderson Fork (9.26)	S. of Lumberton @ US 68	0.20	1.77	39.541675	-83.849881
74	200478	Grassy Run	@ Sabina Road	0.05	8.44	39.542249	-83.779506
75	200476	Grog Run	S of Paintersville @ Bone Road	0.90	8.30	39.564012	-83.823809
76	301735	Painters Creek	At Paintersville @ Bone Road	5.00	5.10	39.588176	-83.820689
77	M02P03	Painters Creek	@ Eleazer Road near Paintersville	0.43	12.80	39.564175	-83.878806
78	M02S16	North Branch Caesar Creek	@ Junkin Road N of Shawnee Hills	6.67	7.00	39.680914	-83.772232
79	M02S15	North Branch Caesar Creek	@ Jasper Road W of Shawnee Hills	1.23	25.70	39.657778	-83.829111
80	301439	South Branch Caesar Creek	Jamestown WWTP effluent	9.00	-	39.656651	-83.738530
81	M02S14	South Branch Caesar Creek	@ Cemetery Road dst Jamestown	8.23	6.50	39.648213	-83.747591
82	M02S13	South Branch Caesar Creek	@ Hoop Road	2.10	17.00	39.630068	-83.834431
83	M02P07	Flat Fork	Oregonia Rd	1.70	15.80	39.473937	-84.045966
84	M02S11	Buck Run	@ SR 380 S of New Burlington	1.18	8.50	39.545585	-83.958596

Site #	Station	Stream	Location	River Mile	Drain. Area	Latitude	Longitude
85	200537	Jonahs Run	@ Oregonia Road	2.10	4.10	39.496403	-84.014212
86	M02P08	Turkey Run	@ Brimstone Mills Road	1.50	3.60	39.520793	-83.963908
87	M01S22	Sugar Creek	@ Wilmington Pike near Centerville	4.11	16.50	39.627479	-84.108111
88	M01P26	Sugar Creek	@ Penewit Road near Spring Valley	0.40	33.20	39.620809	-84.057212
89	M01S51	Little Sugar Creek	Adj Maple Street at Bellbrook	0.45	12.30	39.635009	-84.075304
90	M01W44	Glady Run	Glady Run WWTP effluent	4.93	-	39.658148	-83.964810
91	M01P16	Glady Run	@ Hedges Road near Xenia	4.08	6.90	39.649991	-83.975627
92	M01W60	Glady Run	@ Schnebly Road, south crossing	1.10	12.40	39.623397	-84.005905
93	M01P15	Glady Run	@ SR 725 near Spring Valley	0.54	12.70	39.617156	-84.010139
94	M01P30	Mill Run	@ US 42 near Waynesville	0.59	8.50	39.541697	-84.064396
95	M01P31	Newman Run	@ US 42 near Waynesville	0.27	9.80	39.518320	-84.098827

* The color of the box corresponds to the narrative biological assessment and the site # corresponds to the mapped location in Figure 1.

blue- exceptional to very good (meets EWH goals), green- good to marginally good (meets WWH goals), yellow- fair, orange- poor, red- very poor, and tan no biological assessment

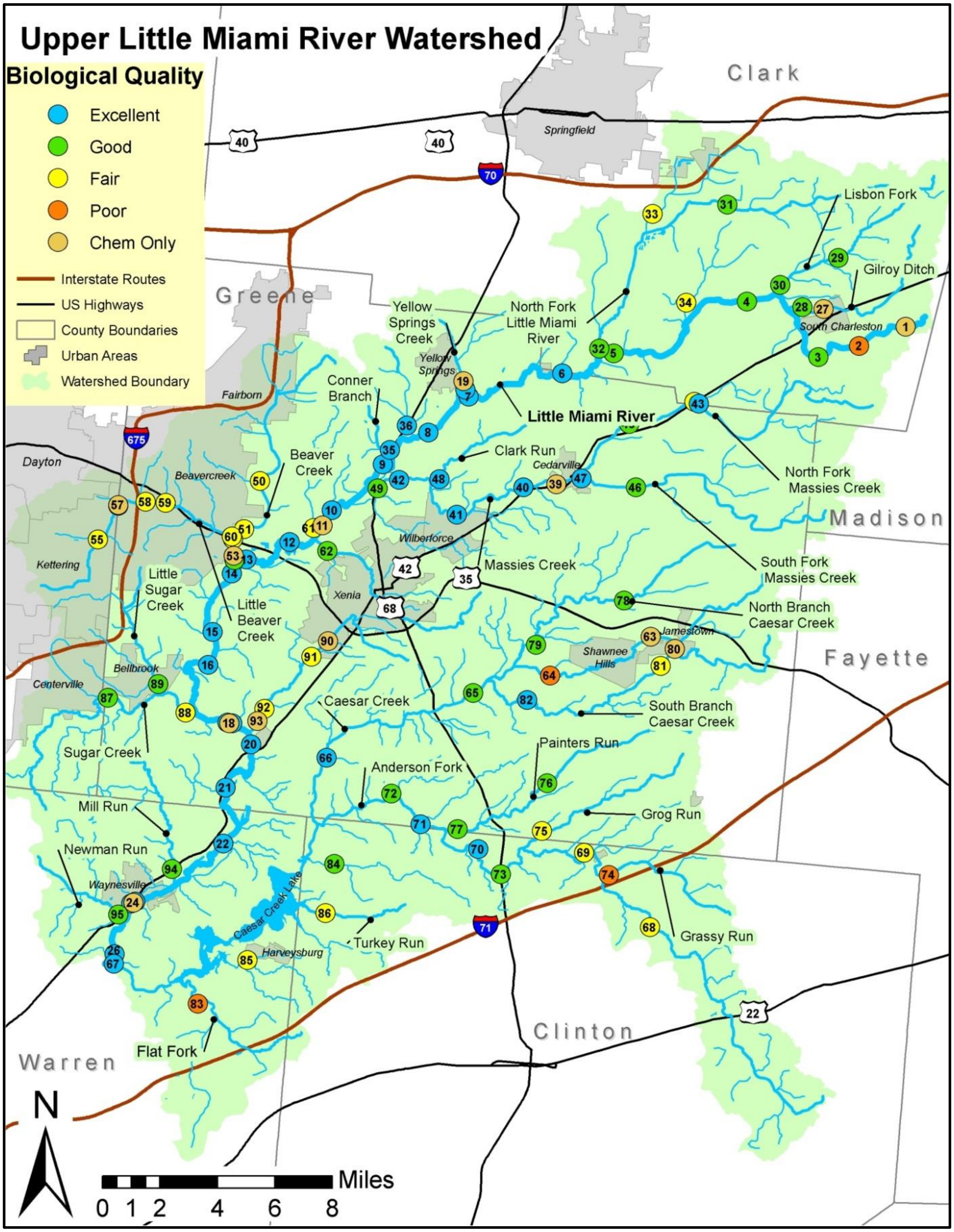


Figure 1. Map of the upper Little Miami River watershed and sampling locations sampled and assessed by the Ohio EPA, 2011-13.

Table 2. Aquatic life use attainment status for stations sampled in the upper Little Miami River basin based on data collected July-October 2011, 2012, and 2013. 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. All sites are located within the Eastern Corn Belt Plain (ECBP) ecoregion.

Stream	Location	River Mile[a]	Drain Area (mi^2)	ALU	IBI	MIwb[b]	QHEI	ICI[c]	Attainment Status[d]	Causes	Sources
Little Miami River	@ SR 41 SE of South Charleston	104.88[H] (M01S27)	4.6	WWH	26*	n/a	59.0	G	**NON**	Direct habitat alterations Organic enrichment Nutrient enrichment	Channelization Agriculture Industrial point source discharge
Little Miami River	@ Jamestown Rd	103.13[H] (M01W64)	6.4	WWH	36[NS]	n/a	59.3	G	FULL		
Little Miami River	@ Dolly Varden Rd near South Charleston	98.98[W] (M01P02)	33.0	WWH	43	8.0[NS]	72.5	48	FULL		
Little Miami River	@ Pitchin Road near Clifton	92.27[W] (M01P06)	53.0	WWH	40	8.0[NS]	75.8	52	FULL		
Little Miami River	Ust sharp bend, adj N. River Road, ½ mile E of SR 72	89.77[W] (M01W67)	94.0	EWH	--	--	--	46	(FULL)		
Little Miami River	@ Grinnel Road near Yellow Springs	85.38[W] (M01P12)	104.0	EWH	52	9.6	87.0	52	FULL		
Little Miami River	Dst Yellow Springs WWTP @ Jacoby Rd	83.14[W] (M01S09)	118.0	EWH	53	9.7	84.0	52	FULL		
Little Miami River	@ US 68	80.63[W] (600570)	129.0	EWH	51	9.8	76.3	46	FULL		
Little Miami River	NW Xenia @ Fairgrounds Road	77.70[B] (M01S25)	217.0	EWH	52	9.5[NS]	82.5	56	FULL		
Little Miami River	@ Trebein Road	75.38[B] (M01W30)	238.0	EWH	53	9.6	76.8	54	FULL		
Little Miami River	0.42 mi ust Beaver Creek at Alpha	73.16[B] (M01W32)	241.0	EWH	--	--	--	46	(FULL)		
Little Miami River	@ Indian Ripple Road near Kettering	72.30[B] (M01P13)	295.0	EWH	54	9.6	85.0	E	FULL		
Little Miami River	@ Upper Bellbrook Road near Bellbrook	69.84[B] (610550)	302.0	EWH	55	10.0	82.8	52	FULL		
Little Miami River	@ Washington Mills Road	68.54[B] (M01W39)	307.0	EWH	52	9.6	81.0	46	FULL		
Little Miami River	Ust Greene Co.-Sugar Creek WWTP	64.44[B] (M01W74)	344.0	EWH	53	9.7	78.3	56	FULL		

Stream	Location	River Mile[a]	Drain Area	ALU	IBI	MIwb[b]	QHEI	ICI[c]	Attainment Status[d]	Causes	Sources
Little Miami River	Dst Greene Co.-Sugar Creek WWTP	64.28[B] (M01S30)	345.0	EWH	50	9.6	77.3	50	FULL		
Little Miami River	@ Spring Valley Roadside Park	63.28[B] (M01W45)	361.0	EWH	52	9.5[NS]	79.0	54	FULL		
Little Miami River	@ Roxanna-N. Burlington Rd at gage	60.84[B] (600600)	367.0	EWH	54	10.2	91.0	E	FULL		
Little Miami River	Dst Sandy Run, ¾ mi SW Spring Valley Lake	58.30[B] (M01W75)	378.0	EWH	--	--	--	46	(FULL)		
Little Miami River	@ SR 73	53.84[B] (M01P29)	395.0	EWH	49	9.6	70.5	48	FULL		
Little Miami River	Adj Corwin Rd, Dst Waynesville WWTP; Ust Newman Run	53.2[B] (M01S29)	402.0	EWH	48	9.7	67.0	58	FULL		
Little Miami River	S of Waynesville; 0.1 miles ust Middletown Road	51.65[B] (M01W55)	413.0	EWH	51	10.2	84.5	48	FULL		
Gilroy Ditch	Dst South Charleston WWTP at ford	0.50[H] (M01W09)	7.5	WWH	44	n/a	58.3	G	FULL		
Lisbon Fork	N of South Charleston @ SR 41	2.80[H] (200567)	7.0	WWH	--	n/a	--	G	--		
Lisbon Fork	@ Old Springfield Road	0.4[H] (M01W10)	11.8	WWH	38[NS]	n/a	64.5	--	(FULL)		
North Fork Little Miami River	At Thorps @ SR 41	9.10[H] (200567)	11.5	WWH	42	n/a	71.5	VG	FULL		
North Fork Little Miami River	@ North River Road	0.37[W] (M01P04)	35.8	WWH	38[NS]	8.1[NS]	71.3	54	FULL		
UT to North Fork Little Miami River (5.60)	S of Springfield @ Crabill Road	0.80[H] (200562)	7.4	WWH[+]	32*	n/a	37.3	MG[NS]	**PARTIAL**	Direct habitat alterations Natural conditions (flow or habitat)	Channelization Natural sources
UT to Little Miami River (96.26)	SE of Pitchin @ Buffenbarger Road	0.60[H] (200565)	6.0	WWH[+]	30*	n/a	55.5	MG[NS]	**PARTIAL**	Direct habitat alterations	Channelization
Conner Branch	@ US 68 near mouth	0.17[H] (M01W79)	2.3	CWH	--	n/a	--	VG	(FULL)	Comment: The presence of 12 cold water macroinvertebrate taxa confirms attainment of the CWH aquatic life use.	
Jacoby Branch	@ US 68 SW of Yellow Springs	0.50[H] (M01W78)	5.1	EWH	46[NS]	n/a	71.0	E	FULL		
Yellow Springs Creek	@ Grinnel Road near mouth	0.10[H] (M01P09)	11.3	EWH	52	n/a	79.5	E	FULL		

Stream	Location	River Mile[a]	Drain Area	ALU	IBI	MIwb[b]	QHEI	ICI[c]	Attainment Status[d]	Causes	Sources
Massies Creek	@ Tarbox Cemetery Road dst Cedarville	7.70[W] (M01S11)	55.0	WWH	56	9.2	82.0	E	FULL		
Massies Creek	@ Wilberforce-Clifton Road NR Wilberforce	4.38[W] (M01P17)	63.2	WWH	52	8.9	87.0	56	FULL		
Massies Creek	@ Fawcett Drive N of Xenia	1.20[W] (M01W83)	73.0	WWH	53	9.3	81.3	46	FULL		
North Fork Massies Creek	Near Selma @ Old Route 42	5.90[H] (200555)	18.6	WWH	46	n/a	61.3	E	FULL		
North Fork Massies Creek	@ US 42	5.73[H] (301220)	17.9	WWH	34*	n/a	55.0	VG	**PARTIAL**	Nutrient enrichment biological indicators Direct habitat alterations	Channelization Onsite treatment systems (septic systems) Animal feeding operations
North Fork Massies Creek	NE of Cedarville @ McMillan Road	2.80[W] (200554)	20.9	WWH	52	8.7	51.3	52	FULL		
South Fork Massies Creek	@ Weimer Road near Cedarville	2.15[W] (M01P19)	17.1	WWH	42	n/a	50.3	VG	FULL		
South Fork Massies Creek	@ RR at Cedarville	0.14[H] (M01P20)	19.9	WWH	46	n/a	64.5	VG	FULL		
Clark Run	@ Stevenson Road NW of Wilberforce	0.44[H] (M01W87)	6.2	EWH	46[NS]	n/a	76.0	E	FULL		
Oldtown Creek	N of Xenia @ Loop Road	0.10 (200546)	9.3	WWH	51	n/a	69.0	MG[NS]	FULL		
Beaver Creek	@ Fairgrounds Road N of Alpha	3.86[H] (M01S53)	14.8	WWH	--	n/a	--	F*	--	Comment: Macroinvertebrate community reflects wetland stream conditions (i.e., slack flow, low D.O.)	
Beaver Creek	@ Dayton-Xenia Road	1.57[W] (M01S37)	20.9	WWH	40	7.7*	62.8	48	**PARTIAL**	Natural conditions (flow or habitat)	Natural sources
Beaver Creek	@ US 35 dst Little Beaver Creek	1.04[W] (M01W56)	48.1	WWH	41	7.3*	67.8	42	**PARTIAL**	Nutrient enrichment biological indicators	Urban runoff/ Storm sewers Municipal point source discharges
Beaver Creek (2011 and 2012)	Adj Factory Road dst Beaver Creek WWTP	0.20[W] (M01S35)	49.4	WWH	51	9.6	80.3	36	FULL		
Little Beaver Creek	@ Vale Road N of Kettering	6.2[H]	3.6	WWH	30*	n/a	59.0	LF*	**NON**	Sedimentation/ siltation Nutrient enrichment	Urban Runoff/ Storm Sewers

Stream	Location	River Mile[a]	Drain Area	ALU	IBI	MIwb[b]	QHEI	ICI[c]	Attainment Status[d]	Causes	Sources
Little Beaver Creek	Ust Montgomery Co Eastern Regional WWTP	4.76[H] (M01W01)	10.0	WWH	--	n/a	--	F*	--	Comment: Macroinvertebrates impacted by nutrient enrichment due to urban runoff.	
Little Beaver Creek	Ust Grange Hall Rd near Dayton	3.54[H] (M01S44)	16.5	WWH	--	n/a	--	LF*	--	Comment: Macroinvertebrates impacted by nutrient enrichment and embedded substrates due to combined effect from WWTP and urban runoff.	
Little Beaver Creek	@ Valleywood	2.83[H] (M01W06)	17.1	WWH	46	n/a	75.3	F*	**PARTIAL**	Nutrient enrichment biological indicators Particle distribution (embeddedness) Other flow regime alterations	Urban runoff/ Storm sewers Municipal point source discharges Municipal (urbanized high density area)
Little Beaver Creek	@ Factory Road near Alpha	0.05[W] (600630)	26.4	WWH	43	7.5*	64.5	F*	**PARTIAL**	Nutrient enrichment biological indicators Particle distribution (embeddedness) Other flow regime alterations	Urban runoff/ Storm sewers Municipal point source discharges Municipal (urbanized high density area)
Ludlow Creek (2011 and 2012)	@ Hilltop Road NW Of Xenia	0.25[H] (M01W84)	6.9	WWH	34*	n/a	64.8	G	**PARTIAL**	Sedimentation/ siltation	Agriculture Site clearance (Land development or redevelopment)
Shawnee Creek	@ Hawkins Road near Xenia	0.65[H] (M01P23)	11.6	WWH	52	n/a	74.0	MG[NS]	FULL		
Caesar Creek	@ Paintersville Road at New Jasper	26.50[H] (M02S08)	12.9	WWH	<u>26*</u>	n/a	57.5	G	**NON**	Natural conditions (flow or habitat)	Natural Sources
Caesar Creek	@ Stone Road SE of Xenia	23.10[W] (M02S07)	64.6	EWH	43*	9.2[NS]	76.8	50	**PARTIAL**	Natural conditions (flow or habitat)	Natural Sources
Caesar Creek	@ Paintersville Road	16.52[W] (M02P13)	88.0	EWH	50	10.4	64.5	E	FULL		
Caesar Creek	@ Corwin Road near Oregonia	0.15[W] (600550)	242.0	EWH	54	9.3[NS]	80.0	42[NS]	FULL		
Anderson Fork	@ Haley Road SE of Port William	18.80[W] (M02S12)	30.0	WWH	30*	7.9[NS]	64.0	48	**PARTIAL**	Direct habitat alterations Fish passage barrier	Channelization Dam or impoundment
Anderson Fork	@ Port William Road W of Port William	13.87[W] (M02S02)	50.0	WWH	53	10.6	70.5	F*	**PARTIAL**	Low flow alterations	Dam or impoundment

Stream	Location	River Mile[a]	Drain Area	ALU	IBI	MIwb[b]	QHEI	ICI[c]	Attainment Status[d]	Causes	Sources
Anderson Fork	@ McKay Road	7.90[W] (301480)	60.3	EWH	53	9.9	79.5	VG[NS]	FULL		
Anderson Fork	@ Old Winchester Trail	4.90[W] (M02S01)	78.0	EWH	50	10.3	78.0	46	FULL		
Anderson Fork	@ Engle Mill Road	3.27[W] (M02P12)	88.0	EWH	48[NS]	9.9	77.5	G*	**PARTIAL**	Natural conditions (flow or habitat)	Natural sources
UT to Anderson Fork (9.26)	S. of Lumberton @ US 68	0.2[H] (301481)	1.80	WWH[+]	44	n/a	64.8	--	(FULL)		
Grassy Run	SE of Port William @ Road off Gallimore Rd	0.05[H] (200478)	7.8	WWH[+]	36[NS]	n/a	40.0	P*	**NON**	Direct habitat alterations	Channelization
Grog Run	S of Paintersville @ Bone Road	0.90[H] (200476)	8.3	WWH[+]	54	n/a	65.0	F*	**PARTIAL**	Organic enrichment biological indicators Sedimentation/ siltation	Unrestricted cattle access
Painters Creek	At Paintersville @ Bone Road	5.0[H] (301735)	5.1	WWH	38[NS]	n/a	53.0	--	(FULL)		
Painters Creek	@ Eleazer Road near Paintersville	0.43[H] (M02P03)	12.8	WWH	--	n/a	--	MG*	--		
North Branch Caesar Creek	@ Junkin Road N of Shawnee Hills	6.67[H] (M02S16)	7.0	WWH	48	n/a	68.0	G	FULL		
North Branch Caesar Creek	@ Jasper Road W of Shawnee Hills	1.23[W] (M02S15)	25.7	WWH	46	7.7*	65.0	48	**PARTIAL**	Natural conditions (flow or habitat)	Natural sources
South Branch Caesar Creek (2011 and 2013)	@ Cemetery Road dst Jamestown	8.23[H] (M02S14)	6.5	WWH	40	n/a	55.5	F*	**PARTIAL**	Sedimentation/ siltation	Agriculture
South Branch Caesar Creek	@ Hoop Road	2.10[H] (M02S13)	17.0	EWH	46[NS]	n/a	72.0	VG[NS]	FULL		
Flat Fork (2011 and 2012)	@ Oregonia Road	1.70[H] (M02P07)	15.80	WWH	24*	n/a	64.3	F*	**NON**	Nutrient and organic enrichment biological indicators	Agriculture
Buck Run	@ SR 380 S of New Burlington	1.18[H] (M02S11)	8.5	WWH	46	n/a	80.3	G	FULL		
Jonahs Run	@ Oregonia Road	2.10[H] (200537)	4.1	WWH	30*	n/a	57.8	LF*	**NON**	Natural conditions (flow or habitat)	Natural Sources
Turkey Run	@ Brimstone Mills Road	1.50[H] (M02P08)	3.8	WWH[+]	46	n/a	66.5	F*	**PARTIAL**	Natural conditions (flow or habitat)	Natural Sources
Sugar Creek	@ Wilmington Pike near Centerville	4.11[H] (M01S22)	16.5	WWH	46	n/a	66.3	MG[NS]	FULL		

Stream	Location	River Mile[a]	Drain Area	ALU	IBI	MIwb[b]	QHEI	ICI[c]	Attainment Status[d]	Causes	Sources
Sugar Creek	@ Penewit Road near Spring Valley	0.40[W] (M01P26)	33.2	WWH	45	8.6	78.0	F*	**PARTIAL**	Natural conditions (flow or habitat)	Natural Sources
Little Sugar Creek	Adj Maple Street at Bellbrook	0.45[H] (M01S51)	12.3	WWH	44	n/a	67.5	MG[NS]	FULL		
Glady Run	@ Hedges Road near Xenia	4.08[H] (M01P16)	6.9	WWH	38[NS]	n/a	68.0	F*	**PARTIAL**	Other[e]	Unspecified urban storm water Urban runoff/storm sewers
Glady Run	@ Schnebly Road, south crossing	1.10[H] (M01W60)	12.4	WWH	34*	n/a	79.0	G	**PARTIAL**	Other[e]	Unspecified urban storm water Urban runoff/storm sewers
Mill Run	@ US 42 near Waynesville	0.59[H] (M01P30)	8.5	WWH	--	n/a	--	MG[NS]	--		
Newman Run	@ US 42 near Waynesville	0.27[H] (M01P31)	9.8	EWH	57	n/a	72.3	G*	**PARTIAL**	Natural conditions (flow or habitat)	Natural Sources

a - Letters in superscript refer to the fish site type and associated biocriteria as indicated in the table below. B = boat; W = wading; and H = headwater. Station ID is included in parentheses below the RM.

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

c - An 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

d - Attainment is given for the proposed aquatic life use when a change is recommended. EWH = Exceptional Warmwater Habitat; WWH = Warmwater Habitat; CWH = Coldwater Habitat.

e - "Other" as a cause refers to not readily identified impacts associated with runoff from impervious surfaces and lawns in urban settings.

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.

+ - Recommended aquatic life use based on data from this survey.

Biological Criteria

	Eastern Corn Belt Plains	
Index – Site Type	**EWH**	**WWH**
IBI – Headwaters	50	40
IBI – Wading	50	40
IBI – Boat	48	42
MIwb – Wading	9.4	8.3
MIwb – Boat	9.6	8.5
ICI	46	36

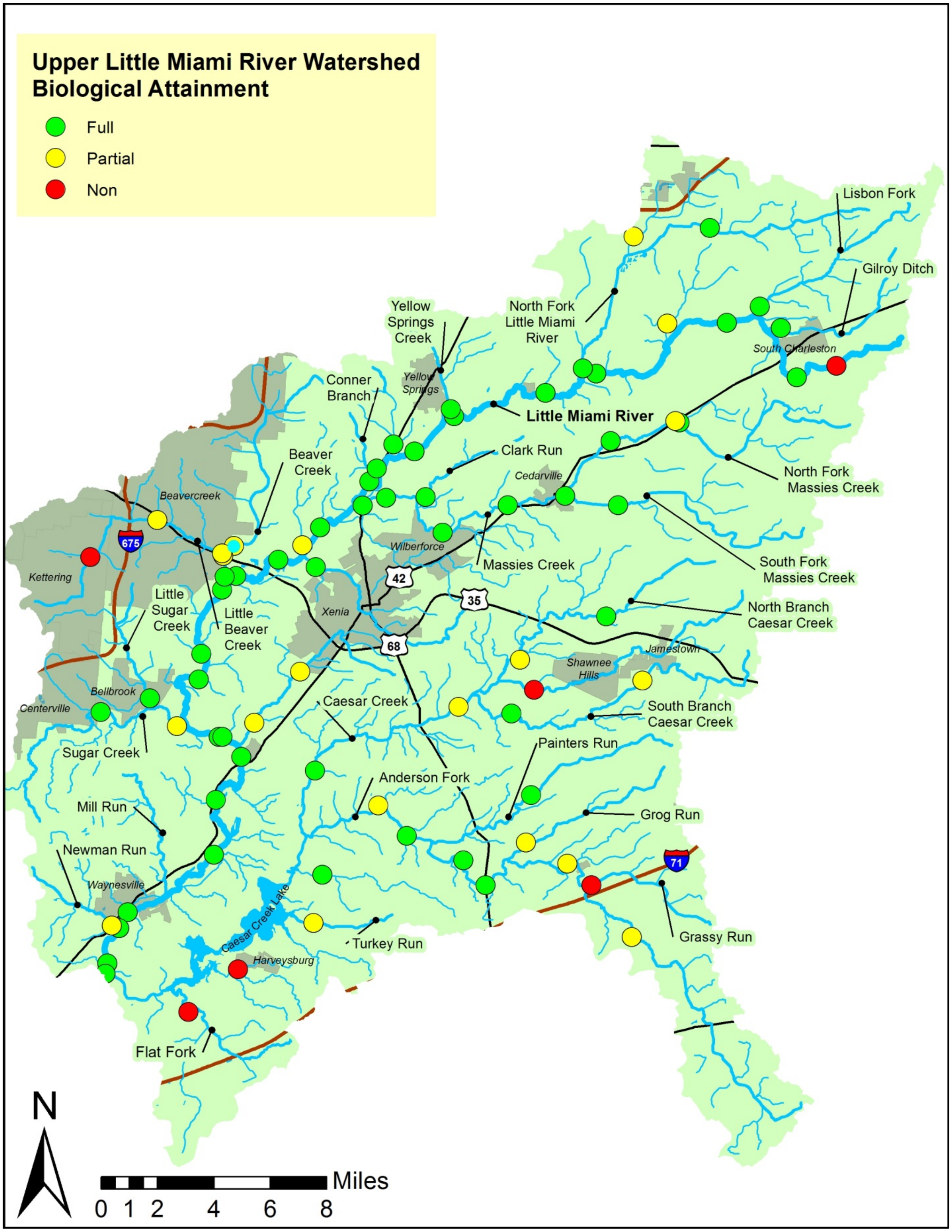


Figure 2. Aquatic life use attainment status of sites sampled for biological communities in the upper Little Miami River watershed, 2011-13.

RECOMMENDATIONS

The streams in the upper Little Miami River study area currently listed in the Ohio Water Quality Standards (WQS) are assigned either the Warmwater Habitat (WWH), Exceptional Warmwater Habitat (EWH), or Coldwater Habitat (CWH) aquatic life use. The unnamed tributary to North Fork Little Miami River (RM 5.60), the unnamed tributary to the Little Miami River (RM 96.26), and the unnamed tributary to Anderson Fork (RM 9.26) are not listed in the WQS. Turkey, Grog and Grassy runs were originally designated for aquatic life uses in the 1978 WQS. The techniques used then did not include the standardized approaches to the collection of instream biological data or numerical biocriteria. All other streams in this survey have had their aquatic life uses previously verified. This study used biological data to evaluate and establish aquatic life uses for streams in the upper Little Miami River study area.

Thirty-five streams in the upper Little Miami River study area were evaluated for aquatic life and recreation use potential in 2011 (Table 3). Significant findings include the following:

- Eight streams have an existing, verified EWH aquatic life use that should be maintained. Biological monitoring on the Little Miami River (downstream from the North Fork confluence at RM 91.64), Jacoby Branch, Yellow Springs Creek, Clark Run, Caesar Creek (downstream from confluence with South Branch), Anderson Fork (downstream from confluence with Grog Run), South Branch Caesar Creek (RM 4.0 to the mouth), and Newman Run confirmed the appropriateness of the EWH aquatic life use.

- Conner Branch has an existing, verified CWH aquatic life use that should be maintained. Twelve cold water macroinvertebrate taxa were collected in Conner Branch at US 68 in 2011. Eleven cold water taxa were collected here in 1998 when the CWH use was recommended. The community collected in 2011 confirmed that the CWH use is still appropriate for Conner Branch.

- Turkey, Grog, and Grassy runs have unverified WWH aquatic life uses in the WQS. Biological sampling conducted on these streams verified that the WWH aquatic life use is appropriate.

- The unnamed tributary to North Fork Little Miami River (RM 5.60), the unnamed tributary to the Little Miami River (RM 96.26), and the unnamed tributary to Anderson Fork (RM 9.26) are not listed in the WQS. Biological sampling on these streams indicated that the WWH aquatic life use is appropriate for these streams.

- The remaining streams and stream segments from the 2011 study all have verified WWH aquatic life uses in the WQS. Biological sampling conducted on these streams verified that the WWH aquatic life use is still appropriate.

The Little Miami River should retain the Primary Contact Recreation Class A use for its entire length. All remaining streams or stream segments in the study area should retain or be assigned the Primary Contact Recreation Class B use. All streams in the study area should retain or be assigned the Agricultural Water Supply and Industrial Water Supply uses.

Channelization is still pervasive in the headwaters of the upper Little Miami River and is implicated in the non-attainment of biological criteria on the mainstem and in two unnamed tributaries. Restoration of these streams would increase the potential for full biological attainment in future surveys.

Channelized habitat of the Little Miami River at State Route 41 (RM 104.88).

In addition to channelization, nutrient enrichment also imperils the biological integrity of the Little Miami River at and upstream from Dolly Varden Road (RM 98.98). The proposed Trophic Index Criterion (TIC), which considers diel DO and pH swings, chlorophyll concentrations, nutrient levels and biological index scores, indicated that nutrient enrichment is evident at the Dolly Varden Road sampling location. Channelization, discharges from an upstream agribusiness, and general agricultural runoff likely contribute to or exacerbate nutrient loads at this location. Habitat restoration and reduction of upstream point and nonpoint nutrient loads would protect this reach from future degradation due to eutrophication.

While great improvements have been realized in Little Beaver Creek, nutrient enrichment still affects biological integrity in this watershed in spite of the implementation of phosphorus removal at the Montgomery County Eastern Regional WWTP. The large volume of effluent that this facility discharges relative to the size of the watershed (13 million gallons per day on a 26 mi^2 stream) continues to present challenges to biological communities. Recognizing the highly urbanized nature of this watershed, it is recommended that urban runoff and storm water controls be investigated in order to further attenuate nutrient loads. Habitat improvements to increase the assimilative capacity of this stream should also be investigated.

Massies Creek at Wilberforce-Clifton Road (RM 4.38).

Massies Creek is on the trajectory to achieve full attainment of EWH biocriteria. In 2011, both IBI and ICI index scores were fully within EWH criteria at all sampling locations. The MIwb scores remain in nonsignificant departure for EWH. In order to assure adequate protection of resource quality in this stream, it is recommended that repeat sampling of the three 2011 Massies Creek sampling locations be undertaken in 3-5 years to reassess the potential for designation of the EWH aquatic life use.

A small dam on Anderson Fork affected fish communities upstream from its location in Port William at RM 14.55 (Figure 26, page 77). The presence of the dam acts as a barrier to fish migration. The removal of the dam would allow for fish passage and consequent improvement of IBI scores at Haley Road (RM 18.8).

Table 3. Beneficial use designations for water bodies in the upper Little Miami River study area. Designations based on the 1978 and 1985 Ohio Water Quality Standards appear as asterisks (*). A plus sign (+) indicates a confirmation of an existing use and a triangle (▲) denotes a new recommended use based on the findings of this report.

Water Body Segment	Use Designations	Aquatic Life Habitat						Water Supply			Recreation			Comments
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
Little Miami River - North fork (RM 91.64) to RM 3.0 (downstream of Beechmont ave.)	+		+						+	+		+		
- all other segments	+	+							+	+		+		
Caesar creek - headwaters to South branch (RM 23.78)		+							+	+		+		
- at RM 7.77			+					+	+	+		+		PWS intake - City of Wilmington
- all other segments			+						+	+		+		
Flat fork		+							+	+		+		
Jonahs run		+							+	+		+		
Trace run		+							+	+		+		
Turkey run		*/+							*/+	*/+		*/+		
Buck run		+							+	+		+		
Anderson fork - Grog run (RM 11.02) to the mouth			+						+	+		+		
- all other segments		+							+	+		+		
Painters creek		+							+	+		+		
Grog run		*/+							*/+	*/+		*/+		
Love run		*							*	*		*		
Grassy 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	
Unnamed tributary (Anderson fork RM 9.26)		▲							▲	▲		▲		
South branch - Paintersville-New Jaspar rd. (RM 4.0) to the mouth			+						+	+		+		
- all other segments		+							+	+		+		
North branch		+							+	+		+		
Newman run			+						+	+		+		
Mill run		+							+	+		+		
Unnamed tributary (Little Miami River RM 60.50)			+						+	+		+		
Unnamed tributary (Little Miami River RM 62.01)		+							+	+		+		
Glady run - Hedges rd. (RM 4.0) to the mouth		+							+	+		+		
- all other segments		**+**							**+**	**+**		▲		
Glady run swale		+							*	*			+	
Sugar creek		+							+	+		+		
Little Sugar creek		+							+	+		+		
Unnamed tributary (Little Miami River RM 69.85)		+							+	+		+		
Beaver creek		+							+	+		+		
Little Beaver creek		+							+	+		+		
Unnamed tributary (RM 6.1)		+							+	+			+	
Shawnee creek		+							+	+		+		
Ludlow creek		+							+	+		+		

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	
Massies creek		+						+	+	+		+		PWS intake - Greene county Cedarville (formerly)
Oldtown creek		+							+	+		+		
Clark run			+						+	+		+		
Unnamed tributary (Massie creek RM 5.3)			+						+	+		+		
North fork		+							+	+		+		
South fork		+							+	+		+		
Conner branch						+			+	+		+		
Jacoby branch			+						+	+		+		
Yellow Springs creek			+						+	+		+		
Unnamed tributary (Little Miami River RM 96.26)		▲							▲	▲		▲		
North fork		+							+	+		+		
Unnamed tributary (North fork RM 5.60)		▲							▲	▲		▲		
Goose creek		+							+	+		+		
Lisbon fork		+							+	+		+		
Gilroy ditch		+							+	+		▲		

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 Waters; PCR=Primary Contact Recreation; SCR=Secondary Contact Recreation

INTRODUCTION

During the 2011 field season (July through October) chemical, physical, and biological sampling was conducted in the upper Little Miami River watershed to assess and characterize water quality conditions. The upper Little Miami River watershed is located in southwestern Ohio and includes streams in Clark, Clinton, Greene, Montgomery and Warren counties (Figure 3). The study covered the Little Miami River mainstem from the headwaters downstream to the confluence with Caesar Creek, and included the 10-digit Hydrologic Unit Codes (HUCs) 0509020201, 0509020202, 0509020203, 0509020204, and 0509020205. Extensive sampling has been conducted by Ohio EPA in this watershed, with the most recent comprehensive survey taking place in 1998. Due to a combination of intense agricultural land use and the existence of numerous wastewater dischargers in the watershed, the upper Little Miami River watershed is prone to the effects of both nutrient and organic over-enrichment. These effects were evident in the 1998 biological and water quality survey via widespread biological partial and non-attainment of aquatic life use criteria (Ohio EPA 2000).

Figure 3. Upper Little Miami River study area.

However, in 2007, the Ohio EPA Biological and Water Quality Study of the Lower Little Miami River report (Ohio EPA 2009) suggested that conditions in the upper watershed had improved. Selected sites on the upper Little Miami River that were previously in biological partial or non-attainment in 1998 were fully meeting the prescribed biological criteria in 2007. Further, the lower Little Miami River mainstem that achieved less than 50% full attainment in 1998 was in 95% full attainment in 2007. Clearly, many changes had transpired in the watershed since 1998, which included the increased WWTP plant capacities and the introduction of phosphorus removal at six major wastewater treatment facilities in the upper watershed. One objective of the 2011 survey was to further characterize the changes in water quality due to changes in wastewater treatment at these facilities.

In addition to the above, specific objectives of the survey were to:

- Establish the present biological conditions in the upper Little Miami River watershed by evaluating fish and macroinvertebrate communities;
- Identify the relative levels of organic, inorganic, and nutrient parameters in surface water;
- Evaluate influences from both NPDES discharges and non-point sources;
- Assess physical habitat influences on stream biotic integrity;
- Evaluate recreation water quality;
- Determine beneficial use attainment status and recommend changes if appropriate,
- Collect fish samples for the Ohio Sport Fish Health and Consumption Advisory Program (used to assess chemical contaminant levels in fish), and
- Compare data to the 1998 TMDL survey in order to track changes in the watershed.

The findings of this evaluation may factor into regulatory actions taken by the Ohio EPA (e.g. NPDES permits, Director's Orders, or the Ohio Water Quality Standards [OAC 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] report).

STUDY AREA DESCRIPTION

The upper Little Miami River watershed analyzed in this study includes the region from the headwaters in Clark County to the confluence with Caesar Creek in Warren County (Figure 1). The Little Miami River flows southwesterly from Clark County through Greene and Warren counties. The watershed also encompasses portions of Montgomery, Clinton, and Madison counties. The drainage area of the upper Little Miami covers 656.6 mi^2. Along its course the river drops from an elevation of 1,137 feet to 700 feet with an average gradient of 7.6 ft/mile. Major tributaries include Caesar Creek, Massies Creek, and Beaver Creek. Impoundments in the watershed include Caesar Creek Lake (6,110 acres) and Shawnee Lake (190 acres).

The topography of the upper Little Miami River watershed has been influenced by glaciation which left distinctive land forms and thick deposits of silt, sand, and gravel. This portion of the watershed is within the ECBP ecoregion, which is characterized by level to gently sloping land, and relatively low gradient streams (ftp://ftp.epa.gov/wed/ecoregions/in/ohin_front.pdf). Deviations from this pattern are the result of a distinctive geological feature evident on several of the streams in the study area. Waterfalls on Massies Creek at Cedarville, Anderson Fork at Port William, and the mainstem of the Little Miami at Clifton reveal a geological structure known as the Niagara Escarpment (ODNR, 1995) in the limestone bedrock and denote a change in the topography. Above this escarpment the land is more level with soils typical of glacial till. Below this break the landform has more relief and the stream gradients increase.

For part of its length the upper Little Miami flows atop a buried valley aquifer composed of highly permeable sands and gravel from past glacial events. Smaller tributaries in this area are known to disappear into the ground during dry periods due to high infiltration rates associated with the sand and gravel aquifer. This aquifer was designated a Sole Source Aquifer by USEPA in 1988 under the authority of section 1424(e) of the Safe Drinking Water Act (http://www.epa.gov/r5water/gwdw/solesourceaquifer/pdfs/ssa-r5-greatermiami.pdf). Designation requires extra review for any federally funded projects proposed for the surface above the aquifer. Most of the communities in the watershed rely heavily on groundwater for a source of drinking water. A combination of development pressures and limited supply has caused the city of Wilmington to begin drawing water from Caesar Creek Lake even though Wilmington is not geographically located in this part of the Little Miami watershed.

Aquatic life use designations for the streams in the watershed reflect the generally good to excellent resource conditions in the watershed. The Little Miami River is designated Exceptional Warmwater Habitat (EWH) from its confluence with the North Fork at RM 91.64 to Beechmont Avenue at RM 3.0. Caesar Creek downstream from the South Branch Caesar Creek, the lower reach of the South Branch Caesar Creek, Anderson Fork downstream from Grog Run, Newman Run, Jacoby Branch, Yellow Springs Creek, and Clark Run are also designated EWH. Conner Branch is designated Coldwater Habitat (CWH). All other tributaries are designated Warmwater Habitat (WWH). With a few exceptions, the streams in the watershed are also designated for Agricultural and Industrial Water Supply and Primary Contact Recreation. Due in part to the status as a State and National Scenic River, the Little Miami River and North Fork Little Miami River are assigned the Outstanding State Waters (OSW) antidegradation category. All or segments of Caesar Creek, Anderson Fork, Massie Creek, and Yellow Springs Creek are assigned the Superior High Quality Waters (SHQW) antidegradation category.

Data from the 2006 National Land Classification Dataset (NLCD) show that land uses in the watershed are principally agricultural in the northern and eastern portions with relatively limited development near cities (Figure 4). Overall, 57.71% of the watershed is used for cultivated crops; if hay/pasture is included, then 67.2% of the watershed is used for agriculture. South Fork Massies Creek and the headwaters of Anderson Fork subwatersheds exceed 90% of their surface area used for cultivation. In sharp contrast to this pattern is the corridor between Dayton and Xenia. The Little Beaver Creek subwatershed is reportedly 96.5% developed and has no agricultural land use. Two other subwatersheds, Beaver Creek (61%) and Sugar Creek (62.2%), are also heavily developed.

This level of development leads to impacts on water quality from the creation of surfaces impervious to infiltration of rainfall. The Center for Watershed Protection defines any watershed with more than 10% total impervious cover as "urban" (Schueler 2004). Three of the 23 watersheds in the study area meet this definition of "urban": Beaver Creek, Little Beaver Creek, and Sugar Creek. The Little Beaver Creek subwatershed is 39.9% impervious. Most impacts to urban streams occur in first, second, and third order streams. Many streams of this size were encased in storm sewers long ago but a few still persist and show the effects of urbanization. Effects include excessive flows during rainfall events with resulting bank erosion and instability of the stream channel. Often efforts are made to "correct" erosion through installation of concrete or stone barriers that actually create more problems downstream. With a reduction in infiltration, streams show a reduction in base flow due to less groundwater recharge. Generally, urban streams exhibit degraded habitat and water quality with declines in biotic communities. Materials deposited on the surface of the land are incorporated into the runoff and enter streams during rainfall events.

Significant development is still occurring in the Dayton-Xenia corridor. Starting with the Xenia area, the river receives effluent from five different waste water treatment plants (WWTPs). As a result, within fourteen river miles the flow is increased by up to 39 million gallons a day (mgd) of treated effluent. The communities of Beavercreek, Bellbrook, and Xenia are trying to keep pace with the pressures that attend to growth, including provision of water and sewage services. After development there is usually more impervious surface, which increases the rate and volume of runoff. While most developing areas in the Little Miami River watershed are not immediately adjacent to the river, the impacts of development are still a potential problem. Numerous residential, industrial, and commercial developments are recently completed, underway, or proposed within the watershed. Some local programs and the NPDES general permit for construction sites attempt to control sediment-laden runoff from these sites during construction. Enforcement of these regulations has not kept pace with the development, however, and a significant amount of sediment enters streams in the watershed as a result. This increased amount of sediment is eventually transported to the Little Miami via tributaries. Already developed areas contribute different types of pollutants to the watershed such as oil and grease from vehicles and pesticides and fertilizers from lawn chemicals.

There are only a few significant reservoirs in the watershed, two of which are private. Shawnee Lake is 178 acres and is surrounded by residential development and was sewered since the last survey in 1998. A 10 acre lake south of Xenia in the Caesar Creek watershed is owned by the Greene County Fish and Game Association and use is limited to their membership. ODNR owns a 60 acre lake as part of the Spring Valley Wildlife Area. The largest reservoir is Caesar Creek Lake, which is owned and operated by the US Army Corps of Engineers. It is used for flood control, navigation augmentation, and recreation. Ohio Department of Natural Resources (ODNR) leases part of the property and operates Caesar Creek State Park. The size during summer is 2,830 acres. There are also a few notable lowhead dams in the watershed all of which were built to support water powered gristmills. The Clifton Mill is still in operation and maintains a dam and millpond on the Little Miami River just above the Clifton Gorge to supply water for its use. A similar dam is located on Anderson Fork in Port William but the mill there is no longer in operation. A third dam on the Little Miami River is located in Corwin and was built to deflect flow into a mill race for a mill that no longer exists.

There are several environmental groups active in the upper Little Miami River watershed. The oldest of these is Little Miami Incorporated (LMI) which has been active for 45 years. Most of LMI's activities have involved the purchase of conservation easements or property purchases in the riparian zone of the river. LMI has also been active in education and outreach programs to promote understanding of the scenic river designation and water quality. Greene and Clinton Soil and Water Conservation Districts (SWCDs) formed a joint board of supervisors to conduct activities in the Caesar Creek watershed and have in the past hired watershed coordinators. Little Miami River Partnership conducted activities such as writing a watershed action plan for Todd Fork, but is no longer in existence. A new group, the Little Miami River Kleeners, has conducted river cleanups and has expressed interest in greater involvement.

Several watershed projects have been initiated to reduce nonpoint source pollution inputs to the various streams in the watershed. The upper reaches of the watershed were included in the “Clark-Greene Little Miami River Restoration Project” that concentrated on demonstrations of agricultural best management practices appropriate for that portion of the watershed. It covered the portion of the watershed upstream from the confluence with Massies Creek. Other projects have included streambank protection on the mainstem and stream restorations on Little Beaver Creek and Massies Creek.

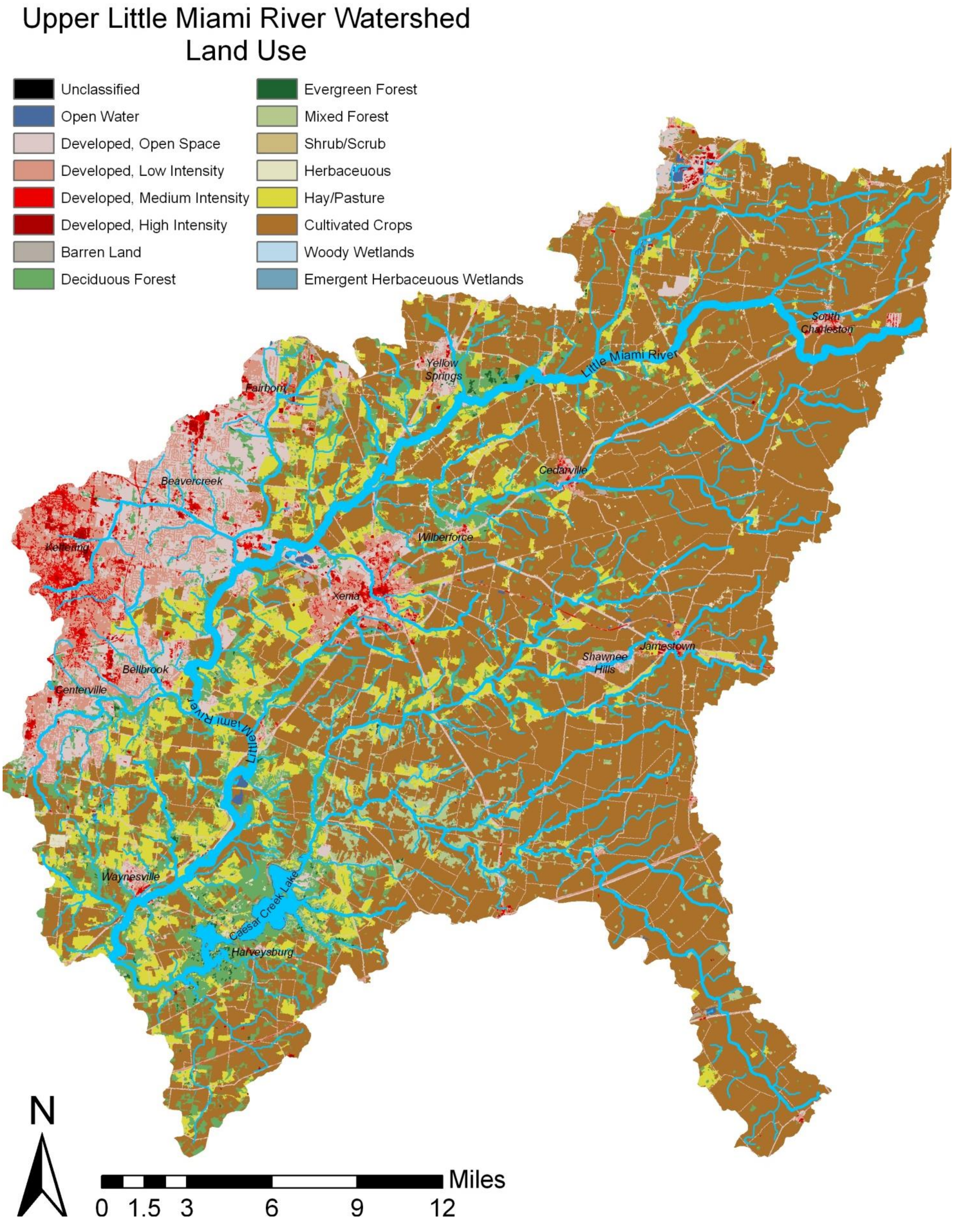


Figure 4. Land use in the upper Little Miami River watershed (Fry et al., 2011).

RESULTS AND DISCUSSION

NPDES Regulated Facilities

A total of 36 known, public and private National Pollutant Discharge Elimination System (NPDES) Ohio EPA permitted facilities discharge either sanitary or industrial wastewater (effluent) and/or industrial storm water into the mainstem and tributaries within the upper Little Miami River watershed (Table 4). Facilities are required by Ohio EPA to conduct self-monitoring of their parameter list for effluent quality and quantity and typically include outflow, nutrients, effluent solids (TDS), and oxygen-demand parameters (dissolved oxygen, cBOD5). Results are reported monthly to Ohio EPA as discharge monitoring reports where the data are screened for compliance with permit requirements and further analyzed for trends.

Concentrations and calculated pollutant loads from NPDES dischargers in the upper Little Miami River basin were evaluated from 2002 through 2011. The following discharger descriptions include facility summaries, permit violations, toxicity results (bioassays) and effluent loading information for selected dischargers in the upper Little Miami River watershed**.** Violations of a facility permit include numeric limit, reporting frequency and code and are defined as follows:

- A numeric violation is related to a permit concentration and/or load.
- A frequency violation is a failure of the permit holder to monitor effluent as stated in their permit.
- A code violation is the use of an incorrect code.

Facilities within the study area that are regulated by a NPDES permit may be found by visiting http://www.epa.ohio.gov/dsw/permits/individuals.aspx. For some pollutants, effluents from point sources represent only a component of the annual load to a watershed's waterways. Nonpoint source or diffuse pollutants from urban and agricultural practices and a continuum of resuspended accumulated pollutants from sediments are all part of the total load to a watershed.

Comparisons of annual median conduit flow from major dischargers in the upper Little Miami River from 1998 to 2011 have demonstrated changes in effluent quantity ranking. The Montgomery County Eastern Regional WWTP remains the largest discharger in the watershed. Sugarcreek WWTP has shown near comparable discharge outflow from surveys conducted in 1993, 1998 and 2011, whereas Beavercreek increased over a million gallons per day (MGD). Both communities are plagued with inflow and infiltration (I/I) problems from antiquated collection systems; however, Sugarcreek has demonstrated twice the number of numeric permit violations. Beavercreek's population increased by 10,000 from 1993 to 2011, while Sugarcreek remained stable for 18 years with about 2,200 people. Beavercreek's increase in annual median flow is perhaps not only attributable to increased population and development, but also to groundwater intrusion and downspout and sump pump connections by homeowners, both of which bring more flow to the facility.

The city of Xenia's population growth pattern has remained largely flat over 25 years, yet Xenia Ford WWTP flow monitoring indicated an upward trend in annual median conduit flow, while Xenia Glady Run WWTP trended downward. Xenia Glady Run WWTP completed an overall wastewater upgrade more recently than at Xenia Ford, whose upgrade in May of 2011 only entailed sludge handling and an outfall headwall. Sanitary sewer overflow (SSO) occurrences continue at Xenia Ford WWTP and are largely absent at Xenia Glady Run WWTP. Yellow Springs WWTP was undergoing a major upgrade to its facility during the survey, adding storm water retention and nutrient removal. Permit violations for Yellow Springs were most likely due to the upgrade, which lasted from 2010 until December of 2011. Total phosphorus loads cannot be compared between watershed surveys for any facility due to insufficient data in the 1990s.

South Charleston WWTP-Permit #-1PB00028 (expires July 31, 2018)
Receiving stream: Gilroy Ditch RM 1.4
Outfall 001 Latitude: 39.829167; Longitude: -83.644444
http://wwwapp.epa.ohio.gov/dsw/permits/doc/1PB00028.pdf

South Charleston wastewater treatment plant is located in Clark County, Ohio at 352 Clifton Road in South Charleston. The facility was built in 1969 with a major modification in 1990. The treatment processes consist of activated sludge (extended aeration), secondary clarification and UV disinfection. There are no combined sewers in the system. The original and current design flow is 0.24 MGD with an average daily flow contribution from industrial users of 0.015 MGD.

In 2011, an Ohio EPA inspection noted duckweed covering the water surface of several tanks, significant foaming in the aeration tanks, a surface layer of fine solids/pin floc in the clarifiers, and a slight amount of suspended solids in the final effluent discharge. There was evidence of solids deposition in the creek and a lack of an outfall sign/marker at the creek. Nearly the same conditions were noted in 2009 and intermittently back to 2004. During the Ohio EPA survey of 2011, field personnel noted clarifiers with a serious sludge blanket. In August 2011, field personnel noted solids in the creek downstream from the outfall at an estimated depth of 1.5 feet. The operator mentioned the facility had wasted sludge and was possibly losing some to the stream.

NPDES numeric limit violations were evaluated at outfall 001 from 2007 to 2011. Data indicated 26 violations reported for those five years. Parameters included total suspended solids (TSS), cBOD5, fecal coliform and ammonia-N. Permit limit violations were explained as a mix of administrative errors, high flows, valve failures, air diffuser leaks, and extensive power outages. Some of the higher ammonia-N violations ranged from 35 to 180 mg/l. Twenty-five percent of the violations occurred in 2011. Under-reporting of numeric limit violations was documented in Ohio EPA inspections at the facility. No violations occurred from November to January for any of the years reported.

NPDES frequency violations were evaluated at outfall 001 from 2007 to 2011. Eighteen violations were reported, with most for ammonia-N and water temperature (50% for those reported in 2011). All violations occurred in spring and summer months.

Yellow Springs Water Reclamation Facility (WRF)- Permit-#1PC00013*JD (expires September 30, 2015)
Receiving stream: Yellow Springs Creek RM 4.4
Outfall 001 Latitude: 39.790278; Longitude: -83.879444
http://wwwapp.epa.ohio.gov/dsw/permits/doc/1PC00013.pdf

Yellow Springs WRF is located in Greene County at 3835 Grinnell Road in Yellow Springs, Ohio. The facility was constructed in 1963 with major modifications completed in 1988 and 2012. It took two years to implement the upgrades of 2012, which included a new computer system with state-of-the-art digital and remote panels. The panels allow staff to check facility levels and troubleshoot issues from anywhere there is an internet connection, thus reducing staffing hours on evenings and weekends. A new 2.5 million gallon storm water retention basin allows the plant to hold excess water during heavy rainfalls. The project also included renovation of screening, new grit removal system, additional biological nitrogen and phosphorous removal, refurbishing the headworks, addition of a new covered storage pad for dewatered sludge which provides 90 days of storage prior to land application, and enhanced controls and automation.

The wastewater treatment plant improvements were funded through an Ohio Public Works Commission (OPWC) grant and sewer rate increases. The wastewater improvements were undertaken with the primary focus of coming into full compliance with the NPDES permit, including the need to implement improved ammonia nitrogen removal, increase dissolved oxygen levels, implement phosphorus removal and manage high flows from intrusion into the collection system. Yellow Springs implemented additional improvements beyond those required to achieve permit compliance. The village of Yellow Springs was under Director's Final Findings and Orders (DFFO) in 2010 to upgrade the facility in order to achieve compliance of its NPDES permit. Bypassing occurred at the time of the upgrade due to construction constraints.

The facility is now able to treat sewage for phosphorus with a new biophosphorus removal system that has lowered the level of phosphorus in the effluent from about 4 mg/l to about 1 mg/l. The level of ammonia has reduced from an average 2.3 mg/l to about 1.1 mg/l, and the level of suspended solids also fell from an average of 30 mg/l to about 18 mg/l.

The average daily design flow is 0.600 MGD with a peak hourly flow of 3.8 MGD. There are no combined sewers in the system, which serves a population of approximately 3,800. The effluent flows through a series of high gradient cascading falls in Glen Helen Preserve before splitting into several channels that enter Yellow Springs Creek over a 100 meter segment. The current estimated average inflow and infiltration (I/I) into the sanitary collection system is 436 gallons per day.

The treatment train consists of a bar screen, aerated grit chamber, activated sludge, two clarifiers, equalization basin, phosphorus removal, chlorination and dechlorination There are no industrial users in the system. Morris Bean, an aluminum casting foundry at the village limits, discharges from a package plant to a settling pond. Discussions to have the facility connect to the village collection system were revived in 2011 and an Ohio EPA permit was granted to move forward on this.

NPDES limit violations were evaluated at outfall 001 from 2007 to 2011 and revealed 150 violations of phosphorus, ammonia-N, cBOD5 and fecal coliform. Fifty-eight percent of the violations occurred from 2010 through 2011 in all seasons but primarily in the summer months. Violations of TSS and cBOD5 in 2011 were due to high flows and lab errors (either in-house or contract lab, depending on the parameter). Excessive I/I caused many of the violations during this time period with flow peaks as high as 6.6 MGD prior to the upgrade. The lift station at US 68 couldn't handle incoming flow and bypassed on a number of occasions in 2010 and 2011 to Yellow Springs Creek. Phosphorus reduction obstacles were ferric dosing, pump and mixer failures, and sludge removal. Limit violations have been reduced drastically in 2011 and 2012.

NPDES frequency violations were evaluated at outfall 001 from 2007 to 2011. For the five years of data, 34 violations were reported in 2007 for chlorine.

Third quarter conduit flows (Figure 5) demonstrate minor variance in percentile loads, lending credence to operational controls for flow on an outdated facility. The elimination of SSOs in the collection system, as well as ongoing inflow and infiltration elimination projects, bring more predictable flow regimes to the facility. In addition, the reductions in flow quantity reflect inflow and infiltration countermeasures the village has implemented through the years.

In spite of biological process control challenges, ammonia and phosphorus were reduced as treatment upgrades were nearing implementation by 2012. Final outfall (001) bracketing of fixed stations 801 and 901, with few exceptions, demonstrated that upstream concentrations of fecal coliform regularly exceeded downstream values for the period of record. Both a park and a large pond located upstream from the outfall may account for the higher bacteria numbers at the 801 station.

Greene County Cedarville WWTP -Permit #-1PB00006*DD (expires August 31, 2014)
Receiving stream: Massies Creek RM 8.9
Outfall 001 Latitude: 39.739722; Longitude: -83.801389
http://wwwapp.epa.ohio.gov/dsw/permits/doc/1PB00006.pdf

Cedarville WWTP is located in Greene County at 152 W. Cedar Street in Cedarville, Ohio. The plant functions as an extended aeration/nitrification treatment system. A new facility was built and went online in May 2004 and included new pump stations, a pretreatment facility, an oxidation ditch, clarifiers, splitter boxes and UV disinfection. The average daily design flow of the new facility is 0.56 MGD.

Phosphorus loads reported by Cedarville at the end of 2011 were achieving compliance with the permitted 1.1 kg/day phosphorus load. The 2011 Compliance Evaluation Inspection (CEI) conducted by Ohio EPA personnel was rated as satisfactory.

NPDES permit limit violations were evaluated at outfall 001 from 2007 to 2011. Seventy-four violations were reported, divided near evenly among TSS, ammonia-N and phosphorus. Thirty-nine percent of these occurred in 2010 and 2011. Since 2009, violations occurred in consecutive months from September 2009 through March 2010. All of the TSS violations in 2009 and during the first two months of 2010 were due to a permitting error. Other violations were due to high flow events.

Percentile flow variance was minimal through the period of record (Figure 6) especially after the construction of the new wastewater facility in 2004. Ammonia-N load reductions were evident after the new facility went online. The removal of nitrogen is effected through the biological oxidation of nitrogen from ammonia to nitrate (nitrification), followed by denitrification. Instream concentrations of ammonia downstream from outfall 001 from 2009-2011 were lower than upstream concentrations.

Montgomery County Eastern Water Regional Reclamation Facility
Permit #-1PL00001*MD (expired July 31, 2013; currently in public comment phase of renewal)
Receiving stream: Little Beaver Creek RM 4.6
Outfall 001 Latitude: 39.724722; Longitude: -84.103611
http://wwwapp.epa.ohio.gov/dsw/permits/doc/1PL00001.pdf

The Montgomery County Eastern Regional WWTP is located in Montgomery County at 1802 Spaulding Road in Kettering, Ohio. Eastern Regional is an advanced treatment facility with an average design flow of 13 MGD with a separate sewer system. Treatment processes include screening, grit and scum removal, flow equalization, primary settling, trickling filtration, activated sludge aeration, phosphorus removal, secondary clarification, chlorination, dechlorination and post-aeration. A small portion of the sewer system serves the cities of Dayton and Riverside and is maintained by the city of Dayton. Another section of the sewer serves and is maintained by Greene County. Eastern Regional has four industrial contributors averaging 1.03 MGD of the flow to the reclamation facility.

The May to October 2011 calculated phosphorus loading was 18.628 kg/day. The target value is 24.6 kg/day, which was compliant with the permitted phosphorus load.

Eastern Regional reported SSOs in 2009 and 2010. Overflows were reported as migrating to unnamed tributaries in the collection system watershed. Overflow locations occurred at Midvale, Sharewood, Spaulding, Waltham, Hempstead Station, Bellfield, Marshall, Santa Rosa, Bulah and Sharon roads. Sewer water in basements was also reported at Aerial, Oakley, Wagner, Shroyer, Carrlands and Barney roads. Several sewer projects were identified in 2010 that addressed exposed sewer pipes in Little Beaver Creek, Holes Creek, Wolf Creek and a tributary to Sugar Creek.

NPDES permit limit violations were evaluated at outfall 001 from 2007 to 2011. Data evaluated revealed eight violations of Eschericia coli bacteria (*E. coli*), mercury and TSS. Seventy-five percent of the violations occurred in 2009 and 2011.

NPDES permit frequency violations were evaluated at outfall 001 from 2007 to 2011. Data evaluated indicated 271 violations of bypass duration and flow rate in 2007 and 2008.

Ohio EPA conducted acute toxicity testing (bioassays) at Eastern Regional outfall 001 using effluent, upstream and mixing zone waters. The sampling events were generally unannounced and were conducted in April and September 2006 and March 2012. None of the tests were acutely toxic to any of the test organisms. These tests do not address the possibility of chronic toxicity.

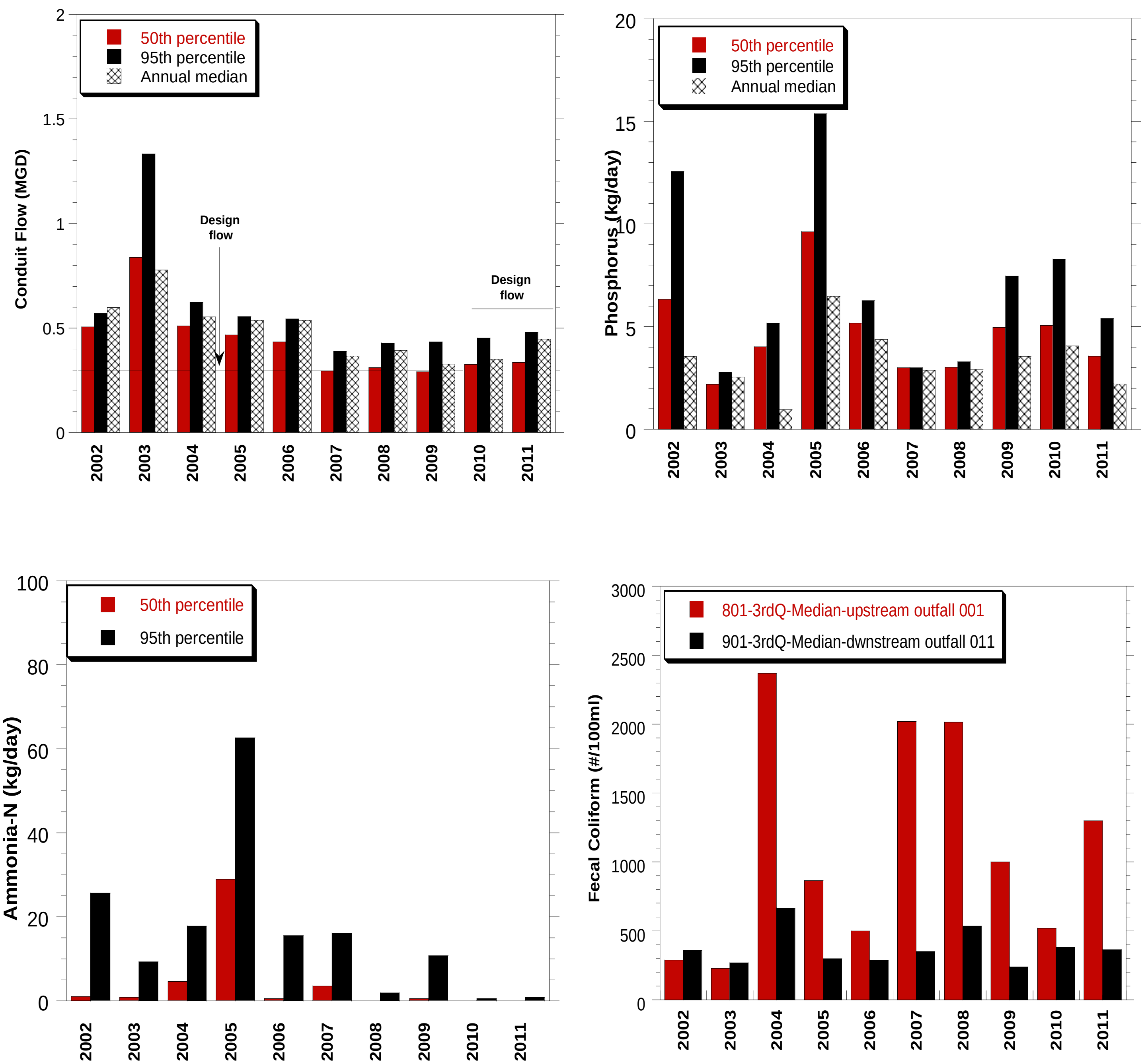


Figure 5. Annual third-quarter loadings of conduit flow, phosphorus, and ammonia-N, and counts of instream fecal coliform bacteria at the Yellow Springs WWTP in the upper Little Miami River study area, 2002-2011.

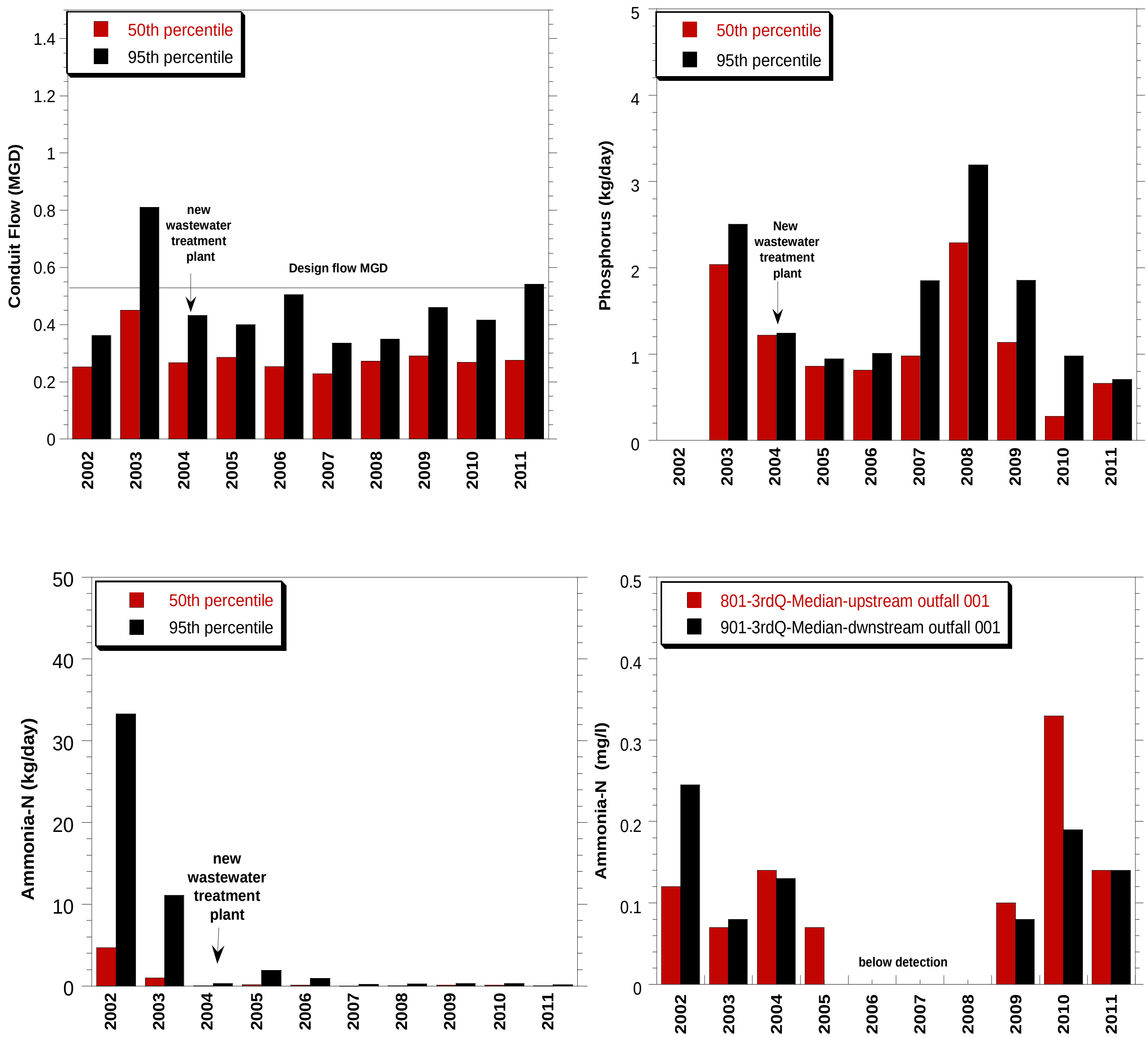


Figure 6. Annual third-quarter loadings of conduit flow, phosphorus, and ammonia-N, and concentrations of instream ammonia-N at the Greene County Cedarville WWTP in the upper Little Miami River study area, 2002-2011.

Beavercreek Water Resource Reclamation Facility (WWRF)
Permit #1PK00003*LD (expired July 31, 2013; currently in public comment phase of renewal)
Receiving stream: Beaver Creek RM 0.4
Outfall 001 Latitude: 39.699167; Longitude: -84.028333
http://wwwapp.epa.ohio.gov/dsw/permits/doc/1PK00003.pdf

The Beavercreek WRRF is located in Greene County, Ohio at 420 Factory Road in Beavercreek, Ohio. Beavercreek WRRF was constructed in 1963 and upgraded in 1999. Beavercreek is an advanced treatment facility with an average design flow of 8.5 MGD with a separate sanitary sewer. Treatment processes include bar screening, primary clarification, flow equalization, primary settling, trickling filtration, activated sludge aeration, phosphorus removal, secondary clarification and ultraviolet disinfection. As of 2011, Beavercreek was meeting the 2013 load requirements for phosphorus reduction. Beavercreek implements an approved industrial pretreatment program. Annual flow rate ranges from 1.66 to 26.7 MGD based on 3,600 observations of nearly ten years of data. The median flow rate was approximately 5.71 MGD during this timeframe.

Two industrial dischargers contribute roughly 0.162 MGD of flow to the wastewater facility. An Ohio EPA inspection in 2012 documented that the flow measurement capabilities of the south plant area had been disabled for a year and thus received a marginal rating for the inspection. The prior years' inspection showed no infractions.

SSO activity has been reported as far back as 2000 for Beavercreek WWRF, even though reporting requirements were not mandatory until 2005. SSOs in 2011 were reported at manhole 44 to the Little Miami River at Hawthorne Glen Trail, lift station 15 to Beaver Creek at 2541 Lantz Road, lift station 17 to Beaver Creek at 3254 Indian Ripple Road, manhole 450 to Beaver Creek at 450 Tanglewood Drive, and manhole at 3218 Indian Ripple Road to Beaver Creek, all occurring from February to July. Volumes reported ranged from 0.003 to 0.054 million gallons. Overflows occurred during heavy precipitation and from debris blocking the lines.

Residential backups of sewage into basements were reported on Grange Hall, Turnbull, Forest Glen and Maginn drives. Many manholes were surcharging in these locations at the time of reporting. Sewer extensions continued to be approved for 20-30 residential subdivisions historically and through 2011.

NPDES permit limit violations were evaluated at outfall 001 from 2007 to 2011. Analysis revealed 37 violations of mostly ammonia-N, mercury, TSS and phosphorus. Seventy-eight percent of the violations occurred up to 2009. Reasons for ammonia-N violations were reportedly due to hydraulic events beyond the peak limits of the facility. Ammonia violations can occur when there's a loss of nitrifiers from the aeration tanks. Phosphorus violations were explained by biological process problems, including alum dosing issues.

Seven NPDES permit frequency violations were reported for outfall 001 from 2007 to 2011. There were less than five code violations for the reporting period.

Ohio EPA conducted bioassays at Beavercreek outfall 001 using effluent, upstream and mixing zone waters. The sampling events were generally unannounced and were conducted in May and August of 2006 and in March and April of 2011. None of the 2006 tests were acutely toxic to any of the test organisms. The March 2011 composite effluents were acutely toxic to the microcrustacean *Ceriodaphnia dubia*. The April 2011 effluent grab sample was acutely toxic to *C. dubia*, with toxicity persisting into the mixing zone. This may have been due to nitrification inhibition in the biological nutrient removal treatment process, thus releasing toxic levels of ammonia into the effluent. These tests do not address the possibility of chronic toxicity.

Percentile flow variance was minimal through the period of record (Figure 7), possibly due to reduced precipitation events in the third quarter of the year. When high precipitation events occur, the collection system overflows at manholes and basements, thus capping the inflow that reaches the facility for treatment. Ammonia load percentile variance was demonstrated graphically; likely due to the loss of nitrifiers from the aeration tanks and heavy precipitation events in July. Phosphorus violations prior to 2009 were explained by biological process problems. Phosphorus removal efforts were noted by 2008. Third quarter median and annual median phosphorus percentiles slowly declined toward 2011. This was corroborated by reduced concentrations downstream from Beavercreek's final outfall.

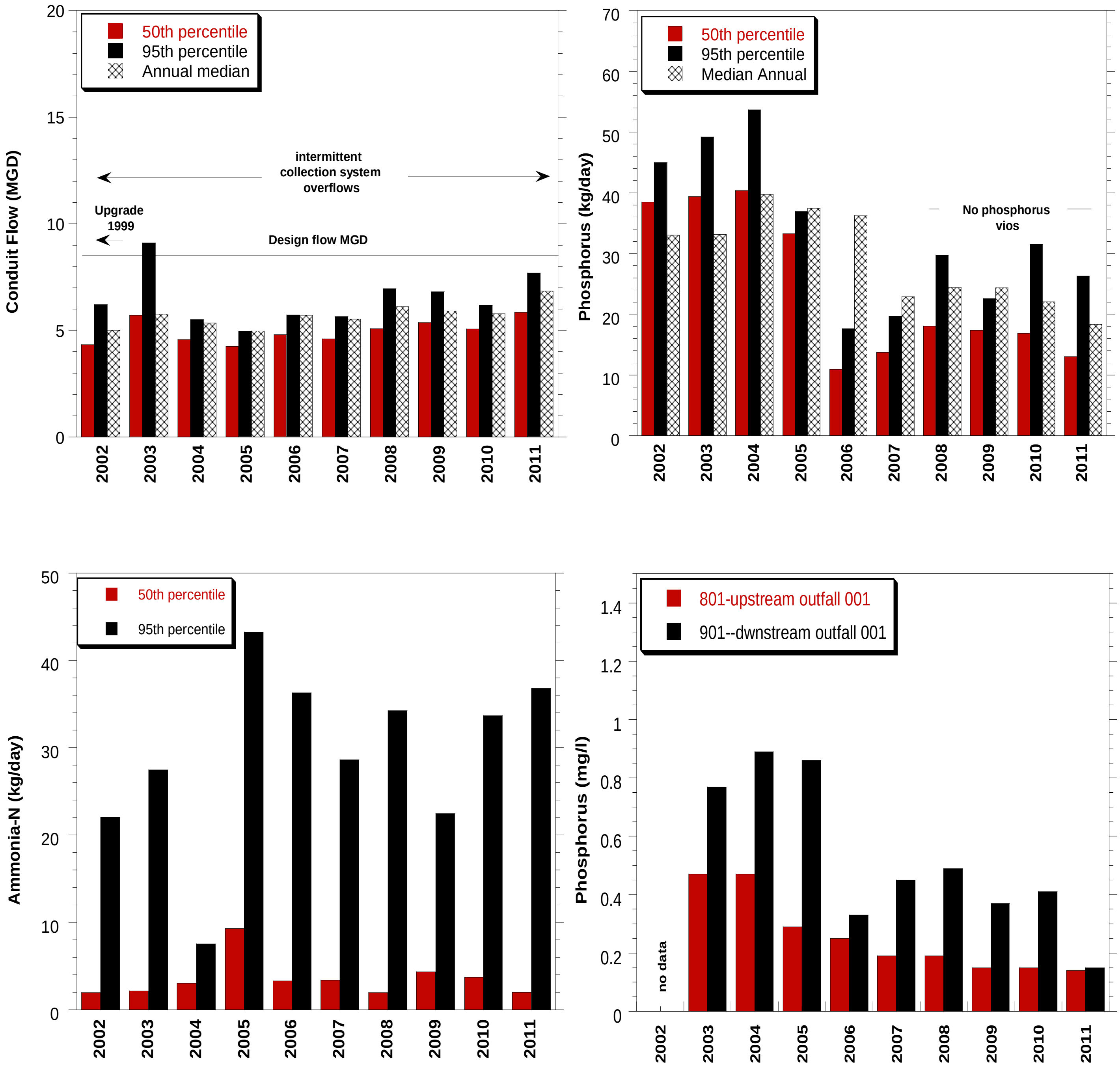


Figure 7. Annual third-quarter loadings of conduit flow, phosphorus, and ammonia-N, and concentrations of instream phosphorus at the Greene County Beavercreek Water Resource Reclamation Facility in the upper Little Miami River study area, 2002-2011.

Xenia Ford WWTP-Permit #1PD00015*KD (expired July 31, 2013)
Receiving stream: Little Miami River RM 77.0
Outfall 001 Latitude: 39.712778; Longitude: -83.966389
http://wwwapp.epa.ohio.gov/dsw/permits/doc/1PD00015.pdf

The Xenia Ford WWTP is located in Greene County at 779 Ford Road in Xenia, Ohio. Xenia Ford was constructed in 1969 and upgraded in 1988. Upgrades were final in 2011 as part of the Contract A Improvement Project precipitated by the completion of the 2008 Ford Road and Glady Run master facilities planning study. Three factors drove the project: infrastructure rehabilitation, regulatory compliance, and operational efficiency. The project entailed three main phases, including a new solids handling structure and conveyance system, a new post-aeration system, and a new headwall. The city secured funding through the Ohio EPA Division of Environmental and Financial Assistance and the Water Pollution Control Loan Fund (WPCLF) for the Contract A Improvement Project

The facility serves the northern region of Xenia with an estimated population of 12,000. Xenia Ford WWTP is an advanced treatment facility with an average design flow of 3.6 MGD and a peak hydraulic flow of 7.5 MGD. Treatment processes include bar screen/fine screen, grit removal, biological phosphorus removal, primary clarification**,** sludge activation, flow equalization (0.278 MG capacity)**,** secondary clarification and ultraviolet disinfection**.** When the equalization basin is at capacity, wastewater discharges through an emergency overflow (outfall 002) to the Little Miami River without treatment. In 2011, a two-hour facility bypass yielded 34,700 gallons to the river. The collection system is fully separate from the storm water collection system and has an inflow/infiltration rate estimated at 0.75 MGD. Sludge from the Ford Road facility is land-applied.

Since at least 2004, SSOs have been reported throughout the collection system in areas such as Towler Road where overflows may cover the ground. Shawnee Creek at Northwest Street receives manhole overflow wastewater. Manhole overflows migrate to a tributary of Shawnee Creek at Hamlet and Marshall drives, and a Shawnee tributary at E. Third Street. Chronic lift station bypasses occur at S. Detroit Street. Public contact health and water quality issues are always a concern for overflow prone areas. The 2008 Master Plan (Arcadis 2008) evaluated the capacities of both Xenia (Ford Road and Glady Run) facilities along with future demands and presented phased improvements to both Xenia facilities.

Four NPDES permit limit violations were reported for outfall 001 from 2007 to 2011. NPDES permit code violations were evaluated at upstream and downstream stations 801 and 901 from 2007 to 2011. Analysis revealed 127 violations were reported in 2009 through 2011, primarily for nutrients and metals.

Ohio EPA conducted bioassays at the Xenia Ford Road outfall 001 using effluent, upstream and mixing zone waters. The sampling events were generally unannounced and were conducted in September and October 1997 and December 2005. None of the 1997 or 2005 tests were acutely toxic to any of the test organisms.

***Jamestown WWTP*-**Permit #-1PB00015*FD (expires August 31, 2018)
Receiving stream: South Branch Caesar Creek RM 9.0
Outfall 001-Latitude: 39.663611; Longitude: -83.740278
http://wwwapp.epa.ohio.gov/dsw/permits/doc/1PB00015.pdf

Jamestown WWTP is located in Greene County at 35 South Limestone Street, Jamestown, Ohio. The Jamestown facility was constructed in 1938 and last upgraded in 1972. The facility serves the village of Jamestown and the community of Shawnee Hills at a combined estimated population of 4,272. Jamestown WWTP is an advanced treatment facility with an average design flow of 0.9 MGD**.** Treatment processes include fine screening, grit removal, orbal oxidation (added in 2002), clarification, UV disinfection and post aeration. Inflow and infiltration into the collection system at Jamestown is currently estimated at 75,000 gpd. From 2006 until 2010, the median daily flow during the months of May through October was 0.4 MGD but increases up to 3.62 MGD were recorded in March 2008. The May-October median daily effluent total phosphorus concentration in 2009 was 0.92 mg/l.

In 2008, an SSO Elimination Study Plan of Action was developed (URS Corporation 2008). It was recommended to not upgrade the facility, but rather to construct an equalization basin in order to handle peak flows. An I/I study also recommended that a water intrusion investigation be conducted in the Shawnee Hills area. In 2008, flows reached up to 793,000 gpd, which caused overflows from the pump station and subsequent migration of raw sewage to Shawnee Hills Lake. Overflows were also reported in Caesar Creek in 2009-2011. In late 2011, Jamestown completed collection system replacements in order to reduce the I/I issues.

NPDES permit limit violations were evaluated at outfall 001 from 2007 to 2011. Twenty-seven violations were noted, with half occurring from 2010-2011. Most violations were for phosphorus and ammonia-N. As of 2012, the facility was still not meeting their phosphorus limits due to flow variations and increased detention times which allow leaching of phosphorus from the settled solids back into the water column. Treatment with alum has only partially helped remediate the concentration. In order to meet phosphorus limits, the facility must maintain an anoxic zone in the outer orbal ring of the oxidation ditch. However, this condition often results in ammonia-N violations due to the lack of oxygen in the ditch. The facility continues to work to find balance between these two opposing phenomenon. NPDES frequency violations were also evaluated at outfall 001 from 2007 to 2011. Twelve violations were reported up through 2009.

Third quarter conduit flows demonstrated no discernible patterns (Figure 8), but instead showed erratic behavior for all parameters represented throughout the period of record. The absence of flow equalization measures, inflow and infiltration and SSOs in the collection system can create unpredictable flow regimes. Ammonia and phosphorus load percentile variances mimic the flow behavior for the annual third quarter loads. This can present treatment challenges for an antiquated facility. Reductions in loads for phosphorus in 2010 and 2011 coincide with the commencement of sewer replacement, thus alleviating treatment process challenges and eliminating possible extra sources of phosphorus leaching out of solids. Final outfall (001) bracketing of fixed stations 801 and 901 demonstrated minor variance in concentrations of ammonia-N for the period of record.

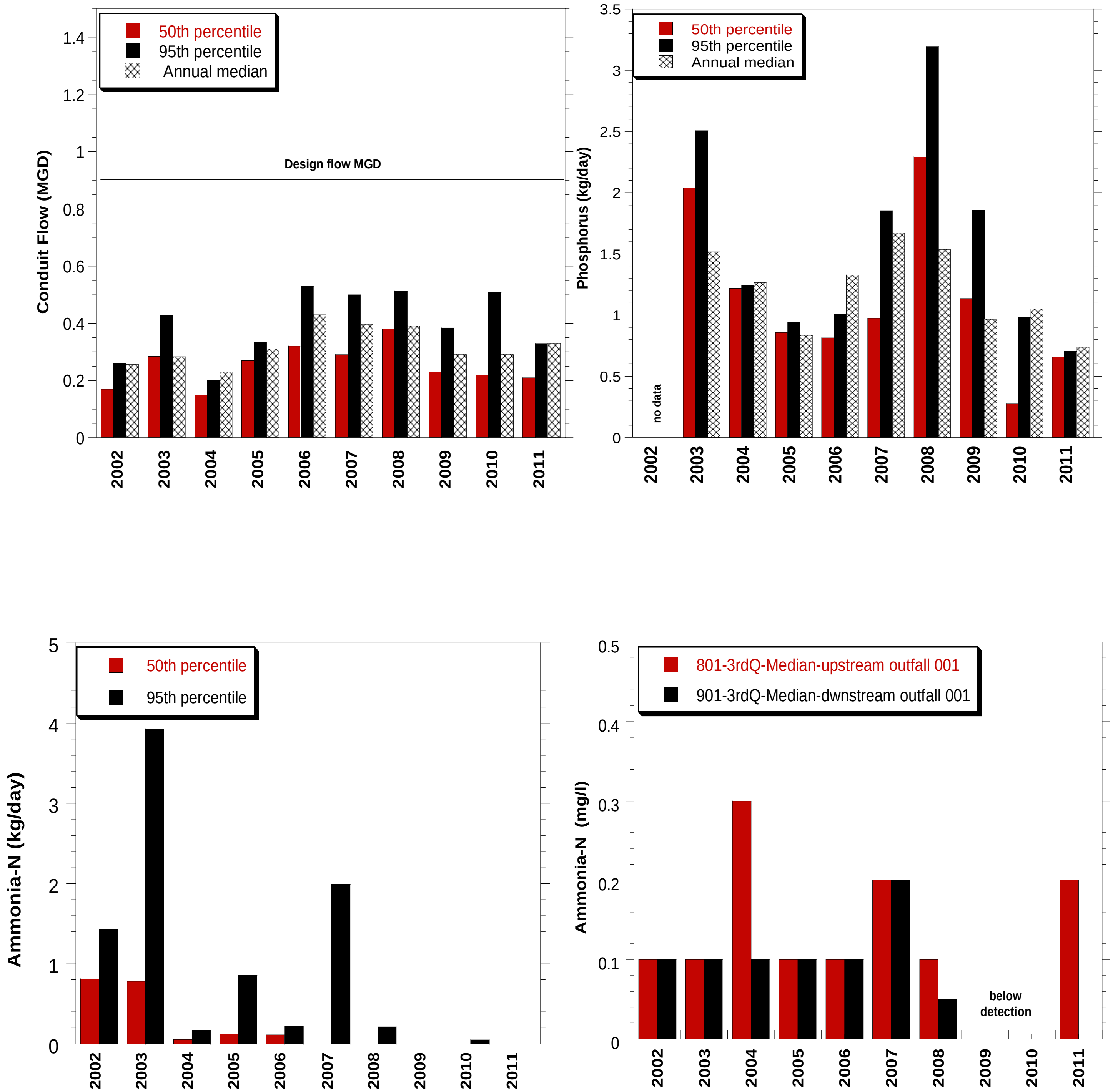


Figure 8. *Annual third-quarter loadings of conduit flow, phosphorus, and ammonia-N, and concentrations of instream ammonia-N at the Greene County Jamestown WWTP in the upper Little Miami River study area, 2002-2011.*

***Xenia Glady Run WWTP*-**Permit #-1PD00016
(expired July 31, 2013; currently in public comment phase of renewal)
Receiving stream: Glady Run RM 4.9
Outfall 001 Latitude: 39.659444; Longitude: -83.965278
Outfall 002-influent bypass from retention basin prior to discharge to Glady Run
http://wwwapp.epa.ohio.gov/dsw/permits/doc/1PD00016.pdf

The Xenia Glady Run WWTP is located in Greene County at 2381 Bellbrook Avenue, Xenia, Ohio. The facility was constructed in 1969 and expansion of the facility was completed in 1999. The demolition of two buildings and unused storage tanks and the construction of a new administration building occurred in 2012 as part of the Contract B-Phase I project. Xenia Glady Run is an advanced treatment facility with an average design flow of 4 MGD and a peak hydraulic flow of 12 MGD. Treatment processes include bar screening, grit removal, flow equalization, biological phosphorus removal, secondary clarification and ultraviolet disinfection. Xenia Glady Run has an approved industrial pretreatment program with one non-categorical and two categorical users discharging to the facility.

Two NPDES permit limit violations were reported at outfall 001 from 2007 to 2011. Four frequency violations were also reported for this time period. Code violations were evaluated at stations 801 and 901 from 2009 to 2011. For the five years of data, 136 violations were reported in 2009 through 2011 for primarily nutrients and metals. Most violations occurred December through March for all years.

Ohio EPA conducted bioassays at Xenia Glady Run outfall 001 using effluent, upstream and mixing zone waters. The sampling events were generally unannounced and were conducted in April and August 1998 and April and July 2006. None of the tests were acutely toxic to any of the test organisms. The July 2006 test results indicated slight mortality in effluent and composite samples, but not enough to consider the test results as acutely toxic. These tests do not address the possibility of chronic toxicity.

Greene County Sugarcreek WWTP-Permit #-1PK00014*ND
(expired July 31, 2013; currently in public comment phase of renewal)
Receiving stream: Little Miami River RM 64.4
Outfall 001 Latitude: 39.615833; Longitude: -84.029167
http://wwwapp.epa.ohio.gov/dsw/permits/doc/1PK00014.pdf

Sugarcreek WWTP is located in Greene County at 2365 SR 725 in Spring Valley, Ohio. The facility was constructed in 1977 at 2.5 MGD and upgraded in 1988 to 4.9 MGD and again to 9.9 MGD in 2009. The facility currently maintains the design flow of 9.9 MGD and a peak hydraulic capacity through the facility at 24 MGD. The treatment system consists of bar screening, grit removal, sludge activation, extended aeration, flow equalization (10.2 million gallons), secondary clarification and ultraviolet disinfection. The sewer system is completely separate with an inflow and infiltration rate of approximately 2.0 MGD. Following the plant upgrade from 2009 to 2011, the median daily flow from May-October was 4.465 MGD. Sewage bypasses at the main pumping station for this facility have occurred historically to Sugar Creek. No bypasses to Sugar Creek have been reported since the new pumping station for the Sugarcreek facility went online in October 2008.

There were nine stream crossings during the replacement of the force main in 2009; one at the Little Miami River, two at Sugar Creek and six at unnamed tributaries. Trenchless technology was employed at the Little Miami River site while open cuts were employed at the other sites.

Nineteen SSOs were reported from 2006-2010. One possible chronic station appeared to be at lift station #24 in the Spring Valley Trailer Park on SR 725. Collection system improvements are needed to address the inflow and infiltration issues that are the catalyst for hydraulic overloading.

NPDES permit limit violations were evaluated at outfall 001 from 2007 to 2011. Data revealed 74 violations that were divided near evenly between TSS, ammonia-N, copper and phosphorus. Twenty-four violations occurred primarily in 2010 and 2011 for phosphorus and ammonia-N. Violations were due to power and blower failures, and new personnel unfamiliar with process control. Five frequency violations were also reported at outfall 001 from 2007 to 2011.

Ohio EPA conducted bioassays at Sugarcreek outfall 001 using effluent, upstream, and mixing zone waters. The sampling events were generally unannounced and were conducted in July and August of 2006 and also in March and May of 2011. No tests were acutely toxic to test organisms.

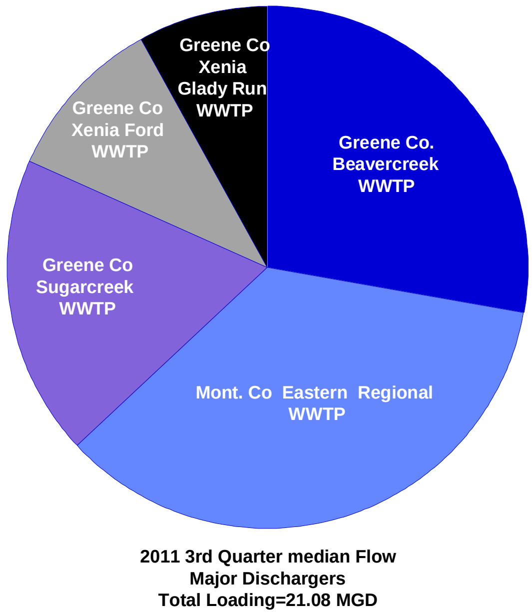
Waynesville WWTP- Permit #-1PB00032*JD (expires August 1, 2016)
Receiving stream: Little Miami River RM 53.8
Outfall 001 Latitude: 39.524167**;** Longitude: - 84.089444
http://wwwapp.epa.ohio.gov/dsw/permits/doc/1PB00032.pdf

Waynesville WWTP is located in Warren County at 444 US RT 42 in Waynesville, Ohio. The facility serves the communities of Waynesville, Harveysburg and Corwin for a population total of approximately 3600. The facility was constructed in 1962 and upgraded in 2000 to 0.710 MGD**.** The average annual flow rate from 2005 until 2012 ranged from 0.44 to 0.73 MGD. Maximum flow rate fluctuated drastically, ranging from 1.3 to 4.4 MGD. The treatment system consists of bar screening, grit removal, combined biological nitrification, chlorination and dechlorination. Average inflow and infiltration is estimated to be 340 gpd. Minimal SSO activity was reported.

Annual average phosphorus loads have declined since 2005, from over 1 mg/l to 0.6 mg/l. The summers of 2006 and 2007 exhibited the highest concentrations of phosphorus loads, which declined significantly in years thereafter once feeds of ferric chloride were begun in 2008 in the effort to meet permit requirements.

NPDES permit limit, frequency and code violations for outfall 001 totaled thirteen for all three categories. Most were reported in 2008.

Phosphorus Loadings to the upper Little Miami River
Graphically, phosphorus loads for the major (>1.0 MGD) wastewater treatment plants support the expectation of a proportional concentration vs. flow relationship (Figure 9). In other words, the largest effluent discharger also contributed the largest load of phosphorus to the Little Miami River and the smallest facility contributed the smallest load. No facility contributed a disproportionately large load of phosphorus to the river relative to its conduit flow. The major dischargers contributed a total 54 mg/l of total phosphorus from July to August of 2011 to the upper Little Miami River watershed.



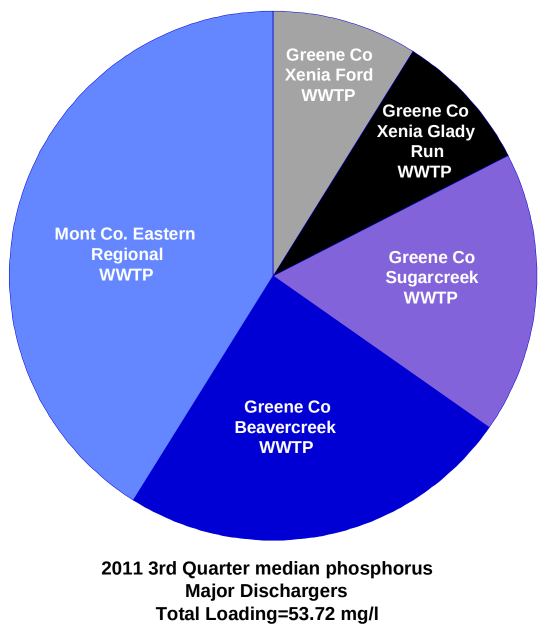


Figure 9. Annual third-quarter conduit flow and phosphorus concentrations for all major dischargers in the upper Little Miami River study area, 2011.

Table 4. Facilities regulated by the National Pollution Discharge Elimination System (NPDES) in the upper Little Miami River study area arranged alphabetically. Facilities shaded in gray are major dischargers over 1 million gallons per day (MGD). River miles represent final outfalls (001).

Permit #	**Permit Name**	**Design flow (MGD)**	**Receiving Stream**	**River Mile**	****Conduit Flow-MGD 2011-3rd qrtr-median**
1PK00003	Beavercreek WRRF	8.50	Beaver Creek	0.4	5.845
1PX00054	Budget Inn	0.02	Unnamed tributary to Anderson Fork (RM 9.26)	1.99	0.002
1PV00114	Caesar Lake MHP	0.02	Unnamed tributary to Little Miami River (RM 59.13)	0.30	0.004
1PB00006	Cedarville WWTP	0.56	Massies Creek	8.9	0.276
1IY00023	Cedarville University WTP	0.01	Unnamed tributary to Massies Creek (~RM 8.61)	n/a	0.008
1IY00020	Central State University WTP	n/a	Unnamed trib to Massies Creek (RM 4.6)	0.20	0.013
1PA00023	Clifton WWTP	0.03	Little Miami River	89.1	0.009
1PT00085	East Clinton High School	0.01	Trib to trib of Anderson Fork (RM 27.82/0.68)	0.27	0.002
1IK00007	Eastwood Dairy LLC	n/a	Unnamed trib to North Fork Massies Creek (RM 5.85)	2.55	-
1IN00288	Garick Corp. Paygro Div	0.40	Little Miami River	106.27	0.121
1PB00028	South Charleston WWTP	0.24	Gilroy Ditch	1.4	0.142
1PB00015	Jamestown STP	0.90	South Branch Caesar Creek	9.0	0.211
1IJ00059	Martin Marietta Clinton Co Limestone Materials	n/a	Drainage ditch to Anderson Fork (RM 19.00)	0.20	0.360
1IJ00022	Martin Marietta Agg.	*3.28	South Fork Massies Creek	1.05	0.576

Permit #	Permit Name	Design flow (MGD)	Receiving Stream	River Mile	**Conduit Flow-MGD 2011-3rd qrtr-median
1IJ00035	Martin Marietta - Xenia Gravel	*1.80	Unnamed tributary to Little Miami River (RM 74.0)	0.82	0.049
1PZ00041	McDonalds Restaurant	0.01	Unnamed tributary to Anderson Fork (RM 9.26)	0.02	0.003
1IJ00040	Melvin Stone Co	n/a	Anderson Fork	23.48	0.470
1IJ00055	Melvin Stone Co LLC	n/a	Unnamed tributary to Grassy Run (RM 1.55)	1.26	0.720
1PL00001	Montgomery Co. Eastern Regional Water Reclamation Facility	13.0	Little Beaver Creek	4.6	0.020
1IN00095	Morris Bean & Co Yellow Springs Plant	0.04	Unnamed tributary to the Little Miami River	84.15	0.055
1IN00266	Morris Bean & Co Yellow Springs Plant	n/a	Unnamed tributary to the Little Miami River	84.15	-
1PZ00019	Pilot Travel Centers LLC No 016	0.01	Unnamed tributary to Anderson Fork (RM 9.26)	0.02	0.005
1PT00120	Reid Primary Middle School	0.01	Unnamed tributary to North Fork Little Miami River	n/a	0.002
1PZ00113	Roberts Development Commerce Park WWTP	0.50	Anderson Fork	9.68	0.847
1IJ00057	Shelly Mats Springfield	*4.76	Furray-Gray stream	1.0	4.760
1IY00153	Spring Valley Waterworks	0.01	Unnamed tributary to Little Miami River (RM 63.30)	0.51	0.005
1PK00014	Sugarcreek WRF	9.9	Little Miami River	64.4	3.887

Permit #	Permit Name	Design flow (MGD)	Receiving Stream	River Mile	**Conduit Flow-MGD 2011-3rd qrtr-median
1IN00029	Tenneco Automotive Operating Co Inc	0.59	Unnamed tributary to Little Beaver Creek (RM 6.1)	0.62 0.67 0.85 0.90 0.55	0.013 0.015 0.048 0.025 0.085
1IN00189	Unison Industries Plant 1	0.35	Beaver Creek	1.23	0.323
1IN00140	Unison Industries Plant 2	0.22	Little Miami River	~73.16	0.273
1PB00032	Waynesville WWTP	0.71	Little Miami River	53.8	0.391
1PV00113	Wayne Mobile Inc	0.02	Little Miami River	54.42	0.017
1IY00220	Xenia WTP	0.04	Massies Creek	0.15	0.038
1PD00015	Xenia Ford Road WWTP	3.60	Little Miami River	77.0	2.191
1PD00016	Xenia Glady Run WWTP	4.0	Glady Run	4.9	1.692
1PC00013	Yellow Springs WWTP	0.60	Yellow Springs Creek	0.4	0.336

* Based on a batch discharge over 24-hrs. **Total-23.789 MGD

Water Chemistry and Recreation Use

Inorganic water chemistry grab samples and field measurements were collected every other week (six times) from late June to mid-September at 91 sites in the upper Little Miami River watershed, including 23 sites on the mainstem, and at 10 WWTPs. Samples were analyzed for a variety of parameters including nutrients and metals (Appendix Table A-1). Additionally, Datasonde® continuous monitors recorded hourly dissolved oxygen (DO), temperature, pH, and specific conductivity for a 48-hour period at 35 sites (Appendix Tables A-4 - A-5). Additional inorganic (and organic) sampling was conducted at select sites throughout the year (See Sentinel Site Monitoring Program, page 75).

Forty-six stream locations in the watershed were tested for *E. coli* levels eight to ten times from June 9 through October 6, 2011 (Appendix A-1). Evaluation of *E. coli* results revealed that 42 of the 46 locations (91%) failed to attain the applicable geometric mean criterion, indicating an impairment of the recreation use at these locations. The locations not attaining the recreation use were impaired by a variety of possible sources. Indicators used to suggest the sources most likely contributing to sites identified in non-attainment included land use data, aerial maps, staff field notes, and the location of Class B biosolids application fields; Class B biosolids are treated but still contain detectible levels of pathogens. Where these indicators failed to suggest a potential source, the source is listed as unknown in Table 10. Agriculture, accounting for 67% of the total land use in the study area, was a potential source of contamination at many of the impaired sites. However, exacerbated by above normal precipitation and higher stream flow, the preponderance of elevated bacteria counts may also be attributed to ubiquitous background contamination. Summarized bacteria results (*E. coli*) are listed in Table 10 and the complete dataset is reported in Appendix Table A-3.

Water chemistry results from daytime grab samples which exceeded Ohio Water Quality Standards (WQS) criteria are presented in Table 8. Additionally, nitrate-nitrite-N and total phosphorus data were compared to the targets recommended to maintain biological integrity in streams and rivers (Ohio EPA 1999). An evaluation of nitrate-nitrite-N and total phosphorus data compared to these recommended targets is detailed in Table 9.

Many of the graphs associated with the following summaries include dotted lines representing percentile concentrations from least impacted regional reference sites of similar size (Ohio EPA 1999). Statistical data were stratified by stream size for these analyses as follows: headwater streams (0-20 mi^2); wadeable streams (> 20-200 mi^2); small rivers (> 200-1000 mi^2) and large river (>1000 mi^2). Additionally, sampling results which were less than detection were included in the analysis at ½ the reporting level.

Little Miami River

A popular recreational resource, the Little Miami River is designated a State and National Scenic River and contains some of Ohio's most scenic and diverse riverine habitat. Stream flow in the mainstem and throughout the study area during the summer of 2011 was generally above normal, reflecting above average precipitation. Total average rainfall of 26.26 inches was recorded from May through October, 2011 in the southwest region of Ohio, almost five inches above normal for the period (Table 5). While not in the study area, the adjacent City of Dayton experienced its second wettest year on record (56.72" - record 59.75" in 1990), its second wettest April (8.72" - record 9.20" in 1996), its third wettest spring (18.95" - record 21.06" in 1989), and its wettest fall (19.65" - previous record 15.35" in 1925) (NOAA 2012).

Stream flows from May through October 2011 as measured by the USGS gage station in the Little Miami River near Oldtown (RM 80.63) are presented in Figure 10. Eighty-one percent of mean daily flows for the period were above the 50% (median) duration exceedance flow of 43 cfs (USGS 2012 and 2000). The 50% duration exceedance flow represents the discharge which was equaled or exceeded 50% of the time over the period of record. On specific water chemistry sampling days mean daily flows ranged from 34 cfs (August 24 and September 14) to 256 cfs on May 17. On Ohio EPA bacteria sampling days, mean daily flows ranged from 32 cfs on August 31 to 285 cfs on June 23.

Table 5. Precipitation in the Southwest region of Ohio May-October, 2011 (ODNR 2011).*

Month	May	June	July	Aug	Sept	Oct	6-month period
Average rainfall (inches)	6.57	4.05	2.66	2.62	6.82	3.54	**26.26**
Departure from Normal**	+2.09	+0.16	-1.44	-0.79	+3.95	+0.92	**+4.89**
% of normal rainfall	147%	104%	65%	77%	238%	135%	**123%**
PDSI*	**+3.7**	**+1.9**	**+0.2**	**-1.4**	**+1.0**	**+2.6**	**+2.6**

* Includes Montgomery, Greene, Clermont, Brown, Highland, Hamilton, Clinton, Warren, Butler, and Preble counties
** Base period 1951 - 2000
*** PDSI (Palmer Drought Severity Index)

Above +4 = Extreme Moist Spell
3.0 to 3.9 = Very Moist Spell
2.0 to 2.9 = Unusual Moist Spell
1.0 to 1.9 = Moist Spell
0.5 to 0.9 = Incipient Moist Spell
0.4 to -0.4 = Near Normal
-0.5 to -0.9 = Incipient Drought
-1.0 to -1.9 = Mild Drought
-2.0 to -2.9 = Moderate Drought
-3.0 to -3.9 = Severe Drought
Below -4.0 = Extreme Drought

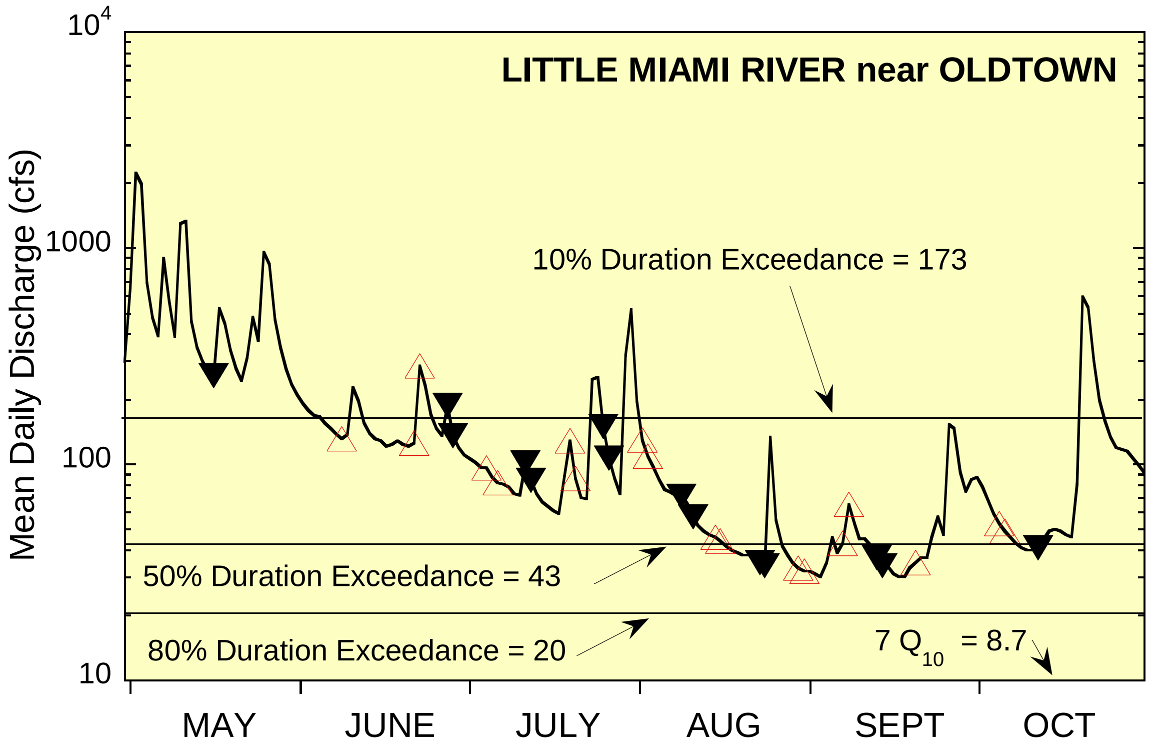


Figure 10. May through October, 2011 flow hydrograph for the Little Miami River near Oldtown (USGS station # 03240000). Solid triangles indicate river discharge on water chemistry sampling days in the Little Miami River mainstem. Open triangles indicate river discharge on bacteriological sampling days. Duration exceedance and $7Q_{10}$ flow lines represent May-Nov period of record 1952-1997.

Water samples collected at the 23 sites in the mainstem generally reflected very good water quality. However, daytime grab dissolved oxygen concentrations fell below critical levels (< 4.0 mg/l) in the headwaters (RMs 106.95 and 103.13) (Table 8, Figure 13). The reach upstream from Paygro (RM 106.95) is a small, narrow, grassy channel with no woody riparian buffer. Additionally, flow at RM 103.13 (Jamestown Rd) became interstitial during the last two weeks of the summer survey. Datasonde® continuous monitors documented supersaturated DO concentrations and wide swings in diel DO and pH at Dolly Varden Road (RM 98.98) from August 9-11 (Figure 12). Supersaturated DO concentrations and wide swings in diel DO and pH are indicative of nutrient enrichment, and in fact, these conditions, along with measured nutrient concentrations, and chlorophyll levels, indicate that nutrient enrichment imperils biological attainment at the Dolly Varden Road site (RM 98.98; Table 11). Otherwise, Datasonde® DO remained remarkably stable longitudinally with overall hourly saturation for the 17 sites downstream from Dolly Varden Road (RM 98.98) ranging from 80.5% to 114%. Datasonde® monitors also documented a marked increase in specific conductivity at RM 72.3 (Indian Ripple Road) downstream from the confluence of Beaver Creek in both August and September, reflecting the combined impact of both the Beavercreek WWTP discharge (RM 0.4 on Beaver Creek) and the Montgomery County Eastern Regional WWTP discharge (RM 4.76 on Little Beaver Creek). In August, the overall median increased from 653 µmhos/cm for the seven mainstem sites upstream from Beaver Creek, to 760 µmhos/cm for the eleven sites downstream from the confluence.

Ammonia-N levels in the mainstem were generally low with medians well below target reference values and the majority (81%) of values less than the reporting limit of 0.05 mg/l (Figure 14). Four of the five highest ammonia-N concentrations in the mainstem occurred on September 14 at the four sites immediately downstream from the Sugarcreek WWTP. None of the ammonia-N values exceeded WQS criteria. One ammonia-N concentration of 7.0 mg/l was measured in the effluent and the facility reported a violation in its self-monitoring report.

Nitrate-nitrite-N concentrations were elevated above target at virtually all sites with an overall median concentration of 3.145 mg/l for all 23 mainstem sites (Table 9, Figure 14**)**. Phosphorus was elevated above the TMDL target of 0.07 mg/l in the headwaters in the vicinity of Paygro and the Ohio Feedlot confined animal feeding operation (CAFO) (RMs 106.95-103.13). Paygro composts cattle manure from Ohio Feedlot and has a processing operation which bales and bags soil and mulch products and both operations have NPDES permits to discharge storm water to the Little Miami River. Samples collected on June 23 from a storm water ditch indicated a total phosphorus concentration of 2.61 mg/l. Longitudinally, phosphorus levels dropped for the next 17 miles downstream before increasing at RM 83.14 downstream from Yellow Springs Creek, and again at RM 72.30 downstream from Beaver Creek. The increases are likely attributable to the Yellow Springs WWTP (discharges to Yellow Springs Creek at RM 0.43) and Beaver Creek, which receives the pollutant loading from both the Beavercreek WWTP and Eastern Regional WWTP on Little Beaver Creek. Higher concentrations were also documented at RM 64.28 downstream from the Sugarcreek WWTP. Notably, the overall median phosphorus concentration for the 12 sites sampled upstream from the Beaver Creek confluence (RMs 106.95 through RM 73.16) was 0.075 mg/l compared to 0.128 mg/l for the 11 sites downstream from the Beaver Creek confluence. The overall median phosphorus concentration for all mainstem sites sampled was 0.100 mg/l. Phosphorus was also elevated above the TMDL target at RM 58.30. The Caesar Lake Mobile Home Park (MHP) discharges to an unnamed tributary (confluence RM 59.13) upstream from this site.

While total suspended solids generally remained below target reference values (Figure 13), concentrations trended upward longitudinally with medians increasing from 3.75 mg/l in the upper reaches near South Charleston (RM 104.88) to 34 mg/l in Waynesville (RM 53.84).

Bacteria samples collected in the mainstem indicate that the Primary Contact Recreation (PCR) Class A use was not attained at any site (Table, 10, Figure 11). Virtually half of all *E.coli* sample results in the mainstem were also above the PCR Class A maximum criterion with the highest bacteria counts typically coinciding with precipitation events and higher stream flows (Figure 10). The highest bacteria levels in the entire survey were documented at RM 104.88 (SR 41) downstream from Paygro and the Ohio Feedlot CAFO (geometric mean 1357). Other potential sources of bacteria in the mainstem include biosolids application to agricultural fields as well as general agricultural and urban runoff. Additionally, while geometric means at the three major wastewater facilities discharging to the mainstem were low, elevated values were noted on occasion in the effluent of both the Sugarcreek and Waynesville WWTPs. Occasionally elevated concentrations in the Beavercreek WWTP discharge (RM 0.4 on Beaver Creek which enters the mainstem at RM 72.74) may also have carried over to the mainstem. Furthermore, the Dale Dakin Wayne MHP (RM 52.45) reported *E.coli* violations in self-monitoring reports from May through October.

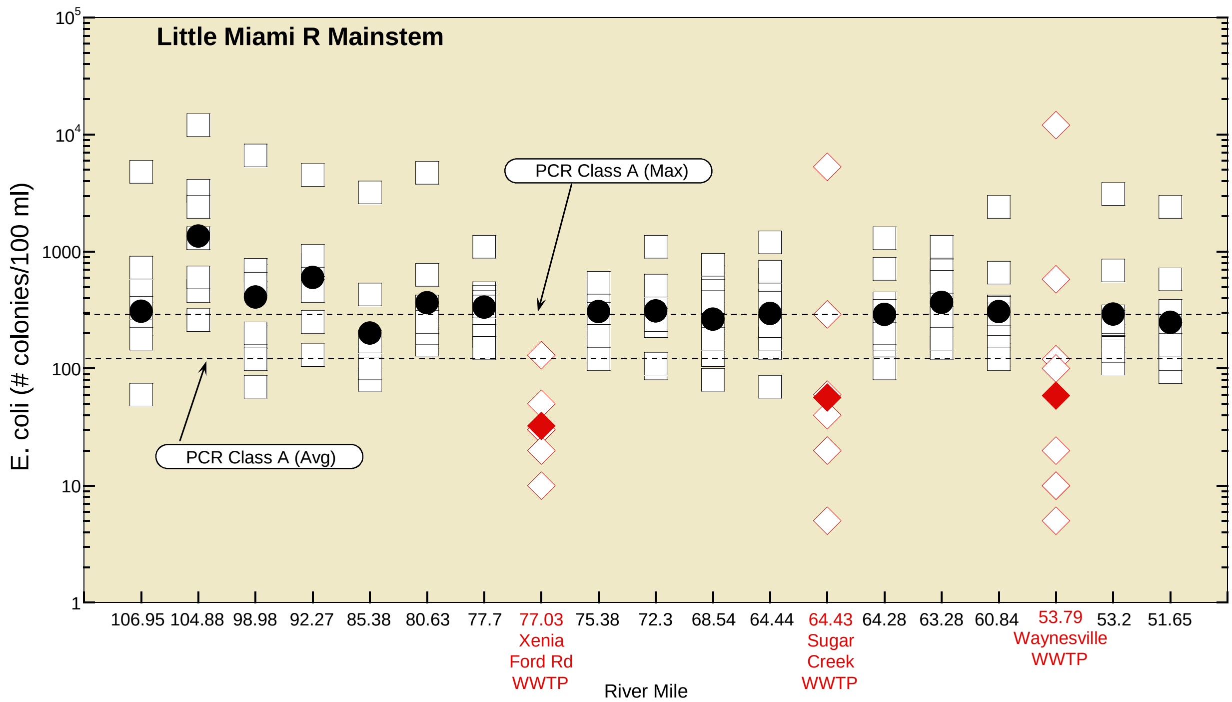


Figure 11. Scatter plots of E. coli concentrations in the mainstem of the Little Miami River, 2011. White squares = site E. coli values, black circles = geometric mean of site E. coli values, white diamonds = effluent E. coli values, red diamonds = geometric mean of effluent E. coli values.

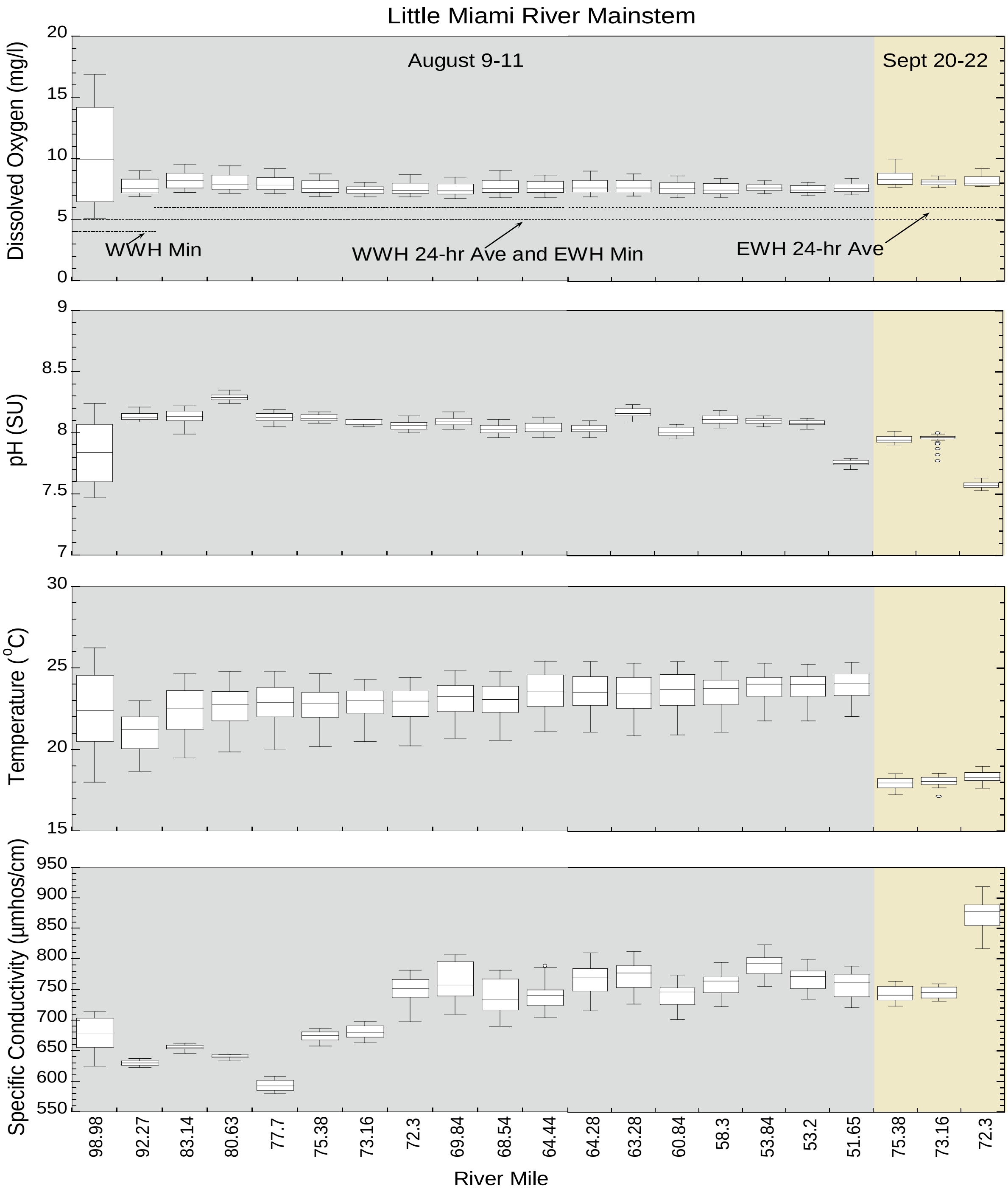


Figure 12. Dissolved oxygen, temperature, pH, and specific conductivity recorded hourly with Datasonde® continuous monitors in the Little Miami River August 9-11 and September 20-22, 2011. WQS criteria lines are shown in the dissolved oxygen plot. (Each box encloses 50% of the data with the median value of the variable displayed as a line. The top and bottom of the box mark the limits of ± 25% of the variable population. The lines extending from the top and bottom of each box mark the minimum and maximum values within the data set that fall within an acceptable range. Values outside of this range are displayed as individual points.)

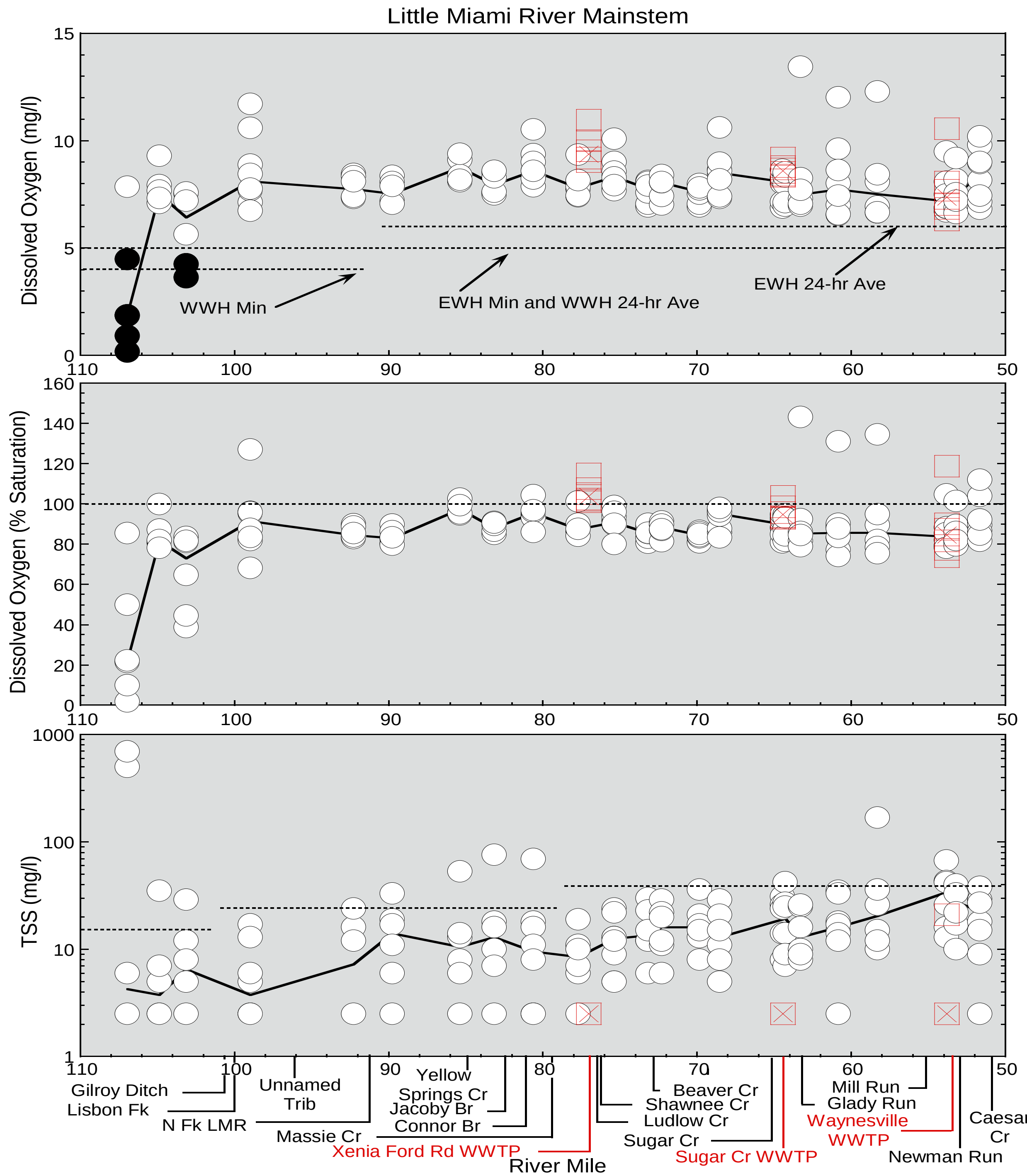


Figure 13. Longitudinal scatter plots of daytime grab dissolved oxygen concentration, dissolved oxygen percent saturation, and TSS in the mainstem Little Miami River (circles) and three wastewater dischargers (squares) during 2011 (May-October). The solid line depicts the median value at each river mile sampled in the mainstem while an 'X' depicts the median of the wastewater final effluent. WQS criteria lines are shown in the dissolved oxygen concentration plot. (Values not meeting criteria are shown as solid circles.) Dashed horizontal lines in the TSS plot represent applicable statewide reference values from sites of similar size.

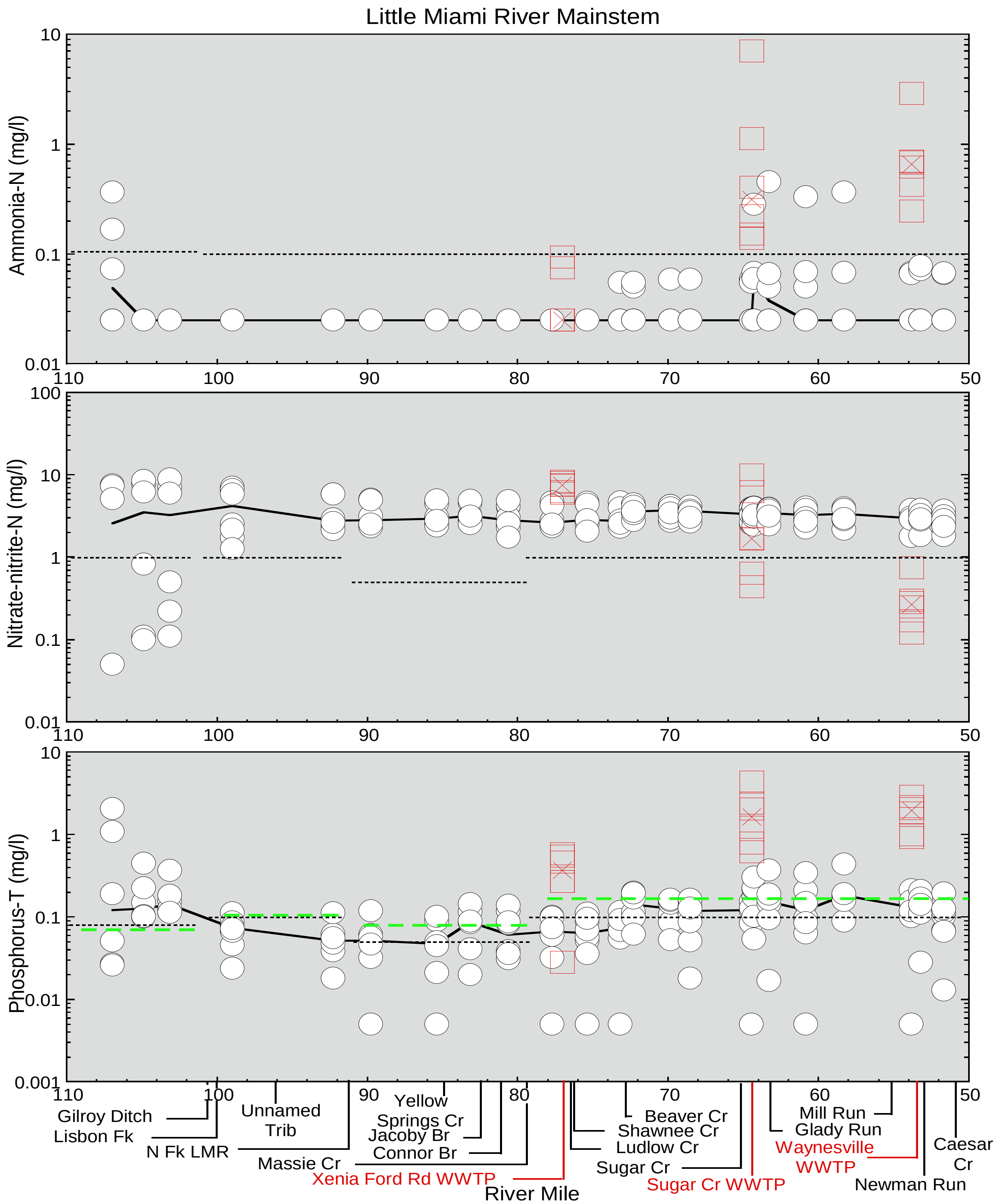


Figure 14. Longitudinal scatter plots of ammonia-nitrogen, nitrate-nitrite-nitrogen, and total phosphorus in the mainstem Little Miami River (circles) and three wastewater dischargers (squares) during 2011 (May-October). The solid line depicts the median value at each river mile sampled while an 'X' depicts the median of the wastewater final effluent. The thinner black dashed horizontal lines represent applicable statewide reference values from sites of similar size. The heavier dashed green line in the phosphorus plot represents the TMDL target value.

Little Miami River Tributaries (headwaters to Massies Creek)

Gilroy Ditch

Gilroy Ditch, draining 7.6 mi^2, receives effluent from the South Charleston WWTP before entering the Little Miami River mainstem at RM 100.65. Chemistry samples were collected from the South Charleston WWTP effluent (RM 1.4) and one instream site downstream from the facility at RM 0.5.

Water quality in Gilroy Ditch was generally good with stable daytime dissolved oxygen levels (median DO saturation 94%) and low ammonia-N. Concentrations of nitrate-nitrite-N and total phosphorus were elevated above statewide target reference levels, reflecting nutrient loading from the South Charleston WWTP in addition to agricultural loads (Table 9). There were no exceedances of WQS criteria at the site and no other elevated parameters.

Bacteria samples collected at RM 0.5 indicated that the recommended PCR Class B use was not attained. Potential sources of bacteria include biosolids application to farm fields, general agricultural and urban runoff, and the South Charleston WWTP.

Lisbon Fork

Lisbon Fork drains 12 mi^2 and enters the mainstem at RM 100.0. Chemistry samples collected during the summer at RM 2.8 (SR 41) indicated several DO concentrations below WQS criteria and one ammonia-N value (3.39 mg/l) that exceeded the WQS criterion on August 9 (Table 8). Field notes indicate the stream was dark brown on this day. Per the Ohio Department of Agriculture (ODA), manure from the Van Raay Dairy was over-applied to a farm field upstream (adjacent to Stewart Rd) and released to a tributary to Lisbon Fork during this time period. Additionally, nitrate-nitrite-N and total phosphorus concentrations were frequently elevated, reflecting the agricultural land use of the drainage area. There were no other elevated parameters.

Tributary to Little Miami River (RM 96.26)

One site (RM 0.6 Buffenbarger Rd) was sampled on this small channelized tributary to the Little Miami River. Ammonia and total phosphorus concentrations were low and nitrate-nitrite-N levels were minimally elevated above statewide targets. There were no other elevated parameters.

North Fork Little Miami River and Tributary to North Fork Little Miami River (RM 5.60)

The North Fork Little Miami River drains 35.9 mi^2 and enters the mainstem at RM 91.64. Agriculture is the predominant land use with cultivated crops accounting for 72.9% of the total watershed area. In addition to two sites (RMs 9.1 and 0.37) sampled on the North Fork Little Miami River, one site (RM 0.8) was sampled in the unnamed tributary entering the North Fork Little Miami River at RM 5.60.

Water quality was relatively good in both the North Fork Little Miami River and the tributary. Ammonia-N and total phosphorus levels were low. Nitrate-nitrite-N concentrations were elevated above the statewide target in the North Fork Little Miami River but remained low in the tributary. Other than one DO value below the average WQS criterion in the tributary, there were no other exceedances of criteria or elevated parameters.

Bacteria samples collected at RM 0.37 indicated that the PCR Class B use was not attained (Table 10). The most likely sources of bacteria were biosolids application and general agricultural runoff.

Yellow Springs Creek

Yellow Springs Creek, draining 11.3 mi^2, receives effluent from the Yellow Springs WWTP before entering the Little Miami River mainstem at RM 85.17. Chemistry samples were collected from the WWTP effluent (RM 0.43) and one instream site downstream from the discharge at RM 0.1 (Grinnell Rd).

Water quality in Yellow Springs Creek downstream from the Yellow Springs WWTP was relatively good with stable daytime grab DO (median saturation 93.4%) and low ammonia-N levels. However, nutrient loading from the WWTP was apparent in the elevated concentrations of nitrate-nitrite-N, and total phosphorus was above reference targets (Table 9). There were no other elevated parameters at the site.

Bacteria samples collected at RM 0.1 indicated that the PCR Class B use was not attained (Table 10). The most likely sources of bacteria were general urban and agricultural runoff.

Jacoby Branch

Jacoby Branch drains 6.28 mi^2 west of the Village of Yellow Springs and enters the mainstem Little Miami River at RM 82.55. Water chemistry as measured at one site (RM 0.5) in this high gradient tributary indicated good water quality. Daytime DO values were normal (median saturation 99.2%) and all ammonia-N concentrations were less than the detection limit. Phosphorus levels were also generally low while nitrate-nitrite-N minimally exceeded statewide target levels. There were no other elevated parameters.

Conner Branch

Conner Branch, a high gradient stream, drains 2.45 mi^2 and enters the mainstem at RM 81.45. Water quality in Connor Branch was very good. However, on August 9 after a rain event the stream was remarkably turbid visually and total suspended solids were exceptionally high (226 mg/l). Other streams in the near vicinity did not appear visually impacted by the rain event on August 9. While there is a small gravel operation adjacent to the stream, follow-up investigations were inconclusive as to a definitive source of the runoff.

Massies Creek Watershed

Massies Creek drains 84.4 mi^2 in Greene and Clark counties and enters the Little Miami River at RM 79.54. Tributaries sampled included North Fork Massies Creek, South Fork Massies Creek, Clark Run, and Oldtown Creek. The Cedarville WWTP discharges to Massies Creek at RM 8.9. Communities in the watershed include Cedarville and Wilberforce. Agriculture is the predominant land use with cultivated crop accounting for 78% of the total watershed area.

Stream flows from May through October 2011 as measured by the USGS gage station on Massies Creek at Wilberforce (RM 4.38) are presented in Figure 15.

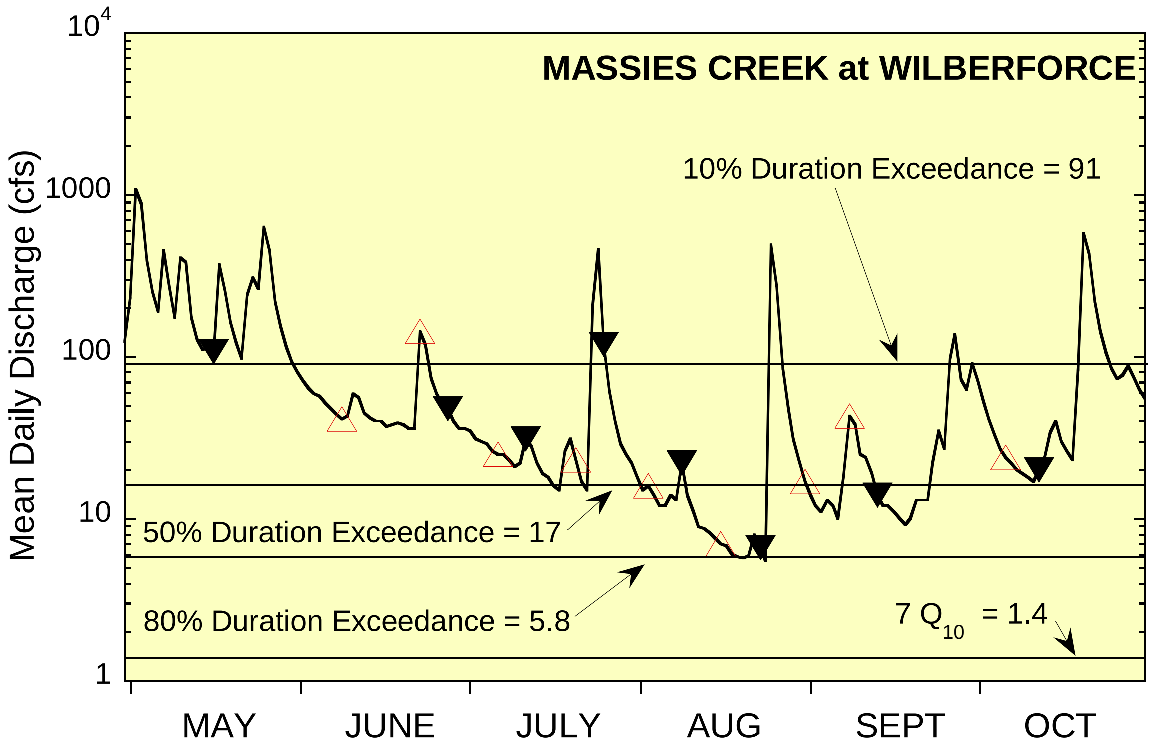


Figure 15. May through October, 2011 flow hydrograph for Massies Creek at Wilberforce (USGS station # 03241500). Solid triangles indicate stream discharge on water chemistry sampling days in the Massies Creek watershed. Open triangles indicate stream discharge on bacteriological sampling days. Duration exceedance and $7Q_{10}$ flow lines represent May-Nov period of record 1952-1997.

Water quality in the Massies Creek watershed was generally very good. Dissolved oxygen, pH, and temperature measured by Datasonde® continuous monitors deployed at three sites in Massies Creek and at RM 0.14 in South Fork Massies Creek were stable, demonstrating normal diurnal variability (Figure 17). However, while DO levels remained above minimum WQS criteria in North Fork Massies Creek at RM 5.73, the site experienced significant diurnal variability, with concentrations and corresponding saturations ranging from 4.98 mg/l (57.9%) to 13.83 mg/l (179.2%). Wide ranges in diurnal temperature and pH were also noted. As with the Dolly Varden site mentioned previously, nutrient levels and diel DO swings (Table 11) indicated that nutrient enrichment is a primary cause (along with poor habitat – see Habitat/Fish section) of aquatic life use partial attainment. The site is adjacent to and downstream from active biosolids application farm fields. Additionally, the Eastwood Dairy discharged storm water (RM 2.55) to an unnamed tributary entering North Fork Massies Creek at RM 5.85. The stream in this area is channelized with minimal riparian vegetation, which accentuated the negative impact of agricultural nutrient loading.

While phosphorus concentrations were generally not elevated in the watershed, 83% of nitrate-nitrite-N concentrations were above target levels (Table 9). There were no other elevated parameters in the watershed.

Bacteria samples collected at six sites in the Massies Creek watershed indicated that the PCR Class B use was not attained (Figure 16, Table 10). Some of the highest concentrations in the survey occurred in North Fork Massies Creek at RM 5.73 downstream from the Eastwood Dairy tributary. Other potential sources of bacteria in the watershed include biosolids application to farm fields as well as general agricultural and urban runoff.

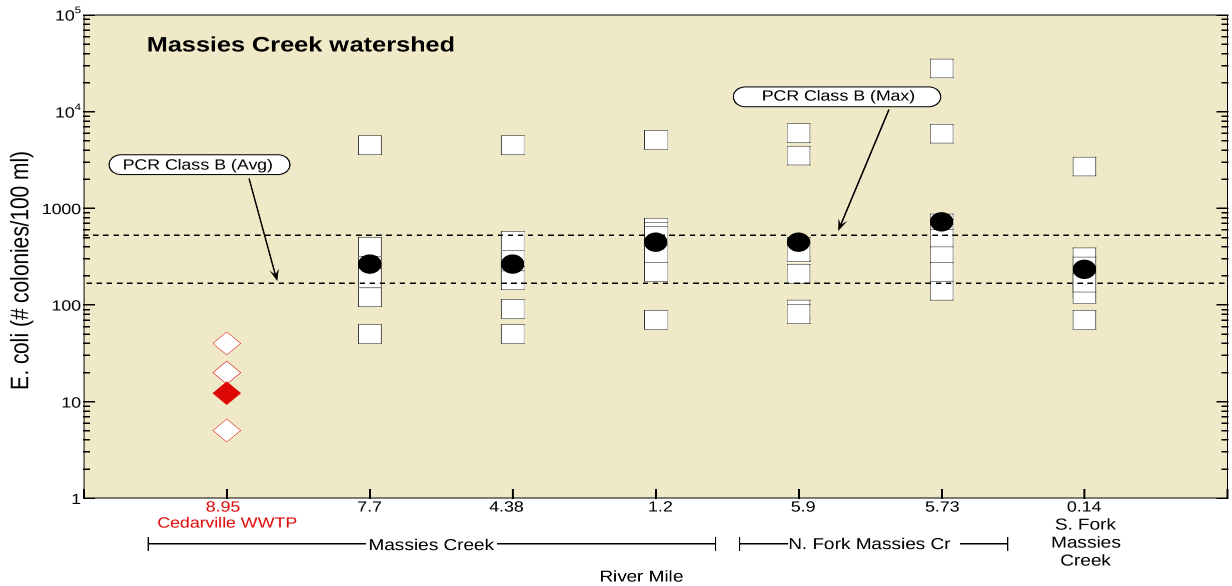


Figure 16. Scatter plots of E. coli bacteria concentrations in the Massies Creek watershed (including the final effluent of the Cedarville wastewater treatment plant) during the 2011 survey. Dotted lines represent Primary Contact Recreation (PCR) WQS criteria. Solid circles (diamonds) represent the geometric mean at each site sampled.

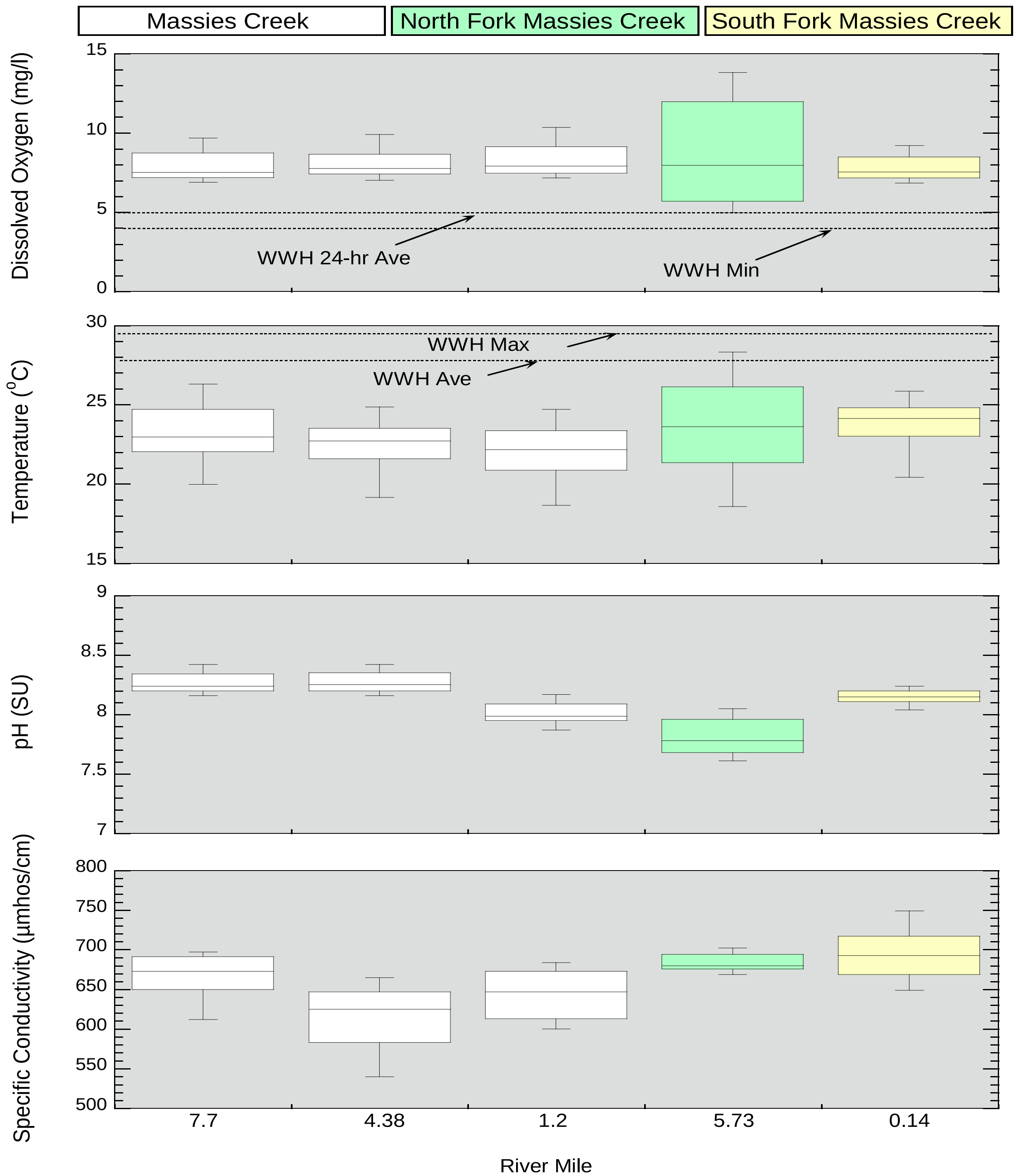


Figure 17. Dissolved oxygen, temperature, pH, and specific conductivity recorded hourly with Datasonde® continuous monitors in the Massies Creek watershed August 9-11, 2011. WQS criteria lines are shown in the dissolved oxygen and temperature plots. (Each box encloses 50% of the data with the median value of the variable displayed as a line. The top and bottom of the box mark the limits of ± 25% of the variable population. The lines extending from the top and bottom of each box mark the minimum and maximum values within the data set that fall within an acceptable range. Values outside of this range are displayed as individual points.)

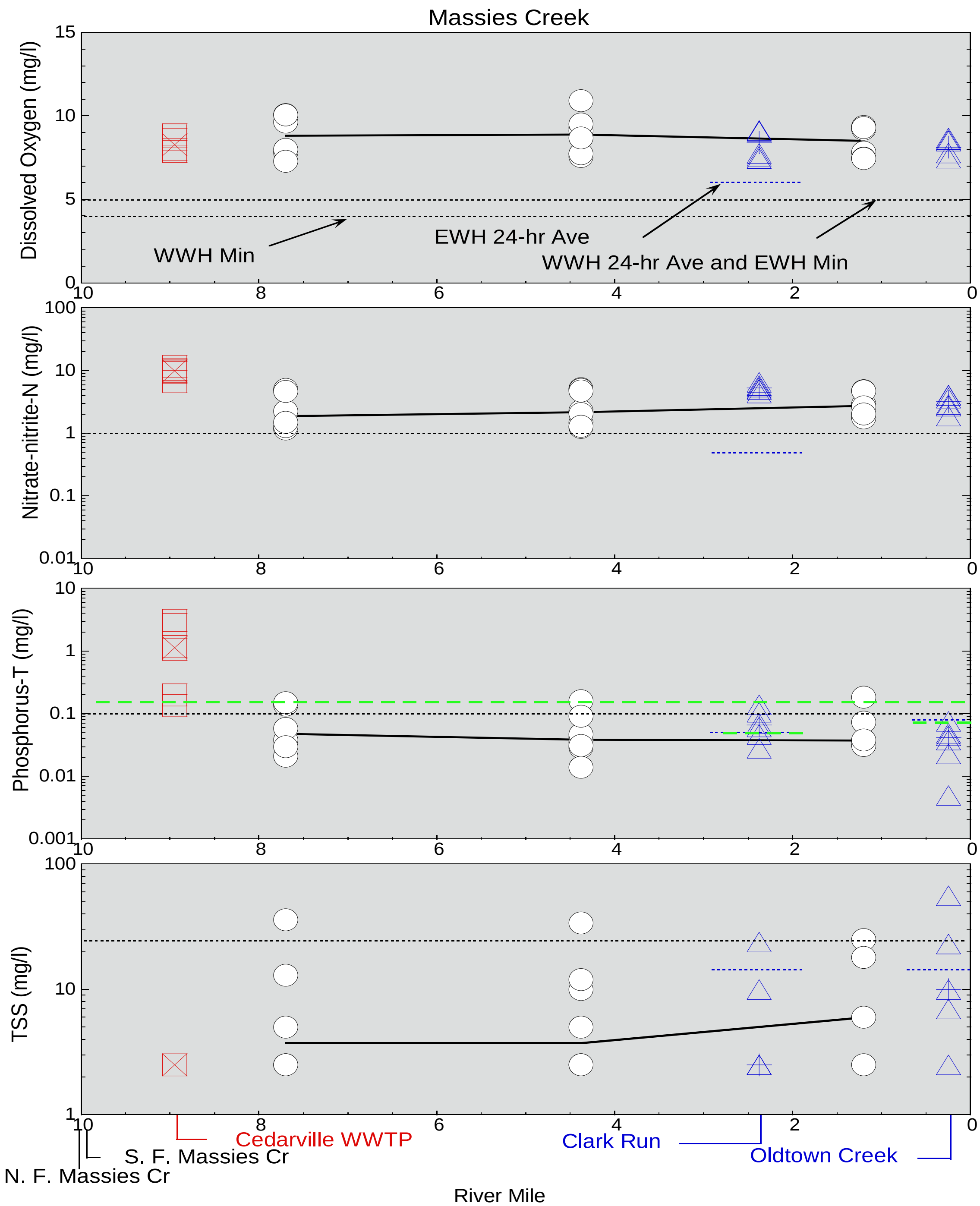


Figure 18. Longitudinal scatter plots of daytime grab dissolved oxygen, nitrate-nitrite-nitrogen, total phosphorus, and total suspended solids (TSS) in Massies Creek (circles), tributaries (triangles) Clark Run (RM 0.44) and Oldtown Creek (RM 0.1), and the Cedarville wastewater treatment plant (squares) May – October, 2011. The solid line depicts the median value at each river mile sampled in Massies Creek. An "X" depicts the median of the wastewater final effluent and a "+" depicts the median in the tributaries. WQS criteria lines are shown in the dissolved oxygen concentration plot. The thinner black dashed horizontal lines in the other plots represent applicable statewide reference values from *sites of similar size. The heavier dashed green line in the phosphorus plot represents the TMDL target value.*

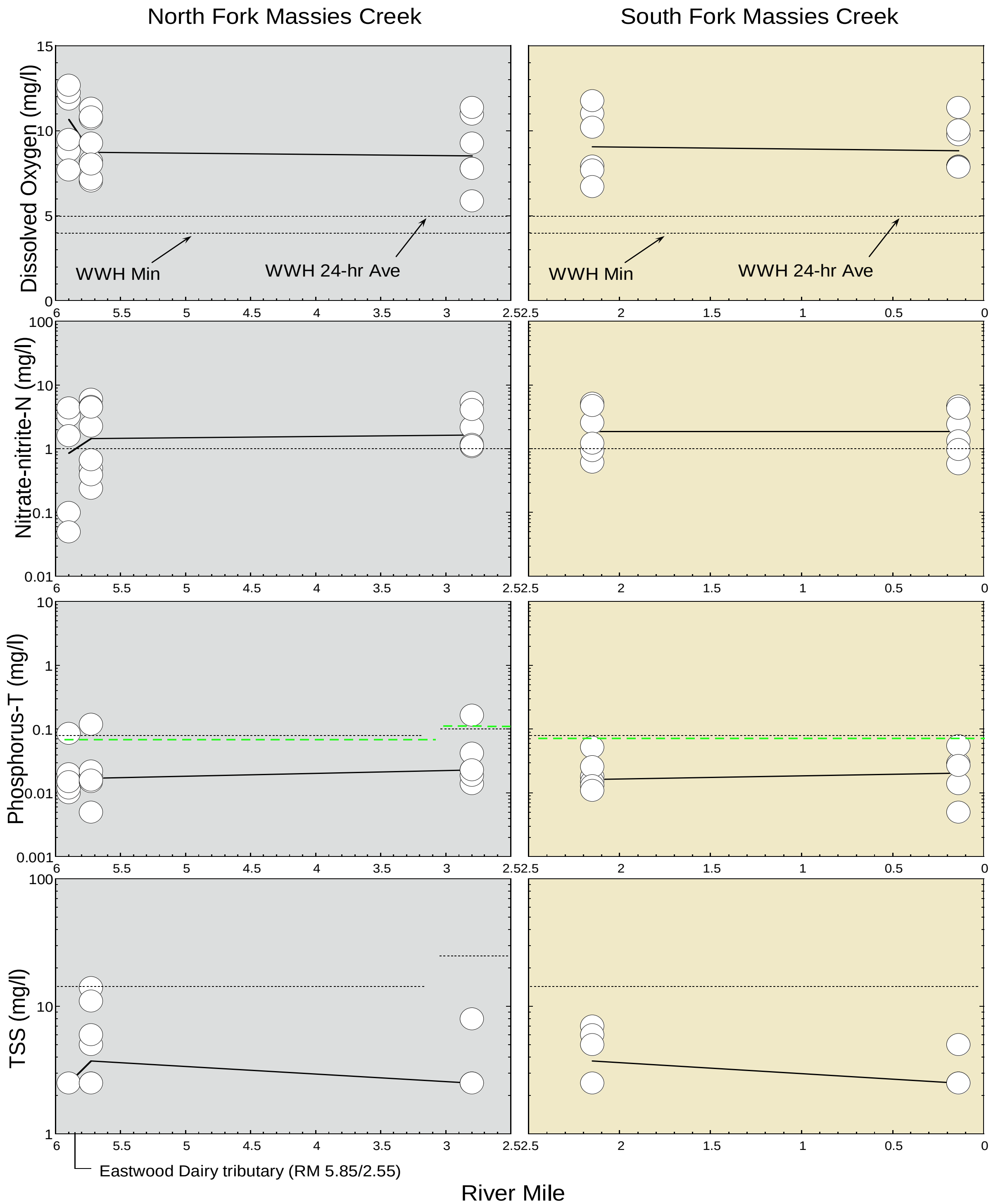


Figure 19. Longitudinal scatter plots of daytime grab dissolved oxygen, nitrate-nitrite-nitrogen, total phosphorus, and total suspended solids (TSS) in North Fork Massies Creek and South Fork Massies Creek , May-October, 2011. WQS criteria lines are shown in the dissolved oxygen concentration plots. The solid line depicts the median value at each river mile sampled. The thinner black dashed horizontal lines in the other plots represent applicable statewide reference values from sites of similar size. The heavier dashed green lines in the phosphorus plots represent TMDL target values.

Little Miami River Tributaries (Massies Creek to Beaver Creek)

Ludlow Creek

Ludlow Creek drains 6.93 mi^2 and enters the Little Miami River at RM 76.63. Chemistry samples collected at RM 0.25 (Hilltop Rd) indicated good water quality. Daytime grab DO levels were stable (median saturation 85%) and concentrations of ammonia-N and total phosphorus were low. Nitrate-nitrite-N was minimally elevated above target levels. There were no other elevated parameters in Ludlow Creek during the summer survey.

Shawnee Creek

Shawnee Creek drains 11.9 mi^2 before entering the Little Miami River at RM 76.42. Land use in the watershed is primarily developed and includes the City of Xenia.

Specific conductivity and total dissolved solids were consistently elevated at RM 0.65 (Hawkins Rd), the only site sampled in this tributary (medians 1021 µmhos/cm and 638 mg/l, respectively). Conductivity is a measure of the ability of water to pass an electrical current and is affected by the presence of inorganic dissolved solids. Magnesium, calcium, hardness, barium, and alkalinity concentrations were also somewhat elevated at the site. While there are no known point source dischargers upstream, there are two closed landfills and an operating demolition landfill in the watershed. Additionally, aerial photographs show what appears to be an automobile junkyard adjacent to the stream immediately upstream from Hawkins Rd.

Bacteria samples collected at RM 0.65 indicated that the PCR Class B use was not attained. Potential sources of bacteria include both general urban runoff from the City of Xenia and biosolids application to an adjacent farm field.

Beaver Creek Watershed

Beaver Creek drains 49.5 mi^2 in Greene and Montgomery counties and enters the Little Miami River at RM 72.74. The Beavercreek WWTP discharges to Beaver Creek at RM 0.4. Additionally, Little Beaver Creek (drainage 26.4 mi^2) receives the discharge from the Montgomery County Eastern Regional WWTP at RM 4.75 before entering Beaver Creek at RM 1.12. The watershed is heavily developed and includes the communities of Kettering and Beavercreek.

Water chemistry grab samples were collected at the two wastewater facilities and at four sites each in both Beaver Creek and Little Beaver Creek during the 2011 survey. Results of select water chemistry parameters are shown in Figure 22. Datasonde® monitors were deployed at six sites in the watershed (Figure 21).

Datasonde® specific conductivity values measured in both July and September near the mouth of Beaver Creek (RM 0.2) were the highest of the survey, reflecting the combined impact of both the Montgomery County Eastern Regional WWTP and the Beavercreek WWTP discharges. Dissolved oxygen, temperature, and pH concentrations measured by Datasonde® monitors in Beaver Creek (July and September) and in Little Beaver Creek (September) were generally unremarkable. However, Datasondes® deployed in July in Little Beaver Creek documented low dissolved oxygen at RM 3.54 (Grange Hall Rd), and the highest temperature and pH values of the survey, respectively, at RM 4.76 (upstream from the Montgomery County Eastern Regional WWTP) and RM 0.05 (Factory Rd). While all DO concentrations measured at RM 3.54 downstream from the Eastern Regional WWTP remained above critical levels (4.00 mg/l), overall levels were low with a median concentration of 4.76 mg/l and corresponding saturation of 55%. Half of the temperatures measured at RM 4.76 from July 5-7 exceeded the average WQS criterion). Little Beaver Creek is impounded by a series of ponds upstream from RM 4.76 and there is little to no woody riparian to shade the stream. The elevated pH and wide fluctuations in both diel DO and pH, and high benthic chlorophyll levels (Table 11) at the mouth of Little Beaver Creek (RM 0.05) were indicative of nutrient enrichment. Therefore, nutrient enrichment (Table 11) likely contributed to aquatic life use impairment in Little Beaver Creek.

Daytime grab dissolved oxygen concentrations fell below the WQS criterion in the headwaters of both Beaver Creek and Little Beaver Creek (Table 8, Figure 22). Additionally, concentrations of dieldrin exceeded the non-drinking water human health WQS criterion in Little Beaver Creek at Factory Road (RM 0.05) on two occasions. There were no other exceedances of WQS criteria in the watershed.

Ammonia-N concentrations were consistently elevated in Little Beaver Creek at RM 3.54 (Grange Hall Rd downstream from the Eastern Regional WWTP) with the highest median levels of the survey (0.195 mg/l). Nitrate-nitrite-N and total phosphorus concentrations in Little Beaver Creek also increased markedly downstream from the Eastern Regional WWTP discharge (RM 4.75) and remained elevated longitudinally to the mouth (RM 0.05). Elevated levels were sustained and delivered into Beaver Creek where added nutrient loading from the Beavercreek WWTP pushed concentrations even higher (Table 9, Figure 22). The highest nitrate-nitrate-N levels (median 6.49 mg/l) and second highest phosphorus concentrations (median 0.439 mg/l) of the 2011 survey occurred at RM 0.2 in Beaver Creek.

Bacteria samples collected at five sites in the Beaver Creek watershed indicated that the PCR Class B use was not attained (Figure 20, Table 10). The most likely source of bacteria was urban runoff given the highly developed nature of the watershed. Additional potential sources of bacteria in Beaver Creek include sanitary sewer overflows (SSOs), wildlife (geese, heron rookery), and the Beavercreek WWTP effluent discharge.

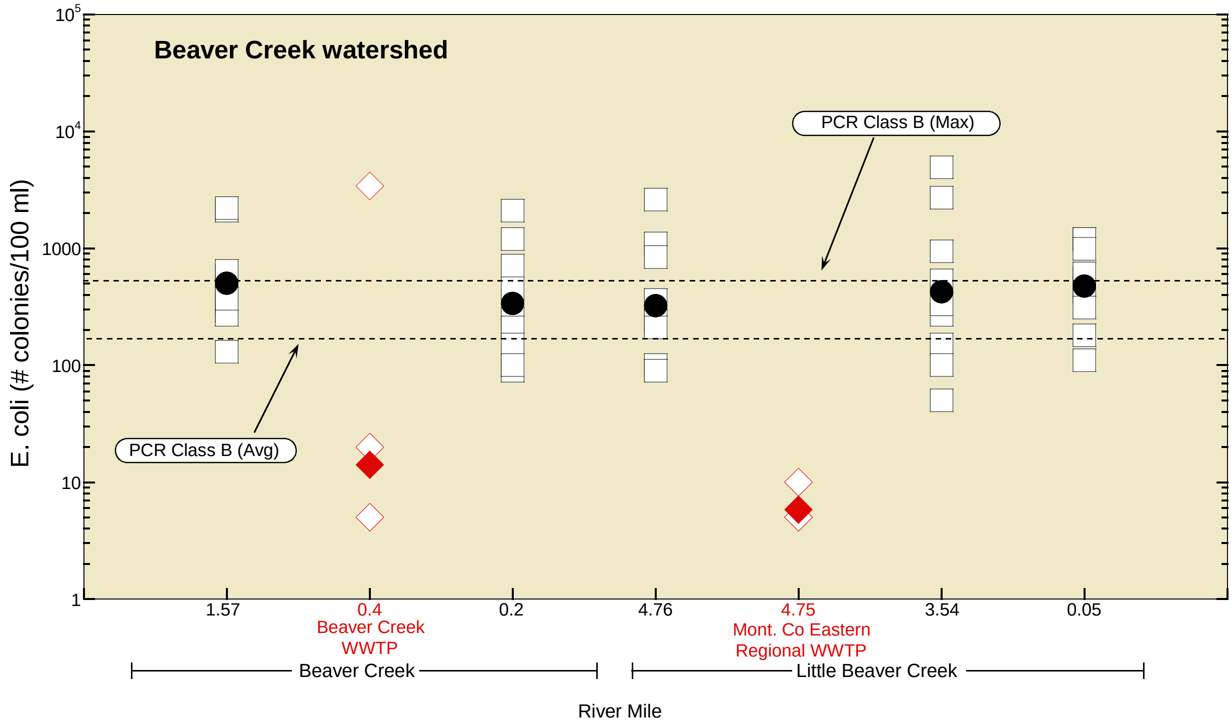


Figure 20. Scatter plots of E. coli bacteria concentrations in the Beaver Creek watershed during the 2011 survey. Effluent concentrations from two wastewater dischargers are represented by diamonds. Dotted lines represent Primary Contact Recreation (PCR) use WQS criteria. Solid circles (diamonds) represent the geometric mean at each site sampled.

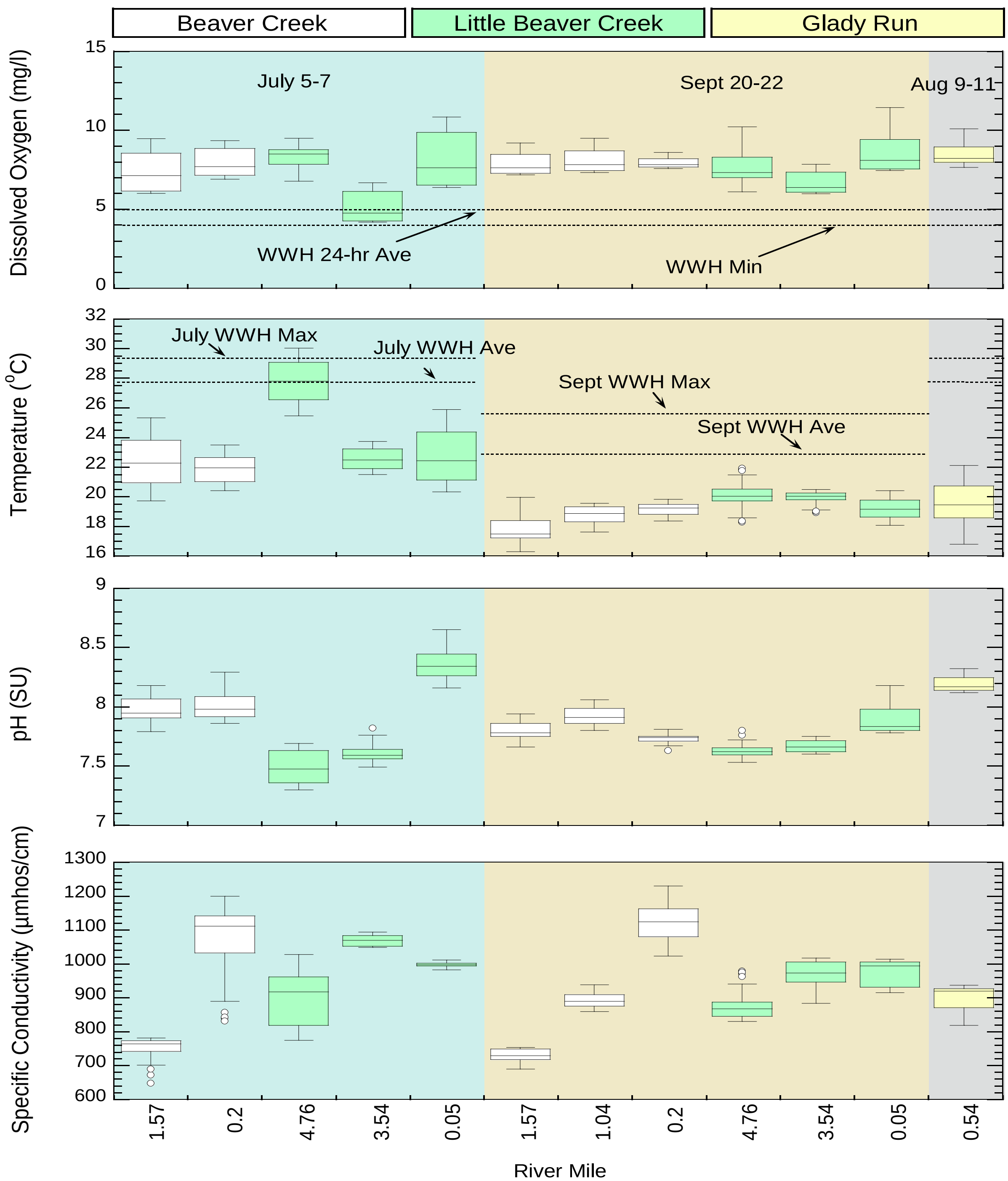


Figure 21. Dissolved oxygen, temperature, pH, and specific conductivity recorded hourly with Datasonde® continuous monitors in Beaver Creek, Little Beaver Creek, and Glady Run July 5-7, August 9-11, and September 20-22, 2011. WQS criteria are shown in the dissolved oxygen and temperature plots. (Each box encloses 50% of the data with the median value of the variable displayed as a line. The top and bottom of the box mark the limits of ± 25% of the variable population. The lines extending from the top and bottom of each box mark the minimum and maximum values within the data set that fall within an acceptable range. Values outside of this range are displayed as individual points.

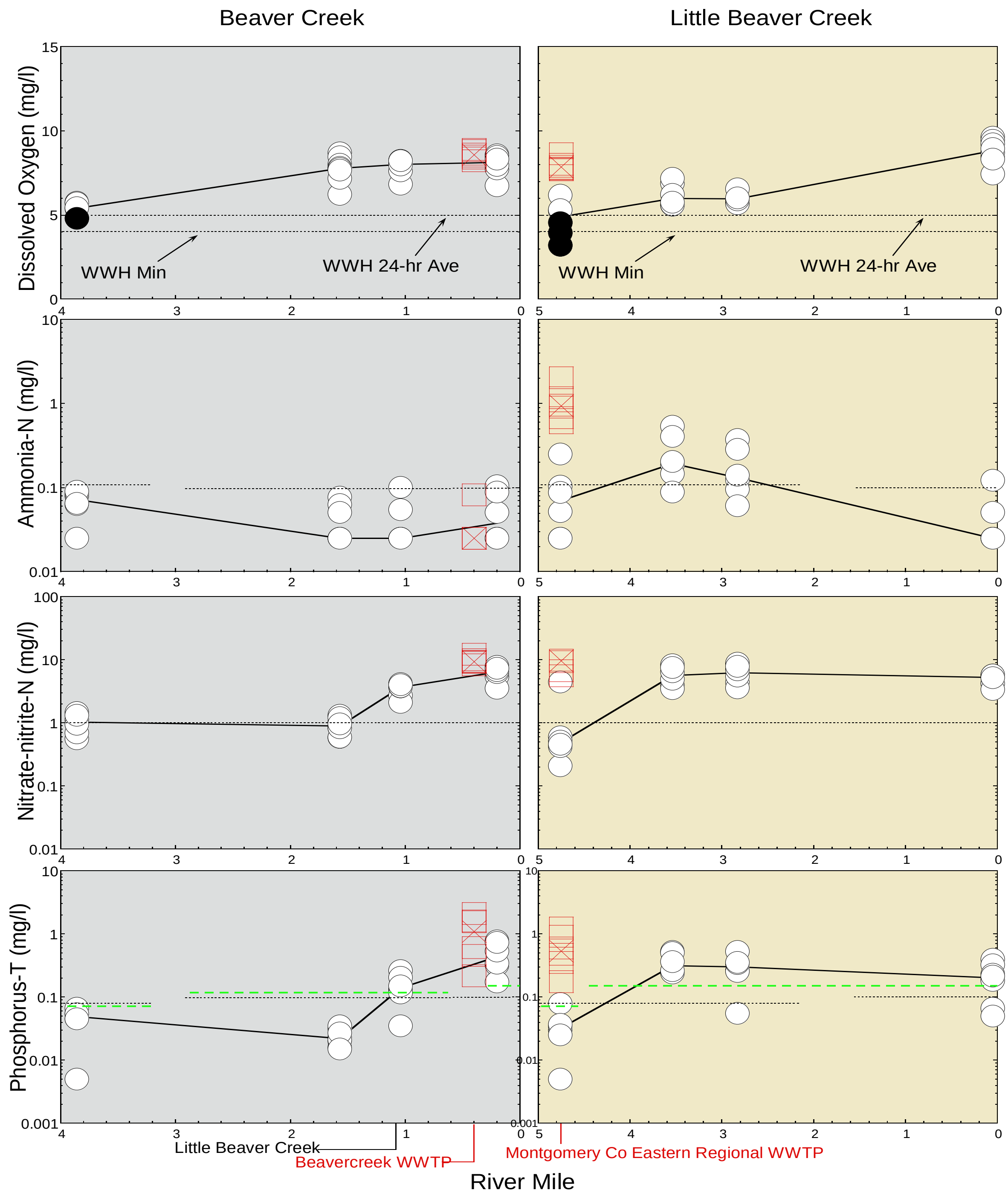


Figure 22. Longitudinal scatter plots of daytime grab dissolved oxygen, ammonia-N, nitrate-nitrite-N, and total phosphorus in Beaver Creek (circles), Little Beaver Creek (circles), and two wastewater dischargers (squares), May-October, 2011. WQS criteria are shown in the dissolved oxygen concentration plots. (Values not meeting criteria are shown as solid circles.) The solid line depicts the median value at each river mile sampled in the streams while an "X" depicts the median of the wastewater final effluent. The thinner black dashed horizontal lines in the other plots represent applicable statewide reference values from sites of similar size. The heavier green dashed lines in the phosphorus plots represent TMDL target values.

Little Miami River Tributaries (Beaver Creek to Caesar Creek)

Sugar Creek and Little Sugar Creek

Sugar Creek drains 33.8 mi^2 in Greene and Montgomery counties and enters the Little Miami River at RM 65.61 east of the City of Bellbrook. Little Sugar Creek, its primary tributary, drains 12.4 mi^2, and enters Sugar Creek at RM 1.55. While the watershed is primarily developed (62%), a significant portion of the land is agricultural (21%) or forested (16%).

Water quality was good at the two sites sampled in Sugar Creek (RMs 4.11, and 0.4) and at RM 0.45 in Little Sugar Creek. All parameters were within normal ranges and there were no exceedances of WQS criteria.

Bacteria samples collected in Sugar Creek at RM 0.4 (Penewit Rd) indicated that the PCR Class B use was not attained (Table 10). Potential sources of bacteria include general urban and agricultural runoff.

Glady Run

Glady Run, draining 13.6 mi^2, receives effluent from the Xenia Glady Run WWTP before entering the Little Miami River at RM 63.72 near Spring Valley. Land use is mixed in the watershed and includes agriculture (54.5%), developed land (32%), and forest (13.5%). Water chemistry samples were collected from the WWTP effluent (RM 4.93) and at two sites downstream from the discharge (RMs 4.08 and 0.54).

Daytime grab dissolved oxygen concentrations in Glady Run were stable with median saturations of 87% (RM 4.08) and 96% (RM 0.54). A Datasonde® monitor deployed in August at RM 0.54 (SR 725) recorded minimal diurnal variability (Figure 21). Total phosphorus and specific conductivity were elevated at Hedges Rd (RM 4.08) downstream from the Xenia Glady Run WWTP discharge, while nitrate-nitrite-N was above target at both RM 4.08 and RM 0.54.

Bacteria samples collected at two sites in Glady Run indicated that the PCR Class B use was not attained (Table 10). Likely sources of bacteria include biosolids application to farm fields as well as general urban and agricultural runoff. Additionally, the Glady Run WWTP discharge may also be a contributing source of bacteria.

Mill Run and Newman Run

Mill Run drains 8.7 mi^2 and enters the Little Miami River at RM 55.44 near Waynesville. Newman Run (drainage area 9.89 mi^2) enters the Little Miami River at RM 53.12 approximately 0.7 miles downstream from the Waynesville WWTP discharge. Chemistry samples collected at one site on each tributary (RM 0.59 on Mill Run and RM 0.27 on Newman Run) indicated good water quality. Nitrate-nitrite-N was minimally elevated above target in Newman Run. There were no exceedances of WQS criteria or any other elevated parameters in either stream. Only three samples were collected in Mill Run given that by mid-survey flows had diminished to the point that there was little to no water in the stream.

Caesar Creek Watershed

Caesar Creek drains 242 mi^2 in Greene, Warren, and Clinton counties and enters the Little Miami River mainstem at RM 50.92. Agriculture is the predominant land use with cultivated crop and pasture/hay, respectively, accounting for 70.5% and 7.0% of the total watershed area. A significant portion of the land (mostly in the Caesar Creek State Park area) is forested (13.4%). Impoundments include Caesar Creek Lake (6,110 acres) and Shawnee Lake (190 acres). Caesar Creek was impounded by the Army Corps of Engineers in 1978 to assist with flood control in the Little Miami River watershed. Caesar Creek

State Park (4,700 acres) and an adjacent 2,500 acre wildlife area were also dedicated that year. Caesar Creek Lake is also used for recreation and as a water supply for the City of Wilmington.

Water chemistry grab samples were collected from 23 sites in the Caesar Creek watershed during the 2011 survey, including nine sites in the Anderson Fork subwatershed. Datasonde® monitors were deployed at five sites (Figure 23). Tributaries sampled included North Branch Caesar Creek, South Branch Caesar Creek, Anderson Fork, Grassy Run, Grog Run, Painters Creek, Buck Run, Turkey Run, Jonahs Run, and Flat Fork.

Caesar Creek, North Branch Caesar Creek, South Branch Caesar Creek
Water chemistry samples were collected in the mainstem of Caesar Creek at four sites upstream from Caesar Creek Lake and at one site downstream from the lake near the mouth (RM 0.15). Samples were also collected at two sites each in North Branch Caesar Creek (drainage 26.7 mi^2) and South Branch Caesar Creek (drainage 19 mi^2) as well as from the Jamestown WWTP discharge on South Branch Caesar Creek. Results of select water chemistry parameters are shown in Figure 24 and Figure 25.

Dissolved oxygen, temperature, and pH measured by Datasonde® continuous monitors from August 9-11 at two sites on Caesar Creek (RMs 16.52 and 0.15) and at RM 2.1 in South Branch Caesar Creek exhibited normal diurnal variability (Figure 23). Values in Caesar Creek were markedly higher downstream from the reservoir at RM 0.15 compared to upstream at RM 16.52 (Paintersville Road). Water released from the reservoir by the Army Corps of Engineers to maintain downstream flow may account for the higher values recorded at RM 0.15. Similar values for DO, temperature, pH, and conductivity were measured in Caesar Creek Lake itself near the dam on August 18. Median DO saturation increased from 68.2% upstream from the reservoir at RM 16.52 to 93.5% at RM 0.15. Numerous daytime grab dissolved oxygen concentrations at RM 16.52 were below the EWH minimum 24-hour average criterion of 6.0 mg/l (Table 8). Dissolved oxygen concentrations also fell below criteria at RM 2.1 (Hoop Road) in the South Branch Caesar Creek (Datasonde® and daytime grab) and at RM 6.67 (Junkin Road) in the North Branch Caesar Creek (daytime grab). Lower values may reflect diminished flows observed at these sites later in the summer.

Nitrate-nitrite-N increased significantly in Caesar Creek at RM 23.1 (Stone Rd) downstream from the confluences of North Branch Caesar Creek and South Branch Caesar Creek, and remained elevated above target reference values downstream. While elevated levels occurred downstream from the Jamestown WWTP in South Branch Caesar Creek at RM 8.23 (median 5.895 mg/l); concentrations were largely assimilated downstream at RM 2.1 (median 0.555 mg/l). Conversely, median concentrations in the North Branch Caesar Creek increased longitudinally from 1.00 mg/l (RM 6.67) to 3.705 mg/l (RM 1.23). Hence, agricultural loading from the North Branch Caesar Creek subwatershed may contribute relatively more to the elevated nitrate concentrations found at RM 23.1 in the Caesar Creek mainstem.

Phosphorus levels were relatively low in both the mainstem of Caesar Creek and North Branch Caesar Creek. Median concentrations were minimally above target reference values in Caesar Creek in the headwaters at RM 30.76 (US 35) near Jamestown and at RM 23.1 (Stone Road), as well as at RM 6.67 (Junkin Road) in North Branch Caesar Creek. Some of the highest phosphorus concentrations of the survey occurred in South Branch Caesar Creek downstream from the Jamestown WWTP (RM 8.23) with a median value of 1.34 mg/l (Figure 25). Concentrations remained elevated above target reference levels downstream at RM 2.1 (median 0.17 mg/l).

Bacteria samples were collected in Caesar Creek (RMs 26.5, 16.52, and 0.15), North Branch Caesar Creek (RM 1.23) and South Branch Caesar Creek (RMs 8.23 and 2.1). While the two downstream locations in Caesar Creek (RMs 16.52 and 0.15) were in full attainment of the PCR Class B (RM 16.52) and Class A (RM 0.15) criteria, the PCR Class B use was not attained at any of the other four sites sampled (Figure 28, Table 10). Agricultural runoff is a potential source of bacteria at all four sites in non-attainment. Land application of Class B biosolids is also common in this watershed. Additionally, likely sources of bacteria in Caesar Creek at RM 26.5 (downstream from Shawnee Lake) include livestock access to the stream and wildlife (geese). Potential sources of bacteria in South Branch Caesar Creek at RM 8.23 include the Jamestown WWTP discharge and general urban runoff from the Village of Jamestown.

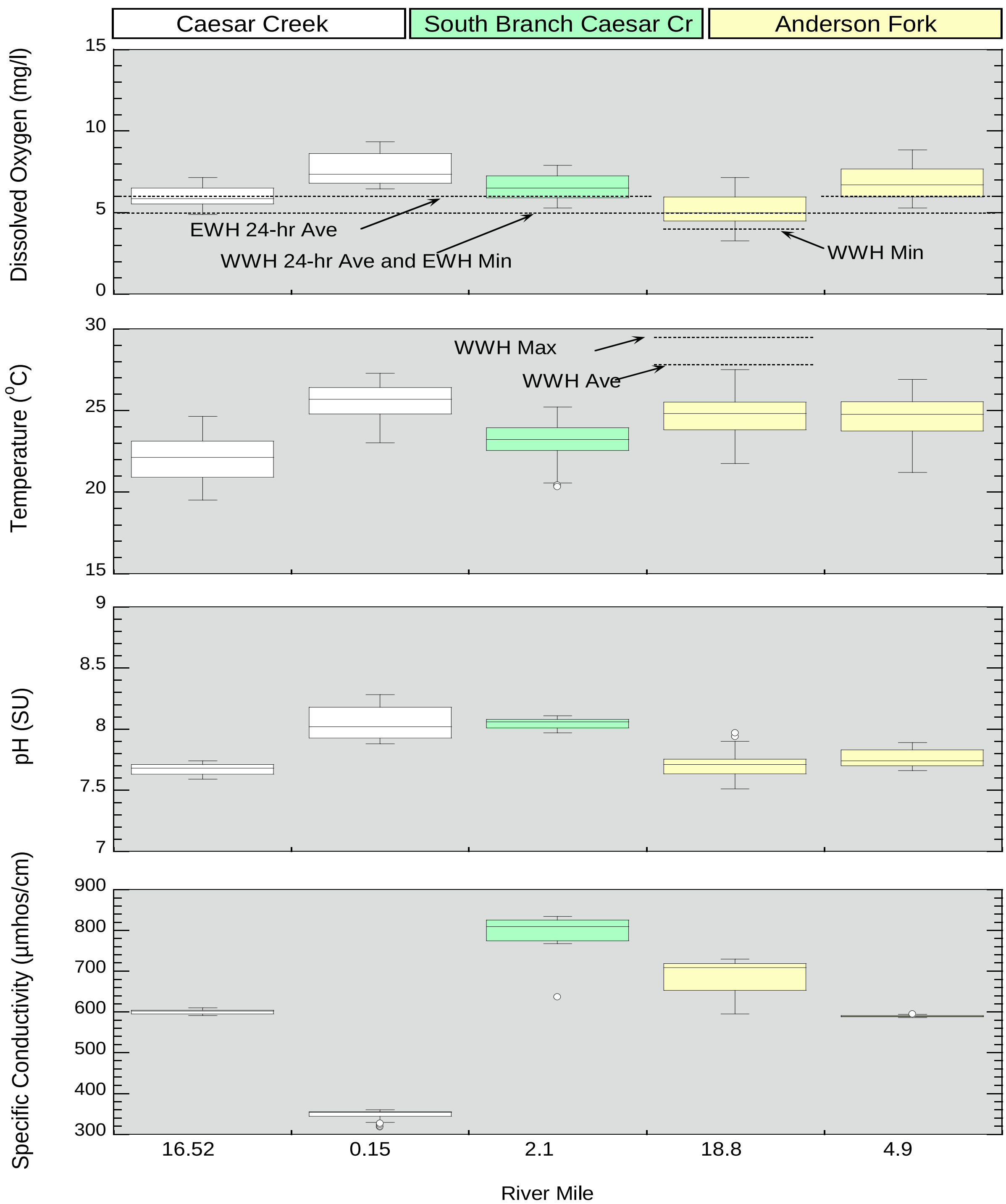


Figure 23. Dissolved oxygen, temperature, pH, and specific conductivity recorded hourly with Datasonde® continuous monitors in Caesar Creek, South Branch Caesar Creek, and Anderson Fork August 9-11, 2011. WQS criteria lines are shown in the dissolved oxygen and temperature plots. (Each box encloses 50% of the data with the median value of the variable displayed as a line. The top and bottom of the box mark the limits of ± 25% of the variable population. The lines extending from the top and bottom of each box mark the minimum and maximum values within the data set that fall within an acceptable range. Values outside of this range are displayed as individual points.)

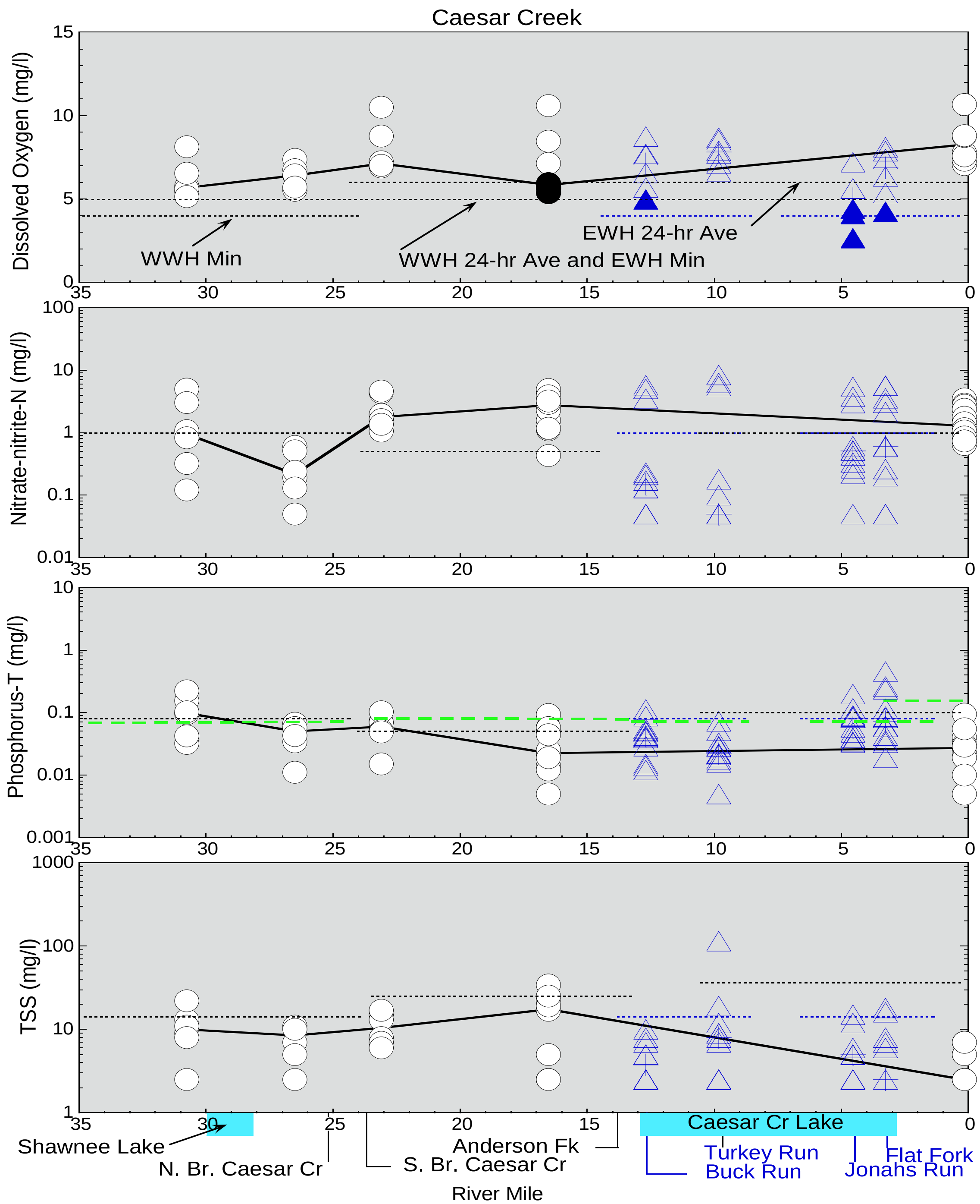


Figure 24. Longitudinal scatter plots of daytime grab dissolved oxygen, nitrate-nitrite-nitrogen, total phosphorus, and TSS in Caesar Creek (circles), and tributaries (triangles) Buck Run (RM 1.18), Turkey Run (RM 1.5), Jonahs Run (RM 2.1), and Flat Fork (RM 1.7) , May-October, 2011. The solid line depicts the median value at each river mile sampled in Caesar Creek while a "+" depicts the median in the tributaries sampled. WQS criteria lines are shown in the dissolved oxygen concentration plot. (Values not meeting criteria are shown as solid circles or triangles.). The thinner black dashed horizontal lines in the other plots represent applicable statewide reference values from sites of similar size. The heavier green dashed line in the phosphorus plot represents the TMDL target value.

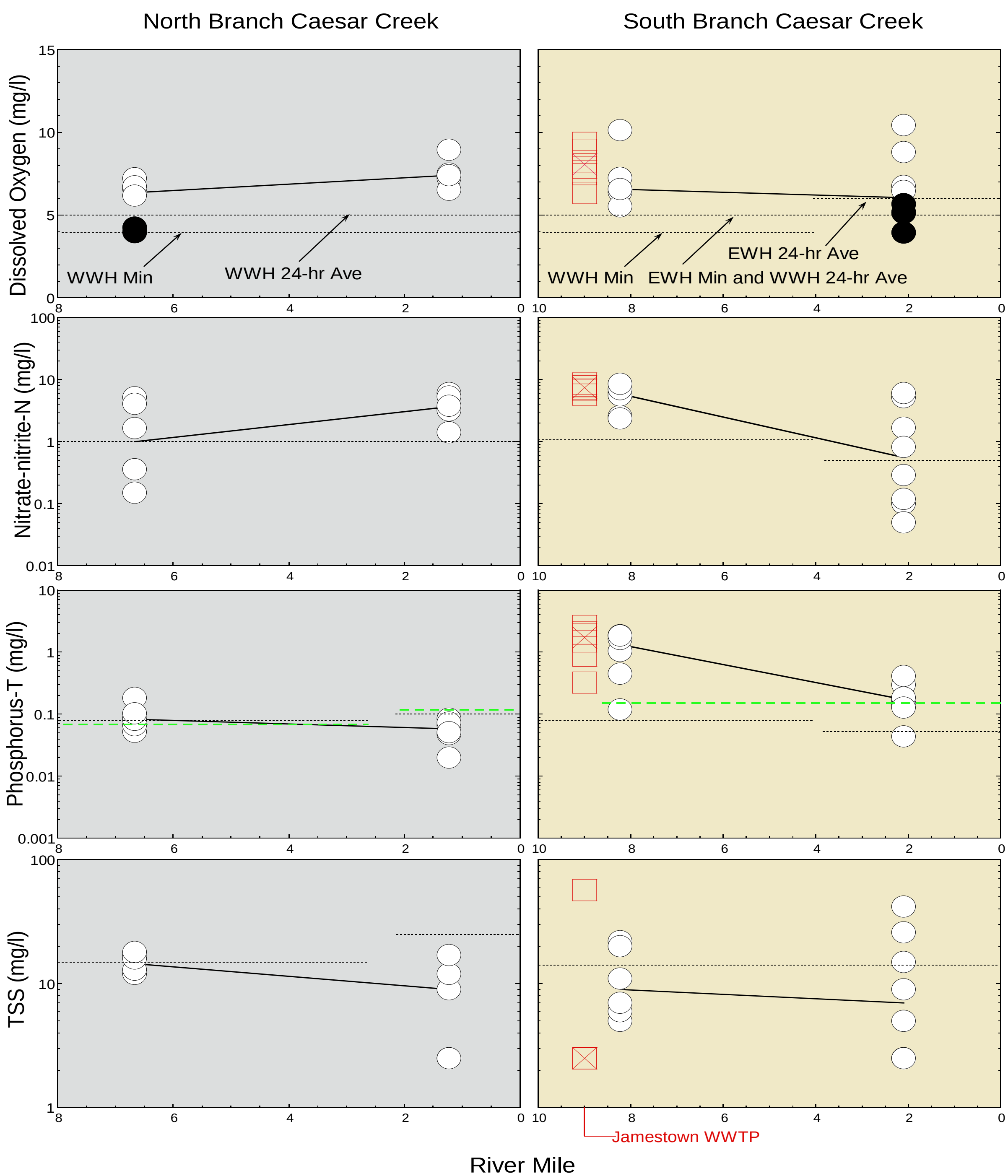


Figure 25. Longitudinal scatter plots of daytime grab dissolved oxygen, nitrate-nitrite-nitrogen, total phosphorus, and TSS in the North Branch Caesar Creek (circles), South Branch Caesar Creek (circles), and the Jamestown wastewater treatment plant (squares) , May-October, 2011. WQS criteria lines are shown in the dissolved oxygen concentration plots. (Values not meeting criteria are shown as solid circles.) The solid line depicts the median value at each river mile sampled in the streams while an "X" depicts the median of the wastewater final effluent. The thinner black dashed horizontal lines in the other plots represent applicable statewide reference values from sites of similar size. The heavier green dashed lines in the phosphorus plots represent TMDL target values.

Anderson Fork, Grassy Run, Grog Run, Tributary to Anderson Fork (RM 9.26), Painters Creek

Anderson Fork, draining 97.7 mi^2, enters Caesar Creek at RM 13.92 just upstream from Caesar Creek Lake. Cultivated crop, the predominant land use, accounts for 82% of the Anderson Fork watershed area. A lowhead dam on Anderson Fork at RM 14.55 in Port William, built to support a water powered gristmill, remains despite the mill being no longer in operation (Figure 26). Five sites were sampled on the mainstem of Anderson Fork and one site each was sampled in select tributaries including Grassy Run (8.05 mi^2), Grog Run (8.61 mi^2), an unnamed tributary to Anderson Fork (1.83 mi^2), and Painters Creek (13.1 mi^2). Results of select water chemistry parameters are shown in Figure 27**.**

Figure 26. Dam on Anderson Fork (RM 14.55) in Port William (August 31, 2011).

Datasonde® monitors deployed in Anderson Fork at RM 18.8 (Haley Rd) and at RM 4.9 (Old Winchester Trail) from August 9-11 indicated normal diurnal variability (Figure 23). However, half of the dissolved oxygen concentrations (28 of 55) measured at RM 18.8 upstream from the Port William dam fell below the WWH minimum 24-hour average criterion of 5.0 mg/l (9 of the 55 measurements also fell below critical level of 4.0 mg/l). Median dissolved oxygen concentration and percent saturation at the site for the 48-hour period were, respectively, 4.98 mg/l and 61.2%. Daytime grab dissolved oxygen concentrations were also minimally below the 24-hour average criterion on one occasion each at RM 7.9 (McKay Rd), RM 4.9 (Old Winchester Trail), and RM 3.27 (Engle Mill Rd). Additionally, flows in two tributaries, Grog Run (RM 0.05) and Painters Creek (RM 0.43), became interstitial by late summer and daytime grab DO levels fell below the WQS criterion at both of these sites as well. Grog Run was completely dry the last two sampling weeks of the survey. Field crews also observed unrestricted livestock access at this site on occasion.

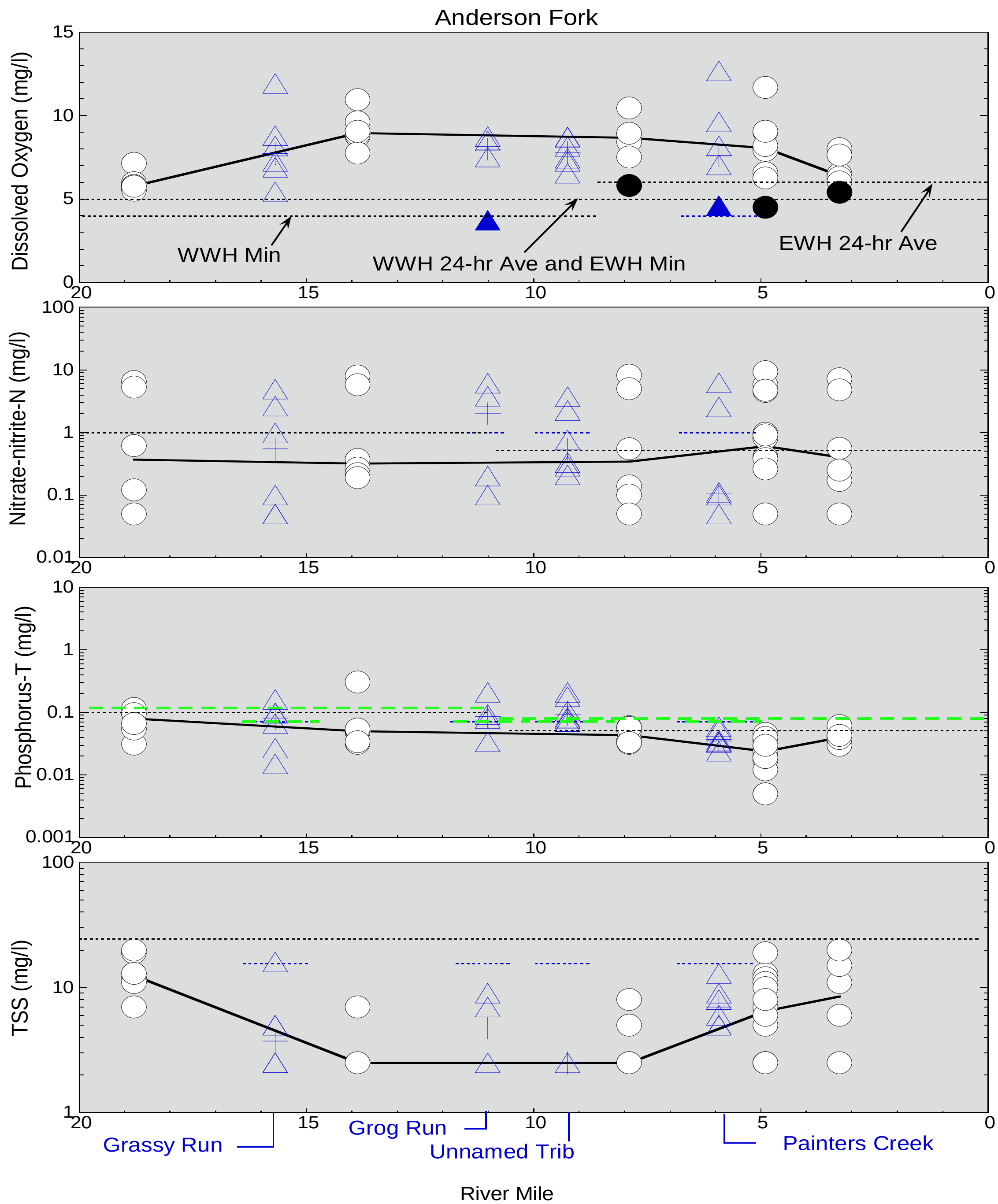


Figure 27. Longitudinal scatter plots of daytime grab dissolved oxygen, nitrate-nitrite-nitrogen, total phosphorus, and TSS in Anderson Fork (circles), and tributaries (triangles) Grassy Run (RM 0.05), Grog Run (RM 0.9), an unnamed tributary (RM 0.2), and Painters Creek (RM 0.43) , May-October, 2011. The solid line depicts the median value at each river mile sampled in Anderson Fork while a "+" depicts the median in the tributaries sampled. WQS criteria lines are shown in the dissolved oxygen concentration plot. (Values not meeting criteria are shown as solid circles or triangles.). The thinner black dashed horizontal lines in the other plots represent applicable statewide reference values from sites of similar size. The heavier green dashed line in the phosphorus plot represents the TMDL target value.

The upper reaches of Anderson Fork (RMs 18.8 and 13.87) and Grassy Run (RM 0.05) also experienced elevated temperatures with values exceeding the WQS criterion on July 28 (Table 8). This upper portion of the watershed is devoid of any significant woody riparian buffer and is characterized by open canopies.

Ammonia-N levels in the Anderson Fork watershed were low with the majority (95%) of concentrations less than the reporting limit of 0.05 mg/l. While the overall median nitrate-nitrite-N concentration for the watershed was low (0.375 mg/l), forty-two percent of concentrations were elevated above target reference values with the highest values occurring during periods of higher flow earlier in the summer. Phosphorus levels were also generally low and relatively stable with an overall median for the nine sites in the watershed at 0.0425 mg/l. The highest values occurred at RM 0.2 (US 68) in the unnamed tributary to Anderson Fork where concentrations minimally exceeded target in all samples.

Bacteria samples were collected in Anderson Fork at four sites (RMs 18.8, 13.87, 7.9, and 4.9), and in Painters Creek at RM 0.43 (Eleazer Rd). Only RM 13.87 on Anderson Fork (Port William Rd) attained the PCR Class B recreation use. The most likely source of bacteria at all four non-attaining sites was agricultural runoff (Table 10, Figure 28).

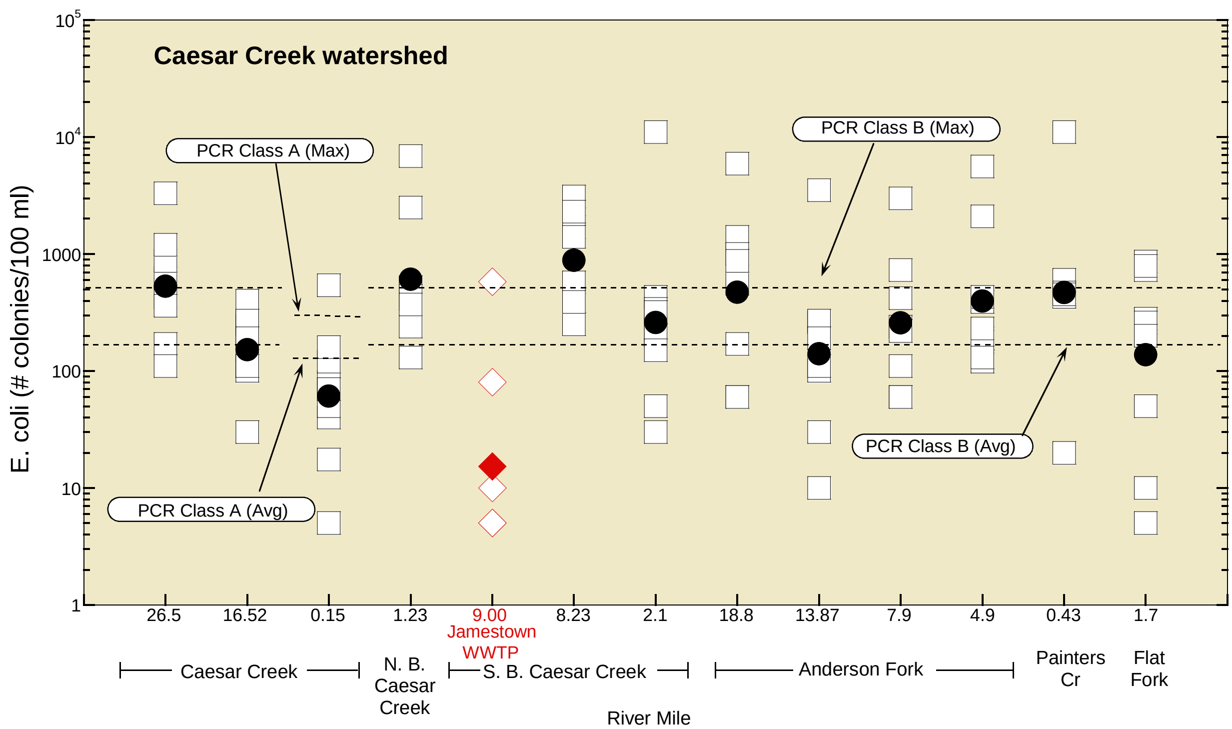


Figure 28. Scatter plots of E. coli bacteria concentrations in the Caesar Creek watershed (including the final effluent of the Jamestown wastewater plant) during the 2011 survey. Dotted lines represent Primary Contact Recreation (PCR) use WQS criteria. Solid circles (diamonds) represent the geometric mean at each site sampled.

Buck Run, Turkey Run, Jonahs Run, Flat Fork

Buck Run (9.65 mi^2), Turkey Run (5.69 mi^2), Jonahs Run (8.36 mi^2), and Flat Fork (16.7 mi^2) all drain directly or indirectly into Caesar Creek Lake. All four high gradient streams drain primarily agricultural land, have a bedrock limestone substrate, and are prone to interstitial or intermittent flows during periods of lower precipitation. One site was sampled on each tributary. Results of select water chemistry parameters are shown in Figure 24.

Dissolved oxygen concentrations fell below the WQS criterion frequently in Jonahs Run at RM 2.1 (Harlan-Carroll Rd) and once each in Buck Run and Flat Fork (Table 8). Field notes indicated interstitial conditions and/or minimal flow in these tributaries later in the summer. Ammonia-N levels were low with all concentrations well below target reference values and the majority of values (89%) less than the reporting limit of 0.05 mg/l. While median nitrate-nitrite-N levels were below target, elevated concentrations were measured at all sites during periods of higher flow earlier in the summer which may be attributable to nonpoint sources. Phosphorus concentrations were also generally low with the majority of values (72%) below target reference values. The highest concentrations occurred in Flat Fork at RM 1.7 (Oregonia Rd), where half the samples exceeded the target.

Bacteria samples were collected in Flat Fork at RM 1.7. Results indicate full attainment of the PCR Class B use designation.

Sentinel Site Monitoring Program

Typically, Ohio EPA chemical water quality sampling occurs within the critical low flow period during the summer season when the attainment status for biological water quality criteria can be assessed. However, recognizing the impact of nonpoint pollution sources on streams and the limited water chemistry data available under varying flow and seasonal conditions, Ohio EPA developed a "sentinel site" sampling approach to develop data sets over an annual period of varying climatic and flow conditions. In addition to assisting in the analysis of causes and sources of any observed non-attainment, the resulting data set supports water quality modeling efforts for pollutants where TMDLs may be necessary.

Sentinel site selection is based on several factors including proximity to the watershed boundary, drainage area size (≥ 20 mi^2), and varying land use (urban, agricultural, etc). If possible, locations are selected that have USGS flow stations. Once the sites are chosen, bridge to water measurements are taken at each site using a weighted tape in conjunction with periodic in-stream flow measurements in order to develop predictive gage height to stream flow relationships.

Fifteen sites sampled during the upper Little Miami River summer survey were also sampled throughout the year as part of the sentinel site program. One pH value of 5.32 was recorded in the mainstem at Trebein Road (RM 75.38) in February which fell outside of the WQS criteria range (6.5-9.0 SU). No other parameters at the site fell outside of the applicable water quality criterion. A comparison of summer and non-summer nutrient results are presented in Table 6.

In addition to inorganic chemistry, sentinel sites were also sampled for organic compounds in the spring and early summer of 2011 (Table 7, Appendix Table A-2). Ten organic compounds were detected in the watershed. Atrazine accounted for 38% of the total detections (21 of 56) followed by the plasticizer bis(2-ethylhexyl)phthalate (27%). Concentrations of the legacy insecticide dieldrin exceeded the non-drinking water human health WQS criterion in Little Beaver Creek at Factory Road (RM 0.05) on two occasions (Table 8). Dieldrin, a highly persistent compound, was banned from agricultural use in 1974, but was still permitted for mothproofing and to fight termite infestations until 1987. The most likely source of the majority of organic contaminants in the watershed is the application of pesticides or herbicides to cropland.

*Table 6. Comparison of summer and non-summer nutrient sampling results at fifteen sentinel sites in the upper Little Miami River watershed, 2011. For each site, the top number in the sample number and geometric mean columns represents samples collected during the summer months (May through October) while the bottom number represents samples collected during the non-summer months (February, March, April, November, and December). Values above applicable statewide reference values (targets) are highlighted in yellow; values above both statewide and TMDL targets are highlighted in orange.**

Stream (aquatic life use designation [a])				Samples (#)	Nitrate-nitrite-N (mg/l)		Phosphorus-T (mg/l)		
RM	AU [b]	Location	Drainage Area (mi^2)		Geometric Mean	Target* statewide	Geometric Mean	Target* statewide	Target* TMDL
Little Miami River (EWH from North Fork Little Miami River (RM 91.64) to RM 3.0 (downstream from Beechmont Avenue; all other segments WWH)									
98.98	01-03	Dolly Varden Rd	33	8 4	3.476 5.936	1.000	0.065 0.028	0.100	0.11
80.63	01-04	US 68	129	8 4	2.991 3.810	0.500	0.061 0.019	0.050	0.08
75.38	02-06	Trebein Rd	238	8 4	3.190 4.215	1.000	0.049 0.049	0.100	0.17
68.54	05-02	Washington Mills Rd	307	8 4	3.470 3.701	1.000	0.088 0.105	0.100	0.17
60.84	05-04	Roxanna-New Burlington Rd	367	8 4	3.159 3.300	1.000	0.089 0.105	0.100	0.17
51.65	05-04	0.1 mi upst Middletown Rd	413	8 4	2.837 2.799	1.000	0.082 0.106	0.100	0.17
Massies Creek (WWH)									
4.38	02-03	Wilberforce-Clifton Rd	63.2	8 4	2.466 4.934	1.000	0.043 0.018	0.100	0.17**
North Fork Massies Creek (WWH)									
5.73	02-01	US 42 (dst tributary)	17.9	8 4	1.312 4.839	1.000	0.019 0.025	0.080	0.07
Beaver Creek (WWH)									
1.57	02-05	Dayton-Xenia Rd	20.9	8 4	0.886 0.557	1.000	0.023 0.018	0.100	0.11
Little Beaver Creek (WWH)									
0.05	02-04	Factory Rd	26.4	8 4	4.867 4.773	1.000	0.171 0.471	0.100	0.17**
Glady Run (WWH)									
0.54	05-03	SR 725	12.7	8 4	4.227 4.391	1.000	0.055 0.067	0.080	0.17**
Caesar Creek (WWH Headwaters to South Branch (RM 23.78); all other segments EWH)									
16.52	04-04	Paintersville Rd	88	14 6	2.218 3.354	0.500	0.022 0.034	0.050	0.08

Stream (aquatic life use designation [a])					Nitrate-nitrite-N (mg/l)		Phosphorus-T (mg/l)		
RM	AU [b]	Location	Drainage Area (mi^2)	Samples (#)	Geometric Mean	Target* statewide	Geometric Mean	Target* statewide	Target* TMDL
0.15	04-06	Corwin Rd	242	14	1.349	1.000	0.021	0.100	0.17
				6	1.558		0.044		
South Branch Caesar Creek (EWH from Paintersville - New Jaspar Rd (RM 4.0) to mouth; all other segments									
2.1	04-03	Hoop Rd	17	8	0.543	0.500	0.165	0.050	0.17**
				3	1.500		0.268		
Anderson Fork (EWH from Grog Run (RM 11.02) to mouth); all other segments WWH									
4.9	03-03	Old Winchester Trail	78	14	0.546	0.500	0.021	0.050	0.08
				6	3.656		0.055		

* Target values per *Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams* –Tables 1 and 2, (Ohio EPA Technical Bulletin MAS/1999-1-1) and per *Total Maximum Daily Loads for the Upper Little Miami River-Final Report (April 2002)*.

Targets	Headwater (0-20mi^2)		Wadeable (>20-200 mi^2)		Small River (>200-1000 mi^2)		Large River (>1000 mi^2)	
	WWH	EWH	WWH	EWH	WWH	EWH	WWH	EWH
Statewide								
NO_3-NO_2-N (mg/l)	1.0	0.5	1.0	0.5	1.5	1.0	2.0	1.5
Phosphorus-T (mg/l)	0.08	0.05	0.10	0.05	0.17	0.10	0.30	0.15
Upper LITTLE MIAMI RIVER TMDL								
Phosphorus-T (mg/l)	0.07	0.05	0.11	0.08	0.17	0.17	-	-

** TMDL total phosphorus target values at these sites are not based on drainage area, but rather compared to the 0.17 mg/l instream TMDL target for the Little Miami River mainstem downstream of the Caesar Creek confluence (RM 50.92). In order to achieve this instream total phosphorus target of 0.17 mg/l, wastewater treatment plants in the upper Little Miami River watershed were given total phosphorus concentration NPDES permit limits of 1.0 mg/l (monthly).

a Use designations (aquatic life)
WWH - warmwater habitat
EWH - exceptional warmwater habitat
CWH - coldwater habitat
Undesignated (WWH criteria apply to 'undesignated' surface waters)

b AU – Assessment Unit

Table 7. Frequency of organic compounds detected in stream water samples at sentinel sites in the upper Little Miami River watershed, 2011. (Number of WQS criteria exceedances / Number of detections).

		Upper Little Miami River Watershed (WAU 05090202-__-__)[a]									
Parameter	**Little Miami River mainstem** RMs 98.98, 80.63, 75.38, 68.54, 60.84, and 51.65	02-03 **Massies Cr** RM 4.38	02-01 **NF Massies Cr** RM 5.73	02-05 **Beaver Cr** RM 1.57	02-04 **Little Beaver Cr** RM 0.05	05-03 **Glady Run** RM 0.54	04-04 **Caesar Cr** RM 0.16.52	04-06 **Caesar Cr** RM 0.0.15	04-03 **SB Caesar Cr** RM 2.1	03-03 **Anderson Fork** RM 4.9	**TOTAL**
Acetochlor*	*/1	-	-	-	-	-	-	*/2	-	*/2	***/5**
Aldicarb sulfoxide*	*/1	-	-	-	*/1	-	-	-	*/1	-	***/3**
Atrazine*	*/9	*/2	*/1	*/1	-	-	*/2	*/2	*/2	*/2	***/21**
α-Hexachlorocyclohexane	0/1	-	0/1	-	-	-	-	-	-	-	**0/2**
Bis(2-Ethylhexyl)adipate*	-	-	-	-	-	-	-	-	*/1	-	***/1**
Bis(2-Ethylhexyl)phthalate	0/6	0/2	0/1	0/1	0/1	-	0/2	0/1	-	0/1	**0/15**
Chloroform	-	-	-	-	0/1	-	-	-	-	-	**0/1**
Dieldrin	-	-	-	-	2/2	-	-	-	-	-	**2/2**
Metolachlor*	*/2	-	-	-	-	-	-	*/2	-	*/1	***/5**
2,4-D*	-	-	-	-	-	-	-	-	*/1	-	***/1**
TOTAL	**0/20**	**0/4**	**0/3**	**0/2**	**2/5**	**-**	**0/4**	**0/7**	**0/5**	**0/6**	**2/56**

* Parameter was detected but no applicable water quality criteria are available.
[a] Watershed Assessment Unit

Table 8. Exceedances of Ohio EPA Water Quality Standards (WQS) (OAC 3745-1) for chemical/physical water parameters measured in grab samples taken from the upper Little Miami River study area , May-October, 2011 (units are µg/l for metals and organics, C° for temperature, SU for pH, µmhos/cm for specific conductivity, and mg/l for all other parameters).

Stream (*use designation* [b])		**Parameter (value)**
12-digit WAU [a]	**River Mile**	
Little Miami River *((EWH from North Fork Little Miami River (RM 91.64) to RM 3.0 (downstream from Beechmont Avenue); all other segments WWH), PCR, AWS, IWS)*		
01-01	106.95	Dissolved oxygen (4.48[g], 1.85[h], 1.87[h], 0.17[h], 0.91[h]) Iron (15900[f])
01-01	103.13	Dissolved oxygen (3.64[h], 4.24[g])
Lisbon Fork *(WWH, PCR, AWS, IWS)*		
01-01	2.80	Dissolved oxygen (4.17[g], 2.89[h], 4.97[g]) Ammonia-N (3.39[c])
Tributary to North Fork Little Miami River (RM 5.60) *(WWH,PCR, AWS, IWS)*		
01-02	0.8	Dissolved oxygen (4.33[g])
Beaver Creek *(WWH, PCR, AWS, IWS)*		
02-05	3.86	Dissolved oxygen (4.80[g])
Little Beaver Creek *(WWH, PCR, AWS, IWS)*		
02-04	4.76	Dissolved oxygen (3.21[h], 4.56[g], 3.94[h])
02-04	0.05	Dieldrin (0.0067[e], 0.0064[e])
Caesar Creek *((WWH Headwaters to South Branch (RM 23.78), all other segments EWH), PCR, AWS, IWS)*		
04-04	16.52	Dissolved oxygen (5.63[g], 5.67[g], 5.94[g], 5.77[g], 5.39[g])
North Branch Caesar Creek *(WWH, PCR, AWS, IWS)*		
04-01	6.67	Dissolved oxygen (3.96[h], 4.24[g])
South Branch Caesar Creek *((EWH from Paintersville - New Jasper Rd (RM 4.0) to mouth; all other segments WWH), PCR, AWS, IWS)*		
04-03	2.1	Dissolved oxygen (5.68[g], 5.17[g], 5.14[g], 3.95[h])
Anderson Fork *((EWH from Grog Run (RM 11.02) to mouth; all other segments WWH), PCR, AWS, IWS)*		
03-01	18.8	Temperature (27.82[c])
03-02	13.87	Temperature (29.59[d])
03-02	7.9	Dissolved oxygen (5.81[g])

Stream (***use designation*** [b])		
12-digit WAU [a]	**River Mile**	**Parameter (value)**
03-03	4.9	Dissolved oxygen (4.52[h])
03-03	3.27	Dissolved oxygen (5.40[g])
Grassy Run *(WWH, PCR, AWS, IWS)*		
03-01	0.05	Temperature (29.37[c])
Grog Run *(WWH, PCR, AWS, IWS)*		
03-02	0.9	Dissolved oxygen (3.72[h])
Painters Creek *(WWH, PCR, AWS, IWS)*		
03-02	0.43	Dissolved oxygen (4.60[g], 4.61[g])
Buck Run *(WWH, PCR, AWS, IWS)*		
04-06	1.18	Dissolved oxygen (4.97[g])
Jonahs Run *(WWH, PCR, AWS, IWS)*		
04-06	2.1	Dissolved oxygen (2.66[h], 4.10[g], 4.41[g])
Flat Fork *(WWH, PCR, AWS, IWS)*		
04-05	1.7	Dissolved oxygen (4.26[g])

a Watershed Assessment Unit

b Use designations:

Aquatic Life Habitat	Water Supply	Recreation
	IWS - industrial water supply	PCR - primary contact
WWH - warmwater habitat	AWS - agricultural water supply	SCR - secondary contact
EWH - exceptional warmwater habitat	PWS- public water supply	BWR -bathing water

c exceedance of numerical criteria for prevention of chronic toxicity (CAC).
d exceedance of numerical criteria for prevention of acute toxicity (AAC).
e exceedance of numerical criteria for the protection of human health (non-drinking-protective of people against adverse exposure to chemicals via eating fish).
f exceedance of agricultural water supply criterion.
g value is below the EWH minimum 24-hour average D.O criterion (6.0 mg/l) or value is below the WWH minimum 24-hour average D.O criterion (5.0 mg/l) or value is below the MWH minimum 24-hour average D.O criterion (4.0 mg/l) as applicable.
‡‡ value is below the EWH minimum at any time DO criterion (5.0 mg/l) or value is below the WWH minimum at any time DO criterion (4.0 mg/l) or value is below the MWH minimum at any time DO criterion (3.0 mg/l) as applicable.

*Table 9. Nutrient sampling results in the upper Little Miami River watershed, May-October, 2011. Values from wastewater treatment plants (final effluent) are italicized in red. Values above applicable statewide reference values (targets) are highlighted in yellow; values above both statewide and total maximum daily load (TMDL) targets are highlighted in orange.**

Stream (aquatic life use designation [a])				Samples (#)	Nitrate-nitrite-N (mg/l)		Phosphorus-T (mg/l)		
RM	AU [b]	Location	Drainage Area (mi^2)		Geometric Mean [c]	Target* (statewide)	Geometric Mean [c]	Target* (statewide)	Target* (TMDL)
Little Miami River (EWH from North Fork Little Miami River (RM 91.64) to RM 3.0 (downstream from Beechmont Avenue; all other segments WWH)									
106.95	01-01	Upst Paygro; upst Huntington Rd	1.4	6	0.572	1.000	0.157	0.080	0.07
104.88	01-01	SR 41 SE of S Charleston	4.6	6	1.242	1.000	0.159	0.080	0.07
103.13	01-01	Jamestown Rd	6.4	6	1.288	1.000	0.160	0.080	0.07
98.98	01-03	Dolly Varden Rd	33	8	3.476	1.000	0.068	0.100	0.11
92.27	01-03	Pitchin Rd	53	6	3.316	1.000	0.049	0.100	0.11
89.77	01-04	Upst Sharp Bend, adj N River Rd	94	6	3.233	0.500	0.038	0.050	0.08
85.38	01-04	Grinnel Rd	104	6	3.235	0.500	0.036	0.050	0.08
83.14	01-04	Dst Yellow Springs WWTP @ Jacoby Rd	118	6	3.414	0.500	0.069	0.050	0.08
80.63	01-04	US 68	129	8	2.991	0.500	0.061	0.050	0.08
77.70	02-06	Fairgrounds Rd.	217	6	3.034	1.000	0.044	0.100	0.17
77.03	***02-06***	***Xenia-Ford Rd WWTP***	***na***	***6***	***7.190***	***na***	***0.258***	***na***	***na***
75.38	02-06	Trebein Rd	238	8	3.190	1.000	0.044	0.100	0.17
73.16	02-06	0.42 mi upst Beaver Cr S Of Alpha	241	6	3.075	1.000	0.050	0.100	0.17
72.30	05-02	Indian Ripple Rd	295	6	3.608	1.000	0.127	0.100	0.17
69.84	05-02	Upper Bellbrook Rd	302	6	3.537	1.000	0.111	0.100	0.17
68.54	05-02	Washington Mills Rd	307	8	3.470	1.000	0.096	0.100	0.17
64.44	05-04	Upst Greene Co Sugar Cr WWTP	345	6	3.225	1.000	0.063	0.100	0.17
64.43	***05-04***	***Greene Co Sugar Cr WWTP***	***na***	***6***	***1.908***	***na***	***1.528***	***na***	***na***
64.28	05-04	Dst Greene Co Sugar Cr WWTP	345	6	3.373	1.000	0.156	0.100	0.17
63.28	05-04	Spring Valley Roadside Park	361	6	3.335	1.000	0.117	0.100	0.17
60.84	05-04	Roxanna - New Burlington Rd	367	8	3.159	1.000	0.085	0.100	0.17
58.30	05-04	Dst Sandy Run, 3/4 mi SW Spring Valley Lake	378	6	3.183	1.000	0.185	0.100	0.17
53.84	05-04	SR 73	398	6	2.888	1.000	0.072	0.100	0.17
53.79	***05-04***	***Waynesville WWTP***	***na***	***6***	***0.262***	***na***	***1.672***	***na***	***na***
53.20	05-04	Dst Waynesville WWTP, upst Newman Run	402	6	2.956	1.000	0.114	0.100	0.17
51.65	05-04	0.1 mi upst Middletown Rd	413	8	2.837	1.000	0.084	0.100	0.17

Stream (aquatic life use designation [a])				Samples (#)	Nitrate-nitrite-N (mg/l)		Phosphorus-T (mg/l)		
RM	AU [b]	Location	Drainage Area (mi^2)		Geometric Mean [c]	Target* (statewide)	Geometric Mean [c]	Target* (statewide)	Target* (TMDL)
Gilroy Ditch (WWH)									
1.4	***01-01***	***South Charleston WWTP***	***na***	***6***	***3.911***	***na***	***0.648***	***na***	***na***
0.5	01-01	Nr Ford, 0.9 mi dst S Charleston WWTP	7.5	6	2.488	1.000	0.170	0.080	0.17**
Lisbon Fork (WWH)									
2.8	01-01	SR 41	7.0	6	2.243	1.000	0.081	0.080	0.07
Tributary to Little Miami River (RM 96.26) (WWH)									
0.6	01-03	Buffenbarger Rd	6.0	6	1.211	1.000	0.026	0.080	0.07
North Fork Little Miami River (WWH)									
9.1	01-02	SR 41	11.5	6	2.607	1.000	0.016	0.080	0.07
0.37	01-02	North River Rd	35.8	6	1.457	1.000	0.027	0.100	0.11
Tributary to North Fork Little Miami River (RM 5.60) (WWH)									
0.8	01-02	Crabill Rd	7.4	6	0.547	1.000	0.025	0.080	0.07
Yellow Springs Creek (EWH)									
0.43	***01-04***	***Yellow Springs WWTP***	***na***	***6***	***9.874***	***na***	***2.766***	***na***	***na***
0.1	01-04	Grinnell Rd	11.3	6	3.842	0.500	0.208	0.050	0.17**
Jacoby Branch (EWH)									
0.5	01-04	US 68	5.1	6	1.509	0.500	0.040	0.050	0.05
Conner Branch (CWH)									
0.17	01-04	US 68	2.3	6	2.491	na	0.024	na	na
Massies Creek (WWH)									
8.95	***02-03***	***Cedarville WWTP***	***na***	***6***	***9.527***	***na***	***0.812***	***na***	***na***
7.7	02-03	Tarbox Cemetery Rd dst Cedarville WWTP	55	6	2.218	1.000	0.055	0.100	0.17**
4.38	02-03	Wilberforce-Clifton Rd	63.2	8	2.466	1.000	0.044	0.100	0.17**
1.2	02-03	Fawcett Dr	73	6	2.929	1.000	0.053	0.100	0.17**
North Fork Massies Creek (WWH)									
5.9	02-01	Old Route 42	15.1	6	0.424	1.000	0.019	0.080	0.07
5.73	02-01	US 42 (dst tributary)	17.9	8	1.312	1.000	0.017	0.080	0.07
2.8	02-01	Mcmillan Rd	20.9	6	2.027	1.000	0.031	0.100	0.11
South Fork Massies Creek (WWH)									

Stream (aquatic life use designation [a])				Samples (#)	Nitrate-nitrite-N (mg/l)		Phosphorus-T (mg/l)		
RM	AU [b]	Location	Drainage Area (mi^2)		Geometric Mean [c]	Target* (statewide)	Geometric Mean [c]	Target* (statewide)	Target* (TMDL)
2.15	02-02	Weimer Rd	17.1	6	1.891	1.000	0.019	0.080	0.07
0.14	02-02	Old RR (bike path)	19.9	6	1.833	1.000	0.016	0.080	0.07
Clark Run (EWH)									
0.44	02-03	Stevenson Rd	6.2	6	5.359	0.500	0.066	0.050	0.05
Oldtown Creek (WWH)									
0.1	02-03	mouth	10.6	6	3.111	1.000	0.030	0.080	0.07
Ludlow Creek (WWH)									
0.25	02-06	Hilltop Rd	6.9	6	2.231	1.000	0.026	0.080	0.07
Shawnee Creek (WWH)									
0.65	02-06	Hawkins Rd	11.6	6	1.752	1.000	0.025	0.080	0.07
Beaver Creek (WWH)									
3.86	02-05	Fairgrounds Rd	14.8	6	0.962	1.000	0.031	0.080	0.07
1.57	02-05	Dayton-Xenia Rd	20.9	8	0.886	1.000	0.023	0.100	0.11
1.04	02-05	US 35 dst L Beaver Cr	48.1	6	3.312	1.000	0.127	0.100	0.11
0.4	***02-05***	***Beavercreek WWTP***	***na***	***6***	***9.662***	***na***	***0.828***	***na***	***na***
0.2	02-05	Adj Factory Rd dst Beaver Cr WWTP	49.4	6	5.996	1.000	0.424	0.100	0.17**
Little Beaver Creek (WWH)									
4.76	02-04	Upst Mont. Co Eastern Regional WWTP	10	6	0.617	1.000	0.027	0.080	0.07
4.75	***02-04***	***Montgomery Co Eastern Regional WWTP***	***na***	***6***	***8.360***	***na***	***0.523***	***na***	***na***
3.54	02-04	Grange Hall Rd	16.5	6	5.493	1.000	0.340	0.080	0.17**
2.83	02-04	at Valleywood	17.1	6	5.879	1.000	0.248	0.080	0.17**
0.05	02-04	Factory Rd	26.4	8	4.867	1.000	0.195	0.100	0.17**
Sugar Creek (WWH)									
4.11	05-01	Wilmington Pike	16.5	6	0.202	1.000	0.030	0.080	0.07
0.4	05-01	Penewit Rd	33.2	6	0.267	1.000	0.024	0.100	0.11
Little Sugar Creek (WWH)									
0.45	05-01	Adj Maple St	12.3	6	0.931	1.000	0.012	0.080	0.07
Glady Run (WWH)									
4.93	***05-03***	***Xenia-Glady Run WWTP***	***na***	***6***	***9.516***	***na***	***0.541***	***na***	***na***
4.08	05-03	Hedges Rd	6.9	6	5.642	1.000	0.228	0.080	0.17**

Stream (aquatic life use designation [a])				Samples (#)	Nitrate-nitrite-N (mg/l)		Phosphorus-T (mg/l)		
RM	AU [b]	Location	Drainage Area (mi^2)		Geometric Mean [c]	Target* (statewide)	Geometric Mean [c]	Target* (statewide)	Target* (TMDL)
0.54	05-03	SR 725	12.7	8	4.227	1.000	0.051	0.080	0.17**
Mill Run (WWH)									
0.59	05-04	US 42	8.5	3	0.452	1.000	0.024	0.080	0.07
Newman Run (EWH)									
0.27	05-04	US 42	9.8	6	0.799	0.500	0.027	0.050	0.05
Caesar Creek (WWH Headwaters to South Branch (RM 23.78); all other segments EWH)									
30.76	04-02	US 35	8.9	6	0.896	1.000	0.088	0.080	0.07
26.5	04-02	Paintersville Rd at New Jasper	12.9	6	0.212	1.000	0.040	0.080	0.07
23.1	04-04	Stone Rd	64.6	6	2.121	0.500	0.052	0.050	0.08
16.52	04-04	Paintersville Rd	88	14	2.218	0.500	0.022	0.050	0.08
0.15	04-06	Corwin Rd	242	14	1.349	1.000	0.021	0.100	0.17
North Branch Caesar Creek (WWH)									
6.67	04-01	Junkin Rd	7.0	6	0.939	1.000	0.088	0.080	0.07
1.23	04-01	Jasper Rd	25.7	6	3.556	1.000	0.052	0.100	0.11
South Branch Caesar Creek (EWH from Paintersville - New Jaspar Rd (RM 4.0) to mouth; all other segments WWH)									
9.00	***04-03***	***Jamestown WWTP***	***na***	***6***	***7.304***	***na***	***1.293***	***na***	***na***
8.23	04-03	Cemetery Rd dst Jamestown WWTP	6.5	6	4.846	1.000	0.829	0.080	0.17**
2.1	04-03	Hoop Rd	17	8	0.543	0.500	0.165	0.050	0.17**
Anderson Fork (EWH from Grog Run (RM 11.02) to mouth); all other segments WWH									
18.8	03-01	Haley Rd	30	6	0.431	1.000	0.070	0.100	0.11
13.87	03-02	Port William Rd	50	6	0.760	1.000	0.060	0.100	0.11
7.9	03-02	Mckay Rd	60.3	6	0.502	0.500	0.043	0.050	0.08
4.9	03-03	Old Winchester Trail	78	14	0.546	0.500	0.021	0.050	0.08
3.27	03-03	Engle Mill Rd	88	6	0.588	0.500	0.041	0.050	0.08
Grassy Run (WWH)									
0.05	03-01	Sabina Rd	8.4	6	0.384	1.000	0.059	0.080	0.07
Grog Run (WWH)									
0.9	03-02	Bone Rd	8.3	4	0.829	1.000	0.085	0.080	0.07
Tributary to Anderson Fork (RM 9.26) (WWH)									
0.2	03-02	US 68	1.8	6	0.708	1.000	0.111	0.080	0.07

Stream (aquatic life use designation [a])				Samples (#)	Nitrate-nitrite-N (mg/l)		Phosphorus-T (mg/l)		
RM	AU [b]	Location	Drainage Area (mi^2)		Geometric Mean [c]	Target* (statewide)	Geometric Mean [c]	Target* (statewide)	Target* (TMDL)
Painters Creek (WWH)									
0.43	03-02	Eleazer Rd	12.8	6	0.276	1.000	0.038	0.080	0.07
Buck Run (WWH)									
1.18	04-06	SR 380	8.5	12	0.258	1.000	0.037	0.080	0.07
Turkey Run (WWH)									
1.5	04-06	Mills Rd	3.8	11	0.227	1.000	0.024	0.080	0.07
Jonahs Run (WWH)									
2.1	04-06	Harlan-Carroll Rd	4.1	11	0.607	1.000	0.064	0.080	0.07
Flat Fork (WWH)									
1.7	04-05	Oregonia Rd	15.8	12	0.587	1.000	0.081	0.080	0.07

* Target values per *Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams* –Tables 1 and 2, (Ohio EPA1999) and per *Total Maximum Daily Loads for the Upper Little Miami River-Final Report (Ohio EPA April 2002)*.

Targets	Headwater (0-20mi^2)		Wadeable (>20-200 mi^2)		Small River (>200-1000 mi^2)		Large River (>1000 mi^2)	
	WWH	EWH	WWH	EWH	WWH	EWH	WWH	EWH
Statewide								
NO_3-NO_2-N (mg/l)	1.0	0.5	1.0	0.5	1.5	1.0	2.0	1.5
Phosphorus-T (mg/l)	0.08	0.05	0.10	0.05	0.17	0.10	0.30	0.15
Upper LITTLE MIAMI RIVER TMDL								
Phosphorus-T (mg/l)	0.07	0.05	0.11	0.08	0.17	0.17	-	-

** TMDL total phosphorus target values at these sites are not based on drainage area, but rather compared to the 0.17 mg/l instream TMDL target for the Little Miami River mainstem downstream of the Caesar Creek confluence (RM 50.92). In order to achieve this instream total phosphorus target of 0.17 mg/l, wastewater treatment plants in the upper Little Miami River watershed were given total phosphorus concentration NPDES permit limits of 1.0 mg/l (monthly).

Stream (aquatic life use designation [a])				Samples (#)	Nitrate-nitrite-N (mg/l)		Phosphorus-T (mg/l)		
RM	AU [b]	Location	Drainage Area (mi^2)		Geometric Mean [c]	Target* (statewide)	Geometric Mean [c]	Target* (statewide)	Target* (TMDL)

a Use designations (aquatic life)
WWH - warmwater habitat
EWH - exceptional warmwater habitat
CWH - coldwater habitat

b AU – Assessment Unit

c Geometric mean calculated from data collected from May 1 - October 31, 2011.

*Table 10. Ohio EPA bacteriological (E. coli) sampling results in the upper Little Miami River study area, 2011. All values are expressed as colony forming units (cfu) or most probable number (MPN) per 100 ml of water. Values from wastewater treatment plants (final effluent) are italicized. Values above WQS criteria are highlighted in red. **

Stream RM	AU [a]	Location	Samples (#)	*E. coli* Geometric Mean	*E. coli* Max Value	Attainment Status	Suspected Sources of Bacteria [b]
***Little Miami River** - PCR-Class A*							
106.95	01-01	Upst Paygro; upst Huntington Rd	8	**309**	**4800**	**NON**	H
104.88	01-01	SR 41 SE of S Charleston	8	**1357**	**12000**	**NON**	H,I
98.98	01-03	Dolly Varden Rd	9	**410**	**6600**	**NON**	H,J
92.27	01-03	Pitchin Rd	8	**602**	**4500**	**NON**	H,J
85.38	01-04	Grinnel Rd	8	**201**	**3200**	**NON**	J
80.63	01-04	US 68	9	**365**	**4700**	**NON**	H
77.7	02-06	Fairgrounds Rd	9	**336**	**1100**	**NON**	H,J
77.03	*02-06*	*Xenia-Ford Rd WWTP final effluent*	*6*	*32*	*130*	*na*	*na*
75.38	02-06	Trebein Rd	10	**307**	**540**	**NON**	G,H,J
72.3	05-02	Indian Ripple Rd	9	**312**	**1100**	**NON**	C,G,H
68.54	05-02	Washington Mills Rd	10	**266**	**770**	**NON**	H
64.44	05-04	Upst Greene Co Sugar Cr WWTP	9	**296**	**1200**	**NON**	H
64.43	*05-04*	*Greene Co Sugar Cr WWTP final effluent*	*7*	*57*	*5300*	*na*	*na*
64.28	05-04	Dst Greene Co Sugar Cr WWTP	9	**291**	**1300**	**NON**	C,H
63.28	05-04	Spring Valley Roadside Pk	9	**368**	**1100**	**NON**	C,G,H
60.84	05-04	Roxanna-N Burlington Rd	10	**308**	**2400**	**NON**	H
53.79	*05-04*	*Waynesville WWTP final effluent*	*9*	*59*	*12000*	*na*	*na*
53.2	05-04	Adj Corwin Rd, dst Waynesville WWTP upst Newman Run	9	**293**	**3100**	**NON**	C,G,H
51.65	05-04	0.1 mi upst Middletown Rd	10	**249**	**2400**	**NON**	C[1], H
***Gilroy Ditch** – PCR Class B*							
1.4	*01-01*	*South Charleston WWTP final effluent*	*8*	*206*	*8500*	*na*	*na*
0.5	01-01	Nr Ford, 0.9 mi dst S Charleston WWTP	8	**1329**	**7700**	**NON**	C,G,H,J
***North Fork Little Miami River**- PCR Class B*							
0.37	01-02	North River Rd	8	**353**	**2600**	**NON**	H,J
***Yellow Springs Creek** – PCR Class B*							
0.43	*01-04*	*Yellow Springs WWTP final effluent*	*8*	*19*	*60*	*na*	*na*

Stream RM	AU [a]	Location	Samples (#)	*E. coli*		Attainment Status	Suspected Sources of Bacteria [b]
				Geometric Mean	Max Value		
0.1	01-04	Grinnell Rd	8	**358**	**3000**	**NON**	G,H
Massies Creek *- PCR Class B*							
8.95	*02-03*	*Cedarville WWTP final effluent*	*7*	*12*	*40*	*na*	*na*
7.7	02-03	Tarbox Cemetery Rd dst Cedarville WWTP	8	**266**	**4500**	**NON**	G,H
4.38	02-03	Wilberforce-Clifton Rd	9	**264**	**4500**	**NON**	G,H
1.2	02-03	Fawcett Dr	8	**447**	**5100**	**NON**	H,J
North Fork Massies Creek *- PCR Class B*							
5.9	02-01	Old US 42	8	**447**	**6000**	**NON**	H,J
5.73	02-01	US 42 (dst tributary)	9	**725**	**28000**	**NON**	H,I,J
South Fork Massies Creek - *PCR Class B*							
0.14	02-02	Old RR (bikepath)	8	**233**	**2700**	**NON**	G,H
Shawnee Creek - *PCR Class B*							
0.65	02-06	Hawkins Rd	9	**395**	**3500**	**NON**	G,J
Beaver Creek *- PCR Class B*							
1.57	02-05	Dayton-Xenia Rd	10	**503**	**2200**	**NON**	F,G
0.4	*02-05*	*Beavercreek WWTP final effluent*	*9*	*14*	*3400*	*na*	*na*
0.2	02-05	Adj Factory Rd dst Beaver Cr WWTP	9	**338**	**2100**	**NON**	C,F,G,K
Little Beaver Creek *- PCR Class B*							
4.76	02-04	Upst Montgomery Co Eastern Regional WWTP	9	**324**	**2600**	**NON**	G
4.75	*02-04*	*Montgomery Co Eastern Regional WWTP final effluent*	*9*	*6*	*10*	*na*	*na*
3.54	02-04	Grange Hall Rd	9	**424**	**4900**	**NON**	G
0.05	02-04	Factory Rd	10	**475**	**1200**	**NON**	G
Sugar Creek *- PCR Class B*							
0.4	05-01	Penewit Rd	9	**600**	**4000**	**NON**	G,H
Glady Run *- PCR Class B*							
4.93	*05-03*	*Xenia-Glady Run WWTP final effluent*	*1*	*NA*	*540*	*na*	*na*
4.08	05-03	Hedges Rd	9	**468**	**990**	**NON**	C,G,H
0.54	05-03	SR 725	10	**422**	**1200**	**NON**	G,H,J
Caesar Creek *- PCR Class A from dam (RM 3.0) to mouth, PCR Class B other segments*							
26.5	04-02	Paintersville Rd at New Jasper	8	**530**	**3300**	**NON**	B,H,J,K
16.52	04-04	Paintersville Rd	10	152	**400**	FULL	

Stream RM	AU [a]	Location	Samples (#)	*E. coli*		Attainment Status	Suspected Sources of Bacteria [b]
				Geometric Mean	Max Value		
0.15	04-06	Corwin Rd	10	61	**540**	FULL	
North Branch Caesar Creek *- PCR Class B*							
1.23	04-01	Jasper Rd	8	**608**	**6900**	**NON**	H,J
South Branch Caesar Creek *- PCR Class B*							
9.00	*04-03*	*Jamestown WWTP final effluent*	*8*	*15*	*580*	*na*	*na*
8.23	04-03	Cemetery Rd dst Jamestown WWTP	8	**885**	**3100**	**NON**	C,G,H
2.1	04-03	Hoop Rd	9	**259**	**11000**	**NON**	H
Anderson Fork *- PCR Class B*							
18.8	03-01	Haley Rd	8	**472**	**5900**	**NON**	H
13.87	03-02	Port William Rd	8	141	**3500**	FULL	
7.9	03-02	Mckay Rd	8	**257**	**3000**	**NON**	H
4.9	03-03	Old Winchester Trail	9	**396**	**5600**	**NON**	H
Painters Creek *- PCR Class B*							
0.43	03-02	Eleazer Rd	8	**469**	**11000**	**NON**	H,J
Flat Fork *- PCR Class B*							
1.7	04-05	Oregonia Rd	9	138	**860**	FULL	

***Stream* RM**	**AU [a]**	**Location**	**Samples (#)**	***E. coli***		**Attainment Status**	**Suspected Sources of Bacteria [b]**
				Geometric Mean	**Max Value**		

* Samples were collected from June 9 - October 6, 2011. **Attainment status is based on the seasonal (May 1- October 31) geometric mean**. The status cannot be determined at locations where fewer than two samples were collected during the recreation season (Ohio Administrative Code 3745-1-07).

Recreation Use	Seasonal geometric mean	Single Sample Maximum
Bathing Water	126	235
Class A primary contact recreation	126	298
Class B primary contact recreation	161	523
Class C primary contact recreation	206	940
Secondary contact recreation	1030	1030

na not applicable

a AU – Assessment Unit

b **Suspected Sources of Bacteria:**

A - Failing home sewage treatment systems
B - Livestock access to stream
C - Wastewater treatment plant
C[1-] package plant(s)
D - Unsewered community
E - Combined sewer overflow (CSOs)
F - Sanitary sewer overflows (SSOs)
G - Urban runoff (city, village, etc.)
H - Agricultural runoff
I - Animal Feedlot Operation
J –Biosolids Application
K - Wildlife (geese, etc)
L - Unknown

Table 11. Parameters used to assess eutrophication levels in the upper Little Miami River watershed, 2011. Values marked with a single asterisk (*) are considered to be elevated; those with a double asterisk (**) are considered to be high.

River Mile	Total phosphorus (mg/l)	Dissolved inorganic nitrogen (mg/l)	Chlorophyll-a (mg/m^2)	24-h D.O. Range
Little Miami River				
98.98	0.068	3.199**	184*	12.2**
92.27	0.049	3.341**	291*	2.19
83.14	0.069*	3.414**	228*	2.28
80.63	0.061*	3.062**	217*	3.64
77.70	0.039	3.059**	37.2	2.06
75.38	0.044	3.073**	90.6	1.84
72.30	0.127*	3.664**	284*	2.25
69.84	0.111*	3.565**	417**	0.30
68.54	0.096	3.437**	409**	4.10
64.44	0.063	3.258**	315*	1.81
64.28	0.156*	3.433**	337**	2.13
63.28	0.117*	3.388**	565**	2.42
60.84	0.085	3.163**	167	2.54
58.30	0.185*	3.230**	160	1.55
53.84	0.072	2.922*	340**	1.47
51.65	0.084	2.814*	446**	1.98
Glady Run				
0.54	0.051	4.258**	163	2.91
Beaver Creek				
3.86	0.031	1.025*	95.6	2.02
1.04	0.127	3.348**	208*	2.16
Little Beaver Creek				
2.83	0.248	6.028**	216*	2.49
0.05	0.195	4.992**	334**	3.98
Massies Creek				
7.70	0.055	2.276*	390**	2.78
4.38	0.044	2.244*	305*	3.50
1.20	0.053	2.954*	499**	3.19
North Fork Massies Creek				
5.73	0.017	1.091*	186*	8.85**

Chemical Water Quality Trends

Little Miami River

The Little Miami River at US 68 (RM 80.63) is monitored as part of the National Ambient Water Quality Monitoring Network (NAWQMN). Established to provide a long-term chemical database at fixed stations, the NAWQMN was established in 1974 using guidance provided by U.S. EPA. Summarized results for 14 years (1998-2011) of nitrate-nitrite-N and total phosphorus data are provided in Figure 29.

While concentrations of ammonia-N were low throughout the period with 85% of values below the minimum detection limit of 0.05 mg/l, nitrate-nitrite-N concentrations were elevated above target (0.5 mg/l) in all years with medians ranging from 2.38 mg/l (2008) to 5.40 mg/l (2001). Median phosphorus concentrations at the site ranged from 0.025 mg/l (2001) to 0.11 mg/l (1999) with 55% of all values recorded during the fourteen year period less than or equal to the TMDL target of 0.08 mg/l.

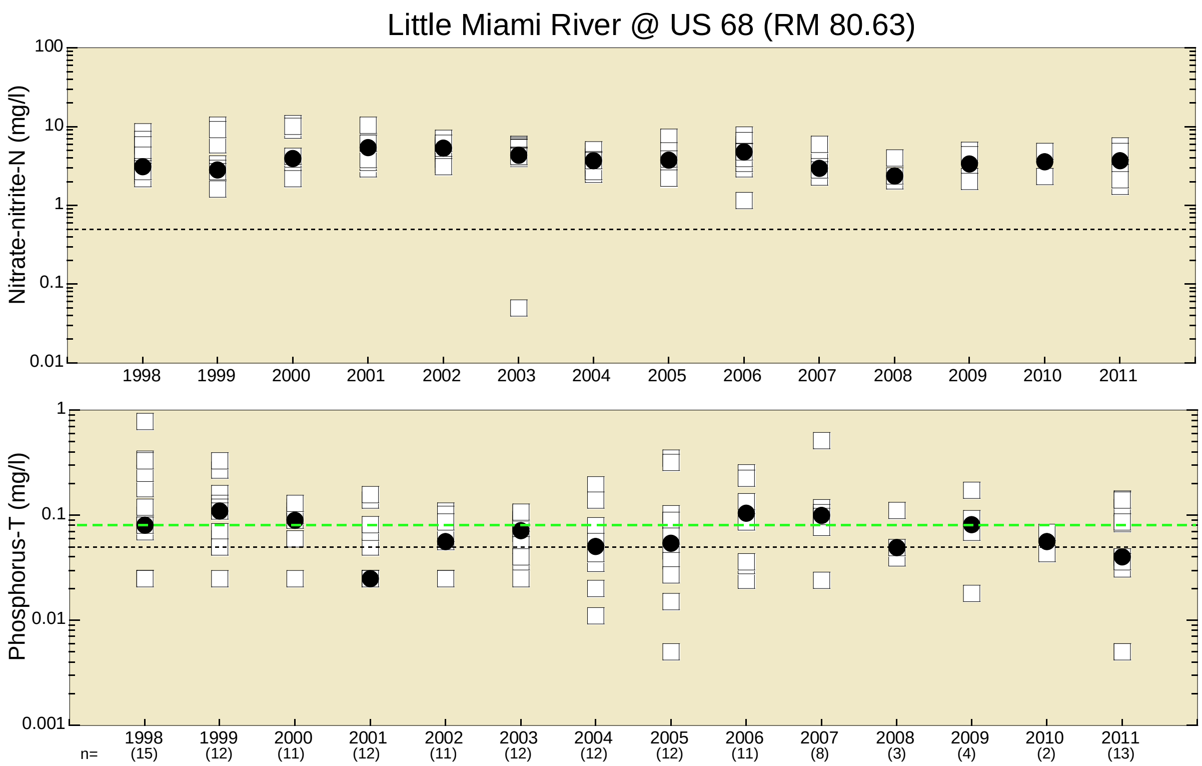


Figure 29. Annual distributions of nitrate-nitrite-N and total phosphorus in the Little Miami River @ US 68 (RM 80.63) from ambient monitoring at the NAWQMN station. The number of samples collected each year is parenthetically indicated beneath the phosphorus plot. Solid circles represent the median for the year. The thinner black dashed horizontal lines represent applicable statewide reference values from sites of similar size. The heavier green dashed line in the phosphorus plot represents the TMDL target value.

Ohio EPA previously conducted intensive biological and water quality studies of the upper Little Miami River watershed in 1983, 1993, and 1998. Additionally, three mainstem sites in the upper Little Miami River watershed (RMs 83.14, 63.30, and 53.84) were included in the 2007 study of the lower Little Miami River watershed. Only the most recent surveys (2011, 2007, and 1998) are included in the following chemical water quality assessments.

May through October stream flows for 2011, 2007,and 1998 as measured by the USGS gage station in the Little Miami River near Oldtown (RM 80.63) are compared in Figure 30 and Table 12. The highest flows were generally measured in 2011, followed by 1998 and 2007. On water chemistry sampling days in the watershed, 2011 flows ranged from 34 to 256 cfs (median 77.5 cfs) compared to 2007 flows of 10 to 38 cfs (median 24 cfs) and 1998 flows of 21 to 103 cfs (median 41 cfs). During the May through October period, eighty-one percent (81%) of 2011 mean daily flows were above the historical median (43 cfs) compared to 32% for 2007 and 52% for 1998.

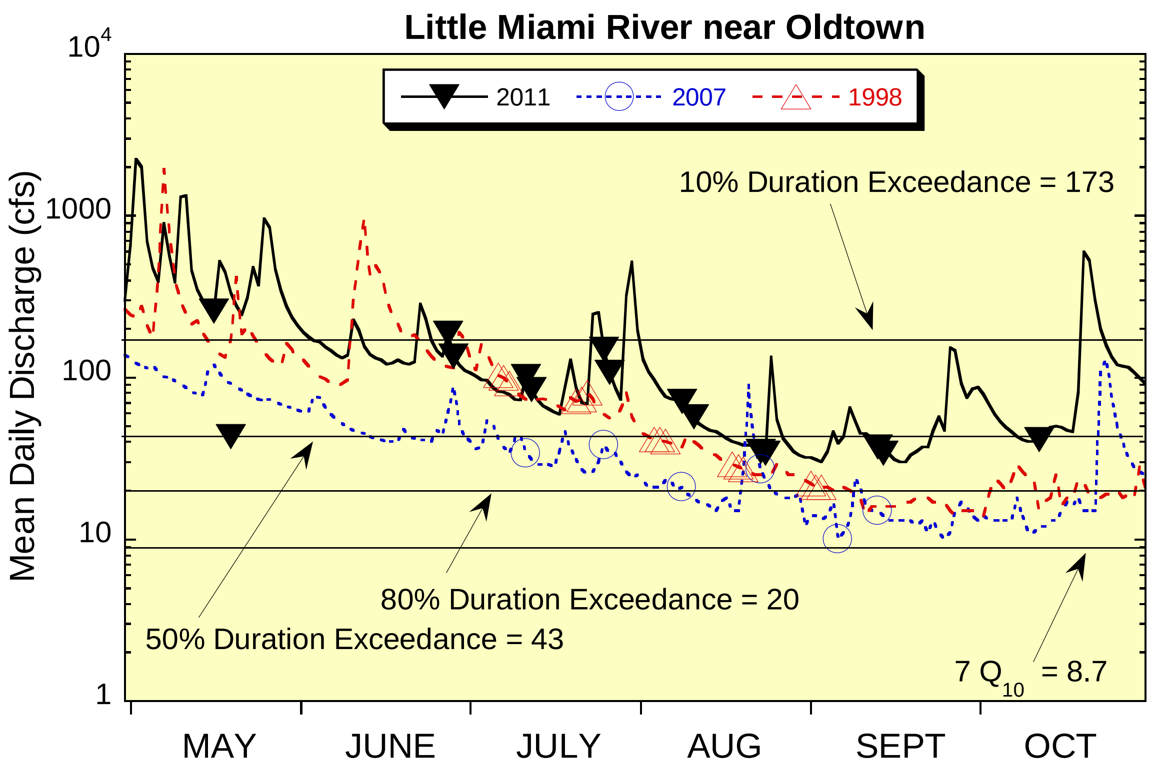


Figure 30. May through October, 2011, 2007, and 1998 flow hydrograph for the Little Miami River near Oldtown (USGS station # 03240000) RM 80.63. Markers indicate river discharge on water chemistry sampling days in the Little Miami River mainstem for each year. Duration exceedance and $7Q_{10}$ flow lines represent May-Nov period of record 1952-1997.

Table 12. Median daily discharge flow (cfs) by month in the Little Miami River near Oldtown (USGS station #03240000) and Massies Creek at Wilberforce (USGS station #03241500) in 2011, 2007 (Little Miami River only), and 1998.

	Little Miami River near Oldtown			Massies Creek at Wilberforce	
Month	**2011**	**2007**	**1998**	**2011**	**1998**
May	446	92	186	231	125
June	142.5	47	142.5	46.5	85
July	86	34	74	26	31
August	47	19	31	12	9.7
Sept	40.5	13	17	14	5.2
Oct	68	15	19	41	5.6
May-Oct	94	29	52	36	15.5

A comparison of mainstem Little Miami River water chemistry data for select parameters is presented in Figure 31 and Figure 32 for the three survey years. Water samples were collected at 23 sites in this upper reach of the mainstem during the 2011 survey compared to 22 sites in the 1998 survey and three sites in 2007.

Dissolved oxygen concentrations (daytime grabs) fell below critical levels (<4.0 mg/l) in the WWH headwaters of the mainstem during both 2011 and 1998. The stream in this area, a small narrow grassy channel with no woody riparian buffer, typically experienced lower flows which exacerbated the impacts of habitat modification. Excluding the headwater WWH sites, DO levels were relatively stable longitudinally with medians ranging from 6.4 mg/l to 8.8 mg/l in 2011 compared to 7.0 mg/l to 9.6 mg/l in 1998.

Median TSS levels generally remained below target reference values, but trended upward longitudinally in all three survey years, with the highest median values generally measured in 2011, the highest flow year.

Ammonia-N levels in the mainstem remained low in all surveys with the majority (77%) of all concentrations measured below the minimum detection limit of 0.05 mg/l. The highest levels in 1998 (median 0.14 mg/l) occurred in the headwaters downstream from Paygro (RM 106.35) while the highest 2011 values (median 0.06 mg/l) occurred downstream from the Sugarcreek WWTP at RM 64.28. There were no exceedances of WQS criteria for ammonia-N in any survey.

For the most part, nitrate-nitrite-N levels in the mainstem were similar longitudinally in all surveys with most values elevated above target. Overall nitrate-nitrite-N levels were little changed with a median of 3.145 mg/l in 2011 (23 sites) compared to 3.22 mg/l in 2007 (3 sites) and 3.53 mg/l in 1998 (22 sites).

Total phosphorus levels in the upper Little Miami River were markedly lower in 2011 with an overall median of 0.100 mg/l compared to 0.235 mg/l in 1998. Thirty percent (30%) of 2011 total phosphorus values were above the TMDL target compared to 71% of 1998 concentrations. Concentrations at the three sites sampled in 2007 (median 0.188 mg/l) were also higher than 2011 levels at these sites (median 0.117 mg/l). Longitudinally, concentrations in both 1998 and 2011 increased downstream from Yellow Springs Creek (RM 83.14), Beaver Creek (RM 72.30), and the Sugarcreek WWTP (RM 64.28). The Yellow Springs WWTP discharges to Yellow Springs Creek at RM 0.43 and Beaver Creek receives the pollutant loading from both the Beavercreek WWTP and Eastern Regional WWTP on Little Beaver Creek.

Little Miami River Tributaries (headwaters to Massies Creek)

Gilroy Ditch

Stream samples were collected at one site (RM 0.5) in Gilroy Ditch in 2011 and at two sites in 1998 (RMs 1.45 and 0.5). While extensive algal growth during the 1998 survey pushed daytime grab DO concentrations in Gilroy Ditch (RM 0.5) to supersaturated levels downstream from the South Charleston WWTP (median DO saturation 181%), 2011 levels at the site were much more stable (median DO saturation 94%). Median concentrations of nitrate-nitrite-N and total phosphorus at the site also dropped from 3.61 mg/l and 0.64 mg/l in 1998, respectively, to 2.68 mg/l and 0.169 mg/l in 2011. Ammonia-N concentrations, generally low in both surveys, exceeded the WQS criterion in 1998 on one occasion at RM 0.5 downstream from the South Charleston WWTP.

North Fork Little Miami River

Water samples were collected at two sites in the North Fork Little Miami River in 2011 (RMs 9.1 and 0.37) and in 1998 (RMs 7.15 and 0.37). Results indicated relatively good water quality in both years. Ammonia-N and total phosphorus concentrations were low, the latter having an overall median of 0.09 mg/l in 1998 compared to 0.028 mg/l in 2011. Nitrate-nitrite-N concentrations typically exceeded statewide targets throughout the North Fork Little Miami River in both survey years (1998 median of 1.245 mg/l and 2011 median of 1.8 mg/l).

Yellow Springs Creek

Yellow Springs Creek was sampled downstream from the Yellow Springs WWTP at RM 0.1 (Grinnell Rd) in both 2011 and 1998. Results indicate little change in water quality between surveys. Ammonia-N was consistently low and dissolved oxygen was stable. Nutrient loading from the WWTP was apparent in both survey years by the elevated levels of nitrate-nitrite-N and total phosphorus. Nitrate-nitrite-N concentrations were higher in 1998 (median 4.22 mg/l) compared to 2011 (3.495 mg/l) while total phosphorus levels in 2011 (median 0.211 mg/l) were minimally higher than 1998 (median 0.18 mg/l).

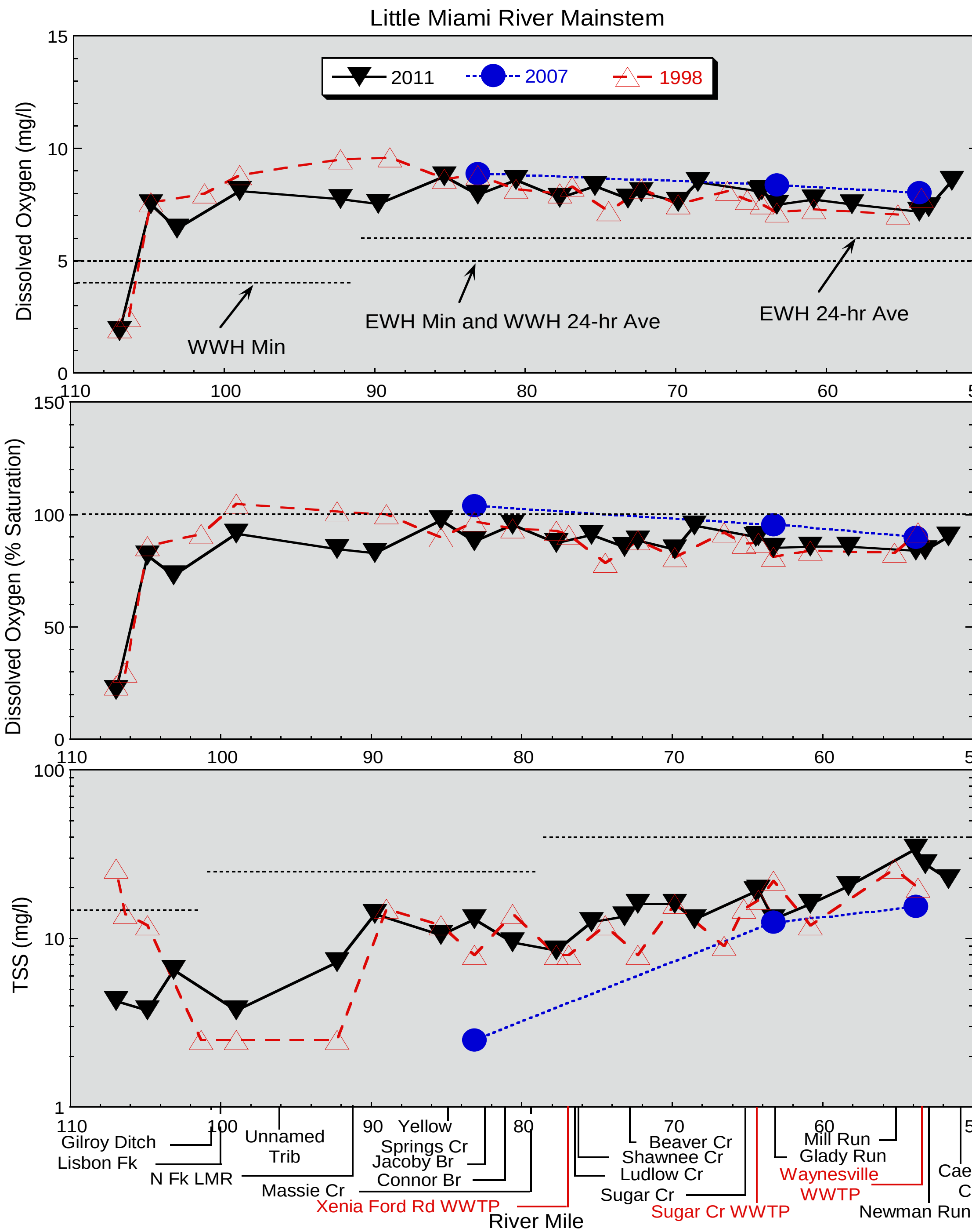


Figure 31. Longitudinal plots of median concentrations of daytime grab dissolved oxygen concentration, dissolved oxygen percent saturation, and TSS in the upper Little Miami River,2011, 2007, and 1998. WQS criteria lines are shown in the dissolved oxygen plot. The dashed horizontal lines in the TSS plot represent applicable statewide reference values from sites of similar size.

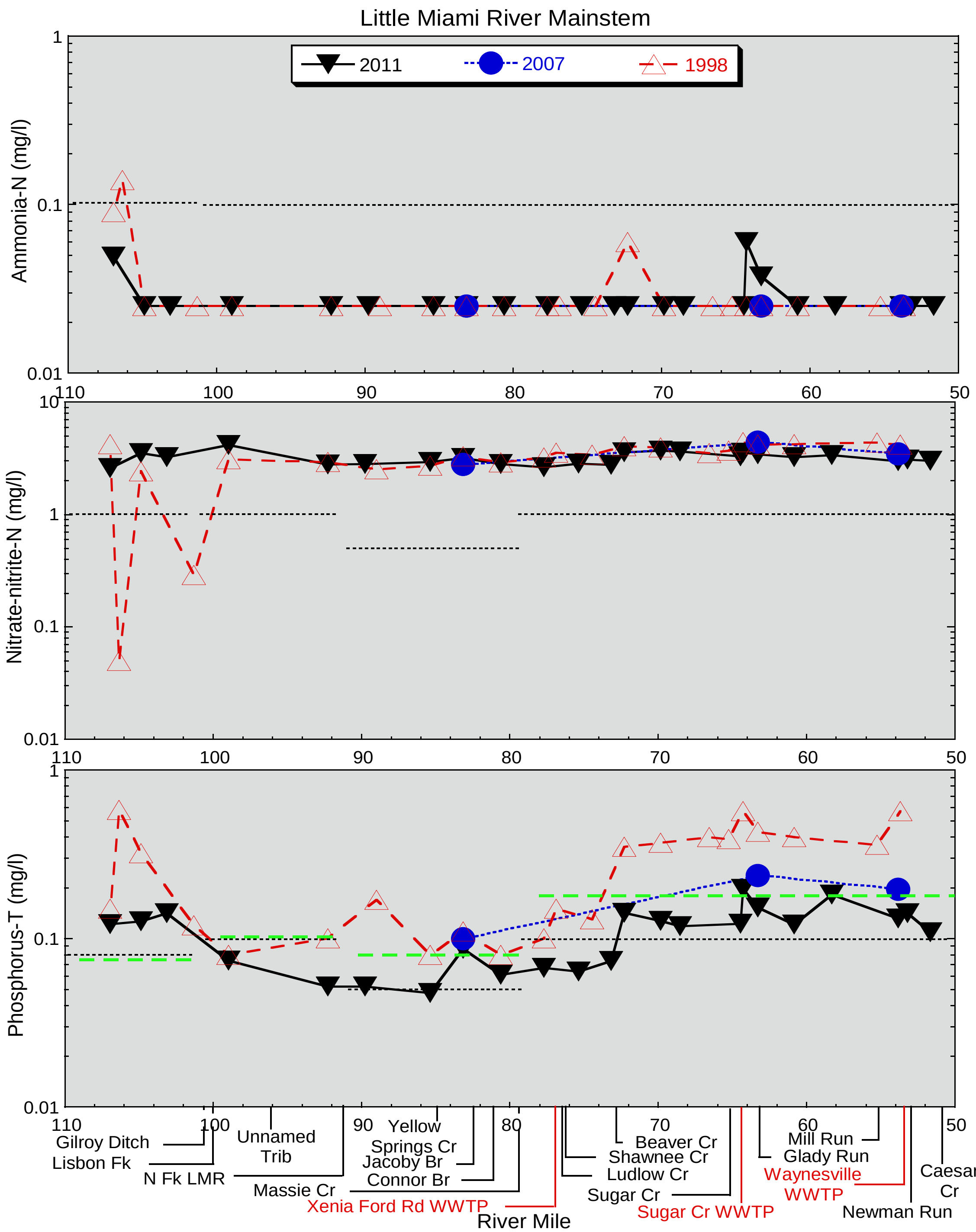


Figure 32. Longitudinal plots of median concentrations of ammonia-N, nitrate-nitrite-N, and total phosphorus in the upper Little Miami River, 2011, 2007, and 1998. The thinner black dashed horizontal lines represent applicable statewide reference values from sites of similar size. The heavier green dashed line in the phosphorus plot represents the TMDL target value.

Massies Creek Watershed

May through October stream flows for 2011 and 1998 as measured by the USGS gage station in Massies Creek at Wilberforce are compared in Figure 33 and Table 12**.** Flows were generally higher in 2011 compared to 1998. On specific water chemistry sampling days in this subwatershed, 2011 flows ranged from 6.6 to 119 cfs (median 26.5 cfs) compared to 1998 flows of 5.0 to 51 cfs (median 10 cfs). During the May through October period, seventy-six percent (76%) of 2011 mean daily flows were above the historical median (17 cfs) compared to 49% for 1998.

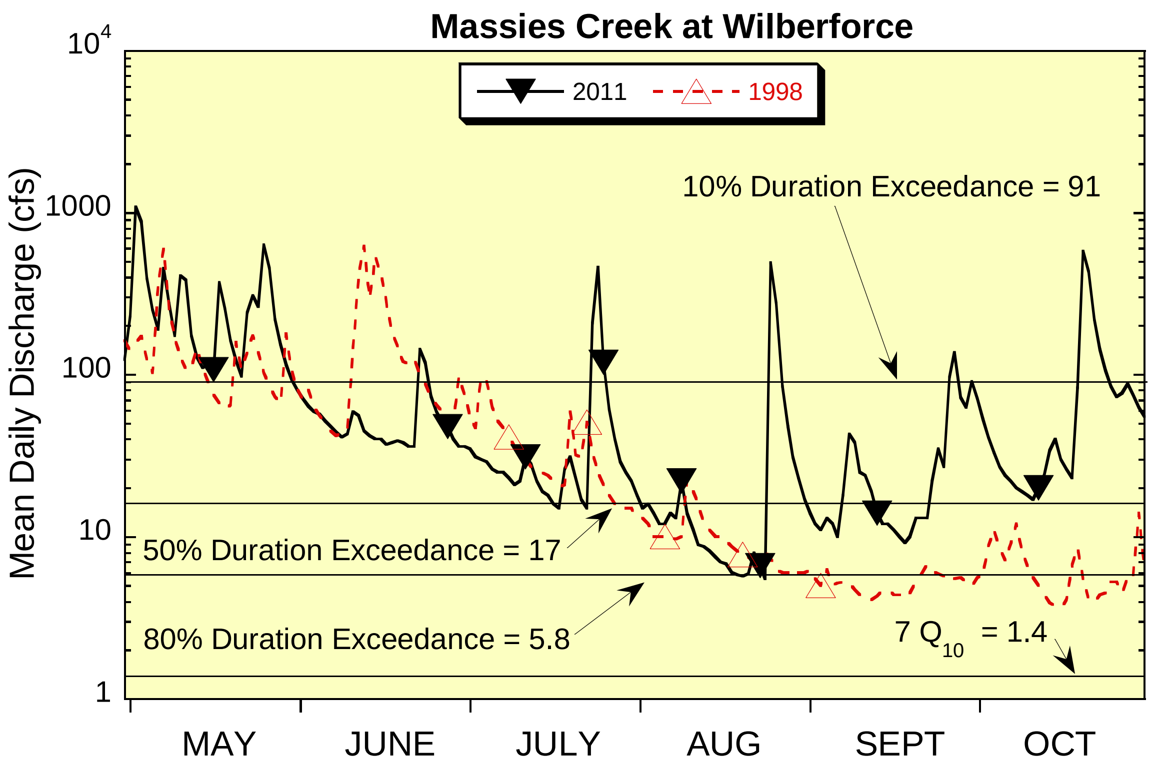


Figure 33. May through October, 2011 and 1998 flow hydrograph for Massies Creek at Wilberforce (USGS station # 03241500). Markers indicate river discharge on water chemistry sampling days for each year. Duration exceedance and 7Q_{10} flow lines represent May-Nov period of record 1952-1997.

Water samples were collected at ten stream sites in the Massies Creek watershed in both 2011 and 1998. A comparison of nitrate-nitrite-N and total phosphorus for the two survey years is presented in Figure 34. Ammonia-N concentrations were generally low in Massies Creek and its tributaries in both 2011 and 1998 with 92% of values equal to or less than the minimum detection limit (0.05 mg/l) in 2011, compared to 83% in 1998. Median nitrate-nitrite-N concentrations were minimally lower in 2011 in Massies Creek, Clark Run, and Oldtown Creek compared to 1998 whereas 2011 values in both North Fork Massies Creek and South Fork Massies Creek were generally elevated over 1998 levels. The majority of nitrate-nitrite-N values in the watershed were elevated above target in both survey years with overall median concentrations of 2.51 mg/l in 2011 compared to 3.4 mg/l in 1998. Phosphorus concentrations were lower throughout the Massies Creek watershed with overall medians of 0.03 mg/l in 2011 compared to 0.08 mg/l in 1998.

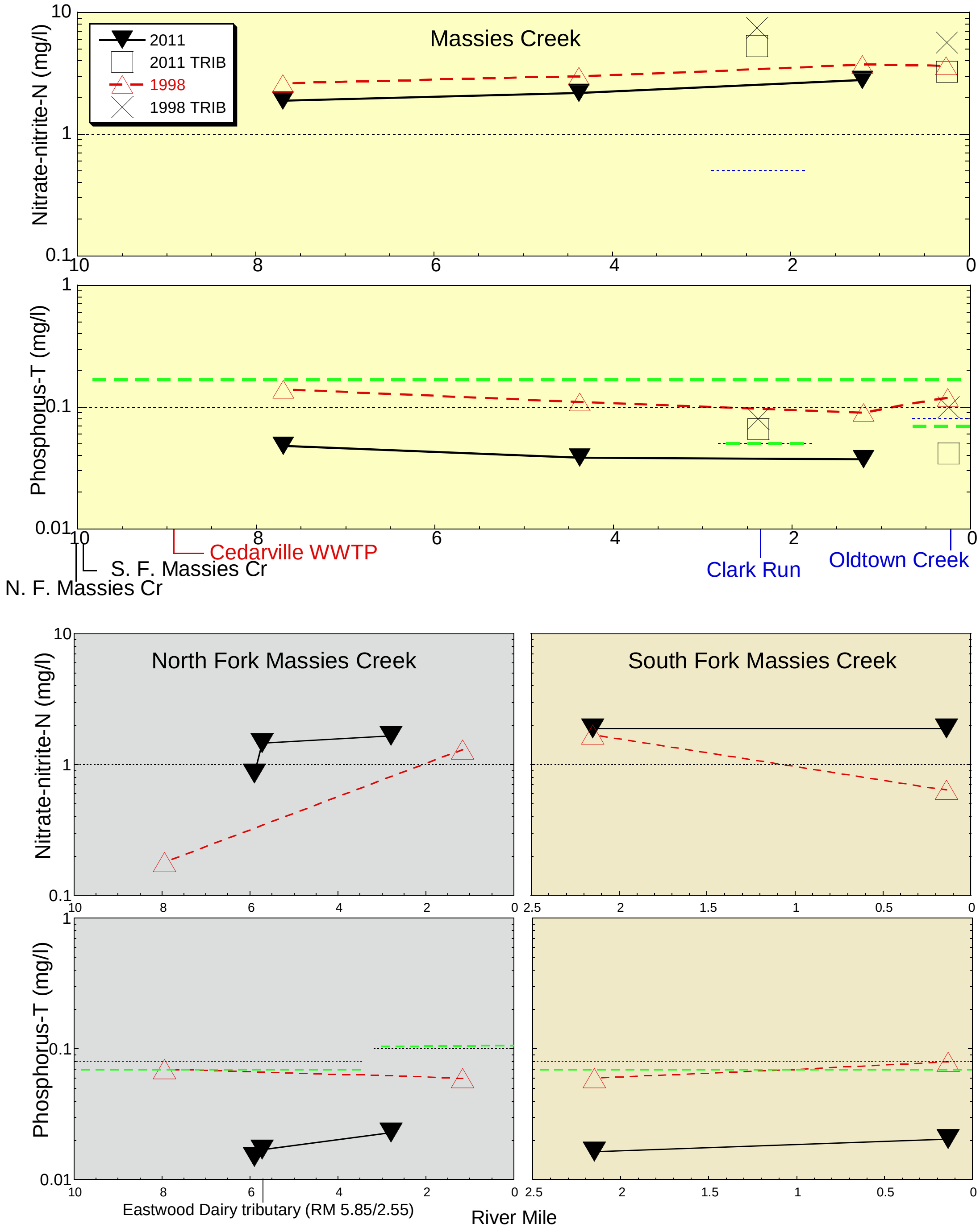


Figure 34. Longitudinal plots of median concentrations of nitrate-nitrite-N and total phosphorus in Massies Creek, Clark Run (RM 0.44), Oldtown Creek (RM 0.10), North Fork Massies Creek, and South Fork Massies Creek, 2011 and 1998. The thinner black dashed horizontal lines represent applicable statewide reference values from sites of similar size. The heavier green dashed lines in the phosphorus plots represent TMDL target values.

Little Miami River Tributaries (Massies Creek to Beaver Creek)

Ludlow Creek

One site was sampled in Ludlow Creek (RM 0.25) in 2011 and 1998. Results in both years indicated good water quality. Daytime DO levels were stable and concentrations of ammonia-N and total phosphorus were low. While nitrate-nitrite-N concentrations were somewhat lower in 2011 (median 2.19 mg/l) compared to 1998 (median 3.12 mg/l), all concentrations were elevated above the statewide reference target (1.00 mg/l) in both years.

Shawnee Creek

Shawnee Creek was sampled at Hawkins Road (RM 0.65) in 2011 and 1998. Dissolved oxygen at the site was normal with overall median daytime saturations approaching 100% in both surveys. While all ammonia-N values were low, all nitrate-nitrite-N concentrations at the site minimally exceeded the 1.0 mg/l target in both years. Phosphorus levels were also generally low with 2011 concentrations (median 0.032 mg/l) minimally higher than 1998 (median 0.025 mg/l). Although specific conductivity and total dissolved solids were consistently elevated at the site during the 2011 survey, lower levels were recorded during the 1998 survey.

Beaver Creek Watershed

A comparison of 2011 and 1998 water chemistry data for select parameters is presented in Figure 35 for Beaver Creek and Little Beaver Creek. Stream water samples were collected at eight sites in 2011 and at eleven sites in 1998.

Water quality in this small watershed in both survey years reflected the ongoing impact of nutrient loadings from both the Montgomery County Eastern Regional WWTP discharge (Little Beaver Creek RM 4.75) and the Beavercreek WWTP discharge (Beaver Creek RM 0.4). Similar longitudinal patterns were observed in both survey years for nutrients. While there were no exceedances of ammonia-N WQS criteria in either survey, concentrations were consistently elevated in Little Beaver Creek downstream from the Montgomery County Eastern Regional WWTP. Nitrate-nitrite-N levels were also elevated above target in 2011 and in 1998 downstream from both the Eastern Regional and Beavercreek WWTPs. There were significant reductions in 2011 total phosphorus concentrations in both Beaver Creek and Little Beaver Creek compared to 1998. The overall median total phosphorus concentration in the Beaver Creek watershed decreased from 0.73 mg/l in 1998 to 0.14 mg/l in 2011. However, levels remained elevated above target in both survey years downstream from the wastewater treatment facilities. Fifty-six percent of 2011 phosphorus values in the watershed were above TMDL targets compared to 80% of 1998 concentrations.

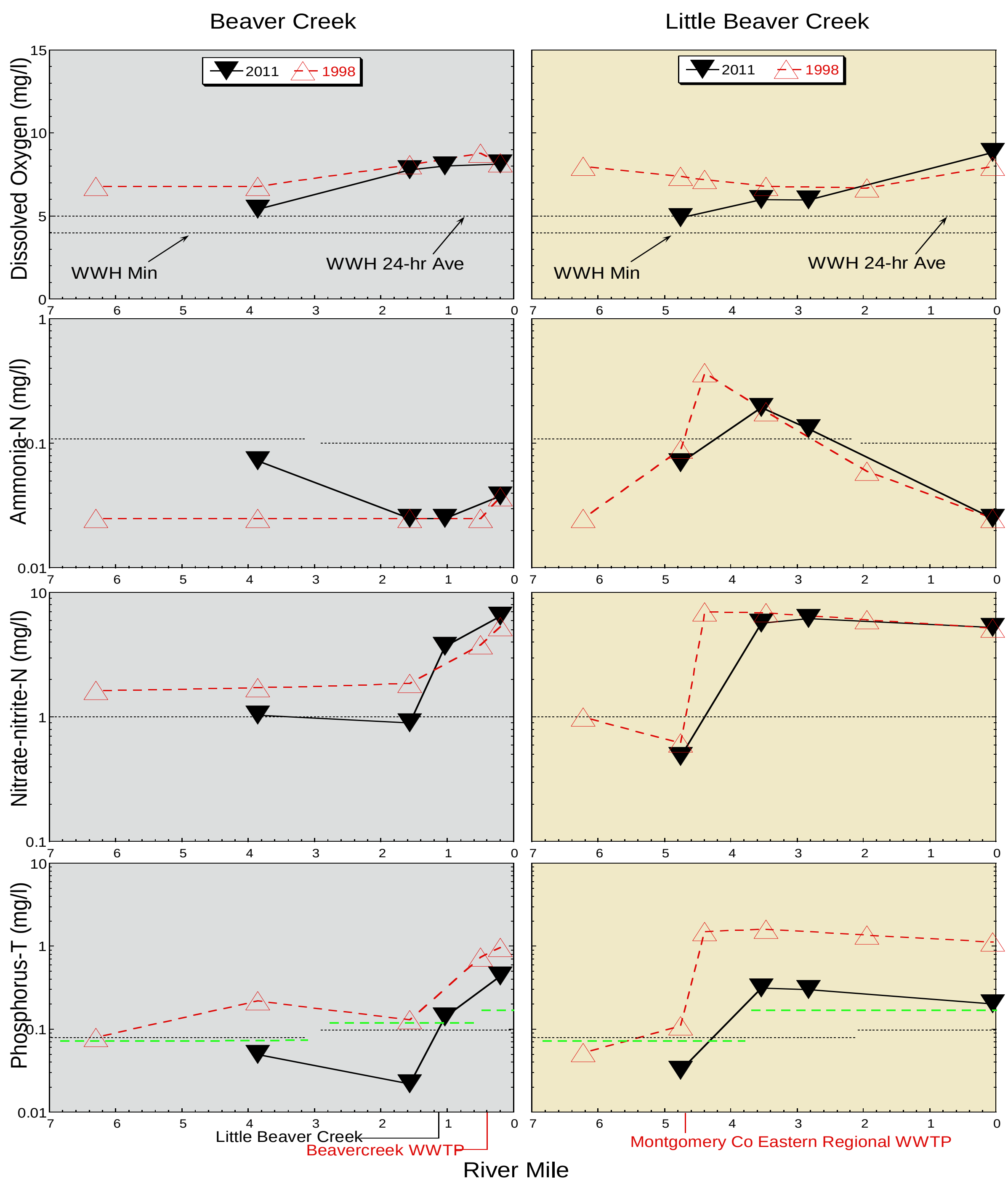


Figure 35. Longitudinal plots of median concentrations of daytime grab dissolved oxygen, ammonia-N, nitrate-nitrite-N, and total phosphorus in Beaver Creek and Little Beaver Creek, 2011 and 1998. WQS criteria lines are shown in the dissolved oxygen plots. The thinner black dashed horizontal lines in other plots represent applicable statewide reference values from sites of similar size. The heavier green dashed lines in the phosphorus plots represent TMDL target values.

Little Miami River Tributaries (Beaver Creek to Caesar Creek)

Sugar Creek and Little Sugar Creek

Water samples were collected at two sites in Sugar Creek in 2011 (RMs 4.11 and 0.4) and in 1998 (RMs 2.13 and 0.4). Little Sugar Creek was sampled adjacent to Maple Street (RM 0.45) in both surveys. Water quality in both streams was good in both years. Ammonia-N, nitrate-nitrite-N, and total suspended solids were low at all sites. While all phosphorus concentrations in this small watershed were below target levels in 2011, just over half (53%) of the values were elevated above target in 1998.

Glady Run

Stream water samples were collected at two sites in Glady Run in 2011 (RMs 4.08 and 0.54) and at three sites in 1998 (RMs 4.99, 4.08, and 2.08). Dissolved oxygen levels were stable at all sites. While ammonia-N concentrations were generally low in both surveys, concentrations exceeded the WQS criterion in 1998 on one occasion at the two sites downstream from the Xenia Glady Run WWTP (RMs 4.08 and 2.08). Although still elevated above target, levels of both nitrate-nitrite-N and total phosphorus improved downstream from the Xenia Glady Run WWTP in 2011 compared to 1998. Nitrate-nitrite-N median concentrations ranged from 5.74 mg/l (RM 4.08) to 4.21 mg/l (RM 0.54) in 2011 compared to 1998 medians of 8.91 mg/l (RM 4.08) and 6.74 mg/l (RM 2.08). Median 2011 phosphorus concentrations ranged from 0.256 mg/l (RM 4.08) to 0.078 mg/l (RM 0.54) compared to median 1998 values of 1.10 mg/l (RM 4.08) and 0.94 mg/l (RM 2.80).

Newman Run

Water samples collected in 2011 and 1998 at US 42 (RM 0.27) in Newman Run indicated good water quality. All ammonia-N concentrations were less than the minimum detection limit (0.05 mg/l). Both nitrate-nitrite-N and total phosphorus concentrations were lower in 2011 compared to 1998 with respective medians of 0.925 mg/l and 0.0365 mg/l in 2011 compared to 1.46 mg/l and 0.17 mg/l in 1998.

Caesar Creek Watershed

Water chemistry samples were collected in Caesar Creek, North Branch Caesar Creek, South Branch Caesar Creek, Buck Run, Jonahs Run, Flat Fork, Anderson Fork, and Painters Creek in both the 2011 and 1998 surveys. A comparison of select water chemistry parameters for the two survey years are presented in Figure 36-Figure 38.

For the most part, median 2011 levels and longitudinal patterns for daytime grab dissolved oxygen, ammonia-N, nitrate-nitrite-N, and TSS mirrored 1998 levels in the mainstem of Caesar Creek, as well as in North Branch Caesar Creek and South Branch Caesar Creek (Figure 36, Figure 37). While ammonia-N concentrations in 2011 were low at RM 8.23 downstream from the Jamestown WWTP, values in 1998 were frequently elevated and exceeded the WQS criterion on one occasion. Nitrate-nitrite-N levels in Caesar Creek increased at RM 23.1 (Stone Rd) downstream from the confluences of North Branch Caesar Creek and South Branch Caesar Creek in both years and remained elevated well above target reference values at downstream sites. Similar to 2011, agricultural loading in 1998 from the North Branch Caesar Creek appeared to contribute more to nitrate-nitrite-N levels in the mainstem of Caesar Creek than the South Branch Caesar Creek (Figure 37). While most phosphorus concentrations in the Caesar Creek watershed were markedly lower in 2011, concentrations in South Branch Caesar Creek were essentially unchanged compared to 1998 levels with some of the highest values of both surveys recorded downstream from the Jamestown WWTP at RM 8.23. The overall median phosphorus concentration for streams common to both surveys in the entire Caesar Creek watershed decreased from 0.210 mg/l in 1998 to 0.048 mg/l in 2011.

Water quality in Anderson Fork generally improved in 2011 compared to 1998 (Figure 38) with concentrations of ammonia-N, nitrate-nitrite-N, phosphorus, and total suspended solids all lower in 2011. Median nitrate-nitrite-N decreased from 1.89 mg/l in 1998 to 0.40 mg/l in 2011. An overall median of 0.23 mg/l was calculated for total phosphorus in the mainstem of Anderson Fork in 1998 with 88% of concentrations exceeding applicable TMDL target values compared to a median of 0.04 mg/l in 2011 and with only 5% of values above target.

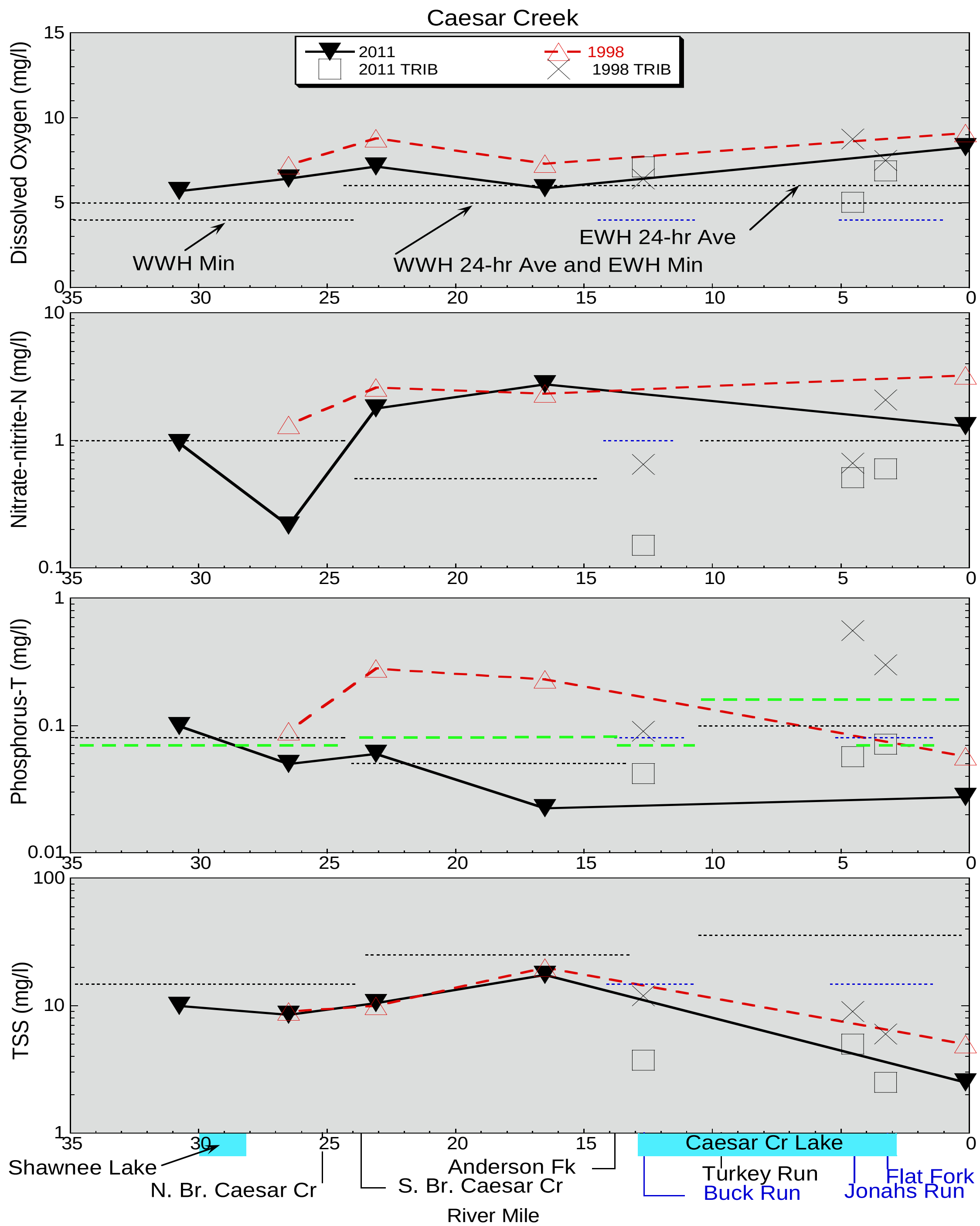


Figure 36. Longitudinal plots of median concentrations of daytime grab dissolved oxygen, nitrate-nitrite-nitrogen, total phosphorus, and total suspended solids in Caesar Creek, Buck Run (RM 1.18), Jonahs Run (2011 RM 2.1, 1998 RM 1.3), and Flat Fork (RM 1.7), 2011 and 1998. WQS criteria lines are shown in the dissolved oxygen plot. The thinner black dashed horizontal lines in other plots represent applicable statewide reference values from sites of similar size. The heavier green dashed line in the phosphorus plot represents the TMDL target value.

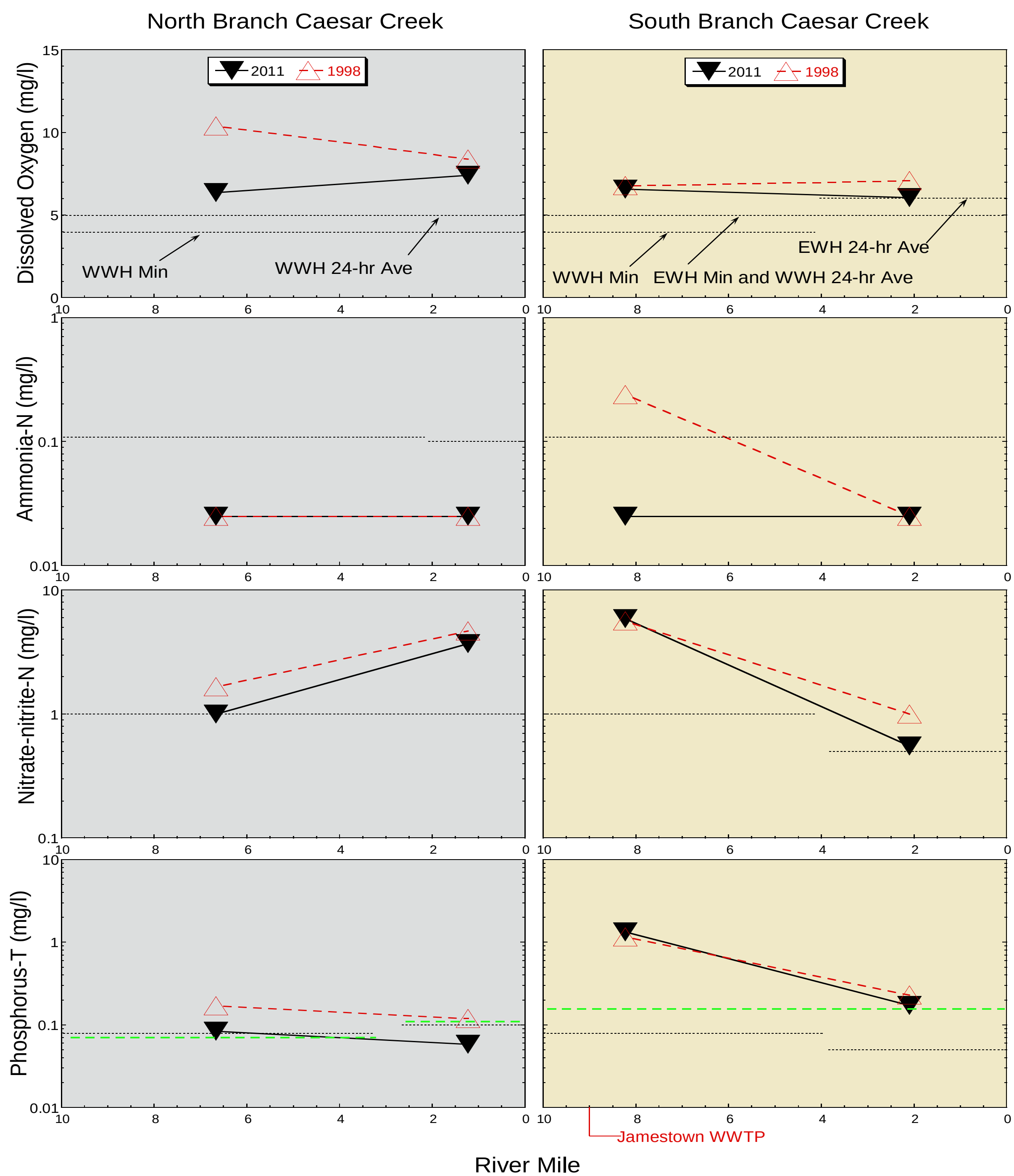


Figure 37. Longitudinal plots of median concentrations of daytime grab dissolved oxygen, ammonia-N, nitrate-nitrite-N, and total phosphorus in North Branch Caesar Creek and South Branch Caesar Creek, 2011 and 1998. WQS criteria lines are shown in the dissolved oxygen plots. The thinner black dashed horizontal lines in other plots represent applicable statewide reference values from sites of similar size. The heavier green dashed lines in the phosphorus plots represent TMDL target values.

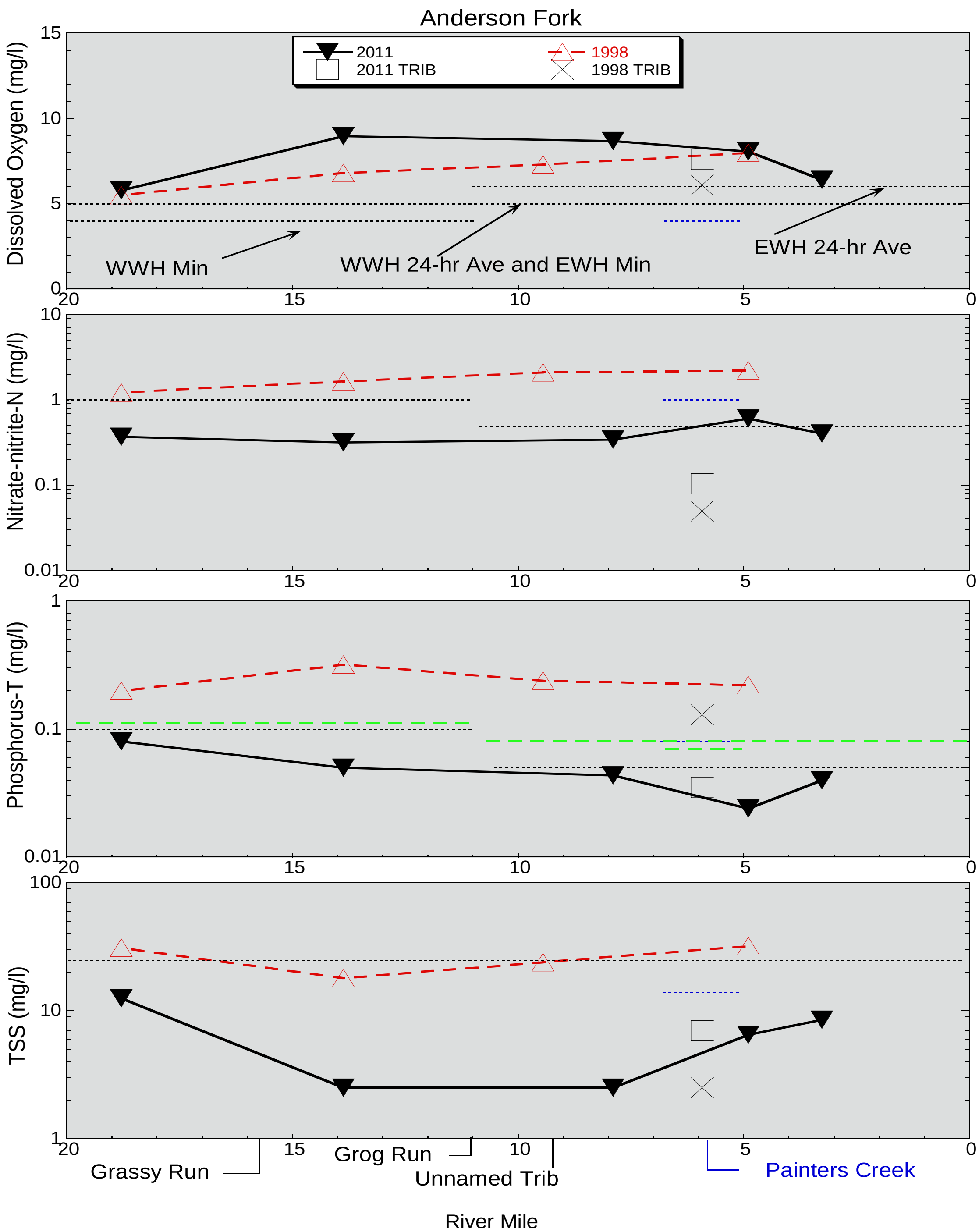


Figure 38. Longitudinal plots of median concentrations of daytime grab dissolved oxygen, nitrate-nitrite-N, total phosphorus, and total suspended solids in Anderson Fork and Painters Creek (RM 0.43), 2011 and 1998. WQS criteria lines are shown in the dissolved oxygen plot. The thinner black dashed horizontal lines in other plots represent applicable statewide reference values from sites of similar size. The heavier green dashed line in the phosphorus plot represents the TMDL target value.

Sediment

In summary, the upper Little Miami River and its tributaries did not have significant sediment contamination. Gilroy Ditch downstream from the South Charleston WWTP was the most contaminated sediment site for metals and other inorganic contaminants. For organic parameters, legacy pesticides and their degradation products were found at 3 sites and low level PCBs were found at two tributary sites. Polycyclic aromatic hydrocarbons (PAHs) were detected at 39% (13/33) of sites, but only three sites had concentrations over the MacDonald Probable Effect Concentration (PEC).

A total of 33 surficial sediment samples were collected in the upper Little Miami River watershed from RM 103.13 (Jamestown Rd) in Clark County to RM 51.65 on Middletown Road in Warren County. Fifteen sediment samples were collected on the mainstem and 18 samples were collected in 12 tributaries. Samples were analyzed for metals, volatile organic compounds, semi-volatile organic compounds, PCBs, pesticides, and nutrients. Sediment metals are listed in Table 13. Sediment organics are listed in Table 14.

Sediment collection involved looking for freshly deposited sediment in the stream bed with a bias toward fine grained material (<60 microns, silt, clay, muck,). Depositional zones on both sides of the stream channel were sampled in an attempt to collect a composite sample representative of the stream segment. Samples were collected with a stainless steel scoop and composited in a stainless steel bucket. The samples were placed in the appropriate containers and placed in a cooler at <6^0C.

A hierarchy of guidelines is used to evaluate organic compounds. Sediment organic samples were evaluated using the MacDonald Sediment Quality Guidelines (SQG) (2000) and the USEPA Region V RCRA Ecological Screening Levels (ESL) (USEPA 2003). MacDonald SQGs are consensus-based sediment guidelines designed to evaluate eco-toxic effects. The USEPA Region V RCRA ESLs are considered protective benchmarks. The MacDonald PEC evaluates the most contaminated organics and indicates that adverse effects are likely to occur in benthic sediments. The RCRA ESL evaluates the lesser contaminated sediment results to determine if the level of contamination meets or exceeds the protective benchmark.

Ohio Specific Sediment Reference Values (SRVs) were developed as guidelines by Ohio EPA to identify representative background sediment metal concentrations for lotic water bodies (Ohio EPA 2008). Sediment samples were collected from reference sites throughout the state that have been used historically to develop the biological criteria as part of the Ohio WQS. These reference sites were selected as being representative of the least impacted conditions in the watershed. SRVs are site-specific background metal concentrations based on ecoregion and identify whether a site has been contaminated. SRVs are not codified in Ohio EPA standards or criteria.

Sediment metal samples were evaluated using the Ohio SRV and the MacDonald SQG. Sediment metals detected between the MacDonald Threshold Effect Concentration (TEC) and PEC, but below the Ohio SRV will defer to Ohio's SRV. This will apply to arsenic, cadmium, copper and nickel. Sediment metals exceeding the MacDonald PEC (adverse effects usually or always occur) are referenced in Table 13.

Sediment nutrients

The sediment ammonia guideline (100 mg/kg) is the Ontario open water disposal guidelines equivalent to the lowest effect level (Persuad 1993). The sediment phosphorus guideline (2000 mg/kg) is the Ontario open water disposal guideline equivalent to the severe effect level, causing disturbances in the benthic community. Both guidelines were developed for harbors and are used only for reference in this document. The comparison of lake sediment toxicity to river sediment toxicity is not equivalent, but is still used in lieu of any criterion established for stream sediment.

Elevated ammonia above the Ontario open water sediment disposal guideline of 100 mg/kg was common throughout the study area in 2011. In the mainstem, ammonia averaged 179 mg/kg with 86% of individual samples over the guideline, while the tributaries averaged 244 mg/kg with 76% of the samples over the guideline. This was much higher than the levels recorded in 1998, where the mainstem averaged 29.7 mg/kg on the mainstem and 30.28 mg/kg in the tributaries. Although rainfall was above average for Dayton in 1998 (44.32 inches), rainfall was significantly above the average of 38.26 inches in 2011 with a total of 60.86 inches (Miami Conservancy District 2012). Runoff from agricultural sources was likely responsible for the increased ammonia in 2011. Wastewater treatment bypasses may have been an additional factor in Yellow Springs Creek and in the Little Miami River downstream from Yellow Springs Creek (RM 83.16). The highest sediment ammonia in the survey was recorded in Yellow Springs Creek at RM 0.1, which is downstream from the Yellow Springs WWTP. Consequently, the highest sediment ammonia on the mainstem was also found downstream from Yellow Springs Creek. Bypasses from the WWTP were a result of construction constraints during upgrades to the plant. Those upgrades were completed in 2012.

Sediment phosphorus levels recorded in the 1998 Little Miami River biological and water quality survey were the highest recorded for a southwest Ohio TMDL watershed study, with a mainstem average of 1819 mg/kg for 12 sites (with six sites above the Ontario open water disposal guideline of 2000 mg/kg). In spite of the much heavier precipitation of 2011, mainstem sediment phosphorus was actually reduced by 46%, with an average 986 mg/kg for 14 sites. The tributary 2011 results averaged 1004.5 mg/kg with only two samples above the Ontario phosphorus guideline. It was unclear the reason for the marked decline in sediment phosphorus during such a high flow year.

Sediment Metals

Glacial outwash and tills make up much of the sediments in the Little Miami River. The parent rock is limestone with varying amounts of calcium and magnesium as the major cation. It is not surprising that calcium and magnesium levels over the Ohio SRV are detected in Little Miami River sediments. Calcium was detected over the Ohio SRV in 20% (3/15) of sites on the mainstem and 28% (5/18) of sites in the tributaries. Magnesium was detected over the Ohio SRV in 13% (2/15) of sites on the mainstem and 39% (7/18) of sites in the tributaries.

Strontium in the sediments of Gilroy Ditch (1500 mg/kg) and the mainstem at Dolly Varden Road (RM 98.98; 406 mg/kg) were above the Ohio SRV. In 1998, Gilroy Ditch had 720 mg/kg and Dolly Varden Road had 266 mg/kg concentrations of strontium. These sites are located in glacial deposits appearing to be high in celestite ($SrSO_4$). High levels of sediment strontium and dissolved strontium are associated with the outwash sand and gravels of the buried valley near South Charleston.

Sediment Organic Chemicals

Dieldrin

Dieldrin is a persistent organic pollutant that bioaccumulates in the environment. Dieldrin was used alone as an insecticide but can also be the toxic oxidation byproduct of aldrin (used as a termiticide). Dieldrin was banned from use in the United States in 1974 and aldrin was banned from use in 1987. Dieldrin was found in sediments at one mainstem site and was not found in the tributaries. Dieldrin was detected in the “not protective” range of the ESL at the Little Miami River at Jamestown Road (RM

103.13), meaning the concentration found may be harmful to aquatic life. Its presence in the sediment at this agricultural location may be legacy contamination.

PAHs

PAHs are the most common organic compounds found in sediments in the Little Miami River. PAHs represent a large class of suspected carcinogens that are freely discharged into the environment. Miles of PAH-laden bitumen act as a binder in asphalt roads. Coal tar emulsion-based sealers consisting of 50% PAH compounds that would otherwise be classified as a hazardous waste (KO87) are routinely applied to driveways and parking lots as a topical coating in the watershed. Internal combustion engines release PAHs into the air as incomplete combustion by-products of burning hydrocarbons. Oils from these engines leak out crankcase oil containing PAHs. Atmospheric deposition of PAHs from home heating fires and coal power plants also are large contributors. All these PAH sources make their way into storm water draining into the Little Miami River. PAHs were detected at 4 of 15 mainstem sediment sites and 9 of 18 tributaries (Table 14). None of the mainstem sites had PAH sediment concentrations over the MacDonald PEC. However, three sites on the tributaries did have PAHs over the MacDonald PEC. These sites were located in urban or industrial areas where these compounds are more likely to be present in storm water. While sediment accumulation may be sparse in many of these streams, such as in a flashy system like Little Beaver Creek, the high concentration of PAHs may suggest the overall need for better storm water management in lieu of any effects on aquatic life.

There are ten fingerprint PAHs that are routinely in sediments. These are:

Benzo(a)anthracene	Benzo(k)fluoranthene
Benzo(a)pyrene,	Benzo(g,h,i)perylene
Benzo(b)fluoranthene,	Indeno[1,2,3-cd]pyrene
Fluoranthene	Chrysene
Fluorene	Pyrene

Chlordane

Chlordane was widely used as an insecticide in agriculture from 1948-1983. It was banned as a termiticide in 1988. Chlordane is a term that represents a large number (140) of individual compounds. Some of them are: cis-chlordane, trans-chlordane, cis-nonachlor, trans-nonachlor, and oxychlordane. Chlordane is bioaccumulative and is toxic to fish. It was not detected in sediments at any mainstem sites and was found in sediments at two of eighteen tributary sites (
Table *14*).

DDT

Dichlorodiphenyltrichloroethane (DDT) was banned from use in the United States in 1972. This pesticide was used extensively in agriculture starting in 1950 and peaked in use by 1959. There are three types of DDTs: the parent compound DDT and the degradation byproducts of dehalogenation (DDD and DDE). All DDT categories were summed and reported as the total DDT value. DDT was not detected in sediments of the mainstem Little Miami River and was detected at two of eighteen tributary sites (Table 14). One value was above the MacDonald PEC and the other was above the USEPA ESL protective benchmark.

Table 13. Concentrations (mg/kg unless otherwise noted) of metals and nutrients in sediment samples collected in the upper Little Miami River watershed, 2011. Parameter concentrations were evaluated based on Ohio EPA sediment metal reference sites (2003), MacDonald (2000) Sediment Quality Guidelines (SQG) and Persuad (1993). Values elevated above guidelines are highlighted.

Parameter	Little Miami River Mainstem River Mile						***Reference***	
	Jamestown Rd RM 103.13	Dolly Varden Rd RM 98.98	Jacoby Rd. RM 83.14	U.S.68 RM 80.63	Fairgrounds Rd RM 77.70	Trebein Rd RM 75.38	**Ohio SRV** ECBP	**MacDonald** PEC
Al-T [O]	10300	7350	3720	3650	5090	7270	39000	*
As-T [OM]	13.5	8.98	4.7	3.88	4.61	5.30	18	>33
Ba-T [O]	138	99.5	153	151	111	117	240	*
Ca-T [O]	58800	99300	179000	175000	97600	91300	120000	*
Cd-T [OM]	0.823	0.657	0.452	0.394	0.43	0.476	0.9	>4.98
Cr-T [OM]	12.2	10.0	5.88	5.00	7.10	9.69	40	>111
Cu-T [OM]	16.1	15.6	8.72	7.56	10.9	14.1	34	>149
Fe-T [O]	27100	18500	9800	8930	11500	13800	33000	*
Hg-T [OM]	0.065	0.065	<0.044	0.165	0.051	0.076	0.12	>1.06
K-T [O]	<1890	<2200	<1820	<2050	<1690	<1970	11000	*
Mg-T [O]	30300	36000	20400	13800	16100	16400	35000	*
Mn-T [O]	717	313	619	549	414	547	780	*
Na-T *	<4710	<5510	<4650	<5130	<4230	<4930	*	*
Ni-T [OM]	20.2	16.7	12.1	11.4	12.0	13.5	42	>48.6
Pb-T [OM]	27.0	13.9	11.0	9.55	12.6	16.0	47	>128
Se-T [O]	<1.89	<2.20	<1.82	<2.05	<1.69	<1.97	2.3	*
Sr-T [O]	93	406	316	309	164	154	390	*
Zn-T [OM]	107	85.7	40.7	36.7	48.8	71.0	160	>459
							Ohio	**Persuad**
NH_3-N [P]	190 L	190 L	380 L	170 L	150 L	200 L	*	100
TOC(%) [P]	3.8	4.8	5.7	6.5	4.5	4.6	*	10.0%
pH (SU) *	7.8	7.5	7.7	7.9	7.6	7.7	*	*
P-T [P]	1370	968	742	1260	631	878	*	2000
%FGM [O]	49%	44%	54%	42%	49%	52%	30.0%	*

%FGM Percent fine grain material in sediment sample
NA Compound not analyzed. * Not evaluated
[O] Evaluated using Ohio EPA (2003) [M] Evaluated using MacDonald (2000) [P] Evaluated using Persuad (1993)

Ohio Sediment Reference Values (SRV) Guidelines (2003)
\+ above reference value for ecoregion

Ontario Sediment Guidelines (Persuad 1993)
L > Open Water Disposal Guidelines; equivalent to the Lowest Effect Level (LEL)-applicable to NH_3-N only.

Table 13. (continued)

Parameter	Ust. Beaver Ck RM 73.16	Indian Ripple RD RM 72.30	Upper Bellbrook RM 69.84	Washington Mill RM 68.54	Ust. Sugar Ck WWTP RM 64.44	Spring Valley Park RM 63.28	***Reference*** Ohio SRV ECBP	***Reference*** MacDonald PEC
	Little Miami River Mainstem River Mile							
Al-T [O]	9730	4060	11900	8400	7840	5830	39000	*
As-T [OM]	6.19	3.91	7.83	4.83	5.06	4.08	18	>33
Ba-T [O]	161	94.6	154	99.5	112	84.0	240	*
Ca-T [O]	142000	100000	112000	87300	95900	27400	120000	*
Cd-T [OM]	0.693	0.353	0.861	0.583	0.556	0.334	0.9	>4.98
Cr-T [OM]	13.0	6.94	19.8	12.3	11.1	7.10	40	>111
Cu-T [OM]	17.0	10.9	24.7	12.1	17.1	10.4	34	>149
Fe-T [O]	17000	10300	20900	14100	14800	11600	33000	*
Hg-T [OM]	<0.066	<0.045	<0.062	<0.047	<0.054	0.039	0.12	>1.06
K-T [O]	<2500	<1470	<1990	<1620	<1840	<1130	11000	*
Mg-T [O]	38100	25500	26300	23100	20000	7970	35000	*
Mn-T [O]	796	464	668	484	590	368	780	*
Na-T *	<6250	<3670	<4980	<4040	<4590	<2820	*	*
Ni-T [OM]	16.3	10.3	18.6	12.6	14.0	10.4	42	>48.6
Pb-T [OM]	19.0	14.8	31.5	15.4	17.1	12.2	47	>128
Se-T [O]	<2.50	<1.47	<1.99	<1.62	<1.84	<1.13	2.3	*
Sr-T [O]	189	118	147	107	116	35	390	*
Zn-T [OM]	74.5	53.2	132	74.1	74.3	42.3	160	>459
							Ohio	**Persuad**
NH_3-N [P]	230 L	96	170 L	150 L	180 L	84	*	100
TOC(%) [P]	5.8	4.4	3.6	3.2	3.90	2.3	*	10.0%
pH (SU) *	7.6	7.9	7.7	7.9	7.5	7.9	*	*
P-T [P]	1260	997	1600	1040	1170	471	*	2000
%FGM [O]	54%	53%	53%	40%	48%	100%	30.0%	*

%FGM Percent fine grain material in sediment sample
NA Compound not analyzed. * Not evaluated
[O] Evaluated using Ohio EPA (2003) [M] Evaluated using MacDonald (2000) [P] Evaluated using Persuad (1993)

Ohio Sediment Reference Values (SRV) Guidelines (2003)
\+ above reference value for ecoregion

Ontario Sediment Guidelines (Persuad 1993)
L > Open Water Disposal Guidelines; equivalent to the Lowest Effect Level (LEL)-applicable to NH_3-N only.

Table 13. (continued)

Parameter	Little Miami River Mainstem (River Mile) Roxanna-Burlington RM 60.84	Dst Waynesville WWTP RM 53.20	Ust Middletown Rd. RM 51.65				*Reference* Ohio SRV ECBP	MacDonald PEC
Al-T [O]	3870	9340	3930				39000	*
As-T [OM]	3.66	6.53	3.36				18	>33
Ba-T [O]	78.6	113	74.0				240	*
Ca-T [O]	61200	56400	73000				120000	*
Cd-T [OM]	0.306	0.511	0.310				0.9	>4.98
Cr-T [OM]	5.93	10.9	6.09				40	>111
Cu-T [OM]	10.0	13.3	9.25				34	>149
Fe-T [O]	9420	18500	9790				33000	*
Hg-T [OM]	<0.034	0.052	0.035				0.12	>1.06
K-T [O]	<1150	<1420	<1450				11000	*
Mg-T [O]	12700	15100	16300				35000	*
Mn-T [O]	405	538	397				780	*
Na-T *	<2870	<3540	<3640				*	*
Ni-T [OM]	9.21	14.2	9.51				42	>48.6
Pb-T [OM]	11.3	18.3	9.41				47	>128
Se-T [O]	<1.15	<1.42	<1.45				2.3	*
Sr-T [O]	77	72	85				390	*
Zn-T [OM]	44.9	73.9	42.4				160	>459
							Ohio	**Persuad**
NH_3-N [P]	180L	130L	---				*	100
TOC(%) [P]	3.1	2.4	3.6				*	10.0%
pH (SU) *	7.6	7.8	7.9				*	*
P-T [P]	590	831	---				*	2000
%FGM [O]	47%	100%	58%				30.0%	*

%FGM Percent fine grain material in sediment sample
NA Compound not analyzed. * Not evaluated
O Evaluated using Ohio EPA (2003) M Evaluated using MacDonald (2000) P Evaluated using Persuad (1993)

Ohio Sediment Reference Values (SRV) Guidelines (2003)
\+ above reference value for ecoregion

Ontario Sediment Guidelines (Persuad 1993)
L > Open Water Disposal Guidelines; equivalent to the Lowest Effect Level (LEL)-applicable to NH_3-N only.

Table 13. (continued)

Parameter	Little Miami River Tributaries (River Mile)						Reference	
	Gilroy Ditch Bearchet Farm RM 0.50	Lisbon Fk @SR41 RM 2.80	Yellow Springs Ck. Grinnel RM 0.10	N.Fk. Massies Ck RM 5.73	Massies Ck Tarbox Cemetary RM 7.70	Massies Ck Clifton Rd. RM 4.38		
							Ohio SRV ECBP	**MacDonald** PEC
Al-T O	14400	9590	4620	5400	9550	3470	39000	*
As-T OM	36.9	11.8	5.24	7.63	8.07	5.48	18	>33
Ba-T O	171	120	139	84.4	176	45.8	240	*
Ca-T O	179000	98900	131000	11900	198000	80600	120000	*
Cd-T OM	1.19	0.648	0.431	0.449	0.680	0.306	0.9	>4.98
Cr-T OM	22.9	12.1	8.47	8.48	13.5	6.05	40	>111
Cu-T OM	42.4	15.8	15.2	9.78	17.4	10.9	34	>149
Fe-T O	58500	22800	12700	14900	18900	10400	33000	*
Hg-T OM	<0,092	0.069	0.059	0.066	<0.063	0.049	0.12	>1.06
K-T O	<4050	<2500	<2180	<1530	<2420	<1290	11000	*
Mg-T O	67500	36600	25900	49900	22700	24300	35000	*
Mn-T O	930	397	478	322	632	324	780	*
Na-T *	<10100	<6250	<5450	<3820	<6050	<3230	*	*
Ni-T OM	41.1	20.4	13.4	13.4	19.0	10.1	42	>48.6
Pb-T OM	31.8	15.7	18.6	353	24.9	10.1	47	>128
Se-T O	<4.05	<2.5	<2.18	<1.53	<2.42	<1.29	2.3	*
Sr-T O	1500	271	62	128	459	85	390	*
Zn-T OM	170	85.8	66.3	49.0	82.6	59.3	160	>459
							Ohio	**Persuad**
NH_3-N P	580	470	610	98	310	40	*	100
TOC(%) P	7.1	4.1	7.4	4.1	5.7	2.7	*	10.0%
pH (SU) *	7.5	7.6	7.5	7.9	7.4	7.9	*	*
P-T P	2590	933	722	452	1080	408	*	2000
%FGM O	66%	72%	57%	35%	51%	29%	30.0%	*

%FGM Percent fine grain material in sample sediment sample

NA Compound not analyzed. * Not evaluated

O Evaluated using Ohio EPA (2003) M Evaluated using MacDonald (2000) P Evaluated using Persuad (1993)

Ohio Sediment Reference Values (SRV) Guidelines (2003)

\+ above reference value for ecoregion

Ontario Sediment Guidelines (Persuad 1993)

L > Open Water Disposal Guidelines; equivalent to the Lowest Effect Level (LEL)-applicable to NH_3-N only.

Table 13. (continued)

Parameter	Little Miami River Tributaries (River Mile)						Reference	
	Little Beaver Ck Grange Hall RM 3.54	Little Beaver Ck Factory Rd RM 0.05	Beaver Creek Dayton-Xenia RM 1.57	Beaver Creek US 35 RM 1.04	Beaver Ck dst Beaver Ck WWTP RM 0.20	S. Br. Caesar Ck Jamestown RM 8.23	**Ohio SRV** ECBP	**MacDonald** PEC
Al-T [O]	3490	4420	6770	4290	10200	8660	39000	*
As-T [OM]	7.65	3.56	5.58	4.71	6.89	12.2	18	>33
Ba-T [O]	67.7	75.7	111	57.8	159	122	240	*
Ca-T [O]	108000	105000	99400	108000	129000	135000	120000	*
Cd-T [OM]	0.517	0.350	0.476	0.356	0.669	0.619	0.9	>4.98
Cr-T [OM]	9.48	7.32	9.01	8.71	16.8	15.8	40	>111
Cu-T [OM]	16.1	7.01	10.1	8.45	27.5	20.6	34	>149
Fe-T [O]	10900	10800	12800	10300	18900	23000	33000	*
Hg-T [OM]	0.049	<0.037	0.060	0.052	0.080	0.121	0.12	>1.06
K-T [O]	<1690	<1260	<1700	<1660	<2410	<3030	11000	*
Mg-T [O]	37400	33800	21500	41700	35400	56900	35000	*
Mn-T [O]	282	345	928	536	704	646	780	*
Na-T *	<4220	<3140	<4260	<4140	<6030	<7580	*	*
Ni-T [OM]	11.7	10.3	12.7	11.0	18.3	20.1	42	>48.6
Pb-T [OM]	24.9	34.8	9.96	10.9	23.1	21.8	47	>128
Se-T [O]	<1.69	<1.26	<1.70	<1.66	<2.41	<3.03	2.3	*
Sr-T [O]	78	75	84	76	106	321	390	*
Zn-T [OM]	84.6	44.6	54.3	53.0	115	108	160	>459
							Ohio	**Persuad**
NH_3-N [P]	170	140	130	88	360	420	*	100
TOC(%) [P]	5.6	3.3	3.8	3.2	4.3	4.2	*	10.0%
pH (SU) *	7.6	8.3	7.8	8.0	7.7	8.0	*	*
P-T [P]	1130	501	659	511	2420	1680	*	2000
%FGM [O]	27%	33%	51%	26%	52%	48%	30.0%	*

%FGM Percent fine grain material in sediment sample
NA Compound not analyzed. * Not evaluated
[O] Evaluated using Ohio EPA (2003) [M] Evaluated using MacDonald (2000) [P] Evaluated using Persuad (1993)

Ohio Sediment Reference Values (SRV) Guidelines (2003)
\+ above reference value for ecoregion

Ontario Sediment Guidelines (Persuad 1993)
L > Open Water Disposal Guidelines; equivalent to the Lowest Effect Level (LEL)-applicable to NH_3-N only.

Table 13. (continued)

Parameter	Little Miami River Tributaries (River Mile)						Reference	
	S.BR.Caesar Ck. Hoop Rd RM 2.10	Caesar Ck. Paintersville Rd RM 16.52	Glady Run Hedges Rd RM 4.08	Glady Run Spring Valley RM 0.54	Shawnee Creek Hawkins Rd. RM 0.65	Anderson Fk Old Winchester RM 4.90		
							Ohio SRV ECBP	**MacDonald** PEC
Al-T [O]	6400	2080	9690	6920	3030	5920	39000	*
As-T [OM]	4.32	2.24	7.31	7.55	4.79	7.44	18	>33
Ba-T [O]	58.4	24.4	96.6	96.1	54.8	55.3	240	*
Ca-T [O]	43700	39000	110000	96500	72500	82200	120000	*
Cd-T [OM]	0.424	0.154	0.570	0.574	0.338	0.458	0.9	>4.98
Cr-T [OM]	9.56	3.85	16.4	10.6	6.90	10.0	40	>111
Cu-T [OM]	11.6	4.20	21.3	14.7	15.2	10.4	34	>149
Fe-T [O]	17800	6110	19400	16200	10600	15700	33000	*
Hg-T [OM]	<0.050	<0.035	<0.069	<0.071	0.038	<0.045	0.12	>1.06
K-T [O]	<1820	<1310	<2570	<2270	<1490	<2140	11000	*
Mg-T [O]	18000	16400	23900	23400	21500	27900	35000	*
Mn-T [O]	400	182	953	596	348	401	780	*
Na-T *	<4550	<3280	<6430	<5680	<3270	<5340	*	*
Ni-T [OM]	11.3	6.24	18.8	16.4	10.1	14.9	42	>48.6
Pb-T [OM]	11.3	4.35	19.5	15.1	30.1	10.7	47	>128
Se-T [O]	<1.72	<1.31	<2.57	<2.27	<1.49	<2.14	2.3	*
Sr-T [O]	119	32	115	89	59	103	390	*
Zn-T [OM]	51.4	20.5	129	86.8	67.9	57.5	160	>459
							Ohio	**Persuad**
NH_3-N [P]	120	---	190	210	93	120	*	100
TOC(%) [P]	2.6	2.1	4.1	3.6	4.4	2.6	*	10.0%
pH (SU) *	7.5	7.9	7.5	7.7	7.7	7.5	*	*
P-T [P]	571	---	1240	940	446	794	*	2000
%FGM [O]	54%	25%	28%	44%	25%	29%	30.0%	*

%FGM Percent fine grain material in sediment sample
NA Compound not analyzed. * Not evaluated
[O] Evaluated using Ohio EPA (2003) [M] Evaluated using MacDonald (2000) [P] Evaluated using Persuad (1993)

Ohio Sediment Reference Values (SRV) Guidelines (2003)
+ above reference value for ecoregion

Ontario Sediment Guidelines (Persuad 1993)
L > Open Water Disposal Guidelines; equivalent to the Lowest Effect Level (LEL)-applicable to NH_3-N only.

Table 14. Concentrations of organic compounds (priority pollutant scan) detected in stream sediments in the upper Little Miami River watershed, 2011. Individual compounds were evaluated by the MacDonald (2000) Sediment Quality Guidelines (SQG) and Ecological Screening Levels (USEPA 2003).

Stream / River mile Location	**Analysis Performed**	**Compound Detected**	**Result** mg/kg unless noted
Little Miami River RM 103.13 Jamestown Rd TOC= 3.8% Fine Grain Material = 49%	1) BNA 2) Pesticides 3) PCBs 4) VOC	 Dieldrin	BRL 8.2 µg/kg # BRL BRL
Little Miami River RM 98.98 Dolly Varden Rd TOC= 4.8% Fine Grain Material =44%	1) BNA 2) Pesticides 3) PCBs 4) VOC		BRL BRL BRL BRL
Little Miami River RM 83.18 Jacoby Rd. TOC= 5.7% Fine Grain Material = 54%	1) BNA 2) Pesticides 3) PCBs 4) VOC		BRL BRL BRL BRL
Little Miami River RM 80.63 U.S.68 TOC= 6.5% Fine Grain Material = 42%	1) BNA 2) Pesticides 3) PCBs 4) VOC		BRL BRL BRL BRL
Little Miami River RM 77.7 Fairgrounds Rd TOC= 4.5% Fine Grain Material = 49%	1) BNA 2) Pesticides 3) PCBs 4) VOC		BRL BRL BRL BRL
Little Miami River RM 75.38 Trebein Rd TOC= 4.6% Fine Grain Material = 52%	1) BNA 2) Pesticides 3) PCBs 4) VOC		BRL BRL BRL BRL
Little Miami River RM 73.16 Ust. Beaver Ck TOC= 5.8% Fine Grain Material = 54%	1) BNA 2) Pesticides 3) PCBs 4) VOC	Fluoranthene Pyrene	1.21**#** 0.99# BRL BRL BRL
Little Miami River RM 72.3 Indian Ripple Road TOC= 4.8% Fine Grain Material = 53%	1) BNA 2) Pesticides 3) PCBs 4) VOC		BRL BRL BRL BRL
Little Miami River RM 69.84 Upper Bellbrook TOC= 3.6% Fine Grain Material = 53%	1) BNA 2) Pesticides 3) PCBs 4) VOC	Fluoranthene	0.78 # BRL BRL BRL

Stream / River mile Location	**Analysis Performed**	**Compound Detected**	**Result** mg/kg unless noted
Little Miami River RM 68.54 Washington Mill TOC= 3.2% Fine Grain Material = 40%	1) BNA 2) Pesticides 3) PCBs 4) VOC	Fluoranthene	0.71# BRL BRL BRL
Little Miami River RM 64.44 Ust. Sugar Ck WWTP TOC= 3.9% Fine Grain Material = 48%	1) BNA 2) Pesticides 3) PCBs 4) VOC	Fluoranthene	0.82# BRL BRL BRL
Little Miami River RM 63.23 Spring Valley Park TOC= 2.3% Fine Grain Material =100%	1) BNA 2) Pesticides 3) PCBs 4) VOC		BRL BRL BRL BRL
Little Miami River RM 60.84 Roxanna-Burlington TOC= 3.1% Fine Grain Material =47%	1) BNA 2) Pesticides 3) PCBs 4) VOC		BRL BRL BRL BRL
Little Miami River RM 53.2 Dst Waynesville WWTP TOC= 2.4% Fine Grain Material =100%	1) BNA 2) Pesticides 3) PCBs 4) VOC		BRL BRL BRL BRL
Little Miami River RM 51.65 Ust Middletown Rd. TOC= 3.6 % Fine Grain Material =58%	1) BNA 2) Pesticides 3) PCBs 4) VOC		BRL BRL BRL BRL
Gilroy Ditch RM 0.50 Bearchet Farm TOC= 7.1 % Fine Grain Material =66%	1) BNA 2) Pesticides 3) PCBs 4) VOC		BRL BRL BRL BRL
Lisbon Fork RM 2.80 SR 41 TOC= 4.1 % Fine Grain Material =72 %	1) BNA 2) Pesticides 3) PCBs	 Alpha-chlordane 4,4'-DDT 4,4'-DDE 4,4'-DDD PCB-1260	BRL 8.7 ug/Kg # 8.4 ug/Kg # 41.7 ug/Kg ■ 28.4 ug/Kg ■ 46.1 ug/Kg +
Yellow Springs Creek RM 0.10 Grinnel Road TOC= 7.4 % Fine Grain Material =57 %	1) BNA 2) Pesticides 3) PCBs		BRL BRL BRL
N. Fk. Massies Ck RM 5.73 **U.S. 42** TOC= 5.7 % Fine Grain Material =51%	1) BNA 2) Pesticides 3) PCBs		BRL BRL BRL

Stream / River mile Location	**Analysis Performed**	**Compound Detected**	**Result** mg/kg unless noted
Massies Creek RM 7.7 Tarbox Cemetary TOC= 5.7 % Fine Grain Material =51%	1) BNA 2) Pesticides 3) PCBs		BRL BRL BRL
Massies Creek RM 4.38 Clifton Rd. TOC= 5.7 % Fine Grain Material =51%	1) BNA 2) Pesticides 3) PCBs		BRL BRL BRL
Little Beaver Creek RM 3.54 Grange Hall TOC= 5.6 % Fine Grain Material =27%	1) BNA	Anthracene Benz(a) anthracene Benzo[a]pyrene Benzo[b]fluoranthene Benzo[g,h,i]perylene Benzo[k]fluoranthene Chrysene Fluoranthene Indeno[1,2,3-cd]pyrene Phenanthrene Pyrene **Total PAH**	1.34■ 1.08 ■ 1.34 # 1.35 + 0.94 # 1.20 # 1.58 ■ 3.02 ■ 0.86 # 1.35 ■ 2.31 ■ **17.09**
	2) Pesticides	4,4'-DDE Alpha-chlordane Gamma-chlordane Trans-nonachlor **Total chlordane**	7.5 ug/Kg # 23.0 ug/Kg 22.5 ug/Kg 16.0 ug/Kg **61.5 ■**
	3) PCBs		BRL
Little Beaver Creek RM 3.54 Factory Road TOC= 3.3 % Fine Grain Material =33%	1) BNA 2) Pesticides 3) PCBs		BRL BRL BRL
Beaver Creek RM 1.57 Dayton-Xenia Rd. TOC= 3.8 % Fine Grain Material =51%	1) BNA 2) Pesticides 3) PCBs	Fluoranthene	0.76 # BRL BRL
Beaver Creek RM 1.04 US 35 TOC= 3.2 % Fine Grain Material =26%	1) BNA 2) Pesticides 3) PCBs	Fluoranthene	0.69 # BRL BRL
Beaver Creek RM 0.20 Dst Beaver Creek WWTP TOC= 4.3 % Fine Grain Material =52%	1) BNA 2) Pesticides 3) PCBs	Fluoranthene	0.70 # BRL BRL

Stream / River mile Location	**Analysis Performed**	**Compound Detected**	**Result** mg/kg unless noted
Shawnee Creek RM 0.65 Hawkins Rd. TOC= 4.4% Fine Grain Material =25%	1) BNA 2) Pesticides 3) PCBs	Benz(a) anthracene Benzo[a]pyrene Benzo[b]fluoranthene Benzo[g,h,i]perylene Benzo[k]fluoranthene Chrysene Fluoranthene Indeno[1,2,3-cd]pyrene Phenanthrene Pyrene **Total PAH**	1.55■ 1.82■ 1.81 + 1.22 # 1.48 # 2.11 ■ 4.31 ■ 1.11 # 2.08 ■ 3.35 ■ **20.84** BRL BRL
Anderson Fork RM 4.90 Old Winchester Rd. TOC= 3.4% Fine Grain Material =29%	1) BNA 2) Pesticides 3) PCBs 4) VOC	Fluoranthene Pyrene	1.50 # 1.15 # BRL BRL
S. Br. Caesar Creek RM 8.23 Cemetery Road TOC= 4.2% Fine Grain Material =48%	1) BNA 2) Pesticides 3) PCBs 4) VOC	Fluoranthene Pyrene	1.50 # 1.15 # BRL BRL
S. Br. Caesar Creek RM 2.10 Hoop Rd. TOC= 2.6% Fine Grain Material =54%	1) BNA 2) Pesticides 3) PCBs		BRL BRL BRL
Caesar Creek Painsville Road TOC= 2.1% Fine Grain Material =25%	1) BNA 2) Pesticides 3) PCBs		BRL BRL BRL
Glady Run RM 4.08 Hedges Road TOC= 4.1% Fine Grain Material =28%	1) BNA 2) Pesticides 3) PCBs 4) VOC	Anthracene Benz(a) anthracene Benzo[a]pyrene Benzo[b]fluoranthene Benzo[g,h,i]perylene Benzo[k]fluoranthene Chrysene Fluoranthene Indeno[1,2,3-cd]pyrene Phenanthrene Pyrene **Total PAH**	0.82# 2.05■ 1.85■ 1.49 0.99■ 1.45■ 2.14■ 4.89■ 0.98■ 2.93■ 3.91■ **23.5** BRL BRL

Stream / River mile Location	**Analysis Performed**	**Compound Detected**	**Result** mg/kg unless noted
Glady Run RM 0.54 S.R 725 TOC= 3.6% Fine Grain Material =44%	1) BNA 2) Pesticides 3) PCBs		BRL BRL BRL

* Not evaluated
BRL Below Reporting Limit
TOC Total Organic Carbon

1) Base Neutral & Acid Extractables (BNA) U.S. EPA Method 8270
2) Pesticides U.S. EPA Methods 8082A
3) Polychlorinated biphenyls (PCBs) U.S. EPA Method 8082A

MacDonald (2000) Sediment Quality Guidelines (SQG)

■ > PEC (Probable effect concentration) Adverse effects usually or always occur (most contaminated designation)

USEPA Region V RCRA Ecological Screening Levels (ESL) 2003

\+ ≤ ESL Protective # >ESL not protective

Stream Physical Habitat

Basin Overview

The physical habitat quality of streams in the ECBP is governed by the juxtaposition of glacial deposits, recent and historic drainage alterations (i.e., channelization), and land use. The need for channelization, actual or perceived, is largely a function of topographic relief, and to a lesser extent surficial glacial deposits. For headwaters in the ECPB, 72 percent of locations assessed for habitat quality with gradients less than 10 ft/mi are either actively maintained as ditches, or recently channelized (Table 15). Channelization is also a cultural artifact, and many streams with local gradients conducive to drainage (and therefore tillage of adjacent land) have been channelized independent of any apparent need, as evidenced by the fact that 40% of headwaters in the ECBP with gradients >20 ft/mi have been recently or historically channelized.

Table 15. Statistics on the frequency of channelization observed in headwater streams of the ECBP in Ohio, and in the upper Little Miami River study area, 2011. Unaltered streams show no signs of previous channel modifications. Recovered channels are those that were historically channelized, but have recovered to a mostly natural state. Channelized streams are those that are actively maintained as ditches, or are recovering from recent channelization. Data from Ohio EPA ECOS database.

	Stream Gradient in Feet/Mile		
	<10	10-20	>20
Channel Condition	All ECBP Headwaters Percent of Streams Surveyed within Gradient Stratum		
Unaltered	16.9	42.4	59.5
Recovered	11.5	19	18.4
Channelized	71.6	38.6	22.1
n=	775	622	587
All ECBP Headwaters Mean QHEI Substrate Score (±SD) within Gradient Stratum			
Unaltered	12.3 (3.9)	14.1 (3.5)	15.2 (3.2)
Recovered	12.6 (4.0)	14.1 (2.9)	15.3 (2.6)
Channelized	8.3 (4.8)	10.7 (4.9)	12.1 (4.9)
Upper Little Miami Headwaters (2011 Survey)			
Percent of Streams Surveyed within Gradient Stratum			
Unaltered	0.0	38.5	50.0
Recovered	30.0	46.2	40.0
Channelized	70.0	15.4	10.0
n=	10	13	10
	Mean QHEI Substrate Score (±SD) within Gradient Stratum		
Unaltered	--	15.0 (1.2)	16.7 (1.9)
Recovered	14 (2.3)	14.8 (1.1)	15.9 (1.7)
Channelized	11.5 (5.1)	14.8 (1.8)	15

Headwater streams in the upper Little Miami basin roughly follow the general trend observed for the ECBP with the highest frequency of recent channelization occurring in streams with gradients less than 10 ft/mi, and the highest frequency of unaltered streams found at gradients > 20 ft/mi (Table 15). Little Miami headwaters differ from the ECBP in having a higher overall frequency of historic channelization, though the proportion of fully recovered streams is also higher – presumably a direct function of loam till in the Little Miami basin compared to high-clay till in the northern half of the ECBP. The upshot of this latter point is that where habitat quality in the Little Miami basin is less than optimal due to channelization, many stream channels have the potential to recover on their own if provided a sufficient streamway (*sensu* Ward and Trimble 2004) and simply left alone.

Little Miami River

Physical habitat quality in the Little Miami River mainstem was sufficiently intact to support assemblages of aquatic organisms consistent with beneficial aquatic life uses. Within the WWH designated reach upstream from the confluence with the North Fork, QHEI scores from four sampling locations averaged 67.0 ± 8.5 SD. Moreover, the number of positive habitat attributes at any given location typical of WWH streams, and integral to supporting WWH assemblages, outnumbered negative habitat attributes wrought directly by channelization or impounding, or indirectly through landscape-level modifications (Table 16). The upper reach of the mainstem had clearly been historically modified, and the upper two sites at SR 41 and Jamestown Road (RMs 104.9 and 103.1, respectively) had little or no sinuosity. Recovery of WWH features following channelization is largely a function of stream power and available bed material. Stream power, in turn, is a function of gradient and flow volume. The WWH reach drains glacial till, and has an average stream gradient of ~ 7 feet/mile, suggesting that further, passive recovery of WWH features is possible. QHEI scores recorded at the same locations between 1993 and 2011 show a general improvement in the reach, but especially for the site at SR 41 where the QHEI scored 12 points higher in 2011 compared to 1998.

For the EWH designated reach downstream from the confluence with the North Fork, QHEI scores averaged 80.0 ± 6.0 SD, indicating that habitat quality was generally excellent and capable of supporting assemblages consistent with the EWH aquatic life use. Locally, the reach through Waynesville had marginally lower habitat quality compared to the rest of the EWH designated reach, owing to historic modifications associated with a mill race and lowhead dam.

North Fork Little Miami River

Three sites were sampled in the North Fork catchment, two on the North Fork proper, and one on an unnamed tributary that confluences with the North Fork at RM 5.6 near Crabill Road. The unnamed tributary drains the outskirts of Springfield and is channelized with no evidence of physical recovery. In its present condition, it cannot be expected to support aquatic life consistent with a WWH use. The two sites sampled on the North Fork Little Miami River demonstrated that habitat quality was not limiting to aquatic life, despite having a history of channelization, including the reach upstream from SR 41 (RM 9.1) being recently modified. The reach upstream from SR 41 (RM 9.1) is a good example of where maintaining a trapezoidal channel is a poor choice, as the stream gradient, flow, and surrounding loamy soils facilitate erosion and meandering to balance sediment transport. A streamway setback with passive recovery would be a better alternative.

Little Miami Headwater Tributaries

The stream network draining the subcatchment around South Charleston has been historically channelized. Again, like the North Fork, the physical setting in this subcatchment facilitates passive recovery of erstwhile ditches, such that extant habitat quality, though marginal, would likely not be limiting to aquatic life in the absence of other stressors (Figure 39).

North and South Forks Massies Creek

On average, habitat quality in the North and South forks of Massies Creek was the lowest for the upper Little Miami River, being the most compromised by recent and historic channelization, and showing comparatively less recovery. Soils in these two catchments tend to have higher clay content, making the streams less able to passively recover. A project to actively recover habitat in the North Fork through the reach downstream from Gravel Pit Road resulted in QHEI scores improving from a score of 33.5 in 1998 to a score of 61.3 in 2011. Coincidentally, fish IBI scores improved from 38 in 1998 to 46 in 2011.

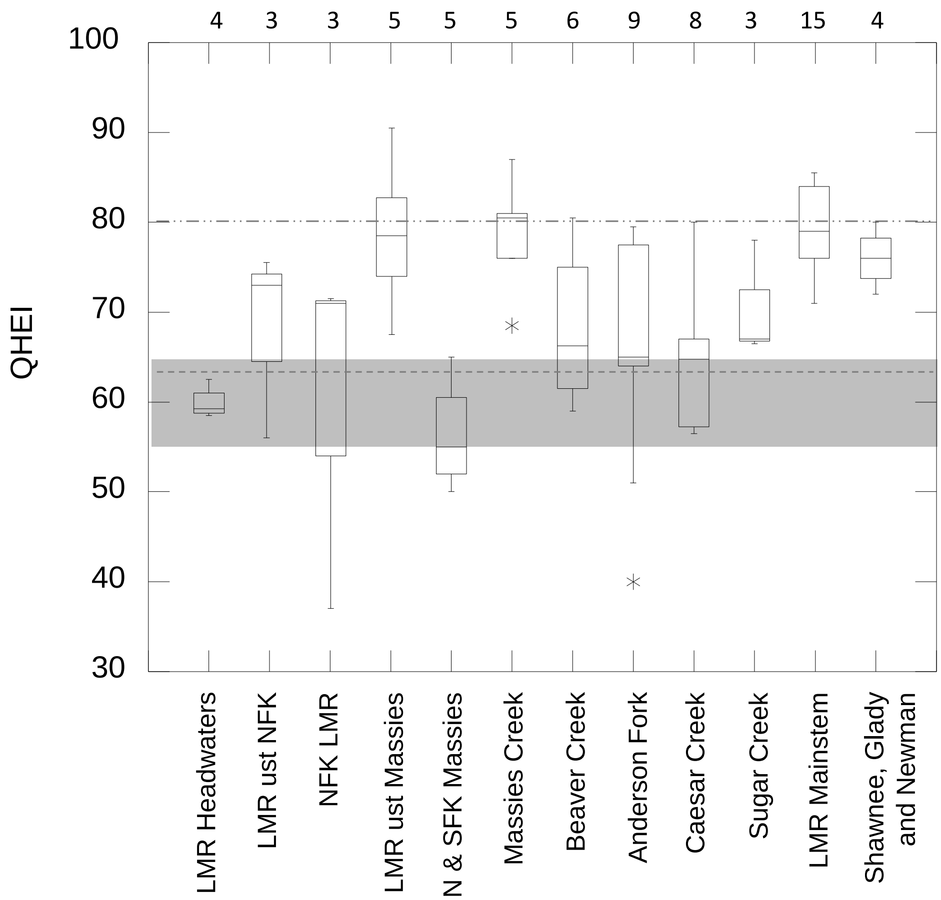


Figure 39. Distributions of QHEI scores recorded during the 2011 survey of the upper Little Miami River basin grouped by tributary and arranged according to the discussion in the preceding and ensuing paragraphs. The shaded region shows the range of QHEI scores that indicate habitat quality is not likely to be limiting to aquatic life in the absence of overriding stressors. The dotted horizontal line joining the y-axis at 64 indicates the QHEI score where the probability of observing a fish IBI greater than WWH is 0.5. Similarly, the stippled line joining the y-axis at 80 is the QHEI score where the probability of a fish IBI score greater than EWH is 0.5.

Massies Creek (including Oldtown Creek and Clark Run)

The mainstem of Massies Creek downstream from the confluence of the two forks is generally unperturbed by direct modifications and consequently possesses excellent habitat quality. QHEI scores recorded from three locations on the mainstem averaged 83 points. Clark Run, at the location sampled, was natural, and had very good habitat. Oldtown Creek in the lower one mile reach was historically channelized, but has recovered a sufficient number of habitat features to support WWH assemblages. In the net, habitat quality in the Massies Creek mainstem catchment is not limiting to aquatic life (Figure 39).

Beaver Creek and Little Beaver Creek

Beaver Creek and Little Beaver Creek drain urbanized landscapes and have been historically channelized. Little Beaver Creek downstream from I-675 is partially confined by revetments and has little room to meander and recover a full suite of positive habitat attributes. That said, stream gradient averaged > 14 ft/mi, allowing for sediment transport, and scour and deposition within the channel such that the stream has defined riffle-pool-run sequences, and where not confined by revetments, assumes a natural character. Upstream from I-675, the stream is impounded by a series of storm water detention ponds, and is modified to the point where the ability of the habitat to support WWH assemblages is compromised.

Beaver Creek upstream from Dayton-Xenia Road (RM 1.57) is a low gradient wetland stream, and naturally has fine-grained substrates and anemic riffles. As such, its potential for recovery from channelization is limited. Fortunately, the channel has been left alone for at least several decades, allowing for as much recovery as possible so that positive habitat attributes were not overwhelmed by modified attributes, and no highly deleterious modified attributes were recorded. Downstream from Dayton-Xenia Road, the stream has a character more in keeping with a typical till plain stream. Excluding the most highly urbanized reach of Little Beaver upstream from I-675, the system has the potential to support WWH assemblages based on measured habitat quality.

Anderson Fork and Tributaries

The lower 14 miles of the Anderson Fork mainstem, downstream from Port William, is natural in character and possess positive habitat attributes typical for a WWH stream. Upstream from Port William, Anderson Fork was historically channelized, but now has alternating segments either maintained as a ditch, or allowed to meander. The one site sampled upstream from Port William (RM 18.8) was in an unmaintained segment, and consequently had marginally good habitat. In contrast, Grassy Run, a tributary to Anderson Fork upstream from Port William, characterizes the segments maintained as ditches by containing little in the way of redeeming habitat features. The cumulative effect of poor habitat quality upstream from Port William appears to negatively influence the downstream reach, as substrates and riffles in the downstream reach were embedded with silt and fine-grained sediment.

Habitat quality in Painters Creek was evaluated at Bone Road (RM 5.0) where the drainage area was 5.4 mi^2. The stream was intermittent and interstitial, but had a well-defined channel with one spring seep in the reach where southern redbelly dace were abundant. Habitat quality was marginal but likely of sufficient quality to support a WWH assemblage given the drainage area.

Grog Run upstream from Wilson Road (RM 3.5) is maintained as a channelized ditch, but downstream is natural or recovered from past channelization. The site surveyed at Bone Road (RM 0.9) was natural and typical of a small, WWH stream with a QHEI score of 65, suggesting that habitat is not limiting. The riffles, however, were non-functional due to limited flow; a possible hydrologic consequence of the upstream drainage network being maintained as ditches.

A small, unnamed tributary to Anderson Fork (confluence at RM 9.26) that drains a service area at the junction of US 68 and I-71 was sampled at US 68 (RM 0.2). Relative to the drainage area (1.8 mi^2), the channel bed was wider than normal, and moderate to heavy bank erosion was noted as a likely consequence of storm water. Also, a segment of the channel had been relocated to apparently accommodate residential development. Despite these negatives and small stream size, and owing to high gradient and sustained flow, the habitat quality was good, and capable of supporting WWH assemblages in the absence of overriding stressors.

Caesar Creek (including the North and South branches)
QHEI score in the Caesar Creek mainstem upstream from Caesar Creek Lake averaged 70.0 points, suggesting that habitat quality is not limiting to aquatic life. QHEI scores in the North and South branches averaged 65.0 points, indicating that, in the absence of any overriding stressor, habitat quality was sufficient to support WWH assemblages. The South Branch was historically channelized, but mostly recovered at Hoop Road (RM 2.1), and recovering at Parker Road (RM 7.8).

Three direct tributaries to Caesar Creek Lake, Jonahs Run, Turkey Run and Buck Run, were assessed for habitat quality. Turkey Run and Buck Run had good to excellent habitat; however, Jonahs Run had marginal habitat due to excessive sedimentation.

Sugar Creek and Little Sugar Creek
Despite having suburbanized catchments, habitat quality at two locations in Sugar Creek and one location in Little Sugar Creek was generally intact, possessing a sufficient number of positive attributes to support WWH assemblages (Table 16). That said, storm water impacts were clearly evident, especially in the upper reach of Sugar Creek at Wilmington Pike (RM 4.1), where bank erosion was significant.

Shawnee Creek, Glady Run and Newman Run
Shawnee Creek runs through Xenia, and consequently receives significant amounts of storm water. Additionally, the reach sampled at Hawkins Road (RM 0.9) was historically channelized. The creek, however, has not been maintained as a ditch, and flows freely so its bed and banks have been allowed to adjust to storm water flows, and have recovered natural attributes, such that overall habitat quality was very good.

Glady Run drains the southern half of Xenia, and so too receives storm water runoff. The upper reach sampled at Hedges Road (RM 4.08) was historically channelized, but recovered. The lower reach, at Schnebly Road (RM 1.10), was natural. The habitat quality at both locations was good to very good, and not limiting to aquatic life.

Habitat quality in Newman Run was good, but the channel appeared wide relative to the drainage area (drainage area = 9.8 mi^2 upstream from US 42 at RM 0.27). Moderate bank erosion and channel incision was noted, suggesting that the stream is readjusting to a grade change by headcutting. The grade change may have been caused when the stream was straightened to fit through a culvert under US 42.

Table 16. QHEI attribute report for locations sampled in the Little Miami basin, 2011.

Key QHEI Components

WWH Attributes

River Mile	QHEI	Gradient (ft/mi)	Not Channelized or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Development	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low/Normal Embeddedness	Max Depth>40cm	Low/Normal Riffle Embeddedness	WWH Attributes
11-001-000 Little Miami River Year 2011													
104.9	59.0	8.33		■				■		■	■	■	5
103.1	59.3	5.95	■	■				■		■	■	■	6
99.0	72.5	8.47	■	■		■	■	■	■	■	■	■	9
92.3	75.8	5.59	■	■		■	■	■	■	■	■	■	9
85.4	87.0	4.90	■	■		■	■	■	■	■	■	■	9
83.1	84.0	25.00	■	■		■	■	■	■	■	■	■	9
80.0	76.3	2.96	■	■		■	■	■	■	■	■	■	9
77.7	82.5	4.98	■	■		■	■	■		■	■	■	8
76.5	76.8	5.38	■	■		■	■	■		■	■	■	8
72.3	85.0	4.78	■	■		■	■	■	■	■	■	■	9
69.8	82.8	3.06	■	■		■	■	■	■	■	■	■	9
68.5	81.0	3.06	■	■		■	■	■	■	■	■	■	9
64.5	78.3	2.60	■	■		■	■	■	■	■	■	■	9
64.2	77.3	2.60	■	■		■	■	■	■	■	■	■	9
63.3	79.0	2.60	■	■		■	■	■	■	■	■	■	9
60.5	91.0	4.46	■	■		■	■	■	■	■	■	■	9
53.8	70.5	3.28	■	■		■	■	■	■	■	■	■	9
53.2	67.0	3.28	■	■				■		■	■		5
51.7	84.5	4.57	■	■		■	■	■	■	■	■	■	9
11-001-007 Shawnee Creek Year 2011													
0.7	74.0	15.38	■	■		■		■	■		■		6
11-001-008 Trib. to Little Miami R. (RM 96.26) Year 2011													
0.6	55.5	5.81						■			■		2
11-030-000 Newman Run Year 2011													
0.3	72.3	41.67	■	■		■	■	■	■	■	■	■	9
11-032-000 Glady Run Year 2011													
4.1	68.0	26.32	■	■		■		■			■		5
1.1	79.0	17.24	■	■		■	■	■	■		■		7

MWH Attributes (High Influence / Moderate Influence)

River Mile	Channelized/No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40cm	Hi-influence Modified Attributes	Recovering Channel	Heavy/Moderate Silt Cover	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	M.I. Modified Attributes	MWH H.I.+1/WWH+1 Ratio	MWH M.I.+1/WWH+1 Ratio
11-001-000 Little Miami River Year 2011																					
104.9			●			1	◆	◆			◆	◆			◆	◆	◆		7	0.50	1.33
103.1						0	◆				◆	◆		◆	◆	◆	◆		7	0.29	1.14
99.0						0	◆	◆								◆	◆		4	0.20	0.60
92.3						0										◆	◆		2	0.10	0.40
85.4						0													0	0.10	0.10
83.1						0											◆		1	0.10	0.20
80.0						0											◆		1	0.10	0.20
77.7						0									◆				1	0.11	0.33
76.5						0									◆	◆	◆		3	0.11	0.56
72.3						0													0	0.10	0.20
69.8						0													0	0.10	0.20
68.5						0													0	0.10	0.20
64.5						0													0	0.10	0.20
64.2						0													0	0.10	0.20
63.3						0										◆			1	0.10	0.30
60.5						0													0	0.10	0.20
53.8						0					◆	◆							2	0.10	0.40
53.2						0					◆	◆			◆			◆	4	0.17	1.00
51.7						0		◆								◆			2	0.10	0.40
11-001-007 Shawnee Creek Year 2011																					
0.7						0		◆				◆				◆	◆		4	0.14	0.71
11-001-008 Trib. to Little Miami R. (RM 96.26) Year 2011																					
0.6						0	◆	◆			◆	◆			◆	◆	◆		7	0.67	3.00
11-030-000 Newman Run Year 2011																					
0.3				●		1					◆						◆		2	0.20	0.30
11-032-000 Glady Run Year 2011																					
4.1						0					◆	◆			◆	◆	◆		5	0.17	1.00
1.1						0										◆	◆		2	0.13	0.50

Table 16. (Continued)

Key: QHEI Components

			WWH Attributes											MWH Attributes: High Influence						MWH Attributes: Moderate Influence														
River Mile	QHEI	Gradient (ft/mi)	Not Channelized or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	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	Hi-Influence Modified Attributes	Recovering Channel	Heavy/Moderate Silt Cover	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	M.I. Modified Attributes	MWH H.I.+1/WWH+1 Ratio	MWH M.I.+1/WWH+1 Ratio
11-033-000 Year 2011	***Sugar Creek***																																	
4.1	66.3	17.54	•	•			•	•			•		5						0					•			•	•	•	•		5	0.17	1.00
0.4	78.0	8.13	•	•		•	•	•	•		•		7						0										•	•		2	0.13	0.38
11-034-000 Year 2011	***Little Sugar Creek***																																	
0.5	67.5	33.33	•	•		•	•	•		•	•		7						0					•	•			•	•	•		5	0.13	0.75
11-035-000 Year 2011	***Beaver Creek***																																	
1.6	62.8	5.21	•				•	•		•	•		5						0		•			•				•	•	•		5	0.17	1.17
1.1	67.8	5.21	•				•	•	•		•		5						0					•					•	•		3	0.17	0.83
0.2	80.3	7.25	•	•		•	•	•	•	•	•		8						0		•								•	•		3	0.11	0.44
11-036-000 Year 2011	***Little Beaver Creek***																																	
6.2	59.0	29.85		•				•					2					•	1	•				•	•			•	•	•		6	1.00	2.67
2.8	75.3	14.29	•	•		•	•	•	•	•	•	•	9						0											•		1	0.10	0.30
0.1	64.5	15.38		•				•	•		•		4	•		•			2	•				•	•				•	•		5	0.60	1.40
11-037-000 Year 2012	***Ludlow Creek***																																	
2.0	64.8	17.86	•				•	•			•		4						0		•			•				•	•	•		5	0.20	1.40
11-039-000 Year 2011	***Jacoby Branch***																																	
0.5	71.0	50.00	•	•		•	•	•	•	•	•	•	9						0								•			•		2	0.10	0.30
11-040-000 Year 2012	***Yellow Springs Creek***																																	
0.1	79.5	35.71	•	•		•	•	•	•	•	•	•	9						0										•	•		2	0.10	0.30
0.1	79.3	35.71	•	•		•	•	•	•		•	•	8						0										•	•		2	0.11	0.33
11-041-000 Year 2011	***North Fork Little Miami River***																																	
9.1	71.5	11.24	•	•		•	•	•	•		•		7						0	•					•				•	•		4	0.25	0.63
0.4	71.3	3.91	•	•		•	•	•		•	•	•	8						0									•				1	0.11	0.33

Table 16. (Continued)

Key: QHEI Components

River Mile	QHEI	Gradient (ft/mi)	WWH Attributes											MWH Attributes: High Influence						MWH Attributes: Moderate Influence														
			Not Channelized or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	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	Hi-influence Modified Attributes	Recovering Channel	Heavy/Moderate Silt Cover	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	M.I. Modified Attributes	MWH H.I.+1/WWH+1 Ratio	MWH M.I.+1/WWH+1 Ratio
11-041-001 *Trib. to N. Fk. Little Miami R. (5.60)*																																		
Year 2011																																		
0.8	37.3	3.76						•			•		2	•	•	•			3	•	•			•	•			•	•		•	7	1.33	2.67
11-043-000 *Lisbon Fork*																																		
Year 2011																																		
0.4	64.5	10.20		•		•	•	•		•	•	•	7				•		1	•				•	•			•	•	•		6	0.38	1.00
11-044-000 *Gilroy Ditch*																																		
Year 2011																																		
0.5	58.3	11.63		•			•				•		3				•		1	•				•	•			•	•	•		6	0.75	1.75
11-300-000 *Caesar Creek*																																		
Year 2011																																		
26.5	57.5	12.66	•	•		•	•				•		5				•		1		•		•				•	•	•		•	6	0.33	1.17
23.1	76.8	13.70	•			•	•	•	•	•	•	•	8						0													0	0.11	0.11
18.0	64.5	6.41	•	•		•	•	•			•		6						0		•			•				•	•		•	5	0.14	0.86
0.2	80.0	8.20	•	•		•	•	•	•	•	•	•	9						0								•					1	0.10	0.30
11-301-000 *Flat Fork*																																		
Year 2012																																		
1.7	64.3	31.25	•			•	•	•		•	•	•	7				•		1		•						•	•	•	•		5	0.25	0.75
11-302-000 *Jonahs Run*																																		
Year 2011																																		
2.1	57.8	12.82	•			•	•	•		•	•		6				•		1		•			•			•	•	•		•	6	0.29	1.14
11-304-000 *Turkey Run*																																		
Year 2011																																		
1.5	66.5	47.62	•	•			•	•		•	•	•	7						0					•				•			•	3	0.13	0.50
11-305-000 *Buck Run*																																		
Year 2011																																		
1.5	80.3	21.74	•	•		•	•	•		•	•	•	8						0									•				1	0.11	0.22

Table 16. (Continued)

Key: QHEI Components

River Mile	QHEI	Gradient (ft/mi)	WWH Attributes											MWH Attributes: High Influence						MWH Attributes: Moderate Influence														
			Not Channelized or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	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	Hi-influence Modified Attributes	Recovering Channel	Heavy/Moderate Silt Cover	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	M.I. Modified Attributes	MWH H.I.+1/WWH+1 Ratio	MWH M.I.+1/WWH+1 Ratio
11-306-000	***Anderson Fork***																																	
Year	**2011**																																	
18.8	64.0	3.55	■	■				■		■	■	■	6						0		◆			◆	◆			◆				4	0.14	0.71
13.8	70.5	6.94	■	■		■	■	■			■	■	7						0		◆							◆	◆	◆		4	0.13	0.63
8.2	79.5	14.29	■	■		■	■	■		■	■	■	8						0		◆							◆	◆	◆		4	0.11	0.56
4.9	78.0	7.35	■	■		■	■	■		■	■		7						0		◆							◆	◆	◆		4	0.13	0.63
3.2	77.5	10.75	■	■		■	■	■		■	■	■	8						0		◆							◆	◆	◆		4	0.11	0.56
11-306-002	***Trib. to Anderson Fork (9.26)***																																	
Year	**2011**																																	
0.2	64.8	45.45	■	■		■	■	■		■	■	■	8						0	◆	◆							◆	◆			4	0.22	0.67
11-307-000	***Painters Creek***																																	
Year	**2011**																																	
5.0	53.0	25.64	■	■		■	■	■		■	■		7				•		1		◆			◆	◆		◆	◆	◆		◆	7	0.25	1.00
11-308-000	***Grog Run***																																	
Year	**2011**																																	
0.9	65.0	14.28	■	■		■	■	■			■		6						0		◆							◆	◆		◆	4	0.14	0.71
11-310-000	***Grassy Run***																																	
Year	**2011**																																	
0.1	40.0	7.87									■		1	•			•		2		◆			◆	◆		◆	◆	◆		◆	7	1.50	4.50
11-311-000	***South Branch Caesar Creek***																																	
Year	**2011**																																	
8.2	55.5	9.43	■	■				■			■		4						0	◆	◆			◆	◆			◆	◆	◆	◆	8	0.40	2.00
2.1	72.0	9.43	■	■		■		■		■	■	■	7						0					◆	◆			◆				3	0.13	0.63
11-312-000	***North Branch Caesar Creek***																																	
Year	**2011**																																	
6.6	68.0	18.87	■	■		■	■	■		■	■	■	8				•		1		◆		◆				◆	◆	◆			5	0.22	0.67
1.3	65.0	12.66	■	■		■	■	■		■	■	■	8				•		1		◆		◆				◆	◆	◆			5	0.22	0.67
11-400-000	***Massies Creek***																																	
Year	**2011**																																	
8.2	82.0	11.76	■	■		■	■	■	■		■	■	8						0										◆	◆		2	0.11	0.44
4.4	87.0	10.75	■	■		■	■	■	■		■		7						0										◆	◆		2	0.13	0.38
1.2	81.3	11.11	■	■		■	■	■	■		■		7						0										◆	◆		2	0.13	0.38

Table 16. (Continued)

Key: QHEI Components

			WWH Attributes											MWH Attributes: High Influence						MWH Attributes: Moderate Influence														
River Mile	QHEI	Gradient (ft/mi)	Not Channelized or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	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	Hi-influence Modified Attributes	Recovering Channel	Heavy/Moderate Silt Cover	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	M.I. Modified Attributes	MWH H.I.+1/WWH+1 Ratio	MWH M.I.+1/WWH+1 Ratio
11-401-000	***Oldtown Creek***																																	
Year	**2011**																																	
0.4	69.0	17.24	•	•		•		•	•	•	•		7						0	•				•	•				•	•		5	0.25	0.88
11-402-000	***Clark Run***																																	
Year	**2011**																																	
0.4	76.0	50.00	•	•		•	•	•	•	•	•	•	9						0													0	0.10	0.10
11-403-000	***North Fork Massies Creek***																																	
Year	**2011**																																	
6.1	61.3	5.26		•		•	•	•		•	•	•	7				•		1	•				•	•			•		•		5	0.38	0.75
5.7	55.0	5.26		•				•			•		3						0	•	•			•	•		•	•	•	•		8	0.50	2.50
2.8	51.3	5.85						•		•	•	•	4		•				1	•	•			•	•		•	•	•			7	0.60	1.80
11-404-000	***South Fork Massies Creek***																																	
Year	**2011**																																	
2.1	50.3	5.81								•	•	•	3				•		1	•				•	•		•	•				5	0.75	1.50
0.1	64.5	23.81	•			•	•	•	•	•	•	•	8				•		1					•			•					2	0.22	0.33

Fish Community

Little Miami River

The condition of fish assemblages in the mainstem of the Little Miami River in 2011 improved significantly compared to 1998, especially for the reach downstream from the village of Clifton where Index of Biotic Integrity (IBI) scores (Figure 40a) improved by 7 points (±2.4 95% C.I.), and Modified Index of Well-being (MIWb) scores (Figure 40b) improved by 0.7 points (±0.4 95% C.I.). Upstream from Clifton, where the mainstem had been historically and recently channelized, and the aquatic life use designation is WWH, the condition of the fish assemblage was essentially unchanged. As in 1998, the fish community was in poor condition at RM 104.88 (SR 41), and was marginal at the remaining three sites in the reach. The improvement downstream from Clifton, however, was dramatic, especially with respect to the frequency of fish showing deformities, erosions, lesions or tumors (DELTs). In 1998, in the reach between the confluence with Beaver Creek and Caesar Creek, nearly 1 in 30 fish carried at least one DELT, whereas in 2011, the frequency was about 1 in 420 fish - essentially background levels for medium-sized rivers (Figure 41). Moreover, structural changes to the fish community were significant. Sensitive species were sampled more frequently in 2011, and omnivorous fishes were proportionately less abundant in 2011 compared to 1998 (Figure 42). Fish assemblages in the mainstem downstream from Clifton are now fully meeting the EWH aquatic life use. This improvement is coincident with lower concentrations of total phosphorus. Total phosphorus concentrations in the upper Little Miami River mainstem decreased from an average[1] concentration of 0.304 mg/l in 1998 to an average concentration of 0.150 mg/l in 2011 (Figure 43). This stands in contrast to other small rivers in the ECBP where phosphorus concentrations and fish IBI scores did not change appreciably between the 1990s and 2000s. Phosphorus concentrations in these rivers averaged 0.117 mg/l and 0.112 mg/l between the time periods, and fish IBI scores averaged 45 and 46, respectively.

Tributaries - Overview

For the upper Little Miami River watershed as a whole, exclusive of the mainstem downstream from Clifton, the trends in phosphorus concentrations and IBI scores mirror that for headwater and wadeable streams in the ECBP. Mean phosphorus concentrations in the upper Little Miami River watershed decreased from 0.170 to 0.066 mg/l, between the 1990s and the 2000s, and mean IBI scores increased from 39 to 45. For the ECBP, phosphorus concentrations decreased from 0.109 to 0.076 mg/l, and IBI scores increased from 38 to 41.

Although the condition of the basin as a whole showed an improving trend, localized areas of impairment were noted. In these cases, the major cause of impairment was poor habitat quality (Figure 44), especially due to riffles being either absent, or shallow and poorly defined (Figure 45). The secondary cause of impairment in these cases was organic or nutrient enrichment, though relative to the effect of habitat, the overall effect of organic or nutrient enrichment in explaining variation in IBI scores was marginal (p=0.09) based on all subsets regression (Figure 45). However, organic and/or nutrient enrichment was evident at several sites. The Little Miami River at Dolly Varden Road (RM 98.98 had pronounced daily variation in dissolved oxygen concentrations (12.2 mg/l) and elevated levels of benthic chlorophyll (184 mg/m2), both of which are signatures of nutrient enrichment. These parameters were likely magnified by poor to marginal habitat associated with channelization upstream from Dolly Varden Road. However, the sampled reach immediately downstream from Dolly Varden Road was not channelized, which likely increased the river's ability to assimilate the nutrient load and thus allowed the fish community to achieve full attainment of the WWH use.

[1] All averages of chemical concentrations reported here are geometric means.

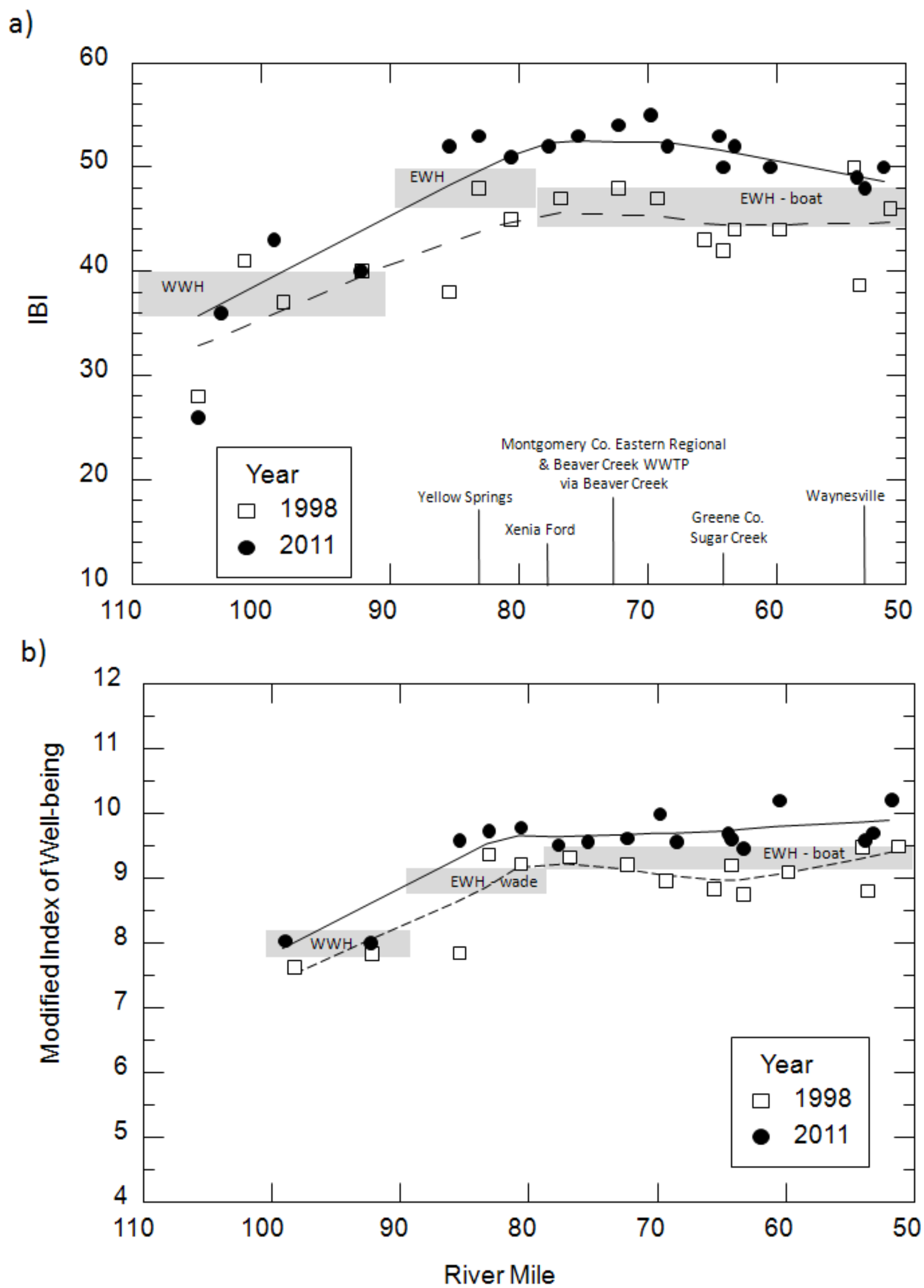


Figure 40. a) Index of Biotic Integrity (IBI), and b) Modified Index of Well-being (MIWb) scores for fish assemblages sampled in the Little Miami River mainstem, 1998 and 2011 in relation to publicly-owned treatment works. The shaded, horizontal bars in each plot show the range of nonsignificant departure from the applicable biocriterion.

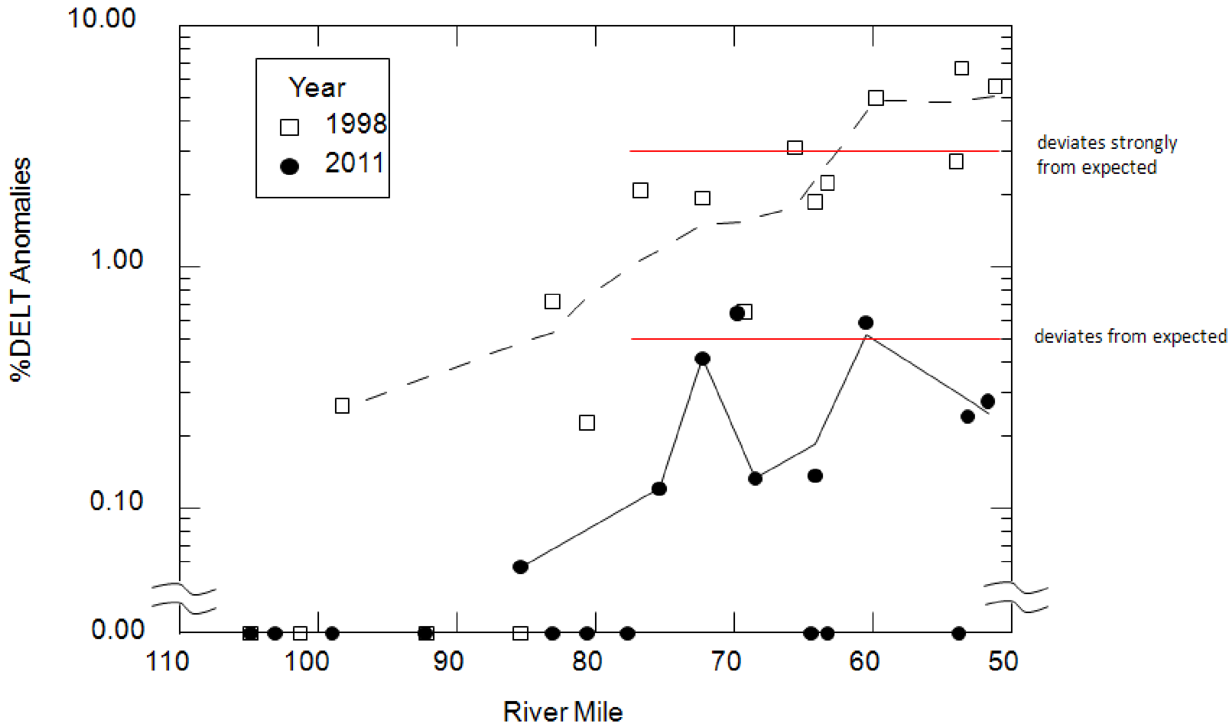


Figure 41. Percent of fish in electrofishing samples collected from the Little Miami River with external DELT anomalies, 1998 and 2011.

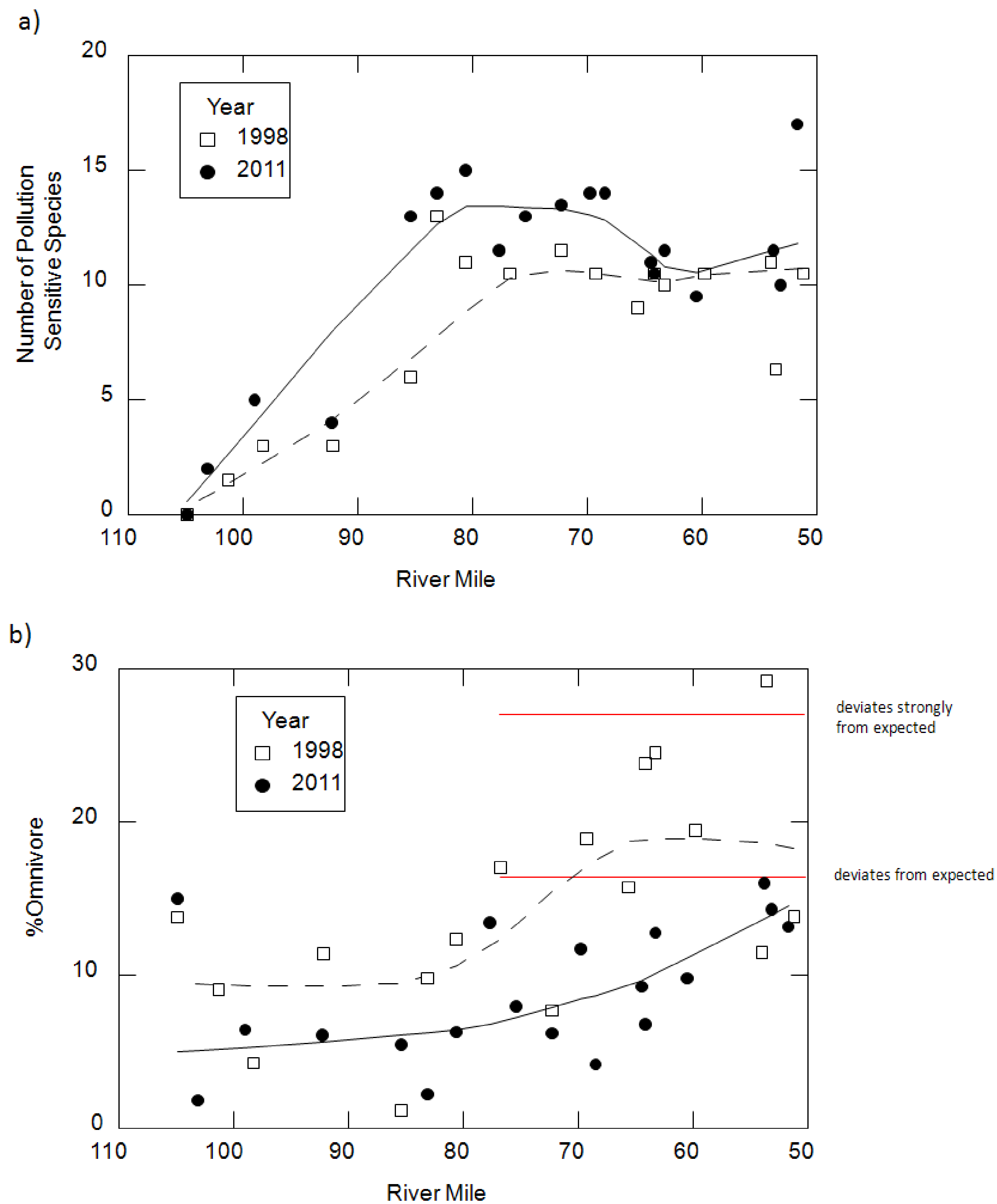


Figure 42. a) Number of pollution sensitive species, and b) percent composition of omnivorous fishes in electrofishing samples collected from the Little Miami River, 1998 and 2011.

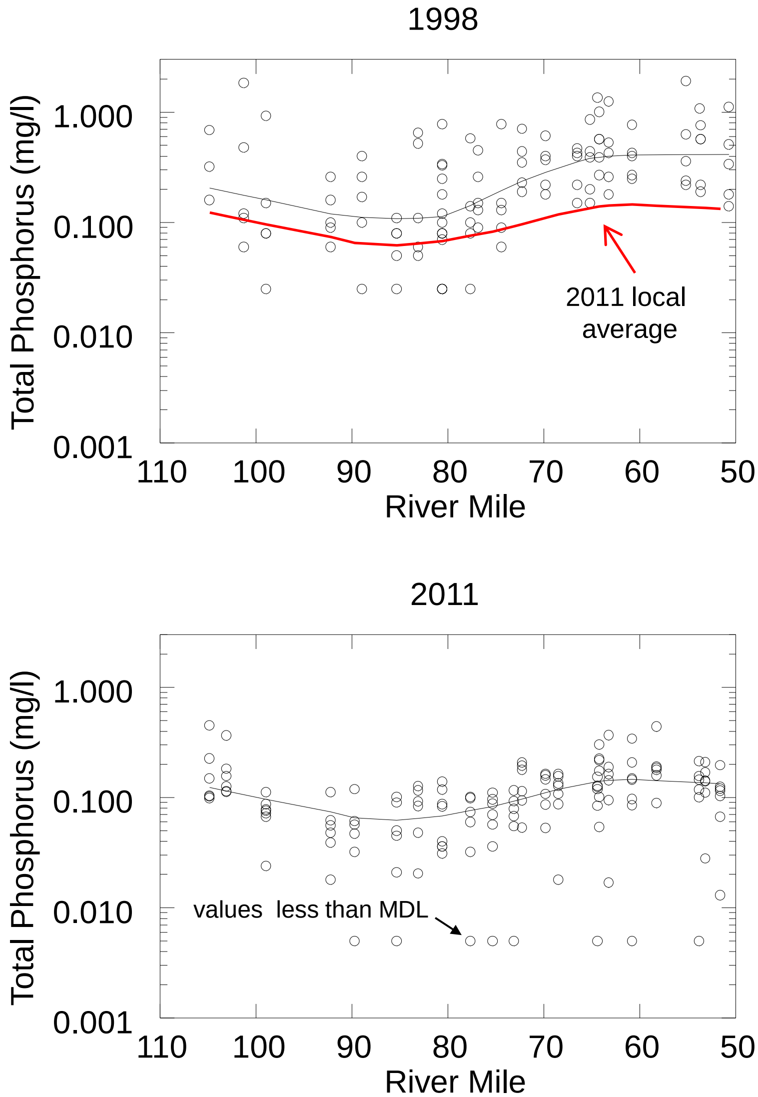


Figure 43. Total phosphorus concentrations in the Little Miami River, 1998 and 2011. The line following the local central tendency in each plot is from LOWESS (q=0.5). The 2011 LOWESS line is superimposed on the 1998 plot. Phosphorus values less than the method detection limit (MDL) were recorded in the reach receiving treated municipal effluent.

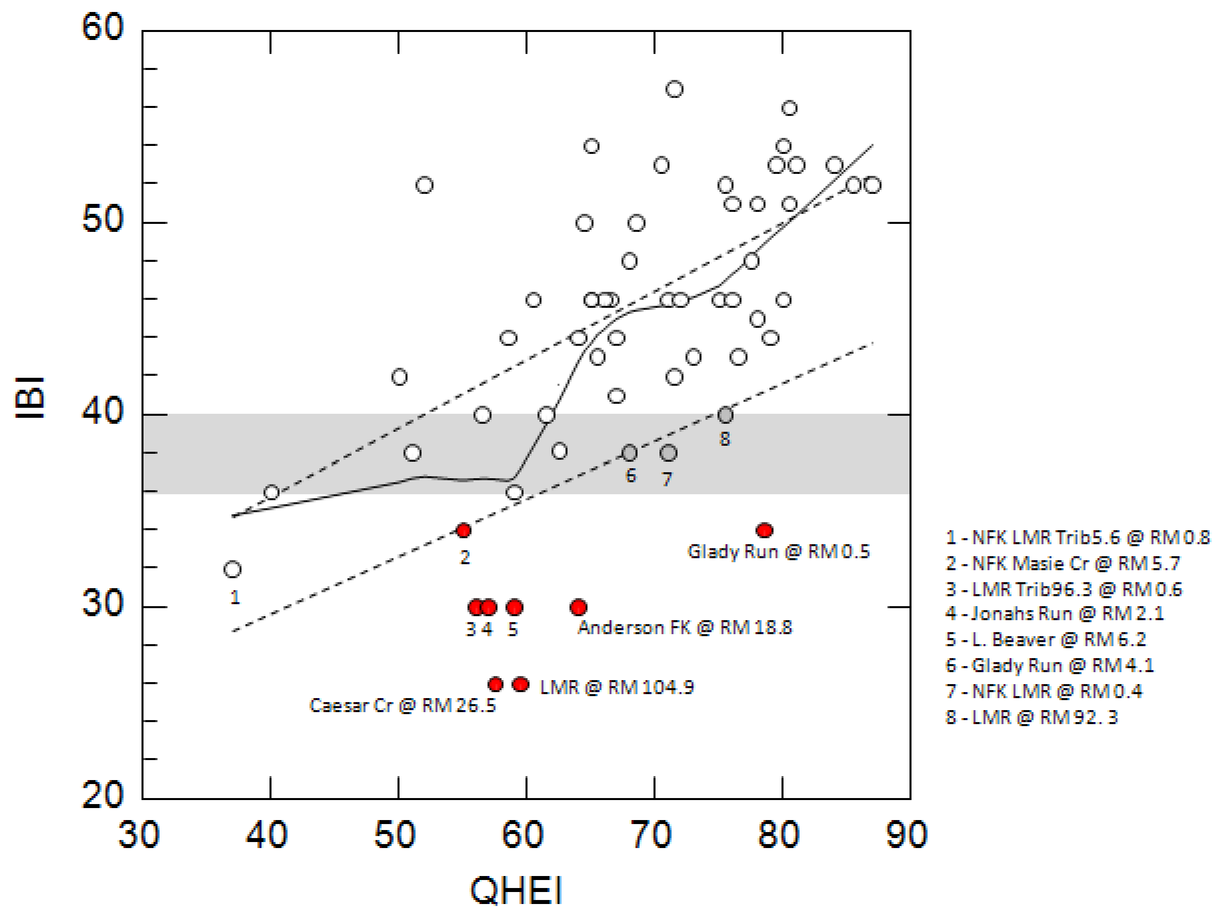


Figure 44. Index of Biotic Integrity (IBI) scores plotted against habitat index (QHEI) scores recorded d for headwater and wadeable streams during 2011 survey of the upper Little Miami River. The shaded region reflects nonsignificant departure from WWH criteria. The solid line following the local central tendency is from LOWESS (q=0.5). The dashed lines show the 95% C.I. for the regression of IBI on QHEI for headwater and wadeable reference sites in the Eastern Cornbelt Plains ecoregion. Shaded points fall outside the lower 95 C.I., with red-shaded points failing the biological criteria.

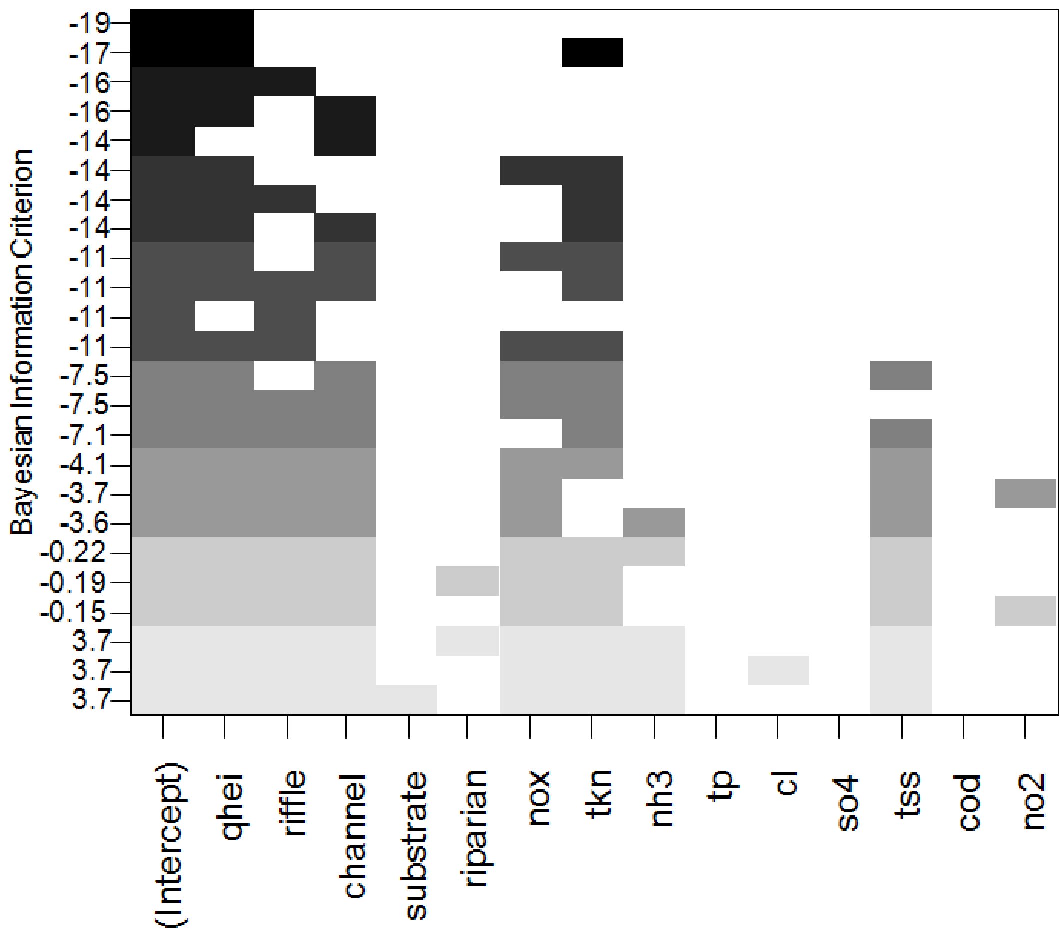


Figure 45. Linear models explaining variation in 2011 upper Little Miami River basin IBI scores ranked by the Bayesian Information Criterion (BIC). The BIC suggests the most plausible model given the extant data (lower scores are better models); in this case, the linear model IBI ~ QHEI is the most parsimonious, followed closely by IBI ~ QHEI + TKN.

The headwater reach of the Little Miami River, including the sites at Jamestown Road (RM 103.13) and SR 41 (RM 104.88), appeared to be affected by organic enrichment in general, as elevated levels of TKN and COD were noted in the reach. Similar to the Little Miami River at Dolly Varden Road (RM 98.98), the North Fork of Massies Creek at US 42 (RM 5.73) is a site situated in a historically modified reach, and also had wide dissolved oxygen swings (8.6 mg/l) coupled with marginally high levels of benthic chlorophyll (187 mg/m2). Little Beaver Creek was also negatively affected by excessive nutrient enrichment, as levels of benthic chlorophyll reached 334 mg/m^2 near Factory Road (RM 0.1). Anderson Fork at Haley Road (RM 18.8) may have been negatively influenced by transient organic enrichment, given that it had episodically low dissolved oxygen levels; however, the only corroborating evidence was elevated levels of *Escherichia coli* bacteria. Concentrations of ammonia nitrogen, total Kjeldahl nitrogen, chemical oxygen demand and total dissolved solids were normal. Also, given that the local reach contains extensive beds of emergent and submerged aquatic macrophytes, the local stream gradient is 3.55 ft/mi, and the stream network upstream from the sampling location is extensively channelized, landscape-level habitat quality and natural factors cannot be ruled out as a cause of the low dissolved oxygen. Lastly, the fish assemblages measured in Glady Run were not consistent with expectations based on available habitat quality. Concentrations of ammonia nitrogen and TKN were elevated, suggesting that organic enrichment may have negatively influenced the community. However, the complexion of the fish assemblage was decidedly cool water, as mottled sculpin composed over 60% of the catch at the two locations. Cold/coolwater fish communities typically have lower than expected taxa richness, and a higher than expected proportion of tolerant fishes when gauged against expectations for warmwater streams.

Beaver Creek and Little Beaver Creek

Fish assemblages sampled in Beaver Creek and Little Beaver Creek improved dramatically in 2011 relative to 1998. In 1998, IBI and MIWb scores either did not meet respective WWH biocriteria, or were marginally departing from them. In 2011, IBI scores met the WWH biocriterion at all sites in the basin, with the exception of the highly urbanized (>30% impervious cover) reach of Little Beaver Creek upstream from the Montgomery County Eastern Regional WWTP (sampled at Vale Road, RM 6.2). However, MIWb scores in Little Beaver Creek at Factory Road (RM 0.1), and in Beaver Creek near US 35 (RM 1.0) failed to meet the WWH biocriterion. The cause was most likely due to a combination of urban runoff and nutrient enrichment. Urban runoff is suggested because sensitive species were rare or absent, and the percent of urban land use in the upstream catchment is approximately 17.1% for Little Beaver Creek and 11.3% for Beaver Creek. Nutrient enrichment is suggested as a contributing cause by high levels of benthic chlorophyll, though follow-up monitoring for dissolved oxygen will be necessary for confirmation.

Caesar Creek and Anderson Fork

The mainstem of Caesar Creek is designated EWH downstream from the confluence with the South Branch (RM 23.78) and WWH upstream from it. Fish assemblages sampled in the EWH reach were meeting, or within the range of nonsignificant departure from the biological criteria (Figure 46; Table 17), except at Stone Road (RM 23.1) where the IBI score was 43. The EWH use has never been demonstrated at this site in historical samples. The IBI score from the site at New Jasper-Paintersville Road (RM 26.5) failed the WWH biocriterion. Biological index scores in 2011 were better than those recorded in 1998, with the exception of the site at New Jasper-Paintersville Road. Water chemistry parameters at this site in 2011 were not unusual, with the exception of elevated TKN values on two sampling dates, and elevated values of *E. coli* bacteria, possibly signaling organic enrichment. However, stream flow at the site was intermittent in 2011, whereas in 1998 it was continuous. The intermittent flow, apart from being stressful in its own right, potentially exacerbated any underlying negative influences.

The South Branch of Caesar Creek is designated EWH downstream from RM 4.0. The North Branch is designated WWH. Biological index scores met, or were within nonsignificant departure of the applicable criteria in all cases. The site sampled in the EWH reach of the South Branch (RM 2.1) had a significantly lower IBI score in 2011 compared to 1998. Flows at the site were interstitial in 2011, but were continuous in 1998. As for the North Branch, IBI scores at the Jasper Road site (RM 1.2) were essentially identical between 2011 and 1998. However, at the Junkin Road site (RM 6.67), the IBI score was significantly higher in 2011 compared to 1998 (Figure 46). And in contrast to the previous examples, flows were sustained at the site in 2011, but intermittent in 1998.

Anderson Fork downstream from the confluence with Grog Run (RM 11.02) is designated EWH. Fish assemblages met the biocriteria, or were within the range of nonsignificant departure, at all three sites sampled within the EWH reach (Figure 47). One site sampled downstream from Port William at Port

William Road (RM 13.87) met the applicable biocriteria for WWH. Fish sampled upstream from Port William at Haley Road (RM 18.8) did not meet WWH. Two physical stressors are working against the fish community in the reach upstream from Port William. Firstly, the stream network is largely channelized. Secondly, and more importantly, a lowhead dam at Port William appears to preclude various fish species from the reach, including rainbow darter, fantail darter, hog sucker, golden redhorse, redfin shiner, striped shiner, stoneroller minnow, and rock bass. Given that sections of Anderson Fork upstream from Port Williams have been allowed (or possibly encouraged) to passively recover, including a three-mile reach immediately upstream from the sampling station at Haley Road, most of the aforementioned species would likely recolonize the reach following removal of the dam. That said, dissolved oxygen concentrations at Haley Road fell below 4 mg/l as recorded by an automated data logger deployed August 9-11, 2011. The reason for the low dissolved oxygen is unknown, but may be related to the scale of channelization upstream from the sampling point, as other water quality parameters were within normal ranges.

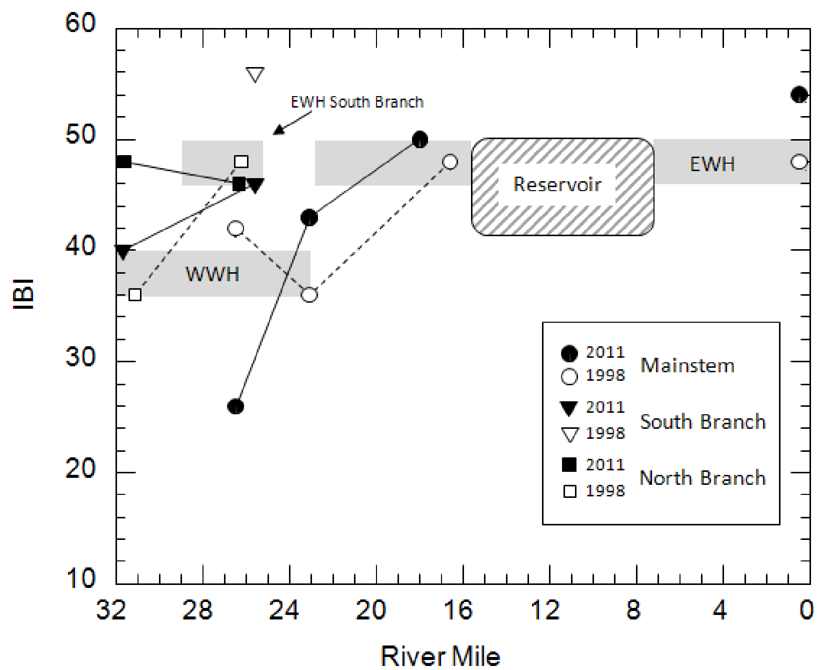


Figure 46. Fish IBI scores recorded from Caesar Creek, including the North Branch and South Branch, 2011 and 1998. The shaded regions represent the range of nonsignificant departure from the respective biocriterion. River miles listed for the two branches are taken as a continuation of the mainstem from the point of their respective confluences.

IBI scores from several direct tributaries to Caesar Creek Lake ranged from 46 for Buck Run and Turkey Run, to 30 for Jonahs Run. Flows in Jonahs Run were interstitial and riffles were nonfunctional. IBI scores from direct tributaries to Anderson Fork ranged from 36 for Grassy Run to 54 for Grog Run, and generally tracked the QHEI (Figure 48). Painters Run and an unnamed tributary at RM 9.1 had IBI scores of 38 and 44, respectively. The unnamed tributary receives storm water from the service areas associated with the I-71/US 68 interchange.

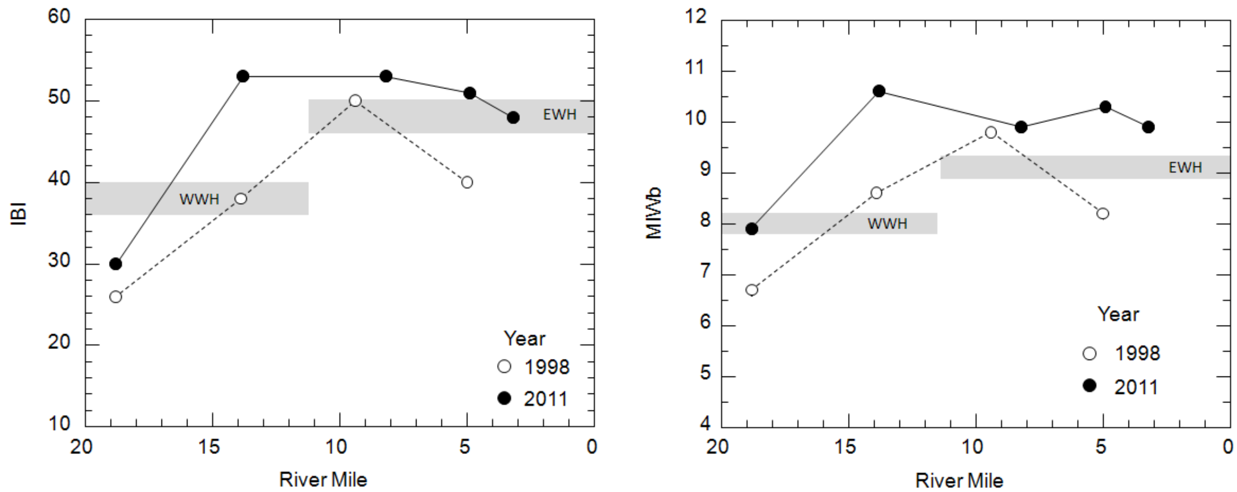
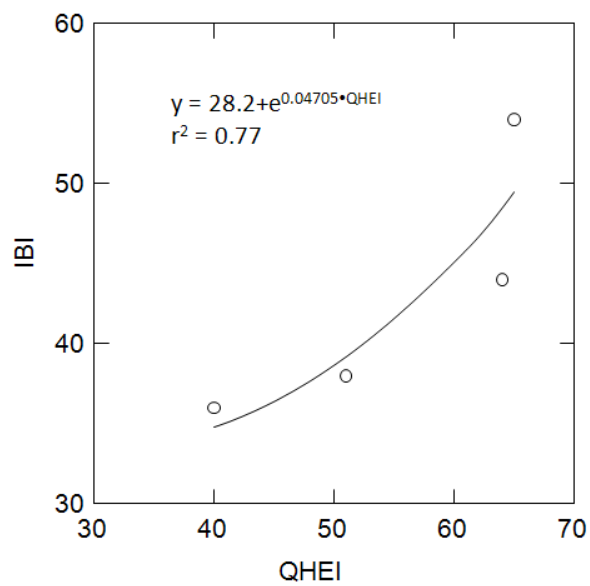


Figure 47. Index of Biotic Integrity (IBI) and Modified Index of Well-being (MIWb) scores recorded from Anderson Fork, 2011 and 1998. The shaded regions in each plot show the range of nonsignificant departure from respective biocriterion.

Figure 48. IBI as a function of QHEI for tributaries to Anderson Fork.



Massies Creek

Fish assemblages measured in the mainstem of Massies Creek all met the biocriteria for WWH, and showed marked improvement compared to 1998 (Figure 49). No longitudinal impact was associated with the Cedarville WWTP. Fish assemblages measured in the South Fork met the WWH biocriterion, and were improved relative to 1998. In the North Fork, recent habitat restoration in the reach upstream

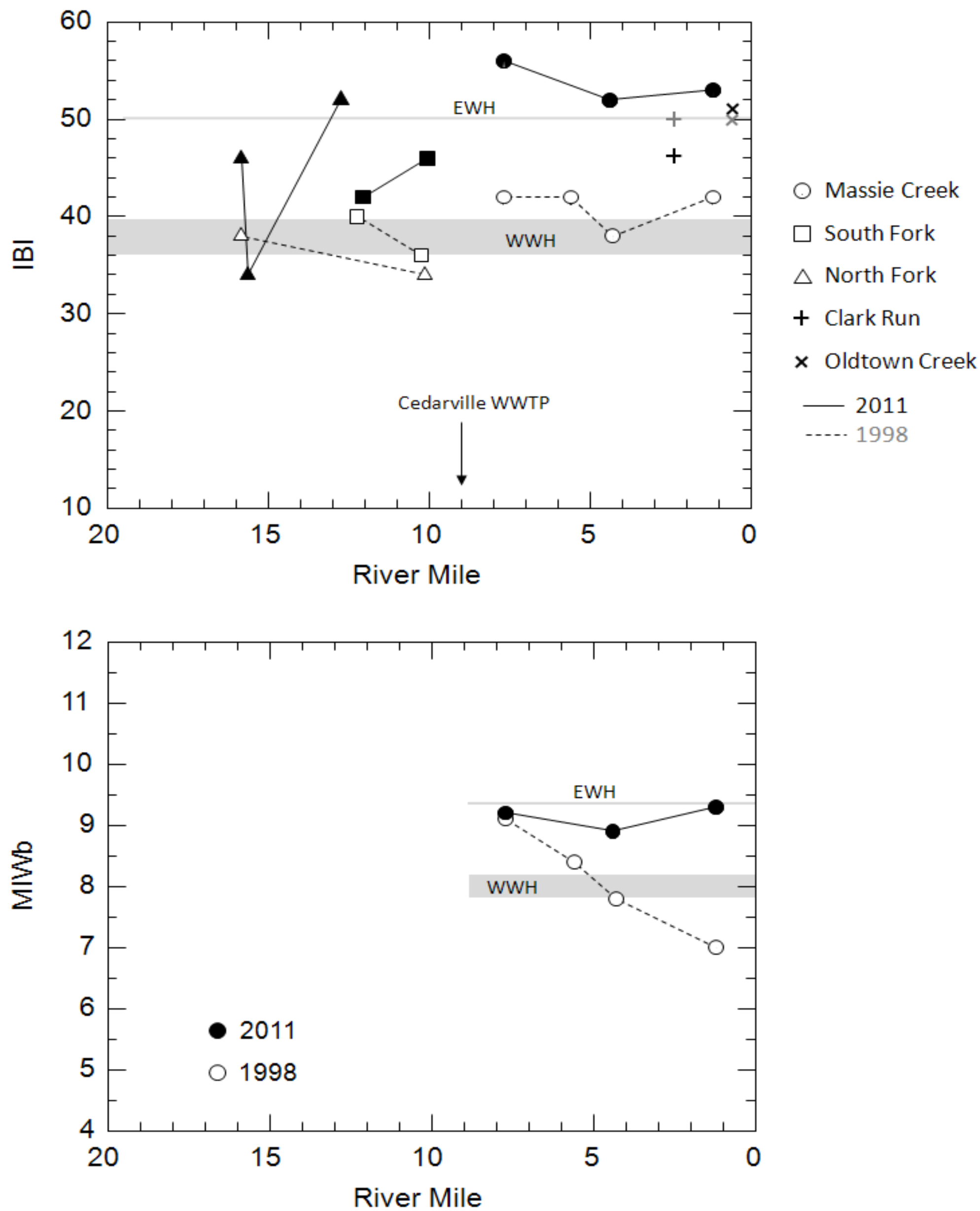


Figure 49. Index of Biotic Integrity (IBI) and Modified Index of Well-being (MIWb) scores recorded from Massie Creek and its tributaries, 2011 and 1998. The range of nonsignificant departure from the WWH biocriterion is shown in each plot as a shaded area. The EWH biocriterion is depicted as a solid gray line, and applies only to Clark Run. The MIwb only applies to sites <20 mi^2.

from US 42 (upper crossing) resulted in a better IBI score in 2011 compared to 1998. Immediately downstream from US 42 (RM 5.7), where the habitat remains impoverished from channelization, the fish IBI score was 34, failing the WWH biocriterion. The site sampled at McMillan Road (RM 2.8) is in a reach that alternates between recent or maintained channelization and recovered channel. Although the QHEI score was 52 at the site, reflecting the history of channelization, only one highly deleterious habitat attribute was noted. The North Fork through this reach is well supplied with bed material, and has sufficient stream power given its drainage area to recover WWH attributes. This suggests that the impaired site downstream from US 42 is likely to passively recover, especially given the restored habitat immediately upstream.

The fish IBI score of 51 from Oldtown Creek in 2011 was essentially identical to the IBI of 50 obtained in 1998, and met the WWH biocriterion. The IBI of 46 for Clark Run in 2011 was within the range of nonsignificant departure for EWH, and though lower than the IBI of 50 in 1998, was within the range of year-to-year variation.

Sugar Creek
The Sugar Creek catchment drains the southeastern suburbs of Dayton. Little Sugar Creek, at RM 0.5 contains approximately 12% urban land use. Despite this relatively high level, the fish assemblage was in good condition, likely owing to riparian buffers being retained along most of the stream network. Urban land use at the two locations sampled on Sugar Creek were estimated at 6.5% and 3.3% for Penewit Road (RM 0.4) and Wilmington Pike (RM 4.1), respectively. As with Little Sugar Creek, riparian buffers have been retained on most of the stream network comprising Sugar Creek, and the lower several miles are protected by park land. IBI scores met applicable WWH biocriteria in Sugar Creek (Table 17).

North Fork Little Miami River
The North Fork Little Miami River was sampled at two locations, Thorps Road (RM 9.1) and North River Road (RM 0.4). The fish assemblage at Thorps Road met WWH, and marginally departed at North River Road. The unnamed tributary (confluence at RM 5.6) sampled at Crabill Road (RM 0.8) was clearly modified (Figure 44), and clearly lacks sufficient stream power to recover WWH attributes in the foreseeable future.

Glady Run
The fish assemblages measured in Glady Run were not consistent with expectations based on available habitat quality (Figure 44), but have remained stable through time (Figure 50). Concentrations of ammonia nitrogen and TKN were slightly elevated at the Hedges Road site (RM 4.08), where the IBI was within the range of nonsignificant departure from WWH, suggesting that organic enrichment may have negatively influenced the community. Note, however, that the Hedges Road site (RM 4.08, IBI = 38) scored better than the Schnebly Road site (RM 1.1, IBI = 34), where water quality appeared unperturbed. Also note that the catchment upstream from Hedges Road is composed of approximately 5.5 percent urban land use, with another 39 percent of all land use made up of lower intensity suburban land uses, such that storm water may be a stressor. Lastly, the complexion of the fish assemblage in

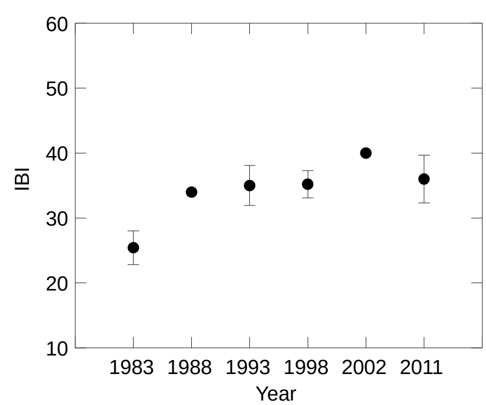


Figure 50. Mean (±SE) IBI scores from Glady Run by year.

Glady Run is decidedly cold/cool water, as mottled sculpin composed over 60% of the electrofishing catch at both sampling locations. Cold/coolwater fish communities typically have lower than expected taxa richness, and a higher than expected proportion of tolerant fishes when gauged against expectations for warmwater streams.

Other Tributaries

Shawnee Creek drains the heart of Xenia, and contains approximately 8.1 percent urban land use. Riparian buffers in the lower reaches of the stream appear to help attenuate storm water impacts. The IBI score at Hawkins Road (RM 0.65) was 52. The IBI score from Newman Run RM 0.27 at US 42 was 57, meeting the EWH criterion. In Yellow Springs Creek, the IBI score of 44 at Grinnel Road (RM 0.1) missed the EWH biocriterion for headwaters in 2011, as the tolerant and omnivore metrics were suppressed by juvenile white suckers being relatively abundant in the electrofishing catch. In this context, the departure from the EWH biocriterion is probably transient. Follow-up sampling conducted in 2012 yielded an IBI score of 52, which met the EWH biocriterion. Jacoby Branch is designated EWH, and the fish community, as in 1998 when the designation was made, was within the range of nonsignificant departure. The fish assemblage measured in the unnamed tributary to the Little Miami River (confluence at RM 96.26) sampled at Buffenbarger Road (RM 0.6) did not meet WWH. The stream presently lacks the physical attributes necessary for supporting a WWH fauna, given that modified attributes exceed WWH attributes by 3 to 1. The stream was historically modified at the sampling location, and the drainage network upstream from the sampling location is actively maintained. Lisbon Fork was sampled at Old Springfield Road (RM 0.4) where the IBI score of 38 was within the range of nonsignificant departure of the WWH biocriterion, essentially unchanged from 1998 when the score was 40, and squarely in the range predicted given the local habitat quality (QHEI = 62.5; see Figure 44). The fish assemblage measured in Gilroy Ditch (RM 0.5) met WWH with an IBI score of 44, and was similar to that measured in 1998, when the IBI was 42.

Table 17. Fish community indices from electrofishing samples collected in the upper Little Miami River basin, 2011.

River Mile	Number of Species	Relative Weight	Relative Number	(all) Relative Number	QHEI	IBI	MIWb[1]	Narratives	
Little Miami River (11-001-000)									
Warmwater									
104.88	9.0	--	110.0	400.0	59.0	26	--	Poor	NA
103.13	10.0	--	222.0	432.0	59.3	36	--	Marginally good	NA
98.98	17.0	11.9	297.0	522.8	72.5	43	8.0	Good	Marginal
92.27	14.0	7.8	719.3	945.8	75.8	40	8.0	Good	Marginal
Exceptional Warmwater									
85.38	28.5	17.9	952.1	1,047.6	87.0	52	9.6	Exceptional	Exceptional
83.14	26.0	60.6	936.8	974.3	84.0	53	9.7	Exceptional	Exceptional
80.63	27.0	40.2	1,560.8	1,709.3	76.3	51	9.8	Exceptional	Exceptional
77.70	21.0	240.8	690.0	801.1	82.5	52	9.5	Exceptional	Very Good
75.38	24.0	166.0	548.0	599.0	76.8	53	9.6	Exceptional	Exceptional
72.30	23.5	170.6	485.0	521.0	85.0	54	9.6	Exceptional	Exceptional
69.84	28.5	292.4	605.0	673.0	82.8	55	10.0	Exceptional	Exceptional
68.54	20.5	186.3	549.0	573.0	81.0	52	9.6	Exceptional	Exceptional
64.44	23.5	148.7	430.0	467.0	78.3	53	9.7	Exceptional	Exceptional
64.28	19.0	227.6	515.0	551.0	77.3	50	9.6	Exceptional	Exceptional
63.28	20.0	238.2	384.0	432.0	79.0	52	9.5	Exceptional	Very Good
60.84	17.5	87.8	352.0	385.0	91.0	54	10.2	Exceptional	Exceptional
53.84	26.0	81.8	285.0	304.0	70.5	49	9.6	Exceptional	Exceptional
53.20	22.0	134.8	332.0	346.0	67.0	48	9.7	Exceptional	Exceptional
51.65	30.5	192.7	511.8	531.7	84.5	51	10.2	Exceptional	Exceptional
Shawnee Creek (11-001-007)									
Warmwater									
0.65	15.0	--	346.0	442.0	74.0	52	--	Exceptional	NA
UT to Little Miami River (96.26) (11-001-008)									
Undesignated- Warmwater recommended									
0.60	12.0	--	86.0	208.0	55.5	30	--	Fair	NA
Newman Run (11-030-000)									
Exceptional Warmwater									
0.27	21.5	--	630.0	765.0	72.3	57	--	Exceptional	NA
Glady Run (11-032-000)									
Warmwater									
4.08	6.0	--	326.0	492.0	68.0	38	--	Marginally good	NA
1.10	7.0	--	360.0	550.3	79.0	34	--	Fair	NA

Table 17 continued

River Mile	Number of Species	Relative Weight	Relative Number	(all) Relative Number	QHEI	IBI	MIWb	Narratives	
Sugar Creek (11-033-000)									
Warmwater									
4.11	14.0	--	1,212.0	1,656.0	66.3	46	--	Very Good	NA
0.40	23.5	8.1	760.5	897.8	78.0	45	8.6	Good	Good
Little Sugar Creek (11-034-000)									
Warmwater									
0.45	14.0	--	1,392.0	1,620.0	67.5	44	--	Good	NA
Beaver Creek (11-035-000)									
Warmwater									
1.57	18.5	7.2	543.8	771.8	62.8	40	7.7	Good	Fair
1.04	17.5	4.7	324.0	400.5	67.8	41	7.3	Good	Fair
0.20	26.0	30.9	663.0	859.5	80.3	51	9.7	Exceptional	Exceptional
Little Beaver Creek (11-036-000)									
Warmwater									
6.23	8.0	--	135.0	987.0	59.0	30	--	Fair	NA
2.83	16.0	--	297.0	412.5	75.3	46	--	Very Good	NA
0.05	19.0	4.4	670.5	812.3	64.5	43	7.5	Good	Fair
Ludlow Creek (11-037-000)									
Warmwater									
2.0	9.0	--	78.0	396.0	64.8	34	--	Fair	NA
Jacoby Branch (11-039-000)									
Exceptional Warmwater									
0.50	14.0	--	224.0	432.0	71.0	46	--	Very Good	NA
Yellow Springs Creek (11-040-000)									
Exceptional Warmwater									
0.10	17.0	--	420.0	498.0	79.5	52	--	Exceptional	NA
North Fork Little Miami River (11-041-000)									
Warmwater									
9.10	9.0	--	374.0	444.0	71.5	42	--	Good	NA
0.37	17.0	6.3	414.0	664.5	71.3	38	8.1	Marginally good	Marg. good
UT to North Fork Little Miami River (5.60) (11-041-001)									
Undesignated –Warmwater Recommended									
0.80	9.0	--	96.0	170.4	37.3	32	--	Fair	NA

Table 17 continued

River Mile	Number of Species	Relative Weight	Relative Number	(all) Relative Number	QHEI	IBI	MIWb	Narratives	
Lisbon Fork (11-043-000)									
Warmwater									
0.40	16.0	--	251.7	521.7	64.5	38	--	Marginally good	NA
Gilroy Ditch (11-044-000)									
Warmwater									
0.50	15.0	--	628.0	900.0	58.3	44	--	Good	NA
Caesar Creek (11-300-000)									
Warmwater									
26.50	14.0	--	88.0	236.0	57.5	26	--	Poor	NA
Exceptional Warmwater									
23.10	27.0	29.9	2,153.2	2,808.9	76.8	43	9.2	Good	Very Good
16.52	33.0	50.8	1,329.0	1,828.5	64.5	50	10.4	Exceptional	Exceptional
0.15	26.5	16.1	1,003.5	1,016.3	80.0	54	9.3	Exceptional	Very Good
Flat Fork (11-301-000)									
Warmwater									
1.70	7.0	--	70.0	456.0	64.3	24	--	Poor	NA
Jonahs Run (11-302-000)									
Warmwater									
2.33	10.0	--	32.0	254.0	57.8	30	--	Fair	NA
Turkey Run (11-304-000)									
Warmwater									
1.50	19.0	--	504.0	1,178.0	66.5	46	--	Very Good	NA
Buck Run (11-305-000)									
Warmwater									
1.18	19.0	--	632.0	990.0	80.3	46	--	Very Good	NA
Anderson Fork (11-306-000)									
Warmwater									
18.80	15.5	7.8	659.3	1,722.0	64.0	30	7.9	Fair	Marginally good
13.87	29.0	56.4	1,294.5	1,590.0	70.5	53	10.6	Exceptional	Exceptional
Exceptional Warmwater									
7.90	27.5	53.0	1,113.0	1,319.3	79.5	53	9.9	Exceptional	Exceptional
4.90	29.0	51.2	1,983.0	2,376.0	78.0	52	10.4	Exceptional	Exceptional
4.90	30.0	33.0	1,978.5	2,487.0	78.0	50	10.3	Exceptional	Exceptional
3.27	31.0	38.7	1,503.0	1,854.0	77.5	48	9.9	Very Good	Exceptional

Table 17 continued

River Mile	Number of Species	Relative Weight	Relative Number	(all) Relative Number	QHEI	IBI	MIWb	Narratives	
UT to Anderson Fork (9.26) (11-306-002)									
Undesignated – Warmwater Habitat Recommended									
0.20	13.0	--	198.0	750.0	64.8	44	--	Good	NA
Painters Creek (11-307-000)									
Warmwater									
5.02	15.0	--	206.0	948.0	53.0	38	--	Marginal	NA
Grog Run (11-308-000)									
Warmwater									
0.90	19.0	--	942.0	1,724.0	65.0	54	--	Exceptional	NA
Grassy Run (11-310-000)									
Warmwater									
0.05	9.0	--	120.0	134.0	40.0	36	--	Marginally good	NA
South Branch Caesar Creek (11-311-000)									
Warmwater									
8.23	15.0	--	248.0	540.0	55.5	40	--	Good	NA
Exceptional Warmwater									
2.10	18.0	--	196.0	332.0	72.0	46	--	Very Good	NA
North Branch Caesar Creek (11-312-000)									
Warmwater									
6.67	17.0	--	660.0	1,036.0	68.0	48	--	Very Good	NA
1.23	19.0	3.2	934.0	1,568.0	65.0	46	7.7	Very Good	Fair
Massies Creek (11-400-000)									
Warmwater									
7.70	25.0	16.2	698.3	723.0	82.0	56	9.2	Exceptional	Very Good
4.38	21.0	9.4	324.0	355.5	87.0	52	8.8	Exceptional	Good
4.38	22.0	18.1	484.5	543.0	87.0	52	9.1	Exceptional	Very Good
1.20	24.0	33.1	1,086.0	1,164.0	81.3	53	9.3	Exceptional	Very Good
Oldtown Creek (11-401-000)									
Warmwater									
0.10	14.5	--	1,237.0	1,455.0	69.0	51	--	Exceptional	NA
Clark Run (11-402-000)									
Exceptional Warmwater									
0.44	12.0	--	566.0	856.0	76.0	46	--	Very Good	NA

Table 17 continued

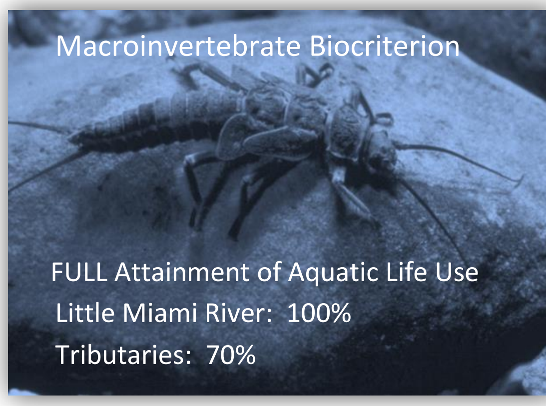
River Mile	Number of Species	Relative Weight	Relative Number	(all) Relative Number	QHEI	IBI	MIWb	Narratives	
North Fork Massies Creek (11-403-000)									
Warmwater									
5.90	17.0	--	1,161.0	1,564.3	61.3	46	--	Very Good	NA
5.73	17.0	--	392.4	866.0	55.0	34	--	Fair	NA
2.80	20.0	7.0	1,110.0	1,486.0	51.3	52	8.7	Exceptional	Good
South Fork Massies Creek (11-404-000)									
Warmwater									
2.15	13.0	--	1,538.0	2,056.0	50.3	42	--	Good	NA
0.14	13.0	--	1,092.0	1,380.0	64.5	46	--	Very Good	NA

Biological Criteria for the Eastern Cornbelt Plains Ecoregion

	IBI			MIWb		
	MWH	WWH	EWH	MWH	WWH	EWH
Headwaters	24	40	50		- NA -	
Wading	24	40	50	6.2	8.3	9.4
Boat	24	42	48	5.8	8.5	9.6

[1] MIWb is not applicable to headwater streams (drainage area < 20 mi^2)

Macroinvertebrate Community



The macroinvertebrate communities from 79 locations in the upper Little Miami River watershed were sampled in 2011. Qualitative multi-habitat composite samples were collected from all sampling locations. Quantitative Hester-Dendy artificial substrate samples were collected from sites with drainage areas that were larger than 20 mi^2. A summary of the macroinvertebrate data are presented in Table 18. The macroinvertebrate raw data are presented in Appendix Table A-12. Sampling locations were evaluated using WWH or EWH biocriteria based on current or recommended aquatic life uses, as well as CWH narrative benchmarks where applicable. Overall, 78.5% of the sites were meeting the applicable biocriterion, with 100% full attainment of biological goals for the Little Miami River mainstem. Impaired communities that were encountered in the tributaries were localized and influenced mostly by land use and stream flow. The 2011 survey represents the first comprehensive reassessment of the watershed since the 1998 biosurvey and the resulting TMDL that was completed in 2002.

Little Miami River Mainstem

Macroinvertebrate communities were evaluated at 22 stations in the Little Miami River mainstem from the headwaters to Middletown Road south of Waynesville (RMs 104.88-51.65). The aquatic life use of the upper Little Miami River is EWH, except from the headwaters to RM 91.64, where it is designated WWH. Resource quality, as indicated by the macroinvertebrate community via the ICI, revealed exceptional communities at all but the two uppermost sites, which were evaluated narratively as good in lieu of the ICI. These results translate to the entire upper Little Miami River mainstem being in full attainment of the applicable macroinvertebrate biocriterion (Table 18). This represents an improvement from 1998, where 6 of 21 sites were not meeting the biocriterion (Figure 51).

One of the main arbiters of this improvement was a large increase in qualitative EPT[2] taxa (Figure 52). Qualitative EPT increased by 34%, from an average of 14.7 in 1998 to an average of 22.3 in 2011. At RM 73.16 upstream from Beaver Creek at Alpha, 31 EPT were collected. The collection of 30 or more EPT is a rare occurrence in the Ohio EPA database. Out of over 12,600 samples in the history of Ohio EPA, only 34 samples have included 30 or more EPT (0.27%). Further, there were also five additional sites that had EPT totals of 26 or more in the upper Little Miami River in 2011. This is also rare, with only 146 samples in the Ohio EPA database (1.16%). Most of these samples were collected in the previously impaired reach downstream from Clifton. No samples in 1998 included qualitative EPT of 26 or more and only two samples eclipsed 20 EPT. In 2011, 18 samples had qualitative EPT of 20 or more. So, while the mean ICI may have only increased slightly over time, (45.6 in 1998 to 50.5 in 2011), outstanding improvement to the benthic community was found in one of the most important water quality indicator groups. As with the fish community, this improvement is also coincident with lower concentrations of total phosphorus in the water column.

[2] EPT stands for Ephemeroptera-Plecoptera-Trichoptera, the orders of invertebrates commonly known as mayflies, stoneflies, and caddisflies, respectively. Their collective presence and abundance in the benthos is generally considered an indicator of high resource quality.

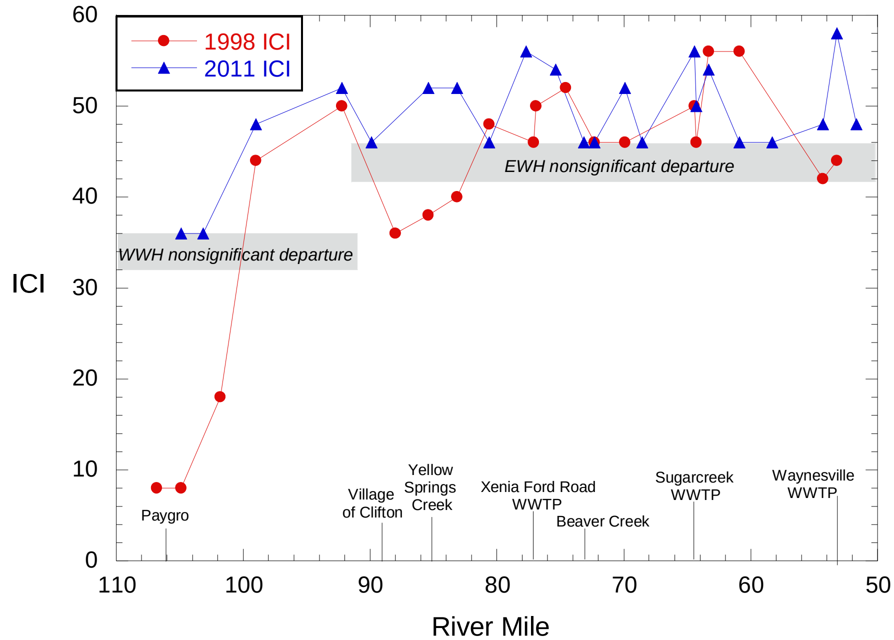


Figure 51. Longitudinal plot of the ICI in the upper Little Miami River mainstem, 1998 and 2011. The ICI is estimated where quantitative data are not available.

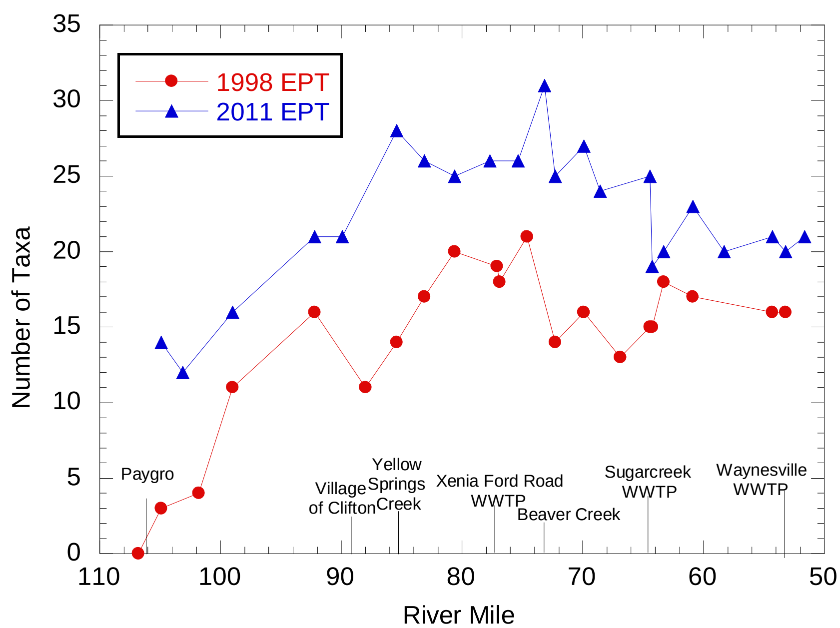


Figure 52. Longitudinal plot of qualitative EPT taxa in the upper Little Miami River, 1998 and 2011.

Tributaries Overview
A total of 57 sites on 33 direct or indirect tributaries to the upper Little Miami River were sampled in 2011. Of these, 40 were meeting the current or recommended aquatic life use criteria (70%). Impaired communities were most frequently encountered in urban streams and in the streams draining into Caesar Creek Lake (Figure 56). Cold water macroinvertebrates were frequently collected in the small tributaries near Yellow Springs, and exceptional communities were common in the Massies Creek and Caesar Creek subwatersheds.

Headwater Tributaries: North Fork Little Miami River, Lisbon Fork, Gilroy Ditch, Unnamed Tributaries
Macroinvertebrate communities in the headwater tributaries to the upper Little Miami River were surprisingly intact in spite of habitat challenges resulting from the surrounding agricultural landscape. Most of the streams in the area were either recently or historically channelized and were surrounded by crop land. The North Fork Little Miami River supported exceptional and very good communities at the two sites sampled in 2011. This result is congruent with the sampling effort of 1998. Lisbon Fork at RM 2.80 was channelized and without riffle habitat, but still managed to meet WWH expectations. In 1998, Lisbon Fork was sampled further downstream at RM 0.40 and performed slightly better due to the presence of riffles. Gilroy Ditch was sampled downstream from the South Charleston WWTP in both 1998 and 2011. Only two qualitative EPT and one sensitive taxon were collected in 1998, and the natural substrates were observed to be predominantly colonized by flatworms, leeches, and snails. The community in 2011 showed marked improvement, with EPT and sensitive taxa rising to 17 and 13, respectively. While snails and flatworms remain dominant components of the macroinvertebrate community in Gilroy Ditch, leeches were replaced by net-spinning caddisflies as a predominant taxon in 2011.

Two unnamed headwater tributaries were sampled for the first time in 2011: the tributary to North Fork Little Miami River (RM 5.60) and the tributary to Little Miami River (RM 96.26). The macroinvertebrate community of the tributary to North Fork Little Miami River (RM 5.60) was sampled at Crabill Road (RM 0.80) south of Springfield and was evaluated as marginally good. The sampled reach was that of a wetland stream, with sand substrate and no riffle habitat. However, the stream was flowing such that debris snags functioned as surrogate riffles, allowing for the collection of rheophilic hydropsychid caddisflies and mayflies of the genus *Baetis*. Similar habitat conditions were encountered at the tributary to Little Miami River (RM 96.26) at Buffenbarger Road. This stream had slow current speed and coarse bottom substrates that allowed for adequate colonization. Benthic community composition was similar to that of the North Fork tributary.

Yellow Springs area tributaries: Conner Branch, Jacoby Branch, Yellow Springs Creek
Small, spring-fed streams are common in the area around and immediately south of Yellow Springs, and as such, the upper Little Miami River tributaries sampled in this reach hosted benthic communities reflective of cool, high quality conditions. Twelve cold water macroinvertebrate taxa were collected in Conner Branch at US 68 (RM 0.17), including the mayfly *Baetis tricaudatis*; stonefly genera *Leuctra sp*. and *Amphinemura sp*.; caddisflies *Diplectrona modesta*, *Ceratopsyche slossonae*, *Lepidostoma sp*., and *Glossosoma sp.*; and midges *Meropelopia sp.*, *Pagastia orthogonia*, *Parametriocnemus sp.*, *Micropsectra sp*., and *Polypedilum aviceps*. Eleven cold water taxa were collected here in 1998 and the CWH use was recommended. The community collected in 2011 confirmed that the CWH use is still appropriate for Conner Branch.

Both Jacoby Branch and Yellow Springs Creek are designated EWH and benthic communities collected in these streams in 2011 supported this use designation. Jacoby Branch was sampled at US 68 (RM 0.50) and Yellow Springs Creek was sampled at Grinnel Road (RM 0.10) and yielded 20 and 21 EPT respectively, with the cold water stonefly genus *Leuctra* observed as a predominant taxon. Similar exceptional communities were collected in Jacoby Branch and Yellow Springs Creek in 1998. A notable change to the benthos in Yellow Springs Creek was the emergence of the cased cold water caddisfly genus *Glossosoma* as a predominant taxon. *Glossosoma* was not collected in the 1998 biosurvey, but in 2011, its cases were encrusting the riffles. This is especially impressive given that the Yellow Springs WWTP discharges upstream at RM 0.4. Improvements to the WWTP may be responsible for this additional positive shift in the biota.

Massies Creek Subwatershed: Massies Creek, North and South forks, Clark Run, and Oldtown Creek
Ten sites on five streams were sampled for macroinvertebrate communities in the Massies Creek subwatershed. With the exception of Oldtown Creek, all sites received either very good to exceptional ICI scores or narratives. Oldtown Creek at US 68 (RM 0.10) received a narrative evaluation of marginally good due to low flows over fine substrates that adversely affected available margin habitat for colonization. However, the marginally good community was within nonsignificant departure of the applicable WWH biocriterion, so Oldtown Creek was not considered to be impaired.

Macroinvertebrate performance in the Massies Creek subwatershed since 1998 has generally been consistent, with ICI scores and narratives routinely scoring within the very good to exceptional range. An improvement to the benthos was noted at North Fork Massies Creek at Old Route 42, where pre-restoration sampling in 2008 revealed a good community of 51 total, 12 pollution-sensitive and 14 EPT taxa. In 2011, these numbers improved to 60, 16, and 22, respectively, and garnered a narrative evaluation of exceptional.

Beaver Creek Subwatershed: Beaver Creek and Little Beaver Creek
The Beaver Creek subwatershed drains the most intensely developed part of the study area (Figure 56) and also receives effluent from two of the largest wastewater treatment facilities in the watershed. Montgomery Eastern Regional WWTP (1.3 MGD design) discharges into Little Beaver Creek at RM 4.6, and Beavercreek WWTP (8.5 MGD design) discharges into Beaver Creek at RM 0.4.

Beaver Creek fared better than its tributary, Little Beaver Creek, in terms of macroinvertebrate community performance. Three out of the four sites sampled on Beaver Creek in 2011 and 2012 met the applicable WWH biocriterion, including the sites located downstream from Little Beaver Creek and the Beavercreek WWTP. The site that did not meet, RM 3.86 at Fairgrounds Road, flowed through a wetland and therefore did not have adequate current to support a diverse assemblage of pollution sensitive and EPT taxa. Benthic community performance in Beaver Creek has remained consistent since 1998, although pollution-sensitive taxa and EPT taxa appear to be trending upwards (Figure 53).

Small increases in pollution-sensitive and EPT taxa were realized in Little Beaver Creek in 2011 and 2012 vs. 1998 (Figure 54), but the narrative evaluations have remained below WWH expectations. Upstream from Montgomery County Eastern Regional WWTP, Little Beaver Creek is highly urbanized. The sampling location at Vale Road (RM 6.2) is located in a residential area and was channelized with embedded substrates that were coated in algae. Only two pollution sensitive taxa were collected from this location in 2012 and the community was evaluated as low fair. The next site at RM 4.76 was downstream from a small impoundment in an industrial park. While diversity improved in terms of taxa richness, the sensitive-to-tolerant taxa ratio of 0.05 was the second lowest in the entire survey. Sponges and bryozoa coated the substrates, indicating that excess nutrients were likely impacting the community.

Downstream from the WWTP, Little Beaver Creek is comprised mostly of sand and fine gravel substrates. The volume of effluent discharged from the WWTP allows for very strong, scouring flows to persist in Little Beaver Creek such that the substrates were unstable and mostly embedded, making colonization difficult for benthic organisms. Unencumbered substrates, when found, were usually coated in hydropsychid caddisfly retreats and midge tubes, indicating that nutrient enrichment was still impacting water quality. As previously mentioned, however, small improvements in community structure have been noted since 1998. This may indicate incremental improvement to water quality in Little Beaver Creek, especially downstream from the WWTP.

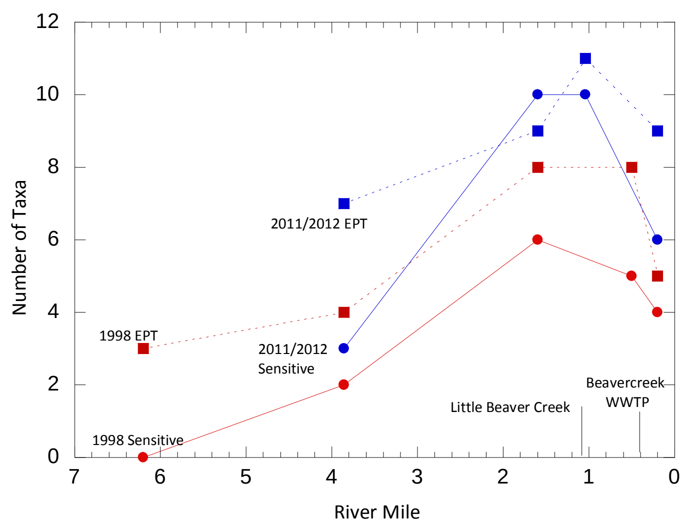


Figure 53. Longitudinal plot of qualitative EPT and total sensitive taxa for Beaver Creek, 1998 and 2011/2012.

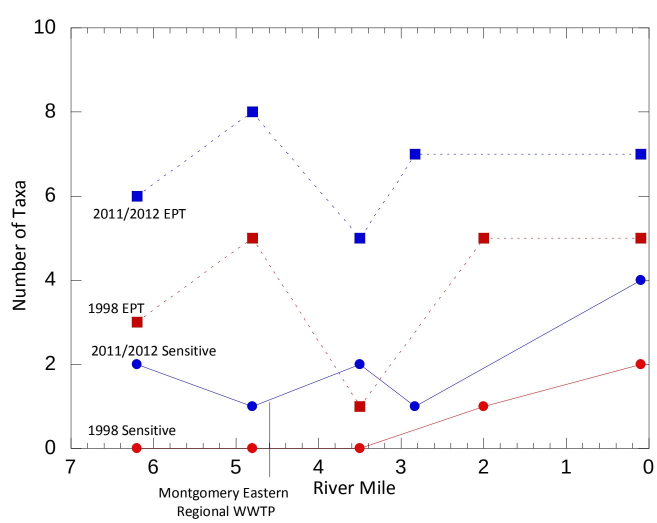


Figure 54. Longitudinal plot of qualitative EPT and qualitative sensitive taxa for Little Beaver Creek, 1998 and 2011/2012.

Anderson Fork Subwatershed: Anderson Fork, Grassy Run, Grog Run, and Painters Creek

Anderson Fork drains a mostly rural landscape. This tributary to Caesar Creek (RM 13.92) is designated WWH from the headwaters to the confluence with Grog Run at RM 11.02, and is EWH downstream from Grog Run to the mouth. Four sites were evaluated in 2011, with macroinvertebrate community performance ranging from fair to exceptional. The fair community at RM 13.87 downstream from Port William was not meeting WWH expectations due to low stream flows. It is suspected that stream flow was impeded in part by a low head dam upstream in the city of Port William. Many caddisfly cases were collected but found to be empty due to the dewatering of margin habitat. In the EWH reach, low stream flows persisted, yet macroinvertebrate communities performed considerably better, with very good and exceptional communities collected at McKay Road (RM 7.90) and Old Winchester Trail (RM 4.90), respectively. The good community at Engle-Mill Road (RM 3.27) was not meeting EWH expectations due to the presence of numerous beaver dams that further impeded flow. Benthic communities in Anderson Fork in 1998 were similar to those of 2011, with the exception of RM 13.87 where sustained flows in 1998 allowed for better diversity and a good assessment of macroinvertebrate community condition, achieving WWH expectations.

Grassy Run and Grog Run were sampled for the first time by Ohio EPA in 2011. Both streams were found to be in non-attainment of WWH macroinvertebrate expectations. Grassy Run at Sabina Road (RM 0.05) cut through crop land and was channelized with no riparian corridor and very little flow. Macroinvertebrate diversity in Grassy Run was the lowest of all streams in the study area with no sensitive taxa collected; therefore, the community was evaluated as poor. Grog Run had considerably better diversity than Grassy Run due to better habitat, but a large component of the community was comprised of tolerant organisms and EPT taxa richness was lower than expected for a WWH stream, resulting in an evaluation of fair. Gray silt and algae coated many of the substrates, indicating that organic enrichment and sedimentation may be limiting the macroinvertebrate community. Cattle were observed in the stream on the day of sampling and their impact may be a source contributing to the impaired benthos.

Macroinvertebrate community performance in Painters Creek at Eleazer Road (RM 0.43) declined from very good in 1998 to marginally good in 2011. Midges were the predominant organism in all habitats in 2011 due to silt and algae-embedded substrates. Field notes from 1998 indicated excellent riparian corridor on both sides of the stream with tree roots holding the banks together. This was not what was observed in 2011, as evidenced in Figure 55. Aerial photographs show that the riparian corridor of Painters Creek to be mostly intact, so the observations in 2011 may be local rather than throughout the extent of Painter's Creek. A marginally good narrative is within nonsignificant departure of the WWH biocriterion, so a TMDL is not warranted; however, this location should certainly be resampled in the next biosurvey to determine if the stream has degraded further.

Figure 55. Painter's Creek RM 0.43 at Eleazer Road, upstream view.

Caesar, North Branch Caesar and South Branch Caesar creeks

Caesar Creek and both North and South Branch Caesar creeks were meeting the expectations of their assigned aquatic life uses at seven of eight locations sampled in 2011. Only South Branch Caesar Creek at Parker Road, located downstream from the city of Jamestown, was found to be performing below expectations. EPT and sensitive taxa were lower than expected for an unimpacted stream, and pollution tolerant organisms were abundant. Both siltation and organic enrichment appeared to be affecting the benthos, but a definitive source was not apparent. The Jamestown WWTP discharges upstream and there are homes in the vicinity with aging septic systems. After sampling in 2011 was completed, Jamestown replaced their sewer system in order to address overflows to both Caesar Creek and the South Branch. South Branch Caesar Creek was resampled in June 2013 in order to determine whether the elimination of the SSOs might have allowed for the benthos to recover. Another fair community was collected in 2013 (Table 18), but the composition indicated that siltation was the overriding influence rather than organic enrichment. Investigation of the area upstream from Jamestown found farm fields tilled close to the floodplain. Based on this information, sedimentation/siltation was listed as the cause for impairment at this location, with agricultural practices as the source.

The eight sites sampled in 2011 were also sampled in 1998. Macroinvertebrate communities were generally comparable both years, with a decline noted at South Branch Caesar Creek downstream from Jamestown, and improvement observed in Caesar Creek at Stone Road and in North Branch Caesar Creek at Jasper Road. Potential reasons for the decline (good in 1998, fair in 2011) at South Branch Caesar Creek were those discussed in the preceding paragraph. Both Caesar Creek at Stone Road and North Branch Caesar Creek at Jasper Road had benthic communities that improved from good in 1998 to exceptional in 2011. Of note was the doubling of EPT and sensitive taxa at the North Branch site from 1998 to 2011 (10 to 22 EPT and 9 to 19 sensitive). A reduction in silt loads to both streams may be responsible for the improvement.

Caesar Creek Lake Tributaries: Buck, Turkey, and Jonahs runs and Flat Fork

Three of four sites on four tributaries to Caesar Creek Lake were found to be in non-attainment of the macroinvertebrate biocriterion in 2011. Flat Fork had a marginally good number of EPT taxa; however, the overwhelming abundance and predominance of tolerant blackflies and pouch snails resulted in an overall evaluation of fair for the community at Oregonia Road. This composition may indicate a potential issue with organic enrichment due to runoff from the surrounding agricultural landscape. Both Turkey Run and Jonahs Run were impacted by periodic low flows. Jonahs Run was additionally affected by the presence of numerous beaver dams and log jams in the stream, which reduced diversity such that the community was comprised mostly of midges. EPT taxa were slightly below expectations in Turkey Run. Empty caddisfly cases of both the genus *Helicopsyche* and *Mystacides* were collected, which may indicate recent intermittency in the absence of a discernible impact. Buck Run at SR 380 was approaching interstitial when the stream was sampled in late July. Unlike Turkey and Jonahs runs, the macroinvertebrate community was not impacted by the declining flows as 14 EPT were collected, with caddisflies and mayflies predominant.

Buck Run, Jonahs Run, and Flat Fork were sampled in 1998, at the same locations as 2011. EPT and sensitive taxa improved from 8 and 3 to 14 and 8, respectively, in Buck Run since 1998. A slight decline was noted in Jonahs Run, likely due to temporal variances in stream flow between sampling years. EPT and sensitive taxa were similar for Flat Fork in both 1998 and 2011, but tolerant taxa comprised a much larger component of the community in 2011, which lowered the evaluation from good to fair.

Sugar Creek, Little Sugar Creek, and Glady Run
The Sugar Creek subwatershed drains the southeastern suburbs of Dayton, including Centerville, Bellbrook, and Kettering. In spite of heavy urban land use, the benthic community of Sugar Creek at Wilmington Pike near Centerville managed to remain within nonsignificant departure of the WWH biocriterion with an evaluation of marginally good. Downstream at Penewit Road, benthic performance declined from both upstream and from that of 1998. EPT and sensitive taxa were decreased by half (8 and 5 in 2011 vs. 16 and 11 in 1998, respectively) due to near interstitial flows in 2011. Stream flow was moderate at this location in 1998. Conversely, benthic communities were comparable in Little Sugar Creek at Maple Street in Bellbrook in 1998 and 2011. Taxa richness, sensitive taxa, and EPT taxa were all within 2-3 taxa of one another between both sampling years, though the community appeared to be more enriched in 1998 due to higher organism densities.

Glady Run drains the southern portion of Xenia, and receives effluent from the Xenia-Glady Run WWTP. The two locations that were sampled in 2011 indicated that macroinvertebrate communities have improved since 1998. Hedges Road at RM 4.08 is located about a mile downstream from the Xenia-Glady Run WWTP outfall. While the ICI of 28 in 1998 and the qualitative evaluation of fair in 2011 were both not meeting the WWH biocriterion, increases in both sensitive and EPT taxa were garnered in 2011. Sampling conducted in 1998 within the Xenia-Glady Run WWTP mixing zone was indicative of severe organic enrichment and low dissolved oxygen. While mixing zone sampling was not conducted in 2011, the community response at Hedges Road did not appear to be the result of such a severe impact. Rather, the community appeared to be affected by only slight to moderate organic enrichment.

The farfield station at Schnebly Road (RM 1.1 in 2011 and RM 2.1 in 1998) exhibited good recovery in both years, but the rebound in 2011 was much more pronounced. Qualitative EPT doubled from 6 in 1998 to 12 in 2011, and qualitative sensitive taxa quadrupled from 3 in 1998 to 12 in 2011. The Xenia-Glady Run WWTP expanded its treatment capacity in 1999, and additional improvements were scheduled for 2012. Given these ongoing improvements to the WWTP, it is recommended that remediation efforts be focused on reducing the impact of urban runoff to Glady Run.

Other Tributaries: Ludlow and Shawnee Creeks, Mill and Newman Runs
Ludlow and Shawnee creeks are located near Xenia, with Shawnee Creek draining the central portion of Xenia proper, and Ludlow Creek draining agricultural land to the northwest of the city. Both streams met WWH expectations in 2011 and in 1998. Both Mill and Newman runs bracket the city of Waynesville in the southern part of the watershed, with Mill Run to the north of Waynesville and Newman Run to the south. In spite of interstitial to near intermittent stream flow conditions, Mill Run managed to support a marginally good macroinvertebrate community in 2011. The macroinvertebrate communities of Newman Run have never fully met the expectations of its EWH use designation. In 1998, the community received a narrative evaluation of very good, which marginally achieves EWH. In 2002 and 2011, benthic communities were evaluated as good, which was below EWH expectations. It is suspected that, like Mill Run, this stream may experience periods of low to intermittent stream flows that affect benthic community stability.

Table 18. Summary of macroinvertebrate data collected from artificial substrates (quantitative data) and natural substrates (qualitative data) in the upper Little Miami River basin, July-September, 2011, 2012, and 2013. Samples collected in 2012 and 2013 are noted in parentheses in the location column.

Location	River Mile	Drain. (mi^2)	Total Taxa	Qual EPT	Total Sens	Total Tol.	CW Taxa	Substrate Density[a]	ICI[b]	Narrative Evaluation	Observations[c]
Little Miami River @ SR 41 SE of South Charleston	104.88	4.60	53	14	7	20	0	Moderate	n/a	Good	*Rheotanytarsus* midges, hydropsychid caddisflies, leeches, and pouch snails predominant.
Little Miami River @ Jamestown Road	103.13	6.40	47	12	6	11	1	Low	n/a	Good	Hydropsychid caddisflies, baetid mayflies, *Rheotanytarsus* midges, and leeches predominant.
Little Miami River @ Dolly Varden Road near South Charleston	98.98	33.00	72	16	18	11	0	2341	48	Exceptional	Hydropsychid caddisflies, baetid mayflies, midges, heptageniid mayflies, and pleurocerid snails predominant.
Little Miami River @ Pitchin Road near Clifton	92.27	53.00	69	21	26	8	1	3173	52	Exceptional	Hydropsychid caddisflies, heptageniid mayflies, *Isonychia* mayflies, waterpenny beetles, and burrowing mayflies predominant.
Little Miami River ust sharp bend, adj N. River Road, ½ mile E of SR 72	89.77	94.00	88	21	24	12	0	1905	46	Exceptional	*Neophylax* cased caddisflies, heptageniid mayflies, damselflies and beetles predominant.
Little Miami River @ Grinnel Road near Yellow Springs	85.38	104.00	76	28	31	6	5	2141	52	Exceptional	*Isonychia* mayflies, hydropsychid caddisflies, baetid , heptageniid , and burrowing mayflies predomimnant.
Little Miami River dst Yellow Springs WWTP @ Jacoby Road	83.14	118.00	88	26	35	7	2	3440	52	Exceptional	*Isonychia* mayflies, hydropsychid caddisflies, heptageniid and burrowing mayflies, and pleurocerid snails predomimnant.
Little Miami River @ US 68	80.63	129.00	66	25	26	6	2	2634	46	Exceptional	*Isonychia* mayflies, hydropsychid caddisflies, heptageniid and burrowing mayflies, and pleurocerid snails predomimnant.
Little Miami River NW Xenia @ Fairgrounds Road	77.70	217.00	86	26	33	12	2	4688	56	Exceptional	Midges and baetid, Isonychia, heptageniid, burrowing, and leptohyphid mayflies predominant.
Little Miami River @ Trebein Road	75.38	238.00	84	26	33	8	3	4809	54	Exceptional	Hydropsychid caddisflies, midges, *Isonychia* and heptageniid mayflies, and pleurocerid snail s predominant.

Location	River Mile	Drain. (mi^2)	Total Taxa	Qual EPT	Total Sens	Total Tol.	CW Taxa	Substrate Density[a]	ICI[b]	Narrative Evaluation	Observations[c]
Little Miami River 0.42 mi ust Beaver Creek at Alpha	73.16	241.00	84	31	32	9	0	7370	46	Exceptional	Baetid,*Isonychia*, and heptageniid mayflies; midges, and pleurocerid snails predominant.
Little Miami River @ Indian Ripple Road near Kettering	72.30	295.00	58	25	23	6	0	Moderate	--	Exceptional	Hydropsychid caddisflies, baetid and *Isonychia* mayflies, midges, and pleurocerid snails predominant.
Little Miami River @ Upper Bellbrook Road near Bellbrook	69.84	302.00	90	27	35	10	0	2473	52	Exceptional	Hydropsychid caddisflies, baetid and heptageniid mayflies, *Petrophila* moths, midges, and pleurocerid snails predominant.
Little Miami River @ Washington Mills Road	68.54	307.00	84	24	34	8	1	2194	46	Exceptional	Baetid and heptageniid mayflies predominant.
Little Miami River ust Greene Co.-Sugar Creek WWTP	64.44	345.00	75	25	27	7	0	5706	56	Exceptional	Hydropsychid caddisflies, midges, Asian clams, baetid and heptageniid mayflies predominant.
Little Miami River dst Greene Co.-Sugar Creek WWTP	64.28	345.00	64	19	28	6	0	12897	50	Exceptional	*Rheotanytarsus* midges, hydropsychid and polycentropid caddisflies, damselflies, and midges predominant.
Little Miami River @ Spring Valley Roadside Park	63.28	361.00	80	20	31	10	0	11077	54	Exceptional	*Rheotanytarsus* midges, hydropsychid and polycentropid caddisflies, and riffle beetles predominant.
Little Miami River @ Roxanna-N. Burlington Road at USGS gage	60.84	367.00	64	23	21	12	0	Moderate-low	--	Exceptional	*Rheotanytarsus* midges, hydropsychid caddisflies, heptageniid and leptohyphid mayflies predominant.
Little Miami River just dst Sandy Run , ¾ mi SW Spring Valley Lake	58.30	378.00	87	20	27	16	1	3366	46	Exceptional	*Rheotanytarsus* midges and baetid mayflies predominant.
Little Miami River adj Corwin Road	54.3	398.00	65	21	26	7	0	2012	48	Exceptional	Baetid and heptageniid mayflies, pleurocerid snails predominant.
Little Miami River adj Corwin Road, dst Waynesville WWTP, ust Newman Run	53.20	402.00	69	20	27	7	0	2849	58	Exceptional	*Rheotanytarsus* midges, hydropsychid caddisflies, baetid and heptageniid mayflies predominant.
Little Miami River S of Waynesville, 0.1 mi ust Middletown Road	51.65	413.00	77	21	28	13	0	1532	48	Exceptional	Hydropsychis caddisflies, pleurocerid snails, heptageniid mayflies, water penny beetles predominant.

Location	River Mile	Drain. (mi²)	Total Taxa	Qual EPT	Total Sens	Total Tol.	CW Taxa	Substrate Density[a]	ICI[b]	Narrative Evaluation	Observations[c]
Gilroy Ditch near ford, 0.9 mi dst South Charleston WWTP	0.50	7.50	60	17	13	11	0	Moderate	n/a	Good	Snails, hydropsychis caddisflies, flatworms, and *Helicopsyche* caddisflies predominant.
Lisbon Fork N of South Charleston @ SR 41	2.80	7.00	51	13	8	17	0	Moderate	n/a	Good	*Caenis* mayflies, *Helicopsyche* caddisflies predominant.
North Fork Little Miami River at Thorps @ SR 41	9.10	11.50	62	19	17	13	1	Moderate	n/a	Very Good	Pleurocerid snails, fingernail clams, *Helicopsyche* caddisflies predominant.
North Fork Little Miami River @ North River Road	0.37	35.80	71	19	20	10	2	946	54	Exceptional	Pleurocerid snails, hydropsychid caddisflies, and heptageniid mayflies predominant.
Tributary to North Fork Little Miami River (5.60) S of Springfield @ Crabill Rd	0.80	7.40	52	11	5	23	0	Moderate	n/a	Marginally Good	Hydropsychid caddisflies, pleurocerid snails, damselflies, beetles predominant.
Tributary to Little Miami River (96.26) SE Pitchin @ Buffenbarger Road	0.60	6.00	55	12	8	23	1	Moderate-low	n/a	Marginally Good	Snails predominant.
Conner Branch @ US 68 near mouth	0.17	2.30	57	17	14	15	12	Moderate	n/a	Very Good	Hydropsychid caddisflies, stoneflies, midges, and blackflies predominant. Very cold water (14°C).
Jacoby Branch @ US 68 SW of Yellow Springs	0.50	5.10	60	20	20	4	5	Moderate	n/a	Exceptional	Hydropsychid caddisflies, *Leuctra* stoneflies, *Neophylax* cased caddisflies, and heptageniid mayflies predominant.
Yellow Springs Creek @ Grinnel Road near mouth	0.10	11.30	59	21	20	11	4	Moderate	n/a	Exceptional	Hydropsychid caddisflies, *Glossosoma* and *Neophylax* cased caddiesflies, *Leuctra* stoneflies, and *Psychomyia* caddisflies predominant.
North Fork Massies Creek near Selma @ Old Route 42	5.90	18.60	60	22	16	9	0	Moderate	n/a	Exceptional	Hydropsychid caddisflies, baetid mayflies, *Helicopsyche* cased caddisflies, *Caenis* mayflies, and midges predominant. Restoration area with little canopy and lots of algae and embedded substrates.
North Fork Massies Creek @ US 42 dst tributary	5.73	17.90	57	18	12	10	0	Moderate	n/a	Very Good	Hydropsychid caddisflies, *Rheotanytarsus* midges, and heptageniid mayflies predominant.
North Fork Massies Creek NE of Cedarville @ McMillan Road	2.80	20.90	87	24	25	14	0	794	52	Exceptional	Hydropsychid caddisflies, baetid mayflies, *Helicopsyche* and *Neophylax* cased caddisflies and water mites predominant.

Location	River Mile	Drain. (mi^2)	Total Taxa	Qual EPT	Total Sens	Total Tol.	CW Taxa	Substrate Density[a]	ICI[b]	Narrative Evaluation	Observations[c]
South Fork Massies Creek @ Weimer Road near Cedarville	2.15	17.10	54	19	11	15	0	Moderate	n/a	**Very Good**	Midges, hydropsychid caddisflies, *Helicopsyche* cased caddisflies, heptageniid and *Caenis* mayflies predominant.
South Fork Massies Creek @ RR at Cedarville	0.14	19.90	53	19	15	9	0	Moderate	n/a	**Very Good**	*Helicopsyche, Neophylax*, and hydropsychid caddisflies predominant.
Massies Creek @ Tarbox-Cemetery Road dst Cedarville	7.70	55.00	67	20	16	13	0	Moderate	--	**Exceptional**	Hydropsychid and *Neophylax* cased caddisflies; baetid,heptageniid and burrowing mayflies predominant.
Massies Creek @ Wilberforce-Clifton Road nr Wilberforce	4.38	63.20	73	20	24	5	1	496	56	**Exceptional**	Hydropsychid and *Neophylax* cased caddisflies, baetid heptageniid, and burrowing mayflies predominant.
Massies Creek @ Fawcett Drive N of Xenia	1.20	73.00	67	24	24	7	1	293	46	**Exceptional**	Hydropsychid and *Neophylax* cased caddisflies, baetid and heptageniid caddisflies predominant.
Clark Run @ Stevenson Road NW of Wilberforce	0.44	6.20	52	21	16	6	1	Moderate-low	n/a	**Exceptional**	Midges, hydropsychid caddisflies, heptageniid and *Isonychia* mayflies predominant.
Oldtown Creek @ mouth near US 68	0.40	10.55	40	10	7	8	2	Moderate-low	n/a	**Marginally Good**	Hydropsychid caddisflies predominant.
Little Beaver Creek @ Vale Road (2012)	6.20	3.60	33	6	2	10	1	Low	n/a	**Low Fair**	Blackflies, water mites, and baetid mayflies predominant. Sampled in 2012.
Little Beaver Creek ust Montgomery Co. Eastern Regional WWTP	4.76	10.00	53	8	1	22	0	High	n/a	**Fair**	Bryozoa, sponge, midges, and flatworms predominant.
Little Beaver Creek ust Grange Hall Road near Dayton	3.54	16.50	37	5	2	10	0	Moderate	n/a	**Low Fair**	Hydropsychid caddisflies and midges predominant.
Little Beaver Creek @ Valleywood	2.83	17.10	29	7	1	7	0	Moderate-low	n/a	**Fair**	Hydropsychid caddisflies predominant.
Little Beaver Creek @ Factory Road near Alpha	0.05	26.40	46	7	4	11	0	Moderate-low	n/a	**Fair**	Midges and hydropsychid caddisflies predominant.
Beaver Creek @ Fairgrounds Road N of Alpha	3.86	14.80	41	7	3	22	0	Moderate	n/a	**Fair**	Polycentropid caddisflies, scuds, water boatmen, and beetles predominant. Wetland habitat.

Location	River Mile	Drain. (mi^2)	Total Taxa	Qual EPT	Total Sens	Total Tol.	CW Taxa	Substrate Density[a]	ICI[b]	Narrative Evaluation	Observations[c]
Beaver Creek @ Dayton-Xenia Road	1.57	20.90	61	9	10	14	0	2484	48	Exceptional	Hydropsychid caddisflies, baetid mayflies, midges predominant.
Beaver Creek @ US 35 dst Little Beaver Creek	1.04	48.10	73	11	10	15	1	5598	42	Very Good	Midges, blackflies, hydropsychid caddisflies and baetid mayflies predominant.
Beaver Creek adj Factory Road dst Beaver Creek WWTP (2012)	0.20	49.40	59	9	6	18	0	14634	36	Good	*Rheotanytarsus* midges, midges, (other), hydropsychid caddisflies, baetid mayflies, Asian clams and pleurocerid snails predominant. Sampled in 2012 due to disturbed samplers in 2011.
Ludlow Creek @ Hilltop Road NW of Xenia	0.25	6.90	39	13	12	2	1	Moderate-low	n/a	Good	Pleurocerid snails, riffle beetles, heptageniid mayflies predominant.
Shawnee Creek @ Hawkins Road near Xenia	0.65	11.60	45	11	7	11	0	Moderate	n/a	Marginally Good	Hydropsychid caddisflies and *Nigronia sp*. fish flies predominant.
Anderson Fork@ Haley Road SE Port William	18.80	30.00	59	9	5	9	0	2168	48	Exceptional	Aquatic worms, flatworms, water mites, riffle beetles and midges predominant.
Anderson Fork @ Port William Road, W of Port William	13.87	50.00	57	8	9	15	0	Moderate	--	Fair	Pleurocerid snails, *Petrophila* moths, micro caddisflies, hydropsychid and philopotamid caddisflies predominant.
Anderson Fork @ McKay Road	7.90	60.32	57	16	12	14	0	Moderate-low	--	Very Good	Hydropsychid and philopotamid caddisflies, midges, heptageniid and caenid mayflies predominant.
Anderson Fork @ Old Winchester Trail	4.90	78.00	87	23	24	12	0	2089	46	Exceptional	Hydropsychid and philopotamid caddisflies, heptageniid and caenid mayflies predominant.
Anderson Fork @ Engle Mill Road	3.27	88.00	53	15	10	14	0	Moderate	--	Good	Hydropsychid and philopotamid caddisflies, riffle beetles, and midges predominant.
Grassy Run @ Sabina Road	0.05	8.44	24	2	0	12	0	Low	n/a	Poor	Snails and midges predominant.
Grog Run S of Paintersville @ Bone Road	0.90	8.30	51	8	3	19	0	Moderate	n/a	Fair	Midges and baetid mayflies predominant.
Painters Creek @ Eleazer Road near Paintersville	0.43	12.80	63	10	6	16	0	Moderate	n/a	Marginally Good	Midges predominant.
North Branch Caesar Creek @ Junkin Road N of Shawnee Hills	6.67	7.00	67	15	9	19	0	Moderate-low	n/a	Good	*Helicopsyche* cased caddisflies, hydropsychid caddisflies, riffle beetles, heptageniid and caenid mayflies predominant.

Location	River Mile	Drain. (mi^2)	Total Taxa	Qual EPT	Total Sens	Total Tol.	CW Taxa	Substrate Density[a]	ICI[b]	Narrative Evaluation	Observations[c]
North Branch Caesar Creek @ Jasper Road W of Shawnee Hills	1.23	25.70	82	22	25	12	1	Moderate-low	48	Exceptional	Hydropsychid caddisflies, riffle beetles, heptageniid and burrowing mayflies predominant.
South Branch Caesar Creek @ Parker Road dst Jamestown (2011)	7.80	7.00	50	8	5	12	0	Moderate-low	n/a	Fair	Flatworms, hydropsychid caddisflies, and riffle beetles predominant.
South Branch Caesar Creek @ Parker Road dst Jamestown (2013)	7.80	7.00	49	5	4	16	0	Moderate-low	n/a	Fair	Fingernail clams, midges, micro-caddisflies, pouch snails, and riffle beetles predominant.
South Branch Caesar Creek @ Hoop Road	2.10	17.00	51	17	12	13	0	Moderate	n/a	Very Good	Philopotamid caddisflies, riffle beetles, heptageniid mayflies and pleurocerid snails predominant.
Caesar Creek @ Paintersville Road at New Jasper	25.55	12.90	71	15	10	17	0	Moderate	n/a	Good	Rheotanytarsus midges, philopotamid mayflies, baetid and heptageniid mayflies, Helicopsyche cased caddisflies, and cap shell snails predominant.
Caesar Creek @ Stone Road SE of Xenia	23.10	64.60	76	17	17	16	1	2364	50	Exceptional	Heptageniid mayflies, Philopotamid and hydropsychid caddisflies predominant.
Caesar Creek @ Paintersville Road	16.52	88.00	69	22	19	14	0	Moderate	--	Exceptional	Hydropsychid and philopotamid caddisflies, baetid, heptageniid, and leptohyphid mayflies, midges predominant.
Caesar Creek @ Corwin Road near Oregonia	0.15	242.00	61	18	26	8	0	355	42	Very Good	Pleurocerid snails, perlid stoneflies, baetid and heptageniid mayflies, and water penny beetles predominant.
Flat Fork @ Oregonia Road	1.70	15.80	53	10	5	19	0	High-moderate	n/a	Fair	Blackflies, midges, baetid mayflies, and pouch snails predominant.
Buck Run @ SR 380 S of New Burlington	1.18	8.50	38	14	8	10	0	Moderate-low	n/a	Good	Hydropsychid caddisflies, heptageniid mayflies, and water penny beetles predominant.
Jonahs Run @ Oregonia Road	2.10	4.10	33	4	1	13	0	Low	n/a	Low Fair	Midges predominant.
Turkey Run @ Brimstone Mills Road	1.50	3.60	44	7	4	11	0	Low	n/a	Fair	Baetid mayflies, riffle beetles and midges predominant.
Little Sugar Creek adj Maple Street at Bellbrook	0.45	12.30	56	10	7	14	2	Moderate-low	n/a	Marginally Good	Hydropsychid caddisflies, water mites, and riffle beetles predominant.

Location	River Mile	Drain. (mi^2)	Total Taxa	Qual EPT	Total Sens	Total Tol.	CW Taxa	Substrate Density[a]	ICI[b]	Narrative Evaluation	Observations[c]
Sugar Creek @ Wilmington Pike near Centerville	4.11	16.50	48	9	7	10	1	Moderate-low	n/a	**Marginally Good**	Hydropsychid and philopotamid caddisflies, pleurocerid snails, and heptageniid mayflies predominant.
Sugar Creek @ Penewit Road near Spring Valley	0.40	33.20	33	8	5	6	0	Low	n/a	**Fair**	Hydropsychid and philopotamid caddisflies and *Stenonema femoratum* heptageniid mayflies predominant.
Glady Run @ Hedges Road near Xenia	4.08	6.90	44	6	8	10	2	Moderate	n/a	**Fair**	Hydropsychid caddisflies, baetid mayflies, and blackflies predominant.
Glady Run @ Schnebly Road, south crossing	1.10	12.40	52	12	12	9	2	Moderate-low	n/a	**Good**	Hydropsychid caddisflies, baetid mayflies, riffle beetles and blackflies predominant.
Mill Run @ US 42 near Waynesville	0.59	8.50	39	10	6	15	0	Moderate-low	n/a	**Marginally Good**	*Helicopsyche* cased caddisflies, and *Stenonema femoratum* heptageniid mayflies predominant.
Newman Run @ US 42 near Waynesville	0.27	9.80	45	12	4	11	2	Moderate-low	n/a	**Good**	Blackflies, midges, sow bugs and hydropsychid caddisflies predominant.

a – Relative density of benthos on natural substrates estimated via narrative (high, moderate, low). For densities on artificial substrates, please refer to Appendix A-12.

b – Invertebrate Community Index. ICI scores are not calculated for sampling locations with drainage area <20mi^2 (excluding reference sites), and are indicated by n/a. Dashed lines (--) indicate sites where quantitative data were not available due to vandalism, dessication, or some other disturbance of Hester Dendy artificial substrates (HDs).

c – Predominant taxa are those observed on natural substrates. Please refer to Appendix table A-12 for predominant taxa on artificial substrates.

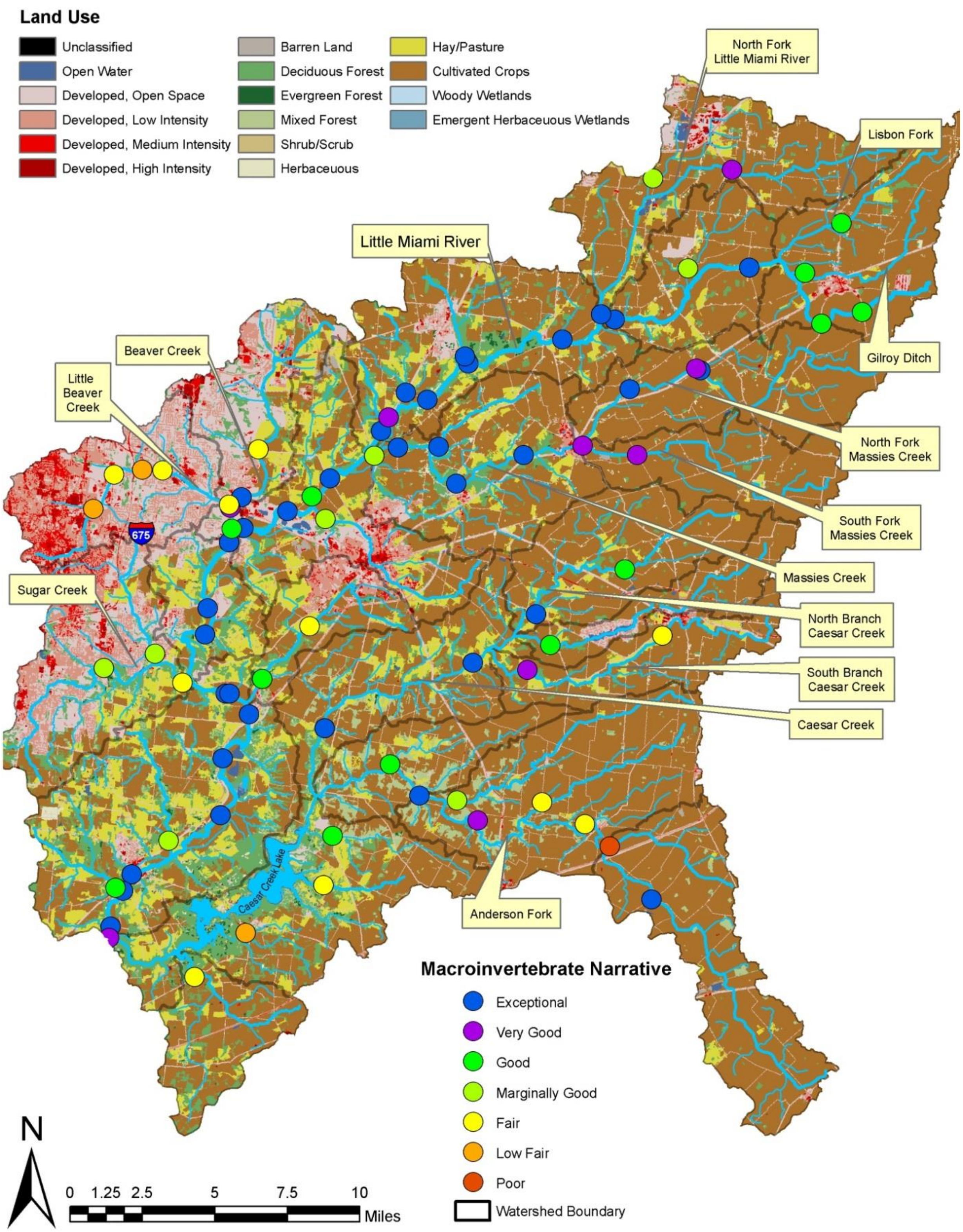


Figure 56. Macroinvertebrate narrative evaluations, mapped with land use (Fry et al., 2011), for sites sampled in the upper Little Miami River basin, 2011, 2012, and 2013.

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 (http://www.epa.state.oh.us/portals/35/fishadvisory/FishAdvisoryProcedure10.pdf).

Fish contaminant data are primarily used for three purposes: 1) to determine fish advisories; 2) to determine attainment with Ohio Water Quality Standards (WQS) criteria; 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 (e.g., two meals a week, one meal a month, do not eat), and a fish advisory is 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: http://www.epa.state.oh.us/dsw/fishadvisory/index.aspx.

The minimum data requirement for issuing a fish advisory is 3 samples of a single species from within the past 10 years. For the Little Miami River from Lower Bellbrook Road to the mouth, enough data were collected to issue advisories due to mercury contamination for common carp, freshwater drum, sauger, silver redhorse, and smallmouth bass. All of these species are in the one meal per month category. All other species caught in the Little Miami River should follow the statewide advice of one meal per week.

For Caesar Creek Lake, enough data were collected to issue an advisory for largemouth bass due to mercury contamination. Largemouth bass should be limited to two meals per week. All other species caught in Caesar Creek Lake should follow the statewide advice of one meal per week.

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 WQS criteria pursuant to OAC Rules 3745-1-33 and 3745-1-34. The human health criteria are presented in water column concentrations of µg/liter, and are then translated into fish tissue concentrations in mg/kg. [See Ohio's 2010 Integrated Report, Section E (http://www.epa.state.oh.us/portals/35/tmdl/2010IntReport/Section%20E.pdf) for further details of this conversion.]

In order to be considered in attainment of the WQS human health use, the sport fish caught within a 12-digit hydrologic unit code (HUC 12) or large river mainstem 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 upper Little Miami River study area, fish tissue data were adequate to determine attainment status within each HUC 12. At least 2 samples from each trophic level 3 and 4 are needed, and both the

Little Miami River and Caesar Creek Lake met that data requirement. On the Little Miami River, only HUC 050902020504 (Newman Run-Little Miami River) was not supporting the human health use because levels of PCBs in fish tissue exceeded the threshold level upon which the WQS criterion is based. Caesar Creek Lake, however, was not impaired and therefore in full attainment of the human health use.

Inland Lakes Monitoring

Figure 57. Caesar Creek Lake, 2011.

Ohio EPA has implemented a sampling strategy that focuses on evaluating chemical conditions near the surface and physical conditions in the water column of inland lakes. Physical profile measurements are summarized either for the entire water column or the epilimnion depending on thermal stratification. The sampling target consists of an even distribution of a total of ten sampling events divided over a two-year period and collected during the index period of May 1 – September 30. Key parameters used to determine the attainment status of lakes include chlorophyll-a, ammonia, dissolved oxygen, pH, total dissolved solids and various metals. Other parameters used to evaluate the degree of support or non-support includes secchi depth, total phosphorus and total nitrogen. Details of the sampling protocol are outlined in Appendix 1 of the Ohio EPA Surface Water Field Sampling Manual, available on Ohio EPA's web page at http://epa.ohio.gov/Portals/35/documents/SW_SamplingManual.pdf

Water Quality Standards for the Protection of Aquatic Life in Lakes

Presently, lakes in Ohio are designated as EWH with respect to the aquatic life use designation. Revisions to Ohio's WQS that would change the aquatic life use from EWH to Lake Habitat (LH) were proposed for adoption in December, 2011, but were subsequently withdrawn. A future rulemaking is anticipated but the timeframe is unknown. A primary reason for this revision is that in Ohio, a set of biological criteria applies to rivers and streams, whereas no biocriteria apply to lakes. The numeric chemical criteria to protect the LH use will remain the same as the criteria to protect the EWH use that currently applies to lakes, with a suite of nutrient criteria added. A set of numeric criteria that applies to all surface waters for the protection of aquatic life, regardless of specific use designation, will also apply to inland lakes and are referred to as "base aquatic life use criteria" in the proposed WQS rules. The base aquatic life use criteria will be the same aquatic life numeric criteria that currently apply to lakes. Examples include various metals such as copper, lead, and cadmium as well as organic chemicals such as benzene and phenol. Specific details concerning the progress of revisions to Ohio's Water Quality Standards involving the proposed Lake Habitat aquatic life use and associated criteria can be found at the following Ohio EPA web site as information becomes available: http://www.epa.ohio.gov/dsw/rules/draftrules.aspx. The chemical criteria specific to the LH aquatic life use in the proposed Water Quality Standards rules are presented in the 2012 Integrated Report, which is available at http://epa.ohio.gov/dsw/tmdl/OhioIntegratedReport.aspx.

Caesar Creek Lake

Caesar Creek Lake is situated four miles east of Waynesville and two miles west of I-71 along SR 73. Congress authorized the creation of Caesar Creek Lake under the Flood Control Act of 1938. The Louisville District of the U.S. Army Corps of Engineers designed, built, and operates Caesar Creek Lake. The park is leased by the state from the U.S. Army Corps of Engineers. The lake is in the Warren County townships of Massie and Wayne.

The surface area of Caesar Creek Lake is 2,830 acres with approximately 40 miles of shoreline. Caesar Creek Lake is a multi-use reservoir that functions for both flood control and recreation. The dam was built in 1971 and water impoundment started January 1978. In an average summer, the lake covers 2,607 acres, fed by a drainage area of 237 mi^2. The dam is located approximately three miles above the mouth of Caesar Creek, which is a tributary of the Little Miami River.

An open-cut spillway exists to the east of the dam to prevent flood waters from topping the dam. Lake water releases are controlled by a series of multi-level gates in the outlet structure which influence water quality in the stream below the dam. In addition to the main dam, four dikes were constructed along the northwest drainage divide between Caesar Creek and the Little Miami River. Caesar Creek is the deepest lake in Ohio, with a maximum water depth of 115 feet near the dam. There are three islands, the largest of which is 40 acres. Dam releases are typically in early spring and late fall.

Caesar Creek Lake has populations of large and smallmouth bass, white bass, Kentucky spotted bass, bluegill, white and black crappie, gizzard shad, channel catfish, flathead catfish, and carp. Fish stocked annually include muskellunge and saugeye.

A water quality survey of Caesar Creek Lake at three lakes stations (L-1 through L-3) was conducted by Ohio EPA in 2011 and 2012 as a part of the Division of Surface Water's Inland Lakes Monitoring Program. Water chemistry samples were collected five times in both 2011 and 2012 and bacteria samples were collected six times in 2011 and five times in 2012. Seven tributaries were sampled eight times in 2011 and nine times in 2012.

Sediment samples were collected once in 2011 at site-L-1. No exceedances of Ohio WQS for arsenic, cadmium, chromium, copper, lead, nickel, selenium, or zinc were found. Bacteria samples were below the recreation use criteria (geometric average <126 cfu/100ml and <298 cfu/100ml as a maximum sample value for Class A Primary Contact Recreation).

Annual daily rainfall amounts in 2011, monitored by the Army Corp of Engineers, were nearly double those of 2012 (60 inches vs. 37 inches). Rainfall amounts during the lake survey period from the first of May until the end of September for both years yielded 22 inches in 2011 and 15 inches in 2012. Secchi disc comparisons align with the conjecture that higher precipitation years (2011) yield higher turbidity rates and thus lower Secchi depth readings (Figure 58). Algae particles also play a role in Secchi depth readings, as does recreational turbidity, both of which increase as the summer progresses.

There were two major algal blooms in 2009 and 2011. One occurred in September 2009 and was a motile green alga, *Chlamydamonas sp*. The other was in December 2011, a cyanobacteria (*Anabaena sp*) bloom that extended from the beach area across the lake to Wilmington's drinking water intake.

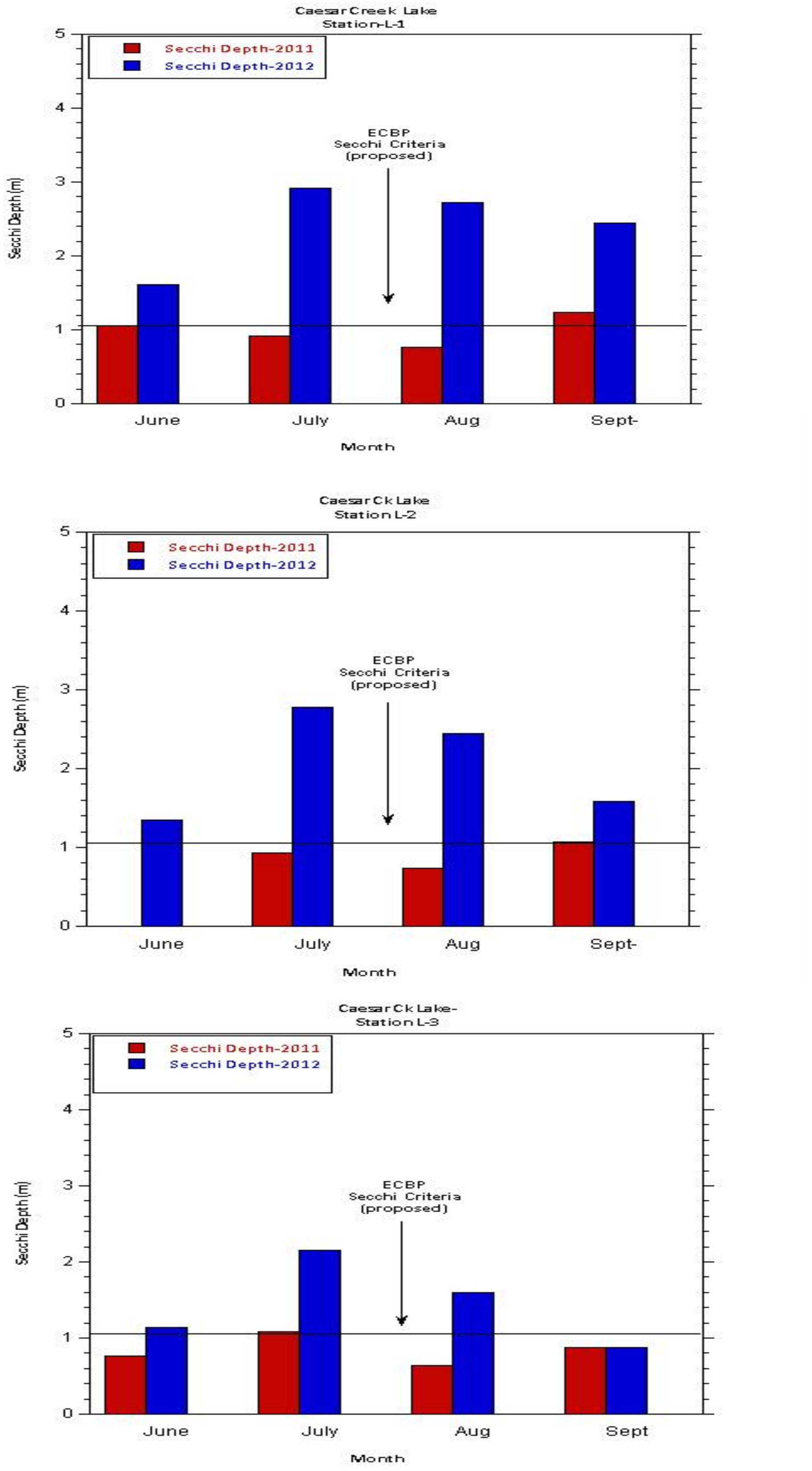


Figure 58. Secchi depth readings (m) at sampling locations in Caesar Creek Lake, 2011 and 2012.

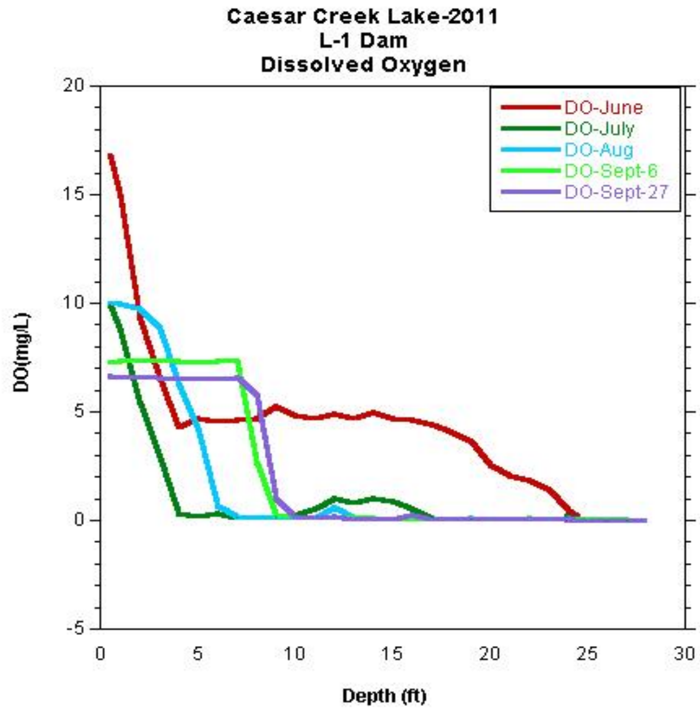


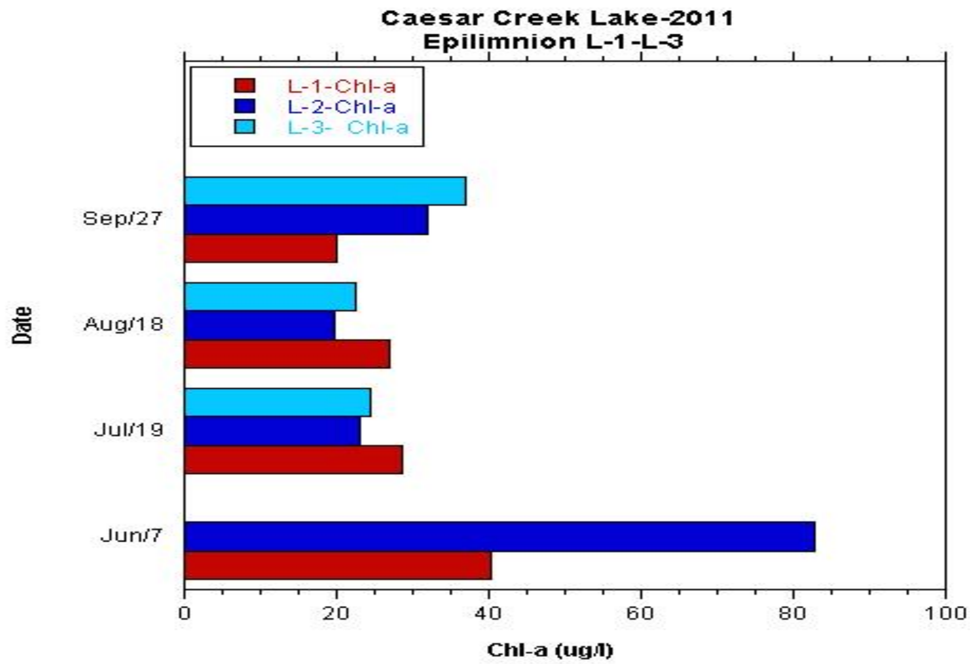
Figure 59. Dissolved oxygen levels in Caesar Creek Lake, 2011.

Dissolved oxygen evaluated in 2011 at the dam (L-1) dropped 10 mg/l by the end of the sampling season, possibly due to higher lake temperatures as summer progressed (Figure 59). Secchi readings at L-1 decreased from June through September 6, which indicated increased turbidity. Assessment of attainment status for this lake was conducted using *epilimnion* data only because of the noted stratification (Table 19).

Caesar Creek Lake is impaired for the proposed LH use due to excessive chlorophyll-a, and for low pH. The 2011 chlorophyll-a levels at the dam (L-1) and at the L-2 sampling location sustained themselves for the most part throughout the sampling season, declining subtly in 2011 while the headwater site at L-3 was nearly inverse in behavior, except in the September 25th sample. Given that Caesar Creek Lake is a drinking water source and is deemed to be impaired by algal growth in response to nutrients (as evidenced by algal bloom observations), it seems appropriate to evaluate this issue further.

During 2011, all sites dominated interchangeably for chlorophyll-a, with the wettest months of May and June surpassing levels of other months in 2011 and for all 2012 sampling events. All sampling dates in 2011 were higher than 2012, possibly due to heavy rains bringing in nutrients from tributaries around the lake instead of from the main channel of Caesar Creek at L-3. Rainfall in early 2011 was the most since 2003 for the spring to summer months**.**

In 2012, a drier spring and summer than 2011, chlorophyll-a presence at all three lake sites indicated that lake site L-3 (located at the headwaters of the lake where Caesar Creek enters) had the highest concentrations of chlorophyll-a. The second highest levels were observed at site L-2 at the drinking water intake sampling station. Sites other than the L-1 dam site exhibited concentrations closer in value and the headwater site was at times twice the concentration of the dam site (Figure 60).



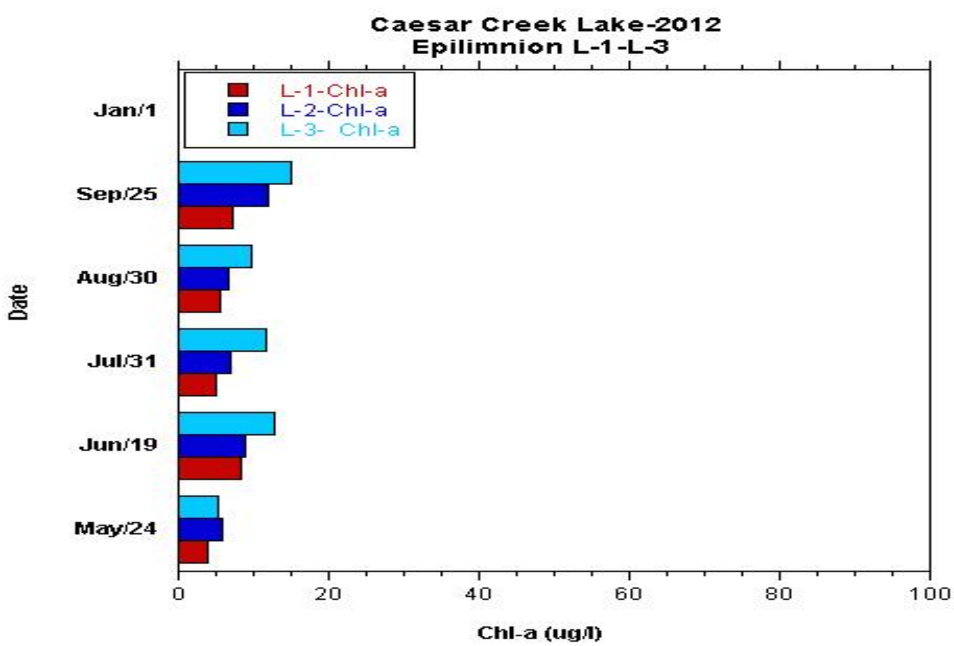
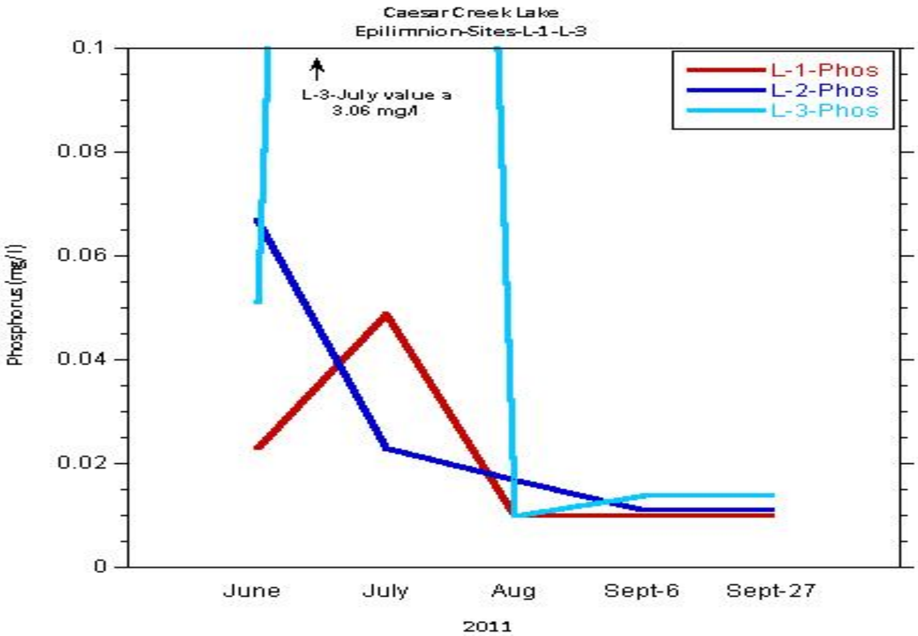


Figure 60. Chlorophyll-a concentrations (ug/l) at sampling locations in Caesar Creek Lake, 2011 and 2012.

For the most part, phosphorus values at L-2 and L-3 sustained higher values than the dam site (L-1), which demonstrated that loads entered the lake via agricultural runoff and diminished in concentration before reaching the dam (L-1), where sediment acts as a nutrient “sink” (Figure 61). The epilimnion layer of the L-1 and L-3 sites in July of 2011 notably increased with just over one and a half inches of rain in the preceding 11 days. Evaluating June and August at the L-3 site for rainfall and phosphorus levels indicated June produced 0.66 inches of rain about 11 days prior to lake sampling, which resulted in a 0.01 mg/l total phosphorus concentration. The August 18th 2011 sampling event had approximately 1.32 inches of rain 11 days prior to lake sampling, which resulted in 0.05 mg/l at-L-3. In 2012 at the same site, 1.33 inches of rain in June showed a value of 0.02 mg/l total phosphorus.

Stream sampling that was conducted by the Ohio EPA was an effort to support the lake sampling by sampling tributaries around the lake. Evaluating the streams sampled in the July, 2011 timeframe revealed streams at the headwaters and dam sites as having the highest concentrations of phosphorus. These streams carried phosphorus concentrations ranging from 0.04 to 0.06 mg/l into the lake. The Caesar Creek mainstem and another large tributary, Anderson Fork, were nearly twice the concentration of the smaller mid-lake tributaries. Jonahs Run, which is near the dam (L-1) in July of 2011 and 2012 carried the highest concentration of phosphorus for all tributaries, followed by Flat Fork (L-1) and Caesar Creek at Paintersville Rd (L-3) in 2011 only. With a few exceptions, phosphorus concentrations generally increased with increased precipitation.



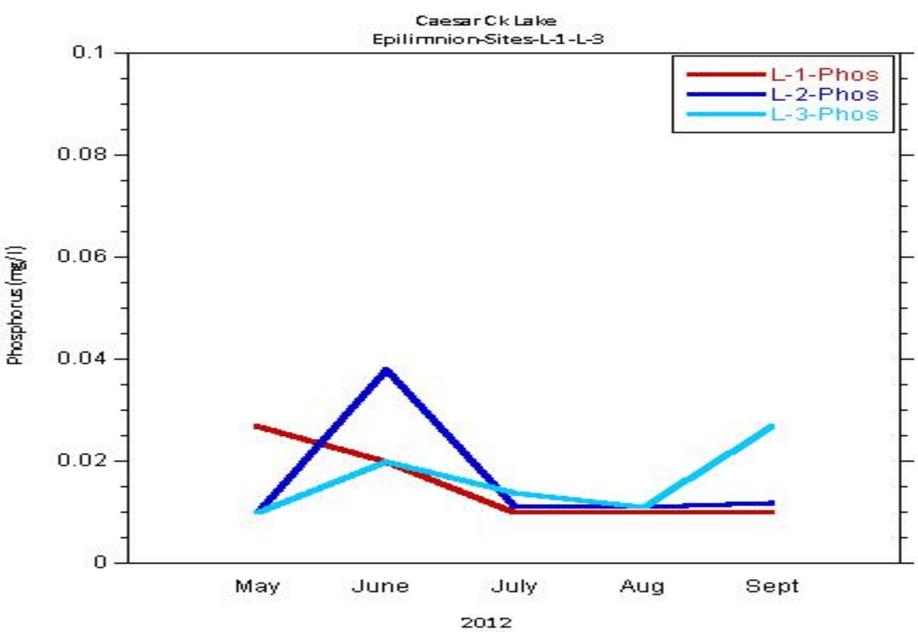


Figure 61. Total phosphorus concentrations (mg/l) at sampling sites in Caesar Creek Lake, 2011 and 2012.

Internal regeneration of nutrients from the hypolimnion of Caesar Creek Lake will be a factor in trying to understand the functioning of this system. Hypolimnetic generation of ammonia during stratification will be rapidly converted to nitrate (NO_2-NO_3) upon autumnal mixing. Likewise, the sequestration of total phosphorus and the generation of orthophosphorus during periods of anoxia in the hypolimnion will affect overall nutrient budgets. A decline in chlorophyll-a occurred in spite of an increase in total phosphorus in the epilimnion. An illustration of the within lake interactions of epilimnion chlorophyll-a, phosphorus and nitrogen at the dam site (L-1) are depicted in Figure 62. While the 2011 graph shows some evidence of nitrogen being the limiting factor in Caesar Creek Lake, an effective lake management strategy would be to target reduction in total phosphorus levels. A comparison of 2011 nitrogen and phosphorus measurements at the three Caesar Creek Lake stations exhibited declining trends as the summer progressed. In July 2011, an anomalous phosphorus spike occurred in the headwaters after agricultural applications and a rainfall event (Figure 63). Composite samples were concentrated at a depth of 0-9 feet for this sampling event. Resampling the headwater region of the lake at various depths to capture where phosphorus might be concentrated is recommended for future surveys.

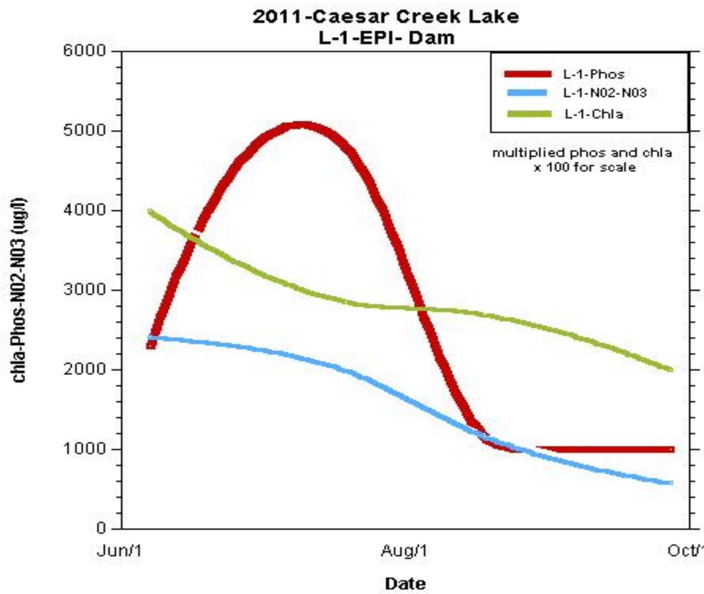


Figure 62. Epilimnion sample results at Caesar Creek Lake dam (L-1) for total phosphorus (ug/lx100), nitrogen and chlorophyl-a (ug/lx100), 2011.

Phosphorus enters lakes when heavy rains and melting snow wash over farm fields and feedlots and carry fertilizer, manure and soil into lakes or carry phosphorus-laden contaminants from urban streets and parking lots. A determined shift to the use of phosphorus free lawn fertilizing blends will reduce the urban/suburban contribution of total phosphorus through storm water runoff. Spot use of phosphorus-containing fertilizers for flower beds, and only where necessary for healthy plant growth, is a contribution that every lakeside and watershed homeowner can accomplish at relatively low expense. Lakeside buffer zones of natural woody or tall grass vegetation will help in intercepting runoff, increase lakeside nutrient assimilation, and discourage nuisance geese populations. This is a relatively inexpensive way to reduce nutrient inputs into Caesar Creek Lake.

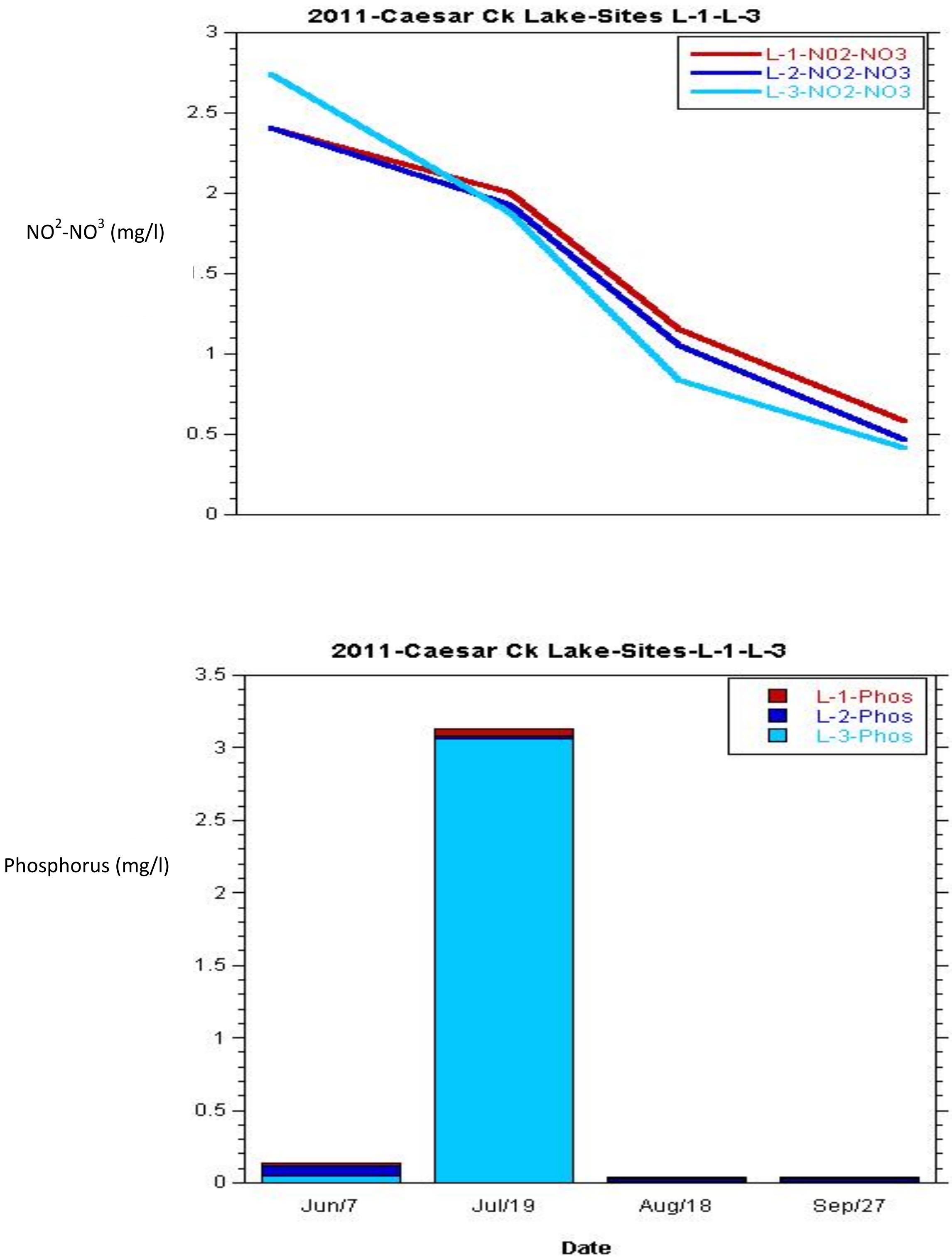


Figure 63. Total nitrogen and phosphorus concentrations (mg/l) at sampling sites in Caesar Creek Lake, 2011.

Table 19. Assessment of lake data collected from Caesar Creek Lake, 2011 and 2012, to determine status of the proposed Lake Habitat aquatic life use and the Primary Contact Recreation Class A use. Note - As of the finalization of this report, the proposed Lake Habitat use and its associated criteria have not been adopted into the Ohio Water Quality Standards and the assessments provided in this table should be considered as examples of how the Lake Habitat use and criteria could be applied.

Parameter	Chl-a (ug/l) ECBP	Secchi Depth (M)	T-Nitrogen (ug/l)	T-Phos (ug/l)	DO (mg/l)	pH (SU)	NH3 (mg/l)	*E. coli*
Proposed Criteria	**14 ug/l median**	**1.19 min**	**930 median**	**34 median**	**6.0**	**6.5-9**	**pH & temp dependent**	**126 cfu/100ml**
6/7/2011								
L-1	**40.3**	**1.05**	**3000**	**23**	**18.26**	**9.60**	**0.050**	
L-2	**82.8**	**-**	**3390**	**67**			**0.050**	
L-3	**31.4**	**1.05**	**3720**	**51**			**0.050**	
7/19/11								
L-1	**28.7**	**0.924**	**3010**	***49**	**10.19**	**8.62**	**0.050**	
L-2	**23.0**	**0.925**	**2540**	***23**			**0.050**	
L-3	**24.4**	**1.089**	**2420**	***3060**			**0.050**	**<10 (7-21) BDL[3] (7-28)**
Beach (7-28)								**17.3**
Boat ramp (7-28)								**1**
8/18/11								
L-1	**27.0**	**0.759**	**2170**	**10**	**11.22**	**8.51**	**0.050**	
L-2	**19.8**	**0.735**	**1920**	**17**			**0.050**	
L-3	**22.4**	**0.635**	**1670**	**10**			**0.176**	**BDL (8-16) 20 (8-22) BDL (8-29)**
Beach (8-22)								**2**
Beach (8-29)								**8.5**
Beach (8-16)								**3**
Boat ramp(8-16)								**BDL**
Boat ramp(8-22)								**5.2**

Parameter	Chl-a (ug/l) ECBP	Secchi Depth (M)	T-Nitrogen (ug/l)	T-Phos (ug/l)	DO (mg/l)	pH (SU)	NH3 (mg/l)	*E. coli*
Proposed Criteria	14 ug/l median	1.19 min	930 median	34 median	6.0	6.5-9	pH & temp dependent	126 cfu/100ml
Boat ramp(8-29)								BDL
9/6/2011								
L-1 Dup A	27.5	0.95	1140	10	7.31	8.81	0.050	
L-1 Dup B	28.5		990	10			0.050	
L-2		-						
L-3								BDL (9-12)
Beach (9-12)								1
Boat ramp (9-12)								1
9/27/11								
L-1	20.0	1.24	1010	10	7.54	8.4	0.053	
L-2	31.9	1.065	0820	11			0.063	
L-3	36.9	0.87	0740	14			0.077	
5/24/12								
L-1	3.8	3.97	3900	27	9.32	8.74	0.107	
L-2	5.8	2.51	3340	10			0.051	
L-3	5.2	2.63	3540	10			0.051	
6/19/12								
L-1	8.3	1.615	2910	20	10.76	8.72	0.050	
L-2	8.8	1.345	3000	38			0.050	
8/30/12								
L-1	5.7	2.72	1700	10	8.87	8.71	0.050	
L-2	6.8	2.45	1360	11			0.050	
L-3 S	9.6	1.6	3170	11			0.050	
9/25/12								
L-1 S	7.3	2.45	1160	10	7.55	8.41	0.057	
L-2 S	11.9	1.585	940	12			0.115	
L-3 S	15.0	0.88	1070	27			0.109	

Median-2011-2012[1]	Chl-a (ug/l) ECBP	Secchi Depth (M)	T-Nitrogen (ug/l)	T-Phos (ug/l)	% DO	% pH	% NH3	Geometric mean *E. coli*
Median-2011-2012[1]	**Chl-a (ug/l) ECBP**	**Secchi Depth (M)**	**T-Nitrogen (ug/l)**	**T-Phos (ug/l)**	**% DO**	**% pH**	**% NH3**	**Geometric mean *E. coli***
L-1	**20**	**1.24**	**1935**	**10**	**0**	**1 of 9 (11%)**	**Below WQS**	
L-2	**16**	**1.35**	**2230**	**15**	**0**	**0**	**“**	
L-3	**19**	**1.07**	**2045**	**17**	**0**	**0**	**“**	**14**
Beach								**4**
Boat ramp								**2**
Narrative[2]	**Non-support**	**Watch list**	**Watch list**	**Watch list**	Support	**Non-support**	Support	Support

1 - Median values of proposed Lake Habitat criteria and number and % of samples exceeding the base aquatic life OMZA criterion.

2 - Narrative descriptions include; ‘Non-support’ which indicates the proposed LH use in not supported, ‘Watch List’ values will be factored into the prioritization process for the lake to receive additional monitoring, and ‘Support’ which indicates the proposed LH use is supported.

3 – Below detection limit

Public Drinking Water Supplies

The public drinking water supply (PDWS) 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. The 2012 Integrated Water Quality Report describes this methodology and is available on OEPA's website:

http://www.epa.state.oh.us/dsw/tmdl/OhioIntegratedReport.aspx.

Impaired source waters may contribute to increased human health risk or treatment costs. For the case when stream water is pumped to a reservoir, the stream and reservoir will be 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. Only one public water system, Wilmington, is directly served by surface water sources within the study area. Wilmington has intakes on Caesar Creek Lake and Cowan Creek. Table 20 provides a summary of water quality data collected to assess the PDWS use.

City of Wilmington

The city of Wilmington operates a community public water system that serves a population of approximately 12,550 people through 4,987 service connections. The water system's treatment capacity is approximately 3.7 million gallons per day, but current average production is 1.52 million gallons per day. Treatment processes include lime softening, coagulation, flocculation, sedimentation, fluoridation, rapid sand filtration, and disinfection. In addition, permanganate is added for iron and manganese removal and powdered activated carbon can be added when necessary for additional treatment.

The public water system obtains its water from Caesar Creek Lake and Cowan Creek. This report focuses on an evaluation of Caesar Creek Lake since Cowan Creek is located in the adjacent Todd Fork watershed and will be assessed during the next survey in that basin. Caesar Creek Lake serves as the primary surface water source for Wilmington's public water system. The Caesar Creek Lake water system intake is located near Harveysburg, slightly more than four river miles from the mouth. The average fall of Caesar Creek (mainstem of Caesar Creek Lake) from headwaters to the intake is 10.6 feet per mile. Caesar Creek Lake is approximately 11 miles in length with a drainage area of 237 mi^2 above the dam, ultimately flowing into the Little Miami River. The primary land use in the watershed is row crop agriculture (70%), followed by hay and pasture (20%).

Ohio EPA collected samples at the Caesar Creek intake for a total of eleven sampling events in 2011, 2012, and 2013. To assess the PDWS beneficial use, samples were analyzed for nitrate and pesticides. Samples were collected in the lake at multiple depths and at the raw water intake. Nitrate ranged from 0.10 mg/L to 3.53 mg/L and averaged 1.53 mg/L. All results were well below the water quality criterion. Atrazine ranged from 0.54 to 5.23 ug/L, with two samples exceeding the WQS criterion of 3.0 ug/L and one quarterly average exceeding the water quality criterion. Caesar Creek Lake will be placed on the watch list for pesticides since at least one quarterly average was greater than the water quality criterion. Since Wilmington has the capacity to blend water from multiple sources and add carbon for pesticide removal, finished (treated) water sampling data are not indicative of source water quality and cannot be used to assess the PDWS beneficial use.

Caesar Creek Lake experienced a harmful algal bloom in December 2011. *Anabaena* was the dominant cyanobacteria genus present. Cyanotoxins were not detected in raw or finished drinking water samples collected in response to the bloom, however low levels of microcystin were detected in a surface sample collected by the U.S. Army Corps of Engineers at a sampling location on the opposite shore of the lake. Even though toxins were not detected at the intake, the water system temporarily transitioned to their alternate Cowan Creek water source as a precaution until the cyanobacteria bloom dissipated.

Table 20. Summary of available water quality data for parameters of interest at public water supply intake sampling sites.

Location(s)	**PDWS Parameters of Interest**				
	Nitrate-Nitrite WQC = 10 mg/L[1,3]		**Atrazine WQC = 3.0 ug/L[2,3]**		
	Average (sample count)[5]	**Maximum (# samples >WQC)**	**Average (sample count)**	**Maximum Quarterly Average[4]**	**Maximum Single Detection**
Wilmington's Caesar Creek Lake Intake	1.53 mg/L n=27	3.53 mg/L (0)	2.16 ug/L n=11	**5.13 ug/L**	5.23 ug/L

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.

3 Insufficient data available to assess the PDWS beneficial use. Need at least ten samples collected and the critical spring runoff period represented.

4 Spring quarter atrazine concentrations in 2012 exceeded the WQC and place Caesar Creek Lake on an atrazine watch list.

5 Nine sampling dates, samples were collected at 2-3 discrete depths on each sampling day.

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Report preparation and analysis:	Angela Dripps, Robert Miltner, Heather Raymond, Louise Snyder, Mary Mahr, Hugh Trimble, and Greg Buthker
Data support:	Dennis Mishne
Reviewers:	Jeff DeShon, Holly Tucker, Diana Zimmerman

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*citations pertaining to Materials and Methods are located following that section in the Appendices to the Upper Little Miami River Biological and Water Quality Report.