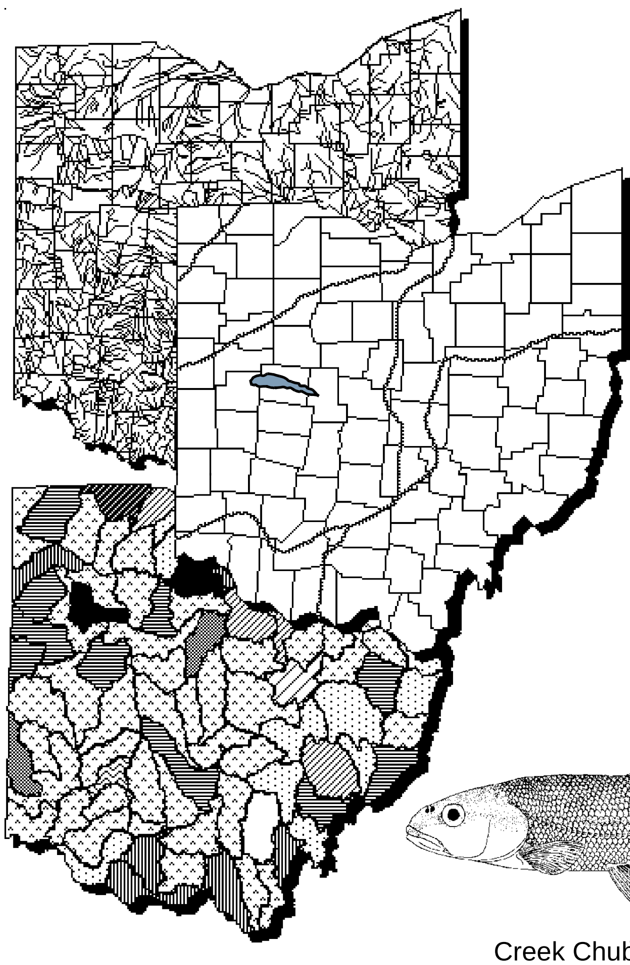
State of Ohio
Environmental Protection Agency

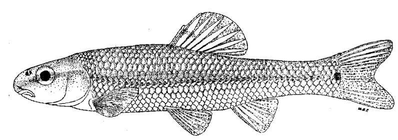
Ecological Assessment
Division of Surface Water

Biological and Water Quality Study of Bokes Creek and Selected Tributaries 1999

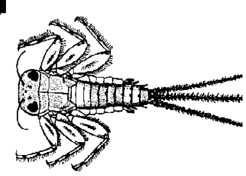
Logan, Union, and Delaware Counties, Ohio

MAS/2000-12-7

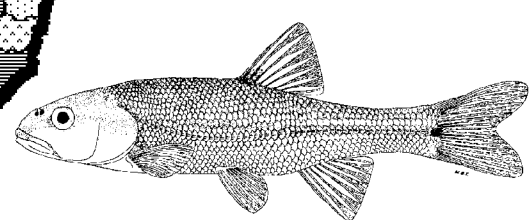




Bluntnose Minnow
(Pimphales notatus)



Mayfly *(Stenonema)*



Creek Chub *(Semolotus atromaculatus)*

July 6, 2001

Bob Taft
Governor, State of Ohio
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OEPA Technical Report MAS/2000-12-7

prepared by

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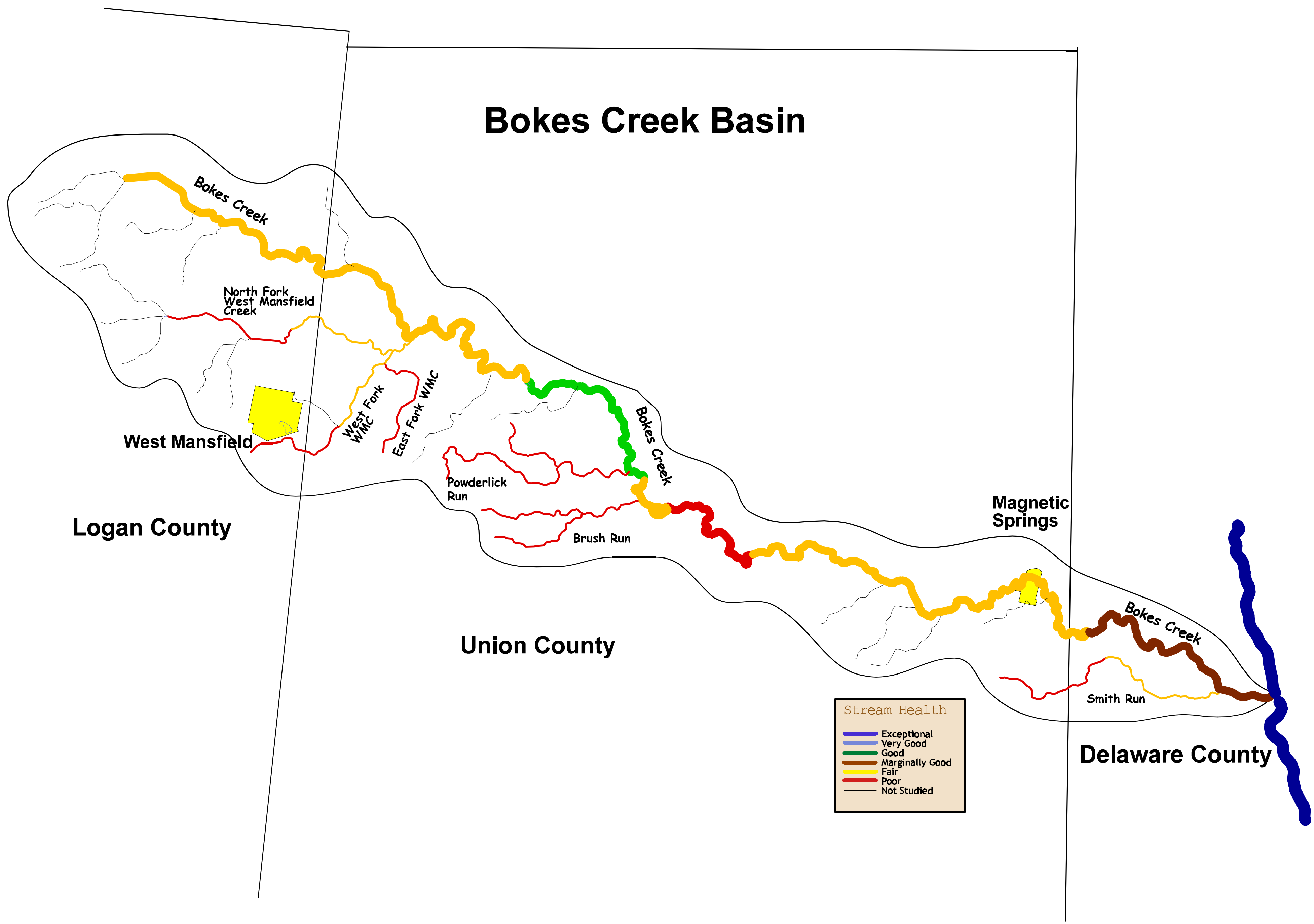
Bokes Creek Basin
Bokes Creek
North Fork West Mansfield Creek
West Fork WMC
East Fork WMC
West Mansfield
Bokes Creek
Powderlick Run
Brush Run
Logan County
Union County
Magnetic Springs
Bokes Creek
Smith Run
Delaware County
Stream Health
Exceptional
Very Good
Good
Marginally Good
Fair
Poor
Not Studied

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NOTICE TO USERS

Ohio EPA incorporated biological criteria into the Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1) regulations in February 1990 (effective May 1990). These criteria consist of numeric values for the Index of Biotic Integrity (IBI) and Modified Index of Well-Being (MIwb), both of which are based on fish assemblage data, and the Invertebrate Community Index (ICI), which is based on macroinvertebrate assemblage data. Criteria for each index are specified for each of Ohio's five ecoregions (as described by Omernik 1987), and are further organized by organism group, index, site type, and aquatic life use designation. These criteria, along with the existing chemical and whole effluent toxicity evaluation methods and criteria, figure prominently in the monitoring and assessment of Ohio's surface water resources.

The following documents support the use of biological criteria by outlining the rationale for using biological information, the methods by which the biocriteria were derived and calculated, the field methods by which sampling must be conducted, and the process for evaluating results:

Ohio Environmental Protection Agency. 1987a. Biological criteria for the protection of aquatic life: Volume I. The role of biological data in water quality assessment. Div. Water Qual. Monit. & Assess., Surface Water Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1987b. Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Div. Water Qual. Monit. & Assess., Surface Water Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1989b. Addendum to Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Div. Water Qual. Plan. & Assess., Ecological Assessment Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1989c. Biological criteria for the protection of aquatic life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities. Div. Water Quality Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

Ohio Environmental Protection Agency. 1990. The use of biological criteria in the Ohio EPA surface water monitoring and assessment program. Div. Water Qual. Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

Rankin, E.T. 1989. The qualitative habitat evaluation index (QHEI): rationale, methods, and application. Div. Water Qual. Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

Since the publication of the preceding guidance documents, the following new publications by the Ohio EPA have become available. These publications should also be consulted as they represent the latest information and analyses used by the Ohio EPA to implement the biological criteria.

DeShon, J.D. 1995. Development and application of the invertebrate community index (ICI), pp. 217-243. in W.S. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Risk-based Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Rankin, E. T. 1995. The use of habitat assessments in water resource management programs, pp. 181-208. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. and E.T. Rankin. 1995. Biological criteria program development and implementation in Ohio, pp. 109-144. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. and E.T. Rankin. 1995. Biological response signatures and the area of degradation value: new tools for interpreting multimetric data, pp. 263-286. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. 1995. Policy issues and management applications for biological criteria, pp. 327-344. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. and E.T. Rankin. 1995. The role of biological criteria in water quality monitoring, assessment, and regulation. Environmental Regulation in Ohio: How to Cope With the Regulatory Jungle. Inst. of Business Law, Santa Monica, CA. 54 pp.

These documents and this report may be obtained by writing to:

Ohio EPA, Division of Surface Water
Ecological Assessment Section
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This evaluation and report was possible only with the assistance of the study team, many full and part time field staff, and the chemistry analyses provided by the Ohio EPA Division of Environmental Services. Property owners who permitted access for sampling are also acknowledged for their cooperation.

Copies of this report are located on the Ohio EPA internet web page (www.epa.state.oh.us) or may be available from:

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Ecological Assessment Section
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Groveport, Ohio 43125
or
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FOREWORD

What is a Biological and Water Quality Survey?
A biological and water quality survey, or "biosurvey", is an interdisciplinary monitoring effort coordinated on a waterbody specific or watershed scale. This effort may involve a relatively simple setting focusing on one or two small streams, one or two principal stressors, and a handful of sampling sites or a much more complex effort including entire drainage basins, multiple and overlapping stressors, and tens of sites. Each year Ohio EPA conducts biosurveys in 10-15 different study areas with an aggregate total of 250-300 sampling sites.

Ohio EPA employs biological, chemical, and physical monitoring and assessment techniques in biosurveys in order to meet three major objectives: 1) determine the extent to which use designations assigned in the Ohio Water Quality Standards (WQS) are either attained or not attained; 2) determine if use designations assigned to a given water body are appropriate and attainable; and 3) determine if any changes in key ambient biological, chemical, or physical indicators have taken place over time, particularly before and after the implementation of point source pollution controls or best management practices. The data gathered by a biosurvey is processed, evaluated, and synthesized in a biological and water quality report. Each biological and water quality study contains a summary of major findings and recommendations for revisions to WQS, future monitoring needs, or other actions which may be needed to resolve existing impairment of designated uses. While the principal focus of a biosurvey is on the status of aquatic life uses, the status of other uses such as recreation and water supply, as well as human health concerns, are also addressed.

The findings and conclusions of a biological and water quality study may factor into regulatory actions taken by Ohio EPA (*e.g.,* NPDES permits, Director's Orders, the Ohio Water Quality Standards [OAC 3745-1], Water Quality Permit Support Documents [WQPSDs]), and are eventually incorporated into State Water Quality Management Plans, the Ohio Nonpoint Source Assessment, and the Ohio Water Resource Inventory (305[b]) report.

Hierarchy of Indicators
A carefully conceived ambient monitoring approach, using cost-effective indicators comprised of ecological, chemical, and toxicological measures, can ensure that all relevant pollution sources are judged objectively on the basis of environmental results. Ohio EPA relies on a tiered approach in attempting to link the results of administrative activities with true environmental measures. This integrated approach outlined in Figure 1 includes a hierarchical continuum from administrative to true environmental indicators. The six "levels" of indicators include: 1) actions taken by regulatory agencies (permitting, enforcement, grants); 2) responses by the regulated community (treatment works, pollution prevention); 3) changes in discharged quantities (pollutant loadings); 4) changes in ambient conditions (water quality, habitat); 5) changes in uptake and / or assimilation

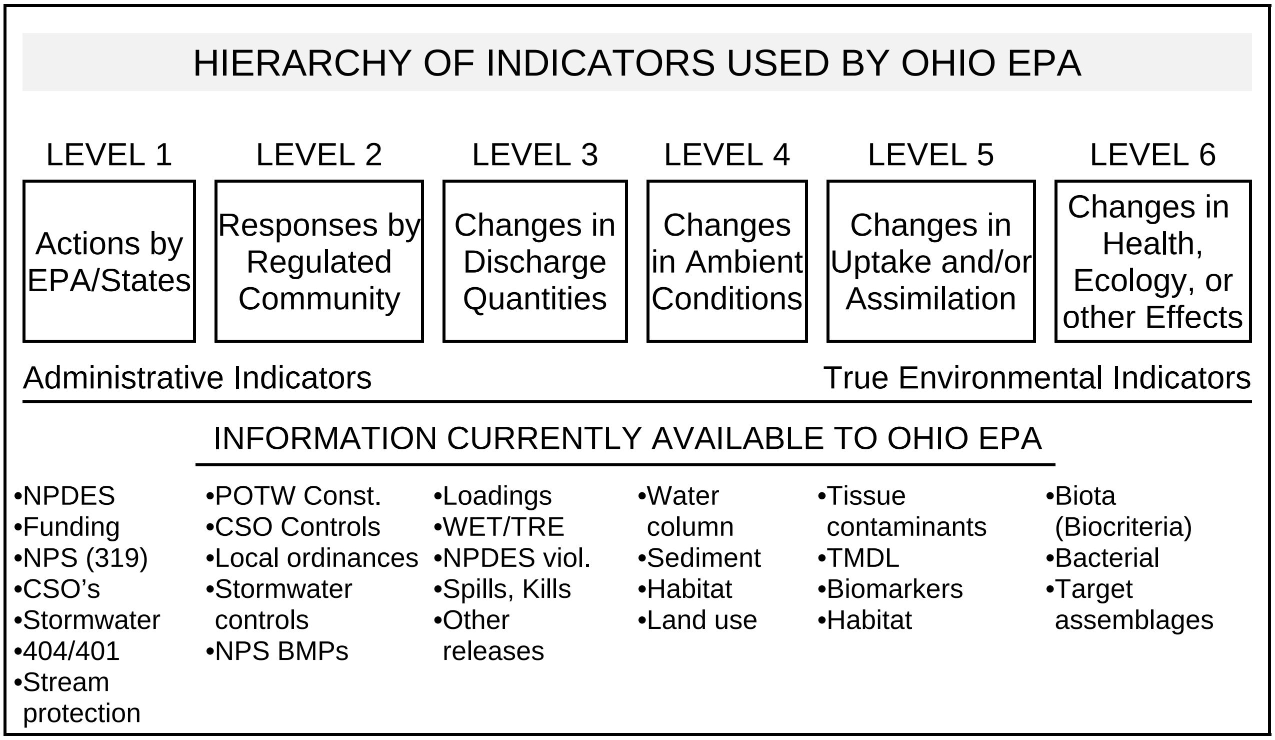

Figure 1. Hierarchy of administrative and environmental indicators used by Ohio EPA for monitoring, assessment, reporting, and evaluating program effectiveness (patterned after a model developed by the U.S.EPA, Office of Water

(tissue contamination, biomarkers, wasteload allocation); and, 6) changes in health, ecology, or other effects (ecological condition, pathogens). In this process the results of administrative activities (levels 1 and 2) can be linked to efforts to improve water quality (levels 3, 4, and 5) which should translate into the environmental "results" (level 6). Thus, the aggregate effect of billions of dollars spent on water pollution control since the early 1970s can now be determined with quantifiable measures of environmental condition.

Superimposed on this hierarchy is the concept of stressor, exposure, and response indicators. *Stressor* indicators generally include activities which have the potential to degrade the aquatic environment such as pollutant discharges (permitted and unpermitted), land use effects, and habitat modifications. *Exposure* indicators are those which measure the effects of stressors and can include whole effluent toxicity tests, tissue residues, and biomarkers, each of which provides evidence of biological exposure to a stressor or bioaccumulative agent. *Response* indicators are generally composite measures of the cumulative effects of stress and exposure and include the more direct measures of community and population response that are represented here by the biological indices which comprise Ohio's biological criteria. Other response indicators could include target assemblages, *i.e.,* rare, threatened, endangered, special status, and declining species or bacterial levels which serve as surrogates for the recreational uses. These indicators represent the essential technical elements for watershed-based management approaches. The key, however, is to use the different indicators *within* the roles which are most appropriate for each.

Describing the causes and sources associated with observed impairments revealed by the biological criteria and linking this with pollution sources involves an interpretation of multiple lines of evidence including water chemistry data, sediment data, habitat data, effluent data, biomonitoring results, land use data, and biological response signatures within the biological data itself. Thus the assignment of principal causes and sources of impairment represents the association of impairments (defined by response indicators) with stressor and exposure indicators. The principal reporting venue for this process on a watershed or subbasin scale is a biological and water quality report. These reports then provide the foundation for aggregated assessments such as the Ohio Water Resource Inventory (305[b] report), the Ohio Nonpoint Source Assessment, and other technical bulletins.

Ohio Water Quality Standards: Designated Aquatic Life Use

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

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

2) *Exceptional Warmwater Habitat (EWH)* - this use designation is reserved for waters which support "unusual and exceptional" assemblages of aquatic organisms which are characterized by a high diversity of species, particularly those which are highly intolerant and/or rare, threatened, endangered, or special status (*i.e.,* declining species); *this designation represents a protection goal for water resource management efforts dealing with Ohio's best water resources.*

3) *Cold-water Habitat (CWH)* - this use is intended for waters which support assemblages of cold water organisms and/or those which are stocked with salmonids with the intent of providing a put-and-take fishery on a year round basis which is further sanctioned by the Ohio DNR, Division of Wildlife; this use should not be confused with the Seasonal Salmonid Habitat (SSH) use which applies to the Lake Erie tributaries which support periodic "runs" of salmonids during the spring, summer, and/or fall.

4) *Modified Warmwater Habitat (MWH)* - this use applies to streams and rivers which have been subjected to extensive, maintained, and essentially permanent hydromodifications such that the biocriteria for the WWH use are not attainable *and where the activities have been sanctioned by state or federal law;* the representative aquatic assemblages are generally composed of species which are tolerant to low dissolved oxygen, silt, nutrient enrichment, and poor quality habitat.

5) *Limited Resource Water (LRW)* - this use applies to small streams (usually <3 $mi.^2$ drainage area) and other water courses which have been irretrievably altered to the extent that no appreciable assemblage of aquatic life can be supported; such waterways generally include small streams in extensively urbanized areas, those which lie in watersheds with extensive drainage modifications, those which completely lack water on a recurring annual basis (*i.e.,* true ephemeral streams), or other irretrievably altered waterways.

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

Ohio Water Quality Standards: Non-Aquatic Life Uses

In addition to assessing the appropriateness and status of aquatic life uses, each biological and water quality survey also addresses non-aquatic life uses such as recreation, water supply, and human health concerns as appropriate. The recreation uses most applicable to rivers and streams are the Primary Contact Recreation (PCR) and Secondary Contact Recreation (SCR) uses. The criterion for designating the PCR use is simply having a water depth of at least one meter over an area of at least 100 square feet or where canoeing is a feasible activity. If a water body is too small and shallow to meet either criterion the SCR use applies. The attainment status of PCR and SCR is determined using bacterial indicators (*e.g.,* fecal coliform, *E. coli)* and the criteria for each are specified in the Ohio WQS.

Water supply uses include Public Water Supply (PWS), Agricultural Water Supply (AWS), and Industrial Water Supply (IWS). Public Water Supplies are simply defined as segments within 500 yards of a potable water supply or food processing industry intake. The Agricultural Water Supply (AWS) and Industrial Water Supply (IWS) use designations generally apply to all waters unless it can be clearly shown that they are not applicable. An example of this would be an urban area where livestock watering or pasturing does not take place, thus the AWS use would not apply. Chemical criteria are specified in the Ohio WQS for each use and attainment status is based primarily on chemical-specific indicators. Human health concerns are additionally addressed with fish tissue data, but any consumption advisories are issued by the Ohio Department of Health.

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INTRODUCTION

As part of the five-year basin approach for monitoring, assessment, and the issuance of National Pollution Discharge Elimination System (NPDES) permits, ambient biological, water column chemical, sediment, and bioassay sampling was conducted in the Bokes Creek basin from June to October 1999. This study area exceeded a 36 mile reach of Bokes Creek from the headwaters upstream from State Route 292 (west of Horton) downstream to the mouth, all of Powderlick Run, and sites on Smith Run, North Fork West Mansfield Creek, West Fork West Mansfield Creek, and South Branch of West Fork West Mansfield Creek. Table 8 illustrates sampling locations.

Specific objectives of this evaluation were to:

1) Monitor and assess the chemical (water and sediment) integrity, physical habitat, and biological integrity (biomonitoring of macroinvertebrates and fish along with fish tissue) of the streams within the 1999 Bokes Creek watershed study area;

2) Evaluate the smaller headwater streams in subwatersheds to assign aquatic life use designation or primary headwater habitat classification as determined;

3) Evaluate effects from egg farms and to assess any other instream impacts to Powderlick Run and Bokes Creek mainstem;

4) Determine the attainment status of the current designated Warmwater Habitat (WWH) aquatic life use and other non-aquatic use designations and recommend changes in use where appropriate; and,

5) Conduct water resource trend assessments where historical data exists.

The findings of this evaluation factor into regulatory actions taken by the Ohio EPA (*e.g.*, NPDES permits, Director's Orders, the Ohio Water Quality Standards [OAC 3745-1], Water Quality Permit Support Documents [WQPSDs]) and are incorporated into State Water Quality Management Plans, the Ohio Nonpoint Source Assessment, and the biennial Water Resource Inventory (305[b]) report.

SUMMARY

Aquatic Life Use Attainment Status

Bokes Creek

The 1999 Bokes Creek study area included a mainstem reach beginning at RM 36.3 (State Route 292) and extending downstream to the mouth and sites on six tributaries. Ambient mainstem water column chemical, physical and bacteriological sampling occurred at 10 stations; biological sampling occurred at 10 segments (Table 4). Based on the performance of biological communities with respect to ecoregional biocriteria, only 9.6 % (3.5 miles) of Bokes Creek was considered to be in FULL attainment of the WWH aquatic life use designation. PARTIAL attainment of the WWH use was demonstrated in 19.5 miles of stream primarily in the middle and lower reaches of Bokes Creek (53.4 %). **NON** attainment of the WWH use was documented in the headwaters and in the dissolved oxygen (D.O.) "sag zone" 2-4 miles downstream from the confluence of Powderlick Run for a total of 13.5 miles (37.0 %).

This level of performance was characterized as fair to marginally good. The non-attainment upstream in the headwater reaches of Bokes Creek were related primarily to excessive agricultural nonpoint source pollution inputs, inadequate nighttime dissolved oxygen (D.O.) concentrations, and habitat deficiencies. Evidence of nutrient runoff and some sedimentation was present throughout the Bokes Creek mainstem. Warmwater communities, though, were present in most downstream reaches. Physical habitat conditions were generally sufficient to support warmwater communities downstream. Where habitat conditions in Bokes Creek were marginally good to good (QHEI/58-60) the biological community generally attained or partially attained WWH performance. The WWH stream use designation was retained for almost all of the Bokes Creek mainstem.

Tributaries

Various tributaries were sampled at 15-17 locations where water column chemical, physical and bacteriological data were recorded. Biological samples were evaluated at 16 sites. These tributaries included North Fork West Mansfield Tributary, West Fork West Mansfield Tributary, South Branch West Fork West Mansfield Tributary, Powderlick Run, Tributary to Powderlick Run (@ RM 2.0), Brush Run, and Smith Run. All tributary locations surveyed throughout the basin failed to meet the assigned WWH aquatic life use as determined by the applicable biological criteria. Eggwash water, nonpoint source pollution (nutrients, manure, sedimentation, and other parameters), possibly land application of wet treated wastewater, and habitat deficiencies (to a lesser degree), in aggregate, degraded water quality and associate aquatic communities. Warmwater biota potential was still present in the majority of stream reaches sampled, so the WWH aquatic life use designations were retained in almost all of the segments.

Biological communities were negatively impacted in Powderlick Run particularly from direct chicken production spills (a fish kill due to eggwash water spill by the Mad River Egg Farm) and nutrient pollution due to runoff from adjacent agricultural fields that were fertilized with chicken manure from the Day Lay Egg farms. These inputs caused excess nutrient enrichment, periodic low D.O.s, and acutely (ammonia) and chronically toxic conditions. This nutrient load certainly contributed to non-attainment in Bokes Creek downstream from the confluence with Powderlick Run (Reed Ford Rd.) which was attributed to impacts from high BOD (Biochemical Oxygen Demand), low diel D.O. concentrations, and other possible chronic toxicity effects.

Table 1. Aquatic life use attainment status of sites sampled in the Bokes Creek basin from June-October, 1999. The Index of Biotic Integrity (IBI), Modified Index of well being (MIwb), and the Invertebrate Community Index (ICI) are scores based on the performance of the biotic community. The Qualitative Habitat Evaluation Index (QHEI) measures the ability of the physical habitat to support a biotic community. Aquatic life uses for the Bokes Creek basin were based on biological sampling conducted during June - October 1999.

RIVER MILE Fish/Invert.	IBI	MIwb	ICI[a]	QHEI	Attainment Status[b]	Site Location
Bokes Creek (02-138) 1999 Eastern Corn Belt Plains (ECBP) - Modified Warmwater Habitat (MWH) Use Designation (**recommended**)						
36.3	26	NA	P*	12.0	**NON**	at SR 292
Bokes Creek (02-138) 1999 *Eastern Corn Belt Plains (ECBP) - WWH Use Designation*						
35.1 / 35.0	28*	NA	F*	42.5	**NON**	dst. Logan Co Rd. 120
31.8 / 31.9	28*	NA	F*	47.5	**NON**	West Mansfield - Mt. Victory Rd.
27.0 / 27.3	34*	8.6	F*	63.0	PARTIAL	dst./ust. Phelps Rd.
21.3 / 21.2	40	8.1_{ns}	36	62.5	FULL	Yearsley Rd. (ust. Powderlick Run)
20.2 / 20.4	34*	7.2*	34^{ns}	58.5	PARTIAL	Adj. SR 31 (dst. Powderlick Run)
17.0 / 16.8	31*	5.7*	MG^{ns}	59.5	**NON**	ust. Reed Ford Rd.
11.4	42	7.2*	MG^{ns}	67.5	PARTIAL	ust. SR 4
5.6 / 5.4	31*	5.9*	G	63.0	PARTIAL	ust./dst. Brown Rd.
0.2	36_{ns}	6.5*	MG^{ns}	63.0	PARTIAL	dst. SR 257 (near mouth)
Bokes Creek 1993						
27.2 / 26.2	40	8.5	42	56.0	FULL	
21.4	34*	6.7*	40	44.0	PARTIAL	
20.2	34*	5.7*	---	63.5	(**NON**)	
14.8	31*	6.2*	38	72.0	PARTIAL	
5.6	34*	7.4*	32^{ns}	64.0	PARTIAL	
0.3	41	7.3*	---	68.0	(PARTIAL)	
Bokes Creek 1992						
27.5 / 26.2	32*	6.3*	44	43.5	PARTIAL	
21.3 / 21.4	30*	6.2*	50	59.0	PARTIAL	
20.2 / 20.5	29*	5.2*	34^{ns}	45.0	**NON**	
14.8	37^{ns}	7.6*	40	78.0	PARTIAL	
5.5 / 5.6	37^{ns}	6.5*	42	68.0	PARTIAL	
0.3 / 0.2	49	9.1	44	81.5	FULL	

RIVER MILE Fish/Invert.	*IBI*	*MIwb*	*ICI*[a]	*QHEI*	*Attainment Status*[b]	*Site Location*
Bokes Creek 1990						
27.2 / 27.5	28*	7.5*	30*	61.0	**NON**	
21.3 / 21.4	34*	6.6*	40	58.5	PARTIAL	
13.2 / 14.8	32*	6.3*	38	82.5	PARTIAL	
5.6	36[ns]	5.6*	32[ns]	65.5	**NON**	
Bokes Creek 1981						
30.6 A	24*	NA	F*	---	**NON**	
30.6 B	28*	NA	MG[ns]	---	PARTIAL	
28.4 A	18*	NA	F*	---	**NON**	
28.4 B	24*	NA	MG[ns]	---	**NON**	
26.1 / 25.9 A	12*	--	F*	---	**NON**	
26.1 / 25.9 A	34*	--	MG[ns]	---	PARTIAL	
23.2 A	--	--	G	---	(FULL)	
23.2 B	--	--	G	---	(FULL)	
Smith Run (02-138) 1999 ECBP - WWH Use Designation						
0.8	20*	NA	F*	61.5	**NON**	Brindle Rd.
Powderlick Run (02-144) 1999 ECBP-Limited Resource Water (LRW) Use Designation (**recommend**)						
4.8c/4.8	22	NA	VP*	31.0	**NON**	Storms Rd. (dst Daylay Egg Farm #3)
3.7c/3.7	24	NA	P	27.0	FULL	Easternmost crossing at Davis Rd. (recovery / ust. Daylay Farm #2)
3.4 / 3.3	18	NA	VP*	39.5	**NON**	St. Rt. 739 (dst. Daylay Farm #2/ upstream Daylay Farm #1 - pullets)
Powderlick Run (02-144) 1999 ECBP - WWH Use Designation						
2.1	24*	NA	P*	45.0	**NON**	West crossing at Powderlick Rd. (dst Daylay Farms /ust Mad River Egg Farm)
1.8/1.6	12*	NA	0*	60.5	**NON**	Ust. Powderlick Rd. just west of Fawley Rd. (dst. tributary draining Mad River Egg Farm)
1.2	--	NA	4*	---	(**NON**)	Dst. Powderlick Rd. E of Fawley Rd.
1.0/0.9	18*	NA	6*	23.0	**NON**	Dst. recovery / ust. cattle farms
Powderlick Run (02-144) 1993 *ECBP - WWH Use Designation*						
0.2	28*	NA	--	34.0	(**NON**)	

RIVER MILE Fish/Invert.	IBI	MIwb	ICI[a]	QHEI	Attainment Status[b]	Site Location
Powderlick Run (02-144) 1992 *ECBP - WWH Use Designation*						
1.6	22*	NA	--	60.5	(**NON**)	
0.2 / 0.1	25*	NA	30*	49.5	**NON**	
Trib. to Powderlick Run (@ RM 2.0) (02-330) 1999 ECBP - WWH Use Designation						
0.1	12*	NA	--	52.0	(**NON**)	dst. Mad River Egg Farm in trib.
West Fork West Mansfield Tributary (02-194) 1999 ECBP - WWH Use Designation						
1.0 /0.8	26*	NA	MG[ns]	39.0	**NON**	ust. St. Rt. 47
West Fork West Mansfield Tributary 1981						
0.8A	14*	NA	F*	59.0	**NON**	
0.8B	34*	NA	F*	59.0	**NON**	
S. Br. West Fork West Mansfield Tributary (02-331) 1999 ECBP - WWH Use Designation						
0.1	--	NA	P*	51.0	(**NON**)	adj. Newton-Perkins Rd. near mouth
East Fork West Mansfield Tributary (02-195) 1981 *ECBP - WWH Use Designation*						
0.3A	20*	NA	--	---	(**NON**)	adj. St. Rt. 47
0.3B	28*	NA	--	---	(**NON**)	adj. St. Rt. 47
North Fork West Mansfield Tributary (02-227) 1999 ECBP - MWH Use Designation (**recommended**)						
5.6	12*	NA	P*	15.0	**NON**	farm rd. off Logan Co. Rd 26
North Fork West Mansfield Tributary (02-227) 1999 ECBP - WWH Use Designation						
3.8/4.0	30*	NA	P*	30.5	**NON**	Co. Rd. 142 (Logan Co.)
1.3	32*	NA	F*	51.0	**NON**	January Rd.
Brush Run (02-228) (2000) ECBP - WWH Use Designation						
0.5[c]	24*	NA	--	49.0	(**NON**)	Yearsley Rd.

Biological Criteria for Eastern Corn Belt Plains (ECBP)

Site Type INDEX	IBI Headwaters	IBI Wading	IBI Boat	MIwb Wading	MIwb Boat	ICI (all sites)
WWH	40	40	42	8.3	8.5	36
MWH	24	24	24	6.2	5.8	22
LRW	18	18	18	4.0	4.0	8

* Significant departure from ecoregion biocriterion; poor and very poor results are underlined.
ns Nonsignificant departure from biocriterion (<4 IBI or ICI units; <0.5 MIwb units).
a Narrative evaluation used in lieu of ICI (E=Exceptional; G=Good; MG=Marginally Good; F=Fair; P=Poor).
b Use attainment status based on one organism group is parenthetically expressed.
c Sampled or evaluated in 2000.
NA Not Applicable. The MIwb (Modified Index of Well-being) is not applicable to headwater sites.

Table 2. Narrative ranges, WWH (bold), MWH (italics), and LRW (underlined), of biocriteria for the Eastern Corn Belt 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 biocriteria departure are the same.

IBI			**MIwb**		**ICI**	**Narrative Evaluation**
Headwater	Wading	Boat	Wading	Boat	All	
50-60	50-60	48-60	$9.4	$9.6	46-60	Exceptional
46-49	46-49	44-47	8.9-9.3	9.1-9.5	42-44	Very Good
Eastern Corn Belt Plains						
40-45	**40**-45	**42**-43	**8.3**-8.8	**8.5**-9.0	**36**-40	Good
36-39	36-39	38-41	7.8-8.2	8.0-8.4	32-34	Marginally Good
28-35	28-35	26-37	5.9-(*6.2*) 7.7	6.4-7.9	14-(*22*) 30	Fair
<u>18</u>-(*24*) 27	<u>18</u>-(*24*) 27	16-(<u>18</u>,*24*) 25	4.5-5.8	5.0-(*5.8*) 6.3	<u>8</u>-12	Poor
12-17	12-17	12-15	0-(<u>4.0</u>) 4.4	0-(<u>4.0</u>) 4.9	≤6	Very Poor

CONCLUSIONS

- C The Bokes Creek mainstem supports fair to marginally good macroinvertebrate and fish communities. With the exception of headwater reaches and a 4-mile segment downstream from Powderlick Run, all 1999 mainstem sampling locations at least partially attained WWH ecoregional expectations.

- C Habitat conditions in Bokes Creek were fairly consistent with the biological performance except for the RM 17.0 site which was influenced biochemically by nutrient inputs from the Powderlick Run subbasin upstream. Better performance in the watershed was usually correlated with better habitat and wider riparian zones (more efficient nutrient and sediment absorption, assimilation, and buffering capacity).

- C The entire Bokes Creek watershed is impacted by excessive concentrations of nutrients along with suspended solids, oxygen demanding substances, and bacteria. These pollutants are often at overwhelming concentrations in the watershed. In many instances, these impacts are direct causes of Ohio Water Quality Sandards criteria violations. Manure spreading on agricultural fields is widespread in the basin, and runoff to streams via surface draining or through field tiles in the area has the potential to negatively affect ambient water quality. Tile drainage accelerated delivery of excess nutrients from agricultural fields where waste manure application occurred and exacerbated nutrient enrichment and low D.O. impacts.

- C Headwaters and tributary areas are severely influenced by agricultural runoff including fertilizers from grain producing fields and manure from livestock operations. Failing on-site wastewater treatment systems are also problematic in the watershed (e.g., Magnetic Springs area). Modifications to the stream channels themselves (e.g. channelization, drainage improvement activities) and the surrounding watershed (e.g. riparian corridor and wetland removal) have diminished the natural assimilative capabilities of this watershed.

- C Other pollutants that likely impacted the environmental quality in the Bokes Creek basin included silt/sedimentation, total dissolved solids (TDS), related high hardness and conductivities, and, to a lesser extent, selected herbicides/pesticides and metals.

- C The Powderlick Run subbasin was unique among Bokes Creek tributaries for the number of egg production facilities and their impact on water quality to this stream and the Bokes Creek mainstem (three Daylay egg / pullet production facilities and the Mad River Egg Farm). Every site biologically evaluated was documented to be *poor or very poor.* *<u>No fish</u> were collected downstream from the Mad River Egg Farm in the tributary to Powderlick Run or in Powderlick Run at RM 1.8. The ICI score was <u>0</u> at the paired macroinvertebrate sample site in Powderlick Run at RM 1.6*.

- The Day Lay Egg Farms were a major source of nutrient and bacterial input to Powderlick Run and, thereby, Bokes Creek. Stormwater was particularly contaminated as it ran off of the Day Lay fields and facilities. This contamination was documented in the Powderlick Run headwaters from sampling during or soon after rain event(s).

- Organic fertilizers/waste from two other concentrated animal feeding operation (CAFO) egg facilities (Weaver's Heartland Egg Farm in eastern Logan County in headwaters of North Fork West Mansfield Tributary and another outside of the basin) likely have contributed to NPS inputs through land application in the Bokes Creek basin.

Table 3. Attainment status and causes and sources of impairment of Bokes Creek basin, 1999.

Waterbody Upper/Lower	Stream Reach (RM) Length (Assessed)	Attainment Miles Status FULL	Partial	**NON**	Threatened	Causes, Sources, and Comments
Bokes Creek Headwaters to Brush Run	RM 39.70-19.71 Total = 19.99 (17.59)	5.74	5.05	**6.80**	5.74	*Causes*: **Organic Enrichment/D.O. (H), Nutrients (H), Direct habitat alteration (H), Siltation (M), Unionized Ammonia (S), Flow Alteration(M)** *Sources*: **Animal Holding Areas/Mgt. Areas (H), Nonirrigated crop production (H), Channelization (H), Removal of riparian vegetation (H/M), Flow regulation/modification (M)**
	Comments: **The biological community in Bokes Creek from the headwaters to Brush Run was impacted by nonpoint source pollution. Excess nutrients from runoff or drainage from fertilized fields (chicken/egg farm (organic) waste fertilizer or direct chemical fertilizer) on tributaries primarily and fields adjacent to mainstem. Channelized segments and riparian-removed reaches (some on mainstem/mostly on tribs.) allowed excess nutrient delivery and siltation to mainstem increasing algal production and diel D.O. sags. Ammonia (possibly hardness, and conductivity) was at high enough concentrations to possibly contribute to chronic effects. Low D.O. (WQS exceedences)and high bacterial conc. (exceedences) contribute to chronic community stressors. Tile modified flow drainage has allowed more nutrients into streams.** ***Threats*****: Yearsley Rd. area (RM 26.5-20.76) upstream from Powderlick Run threatened by nutrients and organic enrichment/D.O. and silt inputs from upstream tributaries and NPS storm runoff.**					

(Table 3 Cont.) Waterbody Upper/Lower	Stream Reach (RM) Length (Assessed)	Attainment Miles Status FULL	Partial	NON	Threatened	Causes, Sources, and Comments
Bokes Creek Brush Run to Scioto River	RM 19.71- 0.00 Total = 19.71 (19.71)		15.0	**4.71**		*Causes*: **Organic Enrichment/D.O. (H), Nutrients (H), Direct habitat alteration (M), Siltation (M), Flow Alteration (M)** *Sources*: **Animal Holding Areas/Mgt. Areas (H), Nonirrigated crop production (H), Removal of riparian vegetation (H/M), Channelization (H), Flow regulation/modification (M), Onsite wastewater systems (septic tanks) (M), Package Plants (Small flows) (S), Pasture land (S)**
	Comments: **The biological community in Bokes Creek from Brush Run to the mouth was impacted by nonpoint source runoff pollution (chiefly & primarily agricultural - Daylay Farm and runoff from fertilized fields but some localized additive effects from unsewered Magnetic Springs and possibly a small wastewater package treatment plant). Very elevated nutrient concentrations , high bacterial concentrations, high algal production, biochemical decay, & consequently chronically low dissolved oxygen concentrations and siltation inhibited community quality improvements. Generally the highest fish and macroinvertebrate diversity, IBI and ICI scores, and number of quality organisms (i.e., EPT taxa) occurred at site(s) upstream from Powderlick Run and Brush Run. Habitat alteration of tributaries (wood removal, field tiles, and loss of riparian corridor) and intensive fertilizer applications resulted in excess nutrients/organic fertilizer and sediment to the lower mainstem.**					

(Table 3 Cont.)

Waterbody Upper/Lower	Stream Reach (RM) Length (Assessed)	Attainment Miles Status FULL	Partial	**NON**	Threatened	Causes, Sources, and Comments
Powderlick Run	RM 5.90 - 0.00 Total = 5.90 (5.10)	0.3		**4.80**		*Causes*: **Organic Enrichment/D.O. (H), Nutrients (H), Direct habitat alteration (H), Siltation (M/H), Flow Alteration (M), Unionized Ammonia (M), Salinity/TDS/chlorides (M/S)** *Sources*: **Animal Holding Areas/Mgt. Areas (H), Nonirrigated crop production (H), Pasture land (H/S), Septage disposal(land application treatment)(M), Minor Industrial Point Source (H/M/S), Removal of riparian vegetation (H), Dredging (H), Channelization (M), Flow regulation/modification (M)**
	Comments: **Excess nutrients from organic and NPS agriculture applications whose transfer from land application to the field and then to the stream is exacerbated by a lack of riparian vegetation, open canopy, and field tiles. These features allowed for gross nutrient enrichment with D.O.'s of zero mg/l (toxicity). Probable chronic ammonia toxicity (possibly acute toxicity) associated with NPS runoff and Mad River Egg Farm egg wash water spill. ICI of zero and no fish collected downstream from Mad River Egg Farm. High TDS, conductivity and fecal coliform bacteria concentations associated with Daylay Farms (particularly Mad River Egg Farm). Very poor to poor conditions will improve with decreasing nutrient inputs and improving the riparian corridor. Siltation affected Bokes Creek shortly after dredging in the lower reach of Powderlick Run. Siltation was a problem in most of Powderlick Run (lack of sufficient riparian habitat and /or unrestricted cattle access) and Bokes Creek (mostly delivery from tributaries).**					

(Table 3 Cont.)

Waterbody Upper/Lower	Stream Reach (RM) Length (Assessed)	Attainment Miles Status FULL	Partial	**NON**	Threatened	Causes, Sources, and Comments
Tributary to Powderlick Run	RM 0 - 0.00 Total = 0 (0.30)			**0.30**		*Causes*: **Organic Enrichment/D.O. (H), Unionized Ammonia (H), Salinity/TDS/chlorides (H)** *Sources*: **Minor Industrial Point Source (H), Spills (H), Onsite wastewater systems (lagoons) (H)**
	Comments: **Mad River Egg Farm Process egg wash water spilled from holding lagoons into a Trib. to Powderlick Run affecting the biological community in the Trib. to Powderlick Run and in Powderlick Run downstream. <u>No fish</u> were collected during fish survey - in the Trib. to Powderlick Run or at RM 1.8 in Powderlick Run (dst. of confluence with Trib. to Powderlick Run) though habitat supported a fish community presence (fish kill and / or fish avoidance). ICI was a <u>zero</u> at RM 1.6 in Powderlick Run - downstream from the Trib to Powderlick Run and Mad River Egg Farm with only tolerant organisms present.**					
Brush Run	RM . - 0.00 Total = . (1.00)			**1.00**		*Causes*: **Organic Enrichment/D.O. (H), Nutrients (H), Siltation (H)** *Sources*: **Nonirrigated crop production (H), Pasture land (H), Removal of riparian vegetation (H), Stream bank modification/destabilization (H), Onsite wastewater systems (septic tanks) (M)**
	Comments: **Nutrients and organic fertilizers from field applications runoff and exposed streams and banks from riparian removal and/or bank destabilization (nonirrigated crop production upstream and/or cattle access) allowed excess nutrients to trigger primary production, subsequent increased algal biomass decay, and lower diel D.O. concentrations. Siltation and sedimentation from erosion of open, unstable streambanks embedded substrates and limited fish and macroinvertebrate habitats, decreasing diversity. Tolerant fish community present indicated poor water quality conditions.**					

(Table 3 Cont.)

Waterbody Upper/Lower	Stream Reach (RM) Length (Assessed)	Attainment Miles Status				Causes, Sources, and Comments
		FULL	Partial	**NON**	Threatened	
North Fork West Mansfield Trib.	RM 8.80 - 0.00 Total = 8.80 (5.30)			**5.30**		*Causes*: **Organic Enrichment/D.O. (H), Nutrients (H), Direct habitat alterations (H), Siltation (H/M)** *Sources*: **Nonirrigated crop prod (H), Pasture land (H), Removal of riparian vegetation (H/M), Flow regulation/modification (M), Channelized (M)**
	Comments: **Land applied organic fertilizers and nutrient (i.e. P or anhydrous ammonia) applications to field without adequate riparian cover or width and field tiles caused excess nutrient enrichment, algal production, decay, and low diel D.O. concentrations (D.O. under 1 mg/l - toxic or avoidance). Siltation embedded and covered substrates and excacerbated low D.O. problems with limited fish and bug habitat. Open canopy (riparian removal) and some channelization allowed more primary production, increased BOD and consequently caused low D.O.'s.**					
Smith Run	RM 4.90 - 0.00 Total = 4.90 (4.90)			**4.90**		*Causes*: **Organic Enrichment/D.O. (H), Nutrients (H), Direct habitat alterations (M), Siltation (M), Flow alteration (M)** *Sources*: **Nonirrigated crop production (H), Removal of riparian vegetation (M), Flow regulation/modification (M)**
	Comments: **Widen riparian corridor in upper reach to intercept/absorb excess nutrients/organic fertilizers to decrease inputs into the stream, stabilize banks and decrease silt loads. Substrate embeddedness inhibited fish and macroinvertebrate populations. Low diel D.O. concentrations (2.7 mg/l -toxic or avoidance) from decaying organic matter (algal production / decay) impacted the aquatic community. High nutrients converted to algal biomass and/or high siltation was illustrated and confirmed by parallel high total suspended solids (TSS). Field tiles allowed quicker nutrient delivery through thinly canopied upper stream affecting all portions of stream (Smith Run had better riparian corridor in lower portions). High nutrient loads & low oxygenated, poor quality water sent to Bokes Creek.**					

(Table 3 Cont.)

Waterbody Upper/Lower	Stream Reach (RM) Length (Assessed)	Attainment Miles Status FULL	Partial	NON	Threatened	Causes, Sources, and Comments
West Fork West Mansfield Trib.	RM 2.50 - 0.00 Total = 2.50 (2.20)			**2.20**		*Causes*: **Organic Enrichment/D.O. (H), Nutrients (H), Siltation (H), Direct habitat alterations (H), Flow alteration (M)** *Sources*: **Nonirrigated crop production (H), Removal of riparian vegetation (H), Septage disposal (land application) (M), Channelization (S), Flow regulation/modification (M), Pasture land (S), Onsite wastewater systems (septic tanks) (S)**
	Comments: **Combined impacts from agriculture (organic fertilizers and nutrients) with organic nutrients runoff from West Mansfield land application fields caused nutrient enrichment / low diel D.O. problems (exceedences) via decay. High NH_3 , nitrogen, and phosphorus resulted in high algal production. High Total suspended solids (TSS) occurred in the form of algal production in suspension and/or sedimentation runoff. Excessive silt load, lack of riparian habitat and unimpeded cattle access limited the fish and macroinvertebrate habitat (not much hard substrates - covered, silted, or embedded). These physical habitat limitations and chemical stressors resulted in tolerant fish populations.**					
South Branch West Fork West Mansfield Trib.	RM 2.42 - 0.00 Total = 2.42 (1.00)			**1.00**		*Causes*: **Organic enrichment/D.O. (H), Direct habitat alterations (M), Salinity/TDS/Chlorides (M), Flow alteration (M), Siltation (S)** *Sources*: **Nonirrigated crop production (H/M), Removal of riparian vegetation (M/S), Septage disposal (land application) (H), Channelization (M), Flow regulaton/modification (M), Dam construction (S)**
	Comments: **Organic nutrients were getting into stream from fertilized field runoff (at WWTP waste - applied fields and other fields). Where no riparian vegetation (open canopy), excess nutrients caused higher primary production and impacts from lower D.O. concentrations via decay. Possible anhydrous NH_3 runoff after field applications or sewage source, bacterial contamination & high Cond./TDS/hardness likely contributed to impacts in biological community. Siltation limiting habitat in parts of stream.**					

RECOMMENDATIONS

Status of Aquatic Life Uses

Most of the streams evaluated in this study were originally designated for aquatic life use in the 1978 and 1985 Ohio WQS (Table 3). The current biological assessment methods and numerical criteria did not exist then. Since this study was the first time a standardized biological approach was used to evaluate aquatic life use designations for several subbasin streams, some changes may appear to be "upgrades" (*i.e.,* WWH to EWH). However, these changes should not be so construed because this study, as an objective and robust use evaluation, is precedent setting in comparison to the 1978 and 1985 designations. Ohio EPA is obligated by a 1981 public notice to review and evaluate all aquatic life use designations outside of the WWH use prior to basing any permitting actions on the existing, unverified use designations. Thus some of the following aquatic life use recommendations constitute a fulfillment of that obligation.

Bokes Creek was originally assigned the WWH aquatic life use in 1981. Given the attainment or partial attainment of WWH biological criteria and QHEI scores near or $\geq$ 60 over a majority of the stream length, it has been demonstrated that this designation of WWH is appropriate and should be retained downstream from RM 35.5. Due to persistent maintenance and acute channel entrenchment, the only segment that was recommended for a use designation change to Modified Warmwater Habitat in the Bokes Creek mainstem was the uppermost stream reach sampled (RM 37.3 to RM 35.51). Bokes Creek has been subject to past modification including channelization, riparian habitat removal and snagging of instream cover; however, cobble and gravel substrates predominate at most sites.

Generally the current WWH aquatic life use designations for the tributaries should also be maintained. These designations were considered appropriate in most cases based on ambient macrohabitat conditions and potential; at least one sampled stream reach in tributary contained QHEI scores in the 50-60 range (Table 1).

However, sampling further upstream in North Fork West Mansfield Tributary revealed a historically entrenched channel and a very narrow, reduced riparian corridor. Due to a general lack of recovery potential and a low QHEI score, the upstream reach of North Fork West Mansfield Tributary (RM 6.1 to RM 4.51) was recommended to be designated Modified Warmwater Habitat (MWH) with the WWH aquatic life use designation continuing downstream from RM 4.50 to the mouth.

Further headwater sampling upstream in Powderlick Run revealed very shallow pools, lack of flow, some entrenchment and lower QHEI scores compared to downstream reaches. With limited recovery potential, the upper portion of Powderlick Run (RM 5.1 to RM 3.01) was recommended to be designated Limited Resource Water (LRW). The remainder of Powderlick Run from RM 3.0 to the mouth retained the designated aquatic life use of Warmwater Habitat.

Table 4. Waterbody use designations for the Bokes Creek basin. Designations based on the 1978 and 1985 water quality standards appear as asterisks (*). Designations based on Ohio EPA biological field assessments appear as a plus sign (+). Designations based on the 1978 and 1985 standards for which results of a biological field assessment are now available are displayed to the right of existing markers. A delta ()) indicates a new recommendation based on the findings of this report.

Stream Segment	Use Designations												
		Aquatic Life Habitat						Water Supply			Recreation		
	SRW	WWH	EWH	MWW	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR
Bokes Creek- RM 37.3-35.51				)					+	+		+	
- RM 35.51 to mouth		+							+	+		+	
Smith Run		*/+							*/+	*/+		*	)
Brush Run		*/+							*/+	*/+		*	)
Powderlick Run - Ust. RM 3.0							)		+	+			+
- RM 3.0 to mouth		+							+	+			+
Trib to Powderlick Run (confluence at RM 2.0)		)							)	)			)
North Fork West Mansfield Tributary ≥ RM 4.51				)									
RM 4.5-0.0		+							+	+			+
West Fork West Mansfield Tributary		+							+	+			+
East Fork West Mansfield Tributary		+							+	+			+
Mayor Painter Ditch							+		+	+			+
South Branch West Fork West Mansfield Tributary		)							)	)			)

Status of Non-Aquatic Life Uses

All non-aquatic life uses should remain as presently designated in the Ohio Water Quality Standards (Table 4). All other beneficial use designations were confirmed for Brush Run and Smith Run except for Primary Contact Recreation (PCR) designation. Both streams were recommended for Secondary Contact Recreation due to lack of deep pools sufficient to meet the primary criteria. All newly sampled streams should be designated for Agricultural and Industrial Water Supply and Secondary Contact Recreation consistent with other tributary streams in the watershed.

Future Monitoring Needs

A revisit of the Bokes Creek study area should be conducted as provided in the five-year basin approach to monitoring and assessment. The reassessment should consider the rate of land use and population changes within the watershed and the current TMDL development ongoing in 2001 and implementation. Priority should be placed on evaluating segments which are identified as impaired in this report. A relationship that was important in this basin and needed further measurement to better determine relationships was fertilizer concentrations and land application rates, retention rates, and related instream chemical concentrations.

Remediation

High chemical pollutant concentrations in the Bokes Creek watershed are perpetuated by several factors. Agriculture, with concentrated animal husbandry and the associated manure management activities, as well as intensive row crop monoculture, with the associated heavy use of fertilizers, are the two main sources of elevated nutrients and oxygen demanding substances in the Bokes Creek watershed. Animal operations also contribute heavily to bacterial contamination due to manure contaminated runoff. Failing on-lot sewage systems in localized areas are a distant second in magnitude to agricultural impacts, but they were an important contributor of oxygen demanding substances and bacterial contamination as well.

There are several ways to begin to mitigate this situation. First, area residents must understand that there are significant problems, and that these problems can only be overcome by changing habits. This may be difficult to accomplish, especially if those changes involve significant costs. The business of improving drainage by removing riparian cover along stream banks, by channel “improvements” (straightening, deepening), by tile drainage of hydric (wetland) soils in areas with marginal agricultural use, or similar practices must change if recovery of the watershed is to occur. Stream modification has associated “costs” which have adversely altered chemical, biological, and physical properties in the watershed. Additionally, residents must be more vigilant in maintaining their home sewage systems. In some cases, this may mean centralized sewers and waste treatment in more populated areas. Natural sinuosity, riffle-run-pool development, and flood plain integrity must be restored along with wetlands and a wooded riparian corridor. These improvements will serve to enhance or stabilize oxygen concentrations and contain and absorb nutrients. In many instances, these mitigation costs may be shared via public funding grants through soil and water conservation districts, federal monies (319), or the Water Pollution Control Loan Fund (sewers, WWTPs).

STUDY AREA

The Bokes Creek watershed encompasses 84.2 square miles in Logan, Union, and Delaware Counties in central Ohio. The Bokes Creek mainstem flows over 36 miles east-southeast from the headwaters originating in Logan County through Union County to its confluence with the Scioto River in Delaware County. The stream basin is entirely within the Eastern Corn Belt Plains ecoregion. The stream's elevation decreases from approx. 1,050 feet above mean sea level (MSL) at its source to 872 feet above MSL at its mouth with an average 6.3 feet per mile gradient (ODNR, 1954). Local relief is generally less than 50 feet. Valleys are typically narrow and shallow. Bokes Creek's major tributaries are Smith Run, Brush Run, and Powderlick Run. The gradient of these tributaries is much steeper than the mainstem (see below) (ODNR, 1954)(OEPA,1995c).

The Bokes Creek watershed lies in the Eastern Corn Belt Plains ecoregion and its soils reflect the influences of the original deciduous forest cover and continental glaciation. It is mainly a loamy calcareous glacial till, overlain by loess deposits in some southern portions of the ecoregion. Soil parent materials are comprised of glacial till, glacial outwash, or recent alluvium via in-stream post-glacial transport from gently rolling glacial till plain intersected by moraines, kames, and outwash plains (U.S.EPA, 1988). The Bokes Creek watershed consists of two soil type asssociations:

Blount - Wetzel - Morely - Pewamo - Milton association: nearly level and sloping, poorly to well drained soils formed on uplands in moderately fine textured glacial till; seasonally wet; major limitations for on-site wastewater treatment systems;

Genesee - Eel - Shoals - Fox association: poorly to well drained soils that formed on floodplains and terraces in medium or fine textured material; subject to flooding; seasonally wet; major limitations for on-site wastewater treatment systems.

Artificial drainage augments the natural poor drainage, and portions of Bokes Creek and its tributaries were modified to promote drainage. Estimates from the USDA - Natural Resources Conservation Service indicate that >10 percent of the Bokes Creek watershed area is considered Highly Erodible Land based on the 1982 National Resource Inventory data base (USDA, 1993).

Land Use

The Bokes Creek watershed is used predominately for crop-based agriculture, with some livestock operations. Point sources in the basin include the West Mansfield WWTP (land application of waste), Heartland Egg Farm (Weaver) in eastern Logan County (North Fork West Mansfield Creek), and Daylay and Mad River Egg Farms (Powderlick Run). The percentage of land in deciduous forests from the headwaters in Logan County downstream to the mouth decreases from 24 percent to 6 percent coverage. Rowcrop agriculture increases from 47 percent in the headwaters to 85 percent near the mouth (OEPA, 1995c). Waste application from egg production is a major contributor to nutrient loads on agricultural fields in the watershed (especially the upper portion). Current land use trends have increased the potential for nonpoint source pollution of the stream system. Failing on-site septic systems in towns such as York Center and Magnetic Springs have likely contributed to nutrient loading in Bokes Creek (OEPA, 1995a,1995c).

Table 5. Stream Characteristics of Bokes Creek Basin Watershed

Stream Length	Length (miles)	Average Fall (feet per minute)	Drainage Area (square miles)
Bokes Creek	39.7	6.3	84.2
North Fork West Mansfield Tributary	8.8	12.5	8.8
West Fork West Mansfield Tributary	2.5	8.0	5.2
East Fork West Mansfield Tributary	2.67	15.0	1.6
South Br. West Fk. West Mansfield Trib	2.40	24.4	2.8
Powderlick Run	5.1	16.8	3.84
Smith Run	4.9	11.0	5.94
Brush Run	3.2	25.3	3.38

(ODNR, 1954)

Table 6. Land Use in Bokes Creek Watershed (based on 1978-79 land cover)

Category	Acres	Percent of Total
Row crops	38,600	72
Deciduous forests	7,020	13
Pasture	3,780	7
Shrub / brush	2,160	4
Farmsteads	1,620	3

(ODNR, 1993)

Table 7. Stream and significant identified pollution sources in the Bokes Creek study area.

Stream Name	Nonpoint Source Pollution Issues	Point Sources Present
Bokes Creek	Agriculture Storm runoff nutrient inputs Sedimentation On-Site septic inputs from unsewered towns Cattle encroachment	
West Fork West Mansfield Tributary	Agriculture Storm runoff nutrient inputs from WWTP application or egg farm nutrient application Sedimentation Cattle encroachment	West Mansfield WWTP (spray application)
South Branch West Fork West Mansfield Tributary (and) Mayor Painter Ditch	Agriculture Storm runoff from nutrients input from WWTP spray land application Sedimentation On-site septic systems	West Mansfield WWTP
North Fork West Mansfield Tributary	Agriculture Storm runoff nutrient inputs from WWTP or egg farm waste nutrient applications Septic systems Sedimentation Cattle encroachment	Heartland Egg Farm (Weaver) Facility in headwaters in extreme eastern Logan County
East Fork West Mansfield Tributary	Agriculture Storm runoff nutrient inputs from egg farm waste nutrient applications Sedimentation	
Powderlick Run	Agriculture Storm runoff nutrient inputs from egg farm waste applications On-site septic systems Sedimentation Cattle encroachment	Daylay Egg Production Facilities #1, #2, and #3 Mad River Egg Facility
Brush Run	Agriculture Storm runoff nutrient inputs from egg farm waste applications On-site septic systems Sedimentation	
Smith Run	Agriculture Storm runoff nutrient inputs from egg farm waste applications On-site septic systems Sedimentation	

Table 8. Sampling locations in the Bokes Creek study area, 1999 (C - conventional water chemistry, S - sediment, D - Datasonde® continuous monitors, F - fish, M - macroinvertebrates, with Mq denoting qualitative samples).

Stream RM Fish/bugs	Type of Sampling	Lat./Long.	Drainage (Mi.²)	Site Location	USGS 7.5' Map
Bokes Creek					
36.34	C	402751/833453	4.2	At Logan County Rd. 292	West Mansfield
36.3	F,Mq	402751/833452	4.2	Logan County Rd. 292	West Mansfield
35.12	C,O	402721/833401	6.0	At Logan County Rd. 120	West Mansfield
35.1	F,D	402722/833401	6.0	Dst. Logan County Rd. 120	West Mansfield
35.0	Mq	402717/833359	6.0	Dst. Logan County Rd. 120	West Mansfield
31.9	Mq	402834/833323	10.0	Ust. West Mansfield - Mt. Victory Rd.	West Mansfield
31.84	C	402627/833140	10.0	At West Mansfield - Mt. Victory Rd.	West Mansfield
31.8	F	402626/833140	10.0	Dst. West Mansfield - Mt. Victory Rd.	West Mansfield
27.3	Mq	402526/832827	31.0	Ust. Phelps Rd.	York Center
27.22	C,O,S,D	402523/832824	31.0	Phelps Rd.	York Center
27.0	F	402516/832827	32.0	Dst. Phelps Rd.	York Center
26.2	C,T	402454/832805	32.0	Ust. Spangler Rd.	York Center
25.07**?**	C,T	402452/832710	35.0	At St. Rt. 739	York Center
21.3	F,C,O,S,D	402327/832445	41.0	Ust./at Yearsley Rd.	York Center
21.2	M	402326/832441	41.0	Dst. Yearsley Rd.	York Center
20.4	M	402302/832422	45.0	Adj. St. Rt. 31	York Center
20.2	F,C,O,S,D	402303/832440	45.0	Adj./ ust. St. Rt. 31	York Center
17.0	F	402203/832235	58.0	Ust. Ford Reed Rd.	Peoria
16.8	Mq	402155/832226	58.0	Ust. Ford Reed Rd.	Magnetic Springs
16.58	C,O,S,D	402155/832229	59.0	At Ford Reed Rd.	Magnetic Springs
14.8	C,O,D	402140/832119	61.0	Ust. Taylor - Claiborne Rd.	Magnetic Springs
11.4	F,Mq,D	402056/831815	67.0	Ust. St. Rt. 4	Magnetic Springs
11.37	C,O	402053/831814	67.0	At St. Rt. 4	Magnetic Springs
5.6	F	402021/831448	74.0	Ust. Brown Rd.	Ostrander
5.54	C,O,S,D	402022/831438	74.0	Brown Rd.	Ostrander
5.4	Mq	402019/831431	75.0	Dst. Brown Rd.	Ostrander
0.3-0.24	C,O,D	401920/831031	84.1	Ust./ at St. Rt. 257	Ostrander
0.2	F,Mq	401920/831029	84.1	Dst. St. Rt. 257	Ostrander
Powderlick Run					
5.5	F,Mq	402317/832848	0.4	Ust. Davis Rd. (ust. Daylay Farms) dry	York Center
4.8	F,Mq	402322/832832	0.6	Storms Rd. and Davis Rd.	York Center
3.75	C	402317/832736	1.4	At east crossing at Davis Rd.	York Center
3.7	F,Mq	402317/832733	1.4	Dst. easternmost crossing at Davis Rd.	York Center
3.4	F	402305/832717	1.6	Ust. St. Rt. 739	York Center
3.35	C	402305/832714	1.6	At St. Rt. 739	York Center
3.3	Mq	402305/832711	1.6	Dst. St. Rt. 739	York Center
2.15	C	402308/832620	2.2	Powderlick Run at Powderlick Rd.	York Center
2.1	F,Mq	402309/832619	2.2	Dst. Powderlick Run Rd (west bridge)	York Center

Table 8. (continued)

Stream / RM	Type of Sampling	Lat./Long.	Drainage (Mi.[2])	Site Location	USGS 7.5' Map
Powderlick Run (cont.)					
1.8	F	402314/832601	2.9	Ust. middle crossing of Powderlick Run Rd. (west of Fawley Rd.)	York Center
1.6	M	402306/832600	3.0	Ust. middle crossing of Powderlick Run Rd. (west of Fawley Rd.)	York Center
1.60	C,O	402305/832559	3.0	At middle crossing of Powderlick Run Rd. (west of Fawley Rd.)	York Center
1.2	M	402303/832538	3.2	Dst. east crossing of Powderlick Run Rd. (east of Fawley Rd.)	York Center
1.0	F,S	402309/832530	3.3	Adj. Powderlick Rd.(downstream sample)	York Center
0.9	M	402305/832521	3.4	Adj. Powderlick Rd.(downstream sample)	York Center
0.2	C,O,D	402304/832452	3.6	Yearsley Rd. near mouth	York Center
Trib. to Powderlick Run (confluence at RM 2.0)					
0.1	F	402311/832840	0.7	Dst. Mad River Egg Farm in trib.	York Center
North Fork West Mansfield Trib.					
5.6	F,Mq	402544/833414	3.1	farm rd. off Logan Co. Rd. 26	West Mansfield
5.58	C	402545/833414	3.1	farm rd. off Logan Co. Rd. 26	West Mansfield
4.0	Mq	402517/833239	5.9	Ust. Co. Rd. 142	West Mansfield
3.97	C,D	402517/833237	5.9	Co. Rd. 142	West Mansfield
3.8	F	402515/831229	5.9	Dst. Co. Rd. 142	West Mansfield
1.3	F,Mq	402509/833027	8.7	Ust. January Rd.	West Mansfield
1.28	C,O,D	402509/833026	8.7	January Rd.	West Mansfield
West Fork West Mansfield Trib.					
1.0	F	402437/833034	4.9	Ust. St. Rt. 47	West Mansfield
0.8	Mq	402442/833029	5.0	Ust. St. Rt. 47	West Mansfield
0.78	C,O,D	402445/833027	5.0	St. Rt. 47	West Mansfield
South Branch of West Fork West Mansfield Trib.					
0.1	F,Mq	402343/833115	2.8	Ust. Newton - Perkins Rd.	West Mansfield
0.02	C	402343/833115	2.8	Ust. Newton - Perkins Rd.	West Mansfield
Brush Run					
0.5	F,Mq	402223/832500	3.2	Yearsley Rd.	Peoria
Smith Run					
3.24	F,Mq,C	401951/831416	2.6	Burnt Pond Rd. dry	Ostrander
0.8	F,Mq	401919/831209	5.6	Brindle Rd.	Ostrander
0.77	C,O,D	401919/831208	5.6	Brindle Rd.	Ostrander

METHODS

All chemical, physical, and biological field, laboratory, data processing, and data analysis methodologies and procedures adhere to those specified in the Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices (Ohio Environmental Protection Agency 1989a) and Biological Criteria for the Protection of Aquatic Life, Volumes I-III (Ohio Environmental Protection Agency 1987a, 1987b, 1989b, 1989c), and The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application (Rankin 1989, 1995) for aquatic habitat assessment. Chemical, physical and biological sampling locations are listed in Table 8.

Determining Use Attainment Status

Use attainment status is a term describing the degree to which environmental indicators are either above or below criteria specified by the Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1). Assessing aquatic use attainment status involves a primary reliance on the Ohio EPA biological criteria (OAC 3745-1-07; Table 7-14). These are confined to ambient assessments and apply to rivers and streams outside of mixing zones. Numerical biological criteria are based on multimetric biological indices including the Index of Biotic Integrity (IBI) and modified Index of Well-Being (MIwb), indices measuring the response of the fish community, and the Invertebrate Community Index (ICI), which indicates the response of the macroinvertebrate community. Numerical endpoints are stratified by ecoregion, use designation, and stream or river size. Three attainment status results are possible at each sampling location - Full, partial, or non-attainment. Full attainment means that all of the applicable indices meet the biocriteria. Partial attainment means that one or more of the applicable indices fails to meet the biocriteria. Non-attainment means that none of the applicable indices meet the biocriteria or one of the organism groups reflects poor or very poor performance. An aquatic life use attainment table (Table 1) is constructed based on the sampling results and is arranged from upstream to downstream and includes the sampling locations indicated by river mile, the applicable biological indices, the use attainment status (*i.e.,* Full, partial, or non), the Qualitative Habitat Evaluation Index (QHEI), and a sampling location description.

The attainment status of aquatic life uses (*i.e.,* full, partial, and non-attainment) is determined by using the biological criteria codified in the Ohio Water Quality Standards (WQS; Ohio Administrative Code [OAC] 3745-1-07, Table 7-14). The biological community performance measures used include the Index of Biotic Integrity (IBI) and Modified Index of Well-Being (MIwb), based on fish community characteristics, and the Invertebrate Community Index (ICI) which is based on macroinvertebrate community characteristics. The IBI and ICI are multimetric indices patterned after an original IBI described by Karr (1981) and Fausch *et al.* (1984). The ICI was developed by Ohio EPA (1987b) and further described by DeShon (1995). The MIwb is a measure of fish community abundance and diversity using numbers and weight information and is a modification of the original Index of Well-Being originally applied to fish community information from the Wabash River (Gammon 1976; Gammon *et al.* 1981).

Performance expectations for the principal aquatic life uses in the Ohio WQS (Warmwater Habitat

[WWH], Exceptional Warmwater Habitat [EWH], and Modified Warmwater Habitat [MWH]) were developed using the regional reference site approach (Hughes *et al.* 1986; Omernik 1987). This fits the practical definition of biological integrity as the biological performance of the natural habitats within a region (Karr and Dudley 1981). Attainment of the aquatic life use is FULL if all three indices (or those available) meet the applicable biocriteria, partial if at least one of the indices does not attain and performance is fair, and non-attainment if all indices fail to attain or any index indicates poor or very poor performance. Partial and non-attainment indicate that the receiving water is impaired and does not meet the designated use criteria specified by the Ohio WQS.

Habitat Assessment

Physical habitat was evaluated using the Qualitative Habitat Evaluation Index (QHEI) developed by the Ohio EPA for streams and rivers in Ohio (Rankin 1989, 1995). Various attributes of the habitat are scored based on the overall importance of each to the maintenance of viable, diverse, and functional aquatic faunas. The type(s) and quality of substrates, amount and quality of instream cover, channel morphology, extent and quality of riparian vegetation, pool, run, and riffle development and quality, and gradient are some of the habitat characteristics used to determine the QHEI score which generally ranges from 20 to less than 100. The QHEI is used to evaluate the characteristics of a stream segment, as opposed to the characteristics of a single sampling site. As such, individual sites may have poorer physical habitat due to a localized disturbance yet still support aquatic communities closely resembling those sampled at adjacent sites with better habitat, provided water quality conditions are similar. QHEI scores from hundreds of segments around the state have indicated that values greater than 60 are *generally* conducive to the existence of warmwater faunas whereas scores less than 45 generally cannot support a warmwater assemblage consistent with the WWH biological criteria. Scores greater than 75 frequently typify habitat conditions which have the ability to support exceptional warmwater faunas.

Macroinvertebrate Community Assessment

Macroinvertebrates were sampled quantitatively using multiple-plate, artificial substrate samplers (modified Hester/Dendy) in conjunction with a qualitative assessment of the available natural substrates. During the present study, macroinvertebrates collected from the natural substrates were also evaluated using an assessment tool currently in the field validation phase. This method relies on tolerance values derived for each taxon, based upon the abundance data for that taxon from artificial substrate (quantitative) samples collected throughout Ohio. To determine the tolerance value of a given taxon, ICI scores at all locations where the taxon has been collected are weighted by its abundance on the artificial substrates. The mean of the weighted ICI scores for the taxon results in a value which represents its relative level of tolerance on the 0 to 60 scale of the ICI. For the qualitative collections in the Bokes Creek study area, the median tolerance value of all organisms from a site resulted in a score termed the Qualitative Community Tolerance Value (QCTV). The QCTV shows potential as a method to supplement existing assessment methods using the natural substrate collections. QCTV use in evaluating sites was restricted to relative site comparisons and wasn't unilaterally used to determine quality or aquatic life use attainment status.

Fish Community Assessment

Fish were sampled once or twice at each site using pulsed DC electrofishing methods. Discussion of the fish community assessment methodology used in this report is contained in Biological Criteria for the Protection of Aquatic Life: Volume III, Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities (Ohio EPA 1989b).

Area of Degradation Value (ADV)

An Area Of Degradation Value (ADV; Rankin and Yoder 1991; Yoder and Rankin 1995) was calculated for the study area based on the longitudinal performance of the biological community indices. The ADV portrays the length or "extent" of degradation to aquatic communities and is simply the distance that the biological index (IBI, MIwb, or ICI) departs from the applicable biocriterion or the upstream level of performance (Figure 3). The "magnitude" of impact refers to the vertical departure of each index below the biocriterion or the upstream level of performance. The total ADV is represented by the area beneath the biocriterion (or upstream level) when the results for each index are plotted against river mile. The results are expressed as ADV/mile to normalize comparisons between segments, sampling years, and other streams and rivers.

Causal Associations

Using the results, conclusions, and recommendations of this report requires an understanding of the methodology used to determine the use attainment status and assigning probable causes and sources of impairment. The identification of impairment in rivers and streams is straightforward - the numerical biological criteria are used to judge aquatic life use attainment and impairment (partial and non-attainment). The rationale for using the biological criteria, within a weight of evidence framework, has been extensively discussed elsewhere (Karr *et al.* 1986; Karr 1991; Ohio EPA 1987a,b; Yoder 1989; Miner and Borton 1991; Yoder 1991; Yoder 1995). Describing the causes and sources associated with observed impairments relies on an interpretation of multiple lines of evidence including water chemistry data, sediment data, habitat data, effluent data, land use data, and biological results (Yoder and Rankin 1995). Thus the assignment of principal causes and sources of impairment in this report represent the association of impairments (based on response indicators) with stressor and exposure indicators. The reliability of the identification of probable causes and sources is increased where many such prior associations have been identified, or have been experimentally or statistically linked together. The ultimate measure of success in water resource management is the restoration of lost or damaged ecosystem attributes including aquatic community structure and function. While there have been criticisms of misapplying the metaphor of ecosystem "health" compared to human patient "health" (Suter 1993), in this document we are referring to the process for evaluating biological integrity and causes or sources associated with observed impairments, not whether human health and ecosystem health are analogous concepts.

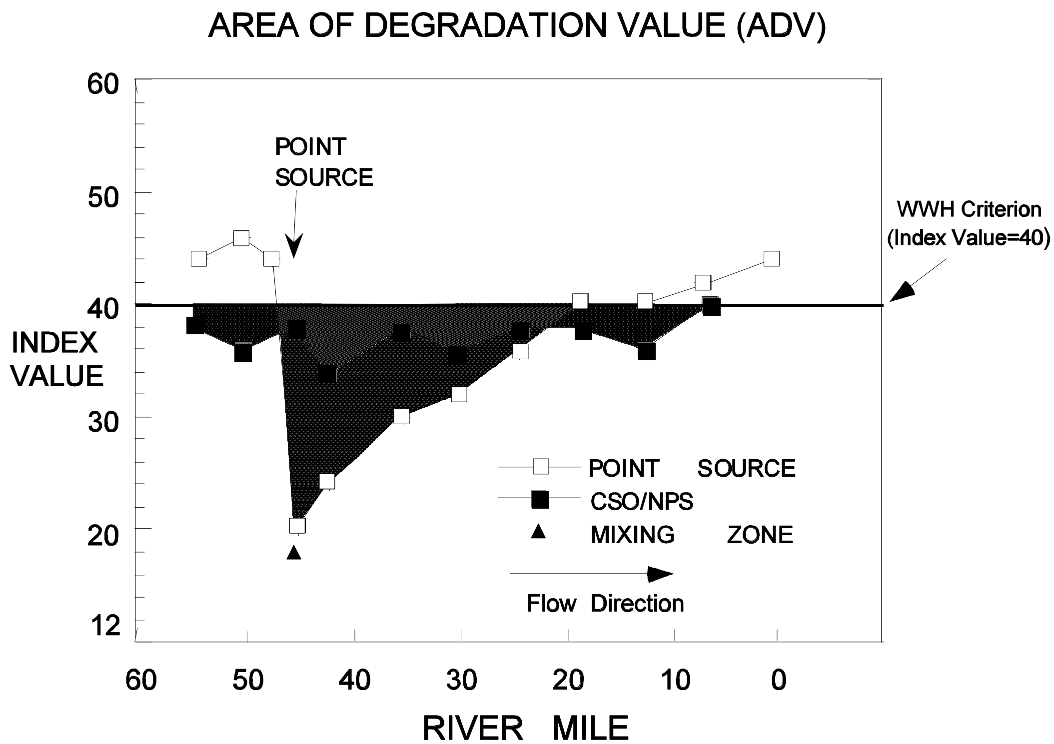


Figure 2. Graphic illustration of the Area of Degradation Value (ADV) based on the ecoregion biocriterion (WWH in this example). The index value trend line indicated by the unfilled boxes and solid shading (area of departure) represents a typical response to a point source impact (mixing zone appears as aa solid triangle); the filled boxes and dashed shading (area of departure) represent a typical response to a nonpoint source or combined sewer overflow impact. The blended shading represents the overlapping impact of the point and nonpoint sources.

RESULTS AND DISCUSSION

Pollutant Loadings

Monthly effluent loadings are reported to Ohio EPA by all NPDES (National Pollutant Discharge Elimination System) permitted discharging entities. There are no major ($\geq$ 1 MGD) permitted facilities discharging in the Bokes Creek basin. The West Mansfield WWTP was changed to land application of wastewater and no longer discharges directly to the surface waters of the state. There is a small unpermitted package plant discharger at Camp Christian that discharges to Bokes Creek from Union Co. Rd. 182 (Maple Dell Rd.) just east of Magnetic Springs. Table 9 provides a list of some historical and current NPDES permit holders in the Bokes Creek Basin.

Table 9. NPDES permitted dischargers in the Bokes Creek study area, 1999. Those in *italics* have been discontinued but are listed to indicate historical presence. Flow is the design capacity of the entity.

Entity	Flow (MGD)	Receiving Stream	River Mile Tributary	River Mile Mainstem
West Mansfield WWTP	*NA*	*Mayor Painter Ditch (Logan Co.)*	*3.30*	
Daylay Egg Farms	*NA*	*Powderlick Run*	*various*	
Mad River Egg Farm		*Trib. to Powderlick Run to P. Run*	*2.0*	
Terra bulk fertilizer facility	*NA*	*Bokes Creek*		*~ 22*
Camp Christian*	0.015	Bokes Creek (Union Co.)	--	~6.2-6.1

* NPDES application to be applied for in 1991 - still have not received permit application.

No loadings or chemical data was available for the Camp Christian package plant. The plant performance at the time of inspection appeared to be acceptable, though the discharge flow from the camp during inspection in winter was low compared to its peak use during summer months.

Pollutant Spills and Unauthorized Releases

In addition to Ohio WQS criteria exceedences, a review of the Ohio EPA Division of Emergency and Remedial Response (DERR) Release Reporting System (RRS) database indicated very few reported, unpermitted releases of potentially toxic substances have occurred in the Bokes Creek study area (Table 10). Accidental spills and unauthorized discharges of pollutants represent a potential impact on aquatic life which may or may not be traceable to a specific source. Spills occur at random and may significantly impact aquatic and terrestrial organisms without leaving obvious signs. It is likely that the reported spills represent a portion of the actual spill occurrences within the Bokes Creek study area.

Table 10. Summary of pollutants released in the Bokes Creek watershed as reported to the Ohio EPA Division of Emergency and Remedial Response, January 1991 to December 1999.

Date	Entity	Material	Amount	Stream
4/14/1991	Bokes Creek	Unknown	Unknown	adjacent SR 31(Union Co.)
11/10/1992	Bokes Creek	Fertilizers	Unknown	Yearsley Rd. (Union Co.)
5/6/1996	Bokes Creek	Unknown	Unknown	adj. SR 37 (Champaign Co.)
2/19/1995	Trib. to Bokes Creek	Oil	Unknown	adj. SR 37 (Union Co.)
8/5-6/1998	Trib. to Powderlick Run	Egg wash water	Unknown	N of Powderlick Run Rd.

Fish Kills

A review of Water Pollution, Fish Kill and Stream Litter Investigation Reports from the Ohio Department of Natural Resources Division of Wildlife covering the period 1980-1999 indicated that 4 reported fish kills occurred in the Bokes Creek basin (Table 11). Likely the reported fish kills were probably an underrepresentation of the actual total number of fish kills which have occurred over time.

Table 11. Summary of the Water Pollution, Fish Kill and Stream Litter Investigation Reports from the Ohio Department of Natural Resources Division of Wildlife in the Bokes Creek watershed, 1980-1999.

Date	Stream	RM	Number killed	Cause
6/13/1983	Trib. to Bokes Creek (Union Co.)	?	11376	Unknown
7/11/1983	Bokes Creek (Logan Co.)	?	4293	Unknown
7/12/1984	Trib. to Bokes Creek (Logan Co.)	?	55	Unknown
11/10/1992	Bokes Creek (Union Co.)	21.8-16.7	344	Fertilizers

Chemical Water Quality

Water chemistry sampling protocols were based on the Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices (Ohio EPA 1989) and samples were collected, preserved, and analyzed for a variety of parameters including demand parameters, nutrients, and metals. A more limited set of grab samples was collected for organic compounds. See Appendix A for a complete listing of the analytical results for all waterbodies studied.

Sampling stations in the Bokes Creek watershed were chosen to provide information concerning ambient water quality. The sampling scheme chosen was based on a geometric progression of drainage areas with more sampling sites at smaller drainage areas and fewer sites at larger drainage areas (Table 8). Sample results were evaluated to determine impacts from land use practices in the watershed and to determine instantaneous exceedences of criteria listed in the Ohio Water Quality Standards (OAC 3745-1). Exceedences were based on Warmwater Habitat (WWH) aquatic life use, Primary or Secondary Contact Recreation (PCR or SCR), Agricultural and Industrial Water Supply (AWS or IWS) and other criterion are summarized in Table 13.

There are no active USGS gauge stations located in the Bokes Creek basin. Data from these facilities are typically used to illustrate flow conditions during the study period. Instead total daily area precipitation was utilized to help estimate flows within the Bokes Creek study area. All attempts were made to collect water chemistry samples under identical weather conditions. However, there were occasions when more precipitation occurred during a sample run (Table 12). A bias for some parameters, such as total suspended solids which generally rise after rainfall, may have resulted from the samples collected on these occasions. The daily precipitation totals for Propsect and Marysville during May, 1999 through December, 1999 which border on the north and south of Bokes Creek basin can be found in Table 12. Rainfall information from Bellefontaine was also used to help extrapolate precipitation totals in Bokes Creek basin (Fig. 3).

Table 12. Precipitation in inches for Marysville, Ohio, and Prospect, Ohio (in *italics*), reported by the National Climatic Data Center, Asheville, North Carolina, May through November 1999. **Bold values indicate days when chemical samples were collected.**

Day	May	*May*	June	*June*	July	*July*	Aug.	*Aug.*	Sept.	*Sept.*	Oct.	*Oct.*	Nov.	*Nov.*	Dec.	*Dec.*
1	0.00	0.00	0.07	0.00	**0.00**	**0.00**	0.14	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.23	0.30	3.50	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.35	0.00	0.00
3	0.00	0.00	0.12	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.78	1.20	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.15	0.00	0.00	0.01	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00
6	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.57
7	0.00	0.00	0.00	0.00	0.03	0.10	0.00	0.00	0.00	1.05	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.53	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.05	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.25	0.21	0.50	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.59	0.26	0.00	0.00	0.00	0.00	0.59	0.45	0.00	0.00	0.76	0.77
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.01	0.01	0.00	0.00	0.02	0.02
12	0.00	0.00	0.65	0.00	**0.00**	**0.00**	**0.00**	**0.00**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.47	0.31	**0.00**	**0.00**	**0.11**	**0.04**	0.02	0.00	0.00	0.00	0.00	0.00	0.37	0.37
14	0.05	0.55	0.09	0.15	0.00	0.00	0.54	0.00	0.00	0.00	0.20	0.30	0.00	0.00	0.52	0.72
15	0.00	0.00	0.41	0.42	0.00	0.00	0.01	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.25
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.12
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.21	0.00	0.00	0.00	0.00
19	0.05	0.10	0.00	0.00	0.00	0.05	0.01	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.39	0.10	0.20	0.06	0.00	0.00	0.00	0.20	0.13	0.08	0.03	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.02	0.00	0.00	0.00	0.00	0.02	0.02
22	0.11	0.35	0.00	0.00	0.50	0.55	0.00	0.00	**0.00**	**0.07**	0.00	0.00	0.00	0.00	0.00	0.00
23	0.60	0.08	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	**0.00**	0.02	0.00	0.00	0.00	0.00	0.00
24	0.25	0.57	0.00	0.00	0.55	0.05	0.00	0.00	0.00	0.00	0.02	0.02	0.06	0.02	0.02	0.00
25	0.13	0.05	0.00	0.02	0.00	0.00	**0.31**	**0.52**	0.08	0.30	0.00	0.00	0.00	0.00	0.00	0.00
26	0.01	0.00	0.00	0.00	0.00	0.00	0.26	0.10	0.00	0.00	0.00	0.00	0.18	0.22	0.00	0.00
27	0.00	0.00	0.02	0.00	**0.11**	**0.25**	0.06	0.60	0.00	0.00	0.00	0.00	0.21	0.25	0.00	0.00
28	0.00	0.00	0.11	0.40	**0.00**	**0.00**	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.03	0.02
29	0.00	0.00	0.10	0.10	0.27	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.03
30	0.00	0.00	**0.00**	**0.00**	0.00	0.00	0.00	0.00	1.16	0.70	0.00	0.00	0.00	0.00	0.00	0.00
31	0.00	0.00	--	--	0.00	0.00	0.00	0.00	--	--	0.00	0.00	--	--	0.00	0.00
Total	1.25	1.80	2.27	1.95	5.94	1.98	2.18	3.09	1.36	2.09	1.30	1.86	1.71	2.12	2.49	2.89
Diff.	-2.54	-2.19	-1.55	-1.78	2.20	-2.00	-0.94	-0.31	-1.54	-1.08	-1.11	-0.65	-1.25	-1.29	-0.18	-0.21

Difference (Diff.) indicates departure from the normal monthly rainfall amounts (averaged from 30 years of data) listed in NOAA National Climatic Data Center publication with precipitation monthly means (NOAA, 1992).

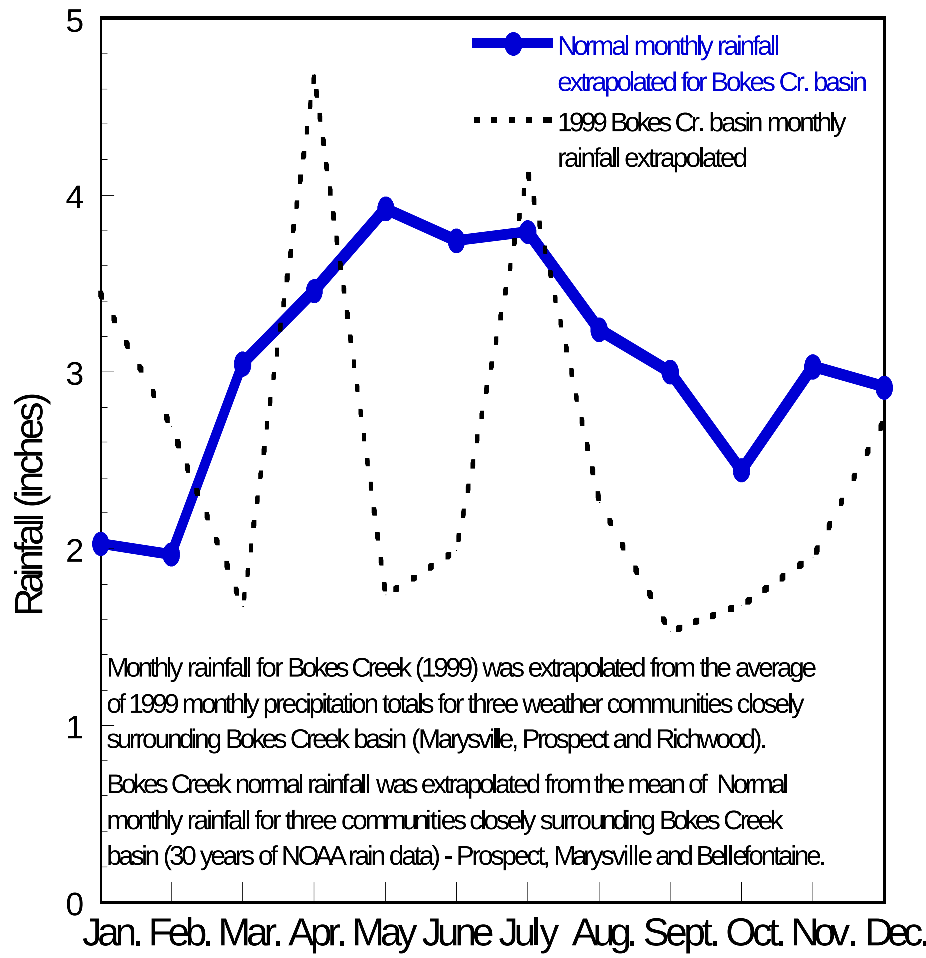


Figure 3. Extrapolated monthly rainfall for Bokes Creek basin for 1999 compared to extrapolated Normal monthly rainfall for Bokes Creek basd on 30 years of NOAA local precipitation data at three sites surrounding the basin, 1961-1990.

Numerical chemical criteria exist for the prevention of acute and chronic toxicity for most pollutants analyzed. The appropriate acute aquatic criterion (AAC) and chronic aquatic criterion (CAC) apply to samples collected outside of mixing zones. Minimum and average criteria exist for dissolved oxygen (D.O.). PCR and SCR criteria apply to fecal coliform bacteria counts. PCR waters are suitable for recreational activities where full body contact with the water is possible. SCR waters are suitable for partial body contact, such as wading.

Mean concentrations of D.O., BOD_5 (5-day biochemical oxygen demand), COD (chemical oxygen demand), NH_3-N (ammonia-N), NO_3+NO_2-N (nitrate+nitrite-N), total phosphorus, total suspended solids (TSS) and others were determined and plotted longitudinally to display trends in these physical and chemical properties (Figures 4-9). In calculating mean concentrations, a value one half of the analytical method detection limit (MDL) was used for results reported less than the MDL. If the resultant mean value was less than the MDL, then the MDL was used for discussion purposes and displayed in figures.

Bokes Creek

Between July and October, 1999, five sets of chemical water quality samples were collected (or attempted) at each of 10 sites on Bokes Creek. Due to the drought conditions, some sites were found to be completely dry at times or not flowing (intermittent pools) and were therefore not sampled; see Appendix A for details on exactly how many samples were taken at each site. Precipitation occurred on two sampling days: 13 August (~0.1 inches) and 25 August (0.3-0.5 inches). Chemical sampling on 6/30 and 7/28 was preceded by precipitation of 0.1 - 0.2 inches the previous day(s). Chemical sampling on 7/13 occurred three days after 0.3 - 0.6 inches of rain (Table 12).

E. coli and fecal coliform bacterial counts above the PCR or SCR criteria were the most frequent violations of WQS in the Bokes Creek mainstem, as runoff translated to exceedences (Figure 6). Additionally, low dissolved oxygen values in violation of both the mean and minimum standards were common (Figures 4 and 6, Table 13). Since these violations are ubiquitous along the mainstem, the entire drainage appears to be impacted by a variety of pollution sources.

Chemical impairment from excess nutrients was evident in Bokes Creek along the entire length, but especially in the extreme headwaters at RM 36.10 (Table 14). Increases of certain nutrient parameters within Bokes Creek were noted downstream from the confluence with Powderlick Run, downstream from Magnetic Springs, and, to a limited extent, downstream from the confluence with West Mansfield Creek (increase less due to lack of flow). Mean concentrations of ammonia (at toxic levels in the upper watershed), organic nitrogen (as measured by total kjeldahl nitrogen or TKN), nitrate+nitrite, and phosphorus were all found to be above the 95th percentile of background for the Eastern Corn Belt Plains (ECBP) ecoregion (Figures 5-9, Table 14). Moving downstream, available nutrient concentrations decreased via primary productivity, increased via new sources, and then slowly decreased (Figures 5-7). It must be noted that most nutrient concentrations continued to exceed the 75th percentile for the ECBP ecoregion throughout most of the mainstem (Figure 5). Total dissolved solids (TDS) concentrations in Bokes Creek paralleled this pattern tracking 1999 nutrient loads in an extreme drought year (Figure 8). Conductivity, hardness, and similar parameters illustrated the same concentration patterns indicating similar nutrient inputs at tributaries (Figure 10). Both organic nitrogen (TKN) and phosphorus seemed to be the major nutrients of concern (found at most sites above the median background) followed by ammonia and nitrate+nitrite (Figures 5-7 and 9).

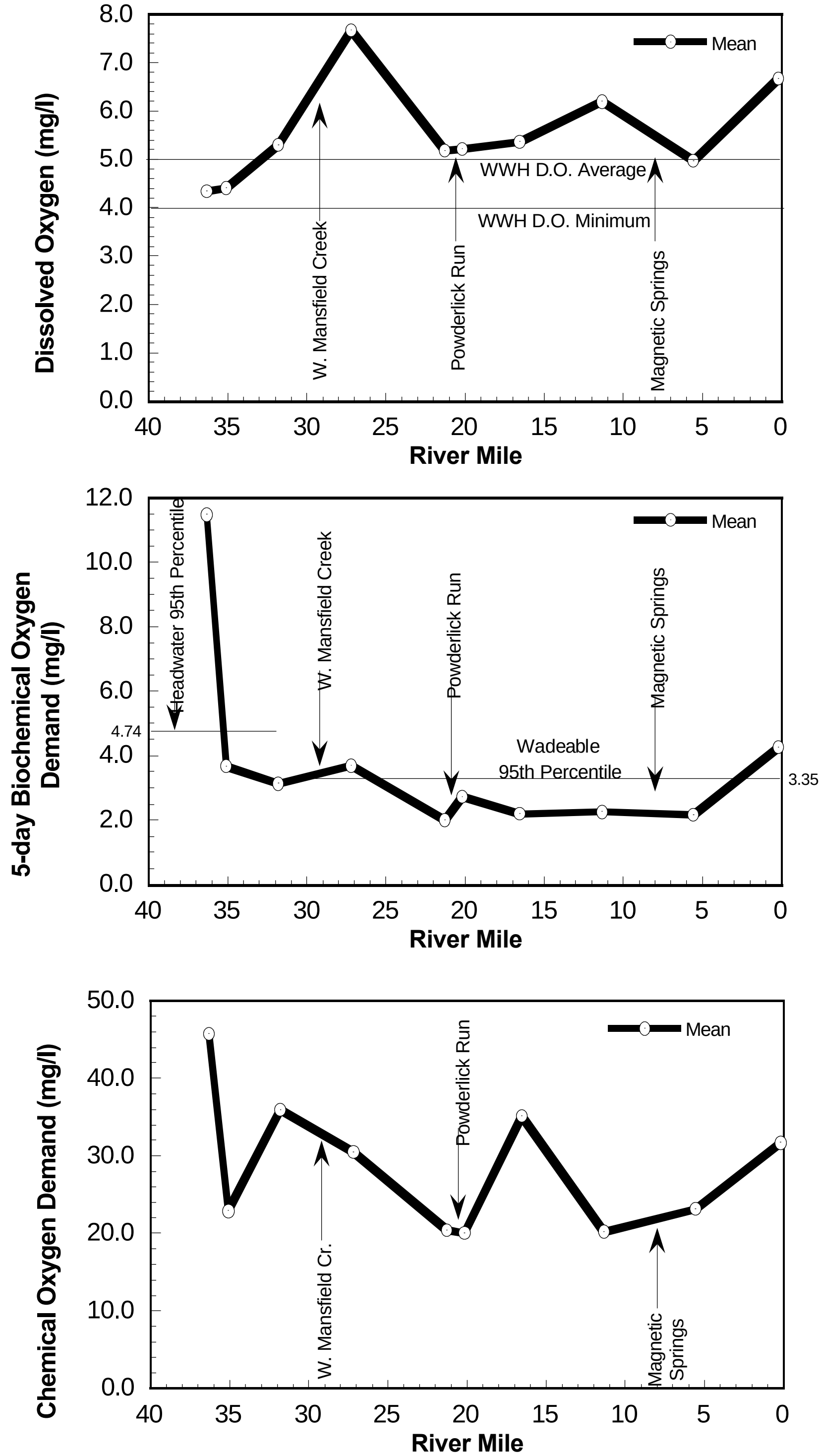


Figure 4. Mean dissolved oxygen (D.O.), biochemical oxygen demand (BOD), and chemical oxygen demand (COD) for Bokes Creek mainstem from June - September, 1999 (mg/l).

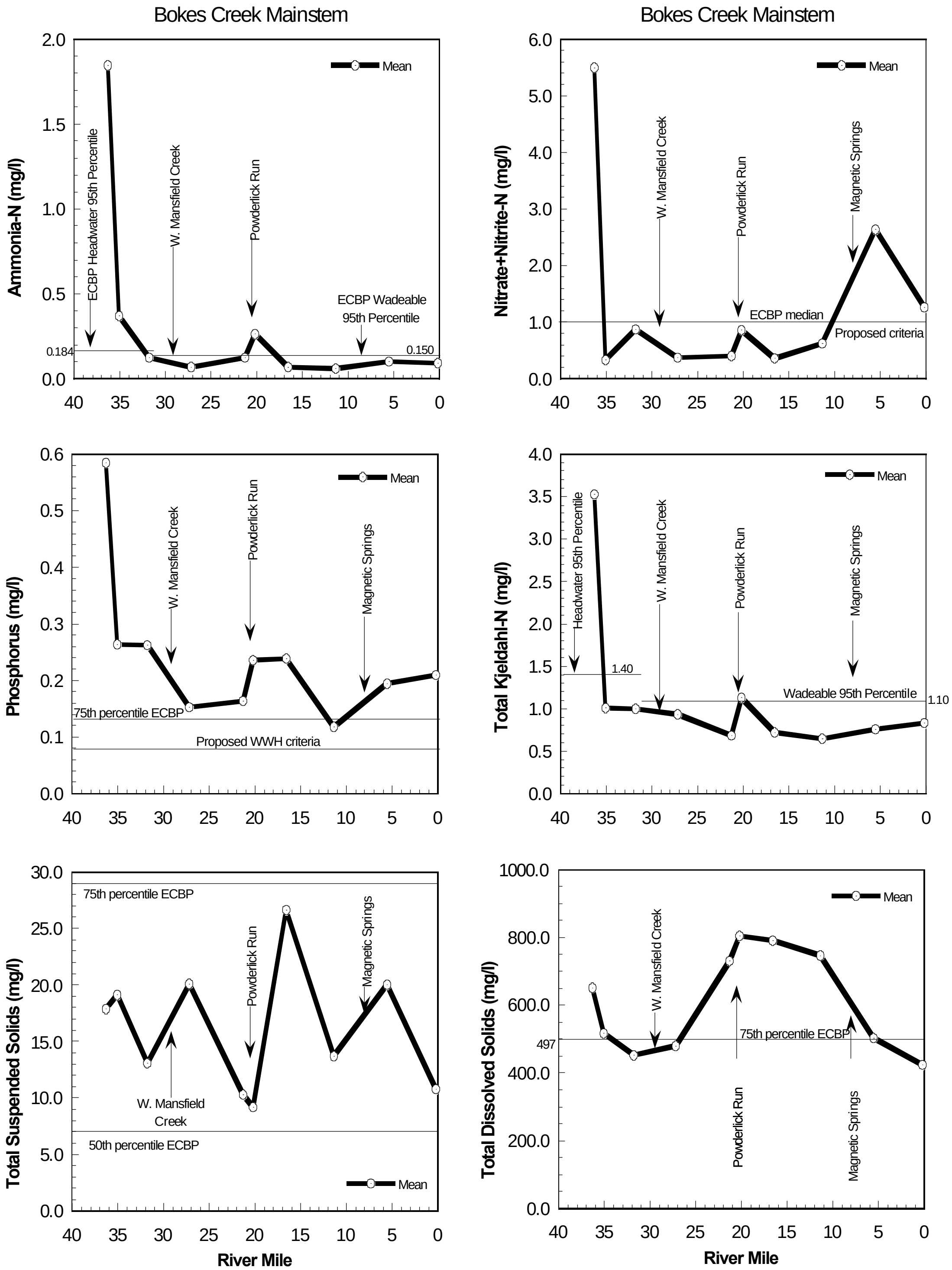


Figure 5. Mean ammonia-N, nitrate-nitrite-N, Total Kjeldahl-N, total Phosphorus, total suspended solids, and total dissolved solids (mg/l) for Bokes Creek mainstem from June-September, 1999.

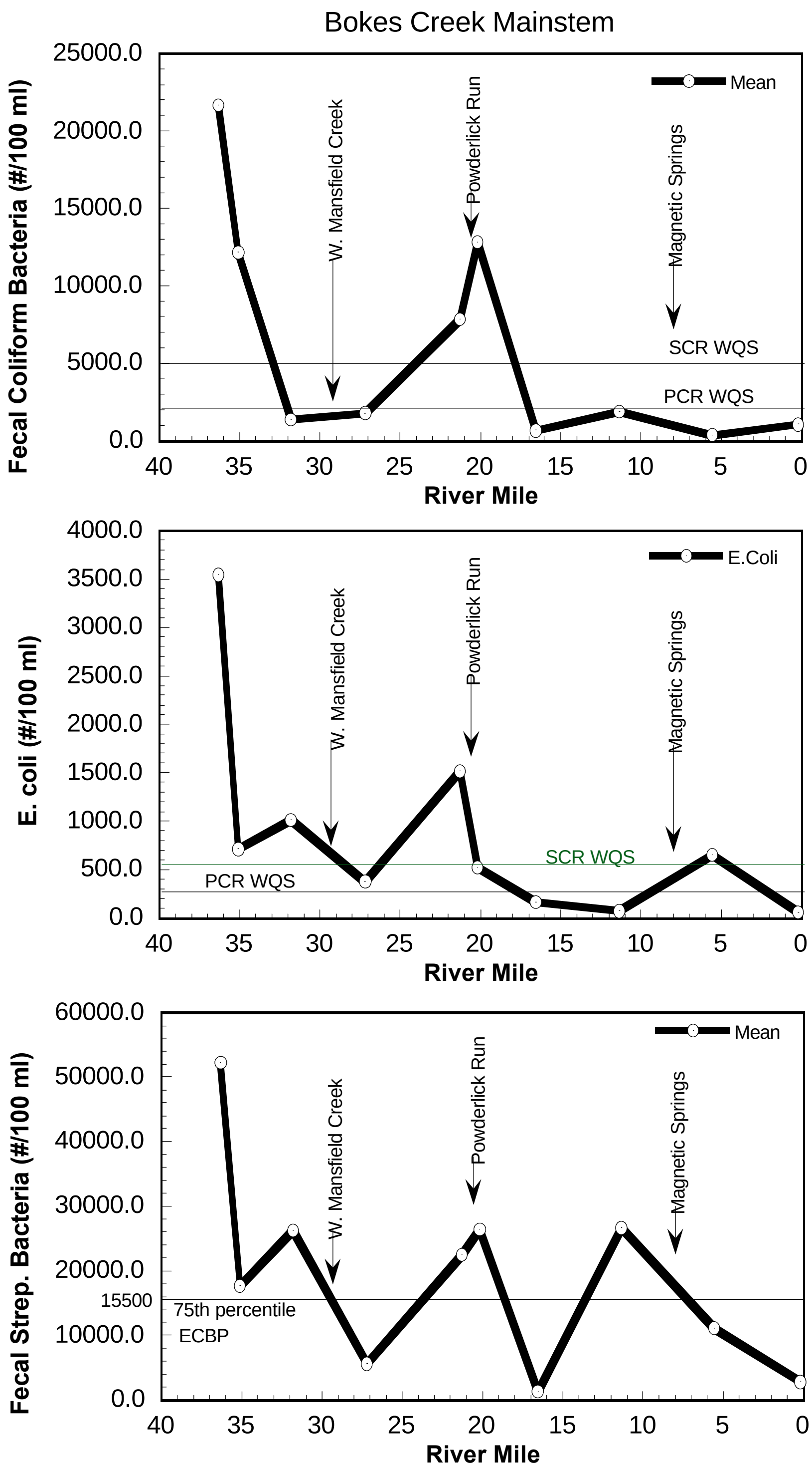


Figure 6. Mean fecal coliform, *E. coli*, and fecal streptococcus bacteria concentrations for Bokes Creek mainstem from June-September, 1999.

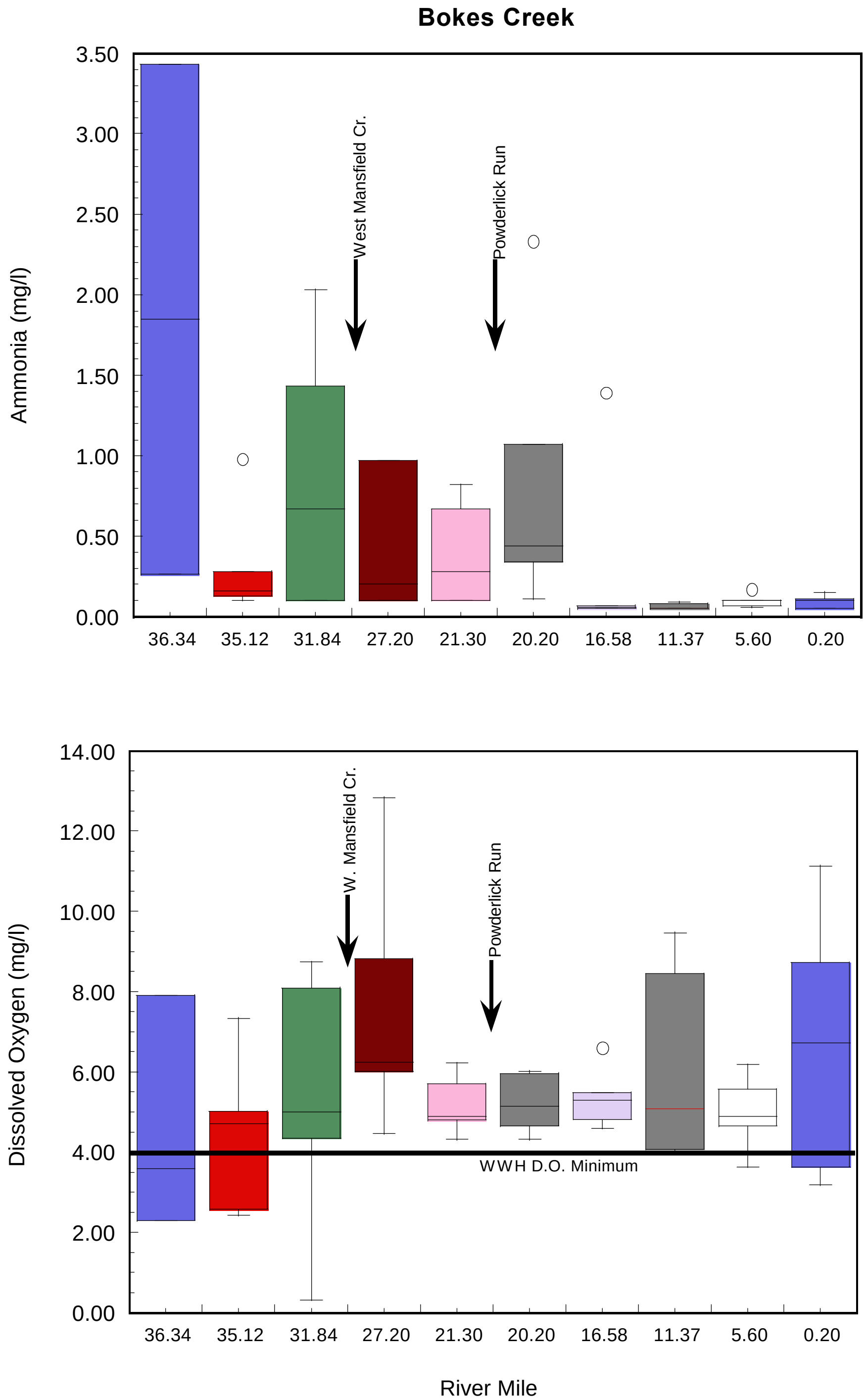


Figure 7. Box and whisker plots of ammonia-Nitrogen and dissolved oxygen concentrations (mg/l) for Bokes Creek mainstem longitudinally from May-September, 1999. The mean, 75th percentile, 25th percentile, maximum and minimum values were indicated.

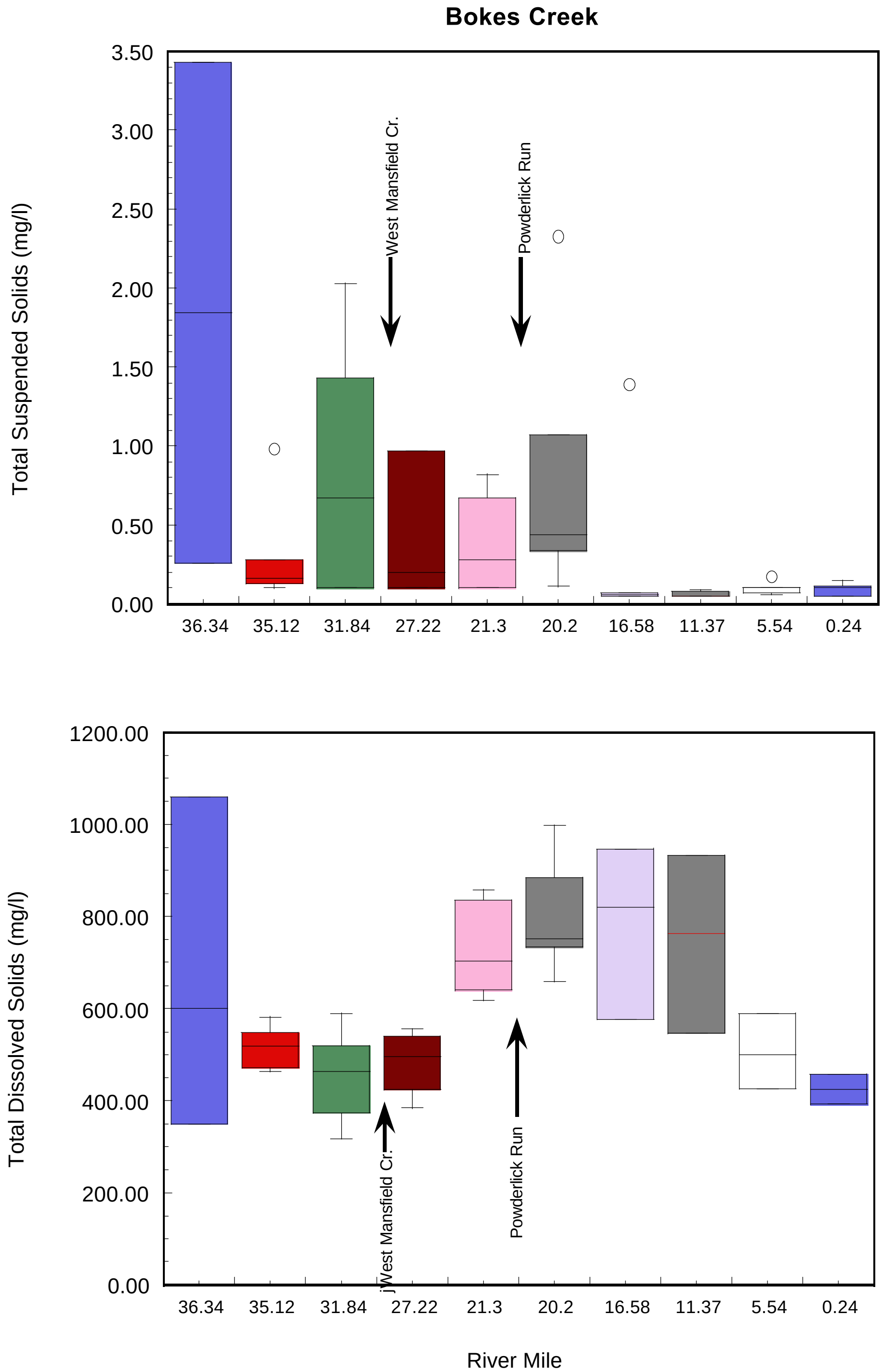


Figure 8. Box and whisker plots of total suspended solids and total dissolved solids concentrations (mg/l) for Bokes Creek mainstem longitudinally from May-September, 1999. The mean, 75th percentile, 25th percentile, maximum and minimum values were indicated.

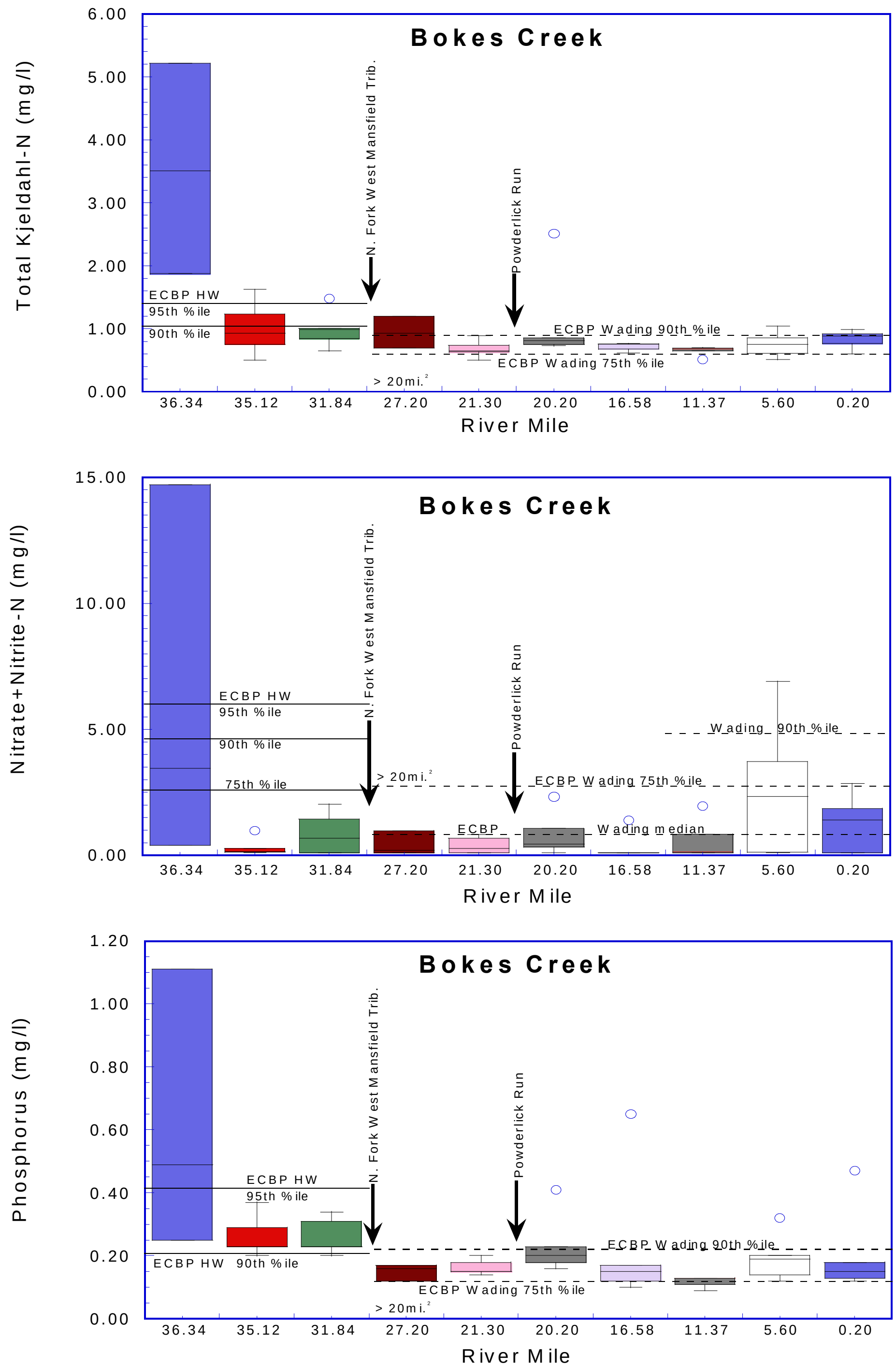


Figure 9. Box and whisker plots of total Kjeldahl nitrogen (TKN), nitrate+nitrite-N, and phosphorus concentrations (all as mg/l) for Bokes Creek mainstem logitudinally from May-September, 1999. The mean, 75th percentile, 25th percentile, maximum and minimum values were indicated.

Table 13. Exceedences of Ohio EPA Warmwater Habitat (WWH) water quality criteria (OAC 3745-1) for chemical/physical parameters in the Bokes Creek study area, 1999. (Units are #/100 ml for bacteria and mg/l for all other parameters).

River/Stream	River Mile	Parameter	Value (code)
Bokes Creek	36.34	Dissolved Oxygen E. coli Fecal Coliform	(4.26)‡, (2.92, 2.30) ‡‡ (400) • •, (873, >2000, 9360) • • • (4000, 4200) • •, (18500) • • •
	35.12	Dissolved Oxygen E. coli Fecal Coliform Dieldrin	(4.71)‡, (2.57, 2.43) ‡‡ (2700) • • • (60000) • • • (0.009)z zz
	31.84	Dissolved Oxygen E. coli Fecal Coliform	(4.35)‡, (0.31) ‡‡ (140) •, (3300) • • • (5400) • • •
	27.22	Dissolved Oxygen E. coli Fecal Coliform	(4.46)‡ (410) • •, (1000, >2000) • • • (1050) •, (2200) • •, (5100) • • •
	21.3	Dissolved Oxygen E. coli Fecal Coliform	(4.32, 4.80, 4.88)‡ (6000) • • • (8636, 30000) • • •
	20.2	Dissolved Oxygen E. coli Fecal Coliform 4,4' DDT Heptachlor	(4.31, 4.64)‡ (365, 400) • •, (1300, >2000) • • • (2500) • •, (60000) • • • (0.007)z zz (0.004)z zz
	16.58	Dissolved Oxygen E. coli Fecal Coliform	(4.59, 4.82)‡ (240) •, (320) • • (1200) •
	11.37	Dissolved Oxygen Fecal Coliform	(4.08)‡, (3.99) ‡‡ (7818) • • •
	5.54	Dissolved Oxygen E. coli Dieldrin	(4.88, 4.65)‡, (3.64) ‡‡ (350) • •, (2200) • • • (0.008)z zz
	0.24	Dissolved Oxygen E. coli Fecal Coliform	(3.62, 3.19) ‡‡ (160) • (4700) • •
Powderlick Run	3.75 (1 storm event only)	Fecal Coliform	(60000) • • •
	3.35 (1 storm event only)	Fecal Coliform	(60000) • • •
	2.15 (3 passes only)	Dissolved Oxygen E. coli Fecal Coliform	(4.25)‡, (1.65)‡‡ (340, >2000) • • (60000) • • •

River/Stream	River Mile	Parameter	Value (code)
Powderlick Run (cont.)	1.60	Dissolved Oxygen	(4.66, 4.10)‡, (1.25, 0.00)‡‡
		Total Dissolved Solids	(2630, 2850, 4110, 6480, 7720)Z
		E. coli	(1210, 2000,>2000, 48000)• • •
		Fecal Coliform	(1600)•, (4000)• •, (60000, 111600)• • •
		Aldrin	0.01Z ZZ
	*1.60 (**1998** egg wash water spill)*	*Total Dissolved Solids*	*(1540)*Z
		Ammonia	*(13.0)*Z
		Fecal Coliform	*(60000)*• • •
	0.2	Dissolved Oxygen	(4.24)‡, (2.10, 0.45, 0.00)‡‡
		Total Dissolved Solids	(2270, 2470, 2880, 5430, 8350)Z
		E. coli	(400)• •, (2350,>2000, 21000)• • •
		Fecal Coliform	(1550)•, (31000, 60000)• • •
N. Fk. W. Mansfield Trib. **(*no flow 3 of 5 sampling passes at RM 5.58)**	5.58*	Dissolved Oxygen	(2.43, 2.47)‡‡
		E. coli	(260)•, (325)• •
		Fecal Coliform	(1330)•
	3.97	Dissolved Oxygen	(0.94, 1.39)‡‡
		E. coli	(240)•, (540)• •, (3600)• • •
		Fecal Coliform	(1700)•, (3300)• •, (5200)• • •
	1.28	Dissolved Oxygen	(4.11, 4.88, 4.96)‡, (3.81)‡‡
		E. coli	(390, 440)• •, (1390)• • •
		Fecal Coliform	(1073, 1080)•, (2100)• •
W. Fk. W. Mansfield Trib.	0.78	Dissolved Oxygen	(4.84)‡. (2.40, 3.20)‡‡
		E. coli	(360)• •
		Fecal Coliform	(2000)• •
Smith Run **(*no flow 3 of 5 sampling passes at RM 3.24)**	3.24*	Dissolved Oxygen	(2.73)‡‡
		E. coli	(200)•, (670)• • •
		Fecal Coliform	(1181)•
	0.77	Dissolved Oxygen	(4.35, 4.68, 4.78)‡
		E. coli	(370, 400)• •
		Fecal Coliform	(3400)• •
		Dieldrin	(0.006)Z ZZ
		Heptachlor	(0.004)Z ZZ
So. Br. West Fork West Mansfield Trib. **(1 pass only)**	0.02	E. coli	(4300)• • •
		Fecal coliform	(6800)• • •

Z exceedence of numerical criteria for the protection of aquatic life
ZZ exceedence of numerical criteria for the protection of human health (nondrinking water)
‡ exceedence of the average warmwater habitat dissolved oxygen criterion (5.0 mg/l).
‡‡ exceedence of the minimum warmwater habitat dissolved oxygen criterion (4.0 mg/l).
• exceedence of the average Primary Contact Recreation criterion (E. coli 126/100 ml, Fecal coliform 1000/100 ml).
• • exceedence of the maximum Primary Contact Recreation criterion (E. coli 298/100 ml, Fecal coliform 2000/100mL).
• • • exceedence of the maximum Secondary Contact Recreation criterion (E. coli 576/100 ml, Fecal coliform 5000/100ml).

Table 14. Comparison of background nutrient and demand parameter concentrations with those found in the Bokes Creek study area, 1999. Comparisons are made to Eastern Corn Belt Plains (ECBP) ecoregion background median (50th percentile), 75th, 90th, and 95th percentile values for both headwater (HW) and wadeable (W) sites. Units are mg/l for all parameters. Sample size, n = 5 unless otherwise stated.

River/Stream	River Mile	Parameter(s)	Value(s)
Bokes Creek	36.34_{HW} n=4	BOD_5	(**28.0**, **12.0**, <u>4.0</u>)
		Total Suspended Solids	(*22.0, 18.5, 18.0,* 13.0)
		Ammonia	(**3.43**, **2.58**, **1.11**, **0.26**)
		Nitrate+Nitrite	(**14.70**, *4.48*, *2.43*)
		Nitrite	(**1.19**, **0.23**, **0.12**)
		Tot. Kjeldahl Nitrogen	(**5.21**, **4.95**, **2.06**, **1.87**)
		Phosphorus	(**1.11**, **0.62**, <u>0.36</u>, <u>0.25</u>)
	35.12_{HW}	BOD_5	(**5.2**, **5.0**, <u>4.2</u>)
		Total Suspended Solids	(*39.0*, *20.0*, *19.0*, 9.5, 8.0)
		Ammonia	(**0.83**, **0.41**, **0.37**, <u>0.13</u>, <u>0.10</u>)
		Nitrate+Nitrite	(0.98)
		Nitrite	(<u>0.08</u>)
		Tot. Kjeldahl Nitrogen	(**1.62**, <u>1.23</u>, *0.93*, *0.75*, 0.50)
		Phosphorus	(<u>0.37</u>, <u>0.29</u>, <u>0.23</u>, <u>0.23</u>, 0.20)
	31.84_{HW}	BOD_5	(<u>4.2</u>, <u>4.2</u>, *2.9*, *2.4*)
		Total Suspended Solids	(*30.0*, *16.0*, 9.0)
		Ammonia	(<u>0.17</u>, <u>0.17</u>, <u>0.13</u>, *0.09*, *0.07*)
		Nitrate+Nitrite	(2.03, 1.43)
		Nitrite	(*0.04*)
		Tot. Kjeldahl Nitrogen	(**1.48**, *1.01*, *0.99*, *0.84*, *0.65*)
		Phosphorus	(<u>0.34</u>, <u>0.31</u>, <u>0.23</u>, <u>0.23</u>, 0.20)
	27.22_{W}	BOD_5	(**6.8**, **5.3**, *2.4*)
		Total Suspended Solids	(*41.0*, 20.0)
		Ammonia	(<u>0.10</u>, *0.08*, *0.06*)
		Nitrate+Nitrite	(0.97)
		Tot. Kjeldahl Nitrogen	(**1.20**, **1.10**, *0.75*, *0.65*)
		Phosphorus	(0.17, 0.17, 0.15, 0.12)
	21.3_{W}	Total Suspended Solids	(19.5)
		Ammonia	(**0.19**, **0.14**, <u>0.13</u>, *0.08*, *0.07*)
		Nitrite	(*0.04*, *0.03*)
		Tot. Kjeldahl Nitrogen	(*0.89*, *0.74*, *0.65*, *0.63*, 0.50)
		Phosphorus	(0.20, 0.18, 0.15, 0.15, 0.14)

River/Stream	River Mile	Parameter(s)	Value(s)
Bokes Creek (cont.)	20.2_W		
		BOD_5	(**5.3**, *2.3*, *2.1*)
		Total Suspended Solids	(22.0)
		Ammonia	(**0.95**, 0.10, *0.09*, *0.09*, *0.08*)
		Nitrate+Nitrite	(2.33, 1.07)
		Nitrite	(**0.26**)
		Tot. Kjeldahl Nitrogen	(**2.51**, *0.86*, *0.81*, *0.75*, *0.73*)
		Phosphorus	(**0.41**, 0.23, 0.20, 0.18, 0.16)
	16.58_W		
		BOD_5	(*2.8*)
		Total Suspended Solids	(*33.5*, 28.0, 23.0, 22.0)
		Ammonia	(0.10, *0.07*, *0.06*)
		Nitrate+Nitrite	(1.39)
		Tot. Kjeldahl Nitrogen	(*0.77*, *0.76*, *0.76*, *0.68*, *0.62*)
		Phosphorus	(**0.65**, 0.17, 0.15, 0.12, 0.10)
	11.37_W		
		BOD_5	(*2.8*)
		Total Suspended Solids	(26.0)
		Ammonia	(*0.09*, *0.08*)
		Nitrate+Nitrite	(1.96, 0.84)
		Tot. Kjeldahl Nitrogen	(*0.70*, *0.69*, *0.68*, *0.65*, 0.51)
		Phosphorus	(**0.32**, 0.20, 0.19, 0.14, 0.12)
	5.54_W		
		BOD_5	(*2.7*)
		Total Suspended Solids	(27.0, 22.0, 16.5, 14.5)
		Ammonia	(**0.17**, 0.10, 0.10, *0.07*, *0.06*)
		Nitrate+Nitrite	(**6.90**, *3.72*, 2.34)
		Nitrite	(**0.11**, **0.08**, *0.03*)
		Tot. Kjeldahl Nitrogen	(1.04, *0.86*, *0.75*, *0.61*, 0.51)
		Phosphorus	(**0.32**, 0.20, 0.19, 0.14, 0.12)
	0.24_W		
		BOD_5	(**11.0**)
		Total Suspended Solids	(17.0, 14.0)
		Ammonia	(**0.15**, 0.11, 0.10)
		Nitrate+Nitrite	(*2.85*, 1.86, 1.41)
		Nitrite	(0.03, 0.03)
		Tot. Kjeldahl Nitrogen	(0.99, 0.92, *0.88*, *0.77*, *0.60*)
		Phosphorus	(**0.47**, 0.18, 0.15, 0.13, 0.12)

River/Stream	River Mile	Parameter(s)	Value(s)
Powderlick Run	3.75_{HW}	BOD_5	(**6.70**)
	n=1	Ammonia	(**1.28**)
		Nitrate+Nitrite	(**29.2**)
		Nitrite	(**1.34**)
		Tot. Kjeldahl Nitrogen	(**4.92**)
		Phosphorus	(**1.24**)
	3.35_{HW}	BOD_5	(**10.0**)
	n=1	Total Suspended Solids	(*36.5*)
		Ammonia	(**1.37**)
		Nitrate+Nitrite	(**26.6**)
		Nitrite	(**1.49**)
		Tot. Kjeldahl Nitrogen	(**22.30**)
		Phosphorus	(**1.39**)
	2.15_{HW}	BOD_5	(**19.0**, **14.0**, **12.0**)
	n=3	Total Suspended Solids	(*44.0*, *30.5*, 9.0)
		Ammonia	(**8.04**, **0.32**, 0.15)
		Nitrate+Nitrite	(**14.60**, **6.44**)
		Nitrite	(**1.42**, **0.68**, **0.22**)
		Tot. Kjeldahl Nitrogen	(**17.90**, **3.54**, **2.46**)
		Phosphorus	(**1.76**, **1.17**, **0.69**)
	1.60_{HW}	BOD_5	(**19.0**, **7.6**, **4.8**)
		Total Suspended Solids	(*18.0*, 9.5, 9.0)
		Ammonia	(**7.70**, **6.64**, **2.89**, **0.34**, *0.09*)
		Nitrate+Nitrite	(**9.25**, 4.62, *4.33*, *2.39*)
		Nitrite	(**3.89**, **1.40**, **0.42**, **0.41**, **0.22**)
		Tot. Kjeldahl Nitrogen	(**13.00**, **12.80**, **6.76**, **3.59**, **2.06**)
		Phosphorus	(**1.45**, **1.44**, **1.29**, **0.58**, 0.41)
	0.2_{HW}	BOD_5	(**23.0**, **18.0**, **17.0**, **16.0**, **5.3**)
		Total Suspended Solids	(**83.5**, **72.5**, **71.0**, *46.5*, *35.2*)
		Ammonia	(**6.04**, **5.32**, **0.51**, **0.43**, **0.33**)
		Nitrate+Nitrite	(**10.50**, **8.11**)
		Nitrite	(**1.52**, **1.43**, **0.15**, 0.06, *0.03*)
		Tot. Kjeldahl Nitrogen	(**11.80**, **10.80**, **4.11**, **3.47**, **2.68**)
		Phosphorus	(**0.91**, **0.83**, **0.82**, **0.45**, 0.23)
N. Fk. W. Mansfield Trib.	5.58_{HW}	BOD_5	(*2.7*)
	n=2	Total Suspended Solids	(*19.0*, 12.0)
		Ammonia	(0.16, *0.06*)
		Nitrite	(0.05, *0.03*)
		Tot. Kjeldahl Nitrogen	(**1.64**, 1.04)
		Phosphorus	(0.28, *0.18*)

River/Stream	River Mile	Parameter(s)	Value(s)
N. Fk. W. Mansfield Trib. (cont.)	3.97_{HW}	BOD_5	(**9.5**, <u>4.4</u>)
		Total Suspended Solids	(*32.0*, *26.0*, 10.0, 9.5)
		Ammonia	(**0.75**, **0.34**, <u>0.16</u>, *0.09*, *0.07*)
		Nitrate+Nitrite	(2.23)
		Nitrite	(*0.03*)
		Tot. Kjeldahl Nitrogen	(**2.71**, **2.64**, **2.40**, **1.90**, <u>1.10</u>)
		Phosphorus	(**0.95**, **0.60**, **0.45**, **0.42**, *0.15*)
	1.28_{HW}	BOD_5	(**7.4**, <u>4.5</u>, <u>3.5</u>)
		Total Suspended Solids	(<u>53.0</u>, *23.0*, *18.0*, *17.0*, *15.0*)
		Ammonia	(**0.29**, <u>0.18</u>, <u>0.11</u>, <u>0.10</u>)
		Nitrate+Nitrite	(*2.41*)
		Nitrite	(*0.04*, *0.03*, *0.03*)
		Tot. Kjeldahl Nitrogen	(**2.71**, **1.45**, <u>1.13</u>, *0.98*, *0.73*)
		Phosphorus	(**0.64**, *0.16*)
W. Fk. W. Mansfield Trib.	0.78_{HW}	BOD_5	(<u>4.2</u>, *2.6*)
		Total Suspended Solids	(*19.0*, *18.0*, *15.0*, 11.5, 10.0)
		Ammonia	(**0.41**, **0.21**, **0.19**, <u>0.12</u>, <u>0.11</u>)
		Nitrite	(*0.03*, *0.03*)
		Tot. Kjeldahl Nitrogen	(**1.72**, <u>1.07</u>, *0.96*, *0.83*, *0.82*)
		Phosphorus	(**0.49**, **0.46**, **0.45**, **0.42**, <u>0.24</u>)
Smith Run	3.24_{HW} n=2	Total Suspended Solids	(10.0)
		Ammonia	(*0.07*)
		Nitrate+Nitrite	(**7.02**, <u>5.71</u>)
		Nitrite	(<u>0.08</u>, *0.03*)
		Tot. Kjeldahl Nitrogen	(*0.89*, 0.54)
		Phosphorus	(*0.17*, *0.09*)
	0.77_{HW}	Total Suspended Solids	(**32.5**, **24.0**, **16.0**, **15.5**, 8.0)
		Ammonia	(<u>0.15</u>, <u>0.13</u>, <u>0.12</u>, <u>0.10</u>, *0.06*)
		Nitrate+Nitrite	(**6.06**, *2.46*)
		Nitrite	(**0.14**, <u>0.09</u>)
		Tot. Kjeldahl Nitrogen	(*0.87*, *0.77*, 0.53, 0.53)
		Phosphorus	(**0.42**, *0.13*, *0.12*, *0.11*, *0.09*)
South Br. W. Fk. West Mansfield Trib. (1 pass only)		Total Suspended Solids	(9.5)
		Ammonia	(**0.28**)
		Tot. Kjeldahl Nitrogen	(<u>1.31</u>)
		Phosphorus	(*0.16*)

Normal print values exceed the 50th percentile background
Italic print values exceed the 75th percentile background
<u>Underlined</u> values exceed the 90th percentile background
Boldfaced values exceed the 95th percentile background

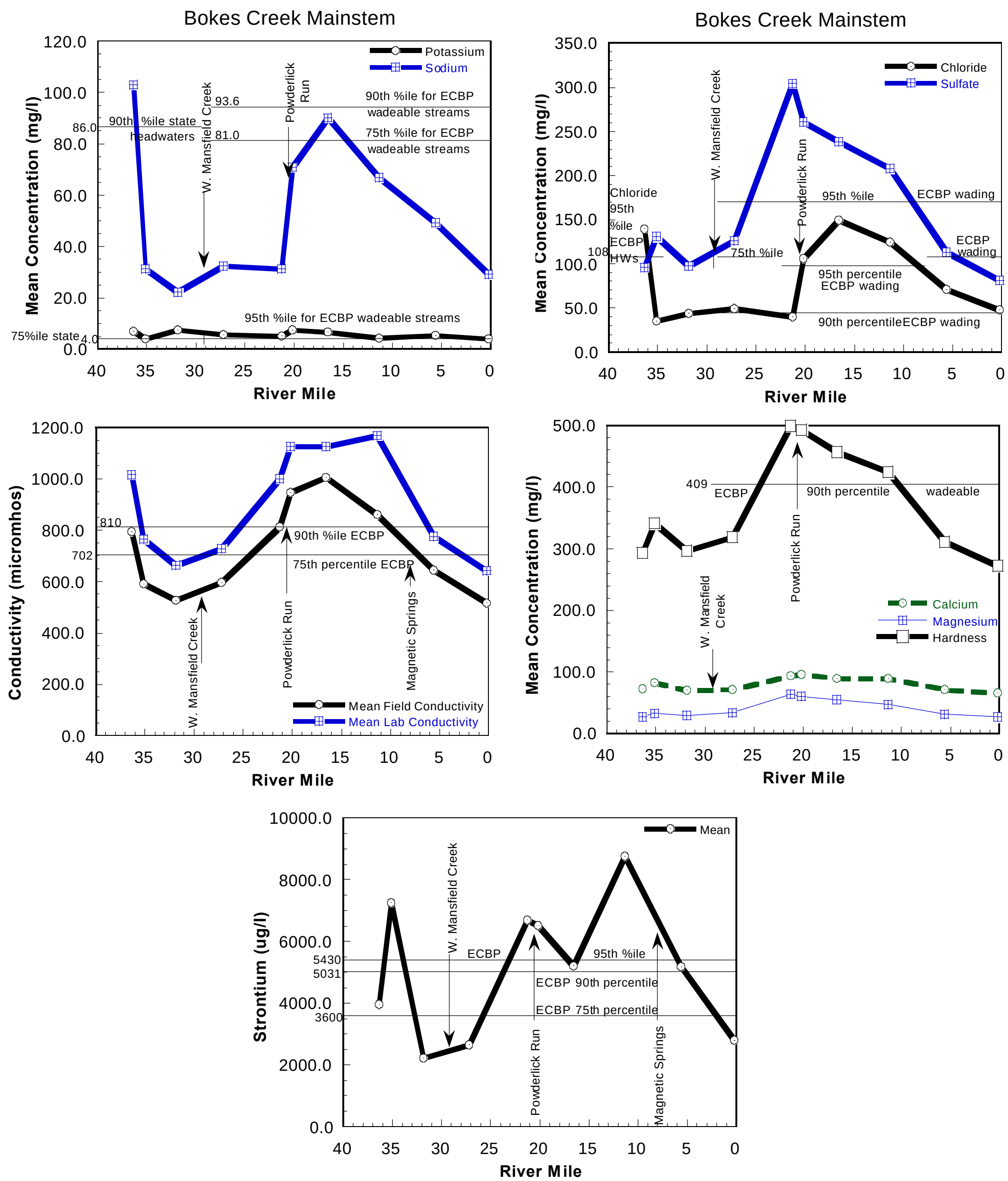


Figure 10. Mean potassium, sodium, chloride, sulfate, hardness/calcium/magnesium, field and lab conductivity, and strontium concentrations for Bokes Creek mainstem, May-September, 1999.

Elevated suspended solids concentrations were noticeable in the headwaters areas. The TSS concentrations often exceeded the 90th percentile of ECBP background. North Fork West Mansfield Tributary seemed to contribute to an increase in suspended solids in Bokes Creek. Even though suspended solids concentrations at the mouth of Powderlick Run were considerable, the spiked TSS pattern directly downstream from Powderlick Run in Bokes Creek was delayed due to sediment deposition and canopy cover preventing immediate massive algal production (Figure 5). The total suspended solids graph in the lower third of the Bokes Creek mainstem seemed to indicate nitrogen and phosphorus loads from likely runoff sources including small mainstem tributaries with historical fertilizer applications on adjacent fields and two small communities (Pharisburg and Magnetic Springs) (Figures 5-7 and 9). High total suspended solids spikes in the Bokes Creek mainstem seemed to parallel where high nutrients instream and open canopy or pooled conditions allowed high primary production to occur (Figures 5, 7, and 8-10).

Chemical impairment was also evidenced by the elevated mean concentrations of biochemical oxygen demand as measured by BOD_5 (Figure 4). BOD levels showed similar patterns instream when compared with nutrients. Extremely elevated concentrations were observed in the upper headwaters followed by a sharp drop and leveling with slight increases downstream from important tributary streams (Figures 4,5,7, and 9). Values were close to or above 95th percentile background values for the ECBP ecoregion, an observation also indicative of impairment (Table 14). However, it is important to note that the *number* of elevated readings at each site was significantly lower at RM 16.58 and downstream when compared with areas upstream (Table 14).

Most physicochemical parameters were highly elevated and further indicated *extreme* nutrient enrichment expecially in the headwaters and upper watershed. Contributions from fertilizer application runoff or field tile runoff occurred in various locales in the basin (e.g., North Fork West Mansfield Trib., Powderlick Run, Brush Run, Smith Run headwaters, and tributaries to Bokes Creek upstream from Magnetic Springs near Pharisburg). Chlorides, sulfates, potassium, sodium and associated conductivity and hardness were very to highly elevated (Figure 10). Elevated arsenic concentrations in the headwaters could be residuals from organic wastes in fertilizers, from herbicide/pesticide residuals or natural sources. The source pattern of elevated strontium concentrations in the headwaters and from RM 25.0 to downstream near RM 5.0 appeared to be nutrient related (in fertilizers - a microcomponent of animal food) and/or natural.

Powderlick Run

Between July and October 1999 five sets of chemical water quality samples were collected (or attempted) at each of 3 sites on Powderlick Run. Due to the drought conditions, some sites were found to be dry at times or not flowing (intermittent pools) and were therefore skipped; see Appendix A for details on exactly how many samples were taken at each site. Precipitation occurred on two sampling days: 13 August (~0.1 inches) and 25 August (0.3-0.5 inches). Chemical sampling on 6/30 and 7/28 was preceded by precipitation of 0.1 - 0.2 inches the previous day(s). Chemical sampling on 7/13 occurred three days after 0.3 - 0.6 inches of rain (Table 12). Additionally, two sites upstream from RM 2.15 were sampled during a single storm event on 8/25 in order to characterize the runoff from the Day Lay Egg Farm.

Dissolved oxygen, *E. coli*/fecal coliform bacteria, and total dissolved solids were the most frequent violations of chemical WQS criteria in Powderlick Run (Table 13). The most incredible violations occurred at 2 sites - RMs 1.60 and 0.20. Dissolved oxygen concentrations dropped to **zero**, and total dissolved solids values violated the WQS criteria for every sampling event at those sites. Bacterial standards were violated on 20 of 28 sampling passes (>70%), as runoff translated to exceedences. Dissolved solids violations in Powderlick Run were directly caused by the discharge of water treatment effluents from Daylay's Mad River Egg Farm (Table 13). Following the 1999 survey work, Daylay water treatment wastewater was rerouted to the egg wash water storage lagoons (which is subsequently land applied), so discharge of water treatment effluents to Powderlick Run have been curtailed. The multitude of other violations, though, indicated serious pollution problems and caused severe impairment to chemical water quality in Powderlick Run.

Nutrients, biochemical oxygen demand (BOD), and suspended solids were also extremely elevated in Powderlick Run (Table 14). In most instances throughout the summer, the 95th percentile of ECBP background was exceeded for BOD, ammonia (at toxic levels), nitrite (possible periodic toxicity), nitrate+nitrite, organic nitrogen (TKN), and phosphorus (Figures 11-13). This was indicative of critical nutrient pollution. Stormwater inputs of nutrients to the creek were also highly elevated even with copious amounts of dilution from rainwater, providing further evidence for impairment due to nutrients (Figures 11-13). Elevated total suspended solids at Yearsley Rd. was indicative of sedimentation and suspended algal biomass (Figures 13 and 14). Sediments had partially filled pools in Bokes Creek immediately downstream from the confluence with Powderlick Run contributing to periodic toxic conditions (some fresh dead clam shells) that were likely a combination of excesses of nutrients, silt, and low dissolved oxygen concentrations. Sources of siltation included NPS storm runoff from agricultural fields and erosion from destabilized banks from dredging the lower reach, and livestock access to the stream.

Metals and salts increased to exceedingly high concentrations (most at > 95%ile of ECBP reference sites) in Powderlick Run (Figures 15 and 16). Conductivity, total dissolved solids, and hardness increased to concentrations where biological functions could likely be impaired (chronic effects) in many organisms (Figures 14 and 15). Large concentrations of micronutrient metals, such as manganese, strontium, and selenium, also indicated that the primary large source of inputs into Powderlick Run were from organic waste or fertilizers from animal facilities (Figure 16). A highly elevated zinc concentration of 83 ug/l, almost three times greater than the 95th percentile ECBP

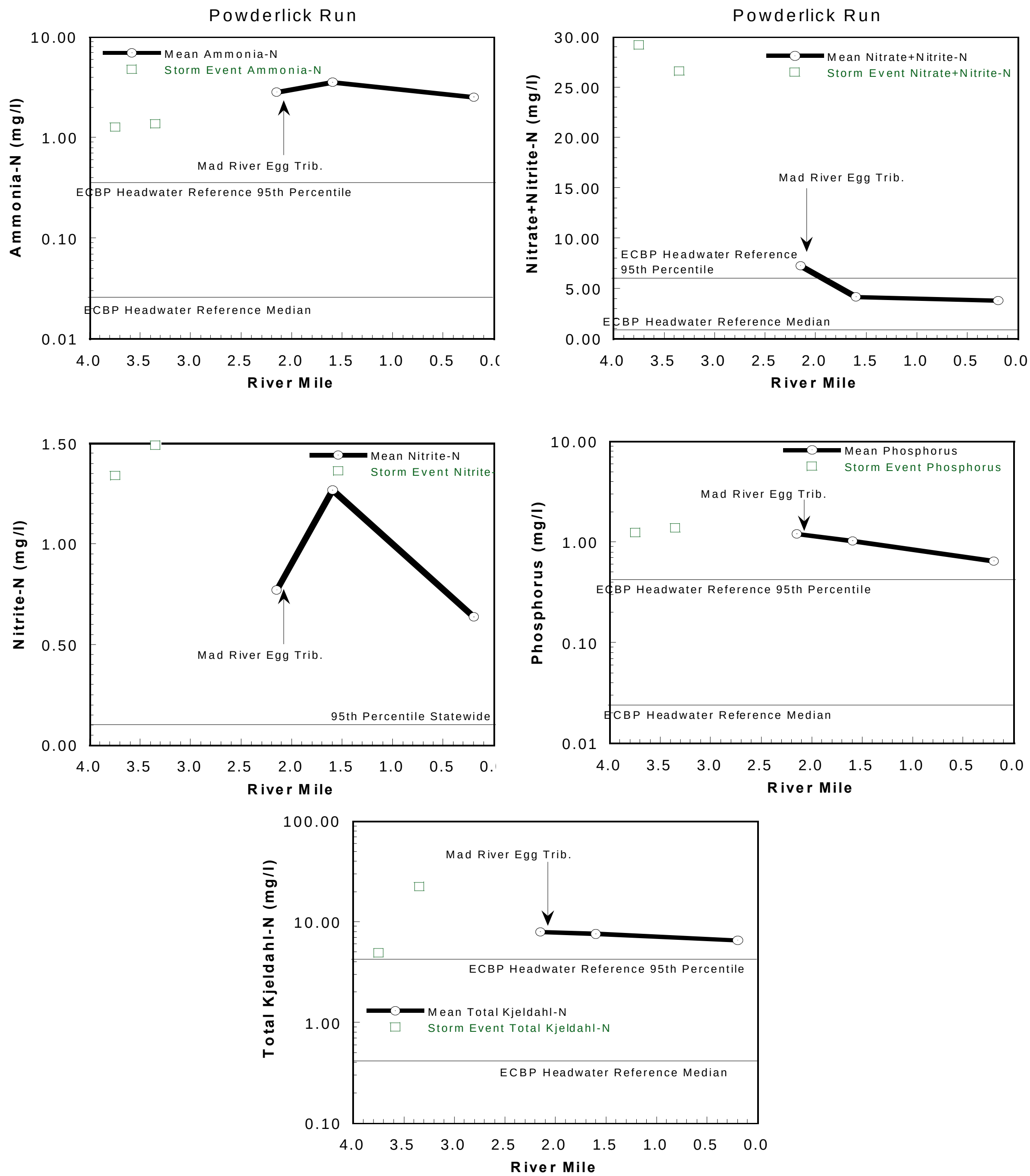


Figure 11. Mean concentrations of ammonia, nitrite, nitrate+nitrite, and total Kjeldahl nitrogen, and phosphorus (in mg/l) during water quality sampling in Powderlick Run, May-October, 1999.

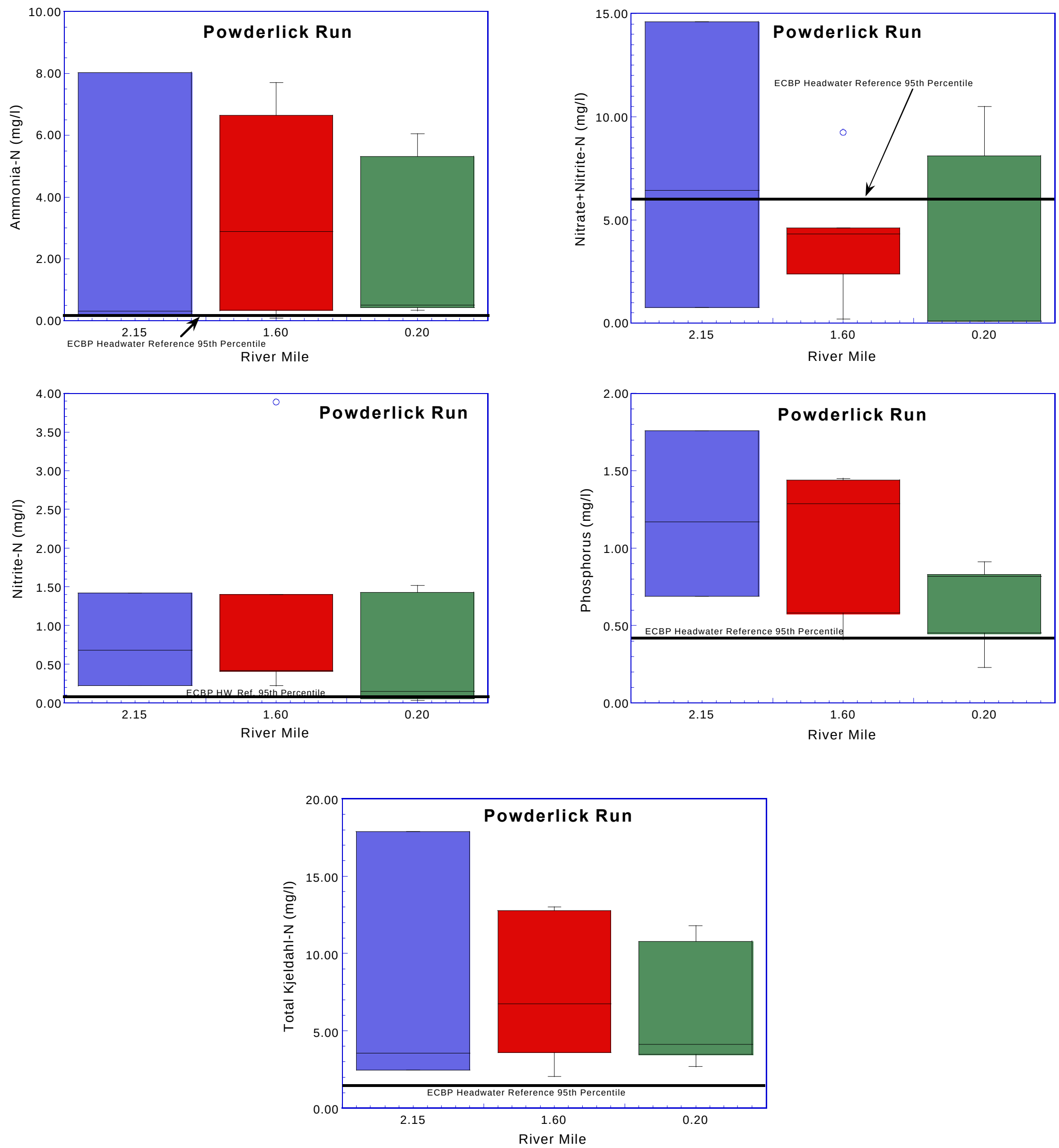


Figure 12. Box and whisker plots of ammonia-nitrogen, nitrate+nitrite-N, nitrite-N, total Kjeldahl nitrogen (TKN), and phosphorus concentrations (all as mg/l) for Powderlick Run longitudinally from May-September, 1999. The mean, 75th percentile, 25th percentile, maximum and minimum values were indicated.

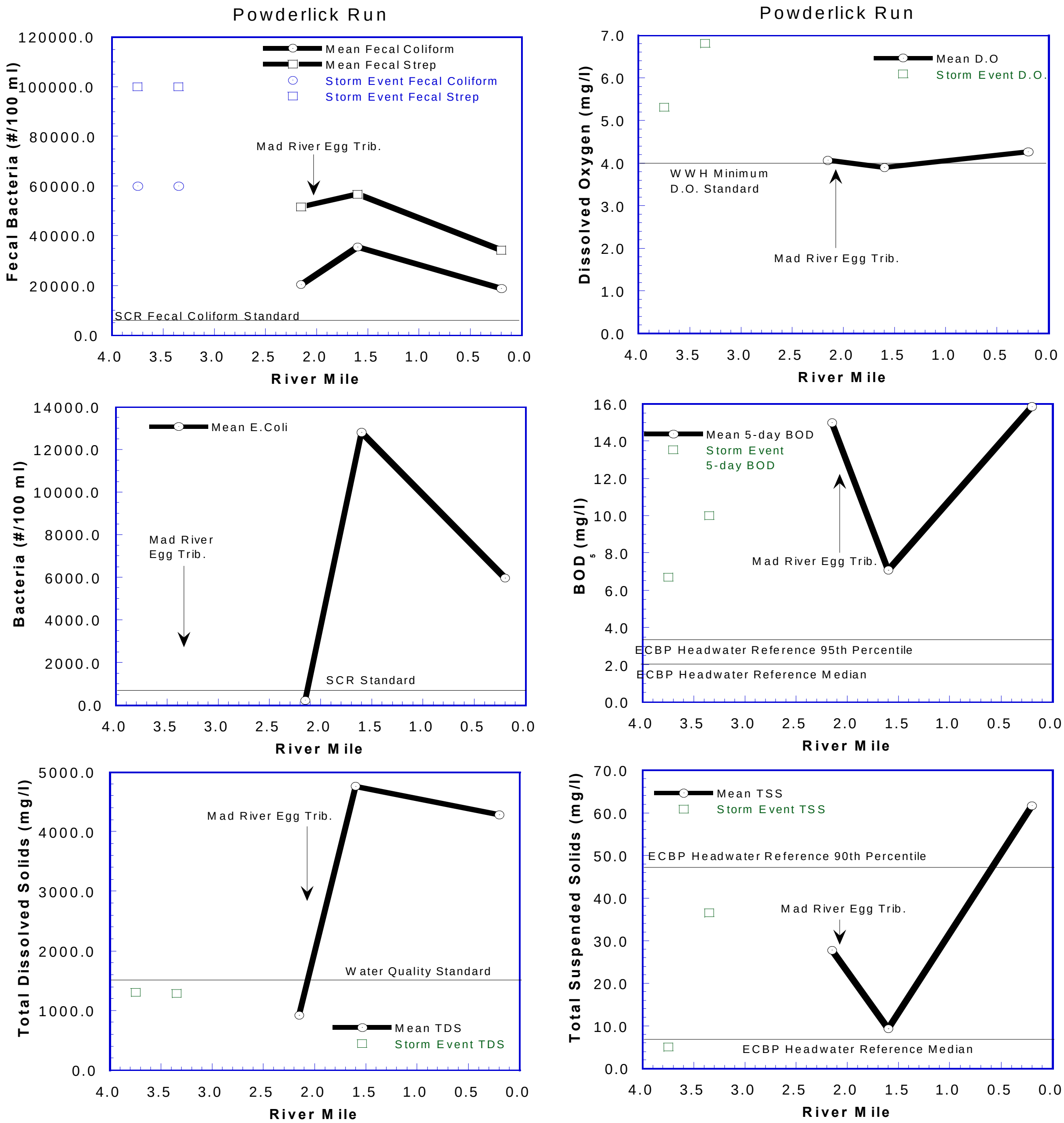


Figure 13. Mean concentrations of fecal bacteria (#/100 ml), *E. coli* bacteria (#/100 ml), total dissolved solids (TDS), dissolved oxygen (D.O.), Biochemical Oxygen Demand (BOD), and total suspended solids (TSS) (if not noted - mg/l) during water quality sampling in Powderlick Run, May-October, 1999.

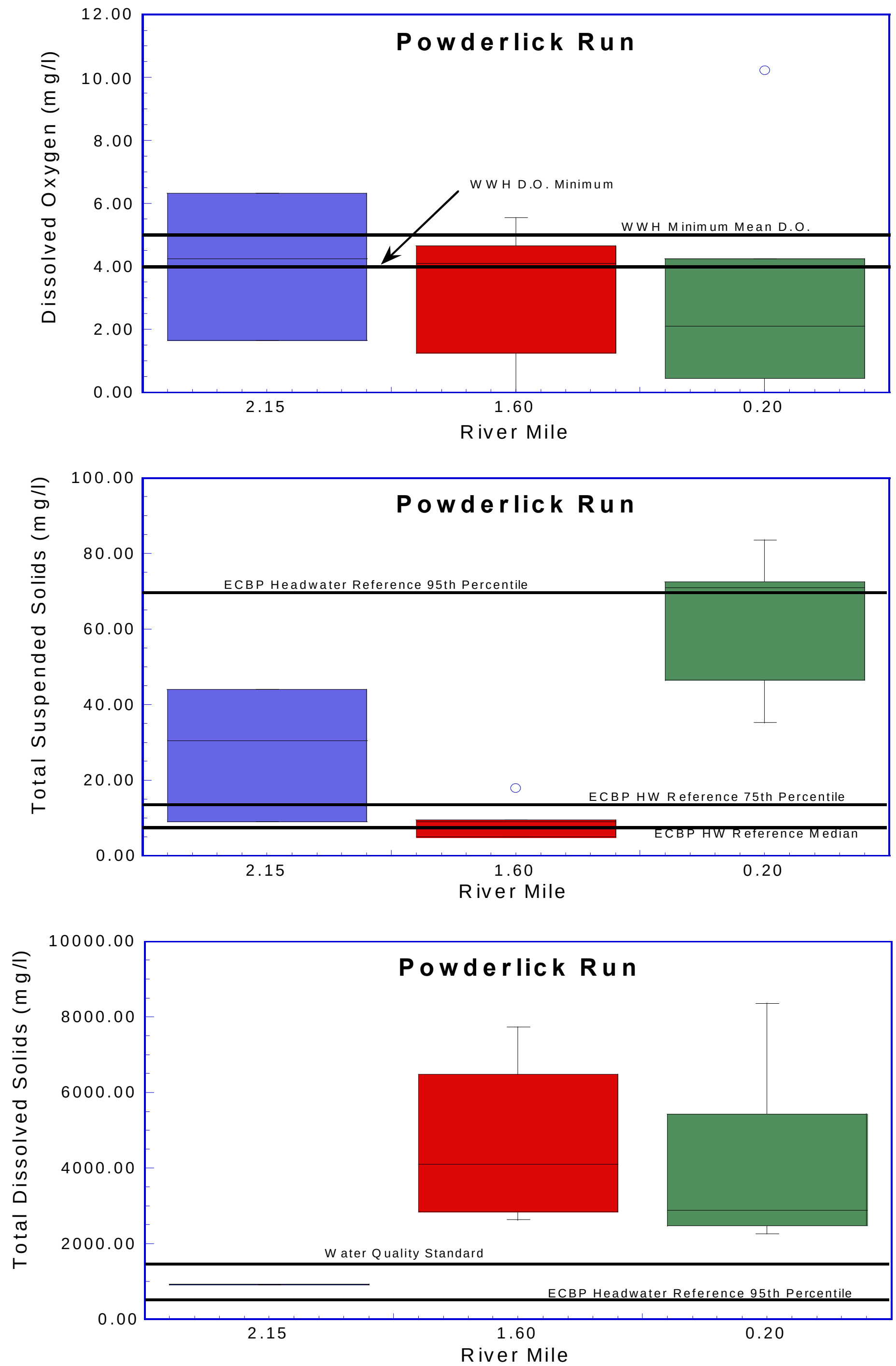


Figure 14. Box and whisker plots of dissolved oxygen (D.O.), total suspended solids (TSS), and total dissolved solids (TSS) (all as mg/l) for Powderlick Run longitudinally from May-September, 1999. The mean, 75th percentile, 25th percentile, maximum and minimum values were indicated.

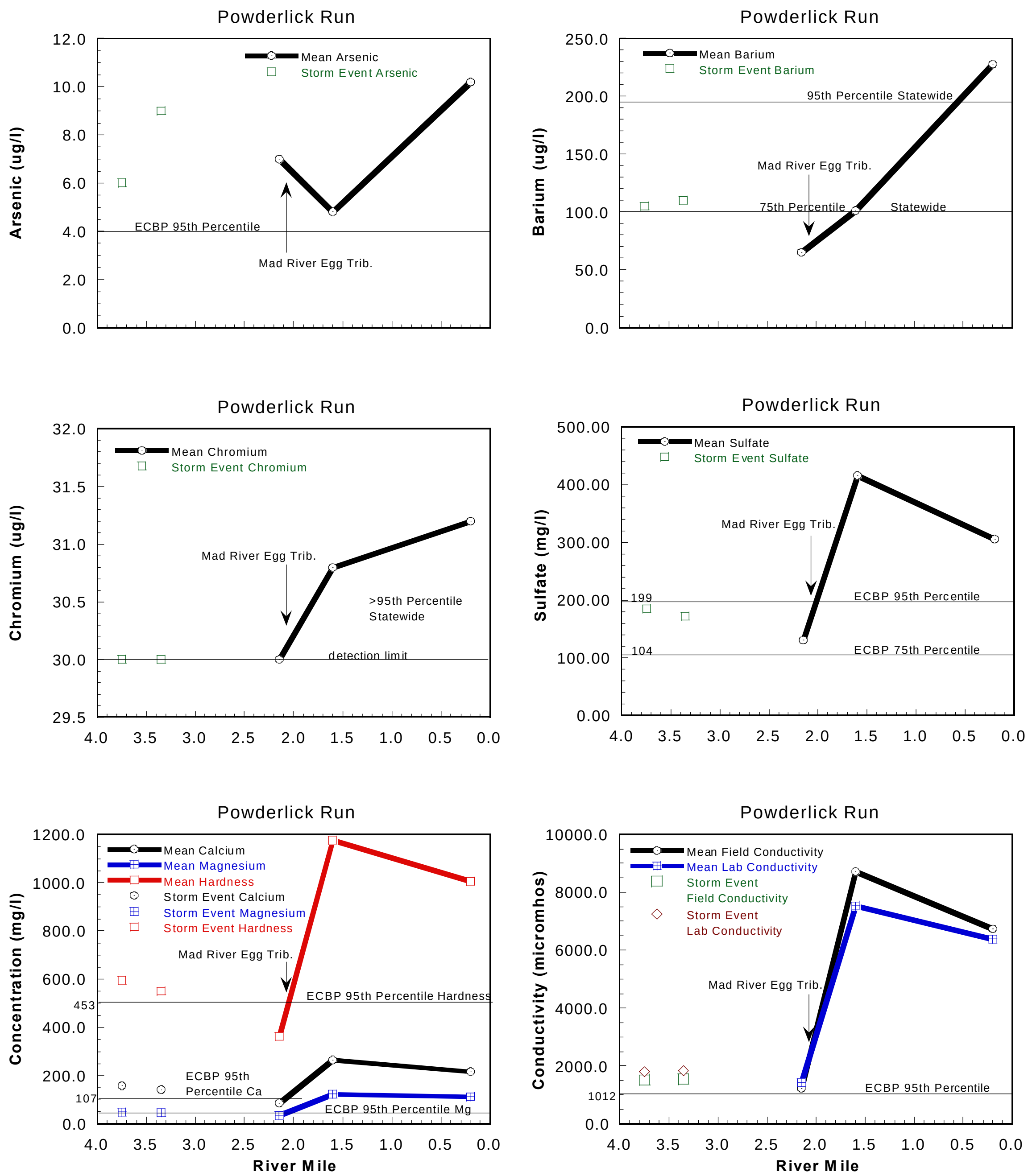


Figure 15. Mean concentrations of Arsenic(ug/l), Barium (ug/l), Chromium (ug/l), sulfates (mg/l), hardness (calcium and magnesium) (mg/l), and conductivity (micromhos) during water quality sampling in Powderlick Run, May through October, 1999.

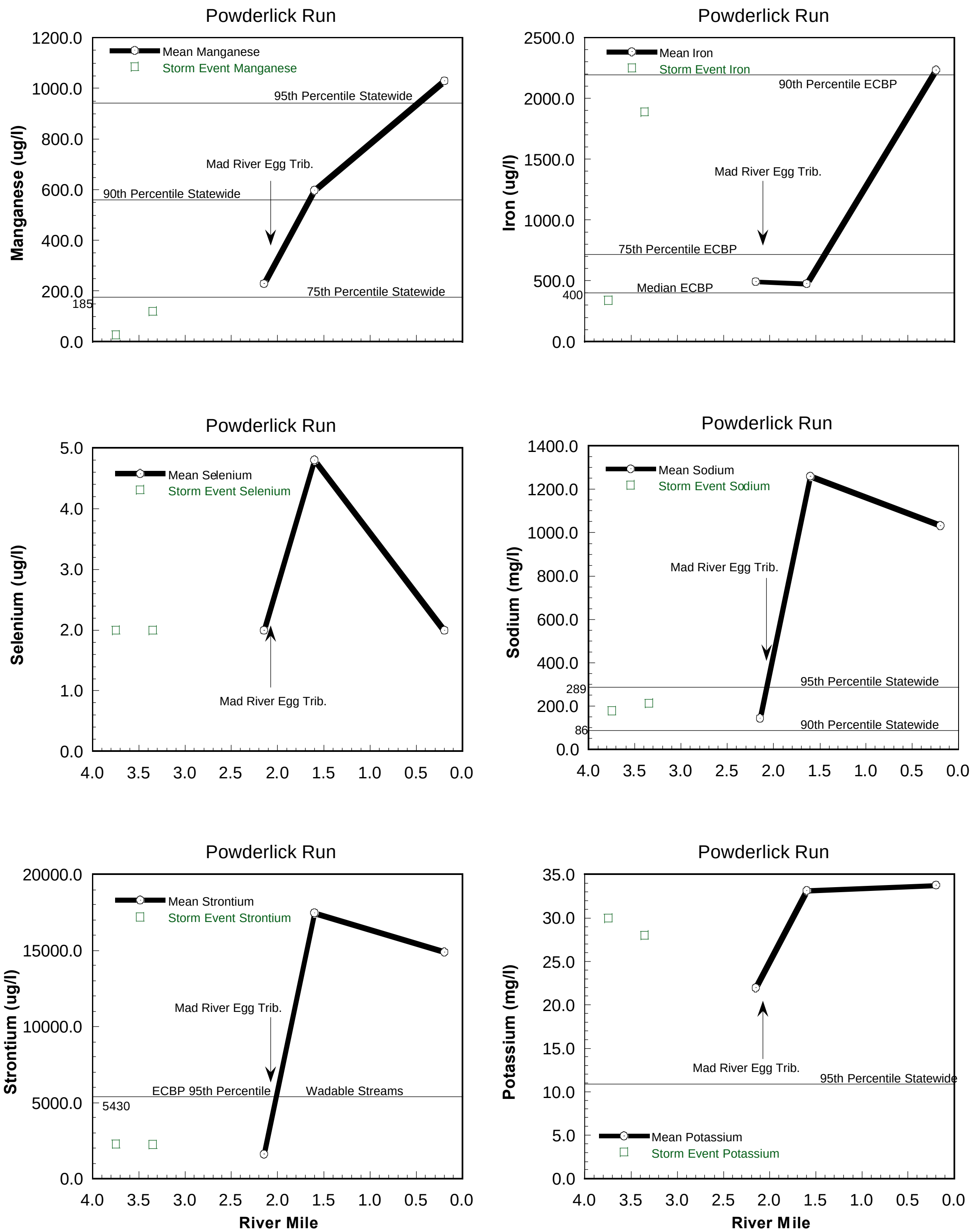


Figure 16. Mean concentrations of Manganese (ug/l), iron (ug/l), selenium (ug/l), strontium (ug/l), sodium (mg/l), and potassium (mg/l) during water quality sampling in Powderlick Run, May-October, 1999.

headwater value of 31 ug/l, was present downstream from waste manure application fields and a pullet farm and was associated with stormwater runoff after precipitation that day (8/25/99) (Tables 12 and A - 8). Iron concentrations, from suspended sediments, increased downstream from cattle pastures and a recently dredged stream reach (Figure 16). Sedimentation and the presence of other stormwater runoff components were implicated by the highly elevated total suspended solids concentrations present at RM 0.2 (Figures 13, 14, and 16). Elevated arsenic concentrations could be residuals from organic wastes in fertilizers, from herbicide/pesticide residuals, or from natural sources (Figure 15). Sources of the WQS criteria violations and exceedences listed above, nutrient enrichment and excess chemicals emanated from the egg farms and/or by runoff from nearby fields (from manure application process or fertilization of fields, herbicides/pesticides possible), drainage tiles, and livestock operations.

North Fork West Mansfield Tributary

Between July and October, 1999, chemical water quality samples were collected from North Fork West Mansfield Tributary (NFWMT) at 3 different sites (RMs 5.58, 3.97, and 1.30). Five sampling passes were completed at the two most downstream stations. Due to the drought conditions, the upstream site was found to be not flowing at times and were therefore only sampled on two occasions (see Appendix A for details). Precipitation occurred on two sampling days: 13 August (~0.1 inches) and 25 August (0.3-0.5 inches). Chemical sampling on 6/30 and 7/28 was preceded by precipitation of 0.1 - 0.2 inches the previous day(s). Chemical sampling on 7/13 occurred three days after 0.3 - 0.6 inches of rain (Table 12). Exceedences of WQS criteria in NFWMT were due to high levels of bacteria and very low dissolved oxygen (D.O.) concentrations (less than the minimum allowed concentration of 4.0 mg/l and less than the minimum average D.O. concentration of 5 mg/l) (Table 13, Figures17 and 18).

Biochemical oxygen demand (BOD), chemical oxygen demand (COD), suspended solids (TSS), and total dissolved solids (TDS) concentrations were measured at concentrations of concern (Figures 17-19). In approximately half of the samples collected, BOD values exceeded the 95th percentile of background concentration of 5.1 mg/l for the ECBP ecoregion or were greater than the 90th percentile (Table 14, Figures 17 and 18). Total suspended solids exceeded the 75th percentile of ECBP background on seven occasions and the 90th percentile once (8 of 12 samples) (Table 14, Figures 18 and 19). TDS exceeded the 90th to 95th percentile for the ECBP background levels in 10 of 12 samples (Table 14, Figure 19). Both were indicators of excess nutrients and enrichment and/or sedimentation.

Nutrient concentrations in NFWMT were highly elevated. Organic nitrogen (TKN) as well as ammonia were critically high with almost all samples above the 90th and/or the 95th percentile of ECBP background (Table 14, Figure19). Phosphorus values were also very high compared to ECBP headwater reference site levels, as six of twelve samples exceeded the 90th -95th percentile

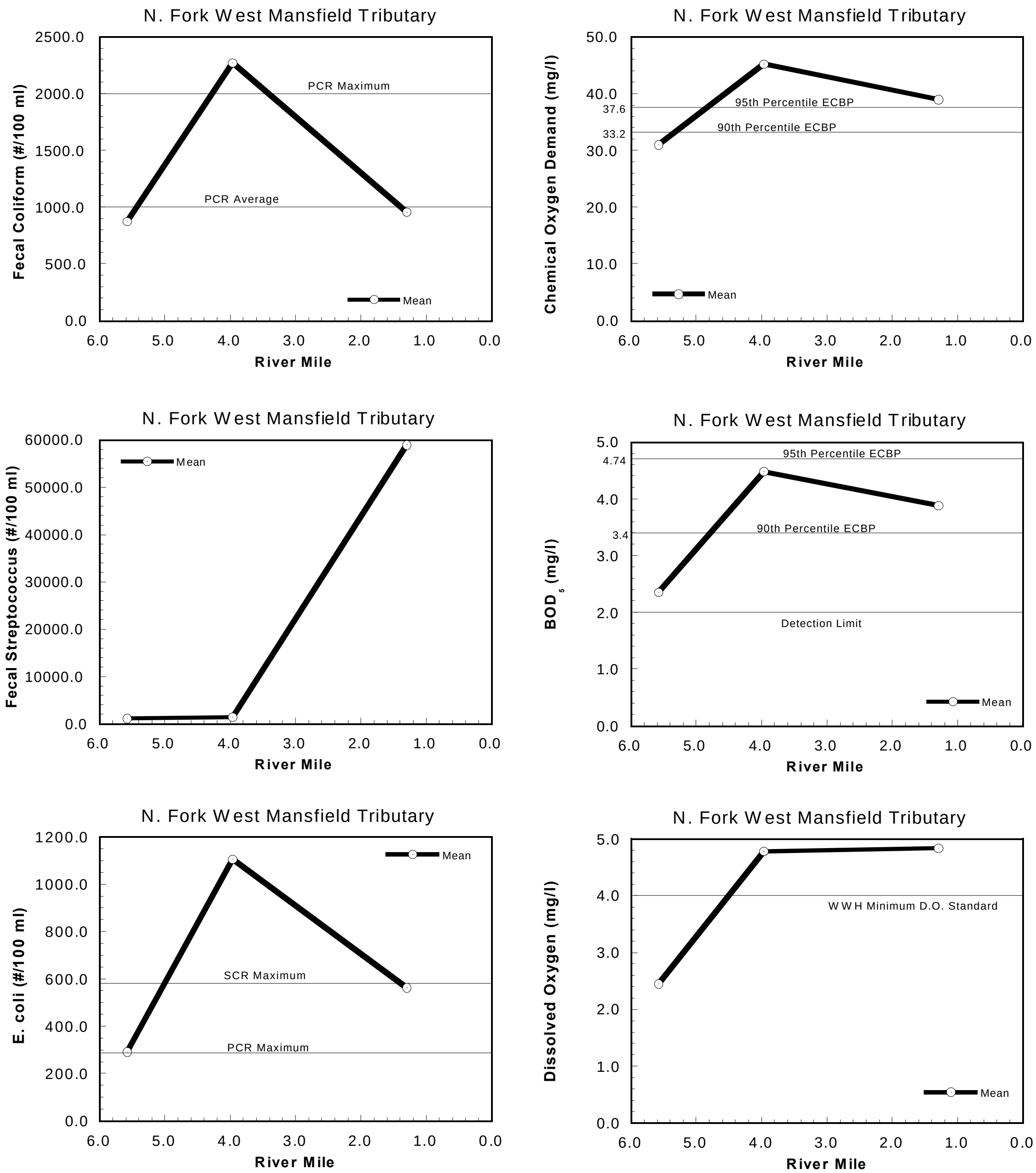


Figure 17. Mean concentrations of fecal coliform bacteria (#/100ml), fecal streptococcus bacteria (#/100ml), *E. coli* bacteria (#/100ml), COD (mg/l), BOD (mg/l), and D.O. (mg/l) during water quality sampling in North Fork West Mansfield Tributary from May-October, 1999.

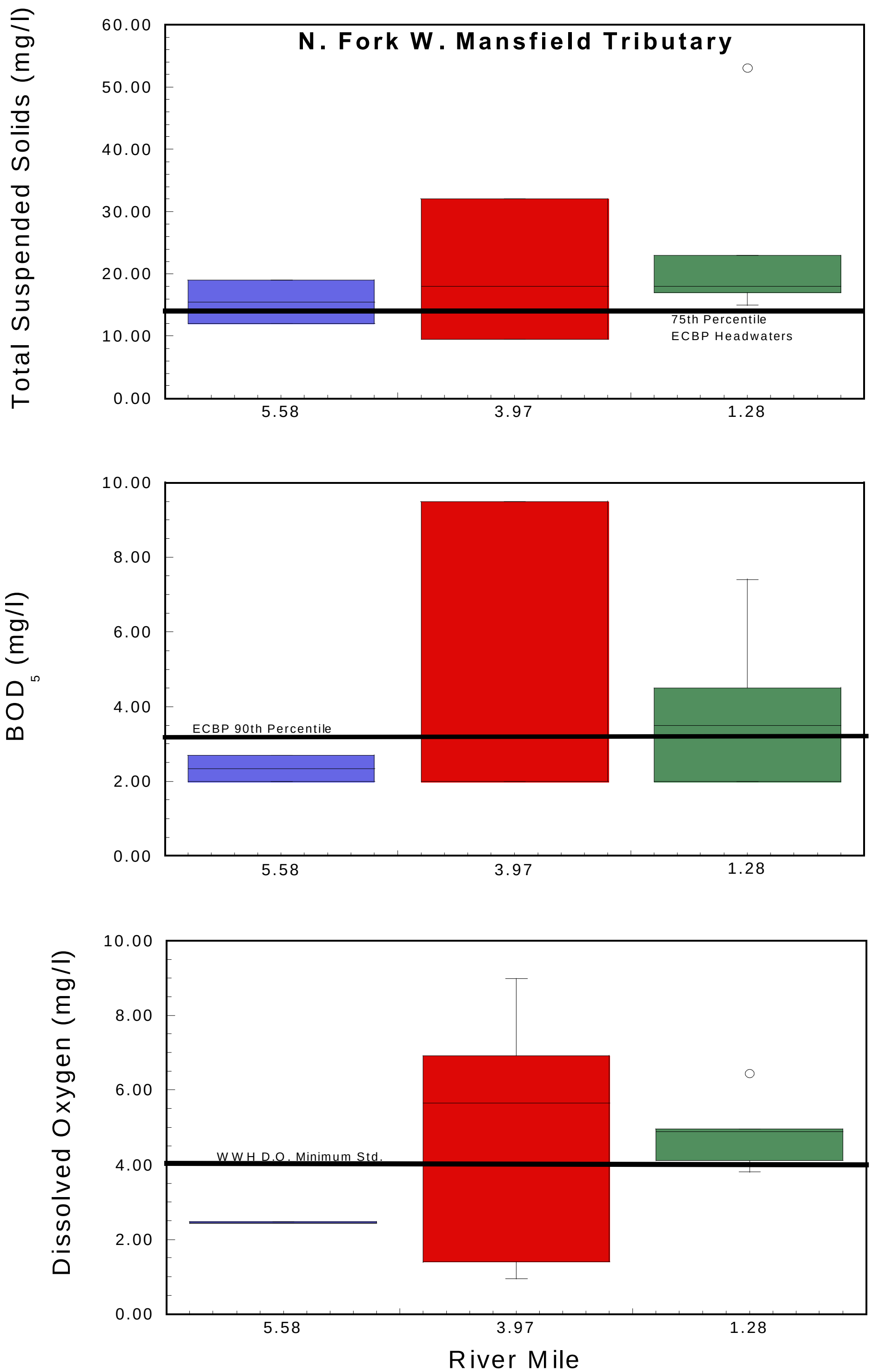


Figure 18. Median, 25th percentile, 75th percentile, maximum, and minimum values for TSS (mg/l), BOD (mg/l), and D.O. (mg/l) during water quality sampling in North Fork West Mansfield Tributary from May-October, 1999.

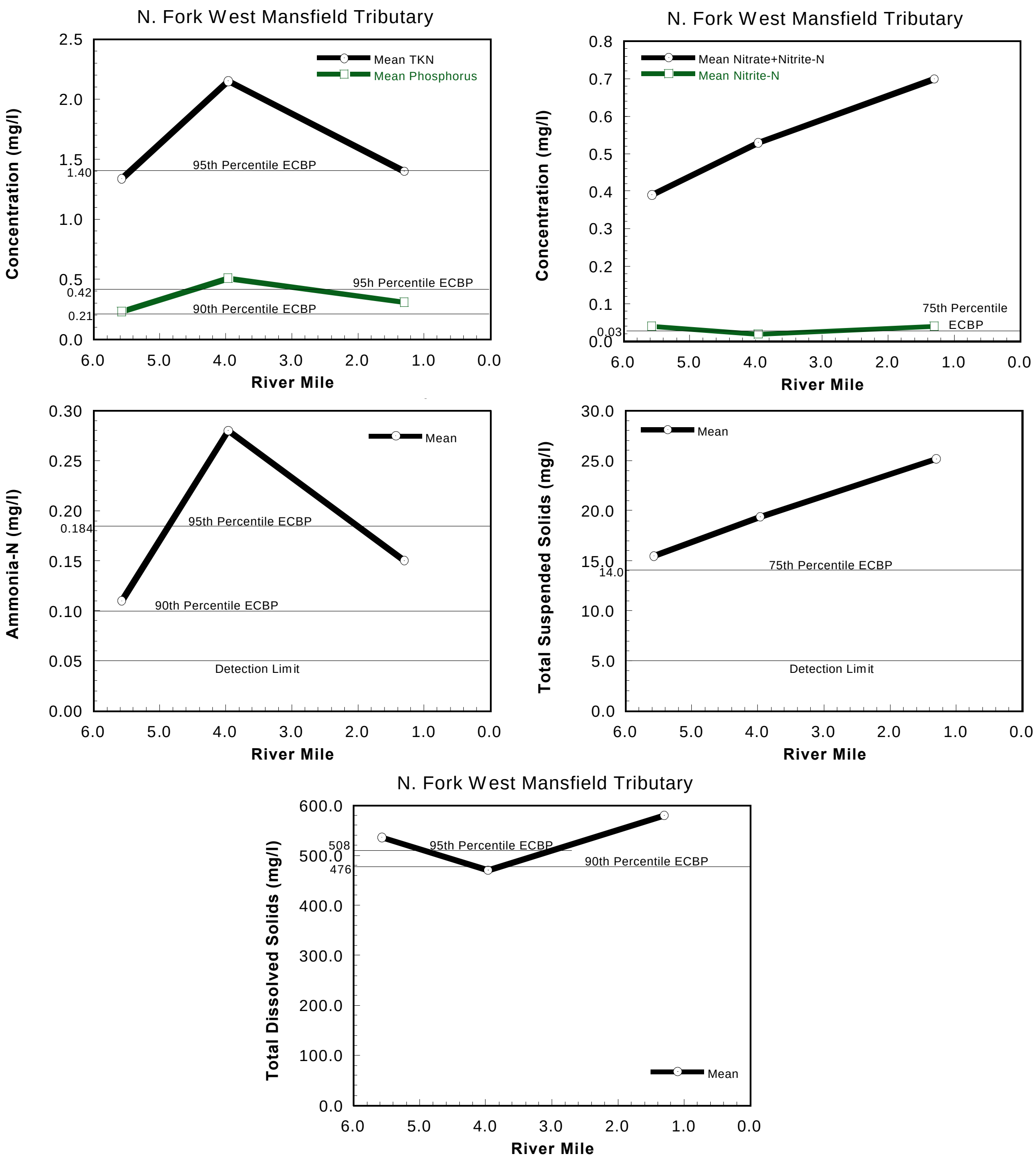


Figure 19. Mean concentrations of total Kjeldahl nitrogen (TKN) / phosphorus, nitrates / nitrites, ammonia-nitrogen, total suspended solids, and total dissolved solids (all units were mg/l) during water quality sampling of North Fork West Mansfield Tributary, May-October, 1999.

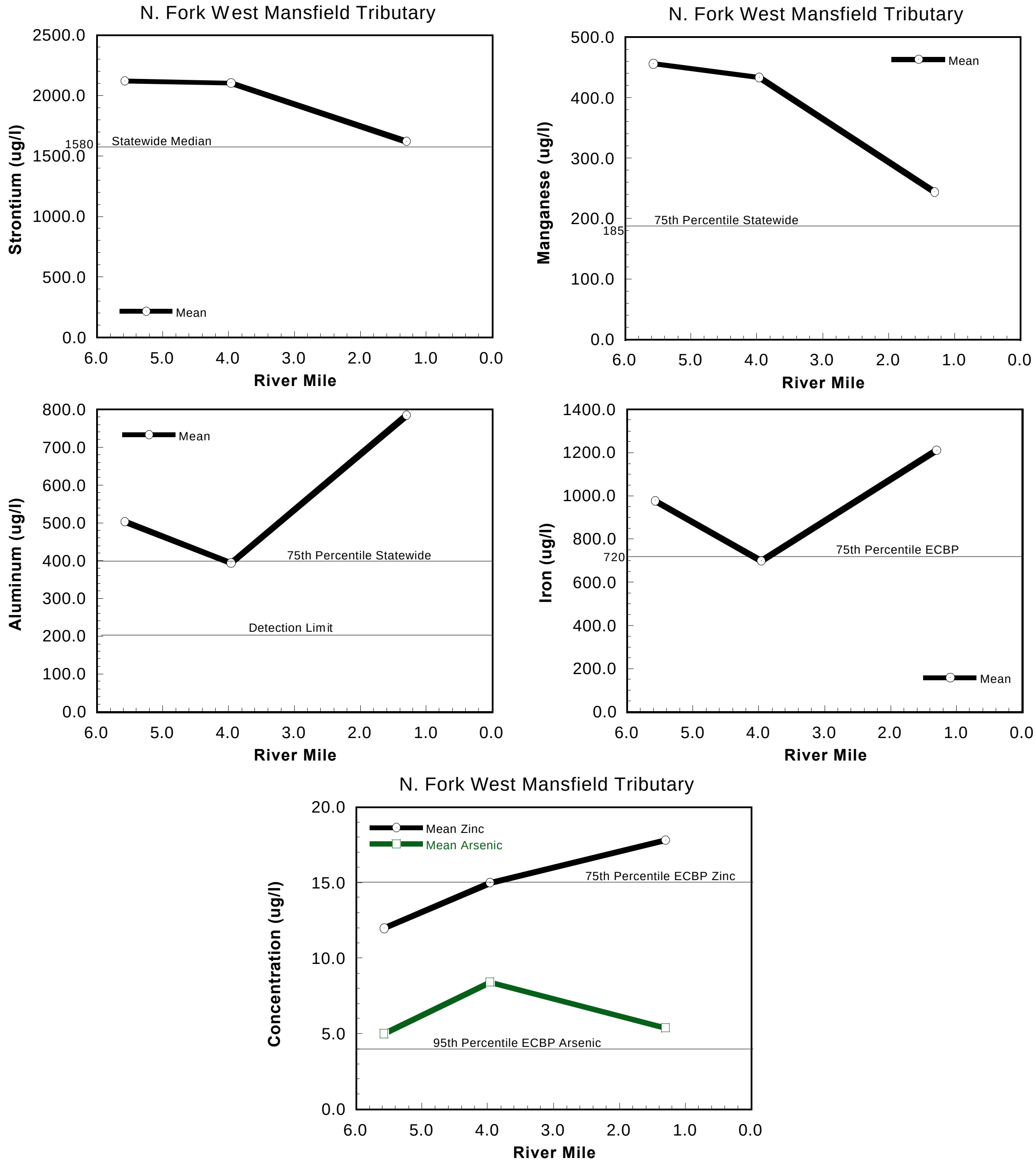


Figure 20. Mean concentrations of Strontium, Manganese, Aluminum, Iron and Zinc/Arsenic (all units in ug/l) during water quality sampling of North Fork West Mansfield Tributary from May-October, 1999.

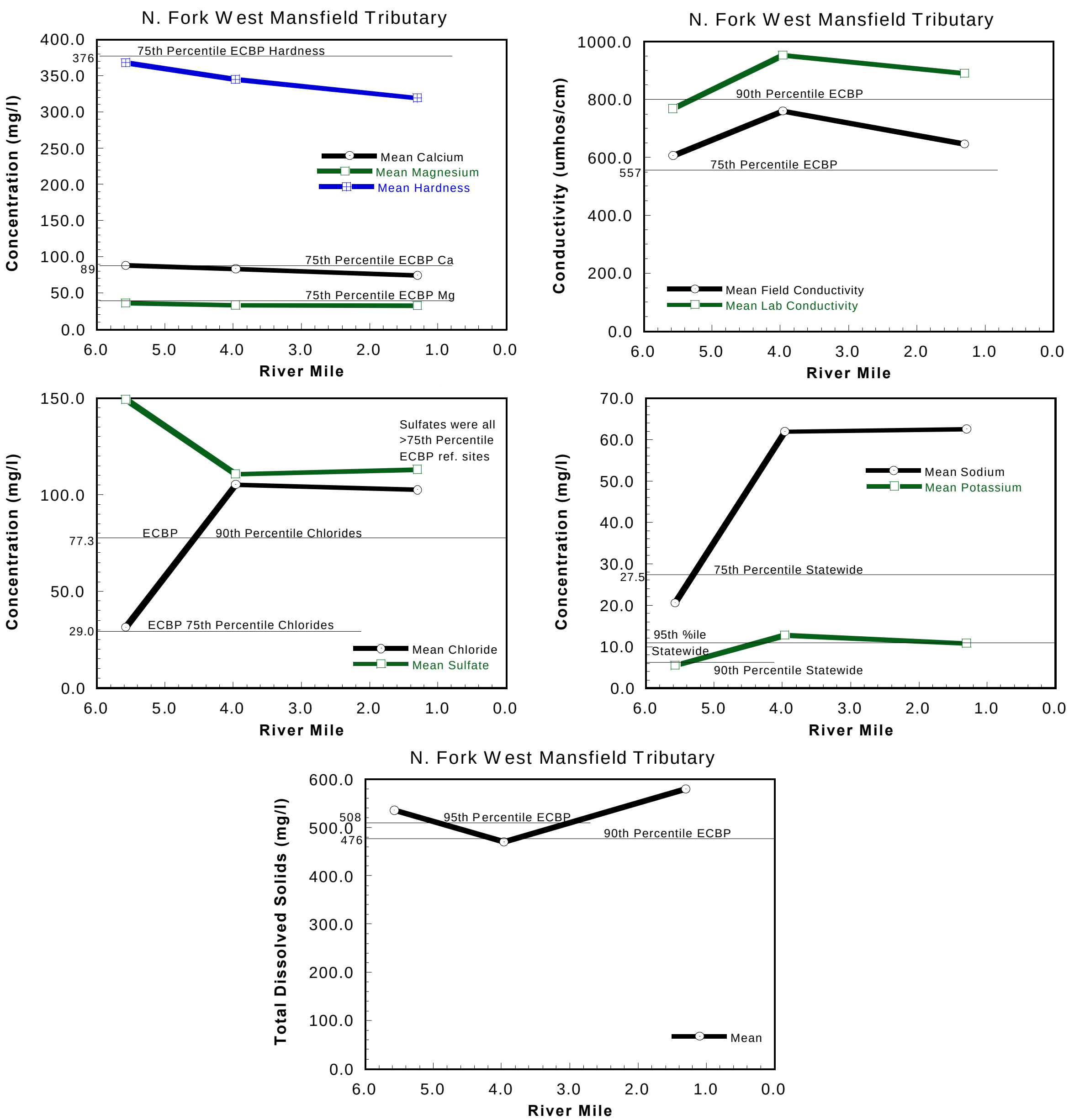


Figure 21. Mean concentrations of Calcium/Magnesium/Hardness, Conductivity (umhos/cm), Chlorides/Sulfates, Sodium/Potassium, and TDS (most units were mg/l) during water quality sampling in North Fork West Mansfield Tributary in May-October, 1999.

with another quarter of the samples exceeding the 75th percentile (Table 14, Figure 19). Nitrite concentrations exceeded the 75th percentile ECBP reference levels for headwater streams in 50 percent of the samples collected (Table 14, Figure 19). The relatively higher amounts of ammonia and nitrites (intermediate of NH_3) compared to nitrates indicated fresher organic sources that had not completed nitrification (Figure 19). High concentrations of some metals and salts were also indicative of nutrient inputs (organic fertilizer used in upper reaches) and/or sedimentation/erosion from limited riparian habitat, tiling and cattle (Figures 20 and 21). Nutrient and sediment pollution were significant problems in North Fork West Mansfield Ttibutary.

West Fork West Mansfield Tributary

Between July and October, 1999, chemical water quality samples were collected five times from a single site (RM 0.78) on the West Fork West Mansfield Creek (WFWMT). Exceedences of WQS criteria in WFWMT were similar to other small headwater streams sampled in the study area. Bacterial criteria for *E. coli* and fecal coliform bacteria and dissolved oxygen minimums and averages were violated with sampled low minimum D.O. concentrations of 2.4 and 3.2 mg/l (Table 13, Figure 22).

Phosphorus (P) and ammonia (NH_3) were found at critically elevated concentrations in WFWMT along with very elevated concentrations of organic nitrogen (TKN). Eighty percent of P values and sixty percent of NH_3 values were greater than the 95th percentile for ECBP reference sites (Figure 23, Table 14). Nitrates were not found at elevated concentrations of concern in WFWMT (most likely had been utilized in algal production or was not in that form), while the presence of NH_3 and nitrite (NH_3 intermediate) indicated more organic sources (Figure 23). All collected samples for TSS, TDS, and field conductivity were elevated indicating accumulated nutrient runoff and /or sedimentation. High COD and periodically elevated BOD inferred potential for low diel D.O. concentrations which, in fact, occurred (Figures 22 and 23, Tables 13 and 14). As is the case in all headwater streams in this study, nutrient (specifically organic) pollution was found to be significant in West Fork West Mansfield Creek.

Smith Run

Between July and October, 1999, chemical water quality samples were collected from Smith Run at 2 different sites (RMs 3.24 and 0.77). Only 2 sampling passes were made at RM 3.24 due to lack of surface flow. Five passes were completed at RM 0.77. As at other headwater sites, violations of WQS criteria included low D.O. concentrations (mean < 5 mg/l with low mean of 4.35 mg/l and mnimum < 4 mg/l with a low of 2.73mg/l) and high bacteria contamination (Table 13, Figure 22). WQS criteria violations in Smith Run were not as numerous as at similar sites on Powderlick Run, though there was significant degradation from similar sources. Nutrients (NH_3, P, and TKN), COD and TSS were found in almost all samples at elevated concentrations in Smith Run with most parameters exceeding the 75th percentile for the ECBP background (Table 14, Figures 22 and 23). Ninety-three percent of TSS, TDS, and COD measurements at RM 0.77 were highly elevated with

60 percent exceeding the 75^{th} - 95^{th} percentile of ECBP background (Table 14, Figures 22, 24 and 25). Metals, salts, and associated hardness and conductivity concentrations were highly elevated corresponding to organic nutrient/fertilizer runoff inputs and/or sedimentation (Figures 24 and 25). Aluminum, strontium, manganese, sulfates and chlorides, among others, were likely linked to food or biological wastes in organic fertilizers and/or in sediment - and both definitely linked to runoff (Figures 24 and 25). Chemical water quality sampling definitely indicated large impacts from agricultural runoff to Smith Run.

South Branch West Fork West Mansfield Tributary

Only one chemical sampling pass was collected on the South Branch West Fork West Mansfield Tributary at the mouth (Table 7). Excessively high bacterial exceedences for *E. coli* and fecal coliform bacteria occurred as well as high fecal streptococcus concentrations (Table 13, Figure 22). Ammonia was highly elevated at greater than the 95^{th} percentile for ECBP headwaters. Total Kjeldahl Nitrogen was collected at > 90^{th} percentile, and phosphorus was between the 75^{th} and 90^{th} percentile of ECBP background (Figure 23). These very elevated nutrients, combined with some reaches of exposed banks, allowed for BODs and CODs at greater than the 75^{th} - 90^{th} percentile of background (Figure 22). There were low diel dissolved oxygen concentrations from nutrient enrichment and decay, as the one D.O. concentration collected was at 4.3 mg/l. Hardness, conductivity, chlorides, and TDS were at high enough concentrations (most >95^{th} percentile) to likely affect biological communities (Figures 24 and 25). The organic nutrient sources likely included the runoff from the West Mansfield WWTP land application fields adjacent to the South Branch West Fork West Mansfield Tributary, NPS runoff from fertilizer-applied agricultural fields, and some home on-site septic system discharges. Regardless of the source(s), nutrient enrichment and low diel D.O. concentrations were major problems, and hydromodification and riparian reductions exacerbated the poor water quality conditions.

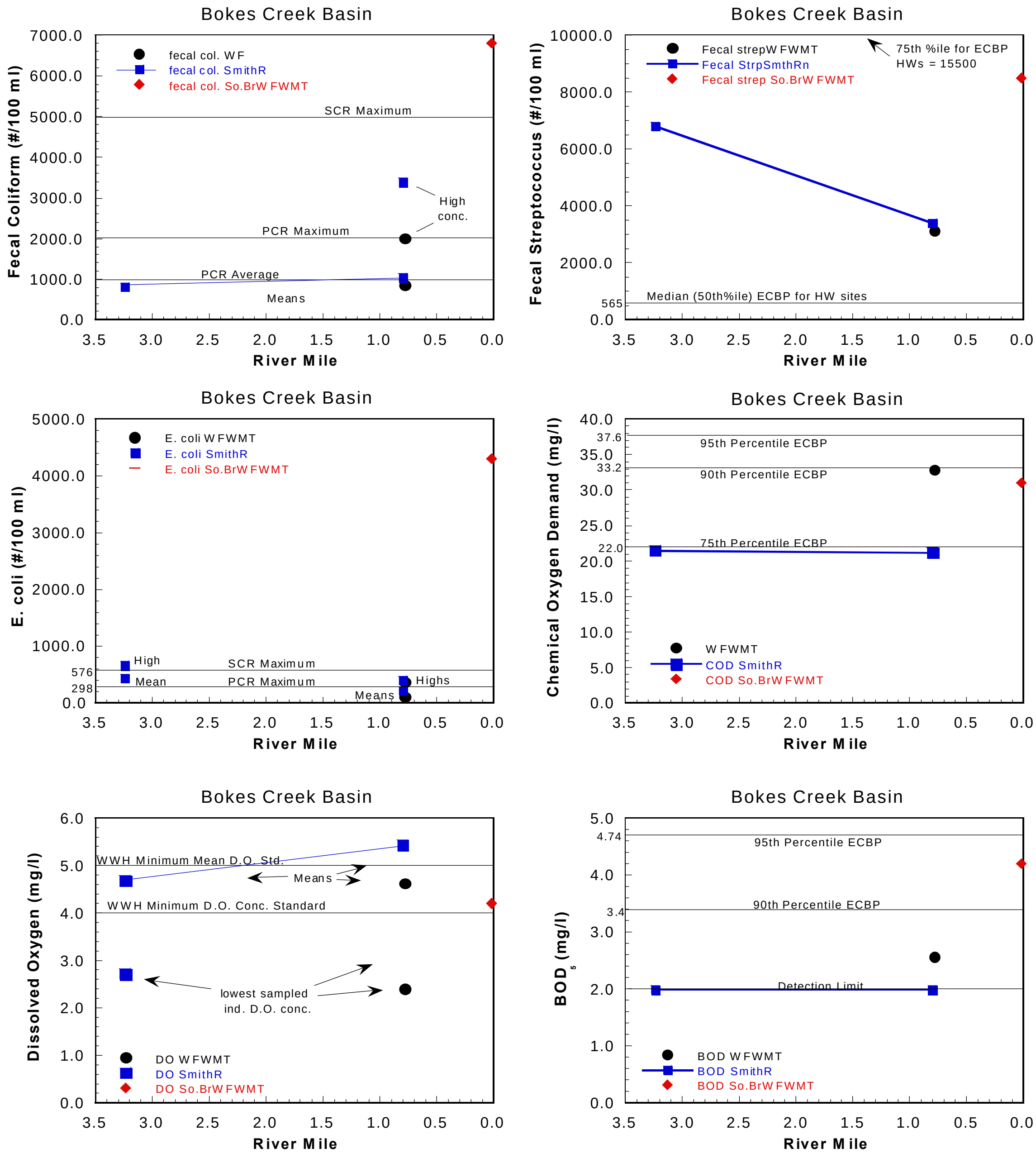


Figure 22. Mean or high concentrations of fecal coliform bacteria (#/100ml), *E. coli* bacteria (#/100ml), fecal streptococcus bacteria (#/100ml), COD (mg/l), BOD (mg/l), and D.O. (mg/l) during water quality sampling in West Fork West Mansfield Tributary, Smith Run, and South Branch West Fork West Mansfield Tributary from May - October, 1999.

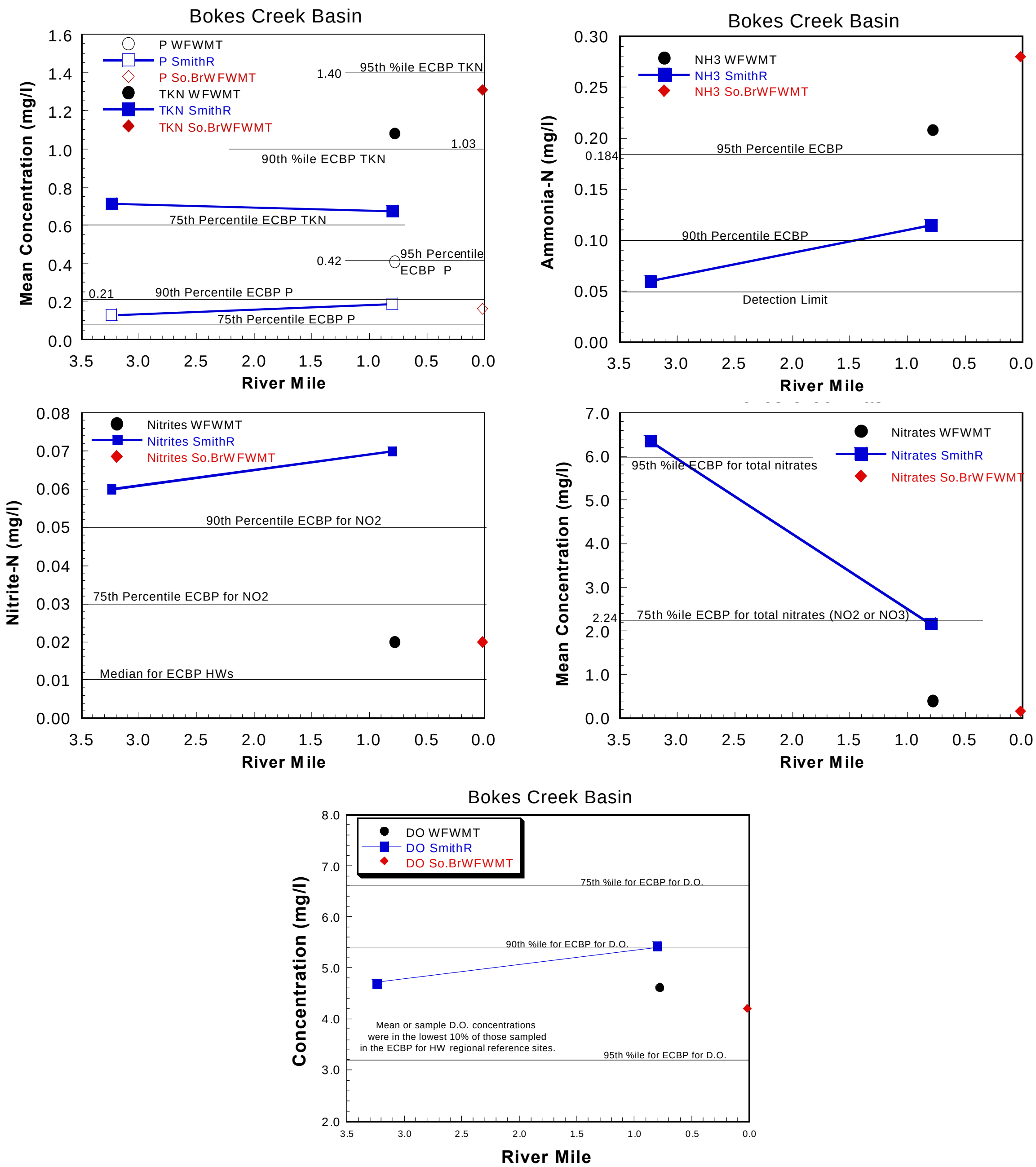


Figure 23. Mean and individual concentrations of total Kjeldahl nitrogen / phosphorus, ammonia-nitrogen, nitrite-N, nitrates, and D.O. (mg/l) for site(s) on West Fork West Mansfield Tributary, Smith Run, and South Branch West Fork West Mansfield Tributary.

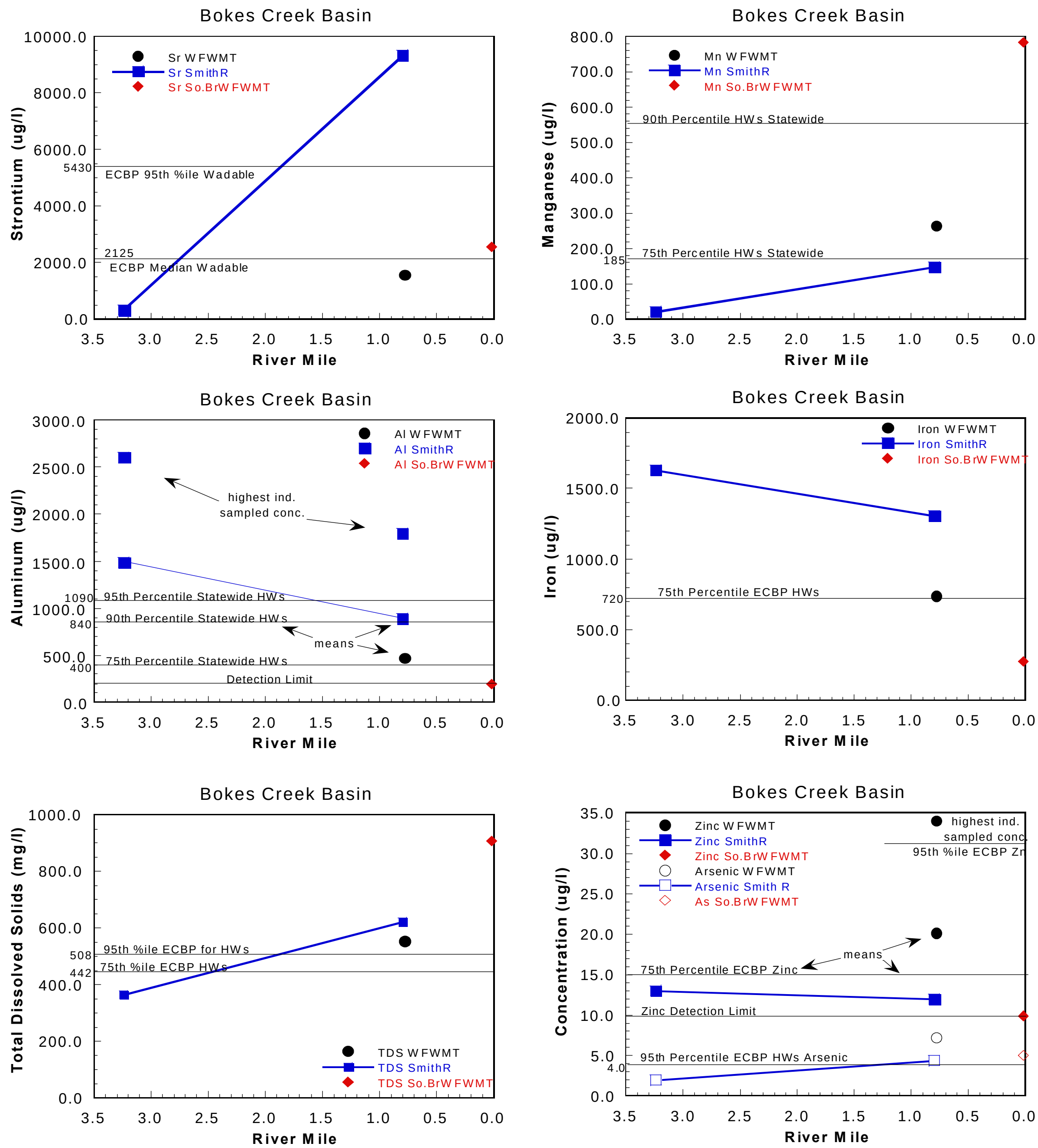


Figure 24. Mean and high concentrations of Strontium, Manganese, Aluminum, Iron, TDS (mg/l), and Zinc/Arsenic (all parameters were ug/l unless noted) during water quality sampling in West Fork West Mansfield Tributary, Smith Run, and South Branch West Fork West Mansfield Tributary from May-October, 1999.

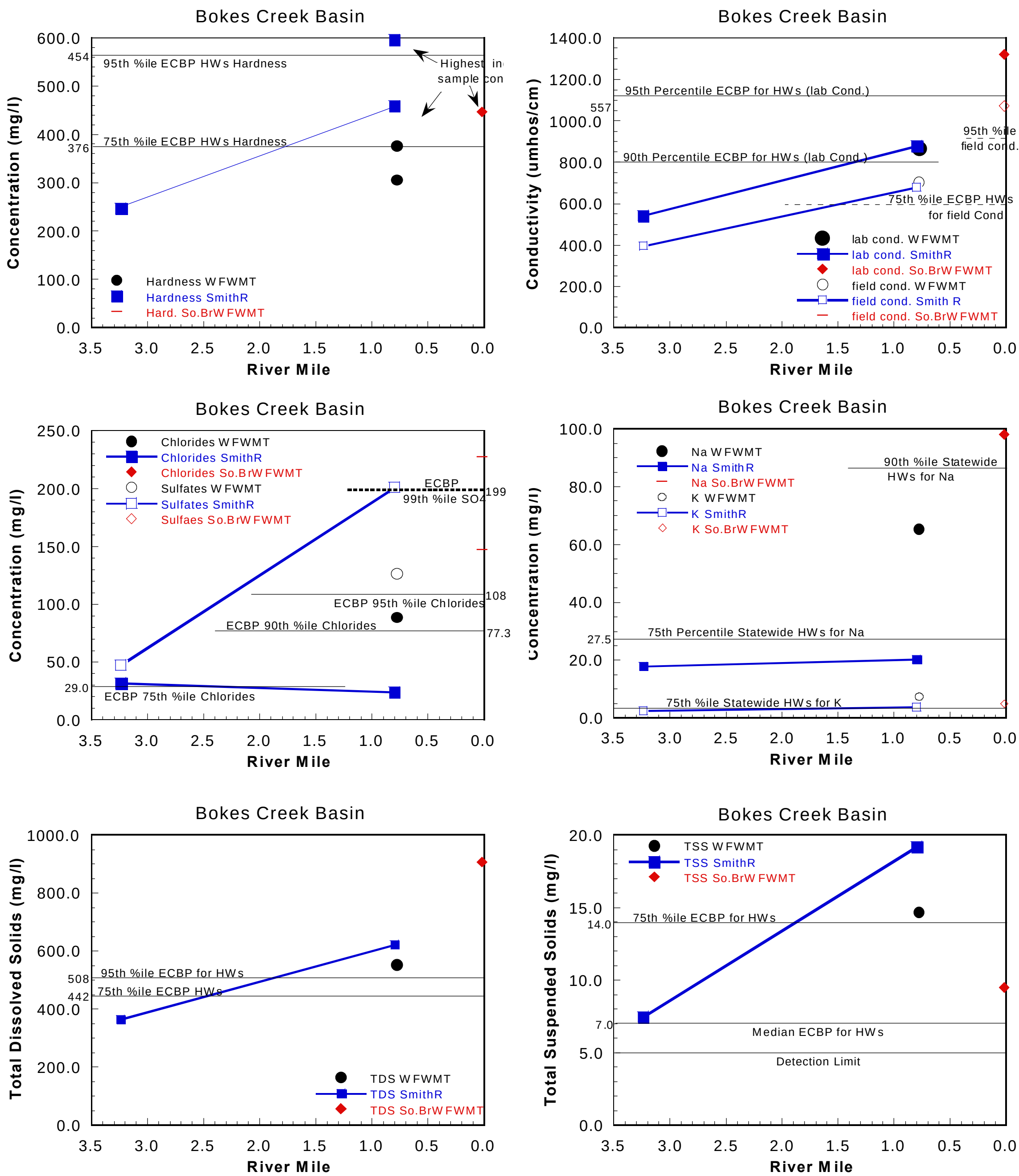


Figure 25. Mean or high concentrations of Hardness (mg/l), Conductivity (umhos/cm), Chlorides/Sulfates, Sodium/Potassium, TDS and TSS (all units were mg/l unless noted) during water quality sampling in West Fork West Mansfield Tributary, Smith Run, and South Branch West Fork West Mansfield Tributary in May-October, 1999.

Diel Dissolved Oxygen Study-Bokes Creek and Tributaries

To determine if diel D.O. concentration fluctuations occurred, Datasonde® continuous sampling monitors, recording hourly measurements over a 48 hr. period, were deployed during late June through early July 1999. There were approximately 0.1 inches of precipitation on 29 June, 1999, during this monitoring effort (Table 12). Other measured parameters were temperature, pH, and conductivity. Datasondes were placed at seven stations on Bokes Creek between RM 35.10 and the mouth (Figures 26-31). Similar data were gathered at stations on North Fork West Mansfield Creek (2 sites), West Fork West Mansfield Creek (1 site), Powderlick Run (1 site) and Smith Run (1 site).

These measurements were useful in evaluating the presence of nuisance growths of algae or extensive oxidation of organic and inorganic matter - indicative of a nutrient enrichment impact. D.O. concentrations cyclically fluctuate from photosynthesis during the daylight hours and decrease from respiration at night due to algal and plant biomass decay. The larger the swing to supersaturated D.O. conditions during the day (high nutrient concentrations present causing large-scale algal growth) and low D.O. concentrations at night from large biomass degradation and decay indicate the magnitude of nutrient enrichment. Shading from mature riparian buffers can reduce or minimize nutrient enrichment. Cloudy weather conditions or turbidity can also reduce D.O. spikes during daylight. Reduced riparian habitat or open canopy conditions can exacerbate the effects of nutrient enrichment.

Bokes Creek

Datasondes® were placed at seven stations on Bokes Creek between RM 35.12 and the mouth (Figures 26-28). The station at RM 35.12 showed significant oxygen depletion during the overnight hours and multiple violations of the 4 mg/l minimum WWH criteria (Fig. 26). Five of the remaining six stations did not show violations of the minimum criterion during the monitoring, but most were at very low concentrations just above 4 ppm. Problems with supersaturated conditions were noted at RMs 35.12 (~120%), 27.20 (~190%), 0.20 (~170%), and RM 11.37 (~140%) (Figures 26 and 27). Supersaturated conditions are typically associated with high primary productivity which in turn is linked with excessive available nutrients. Excess nutrients were also present at Yearsley Rd. (RM 21.3), dst. Powderlick Run at RM 20.2, and at Ford Reed Rd. (RM 16.58), but supersaturated D.O. conditions did not occur during monitoring due to riparian cover limiting primary production instream (Figure 28).

The site at St. Rt. 4 (RM 11.37) had its lowest diel D.O. measurement near the 6 ppm average criterion during datasonde® monitoring. The smaller range of D.O. extremes (~6 to 11 ppm) was more typical of what should be more normal. The less pronounced D.O. spike and sag was due to some assimilation and also the distance from major nutrient source inputs via major upstream tributaries (Figures 4 and 27). However a water quality chemical grab sample measured an exceedence below 4 ppm during routine chemical sampling at this site (Table 13). The dissolved oxygen depletion noted at RM 35.12 was not unexpected when coupled with the elevated nutrient

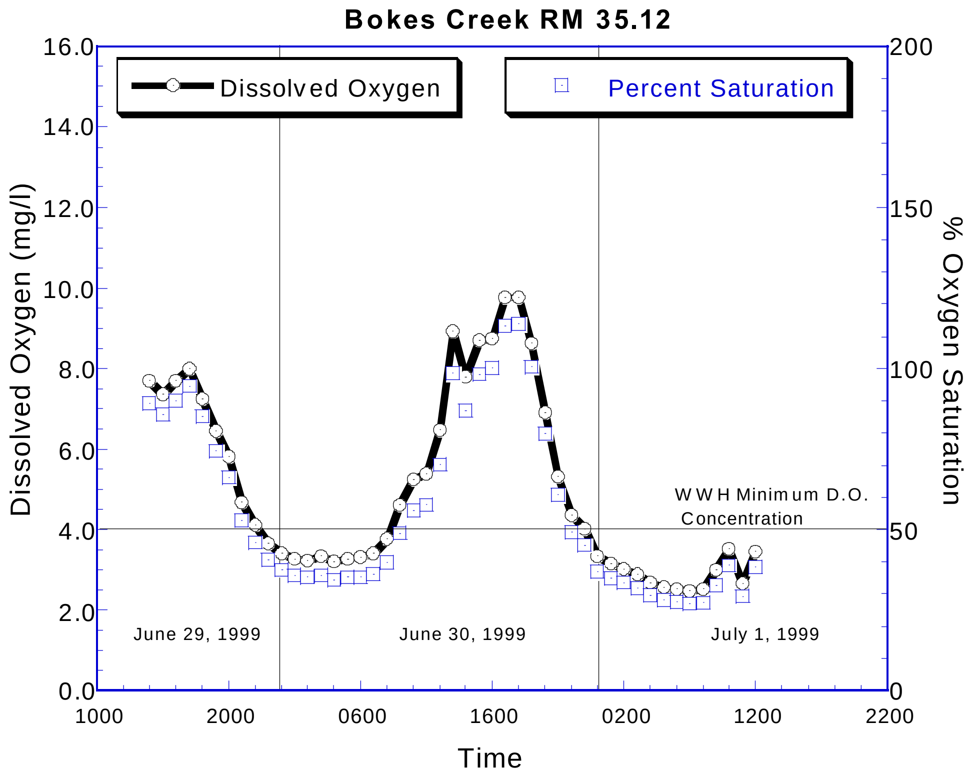


Figure 26. Diel dissolved oxygen concentration readings recorded over 48-hr. period using continuous sampler in Bokes Creek at RM 35.12 from 29 June to 1 July, 1999.

and demand parameters collected there, the high nutrient load upstream at RM 36.34, and the drought conditions present (Table 12, Figures 3 and 26). The whole of Bokes Creek mainstem was found to be threatened by low diel D.O. concentrations from nutrient enrichment with supersatured conditions occurring where riparian vegetation was reduced (Figure 7, Table 13).

Powderlick Run

A single Datasonde® was placed in Powderlick Run at RM 1.60. Dissolved oxygen concentration readings illustrated an atypical diel fluctuation with nighttime levels falling below the minimum criterion of 4 mg/l on July 1, 1999 (Figure 29). Supersaturated conditions were also noted during daylight hours rising to nearly 200% (over 17.5 mg/l D.O.). Excessive primary productivity due to severe nutrient enrichment, the lack of riparian shading, and consequential decay with D.O. losses were the likely causes of the extreme swings in dissolved oxygen concentrations.

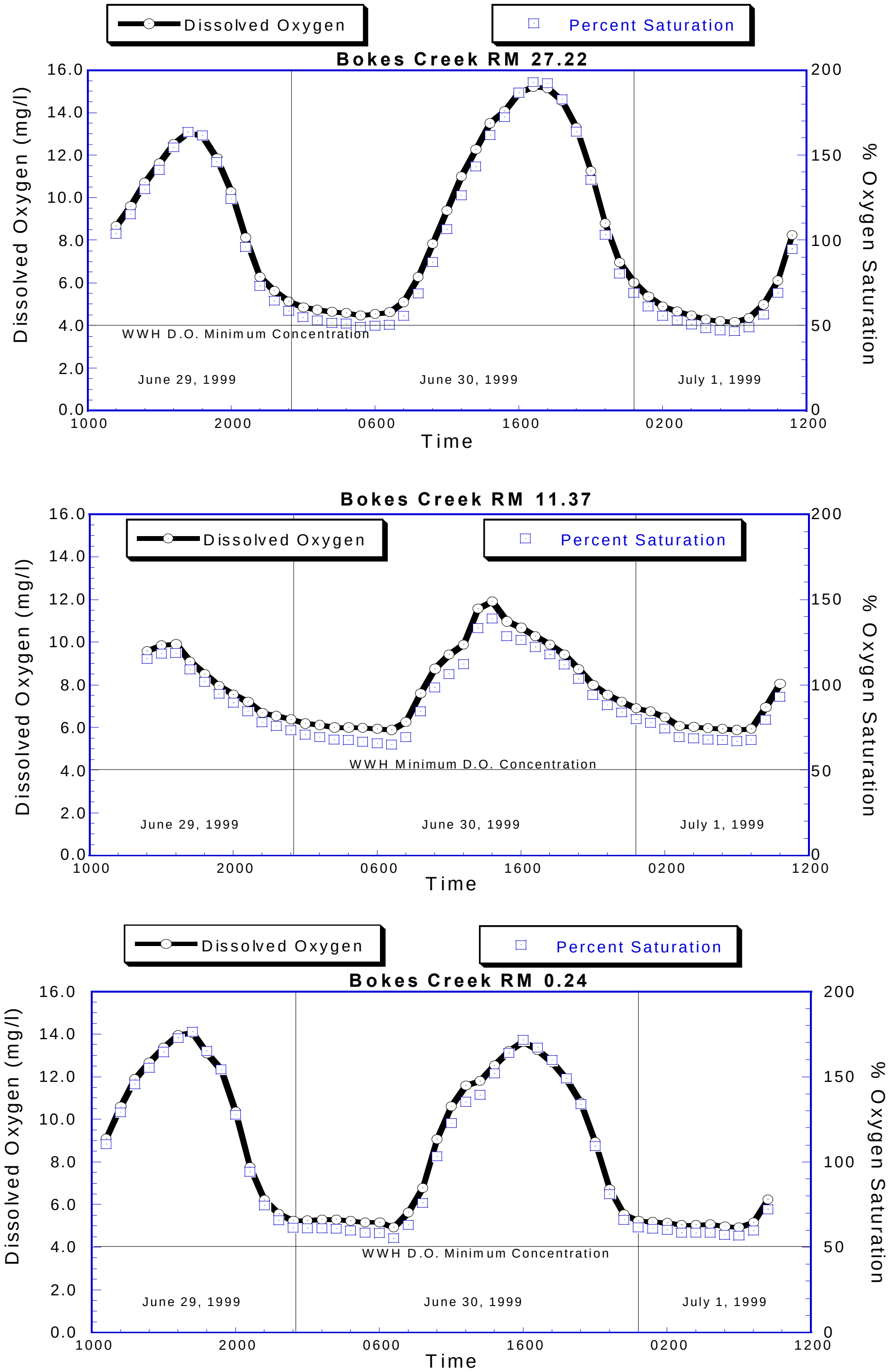


Figure 27. Diel dissolved oxygen concentration readings over 48-hr. period using continuous samplers in Bokes Creek mainstem at Rms 27.22, 11.37, and 0.24 from 29 June to 1 July, 1999.

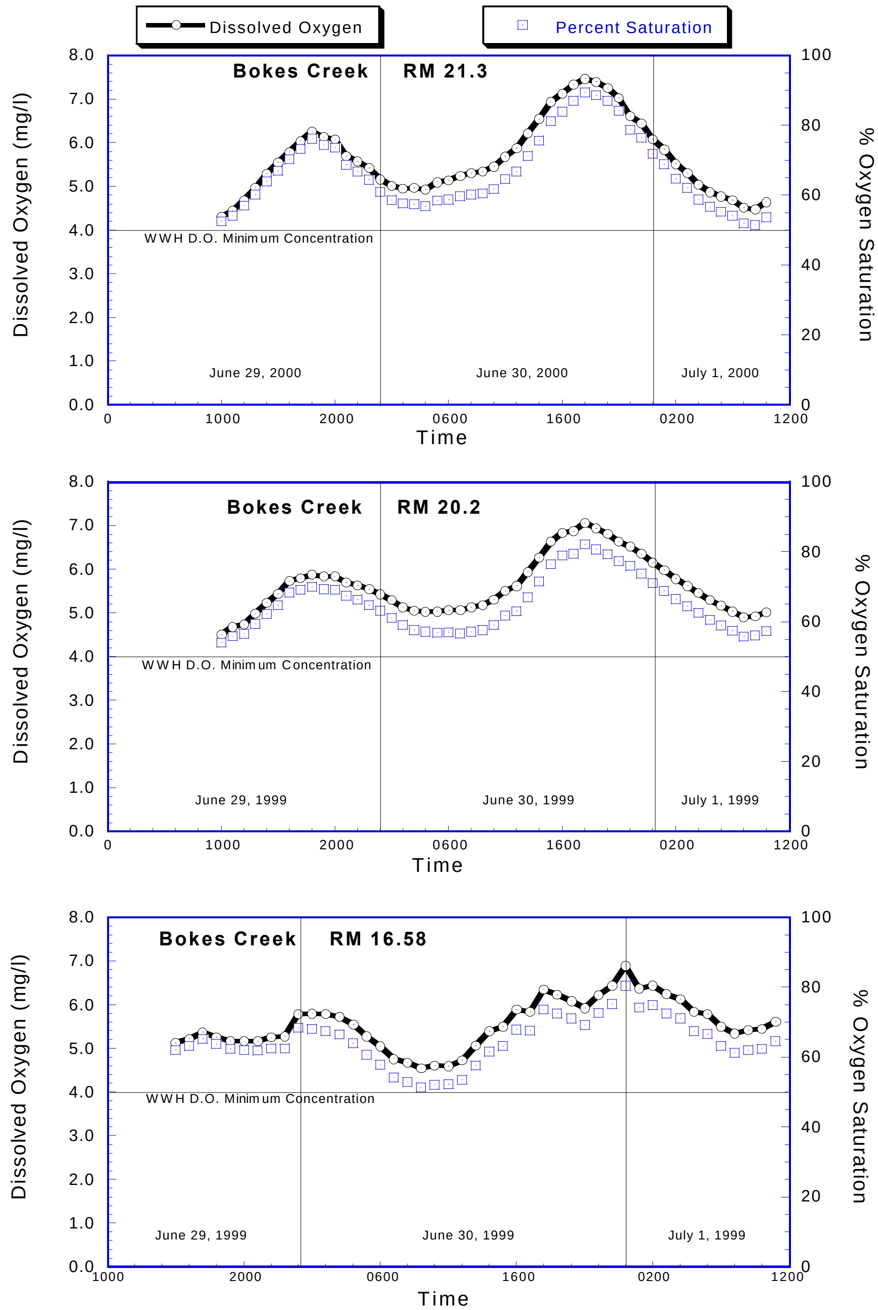


Figure 28. Diel D.O. concentration readings recorded over a 48-hr. period using continuous samplers in Bokes Creek mainstem at RMs 21.3, 20.2, and 16.58 from 29 June to 1 July, 1999.

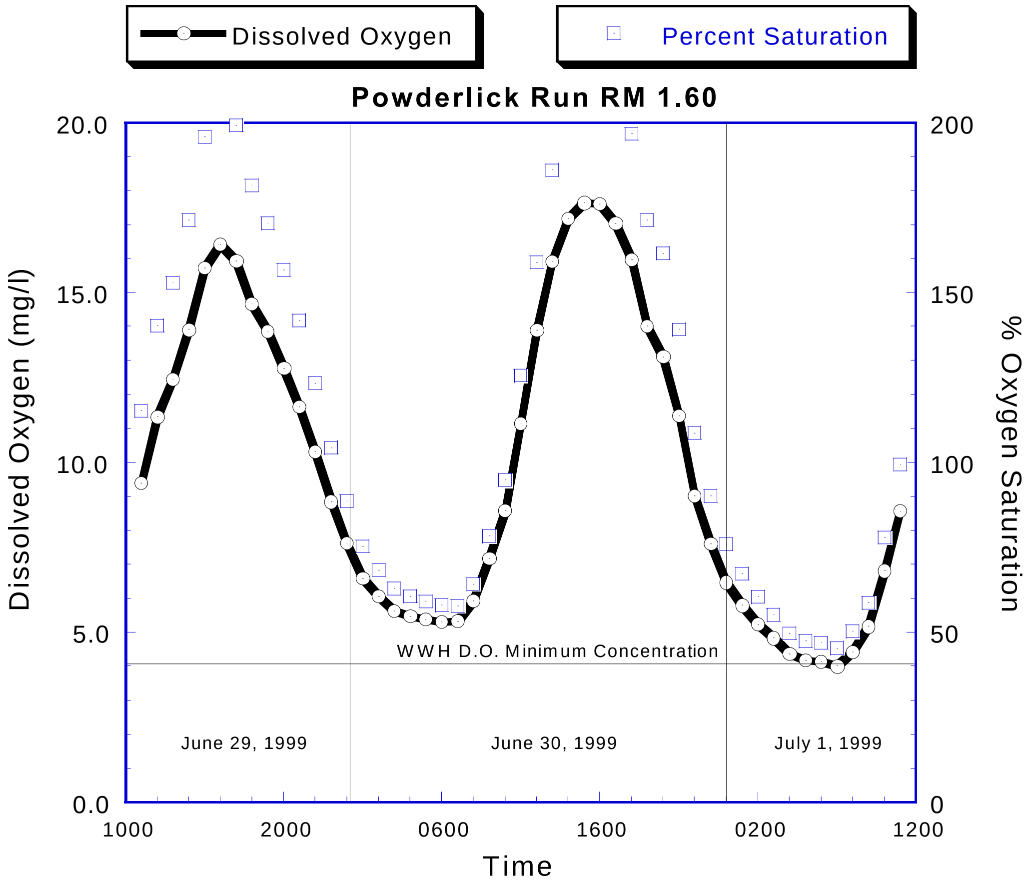


Figure 29. Diel dissolved oxygen concentration readings over 48-hr. period using continuous sampler in Powderlick Run at RM 1.60 from 29 June to 1 July, 1999.

North Fork West Mansfield Creek

Two stations on NFWMC were evaluated with Datasonde® units. The station at RM 3.97 exhibited abnormal diurnal dissolved oxygen fluctuations with high daytime D.O. spikes and were observed to fall to levels just below the minimum criterion of 4 mg/l on June 30, 1999. Supersaturated conditions noted during daylight hours increased to nearly 200% with D.O. values over 19.0 mg/l (most saturated conditions in survey) (Figure 30). Cold groundwater present likely precluded lower D.O.measurements than were recorded during this particular continuous monitoring event, given the excess organic nutrient enrichment and high BODs recorded (> 90th-95th percentile for ECBP headwater sites) (Table 14). Regardless, dissolved oxygen concentrations of < 1.0 to 1.5 mg/l were recorded at this location from water chemistry survey data (Table 13). The sampled station at RM 3.97 was downstream from agricultural fields that historically received organic fertilizer applications (manure) (OEPA, 1995b). Also, adjacent to the stream valley and upstream from this monitored station is the Heartland Egg facility (Weaver) (Logan Co. Rd. 26). As in Powderlick Run, excessive primary productivity and subsequent decay

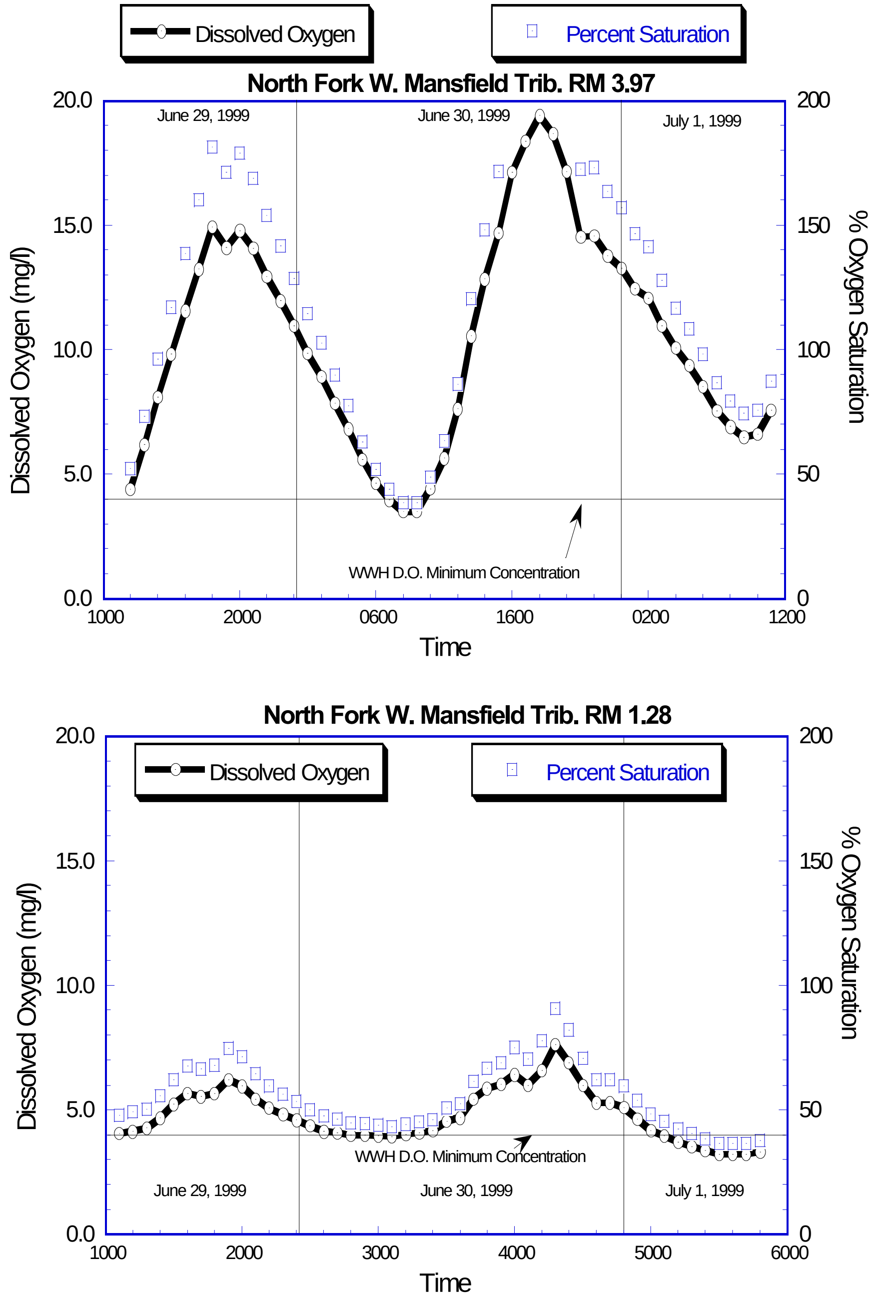


Figure 30. Diel dissolved oxygen concentration readings over 48-hr. period using continuous samplers in North Fork West Mansfield Trib. at RMs 3.97 and 1.28 from 29 June to 1 July, 1999.

due to severe nutrient enrichment and more open canopy (decreased shading) were the likely causes of the extreme swings in dissolved oxygen concentrations. An analogous, but more irregular diel D.O. curve was noted at RM 1.28 with more extensive violations of the WWH minimum dissolved oxygen criterion (Figure 30). Supersaturated conditions were not noted here. Likely that was primarily due to the unusually turbid conditions upstream and at this sample location. High total suspended solids were greater than the 75th-90th percentiles of ECBP headwater streams. Slight precipitation on 29 June, 1999, likely exacerbated those muddy conditions (Table 12). Additionally, there was a thin riparian canopy overstory that may have effectively diminished the D.O. spikes. Dissolved oxygen impairment at RM 1.28 was still related to excess nutrients (P, ammonia, and TKN), high BOD, and COD from accumulated organic matter upstream and from local algal production. Pooled conditions allowed for an organic sink effect.

West Fork West Mansfield Tributary

A single continuous sampler was placed at St. Rt. 47 (RM 0.78) in West Fork West Mansfield Tributary. Diel fluctuations in dissolved oxygen did not follow the usual pattern, but resembled a flattened line (Figure 31). Some violations of the WWH minimum D.O. criterion were noted on 29 June 1999. Dissolved oxygen saturation rarely exceeded 70 percent, although nutrient enrichment was evident from the chemical sampling (high P, NH_3, TKN). Very elevated demand parameters (COD & BOD), TSS, TDS, and conductivity concentrations from nutrient runoff, sedimentation, and varied upstream sources affected D.O. concentrations in the pooled reach upstream from St. Rt. 47. The comparatively larger overstory riparian canopy that was present muted D.O. spikes from excess algal production when the stream was not turbid. Turbidity appeared to restrict algal production. As such, slight rainfall on 29 June 1999 might have caused muddy conditions and thus limited algal production (Table 12). Pooled conditions with very slow flow allowed organic accumulation and decay, thus decreasing dissolved oxygen concentrations to below minimum threshold concentrations . This was confirmed with chemical water quality grab sampling (Figure 31, Table 13).

Smith Run

A single continuous sampler was placed in Smith Run at Brindle Road (RM 0.77). Dissolved oxygen concentrations showed a typical but somewhat irregular diel pattern. Dissolved oxygen concentrations were observed to fall well below the minimum WWH criterion of 4 mg/l (Fig. 31). Supersaturated conditions were not noted at this station; in fact, dissolved oxygen concentrations never became saturated during the monitoring period. A quality riparian buffer along this stream reach appeared to control D.O. spikes from primary production, and turbidity from upstream acted to shade the water column and thus, limited algal production to some extent. Similar to West Fork West Mansfield Tributary and the lower North Fork West Mansfield Tributary site at RM 1.28, the excess nutrients present, along with subsequent high demand parameters (COD, BOD) from

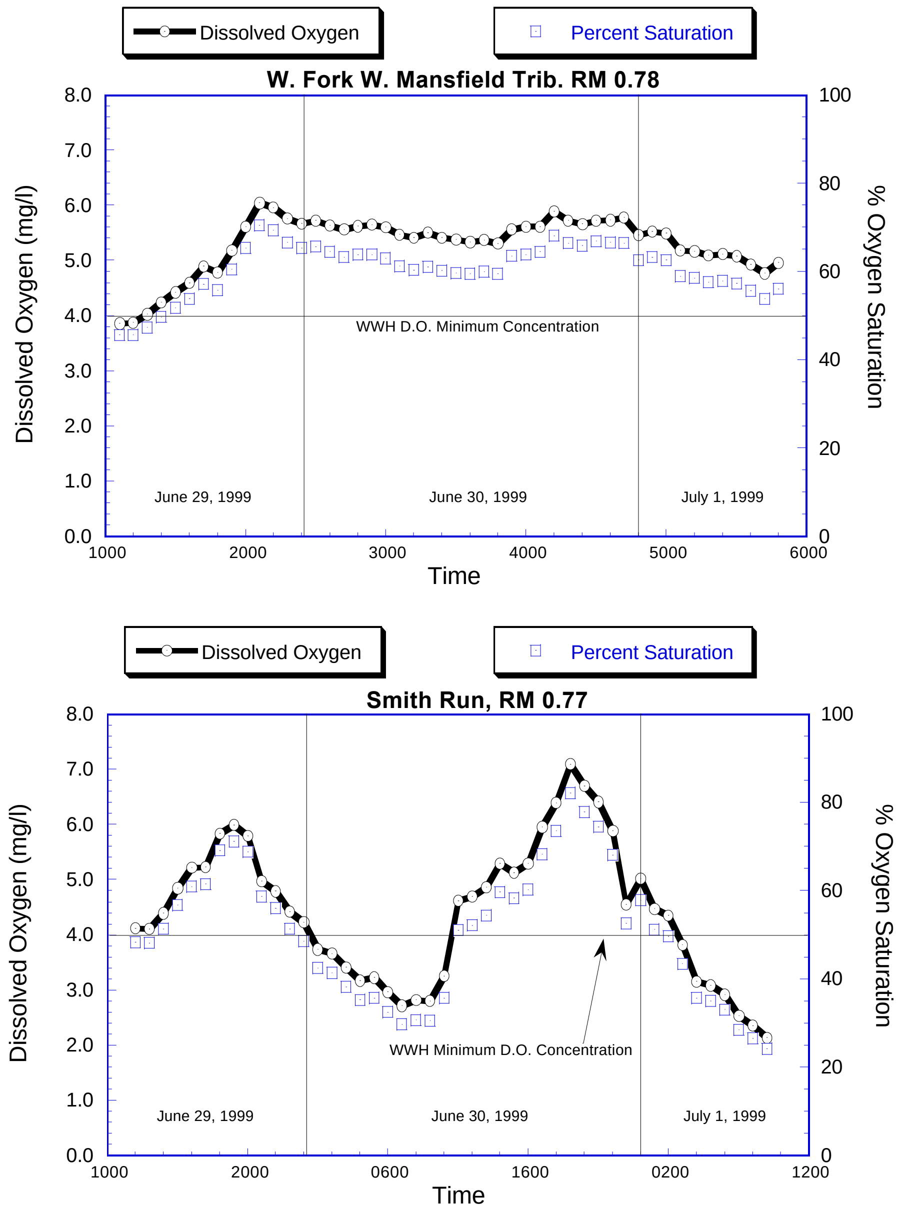


Figure 31. Diel dissolved oxygen concentration readings over 48-hr. period using continuous samplers in West Fork West Mansfield Trib. at RM 0.78 and in Smith Run at RM 0.77 from 29 June to 1 July, 1999.

organic accumulation, suspended and dissolved solids, conductivity and sedimentation from NPS runoff caused dissolved oxygen violations in the intermittent and/or interstitial pooled reach near the sampling station at Brindle Road. Drought induced low flow conditions exacerbated this situation during the 1999 survey at this location.

Chemical Sediment Quality

Sediment samples were obtained from 4 sites on Bokes Creek and 1 site on Powderlick Run. Samples were assessed for percent solids, pH, metals, total organic carbon, pesticides and polychlorinated biphenyls, base neutral and acid extractable compounds, and volatile organic compounds (Tables 15, 16). Samples were typically a composite of the channel cross section substrates. Sediment contamination was characterized with respect to appropriate literature (Kelly and Hite 1984, Persaud *et al.* 1994, MacDonald *et al*. 2000), and metal concentrations were compared with statewide Ohio EPA data (Appendix Table A-12).

The Kelly and Hite stream sediment classification system (Illinois EPA) ranks relative pollutant concentrations, from non-elevated to extremely elevated based on mean values, plus 1, 2, 4, and 8 standard deviations from 94 background sites; it does not directly assess toxicity. In *Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario*, Persaud *et al.* (1994) present a three tiered classification based on ecotoxic effects (No Effect Level, Low Effect Level (**LEL**), and Severe Effect Level (**SEL**)) determined from bioassay testing or predicted toxicity derived from benthic communities in different contaminant concentrations using field data. In *Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems*, a consensus-based Threshold Effect Concentration and Probable Effect Concentration (**TEC** and **PEC**, respectively) were compiled by MacDonald, *et al.* (2000) using the combined knowledge of most other developed threshold effect levels.

Virtually no Base Neutral and Acid Extractable organic compounds (BNAs) were detected in any samples except for one very low-level detection of a plasticizer (bis-2-ethyl-hexyl-phthalate) at RM 5.54 (Table 15). This was likely from some nearby septic or municipal source but was not a factor in Bokes Creek channel sediment quality.

Generally, contamination from metals in Bokes Creek was mostly at lower concentrations and tertiary as far as their priority in environmental concern. Although many different metals were detected in the various samples, most were found at non-elevated or slightly elevated concentrations of those parameters compared to guidelines (Table 16). All of the sampled sediment concentrations were *less than* the **SEL** or the **PEC** for each respective parameter. Aluminum, though, *was* collected at two sites with *elevated* concentrations and one at **highly elevated** concentrations (Table 16). The source of *elevated* sediment aluminum instream at Yearsley Rd. (RM 21.3) and at Brown Rd (RM 5.54) was sedimentation and/or agricultural NPS inputs. The Brown Rd site could have also been contaminated by municipal/septic inputs from Magnetic Springs and other sources just upstream, following a trend for generally increased sediment metals concentrations when compared to the upstream site (a municipal/human footprint). The likely sources for the one **highly elevated** sediment aluminum concentration at RM 20.2 in Bokes Creek was sedimentation inputs from Powderlick Run, but secondary sources may have originated from insecticides or fumigants in agricultural or animal production deposited via NPS runoff from Powderlick Run and adjacent fields.

Data collected indicated the sediments at RM 20.2 were more contaminated than the other sampled survey sites. In addition to the highly elevated aluminum, barium and chromium were also analyzed at *elevated* concentrations (Table 16). The only two sediment parameters collected that exceeded their respective Low Effect Level and/or the Threshold Effect Concentration were chromium and nickel sediment concentrations from RM 20.2 (Table 16). Furthermore, 75 percent of the sediment parameters measured at RM 20.2 in Bokes Creek increased in concentration when compared to upstream results from Powderlick Run at Yearsley Rd (RM 21.3). Finally, the highest measured sediment concentrations for ten of the eighteen scanned parameters were collected downstream from Powderlick Run at RM 20.2 in Bokes Creek (Table 16).

Powderlick Run nearer the mouth atYearsley Road, a lower gradient, short depositional reach at RM 0.3-0.2 (below where some private stream maintenance had occurred), would have better revealed the total sediment metal concentrations transported into Bokes Creek from Powderlick Run. It would have allowed for increased time/distance from source(s) for more complete chemical and colloidal deposition. Some of the sediment metal or other parameter concentrations were not as elevated in Powderlick Run at RM 1.0 compared to RM 21.3 in Bokes Creek (Table 16). However, chemical water quality data parallelled the empirical facts above and suggested that these inputs of metals also arose from the water column itself. This may be related to the water treatment discharge (since ceased) at Day Lay egg farm, and/or from organic NPS runoff from fertilizer-applied fields, and from sedimentation with deposition in lower Powderlick Run or in Bokes Creek downstream from the confluence (Figs. 11-16). Sediment metal concentrations could possibly have added to the biological impact noted at RM 20.2, but it would have been a smaller secondary stressor (see macroinvertebrate section, Figure 33).

Table 15. Results of chemical/physical sediment quality sampling for organic compounds conducted in the Bokes Creek study area during June-September, 1999. NA means not analyzed, **boldface** type indicates values greater than the severe effect level (Persaud and Jaagumagi, 1993) and italic type indicates values greater than the lowest effect level (Ibid, 1993). A blank space indicated that the substance was not detected in the sample.

Bokes Creek Study Area Sediments						
		Bokes Creek				**Powderlick Run**
Compound	Units	RM 21.3	RM 20.2	RM 16.58	RM 5.54	RM 1.0
Solids	%	55.9	53.4	72.4	36.4	51.2
Total Organic Carbon	%	*2.8*	*2.6*	*3.2*	*3.5*	*2.8*
BASE NEUTRAL AND ACID EXTRACTABLE COMPOUNDS (BNAs)						
Bis (2-ethyl hexyl) phthalate	mg/kg				2.8	

Table 16. Results of chemical/physical sediment quality sampling conducted in the Bokes Creek study area during June-September, 1999. Underlined values indicate concentrations below the method detection limits. *Italics* means no comparison guideline. Parameters noted with an [I] are compared with Illinois guidelines (Kelly and Hite, 1984). All other parameters are compared with Ohio EPA sediment reference guidelines. Descriptive guidelines are as follows: Not elevated, slightly elevated, **elevated**, ***highly elevated***, **extremely elevated**. Conc.> than the LEL or TEC was shown as *; >SEL/PEC=**.

Bokes Creek Study Area Sediments						
		Bokes Creek				Powderlick Run
Analyte	Units	RM 21.3	RM 20.2	RM 16.58	RM 5.54	RM 1.0
Solids	%	*63.6*	*57.8*	*58.7*	*58.9*	*53.2*
pH	S.U.	*7.65*	*7.63*	*7.04*	*7.05*	*7.73*
Aluminum	mg/kg	**21000**	***32200***	13200	**21500**	18900
Arsenic	mg/kg	6.34	6.25	6.88	7.04	6.83
Barium	mg/kg	108	**159**	59.3	108	91.5
Cadmium	mg/kg	0.309	0.385	0.214	0.309	0.263
Calcium	mg/kg	*56800*	*7260*	*35300*	*14200*	*32600*
Chromium	mg/kg	24.8	**35.7** *	18.9	25.3	18.8
Copper	mg/kg	14.3	18.4	7.57	13.6	11.3
Iron	mg/kg	15900	23100	13400	16500	14900
Lead	mg/kg	22.1	22.3	25.2	24.7	25.1
Magnesium	mg/kg	*11000*	*7260*	*17700*	*6790*	*6260*
Manganese	mg/kg	325	199	227	192	264
Nickel	mg/kg	22.1	28.5 *	25.2	24.7	25.1
Mercury[I]	mg/kg	0.0331	0.0399	0.0287	0.0352	0.0321
Potassium	mg/kg	*5520*	*7810*	*3150*	*5560*	*5010*
Selenium	mg/kg	*1.10*	*1.17*	*1.26*	*1.23*	*1.25*
Sodium	mg/kg	*2760*	*2790*	*3150*	*3090*	*3130*
Strontium	mg/kg	*325*	*197*	*103*	*204*	*648*
Zinc	mg/kg	63.4	103	51.1	68.5	67.7

Water Column Organics

Standard U.S.EPA methods were used to assess the concentrations of volatile and semi-volatile organic compounds. Fifty-nine volatile organic compounds were analyzed using U.S.EPA method 624. Fifty-three semivolatile organics were analyzed using U.S.EPA method 625. Seven polychlorinated biphenyls (PCBs) and 21 pesticides were analyzed using U.S.EPA method 608. The concentrations of various modern pesticides (atrazine, alachlor, cyanazine, glyphosate, and 2-4-D, amine or ester) were not assessed, because these compounds are not detected by method 608, though atrazine was tentatively identified (Table 17).

Several organic pesticides or herbicides were detected in the waters of Bokes Creek, Powderlick Run, and Smith Run (Table 17). *Heptachlor, aldrin, dieldrin, and 4-4' DDT all exceeded the respective numerical criterion for the prevention of chronic toxicity [Chronic Aquatic Concentration (**CAC**)](Table 17) and the Human Health water quality criteria for nondrinking water.* Heptachlor epoxide (a breakdown product of the pesticide heptachlor) and the herbicide atrazine were the most common substances detected. Both compounds strongly adsorb to suspended and bottom sediments. These persistant compounds would likely move downstream and accumulate in depositional areas (Howard *et al*, 1991). Heptachlor epoxide was found at all sites on Powderlick Run, all sites on Bokes Creek downstream from Powderlick Run, and in Smith Run (heptachlor also elevated there). The bioconcentration factor of heptachlor epoxide in the asiatic clam *Corbicula*,which were present in Bokes Creek basin and also were discovered as freshly dead shells at RM 20.2 in Bokes Creek, can be as high as 2330 (Howard *et al*, 1991). For perspective, all detected organic concentrations of heptachlor epoxide were well below a new CAC Outside Mixing Zone Average of 7.3 ug/l used in Michigan (personal communication, Chris Skalski, March, 2000).

Atrazine was found in ten of fourteen sample sites indicating the agricultural component in the basin. Although no chronic criteria guideline for atrazine was available, the lowest concentration to show chronic effects to aquatic biota was 20 ug/l (Eisler, 1989). All atrazine concentrations tentatively identified at sampled sites in Bokes Creek basin were 1.0 ug/l or less.

Aldrin is an insecticide formerly used against termites and soil pests that since has been banned from manufacture and currently prohibited from use in the United States. Aldrin was detected in Powderlick Run at RM 1.60 at a concentrations equal to the CAC of 0.010 ug/l and exceeded the Human Health criterion for nondrinking water (Table 17). This was surprising, since its half-life is 20-100 days in soil, at which point it degrades to dieldrin (Howard *et al*, 1991). The bioconcentration factor of aldrin in molluscs was also high at 4571 (Hawker and Connell, in Howard, 1991). It was also present at Brown Rd. in Bokes Creek (0.007 ug/l). The source(s) were unknown, but there was no aldrin or dieldrin detected at the downstream sites on Powderlick Run or Bokes Creek. These two detections likely indicated a more recent illegal use, spill, or release.

Dieldrin, an insecticide for corn and also used in termite control, was found to exceed the CAC for the prevention of chronic toxicity and exceeded the Human Health criterion for nondrinking water at three locations: RMs 35.12 and 5.54 in Bokes Creek and in the Smith Run sample (RM 0.77). Dieldrin is extremely persistent with a half-life of greater than seven years and is no longer registered as a general-use insecticide (Howard *et al*, 1991).The RM 35.12 site in the headwaters of Bokes Creek and the Smith Run sample (RM 0.77) were downstream from corn crop row agriculture and a section of woods. The water sample at RM 5.54 (Brown Rd.) was in a depositional area and downstream from municipal and agricultural sources.

There were only two sampled sites with at least two detected organic compounds with exceedences: RM 20.2 downstream from Powderlick Run in Bokes Creek and in Smith Run at RM 0.77 (Table 17). The data indicated that the source of the detected organic compounds in Bokes Creek at RM 20.2 seemed to be emanating from Powderlick Run (Table 17). Both the Smith Run and Powderlick Run samples (inputs to Bokes Cr. upstream from RM 20.2 site) contained a high of four different organic compounds. Both are intense agricultural subbasins with areas that receive large amounts of organic fertilization and have a large percentage of row crop agriculture, Thus, results seemed to coincide with landscape use. Any organic compound detected that exceeded the CAC could possibly have contributed to chronic effects to the biota at those locations (Table 17). The human health exceedences were based on a carcinogenic endpoint (see OEPA Water Quality Criteria).

Table 17. Results of organic chemical water quality sampling conducted in the Bokes Creek study area during August, 1999. **Bold** means value greater than or = CAC for Ohio River Basin Aquatic Life Water Quality Criteria and Human Health Water Quality Criteria for Nondrinking water. *Italicized* means no criteria guidelines.

Bokes Creek Watershed Water Column Organics

Compound (all units in mg/l)	Bokes Creek RM								NF WMT	WF WMT	SR	Powderlick Run	
	35.12	27.22	21.3	20.2	16.58	11.37	5.54	0.24	1.28	0.78	0.77	1.60	0.2
Aldrin							.007					**.010**	
Delta-BHC											.013	.014	
Gamma-BHC	.003							.011				.012	
4-4' DDT				**.007**									
Dieldrin	**.009**						**.008**				**.006**		
Heptachlor				**.004**							**.004**		
Heptachlor Epoxide				.004	.007	.006	.006	.006			.004	.006	.007
*Atrazine**			.300	.600	.500		.400	.500	1.000	1.000	.300		.500
Toluene	.56**												

NFWMT = North Fork West Mansfield Trib.
WFWMT = West Fork West Mansfield Trib.
SR = Smith Run
*tentalively identified compound
**No trip blank submitted with sample.

CACs: Aldrin = 0.010
Dieldrin = 0.005
Heptachlor = 0.001
4-4' DDT = 0.001

Physical Habitat for Aquatic Life

Bokes Creek

In 1999 the quality of the macrohabitats in Bokes Creek was evaluated at 10 fish sampling sites extending from a site at SR 292 (RM 36.3) downstream to a site near the confluence with the Scioto River (SR 37, RM 0.2). Good quality stream macrohabitats were present at locations downstream from Phelps Rd. (RM 27.0) while poor quality habitat was observed upstream (Table 19, see Appendix). QHEI scores in the lower reach ranged from 67.5 at SR 4 (RM 11.4) to 58.5 downstream from Powderlick Run (RM 20.2). The mean QHEI for the seven sites in this reach was 62.4. Generally, QHEI scores above 60 reflect habitat conditions which are able to support aquatic communities consistent with the WWH use designation. Scores of 75 and above are typical of very good to extraordinary macrohabitat conditions (Rankin 1989).

The three upstream sites averaged a poor QHEI score of 34.0. The most upstream location (RM 36.3, QHEI=12) existed as a mostly dry, straight, grass flanked ditch. The next two downstream locations were also limited by flow and the riffles at these sites lacked function. Furthermore, inadequately treated residential sewage was being discharged to Bokes Creek at these sites (RM 35.1 and RM 31.8). Substrates at all three upstream sites were limiting with extensive amounts of silt, little interstitial volume, and a general absence of gravel, cobble or larger aggregates.

Conditions improved at Phelps Rd. (RM 27.0). This site was downstream from the confluence with the West Mansfield Creek subbasin. Bokes Creek is noticeably larger here. Better substrate conditions, more functional cover, and improved morphological conditions resulted in a good QHEI score (63.0) at this site. However, flow continued to be an obvious limiting factor.

Rainfall in the Bokes watershed during the summer of 1999 was less than normal (Figure 3, Table 12). Groundwater contribution to the flow in the upper reaches of the Bokes basin was reduced and water current was slow or nearly imperceptible in the mainstem as the summer progressed. Bokes Creek is also a rather flat stream until it nears the Scioto River. The gradient in much of the Creek is three to four feet per mile. Where Bokes Creek meets the Scioto River it cuts through fissured bedrock limestone (RM 0.2). By late summer this lower site became completely dry as water flowed subsurface to the Scioto River.

Between the sites at RM 27.0 and RM 5.6, Bokes Creek exhibited a mix of typical ecoregional stream characteristics and traits more typical of wetland streams. Substrates through this reach consisted of a good mix of tills but were moderately embedded. A variety of cover types were available as all sites had deep pools, rootwads, and woody debris while patches of aquatic macrophytes were common. The frequency of riffles through this reach was fair to good but riffle function was impaired by lower substrate quality, reduced depth and limited flow. Likewise, runs were infrequent and lacked the definition necessary to produce strong current. This infusion of wetland qualities was expected to exert some negative influences on aquatic communities more adapted to typical stream functions.

The most downstream location on Bokes Creek (RM 0.2) was predominated by bedrock. Habitat at this site was limited by a lack of variety in available substrates, cover, and channel condition. Although some gravels and cobbles were present in this reach, their function was reduced. Similarly, the presence of other attributes which influenced a good QHEI score (63.0) also had diminished function. In any case, the absence of water at this site by late summer eliminated all functional aspects for supporting aquatic life.

Agricultural land use was the most prevalent land use in the watershed although areas adjacent to the stream were interspersed with rural residences and forested tracts. Riparian corridor tended to be narrow to moderate in width (5-50m). The amount of agricultural land use and the naturally low gradient of streams in the Bokes basin may be related to the lack of flow observed in 1999.

Information regarding the amount of tile drainage in an area is not readily available. However, it is not unreasonable to assert given the productive agricultural aspects of the watershed and the benefit derived from tile drainage especially in naturally poorly drained regions, that a large portion of the Bokes basin is artificially drained. As a result perennial flow in the watershed is affected and this influences the performance of aquatic communities.

In summary, macrohabitat conditions in Bokes Creek were adequate to support the WWH use designation. Efforts to enhance stream flow and to increase the width of the riparian corridor in the watershed are recommended as the most effective ways to improve macrohabitat conditions in Bokes Creek.

Smith Run

Habitat quality in Smith Run was considered good (QHEI =61.5) at the one fish sample station (RM 0.8). Limestone bedrock with a variety of other substrates and continuous flow provided suitable conditions for a WWH aquatic community at this location. The proximity to the Scioto River valley influenced this high gradient reach which was in a natural area with a wide riparian corridor.

Powderlick Run

The macrohabitats in Powderlick Run were evaluated at six fish sampling sites from near the streams origin to its confluence with Bokes Creek. The two most upstream sites (RM 4.8 and RM 3.7) were essentially dry in 1999. These sites were also assessed in 2000. Generally, Powderlick Run is regarded as an agricultural drainage although it does run through a few natural areas. Poor quality stream macrohabitats were typical (QHEI =37.7).

Throughout, Powderlick Run was extensively embedded and heavy patches of silt were common. Excepting the site at RM 1.8 where a moderate amount of cover was available, all other sites lacked important instream habitat elements such as deep pools, rootwads, boulders, etc. Additionally, except for the RM 1.8 site, the riffles in Powderlick Run had extremely limited functional influence due to embeddedness.

The RM 1.8 site was unusual because it was downstream from an unnamed tributary which was a source of perennial flow. This flow enhanced the function of riffles in the reach immediately downstream and provided adequate pool depth to facilitate a WWH aquatic community. Otherwise, as with Bokes Creek, flow in Powderlick Run was limited in 1999. The lack of sustained flow probably precluded achievement of WWH biocriteria in the upper reaches of Powderlick Run.

Unnamed Tributary to Powderlick Run at RM 2.0
A fair QHEI score (52) was recorded at a site on an unnamed tributary near the confluence with Powderlick Run. The sustained flow in this stream made it unusual in the Bokes watershed. The better flow resulted in less embeddedness and reduced silt deposition. The riffles exhibited functional qualities and pools retained adequate depth to support a WWH aquatic community. The water in this stream had an unusual reddish tannin color. Egg wash water effluent from Mad River Egg Farm was probably a significant percentage of the flow in this tributary.

West Fork West Mansfield Tributary
A poor QHEI score was determined at RM 1.0 at a single West Fork West Mansfield Tributary site. Intermittent flow, shallow pools, silty, sandy, pea gravel substrates and unfunctional riffles were considered likely to influence biological performance.

South Branch of the West Fork West Mansfield Tributary
The South Branch of the West Fork West Mansfield Tributary was evaluated for habitat quality in 2000 at RM 0.1 where a fair QHEI was determined. More groundwater recharge was evident here than at other area streams which resulted in slightly better QHEI attribute scores.

North Fork West Mansfield Tributary
Habitat quality in the North Fork West Mansfield Tributary improved from upstream channelized conditions to downstream where natural attributes were prevalent. At RM 5.6, a very poor QHEI score (15.0) reflected conditions which were not capable of supporting a WWH aquatic community. At RM 3.8, the stream passed through a cattle pasture where livestock had trampled the stream banks and denuded the riparian vegetation. A poor QHEI score (30.5) was recorded here. Both of these upstream locations lacked functional riffles, were intermittent, and had minimal instream cover. At RM 1.3, the stream remained intermittent but deeper pools and better substrate conditions resulted in a fair QHEI value (51.0).

Brush Run
Brush Run at RM 0.5 was completely dry in 1999. A fair QHEI score (49.0) at this site in 2000 resulted from the presence of flowing water within a second growth woodlot. Although riffle and substrate quality was limited, better morphological and riparian conditions improved the overall habitat assessment.

Biological Assessment: Macroinvertebrate Community

Bokes Creek mainstem, 1999

Ten Bokes Creek mainstem sites were sampled to assess the macroinvertebrate community quality. The macroinvertebrate survey sampling extended from the most upstream site at St. Rt. 292 (RM 36.3) downstream to St. Rt. 257 near the mouth (RM 0.2) or confluence with the Scioto River. Due to lack of flow, the upper two sampling sites on Bokes Creek (St. Rt. 292 and Logan Co. Rd. 120) were evaluated using macroinvertebrate sampling methods. Eight additional sites were originally set on 19-20 July, 1999 with multi-plate substrate samplers to collect quantitative samples. Due to drought conditions causing diminishing flows, depths, or dry conditions where samplers were set, only two of eight quantitative samples were successfully collected. Samplers were reset and checked several times during the colonization period to attempt to successfully collect all of the quantitative samplers but with low success. Qualitative macroinvertebrate samples were collected at each site.

The macroinvertebrate community in the Bokes Creek mainstem in 1999 was primarily fair to marginally good in quality (Figure 32). There was a maximum of 11 EPT taxa and 70 total taxa collected at an individual wading site of ~40 $mi.^2$ drainage (RM 21.2), while the lowest community totals of either one EPT taxon or 23 total taxa occurred at two respective headwater sites (<20 $mi.^2$) in the upper watershed (Table 18). The macroinvertebrate community was typically stressed by excess waste nutrients, enrichment-induced chronic low D.O. and/or periodic anoxia, and sedimentation. Nutrient enrichment, sedimentation and other chemical contaminant inputs resulted from a combination of direct (drainage tile, spills, individual sewage treatment or stormwater discharges, etc.) and diffuse (runoff from field application of manure or wastewater) sources. Though minimally attaining the WWH macroinvertebrate ecoregion criterion downstream from RM 23.5, the community quality was threatened and seemed quite susceptible to degradation. The poor to fair macroinvertebrate communities upstream in the smaller headwater areas had similar impact sources, though physical habitat detriments (e.g., loss of riparian habitat, sedimentation, substrate embeddedness) in those reaches aggravated the excess nutrient/low D.O. symptoms.

Bokes Creek at RM 36.3 was in the upper headwaters of the basin (Logan Co. Rd. 292) where the creek has been channelized through an agricultural field. Very little recovery has occurred. In spite of the cool groundwater sustaining the base stream flow, the macroinvertebrate community was adversely impacted by *toxic* ammonia-nitrogen(NH3) concentrations, excess nutrients (N, P); and extremely high BOD values and periodic low D.O. exceedences (Tables 13, 14). Silty conditions pervaded the reach, as only one *Stenacron* mayfly was collected. Predominant organisms were

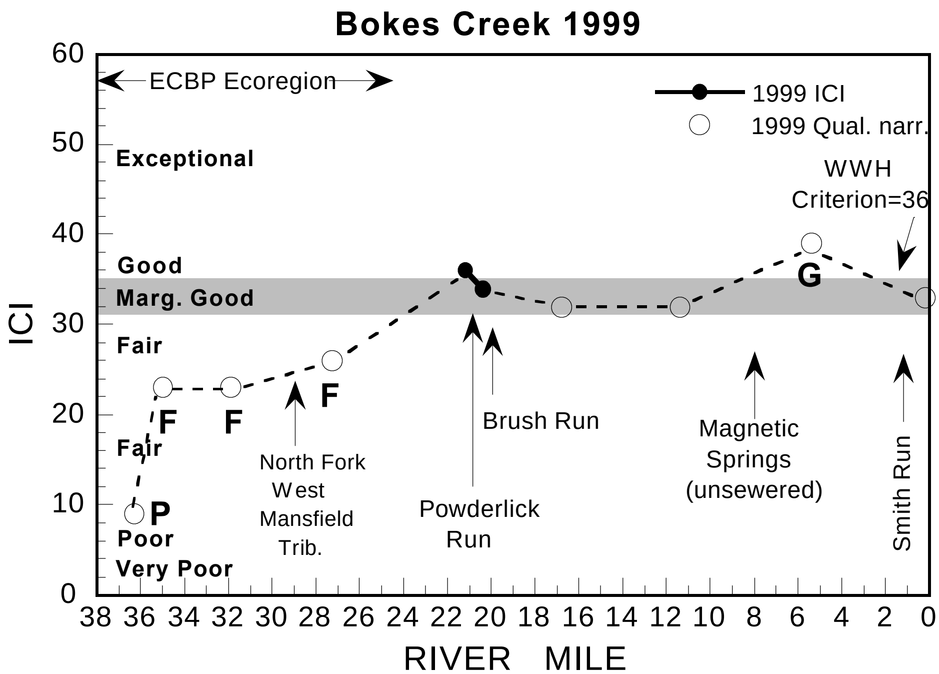


Figure 32. The longitudinal Invertebrate Community Index (ICI) and qualitative narrative assessments for Bokes Creek, June - October, 1999.

adversely impacted by *toxic* ammonia-nitrogen(NH3) concentrations, excess nutrients (N, P); and extremely high BOD values and periodic low D.O. exceedences (Tables 13, 14). Silty conditions pervaded the reach, as only one *Stenacron* mayfly was collected. Predominant organisms were fingernail clams, but most of the *Sphaerium* clams were dead. Other predominant organisms,such as the pond snail *Physella* and the midge genera *Chironomus* and *Tanypus*, indicated a poor quality macroinvertebrate community and were very tolerant or moderately tolerant of organic pollution and low dissolved oxygen concentrations.

Macroinvertebrate communities at the next two sites, Co. Rd. 120 at RM 35.0 and West Mansfield-Mt. Victory Rd. at RM 31.9, were assessed as fair quality despite some of the highest stream gradients (~6 to 10 ft./mile) in the mainstem. There were silty and embedded conditions at both sites with evidence of continued impact from excess runoff nutrients (NH_3, total N, P), high TSS, BOD, bacteria exceedences (*60,000*/100 ml), and low dissolved oxygen concentrations (as low as ***0.31*** mg/l) (Tables 13 and14). The drought flows in 1999 exacerbated conditions with extremely low flows or interstitial conditions likely diminished functions like reaeration and natural chemical assimilation. The macroinvertebrate community typified these repressed conditions as tolerant hemoglobin-rich red midges *Dicrotendipes simpsoni* and *Chironomus (C.) decorus group*, and the very tolerant midge *Goeldichironomus holoprasinus* were present or predominant. Facultative taxa, like the red midge genus *Stictochironomus*, fingernail clams, scuds, and damselflies, represented the other predominant taxa groups in these reaches dominated by slow runs or pools. Three moderately intolerant taxa collected (leptophlebiid mayflies and two cased caddisflies) did indicate potential for improvement despite less taxa collected downstream at RM 35.0 compared to RM 31.9.

Despite better habitat conditions (more rocky substrates and increased cover), the macroinvertebrate community did not improve. A fair macroinvertebrate community was present downstream near Phelps Rd. (RM 27.3). This reach was downstream from the confluence with North Fork West Mansfield Tributary that was infusing lower quality, *nutrient enriched* water into Bokes Creek (low D.O. exceedences, high TSS, and high BOD) (Tables 13 and 14, Figures 27 and 30). Fewer types of mayflies and caddisflies were collected compared to upstream with the lowest EPT (3) and QCTV totals (28.1) of all mainstem sites downstream from the modified segment in the upper headwaters (Table 18, Figure 33). Midges of the genus *Chironomus* and flatworms were among the predominant organisms indicative of lower quality conditions.

From upstream Yearsley Rd. (RM 21.2) to the mouth site at State Route 257 the macroinvertebrate community was marginally good to good quality and achieved the WWH macroinvertebrate biocriterion. The Yearsley Rd. site yielded the highest total taxa (70) and EPT taxa (11) in the survey (Figure 33). Even though downstream from Powderlick Run adjacent to SR 31 the macroinvertebrate community was marginally good (ICI of 34 - nonsignificant departure from the ecoregion biocriterion), there was a *significant 32 percent decrease in overall community diversity as well as a decrease by 45 percent in the total EPT taxa* (Table 18, Figure 33). The larger and more intact riparian corridor (20-30 feet) through this reach protected, softened and retarded adverse effects from large excess nutrient inputs, bacteria and low D.O.s from Powderlick Run (tree shading slowed primary production and flattened diel D.O. and temperature curves, etc.). There was a large silt/sand load in Bokes Creek below the confluence with Powderlick Run with some elevated sediment metals (Table 16). Some fresh dead fingernail clam shells were observed in the pools during sampling which were partially filled with silt/sand. The lower reach had been dredged with sediment piles along the stream banks immediately upstream from Yearsley Rd.

Table 18. Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) from sampled tributaries in the Bokes Creek basin, June - October, 1999. Aquatic life uses listed are those currently designated in the Ohio Water Quality Standards or proposed use changes.

Stream River Mile	Drainage Area (mi.^{2})	Rel. Density (#/ft.^{2})	No. Quant. Taxa	No. Qual. Taxa	Total No. Taxa	Qual. EPT[a]	Total EPT	Predominant Organisms	QCTV[b]	ICI	Narrative Evaluation[c]
Bokes Creek (Modified Warmwater Habitat) ECBP (recommended)											
36.3	4.2	Mod.-Low	--	25	25	1	1	22,27,26,13	23.1	P*	Poor[d]
Bokes Creek (WWH) ECBP											
35.0	6.0	Mod.-Low	--	45	45	5	5	18,24,26,21	29.5	F*	Fair
31.9	10.0	Mod.-Low	--	23	23	4	4	22,8,24,31	31.9	F*	Fair
27.3	31.0	Mod.-Low	--	31	31	3	3	27,29,4,36	28.1	F*	Fair
21.2	41.0	184	47	42	70	9	11	3,22,10,9,5	38.9	36	Good
20.4	45.0	102	29	37	47	5	6	3,9,22,10,6,5	39.1	34[ns]	Marginally Good
16.8	58.0	Mod.-Low	--	38	38	7	7	3,12,22,9,6,18	33.2	MG[ns]	Marginally Good
11.4	67.0	Mod.-Low	--	34	34	6	6	12,6,18,31,9,10	35.6	MG[ns]	Marginally Good
5.4	75.0	Moderate	--	45	45	8	8	3,22,6,12,10	33.2	G	Good
0.2	84.1	Moderate	--	37	37	8	8	18,12,6	35.0	MG[ns]	Marginally Good
Powderlick Run (Limited Resource Water) ECBP (recommended)											
4.8	0.6	Mod.-High	--	12	12	1	1	27, 38	16.0	VP*	Very Poor
3.7	1.4	Moderate	--	16	16	1	1	13,24,31	22.9	P	Poor
3.3	1.6	Moderate	--	15	15	1	1	38,40,13	16.1	VP*	Very Poor
Powderlick Run (WWH) ECBP											
2.1	2.2	Moderate	--	18	18	0	0	13,24	22.9	P*	Poor
1.6	3.0	3084	9	15	16	0	0	37,31,13,16,41	22.7	0*	Very Poor
1.2	3.2	832	17	22	25	1	1	13,37,18,31,27	24.4	4*	Very Poor
0.9	3.4	358	14	20	24	1	1	13,18,27,31,39	24.4	6*	Very Poor
North Fork West Mansfield Trib. (WWH) ECBP											
5.6	3.1	Low	--	9	9	1	1	26,20,21	36.9	P*	Poor
4.0	5.9	Low-High	--	26	26	2	2	21,26,19,18	26.7	P*	Poor
1.3	8.7	Mod.-High	--	29	29	3	3	6,18,26,31	31.9	F*	Fair
West Fork West Mansfield Trib. (WWH) ECBP											
0.8	5.0	Moderate	--	39	39	7	7	22,18,21,42,26	32.0	MG[ns]	Marginally Good
South Branch West Fork West Mansfield Trib. (WWH) ECBP											
0.1	2.8	Moderate	--	13	13	1	1	21,26	19.5	P*	Poor
Smith Run (WWH) ECBP											
0.8	5.6	Mod.-Low	--	19	19	4	4	22,31,6,25,23	31.9	F*	Fair

Ecoregion Biocriteria: Eastern Corn Belt Plains	INDEX	WWH	EWH	MWH [e]	LRW
	ICI	36	46	22	8

[a] EPT=total Ephemeroptera (mayflies), Plecoptera (stoneflies), & Trichoptera (caddisflies) taxa richness.
[b] Qualitative Community Tolerance Value (QCTV) is derived as the median of the tolerance values calculated for each qualitative taxon present (see discussion in Methods Section).
[c] Qualitative narrative evaluation is based on best professional judgment utilizing sample attributes such as taxa richness, EPT richness, and QCTV score and is used when quantitative data are not available to calculate anInvertebrate Community Index (ICI) score.
[d] Qualitative narrative assessment used in lieu of quantitative score due to lack of requisite current velocity and/or vandalism of artificial substrates.
[e] Modified Warmwater Habitat for channel modified areas.
* Significant departure from ecoregion biocriterion (>4 ICI units); poor and very poor results are underlined.
ns Nonsignificant departure from ecoregion biocriterion (≤4 ICI units).

Predominant organism code list

1 Isonychia mayflies	8 minnow mayflies	15 blackflies	22 fingernail clams	29 flatworms	36 Peltodytes beetles
2 Chimarra caddisflies	9 riffle beetles	16 aquatic worms	23 burrowing mayflies	30 tipulids	37 Berosus beetles
3 Hydropsyche caddis	10 river (RH) snails	17 Tricorythodes	24 various beetles	31 corixids	38 mosquito larvae
4 snail-cased caddisfly	11 cased caddis	18 red midges	25 isopods	32 dragonflies	39 Ceratopogonids
5 Tanytarsini midges	12 water pennies	19 bryozoans	26 scuds	33 leeches	40 Psectrotanypus
6 flathead mayflies	13 L-Hand snails	20 Caenus	27 midges	34 Argia	41 Ephydrids
7 nonred midges	14 moth larvae	21 damselflies	28 crayfish	35 limpets	42 Dubiraphia

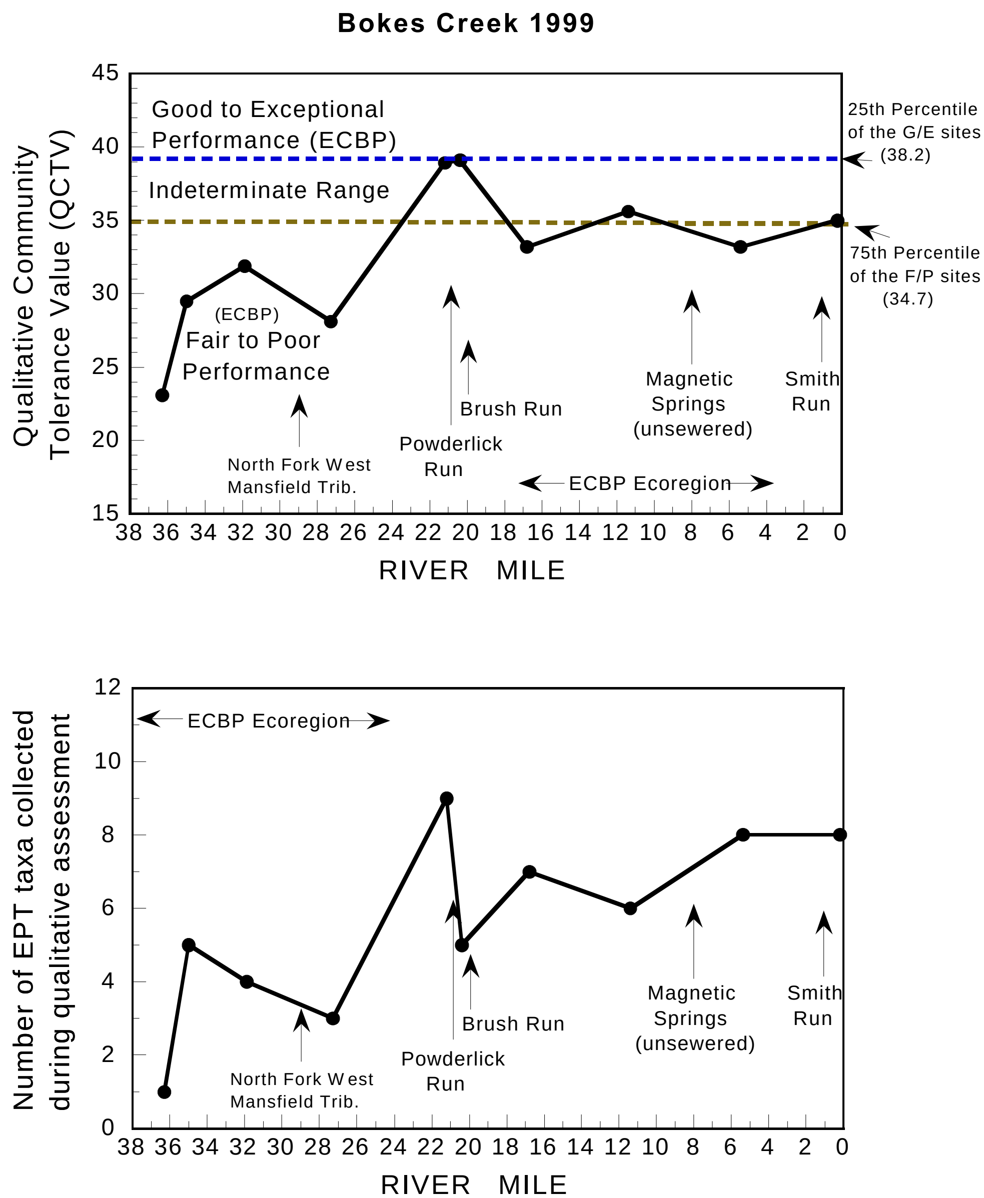


Figure 33. The Qualitative Community Tolerance Values and total number of EPT taxa collected from Bokes Creek, June - October, 1999.

The nutrient enrichment response was exacerbated through the middle and lower reaches, as primary production increased with more sun exposure (thinning of or breaks in the riparian buffer corridor). Diel D.O. curves were more acute with more supersaturated conditions and low D.O. exceedences at night. Other possible sources were cattle encroachment and septic discharges from unsewered communities including Magnetic Springs. Bokes Creek community diversity and quality decreased at RM 0.2 downstream from the Smith Run confluence (RM 1.21) compared to the upstream site at RM 5.4 (Table 18). This could be linked to the less optimal or diverse habitat (an increase in bedrock substrates closer to the mouth) and lack of surface flow, or partially the influence of the Smith Run subbasin nutrient loads and impacts, or both. Data comparison indicated cause to be nutrient impacts magnified by drought conditions. The chronic nature of the water quality conditions in Bokes Creek precluded complete recovery of the macroinvertebrate community to a quality equal to that observed at Yearsley Rd. or to what would be expected at a drainage of ~85 square miles in the ECBP ecoregion (Figure 33). To summarize, Bokes Creek is capable of attaining the WWH biocriterion for macroinvertebrates. Nutrient enrichment (with the subsequent disruption of adequate dissolved oxygen instream), sedimentation (resulting from erosion due to poor farming practices and riparian forest removal), habitat destruction (due to channelization, dredging, and riparian forest removal) and bacterial contamination (due to improper treatment and disposal of human and animal wastes) will prevent the recovery of this stream until measures are taken to mitigate these problems.

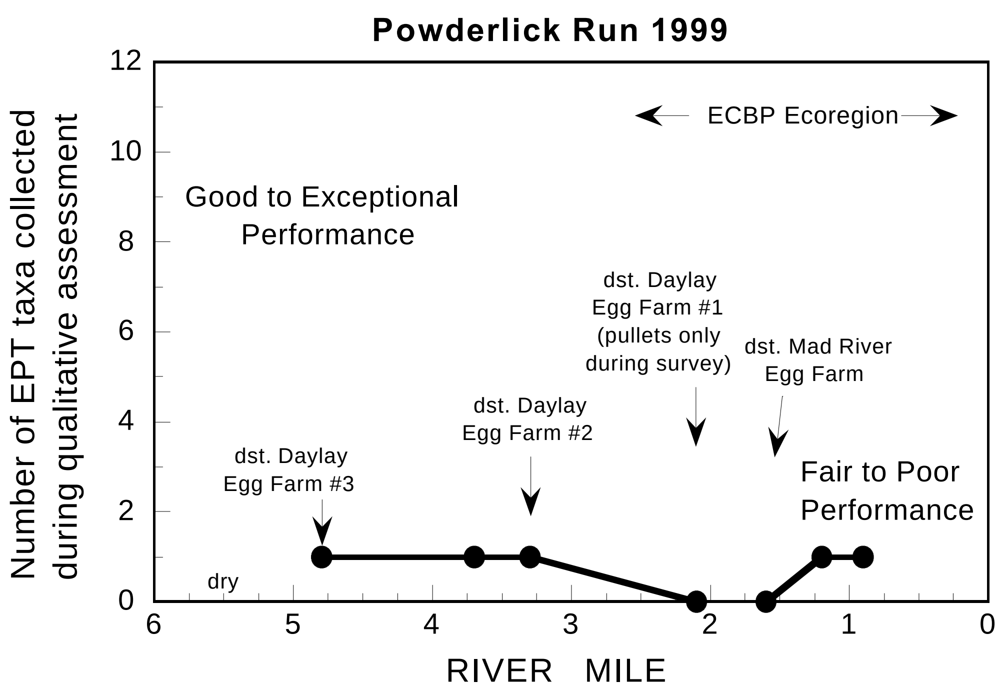


Figure 34. Number of EPT taxa collected during qualitative assessment, June - October, 1999.

Powderlick Run

The macroinvertebrate community was severely impacted throughout the length of Powderlick Run showing either *poor* or *very poor* quality performance. Eight of the ten predominant organisms present were tolerant, including the very tolerant midges *Psectrotanypus dyari* and *Goeldichironomus holoprasinus*, the tolerant snail genus *Physella*, aquatic worms, and the mosquito genus *Culex*. The only mayfly collected was the genus *Callibaetis* which tends toward being tolerant of nutrient degraded conditions (Figures 34 and 35). Downstream from the Mad River Egg Farm where egg wash water spills (and a related fish kill) had occurred, the ICI scored a **zero** with *97 percent* of the sample being aquatic worms. All three sites downstream from the Mad River Egg Farm showed no recovery from very poor conditions and scored ICI values of **0**, **4**, and **6** at RMs 1.6, 1.2, and 0.9, respectively (Figures 34 and 35). The poor or very poor conditions paralleled excessive or *toxic* nutrient loads (NH_3, TDS, N, and P) (Table 14). Listed exceedences for TDS, *E. coli* and fecal coliform bacteria, D.O. (lethal concentations of **0**-2ppm after daytime supersaturation), and some organic herbicides/pesticides present indicated other causative endpoints (Table 13, Figure 29). In conclusion, excessive nutrient loadings, some of which caused toxicity (egg wash water spill), degraded the macroinvertebrate community in Powderlick Run. Habitat destruction via siltation and riparian removal contributed to the poor condition of the invertebrate community. Stream dredging in the lower reach upstream from Yearsley Rd. caused delivery of sediment/silt load to Bokes Creek below the confluence.

North Fork West Mansfield Tributary

The macroinvertebrate stream community exhibited poor to fair performance due to past channelization, excessive nutrient enrichment, and limited riparian buffer in North Fork West Mansfield Tributary (Table 18, Figure 35). Overall, nutrient load runoff (NH_3, P, and total N) from chicken manure land applications adjacent to open, unshaded stream reaches caused excessive diel D.O. swings, and associated exceedences from low night time D.O.s (< 1ppm) and high *E. coli* and fecal coliform bacteria concentrations impacted the aquatic macroinvertebrate community (Tables 13 and 14, Figure 30). No midges were collected at the upstream site (RM 5.6), as anoxic and embedded sediment conditions were present. Tolerant midges of the genus *Chironomus*, along with scuds and damselflies at the most upstream site, were predominant at RM 4.0 (Table 18). No caddisflies were collected at time of sampling, although the presence of empty cases suggested a viable population may have been present during earlier summer; a hatch was likely triggered by stresses from low flow conditions.

Some habitat improvement was evident downstream which resulted in a slight improvement to a fair macroinvertebrate community present at RM 1.3 (Table 18). *Stenonema* mayflies were one of the predominant organisms at RM 1.3, but the total EPT diversity (3) was still low (Figure 35). Again, the effects from nutrient enrichment continued to preclude attainment of the WWH criterion. Moreover, fair community quality conditions continued in Bokes Creek at RM 27.2 below the confluence with North Fork West Mansfield Tributary as a consequence of the problems noted in this tributary.

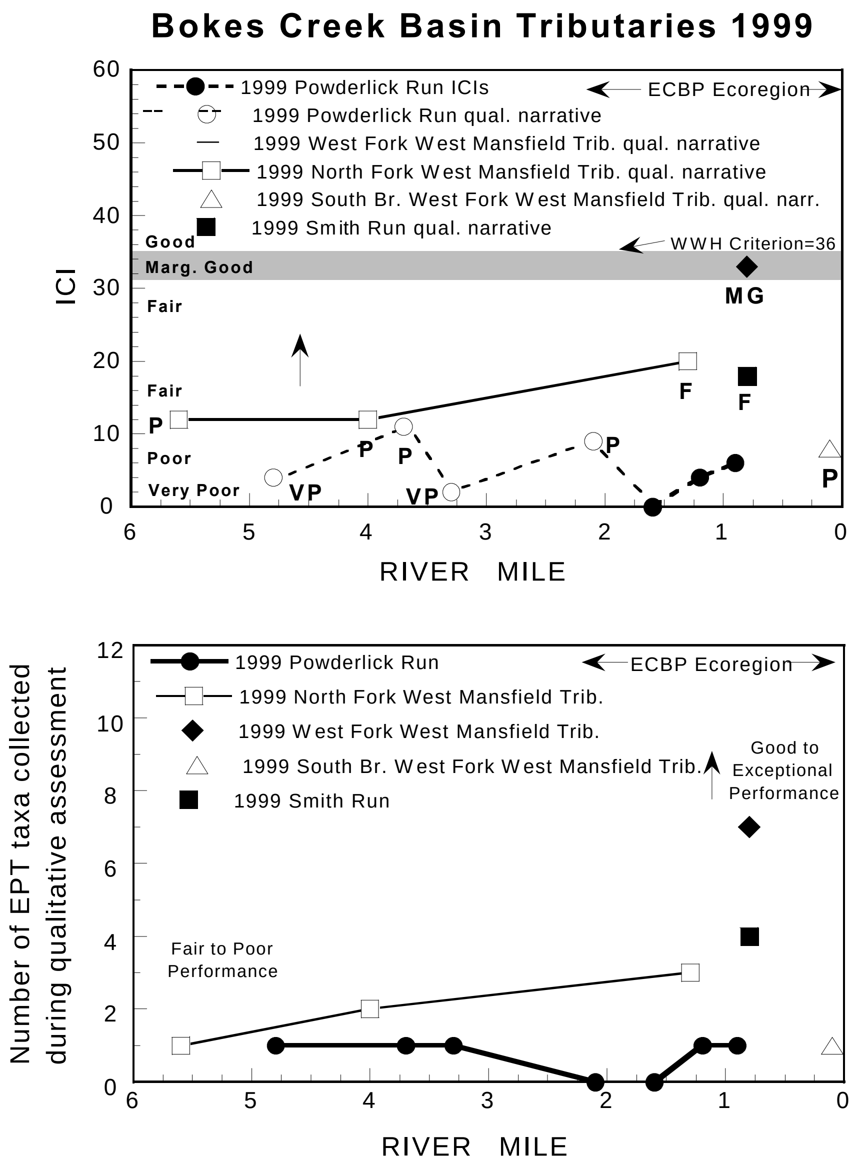


Figure 35. Invertebrate Community Index (ICI) scores and EPT taxa diversity collected from Bokes Creek basin tributaries, June-October, 1999.

West Fork West Mansfield Tributary

There was a marginally good macroinvertebrate community present at RM 0.8, in spite of low flows and only pooled or margin habitat available. Periods of low dissolved oxygen concentrations instream also limited the invertebrate community somewhat. However, a more complete woody riparian buffer with adjacent closed pasture land were positive benefits to stream quality and softened other negative inputs. A total of seven different taxa of mayflies and caddisflies were collected, including the moderately intolerant baetid mayfly genera *Procloeon* and *Centroptilum* and the cased caddisfly genera *Oecetis* and the intolerant *Mystacides* (Figure 35). Midges of the genus *Tanytarsus* were also present indicating better water quality conditions. There was still a considerable amount of sediment/silt present negatively affecting habitat quality. Fingernail clams and an average midge community of mostly facultative taxa were predominant in pool habitats. Flathead mayflies, scuds, pond snails, and flatworms were common in sampled pools or margins (Table 18). West Fork West Mansfield Tributary supported a better quality macroinvertebrate community than any tributary sampled in the Bokes Creek basin. The tolerant organisms present were probably influenced by excess nutrients (P, N, and NH_3) and TSS from West Mansfield WWTP land-applied waste and other sources (e.g., South Branch West Fork West Mansfield Trib.). Overall West Fork West Mansfield Tributary water quality helps moderate North Fork West Mansfield Tributary water quality (confluence at RM 0.75) .

South Branch West Fork West Mansfield Tributary

This small headwater stream had been channelized historically. The natural channel attributes were substantially recovered toward the mouth. Intact wooded riparian areas and higher stream gradient allowed for this recovery. The West Mansfield WWTP spray fields were within this drainage. and was substantially recovered near the mouth. The macroinvertebrate community present was negatively impacted by nutrient inputs from WWTP application runoff and sedimentation embedding some of the rocky substrates. Only one mayfly taxon, the more tolerant genus *Callibaetis*, was collected at RM 0.1. In addition, a low number of total taxa (13) was collected (Table 18, Figure 35). The poor quality macroinvertebrate performance was exemplified by the lowest QCTV value (19.5) calculated in the entire survey (Table 18).

Smith Run

A fair quality macroinvertebrate community was present at the Brindle Rd. sampling site (RM 0.8). Nutrient enrichment from upstream manure field application runoff, fecal bacteria, low diel D.O.s, and very embedded conditions suppressed the presence of more mayflies (e.g., baetids) or caddisflies (Tables 13 and 14). Only four types of mayflies were collected, and no caddisflies were observed during sampling (Figure 35). Predominant organisms ranged from fingernail clams (most predominant) to corixids, aquatic isopods, and flathead and burrowing mayflies (Table 18). The community was of mixed quality, but the continued presence of the mayfly genera *Hexagenia* and *Stenonema* and some Tanytarsini midges indicated the potential for a higher quality community that would meet or exceed the WWH criterion. This condition could also have been an indication of pulsed impacts, particularly since intermittent conditions were prevalent at time of sampling. The lower stream reach benefitted from a more intact but narrow riparian area which buffered the agricultural impacts prevalent in the entire basin, but the presence of five herbicide/pesticides in organic sampling indicated the persistent and chronic agricultural inputs (Table 17). Smith Run inputs into lower Bokes Creek seemed to contribute to lower macroinvertebrate community diversity and quality downstream (see Bokes Creek section). A decrease in sediment runoff, fine silt deposition and upstream nutrient inputs would allow for an improvement in diversity and quality of the aquatic invertebrate community in Smith Run.

Biological Assessment: Fish Community

Bokes Creek

Thirty seven species and one hybrid type of fish (3864 individuals) were collected in Bokes Creek in 1999. Sampling occurred once at the three most upstream sites (RM 36.3, RM 35.1 and RM 31.8) and at two downstream locations (RM 11.4 and RM 0.2). Two sample passes were completed at five sites between RM 27.0 and RM 5.6. Overall, the fish assemblage in Bokes Creek was fair (Table 19). This characterization was based on fish community indices which ranged from good-marginally good (IBI=40, MIwb=8.1 at RM 21.3) to poor (IBI=26 at RM 36.3). Including all sites, the mean IBI was 33.4. The mean MIwb was 7.0 (Figure 36).

Ecoregional expectations for the WWH use designation were only met at one study site (RM 21.3). At all other locations, the fish community failed to meet either the IBI or MIwb nonsignificant WWH departure criterion (36 and 7.8, respectively). The factors which influenced this performance were primarily related to habitat quality.

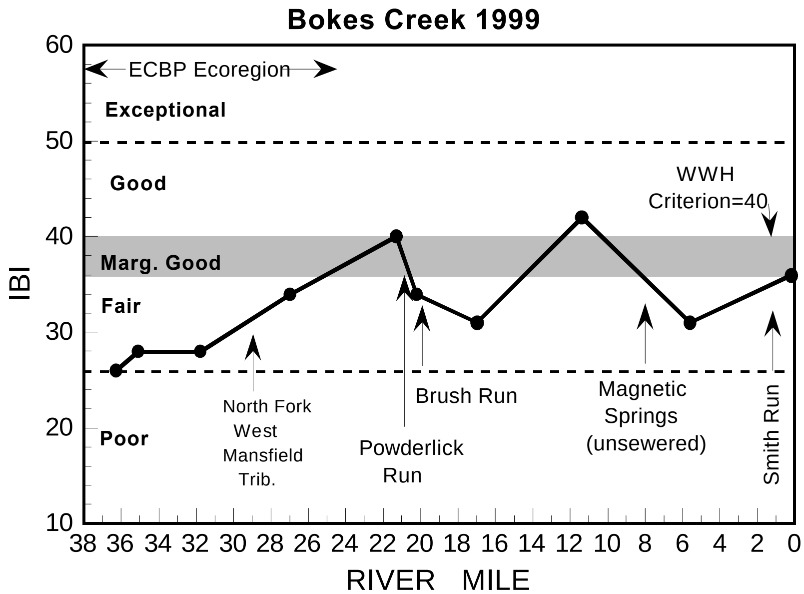
Although the habitat conditions in Bokes Creek were generally good (QHEI=62.4), the influence of wetland attributes was apparent in the fish community. Grass pickerel, a common wetland inhabitant, was collected at every site except the most downstream location where the stream became dry by the end of the summer. Golden shiners, white suckers, and creek chubsuckers were also frequently collected. All of these fish are found in streams with aquatic vegetation and lower gradients. Longear sunfish were particularly abundant (11.1% of the total catch; third most numerous species). Likewise, longear sunfish prefer low gradient pools with adjacent vegetated areas (Trautman 1981).

Conversely, some species of fish which are typical in other local streams were only present in limited abundance. Only one northern hogsucker and twelve golden redhorse were collected in the aggregate of all samples. Smallmouth bass were also infrequent (28 in the total collection). These fish prefer streams which offer areas of swift flow and are generally intolerant of low dissolved oxygen concentrations and other aspects of reduced water quality.

Although the fish community in Bokes Creek may naturally be precluded from achieving high biotic index scores it appeared that factors beyond habitat limitations also influenced community performance. At RM 17.0 sampling in July determined the fish assemblage was performing poorly (IBI=26, MIwb=4.6). The number of species and the number of fish in the sample were

Table 19. Fish community indices based on pulsed D.C. electrofishing samples collected by Ohio EPA within the Bokes Creek study area 1981-2000. Biocriteria and narrative ranges are in Table 2.

Stream River Mile	Mean Number Species	Cumulative Species	Mean Rel. No. (No./0.3Km)	Mean Rel. Wt. (Wt./0.3Km)	QHEI	Mean MIwb	Mean IBI	Narrative Evaluation
Bokes Creek 1999								
Eastern Corn Belt Plains (ECBP) - WWH Use Designation (existing)								
36.3	9.0	9	114	--	12.0	NA	26*	Poor
35.1	11.0	11	1108	--	42.5	NA	28*	Fair
31.8	14.0	14	318	--	47.5	NA	28*	Fair
27.0	21.0	24	1030	25.6	63.0	8.6	34*	Good-Fair
21.3	22.5	26	518	12.5	62.5	8.1$_{ns}$	40	MG-Good
20.2	17.5	21	316	10.2	58.5	7.2*	34*	Fair
17.0	14.5	20	159	14.2	59.5	5.7*	31*	Poor-Fair
11.4	14.0	14	300	2.0	67.5	7.2*	42	Fair-Good
5.6	16.0	18	248	9.1	63.0	5.9*	31*	Fair
0.2	10.0	10	455	1.0	63.0	6.5*	36$_{ns}$	Fair-MG
Bokes Creek 1993								
27.2	20.5	23	1844	11.9	56.0	8.5	40	Good
21.4	20.0	23	407	9.2	44.0	6.7*	34*	Fair
20.2	13.5	19	157	3.5	63.5	5.7*	26*	Poor
14.8	13.0	15	622	3.0	72.0	6.2*	31*	Fair
5.6	22.5	28	451	10.4	64.0	7.4*	34*	Fair
0.3	19.5	23	795	2.7	68.0	7.3*	41	Fair-Good
Bokes Creek 1992								
27.5	15.0	19	561	3.1	43.5	6.3*	32*	Fair
21.3	15.5	18	443	2.9	59.0	6.2*	30*	Fair
20.2	12.5	16	252	3.5	45.0	5.2*	29*	Poor-Fair
14.8	15.5	19	862	5.6	78.0	7.6*	37$_{ns}$	Fair-MG
5.5	17.5	22	357	4.9	68.0	6.5*	37$_{ns}$	Fair-MG
0.3	23.5	29	1166	7.3	81.5	9.1	49	Very Good
Bokes Creek 1990								
27.2	18.0	18	901	8.0	61.0	7.5*	28*	Fair
21.3	14.0	14	274	3.8	58.5	6.6*	34*	Fair
13.2	15.0	15	334	3.9	82.5	6.3*	32*	Fair
5.6	19.0	19	356	9.3	65.5	5.6*	36$_{ns}$	Poor-MG
Bokes Creek 1981								
30.6	8.5	11	228	--	--	--	26*	Poor
28.4	4.5	5	66	--	--	--	19*	Poor
26.1	10.0	16	82	--	--	--	23*	Poor



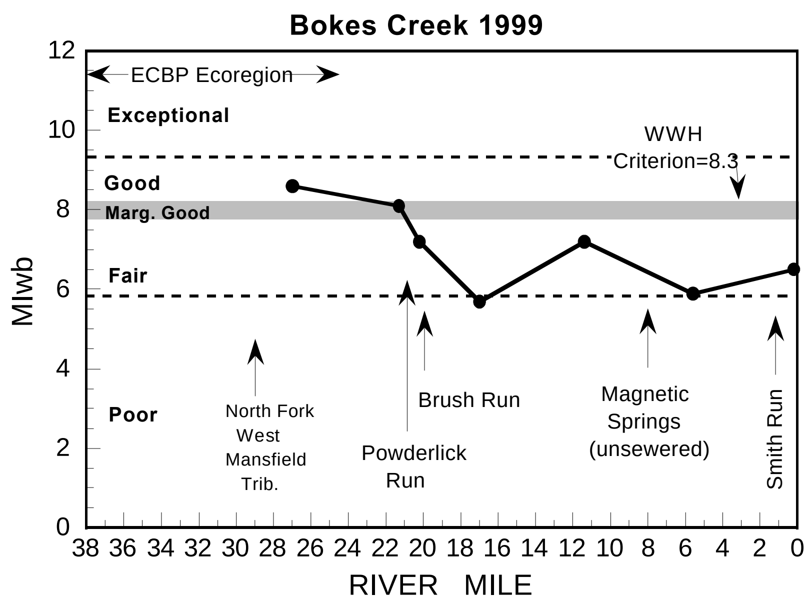


Figure 36. Index of Biotic Integrity (IBI) and Modified Index of Well-being (Miwb) for Bokes Creek survey, June-October, 1999.

both lower than all other Bokes Creek samples. Some recovery was suggested two months later when marginally good-fair results were recorded (IBI=36, MIwb=6.7). This type of response is consistent with the improvement encountered after a release of a toxic substance upstream.

The fish community in Bokes Creek was predominated by fish which are tolerant of pollution. Species richness was modest. Only the site (RM 21.3) which achieved the biocriterion had more than twenty species. Sunfish and sucker species were also modestly represented. However, the number of darter species was inconsistent with this pattern. Many sites had as many as five darter species in the sample.

Wetland streams fit this pattern of modest representation and pollution tolerance. The contrasting presence of so many darters indicates that Bokes Creek has riffle habitat which wetland streams usually lack. That noted, the quality of the riffles and more generally the quality of the substrates in Bokes Creek were likely impaired.

Simple lithophilic fish prefer clean silt free, unembedded substrates. These fish include various darters, minnows, and suckers which broadcast their eggs over the stream bottom. The eggs subsequently hatch within the interstitial voids. Lithophils only comprised a modest to low proportion of the Bokes Creek fish assemblage. Insectivorous fish were also modestly represented. The interstitial voids are an important source for the insect forage base. Since both lithophils and insectivores were consistently reduced but darter species numbers were good, substrate conditions were inferred to be marginal or fair.

In summary, the Bokes Creek fish community reflected wetland conditions which naturally do not score well on Ohio's biotic indices. That acknowledged, the fish community indicated some environmental perturbation occurred at RM 17.0. The fish assemblage also reflected degraded substrate quality. Bokes Creek appeared to lack the flow dynamics to transport smothering sediments. Efforts to improve flow conditions and reduce the sediment load are encouraged. Further investigation is recommended to determine the source of degradation documented at RM 17.0. Although Bokes Creek may naturally be limited by wetland qualities, the fish community should still be capable of achieving the WWH aquatic life use expectation.

Smith Run

Despite good habitat attributes (QHEI=61.5) a poor IBI score (20) was detected at RM 0.8. This location had a drainage area of 41mi^2 but harbored a relatively moderate number of species (12) and individuals (289). Other metrics scored low as the assemblage was predominated by bluntnose minnow (29 %), stoneroller minnow (21 %), and creek chub (15 %). These fish were at odds with the size of stream where a more diverse population was expected. These fish were tolerant as well and also suggest nutrient enrichment effects.

Powderlick Run

The fish community in Powderlick Run was evaluated based on one sample at four locations in 1999 and from two additional samples at two upstream locations in 2000. Poor or very poor performance was observed at all stations. The most significant difference between any of the Powderlick Run sites was that acute toxicity was documented downstream from an unnamed tributary which flows into Powderlick Run at RM 2.0.

Upstream from the unnamed tributary (RM 2.1) a poor IBI score (24) was consistent with the results from other upstream sites. Five species inhabited this flow limited location. Downstream from the unnamed tributary, flow was noticeably improved. Despite increased flow and better habitat conditions (RM 2.1, QHEI = 45.0 vs. RM 1.8, QHEI = 60.5), no fish were collected at the downstream location (IBI=12). The complete absence of fish in this reach indicated the water in the unnamed tributary was toxic to aquatic life. Very limited recovery was noted at RM 1.0 where 12 fish (three species) were collected.

Unnamed Tributary to Powderlick Run at RM 2.0
Acutely toxic conditions were present in the Unnamed Tributary to Powderlick Run at RM 2.0. No fish were present (IBI=12) in the one sample collected near the confluence with Powderlick Run.

West Fork West Mansfield Tributary
A poor fish assemblage (IBI=26) inhabited the West Fork West Mansfield Tributary at RM 1.0. Although a high number of fish species (12) including six minnow types inhabited the site, the community was predominated by pollution tolerant fish (87%) and ninety percent of the population was comprised by pioneering fish. Flow limitations were considered most culpable for the poor performance.

North Fork West Mansfield Tributary
The North Fork West Mansfield Tributary was assessed at three locations in one sample pass. The most upstream location (RM 5.6) was unsuitable for a fish assemblage as it was essentially dry although a total of three yellow and/or black bullhead catfish were collected in this reach (IBI=12). Seven species (57 individuals) inhabited the RM 3.8 site where a fair IBI (30) was achieved. Most of the fish (49%) here were blackstripe topminnows. The unique combination of the fish at this site influenced the IBI score more favorably than habitat quality would have suggested (QHEI=30.5). A fair assessment (IBI=32) was also computed at the most downstream location (RM 1.3). The fifteen species (192 individuals) at this location were consistent with expectations based on habitat quality (51.0).

Brush Run
Brush Run was sampled in 2000 at RM 0.5. This location was dry in 1999. A poor IBI score (24) was calculated based on five species (49 individuals). The proximity of Bokes Creek influenced the ability of these fish to reinvade the location following a drought period.

TREND ASSESSMENT

Chemical Water Quality Trend Assessment: 1981-1999

Historical water column chemistry data from the Bokes Creek watershed was examined to determine long term water quality trends. Data was analyzed from 1981, 1982, 1983, 1990, 1992, 1993, and 1999.

Powderlick Run

Water quality trends data suggested that water quality in Powderlick Run has deteriorated (Figures 37 and 38). In most cases, bacterial concentrations in 1999 were well above those noted in previous years (Figure 37). Dissolved solids mean concentrations were also well above historical concentrations except at the uppermost sampling locale. However, the cessation of the discharge from the Day Lay Egg Farms (including the Mad River Egg Farm) will reduce dissolved solids loadings to Powderlick Run (Figure 37). Ammonia, phosphorus, and organic nitrogen (measured by TKN) concentrations in 1999 were all well above historical means in most cases (Figure 38). The only downward trends were found with nitrate+nitrite and suspended solids which could be related to rain events and associated NPS runoff (Figure 38). While the downward trend for nitrate+nitrite is encouraging, the fact remained that nitrate+nitrite concentrations in Powderlick Run were still excessive.

Bokes Creek

Water chemistry trends in the Bokes Creek mainstem showed little in the way of trends. In most cases, values for 1999 sites were similar to those values found in previous years except for higher means for those parameters associated with spills in the early 1990s (Figures 39 and 40). Nitrate+nitrite seemed to be the only exception to this pattern with most values reduced to below those of previous years (Figure 40). This was a positive development. For many nutrient parameters, the 1992 sampling events appeared to be more elevated above other years (Figure 40). This was likely attributable to spills or samples collected just after rain events as indicated by the very elevated TSS concentrations (Figure 40). Elevated concentrations similar to these likely were attainable throughout other survey years but were dependent on sampling time and location and not shown by the data.

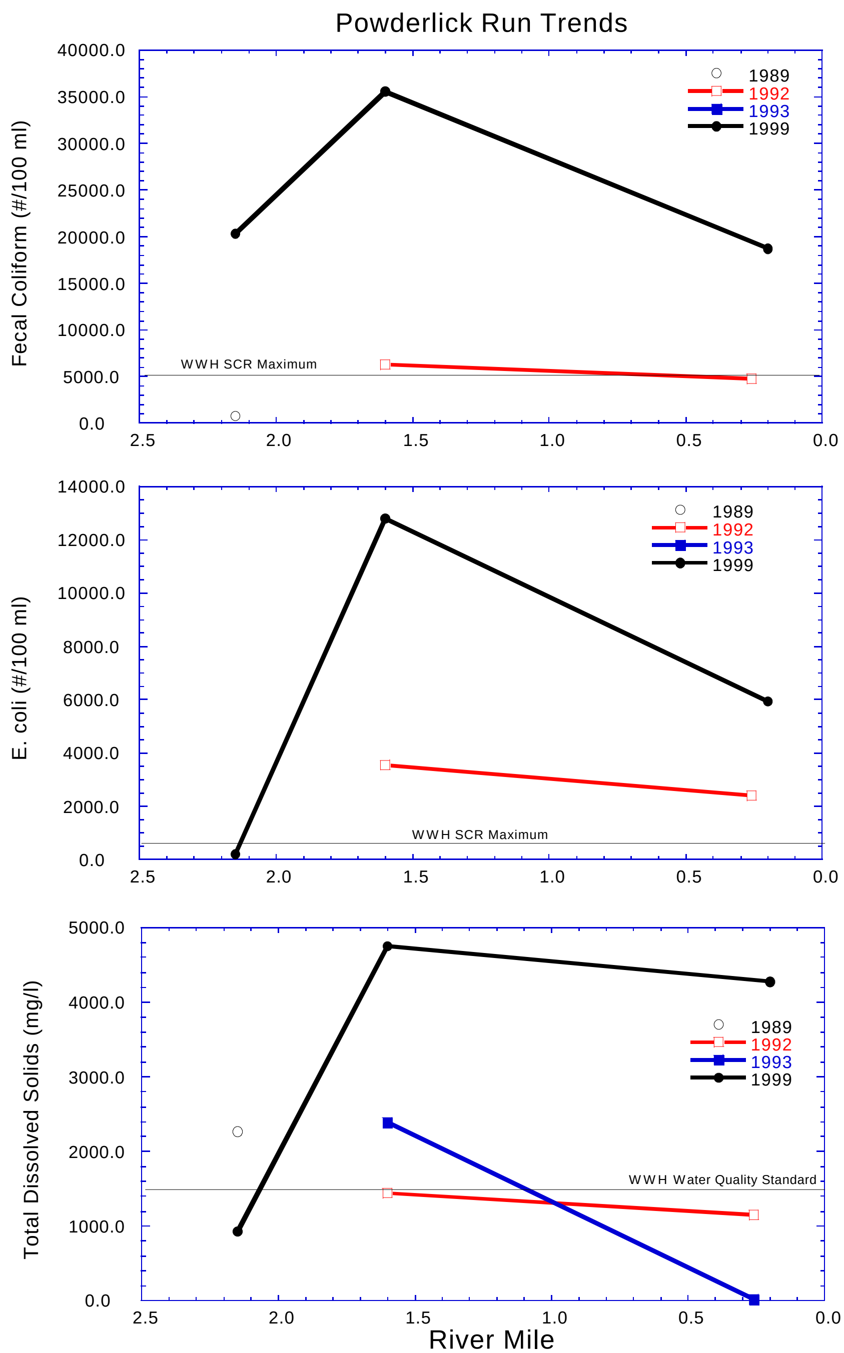


Figure 37. Chemical trends for fecal coliform bacteria (#/100 ml), *E. coli* bacteria (#/100 ml), and total dissolved solids (mg/l) for Powderlick Run, 1989 - 1999.

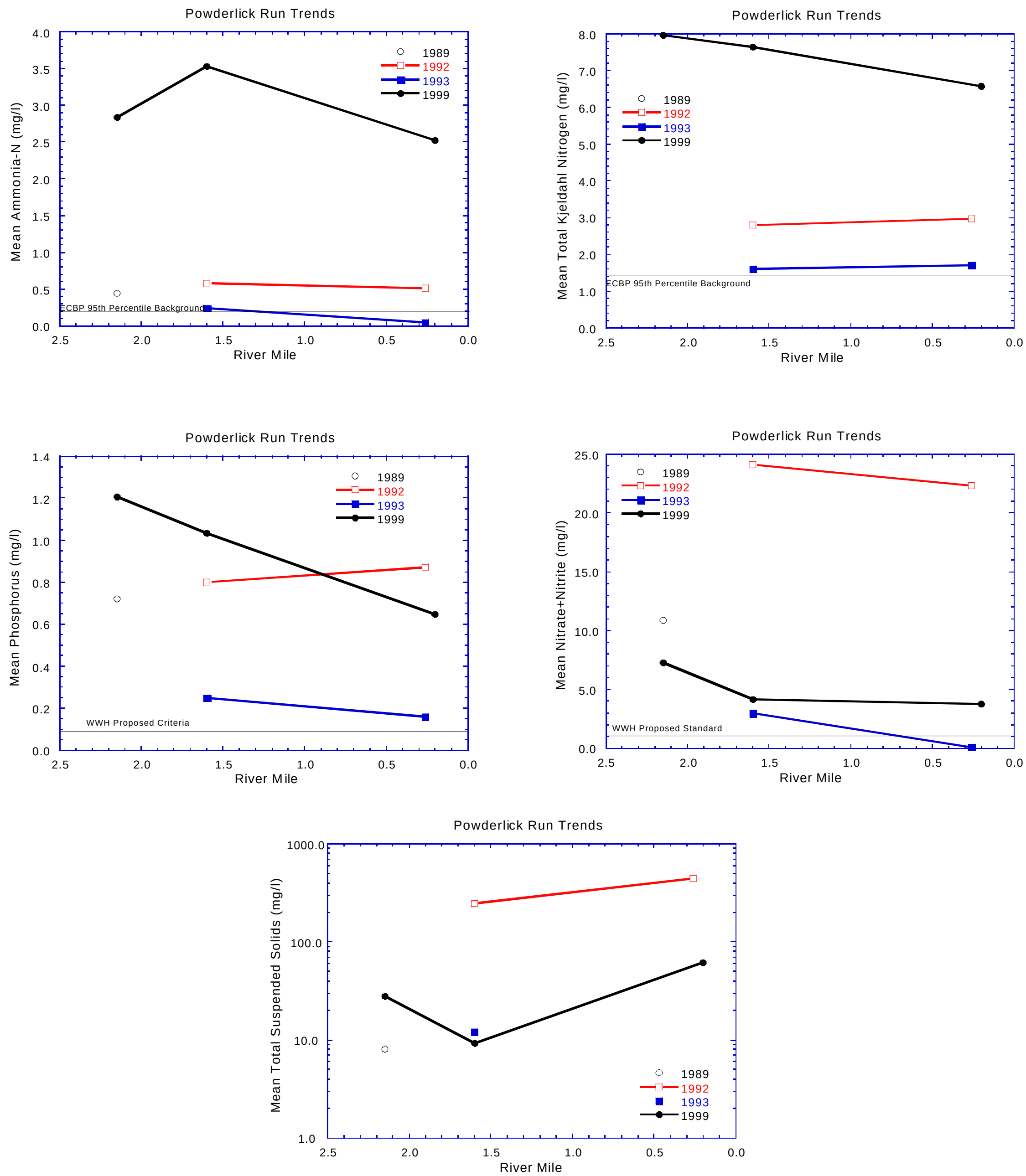


Figure 38. Chemical trends for mean ammonia, total Kjeldahl nitrogen, phosphorus, nitrate+nitrite, and total suspended solids (all units were mg/l) for Powderlick Run, 1989 - 1999.

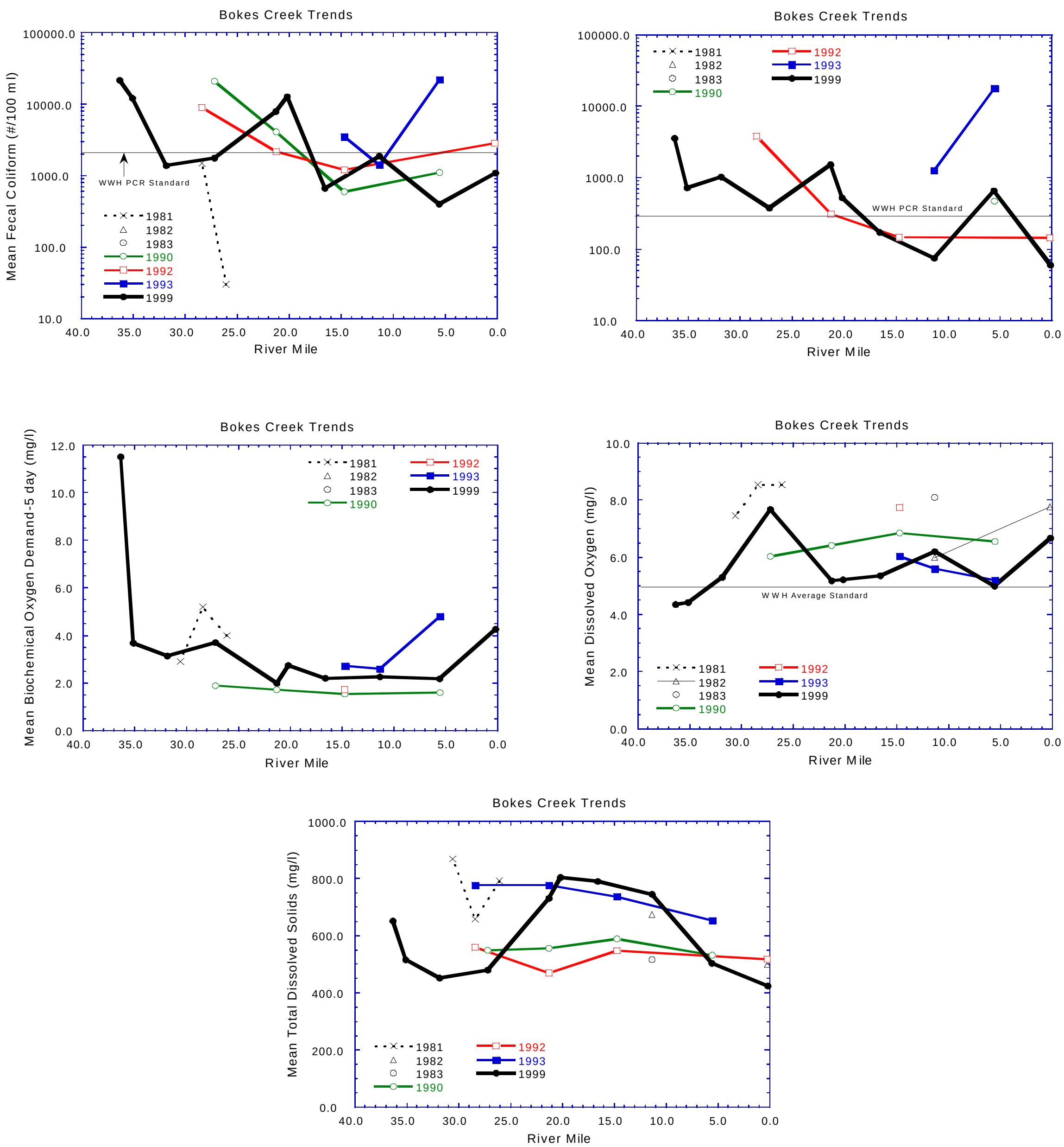


Figure 39. Chemical trends (means) for fecal coliform bacteria (#/100 ml), *E. coli* (#/100 ml), Biochemical Oxygen Demand - 5 day (mg/l), dissolved oxygen (mg/l), and total dissolved solids (mg/l) for Bokes Creek, 1989 - 1999.

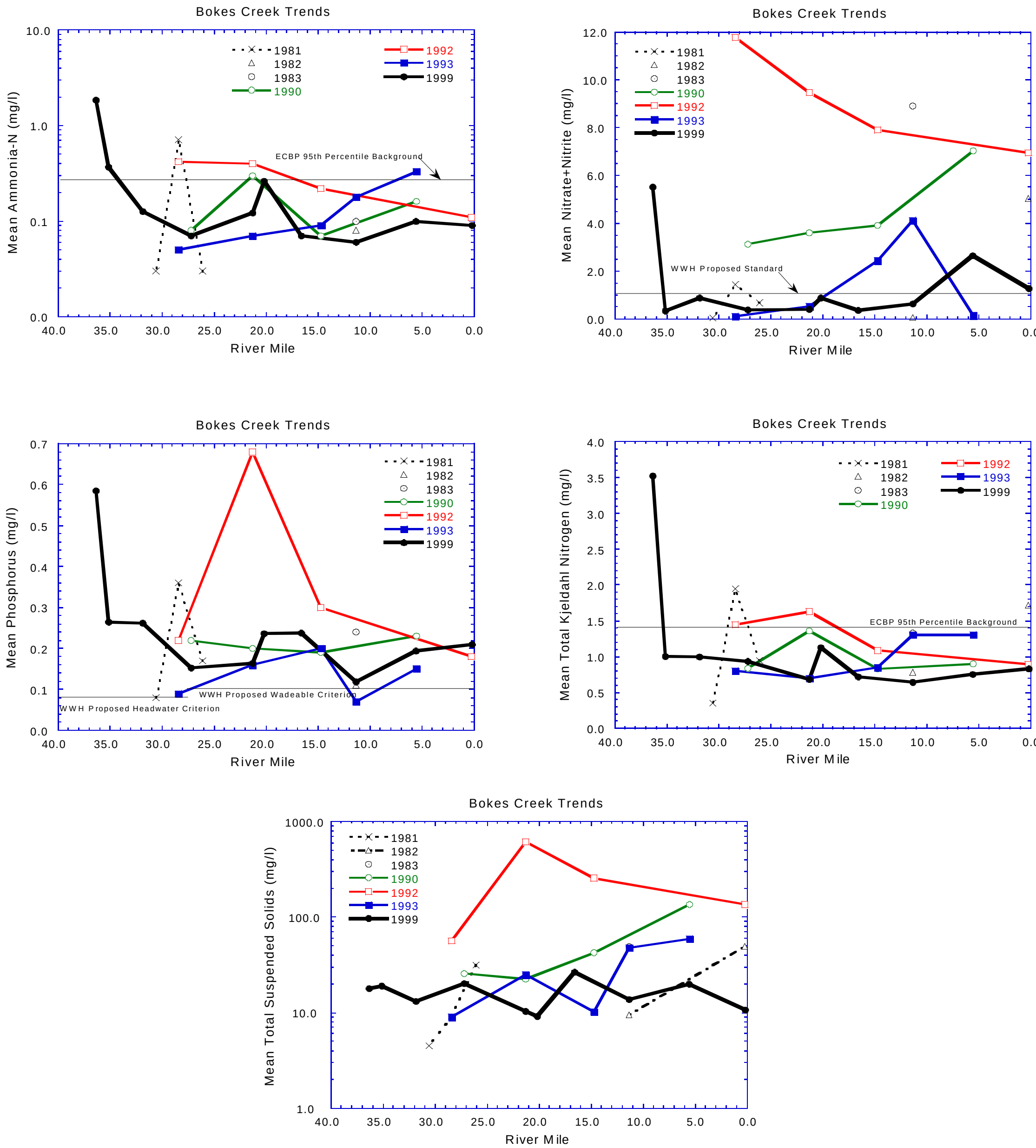


Figure 40. Chemical trends (means) for ammonia-nitrogen, nitrate+nitrites, phosphorus, total Kjeldahl nitrogen, and total suspended solids (all units as mg/l) for Bokes Creek, 1989 - 1999.

Additional water quality data was included from monthly ambient monitoring done at RM 14.80(Taylor-Claibourne Road) between January 1990 and April 1994 (inclusive) showing changes through time at a single station. Most exceedences appeared similar to 1999 results (Table 20). The higher ammonia concentrations in the early 1990s likely were attributable to spills (Table 21). Data trends indicated stable conditions at this site for dissolved oxygen and nitrates, as these remained fairly constant (Figures 41 and 42). Box and whisker plots occasionally showed that dissolved oxygen concentrations did fall below the minimum WQS criterion of 4 mg/l (Figure 42). Nitrates also exhibited regular spikes of over 10 mg/l with one measurement over 25 mg/l (Figure 39). Both phosphorus and suspended solids exhibited some fluctuations from year to year (Figures 41 and 42). Box and whisker plots of each showed significant spikes for both parameters - over 2 mg/l for phosphorus and over 150 mg/l for suspended solids (Figure 42). Ammonia values were elevated in 1990 but decreased and remained low through 1994 (Table 21, Figure 41). If anything, the ambient data revealed variability in chemical concentrations and in water quality based on summer/fall precipitation totals and temporal proximity of sampling to rain events.

Table 20. Exceedences of Ohio EPA Warmwater Habitat (WWH) water quality criteria (OAC 3745-1) for chemical/physical parameters at Bokes Creek at Taylor-Claibourne Road 1990-1994 (Units are #/100 ml for bacteria and mg/l for all other parameters).

River/Stream	Year	Parameter	Value (code)
Bokes Creek @ Taylor-Claibourne Road	1990	Ammonia	(16.20)**Z**
	1991	D.O. Fecal Coliform	(3.30) ‡‡ (1080)•, (8000)• • •
	1992	None	None
	1993	D.O. Fecal Coliform	(2.90)‡‡ (2200, 3000, 4200)• •, (16000)• • •
	1994	Fecal Coliform	(1400)•

Z exceedence of numerical criteria for the protection of aquatic life
‡‡ exceedence of the minimum warmwater habitat dissolved oxygen criterion (4.0 mg/l).
• exceedence of the average Primary Contact Recreation criterion (Fecal coliform 1000/100 ml).
• • exceedence of the maximum Primary Contact Recreation criterion (Fecal coliform 2000/100 ml).
• • • exceedence of the maximum Secondary Contact Recreation criterion (Fecal coliform 5000/100ml).

Table 21. Comparison of background nutrient and demand parameter concentrations with those found at Bokes Creek at Taylor-Claibourne Road, 1990-1994. Comparisons are made to Eastern Corn Belt Plains (ECBP) ecoregion background median (50th percentile), 75th, 90th, and 95th percentile values for both headwater (HW) and wadeable (W) sites. Units are mg/l for all parameters.

River/Stream	Year	Parameter(s)	Value(s)
Bokes Creek	1990 n=7	BOD_5 TSS Ammonia Nitrate+Nitrite Phosphorus	*2.1* <u>58.0</u>, *30.0*, 22.0, 19.0, 18.0 **16.20** **11.30**, **6.61**, **6.55**, <u>5.36</u>, *4.61*, *2.88*, 1.82 **0.66**, *0.19*, *0.13*, 0.12, 0.11, 0.08
	1991 n=12	BOD_5 TSS Ammonia Nitrate+Nitrite Phosphorus	**7.1**, **6.3**, **5.6**, **5.3**, <u>3.0</u>, *2.4*, *2.3*, *2.2* **153.0**, **140.0**, *46.0*, *41.0*, 24.0, 23.0, 20.0, 16.0, 15.0 **0.23**, <u>0.12</u>, *0.09*, *0.08* **10.20**, *4.60*, *4.31*, *4.30*, *4.14*, 1.04 **2.03**, <u>0.28</u>, <u>0.26</u>, *0.18*, *0.17*, *0.17*, *0.16*, *0.13*, 0.12, 0.08, 0.08, 0.08
	1992 n=10	BOD_5 TSS Ammonia Nitrate+Nitrite Phosphorus	**5.0**, **3.7**, <u>2.9</u>, 1.6, 1.4 *32.0* **0.26**, *0.08*, *0.08* **26.9**, **9.55**, **8.93**, **6.44**, <u>5.47</u>, *4.55*, *4.25* *0.20*, *0.15*, *0.14*, *0.13*, 0.12, 0.11, 0.08
	1993 n=12	BOD_5 TSS Ammonia Nitrate+Nitrite Phosphorus	**6.2**, **4.9**, **4.8**, **3.5**, <u>3.0</u>, *2.7*, *2.1*, 1.8, 1.6 **124.0**, **90.0**, *51.0*, 26.0, 26.0, 25.0, 24.0 **0.28**, **0.24**, **0.25**, *0.07*, *0.07* **10.60**,**6.73**, **6.52**, <u>5.42</u>, *4.79*, *4.34*, *3.96*, 2.42, 2.16 **0.60**, **0.37**, **0.35**, **0.34**, **0.30**, <u>0.22</u>, 0.15, 0.14, 0.08
	1994 n=4	BOD_5 TSS Ammonia Nitrate+Nitrite Phosphorus	**4.10**, 1.60 **112.0** *0.09* **7.14**, *4.03*, *2.89*, *2.87* **0.50**, *0.20*

Normal print values exceed the 50th percentile background
Italic print values exceed the 75th percentile background
<u>Underlined</u> values exceed the 90th percentile background
Boldfaced values exceed the 95th percentile background

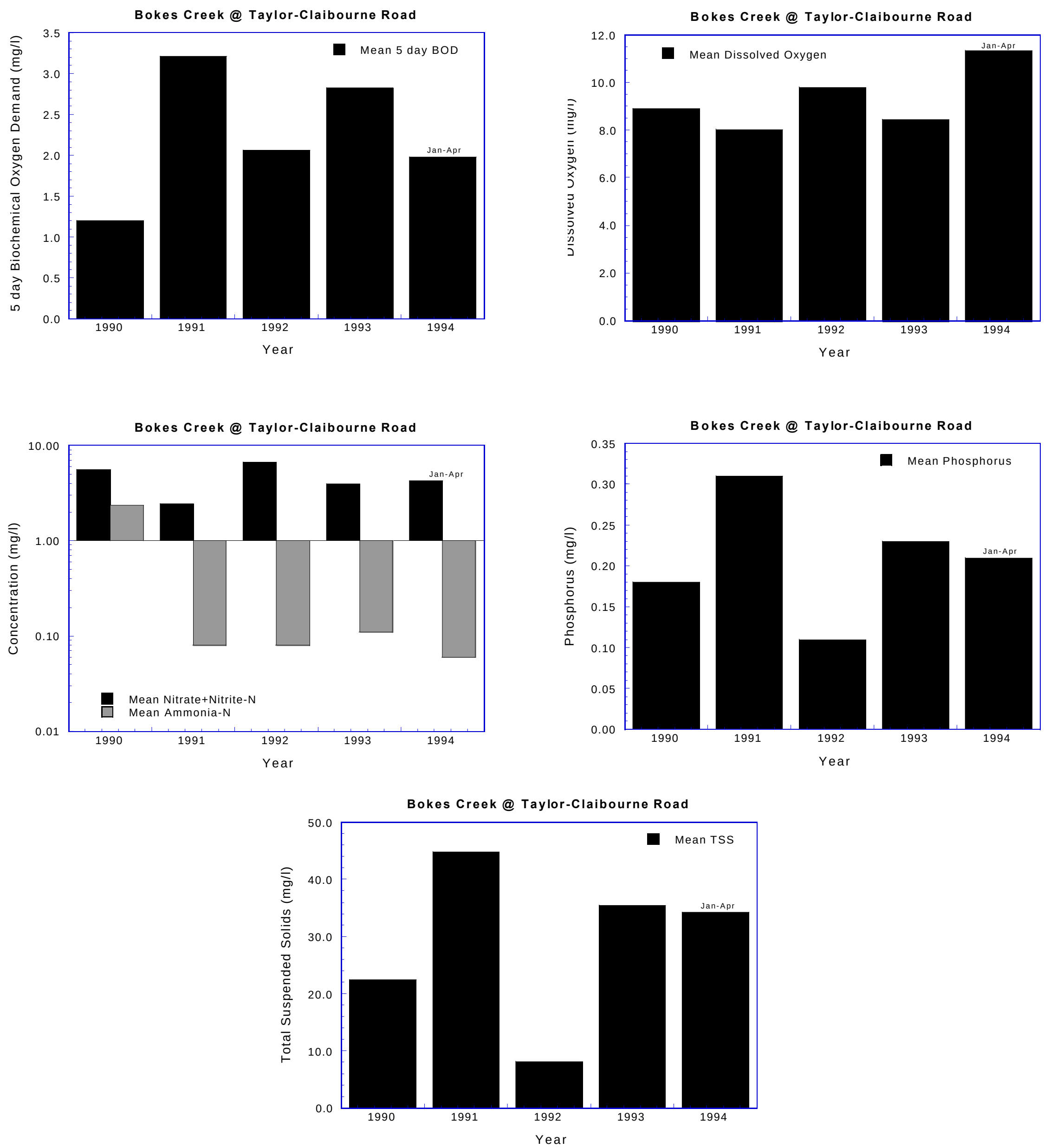


Figure 41. Chemical trends (means) for BOD_5, dissolved oxygen, nitrate+nitrite and ammonia-nitrogen, phosphorus, and total suspended solids (all as mg/l) at the Bokes Creek ambient site at Taylor-Claiborne Rd. (RM 14.8), 1990 - 1994.

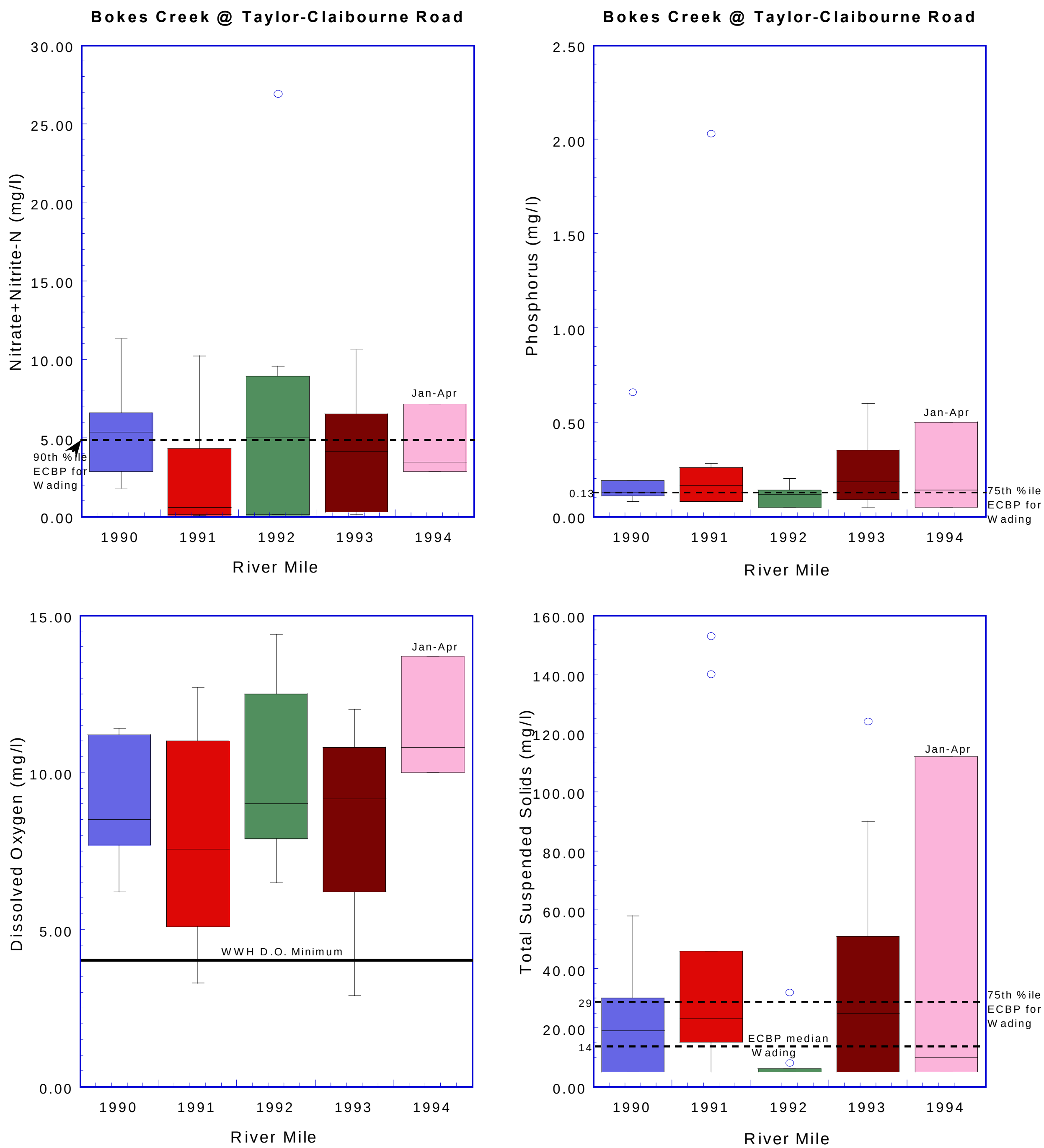


Figure 42. Chemical trends (means) for nitrate+nitrite-N, phosphorus, dissolved oxygen, and total suspended solids (all as mg/l) at Bokes Creek ambient site at Taylor-Claiborne Rd. (RM 14.8), 1990 - 1994.

Biological Trend Assessment: Macroinvertebrate Community 1981-1999

Bokes Creek, 1981 - 1999

A comparison of macroinvertebrate community results from Bokes Creek biosurveys conducted in 1992, 1993 and 1999 indicated very similar communities, although there were some slight differences (Figure 43). Marginally good conditions were observed just downstream from the confluence of Powderlick Run in 1999 and 1992. The difference between ICI site scores upstream and downstream from Powderlick Run in 1999 was negligible (36 vs. 34), but the 1992 survey indicated a significant difference of 16 points (50 vs. 34 downstream) (Table 1). This reflected the current pressure and effect from the upper watershed of Bokes Creek (nutrient loads, sedimentation, and low D.O. conc.) on resource quality. It also indicated two conclusions:
1.) Bokes Creek upstream from Powderlick Run is decreasing in quality; and 2.) Powderlick Run is still negatively affecting Bokes Creek.

In 1999, an additional sample approximately three miles downstream from Powderlick Run (RM 16.8) was collected to evaluate possible D.O. sag zones downstream along with any influences from the Brush Run drainage. The marginally good conditions observed in 1999 and earlier survey results inferred at least marginally good conditions present downstream from Powderlick Run. However almost every survey demonstrated that the macroinvertebrate community in Bokes Creek and its environs are in a tenuous and vulnerable state (Figure 43).

Powderlick Run, 1992 - 1999

No sites were duplicated, so it was not possible to ascertain trends. However the ICI of 6 at RM 0.9 in 1999 was much lower than the 30 scored at RM 0.1 in 1992 (Table 1). This may have been a reflection of more serious and severe influences from upstream egg farm waste land applications.

West Fork West Mansfield Creek, 1981 - 1999

The 1999 macroinvertebrate community in West Fork West Mansfield Tributary at RM 0.8 achieved WWH quality with a narrative evaluation of marginally good. This was an improvement from fair conditions observed in the 1981 biosurvey (Table 1). This slight improvement was possibly attributable to changes at the West Mansfield WWTP (from direct discharge to land application), though any positive improvements have seemingly been dampened by riparian encroachment, sedimentation, and excess nutrient inputs into West Fork West Mansfield Tributary.

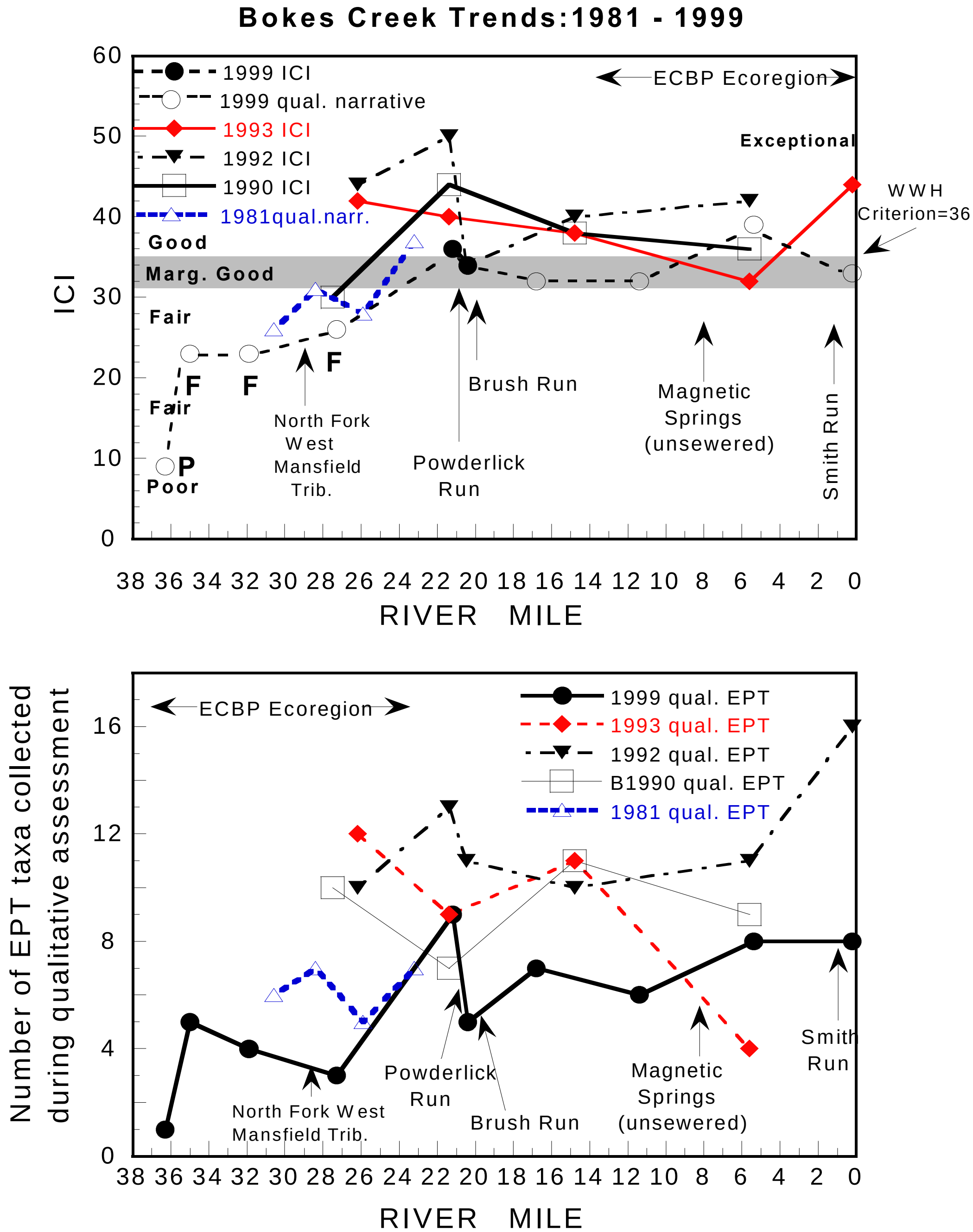


Figure 43. Comparisons of ICI and qualitative narrative scores and number of EPT taxa collected during Bokes Creek survey from 1981 through 1999.

Biological Trend Assessment: Fish Community 1981-1999

Changes in Biological Community Performance: 1981-1999

Bokes Creek

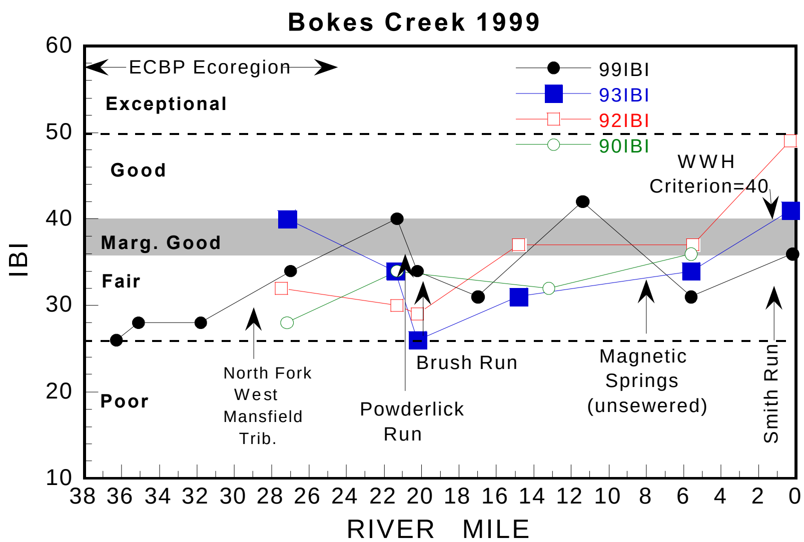
Fish sampling has occurred five times in Bokes Creek between 1999 and 1981. Generally, fish community performance has always been fair (Figure 44). As discussed in the fish community section, the wetland attributes of Bokes Creek are naturally limiting when assessed using Ohio EPA's biotic indices. Even so, the aspects of increased sedimentation and nutrient loading were documented in the earlier surveys.

Review of the various metrics within the IBI calculation indicates the fish community in Bokes Creek in 1999 was similar to that encountered 18 years previously. Species richness has been moderate as have the number of sunfish and sucker species in most samples. Pollution tolerant fish have predominated all samples and the percentage of simple lithophils has typically been moderate at best.

Despite the generally fair performance, instances of achievement of the biocriterion have occurred. The overwhelming impression is that Bokes Creek is influenced by polluted runoff from agricultural sources and from poorly treated septage. In different sample passes the influence of these sources varied but has been prevalent enough to supress the best possible community performance. Both trend figures illustrate this observation. In different years performance is better at different sites.

In 1999 the performance at RM 17.0 was influenced by poor dissolved D.O. concentrations that were linked to excessive nutrient loads in the Powderlick sub-basin. In other years similar trends were also observed.

In summary, the Bokes Creek fish community is modestly limited by natural wetland habitat attributes, but it is further supressed by polluted runoff. This condition has existed for at least 18 years. The 1999 performance at RM 17.0 downstream from the Powderlick Creek confluence remained consistent with a trend of diminished community scores in that reach.



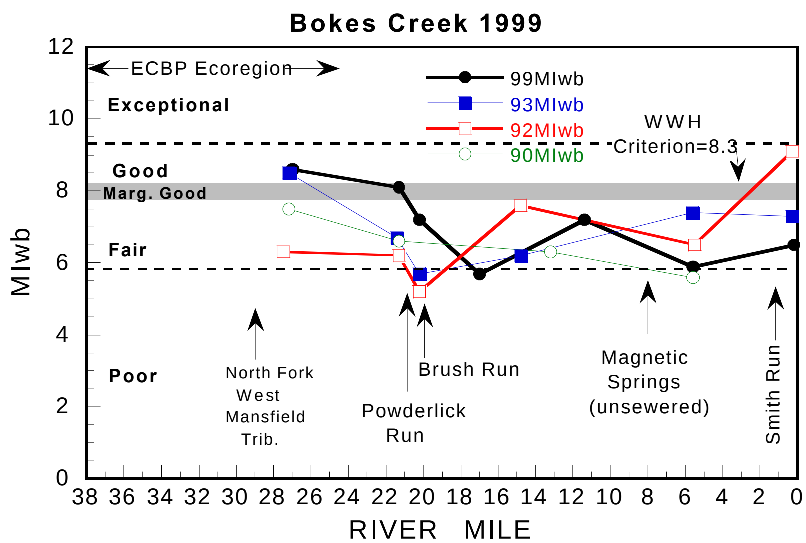


Figure 44. Fish IBI and Miwb trends for data from 1990 - 1999 for Bokes Creek.

Area of Degradation Value Trend Assessment: 1981-1999

The Area of Degradation Value (ADV) portrays the length and amount of departure from a biocriterion by an aquatic community. It reflects the distance that the biological index (IBI, MIwb, or ICI) moves longitudinally from the applicable biocriterion or from an upstream measurement of performance. A positive ADV is represented by the area above the biocriterion (or upstream level) when the results for each index are plotted against river mile. Conversely, a negative ADV represents the more typical degradation (Figure 3). The results are also expressed as ADV/mile to normalize comparisons between segments and other streams and rivers. ADV statistics reported in Table 22 reflect positive and negative influences on the aquatic communities because a given reach can have segments which exceed and which do not attain biocriteria.

Comparative reaches of Bokes Creek are represented in Table 18. The attainment statistics imply that 7 percent of the Bokes Creek fully met the WWH biocriteria in 1999. There were 21.5 miles of stream in partial attainment of the biocriteria. Nonattainment of WWH biocriteria increased one mile to 4.4 miles of the Bokes Creek mainstem. Totals were similar for Bokes Creek from 1993 to1999, but there was a slight overall decline. Powderlick Run biological performance was similarly poor in both 1993 and 1999. There was little difference between the 1981 and 1999 West Fork West Mansfield Tributary results. Basinwide, there has not been much positive change in biological community performance between survey years.

Table 22. Area of Degradation Values (ADV) statistics for Bokes Creek basin,1981-1999. Values were calculated using Eastern Corn Belt Plain WWH biocriteria as the baseline for community performance.

Stream (Year)			Biological Index Values		ADV Statistics				Attainment Status		
	Reach				Positive		Negative		(miles)		
Index	Upper RM	Lower RM	Min.	Max	ADV	**ADV/ Mile**	ADV	**ADV/ Mile**	FULL	PARTIAL	**NON**
Bokes Creek (1999)											
IBI	27.8	0.1	31	42	332	**12.0**	284	**10.3**	1.9	21.5	**4.4**
MIwb			5.7	8.10	16	**0.5**	1532	**55.7**			
ICI			25	36	332	**11.9**	171	**6.1**			
Bokes Creek (1993)											
IBI	27.7	0.1	31	41	202	**7.2**	570	**20.5**	3.1	21.2	**3.4**
MIwb			5.7	8.5	70	**2.5**	1302	**46.9**			
ICI			32	42	1224	**56.3**	0	**0.0**			

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APPENDIX Tables for Bokes Creek Basin

Table A-1. Results of chemical/physical water quality sampling conducted in the Bokes Creek study area during July-September, 1999. Underlined values indicate concentrations below the method detection limit. NA means not analyzed. CG indicates confluent growth for microbiological results and italicized print indicates an effluent sample.

Bokes Creek A-1

RM	Date	Cu	Hard	Fe	Mg	Mn	Ni	K	Na	Sr	Zn	Hg	As
	mmdd	µg/l	mg/l	µg/l	mg/l	µg/l	µg/l	mg/l	mg/l	µg/l	µg/l	µg/l	µg/l
36.34	7/1	10	317	1030	31	233	40	5	36	2910	10	0.2	4
	7/12	10	296	660	30	267	40	8	126	4400	10	0.2	5
	7/27	10	177	2290	15	81	40	4	8	1600	26	0.2	3
	8/12	No Flow											
	8/25	12	383	892	33	454	40	11	242	6940	36	0.2	4
	Mean	10.5	293	1218	27.3	259	40	7	103	3963	20.5	0.2	4
35.12	7/1	10	357	572	34	238	40	3	23	6480	10	0.2	3
	7/12	10	341	577	33	293	40	3	24	6550	10	0.2	5
	7/27	10	251	1410	24	217	40	6	40	4890	23	0.2	6
	8/12	10	404	999	37	1100	40	4	36	10000	10	0.2	7
	8/25	10	352	676	34	1270	40	5	34	8310	31	0.2	9
	Mean	10	341	847	32.4	624	40	4.2	31.4	7246	16.8	0.2	6
31.84	7/1	10	387	251	37	74	40	5	19	2550	23	0.2	3
	7/12	10	375	299	36	112	40	5	30	3020	10	0.2	3
	7/27	10	164	2240	15	165	40	7	12	1100	33	0.2	4
	8/12	10	314	826	32	1610	40	12	26	2540	11	0.2	8
	8/25	10	244	834	26	1560	40	9	25	1960	25	0.2	6
	Mean	10	297	890	29.2	704	40	7.6	22.4	2234	20.4	0.2	4.8
27.22	6/30	10	376	312	38	42	40	4	26	2570	19	0.2	2
	7/12	10	376	496	41	166	40	4	33	3070	11	0.2	3
	7/27	10	286	915	30	103	40	6	43	2200	14	0.2	5

Bokes Creek A-1

RM	Date	Cu	Hard	Fe	Mg	Mn	Ni	K	Na	Sr	Zn	Hg	As
	mmdd	µg/l	mg/l	µg/l	mg/l	µg/l	µg/l	mg/l	mg/l	µg/l	µg/l	µg/l	µg/l
	8/12	10	298	1190	33	166	40	7	30	2940	14	0.2	5
	8/25	10	261	728	30	168	40	7	30	2470	21	0.2	4
	Mean	10	319	728	34.4	129	40	5.6	32.4	2650	15.8	0.2	3.8
21.3	6/30	10	394	368	46	54	40	4	24	3890	10	0.2	3
	7/12	10	444	230	55	66	40	5	30	5650	10	0.2	3
	7/27	10	563	623	73	153	40	5	30	7800	18	0.2	3
	8/12	10	597	253	80	204	40	7	38	9050	10	0.2	3
	8/25	10	499	1000	66	102	40	5	35	7060	16	0.2	2
	Mean	10	499	495	64	116	40	5.2	31.4	6690	12.8	0.2	2.8
20.2	6/30	10	444	500	52	58	40	5	36	4460	10	0.2	3
	7/13	10	445	414	54	67	40	6	56	5270	10	0.2	3
	7/28	10	558	266	70	117	40	7	67	9580	10	0.2	3
	8/13	10	471	397	61	235	40	8	55	5870	10	0.2	4
	8/25	10	542	998	68	128	40	12	140	7400	20	0.2	3
	Mean	10	492	515	61	121	40	7.6	70.8	6516	12	0.2	3.2
16.58	6/30	10	393	1070	42	70	40	5	23	3270	17	0.2	3
	7/13	10	418	1500	50	190	40	5	86	4830	10	0.2	3
	7/28	10	446	1100	55	124	40	7	75	4740	10	0.2	4
	8/13	10	502	921	63	113	40	8	89	6060	10	0.2	4
	8/26	10	527	1070	68	106	40	9	178	7120	13	0.2	3
	Mean	10	457	1132	55.6	121	40	6.8	90.2	5204	12	0.2	3.4
11.37	6/30	10	378	302	39	18	40	4	19	4060	10	0.2	2
	7/13	10	415	372	48	43	40	5	100	5310	10	0.2	2

Bokes Creek A-1

RM	Date	Cu	Hard	Fe	Mg	Mn	Ni	K	Na	Sr	Zn	Hg	As
	mmdd	µg/l	mg/l	µg/l	mg/l	µg/l	µg/l	mg/l	mg/l	µg/l	µg/l	µg/l	µg/l
	7/28	10	340	419	39	96	40	4	41	4360	10	0.2	4
	8/13	10	521	532	58	183	40	5	108	14200	10	0.2	4
	8/26	10	465	685	51	221	40	4	66	15900	24	0.2	4
	Mean	10	424	462	47	112	40	4.4	66.8	8766	12.8	0.2	3.2
5.54	6/30	10	350	626	34	37	40	5	30	4410	10	0.2	2
	7/13	10	266	1560	27	45	40	5	29	3560	13	0.2	2
	7/28	10	243	2070	22	85	40	6	48	3460	13	0.2	3
	8/13	10	346	1190	36	121	40	5	61	6930	10	0.2	4
	8/26	10	352	1020	40	139	40	6	79	7560	12	0.2	4
	Mean	10	311	1293	31.8	85.4	40	5.4	49.4	5184	11.6	0.2	3
0.24	6/30	10	317	313	31	21	40	4	19	2910	10	0.2	2
	7/13	10	296	484	30	20	40	4	23	3260	10	0.2	2
	7/28	10	226	1220	21	47	40	4	24	2090	11	0.2	3
	8/13	10	279	713	29	104	40	4	37	3010	10	0.2	4
	8/26	10	240	843	28	106	40	4	43	2770	18	0.2	3
	Mean	10	272	715	27.8	59.6	40	4	29.2	2808	11.8	0.2	2.8

Table A-2. Results of chemical/physical water quality sampling conducted in the Bokes Creek study area during July-September, 1999. Underlined values indicate concentrations below the method detection limit. CG indicates confluent growth for microbiological results. NA means not analyzed

Bokes Creek A-2

RM	Date mmdd	Cd µg/l	Pb µg/l	Se µg/l	E coli #/100 ml	E coli (Q-Tray) #/100 ml	Fecal coliform #/100 ml	Fecal strep #/100 ml
36.34	0701	0.2	2	2	400	NA	4200	6400
	0712	0.2	2	2	9360	NA	18500	NA
	0727	0.2	2	2	873	NA	4000	50500
	0812	No Flow						
	0825	0.2	2	2	NA	2005	60000	100000
	Mean	0.2	2	2	3544.33	2005	21675	52300
35.12	0701	0.2	2	2	50	NA	250	725
	0712	0.2	2	2	120	NA	160	NA
	0727	0.2	2	2	2700	NA	300	66000
	0812	0.2	2	2	10	NA	60	345
	0825	0.2	2	2	NA	NA	60000	3450
	Mean	0.2	2	2	720	0	12154	17630
31.84	0701	0.2	2	2	140	NA	405	1120
	0712	0.2	2	2	100	NA	340	NA
	0727	0.2	2	2	3800	NA	5400	100000
	0812	0.2	2	2	30	NA	130	190
	0825	0.2	2	2	NA	NA	691	3800
	Mean	0.2	2	2	1017.5	0	1393.2	26277.5
27.22	0630	0.2	2	2	10	NA	470	360
	0712	0.2	2	2	410	NA	1050	NA
	0727	0.2	2	2	1040	NA	2200	5600
	0812	0.2	2	2	50	NA	60	9000
	0825	0.2	2	2	NA	2005	5100	7700
	Mean	0.2	2	2	377.5	2005	1776	5665

Bokes Creek A-2

RM	Date	Cd	Pb	Se	E coli	E coli (Q-Tray)	Fecal coliform	Fecal strep
	mmdd	µg/l	µg/l	µg/l	#/100 ml	#/100 ml	#/100 ml	#/100 ml
21.3	0630	0.2	2	2	10	NA	290	585
	0712	0.2	2	2	30	NA	290	NA
	0727	0.2	2	2	6000	NA	8636	26000
	0812	0.2	2	2	30	NA	100	370
	0825	0.2	2	2	NA	2005	30000	63000
	Mean	0.2	2	2	1517.5	2005	7863.2	22488.75
20.2	0630	0.2	2	2	30	NA	190	1060
	0713	0.2	2	2	1300	NA	2500	NA
	0728	0.2	2	2	365	NA	850	3300
	0813	0.2	2	2	400	NA	530	1210
	0825	0.2	2	2	NA	2005	60000	100000
	Mean	0.2	2	2	523.75	2005	12814	26392.5
16.58	0630	0.2	2	2	30	NA	1200	1790
	0713	0.2	2	2	320	NA	820	NA
	0728	0.2	2	2	240	NA	200	1080
	0813	0.2	2	2	90	NA	270	850
	0826	0.2	2	2	NA	NA	841	1350
	Mean	0.2	2	2	170	0	666.2	1267.5
11.37	0630	0.2	2	2	10	NA	510	580
	0713	0.2	2	2	100	NA	400	NA
	0728	0.2	2	2	160	NA	600	100000
	0813	0.2	2	2	30	NA	100	2200
	0826	0.2	2	2	NA	NA	7818	3900
	Mean	0.2	2	2	75	0	1885.6	26670

Bokes Creek A-2

RM	Date mmdd	Cd µg/l	Pb µg/l	Se µg/l	E coli #/100 ml	E coli (Q-Tray) #/100 ml	Fecal coliform #/100 ml	Fecal strep #/100 ml
5.54	0630	0.2	2	2	60	NA	550	1010
	0713	0.2	2	2	350	NA	736	NA
	0728	0.2	2	2	2200	NA	NA	15000
	0813	0.2	2	2	10	NA	190	28000
	0826	0.2	2	2	NA	NA	130	240
	Mean	0.2	2	2	655	0	401.5	11062.5
0.24	0630	0.2	2	2	10	NA	280	540
	0713	0.2	2	2	50	NA	120	NA
	0728	0.2	2	2	160	NA	280	5700
	0813	0.2	2	2	20	NA	60	2000
	0826	0.2	2	2	NA	NA	4700	3100
	Mean	0.2	2	2	60	0	1088	2835

Table A-3. Results of chemical/physical water quality sampling conducted in the Bokes Creek study area during July-September, 1999. Underlined values indicate concentrations below the method detection limit. NA means not analyzed. Italicized print indicates an effluent sample.

Bokes Creek A-3

RM	Date	Alkalinity	COD	Cl	NH_3	NO_3+NO_2	NO_2	SO_4	TKN	P
	mmdd	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
36.34	0701	190	23	49	1.11	2.43	0.02	107	1.87	0.36
	0712	206	44	178	3.43	0.40	0.12	87	5.21	0.62
	0727	90	43	14	0.26	14.70	0.23	42	2.06	0.25
	0812	No Flow								
	0825	256	73	317	2.58	4.48	1.19	146	4.95	1.11
	Mean	185.5	45.75	139.5	1.845	5.5025	0.39	95.5	3.523	0.585
35.12	0701	201	14	30	0.10	0.28	0.02	140	0.50	0.20
	0712	203	18	30	0.13	0.13	0.02	114	0.75	0.23
	0727	139	34	50	0.37	0.98	0.08	107	1.62	0.29
	0812	265	25	36	0.83	0.10	0.02	153	1.23	0.23
	0825	232	24	31	0.41	0.16	0.02	139	0.93	0.37
	Mean	208	23	35.4	0.368	0.33	0.03	130.6	1.006	0.264
31.84	0701	216	14	41	0.07	1.43	0.04	127	0.65	0.20
	0712	207	20	49	0.09	0.67	0.02	130	0.84	0.23
	0727	92	71	30	0.17	2.03	0.02	46	1.48	0.34
	0812	193	39	52	0.13	0.10	0.02	107	1.01	0.23
	0825	155	36	46	0.17	0.10	0.02	77	0.99	0.31
	Mean	172.6	36	43.6	0.126	0.866	0.02	97.4	0.994	0.262
27.22	0630	190	14	50	0.06	0.97	0.02	157	0.69	0.15
	0712	175	23	50	0.08	0.10	0.02	173	0.75	0.12
	0727	152	37	63	0.10	0.30	0.02	108	1.20	0.17

Bokes Creek A-3

RM	Date	Alkalinity	COD	Cl	NH_3	NO_3+NO_2	NO_2	SO_4	TKN	P
	mmdd	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
	0812	175	48	43	0.05	0.10	0.02	112	1.10	0.17
	0825	153	NA	42	NA	NA	0.02	80	NA	NA
	Mean	169	30.5	49.6	0.07	0.3675	0.02	126	0.935	0.153
	0630	171	14	42	0.13	0.82	0.03	189	0.74	0.15
	0712	173	17	44	0.07	0.10	0.02	85	0.63	0.20
21.3	0727	166	25	32	0.19	0.28	0.03	407	0.89	0.14
	0812	170	25	46	0.08	0.10	0.02	479	0.65	0.15
	0825	128	21	34	0.14	0.67	0.04	364	0.50	0.18
	Mean	161.6	20.4	39.6	0.122	0.394	0.03	304.8	0.682	0.164
	0630	180	11	65	0.09	1.07	0.02	243	0.73	0.23
	0713	174	17	91	0.08	0.44	0.02	202	0.81	0.18
20.2	0728	142	19	86	0.09	0.34	0.02	287	0.75	0.20
	0813	178	23	80	0.10	0.11	0.02	261	0.86	0.16
	0825	132	30	207	0.95	2.33	0.26	310	2.51	0.41
	Mean	161.2	20	105.8	0.262	0.858	0.07	260.6	1.132	0.236
	0630	181	75	41	0.10	1.39	0.02	182	0.77	0.17
	0713	160	23	152	0.06	0.10	0.02	193	0.68	0.15
16.58	0728	156	26	117	0.05	0.10	0.02	246	0.76	0.65
	0813	176	23	153	0.05	0.10	0.02	300	0.62	0.10
	0826	137	29	286	0.07	0.10	0.02	270	0.76	0.12
	Mean	162	35.2	149.8	0.07	0.358	0.02	238.2	0.718	0.238
11.37	0630	186	14	34	0.09	1.96	0.02	156	0.70	0.13
	0713	154	26	172	0.05	0.84	0.02	191	0.65	0.09

Bokes Creek A-3

RM	Date	Alkalinity	COD	Cl	NH_3	NO_3+NO_2	NO_2	SO_4	TKN	P
	mmdd	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
	0728	NA	19	NA	0.05	0.14	NA	NA	0.68	0.13
	0813	216	19	210	0.05	0.10	0.02	255	0.69	0.11
	0826	213	23	83	0.08	0.10	0.02	228	0.51	0.13
	Mean	192.25	20.2	124.8	0.06	0.628	0.02	207.5	0.646	0.118
5.54	0630	186	20	53	0.10	3.72	0.03	132	0.86	0.20
	0713	124	20	45	0.07	6.90	0.08	92	0.75	0.19
	0728	134	32	73	0.17	2.34	0.11	42	1.04	0.32
	0813	200	26	94	0.06	0.12	0.02	129	0.61	0.14
	0826	191	18	91	0.10	0.10	0.02	168	0.51	0.12
	Mean	167	23.2	71.2	0.1	2.636	0.05	112.6	0.754	0.194
0.24	0630	172	20	36	0.10	2.85	0.03	98	0.99	0.15
	0713	144	20	34	0.05	1.86	0.02	108	0.88	0.18
	0728	125	65	42	0.05	1.41	0.03	62	0.60	0.47
	0813	164	23	64	0.15	0.10	0.02	77	0.77	0.12
	0826	137	31	62	0.11	0.10	0.02	62	0.92	0.13
	Mean	148.4	31.8	47.6	0.09	1.264	0.02	81.4	0.832	0.21

Table A-4. Results of chemical/physical water quality sampling conducted in the Bokes Creek study area during July-September, 1999. Underlined values indicate conc. below method detection limit. NA means not analyzed.

Bokes Creek A-4

RM	Date	Field Parameters Cond	Temp	D.O.	pH	BOD_5	Cond	TDS	TSS	Al	Ba	Ca	Cr
	mmdd	µmhos	°C	mg/l	S.U.	mg/l	µmhos	mg/l	mg/l	µg/l	µg/l	mg/l	µg/l
36.34	7/1	844	20.29	7.91	7.62	4	771	528	18	673	68	76	30
	7/12	630	17.09	2.92	7.33	12	1190	672	13	443	58	69	30
	7/27	375	21.32	4.26	7.10	2.0	456	350	22	2040	46	46	30
	8/12	No Flow											
	8/25	1326	18.69	2.30	7.44	28	1650	1060	18.5	745	70	99	30
	Mean	794	19.3	4.35	7.37	11.5	1017	653	17.9	975	60.5	72.5	30
35.12	7/1	624	20.81	7.34	7.73	2.0	777	548	8	296	61	87	30
	7/12	536	17.94	5.01	7.41	2.0	731	464	9.5	286	57	82	30
	7/27	546	22.04	4.71	7.37	4.2	679	472	20	984	60	61	30
	8/12	647	18.69	2.57	7.50	5.0	906	582	39	482	67	101	30
	8/25	609	18.73	2.43	7.54	5.2	731	518	19	235	54	85	30
	Mean	592	19.6	4.41	7.51	3.68	765	517	19.1	457	59.8	83.2	30
31.84	7/1	645	20.33	8.09	7.98	2.4	817	590	5.5	200	61	94	30
	7/12	628	18.92	8.75	7.89	2.0	820	520	5	200	58	91	30
	7/27	324	21.85	4.35	7.32	4.2	405	318	30	1760	45	41	30
	8/12	575	20.35	0.31	7.86	2.9	735	464	16	280	69	73	30
	8/25	461	19.06	5.00	7.74	4.2	543	374	9	406	65	55	30
	Mean	527	20.1	5.3	7.76	3.14	664	453	13.1	569	59.6	70.8	30
27.22	6/30	683	21.44	12.84	8.20	2.0	824	556	9.5	226	60	88	30
	7/12	639	19.41	6.24	7.66	2.0	829	540	9	335	62	83	30

Bokes Creek A-4

RM	Date	Cond (Field Parameters)	Temp (Field Parameters)	D.O. (Field Parameters)	pH (Field Parameters)	BOD_5	Cond	TDS	TSS	Al	Ba	Ca	Cr
	mmdd	µmhos	°C	mg/l	S.U.	mg/l	µmhos	mg/l	mg/l	µg/l	µg/l	mg/l	µg/l
	7/27	615	23.93	6.02	7.60	2.4	736	496	20	685	54	65	30
	8/12	564	23.27	8.81	8.44	6.8	690	424	41	805	64	65	30
	8/25	479	20.18	4.46	7.86	5.3	558	384	21	484	60	55	30
	Mean	596	21.6	7.67	7.95	3.7	727	480	20.1	507	60	71.2	30
21.3	7/1	678	20.37	6.23	7.90	2.0	845	640	8	287	59	82	30
21.3	7/12	734	20.77	5.70	7.89	2.0	926	618	5	200	60	87	30
21.3	7/27	920	23.99	4.32	7.47	2.0	1090	836	13	487	80	105	30
21.3	8/12	955	21.22	4.88	7.90	2.0	1220	858	6	200	85	107	30
21.3	8/25	776	19.79	4.80	7.71	2.0	916	704	19.5	827	70	91	30
21.3	Mean	813	21.2	5.19	7.77	2	999	731	10.3	400	70.8	94.4	30
20.2	6/30	773	19.47	6.01	7.79	2.0	990	660	5	390	70	92	30
20.2	7/13	803	19.56	5.97	7.89	2.0	1020	734	8	349	60	89	30
20.2	7/28	1103	24.25	4.31	NA	2.1	1120	884	6	200	83	108	30
20.2	8/13	870	20.66	4.64	8.13	2.3	1090	752	5	372	65	88	30
20.2	8/25	1190	20.01	5.15	7.69	5.3	1410	998	22	605	84	105	30
20.2	Mean	948	20.8	5.22	7.88	2.74	1126	806	9.2	383	72.4	96.4	30
16.58	6/30	674	19.90	5.30	7.82	2.0	847	576	28	797	67	88	30
16.58	7/13	926	20.09	6.59	7.80	2.0	1160	780	33.5	1120	73	85	30
16.58	7/28	992	24.67	4.59	NA	2.0	1170	858	22	758	80	88	30
16.58	8/13	1064	22.09	4.82	8.00	2.8	1330	946	23	759	92	97	30
16.58	8/26	1377	19.66	5.49	7.61	2.0	1750	1060	26	781	101	99	30
16.58	Mean	1007	21.3	5.36	7.81	2.16	1251	844	26.5	843	82.6	91.4	30

Bokes Creek A-4

RM	Date	Field Parameters											
RM	Date	Cond	Temp	D.O.	pH	BOD_5	Cond	TDS	TSS	Al	Ba	Ca	Cr
	mmdd	µmhos	°C	mg/l	S.U.	mg/l	µmhos	mg/l	mg/l	µg/l	µg/l	mg/l	µg/l
11.37	6/30	635	19.62	9.47	8.01	2.0	803	546	5	272	58	87	30
	7/13	958	19.76	8.45	7.98	2.0	1220	762	26	341	65	87	30
	7/28	703	23.75	5.07	NA	NA	NA	NA	NA	285	57	72	30
	8/13	1165	21.48	4.08	7.78	2.8	1480	932	10	354	79	113	30
	8/26	851	19.35	3.99	7.70	2.3	1120	718	15	420	70	102	30
	Mean	862	20.8	6.21	7.87	2.28	1156	740	14	334	65.8	92.2	30
5.54	6/30	648	19.44	4.88	7.46	2.0	821	534	14.5	475	59	84	30
	7/13	505	19.80	6.18	7.69	2.0	641	426	22	1220	50	62	30
	7/28	599	23.56	3.64	NA	2.7	721	468	27	1570	55	61	30
	8/13	732	21.17	5.57	8.02	2.0	921	590	16.5	1060	62	79	30
	8/26	742	19.79	4.65	7.90	2.0	964	590	15	838	65	75	30
	Mean	645	20.8	4.98	7.77	2.14	814	522	19	1033	58.2	72.2	30
0.24	6/30	560	20.30	8.73	7.50	2.0	698	458	5	255	56	76	30
	7/13	532	22.23	11.13	8.23	2.0	649	434	7	405	49	69	30
	7/28	470	24.00	6.73	NA	11.0	556	392	17	931	51	56	30
	8/13	532	21.85	3.19	7.84	2.0	665	414	14	599	56	64	30
	8/26	483	19.79	3.62	7.90	4.2	633	384	25	677	52	50	30
	Mean	515	21.6	6.68	7.87	4.24	640	416	13.6	573	52.8	63	30

Table A-5. Results of organic chemical water quality sampling conducted in the Bokes Creek study area during June-September, 1999.

Bokes Creek Water Column Organics									
		River Mile							
Compound	*Units*	*35.12*	*27.22*	*21.3*	*20.2*	*16.58*	*11.37*	*5.54*	*0.24*
Gamma-BHC	µg/l	0.003							0.011
Dieldrin	µg/l	0.009						0.008	
Heptachlor Eploxide	µg/l				0.004	0.008	0.006	0.006	0.006
4-4' DDT	µg/l				0.007				
Heptachlor	µg/l				0.004				
Atrazine	µg/l			0.300	0.600	0.500		0.400	0.500
Tolune	µg/l	0.56*							

*No trip blank submitted with sample.

Table A-6. Results of chemical/physical water quality sampling conducted in the Bokes Creek study area from April 1990 through April 1994. Underlined values indicate concentrations below the method detection limit. NA means not analyzed. CG indicates confluent growth for microbiological results and italicized print indicates an effluent sample.

Bokes Creek Ambient at Taylor Claibourne Rd.														
Date	Field Parameters				Water Chemistry								Fecal Bacteria	
	Cond	Temp	D.O.	pH	BOD_5	pH	TSS	NO_2+NO_3	NH_3	SO_4	P	Coli-form	Strep	
mmdd	µmhos	ºC	mg/l	S.U.	mg/l	S.U.	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml		
1990														
0423	475	15.0	8.3	7.8	2.1	7.92	30	6.55	<u>0.05</u>	NA	0.11	330	NA	
0524	620	14.7	9.1	NA	1.0	NA	18	6.61	<u>0.05</u>	NA	0.13	140	NA	
0622	800	20.8	6.2	8.1	1.1	NA	58	5.36	<u>0.05</u>	NA	0.19	30	58000	
0808	790	18.2	7.7	8.5	<u>1.0</u>	7.88	22	1.82	<u>0.05</u>	NA	0.12	380	200	
1025	462	9.1	8.5	7.9	1.0	7.86	19	2.88	0.05	NA	NA	330	300	
1114	530	4.5	11.2	8.4	1.2	8.14	<u>5</u>	11.3	16.2	NA	0.66	190	150	
1213	600	6.0	11.4	8.3	1.0	8.00	5	4.61	<u>0.05</u>	NA	0.08	150	130	
1991														
0115	330	3.0	12.0	7.8	<u>1.0</u>	7.97	24	4.30	0.09	NA	0.17	505	365	
0204	195	0.0	12.7	NA	2.3	7.94	153	4.31	0.12	NA	0.26	1080	1160	
0308	250	2.5	11.0	7.4	7.1	7.61	140	4.60	0.23	NA	0.28	8000	26000	
0425	460	8.8	10.7	7.8	1.0	8.14	20	4.14	<u>0.05</u>	NA	0.17	<u>10</u>	150	
0514	940	24.9	6.7	8.2	2.2	8.01	15	1.04	0.08	NA	0.08	13	30	
0606	660	17.5	6.9	8.0	1.2	8.07	16	10.2	0.05	NA	0.12	420	180	
0710	800	22.0	3.3	7.9	2.4	7.98	NA	0.11	<u>0.05</u>	NA	2.03	120	160	
0805	1010	21.5	5.1	8.4	5.6	8.38	46	<u>0.10</u>	<u>0.05</u>	NA	0.18	560	330	
0918	980	20.0	4.5	8.2	5.3	NA	41	<u>0.10</u>	<u>0.05</u>	NA	0.16	<u>10</u>	10	

Bokes Creek Ambient at Taylor Claibourne Rd.

Date	Field Parameters				Water Chemistry							Fecal Bacteria	
	Cond	Temp	D.O.	pH	BOD_5	pH	TSS	NO_2+NO_3	NH_3	SO_4	P	Coli-form	Strep
mmdd	μmhos	ºC	mg/l	S.U.	mg/l	S.U.	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	
1023	900	14.0	6.6	7.1	6.3	NA	23	0.05	0.05	NA	0.13	20	200
1106	850	3.2	8.6	8.0	3.0	NA	5	0.10	0.05	NA	0.08	20	10
1218	880	1.9	8.2	NA	1.1	8.07	10	0.10	0.05	NA	0.08	50	40
1992													
0107	920	2.5	9.5	8.1	1.2	NA	5	0.10	0.05	NA	0.08	35	125
0206	445	1.1	14.4	8.4	5.0	NA	5	8.93	0.05	NA	0.05	10	60
0313	690	1.1	12.8	8.3	1.0	8.77	5	26.9	0.08	NA	0.20	130	50
0611	850	18.3	8.5	8.2	1.3	NA	5	9.55	0.05	NA	0.11	140	820
0706	670	21.0	6.5	8.3	2.9	NA	32	6.44	0.05	NA	0.14	570	320
0824	1020	20.4	7.4	8.2	1.3	NA	8	0.10	0.05	187	0.05	120	230
0916	790	19.5	8.4	8.1	3.7	8.08	5	0.11	0.05	207	0.05	430	270
1023	610	8.2	7.9	7.8	1.4	NA	5	4.25	0.05	140	0.15	20	40
1119	480	5.5	10.0	8.1	1.2	NA	6	5.47	0.08	141	0.13	530	2400
1215	580	2.9	12.5	NA	1.6	8.11	5	4.55	0.26	149	0.12	490	425
1993													
0112	408	1.2	12.0	8.12	1.0	NA	5	5.42	0.05	133	0.08	120	170
0223	210	0.0	10.8	8.18	1.8	NA	25	6.52	0.07	NA	0.22	535	340
0323	223	5.2	10.5	7.80	3.0	NA	51	4.79	0.25	43	0.35	2200	7100
0427	235	7.8	9.8	7.90	3.5	NA	124	3.96	0.07	50	0.37	3000	9600
0507	660	17.4	11.7	8.40	2.7	NA	9	2.16	0.05	145	0.05	4800	30
0615	800	20.0	5.6	7.96	1.6	NA	26	2.42	0.05	178	0.14	560	195

Bokes Creek Ambient at Taylor Claibourne Rd.													
Date	Field Parameters				Water Chemistry							Fecal Bacteria	
	Cond	Temp	D.O.	pH	BOD_5	pH	TSS	NO_2+NO_3	NH_3	SO_4	P	Coli-form	Strep
mmdd	µmhos	ºC	mg/l	S.U.	mg/l	S.U.	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	
0702	245	20.3	6.3	7.50	4.9	NA	26	10.6	0.28	23	0.60	16000	74000
0809	810	19.7	6.9	8.15	1.0	NA	5	0.26	0.05	242	0.10	490	270
0928	820	13.1	8.5	8.04	1.3	NA	5	0.10	0.05	290	0.09	380	460
1022	980	3.8	2.9	7.60	4.8	NA	NA	0.10	0.05	288	0.15	75	170
1115	238	12.8	6.2	7.45	6.2	NA	90	6.73	0.24	35	0.30	4200	95000
1207	242	4.1	10.2	7.77	2.1	NA	24	4.34	0.05	57	0.34	560	3000
1994													
0103	610	0.2	13.7	8.23	1.2	NA	5	2.89	0.05	245	0.05	120	170
0201	244	0.5	10.0	7.80	1.6	NA	10	2.87	0.05	62	0.20	570	4300
0321	440	6.9	11.0	8.27	1.0	NA	10	4.03	0.05	110	0.08	10	40
0412	240	7.2	10.6	7.83	4.1	NA	112	7.14	0.09	40	0.50	1400	1200

Table A-7. Results of chemical/physical water quality sampling conducted in the Bokes Creek study area during July-September, 1999. Underlined values indicate concentrations below the method detection limit. NA means not analyzed. Italicized print indicates an effluent sample. An * means sampling during rain event only.

Bokes Creek Tributaries A-7

		Field Parameters											
RM	Date	Cond	Temp	D.O.	pH	BOD_5	Cond	TDS	TSS	Al	Ba	Ca	Cr
	mmdd	µmhos	ºC	mg/l	S.U.	mg/l	µmhos	mg/l	mg/l	µg/l	µg/l	mg/l	µg/l
POWDERLICK RUN													
3.75*	0825	1507	19.48	5.31	7.41	6.7	1800	1300	5	200	105	158	30
3.35*	0825	1547	19.82	6.80	7.68	10	1840	1290	36.5	1210	110	143	30
2.15	0630	No Flow											
	0713	1252	18.43	4.25	7.59	12.0	1470	930	30.5	282	65	89	30
	0728	1321	23.60	1.65	NA	19.0	1480	918	44	249	69	81	30
	0813	No Flow											
	0825	1108	20.16	6.32	7.78	14	1320	926	9	220	62	88	30
	Mean	1227	20.7	4.07	7.69	15	1423	925	27.8	250	65.3	86	30
1.60	0630	16933	20.18	4.66	7.53	2.0	12000	7720	5	200	141	366	34
	0713	5417	17.69	4.10	7.63	4.8	6990	4110	5	200	102	206	30
	0728	3260	19.21	1.25	NA	7.6	4400	2630	18	200	79	192	30
	0813	14160	20.78	NA	7.40	2.0	10100	6480	9	200	114	400	30
	0825	3799	20.11	5.55	7.64	19.0	4250	2850	9.5	200	67	167	30
	Mean	8714	19.6	3.89	7.55	7.08	7548	4758	9.3	200	101	266	30.8
0.2	0630	6602	19.44	10.24	7.71	17	7830	5430	72.5	767	346	262	36
	0713	2783	19.27	4.24	7.84	5.3	3520	2270	35.2	953	105	133	30
	0728	11420	24.53	2.10	NA	18	12000	8350	71	613	452	420	30
	0813	3821	22.05	0.45	7.53	23	4840	2880	83.5	1710	146	130	30
	0825	9112	19.84	NA	7.30	16	3710	2470	46.5	1280	89	146	30

Bokes Creek Tributaries A-7

RM	Date	Field Parameters Cond	Temp	D.O.	pH	BOD_5	Cond	TDS	TSS	Al	Ba	Ca	Cr
	mmdd	µmhos	ºC	mg/l	S.U.	mg/l	µmhos	mg/l	mg/l	µg/l	µg/l	mg/l	µg/l
	Mean	6748	21	4.26	7.6	15.86	6380	4280	61.7	1065	228	218	31.2
BRUSH RUN													
0.53	0630	No Flow Entire Summer											
	0713												
	0728												
	0813												
	0825												
SMITH RUN													
3.24	0630	No Flow											
	0713	462	18.48	6.64	7.65	2.0	601	380	5	372	43	78	30
	0728	328	21.61	2.73	NA	2.0	486	352	10	2600	53	58	30
	0813	No Flow											
	0826	No Flow											
	Mean	395	20	4.69	7.65	2	544	366	7.5	1486	48	68	30
0.77	0630	876	17.75	4.35	7.53	2.0	1120	812	32.5	1020	77	130	30
	0713	493	20.26	8.00	7.91	2.0	623	412	15.5	987	50	78	30
	0728	418	22.57	4.78	NA	2.0	520	376	24	1790	50	62	30
	0813	839	20.81	4.68	7.81	2.0	1090	794	16	385	98	137	30
	0826	776	18.62	5.32	7.86	2.0	1040	720	8	272	90	121	30
	Mean	680	20	5.43	7.78	2	879	623	19.2	891	73	106	30
NORTH FORK WEST MANSFIELD CREEK													
5.58	0701	617	20.92	2.47	7.36	2.0	762	568	12	351	44	87	30

Bokes Creek Tributaries A-7

RM	Date	Field Parameters Cond	Temp	D.O.	pH	BOD_5	Cond	TDS	TSS	Al	Ba	Ca	Cr
	mmdd	µmhos	ºC	mg/l	S.U.	mg/l	µmhos	mg/l	mg/l	µg/l	µg/l	mg/l	µg/l
	0712	594	18.60	2.43	7.19	2.7	776	504	19	655	46	89	30
	0727	No Flow											
	0812	No Flow											
	0825	No Flow											
	Mean	606	19.8	2.45	7.28	2.35	769	536	15.5	503	45	88	30
3.97	0701	654	21.20	8.98	7.77	2.0	800	580	26	642	56	84	30
	0712	616	19.24	6.92	7.71	2.0	802	504	10	431	45	77	30
	0727	672	23.38	1.39	7.15	NA	NA	NA	NA	200	56	80	30
	0812	822	21.04	5.65	8.17	9.5	1060	65	32	498	70	92	30
	0825	1035	19.36	0.94	7.59	4.4	1150	736	9.5	200	67	85	30
	Mean	760	20.8	4.78	7.68	4.475	953	471	19.4	394	58.8	83.6	30
1.28	0701	661	20.45	4.88	7.54	2.0	829	594	18	579	59	84	30
	0712	564	19.18	6.44	7.77	2.0	742	490	15	740	56	69	30
	0727	607	22.58	4.11	7.77	4.5	747	520	23	898	65	66	30
	0812	734	20.37	4.96	7.97	7.4	1170	682	17	230	70	83	30
	0825	662	19.45	3.81	7.76	3.5	966	612	53	1480	78	69	30
	Mean	646	20.4	4.84	7.76	3.88	891	580	25.2	785	65.6	74.2	30
WEST FORK WEST MANSFIELD CREEK													
0.78	0630	802	19.70	6.05	7.82	2.0	994	672	19	496	67	85	30
	0712	749	18.51	6.63	7.78	2.0	998	620	15	560	60	77	30
	0727	583	22.89	2.40	7.21	2.6	661	432	18	691	52	56	30
	0812	705	20.26	4.84	7.88	4.2	869	512	10	200	55	70	30

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RM	Date	Field Parameters Cond	Temp	D.O.	pH	BOD$_5$	Cond	TDS	TSS	Al	Ba	Ca	Cr
	mmdd	µmhos	ºC	mg/l	S.U.	mg/l	µmhos	mg/l	mg/l	µg/l	µg/l	mg/l	µg/l
	0825	678	19.24	3.20	7.73	2.0	803	528	11.5	404	52	66	30
	Mean	703	20.1	4.62	7.68	2.56	865	553	14.7	470	57.2	70.8	30
SOUTH BRANCH WEST FORK WEST MANSFIELD CREEK													
	0701	1072	20.77	4.37	7.47	4.2	1320	908	9.5	200	74	100	30
	0712	No Flow											
0.02	0727	No Flow											
	0812	No Flow											
	0825	No Flow											

Table A-8. Results of chemical/physical water quality sampling conducted in the Bokes Creek study area during July-September, 1999. Underlined values indicate concentrations below the method detection limit. NA means not analyzed. CG indicates confluent growth for microbiological results and italicized print indicates an effluent sample. An * means sampling during rain event only.

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RM	Date	Cu	Hard	Fe	Mg	Mn	Ni	K	Na	Sr	Zn	Hg	As
	mmdd	µg/l	mg/l	µg/l	mg/l	µg/l	µg/l	mg/l	mg/l	µg/l	µg/l	µg/l	µg/l
POWDERLICK RUN													
3.75*	0825	<u>10</u>	596	340	49	27	<u>40</u>	30	180	2300	17	<u>0.2</u>	6
3.35*	0825	<u>10</u>	551	1890	47	121	<u>40</u>	28	212	2240	21	<u>0.2</u>	9
2.15	0630	No Flow											
	0713	<u>10</u>	366	515	35	363	<u>40</u>	21	144	1600	<u>10</u>	<u>0.2</u>	6
	0728	<u>10</u>	346	554	35	254	<u>40</u>	19	152	1590	11	<u>0.2</u>	9
	0813	No Flow											
	0825	22	380	422	39	76	<u>40</u>	26	133	1640	83	<u>0.2</u>	6
	Mean	14	364	497	36.3	231	40	22	143	1610	34.7	0.2	7
1.60	0630	<u>10</u>	1720	202	195	88	<u>40</u>	25	1980	26000	13	<u>0.2</u>	<u>2</u>
	0713	<u>10</u>	864	397	85	494	<u>40</u>	36	1230	10400	20	<u>0.2</u>	5
	0728	<u>10</u>	805	870	79	1550	<u>40</u>	38	658	12100	20	<u>0.2</u>	8
	0813	<u>10</u>	1800	418	196	633	<u>40</u>	30	1720	30700	13	<u>0.2</u>	5
	0825	<u>10</u>	693	514	67	229	<u>40</u>	37	709	8290	71	<u>0.2</u>	4
	Mean	10	1176	480	124	599	40	33.2	1259	17498	27.4	0.2	4.8
0.2	0630	<u>10</u>	1350	2100	168	1270	<u>40</u>	27	1220	19000	28	<u>0.2</u>	8
	0713	<u>10</u>	563	1550	56	135	<u>40</u>	25	494	5040	13	<u>0.2</u>	4
	0728	<u>10</u>	1780	2780	179	2670	<u>40</u>	50	2090	32900	<u>10</u>	<u>0.2</u>	16
	0813	<u>10</u>	724	2860	97	764	<u>40</u>	40	748	9350	19	<u>0.2</u>	18
	0825	<u>10</u>	608	1880	59	309	<u>40</u>	27	613	8270	58	<u>0.2</u>	5

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RM	Date	Cu	Hard	Fe	Mg	Mn	Ni	K	Na	Sr	Zn	Hg	As
	mmdd	µg/l	mg/l	µg/l	mg/l	µg/l	µg/l	mg/l	mg/l	µg/l	µg/l	µg/l	µg/l
	Mean	10	1005	2234	112	1030	40	33.8	1033	14912	25.6	0.2	10.2
						BRUSH RUN							
0.53	0630												
	0713												
	0728						No Flow Entire Summer						
	0813												
	0825												
						SMITH RUN							
3.24	0630						No Flow						
	0713	10	282	429	23	12	40	2	20	367	10	0.2	2
	0728	10	211	2830	16	32	40	3	16	302	16	0.2	2
	0813						No Flow						
	0826						No Flow						
	Mean	10	247	1630	19.5	22	40	2.5	18	335	13	0.2	2
0.77	0630	10	596	1620	66	307	40	4	24	13900	10	0.2	6
	0713	10	310	1440	28	70	40	3	13	3670	10	0.2	2
	0728	10	229	2570	18	53	40	4	17	2200	20	0.2	3
	0813	10	597	543	62	219	40	4	23	13200	10	0.2	6
	0826	10	562	365	63	96	40	4	25	13700	10	0.2	5
	Mean	10	459	1308	47.4	149	40	3.8	20.4	9334	12	0.2	4.4
						NORTH FORK WEST MANSFIELD CREEK							
5.58	0701	10	361	709	35	271	40	3	19	1860	14	0.2	5
	0712	10	374	1240	37	640	40	8	22	2380	10	0.2	5

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RM	Date	Cu	Hard	Fe	Mg	Mn	Ni	K	Na	Sr	Zn	Hg	As
	mmdd	µg/l	mg/l	µg/l	mg/l	µg/l	µg/l	mg/l	mg/l	µg/l	µg/l	µg/l	µg/l
	0727						No Flow						
	0812						No Flow						
	0825						No Flow						
	Mean	10	368	975	36	456	40	5.5	20.5	2120	12	0.2	5
	0701	10	358	917	36	58	40	4	26	1470	13	0.2	3
	0712	10	336	591	35	62	40	6	40	1770	12	0.2	6
3.97	0727	10	319	386	29	517	40	15	42	1890	17	0.2	10
	0812	10	370	891	34	332	40	22	74	2340	12	0.2	9
	0825	10	344	706	32	1200	40	17	128	3040	21	0.2	14
	Mean	10	345	698	33.2	434	40	12.8	62	2102	15	0.2	8.4
	0701	10	350	810	34	81	40	3	32	1320	12	0.2	2
	0712	10	304	1050	32	105	40	6	35	1410	10	0.2	4
1.28	0727	10	284	1320	29	175	40	19	38	1500	23	0.2	8
	0812	10	351	651	35	317	40	14	102	2060	10	0.2	7
	0825	10	304	2230	32	542	40	12	106	1810	34	0.2	6
	Mean	10	319	1212	32.4	244	40	10.8	62.6	1620	17.8	0.2	5.4
							WEST FORK WEST MANSFIELD CREEK						
0.78	0630	10	377	710	40	131	40	4	58	1490	26	0.2	4
	0712	10	345	806	37	106	40	7	80	2000	10	0.2	6
	0727	10	234	1110	23	297	40	9	42	1190	21	0.2	8
	0812	10	290	459	28	438	40	9	67	1600	10	0.2	9
	0825	10	284	611	29	341	40	8	80	1580	34	0.2	9

Bokes Creek Tributaries A-8

RM	Date	Cu	Hard	Fe	Mg	Mn	Ni	K	Na	Sr	Zn	Hg	As
	mmdd	µg/l	mg/l	µg/l	mg/l	µg/l	µg/l	mg/l	mg/l	µg/l	µg/l	µg/l	µg/l
	Mean	10	306	739	31.4	263	40	7.4	65.4	1572	20.2	0.2	7.2
SOUTH BRANCH WEST FORK WEST MANSFIELD CREEK													
	0701	10	447	277	48	783	40	5	98	2560	10	0.2	5
	0712	No Flow											
0.02	0727	No Flow											
	0812	No Flow											
	0825	No Flow											

Table A-9. Results of chemical/physical water quality sampling conducted in the Bokes Creek study area during July-September, 1999. Underlined values indicate concentrations below the method detection limit. NA means not analyzed. CG indicates confluent growth for microbiological results and italicized print indicates an effluent sample. An * means sampling during rain event only.

Bokes Creek Tributaries A-9								
RM	Date	Cd	Pb	Se	E. coli	E.coli MMO	Fecal Coliform	Fecal Strep
	mmdd	μg/l	μg/l	μg/l	#/100 ml	#/100 ml	#/100 ml	#/100 ml
				POWDERLICK RUN				
3.75*	0825	0.2	2	2	NA	NA	60000	100000
3.35*	0825	0.2	2	2	NA	NA	60000	100000
2.15	0630					No Flow		
	0713	0.2	2	2	340	NA	480	NA
	0728	0.2	2	2	90	NA	600	3200
	0813					No Flow		
	0825	0.2	2	2	NA	2005	60000	100000
	Mean	0.2	2	2	215	2005	20360	51600
1.60	0630	0.2	2	8	40	NA	495	1930
	0713	0.2	2	8	1210	NA	1600	NA
	0728	0.2	2	2	48000	NA	111600	113000
	0813	0.2	2	4	2000	NA	4000	12300
	0825	0.2	2	2	NA	2005	60000	100000
	Mean	0.2	2	4.8	12812.5	2005	35539	56807.5
0.2	0630	0.2	2	2	400	NA	940	665
	0713	0.2	2	2	2350	NA	1550	NA
	0728	0.2	2	2	21000	NA	31000	36000
	0813	0.2	2	2	55	NA	130	655
	0825	0.2	2	2	NA	2005	60000	100000

Bokes Creek Tributaries A-9

RM	Date	Cd	Pb	Se	E. coli	E.coli MMO	Fecal Coliform	Fecal Strep
	mmdd	µg/l	µg/l	µg/l	#/100 ml	#/100 ml	#/100 ml	#/100 ml
	Mean	0.2	2	2	5951.25	2005	18724	34330
					BRUSH RUN			
0.53	0630							
	0713							
	0728				No Flow Entire Summer			
	0813							
	0825							
					SMITH RUN			
3.24	0630				No Flow			
	0713	0.2	2	2	670	NA	1181	NA
	0728	0.2	2	2	200	NA	450	6800
	0813				No Flow			
	0826				No Flow			
	Mean	0.2	2	2	435	0	815.5	6800
0.77	0630	0.2	2	2	60	NA	290	760
	0713	0.2	2	2	400	NA	420	NA
	0728	0.2	2	2	370	NA	3400	7800
	0813	0.2	2	2	80	NA	130	2600
	0826	0.2	2	2	NA	NA	964	2500
	Mean	0.2	2	2	227.5	0	1040.8	3415
					NORTH FORK WEST MANSFIELD CREEK			
5.58	0701	0.2	2	2	325	NA	1330	1180
	0712	0.2	2	2	260	NA	420	NA

Bokes Creek Tributaries A-9

RM	Date	Cd	Pb	Se	E. coli	E.coli MMO	Fecal Coliform	Fecal Strep
	mmdd	µg/l	µg/l	µg/l	#/100 ml	#/100 ml	#/100 ml	#/100 ml
	0727					No Flow		
	0812					No Flow		
	0825					No Flow		
	Mean	0.2	2	2	292.5	0	875	1180
	0701	0.2	2	2	40	NA	545	980
	0712	0.2	2	2	540	NA	1700	NA
3.97	0727	0.2	2	2	3600	NA	5200	3300
	0812	0.2	2	2	240	NA	600	530
	0825	0.2	2	2	NA	831	3300	920
	Mean	0.2	2	2	1105	831	2269	1432.5
	0701	0.2	2	2	440	NA	1080	2240
	0712	0.2	2	2	390	NA	440	NA
1.28	0727	0.2	2	2	1390	NA	2100	227000
	0812	0.2	2	2	30	NA	80	790
	0825	0.2	2	2	NA	1091	1073	5800
	Mean	0.2	2	2	562.5	1091	954.6	58957.5
					WEST FORK WEST MANSFIELD CREEK			
0.78	0630	0.2	2	2	10	NA	890	970
	0712	0.2	2	2	360	NA	530	NA
	0727	0.2	2	2	50	NA	2000	6100
	0812	0.2	2	2	20	NA	120	1380
	0825	0.2	2	2	NA	384	700	4000

Bokes Creek Tributaries A-9

RM	Date	Cd	Pb	Se	E. coli	E.coli MMO	Fecal Coliform	Fecal Strep
	mmdd	µg/l	µg/l	µg/l	#/100 ml	#/100 ml	#/100 ml	#/100 ml
	Mean	0.2	2	2	110	384	848	3112.5
SOUTH BRANCH WEST FORK WEST MANSFIELD CREEK								
	0701	0.2	2	2	4300	NA	6800	8500
	0712				No Flow			
0.02	0727				No Flow			
	0812				No Flow			
	0825				No Flow			

Table A-10. Results of chemical/physical water quality sampling conducted in the Bokes Creek study area during July-September, 1999. Underlined values indicate concentrations below the method detection limit. NA means not analyzed. CG indicates confluent growth for microbiological results and italicized print indicates an effluent sample. An * means sampling during rain event only.

Bokes Creek Tributaries A-10

RM	Date	Alkalinity	COD	Cl	NH_3	$NO_{2/3}$	NO_2	SO_4	TKN	P
	mmdd	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
					POWDERLICK RUN					
3.75*	0825	105	57	360	1.28	29.20	1.34	185	4.92	1.24
3.35*	0825	107	64	382	1.37	26.60	1.49	172	22.30	1.39
2.15	0630	No Flow								
	0713	129	65	303	0.15	6.44	0.68	130	2.46	1.17
	0728	145	99	299	0.32	0.75	0.22	97	3.54	0.69
	0813	No Flow								
	0825	136	82	212	8.04	14.60	1.42	164	17.90	1.76
	Mean	136.666666667	82	271.3	2.837	7.263	0.773	130.3	7.967	1.207
1.60	0630	283	<u>100</u>	3850	0.09	4.33	0.22	724	2.06	0.41
	0713	284	68	1940	2.89	4.62	3.89	345	6.76	1.44
	0728	282	89	1150	7.70	0.19	0.42	225	13	1.29
	0813	331	71	2940	0.34	2.39	0.41	587	3.59	0.58
	0825	145	89	1280	6.64	9.25	1.40	194	12.80	1.45
	Mean	265	83.4	2232	3.532	4.156	1.268	415	7.642	1.034
0.2	0630	144	<u>100</u>	2460	0.43	<u>0.10</u>	0.06	408	3.47	0.91
	0713	132	56	947	0.51	8.11	1.43	160	2.68	0.23
	0728	280	112	3780	5.32	0.10	0.15	490	10.80	0.82
	0813	170	135	1300	0.33	0.10	0.03	293	4.11	0.45
	0825	120	79	1090	6.04	10.5	1.52	177	11.80	0.83

Bokes Creek Tributaries A-10

RM	Date	Alkalinity	COD	Cl	NH_3	$NO_{2/3}$	NO_2	SO_4	TKN	P
	mmdd	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
	Mean	169.2	96.4	1915	2.526	3.782	0.638	305.6	6.572	0.648
BRUSH RUN										
0.53	0630									
	0713									
	0728	No Flow Entire Summer								
	0813									
	0825									
SMITH RUN										
3.24	0630	No Flow								
	0713	165	11	34	<u>0.05</u>	7.02	0.03	59	0.54	0.09
	0728	122	32	30	0.07	5.71	0.08	36	0.89	0.17
	0813	No Flow								
	0826	No Flow								
	Mean	143.5	21.5	32	0.06	6.365	0.06	47.5	0.715	0.13
0.77	0630	286	28	22	0.12	<u>0.10</u>	<u>0.02</u>	372	0.53	0.13
	0713	159	17	24	0.06	6.06	0.09	90	0.77	0.09
	0728	130	26	32	0.13	2.46	0.14	50	0.87	0.42
	0813	297	14	19	0.15	<u>0.10</u>	<u>0.02</u>	292	0.53	0.11
	0826	259	12	14	0.10	<u>0.10</u>	<u>0.02</u>	324	0.36	0.12
	Mean	218	21.25	24.25	0.115	2.18	0.07	201	0.675	0.188
NORTH FORK WEST MANSFIELD CREEK										
5.58	0701	190	28	32	0.06	0.26	0.03	144	1.04	0.18
	0712	184	34	31	0.16	0.51	0.05	155	1.64	0.28

Bokes Creek Tributaries A-10

RM	Date (mmdd)	Alkalinity mg/l	COD mg/l	Cl mg/l	NH_3 mg/l	$NO_{2/3}$ mg/l	NO_2 mg/l	SO_4 mg/l	TKN mg/l	P mg/l
	0727				No Flow					
	0812				No Flow					
	0825				No Flow					
	Mean	187	31	31.5	0.11	0.385	0.04	149.5	1.34	0.23
3.97	0701	185	20	46	0.09	2.23	0.03	133	1.10	0.15
	0712	188	35	66	0.16	0.10	0.02	111	1.90	0.42
	0727	NA	43	NA	0.34	0.10	NA	NA	2.71	0.60
	0812	240	77	114	0.07	0.10	0.02	119	2.40	0.45
	0825	257	51	195	0.75	0.10	0.02	80	2.64	0.95
	Mean	217.5	45.2	105.3	0.282	0.526	0.02	110.8	2.15	0.514
1.28	0701	175	17	64	0.10	2.41	0.04	134	0.73	0.64
	0712	150	29	63	0.11	0.63	0.02	116	1.13	0.16
	0727	165	65	66	0.18	0.27	0.07	100	2.71	0.29
	0812	223	45	159	0.05	0.10	0.02	118	1.45	0.21
	0825	183	39	162	0.29	0.10	0.04	98	0.98	0.24
	Mean	179.2	39	102.8	0.146	0.702	0.04	113.2	1.4	0.308
				WEST FORK WEST MANSFIELD CREEK						
0.78	0630	197	23	94	0.19	0.97	0.03	167	0.83	0.24
	0712	169	29	102	0.12	0.50	0.02	171	0.82	0.49
	0727	137	46	62	0.41	0.36	0.03	86	1.72	0.45
	0812	195	39	84	0.11	0.10	0.02	114	1.07	0.46
	0825	185	27	103	0.21	0.10	0.02	96	0.96	0.42

Bokes Creek Tributaries A-10

RM	Date	Alkalinity	COD	Cl	NH_3	$NO_{2/3}$	NO_2	SO_4	TKN	P
	mmdd	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
	Mean	176.6	32.8	89	0.208	0.406	0.02	126.8	1.08	0.412
					SOUTH BRANCH WEST FORK WEST MANSFIELD CREEK					
	0701	200	31	147	0.28	0.17	0.02	227	1.31	0.16
	0712				No Flow					
0.02	0727				No Flow					
	0812				No Flow					
	0825				No Flow					

Table A-11. Results of organic chemical water quality sampling conducted in the Bokes Creek study area during June-September, 1999.

Bokes Creek Tributary Water Column Organics A-11						
Compound	**Units**	**Powderlick Run**		**N. Fork W. Mans. Tr.**	**W. Fork W. Mans. Tr.**	**Smith Run**
River Mile		*1.60*	*0.2*	*1.28*	*0.78*	*0.77*
Gamma-BHC	µg/l	0.012				
Dieldrin	µg/l					0.006
Heptachlor Eploxide	µg/l	0.006	0.007			0.004
Delta-BHC	µg/l	0.014				0.013
Aldrin	µg/l	0.010				
Heptachlor	µg/l					0.004
Atrazine	µg/l		0.500	1.000	1.000	0.300

Table A-12. Comparison of Ohio EPA database sediment chemistry statistics (Table 16) with values reported for use in Illinois (Kelly and Hite 1984), Ontario (Persaud *et al.* 1994), and consensus-based guidelines (CSBG) (MacDonald et al. 2000). Ohio elevation catagories based on median value plus 1, 2, 4 and 8 inter-quartile range values for ECBP. All values expressed as mg/kg.

Parameter	State	Non-Elevated	Slightly Elevated	Elevated	Highly Elevated	Extremely Elevated
Arsenic	OH ECBP	<9.5	9.5-13.4	13.5-21.1	21.2-36.6	>36.6
	Illinois	<8.0	8.0-10.9	11.0-16.9	17.0-28.0	>28.0
	Ontario	<6.0	Low Effect Level (LEL) ≥ 6.0< 33.0		Severe Effect Level (SEL) ≥ 33.0	
	CSBG	<9.79	Threshold Effect Concentration (TEC) ≥ 9.79 < 33.0		Probable Effect Concentration (PEC) ≥ 33.0	
Cadmium	OH ECBP	<0.563	0.563-0.744	0.745-1.106	1.107-1.830	>1.830
	Illinois	<0.500	0.500-1.000	1.001-2.000	2.001-20.00	>20.00
	Ontario	<0.600	LEL ≥ 0.6 < 10.0		SEL ≥ 10.0	
	CSBG	<0.99	TEC ≥ 0.99 < 4.98		PEC ≥ 4.98	
Chromium	OH ECBP	<20.2	20.2-26.4	26.5-38.8	38.9-63.6	>63.6
	Illinois	<16.0	16.0-23.0	23.1-38.0	38.1-60.0	>60.0
	Ontario	<26.0	LEL ≥ 26.0 < 110.0		SEL ≥ 110	
	CSBG	<43.4	TEC ≥ 43.4 < 111		PEC ≥ 111	
Copper	OH ECBP	<20.2	20.2-26.4	26.5-38.8	38.9-63.6	>63.6
	Illinois	<38.0	38.0-60.0	60.1-100	101-200	>200
	Ontario	<16.0	LEL ≥ 16.0 < 110.0		SEL >110	
	CSBG	<31.6	TEC ≥ 31.6 < 149		PEC ≥ 149	
Iron	OH ECBP	<21900	21900-28300	28301-41100	41101-66700	>66700
	Illinois	<18000	18000-23000	23001-32000	32001-50000	>50000
	Ontario	<20000	LEL ≥ 20000 < 40000		SEL ≥ 40000	
	CSBG	--	--		--	
Lead	OH ECBP	<45.3	45.3-69.6	69.7-118	119-215	>215
	Illinois	<28.0	28.0-38.0	38.1-60.0	60.1-100	>100
	Ontario	<31.0	LEL ≥ 31.0 < 250.0		SEL ≥ 250	
	CSBG	<35.8	TEC ≥ 35.8 < 128		PEC ≥ 128	
Manganese	OH ECBP	<328	328-466	467-742	743-1294	>1294
	Illinois	<1300	1300-1800	1801-2800	2801-5000	>5000
	Ontario	<460	LEL ≥ 460 < 1100.0		SEL ≥1100	
	CSBG	--	--		--	
Nickel	OH ECBP	<28.1	28.1-40.1	40.2-64.1	64.2-112	>112
	Illinois	N/A				N/A
	Ontario	<16.0	LEL ≥ 16.0 < 75.0		SEL ≥ 75.0	
	CSBG	<22.7	TEC ≥ 22.7 < 48.6		PEC ≥ 48.6	
Zinc	OH ECBP	<101	101-143	144-228	229-397	>397
	Illinois	<80.0	80.0-100	101-170	171-300	>300
	Ontario	<120	LEL ≥ 120 < 820		SEL ≥ 820	
	CSBG	<121	TEC ≥ 121 < 459		PEC ≥ 459	

Biological Data for Bokes Creek Survey, 1999-2000

Key QHEI Components

WWH Attributes: No Channelization or Recovered; Boulder/Cobble/Gravel Substrates; Silt Free Substrates; Good/Excellent Substrates; Moderate/High Sinuosity; Extensive/Moderate Cover; Fast Current/Eddies; Low-Normal Overall Embeddedness; Max Depth > 40 cm; Low-Normal Riffle Embeddedness

MWH Attributes

High Influence: Channelized or No Recovery; Silt/Muck Substrates; No Sinuosity; Sparse/No Cover; Max Depth < 40 cm (WD, HW)

Moderate Influence: Recovering Channel; Heavy/Moderate Silt Cover; Sand Substrates (Boat); Hardpan Substrate Origin; Fair/Poor Development; Low Sinuosity; Only 1-2 Cover Types; Intermittent and Poor Pools; No Fast Current; High/Mod. Overall Embeddedness; High/Mod. Riffle Embeddedness; No Riffle

River Mile	QHEI	Gradient (ft/mile)	Total WWH Attributes	Total H.I. MWH Attributes	Total M.I. MWH Attributes	(MWH H.I.+1)/(WWH+1) Ratio	(MWH M.I.+1)/(WWH+1) Ratio
(02-138) Bokes Creek							
Year 1999							
0.2	63.0	14.71	7	2	4	0.38	0.88
5.6	63.0	3.61	5	0	5	0.17	1.00
11.4	67.5	5.52	4	0	5	0.20	1.20
17.0	59.5	3.10	4	1	6	0.40	1.60
20.2	58.5	2.33	6	1	5	0.29	1.00
21.3	62.5	3.45	6	0	4	0.14	0.71
27.0	63.0	4.42	6	1	6	0.29	1.14
31.8	47.5	10.42	2	2	6	1.00	3.00
35.1	42.5	6.25	4	2	6	0.60	1.80
36.3	12.0	4.10	0	5	8	6.00	*.**
(02-139) Smith Run							
Year 1999							
0.8	61.5	15.87	6	2	4	0.43	1.00
(02-144) Powderlick Run							
Year 1999							
1.0	23.0	8.33	0	5	7	6.00	*.**
1.8	60.5	11.90	5	0	5	0.17	1.00
2.1	45.0	12.50	4	1	5	0.40	1.40
3.4	39.5	20.00	2	3	7	1.33	3.67
Year 2000							
3.7	27.0	19.23	0	5	6	6.00	*.**
4.8	31.0	18.52	1	4	6	2.50	5.50
(02-194) West Fork West Mansfield Trib.							
Year 1999							
1.0	39.0	6.41	2	3	7	1.33	3.67
(02-227) North Fork West Mansfield Trib.							
Year 1999							
1.3	51.0	7.14	5	1	5	0.33	1.17
3.8	30.5	6.41	3	2	6	0.75	2.25

Key
QHEI
Components

River Mile	QHEI	Gradient (ft/mile)	WWH Attributes (marked)	Total WWH Attributes	MWH High Influence Attributes (marked)	Total H.I. MWH Attributes	MWH Moderate Influence Attributes (marked)	Total M.I. MWH Attributes	(MWH H.I.+1)/(WWH+1) Ratio	(MWH M.I.+1)/(WWH+1) Ratio
(02-227) North Fork West Mansfield Trib.										
Year 1999										
5.6	**15.0**	9.43		0	◆ Max Depth < 40 cm (WD, HW)	5	■ Heavy/Moderate Silt Cover; ■ Intermittent and Poor Pools; ■ High/Mod. Overall Embeddedness; ■ No Riffle	8	6.00	*.**
(02-228) Brush Run										
Year 2000										
0.5	**49.0**	5.95	■ Boulder/Cobble/Gravel Substrates; ■ Extensive/Moderate Cover; ■ Max Depth > 40 cm	5	◆ Silt/Muck Substrates; ◆ Sparse/No Cover	2	■ Heavy/Moderate Silt Cover; ■ Fair/Poor Development; ■ High/Mod. Riffle Embeddedness	5	0.50	1.33
(02-330) Trib. to Powderlick Run										
Year 1999										
0.1	**52.0**	20.00	■ Boulder/Cobble/Gravel Substrates; ■ Max Depth > 40 cm	3	◆ Sparse/No Cover	2	■ Heavy/Moderate Silt Cover; ■ Low Sinuosity; ■ High/Mod. Riffle Embeddedness	6	0.75	2.25
(02-331) S. Br. W. Fk. West Mansfield Creek										
Year 2000										
0.1	**51.0**	5.38	■ Boulder/Cobble/Gravel Substrates; ■ Moderate/High Sinuosity; ■ Max Depth > 40 cm	6	◆ Sparse/No Cover	1	■ Heavy/Moderate Silt Cover; ■ Fair/Poor Development; ■ High/Mod. Riffle Embeddedness	6	0.29	1.14

WWH Attributes: No Channelization or Recovered; Boulder/Cobble/Gravel Substrates; Silt Free Substrates; Good/Excellent Substrates; Moderate/High Sinuosity; Extensive/Moderate Cover; Fast Current/Eddies; Low-Normal Overall Embeddedness; Max Depth > 40 cm; Low-Normal Riffle Embeddedness

MWH Attributes — High Influence: Channelized or No Recovery; Silt/Muck Substrates; No Sinuosity; Sparse/No Cover; Max Depth < 40 cm (WD, HW)

MWH Attributes — Moderate Influence: Recovering Channel; Heavy/Moderate Silt Cover; Sand Substrates (Boat); Hardpan Substrate Origin; Fair/Poor Development; Low Sinuosity; Only 1-2 Cover Types; Intermittent and Poor Pools; No Fast Current; High/Mod. Overall Embeddedness; High/Mod. Riffle Embeddedness; No Riffle

Species List

No of Streams: 6   Dist Fished: 3.96 km   No of Passes: 27

Grand Total of All Streams
Date Range: 06/30/1999
Thru: 10/30/2000

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
Gizzard Shad		O	M		19	1.69	0.44	0.14	1.44	211.75
Grass Pickerel		P	M	P	137	9.39	2.42	0.42	4.17	33.53
Golden Redhorse	R	I	S	M	12	0.78	0.20	0.13	1.26	84.30
Northern Hog Sucker	R	I	S	M	1	0.09	0.02	0.02	0.21	103.00
White Sucker	W	O	S	T	372	27.14	6.99	2.05	20.35	62.66
Creek Chubsucker	R	I	M		39	2.96	0.76	0.01	0.10	10.00
Common Carp	G	O	M	T	13	0.81	0.21	2.16	21.53	1,218.25
Golden Shiner	N	I	M	T	54	4.59	1.18	0.03	0.25	9.33
Creek Chub	N	G	N	T	908	72.15	18.58	0.88	8.71	38.13
Emerald Shiner	N	I	S		23	1.28	0.33	0.00	0.02	0.84
Redfin Shiner	N	I	N		34	1.93	0.50	0.01	0.10	2.44
Rosefin Shiner	N	I	S	M	69	4.56	1.18	0.01	0.12	1.89
Striped Shiner	N	I	S		121	8.15	2.10	0.20	1.97	18.09
Spotfin Shiner	N	I	M		2	0.19	0.05			
Sand Shiner	N	I	M	M	1	0.06	0.01	0.00	0.00	2.00
Silverjaw Minnow	N	I	M		13	1.20	0.31			
Fathead Minnow	N	O	C	T	304	31.02	7.99	0.00	0.00	2.00
Bluntnose Minnow	N	O	C	T	1,046	77.87	20.06	0.11	1.12	1.99
Central Stoneroller	N	H	N		241	17.91	4.61	0.04	0.41	3.06
Yellow Bullhead		I	C	T	97	6.83	1.76	0.65	6.47	68.46
Black Bullhead		I	C	P	14	1.14	0.29	0.10	0.98	111.67
Stonecat Madtom		I	C	I	2	0.12	0.03	0.01	0.06	20.00
Blackstripe Topminnow		I	M		106	9.50	2.45	0.01	0.09	3.87
White Crappie	S	I	C		1	0.09	0.02	0.03	0.33	158.00
Rock Bass	S	C	C		130	7.95	2.05	0.65	6.51	39.46
Smallmouth Bass	F	C	C	M	29	1.67	0.43	0.04	0.39	11.07
Largemouth Bass	F	C	C		10	0.65	0.17	0.16	1.64	124.89
Green Sunfish	S	I	C	T	434	27.24	7.02	1.35	13.45	25.74
Bluegill Sunfish	S	I	C	P	2	0.19	0.05	0.02	0.21	103.00
Longear Sunfish	S	I	C	M	445	28.65	7.38	0.71	7.09	12.27
Green Sf X Longear Sf					1	0.07	0.02			
Blackside Darter	D	I	S		31	1.85	0.48	0.02	0.21	6.00
Logperch	D	I	S	M	7	0.39	0.10	0.02	0.15	17.57
Johnny Darter	D	I	C		221	17.14	4.41	0.01	0.14	1.36
Greenside Darter	D	I	S	M	150	8.47	2.18	0.04	0.36	1.95
Banded Darter	D	I	S	I	13	0.72	0.19	0.00	0.01	0.58
Rainbow Darter	D	I	S	M	51	3.67	0.94	0.01	0.06	1.82
Orangethroat Darter	D	I	S		58	4.52	1.16	0.00	0.00	2.00
Fantail Darter	D	I	C		61	3.59	0.93	0.01	0.12	1.67
No Fish					0	0.00	0.00			
	Grand Total				5,272	388.22		10.06		
	Number of Species				38					
	Number of Hybrids				1					

Species List

River Code: **02-138** River Mile: **36.30**	Stream: **Bokes Creek** Basin: Scioto River Time Fished: 1080 sec Drain Area: 4.2 sq mi Dist Fished: 0.10 km No of Passes: 1	Sample Date: **1999** Date Range: 08/10/1999 Sampler Type: E

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
Grass Pickerel		P	M	P	3	9.00	7.89			
Creek Chubsucker	R	I	M		2	6.00	5.26			
Creek Chub	N	G	N	T	21	63.00	55.26			
Silverjaw Minnow	N	I	M		1	3.00	2.63			
Fathead Minnow	N	O	C	T	1	3.00	2.63			
Bluntnose Minnow	N	O	C	T	3	9.00	7.89			
Central Stoneroller	N	H	N		2	6.00	5.26			
Blackstripe Topminnow		I	M		4	12.00	10.53			
Johnny Darter	D	I	C		1	3.00	2.63			
Mile Total					38	114.00				
Number of Species					9					
Number of Hybrids					0					

River Code: **02-138**	Stream: **Bokes Creek**		Sample Date: **1999**
River Mile: **35.10**	Basin: Scioto River		Date Range: 08/09/1999
	Time Fished: 1800 sec	Drain Area: 6.0 sq mi	
	Dist Fished: 0.15 km	No of Passes: 1	Sampler Type: E

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
Grass Pickerel		P	M	P	22	44.00	3.97			
White Sucker	W	O	S	T	8	16.00	1.44			
Creek Chubsucker	R	I	M		16	32.00	2.89			
Creek Chub	N	G	N	T	346	692.00	62.45			
Silverjaw Minnow	N	I	M		1	2.00	0.18			
Bluntnose Minnow	N	O	C	T	22	44.00	3.97			
Central Stoneroller	N	H	N		58	116.00	10.47			
Blackstripe Topminnow		I	M		11	22.00	1.99			
Longear Sunfish	S	I	C	M	1	2.00	0.18			
Johnny Darter	D	I	C		37	74.00	6.68			
Orangethroat Darter	D	I	S		32	64.00	5.78			
	Mile Total				554	1,108.00				
	Number of Species				11					
	Number of Hybrids				0					

Species List

River Code: **02-138**	Stream: **Bokes Creek**	Sample Date: **1999**
River Mile: **31.80**	Basin: Scioto River	Date Range: 08/10/1999
	Time Fished: 1055 sec Drain Area: 10.0 sq mi	
	Dist Fished: 0.15 km No of Passes: 1	Sampler Type: E

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
Grass Pickerel		P	M	P	2	4.00	1.26			
Golden Shiner	N	I	M	T	1	2.00	0.63			
Creek Chub	N	G	N	T	33	66.00	20.75			
Redfin Shiner	N	I	N		2	4.00	1.26			
Rosefin Shiner	N	I	S	M	11	22.00	6.92			
Striped Shiner	N	I	S		1	2.00	0.63			
Fathead Minnow	N	O	C	T	7	14.00	4.40			
Bluntnose Minnow	N	O	C	T	64	128.00	40.25			
Central Stoneroller	N	H	N		4	8.00	2.52			
Blackstripe Topminnow		I	M		1	2.00	0.63			
Green Sunfish	S	I	C	T	2	4.00	1.26			
Longear Sunfish	S	I	C	M	2	4.00	1.26			
Johnny Darter	D	I	C		16	32.00	10.06			
Orangethroat Darter	D	I	S		13	26.00	8.18			
	Mile Total				159	318.00				
	Number of Species				14					
	Number of Hybrids				0					

Species List

River Code: **02-138**	Stream: **Bokes Creek**		Sample Date: **1999**
River Mile: **27.00**	Basin: Scioto River		Date Range: 08/09/1999
	Time Fished: 3042 sec	Drain Area: 32.0 sq mi	Thru: 09/07/1999
	Dist Fished: 0.30 km	No of Passes: 2	Sampler Type: E

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
Grass Pickerel		P	M	P	29	29.00	2.82	1.80	7.03	47.37
Golden Redhorse	R	I	S	M	4	4.00	0.39	0.08	0.31	20.00
White Sucker	W	O	S	T	147	147.00	14.27	9.73	37.99	61.59
Creek Chubsucker	R	I	M		21	21.00	2.04	0.12	0.47	10.00
Common Carp	G	O	M	T	1	1.00	0.10			
Golden Shiner	N	I	M	T	14	14.00	1.36	0.01	0.05	2.33
Creek Chub	N	G	N	T	39	39.00	3.79	2.02	7.90	36.14
Rosefin Shiner	N	I	S	M	7	7.00	0.68	0.01	0.05	1.50
Striped Shiner	N	I	S		30	30.00	2.91	0.57	2.21	18.86
Bluntnose Minnow	N	O	C	T	334	334.00	32.43	0.17	0.66	0.65
Central Stoneroller	N	H	N		20	20.00	1.94	0.16	0.62	4.00
Yellow Bullhead		I	C	T	59	59.00	5.73	2.60	10.15	39.39
Black Bullhead		I	C	P	4	4.00	0.39	0.60	2.34	100.00
Blackstripe Topminnow		I	M		14	14.00	1.36	0.02	0.08	1.43
Rock Bass	S	C	C		19	19.00	1.84	1.20	4.68	54.55
Smallmouth Bass	F	C	C	M	1	1.00	0.10	0.04	0.16	20.00
Largemouth Bass	F	C	C		5	5.00	0.49	1.00	3.90	125.00
Green Sunfish	S	I	C	T	47	47.00	4.56	1.00	3.90	18.52
Longear Sunfish	S	I	C	M	165	165.00	16.02	4.39	17.15	17.86
Green Sf X Longear Sf					1	1.00	0.10			
Johnny Darter	D	I	C		41	41.00	3.98	0.05	0.19	1.14
Greenside Darter	D	I	S	M	1	1.00	0.10	0.00	0.02	2.00
Rainbow Darter	D	I	S	M	23	23.00	2.23	0.02	0.09	1.50
Orangethroat Darter	D	I	S		1	1.00	0.10	0.00	0.02	2.00
Fantail Darter	D	I	C		3	3.00	0.29	0.01	0.04	1.67
	Mile Total				1,030	1,030.00		25.62		
	Number of Species				24					
	Number of Hybrids				1					

River Code: **02-138**	Stream: **Bokes Creek**		Sample Date: **1999**
River Mile: **21.30**	Basin: Scioto River		Date Range: 08/09/1999
	Time Fished: 3189 sec	Drain Area: 41.0 sq mi	Thru: 09/07/1999
	Dist Fished: 0.40 km	No of Passes: 2	Sampler Type: D

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
Gizzard Shad		O	M		1	0.75	0.14	0.19	1.53	253.00
Grass Pickerel		P	M	P	27	20.25	3.91	0.76	6.08	37.41
Golden Redhorse	R	I	S	M	6	4.50	0.87	0.42	3.33	92.17
White Sucker	W	O	S	T	74	55.50	10.72	3.11	24.99	56.08
Common Carp	G	O	M	T	1	0.75	0.14	0.20	1.57	260.00
Golden Shiner	N	I	M	T	5	3.75	0.72	0.02	0.17	5.60
Creek Chub	N	G	N	T	63	47.25	9.13	1.57	12.60	33.21
Redfin Shiner	N	I	N		3	2.25	0.43	0.01	0.06	3.00
Rosefin Shiner	N	I	S	M	15	11.25	2.17	0.02	0.13	1.40
Striped Shiner	N	I	S		27	20.25	3.91	0.33	2.65	16.30
Sand Shiner	N	I	M	M	1	0.75	0.14	0.00	0.01	2.00
Fathead Minnow	N	O	C	T	1	0.75	0.14	0.00	0.01	2.00
Bluntnose Minnow	N	O	C	T	119	89.25	17.25	0.27	2.18	3.04
Central Stoneroller	N	H	N		1	0.75	0.14	0.00	0.03	5.00
Yellow Bullhead		I	C	T	16	12.00	2.32	1.23	9.88	102.50
Black Bullhead		I	C	P	2	1.50	0.29	0.16	1.26	105.00
Blackstripe Topminnow		I	M		2	1.50	0.29	0.00	0.03	2.50
Rock Bass	S	C	C		39	29.25	5.65	1.53	12.26	52.18
Smallmouth Bass	F	C	C	M	3	2.25	0.43	0.06	0.48	26.67
Green Sunfish	S	I	C	T	81	60.75	11.74	1.34	10.74	22.01
Longear Sunfish	S	I	C	M	176	132.00	25.51	1.19	9.58	9.03
Blackside Darter	D	I	S		7	5.25	1.01	0.02	0.18	4.29
Johnny Darter	D	I	C		5	3.75	0.72	0.01	0.06	1.90
Greenside Darter	D	I	S	M	9	6.75	1.30	0.02	0.13	2.33
Rainbow Darter	D	I	S	M	3	2.25	0.43	0.01	0.05	2.67
Fantail Darter	D	I	C		3	2.25	0.43	0.01	0.04	2.33
Mile Total					690	517.50		12.45		
Number of Species					26					
Number of Hybrids					0					

River Code: **02-138**	Stream: **Bokes Creek**	Sample Date: **1999**
River Mile: **20.20**	Basin: Scioto River	Date Range: 08/09/1999
	Time Fished: 2728 sec Drain Area: 45.0 sq mi	Thru: 09/07/1999
	Dist Fished: 0.38 km No of Passes: 2	Sampler Type: D

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
Gizzard Shad		O	M		1	0.83	0.26	0.13	1.24	152.00
Grass Pickerel		P	M	P	24	19.00	6.01	0.68	6.66	35.72
White Sucker	W	O	S	T	19	15.42	4.87	1.58	15.49	102.79
Golden Shiner	N	I	M	T	6	5.00	1.58	0.04	0.41	8.33
Creek Chub	N	G	N	T	53	42.00	13.28	2.17	21.29	51.75
Rosefin Shiner	N	I	S	M	10	8.33	2.64	0.03	0.25	3.00
Striped Shiner	N	I	S		2	1.58	0.50	0.06	0.57	36.50
Bluntnose Minnow	N	O	C	T	13	10.25	3.24	0.04	0.37	3.69
Yellow Bullhead		I	C	T	13	10.50	3.32	0.86	8.46	82.34
Black Bullhead		I	C	P	1	0.83	0.26	0.13	1.31	160.00
Stonecat Madtom		I	C	I	2	1.67	0.53	0.03	0.33	20.00
Blackstripe Topminnow		I	M		4	3.25	1.03	0.03	0.31	9.50
Rock Bass	S	C	C		39	30.83	9.75	0.99	9.70	31.85
Largemouth Bass	F	C	C		2	1.58	0.50	0.37	3.58	230.00
Green Sunfish	S	I	C	T	119	94.75	29.96	2.52	24.67	26.61
Longear Sunfish	S	I	C	M	59	47.83	15.13	0.48	4.69	10.02
Blackside Darter	D	I	S		5	3.92	1.24	0.02	0.22	5.60
Logperch	D	I	S	M	1	0.75	0.24	0.01	0.13	18.00
Johnny Darter	D	I	C		18	14.83	4.69	0.02	0.16	1.11
Greenside Darter	D	I	S	M	3	2.33	0.74	0.02	0.17	7.33
Fantail Darter	D	I	C		1	0.75	0.24	0.00	0.02	3.00
	Mile Total				395	316.25		10.20		
	Number of Species				21					
	Number of Hybrids				0					

River Code: **02-138**	Stream: **Bokes Creek**		Sample Date: **1999**
River Mile: **17.00**	Basin: Scioto River		Date Range: 07/06/1999
	Time Fished: 4097 sec	Drain Area: 58.0 sq mi	Thru: 09/08/1999
	Dist Fished: 0.32 km	No of Passes: 2	Sampler Type: D

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
Gizzard Shad		O	M		2	2.50	1.57	0.55	3.88	221.00
Grass Pickerel		P	M	P	6	5.50	3.45	0.11	0.80	22.00
Golden Redhorse	R	I	S	M	2	2.00	1.26	0.30	2.12	125.00
Northern Hog Sucker	R	I	S	M	1	1.25	0.78	0.13	0.90	103.00
White Sucker	W	O	S	T	14	17.00	10.68	1.75	12.28	100.14
Common Carp	G	O	M	T	4	4.00	2.51	7.69	53.92	1,887.50
Golden Shiner	N	I	M	T	1	1.25	0.78	0.05	0.33	38.00
Bluntnose Minnow	N	O	C	T	9	7.75	4.87	0.02	0.16	3.00
Central Stoneroller	N	H	N		2	1.50	0.94	0.00	0.02	1.50
Yellow Bullhead		I	C	T	4	4.00	2.51	0.51	3.58	127.00
Blackstripe Topminnow		I	M		2	2.50	1.57	0.01	0.05	2.50
White Crappie	S	I	C		1	1.25	0.78	0.20	1.39	158.00
Rock Bass	S	C	C		15	14.75	9.26	0.41	2.89	26.80
Largemouth Bass	F	C	C		1	0.75	0.47	0.09	0.65	124.00
Green Sunfish	S	I	C	T	75	66.75	41.92	2.06	14.43	30.53
Bluegill Sunfish	S	I	C	P	1	1.25	0.78	0.13	0.90	103.00
Longear Sunfish	S	I	C	M	20	19.50	12.24	0.23	1.63	11.20
Blackside Darter	D	I	S		1	0.75	0.47	0.00	0.02	4.00
Johnny Darter	D	I	C		3	3.75	2.35	0.01	0.04	1.33
Rainbow Darter	D	I	S	M	1	1.25	0.78	0.00	0.02	2.00
Mile Total					165	159.25		14.26		
Number of Species					20					
Number of Hybrids					0					

River Code: **02-138**	Stream: **Bokes Creek**		Sample Date: **1999**
River Mile: **11.40**	Basin: Scioto River		Date Range: 06/30/1999
	Time Fished: 1320 sec	Drain Area: 67.0 sq mi	
	Dist Fished: 0.20 km	No of Passes: 1	Sampler Type: D

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
Grass Pickerel		P	M	P	2	3.00	1.00	0.01	0.60	4.00
Creek Chub	N	G	N	T	20	30.00	10.00	0.55	27.83	18.42
Redfin Shiner	N	I	N		17	25.50	8.50	0.06	3.02	2.35
Striped Shiner	N	I	S		7	10.50	3.50	0.15	7.55	14.29
Bluntnose Minnow	N	O	C	T	27	40.50	13.50	0.12	5.89	2.89
Central Stoneroller	N	H	N		2	3.00	1.00	0.02	0.75	5.00
Rock Bass	S	C	C		10	15.00	5.00	0.30	15.10	20.00
Green Sunfish	S	I	C	T	6	9.00	3.00	0.17	8.71	19.17
Longear Sunfish	S	I	C	M	8	12.00	4.00	0.16	7.95	13.13
Blackside Darter	D	I	S		2	3.00	1.00	0.02	0.86	5.50
Johnny Darter	D	I	C		15	22.50	7.50	0.04	2.01	1.77
Greenside Darter	D	I	S	M	43	64.50	21.50	0.27	13.39	4.12
Rainbow Darter	D	I	S	M	7	10.50	3.50	0.03	1.46	2.80
Fantail Darter	D	I	C		34	51.00	17.00	0.10	4.98	1.94
	Mile Total				200	300.00		1.99		
	Number of Species				14					
	Number of Hybrids				0					

River Code: **02-138**	Stream: **Bokes Creek**	Sample Date: **1999**
River Mile: **5.60**	Basin: Scioto River	Date Range: 07/06/1999
	Time Fished: 3655 sec Drain Area: 74.0 sq mi	Thru: 09/09/1999
	Dist Fished: 0.40 km No of Passes: 2	Sampler Type: D

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
Grass Pickerel		P	M	P	11	8.25	3.33	0.06	0.63	6.97
White Sucker	W	O	S	T	32	24.00	9.70	0.97	10.60	40.31
Common Carp	G	O	M	T	1	0.75	0.30	5.10	55.88	6,800.00
Golden Shiner	N	I	M	T	3	2.25	0.91	0.03	0.37	15.00
Creek Chub	N	G	N	T	7	5.25	2.12	0.23	2.51	43.57
Redfin Shiner	N	I	N		12	9.00	3.64	0.02	0.24	2.42
Rosefin Shiner	N	I	S	M	17	12.75	5.15	0.02	0.25	1.76
Striped Shiner	N	I	S		31	23.25	9.39	0.44	4.83	18.95
Bluntnose Minnow	N	O	C	T	87	65.25	26.36	0.12	1.31	1.84
Rock Bass	S	C	C		8	6.00	2.42	0.25	2.76	41.88
Largemouth Bass	F	C	C		2	1.50	0.61	0.03	0.33	20.00
Green Sunfish	S	I	C	T	79	59.25	23.94	1.59	17.40	26.80
Longear Sunfish	S	I	C	M	8	6.00	2.42	0.10	1.06	16.13
Blackside Darter	D	I	S		13	9.75	3.94	0.07	0.78	7.31
Logperch	D	I	S	M	6	4.50	1.82	0.08	0.87	17.50
Johnny Darter	D	I	C		8	6.00	2.42	0.01	0.09	1.38
Greenside Darter	D	I	S	M	4	3.00	1.21	0.01	0.09	2.75
Fantail Darter	D	I	C		1	0.75	0.30	0.00	0.02	2.00
	Mile Total				330	247.50		9.13		
	Number of Species				18					
	Number of Hybrids				0					

River Code: **02-138**	Stream: **Bokes Creek**		Sample Date: **1999**
River Mile: **0.20**	Basin: Scioto River		Date Range: 06/30/1999
	Time Fished: 2100 sec	Drain Area: 84.1 sq mi	
	Dist Fished: 0.20 km	No of Passes: 1	Sampler Type: D

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
Common Carp	G	O	M	T	6	9.00	1.98	0.01	1.39	1.50
Emerald Shiner	N	I	S		23	34.50	7.59	0.03	2.87	0.84
Bluntnose Minnow	N	O	C	T	52	78.00	17.16	0.17	16.35	2.12
Central Stoneroller	N	H	N		74	111.00	24.42	0.31	30.53	2.77
Smallmouth Bass	F	C	C	M	24	36.00	7.92	0.32	31.22	8.75
Green Sunfish	S	I	C	T	2	3.00	0.66	0.06	5.95	20.00
Greenside Darter	D	I	S	M	87	130.50	28.71	0.08	8.03	0.62
Banded Darter	D	I	S	I	13	19.50	4.29	0.01	1.09	0.58
Rainbow Darter	D	I	S	M	7	10.50	2.31	0.01	0.79	0.80
Fantail Darter	D	I	C		15	22.50	4.95	0.02	1.88	0.83
	Mile Total				303	454.50		1.01		
	Number of Species				10					
	Number of Hybrids				0					

River Code: **02-139**	Stream: **Smith Run**	Sample Date: **1999**
River Mile: **0.80**	Basin: Scioto River	Date Range: 08/10/1999
	Time Fished: 1440 sec Drain Area: 5.6 sq mi	
	Dist Fished: 0.12 km No of Passes: 1	Sampler Type: E

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
Gizzard Shad		O	M		15	37.50	5.19			
White Sucker	W	O	S	T	25	62.50	8.65			
Creek Chub	N	G	N	T	44	110.00	15.22			
Rosefin Shiner	N	I	S	M	9	22.50	3.11			
Spotfin Shiner	N	I	M		2	5.00	0.69			
Fathead Minnow	N	O	C	T	4	10.00	1.38			
Bluntnose Minnow	N	O	C	T	84	210.00	29.07			
Central Stoneroller	N	H	N		62	155.00	21.45			
Blackstripe Topminnow		I	M		1	2.50	0.35			
Smallmouth Bass	F	C	C	M	1	2.50	0.35			
Johnny Darter	D	I	C		30	75.00	10.38			
Orangethroat Darter	D	I	S		12	30.00	4.15			
Mile Total					289	722.50				
Number of Species					12					
Number of Hybrids					0					

River Code: **02-144**	Stream: **Powderlick Run**	Sample Date: **2000**
River Mile: **4.80**	Basin: Scioto River	Date Range: 10/30/2000
	Time Fished: 1800 sec Drain Area: 0.6 sq mi	
	Dist Fished: 0.10 km No of Passes: 1	Sampler Type: E

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
White Sucker	W	O	S	T	1	3.00	0.58			
Creek Chub	N	G	N	T	12	36.00	6.94			
Fathead Minnow	N	O	C	T	153	459.00	88.44			
Green Sunfish	S	I	C	T	7	21.00	4.05			
Mile Total					173	519.00				
Number of Species					4					
Number of Hybrids					0					

River Code: **02-144**	Stream: **Powderlick Run**		Sample Date: **2000**
River Mile: **3.70**	Basin: Scioto River		Date Range: 10/30/2000
	Time Fished: 900 sec	Drain Area: 1.4 sq mi	
	Dist Fished: 0.10 km	No of Passes: 1	Sampler Type: E

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
Creek Chub	N	G	N	T	2	6.00	7.14			
Fathead Minnow	N	O	C	T	10	30.00	35.71			
Blackstripe Topminnow		I	M		16	48.00	57.14			
	Mile Total				28	84.00				
	Number of Species				3					
	Number of Hybrids				0					

River Code: **02-144**	Stream: **Powderlick Run**		Sample Date: **1999**
River Mile: **3.40**	Basin: Scioto River		Date Range: 08/10/1999
	Time Fished: 588 sec	Drain Area: 1.6 sq mi	
	Dist Fished: 0.12 km	No of Passes: 1	Sampler Type: E

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
Creek Chub	N	G	N	T	6	15.00	5.56			
Fathead Minnow	N	O	C	T	100	250.00	92.59			
Blackstripe Topminnow		I	M		1	2.50	0.93			
Green Sunfish	S	I	C	T	1	2.50	0.93			
Mile Total					108	270.00				
Number of Species					4					
Number of Hybrids					0					

River Code: **02-144** River Mile: **2.10**	Stream: **Powderlick Run** Basin: Scioto River Time Fished: 922 sec Drain Area: 2.2 sq mi Dist Fished: 0.12 km No of Passes: 1	Sample Date: **1999** Date Range: 08/11/1999 Sampler Type: F

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
Creek Chub	N	G	N	T	9	22.50	18.75			
Fathead Minnow	N	O	C	T	17	42.50	35.42			
Central Stoneroller	N	H	N		4	10.00	8.33			
Blackstripe Topminnow		I	M		16	40.00	33.33			
Green Sunfish	S	I	C	T	2	5.00	4.17			
Mile Total					48	120.00				
Number of Species					5					
Number of Hybrids					0					

River Code: **02-144**	Stream: **Powderlick Run**		Sample Date: **1999**
River Mile: **1.80**	Basin: Scioto River		Date Range: 08/11/1999
	Time Fished: 641 sec	Drain Area: 2.9 sq mi	
	Dist Fished: 0.12 km	No of Passes: 1	Sampler Type: F

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
No Fish					0	0.00	0			
	Mile Total				0					
	Number of Species				0					
	Number of Hybrids				0					

Species List

River Code: **02-144**	Stream: **Powderlick Run**	Sample Date: **1999**
River Mile: **1.00**	Basin: Scioto River	Date Range: 08/11/1999
	Time Fished: 390 sec Drain Area: 3.4 sq mi	
	Dist Fished: 0.12 km No of Passes: 1	Sampler Type: E

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
Creek Chub	N	G	N	T	5	12.50	41.67			
Fathead Minnow	N	O	C	T	4	10.00	33.33			
Blackstripe Topminnow		I	M		3	7.50	25.00			
	Mile Total				12	30.00				
	Number of Species				3					
	Number of Hybrids				0					

River Code: **02-194**	Stream: **West Fork West Mansfield Creek**	Sample Date: **1999**
River Mile: **1.00**	Basin: Scioto River	Date Range: 08/11/1999
	Time Fished: 1500 sec Drain Area: 4.9 sq mi	
	Dist Fished: 0.12 km No of Passes: 1	Sampler Type: E

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
Grass Pickerel		P	M	P	2	5.00	0.45			
White Sucker	W	O	S	T	25	62.50	5.57			
Creek Chub	N	G	N	T	169	422.50	37.64			
Striped Shiner	N	I	S		8	20.00	1.78			
Silverjaw Minnow	N	I	M		9	22.50	2.00			
Fathead Minnow	N	O	C	T	7	17.50	1.56			
Bluntnose Minnow	N	O	C	T	188	470.00	41.87			
Central Stoneroller	N	H	N		9	22.50	2.00			
Blackstripe Topminnow		I	M		2	5.00	0.45			
Green Sunfish	S	I	C	T	1	2.50	0.22			
Bluegill Sunfish	S	I	C	P	1	2.50	0.22			
Johnny Darter	D	I	C		28	70.00	6.24			
Mile Total					449	1,122.50				
Number of Species					12					
Number of Hybrids					0					

River Code: **02-227**	Stream: **North Fork West Mansfield Creek**	Sample Date: **1999**
River Mile: **5.60**	Basin: Scioto River	Date Range: 08/11/1999
	Time Fished: 876 sec Drain Area: 3.1 sq mi	
	Dist Fished: 0.10 km No of Passes: 1	Sampler Type: F

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
Yellow Bullhead		I	C	T	2	6.00	66.67			
Black Bullhead		I	C	P	1	3.00	33.33			
Mile Total					3	9.00				
Number of Species					2					
Number of Hybrids					0					

River Code: **02-227**	Stream: **North Fork West Mansfield Creek**	Sample Date: **1999**
River Mile: **3.80**	Basin: Scioto River	Date Range: 08/11/1999
	Time Fished: 900 sec Drain Area: 5.9 sq mi	
	Dist Fished: 0.12 km No of Passes: 1	Sampler Type: F

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
Golden Shiner	N	I	M	T	5	12.50	8.77			
Creek Chub	N	G	N	T	3	7.50	5.26			
Striped Shiner	N	I	S		4	10.00	7.02			
Yellow Bullhead		I	C	T	3	7.50	5.26			
Black Bullhead		I	C	P	6	15.00	10.53			
Blackstripe Topminnow		I	M		28	70.00	49.12			
Green Sunfish	S	I	C	T	8	20.00	14.04			
Mile Total					57	142.50				
Number of Species					7					
Number of Hybrids					0					

River Code: **02-227**	Stream: **North Fork West Mansfield Creek**	Sample Date: **1999**
River Mile: **1.30**	Basin: Scioto River	Date Range: 08/11/1999
	Time Fished: 1208 sec Drain Area: 8.7 sq mi	
	Dist Fished: 0.12 km No of Passes: 1	Sampler Type: E

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
Grass Pickerel		P	M	P	5	12.50	2.60			
White Sucker	W	O	S	T	20	50.00	10.42			
Creek Chub	N	G	N	T	60	150.00	31.25			
Striped Shiner	N	I	S		11	27.50	5.73			
Silverjaw Minnow	N	I	M		2	5.00	1.04			
Bluntnose Minnow	N	O	C	T	44	110.00	22.92			
Central Stoneroller	N	H	N		3	7.50	1.56			
Blackstripe Topminnow		I	M		1	2.50	0.52			
Green Sunfish	S	I	C	T	1	2.50	0.52			
Longear Sunfish	S	I	C	M	6	15.00	3.13			
Blackside Darter	D	I	S		3	7.50	1.56			
Johnny Darter	D	I	C		19	47.50	9.90			
Greenside Darter	D	I	S	M	3	7.50	1.56			
Rainbow Darter	D	I	S	M	10	25.00	5.21			
Fantail Darter	D	I	C		4	10.00	2.08			
Mile Total					192	480.00				
Number of Species					15					
Number of Hybrids					0					

River Code: **02-228** River Mile: **0.50**	Stream: **Brush Run** Basin: Scioto River Time Fished: 1800 sec Drain Area: 3.2 sq mi Dist Fished: 0.10 km No of Passes: 1	Sample Date: **2000** Date Range: 10/30/2000 Sampler Type: E

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
Grass Pickerel		P	M	P	4	12.00	8.16			
White Sucker	W	O	S	T	7	21.00	14.29			
Golden Shiner	N	I	M	T	19	57.00	38.78			
Creek Chub	N	G	N	T	16	48.00	32.65			
Green Sunfish	S	I	C	T	3	9.00	6.12			
	Mile Total				49	147.00				
	Number of Species				5					
	Number of Hybrids				0					

Species List

River Code: **02-330**	Stream: **Trib. to Powderlick Run**	Sample Date: **1999**
River Mile: **0.10**	Basin: Scioto River	Date Range: 08/11/1999
	Time Fished: 832 sec Drain Area: 0.7 sq mi	
	Dist Fished: 0.10 km No of Passes: 1	Sampler Type: F

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
No Fish					0	0.00	0			
	Mile Total				0					
	Number of Species				0					
	Number of Hybrids				0					

Ohio EPA/DSW Ecological Assessment Section
Macroinvertebrate Collection

Collection Dat 08/30/1999 02-138 Bokes Creek RM: 36.30

Taxa Code	Taxa	Quant/Qual
04664	*Helobdella stagnalis*	+
04666	*Helobdella triserialis*	+
04935	*Erpobdella punctata punctata*	+
06201	*Hyalella azteca*	+
08250	*Orconectes (Procericambarus) rusticus*	+
13400	*Stenacron sp*	+
22001	*Coenagrionidae*	+
28955	*Libellula lydia*	+
42700	*Belostoma sp*	+
45400	*Trichocorixa sp*	+
47600	*Sialis sp*	+
60900	*Peltodytes sp*	+
67000	*Helophorus sp*	+
67800	*Tropisternus sp*	+
68700	*Dubiraphia sp*	+
71300	*Limonia sp*	+
79030	*Tanypus "punctipennis" (sensu Roback, 1977)*	+
82730	*Chironomus (C.) decorus group*	+
83300	*Glyptotendipes (G.) sp*	+
84750	*Stictochironomus sp*	+
86200	*Tabanus sp*	+
86501	*Stratiomyidae*	+
95100	*Physella sp*	+
96264	*Planorbella (Pierosoma) pilsbryi*	+
98600	*Sphaerium sp*	+

No. Quantitative Taxa: 0 Total Taxa: 25

No. Qualitative Taxa: 25 ICI:

Number of Organisms: 0 Qual EPT: 1

Ohio EPA/DSW Ecological Assessment Section
Macroinvertebrate Collection

Collection Dat 08/30/1999 02-138 Bokes Creek RM: 35.00

Taxa Code	Taxa	Quant/Qual
01900	*Nemertea*	+
02600	*Nematomorpha*	+
03600	*Oligochaeta*	+
04687	*Placobdella parasitica*	+
04935	*Erpobdella punctata punctata*	+
05800	*Caecidotea sp*	+
06201	*Hyalella azteca*	+
08250	*Orconectes (Procericambarus) rusticus*	+
11200	*Callibaetis sp*	+
13400	*Stenacron sp*	+
13521	*Stenonema femoratum*	+
17200	*Caenis sp*	+
22001	*Coenagrionidae*	+
22300	*Argia sp*	+
23600	*Aeshna sp*	+
23909	*Boyeria vinosa*	+
24900	*Gomphus sp*	+
27500	*Somatochlora sp*	+
28955	*Libellula lydia*	+
42700	*Belostoma sp*	+
45100	*Palmacorixa sp*	+
45300	*Sigara sp*	+
47600	*Sialis sp*	+
59500	*Oecetis sp*	+
60900	*Peltodytes sp*	+
63300	*Hydroporus sp*	+
63700	*Ilybius sp*	+
63900	*Laccophilus sp*	+
67000	*Helophorus sp*	+
67800	*Tropisternus sp*	+
68702	*Dubiraphia bivittata*	+
69713	*Lutrochus laticeps*	+
72900	*Culex sp*	+
78680	*Procladius (Psilotanypus) bellus*	+
82730	*Chironomus (C.) decorus group*	+
83040	*Dicrotendipes neomodestus*	+
83051	*Dicrotendipes simpsoni*	+
83380	*Goeldichironomus holoprasinus*	+
84210	*Paratendipes albimanus or P. duplicatus*	+
84460	*Polypedilum (P.) fallax group*	+
84750	*Stictochironomus sp*	+
86100	*Chrysops sp*	+
86501	*Stratiomyidae*	+
95100	*Physella sp*	+
98600	*Sphaerium sp*	+

No. Quantitative Taxa: 0 Total Taxa: 45

No. Qualitative Taxa: 45 ICI:

Number of Organisms: 0 Qual EPT: 5

Ohio EPA/DSW Ecological Assessment Section
Macroinvertebrate Collection

Collection Dat 08/30/1999 02-138 Bokes Creek RM: 31.90

Taxa Code	Taxa	Quant/Qual
01801	*Turbellaria*	+
03360	*Plumatella sp*	+
04935	*Erpobdella punctata punctata*	+
06201	*Hyalella azteca*	+
08250	*Orconectes (Procericambarus) rusticus*	+
14950	*Leptophlebia sp or Paraleptophlebia sp*	+
22001	*Coenagrionidae*	+
22300	*Argia sp*	+
28500	*Libellula sp*	+
45300	*Sigara sp*	+
45400	*Trichocorixa sp*	+
52200	*Cheumatopsyche sp*	+
59310	*Mystacides sepulchralis*	+
59500	*Oecetis sp*	+
60900	*Peltodytes sp*	+
65800	*Berosus sp*	+
68707	*Dubiraphia quadrinotata*	+
68708	*Dubiraphia vittata group*	+
71300	*Limonia sp*	+
86501	*Stratiomyidae*	+
94400	*Fossaria sp*	+
95100	*Physella sp*	+
98600	*Sphaerium sp*	+

No. Quantitative Taxa: 0 Total Taxa: 23

No. Qualitative Taxa: 23 ICI:

Number of Organisms: 0 Qual EPT: 4

Ohio EPA/DSW Ecological Assessment Section
Macroinvertebrate Collection

Collection Dat 08/31/1999 02-138 Bokes Creek RM: 27.30

Taxa Code	Taxa	Quant/Qual
01801	*Turbellaria*	+
0260C	*Nematomorpha*	+
0360C	*Oligochaeta*	+
04685	*Placobdella ornata*	+
06201	*Hyalella azteca*	+
1340C	*Stenacron sp*	+
22001	*Coenagrionidae*	+
2230C	*Argia sp*	+
2850C	*Libellula sp*	+
4270C	*Belostoma sp*	+
4330C	*Ranatra sp*	+
4510C	*Palmacorixa sp*	+
4540C	*Trichocorixa sp*	+
4760C	*Sialis sp*	+
5220C	*Cheumatopsyche sp*	+
58505	*Helicopsyche borealis*	+
6090C	*Peltodytes sp*	+
6580C	*Berosus sp*	+
6650C	*Enochrus sp*	+
6780C	*Tropisternus sp*	+
6942C	*Stenelmis sexlineata*	+
7130C	*Limonia sp*	+
77355	*Clinotanypus pinguis*	+
8273C	*Chironomus (C.) decorus group*	+
8454C	*Polypedilum (Tripodura) scalaenum group*	+
8475C	*Stictochironomus sp*	+
8550C	*Paratanytarsus sp*	+
9510C	*Physella sp*	+
9860C	*Sphaerium sp*	+
9910C	*Pyganodon grandis*	+
9986C	*Lampsilis radiata luteola*	+

No. Quantitative Taxa: 0 Total Taxa: 31

No. Qualitative Taxa: 31 ICI:

Number of Organisms: 0 Qual EPT: 3

Ohio EPA/DSW Ecological Assessment Section
Macroinvertebrate Collection

Collection Dat 08/31/1999 02-138 Bokes Creek RM: 21.20

Taxa Code	Taxa	Quant	Qual
00805	*Spongilla lacustris*		+
01320	*Hydra sp*	14	
01801	*Turbellaria*	9	+
03600	*Oligochaeta*	1	
04964	*Mooreobdella microstoma*		+
06201	*Hyalella azteca*		+
08250	*Orconectes (Procericambarus) rusticus*		+
08601	*Hydracarina*		+
11020	*Acerpenna pygmaeus*	19	+
11120	*Baetis flavistriga*	1	
11130	*Baetis intercalaris*	3	
13000	*Leucrocuta sp*	9	+
13400	*Stenacron sp*	27	+
13521	*Stenonema femoratum*		+
17200	*Caenis sp*	2	+
21200	*Calopteryx sp*		+
22300	*Argia sp*	48	+
43300	*Ranatra sp*		+
45400	*Trichocorixa sp*		+
47600	*Sialis sp*	1	+
51600	*Polycentropus sp*		+
52200	*Cheumatopsyche sp*	88	+
57400	*Neophylax sp*		+
57900	*Pycnopsyche sp*		+
59970	*Petrophila sp*		+
66500	*Enochrus sp*		+
67300	*Hydrochus sp*		+
68075	*Psephenus herricki*		+
68201	*Scirtidae*	6	+
68708	*Dubiraphia vittata group*	1	
68901	*Macronychus glabratus*	33	+
69400	*Stenelmis sp*	21	+
69420	*Stenelmis sexlineata*	23	+
71300	*Limonia sp*		+
71900	*Tipula sp*		+
77120	*Ablabesmyia mallochi*		+
77500	*Conchapelopia sp*	3	
77740	*Hayesomyia senata*	10	+
78140	*Labrundinia pilosella*	6	
78450	*Nilotanypus fimbriatus*	16	
78655	*Procladius (Holotanypus) sp*	3	
80360	*Corynoneura "celeripes" (sensu Simpson & Bode, 1980)*	6	
80370	*Corynoneura lobata*	21	
81825	*Rheocricotopus (Psilocricotopus) robacki*	3	
82730	*Chironomus (C.) decorus group*	7	
83040	*Dicrotendipes neomodestus*	3	
83300	*Glyptotendipes (G.) sp*	7	
83820	*Microtendipes "caelum" (sensu Simpson & Bode, 1980)*	3	
83840	*Microtendipes pedellus group*	72	
84210	*Paratendipes albimanus or P. duplicatus*	26	
84450	*Polypedilum (P.) flavum*	101	+
84460	*Polypedilum (P.) fallax group*	13	
84470	*Polypedilum (P.) illinoense*	16	+
84540	*Polypedilum (Tripodura) scalaenum group*	7	
84888	*Xenochironomus xenolabis*		+
85500	*Paratanytarsus sp*	7	
85625	*Rheotanytarsus exiguus group*	29	+
85720	*Stempellinella n.sp nr. flavidula*	3	
85800	*Tanytarsus sp*	10	
85802	*Tanytarsus curticornis group*	10	
85821	*Tanytarsus glabrescens group sp 7*	10	
85840	*Tanytarsus guerlus group*	20	
93200	*Hydrobiidae*	1	
93900	*Elimia sp*	140	+
94400	*Fossaria sp*		+
95100	*Physella sp*	9	
96900	*Ferrissia sp*	35	+
98600	*Sphaerium sp*	15	+
99160	*Anodontoides ferussacianus*		+
99860	*Lampsilis radiata luteola*		+

No. Quantitative Taxa: 47 Total Taxa: 70

No. Qualitative Taxa: 42 ICI: **36**

Number of Organisms: 918 Qual EPT: 9

Ohio EPA/DSW Ecological Assessment Section
Macroinvertebrate Collection

Collection Dat 08/31/1999 02-138 Bokes Creek RM: 20.40

Taxa Code	Taxa	Quant/Qual	
03600	*Oligochaeta*	8	
07840	*Cambarus (Cambarus) sciotensis*		+
08250	*Orconectes (Procericambarus) rusticus*		+
11020	*Acerpenna pygmaeus*	2	
13400	*Stenacron sp*	44	+
13521	*Stenonema femoratum*	1	+
18501	*Ephemeridae*		+
21200	*Calopteryx sp*		+
22001	*Coenagrionidae*	1	
22300	*Argia sp*	32	+
24107	*Nasiaeschna pentacantha*		+
45400	*Trichocorixa sp*	2	+
47600	*Sialis sp*		+
52200	*Cheumatopsyche sp*	66	+
57900	*Pycnopsyche sp*		+
63300	*Hydroporus sp*		+
68075	*Psephenus herricki*		+
68708	*Dubiraphia vittata group*	1	+
68901	*Macronychus glabratus*	12	+
69225	*Optioservus fastiditus*		+
69400	*Stenelmis sp*		+
69420	*Stenelmis sexlineata*	5	+
71300	*Limonia sp*		+
72501	*Culicidae*		+
77500	*Conchapelopia sp*	8	
77750	*Hayesomyia senata or Thienemannimyia norena*	2	+
80370	*Corynoneura lobata*	99	
82730	*Chironomus (C.) decorus group*	2	
83040	*Dicrotendipes neomodestus*	6	
83300	*Glyptotendipes (G.) sp*	17	+
83840	*Microtendipes pedellus group*	4	+
84210	*Paratendipes albimanus or P. duplicatus*	6	+
84450	*Polypedilum (P.) flavum*	33	+
84460	*Polypedilum (P.) fallax group*	10	
84540	*Polypedilum (Tripodura) scalaenum group*	2	
84750	*Stictochironomus sp*		+
85625	*Rheotanytarsus exiguus group*	83	+
85800	*Tanytarsus sp*	8	+
85821	*Tanytarsus glabrescens group sp 7*	8	+
86100	*Chrysops sp*		+
87540	*Hemerodromia sp*	6	

Taxa Code	Taxa	Quant/Qual	
93900	*Elimia sp*	32	+
95100	*Physella sp*	1	+
96900	*Ferrissia sp*	5	+
98600	*Sphaerium sp*		+
99001	*Unionidae*		+
99100	*Pyganodon grandis*		+

No. Quantitative Taxa: 29 Total Taxa: 47

No. Qualitative Taxa: 37 ICI: **34**

Number of Organisms: 508 Qual EPT: 5

Ohio EPA/DSW Ecological Assessment Section
Macroinvertebrate Collection

Collection Dat 08/31/1999 02-138 Bokes Creek RM: 16.80

Taxa Code	Taxa	Quant/Qual
01801	*Turbellaria*	+
03301	*Plumatellidae*	+
03600	*Oligochaeta*	+
08250	*Orconectes (Procericambarus) rusticus*	+
08601	*Hydracarina*	+
11651	*Procloeon sp (w/o hindwing pads)*	+
13400	*Stenacron sp*	+
13521	*Stenonema femoratum*	+
17200	*Caenis sp*	+
22001	*Coenagrionidae*	+
22300	*Argia sp*	+
29000	*Sympetrum sp*	+
45300	*Sigara sp*	+
47600	*Sialis sp*	+
51600	*Polycentropus sp*	+
52200	*Cheumatopsyche sp*	+
58505	*Helicopsyche borealis*	+
59970	*Petrophila sp*	+
60900	*Peltodytes sp*	+
68075	*Psephenus herricki*	+
68708	*Dubiraphia vittata group*	+
69420	*Stenelmis sexlineata*	+
77120	*Ablabesmyia mallochi*	+
82730	*Chironomus (C.) decorus group*	+
82820	*Cryptochironomus sp*	+
83040	*Dicrotendipes neomodestus*	+
83300	*Glyptotendipes (G.) sp*	+
83840	*Microtendipes pedellus group*	+
84210	*Paratendipes albimanus or P. duplicatus*	+
84450	*Polypedilum (P.) flavum*	+
84470	*Polypedilum (P.) illinoense*	+
84750	*Stictochironomus sp*	+
93200	*Hydrobiidae*	+
95100	*Physella sp*	+
98200	*Pisidium sp*	+
98600	*Sphaerium sp*	+
99100	*Pyganodon grandis*	+
99860	*Lampsilis radiata luteola*	+

Taxa Code	Taxa	Quant/Qual

No. Quantitative Taxa: 0
No. Qualitative Taxa: 38
Number of Organisms: 0
Total Taxa: 38
ICI:
Qual EPT: 7

Ohio EPA/DSW Ecological Assessment Section
Macroinvertebrate Collection

Collection Dat 09/01/1999 02-138 Bokes Creek RM: 11.40

Taxa Code	Taxa	Quant/Qual
00401	*Spongillidae*	+
01801	*Turbellaria*	+
03600	*Oligochaeta*	+
04660	*Helobdella sp*	+
04685	*Placobdella ornata*	+
06201	*Hyalella azteca*	+
08250	*Orconectes (Procericambarus) rusticus*	+
08601	*Hydracarina*	+
13400	*Stenacron sp*	+
13521	*Stenonema femoratum*	+
17200	*Caenis sp*	+
22300	*Argia sp*	+
23909	*Boyeria vinosa*	+
45300	*Sigara sp*	+
47600	*Sialis sp*	+
51600	*Polycentropus sp*	+
57400	*Neophylax sp*	+
58505	*Helicopsyche borealis*	+
60900	*Peltodytes sp*	+
66500	*Enochrus sp*	+
67800	*Tropisternus sp*	+
68075	*Psephenus herricki*	+
69400	*Stenelmis sp*	+
69420	*Stenelmis sexlineata*	+
74501	*Ceratopogonidae*	+
78655	*Procladius (Holotanypus) sp*	+
83040	*Dicrotendipes neomodestus*	+
83840	*Microtendipes pedellus group*	+
84210	*Paratendipes albimanus or P. duplicatus*	+
84750	*Stictochironomus sp*	+
93900	*Elimia sp*	+
95100	*Physella sp*	+
98600	*Sphaerium sp*	+
99860	*Lampsilis radiata luteola*	+

No. Quantitative Taxa: 0 Total Taxa: 34
No. Qualitative Taxa: 34 ICI:
Number of Organisms: 0 Qual EPT: 6

Ohio EPA/DSW Ecological Assessment Section
Macroinvertebrate Collection

Collection Dat 09/01/1999 02-138 Bokes Creek RM: 5.40

Taxa Code	Taxa	Quant/Qual
00805	*Spongilla lacustris*	+
01801	*Turbellaria*	+
03362	*Plumatella casmiana*	+
03600	*Oligochaeta*	+
04964	*Mooreobdella microstoma*	+
05800	*Caecidotea sp*	+
06201	*Hyalella azteca*	+
06700	*Crangonyx sp*	+
08250	*Orconectes (Procericambarus) rusticus*	+
11020	*Acerpenna pygmaeus*	+
11130	*Baetis intercalaris*	+
13000	*Leucrocuta sp*	+
13400	*Stenacron sp*	+
13521	*Stenonema femoratum*	+
17200	*Caenis sp*	+
18704	*Hexagenia atrocaudata*	+
22001	*Coenagrionidae*	+
22300	*Argia sp*	+
23804	*Basiaeschna janata*	+
44700	*Corisella sp*	+
45300	*Sigara sp*	+
45400	*Trichocorixa sp*	+
48410	*Corydalus cornutus*	+
52200	*Cheumatopsyche sp*	+
67500	*Laccobius sp*	+
68075	*Psephenus herricki*	+
68707	*Dubiraphia quadrinotata*	+
69420	*Stenelmis sexlineata*	+
71300	*Limonia sp*	+
72700	*Anopheles sp*	+
77120	*Ablabesmyia mallochi*	+
77750	*Hayesomyia senata or Thienemannimyia norena*	+
78655	*Procladius (Holotanypus) sp*	+
80370	*Corynoneura lobata*	+
82820	*Cryptochironomus sp*	+
83040	*Dicrotendipes neomodestus*	+
83840	*Microtendipes pedellus group*	+
84210	*Paratendipes albimanus or P. duplicatus*	+
84450	*Polypedilum (P.) flavum*	+
84460	*Polypedilum (P.) fallax group*	+
84470	*Polypedilum (P.) illinoense*	+
84750	*Stictochironomus sp*	+
93900	*Elimia sp*	+
96900	*Ferrissia sp*	+
98600	*Sphaerium sp*	+

No. Quantitative Taxa: 0 Total Taxa: 45

No. Qualitative Taxa: 45 ICI:

Number of Organisms: 0 Qual EPT: 8

Ohio EPA/DSW Ecological Assessment Section
Macroinvertebrate Collection

Collection Dat 09/01/1999 02-138 Bokes Creek RM: 0.20

Taxa Code	Taxa	Quant/Qual
01801	*Turbellaria*	+
03360	*Plumatella sp*	+
03600	*Oligochaeta*	+
04685	*Placobdella ornata*	+
04686	*Placobdella papillifera*	+
05900	*Lirceus sp*	+
06201	*Hyalella azteca*	+
08250	*Orconectes (Procericambarus) rusticus*	+
08601	*Hydracarina*	+
13400	*Stenacron sp*	+
13521	*Stenonema femoratum*	+
17200	*Caenis sp*	+
18704	*Hexagenia atrocaudata*	+
22001	*Coenagrionidae*	+
22300	*Argia sp*	+
30000	*Plecoptera*	+
43205	*Nepa apiculata*	+
43300	*Ranatra sp*	+
45300	*Sigara sp*	+
47600	*Sialis sp*	+
51600	*Polycentropus sp*	+
52200	*Cheumatopsyche sp*	+
57400	*Neophylax sp*	+
60900	*Peltodytes sp*	+
63300	*Hydroporus sp*	+
66500	*Enochrus sp*	+
67800	*Tropisternus sp*	+
68075	*Psephenus herricki*	+
69420	*Stenelmis sexlineata*	+
72700	*Anopheles sp*	+
83840	*Microtendipes pedellus group*	+
84210	*Paratendipes albimanus or P. duplicatus*	+
84750	*Stictochironomus sp*	+
93200	*Hydrobiidae*	+
95100	*Physella sp*	+
96900	*Ferrissia sp*	+
98600	*Sphaerium sp*	+

No. Quantitative Taxa: 0 Total Taxa: 37

No. Qualitative Taxa: 37 ICI:

Number of Organisms: 0 Qual EPT: 8

Ohio EPA/DSW Ecological Assessment Section
Macroinvertebrate Collection

Collection Dat 09/07/1999 02-139 Smith Run RM: 0.80

Taxa Code	Taxa	Quant/Qual
03600	*Oligochaeta*	+
04935	*Erpobdella punctata punctata*	+
05900	*Lirceus sp*	+
06201	*Hyalella azteca*	+
08250	*Orconectes (Procericambarus) rusticus*	+
13400	*Stenacron sp*	+
13521	*Stenonema femoratum*	+
17200	*Caenis sp*	+
18700	*Hexagenia sp*	+
22001	*Coenagrionidae*	+
24900	*Gomphus sp*	+
45100	*Palmacorixa sp*	+
47600	*Sialis sp*	+
60900	*Peltodytes sp*	+
67800	*Tropisternus sp*	+
82730	*Chironomus (C.) decorus group*	+
85800	*Tanytarsus sp*	+
95100	*Physella sp*	+
98600	*Sphaerium sp*	+

No. Quantitative Taxa: 0 Total Taxa: 19
No. Qualitative Taxa: 19 ICI:
Number of Organisms: 0 Qual EPT: 4

Ohio EPA/DSW Ecological Assessment Section
Macroinvertebrate Collection

Collection Dat 09/03/1999 02-144 Powderlick Run RM: 4.80

Taxa Code	Taxa	Quant/Qual
11200	*Callibaetis sp*	+
28955	*Libellula lydia*	+
45400	*Trichocorixa sp*	+
63900	*Laccophilus sp*	+
65800	*Berosus sp*	+
67800	*Tropisternus sp*	+
72900	*Culex sp*	+
74501	*Ceratopogonidae*	+
78702	*Psectrotanypus dyari*	+
79020	*Tanypus neopunctipennis*	+
83380	*Goeldichironomus holoprasinus*	+
87400	*Stratiomys sp*	+

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

Ohio EPA/DSW Ecological Assessment Section
Macroinvertebrate Collection

Collection Dat 09/03/1999 02-144 Powderlick Run RM: 3.70

Taxa Code	Taxa	Quant/Qual
1120C	*Callibaetis sp*	+
2881C	*Pantala flavescens*	+
28955	*Libellula lydia*	+
4270C	*Belostoma sp*	+
4530C	*Sigara sp*	+
6090C	*Peltodytes sp*	+
6330C	*Hydroporus sp*	+
6570C	*Anacaena sp*	+
6580C	*Berosus sp*	+
6620C	*Cymbiodyta sp*	+
6780C	*Tropisternus sp*	+
74501	*Ceratopogonidae*	+
7900C	*Tanypus sp*	+
8952C	*Ephydra (E.) sp*	+
9390C	*Elimia sp*	+
9510C	*Physella sp*	+

No. Quantitative Taxa: 0 Total Taxa: 16

No. Qualitative Taxa: 16 ICI:

Number of Organisms: 0 Qual EPT: 1

Ohio EPA/DSW Ecological Assessment Section
Macroinvertebrate Collection

Collection Dat 09/03/1999 02-144 Powderlick Run RM: 3.30

Taxa Code	Taxa	Quant/Qual
11200	*Callibaetis sp*	+
22700	*Ischnura sp*	+
28955	*Libellula lydia*	+
45300	*Sigara sp*	+
60900	*Peltodytes sp*	+
63900	*Laccophilus sp*	+
67800	*Tropisternus sp*	+
72900	*Culex sp*	+
78655	*Procladius (Holotanypus) sp*	+
78702	*Psectrotanypus dyari*	+
82711	*Chironomus (C.) sp 1*	+
82730	*Chironomus (C.) decorus group*	+
86202	*Tabanus atratus*	+
93900	*Elimia sp*	+
95100	*Physella sp*	+

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

Ohio EPA/DSW Ecological Assessment Section
Macroinvertebrate Collection

Collection Dat 09/03/1999 02-144 Powderlick Run RM: 2.10

Taxa Code	Taxa	Quant/Qual
03360	*Plumatella sp*	+
03600	*Oligochaeta*	+
23704	*Anax junius*	+
28955	*Libellula lydia*	+
42700	*Belostoma sp*	+
45300	*Sigara sp*	+
45400	*Trichocorixa sp*	+
60900	*Peltodytes sp*	+
63700	*Ilybius sp*	+
65800	*Berosus sp*	+
66500	*Enochrus sp*	+
67800	*Tropisternus sp*	+
78702	*Psectrotanypus dyari*	+
83380	*Goeldichironomus holoprasinus*	+
84750	*Stictochironomus sp*	+
86100	*Chrysops sp*	+
93900	*Elimia sp*	+
95100	*Physella sp*	+

No. Quantitative Taxa: 0 Total Taxa: 18

No. Qualitative Taxa: 18 ICI:

Number of Organisms: 0 Qual EPT: 0

Ohio EPA/DSW Ecological Assessment Section
Macroinvertebrate Collection

Collection Dat 09/02/1999 02-144 Powderlick Run RM: 1.60

Taxa Code	Taxa	Quant	Qual
03600	*Oligochaeta*	1195	+
22001	*Coenagrionidae*		+
22700	*Ischnura sp*		+
28500	*Libellula sp*		+
45400	*Trichocorixa sp*		+
60900	*Peltodytes sp*		+
65800	*Berosus sp*		+
66500	*Enochrus sp*		+
67800	*Tropisternus sp*	3	+
74501	*Ceratopogonidae*	14	+
79000	*Tanypus sp*	80	
79010	*Tanypus carinatus*		+
79020	*Tanypus neopunctipennis*		+
82730	*Chironomus (C.) decorus group*		+
89001	*Sciomyzidae*		+
89510	*Ephydra sp*	11	+

No. Quantitative Taxa: 9 Total Taxa: 16

No. Qualitative Taxa: 15 ICI: **0**

Number of Organisms: 12337 Qual EPT: 0

Ohio EPA/DSW Ecological Assessment Section
Macroinvertebrate Collection

Collection Dat 09/02/1999 02-144 Powderlick Run RM: 1.20

Taxa Code	Taxa	Quant/Qual	
0360	*Oligochaeta*	200	+
1120	*Callibaetis sp*	1	+
2230	*Argia sp*		+
2270	*Ischnura sp*		+
2760	*Epitheca (Tetragoneuria) sp*		+
2895	*Libellula lydia*		+
4540	*Trichocorixa sp*		+
6090	*Peltodytes sp*		+
6330	*Hydroporus sp*		+
6580	*Berosus sp*	23	+
6650	*Enochrus sp*		+
6750	*Laccobius sp*		+
6770	*Paracymus sp*		+
6780	*Tropisternus sp*		+
68201	*Scirtidae*	4	
6942	*Stenelmis sexlineata*	8	
7110	*Hexatoma sp*		+
74501	*Ceratopogonidae*	28	+
7902	*Tanypus neopunctipennis*	22	+
82711	*Chironomus (C.) sp 1*	11	+
8338	*Goeldichironomus holoprasinus*	2	+
89001	*Sciomyzidae*		+
8951	*Ephydra sp*		+
9510	*Physella sp*	122	+
9690	*Ferrissia sp*	4	

No. Quantitative Taxa: 17 Total Taxa: 25

No. Qualitative Taxa: 22 ICI: **4**

Number of Organisms: 4158 Qual EPT: 1

Ohio EPA/DSW Ecological Assessment Section
Macroinvertebrate Collection

Collection Dat 09/02/1999 02-144 Powderlick Run RM: 0.90

Taxa Code	Taxa	Quant/Qual	
0360C	*Oligochaeta*	1535	
0825C	*Orconectes (Procericambarus) rusticus*		+
1120C	*Callibaetis sp*		+
22001	*Coenagrionidae*	2!	+
2850C	*Libellula sp*		+
4270C	*Belostoma sp*		+
4530C	*Sigara sp*		+
4540C	*Trichocorixa sp*		+
6330C	*Hydroporus sp*		+
6390C	*Laccophilus sp*		+
6580C	*Berosus sp*	:	+
6780C	*Tropisternus sp*		+
68201	*Scirtidae*		+
6940C	*Stenelmis sp*	1	
74501	*Ceratopogonidae*	2ξ	+
7902C	*Tanypus neopunctipennis*	1:	+
82711	*Chironomus (C.) sp 1*	:	+
8338C	*Goeldichironomus holoprasinus*	9:	+
8400C	*Parachironomus sp*	2	
8496C	*Pseudochironomus sp*	:	+
8550C	*Paratanytarsus sp*	1	
8580C	*Tanytarsus sp*	:	+
8610C	*Chrysops sp*	:	+
9510C	*Physella sp*	8‹	+

No. Quantitative Taxa: 14 Total Taxa: 24

No. Qualitative Taxa: 20 ICI: **6**

Number of Organisms: 1791 Qual EPT: 1

Ohio EPA/DSW Ecological Assessment Section
Macroinvertebrate Collection

Collection Dat 09/03/1999 02-194 West Fork West Mansfield Creek RM: 0.80

Taxa Code	Taxa	Quant/Qual
01801	*Turbellaria*	+
03600	*Oligochaeta*	+
04666	*Helobdella triserialis*	+
06201	*Hyalella azteca*	+
11250	*Centroptilum sp (w/o hindwing pads)*	+
11651	*Procloeon sp (w/o hindwing pads)*	+
13400	*Stenacron sp*	+
13521	*Stenonema femoratum*	+
17200	*Caenis sp*	+
22001	*Coenagrionidae*	+
22300	*Argia sp*	+
27500	*Somatochlora sp*	+
45100	*Palmacorixa sp*	+
47600	*Sialis sp*	+
59300	*Mystacides sp*	+
59500	*Oecetis sp*	+
60400	*Gyrinus sp*	+
60900	*Peltodytes sp*	+
65800	*Berosus sp*	+
68300	*Cyphon sp*	+
68707	*Dubiraphia quadrinotata*	+
68708	*Dubiraphia vittata group*	+
71900	*Tipula sp*	+
72700	*Anopheles sp*	+
77500	*Conchapelopia sp*	+
78401	*Natarsia species A (sensu Roback, 1978)*	+
78655	*Procladius (Holotanypus) sp*	+
83002	*Dicrotendipes modestus*	+
83040	*Dicrotendipes neomodestus*	+
83051	*Dicrotendipes simpsoni*	+
84210	*Paratendipes albimanus or P. duplicatus*	+
84315	*Phaenopsectra flavipes*	+
84470	*Polypedilum (P.) illinoense*	+
84750	*Stictochironomus sp*	+
85800	*Tanytarsus sp*	+
85821	*Tanytarsus glabrescens group sp 7*	+
95100	*Physella sp*	+
96002	*Helisoma anceps anceps*	+
98600	*Sphaerium sp*	+

No. Quantitative Taxa: 0 Total Taxa: 39

No. Qualitative Taxa: 39 ICI:

Number of Organisms: 0 Qual EPT: 7

Ohio EPA/DSW Ecological Assessment Section
Macroinvertebrate Collection

Collection Dat 09/03/1999 02-227 North Fork West Mansfield Creek RM: 5.60

Taxa Code	Taxa	Quant/Qual	Taxa Code	Taxa	Quant/Qual
06201	*Hyalella azteca*	+			
17200	*Caenis sp*	+			
22001	*Coenagrionidae*	+			
22700	*Ischnura sp*	+			
42700	*Belostoma sp*	+			
66500	*Enochrus sp*	+			
68707	*Dubiraphia quadrinotata*	+			
89716	*Limnophora discreta*	+			
95100	*Physella sp*	+			

No. Quantitative Taxa: 0 Total Taxa: 9

No. Qualitative Taxa: 9 ICI:

Number of Organisms: 0 Qual EPT: 1

Ohio EPA/DSW Ecological Assessment Section
Macroinvertebrate Collection

Collection Dat 09/03/1999 02-227 North Fork West Mansfield Creek RM: 4.00

Taxa Code	Taxa	Quant/Qual
01801	*Turbellaria*	+
03040	*Fredericella sp*	+
03360	*Plumatella sp*	+
03600	*Oligochaeta*	+
04666	*Helobdella triserialis*	+
04964	*Mooreobdella microstoma*	+
06201	*Hyalella azteca*	+
11200	*Callibaetis sp*	+
17200	*Caenis sp*	+
22700	*Ischnura sp*	+
27500	*Somatochlora sp*	+
28705	*Pachydiplax longipennis*	+
29000	*Sympetrum sp*	+
42700	*Belostoma sp*	+
60900	*Peltodytes sp*	+
65800	*Berosus sp*	+
67000	*Helophorus sp*	+
68702	*Dubiraphia bivittata*	+
68707	*Dubiraphia quadrinotata*	+
78655	*Procladius (Holotanypus) sp*	+
82711	*Chironomus (C.) sp 1*	+
82730	*Chironomus (C.) decorus group*	+
82800	*Cladopelma sp*	+
83002	*Dicrotendipes modestus*	+
83158	*Endochironomus nigricans*	+
95100	*Physella sp*	+

No. Quantitative Taxa: 0 Total Taxa: 26

No. Qualitative Taxa: 26 ICI:

Number of Organisms: 0 Qual EPT: 2

Ohio EPA/DSW Ecological Assessment Section
Macroinvertebrate Collection

Collection Dat 09/03/1999 02-227 North Fork West Mansfield Creek RM: 1.30

Taxa Code	Taxa	Quant/Qual
03360	*Plumatella sp*	+
03600	*Oligochaeta*	+
05800	*Caecidotea sp*	+
06201	*Hyalella azteca*	+
08250	*Orconectes (Procericambarus) rusticus*	+
13400	*Stenacron sp*	+
13521	*Stenonema femoratum*	+
17200	*Caenis sp*	+
22001	*Coenagrionidae*	+
22300	*Argia sp*	+
27500	*Somatochlora sp*	+
45300	*Sigara sp*	+
45400	*Trichocorixa sp*	+
45900	*Notonecta sp*	+
47600	*Sialis sp*	+
63300	*Hydroporus sp*	+
68201	*Scirtidae*	+
68708	*Dubiraphia vittata group*	+
69400	*Stenelmis sp*	+
71300	*Limonia sp*	+
82730	*Chironomus (C.) decorus group*	+
83300	*Glyptotendipes (G.) sp*	+
83840	*Microtendipes pedellus group*	+
84315	*Phaenopsectra flavipes*	+
84470	*Polypedilum (P.) illinoense*	+
84750	*Stictochironomus sp*	+
95100	*Physella sp*	+
96900	*Ferrissia sp*	+
98600	*Sphaerium sp*	+

No. Quantitative Taxa: 0 Total Taxa: 29

No. Qualitative Taxa: 29 ICI:

Number of Organisms: 0 Qual EPT: 3

Ohio EPA/DSW Ecological Assessment Section
Macroinvertebrate Collection

Collection Dat 09/03/1999 02-331 S. Br. W. Fk. West Mansfield Creek RM: 0.10

Taxa Code	Taxa	Quant/Qual	Taxa Code	Taxa	Quant/Qual
04664	*Helobdella stagnalis*	+			
05800	*Caecidotea sp*	+			
06700	*Crangonyx sp*	+			
11200	*Callibaetis sp*	+			
22700	*Ischnura sp*	+			
28955	*Libellula lydia*	+			
60900	*Peltodytes sp*	+			
63900	*Laccophilus sp*	+			
67700	*Paracymus sp*	+			
68201	*Scirtidae*	+			
95100	*Physella sp*	+			
95907	*Gyraulus (Torquis) parvus*	+			
98200	*Pisidium sp*	+			

No. Quantitative Taxa: 0 Total Taxa: 13

No. Qualitative Taxa: 13 ICI:

Number of Organisms: 0 Qual EPT: 1