Ohio Environmental Protection Agency

Biological and Water Quality Study of the Bokes Creek Basin, 2013

Logan, Union and Delaware Counties

OHIO EPA Technical Report EAS/2015-04-03

Division of Surface Water

May 1, 2015

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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 also to determine if the use is meeting the goals of the federal Clean Water Act. In 2013, eight streams in the Bokes Creek survey area, located in Logan, Union and Delaware counties, were evaluated for aquatic life and recreation use potential (Table 1).

The 2013 survey largely mirrored work done in the Bokes Creek watershed in 1999. Two additional direct tributaries to the Scioto River were assessed for proper aquatic life use (ALU) designation and attainment status. All of the sites sampled were evaluated based on the Warmwater Habitat (WWH) use except for the upstream sites on Bokes Creek (RM 36.30) and North Fork West Mansfield Tributary (RM 5.58) which are designated Modified Warmwater Habitat (MWH). The appropriateness of the current aquatic life uses were confirmed for all previously sampled stream segments. Additionally, the WWH ALU was verified for Moors Run and Prairie Run.

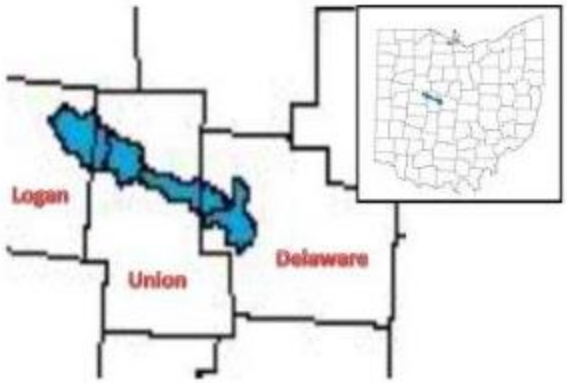


Figure 1. Location of Bokes Creek watershed, Ohio.

The Ohio EPA produced a Total Maximum Daily Load (TMDL) report in 2002 based on sampling done in 1999. The TMDL report (Ohio EPA, 2002) described the study area, causes and sources of impairment, and pollutant reductions needed for attainment of applicable aquatic life and recreational uses. Excessive nutrients impacted the entire watershed in 1999. Additionally, sedimentation, habitat alterations and tile drainage reduced nutrient assimilative capacity of surveyed streams. Row crop agricultural and large scale confined animal feeding operations with the resultant manure management issues were the primary sources of impact. The unsewered community of Magnetic Springs was a source of organic enrichment and bacterial contamination.

In 2013, fourteen years after the last comprehensive assessment of Bokes Creek, modest ecological improvement was documented in the watershed. Of the 20 biological stations assessed, 10 sites (50%) were fully meeting the designated ALU, 5 (25%) were partially attaining, and 5 (25%) were not attaining (Figure 3; Table 2).

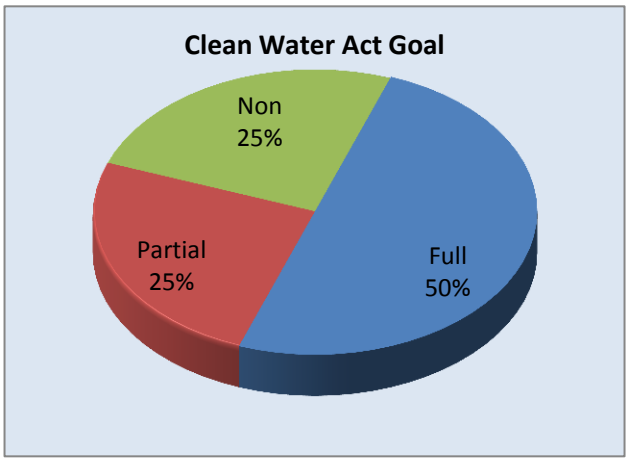


Figure 2. 50% of the sites sampled in the Bokes Creek study area met their designated aquatic life use biocriteria.

Repeat sampling of fifteen sites allowed for a direct comparison of contemporary conditions with those of the earlier survey (Figure 3). In 1999, none of nine headwater sites (<20 mi.^{2} drainage) met aquatic life use expectations. The 2013 survey produced one site in full attainment of the designated ALU. Five sites partially met and three headwater sites did not meet

expectations. Five of six wadeable sites sampled both years on Bokes Creek were fully attaining the WWH use in 2013; the remaining sites partially met the ALU. This same group of sites had one site in full attainment, four partially attaining and one site that failed to meet the WWH use in 1999. More than 70% of the Bokes Creek mainstem sampling locations were fully meeting their designated aquatic life use in the 2013 assessment. Drought conditions in 1999 resulted in reduced flows with several sites completely dry or with no perceptible surface flow. More water in the system in subsequent years offered for deeper pool and riffle depths and a more heterogeneous habitat; enabling the establishment of a more diverse fish community and produced invertebrate community index (ICI) scores in the good to exceptional range at several locations that previously had little to no flow.

Significant portions of the study area remain impaired by nutrients, are typified by substrates that are smothered by siltation, or have a sub-par habitat incapable of supporting robust stream ecology and associated nutrient assimilation. A diel dissolved oxygen swing in excess of 20 ppm documented at RM 23.20 (Bitler Rd.) and 2013 nutrient concentrations that were elevated above 1999 levels in the lower eleven miles of Bokes Creek indicate that the ecological recovery documented in the mainstem is tenuous.

Nine locations in the Bokes Creek study area were tested for *Escherichia coli* bacteria five to eight times apiece in 2013 during the designated annual recreation season (May 1 through the end of October). High bacteria concentrations were found in streams throughout the study area. Each of the nine locations tested had *E. coli* in excess of the geometric mean recreation use criterion, often by a wide margin. The recreation use attainment status of each Bokes Creek watershed sampling location is outlined in Table 11.

Chemical water quality parameters were measured at 20 locations. There were no metals WQS criteria exceedances. Nutrient concentrations (ammonia, TP, and TKN) in 2013 were reduced compared to 1999 for Bokes Creek headwaters sites and in the North Fork West Mansfield Tributary subwatershed. Conversely, the lower third of the Bokes Creek mainstem, particularly RMs 11.37 and 5.55, had consistently higher nutrient concentrations in 2013 than in 1999. Most of the sediment samples from Bokes Creek and tributary sites were free from contaminants in concentrations that affect aquatic life. However, in a subset of sampling locations, several metals were present in concentrations exceeding reference guidelines. Sediment nutrients were present in excess of the Lowest Effect Level at all sampling locations (Table 12).

Table 1. Bokes Creek watershed sampling locations from the Ohio EPA 2013 survey.

Site Number*	Stream Name /Location	River Mile	Drainage Area (Mi^2)	Longitude	Latitude
1	MOORS RUN N OF WARRENSBURG @ S.R. 257	0.32	5.60	40.31879	-83.17459
2	PRAIRIE RUN N OF WARRENSBURG @ S.R. 37	0.07	5.60	40.32203	-83.16781
3	BOKES CREEK NW OF HORTON @ C.R. 292	36.30	4.70	40.46420	-83.58110
4	BOKES CREEK NEAR HORTON @ C.R. 120	35.10	7.10	40.45610	-83.56690
5	BOKES CREEK @ WEST MANSFIELD-MT. VICTORY RD.	31.80	11.40	40.44060	-83.52780
6	BOKES CREEK @ HOOVER-MOFFITT RD.	28.40	34.00	40.42500	-83.48430
7	BOKES CREEK E OF YORK CENTER @ BITLER RD.	23.20	44.00	40.40810	-83.42750
8	BOKES CREEK SE OF YORK CENTER @ YEARSLEY RD.	21.29	46.00	40.39080	-83.41250
9	BOKES CREEK ADJ. S.R. 31, UPST BRUSH RUN/DST POWDER LICK RUN	20.20	51.00	40.38080	-83.40740
10	BOKES CREEK @ FORD REED RD.	16.58	58.00	40.36220	-83.37470
11	BOKES CREEK N OF MARYSVILLE @ S.R. 4	11.37	63.00	40.34837	-83.30379
12	BOKES CREEK DST. MAGNETIC SPRINGS @ BROWN RD.	5.55	72.00	40.33920	-83.24390
13	BOKES CREEK N OF WARRENSBURG @ S.R. 257	0.25	83.10	40.32210	-83.17500
14	BRUSH RUN S OF SOMERSVILLE @ YEARSLEY RD.	0.60	2.60	40.37440	-83.41690
15	POWDER LICK RUN NEAR MOUTH, 100 YDS. DST. YEARSLEY RD.	0.17	4.10	40.38560	-83.41390
16	N. FK. WEST MANSFIELD TRIBUTARY @ FARM LANE OFF C.R. 26	5.58	3.70	40.42890	-83.57060
17	N. FK. WEST MANSFIELD TRIBUTARY @ C.R. 142	3.96	8.00	40.42140	-83.54330
18	N. FK. WEST MANSFIELD TRIBUTARY @ JANUARY RD.	1.28	11.40	40.41920	-83.50750
19	W. FK. WEST MANSFIELD TRIBUTARY NEAR YORK CENTER @ S.R. 47	0.78	6.10	40.41250	-83.50750
20	SMITH RUN NW OF WARRENSBURG, UPST. BRINDLE RD.	0.80	5.50	40.32190	-83.20250

*The color of the site number corresponds to the narrative biological score (blue is exceptional to very good (meets EWH goals), green is good to marginally good (meets WWH goals) yellow is fair, orange is poor and red is very poor (fair, poor and very poor do not meet the goals of WWH).

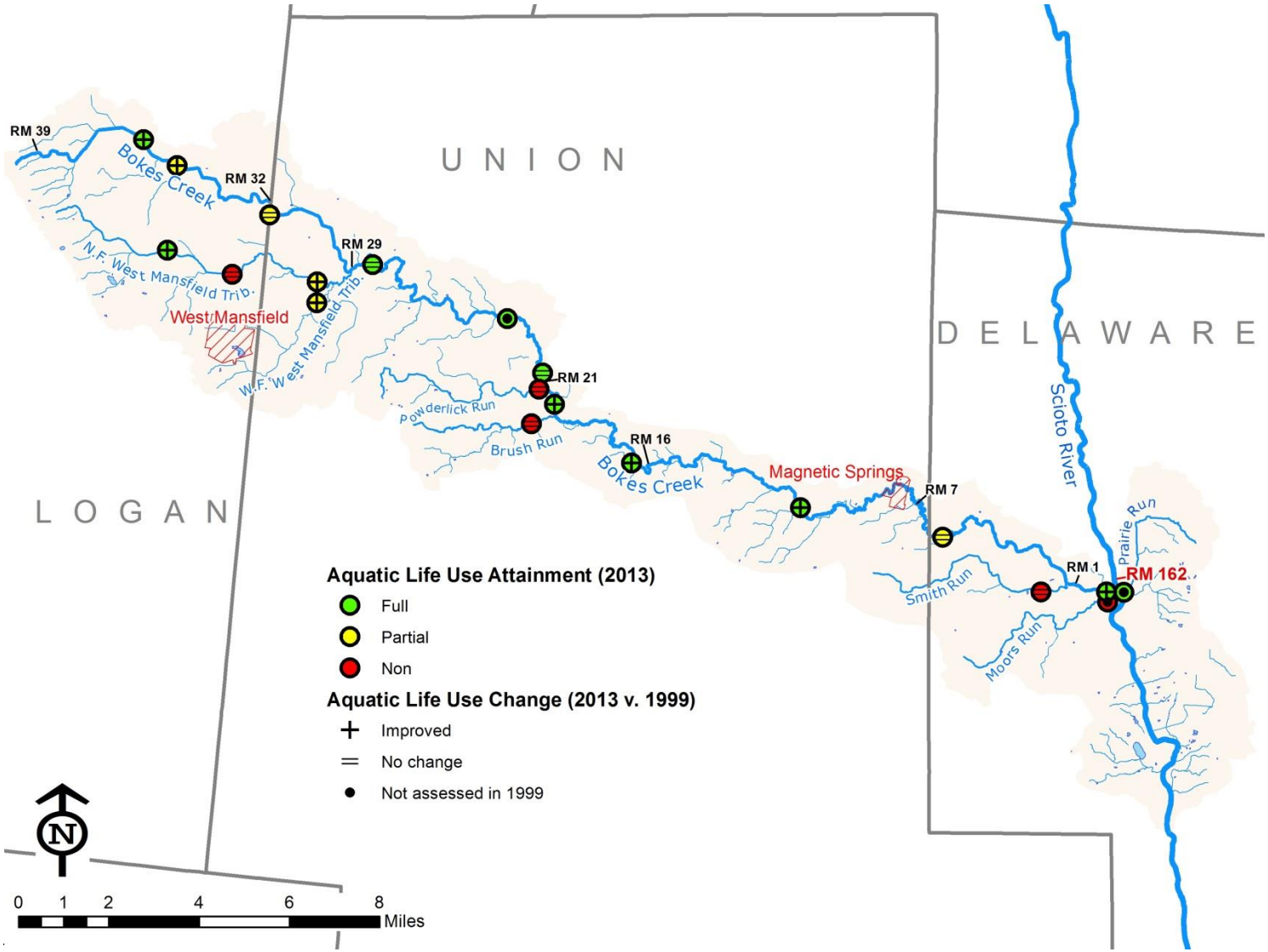


Figure 3. Aquatic life use attainment status of sites in the Bokes Creek study area, 2013 and applicable changes in attainment status versus conditions encountered in 1999.

Table 2. Aquatic life use attainment status for stations sampled in the Bokes Creek study area based on data collected June-October 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 of the stream to support a biotic community. Bokes Creek is located in the Eastern Corn Belt Plains (ECBP) ecoregion. If biological impairment has occurred, the cause(s) and source(s) of the impairment are noted. NA = not applicable.

Stream/ Location	Station Code	River Mile[a]	Drainage (mi^2)	IBI	MIwb[b]	ICI[c]	QHEI	Status	Cause	Sources
Moors Run (02-136-000) WWH existing										
@ S.R. 257	302208	0.32	5.60	30*		Fair	77.30	NON	Nutrient enrichment	Agriculture
Prairie Run (02-136-000) WWH existing										
@ S.R. 37	302209	0.07	5.60	38^{ns}		N/A	80.00	(FULL)		
Bokes Creek (02-136-000) MWH existing										
@ C.R. 292	V02K08	36.30	4.70	38		Fair	53.00	FULL		
Bokes Creek (02-136-000) WWH existing										
@ C.R. 120	V02K07	35.10	7.10	32*		MG	63.00	PARTIAL	Nutrient enrichment Sedimentation/ siltation	Agriculture
@ WEST MANSFIELD-MT. VICTORY RD.	V02K06	31.80	11.40	34*		MG	44.00	PARTIAL	Nutrient enrichment Sedimentation/ siltation	Agriculture
@ HOOVER-MOFFITT RD.	V02W04	28.40	34.00	39^{ns}	8.23^{ns}	40	77.50	FULL		
@ BITLER RD.	203100	23.20	44.00	36^{ns}	7.80^{ns}	Good	58.00	FULL		
@ YEARSLEY RD.	V02S22	21.29	46.00	43	8.55	40	68.30	FULL		
ADJ. S.R. 31, UPST BRUSH RUN/DST POWDER LICK RUN	V02K05	20.20	51.00	42	8.09^{ns}	40	73.00	FULL		
@ FORD REED RD.	V02K04	16.58	58.00	44	9.05	36	77.80	FULL		

Stream/ Location	Station Code	River Mile[a]	Drainage (mi^2)	IBI	MIwb[b]	ICI[c]	QHEI	Status	Cause	Sources
@ S.R. 4	V06P10	11.37	63.00	42	8.20[ns]	42	73.25	FULL		
@ BROWN RD.	V02S20	5.55	72.00	42	6.86*	44	84.30	PARTIAL	Nutrient and organic enrichment	Agriculture, Unsewered Community
@ S.R. 257	V06P09	0.25	83.10	48	9.29	44	87.80	FULL		
Brush Run (02-136-000) WWH existing										
@ YEARSLEY RD.	V02W27	0.60	2.60	34*		Fair	60.30	NON	Nutrient enrichment Sedimentation/ siltation	Agriculture
Powderlick Run (02-136-000) WWH existing										
DST. YEARSLEY RD.	V02W25	0.17	4.10	44		Poor	45.50	NON	Nutrient enrichment biological indicators, Organic enrichment (sewage) biological indicators, Sedimentation/ siltation	Agriculture, Manure runoff
North Fork West Mansfield Tributary (02-136-000) MWH existing										
@ FARM LANE OFF C.R. 26	V02K14	5.58	3.70	34		MG	30.00	FULL		
North Fork West Mansfield Tributary (02-136-000) WWH existing										
@ C.R. 142	V02K13	3.96	8.00	32*		Poor	52.50	NON	Nutrient enrichment Sedimentation/ siltation	Agriculture, Channelization, Manure runoff
@ JANUARY RD.	V02K12	1.28	11.40	30*		MG	73.00	PARTIAL	Nutrient enrichment Sedimentation/ siltation	Agriculture Animal feeding operations

Stream/ Location	Station Code	River Mile[a]	Drainage (mi^2)	IBI	MIwb[b]	ICI[c]	QHEI	Status	Cause	Sources
West Fork West Mansfield Tributary (02-136-000) WWH existing										
@ S.R. 47	601160	0.78	6.10	40		Fair	64.30	PARTIAL	Nutrient enrichment Sedimentation/ siltation	Agriculture Onsite treatment systems (septic systems) Impacts from land application of wastes
Smith Run (02-136-000) WWH existing										
UPST. BRINDLE RD.	203120	0.80	5.50	26*		Fair	73.50	NON	Nutrient enrichment	Agriculture

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

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

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

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

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

Biological Criteria Eastern Corn Belt Plains			
Index – Site Type	**EWH**	**WWH**	**MWH**
IBI – Headwaters	50	40	24
IBI – Wading	50	40	24
IBI – Boat	48	42	24
MIwb – Wading	9.4	8.3	6.2
MIwb – Boat	9.6	8.5	5.8
ICI	46	36	22

Beneficial Use Designations and Recommendations

The streams in the Bokes Creek study area currently listed in the Ohio Water Quality Standards (WQS) are assigned the Warmwater Habitat (WWH) and Modified Warmwater Habitat-Channel Modification (MWH-C) aquatic life use designations. The aquatic life use designations of all streams sampled during this survey were verified in past surveys with the exception of two direct Scioto River tributaries. Moors Run and Prairie Run were originally designated for aquatic life use in the 1978 Ohio WQS but the techniques used then did not include standardized approaches to the collection of instream biological data or numerical biological criteria. This study used biological data to evaluate and establish aquatic life uses.

Eight streams in the Bokes Creek watershed were evaluated for aquatic life and recreational use status in 2013 (Table 3). Significant findings include the following**:**

- Aquatic life uses should be maintained for all previously designated WWH and MWH-C stream reaches. The WWH designation applies to: Bokes Creek downstream from RM 37.30, Smith Run, Brush Run, Powderlick Run downstream from RM 3.0, North Fork West Mansfield Tributary downstream from RM 4.51, and the West Fork of the West Mansfield Tributary. The MWH-C designation applies to: Bokes Creek from RM 37.30 to 35.51 and the headwaters of North Fork West Mansfield Tributary downstream to RM 3.0.

- Biological and habitat assessments confirmed the WWH use designation for Moors Run and Prairie Run.

- Bokes Creek, Smith Run, Brush Run, Moors Run and Prairie Run should retain the Primary Contact Recreation use (Class B). Additionally, Powderlick Run and named streams in the North Fork West Mansfield Tributary watershed should be redesignated Primary Contact Recreation Class B to be consistent with current protocols concerning streams with the potential for occasional recreational activity. The Agricultural Water Supply and Industrial Water Supply uses apply to all the study area streams.

The 2002 TMDL report identified specific opportunities for improving on impairments affecting the Bokes Creek basin; impairments included nutrient enrichment, low instream dissolved oxygen, sedimentation and habitat degradation and bacteria. Instream dissolved oxygen levels were not seen as a cause of impairment in 2013; however, a number of low dissolved oxygen readings were recorded. Nutrient enrichment, sedimentation, habitat degradation and bacteria continue to impact the Bokes Creek watershed and need to be addressed.

Outreach efforts to the local farming community should be continued to encourage best management practices (BMPs) aimed at addressing the effects of agricultural activities on water quality. Particular attention should be paid to livestock operations which significantly contribute to nutrient impacts noted during the survey. The timing and rates of manure disposal on the landscape are of particular concern given the potential to affect nutrient loadings. The effectiveness of controlled drainage systems should be investigated as a way to manage discharge flows and nutrient transport and to determine their applicability for agricultural fields that receive commercial fertilizer versus manure applications.

All of the streams in the study area were affected in all or parts of their reaches by agricultural runoff, sedimentation, and direct habitat alterations. Re-establishing natural riparian buffers (wetland and wooded riparian corridors) in the watershed to help slow storm water and filter pollutants before they reach surface waters are positive mechanisms to reduce polluted agricultural runoff. In addition to restoring riparian buffers, an effort to restore the natural assimilative capacity of streams would lessen pollutant impacts. Natural development of stream channels provide an array of beneficial services including settling fine sediments into adjacent floodplains, processing of nutrients into productive biomass instead of nuisance algae, improvement of water quality, creation of natural instream habitats to increase carrying capacity of biomass, and ultimately evolution into a stable channel and the slowing of erosion.

Livestock production and resultant manure handling practices were identified as a pervasive source of bacterial contamination along with insufficient sewage treatment from the unsewered community of Magnetic Springs as a second, more localized, source. Bacteria levels can be addressed by managing manure applications throughout the watershed. Inadequately treated sewage in the vicinity of Magnetic Springs requires that local and/or county entities develop a specific plan to address this environmental and public health issue.

Table 3. Waterbody use designation recommendations for the Bokes Creek watershed. 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												Comments
		Aquatic Life Habitat						Water Supply			Recreation		
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
Moors run		+*							+*	+*		+*		
Prairie run		+*							+*	+*		+*		
Bokes creek - RM 35.51 (0.66 river miles downstream of st. rte.292) to				+					+	+		+		ECBP ecoregion - channel modification
RM 37.30 (1.13 river miles upstream of st. rte. 292)														
- all other segments		+							+	+		+		
Smith run		+							+	+		+		
Brush run		+							+	+		▲		
Powderlick run - headwaters to RM 3.0 (0.35 river miles														Small drainageway maintenance
downstream of st. rte. 739)							+		+	+		▲		
- all other segments		+							+	+		▲		
North Fork West Mansfield tributary - headwaters to RM 4.51														ECBP ecoregion - channel modification
(0.15 river miles upstream of Conrail railroad tracks)				+					+	+			+	
- all other segments		+							+	+			+	
West Fork West Mansfield tributary		+							+	+			+	
East Fork West Mansfield tributary		+							+	+			+	

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

Introduction

During 2013, Ohio EPA conducted a water resource assessment of eight streams in the Bokes Creek study area using standard Ohio EPA protocols as described in Appendix F. Included in this study were assessments of the biological, surface water and recreational (bacterial) condition. A total of 20 biological, 20 water chemistry, and 9 bacterial stations were sampled in the Bokes Creek study area. Summarized biological and raw chemical and bacterial results can be viewed in appendices B, C, D, E and G.

Specific objectives of the evaluation were to:

- monitor and assess the chemical, physical, and biological integrity of the water bodies within the Bokes Creek watershed study area,
- assess physical habitat influences on stream biotic integrity,
- determine recreational water quality,
- evaluate the appropriateness of existing use designations and assign uses to undesignated streams (Moors Run and Prairie Run, both of which are direct tributaries to Scioto River),
- characterize the amount of aquatic resource degradation attributable to various land uses, including agricultural practices, and urbanization,
- determine any aquatic impacts from known potential sources, including point source dischargers, and from unsewered communities,
- collect samples for the Ohio Sport Fish Consumption Advisory program (used to assess chemical contaminant levels in fish), and
- follow-up on the 1999 survey data and 2002 TMDL recommendations http://epa.ohio.gov/dsw/tmdl/SciotoRiver.aspx.

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, TMDLs and the biennial Integrated Water Quality Monitoring and Assessment Report (305[b] and 303[d] report).

Results

Water Chemistry

Sampling Rationale and Methods

Chemical sampling took place from late spring to early fall 2013 during the same general timeframe and at the same locations where biological sampling was being performed. Chemical sampling took place at 20 Bokes Creek and tributary sites and the nearby direct Scioto River tributaries of Prairie Run and Moors Run.

Surface water chemical data is used in this report to illuminate potential causes and sources of impairment to aquatic life use or recreation use. These designated beneficial uses provide for a robust aquatic ecosystem and safe human recreation. Specific beneficial use designations, i.e. Warmwater Habitat or Primary Contact Recreation, are localized, codified applications of the more general 'biological integrity' and 'fishable and swimmable' standards established by the Clean Water Act. Furthermore, newly collected chemical data was used to make comparisons to a similar chemical dataset collected during the last watershed-scale assessment in 1999. Comparing similar data across time can either document water quality improvement or identify specific problem areas where additional conservation efforts are warranted.

Bokes Creek summer 'field season' chemical sampling in 2013 was carried out in five passes (four three-day sampling runs and one two-day sampling run) on the following dates: June 10-12, June 25-27, July 9-11, July 30-August 1 and August 14-15. Each of the 14 sampling dates included visits to six or seven stream sites apiece.

Sampling sites were typically located at or near bridge crossings. At these sites, water samples were collected in free flowing sections of the stream within close proximity to the bridge or in some cases to an adjacent road. Wherever possible, sampling sites were kept consistent with previous Ohio EPA studies. All water samples were collected using procedures and materials outlined in the guidance document *Surface Water and Field Sampling Manual for water column chemistry, bacteria and flows* (Ohio EPA 2013). Shortly after collection, all samples were delivered to the Ohio EPA Division of Environmental Services for laboratory analysis.

Types of Water Chemistry Data Collected

Most of the surface water samples were analyzed following a specific laboratory template ("Stream Survey") that includes tests for nutrients, alkalinity, suspended and dissolved solids, and chemical oxygen demand (COD). At select stream locations, known as *sentinel sites*, samples were analyzed for additional parameters such as bacteria, metals, orthophosphate and 20-day biochemical oxygen demand (CBOD-20). Stream temperature, pH, conductivity, dissolved oxygen (D.O.), and percent D.O. saturation were measured within the stream during each sample collection using a handheld meter.

Multiprobe water quality recorders were also deployed at 14 locations along Bokes Creek, North Fork West Mansfield Tributary and Smith Run over a 48-hour period to monitor diel levels of dissolved oxygen, pH, temperature, and conductivity. During the multiprobe deployment timeframe, benthic and sestonic (water column) chlorophyll-*a* concentrations were measured at five sites. Select multiprobe and chlorophyll-a results are included in Chemistry Results and Discussion by HUC-12 section below; for a complete presentation of these data and a more detailed discussion of this data, see Water Quality Sonde Exceedance Summary section below.

E. coli samples were collected during the designated recreation season of May 1 through October 31, 2013 and compared to the Ohio Recreation Use Water Quality Standards criteria. During that timeframe, stream samples intended for bacterial analysis were collected during the same sampling events as samples that were analyzed for other chemistry parameters. Bacteria samples were collected at nine locations, all of which were found to be in non-attainment of the applicable WQS criterion. Bacteria data are more specifically discussed in the Recreation Use portion of this report.

Water Quality Standards Criteria Exceedances

The concentrations of certain chemicals and physical parameters in surface water are subject to the Ohio WQS outlined in OAC 3745-1. The only WQS exceedances in the Bokes Creek watershed were for D.O. criteria, and those are outlined in Table 4 below. D.O. concentrations were compared to both aquatic life use Outside Mixing Zone Minimum (OMZM) and Average (OMZA) criteria (4.0 and 5.0 mg/l respectively for WWH). The magnitude of an exceedance is presented as the most extreme value measured that exceeds the criteria. The count of consecutive exceedances and the proportion of samples which exceeded the criteria are listed in parentheses. All exceedances were observed during a two-day deployment on Sept. 4th-6th 2013. *E. coli* exceedances of the Recreation Use criteria are presented separately in the Recreation Use Section.

Table 4. Exceedances of Ohio Water Quality Standards aquatic life use criteria (OAC3745-1) for chemical/physical parameters measured in the Bokes Creek study area, 2013. Dissolved oxygen values exceeded the WWH aquatic life use Outside Mixing Zone Minimum criterion unless otherwise noted.

Stream/RM	**Location**	**Chemical Parameter (mg/l)**
Bokes Creek Headwaters HUC-12 (05060001-07-01), *WWH Existing*		
35.1	Bokes Creek near Horton at C.R. 120	D.O. minimum: **2.87** (14 hrs exceed, of 45 total readings: 31%) D.O. average: **4.23**
31.8	Bokes Creek at W. Mansfield - Mt. Victory	D.O. minimum: **0.92** (30 hrs exceed, of 47 total readings: 64%) D.O. average: **3.32**
Brush Run Bokes Creek HUC-12 (05060001-07-02), WWH Existing		
21.29	Bokes Creek at Yearsley Road	D.O. minimum: **3.35** (6 hrs exceed, of 45 total readings: 13%) D.O. average: **4.53**

For nutrients, Ohio EPA has developed benchmark concentrations based on decades of ecological monitoring and incorporating statistical analysis of many thousands of biological and chemical data. These *targets*, discussed in sections below, are not WQS criteria; however they can be used to identify where a stream may be impaired or susceptible to future degradation in water quality due to nutrient enrichment.

Nutrient Enrichment and Nutrient Targets

Nutrient enrichment is one of the most important and widespread drivers of diminished surface water quality in Ohio today, and the Bokes Creek watershed is no exception. High levels of nutrients can accelerate cycles of primary productivity and decomposition in a body of water to a point where oxygen resources become depleted or harmful byproducts begin to accumulate, i.e., the various toxins released from harmful algae blooms (HABs). Nutrient enrichment affects the usability of Ohio's surface water resources and at the same time negatively impacts the communities of aquatic organisms they contain.

Ohio streams are usually considered to be saturated in nitrate (given here as the sum of nitrate and nitrite, NO_3+NO_2), an inorganic form of nitrogen that is available for direct algal and plant uptake. This means that additional nitrate inputs to a stream do not necessarily equate to additional primary productivity. Elevated concentrations of nitrate are not typically considered the most proximal cause of the ecological impacts stemming from nutrient enrichment, however high nitrate concentrations are a specific concern in relation to human health via public drinking water supplies. Bokes Creek is not used as a municipal public drinking water supply; however the city of Columbus withdraws a significant portion of its drinking water downstream from Griggs Reservoirs on the Scioto River. Recognition that nutrient pollution in headwater streams can affect surface water resources miles downstream is a primary reason why Columbus has become involved in efforts to improve water quality within the Bokes Creek basin, *i.e*. partnering with Ohio EPA and local stakeholders in the *Bokes Creek Water Quality Enhancement Project* in Powderlick Run. More detail on this project can be accessed via the U.S. EPA website: http://www.epa.gov/Region5/agriculture/spotlight200609.html

Total phosphorous (TP) concentration is generally considered the limiting nutrient to algal productivity in surface waters of this region. Ohio streams that have high TP concentrations have been correlated with stream conditions that are dominated by pollution tolerant, less diverse biological communities and vice versa (Ohio EPA 1999). When the biology of a stream such as Bokes Creek has been impaired by nutrient enrichment, a TMDLis developed which often focuses on limiting phosphorous. TMDLs were developed for Bokes Creek following the 1999 watershed assessment (Ohio EPA 2002).

Bokes Creek TMDLs drew upon the same source data and analysis that was used to develop the surface water nutrient concentration targets recommended by Ohio EPA in the 1999 report *Association Between Nutrients, Habitat and the Aquatic Biota in Ohio Rivers and Streams* (Ohio EPA 1999). Within this document, statewide nutrient targets were established for tiered aquatic life use designations using multiyear data from the period of June 15 through October 15 and serve as a basis of comparison for 2013 Bokes Creek nutrient data.

The statewide nutrient targets for WWH streams of *wadeable* size (drainage area 20 to 200 mi^2) apply to Bokes Creek mainstem sites from the mouth to RM 28.4. Sampling locations upstream from RM 28.4 and all tributary sampling locations are designated *headwater streams* because they have a drainage area less than 20 mi^2 (Table 5). Geometric mean (geomean) Bokes Creek NO_3+NO_2 and TP chemistry data were compared to these targets; any sample results from outside the June 15 through October 15, 2013 timeframe were excluded from the discussion below in order to facilitate a direct comparison between Bokes Creek nutrient data and the established targets. Geomeans are the measure of central tendency used to describe most of the chemical data results within this report because a geomean minimizes the influence of extremely high or low outlier data points. Furthermore, geomeans of chemical data facilitate direct comparison with targets which are given in the form of a geomean. A complete data set, for nutrient and other chemical parameters, can be found in Appendix G.

Table 5. Nutrient, D.O. and *E. coli* Threshold Values for WWH Streams

Parameter	**WWH headwater streams (drainage < 20mi^2)**	**WWH wading streams (20mi^2 < drainage < 200mi^2)**
Total Phosphorous (TP) [1]	0.08 mg/l	0.1 mg/l
Nitrate+Nitrite (NO_3+NO_2) [1]	1.0 mg/l	
Dissolved Oxygen (D.O.) [2,3]	4.0 mg/l (acute), 5.0 mg/l (24-hr avg.), diel range[3] < 7.0 mg/l	
Benthic chlorophyll-a (chl-a)[3]	183 mg/m^2	
E. coli, Recreation Use[2]	161 cfu/100 ml, PC.R. B / 1030 cfu/100 ml SCR	

[1]Ohio EPA 1999 target; [2]Water Quality Standard; [3]Miltner 2010 target

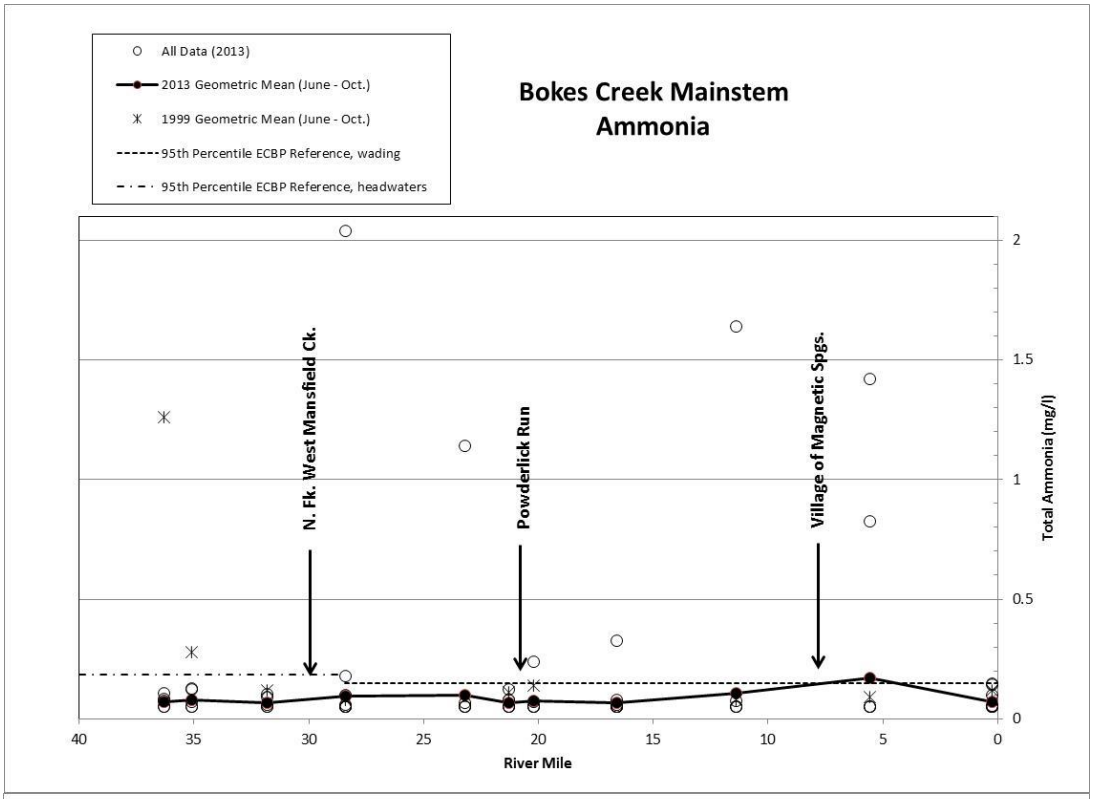
Water Chemistry Results Overview

The last comprehensive assessment by Ohio EPA of the Bokes Creek watershed was carried out in 1999 and found that only 10% of stream sampling locations were meeting aquatic life use criteria, 90% of the sampling locations being in either partial- or non-attainment. Nutrient runoff, organic enrichment and associated dissolved oxygen stressors, combined with habitat and flow alteration, were listed as the predominant causes of aquatic life use impairment in Bokes Creek (Ohio EPA 2001).

In 2010, four Bokes Creek mainstem sites near Powderlick Run and two Powderlick Run sites were included in the assessment of the Middle Scioto River and Select Tributaries. All of the Bokes Creek sites that were assessed were meeting WWH goals (RMs 27.22, 22.23, 20.2, and 14.73) indicating that water quality conditions were improving in an area of Bokes Creek where certain sites had historically been heavily impacted by nutrient and organic enrichment. Assessments of the Powderlick Run sampling locations at RMs 3.4 and 1.2 indicated that aquatic life use at those locations had rebounded compared to the 1999 assessment. Powderlick Run at RM 3.4 was meeting the aquatic life use criteria for LRW. Recovery of the fish community was apparent at RM 1.2, however a poor ICI score drove non-attainment of the WWH use; nutrients, organic enrichment, siltation, embeddedness, and related stressors were cited as the causes (Ohio EPA 2012).

A comparison of 2013 and 1999 sampling results for nutrients that have been linked in the past to the degradation of Bokes Creek biological communities, are presented in Figure 4 and Figure 5. Chemical concentration data is plotted by river mile for total ammonia, total phosphorous (TP), nitrate (NO_3+NO_2) and total Kjeldahl nitrogen (TKN). Individual sampling events are shown as open circles and the 2013 geomean from each site is plotted as a darkened circle. For trend comparison purposes, 1999 geomean concentrations (where available) are shown as an asterisk. Insufficient nitrate data were collected in 1999 for a meaningful trend comparison; therefore 1999 nitrate data are not displayed. Tributary data of the same chemical parameters are presented in a similar fashion in Figure 6 and Figure 7, with each tributary sampling location plotted individually.

The chemical concentration plots illustrate several important spatial and temporal trends in Bokes Creek. Lowered concentrations of nutrients (ammonia, TP, and TKN) were the most evident among the Bokes Creek headwaters sites and in all of the North Fork West Mansfield Tributary sampling locations. Conversely, the downstream-most third of the Bokes Creek mainstem, particularly RMs 11.37 and 5.55, had consistently higher nutrient concentrations in 2013 than in 1999. These two sampling locations are the only Bokes Creek mainstem sites with increased ammonia geomeans in 2013 vs. 1999. In 2013, phosphorous concentrations were higher than those in the 1999 study from RM 28.4 to the mouth.



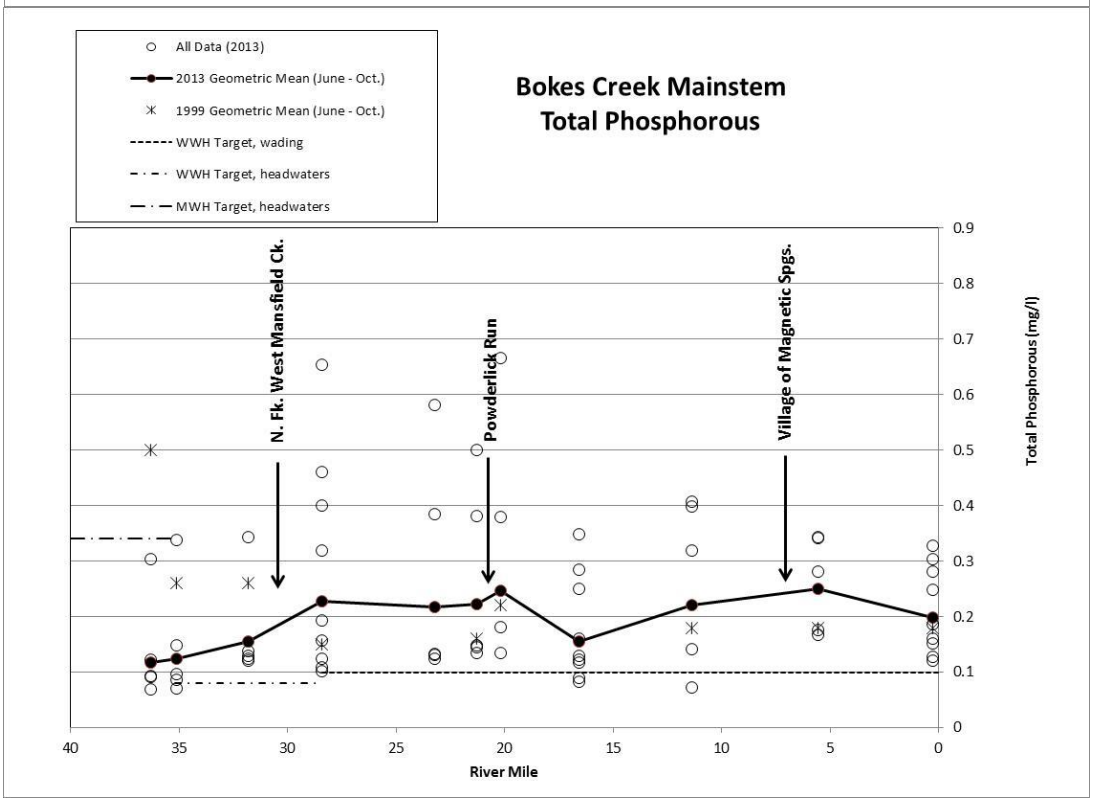
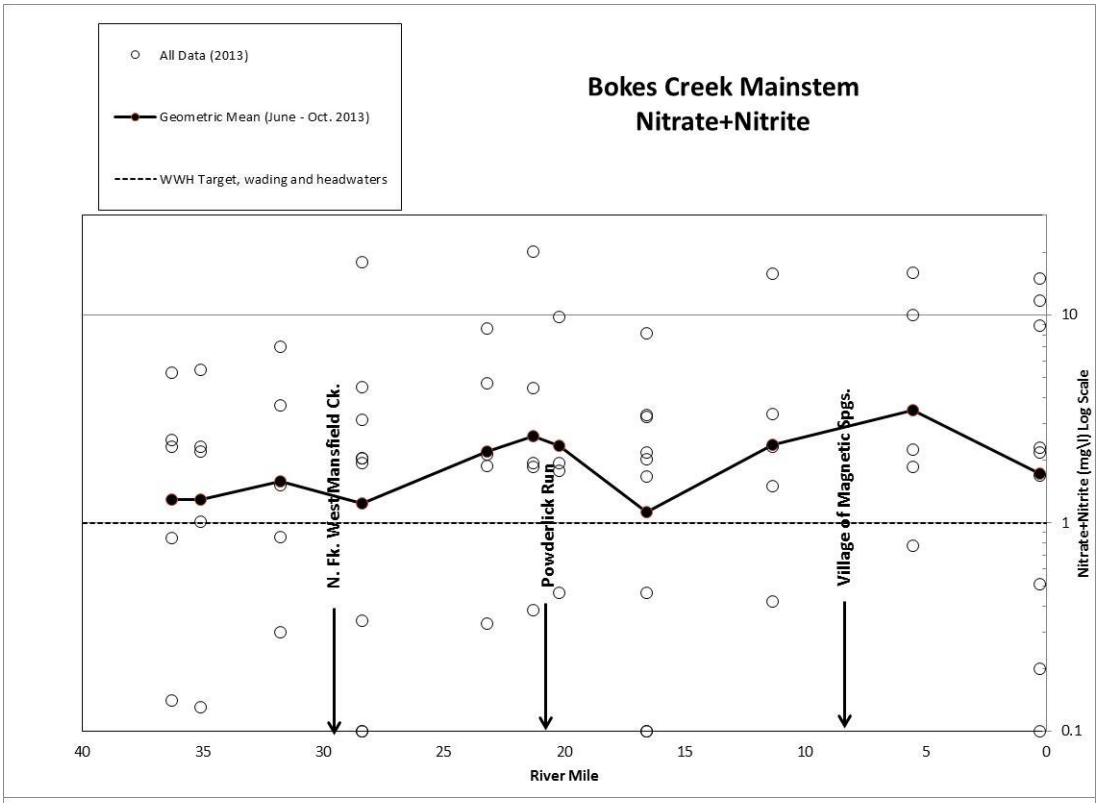


Figure 4. Longitudinal trend of ammonia (mg/l) and total phosphorus (mg/l) concentrations for the Bokes Creek mainstem, 1999 and 2013.



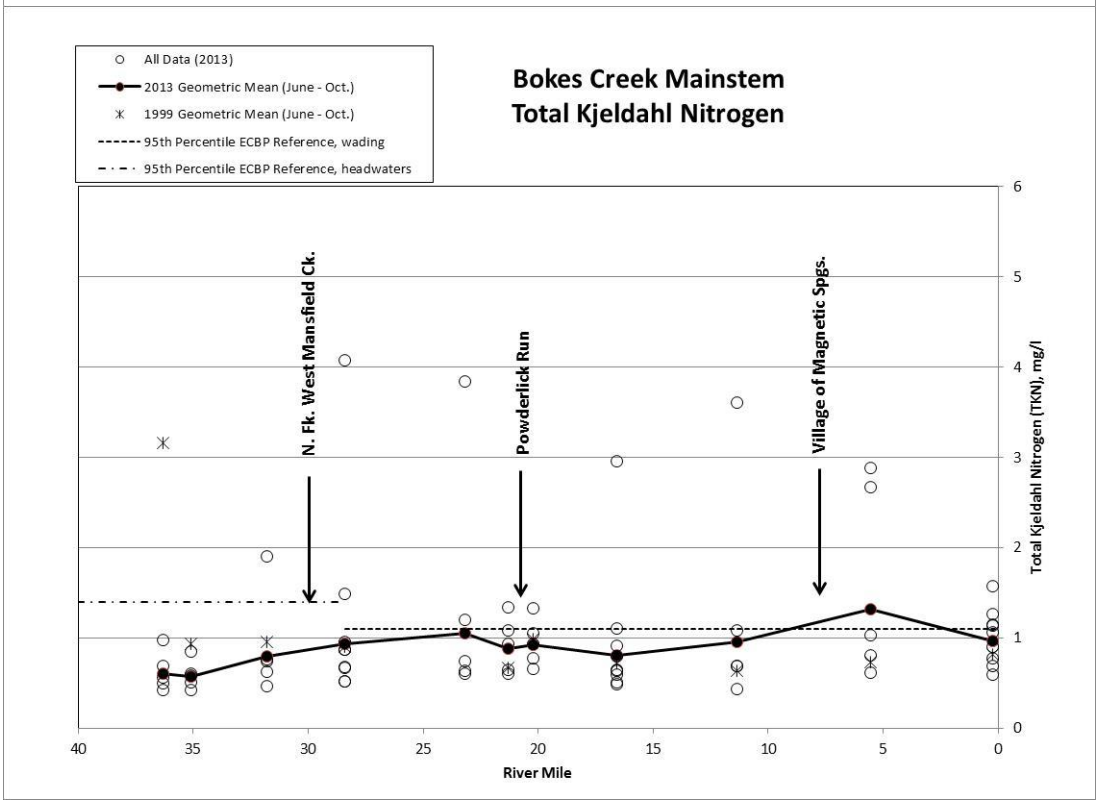


Figure 5. Longitudinal trend of nitrate+nitrite (mg/l) and total Kjeldahl nitrogen (mg/l) concentrations for the Bokes Creek mainstem, 1999 (where available) and 2013.

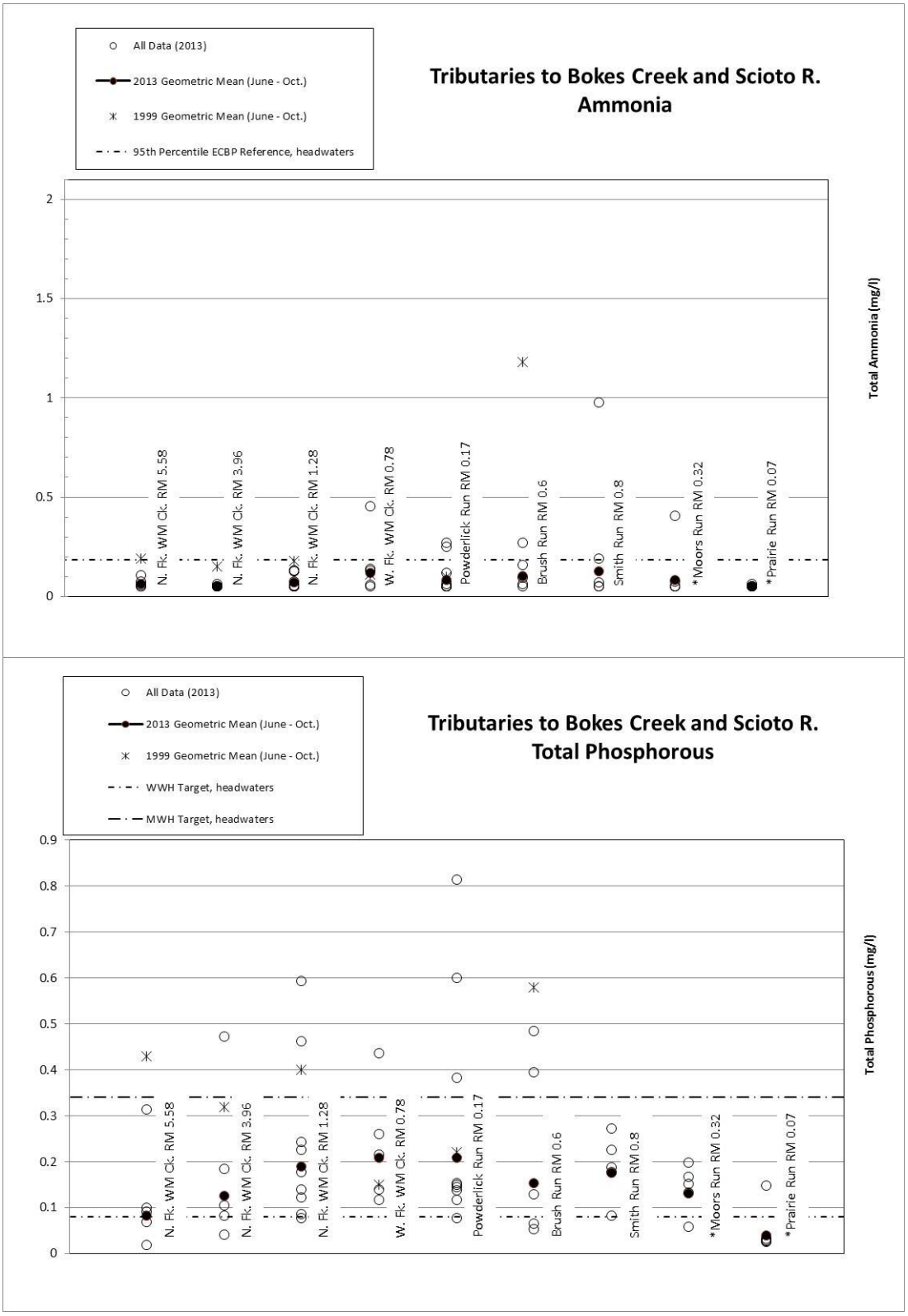


Figure 6. Ammonia (mg/l) and total phosphorus (mg/l) concentrations for tributaries in the Bokes Creek study area listed by sampling location, 2009 (where available) and 2013.

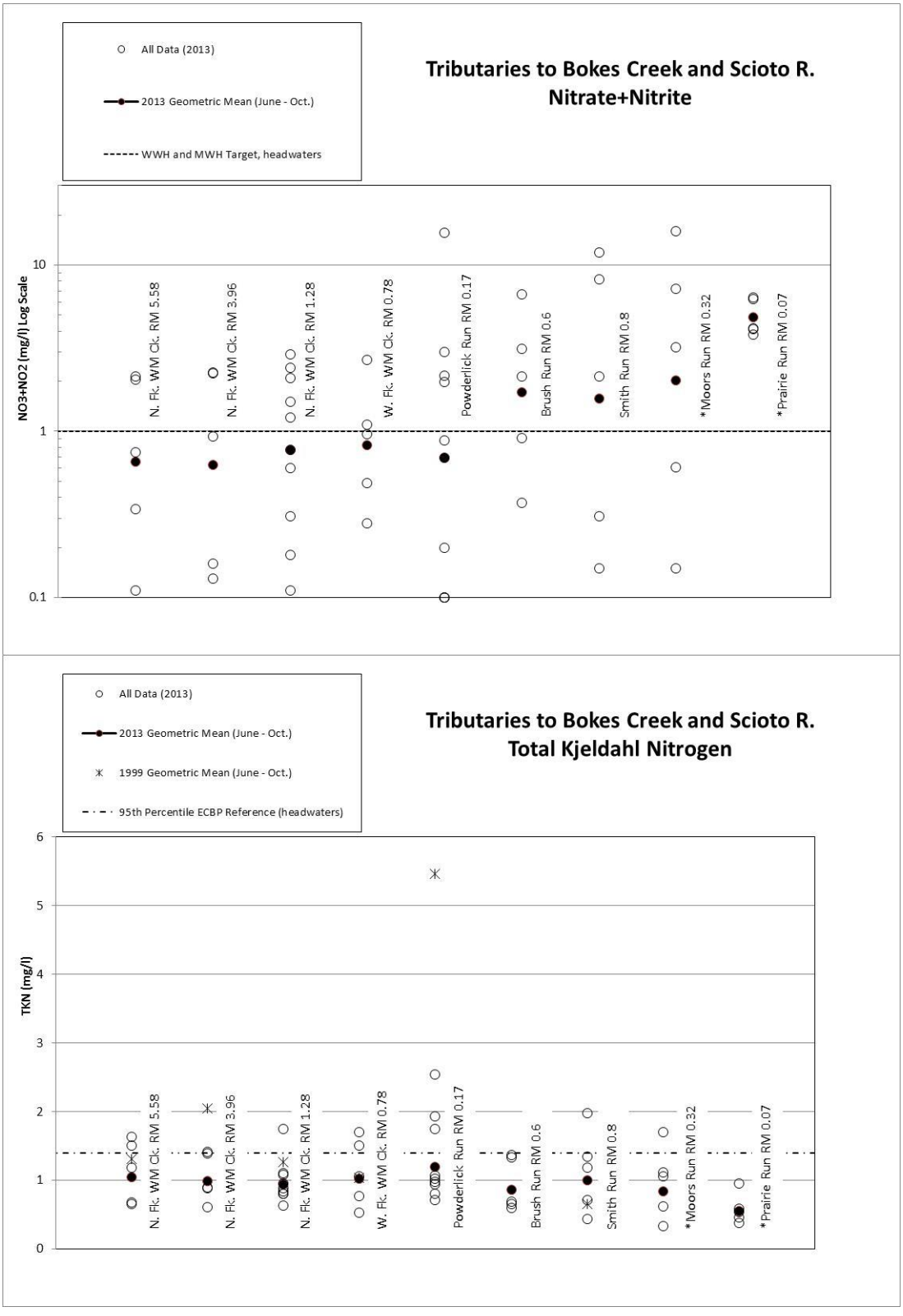


Figure 7. Nitrate+nitrite (mg/l) and total Kjeldahl nitrogen (mg/l) concentrations for tributaries in the Bokes Creek study area listed by sampling location, 2009 (where available) and 2013.

Direct comparisons were made between 1999 and 2013 geometric mean concentrations of several key nutrient parameters (TP, ammonia, nitrate+nitrite, nitrite, TKN) and total suspended solids (TSS) at 16 of the 20 sampling locations in the current study. Tables 6 through 9 are included in the Chemistry Results and Discussion by HUC-12 section below, listing key nutrient geomeans side-by-side within each HUC-12 for the 16 sites that were included in both studies. A comparison of nutrient concentrations between 1999 and 2013 at these locations essentially fit a bell curve; while the bulk of the sampling locations had similar instream nutrient concentrations between study years, about a quarter of the sites showed reductions in key nutrients and about a quarter of the sites had increased concentrations of some or all key nutrient parameters in 2013 when compared to, 1999 data.

The four sites with the greatest overall reduction in water column nutrient concentrations were concentrated in the headwaters: Bokes Creek RM 36.3 (NW of Horton at C.R. 292), Bokes Creek RM 35.1 (near Horton at C.R. 120), N. Fork of West Mansfield Tributary RM 3.96 (C.R. 142) and Powderlick Run RM 0.17. At Powderlick Run RM 0.2, the concentrations of certain nutrients have diminished by as much as 95%. Each of these stream locations showed at least some improvement in fish and macroinvertebrate metrics over time. Bokes Creek RM 36.3 went from non-attainment of MWH in 1999 to full attainment of MWH in 2013.

At the other end of the spectrum, four mainstem sampling locations on Bokes Creek had higher nutrient concentrations in 2013 vs. 1999: Bokes Creek RM 28.4 (at Hoover Moffitt Rd.), Bokes Creek RM 21.29 (southeast of York Center at Yearsley Rd.), Bokes Creek RM 11.37 (at S.R. 4) and Bokes Creek RM 5.54 (downstream Magnetic Springs at Brown Rd.). Despite having higher nutrient concentrations, modest improvements in fish and macroinvertebrate scores were still evident at each of these sites that were sampled in both surveys (excluding Bokes RM 28.4 which was not sampled in 1999).

Select chemistry results and trends are discussed within each HUC-12 sub-watershed below, beginning in the headwaters and moving in a downstream direction.

Water Chemistry Results and Discussion by HUC-12

Headwaters Bokes Creek HUC-12 (05060001-07-01)

This subwatershed area encompasses 36 mi^2, or roughly 23,000 acres, flowing from the headwaters of Bokes Creek and North-, West- and East- Forks of West Mansfield Tributary downstream to a point just below the confluence of these stream networks. Slightly more than half of this drainage area lies among the various Forks of the West Mansfield Tributary watershed (19.5 mi^2) which contains the village of West Mansfield (2010 census population of around 700). The remainder of the drainage area consists of the Bokes Creek headwaters.

In 1999, organic and nutrient enrichment combined with habitat and flow alteration and siltation caused widespread non-attainment of the associated aquatic life uses in this HUC-12. None of the seven sites in this HUC-12 attained their designated aquatic life use in 1999. In 2013 two fully attained and three showed a modest improvement in status, moving from 'non-attainment' to 'partial attainment'.

Water samples in this HUC-12 were collected at three sites along the upper six miles of Bokes Creek, three sites along North Fork of West Mansfield Tributary and one site on West Fork of West Mansfield Tributary. The most upstream Bokes Creek site at RM 36.3, situated northwest of Horton at C.R. 292, met aquatic life use criteria for MWH, the designation assigned to this reach due to historic stream channelization activities. Three miles downstream, RM 35.1 at C.R. 120 near Horton, the fish community

T IBI dropped to 32, triggering partial attainment of the WWH designated use. Continuing downstream, RM 31.80 was also in partial attainment of WWH due to an IBI score of 34.

Nutrient concentrations at all sampling locations in this HUC-12 were either similar or lower in magnitude than the 1999 study. The headwaters sites along Bokes Creek, RMs 36.3 through 31.8, experienced the most dramatic reductions in nutrient concentration of all the sites along the Bokes Creek mainstem, when comparing 2013 to 1999 data. Among these sites, reduction in total phosphorus concentration ranged from 38% to 76% and the reduction in ammonia concentrations ranged from 30% to 94% (Table 6). Despite improvement in nutrient concentration stressors, periodic low dissolved oxygen concentrations persisted in this segment of Bokes Creek. In about half of the sampling locations, TSS concentrations were higher than in 1999 highlighting the potential for siltation or suspended algae to be ongoing stressors.

Table 6. Nutrient concentrations and trends in the Bokes Creek Headwaters HUC-12 (05060001-07-01). Site description includes aquatic life use designation and number of samples per study. Geomean is listed by study year; TP and NO3+NO2 geomeans in excess of targets are listed in bold. Single sample maximum is listed in parenthesis. Percent change in geomean: "-" indicates decrease, "+" indicates increase.

Site Description	Parameter	1999 Geomean (max)	2013 Geomean (max)	ALU Status Change and % Geomean Change (1999 vs 2013)
Headwaters Bokes Creek (05060001-07-01)				
Bokes Creek, RM 36.3 NW of Horton at C.R. 292 MWH wading 1999 n = 3-4 2013 n = 5	*ALU Attainment Status*	*NON*	*FULL*	*improved*
	Total P	**0.50** (1.11)	**0.12** (0.30)	-76%
	Ammonia	1.26 (3.43)	0.07 (0.13)	-94%
	Nitrate+Nitrite	**5.43** (14.70)	**1.30** (5.26)	-76%
	Nitrite	0.32 (1.19)	0.03 (0.06)	-91%
	TKN	3.16 (5.21)	0.60 (0.98)	-81%
	TSS	17.56 (22.0)	22 (47)	+25%
Bokes Creek, RM 35.1 near Horton at C.R. 120 WWH wading 1999 n = 5 2013 n = 5	*ALU Attainment Status*	*NON*	*PARTIAL*	*slightly improved*
	Total P	**0.26** (0.37)	**0.12** (0.34)	-54%
	Ammonia	0.28 (0.83)	0.08 (0.13)	-71%
	Nitrate+Nitrite	0.98, n = 1	**1.30** (5.43)	--
	Nitrite	0.08, n = 1	0.03 (0.07)	-63%
	TKN	0.93 (1.62)	0.58 (0.85)	-38%
	TSS	16.2 (39)	14 (40)	-14%
Bokes Creek, RM 31.8 at West Mansfield - Mt. Victory Rd. WWH wading	*ALU Attainment Status*	*NON*	*NON*	*no status change*
	Total P	**0.26** (0.34)	**0.16** (0.34)	-38%
	Ammonia	0.12 (0.17)	0.07 (0.10)	-42%

1999 n = 5 2013 n = 5	Nitrate+Nitrite	**1.70** (2.03), n = 2	**1.59** (7.02)	-6%
	Nitrite	0.04, n = 1	0.03 (0.08)	-25%
	TKN	0.96 (1.48)	0.79 (1.90)	-18%
	TSS	16.3 (30)	20 (121)	+23%
N. Fk. West Mansfield Ck, RM 5.58 *at Farm Lane off C.R. 26* MWH headwaters 1999 n = 2 2013 n = 5	*ALU Attainment Status*	*NON*	*FULL*	*improved*
	Total P	**0.22** (0.28)	**0.08** (0.31)	-64%
	Ammonia	0.1 (0.16)	0.07 (0.12)	-30%
	Nitrate+Nitrite	not measured	0.66 (2.14)	--
	Nitrite	0.04 (0.05)	0.03 (0.06)	-25%
	TKN	1.31 (1.64)	1.05 (1.63)	-20%
	TSS	15.1 (19)	33 (47)	+119%
N. Fk. West Mansfield Ck, RM 3.96 *at C.R. 142* WWH headwaters 1999 n = 5 2013 n = 5	*ALU Attainment Status*	*NON*	*NON*	*no status change*
	Total P	**0.43** (0.95)	**0.13** (0.47)	-70%
	Ammonia	0.19 (0.75)	0.05 (0.06)	-74%
	Nitrate+Nitrite	**2.23**, n = 1	0.63 (2.25)	--
	Nitrite	0.03, n = 1	0.03 (0.05)	--
	TKN	2.05 (2.71)	0.99 (1.42)	-52%
	TSS	16.77 (32)	7 (34)	-58%
N. Fk. West Mansfield Ck, RM 1.28 *at January Rd.* WWH headwaters 1999 n = 5 2013 n = 9	*ALU Attainment Status*	*NON*	*PARTIAL*	*slightly improved*
	Total P	**0.32** (0.64), n = 2	**0.18** (0.59)	-44%
	Ammonia	0.15 (0.29)	0.07 (0.13)	-53%
	Nitrate+Nitrite	**2.41**, n = 1	0.77 (2.89)	--
	Nitrite	0.03 (0.04), n = 3	0.03 (0.06)	0%
	TKN	1.26 (2.71)	0.94 (1.75)	-25%
	TSS	22.4 (53)	10 (24)	-55%
W. Fk. West Mansfield Ck, RM 0.78 *at S.R. 47* WWH headwaters 1999 n = 5 2013 n = 5	*ALU Attainment Status*	*NON*	*PARTIAL*	*slightly improved*
	Total P	**0.40** (0.49)	**0.21** (0.44)	-48%
	Ammonia	0.18 (0.41)	0.12 (0.46)	-33%
	Nitrate+Nitrite	not measured	0.83 (2.70)	--
	Nitrite	0.03, n = 2	0.04 (0.08)	+33%
	TKN	1.04 (1.72)	1.02 (1.51)	-2%
	TSS	14.26 (19)	8 (43)	-44%

Low nighttime concentrations of dissolved oxygen were observed during a 48-hour period from 9/4/13 to 9/6/13 at the two Bokes Creek mainstem locations (RMs 35.1 and 31.8). During the same observation

period, both locations had instantaneous and 24-hour average concentrations of dissolved oxygen that were lower than the applicable Ohio WQS criteria. Dissolved oxygen levels fell to a minimum of 2.87 mg/l (4.23 mg/l daily average) at RM 35.1 and to a minimum of 0.92 mg/l (3.32 mg/l daily average) at RM 31.8.

Higher nitrate concentrations were measured in the Bokes Creek portion of this HUC-12, with geomeans ranging from 1.30 to 1.59 mg NO_3-NO_2/l, in excess of the WWH target of 1.0 mg NO_3-NO_2/l. The West Mansfield Tributary tributaries had slightly lower nitrate geomean concentrations, ranging from 0.63 to 0.83 mg NO_3-NO_2/l.

Ammonia geomean concentrations in Bokes Creek and North Fork West Mansfield Tributary ranged from 0.052 to 0.072 mg NH_4/l with a maximum concentration at most sites of around 0.1 mg NH_4/l. Higher ammonia concentrations were measured in West Fork West Mansfield Tributary at S.R. 47 (RM 0.78) which had a geomean of 0.120 mg NH_4/l and a single-sample maximum of 0.455 mg NH_4/l.

Total phosphorous geomean concentrations were in excess of targets and were evenly distributed between the two main stream networks in this HUC-12, with overall geomeans ranging from 0.08 to 0.21 mg TP/l.

North Fork West Mansfield Tributary at RM 1.28 had the highest levels of benthic and sestonic (water column) chlorophyll-*a* (239 mg chl.-a/m^2 benthic, 11.4 µg/l sestonic) of the five sites that were sampled for these parameters in the Bokes Creek watershed. This was also the only location that exceeded management targets for benthic algae. Benthic algae density (measured as chlorophyll-a[chl.-a] per unit area of streambed) has been correlated with nutrient enrichment conditions, and a management threshold value of 183 mg chl.-a/m^2 has been recommended as a maximum value for the protection of aquatic life (Miltner 2010; Miltner 2011). The complete chlorophyll-*a* dataset is included in Appendix G.

Brush Run – Bokes Creek HUC-12 (05060001-07-02)

This 20 mi^2 (13,000 acre) watershed unit encompasses a little over eight miles of Bokes Creek in the middle portion of its extent, starting just downstream from the confluence with the West Mansfield Tributary and continuing downstream to below the confluence with Brush Run. The tributaries of Powderlick Run and Brush Run are also included in this HUC-12. The small communities of York Center and Somersville are the only population centers in this portion of the Bokes Creek watershed.

In 1999, the aquatic life stressors that affected Bokes Creek headwater sites extended downstream though this HUC-12. Powderlick Run and its tributaries, and also Brush Run, were heavily affected by organic and nutrient inputs, dissolved solids and siltation. Enriching conditions from Powderlick Run continued into Bokes Creek, causing non-attainment of the WWH aquatic life use at Bokes Creek RM 20.2. In the 1999 assessment, the reach of Bokes Creek immediately upstream from Powderlick Run met WWH biocriteria but was considered “threatened by nutrients and organic enrichment/D.O. and silt inputs from upstream tributaries and non-point source storm runoff.” Sites on Bokes Creek in this reach met WWH criteria in 2010 and 2013; however, strong indications of nutrient enrichment persisted and the same threats remain. In 2013, diel D.O. ranges greater than 7.0 mg/l, which is a threshold indicator of nutrient enrichment (see Miltner 2010), were present at Hoover Moffit Rd., RM 28.4, (ranges of 7.25 to 7.65 mg/l) and were even more pronounced five miles downstream at Bitler Rd, RM 23.2, with ranges up to 20.62 mg/l over a 24-hour period.

Bokes Creek at Hoover Moffitt Rd. (RM 28.4) has shown a decline in chemical water quality since the 1999 bioassessment with higher concentrations of total phosphorous, ammonia and TKN measured in

this survey (Table 7). Bokes Creek at Yearsley Rd. (RM 21.29) followed a similar pattern, having 2013 geomean concentrations of total phosphorous and TKN that were greater than in 1999.

High single-sample ammonia concentrations were documented in Bokes Creek at Hoover Moffitt Rd. (RM 28.4) and at Bitler Rd. (RM 23.2), 2.04 mg/l and 1.14 mg/l, respectively. Chronically recurring concentrations in this range, co-occurring with warm summertime stream temperatures, have the potential to cause acute ammonia toxicity to aquatic organisms.

Total phosphorous concentrations were highest in this portion of Bokes Creek, relative to the upstream and downstream portions of the watershed. All sample locations had TP in excess of the 0.1 mg/l WWH target. Geomean TP concentrations ranged from 0.21 mg/l to 0.25 mg/l in Bokes Creek. Powderlick Run RM 0.17 had a geomean TP concentration of 0.16 mg/l and Brush Run RM 0.6 had a geomean TP concentration of 0.15 mg/l.

Table 7. Nutrient concentrations and trends in the Brush Run Bokes Creek HUC-12, 1999 vs. 2013 (05060001-07-02). Site description includes aquatic life use designation and number of samples per study. Geomean is listed by study year; TP and NO3+NO2 geomeans in excess of target are listed in bold. Single sample maximum is listed in parenthesis. Percent change in geomean: "-" indicates decrease, "+" indicates increase.

Site Description	Parameter	1999 Geomean (max)	2013 Geomean (max)	ALU Status Change and % Geomean Change (1999 vs 2013)
Brush Run – Bokes Creek (05060001-07-02)				
Bokes Creek, RM 28.4 at Hoover Moffitt Rd. WWH wading 1999 n = 4, sampled at RM 27.2 2013 n = 9	*ALU Attainment Status*	*FULL*	*FULL*	*no status change*
	Total P	**0.15** (0.17)	**0.21** (0.65)	+40%
	Ammonia	0.08 (0.10)	0.10 (2.04)	+25%
	Nitrate+Nitrite	0.97, n = 1	0.98 (17.8)	--
	Nitrite	not measured	0.03 (0.07)	--
	TKN	0.90 (1.2)	0.93 (4.08)	+3%
	TSS	28.7 (41), n = 2	16 (618)	-44%
Bokes Creek, RM 23.2 at Bitler Rd. WWH wading 1999 not sampled 2013 n = 5	*ALU Attainment Status*	*not assessed*	*FULL*	--
	Total P	--	**0.22** (0.58)	--
	Ammonia	--	0.10 (1.14)	--
	Nitrate+Nitrite	--	**2.21** (4.69)	--
	Nitrite	--	0.04 (0.16)	--
	TKN	--	1.06 (3.84)	--
	TSS	--	24 (498)	--
Bokes Creek, RM 21.29 SE York Center at Yearsley Rd.	*ALU Attainment Status*	*FULL*	*FULL*	*no status change*
	Total P	**0.16** (0.2)	**0.22** (0.50)	+38%

WWH wading 1999 n = 5 2013 n = 5	Ammonia	0.11 (0.19)	0.07 (0.12)	-36%
	Nitrate+Nitrite	not measured	**2.62** (20.2)	--
	Nitrite	0.03 (0.04), n = 2	0.04 (0.103)	+33%
	TKN	0.67 (0.89)	0.88 (1.34)	+31%
	TSS	19.5, n = 1	15 (34)	--
Powderlick Run, RM 0.17 *at Yearsley Rd.* WWH headwaters 1999 n = 5 sampled at RM 0.2 2013 n = 8	*ALU Attainment Status*	*NON*	*NON*	*no status change*
	Total P	**0.58** (0.91)	**0.16** (0.82)	-72%
	Ammonia	1.18 (6.04)	0.08 (0.27)	-93%
	Nitrate+Nitrite	**9.23** (10.5), n = 2	0.42 (15.7)	-95%
	Nitrite	0.23 (1.52)	0.03 (0.11)	-87%
	TKN	5.46 (11.8)	1.19 (2.54)	-78%
	TSS	58.81 (83.5)	15 (338)	-74%
Bokes Creek, RM 20.2 adj S.R. 31, dst. Powderlick Run WWH wading 1999 n = 5 2013 n = 5	*ALU Attainment Status*	*PARTIAL*	*FULL*	*improved*
	Total P	**0.22** (0.41)	**0.25** (0.67)	+14%
	Ammonia	0.14 (0.95)	0.07 (0.24)	-50%
	Nitrate+Nitrite	**1.58** (2.33), n = 2	**2.35** (9.81)	+49%
	Nitrite	1.39, n = 1	0.03 (0.04)	--
	TKN	0.99 (2.51)	0.92 (1.33)	-7%
	TSS	22.0, n = 1	31 (440)	--
Brush Run, RM 0.60 S. of Somersville @ Yearsley Rd. WWH headwaters 1999 not sampled 2013 n = 5	*ALU Attainment Status*	*NON*	*NON*	*no status change*
	Total P	--	**0.15** (0.49)	--
	Ammonia	--	0.10 (0.27)	--
	Nitrate+Nitrite	--	**1.72** (6.67)	--
	Nitrite	--	0.04 (0.14)	--
	TKN	--	0.87 (1.37)	--
	TSS	--	18 (234)	--

Nitrate concentrations were approaching or in excess of the 1.0 mg/l WWH target at all locations, ranging from 0.98 mg/l to 2.62 mg/l, except Powderlick Run which had a nitrate geomean of 0.42 mg/l.

Powderlick Run, which in places was nearly devoid of aquatic life and was heavily polluted by nutrients and organic matter in 1999, had undergone noteworthy water quality improvement by 2013 with substantial reductions in the concentrations of several nutrient parameters. Specifically, concentrations of ammonia were in the range of chronic toxicity in 1999, 1.18 mg/l geomean, whereas 2013 ammonia concentrations were similar to typical Bokes Creek background conditions with a 0.08 mg/l geomean concentration. Total phosphorous concentrations decreased from 0.58 to 0.16 mg/l, nitrite from 0.23

mg/l to 0.03 mg/l and TKN decreased from 5.46 mg/l to 1.19 mg/l. No TDS WQS criterion exceedances were found, and TDS concentrations were an order of magnitude lower than 1999 levels. However, the 479 mg/l TDS geomean remained above the 90th percentile of ECBP headwaters reference sites (477 mg/l).

Although Powderlick Run still contains nutrients at levels that exceed targets and continues to rank among the more nutrient enriched sites in the Bokes Creek watershed, there is evidence that habitat restoration and pollution reduction activities upstream on Powderlick Run have been effective at stanching the bulk of the nutrient runoff reaching the stream and increasing nutrient assimilative capacity within the stream.

Improvement in Powderlick Run water quality appears to have diminished the 'point-source' type of near field impact to Bokes Creek biology that has been documented in past studies. Ammonia and TKN concentrations are lower in Bokes Creek downstream from Powderlick Run, for example, compared to past studies. This trend has been reflected by a rebound in Bokes Creek RM 20.2 aquatic life scores in both 2010 and 2013 assessments. Bokes Creek RM 20.2 improved by 8-10 IBI points and 4-6 ICI points, moving from partial attainment of WWH in the 1999 assessment to full attainment of WWH in 2010 and 2013. Similar to Powderlick Run, and sites upstream from Powderlick Run within Bokes Creek, nutrient enrichment pressure remains at RM 20.2 and a wider scale trend toward higher concentrations of in-stream inorganic nutrients existed. Near the downstream end of this HUC-12, Bokes Creek total phosphorous and nitrate concentrations remained elevated when compared to 1999 concentrations and established targets. Dissolved oxygen concentrations were in a normal range for WWH streams at this location. Good quality habitat characterized Bokes Creek near RM 20.2 (QHEI=73), and an intact riparian zone shaded the stream serving as a counterbalance to high nutrient concentrations keeping algae production below problematic levels.

Brush Run joins Bokes Creek at RM 19.7. In 2013, habitat quality and IBI scores had improved since 1999 (60.3 vs. 49.0 QHEI, 34 vs. 24 IBI), but overall non-attainment of WWH in Brush Run had not changed since the last survey when there was insufficient flow to collect water samples. Nitrate (1.72 mg/l) and TP (0.15 mg/l) were each in excess of nutrient targets at this location.

Smith Run – Bokes Creek HUC-12 (05060001-07-03)

The lower half of Bokes Creek, from just downstream from Brush Run to the mouth, and the Bokes Creek tributary of Smith Run together comprise a 28 mi^2 (18,000 acre) drainage area. This portion of Bokes Creek, in contrast to headwater locations, had average nutrient concentrations that were higher in 2013 than in 1999, in some cases nearly twofold higher (Table 8). From the most upstream sampling location in this HUC-12 at Ford-Reed Rd. (RM 16.58), nutrients increased in concentration over the next ten miles of Bokes Creek peaking at RM 5.55 downstream from Pharisburg and Magnetic Springs. The highest concentrations of many of the nutrients sampled in Bokes Creek were measured at RM 5.55, downstream from Magnetic Springs. This sampling location had geomean TKN and ammonia concentrations in excess of 95th percentile ecoregional reference concentrations and TP and nitrate at levels two to three times greater than their respective targets.

Table 8. Nutrient concentrations and trends in Smith Run and Bokes Creek HUC-12, 1999 vs. 2013 (05060001-07-03). Site description includes aquatic life use designation and number of samples per study. Geomean is listed by study year; TP and NO3+NO2 geomeans in excess of established target are listed in bold. Single sample maximum is listed in parenthesis. Percent change in geomean: "-" indicates decrease, "+" indicates increase.

Site Description	Parameter	1999 Geomean (max)	2013 Geomean (max)	ALU Status Change and % Geomean Change (1999 vs 2013)
Smith Run – Bokes Creek (05060001-07-03)				
Bokes Creek, RM 16.58 at Ford Reed Rd. WWH wading 1999 n = 5 2013 n = 8	*ALU Attainment Status*	*NON*	*FULL*	*improved*
	Total P	**0.18** (0.65)	**0.15** (0.35)	-17%
	Ammonia	0.07 (0.07), n = 3	0.07 (0.33)	0%
	Nitrate+Nitrite	**1.39**, n = 1	0.87 (8.14)	--
	Nitrite	not measured	0.03 (0.04)	--
	TKN	0.72 (0.77)	0.81 (2.96)	+13%
	TSS	26.2 (33.5), n = 4	10 (29)	-62%
Bokes Creek, RM 11.37 N of Marysville at S.R. 4 WWH wading 1999 n = 5 2013 n = 5	*ALU Attainment Status*	*PARTIAL*	*FULL*	*improved*
	Total P	**0.18** (0.32)	**0.22** (0.41)	+22%
	Ammonia	0.08 (0.09), n = 2	0.11 (1.64)	+38%
	Nitrate+Nitrite	**1.28** (1.96), n = 2	**2.39** (15.8)	+87%
	Nitrite	0.06 (0.11), n = 3	0.04 (0.34)	-33%
	TKN	0.64 (0.70)	0.96 (3.61)	+50%
	TSS	26, n = 1	21 (128)	--
Bokes Creek, RM 5.54 dst. Magnetic Springs at Brown Rd. WWH wading 1999 n = 5 2013 n = 5	*ALU Attainment Status*	*PARTIAL*	*PARTIAL*	*no status change*
	Total P	**0.18** (0.32)	**0.25** (0.34)	+39%
	Ammonia	0.09 (0.17)	0.17 (1.42)	+89%
	Nitrate+Nitrite	**3.92** (6.9), n = 3	**3.49** (9.95)	-11%
	Nitrite	0.06 (0.11), n = 3	0.07 (0.45)	+17%
	TKN	0.73 (1.04)	1.32 (2.88)	+81%

	TSS	19.4 (27)	23 (155)	+19%
Smith Run, RM 0.8 *at Brindle Rd.* WWH headwaters 1999 n = 5, sampled at RM 0.77 2012 n = 5	*ALU Attainment Status*	*NON*	*NON*	*no status change*
	Total P	**0.15** (0.42)	**0.18** (0.27)	+20%
	Ammonia	0.11 (0.15)	0.13 (0.98)	+15%
	Nitrate+Nitrite	**3.86** (6.06), n = 2	**1.58** (11.9)	-59%
	Nitrite	0.11 (0.14), n = 2	0.06 (0.37)	-45%
	TKN	0.66 (0.87)	1.00 (1.98)	+52%
	TSS	17.3 (32.5)	11 (34)	-36%
Bokes Creek, RM 0.25 at S.R. 257 WWH wading 1999 n = 5 2013 n = 8	*ALU Attainment Status*	*PARTIAL*	*FULL*	*improved*
	Total P	**0.18** (0.47)	**0.20** (0.33)	+11%
	Ammonia	0.12 (0.15)	0.07 (0.15)	-42%
	Nitrate+Nitrite	**1.96** (2.85)	**1.29** (14.9)	-34%
	Nitrite	0.03 (0.03), n = 2	0.04 (0.11)	+33%
	TKN	0.82 (0.99)	0.97 (1.57)	+18%
	TSS	15.4 (17), n = 2	10 (128)	-35%

Previous Ohio EPA studies of Bokes Creek have highlighted failing home sewage treatment systems in Magnetic Springs and nearby unsewered areas as a source of nutrient enrichment in this vicinity (Ohio EPA, 2001). Field observations suggest that this source of pollutants has been getting worse over time, and TKN and ammonia concentrations that have increased by 80% to 90% support that conclusion. Inadequately treated wastewater was observed flowing into Bokes Creek via approximately 1-foot diameter concrete pipes in two locations near Magnetic Springs, and at one of these locations the septic material was emptying into a stagnant backwater channel adjacent to Bokes Creek. This area in particular warrants local attention because, aside from ongoing ecological concerns, the health of anyone directly exposed to this area may be put at risk given the nature and extent of waste matter that can accumulate between high flow events. *E. coli* bacteria results and a discussion specific to pathogen concentrations in Bokes Creek are located in the Recreation Use section of this report.

Moors Run – Scioto River HUC-12 (05060001-07-04)

The direct Scioto River tributaries of Moors Run and Prairie Run had not been assessed previously, and they were incorporated into this study for practical purposes given their proximity to the lower Bokes Creek sampling sites. Each of these tributaries has a drainage area of 5.6 mi^2 and each was sampled at the bridge crossing nearest its confluence with the Scioto River.

Table 9. Nutrient concentrationsin Moors Run – Scioto River HUC-12, 2013 (05060001-07-04). Site description includes aquatic life use designation and number of samples per study. Geomean is listed by study year; TP and NO3+NO2 geomeans in excess of established target are listed in bold. Single sample maximum is listed in parenthesis. Percent change in geomean: "-" indicates decrease, "+" indicates increase.

Site Description	Parameter	2013 Geomean (max)
Moors Run – Scioto River (05060007-07-04) Nearby direct tributaries to the Scioto River, previously unassessed		
Moors Run, RM 0.32 *at S.R. 257 (Trib. to Scioto R.)* WWH headwaters no previous sampling 2013 n = 5	ALU Attainment Status	NON
	Total P	**0.13** (0.20)
	Ammonia	0.08 (0.41)
	Nitrate+Nitrite	**2.02** (15.9)
	Nitrite	0.06 (0.51)
	TKN	0.84 (1.7)
	TSS	6 (11)
Prairie Run, RM 0.07 *at S.R. 37 (Trib. to Scioto R.)* WWH headwaters no previous sampling 2013 n = 5	ALU Attainment Status	FULL
	Total P	0.04 (0.15)
	Ammonia	0.05 (0.06)
	Nitrate+Nitrite	**4.83** (6.38)
	Nitrite	0.03 (0.03)
	TKN	0.56 (0.96)
	TSS	7 (14)

Moors Run joins the Scioto River from the west, just downstream and within eyesight of the trees that line the lower reach of Bokes Creek. The habitat quality was good, with a QHEI of 77.3; however, the fish and macroinvertebrate communities failed to meet WWH standards. Total phosphorous and nitrate were higher than WWH targets, and other key nutrients were at levels similar to nearby non-attaining Bokes Creek tributaries sites.

Prairie Run flows from east to west toward the Scioto River, combining with another small stream, Eagon Run, just upstream from the sampling location at S.R. 37. The confluence of Prairie Run with the Scioto River lies immediately downstream and opposite from Bokes Creek. Nitrate concentration was consistently high on Prairie Run (4.83 mg/l geomean); however, other nutrients were within target concentration ranges and in lower concentrations than were typically found in the nearby headwater tributaries to Bokes Creek. Habitat characteristics were excellent in Prairie Run (QHEI=80) and the fish and macroinvertebrate assemblages attained WWH criteria.

Water Quality Sonde Exceedance Summary

Multi-parameter water quality sondes were deployed to monitor temperature, D.O., pH and specific conductance (conductivity). Temperature, D.O. and pH are influenced by diel patterns. These diel patterns have the greatest impact for streams during certain critical conditions that include stable, low stream flow. Specific conductance is not influenced by the same diel triggers but is monitored because it is a strong indicator of changes in stream flow. The water quality sondes collect readings hourly to monitor parameters throughout the diel cycle. Grab readings differ because they only represent one point on the diel curve. While grab readings are effective at characterizing water quality parameters that change based on hydrologic regime or season; they can miss or not fully characterize parameters that exhibit diel patterns. When the diel fluctuations are of concern, continuous monitoring at regular intervals throughout the diel cycle is needed to characterize the parameter of concern.

Diel patterns in temperature reflect air temperature, solar radiation, base flow (groundwater), discharge, and shading. In general, diel fluctuations in temperature increase as base flow, discharge, and shading decrease. The inverse is also true.

Dissolved oxygen responds in a similar diel pattern to temperature, as they are affected by similar factors. In addition, dissolved oxygen trends are directly dependent on temperature. At high temperatures the solubility of oxygen in water decreases, resulting in an inverse relationship. Without the influence of other environmental conditions this would cause the two parameters to follow opposite trends. However, the dissolved oxygen produced by photosynthesis is, in most instances, enough to overwhelm the inverse relationship causing the trends to follow similar trajectories. Increasing diel fluctuation relates to an increase in productivity due to dissolved oxygen concentrations reaching super saturation during the day and subsequently depleting by respiration at night. The result is a diel trend that typically reaches a maximum in the early evening and a minimum preceding sunrise. In some cases, dissolved oxygen does not exhibit strong diel trends in low flow, warm conditions where either primary productivity is limited or decomposition of organic matter in the stream is controlling the dissolved oxygen concentrations. Sonde monitoring contributes to the body of evidence to identify dissolved oxygen trends that are more influenced by primary productivity or decomposition.

Diel patterns in pH are also reflective of primary productivity. Carbon dioxide, which dissolves in water to form carbonic acid, is consumed during photosynthesis, raising the pH of the stream. The result is a maximum pH value observed at a similar time to the maximum dissolved oxygen.

Ohio promulgates water quality standards through Ohio Administrative Code Chapter 3745-1. The data collected during the sonde deployments are sufficient to evaluate exceedances of the criteria established for the protection of aquatic life for maximum daily temperature, minimum at any time dissolved oxygen, 24-hour average dissolved oxygen, 24-hour maximum/minimum pH, and 24-hour average specific conductivity. Absolute minima or maxima exceedances are compared directly to hourly readings reported from the water quality sondes. An exceedance of a WQS criterion does not represent stream impairment; rather, if biological impairment is present the exceedances help develop a body of evidence that identifies the conditions that are stressing aquatic life.

The land use in the watershed is largely row crop agriculture; the only wastewater treatment plant discharging to Bokes Creek is a 0.015 mgd package plant serving a youth camp downstream from

Magnetic Springs. Fourteen sites were sampled with water quality sondes to represent the general watershed area as well as target areas of concern. Critical conditions for temperature and dissolved oxygen are times when flows are low, temperatures are high, and daylight is long. These are the times that streams are most sensitive to organic and nutrient enrichment. To capture these conditions, sondes are typically deployed in low flow conditions from June to September. Sondes were deployed September 4-6, 2013 primarily in the Bokes Creek mainstem. Three sondes were deployed in the North Fork West Mansfield Tributary near the town of West Mansfield, and one sonde was placed in Smith Run near the confluence of the Scioto River (Figure 8).

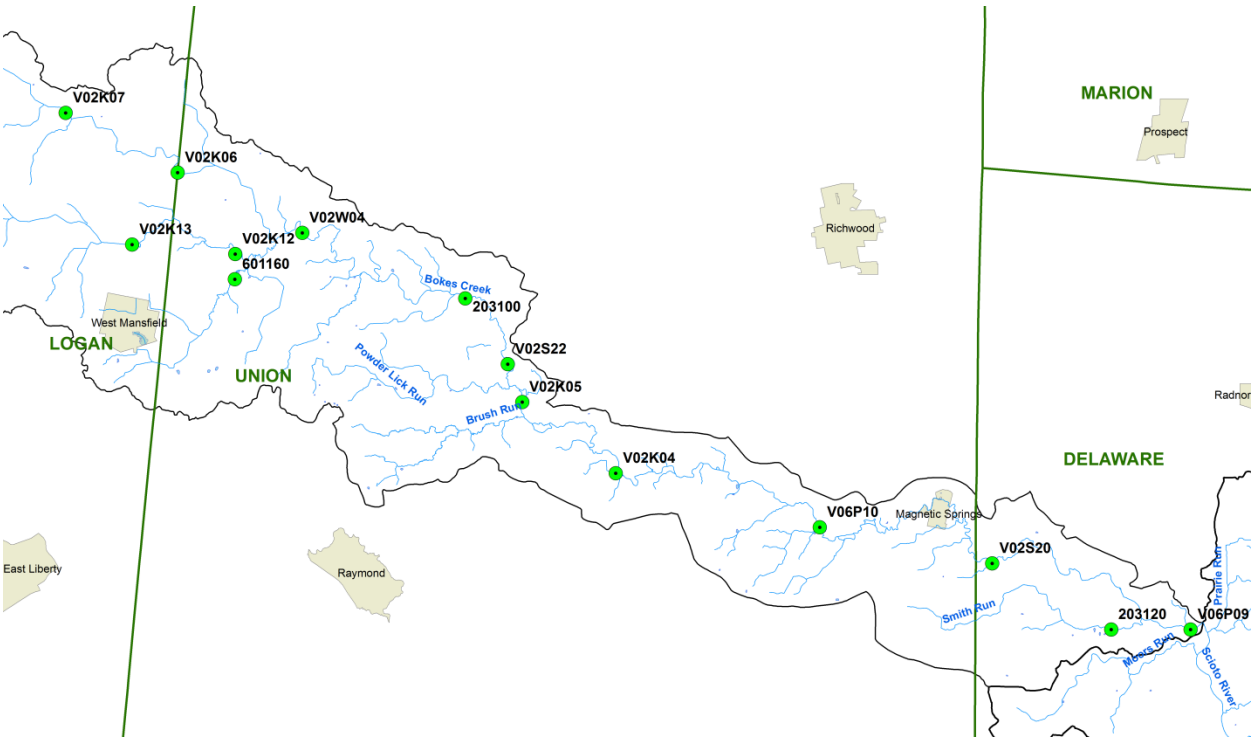


Figure 8. Map showing locations and station codes of sondes deployed in the Bokes Creek watershed.

Summer 2013 weather conditions were generally wetter than normal, though flows in nearby Mill Creek were close to median during the deployment period (Figure 9). Summary plots and tables of all data collected are included in Appendix I of this document. The plots are of hourly readings taken for temperature, dissolved oxygen, pH, and specific conductance.

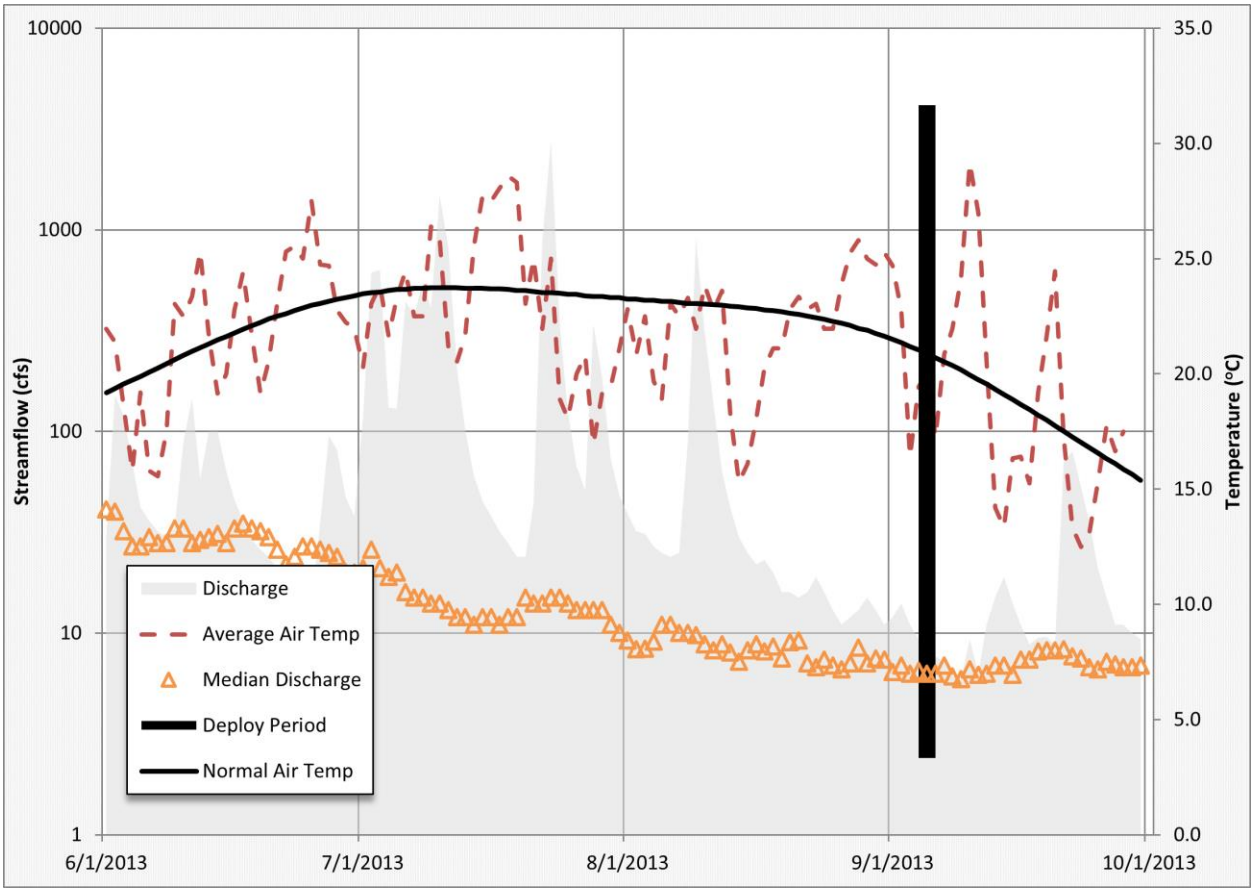


Figure 9. Graph of average daily stream flow relative to long term daily median stream flow for Mill Creek near Bellepoint, Ohio (USGS 03220000) including the average and normal daily air temperature (NOAA - GHCND:USC00334979) for the sampling season. No active gage was present in the study area; however, this nearby gage represents general hydrological conditions for the region.

A summary of the exceedances is presented in Table 10. Exceedances of Ohio Water Quality Standards criteria (OAC 3745-1) for chemical and physical parameters derived from diel monitoring, 2013. Sondes collected 42-47 hours of data at 14 sites. Sonde water quality monitors record hourly readings for the duration of the deployment. Consequently, exceedances can be presented as both a measure of magnitude and duration. Rolling 24-hour averages were calculated using the hourly readings for comparison against the average criteria. The magnitude of an exceedance is presented as the most extreme value measured that exceeds the criteria. The duration is the count of consecutive hours that exceeded the criteria and is presented in parenthesis after the measure of magnitude. Applicable water quality criteria include: minimum D.O., average D.O., maximum temperature, pH and specific conductance. Of these criteria, only D.O. was not met. Figure 10 shows box-and-whisker plots of the D.O. for each site.

Table 10. Exceedances of Ohio Water Quality Standards criteria (OAC 3745-1) for chemical and physical parameters derived from diel monitoring, 2013.

RM	Site Code	Non-attaining D.O. in mg/L (consecutive hours standard not met)	Comments
Bokes Creek		***ECBP - Warmwater Habitat (Existing)***	
35.1	V02K07	D.O. min.: 2.87 (10)	Partial attainment, Nutrient enrichment
		D.O. avg.: 4.23 (18)	Same
31.8	V02K06	D.O. min.: 0.92 (15)	Partial attainment, Nutrient enrichment
		D.O. avg.: 3.32 (18)	Same
28.4	V02W04	---	---
23.2	203100	---	---
21.29	V02S22	D.O. min.: 3.35 (3)	Full attainment
		D.O. avg.: 4.53 (13)	Same
20.2	V02K05	---	---
16.58	V02K04	---	---
11.37	V06P10	---	---
5.55	V02S20	---	---
0.25	V06P09	---	---
North Fork West Mansfield Tributary		***ECBP - Warmwater Habitat (Existing)***	
3.96	V02K13	---	---
1.28	V02K12	D.O. avg.: 4.99 (14)	Partial attainment, Nutrient enrichment
West Fork West Mansfield Tributary		***ECBP - Warmwater Habitat (Existing)***	
0.78	601160	---	---
Smith Run		***ECBP - Warmwater Habitat (Existing)***	
0.8	203120	---	---

Notes: ECBP – Eastern Corn Belt Plains
[a] The General Ohio River basin temperature criteria apply; See OAC 3745-1-07, Table 7-14(A).
[b] Applicable minimum 24-hour average D.O. criterion - WWH: 5.0 mg/l.
[c] Applicable minimum D.O. criterion - WWH: 4.0 mg/l.

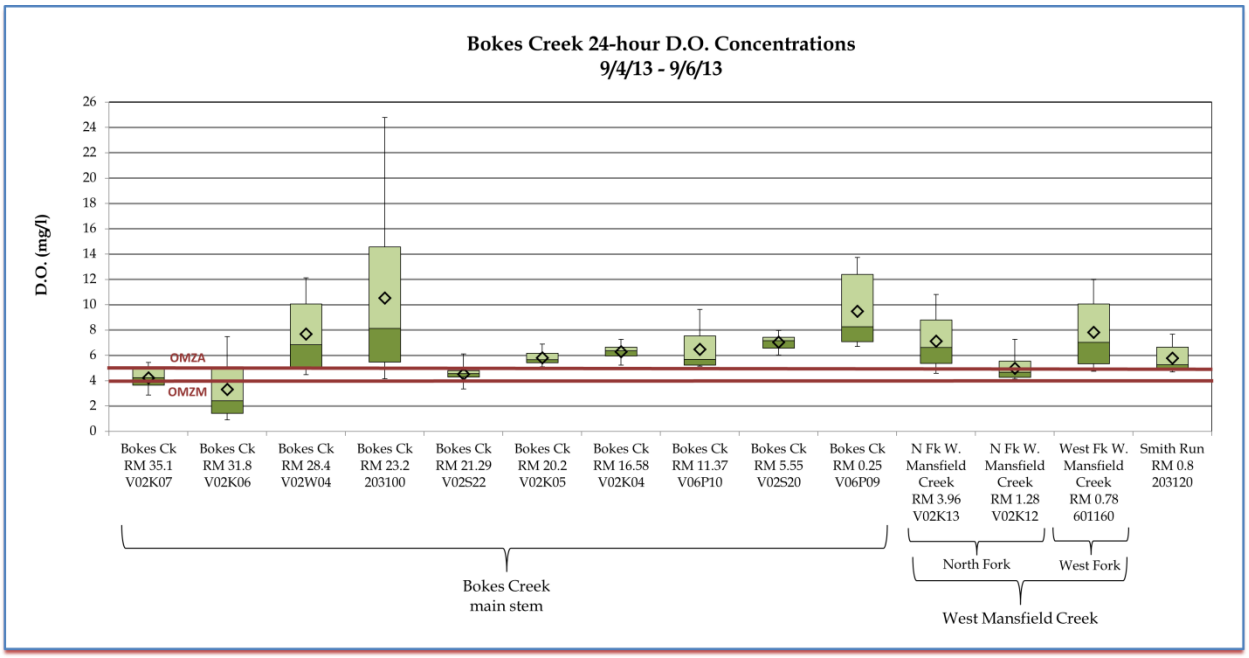


Figure 10. Box-and-whisker plots of daily D.O. at each sonde site, Bokes Creek watershed, 2013.

Four of the fourteen sondes deployed in the Bokes Creek watershed recorded exceedances. Bokes Creek at RMs 35.1 and 31.8 failed to meet both minimum and average D.O. criteria. At these two sites, biological indicators point to excessive nutrients. The source of nutrients is believed to be from the surrounding agricultural landscape. Geometric means for both nitrate-nitrite and total phosphorus exceeded established targets.

Bokes Creek at RM 21.29 was in full attainment of the WWH aquatic life use despite an average D.O. concentration of about 4.5 mg/L and a minimum reading of 3.4 mg/L. Concentrations below the 4.0 mg/L minimum criterion occurred for only a brief period of time (three hours). Nitrate and phosphorus exceeded the established targets.

The fourth site, the North Fork West Mansfield Tributary at RM 1.28, had a minor D.O. excursion. The average D.O. (4.99 mg/L) was barely below the WQS criterion of 5.0 mg/L. Total phosphorus was elevated though nitrate was not. Biological indicators indicate excessive nutrients. An upstream confined animal feeding operation (CAFO) was also believed to be contributing to the partial attainment at this site.

Recreation Use

Wading or swimming in Bokes Creek and other streams in this area involves an elevated risk of contracting infections of the ear, nose, and throat, as well as stomach upsets, skin rashes, and diarrhea, based on the results of *Escherichia coli* (*E. coli*) bacteria sampling carried out in this study and past studies. Young children, the elderly, and those with depressed immune systems are most at risk. The exact source of high bacteria content at any stream location is dependent on upstream land use.

In order to determine the suitability of surface waters for human recreation, water quality criteria are established in the Ohio Water Quality Standards (Table 7-13 in OAC 3745-1-07) based upon measured concentrations of the indicator bacteria *E. coli* in streams, rivers and lakes. *E. coli* bacteria are

microscopic organisms that are abundant in the feces and intestinal tracts of warm-blooded animals. The analytical method used by this study does not differentiate between human and animal sources of coliform bacteria in surface waters. However, when *E. coli* is found in a water sample it signals that the water has come into contact with fecal matter from one source or another.

Most of the streams of the Bokes Creek watershed evaluated in this survey were designated Primary Contact Recreation (PCR) Class B, which applies to streams that support or potentially support occasional primary contact recreation activities such as wading, canoeing, kayaking or swimming. Powderlick Run, Smith Run and Brush Run were previously designated Secondary Contact Recreation (SCR), which applies to streams that are rarely used for water based recreation, such as wading, or are situated more remotely from populated areas. However, when these streams originally received the SCR designation, it was based on the understanding that PCR only applied to streams of sufficient depth and breadth to allow for full body immersion and swimming by adults. Today, PCR is looked upon from a more general perspective, in that if access is available and people live within the vicinity, children are likely to play and come into contact with the waters of the stream. Field observations, combined with a review of aerial photos, indicate potential for easy access to the stream through residential yards. Recreation use designations are outlined in detail in OAC Rule 3745-1-24.

The *E. coli* concentration criteria that apply to Bokes Creek (PCR Class B) include a geometric mean of 161 colony forming units (cfu) per 100 ml, and a single sample maximum of 523 cfu/100 ml. The geometric mean is used as the basis for determining attainment status when more than one sample has been collected at a given location, as was the case for all sampling locations in this study. Summarized stream bacteria data are listed in Table 11.

Nine locations in the Bokes Creek study area were tested for *E. coli* five to eight times apiece in 2013 during the designated annual recreation season (May 1 through the end of October). High bacteria concentrations were found in streams throughout the study area. Each of the nine locations tested had *E. coli* in excess of the geomean recreation use criterion, often by a wide margin. The recreation use attainment status of each Bokes Creek watershed sampling location is outlined in Table 11.

Table 11. Recreation use attainment status in the Bokes Creek watershed (0506000107), May 1 through October 31, 2013. Primary Contact Recreation (PCR) Class B applies to all sites. To determine attainment status, geometric mean *E. coli* concentrations were compared to the WQS criterion of 161 cfu/100 ml.

Location	River Mile	Rec. Class	n	Geomean	Max	Attainment	Sources
(0506000107-01)							
N. Fk. West Mans. Ck. @ January Rd.	1.28	PCR B	8	1168	4100	NON	Agriculture / HSTS[1]
(0506000107-02)							
Bokes Creek @ Hoover-Moffitt Rd.	28.4	PCR B	8	1058	32000	NON	Agriculture / HSTS
Powderlick Run DST Yearsley Rd.	0.17	PCR B*	7	757	28000	NON	Agriculture
(0506000107-03)							
Bokes Creek @ Ford-Reed Rd.	16.58	PCR B	8	469	2800	NON	Agriculture / HSTS
Bokes Creek @ S.R. 4	11.37	PCR B	5	501	6600	NON	Agriculture / HSTS
Bokes Creek @ Brown Rd.	5.55	PCR B	5	1030	6500	NON	HSTS: Magnetic Springs area
Bokes Creek @ S.R. 257	0.25	PCR B	8	207	5100	NON	Agriculture / HSTS
(**0506000107-04)**							
Moors Run @ S.R. 257	0.3	PCR B	5	322	890	NON	HSTS
Prairie Run @ S.R. 37	0.07	PCR B	5	472	970	NON	HSTS, Agriculture

*- Recommended classification

[1] Home sewage treatment system

Relationship with Stream Flow and Runoff

The precipitation and stream flow trend when a set of *E. coli* samples was collected can provide important information about potential bacteria sources. For instance, one of the sampling events in the Bokes Creek watershed took place on three consecutive days at the end of June 2013, and local weather patterns strongly influenced runoff and stream flow during that period.

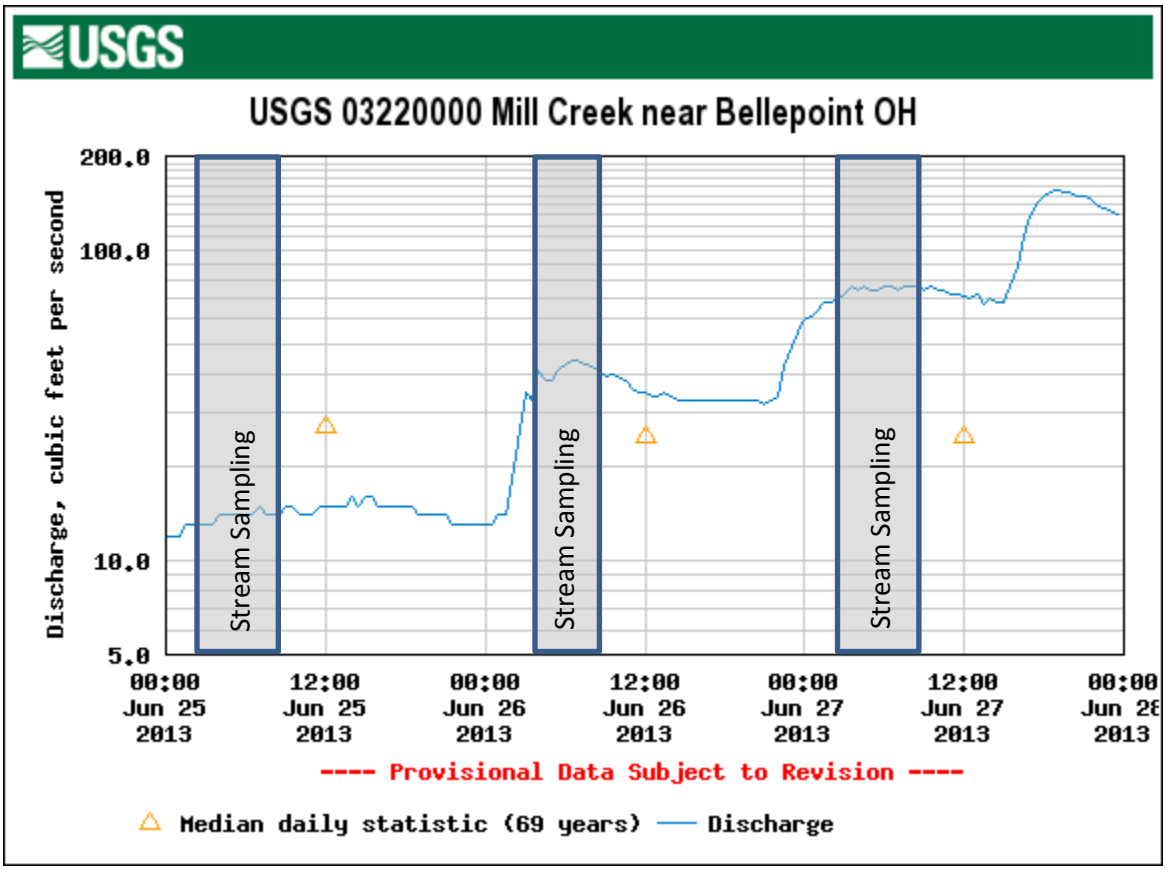


Figure 11. Stream flow on nearby Mill Creek, June 25-27 2013.

Isolated thunderstorms began moving through the region late in the evening on June 25 and continued overnight into the early morning on June 26. The resulting surface runoff caused stream flows to rise. On the following two days when stream sites were sampled, small logs, leaves and other debris were observed floating downstream in turbid water. Stream flow quantity is monitored continuously by the US Geological Survey at a gaging station on Mill Creek, the adjacent watershed to the south, which likely experienced similar weather conditions. The increased flows in Mill Creek after the June 25-26 storm are depicted in Figure 11. *E. coli* concentrations were elevated following this storm at most sampling sites in Bokes Creek, but extraordinarily high *E. coli* was measured at Bokes Creek at Hoover-Moffitt Rd, RM 28.4, (32,000 cfu/100 ml) and Powderlick Run at Yearsley Rd, RM 0.17, (28,000 cfu/100 ml).

Agricultural land use and underperforming home sewage treatment systems (HSTS) are typical contributors of fecal indicator bacteria to streams in areas like the locations listed above which are separated by several miles from population centers. High bacteria concentration in response to a precipitation and runoff event, such as this early summer thunderstorm, indicates that bacteria are being washed off land surfaces and into waterways. If untreated residential wastewater, a common contributor of *E. coli* to streams, or any other localized point source, were the sole source of *E. coli* in these areas, the diluting effect of precipitation might be expected to decrease the concentration of *E. coli* in surface water samples. However, the opposite of the trend was observed in rural parts of the Bokes Creek watershed following this storm event.

Agricultural sources of bacteria in Bokes Creek range from disperse small-scale livestock production to large concentrated poultry production facilities. A visual survey of the watershed indicated that cattle,

horses, sheep, goats and chickens are raised in many locations spread throughout the watershed. Carefully managing manure and restricting livestock access to waterways at these locations are among the solutions these entities can employ to limit the contribution of pathogen concentrations to nearby surface waters. Large scale poultry and egg production facilities are located in the headwaters of the study area, and facilities such as these often employ on-site storage and field broadcasting at different points in the waste management process. When there is enough precipitation to cause runoff, these areas can become a source of bacterial and nutrient contamination. The careful management of waste storage and land applications represents an ongoing opportunity to employ best management practices to minimize bacteria contribution to nearby streams.

Failing Home Sewage Treatment Systems

Unsewered areas where homes and businesses are concentrated can also be significant point sources of bacteria. Portions of the village of Magnetic Springs (population 270, approximately 110 homes) have been identified by Ohio EPA as a source of inadequately treated wastewater flowing via cement pipes directly into Bokes Creek, in at least two confirmed locations. Samples collected directly from the outlets where these pipes discharge to Bokes Creek on September 5, 2013 contained *E. coli* in amounts up to 7,000 times greater than the concentration that would be allowable within Bokes Creek, ranging from 720,000 to 1.2 million cfu/100 ml *E. coli* (compared to the PCR Class B 161 cfu/100 ml criterion). Concentrations of *E. coli*, as well as nutrients, increase in Bokes Creek as it flows past Magnetic Springs.

The water quality effect of point sources such as Magnetic Springs, where there are concentrated underperforming HSTS, is most pronounced under dry weather flow conditions when less dilution is available in the receiving stream and precipitation runoff is not occurring. Samples were collected on two occasions upstream and downstream from Magnetic Springs in August 2013 in dry weather, under normal to low flow conditions. Upstream samples were taken at Bokes Creek at S.R. 4 (RM 11.37), near Pharisburg and downstream samples were collected at Bokes Creek at Brown Rd. (RM 5.55). In both cases, higher *E. coli* counts were found in the samples downstream from Magnetic Springs. On August 1, *E. coli* increased from 270 cfu/100 ml at RM 11.37 to 1,300 cfu/100 ml at RM 5.55. Then, on August 15, the same pattern was observed with 280 cfu/100 ml at RM 11.37 and 450 cfu/100 ml at RM 5.55.

Unabated pollution of Bokes Creek by inadequately treated sewage in the vicinity of Magnetic Springs is a situation known to have been ongoing for a time period of at least a decade as of the writing of this report, based on Ohio EPA records and previous sampling reports (Ohio EPA 2001). It is recommended that local and/or county entities develop a specific plan to address this environmental and public health issue.

Sediment Sampling Methods and Analysis

Sediment samples were collected from seven sites in the Bokes Creek study area in September, 2013 – four locations in Bokes Creek (RMs 28.4, 20.2, 16.58, and 5.55), one site in North Fork West Mansfield Tributary (RM 1.28), one in Powderlick Run near the mouth (0.17), and one in Smith Run (0.80) . A sample from each site was analyzed for nutrients, total organic carbon (TOC), metals and 130 organic parameters including polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and various pesticides. Analytical results are summarized in Table 12.

Sample collection focused on depositional areas of fine grain material (silts and clays), and one spatial composite sample was created for each sampling location. Sampling staff walked a zone of each stream site within approximately 100 feet downstream and/or upstream from the bridge crossing or road access, collecting scoops of depositional material wherever it could be found and mixing all subsamples

together in a stainless steel pan. The fine grained materials found in depositional areas of the stream were the focus of this sampling because contaminants typically adsorb to, or co-occur with, these sediment types compared to sands and gravels.

All sediment sampling took place within or directly adjacent to the wetted stream channel. Sampling locations were represented at times by sparse deposits of fine grained material. It should be noted that the proportion of depositional areas within a stream reach, or the volume of depositional material relative to larger substrates, varied widely by sampling location. Clay and silt comprised a small proportion of the bottom substrates in some of the stream sites surveyed, *i.e.*, North Fork West Mansfield Tributary, Smith Run, Bokes Creek RM 16.58 at Ford Reed Rd. Bottom substrates at these locations were dominated by sand, gravel and/or cobble. Other sampling locations were more replete with fine grained sediments, *i.e.*, Powderlick Run and Bokes Creek RM 20.20, adjacent S.R. 31.

Pollutant levels in Bokes Creek sediment samples were reviewed based upon the Ohio EPA 2010 *Guidance on Evaluating Sediment Contaminant Results* document. This document outlines an ecological impact screening protocol where contaminant concentrations are first compared to published guidelines from *Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems* (MacDonald, et. al. 2000) and Ohio EPA Sediment Reference Values (Ohio EPA 2003), and further risk assessment is carried out if those guidelines are exceeded. Not every pollutant type is included in each of these studies, while some pollutant types are included in more than one study. Furthermore, because nutrients are not included in this protocol, nutrient parameters were compared separately to thresholds published by the Ontario Ministry for the Environment (Persaud et al. 1993).

Following is a brief explanation of the ecological sediment quality guidelines which specifically apply to contaminants found in Bokes Creek:

Lowest Effect Level (LEL)
Sediment nutrient concentrations were compared to the LEL, which was defined by Persaud et al., (1993) as " . . . a level of contamination which has no effect on the majority of the sediment-dwelling organisms. The sediment is clean to marginally polluted." The LEL is paired with a less conservative concentration level, the Severe Effect Level (SEL), which was not exceeded by any of the sediment chemical concentrations in this study. Metals and organic compounds were included in the consensus based criteria listed below, which incorporate LEL and SEL criteria; therefore, metals and organic compounds were not compared separately to the LEL for the purpose of this report.

Threshold Effect Concentration (TEC) and Probable Effect Concentration (PEC)
This concentration level is the more conservative of a two-level set of guidelines developed by MacDonald, et al. (2000) to describe levels of contaminants based on the probability of ecological effects that arise from a given concentration. The threshold effect concentrations (TEC) " . . . were intended to identify contaminant concentrations below which harmful effects on sediment dwelling organisms were not expected." None of the Bokes Creek samples contained contaminants in excess of a paired, more protective reference value, the probable effect concentration (PEC), at which " . . . effects on sediment dwelling organisms were expected to occur frequently."

Ohio EPA Sediment Reference Values (SRV)
These values were developed for sediment metals using the same set of statewide ecoregion-based reference sites that were used in the development of Ohio EPA tiered aquatic life use biocriteria. The sediment reference values that were generated from this study are considered a screening tool;

however, contaminants at lower concentrations than an ecoregion specific SRV can be considered unlikely to cause deleterious aquatic life impact.

Sediment Chemical Results

Most of the sediment samples from Bokes Creek and the tributary sites were free from contaminants in high enough concentrations to affect aquatic life. However, in a subset of sampling locations, several metals were present in concentrations exceeding reference guidelines. Sediment nutrients were present in excess of the LEL at all sampling locations (Table 12).

North Fork West Mansfield Tributary RM 1.28, at January Rd.

Percent total organic carbon (TOC) and total phosphorous were in excess of LEL criteria at this location. No metals were in excess of sediment quality guidelines and none of the organic compounds analyzed were at detectable concentrations.

Bokes Creek RM 28.40, at Hoover-Moffit Rd.

Percent TOC and total phosphorous were in excess of LEL criteria at this location as well. The percent total organic carbon at Bokes Creek RM 28.4 was the highest level in the Bokes watershed, at 9.1 mg/kg-- approaching the 10 mg/kg Severe Effect Level. No metals were in excess of sediment quality guidelines and none of the organic compounds analyzed were at detectable concentrations.

Powderlick Run RM 0.17, at Yearsley Rd.

Since the last watershed assessment of Bokes Creek and tributary streams by Ohio EPA, significant stream channel restoration has been completed along upstream reaches of Powderlick Run. Bank stability provided by this work was expected to be among a variety of water quality benefits realized, and this in turn would reduce the amount of suspended material exported to downstream locations in Powderlick Run and in Bokes Creek downstream from the confluence. More detail on the Bokes Creek Water Quality Enhancement Project can be accessed via the U.S. EPA website at the following link: http://www.epa.gov/Region5/agriculture/spotlight200609.html

Powderlick Run samples in 1999 were collected at RM 1.0, and elevated concentrations of several metals were detected, particularly aluminum (18,900 mg/kg). The 1999 sampling report recommended sediment sampling at RM 0.17 where it was suspected there could be greater concentrations of contaminants due to depositional channel morphology and elevated concentrations of various contaminants detected within Bokes Creek downstream from the confluence with Powderlick Run (Ohio EPA, 2001).

Further interest in investigating potential sediment toxicity in Powderlick Run was raised by the Ohio EPA (2012) *Biological and Water Quality Report of the Middle Scioto River and Selected Tributaries* which included post-restoration biological assessment of upstream sites in Powderlick Run (RMs 1.2 and 3.4).

As a result, sediment samples were collected from RM 0.17 near the Yearsley Rd. bridge crossing in 2013. Most contaminant concentrations were at roughly half of the levels measured in 1999 at RM 1.0. None of the metal parameters were in excess of the TEC threshold, and none of the analyzed organic parameters were in detectable concentrations. Sediment nutrients were in excess of the LEL; however, these levels were on par with other Bokes Creek sediment sites, many of which met their aquatic life use designation. Because this is a different sampling location than in 1999, and it is not the same location as the upstream 2010 bioassessment, it is not possible to state conclusively whether the overall concentration of sediment contaminants in Powderlick Run has diminished over time, nor can it be

stated that sediment toxicity does not exist in upstream reaches. It is unlikely, however, that sediment toxicity is contributing to non-attainment at Powderlick Run RM 0.17.

Bokes Creek RM 20.2, adjacent S.R. 31 (downstream Powderlick Run)
In 1999, the most contaminated sediments in Bokes Creek were collected at RM 20.2. Powderlick Run, which enters Bokes Creek just upstream from this site, was considered the most probable source of contamination because similar sediment chemical profiles were found in Powderlick Run and Bokes Creek RM 20.2, in addition to the comparatively large amount of depositional material that appeared in Bokes Creek downstream from Powderlick Run. Elevated sediment metal concentrations (aluminum, chromium, nickel, etc.) were deemed a secondary stressor to aquatic life, following nutrient and organic enrichment related causes.

In 2013, Bokes Creek RM 20.2 had the highest sediment phosphorus content, in excess of the LEL, at 1,070 mg/kg (sediment phosphorus was not measured in 1999). Particle size distribution within the sediment sample was skewed toward fine grained sediments, which indicates a potential for embedded substrates at this site. Sediment metal concentrations were lower than TEC thresholds, and they were a fraction of the amounts measured in 1999. For example, comparing 1999 to 2013 concentrations in mg/kg, aluminum decreased from 32,200 to 14,800 (-54%), chromium from 35.7 to 12.8 (-64%), and nickel from 28.5 to 20.5 (-28%).

Bokes Creek RM 16.58, at Ford-Reed Rd.
Arsenic was found in the sediment sample from Bokes Creek at the Ford-Reed Rd. site at 11.8 mg/kg, a concentration that exceeds the 9.79 mg/kg TEC and represents a stressor to aquatic life. While in attainment of the WWH aquatic life use, the macroinvertebrate community was not as robust here compared to other Bokes Creek sampling sites. This was reflected in a relatively lower ICI score of 36 (versus 40 to 44 at nearby Bokes Creek sites). Previous Bokes Creek studies have attributed elevated sediment arsenic to organic wastes in fertilizers, pesticide residuals or natural sources.

Bokes Creek RM 5.55, at Brown Rd.
Flouranthene was the only organic compound detected in any of the sediment samples, and was found at the Bokes Creek RM 5.55 site at a concentration of 0.76 mg/kg, a level below what is likely to cause ecological harm (LEL = 0.75 mg/kg; TEC = 423 mg/kg) particularly because no other PAH compounds were detected in the sample. Flouranthene is a polycyclic aromatic hydrocarbon (PAH) most commonly associated with petrochemical products such as coal, motor oil or asphalt.

Also at Bokes Creek RM 5.55, several 'alkaline-earth group' metals including barium, calcium, magnesium and strontium were found in much higher concentrations than sediments at other locations. Each of these was approaching or was in excess of the SRV and most was present in twice the concentration found at other sites. In the case of strontium, the concentration was 15 times greater than other Bokes Creek watershed sites and nearly an order of magnitude greater than the SRV. This set of metals is associated with shale or limestone geology and can be naturally occurring in sediments within this region, though not typically at this high of a concentration.

The RM 5.55 sediment samples were also atypical for this watershed in terms of particle size distribution. No sand or larger particles were present in the sample, meaning the sample was dominated by very fine silts and clays. Field notes document that sediments were collected within a close radius of the bridge crossing at Brown Rd., and this bridge had been replaced and repaved shortly prior to the commencement of sampling in 2013. It is conceivable given the nature and proximity of the disturbance

that repaving work, importing gravel and related temporary disturbances to the stream bank associated with bridge reconstruction contributed the PAH and elevated limestone associated metals found in the sediments at Brown Rd. The fact that sediment samples collected from this location during the summer of 1999 did not contain detectable levels of PAH compounds or elevated concentrations of barium, magnesium or strontium supports the likelihood of the bridge work as a source of the contaminants (Ohio EPA 2001). Additional Bokes Creek sediment sampling upstream and farther downstream from the new Brown Rd. bridge would be required to confirm this as a localized source of sediment contamination.

Smith Run RM 0.80, at Brindle Rd.

Percent TOC and total phosphorus were in excess of LEL criteria at this location. No metals were in excess of sediment quality guidelines and none of the organic compounds analyzed were at detectable concentrations. It is unlikely that sediment toxicity contributed to non-attainment at this location.

Table 12. Selected results of chemical and physical sediment sampling in the Bokes Creek study area, 2013. Parameters having all analytical results below detection level were omitted. Data in bold were in excess of the specific guideline indicated by footnote, and the guideline value is listed in parentheses below the measured value.

	Parameter	Units	**N. Fork WMC** Jan. Rd. RM 1.28	**Bokes Ck** Hoover-Moffitt RM 28.40	**Powder-lick Run** Yearsley RM 0.17	**Bokes Ck** adj S.R. 31 RM 20.20	**Bokes Ck** Ford-Reed RM 16.58	**Bokes Ck** Brown Rd. RM 5.55	**Smith Run** Brindle Rd. RM 0.80
% Solids		%	58.95	56.1	57.95	43.8	62.05	57.85	54.3
Organics	Fluoranthene	mg/kg	BDL	BDL	BDL	BDL	BDL	0.76	BDL
Metals	Aluminum	mg/kg	5710	7280	8740	14800	9820	8790	6470
	Arsenic	mg/kg	5.91	6.37	6.49	7.95	**11.8* (9.79)**	8.99	7.6
	Barium	mg/kg	46.2	49.6	57.6	107	76.7	**414† (240)**	46.9
	Cadmium	mg/kg	0.48	0.481	0.539	0.847	0.437	0.513	0.481
	Calcium	mg/kg	24400	44400	36900	20400	13600	116000	9710
	Chromium	mg/kg	9.87	11.4	12.8	19.8	13.6	11.7	9.11
	Copper	mg/kg	12.7	13.1	15.1	22.7	14.6	13.9	11.8
	Iron	mg/kg	14000	15400	16700	26200	24200	18000	16200
	Lead	mg/kg	9.48	10.1	11.3	17.5	12	20.9	9.95
	Magnesium	mg/kg	8150	13600	16400	12100	7070	**44900† (35000)**	5060
	Manganese	mg/kg	287	255	308	432	331	333	127
	Mercury	mg/kg	BDL	0.05	0.055	BDL	0.051	0.041	BDL
	Nickel	mg/kg	14.9	16.2	20.5	27.7	18.5	21.6	14.6
	Potassium	mg/kg	BDL	1430	1550	2380	1590	1960	BDL
	Strontium	mg/kg	96	171	102	201	147	**3190† (390)**	200
	Zinc	mg/kg	47.1	50.2	87.1	112	68	72.7	53.9
Nutrients	Ammonia	mg/kg	100	140	120	260	150	170	130
	TOC	%	**3.8†† (1)**	**9.1†† (1)**	**2.3†† (1)**	**4.9†† (1)**	**3.0†† (1)**	**4.6†† (1)**	**6.2†† (1)**
	Total Phosphorus	mg/kg	**707†† (600)**	**803†† (600)**	**737†† (600)**	**1070†† (600)**	**802†† (600)**	**617†† (600)**	**645†† (600)**
Particle Size	Fine clay (<1 µm)	%	12	21	18	27	18	22	16
	Medium clay (1-2 µm)	%	3.9	7.1	5.9	11	6.1	9.4	4
	Coarse clay (2-4 µm)	%	1.9	4.7	4	8	4	11	4
	Very fine silt (4-8 µm)	%	1.9	4.7	5.9	5.4	6.1	28	2
	Fine silt (8-15 µm)	%	3.9	12	14	16	8.1	13	6
	Medium silt (15-30 µm)	%	7.8	4.7	4	5.4	2	3.7	7.9
	Coarse silt (30-60 µm)	%	1.9	4.7	5.9	0	2	12	2
	Sand, larger (>60 µm)	%	67	41	43	28	54	0	58
pH	pH	s.u.	7.5	7.3	7.5	7.3	7.5	7.7	6.9

* Value is greater than TEC, from MacDonald et al. 2000.

†Value is greater than Ohio EPA SRV.

††Nutrient value is greater than LEL) from Persaud et al. 1993.

NPDES Permitted Facilities

There are several significant regulated facilities located in the Bokes Creek watershed. These include facilities regulated by Ohio EPA's NPDES permit program and facilities regulated by the Ohio Department of Agriculture Division of Livestock Environmental Permitting (DLEP). Combined there are ten regulated facilities as listed in Table 13. The facility locations in the watershed are shown in Figure 12.

Water quality conditions in the Brush Run subwatershed are heavily influenced by four regulated CAFOs. New Day Farms operates two facilities that have both Ohio EPA NPDES individual permits and ODA DLEP permits-to-operate (PTO). The New Day Farms facilities contain approximately 2.4 million animal units. The NPDES permits for these facilities cover the discharge of industrial storm water and manure. Other CAFOs included in this watershed include Topaz Farms (423,000 animal units) and Nature Pure (344,000 animal units). These facilities are covered by ODA DLEP PTOs only.

Other regulated facilities include Heartland Egg (DLEP CAFO) and West Mansfield WWTP both located in the Bokes Creek headwaters subwatershed. The West Mansfield WWTP is a non-discharging minor municipal facility that land applies treated effluent. Heartland Egg houses approximately 1.75 million animal units. Water quality conditions in the West Fork and North Fork West Mansfield Tributaries would be influenced by these facilities.

Three individual industrial NPDES permits have been issued to stone and gravel mining operations in the watershed. These permits cover the periodic discharge of process wastewaters associated with mining. One facility located near York Center (Shelley Company) discharges to Bokes Creek RM 25.2. Permitted discharges from the National Lime & Stone facilities (Warrensburg and Delaware) occur to the Scioto River in the lower Bokes Creek watershed (Moors Run subwatershed).

Table 13. Regulated facilities in the Bokes Creek watershed, 2013.

Map ID	Name	Permit	Type	Stream	River Mile	County	Hydrologic Unit	Comments
1	Heartland Egg Farm	ODA PTI/PTO	CAFO	N.F. West Mansfield Trib.	0.7	Logan	07 01 Headwaters	1.75 million animal units
2	West Mansfield WWTP	NPDES	Non Discharging	W.F. West Mansfield Trib.	0.9	Logan	07 01 Headwaters	Land apply all effluent
3	The Shelly Co. York Center Plant	4IJ00107	IND NPDES	Bokes Creek	25.2	Union	07 02 Brush Run	Quarry
4	New Day Farms #3	4IK00032 ODA PTI/PTO	IND NPDES CAFO	U.T. Powderlick Run	NA	Union	07 02 Brush Run	CAFO with an OEPA NPDES Industrial Permit 800,000 animal units
5	New Day Farms Mad R	4IK00005 ODA PTI/PTO	IND NPDES CAFO	U.T. Powderlick Run	NA	Union	07 02 Brush Run	CAFO with an OEPA NPDES Industrial Permit 1.6 million animal units
6	Topaz Farm #2	ODA PTI/PTO	CAFO	Powderlick Run	NA	Union	07 02 Brush Run	423,000 animal units
7	Nature Pure Farm #1	ODA PTO	CAFO	U.T. Powderlick Run	NA	Union	07 02 Brush Run	344,000 animal units
8	Camp Christian WWTP	4GS00010	GEN NPDES	Bokes Creek	6.2	Union	07 03 Smith Run	Small Sanitary Discharger
9	National Lime Warrensburg Plant	4IJ00103	IND NPDES	Scioto R.	160.6	Delaware	07 04 Moors Run	Quarry
10	National Lime Delaware Plant	4IJ00029	IND NPDES	U.T. Scioto R. (RM 158.2)	1.0 1.1	Delaware	07 04 Moors Run	Quarry / 2 outfalls

Sources: http://wwwapp.epa.ohio.gov/dsw/gis/cafo/ and
http://epa.ohio.gov/portals/35/tmdl/Bokes%20Creek%20TMDL%20Final%20Aug%205,%2002.pdf

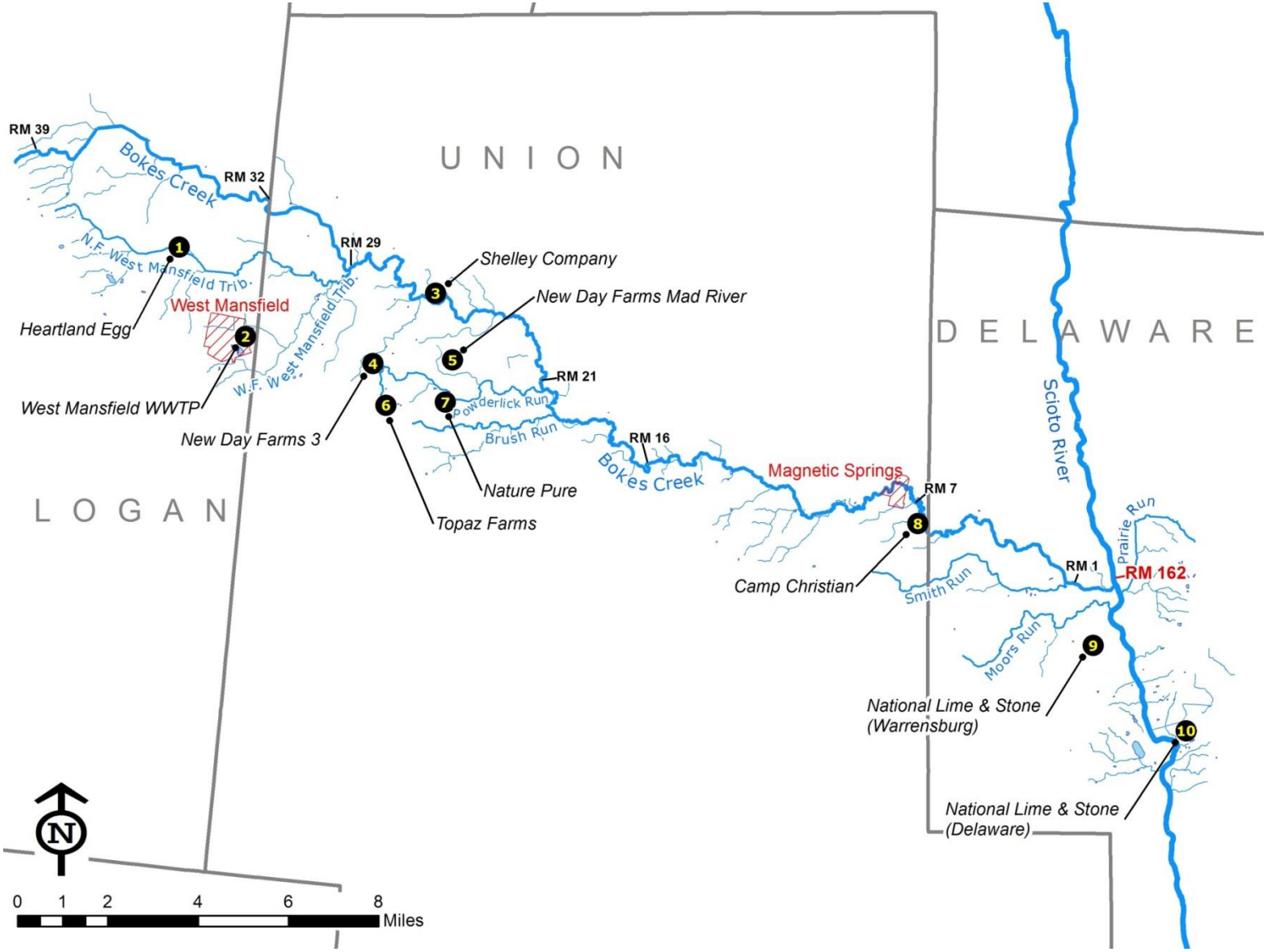


Figure 12. Regulated facilities in the Bokes Creek watershed, 2013.

Macroinvertebrate Community

The 2002 Bokes Creek TMDL noted that tile drainage speeds the delivery of excess nutrients to Bokes Creek. Additionally, the contribution of subsurface moisture to the summer streamflows is reduced. As a result, the 2013 quantitative macroinvertebrate sampling results were compromised by a lack of surface flows and velocities and the concurrent effects on the efficacy of the artificial substrate collections. It appears that the total acreage of tiled agricultural fields will only increase in the future. One recent project was adjacent Bokes Creek near Bitler Rd. (Figure 13).

Figure 13. Installation of tile drainage in agricultural fields adjacent to Bokes Creek, 2013.

Macroinvertebrate community condition was assessed at eleven Bokes Creek sites in 2013. Sampling results were consistent with designated aquatic life uses at all sites even though sediment, habitat and nutrient influences were apparent. The uppermost site (RM 36.30) is designated MWH due to ongoing channel maintenance and supported a fair community including ten EPT (Ephemeroptera, Plecoptera, Trichoptera) taxa. Artificial substrates were collected from seven of the remaining ten locations but all were affected by little or no current velocity or partially exposed due to low flow conditions. The resultant Invertebrate Community Index (ICI) scores were still in the good to very good range (Table 14) but concurrent qualitative sampling of natural habitat and substrates suggested somewhat lower quality macroinvertebrate community conditions in the marginally good to good range. Sedimentation and nutrient loading from row crop fertilization and manure spreading were two stressors that limited the diversity and occurrence of EPT and sensitive taxa throughout the study area. Additionally, pollution sensitive taxa diversity declined downstream from the unsewered community of Magnetic Springs.

Shallow bedrock predominated near the mouth of Bokes Creek (RM 0.25) and sun exposed areas supported a thick growth of filamentous algae. Sampling of the natural substrates revealed a high density of flatworms consuming algal detritus. The macroinvertebrate community at RM 0.25 was considered in marginally good condition even though the ICI score of 44 suggested a better result. High quality habitat was present (QHEI= 87.8) and should have supported a higher diversity of organisms. Enriched conditions at RM 0.25 suggests that Bokes Creek is contributing significant nutrients to the Scioto River.

In 1999, seven Bokes Creek sites were sampled from the headwaters (RM 36.30) to near the confluence with the Scioto River (RM 0.25). Comparable ICI scores between 1999 and 2013 were limited but qualitative sampling results allowed assessment of changes in community condition. Overall, the Bokes Creek macroinvertebrate results showed modest improvement over the past 14 years. Pollution sensitive taxa diversity was higher in 2013, but 10 of the 11 macroinvertebrate collections remained suppressed below the level expected from typical WWH sites of similar drainage area (Figure 14). EPT taxa collected from the natural substrates demonstrated similar modest improvement and met WWH expectations at six locations. One site where both pollution sensitive taxa and EPT diversity was unchanged (RM 21.29, Yearsley Rd.) was affected by the slow current and limited microhabitats within the sampled reach.

Two of three sites in the North Fork West Mansfield Tributary supported improved macroinvertebrate communities compared to the 1999 survey. The principle impacts were associated with operations at Weaver's Heartland Farms, chiefly land application of manure on surrounding agricultural fields. Marginally good conditions encountered at the upper site (RM 5.58) were related to the sustained contribution of groundwater to the stream. Excess nutrients affected the stream at RM 3.96. A poor macroinvertebrate community was present; flatworms were overwhelmingly predominant and just one EPT taxon was recorded. Conditions improved to marginally good and ten EPT taxa were collected at RM 1.28.

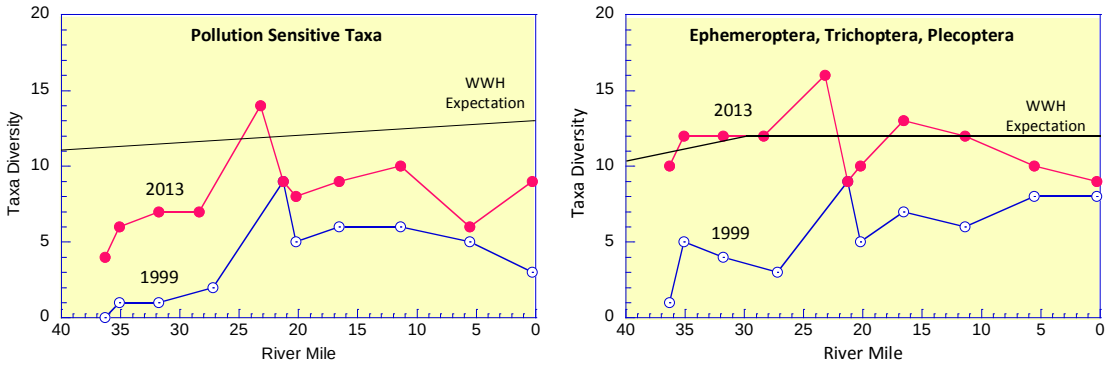


Figure 14. Longitudinal trend of the number of pollution sensitive and EPT taxa collected from the natural substrates plotted by river mile in Bokes Creek from 1999 and 2013.

Two of three direct Scioto River tributaries sampled, Moors Run and Smith Run, supported macroinvertebrate communities reflective of the stressors related to agricultural practices and the resultant over enrichment of headwater streams within the study area. The macroinvertebrate communities were in fair condition and predominated by facultative and tolerant invertebrates with a paucity of sensitive taxa. The benthos at a third stream, Prairie Run, was somewhat more diverse and was reflective of a marginally good resource condition.

Since 1999, significant resources have been dedicated to improving the severely degraded water quality and habitat impairments in Powderlick Run related to large poultry operations in the watershed . Acutely lethal conditions have been eliminated but the poor macroinvertebrate community near the confluence with Bokes Creek was evidence that impacts persist. Sediment and an excess of nutrients in Powderlick Run limited the benthic fauna almost exclusively to facultative and tolerant taxa.

Table 14. Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) in the Bokes Creek study area, June to October, 2013[a].

River Mile	Drainage (mi^2)	Total Taxa	Quant Taxa	Qual Taxa	Qual EPT[b]	Qual Sens.	Qual Tolrnt	Density #/sq ft	Narr./ ICI[c]	Current (fps)	Predominant Taxa[d]
02-136-000		**Moors Run**									
0.32	5.60	57		57	8	6	21	Mod.	F*		isopods(MT,T)
02-137-000		**Prairie Run (2014)**									
0.07	5.60	54		54	10	8	15	Low	MG		isopods(T), baetid mayflies(F), blackflies(F)
02-138-000		**Bokes Creek**									
36.30	4.70	41		41	10	4	15	Mod.	F		midges(F,T)
35.10	7.10	50		50	12	6	17	Low	MG[ns]		midges(F,T), damselflies(F,T)
31.80	11.40	52		52	12	7	13	Mod.	MG[ns]		midges(F,T), baetid mayflies(F)
28.40	34.00	74	45	57	12	7	14	1180	40	0.15	midges(F), hydropsychid caddisflies(F)
23.20	44.00	64		64	16	14	12	Low	G		midges(F,T), baetid mayflies(F)
21.29	46.00	71	35	54	9	9	12	1156	40	0.15	midges(F)
20.20	51.00	68	28	49	10	8	11	316	40	0.50	midges(F), baetid mayflies(MI,F)
16.58	58.00	73	35	56	13	9	14	605	36	0.20	midges(F), mayflies(F)
11.37	63.00	75	42	57	12	10	15	475	42	0.15	midges(F), mayflies(F)
5.55	72.00	71	50	50	10	6	11	567	44	0.04	midges(F), mayflies(MI,F)
0.25	83.10	65	42	40	9	9	8	689	44	0.04	flatworms(F)
02-138-001		**Brush Run**									
0.60	2.60	50		50	7	2	21	Mod.	F*		midges(F,T)
02-138-002		**Powderlick Run**									
0.17	4.10	41		41	4	1	21	Low	P*		midges(F,T)
02-138-004		**North Fork West Mansfield Tributary**									
5.58	3.70	45		45	10	4	20	High	MG		amphipods(F)
3.96	8.00	25		25	1	0	14	High	P*		flatworms(F)
1.28	11.40	34		34	10	4	11	Mod.	MG[ns]		midges(F,T)

River Mile	Drainage (mi^2)	Total Taxa	Quant Taxa	Qual Taxa	Qual EPT[b]	Qual Sens.	Qual Tolrnt	Density #/sq ft	Narr./ ICI[c]	Current (fps)	Predominant Taxa[d]
02-138-006		**West Fork West Mansfield Tributary**									
0.78	6.10	34		34	6	1	14	Low	F		midges(F,T), flatworms(F), planorbid snails(F,MT)
02-139-000		**Smith Run**									
0.80	5.50	52		52	8	0	23	Mod.High	F		flatworms(F), isopods(MT)

Ecoregion Biocriterion: Eastern Corn Belt Plains (ECBP)			
INDEX	MWH	WWH	EWH
ICI	22	36	46

a - Prairie Run was sampled in 2014.
b - Qual. EPT=Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) taxa richness.
c - Narrative assessment used in lieu of ICI score based on qualitative sampling data when no quantitative data are collected.
d - Tolerance Categories: VT=Very Tolerant, T=Tolerant, MT=Moderately Tolerant, F=Facultative, MI=Moderately Intolerant, I=Intolerant.
ns- Nonsignificant departure from applicable biocriterion .
* Significant departure from applicable biocriterion; poor and very poor results are underlined.

Fish Community

Fish sampling was conducted at 20 sites in the Bokes Creek study area in 2013. Relative numbers of fish species collected per location are presented in Appendix C. Index of Biotic Integrity (IBI) and Modified Index of wellbeing (MIwb) scores are presented in Table 15 and Figure 16. IBI metric breakdowns can be found in Appendix B. Sampling locations were evaluated using WWH biocriteria with the exception of the upstream sites on Bokes Creek (RM 36.30) and North Fork West Mansfield Tributary (RM 5.58) which are designated MWH.

Bokes Creek watershed sites achieved the applicable fish biocriteria at 12 of the 20 sites evaluated (60%). Fish communities partially achieved the applicable biocriteria at one wading (>20 mi^2) site (Bokes Creek RM 5.55). Seven sites (wading and headwater) were not achieving the applicable biocriteria, representing 35% of the fish sites (Moors Run RM 0.32, Bokes Creek RMs 35.10 and 31.80, Brush Run RM 0.60, North Fork West Mansfield Tributary RMs 3.96 and 1.28,and Smith Run RM 0.80). The average IBI score among the 20 survey sites was 37.7.

IBI scores generally increased with increasing drainage area. MIwb scores held steady at or nearly meeting expectations but demonstrated a marked decline downstream from Magnetic Springs (RM 5.55) where ten fewer species were recorded compared to the upstream site.

Pollution sensitive fish species demonstrated significant increases in abundance between 1999 and 2013 and are evidence of improved water quality in Bokes Creek (Figure 15). Banded darters (*Etheostoma zonale*) have gradually increased their number and distribution in Bokes Creek. In 1999, a total of 13 individuals were collected at a single site near the mouth of Bokes Creek (RM 0.25), likely originating from the Scioto River. Separate sampling events at the same site produced 34 and 56 individuals in 2013 and this species was also recorded, in low numbers, upstream at RMs 5.55 and 11.37. Golden redhorse (*Moxostoma erythrurum*) distribution and frequency has similarly expanded. Six individuals were collected from two sites in 1999; 126 golden redhorse were collected from six locations in 2013.

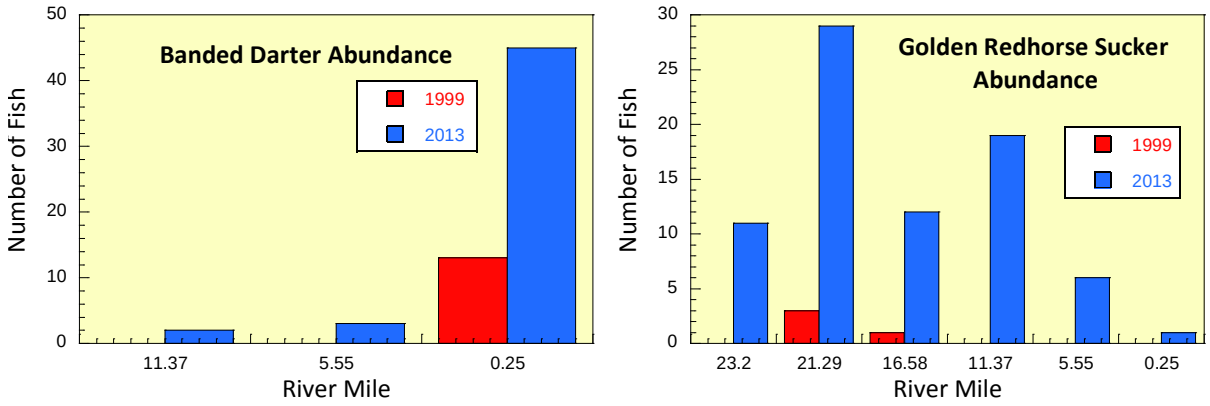


Figure 15. Increased longitudinal distribution and average abundance of banded darters (*Etheostoma zonale*) and golden redhorse suckers (*Moxostoma erythrurum*) in Bokes Creek in 2013 versus 1999.

Overall the fish community of Bokes Creek was modestly improved at nine comparable sites in 2013. Seven sites failed to meet ALU expectations in 1999 versus two sites in 2013 (Figure 16). Average number of native fishes increased from 13.9 in 1999 to 22.0 in 2013. Among the sites that had impaired

fish communities in 1999, both RMs 16.58 and 0.25 saw the largest improvements in MIwb scores resulting from increases in both diversity and abundance. However, the MIwb score, while somewhat higher than in 1999, decreased below the criterion downstream from Magnetic Springs at RM 5.55 and ten fewer species were recorded than at the next upstream site.

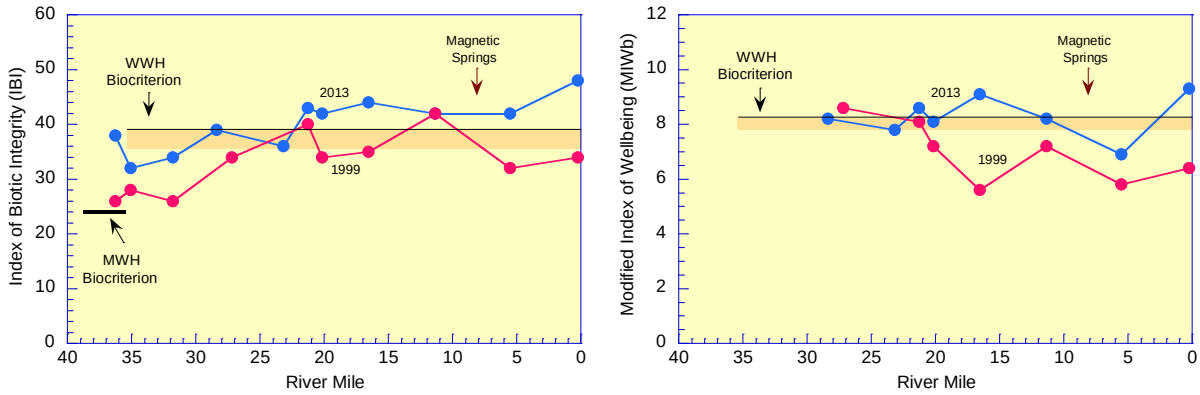


Figure 16. Longitudinal trend of IBI and MIwb scores plotted by river mile in 1999 and 2013.

Table 15. Fish community status for stations sampled in the Bokes Creek study area, 2013. The IBI and MIwb are scores based on the performance of the fish community. The narrative fish evaluations (Exceptional, Very Good, etc.) were based upon the corresponding IBI and MIwb relative to the drainage area, ecoregion, and the assigned aquatic life use. The Qualitative Habitat Evaluation Index (QHEI) is a measure of the ability of the physical habitat to support a biotic community. Relative numbers and weights are per 0.3 km for wading and headwater sites.

River Mile		Number of Species	Relative Weight (kg)	Rel. No. minus tolerants	(all) Relative Number	QHEI	IBI	MIWb	Narratives			Drainage Area (mi^2)
Moors Run (02-136-000) *Warmwater*												
0.32	H	11.00		130.0	310.0	77.3	30	NA	Fair	:	NA	5.6
Prairie Run (02-137-000) *Warmwater*												
0.07	H	12.00		174.0	396.0	80.0	38	NA	Marginally Good	:	NA	5.6
Bokes Creek (02-138-000) *Channel – Modified Warmwater Habitat*												
36.30	H	18.00		798.0	2394.0	53.0	38	NA	Marginally Good	:	NA	4.7
Warmwater												
35.10	H	17.00		472.0	1524.0	63.0	32	NA	Fair	:	NA	7.1
31.80	H	15.00		616.0	1278.0	48.5	34	NA	Fair	:	NA	11.4
28.40	W	20.50	3.00	498.8	857.3	77.5	39	8.2	Marginally Good	:	Marginally Good	34.0
23.20	W	23.00	21.10	492.8	1023.8	58.0	36	7.8	Marginally Good	:	Marginally Good	44.0
21.29	W	23.00	31.50	336.8	574.5	68.3	43	8.6	Good	:	Good	46.0
20.20	W	23.50	3.80	515.3	1053.0	73.0	42	8.1	Good	:	Marginally Good	51.0
16.58	W	25.00	14.50	606.7	973.8	77.8	44	9.1	Good	:	Very Good	58.0
11.37	W	31.00	14.90	471.8	1128.0	73.3	42	8.2	Good	:	Marginally Good	63.0
5.55	W	20.50	4.90	165.8	314.3	84.3	42	6.9	Good	:	Fair	72.0
0.25	W	25.00	29.30	717.8	960.0	87.8	48	9.3	Very Good	:	Very Good	83.1
Brush Run (02-138-001) *Warmwater*												
0.60	H	13.00		98.0	312.0	60.3	34	NA	Fair	:	NA	2.6
Powderlick Run (02-138-002) *Warmwater*												
0.17	H	20.00		354.0	1050.0	45.5	44	NA	Good	:	NA	4.1

River Mile		Number of Species	Relative Weight (kg)	Rel. No. minus tolerants	(all) Relative Number	QHEI	IBI	MIWb	Narratives			Drainage Area (mi^2)
North Fork West Mansfield Tributary (02-138-004) *Modified Channel Modified*												
5.58	H	18.00		192.0	534.0	30.0	34	NA	Fair	:	NA	3.7
		Warmwater										
3.96	H	17.00		624.0	1976.0	52.5	32	NA	Fair	:	NA	8.0
1.28	H	16.00		446.0	1610.0	73.0	30	NA	Fair	:	NA	11.4
West Fork West Mansfield Tributary (02-138-006) *Warmwater*												
0.78	H	16.00		278.0	574.0	64.3	40	NA	Good	:	NA	6.1
Smith Run (02-139-000) *Warmwater*												
0.80	H	10.00		288.0	930.0	73.5	26	NA	Poor	:	NA	5.5

Narrative ranges and WWH biocriteria (bold) for the ECBP ecoregion. Exceptional (EWH biocriteria), very good (EWH nonsignificant departure), poor and very poor evaluations are common statewide. For WWH, the ranges of marginally good and nonsignificant departure are the same.

IBI			**MIwb**		**Narrative Evaluation**
Headwater	Wading	Boat	Wading	Boat	
50-60	50-60	48-60	≥9.4	≥9.6	Exceptional
46-49	46-49	44-47	8.9-9.3	9.1-9.5	Very Good
Eastern Corn Belt Plains					
40-45	**40**-45	**42**-43	**8.3**-8.8	**8.5**-9.0	Good
36-39	36-39	38-41	7.8-8.2	8.0-8.4	Marginally Good
28-35	28-35	26-37	5.9-7.7	6.4-7.9	Fair
18-27	18-27	16-25	4.5-5.8	5.0-6.3	Poor
12-17	12-17	12-15	0-4.4	0-4.9	Very Poor

NA -Headwater site, MIwb is not applicable
H -Headwater site
W -Wading site

Stream Physical Habitat

Stream habitat was evaluated using the Qualitative Habitat Evaluation Index (QHEI) at 20 fish sampling locations throughout the Bokes Creek study area in 2013. As measured by QHEI scores, the Bokes Creek study sites reflected good to excellent stream habitats (Figure 18). Good to excellent stream habitat was recorded at 14 sites while only six sites scored fair to poor. The average QHEI score for the Bokes Creek watershed was 65.8 which showed the overall good habitat quality in the study area (Table 16 and Appendix A).

Overall, QHEI scoring in the Bokes Creek watershed increased compared to conditions documented in 1999. It is likely that the improved QHEI scores were at least partially attributable to increased precipitation throughout the watershed along with the establishment of a vegetated riparian buffer in the headwaters. Stream conditions were desiccated during the 1999 summer with much lower pool and riffle depths compared to those noted on the 2013 QHEI data sheets (Figure 18 and Appendix A). Many WWH attributes such as undercut banks, rootwads, rootmats, and boulders may have been left high and dry during the 1999 summer. However, natural recovery of past physical alterations and improved quality of riparian corridors may also be contributing to the improved habitat scores.

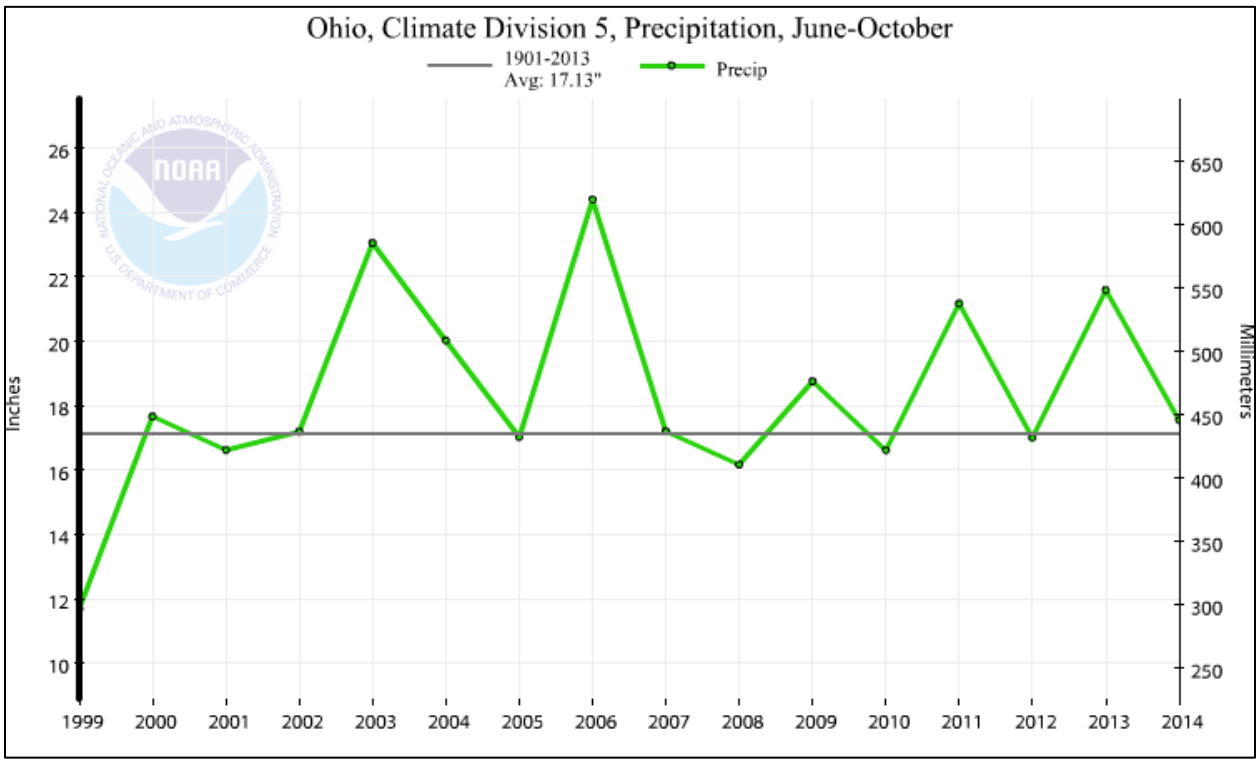


Figure 17. Precipitation totals for the five month period, June- October, recorded in central Ohio, 1999-2014. http://www.ncdc.noaa.gov/cag/time-series/us.

The six sites which scored fair to poor quality habitat were Bokes Creek (RMs 36.3, 31.8 and 23.2), Powderlick Run, and North Fork West Mansfield Tributary (RMs 5.58 and 3.96) (Table 16). Despite the fair quality habitat score in the Bokes Creek headwaters (RM 36.3, QHEI=53.0), ongoing recovery from previous channel modifications has occurred since 1999 (Figure 20). The improved fish community at this location clearly demonstrated the link between the stream's improved habitat conditions compared to the 1999 survey (Figure 19). It can be surmised that the silt and sediment has reduced throughout the downstream reaches in Bokes Creek due to the formation of a more stable headwater channel. Bokes Creek at RM 31.8 showed signs of recovery from instream livestock, during the 1999 survey this area had broken down banks with cattle in the stream. During the 2013 sampling a vegetated riparian buffer was present and no signs of instream livestock were encountered. Stream banks at RM 23.3 appeared to be actively eroding (Figure 19). A very narrow riparian corridor in this reach was comprised mostly of grass with just a few trees. Localized affects from erosion and downstream sedimentation could be lessened with the establishment of a wider treed riparian buffer.

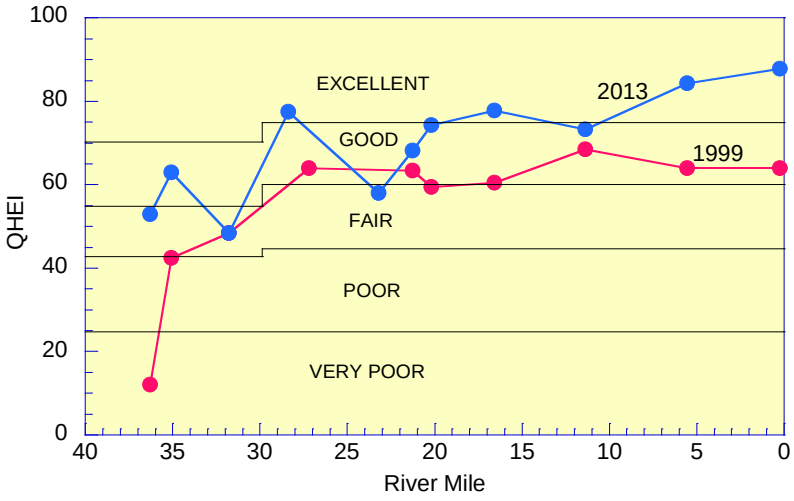


Figure 18. Longitudinal trend of Qualitative Habitat Evaluation Index (QHEI) scoring for Bokes Creek, 1999 and 2013.

Both Powderlick Run and North Fork West Mansfield Tributary (RM 3.96) had poor substrates comprised mostly of silt. However, these stream segments were found to be recovering toward a more natural and stable stream channel with riparian vegetation becoming established (Figure 20). Downstream from county road 142 along the North Fork West Mansfield Tributary, cows had free access to the stream and the banks were eroded and devoid of trees. Localized and downstream water quality improvements will be achieved by fencing the cows out of this stream segment. No signs of channel recovery were documented in the headwaters of North Fork West Mansfield Tributary (RM 5.58), which scored the lowest quality stream habitat in the watershed (QHEI=30) (Table 16). This stream segment appeared to have been more recently maintained. Habitat improvements in this reach can have positive local and downstream affects in the watershed.

Covering over five river miles, the lower two sampling sites on Bokes Creek had some of the best available habitat for fish communities in the watershed (Table 16). From 1999 to 2013, habitat quality at these two sites improved from good to excellent (Figure 18). In 1999, a total of eleven MWH attributes were scored among these two locations and in 2013 only one attribute was scored (Table 16). Similarly, the fish community performance also showed improvements. The largest increase in QHEI score for Bokes Creek was documented in the headwaters at RM 36.3. Twelve MWH attributes were scored along with no WWH attributes in 1999. Results from the 2013 QHEI score yielded three WWH and a total of seven MWH attributes (Appendix A).

Figure 19. Pictured above looking upstream and looking downstream below, a very narrow riparian buffer with row crops planted less than 5m from Bokes Creek at RM 23.32. Further erosion and loss of farm land could be reduced by allowing the establishment of or actively planting a wider riparian buffer.

Figure 20. Ongoing recovery from channelization at sites in the Bokes Creek headwaters RM 36.3 pictured above and the North Fork Mansfield Tributary RM 3.96 pictured below has resulted in improved fish communities.

Table 16. Summarized results of QHEI scores for the Bokes Creek study area, 2013.

Stream Name	River Mile	Drainage (mi^2)	QHEI
MOORS RUN @ S.R. 257	0.32	5.60	77.3
PRAIRIE RUN @ S.R. 37	0.07	5.60	80.0
BOKES CREEK NW OF HORTON @ C.R. 292	36.30	4.70	53.0
BOKES CREEK NEAR HORTON @ C.R. 120	35.10	7.10	63.0
BOKES CREEK @ WEST MANSFIELD-MT. VICTORY RD.	31.80	11.40	44.0
BOKES CREEK @ HOOVER-MOFFITT RD.	28.40	34.00	77.5
BOKES CREEK E OF YORK CENTER @ BITLER RD.	23.20	44.00	58.0
BOKES CREEK SE OF YORK CENTER @ YEARSLEY RD.	21.29	46.00	68.3
BOKES CREEK ADJ. S.R. 31	20.20	51.00	73.0
BOKES CREEK @ FORD REED RD.	16.58	58.00	77.8
BOKES CREEK @ S.R. 4	11.37	63.00	73.3
BOKES CREEK @ BROWN RD.	5.55	72.00	84.3
BOKES CREEK @ S.R. 257	0.25	83.10	87.8
BRUSH RUN S OF SOMERSVILLE @ YEARSLEY RD.	0.60	2.60	60.3
POWDER LICK RUN 100 YDS. DST. YEARSLEY RD.	0.17	4.10	45.5
N. FK. WEST MANSFIELD TRIBUTARY @ OFF C.R. 26	5.58	3.70	30.0
N. FK. WEST MANSFIELD TRIBUTARY @ C.R. 142	3.96	8.00	52.5
N. FK. WEST MANSFIELD TRIBUTARY @ JANUARY RD.	1.28	11.40	73.0
W. FK. WEST MANSFIELD TRIBUTARY @ S.R. 47	0.78	6.10	64.3
SMITH RUN UPST. BRINDLE RD.	0.80	5.50	73.5

General narrative ranges assigned to QHEI scores.			
Narrative Rating		QHEI Range	
		Headwaters ($\leq$20 mi^2)	Larger Streams
Excellent		$\geq$70	$\geq$75
Good		55 to 69	60 to 74
Fair		43 to 54	45 to 59
Poor		30 to 42	30 to 44
Very Poor		<30	<30

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 the water quality standards; and 3) to examine trends in fish contaminants over time.

Fish advisories

Fish contaminant data are used to determine a meal frequency that is safe for people to consume (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 per 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 Bokes Creek, no species met this requirement. Therefore, the statewide advisories apply, which are: two meals a week for sunfish (e.g., bluegill) and yellow perch, one meal a week for most other fish, and one meal a month for flathead catfish 23" and over, and northern pike 23" and over. It is noted that all of the fish tissue data available for Bokes Creek is comparable to or slightly better than the thresholds for the statewide advisories due to mercury, and PCBs were not detected in these fish tissue samples.

For a listing of fish tissue data collected from Bokes Creek in support of the advisory program, and how the data compare to advisory thresholds, see Table 17.

Fish tissue/human health use attainment

In addition to determining safe meal frequencies, fish contaminant data are also used to determine attainment with the human health water quality criteria pursuant to OAC Rules 3745-1-33 and 3745-1-34. The human health water quality criteria are presented in water column concentrations of µg/Liter, and are then translated into fish tissue concentrations in mg/kg. (http://www.epa.state.oh.us/portals/35/tmdl/2010IntReport/Section%20E.pdf)

In order to be considered in attainment of the Ohio Water Quality Standards criteria, the sport fish caught within a HUC-12 in the Ohio River basin must have a weighted average concentration of the geometric means for all species below 1.0 mg/kg for mercury, and below 0.054 mg/kg for PCBs.

Within the Bokes Creek study area (including two HUC-12s: 05060001 07 02 and 05060001 07 03), fish tissue data were not adequate to determine attainment status. At least 2 samples from each trophic level 3 and 4 are needed; however, neither of the two HUC-12 watersheds sampled as part of Bokes Creek met the requirements for trophic level 4 fish. No PCBs were detected in fish (reporting limit of 0.05 mg/kg) from either HUC-12. No fish had mercury levels above the criterion of 1.0 mg/kg (reporting limit of 0.024 mg/kg; max detect 0.201 mg/kg). Both HUC-12s are found to be lacking sufficient information to make a determination regarding impairment status, but all of the data available from the present survey is below the thresholds for impairment in fish tissue.

Fish contaminant trends

Fish contaminant levels can be used as an indicator of pollution in the water column at levels lower than laboratory reporting limits for water concentrations but high enough to pose a threat to human health from eating fish. Most bioaccumulative contaminant concentrations are decreasing in the environment because of bans on certain types of chemicals like PCBs, and because of stricter permitting limits on dischargers for other chemicals. However, data show that PCBs continue to pose a risk to humans who consume fish, and mercury concentrations have been increasing in some locations because of increases in certain types of industries for which mercury is a byproduct that is released to air and/or surface water.

For this reason, it is useful to compare the results from the survey presented in this TSD with the results of the previous surveys done in the study area. Recent data can be compared against historical data to determine whether contaminant concentrations in fish tissue appear to be increasing, decreasing, or staying the same in a water body or watershed.

This is the first time that fish tissue has been sampled from Bokes Creek; therefore, no such trends analysis can be conducted at this time.

Table 17. A summary of the Bokes Creek fish tissue data from 2013. Green shading indicates the data is better than the statewide advisory threshold of "one meal per week" (e.g., "two meals per week" or "unrestricted" levels). Gray shading indicates data which is comparable to the statewide advisory level of "one meal per week."

Species	Sample Size	Avg Arsenic	Avg Cadmium	Avg Lead	Avg Mercury	Avg Selenium	Avg Of Total PCBs
BLACK CRAPPIE	1	0.024	0.002	0.112	0.142	0.699	ND
CHANNEL CATFISH	1	0.025	0.002	0.356	0.104	0.351	ND
COMMON CARP	1	0.144	0.010	0.020	0.094	0.419	ND
ROCK BASS	2	0.024	0.005	0.037	0.178	0.517	ND
SMALLMOUTH BASS	1	0.061	0.002	0.020	0.141	0.762	ND
WHITE CRAPPIE	1	0.025	0.002	0.020	0.136	0.540	ND
YELLOW BULLHEAD	2	0.024	0.010	0.063	0.093	0.405	ND

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References

MacDonald D.D., Ingersoll C.G., Berger T.A. 2000. Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems. Archives of Environmental Contamination and Toxicity.

Miltner, R.J. 2011. Technical Support Document for Nutrient Water Quality Standards for Ohio Rivers and Streams. Draft Ohio EPA Technical Support Document dated 12/1/2011. Available on line at http://www.epa.state.oh.us/Portals/35/rules/Nutrient_Criteria_Technical_Support_Document_12-2-2011%20DRAFT.pdf

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

Ohio EPA. 2013. Surface Water and Field Sampling Manual for water column chemistry, bacteria and flows. Division of Surface Water. Columbus, Ohio.

Ohio EPA. 2012. Biological and Water Quality Study of the Middle Scioto River and Select Tributaries, 2010: Delaware, Franklin, Pickaway, and Union Counties. Ecological Assessment Section. Columbus, Ohio.

Ohio EPA. 2010. Guidance on Evaluating Sediment Contaminant Results. Division of Surface Water, Columbus, Ohio.

Ohio EPA. 2009. Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices. Updated edition. Division of Water Quality Planning and Assessment, Surface Water Section, Columbus, Ohio.

Ohio EPA. 2003. Ohio Specific Sediment Reference Values. EPA DERR Ecological Risk Assessment Guidance. Division of Emergency and Remedial Response, Columbus, Ohio.

Ohio EPA. 2002. Total Maximum Daily Loads for Bokes Creek, Final Report. Division of Surface Water, Columbus, Ohio.

Ohio EPA. 2001. Biological and Water Quality Study of Bokes Creek and Selected Tributaries, 1999: Logan, Union and Delaware Counties, Ohio. Division of Surface Water. Ecological Assessment Unit. Columbus, Ohio.

Ohio EPA. 1999. Association Between Nutrients, Habitat, and Aquatic Biota in Ohio Rivers and Streams. Ohio EPA Tech. Bull. EAS/2006-06-1. Division of Surface Water, Ecological Assessment Section, Columbus, Ohio.

Persaud D., J. Jaagumagi, and A. Hayton. 1993. Guidelines for the protection and management of aquatic sediment quality in Ontario. Ontario Ministry of the Environment. Toronto. 24 pp.

U.S. Environmental Protection Agency. 1993. Sediment Quality Criteria for the Protection of Benthic Organisms: Fluoranthene. EPA-822-R-93-012. Washington, D.C.

USEPA Making a Difference: An Ohio Non-point Source Project http://www.epa.gov/Region5/agriculture/spotlight200609.html 6/5/2013, Accessed 1/8/2015