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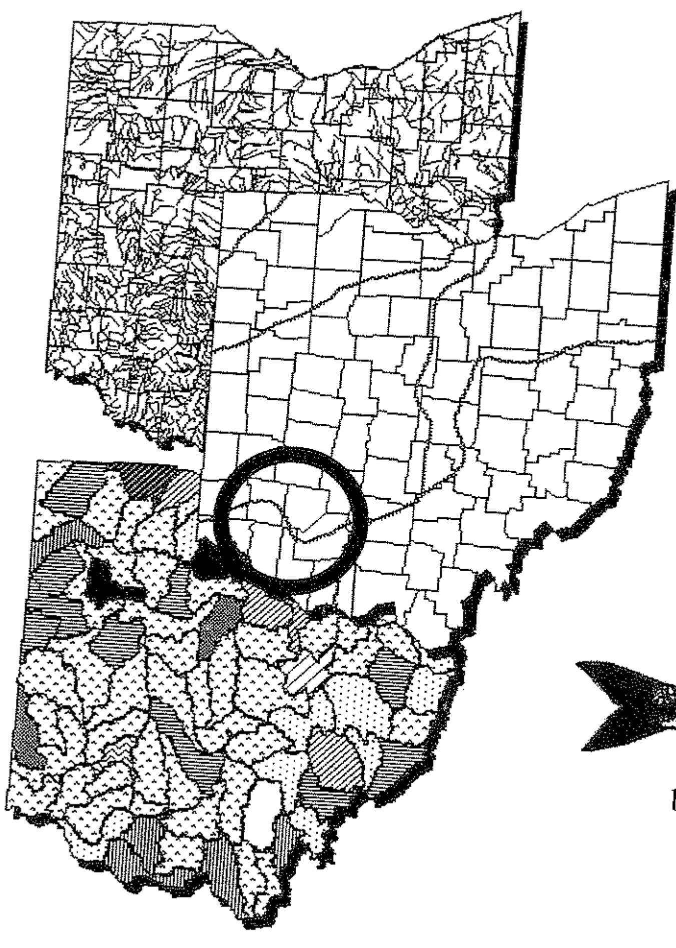
State of Ohio
Environmental Protection Agency

Ecological Assessment Unit
Monitoring and Assessment Section
Division of Surface Water

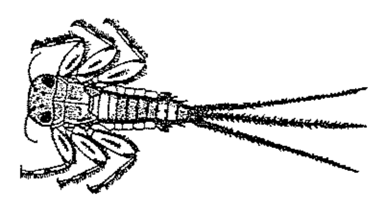
Biological and Water Quality Study of the Little Miami River and Selected Tributaries

Clark, Greene, Montgomery, Warren, Clermont, and Hamilton Counties (Ohio)

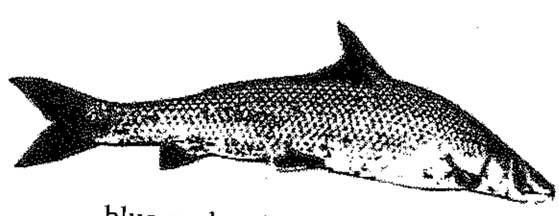
Volume 1



zebra mussel *(Dreissena polymorpha)*
(exotic introduced species)



mayfly nymph *(Stenonema sp.)*



blue sucker *(Cycleptus elongatus)*
(native Ohio Endangered species)

P.O. Box 1049, 1800 WaterMark Dr., Columbus, Ohio 43216-1049

Biological and Water Quality Study of the Little Miami River and Selected Tributaries

Clark, Greene, Montgomery, Warren, Clermont, and Hamilton Counties (Ohio)

OEPA Technical Report MAS/1994-12-11

Volume I

State of Ohio Environmental Protection Agency
Division of Surface Water
Monitoring and Assessment Section
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and
Nonpoint Source Program
1800 WaterMark Drive
Columbus, Ohio 43266-0149
and
Southwest District Office
401 East Fifth Street
Dayton, Ohio 45402-2911

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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 Ohio EPA 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. Division of Water Quality Monitoring & Assessment, 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. Division of Water Quality Monitoring & Assessment, 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. Division of Water Quality Planning & Assessment, 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. Division of Water Quality Planning & Assessment, Ecological Assessment Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1990. The use of biological criteria in the Ohio EPA surface water monitoring and assessment program. Division of Water Quality Planning & Assessment, Ecological Assessment Section, Columbus, Ohio.

Rankin, E.T. 1989. The qualitative habitat evaluation index (QHEI): rationale,methods, and application. Division of Water Quality Planning & Assessment, Ecological Assessment Section, Columbus, Ohio.

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

Ohio EPA, Division of Surface Water
Monitoring and Assessment Section
1685 Westbelt Drive
Columbus, Ohio 43228-3809
(614) 728-3377

ACKNOWLEDGEMENTS

The following persons are acknowledged for their significant contributions to this report.

Report Coordinator, Plates, Introduction, and Summary - Randall E. Sanders
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Macroinvertebrate Assemblages - Mike Bolton
Fish Assemblages - Randall E. Sanders
Programming and Data Management - Charlie Staudt, Edward T. Rankin, and Dennis Mishne
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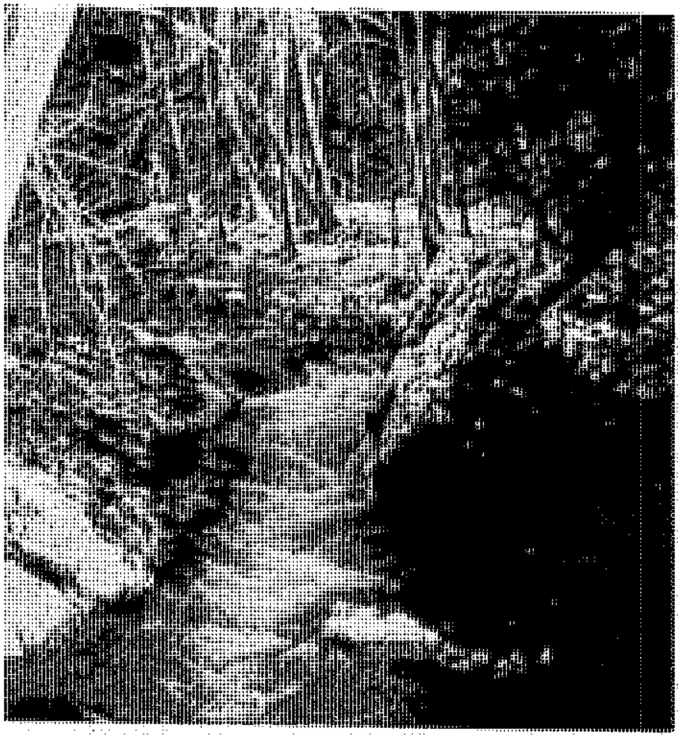
This evaluation and report would not have been possible without the assistance of the study team and numerous full and part time staff in the field and offices. The chemistry analyses (laboratory) were conducted by the Ohio EPA, Division of Environmental Services. Datasonde results were provided by the Water Quality Modeling Unit. The Ohio EPA also thanks and acknowledges the following property owners who permitted access to the sampling locations throughout the study area: D. Halder, Greene County Parks, the Beavercreek and Sugarcreek WWTPs, the City of Beavercreek, Montgomery County Eastern Regional WWTP, Xenia Glady Run WWTP and Xenia Water Department, the City of Waynesville, the City of Loveland, Hamilton Co. Parks, the City of Milford, the City of Indian Hill, Little Miami Incorporated, the Clermont Co. Fish and Game Club, and Shelter Cove Marina.

The following individuals are acknowledged for providing photos that appear in the color plates:

John Kopec and Stu Lewis - Ohio Department of Natural Resources, Division of Natural Areas and Preserves (Plate 1. Top Photos; Plate 2. Top and Bottom Right Photos; Plate 4. Top Left Photo; and Plate 12. Top Right Photo).
Dave Ross - Ohio Department of Natural Resources, Division of Wildlife (Plate 7. Bottom Left; and Plate 9. Top Left Photo).
Dr. Michael Hoggarth - Otterbein College (Plate 7. Bottom Right Photo).

All other photos were provided by Ohio EPA, Division of Surface Water staff.



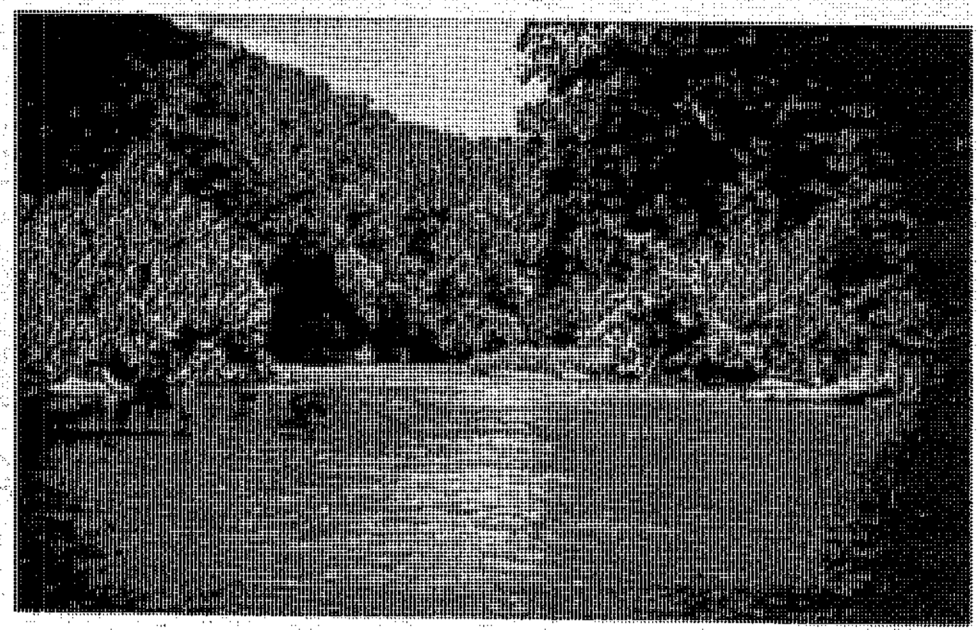


PLATE 1. WATER RESOURCE: Draining 1,757 square miles of glaciated southwest Ohio, the Little Miami River mainstem is the state's fourth largest Ohio River tributary. The river maintains a relatively steep gradient throughout it's 105.5 mile length and flows through several steep-sloped, forested gorges. The Little Miami River was the state's first designated national and state scenic river and contains some of Ohio's most beautiful and diverse riverine habitats. Two of the most scenic sections are located in the Clifton Gorge ***(Top Photos)*** and Fort Ancient ***(Bottom Photos)*** segments. The mainstem is the longest stream in Ohio designated Exceptional Warmwater Habitat.

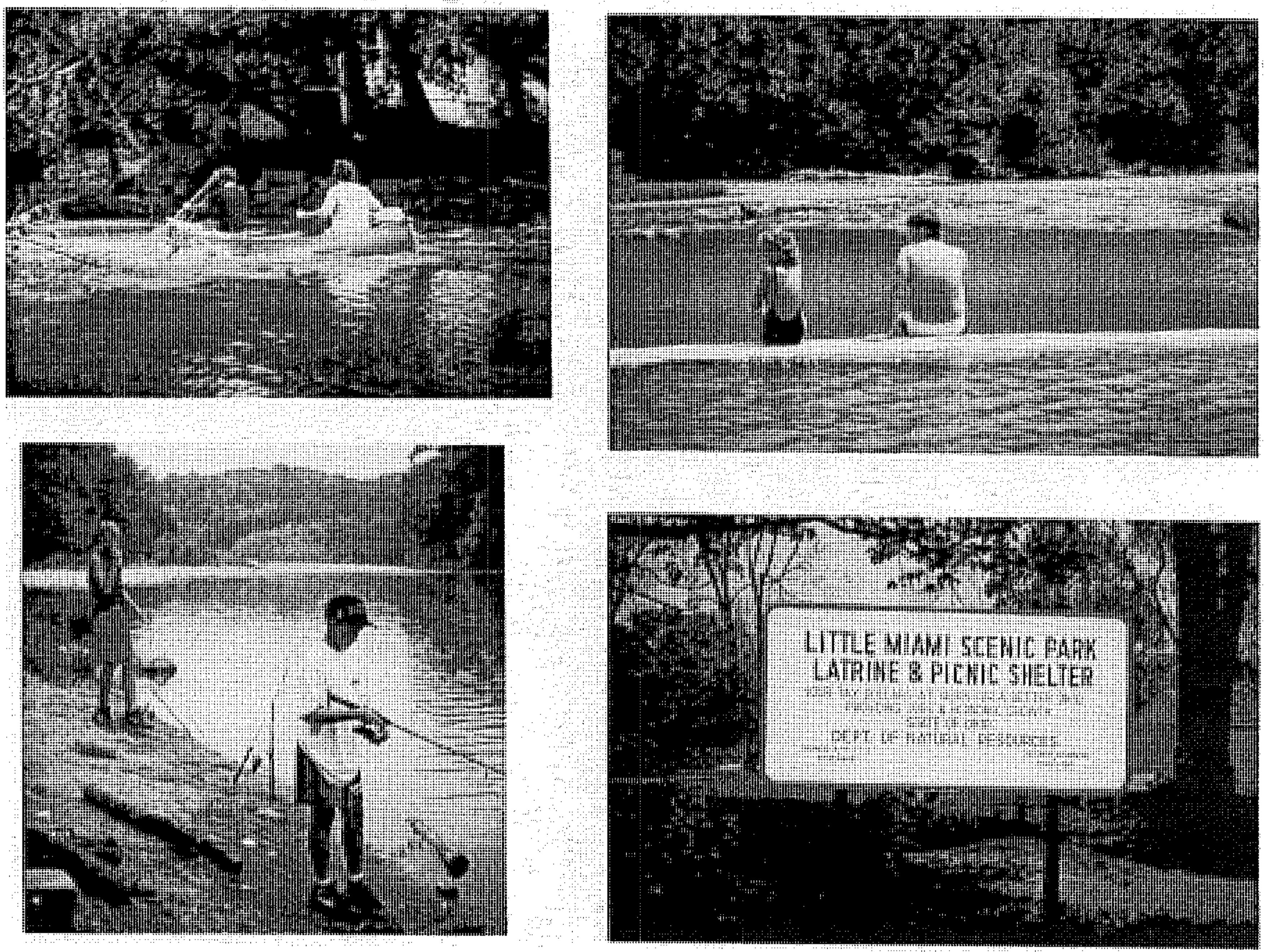


PLATE 2. RECREATIONAL USE: With seven canoe liveries located on the mainstem, the Little Miami River is one of Ohio's most popular canoeing streams ***(Top Left)***. The mainstem and large tributaries also support other recreational uses such as wading and swimming ***(Top Right)*** and sport fishing ***(Bottom Left)***. The floodplain contains a number of State, County, and City parks ***(Bottom Right)*** which provide public access to the mainstem.

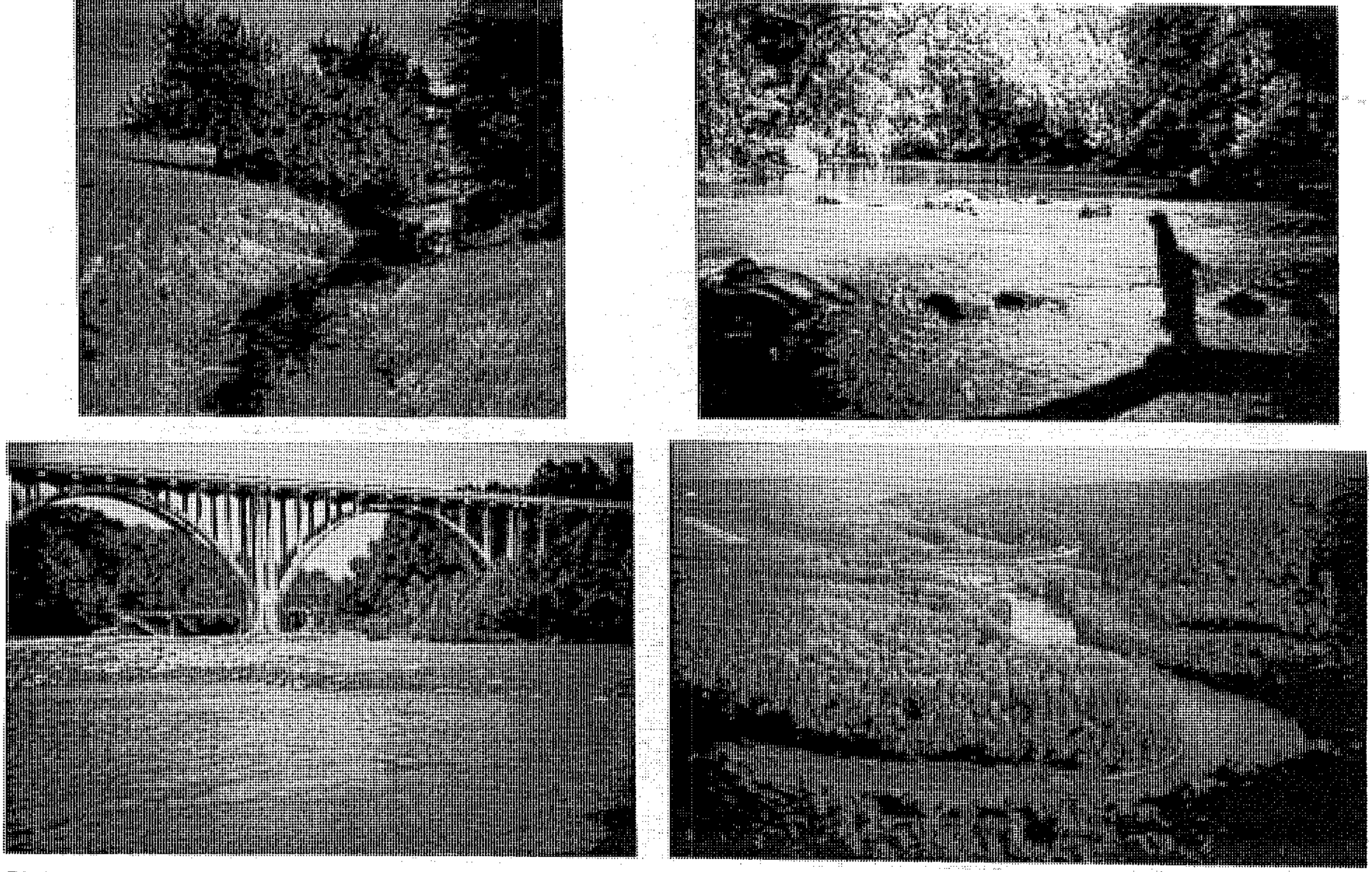
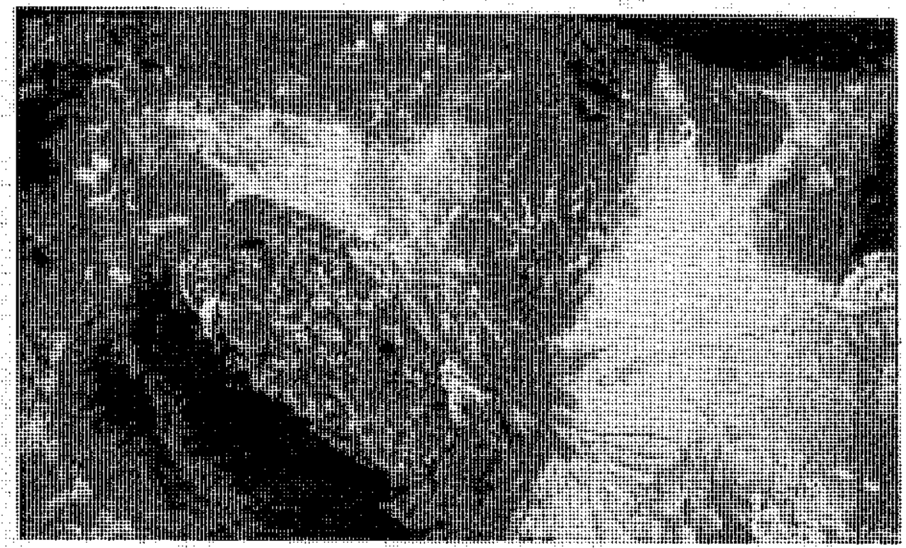


PLATE 3. MAINSTEM PHYSICAL HABITATS: Between South Charleston ***(Top Left)*** and Cincinnati ***(Bottom Right)***, the Little Miami River changes from a small, shallow headwater stream to a deeper large river. The quality of the stream habitat has been adversely impacted by agricultural practices within the headwaters, but improves downstream from Clifton and remains of good to exceptional quality to Cincinnati (RM 3.0). ***Top Right:*** View of the mainstem at Jacoby Road Reserve near Goes (RM 83.1) showing a well-defined riffle-run complex, pool, and streamside forests. ***Bottom Left:*** Mainstem view at Foster showing large river attributes comprised of extensive riffle-run complexes with limestone bedrock fragments and large pools. ***Bottom Right:*** Aerial view of the Little Miami River just upstream from its confluence with the Ohio River. The quality of habitat here has been markedly altered by impoundment from the Markland Dam on the Ohio River. This report recommends that the aquatic life use designation for this section of the river be changed to Warmwater Habitat (WWH) from the existing Exceptional Warmwater Habitat (EWH) designation because of the impounding effect of the Ohio River.

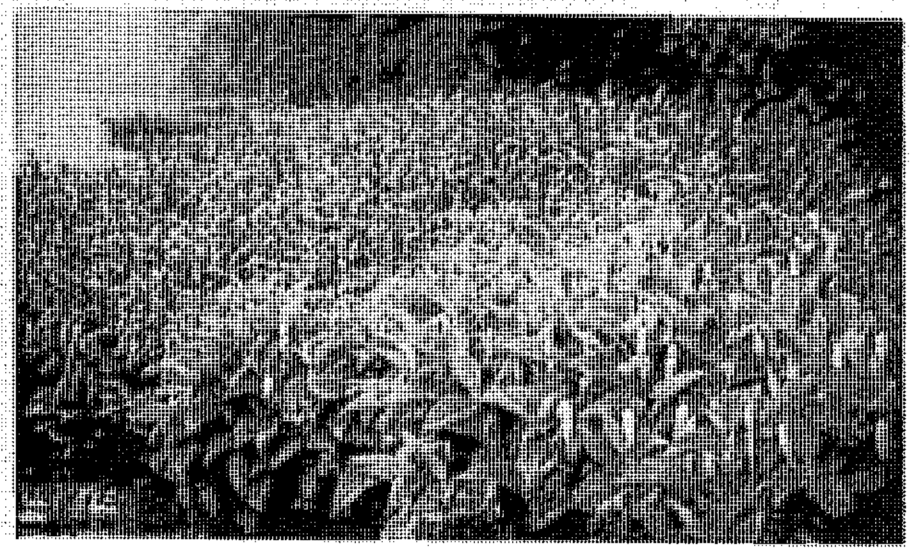


PLATE 4. EXCEPTIONAL WARMWATER HABITAT (EWH): Physical attributes indicative of an EWH stream in Ohio include: a predominantly rural watershed; natural and meandering stream channel; good quality streamside forests; clear water and silt-free substrates comprised of sand, gravel, cobble, and boulder size rocks; constricted low flow channels with vegetated islands and high flow channels; and pollution sensitive aquatic vegetation. ***Top Left:*** Aerial view (1982) of the meandering Little Miami River in Greene County near Trebein. Streamside forests protect and enhance water resources by providing shade, instream cover, and stable banks which result in narrower deeper channels, stable substrates, and clearer water. This view also shows encroachment by agricultural land uses resulting in severely eroding banks which further threaten EWH attainment by contributing excessive sediment loads which result in shifting substrates, increased levels of suspended solids, and wide shallow low flow channels with embedded substrates. Through time, property owners typically lose more acres than are initially gained by streambank encroachment. Bank stabilization techniques should be implemented to prevent further erosion coupled with land use set backs to prevent future problems. ***Top Right:*** Clear water and silt-free substrates in the Little Miami River near Trebein during 1993. ***Bottom Left:*** View of a deep, swift, narrow chute adjacent to a vegetated island located downstream from the Hamilton County MSD Polk Run WWTP. Small islands are common in high quality streams and increase the diversity of physical habitats. ***Bottom Right:*** Dense patches of water willow and lizard's tail, two pollution sensitive aquatic plants common within the Little Miami River stream channel.

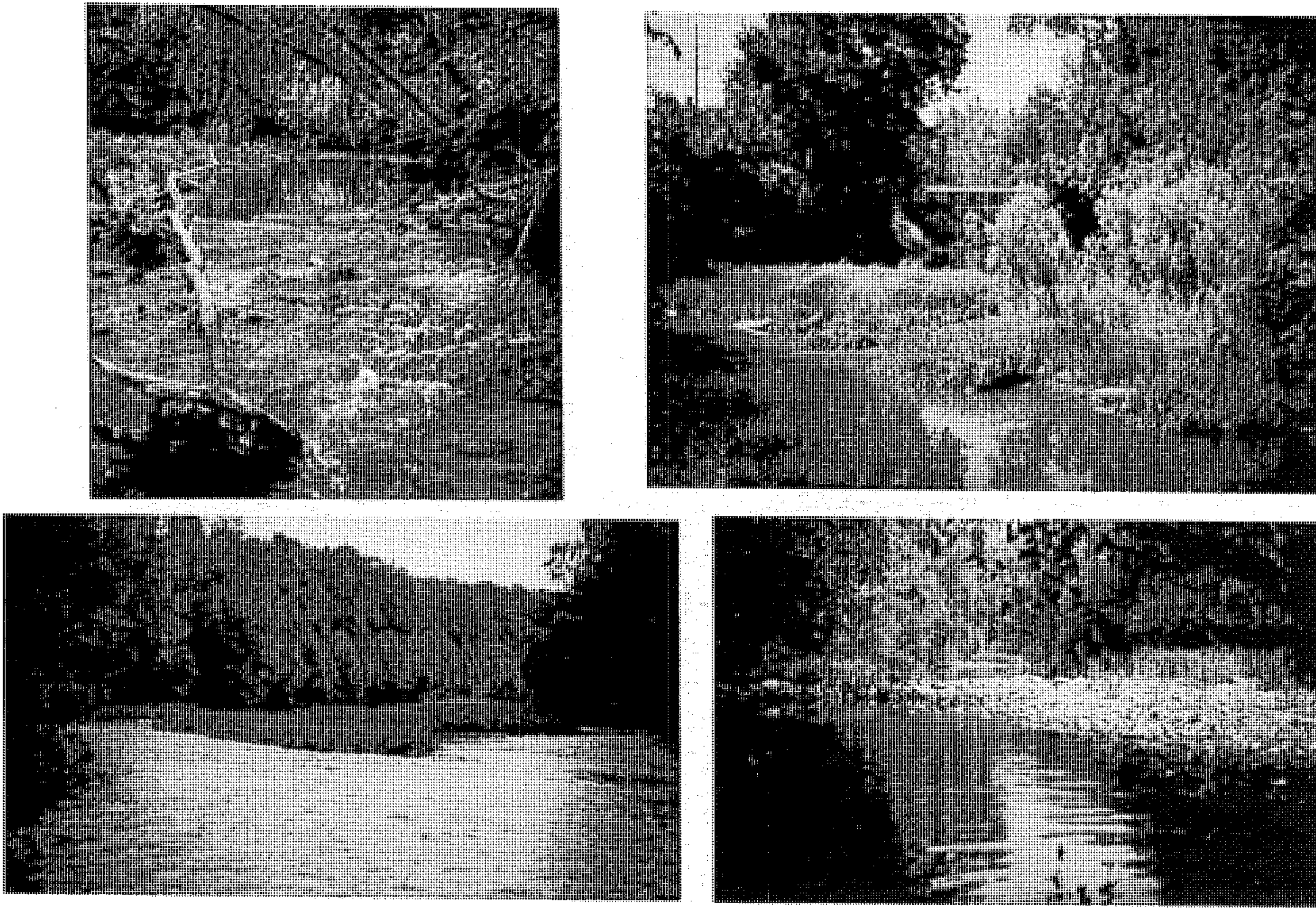


PLATE 5. TRIBUTARY PHYSICAL HABITATS: Most tributaries also contain good to exceptional quality physical habitats consisting of high-gradient riffle-run complexes, deep pools, and forested riparian corridors. ***Top Left:*** Yellow Springs Creek near the Yellow Springs WWTP. ***Top Right:*** View of Turtle Creek looking upstream towards Mason Road. Dense patches of water willow (shown in the middle of the channel) stabilize gravel bars and create narrow, swift-flowing, deeper aquatic habitats. This area has been recently impacted by reduced stream flows. ***Bottom Left:*** The East Fork of the Little Miami River downstream from Batavia. ***Bottom Right:*** Stonelick Creek upstream from the U.S. 50 bridge.

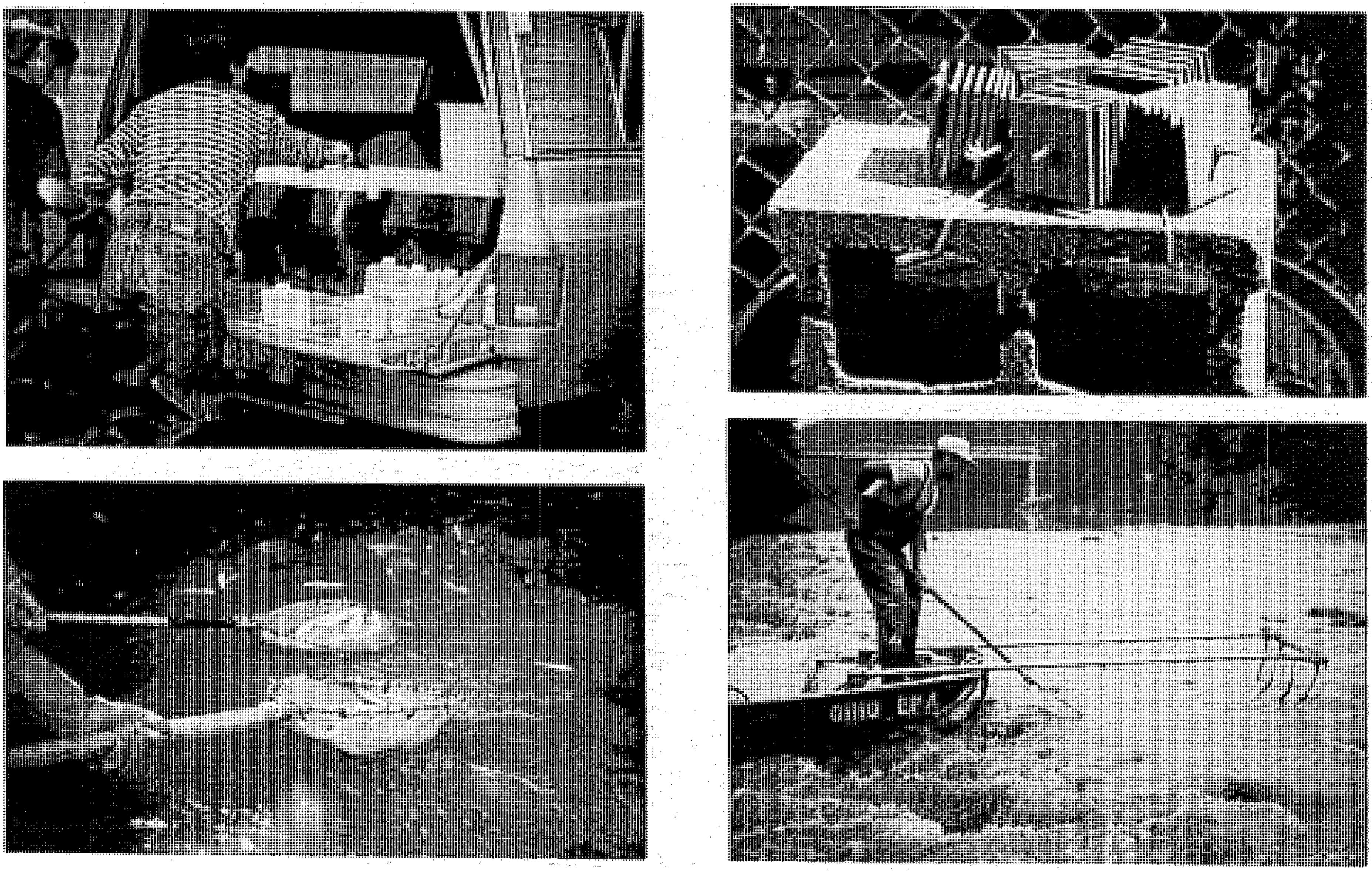


PLATE 6. DATA COLLECTION METHODS: Standardized collecting methods used by Ohio EPA personnel in the Little Miami River study area during 1993. ***Top Left:*** Preparation of water samples for chemical lab analyses. ***Top Right:*** Quantitative macroinvertebrate data was collected by submersing sets of five modified Hester-Dendy artificial substrate samplers for a six week colonization period between July 1 and September 30. Wading ***(Bottom Left)*** and boat ***(Bottom Right)*** electrofishing techniques were used to sample fish assemblages in different sizes of streams. Using this method, biologists can collect information about the fish community including diversity, quantitative relative abundance, biomass, and health data from the temporarily stunned fish before releasing them alive.

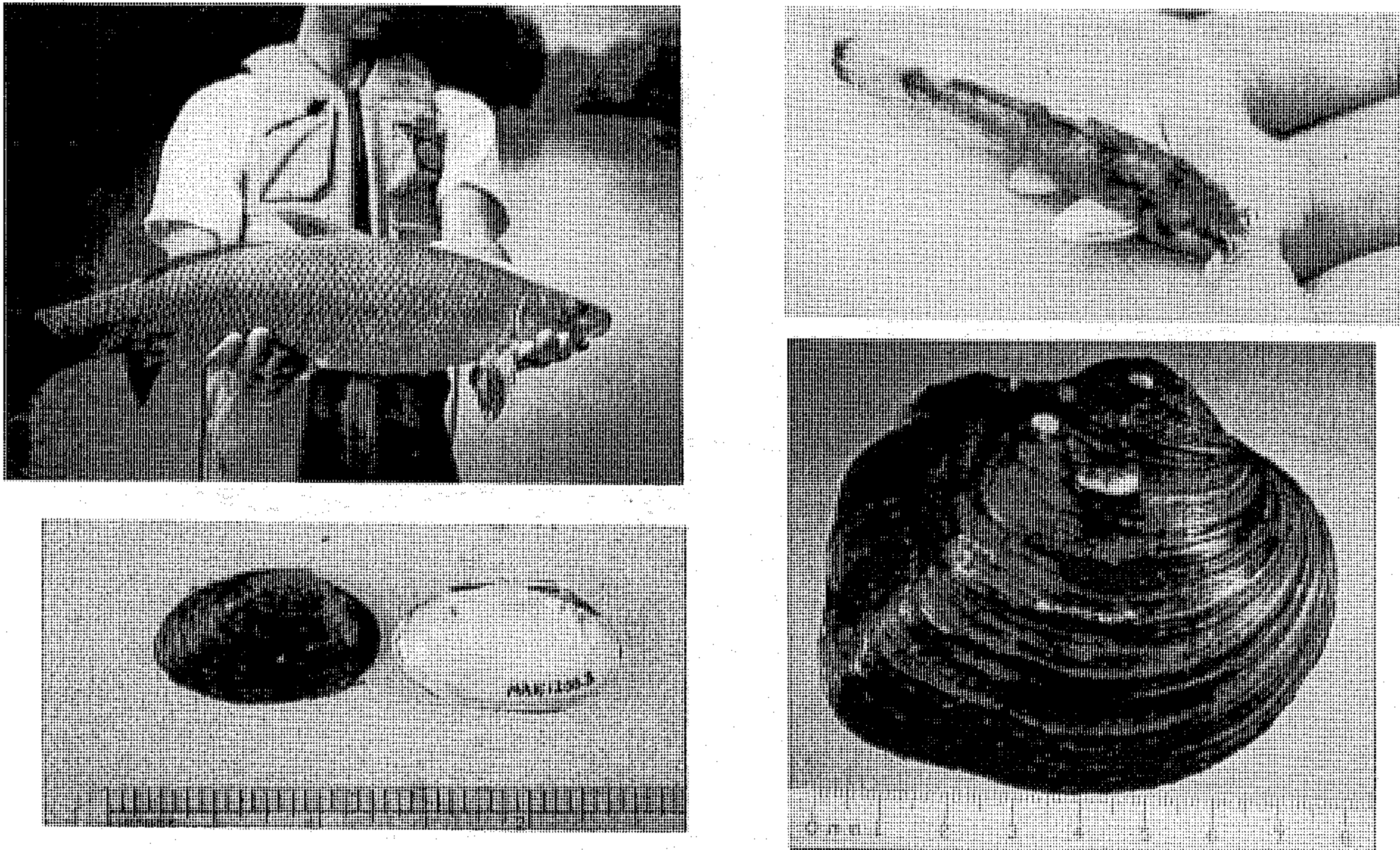
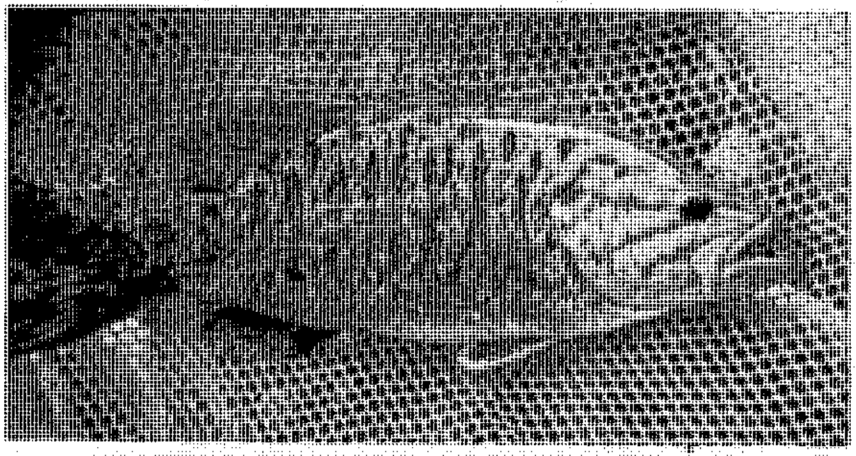
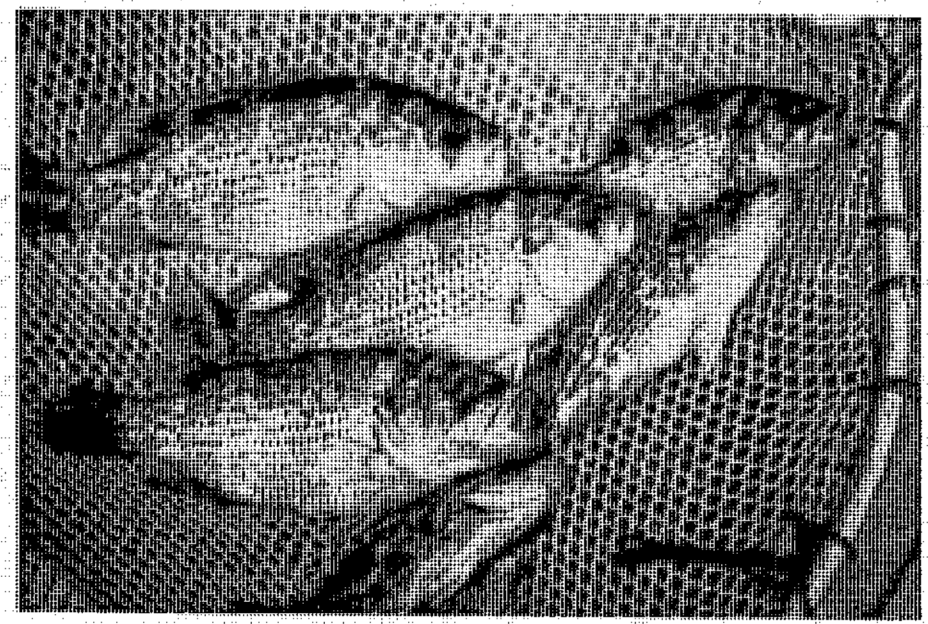
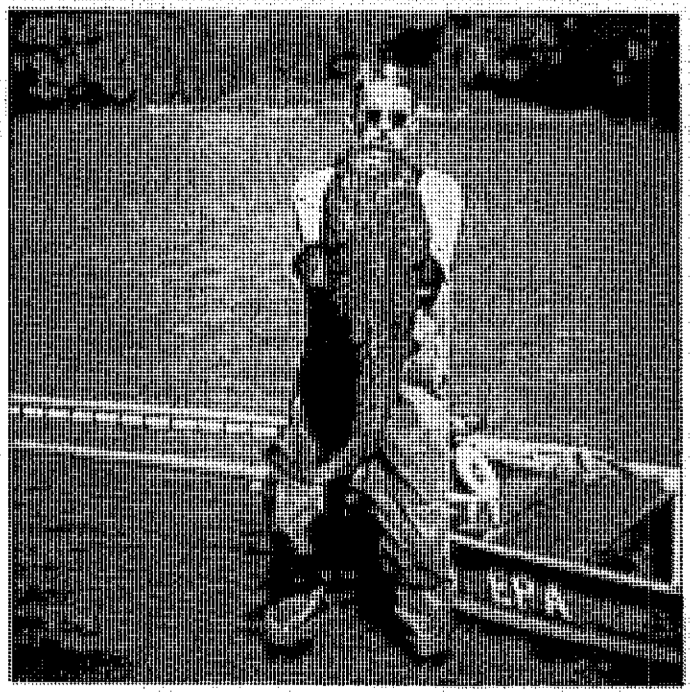


PLATE 7. BIOLOGICAL DIVERSITY/IMPERILED SPECIES: The Little Miami River watershed contains a high diversity of aquatic organisms, including six (6) Ohio endangered, two (2) threatened, and eight (8) special interest species. Eighty-seven (87) fish species and 349 taxa of aquatic macroinvertebrates have been recently collected from streams within the basin. ***Top Left:*** Blue suckers, one of Ohio's rarest and most endangered fish species, were discovered for the first time in the Little Miami River near Cincinnati during the 1993 Ohio EPA survey. ***Top Right:*** Mountain madtom, one of Ohio's smallest endangered catfishes, were also collected at four (4) sites in the lower Little Miami and East Fork mainstems. The Little Miami River, at Bass Island (RM 8.0), contains one of the largest populations of this species in the state. Most of the time, this species lives buried in gravelly riffles. ***Bottom Left:*** The rayed bean mussel (Ohio endangered) was collected at five (5) locations in the Little Miami and East Fork rivers (Hoggarth 1992). ***Bottom Right:*** The wartyback mussel, also endangered in Ohio, was reported by Hoggarth (1992) at two (2) locations in the lower Little Miami River (RM 23.9 and 8.0). Freshwater mussels have an unusual life cycle. Upon being released from a female clam, the larvae (called glochidia) drift and must attach to and successfully parasitize certain fish species in order to metamorphose into the adult mussel form.







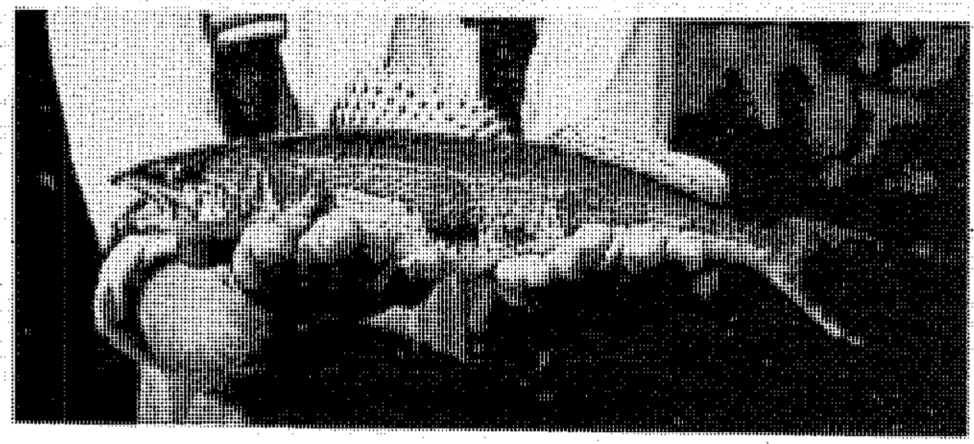
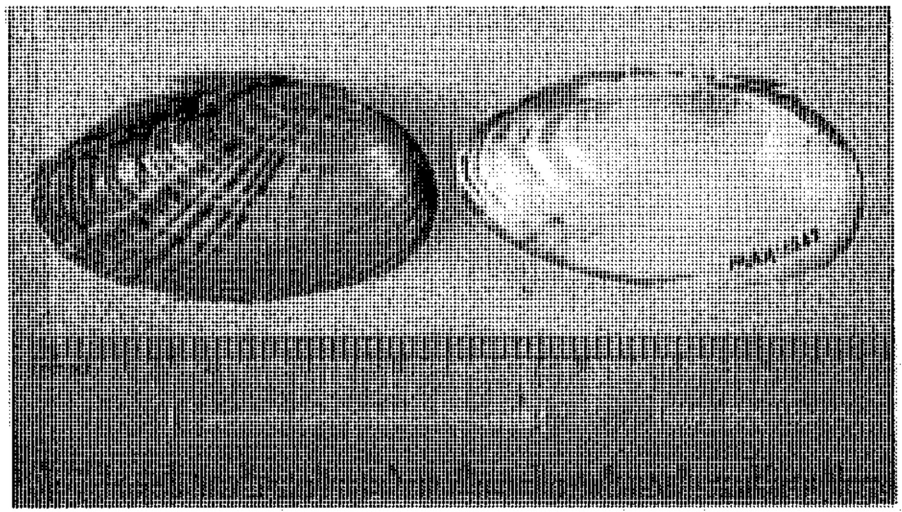
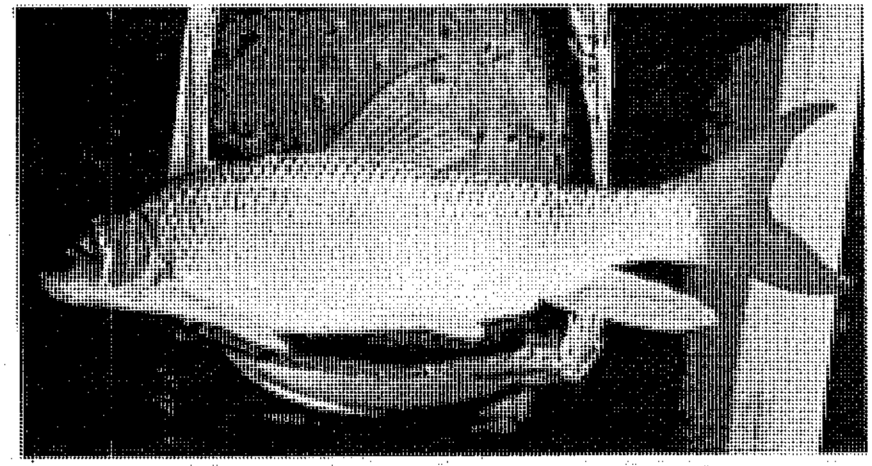
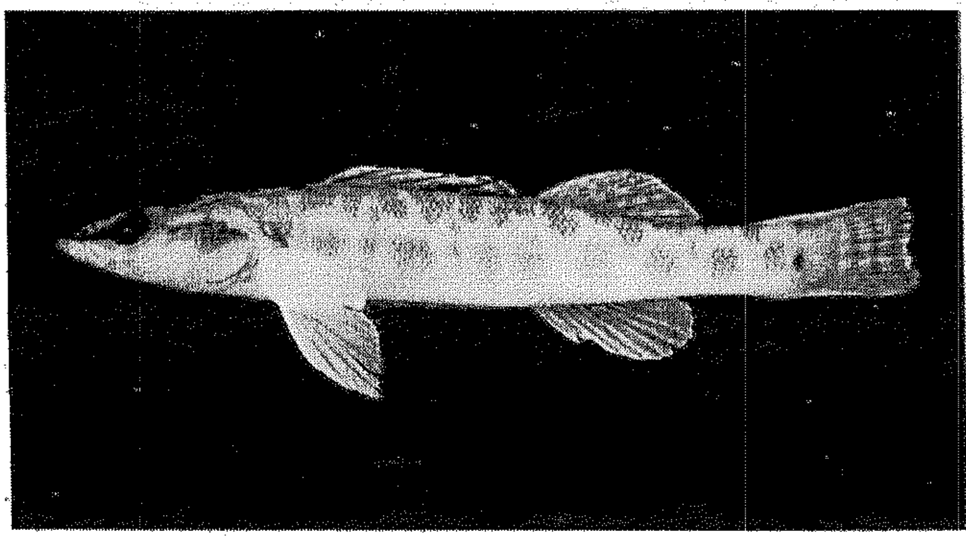


PLATE 8. GAME FISH: Four (4) of the sport species collected from the Little Miami River during the 1993 survey. ***Top Left:*** Smallmouth bass were collected at 30 of 31 locations between RMs 92.2 and 3.5. This popular species was most abundant near Goes, Foster, Branch Hill, and Milford, OH. Since 1983, the distribution of smallmouth bass has remained similar, but the mean relative abundance (number of fish collected per kilometer) has increased from 6.5 per km in 1983 to 13.4 per km in 1993. ***Top Right:*** Rock bass, a smaller sunfish species, were collected from 31 of 32 locations between RMs 102.1 and 8.0 and reached their greatest abundance in the upper half of the river between Goes and Trebein. The mean number of rock bass increased slightly from 4.3 fish per km in 1983 to 5.5 per km in 1993. ***Bottom Left:*** Flathead catfish, the largest fish species captured in the Little Miami River (view of 27.5 lb. specimen captured at Milford), were collected from 19 of 22 sampling locations between Waynesville and the Ohio River (RM 53.5 - 0.2). This species's catch rate increased from 0.5 per km in 1983 to 1.4 per km in 1993. ***Bottom Right:*** Since 1983, the distribution of sauger has expanded in the upper half of the mainstem. Sauger were collected from 24 of 28 locations between Alpha and the Ohio River (RM 74.5 - 0.2) during 1993. The mean catch rate increased slightly from 1.3 per km in 1983 to 2.5 per km in 1993.







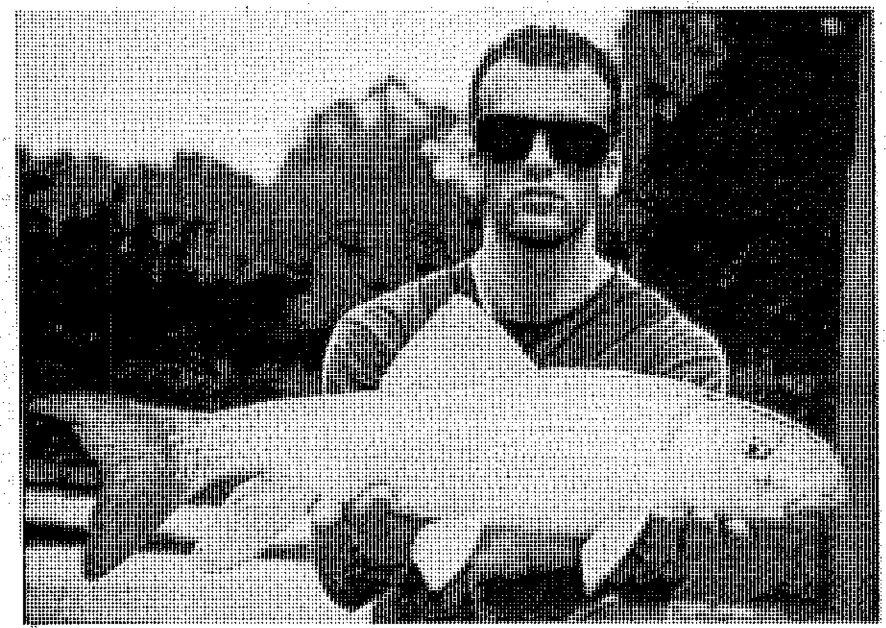


PLATE 9. NONGAME SPECIES: Four (4) of the pollution sensitive species collected from the Little Miami River during 1993. ***Top Left:*** The rainbow mussel inhabits small to medium size streams with coarse sand or gravel bottoms (Cummings and Mayer 1992). Hoggarth (1992) reported the species in the Little Miami River at four (4) locations which fully attained EWH during 1993. ***Top Right:*** Shorthead redhorse, a signature species for the Little Miami River mainstem which inhabits the swiftest waters, were collected at 27 of 30 sampling locations between Goes and Lunken Airport (RM 83.1 - 3.5). This intolerant species was most abundant between Foster and Branch Hill (RM 27.9 - 21.4). The mean number of shorthead redhorse captured per km has increased from 10.3 to 28.1 in 1993. The species's maximum abundance increased from 42.0 per km in 1983 to 124.3 per km in 1993. The marked increase in the relative abundance of this sucker since 1983 is a positive sign for the mainstem. ***Bottom Right:*** River redhorse, a large special interest sucker species, were collected from eight (8) of 19 locations between Oregonia and Lunken Airport (RM 47.5 - 3.5). During 1983, it was collected only between RM 36.0 and 13.1. ***Bottom Left:*** The slenderhead darter, a small fish in the perch family, was not collected from the Little Miami River during 1983, but was captured at five (5) of 12 sampling locations between South Lebanon and Plainville (RM 32.9 - 8.3) during 1993.

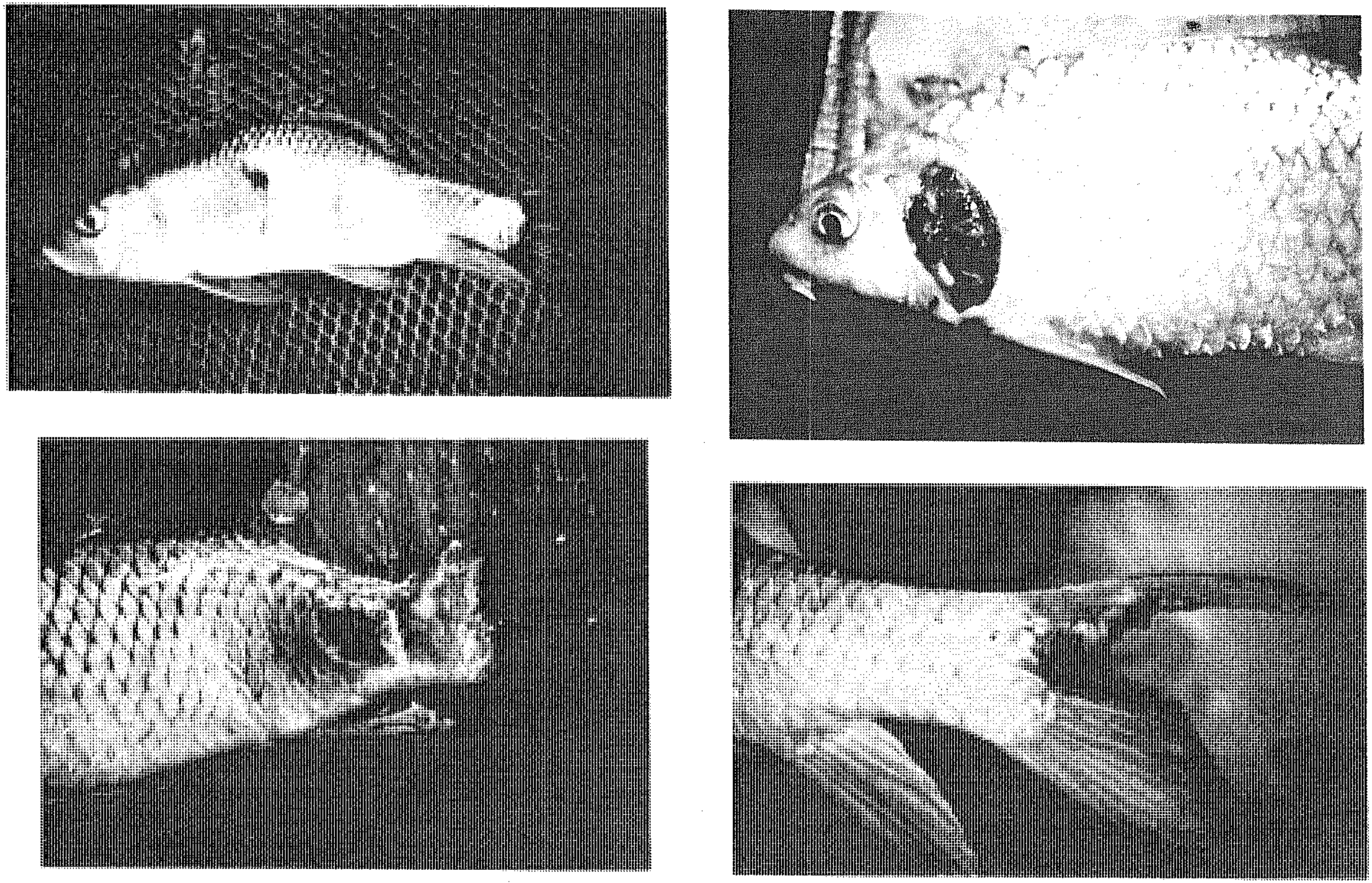
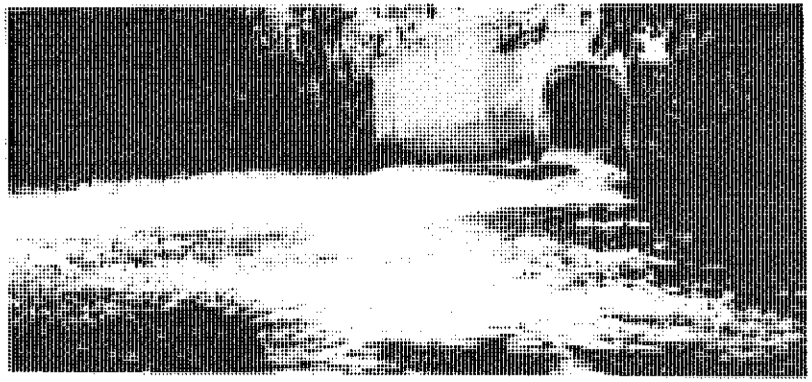
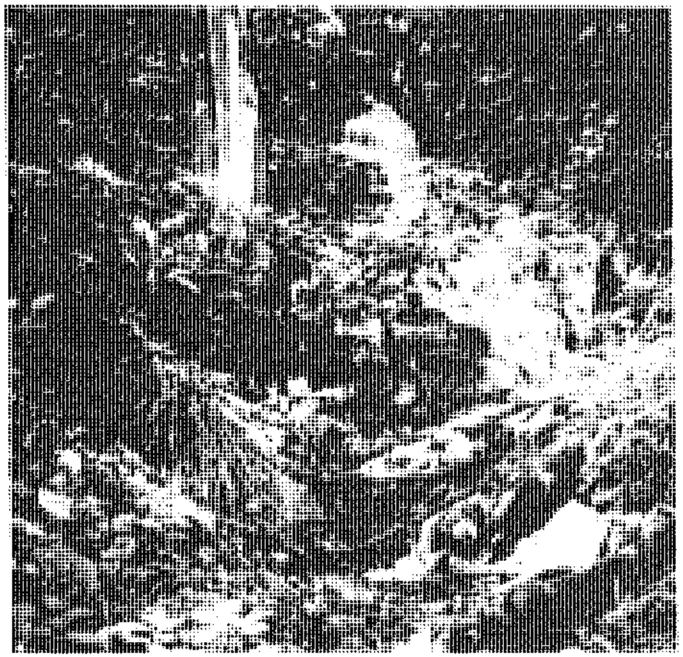


PLATE 10. EVIDENCE OF IMPACTS: Fish captured in the Little Miami River during 1993 with external deformity, erosion, lesion/ulcer, and tumor (DELT) anomalies. ***Top Left:*** A golden redhorse with a severe spinal deformity. ***Top Right:*** A quillback with a heavily eroded gill cover. ***Bottom Left:*** A common carp with a large lesion and deformed caudal peduncle. ***Bottom Right:*** A silver redhorse with heavy tumors and eroded caudal fin. These types of anomalies indicate sub-lethal stresses generally associated with marginal dissolved oxygen levels and/or chronic or acute toxic impacts. The highest incidence of DELT anomalies (6.0 - 11.7% of the fish captured) in the Little Miami River during 1993 occurred between Bellbrook and Waynesville.





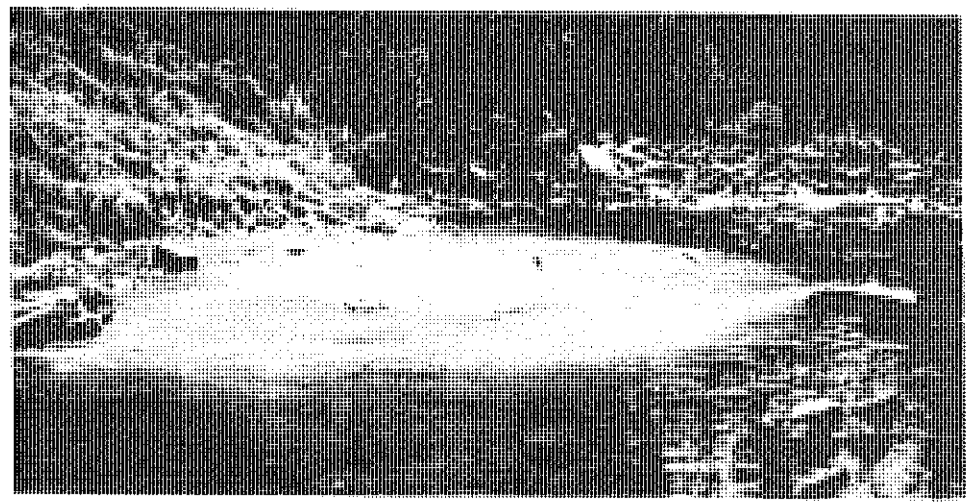


PLATE 11. POINT SOURCES OF POLLUTION: The Little Miami River watershed receives a cumulative total of more than 50 million gallons per day (MGD) of treated wastewater from permitted point source dischargers. The majority (99.2%) of effluent comes from municipal wastewater treatment plants (WWTPs) most of which have been upgraded during the last decade to meet state water quality standards. ***Top Left:*** The Montgomery County Eastern Regional WWTP discharges approximately 8.2 MGD to Little Beaver Creek, a tributary of Beaver Creek which also receives 4.3 MGD of treated effluent from the Greene County Beaver Creek WWTP ***(Top Right)*** before its confluence with the Little Miami River (RM 72.74). ***Bottom Left:*** The Yellow Springs WWTP discharges 0.8 MGD to Yellow Springs Creek through a cascading waterfall. Fish and macroinvertebrate communities attained Exceptional Warmwater Habitat biocriteria in Yellow Springs both upstream and downstream from the discharge. ***Bottom Right:*** Cincinnati Milacron, one of the few industries in the watershed, formerly had a similar type of cascading discharge, but now releases 0.08 MGD directly into Turtle Creek through a diffuser. During 1993, biological attainment of Warmwater Habitat criteria was FULL upstream, but only PARTIAL downstream from the discharge. The attainment status downstream from the industry was FULL from 1989 through 1992.

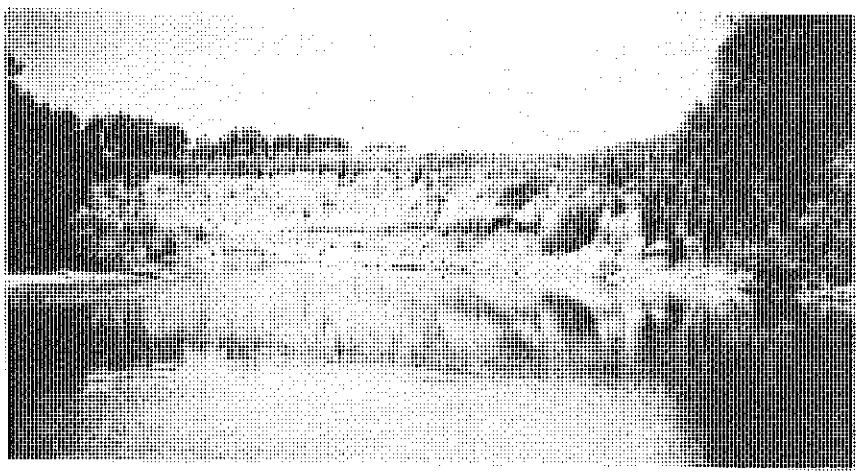
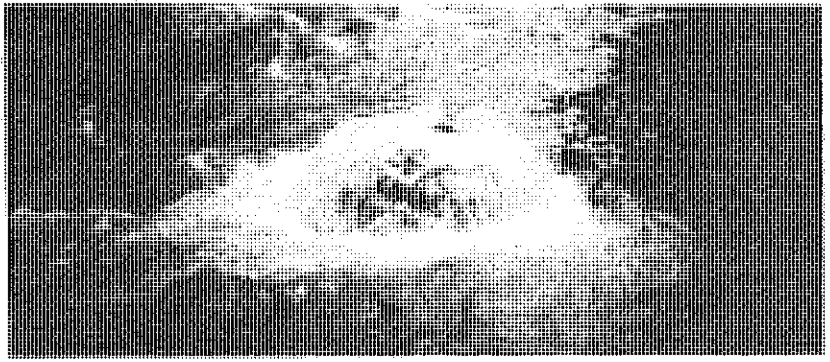
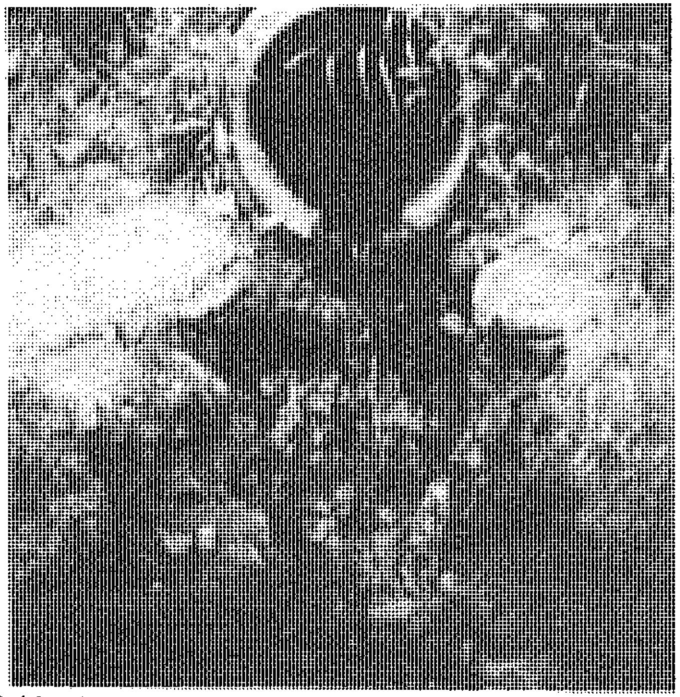


PLATE 12. NONPOINT SOURCES OF POLLUTION: High levels of sediment from soil erosion frequently enter the Little Miami River and tributaries through surfacewater runoff. Fluvial-sediment studies in Ohio (Hindall 1989) reports a mean annual suspended sediment discharge of 474,000 tons in the Little Miami River at Milford between 1977-1986. ***Top Left:*** Clifton Gorge view of the turbid Little Miami River during high flows. Three sources of excessive soil erosion are conventional row crop agriculture ***(Top Right)***, new construction sites ***(Bottom Right)***, and severely eroding banks ***(Bottom Left)*** which commonly occur subsequent to the removal of mature riparian vegetation. Streamside forests are a vital component of a healthy stream ecosystem. High suspended sediment loadings degrades both water quality and physical habitats, thus are not conducive to most pollution sensitive aquatic organisms. High turbidity levels can interfere with respiration, feeding, and reproduction. The retention of sediment within the low flow channel degrades substrate quality by embedding or burying preferred materials comprised of silt-free sand, gravel, and larger sized rocks. Surface runoff also contributes excessive nutrients, pesticides, and other chemicals. Streams with degraded physical habitats become more susceptible to the adverse effects of nonpoint source pollutants.





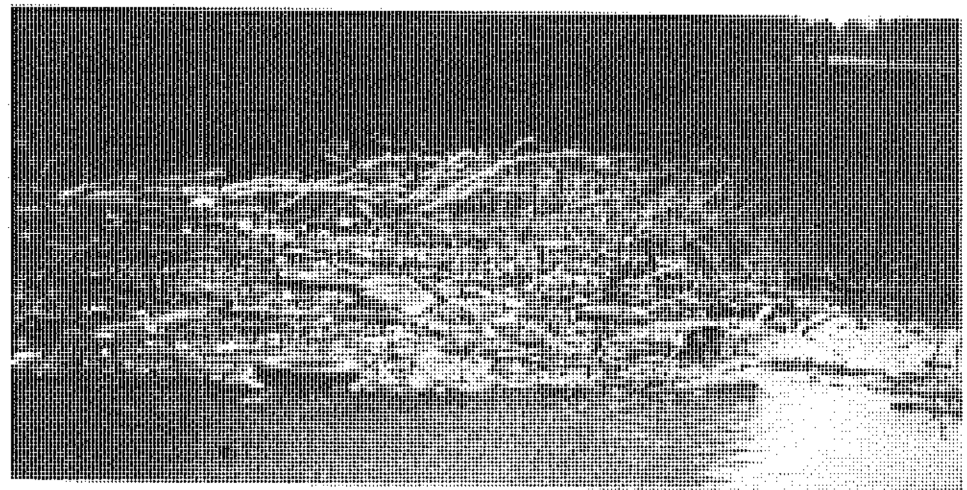


PLATE 13. ADDITIONAL WATERSHED THREATS: Human influences within the watershed increase as the Little Miami River flows into and through the greater Cincinnati metropolitan area. While most upstream sections of the Little Miami River have demonstrated improved aquatic life use attainment since 1983, the lower 19 miles has shown no significant change with some indications of deterioration. ***Top Right:*** Physical habitats and water quality within Sycamore Creek and its tributaries have been negatively impacted by the construction of gravity fed sewer lines, sanitary sewer overflows, and urban runoff from a predominantly suburban watershed. Sycamore Creek was in **NON** attainment of WWH upstream from the WWTP during 1993. ***Top Left:*** A 1990 view of an unauthorized release from a separate sanitary overflow in Raiders Run, a tributary to Sycamore Creek. New sewer lines with sealed man holes have been installed to prevent future releases. Between 1983 and 1993, more than 1500 spills (and other unauthorized releases) and 58,590 dead fish were reported throughout the Little Miami River watershed. ***Bottom Left:*** View of a small, dry-weather combined sewer overflow (CSO) discharge to the Little Miami River downstream from Beechmont Avenue (RM 3.5), the area inhabited by blue suckers. Forty-eight (48) of the 53 CSOs identified by the Hamilton County Metropolitan Sewer District (MSD) discharge to the Duck Creek subbasin which enters the mainstem upstream from Beechmont Avenue. Data collected by the MSD during October 1993 through February 1994 reveals 13 of the structures overflowed a total of 295 times and discharged approximately 232.2 million gallons. Sediments in the Little Miami River at RM 3.5 had some of the highest pollutant concentrations within the study area. ***Bottom Right:*** Flotsam (urban trash and debris from stormwater runoff and CSO discharges) was most common near Kellog Avenue (RM 1.6) in the backwaters of the Ohio River.

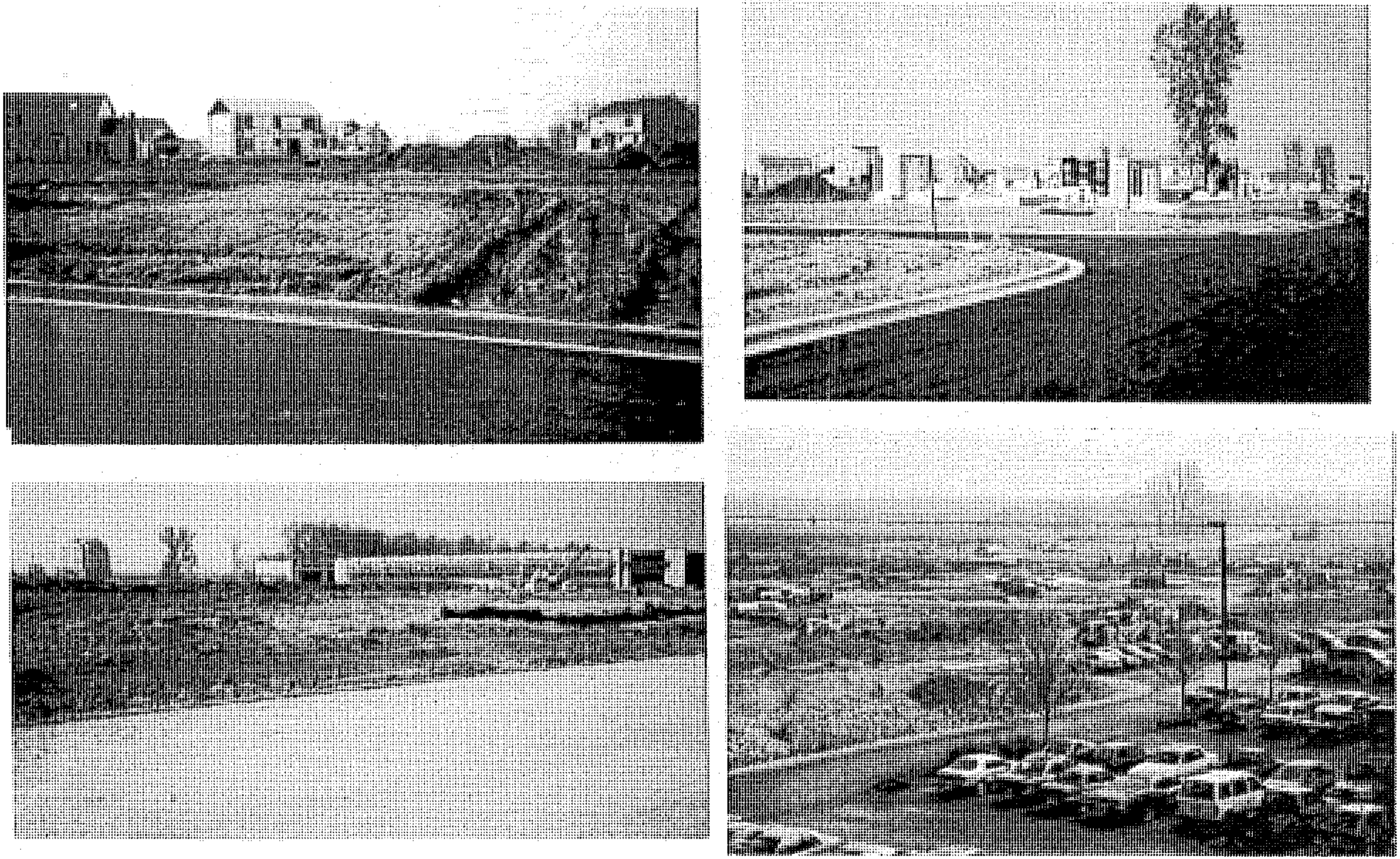


PLATE 14. SUBURBAN WATERSHED MODIFICATIONS: Residential ***(Top Photos)*** and commercial ***(Bottom Photos)*** developments replacing rural land use. FULL attainment of the EWH use designation by the Little Miami and East Fork rivers is threatened by new residential and commercial development within the watersheds. Portions of each stream presently are not in FULL attainment due in part to the effects (*i.e.*, sedimentation, runoff rates, nutrient enrichment) of suburban development. Without adequate controls to minimize runoff and protect headwater stream habitats, the ability to restore the mainstem to the designated EWH use will be seriously limited. A secondary result of the recent developments are requests by most WWTPs for larger discharge volumes to accommodate new sewer connections. Over the next decade, the total volume of treated wastewater discharged by WWTPs throughout the watershed is expected to increase causing stream flows to become increasingly effluent dominated. Other adverse changes include drainage pattern changes created by the conversion of headwater streams to channelized ditches, drainage of wetlands, and increased amounts of impervious surfaces (pavement and roofs) which contribute to a higher rate of runoff and less groundwater recharge.

Biological and Water Quality Study of the Little Miami River and Selected Tributaries

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INTRODUCTION

The Little Miami River is 105.5 miles long and contains the longest Exceptional Warmwater Habitat (EWH) segment of any stream or river in Ohio. The watershed occupies 1,757 square miles of land area, includes 133 named streams, and was principally formed by three glacial events (Krolczyk 1960, Cross 1967, Goldthwait 1979). The Little Miami River flows through several steep-sloped, forested gorges and contains some of Ohio's most scenic and diverse riverine habitats (Plate 1). Sections of the mainstem became Ohio's first state and national designated scenic river in 1969 and 1973, respectively (J. Kopec pers. comm.). Land use within the basin is predominately agricultural, but suburban land uses (*i.e.*, residential and commercial development) are rapidly increasing. The mainstem and larger tributaries are popular recreational retreats for many Ohioans (Plate 2).

As part of Ohio EPA's Five-year Basin Approach for Monitoring and National Pollutant Discharge Elimination System (NPDES) permitting, chemical, physical, and biological sampling was conducted in the Little Miami River and selected tributaries during the summer of 1993. The principal objectives of this study were to:

1) evaluate existing aquatic life use designations and use attainment status;
2) evaluate non-aquatic life uses (*i.e.*, recreational, water supply uses) and status;
3) identify causes and sources associated with **NON** and PARTIAL attainment;
4) provide data in support of NPDES permit reissuance; and,
5) assess changes (trends) in chemical water quality and biological performance since previous surveys and subsequent upgrades by major wastewater treatment facilities.

Similar to the previous surveys of 1982 and 1983, standardized methods were used throughout the study area to collect quantitative and qualitative biological, chemical, and physical data. During the 1993 study, a cumulative total of 178 river miles were evaluated by sampling 36 sites of the Little Miami River mainstem and 51 sites in 18 tributaries (Table 1). Eighteen (18) point source discharges were directly evaluated (*i.e.*, including analyses of pollutant loading trends based on monthly operating reports [MORs], NPDES permit violations, combined sewer overflows, and whole effluent toxicity tests) and other relevant information indicative of potential environmental impacts within the Little Miami River watershed (*e.g.*, spills, overflows, bypasses, unauthorized releases of pollutants, Ohio Department of Natural Resources fish kill reports, and other biological data) was also reviewed and summarized.

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

SUMMARY

Aquatic Life Use Attainment

Little Miami River

Of the 102.1 mainstem miles evaluated in 1993, 41% were in FULL attainment of Exceptional Warmwater Habitat (EWH) criteria, 57% were in PARTIAL attainment, and 2.9% were in **NON** attainment. Within the free-flowing mainstem, macroinvertebrate communities attained the Exceptional Warmwater Habitat (EWH) biocriterion for the Invertebrate Community Index (ICI) at all except one location. The PARTIAL attainment, therefore, was due to the failure of the fish community to meet the EWH criteria for the Index of Biotic Integrity (IBI) and/or modified Index of Well-Being (MIwb) at 14 locations. Both organism groups failed to attain the recommended WWH use designation within the lower three miles of the mainstem which is impounded by the Ohio River.

Within the upper half of the mainstem, a total of 19.5 and 32.6 miles, respectively, were in FULL and PARTIAL attainment of the existing EWH use designation. The PARTIAL attainment in the segment from South Charleston to Clifton was due primarily to excessive organic and nutrient enrichment, fecal contamination, and toxic impacts. The highest fecal bacteria and nitrate-N and the lowest dissolved oxygen (D.O.) levels within the mainstem were recorded in this segment. Sources of pollutants include runoff from a commercial manure storage area in South Charleston, to which a large fish kill in 1992 was attributed, and the South Charleston WWTP. Agricultural activities (*i.e.*, riparian encroachment and unrestricted livestock access) have also adversely impacted the quality of riparian and stream habitat within this segment. The segments from Clifton Gorge to the Narrows and immediately below the Sugar Creek WWTP exhibited FULL attainment of EWH. PARTIAL attainment was observed in the mainstem downstream from Bellbrook and between Spring Valley and Waynesville due to excessive pollutant loadings (*i.e.*, nutrients, oxygen demanding wastes, suspended solids) from the major municipal discharges within and upstream from the segment. Although most of the facilities have improved significantly since 1983 (*i.e.*, reduced loadings of pollutants), the cumulative amounts of pollutants discharged still exceeds the assimilative capacity of the Little Miami River. Higher than expected numbers of fish with external deformities, eroded fins, lesions/ulcers, and tumors (DELT anomalies) were observed and the incidence was correlated with loadings of these pollutants.

Within the lower half of the Little Miami River (downstream from Waynesville) a total of 21.4 miles was in FULL attainment of EWH, 25.6 miles in PARTIAL attainment, and 3.0 miles in **NON** attainment of WWH. The PARTIAL attainment of EWH downstream from Waynesville to Oregonia represents the continued assimilation of point source loadings discharged in the upper half of the mainstem. Recovery to FULL attainment occurred from Fort Ancient to Lake Isabel, but returned to PARTIAL attainment downstream from Sycamore Creek to Beechmont Avenue. In addition to a number of WWTP discharges, this segment also receives excessive amounts of sewage and other pollutants from combined sewer and sanitary sewer overflows (CSOs and SSOs). Downstream from Beechmont Avenue, **NON** attainment of WWH occurred at both sampling locations within the section impounded by the Ohio River. The **NON** attainment was attributed to a combination of chemical impacts from upstream sources and lower habitat quality due to the impoundment effect caused by the Ohio River backwater. The associated causes and sources of the PARTIAL and **NON** attainment in the mainstem are summarized by waterbody segments (Table 2).

Selected Tributaries
Sampling results in selected tributaries showed 41% of the 44 tributary locations (excluding mixing zones) were in FULL attainment of existing and recommended aquatic life use designation criteria, 36% were in PARTIAL attainment, and 23% were in **NON** attainment (Table 1). The associated causes and sources of the PARTIAL and **NON** attainment in the tributaries are summarized by waterbody segments (Table 2).

Chemical Water Quality
Chemical sampling (daytime grabs) indicated relatively good water quality throughout most of the study area. Approximately 96.3% (13,056) of the total possible parameter tests were within Ohio WQS criteria or guidelines. A total of 499 parameter values (one or more parameters at most locations) however, did not meet criteria or recommended guidelines (Table 5). By category, fecal bacteria counts had the highest rate of exceedence (204 values; 38.9% of the possible tests) followed by conventional parameters (178; 2.3% of the possible tests), and organic compounds (117; 2.3% of the possible tests). Elevated bacteria counts are a good indication of fecal contamination. The *E. coli* criterion was more frequently exceeded (138 values; 67.6%) than for fecal coliform (66 values). Twenty (20) mainstem locations and 14 sites in eight (8) tributaries designated for the Primary Contact Recreation (PCR) use had one or more values which exceeded the maximum criterion. Eleven (11) locations in four (4) tributaries designated for the Secondary Contact Recreation (SCR) use had one or more values which exceeded the maximum criterion.

Phosphorus concentrations above the WQS narrative guideline were the most numerous of the conventional parameter exceedences with 78 values (15.6% of 499 values) greater than 1.0 mg/l. Excluding iron exceedences (which are usually due to natural sources), the most frequent WQS criteria exceedences were for dissolved oxygen (28), temperature (18), and total residual chlorine (16). The lowest D.O. concentrations in the Little Miami River occurred at three daytime grab sample locations upstream from Clifton (RMs 101.3 - 89.98, minimum = 3.5 - 5.6 mg/l). Values below the D.O. criteria were also recorded at 14 locations in seven (7) tributaries. D.O. concentrations below 3.0 mg/l were recorded in Flat Fork (RM 1.7; range = 1.1 - 2.9 mg/l), Turtle Creek (RM 0.70; 2.8 mg/l), and Stonelick Creek (RM 16.74; 2.4 mg/l). D.O. concentrations at most other sites were >6.0 mg/l and considered conducive to healthy and diverse aquatic assemblages. Copper was the most common heavy metal to exceed criteria with eight (8) of the 10 exceedences recorded in Turtle Creek downstream from Cincinnati Milacron. Iron concentrations exceeded the 1.0 mg/l criterion in 130 (33%) of the 392 non-mixing zone samples and exceeded or equaled 5.0 mg/l in 16 of 499 samples (Table 6). Two sites downstream from point source discharges had the highest number of conventional parameter exceedences. These include Turtle Creek downstream from Cincinnati Milacron (RM 0.52; 6 parameters with 15 exceedences) and the Little Miami River downstream from the Lower LMR WWTP (RM 28.0; 4 parameters with 10 exceedences).

Priority pollutant scans of the water column detected one or more organic compounds at 33 of 34 locations (Appendix Table A-5). Dieldrin, an insecticide no longer manufactured in the U.S., was detected at 30 of the 34 locations. Other pesticides detected included aldrin, endrin, endosulfan II, methoxychlor, and heptachlor with several appearing in WWTP mixing zones or immediately downstream. Caesar Creek upstream from the reservoir (RM 16.52) was the only location sampled with no organic compounds detected. Sampling locations with the highest number of organic priority pollutants detected were; Little Beaver Creek downstream from the Montgomery Co. Eastern Regional WWTP (RM 4.53; 15 compounds), the mainstem at Indian Ripple Road (RM 72.30; 13

compounds), Totes, Inc. mixing zone (RM 22.20; 12 compounds) and Sycamore Creek downstream from the Sycamore Creek WWTP (RM 0.05; 12 compounds). Priority pollutant scans from the two locations sampled in the East Fork showed no noticeable change in the number of organic compounds from upstream to downstream from four WWTPs.

Chemical Sediment Quality

Sediment chemistry results from 39 locations revealed non-elevated to slightly elevated (Kelly and Hite 1984) concentrations of eight (8) heavy metals at most sites with higher concentrations at a few scattered locations (Table 7). Arsenic was elevated at three (3) sites with the highest concentration recorded in Turtle Creek downstream from Cincinnati Milacron. Other elevated values occurred at two (2) predominantly rural locations, the mainstem at Dolly Varden Rd. (RM 98.98) and in Flat Fork (RM 1.70). Possible source(s) of the arsenic include past use of pesticides and natural occurrence in groundwater. An elevated lead value was recorded downstream from Simpson Creek (RM 28.0) and three (3) slightly elevated values were found in the urbanized Beaver Creek watershed. Cadmium, nickel, and chromium concentrations were non-elevated or slightly elevated throughout the study area. Elevated zinc concentrations were detected at three (3) locations (Beechmont Ave., Oldtown Creek, and Turtle Creek at RM 6.23). The Beechmont Ave. location was the one site in the study area with multiple parameters in the slightly elevated to elevated ranges (copper, chromium, zinc) and highly to extremely elevated heavy metal concentrations of iron and mercury. This site is immediately downstream from Duck Creek which is extensively impacted by urban runoff, CSOs, spills, and other sources.

Similar to the water column results, sediment scans for priority organic pollutants detected one or more compounds at 82% of the 39 sampling locations. Phthalates or polycyclic aromatic hydrocarbons (PAHs) were detected at 16 locations, volatile organic compounds at a single location, and organochlorine pesticides at 30 locations (Table 8, Appendix Table A-8a). The seven (7) locations with no organic compounds detected were in the East Fork (RMs 15.60, 13.35, 12.59, and 0.77), Stonelick Creek (RM 1.0), Caesar Creek (RM 16.52), and Newman Run (RM 0.27). The highest number and total quantity of semi-volatile organic compounds in the study area occurred in Sycamore Creek downstream from the Sycamore Creek WWTP (RM 0.05). Thirteen (13) different PAH compounds were detected with a relatively high total concentration of 36.6 mg/kg (ppm). The sediment sample at this location also contained toluene (a solvent), the only volatile organic compound detected. Although potentially due to different particle sizes in the sediment sample, only two (2) PAH compounds, both at markedly lower concentrations, were collected immediately upstream from the WWTP. Sludge deposits were observed downstream from the WWTP during the survey. Sediments in the Little Miami River at Beechmont Ave. contained the second highest number (9) and total quantity of PAH compounds (17.8 mg/kg). Possible sources include the Norwood/Duck Creek landfill (closed) which has an eroding bank along Duck Creek, urban runoff, spills, and numerous CSOs in the Duck Creek subbasin. Turtle Creek at Glosser Road (RM 6.23) contained the next highest number of PAHs (7 compounds; 10.8 mg/kg). The most frequently detected compounds were bis (2-ethylhexyl) phthalate, benzo [B&K] fluoranthene, and fluoranthene. Up to four (4) organochlorine pesticides were detected in the sediment at 77% of the 39 sampling locations (Table 8). Dieldrin was detected at 22 sites, DDT and endosulfan II at eight (8) sites each, aldrin at four (4) sites, and endosulfan sulfate at one (1) site. The highest dieldrin value (highly elevated; Kelly and Hite 1984) occurred in the upper mainstem at Dolly Varden Rd. Three (3) other mainstem and a single tributary value were slightly elevated. Total DDT concentrations were non-elevated with the exception of Beechmont Ave. where it was elevated. Four (4) different organochlorine pesticides were detected at Beechmont Ave. which was the only location with more than two of these compounds.

Fish Tissue Contaminants

Chemical analyses of 34 fish tissue samples suggests relatively little contamination of fish tissue throughout the Little Miami River mainstem. At least two of eight different species were tested for selected heavy metals, pesticides, and PCB compounds at 11 locations between RMs 83.1 and 3.5. All concentrations of compounds from seven (7) sport species (composite fillets) and common carp (whole body composite) were below U.S. FDA action levels (Appendix Table A-8b). Slightly elevated (>50, ≤ 300 µg/kg) concentrations of PCBs, however, were detected in two white bass samples, one freshwater drum sample, and three channel catfish samples. Whole body composite values for eight common carp samples were slightly elevated at six locations, elevated (>300, <1000 µg/kg) at one location, and highly elevated (>1000, <5000 µg/kg) at Beechmont Ave.

A total of seven (7) organochlorine pesticides and derivatives were detected in fish tissues. Similar to the water and sediment scans, dieldrin was the most frequently occurring pesticide with a detection rate of 76.5%. This is higher than the statewide detection rate of 48.1% reported by Estenik and Smith (1992). The second most frequently detected organic compound was 4,4'-DDE (a DDT derivative) with a detection rate of 73.5% (compared to a 60.5% statewide rate of detection). The total PCB detection rate in the mainstem was considerably lower than the reported statewide rate of 97.6%. PCB-1260, the most resilient and only PCB congener detected, was found in 64.7% of the Little Miami River samples. No pesticides or PCBs were detected in composite fillets from smallmouth bass, sauger, or channel catfish at RM 31.9, spotted bass and sauger at RM 18.5, smallmouth bass and freshwater drum at RM 8.0, and smallmouth bass at RM 3.5. The highest number of contaminants detected in the study area again occurred in the whole body composite sample of common carp collected at Beechmont Avenue.

The highest mercury concentration, 0.7 µg/g, occurred in spotted bass fillets collected downstream from the confluence of Sycamore Creek (RM 18.5). This concentration is the highest value recorded to date for mercury in the Ohio EPA fish tissue database and may be related to the re-occurring mercury exceedences in the Sycamore Creek WWTP effluent. Concentrations of cadmium and lead (maximum values of 0.046 and 1.88 µg/g, respectively) were low throughout the mainstem.

Physical Habitat for Aquatic Life

As the result of a complex geological history and predominantly natural stream channels, the Little Miami River watershed contains some of the highest quality riverine habitats in Ohio (Plates 3 through 5). Physical habitats within the mainstem and most tributaries exhibited good to exceptional quality attributes including moderate to high gradients, coarse substrates comprised of mixed glacial till and/or limestone fragments, and wooded riparian corridors. The quality of physical habitats within the mainstem and tributaries has been locally impacted by dams, unrestricted livestock access, channelization, removal of woody riparian vegetation, and excessive soil erosion. Embedded substrates and thick silt deposits were observed in most of the larger pools in the lower mainstem and the East Fork. Flows are also becoming increasingly controlled by reservoir releases and wastewater discharges. The implementation of stream protection measures such as maintaining natural flow regimes, the protection and restoration of wooded riparian zones, bank stabilization, and upland soil erosion control throughout the watershed is critical to the future protection and maintenance of physical habitats conducive to exceptional aquatic faunas.

Biological Community Performance

The overall performance of the biological communities within the Little Miami River study area ranged from exceptional to poor, with good to exceptional quality assemblages present at most locations. The 1993 study yielded a cumulative total of 408 different taxa (321 macroinvertebrate taxa and 87 fish species [109 fish species have historically been recorded]) throughout the study area, with 319 of these taxa (236 macroinvertebrate taxa and 83 fish species) from the Little Miami River mainstem alone. Three Ohio endangered fish species, the tonguetied minnow (*Exoglossum laurae*), mountain madtom (*Noturus eleuthrus*), and blue sucker (*Cycleptus elongatus*; a new record), were collected from the mainstem. A recent survey of Unionidae (freshwater mussels) sponsored by the Ohio DNR, Division of Natural Areas and Preserves (Hoggarth 1992) found two additional state endangered species, the rayed bean mussel and the wartyback mussel, in the mainstem and the little spectaclecase mussel in the East Fork upstream from Harsha Reservoir. Longitudinal trends in the diversity (total cumulative number of taxa collected) of macroinvertebrate, fish, and freshwater mussel species (1993 Ohio EPA collections and Hoggarth 1992) is illustrated in Figure 1. The most diverse faunas were found at South Lebanon (86 taxa of macroinvertebrates at RM 32.9), Loveland (18 mussel species at RM 23.9), and Plainville adjacent to Bass Island (41 fish species at RM 8.0).

Macroinvertebrate community performance was consistent with the applicable Invertebrate Community Index (ICI) criteria at 90.9% of the 33 mainstem sites and 64.3% of the 42 tributary locations. ICI scores or qualitative evaluations were indicative of exceptional to very good quality at most locations in the Little Miami River, Yellow Springs Creek, South Fork of Massies Creek, and the East Fork. Fair or poor quality macroinvertebrate assemblages, however, predominated the lower two miles of the mainstem, South Fork of Massies Creek, Little Beaver Creek downstream from the Montgomery Co. Eastern Regional WWTP, Beaver Creek near the mouth (downstream from the Greene Co. Beavercreek WWTP), Glady Run (and swale) downstream from the Xenia Glady Run WWTP, Newman Run, Flat Fork, Dry Run, and Sycamore Creek.

Fish community performance was consistent with the applicable Modified Index of Well-Being (MIwb) and Index of Biotic Integrity (IBI) criteria at 74.2% and 53.1%, respectively, of the mainstem sites and 80% and 53.5% of the tributary locations. Fish assemblages were indicative of exceptional to very good quality in the mainstem from Clifton Gorge to Lake Isabel, Yellow Springs Creek, Old Town Creek, Massies Creek, Newman Run, Anderson Fork, Caesar Creek upstream from the reservoir, Muddy Creek, Turtle Creek upstream from Cincinnati Milacron, Stonelick Creek near the mouth, and at most sites in the East Fork upstream from Milford. Fair or poor quality assemblages, however, predominated in the lower two miles of the mainstem, Little Beaver Creek both upstream and downstream from the Montgomery Co. Eastern Regional WWTP, Beaver Creek upstream from Little Beaver Creek, Glady Run Swale upstream from the Xenia Glady Run WWTP, Glady Run upstream and immediately downstream from the Xenia Glady Run WWTP, Flat Fork, Dry Run, Stonelick Creek within and upstream from the reservoir, and Sycamore Creek upstream from the Sycamore Creek WWTP.

Although significant improvements have occurred in the mainstem since 1983, biological recovery was not complete in 1993. Evidence of adverse impacts included lower than expected biological index scores, elevated numbers of fish with DELT anomalies, predominance by tolerant species, and fish kills. While the specific types of impacts varied throughout the watershed, most included the inadequate disposal and/or treatment of human and other animal wastes. Associated causes and sources of non-attainment by waterbody segment are listed in Table 2.

Trend Analysis

Little Miami River

During the past decade, significant progress has been made towards restoring the chemical, physical, and biological integrity of the Little Miami River mainstem and tributaries. From 1983 to 1993, the number of miles in FULL attainment of EWH has increased from 1.5 to 40.9 miles while the number of miles in **NON** attainment decreased from 45.4 to 3.0 miles (Table 13). Complete recovery was not evident in 1993, however, because 58.2 miles were in PARTIAL attainment due primarily to a failure of fish assemblages to meet the IBI criteria. The most significant improvements (*i.e.*, restored to FULL attainment) in the mainstem occurred within Greene, southern Warren, and northern Hamilton and Clermont Counties and are due primarily to the improved treatment of sewage by county and municipal WWTPs. Since 1983, the aquatic life use attainment status improved (*i.e.*, changed from **NON** to PARTIAL or PARTIAL to FULL) in all 11 of the similarly sampled segments within the upper half of the mainstem, but improved in only six (6) of the 13 previously PARTIAL or **NON** attaining segments within the lower half (Table 3).

Comparisons of the biological index (ICI, MIwb, and IBI) scores and Area of Degradation (ADV) values (see page 37 for description of ADV) from 1983 to 1993 for similarly sampled segments also confirms that the greatest improvements have occurred within the upper half of the Little Miami River mainstem (Tables 3 and 13). The average increase in ICI scores (>4 ICI units is considered significant) between 1983 and 1993 was higher in the upper half (+13.8 units; range of +2 to +32) than in the lower half (+5.8 units; range of -2 to +18). Area of Degradation Values (ADV) for the ICI declined from 116.9 units/mile to 0.8 units/mile in the upper half and from 21.4 units/mile to 14.9 units/mile in the lower half between 1983 and 1993. The average increase in MIwb scores (>0.5 MIwb units is considered significant) was also higher in the upper half (+1.0 units; range of -0.3 to +2.1) than in the lower half (+0.5 units; range of -0.7 to +1.7). ADV values for the MIwb declined from 45.5 units/mile to 6.1 units/mile in the upper half and from 12.5 units/mile to 5.1 units/mile in the lower half from 1983 to 1993. The average difference between 1983 and 1993 IBI scores (>4 IBI units is considered significant) were only slightly higher in the upper half (+2.8 units; range of -4 to +13) than in the lower half (+1.6 units; range of -8 to +9). ADV values for the IBI declined from 84.7 units/mile to 46.3 units/mile in the upper half and from 39.0 units/mile to 32.6 units/mile in the lower half. ADV/mile values for the IBI showed the least improvement during 1993, an indication that fish assemblages remain functionally impaired in both segments. The cumulative number of fish species collected in the Little Miami River increased from 71 in 1983 to 83 in 1993.

Beaver Creek and Little Beaver Creek

Since 1983, the aquatic life use attainment status in Beaver Creek has shown no significant change downstream from Little Beaver Creek or the Greene Co. Beavercreek WWTP. Miles in PARTIAL attainment of WWH have remained at 0.4. Little Beaver Creek has improved only slightly with a decrease of miles in **NON** attainment (4.2 to 2.1) and an increase of in PARTIAL attainment (0.0 to 0.7 miles) of WWH. NON attainment was observed both upstream and downstream from the Montgomery Co. Eastern Regional WWTP. ADV/mile for the IBI and ICI both showed declines of approximately 50% between 1982 and 1993.

Turtle Creek

Aquatic life use attainment status (WWH) in Turtle Creek improved between 1983 and 1993. Miles in FULL attainment increased from 1.6 to 5.9 while miles in **NON** attainment decreased from 4.0 to 0.0. ADV statistics show a substantial decline to ADV/mile values at or near 0 in 1993. The WWH attainment status immediately downstream from Cincinnati Milacron, however, has recently decreased from FULL attainment during 1989 through 1992 to PARTIAL attainment in 1993.

Sycamore Creek
Since 1983, the aquatic life use attainment status in the lower one-half mile of Sycamore Creek has shown a slight improvement downstream from the Hamilton Co. MSD Sycamore Creek WWTP. The number of miles in PARTIAL attainment of WWH has increased from 0.0 to 0.3 with the miles in the poor to very poor performance range decreasing from 0.6 to 0.1 miles. ADV/mile values declined correspondingly, but still indicated significant impairment in 1993. Impairments exist both upstream and downstream from the Hamilton Co. Sycamore Creek WWTP. The upstream problems are primarily associated with instream sewer line construction and sanitary sewer overflows (Ohio EPA 1992b).

East Fork Little Miami River
The 1993 results show the attainment status within the East Fork has marginally deteriorated since 1982 due primarily to declines in IBI scores. Miles in FULL attainment of EWH decreased from 10.0 in 1982 to 7.1 in 1993, while the miles in PARTIAL attainment increased from 4.8 to 7.8 (Table 13). Compared to 1982, ICI scores increased in four segments, but declined in three (average increase of +1.4 units; range of -6 to +8), MIwb values increased in six segments and decreased in one (average increase of +0.7 units; range of -0.2 to +1.9), and IBI values declined in four segments and increased in three (average decrease of -1.4 units; range of -7 to +7). ADV values, however, indicate the slight magnitude of the declines with the greatest change exhibited by the IBI ADV/mile of 6.9 in 1982 to 15.7 in 1993. Neither value approaches those observed for the mainstem Little Miami River. The ADV/mile for the ICI and MIwb registered little if any changes.

Since 1982, commonly sampled segments upstream and downstream from the Batavia WWTP improved from PARTIAL to FULL (RM 15.5 - 12.7). The reach downstream from the Clermont Co. Middle East Fork WWTP to the confluence of Stonelick Creek has remained FULL. The site at Perintown (RM 6.7), however, decreased from FULL to PARTIAL attainment status. Suspected sources of impact may include the discharge of sewage to Sugar Camp Run, Shayler Run, and other nearby tributaries by SSOs, leaking interceptor sewers, and increased siltation from suburban development. Downstream from the Clermont Co. Lower East Fork WWTP use attainment status improved from PARTIAL to FULL, but evidence of impacts remained (*i.e.*, DELT anomalies). Use attainment in the segment upstream from the Milford WWTP remained PARTIAL and decreased from FULL to PARTIAL downstream from the Milford WWTP.

Point Source Discharge Summaries

The following are general summaries of information about the major point sources evaluated during the 1993 survey, arranged longitudinally from upstream to downstream:

City of Yellow Springs WWTP (Yellow Springs Cr. RM 0.44; Little Miami River (LMR) RM 85.17)
Macroinvertebrate and fish assemblages in Yellow Springs Creek showed no discernable evidence of adverse impacts from the Yellow Springs WWTP. Sites immediately upstream and downstream were in FULL attainment of EWH biocriteria, thus a use designation change from WWH to EWH is recommended. Mixing zone (the effluent splits into several channels in the floodplain and enters the headwater tributary at the upstream and downstream ends of a large bend) results indicated no obvious evidence of acute toxicity. Sludge deposits, however, were observed within the effluent channels and in Yellow Springs Creek immediately downstream. The incidence of DELT anomalies increased slightly in the Little Miami River mainstem downstream from Yellow Springs Creek (0.3 to 0.8%). Ammonia-N violations and phosphorus exceedences were also recorded downstream from the WWTP. The facility reported 25 NPDES permit violations (primarily for ammonia-N and suspended solids) during 1992. The potential impact of the effluent is apparently mitigated by the cascading falls and divided effluent channels that allow the discharge to enter Yellow Springs Creek at two or more widely spaced locations.

City of Xenia-Ford Road WWTP (Little Miami River RM 77.05)
Biological sampling in the mainstem revealed FULL attainment of the EWH biocriteria upstream and downstream from the Xenia Ford Rd. WWTP. The incidence of DELT anomalies increased within the mixing zone and downstream from the WWTP indicating some degree of impact, possibly a mild toxicity. The mean percentage of fish with DELT anomalies increased from 0.6% upstream to 4.1% in mixing zone to 1.6% downstream from the WWTP indicating some degree of impact. The mean number of fish with DELT anomalies increased from 7.8 to 51.8 to 16.6, respectively. Figures 76a - 77c show a positive relationship to the incidence of anomalies and total volume of effluent discharged to the upper half of the Little Miami River mainstem. The source(s) of stress within the effluent causing the higher than normal numbers of anomalies is not known, but may be due to a mild toxicity. A direct relationship with anomalies is also suggested in the mainstem with mean total phosphorus and total suspended solids concentrations, two common constituents of municipal WWTP effluent. These results do not, however, indicate widespread avoidance or acute toxicity. The facility reported 5 NPDES permit violations (primarily fecal coliform) during 1992. Grab water samples from the mainstem revealed one phthalate exceedence downstream from the WWTP and upstream from Shawnee Creek. Compared to 1983, the 1993 results reveal increased ICI, MIwb, and IBI scores (+6, +1.6, and +3 units, respectively). The use attainment status of the Little Miami River downstream from the WWTP improved to FULL from PARTIAL.

Montgomery Co. Eastern Regional WWTP (Little Beaver Cr. RM 4.57; Beaver Cr. RM 1.12)
Macroinvertebrate community performance declined from good upstream from the WWTP to poor downstream and further indicated an acutely toxic impact. Fish assemblages, however, were of poor quality both upstream and downstream from the WWTP suggesting an upstream source of impact as well. The tolerant fish assemblage showed no indication of avoiding the mixing zone. Habitat quality markedly declined downstream from the WWTP mixing zone, possibly the after-effect of old channelization. The channel was wide, shallow, and uniform with little instream cover. The macroinvertebrate and fish assemblages improved to good and fair quality, respectively, near the mouth. A large fish kill occurred downstream from the WWTP during 1992 due to a sewage spill. The facility reported 20 NPDES permit violations (primarily metals) during 1992. Ambient water chemistry showed elevated phosphorus levels throughout the four mile reach downstream from the WWTP. The mean number of fish species collected from Little Beaver Creek near the mouth increased from one (1) in 1982 to 15 in 1993.

Greene Co. Beavercreek WWTP (Beaver Creek RM 0.4; LMR RM 72.74)
Biological results from the mixing zone suggested no significant acute toxicity. Macroinvertebrates, however, declined from exceptional quality upstream from the WWTP to only fair quality downstream from the mixing zone. The fish community also changed with a decline in the MIwb and a reduction in the number of redhorse. Ambient water chemistry showed elevated phosphorus levels both upstream and downstream from the WWTP. The facility reported 4 NPDES permit violations (primarily mercury) during 1992. ICI, MIwb, and IBI scores in the mainstem of the Little Miami River downstream from Beaver Creek have significantly improved since 1983 (+24, +1.1, and +7 units, respectively) resulting in a use attainment status change from PARTIAL to FULL at the Narrows. All three biological index scores also increased (+10, +2.1, and +10 units, respectively) further downstream, however, the use attainment status changed from NON to only PARTIAL suggesting an impact due to the assimilation of an excessive total nutrient/organic loading from upstream discharges. Since 1983, the incidence of DELT anomalies in mainstem has decreased immediately downstream from Beaver Creek, but increased near Bellbrook within the impaired segment. Elevated phosphorus concentrations both upstream and downstream from this WWTP is also an indication of the high nutrient/organic loadings within the watershed.

Greene Co. Sugarcreek WWTP (Little Miami River RM 64.43)
Biological sampling in the mixing zone showed no evidence of significant acute toxicity to fish or macroinvertebrates. The fish community performance improved (*e.g.,*, higher MIwb and IBI values, high diversity, and slightly lower, but still elevated incidence of DELT anomalies) downstream from the WWTP, but returned to an impaired state at Spring

Valley. Ambient water chemistry results downstream from the WWTP showed the highest mean and maximum concentrations of ammonia-N and $CBOD_5$ within the upper half of the mainstem. A highly elevated concentration of bis (2-ethylhexyl) phthalate was also detected. The facility reported no NPDES permit violations during 1992.

City of Xenia-Glady Run WWTP (Glady Run RM 4.78; LMR RM 63.72)
Biological sampling in the mixing zone showed no evidence of significant acute toxicity, although macroinvertebrate community performance declined downstream from the WWTP. Ambient water chemistry showed elevated phosphorus levels along with residual chlorine and pesticide exceedences downstream from the WWTP. The facility reported only 3 NPDES permit violations (D.O. and mercury) during 1992. Downstream from the confluence of Glady Run, the Little Miami River had the highest mean concentration of phosphorus within the upper half of the mainstem. The incidence of DELT anomalies in the mainstem has increased since 1983 (from 5.0%/10.5/km in 1983 to 7.3%/34.2/km in 1993). Since 1983, however, biological index values have significantly increased (+ 10 ICI units, +1.6 MIwb units, and +13 IBI units) and the attainment the attainment status has improved from **NON** to PARTIAL.

City of Waynesville WWTP (Little Miami River RM 53.7)
The 1993 biological index scores from the Little Miami River mainstem downstream from the Waynesville WWTP indicate an impact from this facility and upstream WWTPs, but may also reflect physical habitat change from a predominance of high-gradient shallower habitats to large, deep low-gradient pools. The facility reported 7 fecal coliform NPDES permit violations during 1992 and 8 (primarily ammonia-N and D.O.) violations during 1993. Biological index scores since 1983, have remained similar for the ICI and IBI (+2 and -1 units, respectively) and increased moderately for the MIwb (+0.7 units). The aquatic life use attainment status of the mainstem has improved from **NON** to PARTIAL in the vicinity of the WWTP. The highest percentage (mean) of DELT anomalies (9.3%) in 1993 occurred in the mainstem downstream from this facility.

Cincinnati Milacron (Turtle Creek RM 0.5; LMR RM 33.2)
Turtle Creek, downstream from Cincinnati Milacron, the highest number of conventional parameter exceedences in the study area (6 parameters, 15 values) was observed. The facility reported only 4 NPDES permit violations (nickel and residual chlorine) during 1992; nine violations (silver and copper) were reported in 1993. Fish sampling in the mixing zone showed no evidence of significant acute toxicity. The presence of pollution sensitive fish species and IBI and ICI scores consistent with WWH biocriteria suggests the below standard MIwb value (which resulted in PARTIAL attainment) was due to the loss of deeper habitats as opposed to chemical impacts from Cincinnati Milacron. Water levels and flows in Turtle Creek (upstream and downstream from this discharger) were noticeably lower in 1993 than during previous years. De-watering appears to be the cause of the shallower than normal pool and run-riffle habitats, but the source(s) are in dispute. Biological sampling results prior to the de-watering impacts indicated FULL attainment of WWH under similar loadings from Cincinnati Milacron. Ambient water chemistry results, however, revealed copper, conductivity, total dissolved solids, ammonia-N, and phosphorus exceedences downstream from the facility. An elevated cadmium value was also recorded in the Little Miami River mainstem downstream from the confluence of Turtle Creek. Despite these exceedences, aquatic life use attainment has been FULL and is partially explained by the dynamics of the discharge. A diffuser was installed in 1993 in an attempt to alleviate effluent and mixing zone toxicity. The high number of exceedences are likely due to less dilution caused by the lower than normal flow. The industry reported a significant number of failed bioassays during 1992 and 1993.

City of Lebanon WWTP (Little Miami River RM 32.12)
Biological sampling within the mixing zone also showed no significant acute toxicity. Ambient water chemistry showed elevated concentrations of ammonia-N and phosphorus in the mixing zone. Fish in the mixing zone had an elevated incidence of DELT anomalies (6.1%, 40.3/km). The Lebanon WWTP reported no NPDES permit violations during 1992. Compared to 1983, the 1993 results showed significant biological improvements (+8 ICI units, +1.7 MIwb units, and +7 IBI units). Use aquatic life use attainment status downstream from the WWTP improved from PARTIAL to FULL attainment.

City of Mason WWTP (Muddy Creek RM 3.24; LMR RM 31.9)
Macroinvertebrate and fish community samples from Muddy Creek fully attained WWH biocriteria during the 1993 survey. An abundance of common carp and high percentage of other diptera/non-insects, however, were indicative of nutrient/organic enrichment from the WWTP. Sludge deposits were also evident along the stream margins at RM 2.5. Ambient water chemistry results downstream from the WWTP detected exceedences for residual chlorine, copper, phosphorus, and fecal bacteria. The facility reported 70 NPDES permit violations (primarily BOD_5 and suspended solids) during 1990 and 42 violations during 1992. The fish community at RM 1.6 has improved dramatically since 1981 when the IBI scored a 15 (and only 3 fish species were collected) compared to an IBI of 46 in 1993 (and 21 fish species were collected). Macroinvertebrates were not sampled in 1981 and have shown a slight improvement at RM 2.5 since 1989 (ICI scored a 28 in 1989 and a 34 in 1993). Fish sampling at RM 2.4/2.5 yielded an IBI of 23 in 1981, a 37 in 1989, and a 30 in 1991.

Warren Co. Lower LMR WWTP (Simpson Creek RM 0.1; LMR RM 28.1)
Ambient water chemistry samples from the Little Miami River downstream from Simpson Creek had the highest number of conventional parameter exceedences (4 parameters, 10 values) of all the mainstem sampling locations. Six (6) values exceeded the water quality standard for total residual chlorine, two (2) values for temperature, one (1) value for mercury, and one (1) value for phosphorus. The facility reported only 7 NPDES permit violations (primarily ammonia-N) during 1992. Biological sampling immediately downstream from Simpson Creek showed no evidence of significant acute toxicity. Since 1983, mean biological index scores have increased (+2 ICI units, +1.7 MIwb units, and +9 IBI units). The use attainment status has improved to FULL throughout an eight mile reach downstream from the WWTP.

Totes Inc. (Little Miami River RM 22.2)
Ambient water chemistry samples detected an elevated phosphorus value and highly elevated zinc concentration downstream from this industrial discharge. NPDES permit violations were reported for BOD_5 (7 in 1992) and suspended solids during 1992-3. The industry discharges to a large pool which has been adversely impacted by sedimentation. The PARTIAL use attainment status downstream from the discharge was due to a low MIwb value which was most likely due to a combination of excessive sedimentation and the lack of riffle-run habitat in the sampling zone. The incidence of DELT anomalies downstream from the discharge was one of the lowest in the mainstem (1.0%, 2.7/km).

Hamilton Co. MSD Polk Run WWTP (Unnamed Tributary RM 0.1; LMR RM 21.5)
Ambient water chemistry showed fecal bacteria and temperature exceedences in the mainstem downstream from the WWTP. The facility reported only one NPDES permit violation during 1992. Sanitary sewer overflows (SSO) begin to enter the mainstem here. Compared to the 1983 biological results, the 1993 samples show marked improvement has occurred to macroinvertebrate and fish assemblages downstream from the WWTP (+18 ICI units, +0.7 MIwb units, and +6 IBI units). Since 1983, the aquatic life use attainment status downstream from the facility has improved from NON to FULL.

Hamilton Co. MSD Sycamore Creek WWTP (Sycamore Creek RM 0.26; LMR RM 19.2)
Biological sampling in Sycamore Creek during 1993 detected no acnte toxicity within the WWTP mixing zone and non attaining (fair) macroinvertebrate assemblages both upstream and downstream from the discharge. Fish assemblages improved from fair quality upstream from the WWTP to marginal good quality (attained WWH) downstream from the mixing zone. Sludge deposits, however, were observed only in the large pool downstream from the WWTP in 1993. Ambient water chemistry downstream from the WWTP in 1993 detected elevated phosphorus and fecal bacteria levels Elevated fecal bacteria levels were also detected in Sycamore Creek upstream from the WWTP. The highest number and total quantity of semi-volatile organic compounds in the study area occurred in Sycamore Creek downstream from the Sycamore Creek WWTP (RM 0.05). Thirteen (13) different PAH componnds were detected with a relatively high total concentration of 36.6 mg/kg (ppm). The sediment sample at this location also contained toluene (a solvent), the only

detected volatile organic compound. Only two (2) PAH compounds, both at markedly lower concentrations, were collected immediately upstream from the WWTP. The WWTP reported 20 NPDES permit violations for mercury in 1992 and a extremely high ambient mercury value (2.4 ug/l) was recorded in January 1994. In the Little Miami River downstream from the confluence of Sycamore Creek, mercury contamination was detected in spotted bass fillets (RM 18.5) and the use attainment status has remained PARTIAL since 1983, unlike many segments which have demonstrated improvement.

City of Batavia WWTP (East Fork LMR RM 13.5; LMR RM 11.5)
No ambient water quality exceedences were detected in 1993 downstream from the WWTP. Biological sampling in 1993 showed no evidence of significant acute toxicity. However, there was a marked decline in the percentage of top carnivores in the East Fork downstream from Batavia. The total relative numbers (density) of rock bass, smallmouth bass, and spotted bass combined (the three most abundant game species) declined from 167/km at RM 15.5 to 26/km at RM 12.7. Densities fluctuated further downstream, but remained low (6-61/km) to the mouth. The mean relative number of these three common game species in the lower 13 miles of the East Fork declined from 59/km in 1982 to 26/km in 1993. Compared to the 1982 results, the 1993 samples showed a decline of 2 ICI units, but higher MIwb (+1.4 units) and IBI values (+7 units, the largest IBI increase from 1982 to 1993 of the eight East Fork sampling locations). A higher ICI value of 54 was recorded further downstream from the WWTP and immediately upstream from the Middle East Fork WWTP. The RM 2.7 macroinvertebrate sample also had the highest numbers of EPT taxa collected in the study area. Since 1982, however, the use attainment status improved from PARTIAL (1982) to FULL (1993) downstream from the WWTP. The 1993 incidence of DELT anomalies downstream from this discharge (0.9% at RM 12.7) was only slightly higher than upstream (0.7% at RM 15.5). Compared to the 1982 DELT percentages, the incidence of DELT anomalies in 1993 were lower at RM 15.5 (2.1% in 1982), but slightly higher at RM 12.7 (0.3% in 1982).

Clermont Co. Middle East Fork Regional WWTP (East Fork LMR RM 12.6; LMR RM 11.5)
Ambient water chemistry showed elevated phosphorus levels downstream from the WWTP. Biological sampling downstream from the WWTP showed no evidence of acute toxicity. Compared to the 1982 biological index scores, the 1993 results from RM 12.4 to 12.2 showed higher MIwb and IBI values (+1.9 and +2 units, respectively). The use attainment status was FULL in 1982 and 1993. The use attainment further downstream (RM 10.1/9.1) was also FULL despite a 5 unit decline in the IBI from 1982 to 1993 (the ICI and the MIwb increased +2 and +0.6 units, respectively). At Perintown (RM 6.7/6.6), the IBI also declined 5 units causing the use attainment status to change from FULL (1982) to PARTIAL (1993). The ICI also decreased 6 units while the MIwb remained unchanged since 1982. In addition to the assimilation of pollutants discharged by the two upstream WWTPs, sanitary sewer overflows (SSO) in Sugar Camp Run and other tributaries from within the Lower East Fork WWTP infrastructure may also contribute to the impacts observed at Perintown. Other possible sources include land development and spills. Since the previous survey, the incidence of DELT anomalies downstream from this discharge (RM 12.5 - 6.6) has increased (ranged from 0.9 - 1.5% in 1982 and 2.7 - 4.6% in 1993).

Clermont Co. Lower East Fork Reg.WWTP (East Fork LMR RM 4.9; LMR RM 11.5)
Ambient water chemistry showed elevated levels of phosphorus and fecal bacteria downstream from the WWTP. Biological results were indicative of no acute toxicity downstream from the effluent tributary, however, patches of waterwillow (a pollution sensitive aquatic plant) noticeably declined within the East Fork's channel downstream from the discharge. Although two (2) of the three (3) 1993 biological index scores from RMs 4.7 and 4.1 were slightly lower than in 1982 (- 4 ICI units, and - 0.2 MIwb units), the aquatic life use attainment status changed from PARTIAL to FULL due to a one (1) unit IBI increase. Further downstream (RM 2.4/1.7), the 1993 results showed higher values for the ICI (+4 units) and the MIwb (+0.5 units), but a lower IBI score (- 4 units). Longitudinally, the IBI also declined in 1993 from a 44 at RM 4.7 to a 36 at RM 1.7 (upstream from the Milford WWTP). The PARTIAL use attainment status has not changed in this segment since 1982.

City of Milford WWTP (East Fork LMR RM 1.3; LMR RM 11.5)
Ambient water chemistry downstream from the WWTP showed a below standard D.O. value and elevated levels of fecal bacteria. The WWTP reported 11 NPDES permit violations (mostly TSS) during 1992. Compared to the 1982 results, the 1993 samples showed increased values for the ICI and MIwb (+8 and +0.5 units), but lower IBI (-7 units) that caused the use attainment status to changed from FULL (1982) to PARTIAL (1993). The lower IBI score in 1993 may be partially attributed to sampling a different location which was comprised mostly of large deep pools. The Qualitative Habitat Evaluation Index (QHEI) scored a 65, the lowest value of the 8 East Fork sites.

CONCLUSIONS

- With more than 83 fish species, 36 mussel species, and 234 additional taxa of aquatic macroinvertebrates, the mainstem of the Little Miami River is one of the most biologically diverse rivers in Ohio. The mainstem fauna includes five (5) Ohio endangered species; blue sucker, mountain madtom, tonguetied minnow, rayed bean mussel, and wartyback mussel (Plates 7 - 8).

- Significant improvements have occurred since the 1983 survey, but recovery was not yet complete in 1993 due to a variety of impacts. The principal cause of the observed PARTIAL and **NON** attainment of aquatic life use designations are organic and nutrient enrichment from point sources. More than 99% of the effluent discharged by point sources is from municipal and county WWTPs as opposed to industrial sources. Although most of the WWTPs have significantly reduced total annual loadiugs of pollutants since 1983, the cumulative total amount of pollutants still exceeds the assimilative capacity of the Little Miami River between Bellbrook and Oregonia and in Hamilton and Clermont counties as evidenced by a failure to attain the EWH use designation.

- Higher than expected numbers of fish with external deformities, eroded fins, lesions/ulcers, and tumors (DELT anomalies) were collected in the mainstem downstream from many of the WWTPs, even in sections currently meeting EWH criteria (Plate 10). Expansion of flows at most of WWTPs poses a threat to the recovery of the mainstem to FULL EWH attainment and the specter of higher than normal DELT anomalies. The incidence of DELT anomalies was correlated with phosphorus levels in the mainstem.

- Nonpoint source pollutants, such as silt, manure runoff, and habitat alterations also impact streams throughout the watershed and pose a threat to the EWH goals. Stream protection measures, such as erosion controls, and improved riparian management and restoration are needed to bring other sections of the mainstem and tributaries into FULL attainment and protect and preserve the existing high quality segments.

- Future strategies to accomplish meeting WQS goals need to include reduced nutrient loadings, controlling the total volume of effluent discharged, watershed programs to reduce soil erosion, the virtual elimination of raw sewage releases (*i.e.*, CSO and SSO discharges), and the reduction and elimination of spills and other unauthorized releases throughout the basin.

- Pollutant discharges from spills, overflows, permit violations, and unauthorized releases are a significant source of acute and chronic stresses for aquatic communities in the Little Miami River watershed (Plate 10). Of the approximately 1500 incidents recorded by the Ohio EPA from 1983 to 1993, the most significant spills resulted in the cumulative discharge of more than 78,393,659 gallons and 48,326 pounds of pollutants (Appendix Table A-1). Sewage overwhelmingly predominated these releases comprising 98.1% by volume and 53% of the spill events. Other pollutants included petroleum products (22%, 52 events), chemicals (13%, 32 events), and agricultural related activities (9%, 21 events). Spills and other pollutant releases have killed approximately 58,590 fish and other wild animals within the Little Miami River watershed since 1983 (Ohio DNR pollution investigations listed 49 incidents). Agricultural related activities (primarily manure runoff and fertilizer spills) were the leading cause (accounted for 37.3% of the total kill) followed by chemical/industrial sources (26.7%; primarily petroleum products and chemicals), public services (21.7%; primarily municipal sewage), and unknown causes (14.3%). The highest number of incidents in tributaries occurred within Greene (13), Clinton (12), and Clermont (11) counties. The highest number of incidents by subbasin occurred in the Todds Fork subbasin (12), East Fork subbasin (8); Shawnee Creek (6); Caesar Creek subbasin (6), and the Little Beaver Creek subbasin (3). Eighteen (18) of the kills have occurred during the last four years (1990-1993).

- The cumulative pattern of non-compliance with NPDES permit limits within the study area shows there is a high probability that one or more of the point sources will record a violation in any given month. During 1992, the 21 major point source dischargers reported a cumulative total of 225 NPDES permit violations (Table A-3). The highest number of exceedences were reported by the Mason WWTP (42), Cedarville WWTP (28), Yellow Springs WWTP (25), Hamilton County MSD Sycamore Creek WWTP (22), and the Montgomery County Eastern Regional WWTP (20). The combination of permit violations and pollutant discharges from spills, CSOs, SSOs, and stormwater outfalls subject the mainstem and tributaries to frequent episodes of ambient chemistry which approach or exceed water quality criteria. These episodes undoubtedly contribute to the observed PARTIAL and **NON** attainment of designated aquatic life uses and other symptoms of impacted aquatic communities (*i.e.*, increased incidence of external DELT anomalies, below standard biological index values).

- Sediments in the Little Miami River at Beechmont Avenue had the greatest number and the highest concentrations of contaminants in the study area. Contaminants included four (4) pesticides and nine (9) PAH compounds. Beechmont Avenue was the only site with highly to extremely elevated concentrations of heavy metals in the sediment. While future abatement efforts are needed throughout the basin, they are particularly important in Hamilton and Clermont counties to protect and enhance the only known reproducing Ohio population of blue suckers, one of the State's rarest endangered species.

- The frequency and distribution of fecal coliform and *E. coli* bacterial exceedences in the study area are also indicative of negative water quality impacts throughout the basin. Fecal bacteria counts exceeded the maximum criteria for the designated contact recreation use in 38.9% of the possible tests during the 1993 survey. Thirty-four (34) locations in nine (9) streams designated for Primary Contact Recreation (PCR) had one or more values which exceeded the maximum criterion. Eleven (11) locations in four (4) tributaries designated for Secondary Contact Recreation (SCR) had one or more values which exceeded the maximum criterion. Water with high fecal bacteria counts has been contaminated by human and/or animal wastes and may contain other harmful bacteria and/or viruses, thus posing an increased risk to humans for water borne disease and/or illness. Major sources of fecal contamination include WWTPs (spills, malfunctioning systems, and bypassing), CSOs, SSOs, failing on-site (septic) systems, livestock, wild animals, and urban runoff.

- Ambient fecal bacteria counts were usually highest immediately following a rainfall/runoff event. The highest counts within the study area occurred in the Little Miami River downstream from

South Charleston (fecal coliform; RM 101.3) and downstream from Sycamore Creek (*E. coli;* RM 18.14). Sites with the most exceedences were Sycamore Creek downstream from the Hamilton Co. Sycamore Creek WWTP (12 values; RM 0.05) and the Little Miami River downstream from the Lebanon WWTP (nine values; RM 31.96).

- Excessive levels of suspended sediment from soil erosion continue to enter the Little Miami River and tributaries following rainfall/runoff events. Fluvial sediment data from the Little Miami River at Milford between 1977 and 1986 showed a mean annual suspended sediment discharge of 474,000 tons. The Little Miami River had the third highest watershed rate (394 tons/year/square mile) of the 10 monitoring stations throughout Ohio with daily data reported between 1977 and 1986 (Hindall 1989). The Little Miami R. also had the highest rate for the four largest tributary rivers to the Ohio River mainstem. Major sources of sediment include agricultural runoff (row crops), construction activities, and severely eroding banks (Plate 12).

- Land use within the Little Miami River watershed is becoming increasingly developed (Plate 14). NPDES permit requests for new WWTPs and the expansion of existing WWTPs is an indication of increased suburbanization. The principal threats to rivers and streams from the increasing development include an increased demand for raw water supplies, increasing volumes of wastewater (resulting in increasingly effluent dominated stream flows), increased rates of runoff, riparian encroachment, and decreased groundwater recharge which helps maintain surface water base flows. To mitigate the negative effects of increased land development, resource management strategies such as stream protection measures, adequate and efficient WWTPs, pollution prevention, the implementation of new abatement programs (*e.g.*, stormwater runoff and CSO controls), and the protection and restoration of wooded areas (*e.g.*, Greene Co. Parks, City of Indian Hill Green Areas, and Little Miami Incorporated programs) are essential to restore and maintain this high quality water resource.

RECOMMENDATIONS

Based upon the findings of this report, the following general recommendations are made.

Point Sources

- Past upgrades at most WWTPs within the watershed have improved the aquatic life use attainment status in the mainstem and many streams throughout the watershed. Results from this study, however, indicate that the total cumulative pollutant loading discharged to the Little Miami River (directly or via tributaries) still exceeds the assimilative capacity of the mainstem. Evidence of point source impacts include elevated levels of DELT anomalies on fish, below standard biological index scores, and chemical criteria and fecal bacteria exceedences. The amount of flow from WWTPs in the Little Miami River watershed has increased since 1983 and the overall quality of macroinvertebrate and fish assemblages have generally improved. However, the highest performing EWH streams in Ohio receive markedly lower volumes of WWTP effluent (*e.g.*, Big Darby Creek). At approximately 50 MGD discharged during the third quarter of 1993, the Little Miami River mainstem receives the greatest volume of any EWH stream in the state. Conditions for granting increased volumes of effluent should be conservative and may need to include heretofore unconventional measures (*e.g.*, nutrient removal) in order to insure the restoration and maintenance of the EWH use designation.

- The source(s) of mercury and PAHs in Sycamore Creek downstream from the Hamilton County

MSD Sycamore Creek WWTP should be determined and controlled. Sludge samples from within the WWTP should be analyzed for these parameters as soon as possible to determine if the facility is responsible.

- The relatively frequent incidence of pesticides detected in excess of water quality criteria merits further investigation. While these compounds were found in upstream segments, the frequency of detection and exceedence was highest immediately downstream from selected WWTPs. The source of these compounds should be ascertained.

- Major sources of fecal bacteria contamination should be identified and corrected to improve the attainment of the Primary Contact Recreation (PCR) use designation within the Little Miami River mainstem and tributaries. Fecal bacteria counts exceeded the maximum criteria for the designated recreational use in 38.9% of the possible tests during the 1993 survey. Thirty-four (34) locations in nine (9) streams designated for Primary Contact Recreation (PCR) had one or more values which exceeded the maximum criterion. Eleven (11) locations in four (4) tributaries designated for Secondary Contact Recreation (SCR) had one or more values which exceeded the maximum criterion.

- The lime sludge discharge to the Little Miami River by the City of Milford Water Treatment Plant should be eliminated.

Nonpoint Sources

- A variety of stream protection techniques should be widely implemented throughout the watershed to significantly reduce soil erosion including (but not limited to) bank stabilization, restoring woody riparian vegetation, and best management practices for stormwater and soil erosion at construction sites.

- The number and quantity of spills and other unauthorized releases should be reduced and eliminated whenever possible. Actions should be taken against on-going sources of spills, overflows, and other unauthorized releases. SSO and CSO discharges should be eliminated, or controlled by treatment, particularly those that discharge during dry weather and under minimal precipitation events.

Status of Aquatic Life Uses

- Aquatic life uses for some streams evaluated during this study were originally designated in the 1978 Ohio WQS without the presently employed standardized approaches to the collection of instream biological data and numerical biocriteria. Revisions are recommended for certain stream segments because this study represents the first use of biological data and numerical biocriteria to evaluate and establish aquatic life use designations. While some of the changes may appear to constitute "downgrades" (*i.e.,* EWH to WWH, WWH to MWH, etc.) or "upgrades" (*i.e.,* LWH to WWH, WWH to EWH, etc.), these should not be construed as such because this constitutes the first use of an objective and robust use evaluation system and database. Ohio EPA is under obligation by a 1981 public notice to review and evaluate all aquatic life use designations made in 1978 (other than WWH) prior to basing any permitting actions on these existing, unverified use designations. Thus, some of the following aquatic life use recommendations constitute a fulfillment of that obligation. Based on the 1993 survey results, the following aquatic life use designation changes are recommended for streams within the Little Miami River basin study area.

Little Miami River: EWH Use Designation Existing; *WWH Recommended for Ohio R. backwaters (RM 3.0 - 0.0).*

Yellow Springs Creek: WWH Use Designation Existing; *EWH Recommended (entire length).*
Glady Run Swale: No Use Designation Existing; *WWH Recommended.*

No changes are recommended for the remaining 15 rivers and streams which were sampled.

Status of Non-Aquatic Life Uses

- Results of the present study support the existing non-aquatic life uses (Agricultural Water Supply, Industrial Water Supply, Primary Contact Recreation, and Secondary Contact Recreation) currently designated for the Little Miami River and selected tributaries. During the summer of 1993, fecal coliform and *E. coli* bacteria counts exceeded the Primary and Secondary Contact Recreation criteria in many of the streams sampled.

Future Monitoring

- Biological and water quality sampling should continue in the Little Miami River basin to track the progress in attaining improved water quality. The next complete survey for the watershed is scheduled for 1998 according to the Five-Year Basin Approach to Monitoring and NPDES Permit Reissuance. In addition to re-sampling the mainstem, biological and chemical monitoring should also be conducted in tributaries with reoccurring spills, fish kills, and other unauthorized releases. The highest number of incidents (12) occurred in the Todd Fork subbasin, with two tributaries (Lytle and Cowan Creeks) having received high ammonia-N concentrations from deicing chemicals and jet fuel from Airborne Express. Other areas with these types of incidents include the East Fork sub-basin (8), Shawnee Creek (6), Caesar Creek subbasin (6), and Little Beaver Creek subbasin (3).

- To determine the source(s) of the high number of water column organic exceedences in Little Beaver Creek and other streams with WWTPs, chemical water samples from locations upstream of the point source discharges should also be collected and analyzed for organics.

Table 1. Aquatic life use attainment status for the streams sampled in the Little Miami River basin, June-October 1993. Italics denote effluent mixing zone sampling locations.

RIVER MILE Fish/Invert.	IBI	Modified Iwb	ICI[a]	QHEI[b]	Use Attain-ment Status[c]	Comment
Little Miami River						
		Eastern Corn Belt Plains - EWH Use Designation (Existing)				
102.1/101.5	33*	NA	E	62.0	PARTIAL	Dst. South Charleston
98.3/98.8	35*	7.8*	50	75.0	PARTIAL	Dolly Varden Road
92.2/89.2	35*	7.9*	E	68.5	PARTIAL	Pitchin Road /SR 72
85.4/85.3	47[ns]	9.0[ns]	46	87.0	PARTIAL	Grinnel Road
83.1/83.1	45[ns]	10.1	48	76.5	FULL	Jacoby Road
77.3/80.6	48	10.3	46	78.0	FULL	Ust. Xenia-Ford WWTP
77.0/77.0	*42*	*10.1*	*G*	*63.5*	*NA*	*Xenia-Ford Rd. WWTP mixing zone*
76.8/76.7	49	10.1	44[ns]	76.0	FULL	Dst. Xenia-Ford Road WWTP
74.5/74.6	48	10.5	E	77.5	FULL	Ust. Beaver Cr. (Beavercreek WWTP)
71.8/72.3	52	9.9	52	77.5	FULL	Dst. Beaver Cr. (Beavercreek WWTP)
64.7/65.6	41*	9.0*	44[ns]	73.0	PARTIAL	Ust Sugar Creek WWTP
64.4/64.4	*33*	*9.2*	*38*	*62.5*	*NA*	*Sugar Cr. WWTP mixing zone*
64.2/64.2	46[ns]	9.6	46	74.0	FULL	Dst. Sugar Cr. WWTP
63.4/63.0	39*	8.5*	46	71.0	PARTIAL	Spring Valley
53.5/53.2	33*	9.3[ns]	40*	65.0	PARTIAL	Dst. Waynesville WWTP
		Interior Plateau - EWH Use Designation (Existing)				
47.5/47.5	39*	9.3[ns]	VG[ns]	76.5	PARTIAL	Oregonia, OH
44.2/43.7	49	9.8	48	83.5	FULL	Ust. SR 350 near Ft. Ancient
38.6/38.6	47[ns]	10.0	50	83.5	FULL	SR 123, Morrow
35.50/35.9	49	10.2	VG[ns]	76.5	FULL	Stubbs Mill Rd. near Morrow
32.9/32.9	47[ns]	9.3[ns]	56	74.0	FULL	Ust. Lebanon WWTP
32.1/32.1	*37*	*9.6*	*34*	*77.0*	*NA*	*Lebanon WWTP mixing zone*
31.9/32.0	48	11.0	56	86.5	FULL	Dst. Lebanon WWTP
- /30.7	-	-	52	-	[FULL]	Grandin Road
28.3/29.2	34*	9.0*	52	57.5	PARTIAL	Ust. Simpson Creek
27.9/28.0	50	10.7	E	80.0	FULL	Dst. Lower LMR WWTP
23.9/23.9	47[ns]	10.2	50	82.5	FULL	Loveland, OH
22.1/22.2	46[ns]	8.7*	VG[ns]	63.5	PARTIAL	Dst. Tote's
21.5/21.4	49	10.4	56	84.0	FULL	Dst. Polk Run WWTP
20.9/20.6	45[ns]	9.6	58	80.0	FULL	I-275
18.5/18.9	40*	9.3[ns]	VG[ns]	72.5	PARTIAL	Ust. Camargo Road
13.3/13.1	35*	8.8*	VG[ns]	86.5	PARTIAL	Milford, OH
8.3/8.8	33*	8.9*	52	73.0	PARTIAL	Newtown Road
8.0/8.8	43*	10.1	52	82.0	PARTIAL	Bass Island
3.5/3.4	40*	9.9	42[ns]	77.5	PARTIAL	Beechmont Avenue
		Interior Plateau - EWH Use Designation (WWH Recommended)				
1.6/1.6	33*	7.4*	F*	51.0	**NON**	Kellogg Avenue
0.2/0.4	29*	7.3*	F*	50.0	**NON**	Ust. mouth

Table 1. (continued).

RIVER MILE Fish/Invert.	IBI	Modified Iwb	ICI[a]	QHEI[b]	Use Attain-ment Status[c]	Comment
Yellow Springs Creek						
Eastern Corn Belt Plains - EWH Use Designation (Recommended)						
0.5/0.5	48[ns]	NA	46	80.0	FULL	Ust. Yellow Springs WWTP
0.43/0.43	*51*	*NA*	*36*	*73.5*	*NA*	*Y.S.WWTP mixing zone*
0.3/0.3	50	NA	46	79.0	FULL	Dst. Yellow Springs WWTP
Oldtown Creek						
Eastern Corn Belt Plains - WWH Use Designation (Existing)						
0.1/0.4	56	NA	38	82.5	FULL	Ust. mouth
South Fork Massies Creek						
Eastern Corn Belt Plains - WWH Use Designation (Existing)						
- /2.1	-	-	E	-	[FULL]	Dst. Weimer Road, ust. quarry
1.1/1.1	30*	NA	VG	66.5	PARTIAL	Adj. Quarry
Massies Creek						
Eastern Corn Belt Plains - WWH Use Designation (Existing)						
0.3/0.3	46	9.0	G	67.5	FULL	US 68
Beaver Creek						
Eastern Corn Belt Plains - WWH Use Designation (Existing)						
1.6/1.6	28*	6.8*	48	54.5	PARTIAL	Dayton-Xenia Road
0.5/0.5	32*	8.7	48	74.0	PARTIAL	Ust. Beaver Cr. WWTP
0.39/0.39	*37*	*8.0*	*36*	*64.0*	*NA*	*Beaver Cr. WWTP mix zone*
0.3/0.2	32*	7.9[ns]	F*	70.5	PARTIAL	Dst. Beaver Creek WWTP
Little Beaver Creek						
Eastern Corn Belt Plains - WWH Use Designation (Existing)						
4.7/4.7	26*	NA	40	67.5	**NON**	Ust. Montg. Co. E. WWTP
4.57/4.57	*23*	*NA*	*4*	*72.0*	*NA*	*Montg. WWTP mixing zone*
4.4/4.4	24*	NA	P*	48.5	**NON**	Dst. Montg. Co. E. WWTP
2.1/2.0	31*	NA	20*	76.0	**NON**	N. Fairfield Road
0.1/0.1	33*	7.0*	38	70.5	PARTIAL	Factory Road
Glady Run						
Eastern Corn Belt Plains - WWH Use Designation (Existing)						
4.9/4.9	34*	NA	36	54.0	PARTIAL	Ust. Xenia WWTP swale
4.7/4.7	33*	NA	28*	66.0	**NON**	Dst. Xenia WWTP swale
0.3/0.3	40	NA	24*	69.0	PARTIAL	SR 725

Table 1. (continued).

RIVER MILE Fish/Invert.	IBI	Modified Iwb	ICI[a]	QHEI[b]	Use Attainment Status[c]	Comment
Glady Run Swale						
	Eastern Corn Belt Plains - WWH Use Designation (Recommended)					
0.3/0.3	24*	NA	F*	53.0	**NON**	Ust. Xenia WWTP
0.20/-	*28*	*NA*	-	*49.0*	*NA*	*Xenia WWTP mix zone*
0.1/-	40	NA	-	48.5	[FULL]	Dst. Xenia WWTP
Newman Run						
	Eastern Corn Belt Plains - WWH Use Designation (Existing)					
0.3/0.3	54	NA	F*	76.0	PARTIAL	US 42 near Waynesville
Anderson Fork						
	Eastern Corn Belt Plains - EWH Use Designation (Existing)					
5.0/5.0	54	10.0	G*	75.0	PARTIAL	Old Winchester Trail
Flat Fork						
	Eastern Corn Belt Plains - WWH Use Designation (Existing)					
1.7/1.7	24*	NA	F*	50.0	**NON**	Nonpoint at Oregonia Road
Caesar Creek						
	Eastern Corn Belt Plains - EWH Use Designation (Existing)					
16.5/16.5	46[ns]	9.5	VG[ns]	76.0	FULL	Springvalley-Paintersville Road
	Eastern Corn Belt Plains - WWH Use Designation (Existing)					
0.1/0.1	50	8.7	F*	81.5	PARTIAL	Dst. Reservoir at Corwin Road
Dry Run						
	Interior Plateau - WWH Use Designation (Existing)					
1.8/1.8	34*	NA	F*	54.5	**NON**	Snook Road
Turtle Creek						
	Interior Plateau - WWH Use Designation (Existing)					
6.3/6.3	43	NA	26[ns]	69.5	FULL	Glosser Road
4.7/4.3	39[ns]	8.5	36	69.5	FULL	McClure Road
0.6/0.6	50	10.1	MG[ns]	75.5	FULL	Mason Road
0.5/-	*41*	*8.3*	-	*68.0*	*NA*	*Dst. C. Mil. diffuser*
0.4/0.4	41	6.7*	26[ns]	68.0	PARTIAL	Dst. Cincinnati Milacron
0.1/0.1	46	8.9	16*	68.5	PARTIAL	Near mouth
Muddy Creek						
	Interior Plateau - WWH Use Designation (Existing)					
1.6/2.5	46	NA	34	78.0	FULL	Mason-Morrow Road

Table 1. (continued).

RIVER MILE Fish/Invert.	IBI	Modified Iwb	ICI[a]	QHEI[b]	Use Attain-ment Status[c]	Comment
Sycamore Creek						
		Interior Plateau - WWH Use Designation (Existing)				
0.4/0.5	34*	6.6*	F*	76.0	**NON**	Ust. Sycamore Cr. WWTP
0.26/0.26	*29*	*6.6*	*32*	*70.5*	*NA*	*Sycamore WWTP mixing zone*
0.2/0.1	38ns	7.7ns	20*	75.0	PARTIAL	Dst. Sycamore Cr. WWTP
Stonelick Creek						
		Interior Plateau - WWH Use Designation (Existing)				
20.0/17.7	30*	NA	24*	69.0	**NON**	Dst. Woodville Road
16.7/ -	30*	7.5*	-	48.0	**[NON]**	Stonelick Lake at SR 133
3.1/2.9	45	8.8	32	73.5	FULL	Dst. Lick Fork
1.2/1.0	49	10.4	36	78.0	FULL	US 50
East Fork Little Miami River						
		Interior Plateau - EWH Use Designation (Existing)				
15.5/15.5	45ns	9.4ns	54	86.0	FULL	Ust. Batavia at SR 222
-/13.3	-	-	46	-	[FULL]	Dst. Batavia WWTP
12.7/12.7	47ns	10.5	54	83.5	FULL	Dst. Batavia WWTP
12.4/-	47ns	11.1	-	87.0	[FULL]	Dst. Middle EFK WWTP
9.2/9.2	44ns	10.4	54	86.0	FULL	Olive Branch Stonelick Rd.
6.6/6.7	42*	9.4ns	46	87.0	PARTIAL	Roundbottom Road
4.7/4.7	44ns	10.1	44ns	68.5	FULL	Dst. Lower EFK WWTP
1.7/1.9	36*	10.2	48	70.5	PARTIAL	I-275, ust. Milford WWTP
1.4/0.8	39*	10.0	50	65.0	PARTIAL	Dst. Milford WWTP

Ecoregional Biological Criteria:

INDEX - Site Type	*E. Corn Belt Plains (ECBP)* WWH	EWH	MWH[d]	*Interior Plateau (IP)* WWH	EWH	MWH[d]
IBI - Headwaters	40	50	24	40	50	24
IBI - Wading	40	50	24	40	50	24
IBI - Boat	42	48	24	38	48	24
Mod. Iwb - Wading	8.3	9.4	6.2	8.1	9.4	6.2
Mod. Iwb - Boat	8.5	9.6	5.8	8.7	9.6	5.8
ICI	36	46	22	30	46	22

* significant departure from ecoregional biocriteria; poor and very poor results are underlined.
ns nonsignificant departure from ecoregional biocriteria for WWH or EWH (≤4 IBI, ≤4 ICI, ≤0.5 MIwb units).
NA Not applicable.
a Narrative evaluation used in lieu of ICI (E=Exceptional; VG= Very Good; G=Good; MG=Marginally good; F=Fair; P=Poor; VP=Very Poor).
b Qualitative Habitat Evaluation Index (QHEI) values based on Rankin (1989).
c Attainment status based on one organism group is parenthetically expressed.
d MWH (Modified Warmwater Habitat) for channel modified areas.

Table 2. Waterbody segment (305b) summaries for streams sampled in the Little Miami River basin during 1993.

Waterbody (RM) Upper/Lower	Segment Length	Attainment Miles FULL	PARTIAL	NON	Unknown	Causes, Sources, and Comments
Little Miami River (Exceptional Warmwater Habitat)						
105.5/91.6	13.8	0.0	10.5	0.0	3.3	*Causes:* ammonia, nutrients, organic enrichment/D.O., residual chlorine, habitat alteration, silt, pesticides *Sources:* manure runoff (Pay Gro), S. Charleston WWTP, agriculture, livestock *Comments:* low D.O., fecal bacteria and pesticide exceedences, large fish kill in 1992
91.6/79.5	12.1	5.9	6.2	0.0	0.0	*Causes:* metals (Cu), D.O., habitat alteration, silt, ammonia, nutrients, pesticides *Sources:* manure runoff (Pay Gro), S. Charleston WWTP, agriculture, livestock *Comments:* ambient D.O., fecal bacteria, Cu, and pesticide exceedences; elevated incident of DELT anomalies
79.5/72.7	6.8	6.8	0.0	0.0	0.0	*Comments:* ambient residual chlorine, fecal bacteria, phosphorus, phthalate, and pesticide exceedences; sewage and chemical spills in Shawnee Cr., elevated incident of DELT anomalies
72.7/63.7	9.0	6.5	2.5	0.0	0.0	*Causes:* ammonia, CBOD, TSS, cumulative nutrient load, large D.O. swing *Sources:* Montgomery Co. East Reg. WWTP, Greene Co. Beaver Creek and Sugar Creek WWTPs, Xenia Glady Run WWTP, Xenia-Ford WWTP *Comments:* improving quality, but elevated incidence of DELT anomalies; ambient fecal bacteria, phthalate, and pesticide exceedences
63.7/50.9	12.8	0.3	12.5	0.0	0.0	*Causes:* nutrients, CBOD, TSS *Sources:* Xenia Glady Run WWTP, Waynesville WWTP, cumulative nutrient load from other upstream WWTPs *Comments:* improving quality, but elevated incidence of DELT anomalies; ambient fecal bacteria and phosphorus exceedences
50.9/38.5	12.4	5.7	6.7	0.0	0.0	*Causes:* nutrients, TSS, sedimentation *Sources:* cumulative nutrient load from upstream WWTPs, land development, agriculture *Comments:* ambient fecal bacteria and pesticide exceedences
38.5/33.2	5.3	5.3	0.0	0.0	0.0	*Comments:* ambient pesticide exceedences, frequent spills in Todd Fork basin

Table 2. Continued.

Waterbody (RM) Upper/Lower	Segment Length	Attainment Miles FULL	PARTIAL	NON	Unknown	Causes, Sources, and Comments
Little Miami River, continued						
33.2/24.0	9.2	8.2	1.0	0.0	0.0	*Causes:* sedimentation, nutrients, ammonia, metals (Cd, Hg) *Sources:* Cincinnati Milacron, Lebanon WWTP, Mason WWTP, Warren Co. Lower LMR WWTP, cumulative nutrient load, land development, agriculture *Comments:* ambient fecal bacteria, cadmium, phosphorus, pesticide, temperature, residual chlorine, and mercury exceedences
24.0/11.5	12.5	2.2	10.3	0.0	0.0	*Causes:* metals (Hg), nutrients, sedimentation, CBOD, ammonia, TSS *Sources:* Hamilton Co. MSD Polk Run and Sycamore Cr. WWTPs, Batavia WWTP, Clermont Co. Middle and Lower East Fork WWTP's, Milford WWTP; CSOs, SSOs, cumulative nutrient load, land development, agriculture *Comments:* ambient phosphorus, zinc, temperature, fecal bacteria, and pesticide exceedences
11.5/0.0	11.5	0.0	8.5	3.0	0.0	*Causes:* CSOs, sedimentation, nutrient enrichment, hydromodification *Sources:* Hamilton Co. MSD, Clermont Co. MSD, Ohio River backwater, landfills, cumulative nutrient load, land development, agriculture *Comments:* segment contains Ohio endangered species; temperature, ambient phosphorus, fecal bacteria, and pesticide exceedences; WWH recommended for lower three miles
Yellow Springs Creek (Exceptional Warmwater Habitat)						
2.5/0.0	2.5	0.5	0.0	0.0	2.0	*Comments:* fecal bacteria, phosphorus, ammonia, and pesticide exceedences; sludge deposits from Yellow Springs WWTP, EWH use recommended
Oldtown Creek (Warmwater Habitat)						
6.0/0.0	6.0	0.4	0.0	0.0	5.6	*Comments:* ambient fecal bacteria and pesticide exceedences; lower section predominantly channelized.
Massies Creek (Warmwater Habitat)						
9.9/0.0	9.9	0.3	0.0	0.0	9.6	*Comments:* ambient fecal bacteria exceedences; numerous permit violations by Cedarville WWTP
South Fork Massies Creek (Warmwater Habitat)						
9.6/0.0	9.6	0.5	1.0	0.0	8.1	*Causes:* habitat modifications, channelization, unknown *Sources:* agriculture, quarry *Comments:* historical hydromodification adjacent to quarry

Table 2. Continued.

Waterbody (RM) Upper/Lower	Segment Length	Attainment Miles FULL	PARTIAL	NON	Unknown	Causes, Sources, and Comments
Beaver Creek (Warmwater Habitat)						
8.4/0.0	8.4	0.0	1.6	0.0	6.8	*Causes:* habitat, nutrients, unknown *Sources:* Greene Co. Beaver Creek WWTP, Montgomery Co. East Reg. WWTP, unknown *Comments:* ambient phosphorus, fecal bacteria, and pesticide exceedences; ICI and MIwb decline downstream from the Beaver Creek WWTP
Little Beaver Creek (Warmwater Habitat)						
9.0/0.0	9.0	0.0	0.1	4.6	4.3	*Causes:* metals (Ag, Zn, Cu, Cn, Ni), ammonia, unknown , habitat *Sources:* Montgomery Co. Eastern WWTP, unknown upstream source (possibly spills) *Comments:* ambient temperature phosphorus, fecal bacteria, and pesticide exceedences; fish kill, toxicity to macroinvertebrates in the mixing zone of the Mont. Co. WWTP
Glady Run Swale (Warmwater Habitat)						
0.6/0.0	0.6	0.1	0.1	0.0	0.4	*Causes:* channelization, nutrients *Sources:* Xenia Glady Run WWTP *Comments:* ambient phosphorus exceedences, recovering channel downstream from railroad grade
Glady Run (Warmwater Habitat)						
6.3/0.0	6.3	0.0	0.5	4.4	1.9	*Causes:* flow alteration, bacteria, chlorine, phosphorus, pesticides *Sources:* natural, Xenia Glady Run WWTP *Comments:* ambient residual chlorine, phosphorus, and pesticide exceedences, washout has rerouted Glady Run's flow into the WWTP Swale, macroinvertebrates declined in Glady Run downstream from the swale (WWTP)
Newman Run (Warmwater Habitat)						
4.0/0.0	4.0	0.0	0.3	0.0	3.7	*Causes:* flow alteration *Sources:* natural drought conditions *Comments:* exceptional fish assemblage during early summer, but only fair macroinvertebrate assemblage on 31 August
Anderson Fork (Exceptional Warmwater Habitat)						
18.3/11.0	7.3	0.0	0.5	0.0	6.8	*Causes:* unknown *Sources:* unknown, natural (possibly drought affected) *Comments:* exceptional fish assemblage, but only a good macroinvertebrate assemblage; ambient D.O. and pesticide exceedences
Flat Fork (Warmwater Habitat)						
3.7/0.0	3.7	0.0	0.0	1.7	2.0	*Causes:* organic enrichment/low dissolved oxygen, low flow *Sources:* agriculture (possibly animal husbandry), natural drought *Comments:* ambient bacteria, DO, and pesticide exceedences, poor fish and fair macroinvertebrate assemblages

Table 2. Continued.

Waterbody (RM) Upper/Lower	Segment Length	Attainment Miles FULL	PARTIAL	**NON**	Unknown	Causes, Sources, and Comments
Caesar Creek (Exceptional Warmwater Habitat/Warmwater Habitat)						
23.7/13.9	9.9	2.6	0.0	0.0	7.3	*Comments:* ambient dissolved oxygen and phosphorus exceedences
13.9/0.0	13.9	0.0	0.1	0.0	13.8	*Causes:* unknown, reservoir releases, controlled flow *Sources:* Ceasar Creek Lake *Comments:* ambient temperature exceedence, fair macroinvertebrate assemblage
Dry Run (Warmwater Habitat)						
4.0/0.0	4.0	0.0	0.0	0.5	3.5	*Causes:* dissolved oxygen, siltation, low flow, unknown *Sources:* natural drought condition, unknown, land development *Comments:* ambient D.O. exceedence; reference site; declining quality
Turtle Creek (Warmwater Habitat)						
12.0/0.0	12.0	5.9	0.4	0.0	5.7	*Causes:* ammonia-N, metals (Cu), organic enrichment, nutrients, suspended solids, flow alteration (possible dewatering) *Sources:* Cincinnati Milacron, unknown source(s) of dewatering *Comments:* ambient temperature, D.O., pesticide, fecal bacteria, lead, copper, conductivity, total dissolved solids, ammonia, and phosphorus exceedences.
Muddy Creek (Warmwater Habitat)						
8.9/0.0	8.9	2.5	0.0	0.0	6.4	*Comments:* frequent NPDES violations by Mason WWTP, SSO overflows, ambient residual chlorine, phosphorus, fecal bacteria, copper, and pesticide exceedences.
Sycamore Creek (Warmwater Habitat)						
4.5/0.0	4.5	0.0	0.2	0.2	4.1	*Causes:* organic enrichment, metal (Hg), PAH's, nutrients, hydromodification *Sources:* Hamilton Co. MSD Sycamore Cr. WWTP and SSO overflows, land development, spills, urban runoff, sewerline construction, sludge deposits, unknown *Comments* : phosphorus, fecal bacteria, and pesticide exceedences
Stonelick Creek (Warmwater Habitat)						
22.9/0.0	22.9	3.1	3.3	0.0	16.5	*Causes:* sedimentation, nutrient enrichment, habitat modification, low flow *Sources:* agriculture, unknown *Comments:* natural drought condition; impoundment; unknown; spills acutely toxic to fish; ambient D.O. fecal bacteria, lead, and pesticide exceedences.
East Fork Little Miami River (Exceptional Warmwater Habitat)						
20.5/8.8	11.7	6.7	0.0	0.0	5.0	*Comments:* improving quality; ambient pesticide, temperature, phosphorus, and D.O. exceedences
8.8/0.0	8.8	5.2	2.2	0.0	1.4	*Causes:* sedimentation, nutrient enrichment, ammonia, possible toxicity (*i.e.*, waterwillow disappears downstream from Lower E.FK. WWTP), habitat *Sources:* Clermont Co. WWTPs and SSOs, agriculture, land development, lower gradient *Comments:* fish kills, spills, declining quality at some sites, ambient pesticide, temperature, fecal bacteria, phosphorus, and D.O. exceedences.

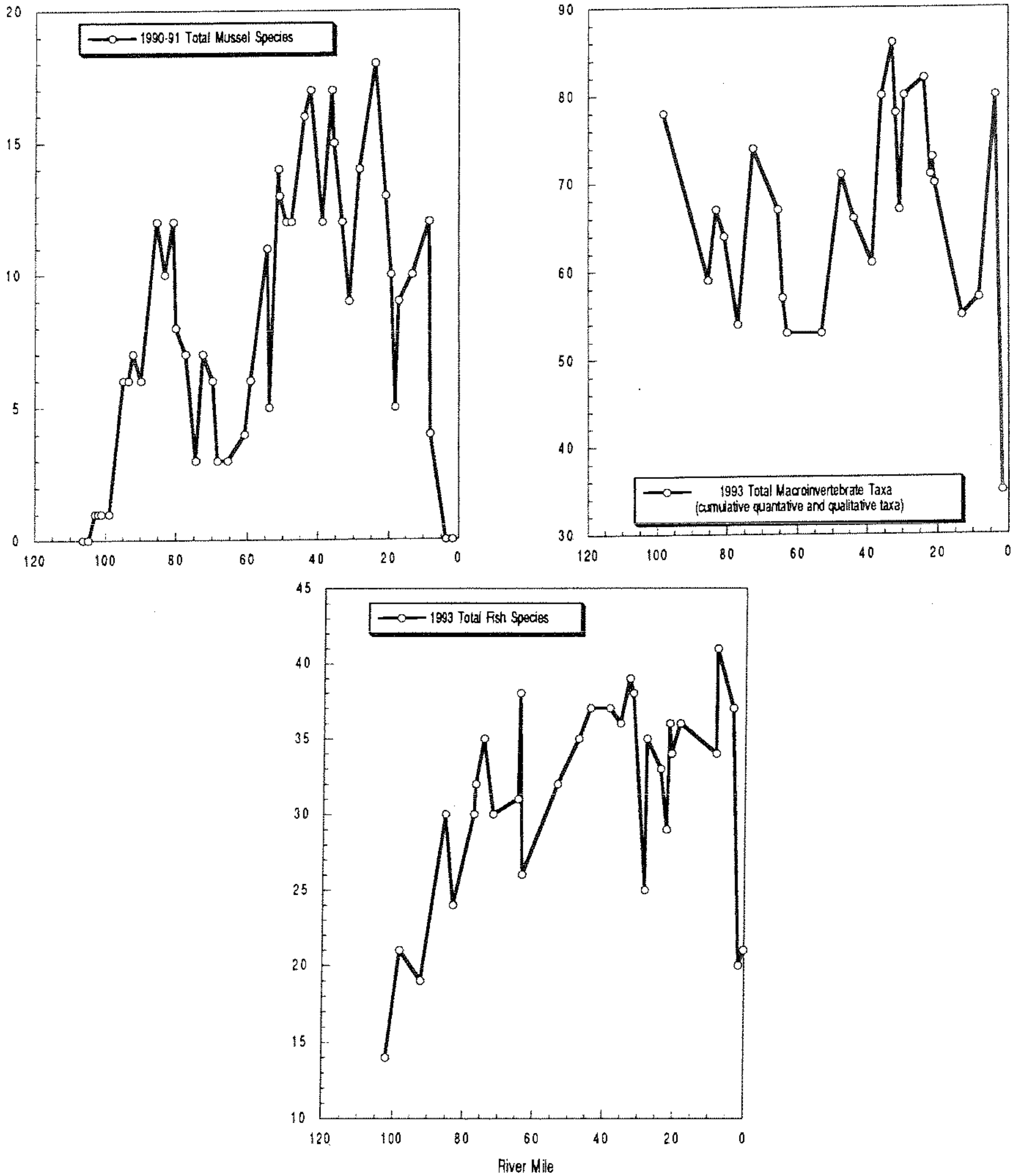


Figure 1. Longitudinal trends in the total cumulative number of aquatic macroinvertebrates (1993 Ohio EPA collections; upper left), Unionidae species, excluding subfossil shells (Hoggarth 1992; upper right), and fish species (1993 Ohio EPA; bottom) recently collected from the Little Miami River mainstem.

Table 3. Comparison of 1983[a] and 1993 biological index scores (Modified Index of Well-Being [MIwb], Index of Biotic Integrity [IBI], and Invertebrate Community Index [ICI]) and the aquatic life use attainment status for commonly sampled segments in the Little Miami River mainstem and East Fork.

Segment RM	MIwb 1983/1993 (Diff.)	IBI 1983/1993 (Diff.)	ICI 1983/1993 (Diff.)	Attainment Status 1983/1993 (Overall Change)
Upper Little Miami River				
102.1-101.3	- /-	35/33 (-2)	38/Except. (+8)	**NON**/PARTIAL (Improved)
98.9-98.3	7.8/7.8 (0.0)	29/35 (+6)	18/50 (+32)	**NON**/PARTIAL (Improved)
92.2-89.1	8.2/7.9 (-0.3)	32/35 (+3)	20/Except. (+26)	**NON**/PARTIAL (Improved)
86.4-85.3	8.7/9.0 (+0.3)	51/47 (-4)	36/46 (+10)	PARTIAL/FULL (Improved)
83.1	9.4/10.1 (+0.7)	49/45 (-4)	36/48 (+12)	PARTIAL/FULL (Improved)
80.8-77.3	8.4/10.3 (+1.9)	48/48 (0)	34/46 (+12)	PARTIAL/FULL (Improved)
76.2-74.5	8.9/10.5 (+1.6)	45/48 (+3)	38/44 (+6)	PARTIAL/FULL (Improved)
72.5-71.8	8.8/9.9 (+1.1)	45/52 (+7)	28/52 (+24)	PARTIAL/FULL (Improved)
66.6-64.7	6.9/9.0 (+2.1)	31/41 (+10)	34/44 (+10)	**NON**/PARTIAL (Improved)
63.4-63.0	6.9/8.5 (+1.6)	26/39 (+13)	36/46 (+10)	**NON**/PARTIAL (Improved)
53.9-53.2	8.6/9.3 (+0.7)	34/33 (-1)	38/40 (+2)	**NON**/PARTIAL (Improved)
Lower Little Miami River				
47.5	9.3/9.3 (0.0)	41/39 (-2)	-/VG	PARTIAL/PARTIAL (No Change)
44.2-43.7	9.2/9.8 (+0.6)	44/49 (+5)	32/48 (+16)	PARTIAL/FULL (Improved)
38.6	9.2/10.0 (+0.8)	48/47 (-1)	-/50	[FULL]/FULL [No Change]
36.0-35.5	9.5/10.2 (+0.7)	45/49 (+4)	42/VG [0]	FULL/FULL [No Change]
33.0-32.9	8.6/9.3 (+0.7)	39/47 (+8)	44/56 (+12)	PARTIAL/FULL (Improved)
31.9-30.7	9.3/11.0 (+1.7)	41/48 (+7)	44/52 (+8)	PARTIAL/FULL (Improved)
29.5-28.3	9.1/9.0 (-0.1)	39/34 (-5)	46/52 (+6)	PARTIAL/PARTIAL (No Change)
28.0-27.9	9.0/10.7 (+1.7)	41/50 (+9)	44/Except. (+2)	PARTIAL/FULL (Improved)
24.2-23.9	9.2/10.2 (+1.0)	42/47 (+5)	52/50 (-2)	PARTIAL/FULL (Improved)
20.9-20.6	8.9/9.6 (+0.7)	39/45 (+6)	40/58 (+18)	**NON**/FULL (Improved)
18.9-18.5	9.2/9.3 (+0.1)	39/40 (+1)	42/V. Good (0)	PARTIAL/PARTIAL [No Change]
13.3-13.1	8.4/8.8 (+0.4)	34/35 (+1)	44/V. Good (0)	PARTIAL/PARTIAL [No Change]
8.8-8.4	8.7/8.9 (+0.2)	41/33 (-8)	48/52 (+4)	PARTIAL/PARTIAL [No Change]
1.6	8.1/7.4 (-0.7)	35/33 (-2)	-/12	[**NON**]/**NON** [No Change]
0.4-0.2	7.5/7.3 (-0.2)	33/29 (-4)	-/Fair	[**NON**]/**NON** (No Change]
East Fork Little Miami River				
15.5-15.4	8.9/9.4 (+0.5)	45/45 (0)	46/54 (+8)	PARTIAL/FULL (Improved)
13.3-12.7	9.1/10.5 (+1.4)	40/47 (+7)	48/46 (-2)	PARTIAL/FULL (Improved)
12.4-11.5	9.2/11.1 (+1.9)	45/47 (+2)	50/-	FULL/[FULL] [No Change]
10.1-9.1	9.8/10.4 (+0.6)	49/44 (-5)	52/54 (+2)	FULL/FULL [No Change]
6.7-6.6	9.4/9.4 (0)	47/42 (-5)	52/46 (-6)	FULL/PARTIAL (**Decreased**)
4.7-4.1	10.3/10.1 (-0.2)	43/44 (+1)	48/44 (-4)	PARTIAL/FULL [Improved]
2.4-1.7	9.7/10.2 (+0.5)	40/36 (-4)	44/48 (+4)	PARTIAL/PARTIAL [No Change]
1.4-0.8	9.5/10.0 (+0.5)	46/39 (-7)	42/50 (+8)	FULL/PARTIAL (**Decreased**)

[a] the East Fork was previously sampled in 1982.

Study Area

Originating in southeastern Clark County, the Little Miami River flows 105.5 miles in a southwesterly direction into Greene, Warren, Clermont, and Hamilton counties to the confluence with the Ohio River east of Cincinnati (Figures 2 and 3). The 1757 square mile watershed also encompasses portions of Montgomery, Clinton, Brown, Highland, and Madison counties. The mainstem throughout the length falls at an average gradient of 6.5 feet per mile (from an elevation of 1137 to 448 feet above mean sea level). Major tributaries include the East Fork Little Miami River, Caesar Creek, Todd Fork, Massies Creek, Beaver Creek, Turtle Creek, Muddy Creek, O'Bannon Creek, and Sycamore Creek. The largest impoundments within the basin are Caesar Creek (6110 acres), East Fork (4600 acres; also called W.H. Harsha Lake), and Cowan Lake (720 acres).

The Little Miami River watershed was formed by three glacial events which left distinctive landforms including thick deposits of silt, sand, and gravel. The upper (northern) one-half of the watershed is in the Eastern Corn Belt Plains ecoregion which is characterized by level to gently sloping land. Eastern Corn Belt streams typically contain substrates predominated by coarse glacial material (*i.e.*, gravel, cobble, and boulders) and some are fed by springs which maintain permanent flow regimes even during extended periods of dry weather. The lower (southern) one-half of the watershed (south of Waynesville) is located in the Interior Plateau ecoregion which has a higher relief and higher gradient streams with predominately bedrock and bedrock fragment substrates. Most small Interior Plateau streams experience intermittent or interstitial flows during the late summer and fall months. Underlying bedrock within the Little Miami River watershed consists of various types of Silurian and Ordovician limestone and shale.

In addition to a State and National Scenic River designation, the Ohio Water Quality Standards (WQS; OAC 3745-1) list the current use designations for the Little Miami River as: Exceptional Warmwater Habitat (EWH); Agricultural and Industrial Water Supply; Primary Contact Recreation; and State Resource Water (SRW). Several tributaries also contain Public Water Supply designated segments. Wilmington and Fayetteville, located in the southeastern portion of the watershed, utilize surface waters for their drinking water supplies. Extensive ground water deposits are a result of the extensive glacial deposits in the basin, thus most communities rely on wells for their raw water source. The Little Miami River flows on top of a buried valley aquifer composed of highly permeable sands and gravel. The aquifer was designated a sole source aquifer (*i.e.*, requires additional review for any federal projects proposed on the surface) by U.S. EPA and produces yields which can exceed 100 to >500 gallons per minute (Durrell and Durrell 1979). Some communities also utilize water from the Caesar Creek and East Fork (W. H. Harsha) reservoirs due to increasing developmental pressures.

Land use within the watershed is predominantly agricultural, but is becoming increasingly suburban (Plate 14). The Little Miami River watershed is unique because it is one of Ohio's largest watershed with no large industrial discharges. The low flow regime of the Little Miami River and the many tributaries are, however, becoming increasingly dominated by municipal WWTPs (Plate 11). Currently, 24 NPDES permitted entities throughout the watershed discharged a combined total of 50.5 million gallons (1993 third quarter) of treated wastewater per day (*i.e.*, 50 MGD equals 77.4 cubic feet per second [cfs] of flow). The minimum recorded discharge rates at the two U.S. gaging stations located on the Little Miami River mainstem were 2.8 cfs at Oldtown [RM 80.6] in 1988 and 27.0 cfs at Milford [RM 13.07] in 1984). Of the 24 entities shown in Figure 22, twenty-two (22) municipal WWTPs discharged 99.2% of the total volume while two industries contributed the remaining 0.8%. This volume will increase substantially as WWTP flows throughout the watershed increase in response to numerous residential and commercial developments. Many communities are attempting to keep pace with the pace of development by increasing the capacity of water and sewage services. However, several WWTPs are operating at or above design capacity which has contributed to violations of NPDES permit limits.

In addition to increasing volumes of wastewater, changing land use patterns are also altering the rates and types of nonpoint source pollutants discharged within the watershed. Initial site preparations for construction results in accelerated rates of runoff, increased soil erosion, and the subsequent deposition of excess sediment in streams and rivers. Riparian encroachment is also a problem which adds to these types of problems. The NPDES general permit for construction sites and local efforts are an attempt to control and prevent adverse environmental impacts. Following construction, stormwater runoff from suburban areas typically enters streams quicker, yields higher volumes of water over a relatively short time, and contributes different pollutants (*e.g.*, combined sewer overflows (CSOs), de-icing chemicals applied to airport runways, heavy metals, etc.) than do rural areas.

Table 4. Stream characteristics and significant pollution sources which were directly evaluated in the Little Miami River study area.

Stream/River	Length (mi.)	Gradient (ft./mi.)	Drainage Area (sq./mi.)	Nonpoint Source Pollution Categories	Point Sources Evaluated
Little Miami River	105.5	6.5	1755.3	Agriculture Urban Resource Extraction Composting	S. Charleston WWTP Xenia-Ford Rd.WWTP Sugarcreek WWTP Waynesville WWTP Lebanon WWTP Totes, Inc. Polk Run WWTP
Yellow Springs Creek	2.5	42.0	11.5	Agriculture, Urban	Yellow Springs WWTP
Oldtown Creek	31.2	10.09	10.0	Agriculture, Urban	
Massies Creek	9.5	22.0	86.6	Agriculture	
Beaver Creek	8.4	7.4	46.98	Agriculture, Urban Resource Extraction	Greene County Beaver Creek WWTP
Little Beaver Creek	9.0	18.8	25.97	Urban	Montgomery Co. Eastern Regional WWTP
Glady Run	6.3	26.5	14.0	Agriculture	Xenia-Glady Run WWTP
Newman Run	4.0	62.5	9.89	Agriculture, Urban	

Table 4. (continued)

Stream/River	Length (mi.)	Gradient (ft./mi.)	Drainage Area (sq./mi.)	Nonpoint Source Pollution Categories	Point Sources Evaluated
Mill Run	5.8	40.7	8.74	Agriculture	
Anderson Fork	28.28	8.1	93.3	Agriculture	
Flat Fork	3.7	17.3	16.76	Agriculture	
Caesar Creek	33.9	10.6	238.6	Agriculture	
Dry Run	1.3	26.9	7.35	Agriculture	
Turtle Creek	12.0	23.5	65.55	Agriculture, Urban	Cincinnati Milacron
Muddy Creek	8.9	31.9	15.67	Agriculture, Urban	Mason WWTP
Simpson Creek	4.0	67.5	4.33	Agriculture, Urban	Warren Co. Lower L. Miami WWTP
Stonelick Creek	22.9	18.7	77.6	Agriculture In-place Pollutants	
Polk Run	5.5	62.0	10.89	Agriculture, Urban, Sewer Lines	
Sycamore Creek	4.5	65.8	24.45	Urban Sewer Lines	Hamilton Co. Sycamore Cr. WWTP
O'Bannon Creek	12.0	24.0	58.5	Agriculture Urban	Clermont Co. O'Bannon Cr. WWTP
East Fork Little Miami R.	81.7	7.6	500.7	Agriculture Urban Resource Extraction	Batavia WWTP Clermont Co. Middle E. F. WWTP Lower E. F. WWTP

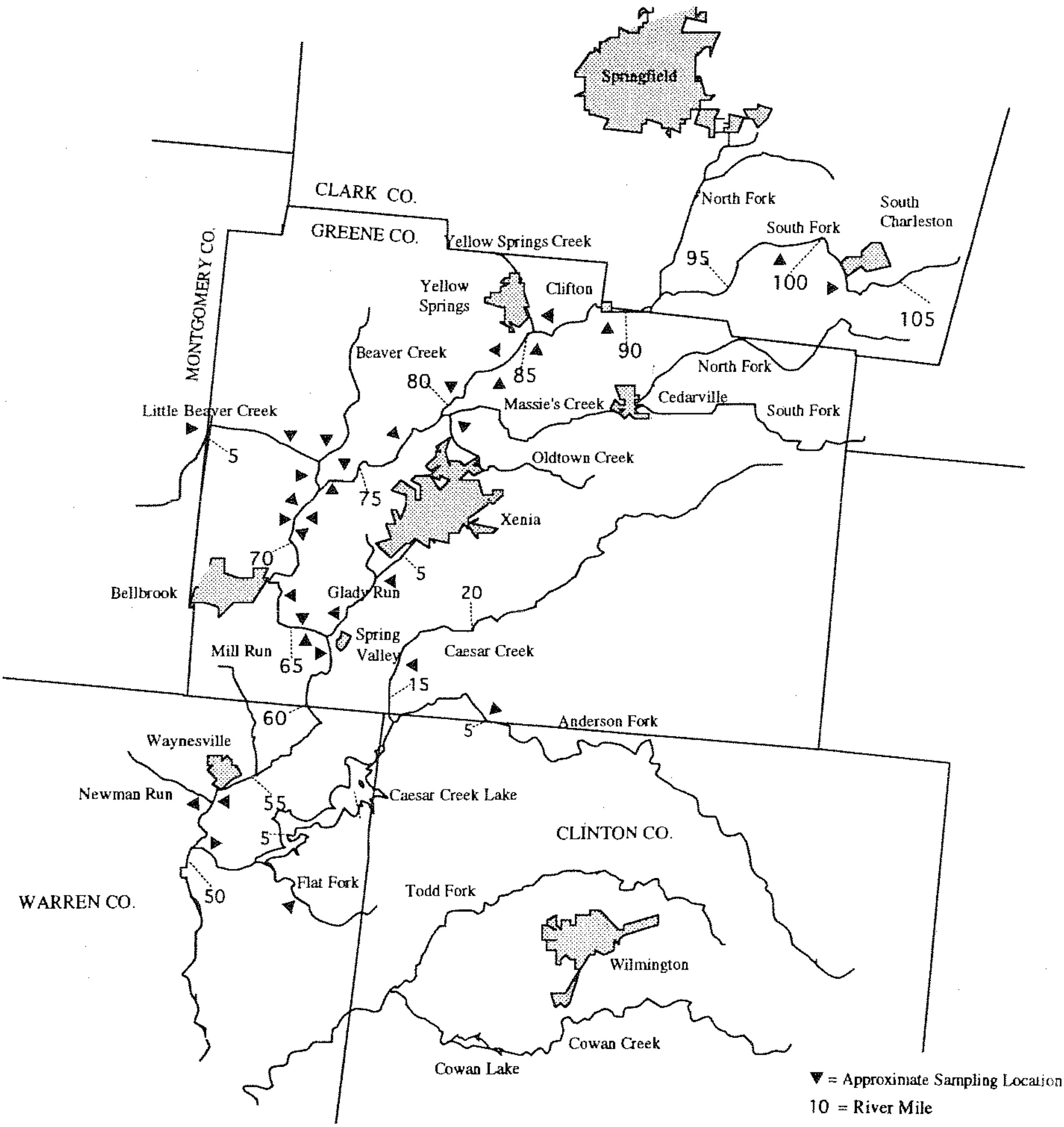


Figure 2. The upper portion of the Little Miami River study area showing principal streams and tributaries, population centers, and pollution sources.

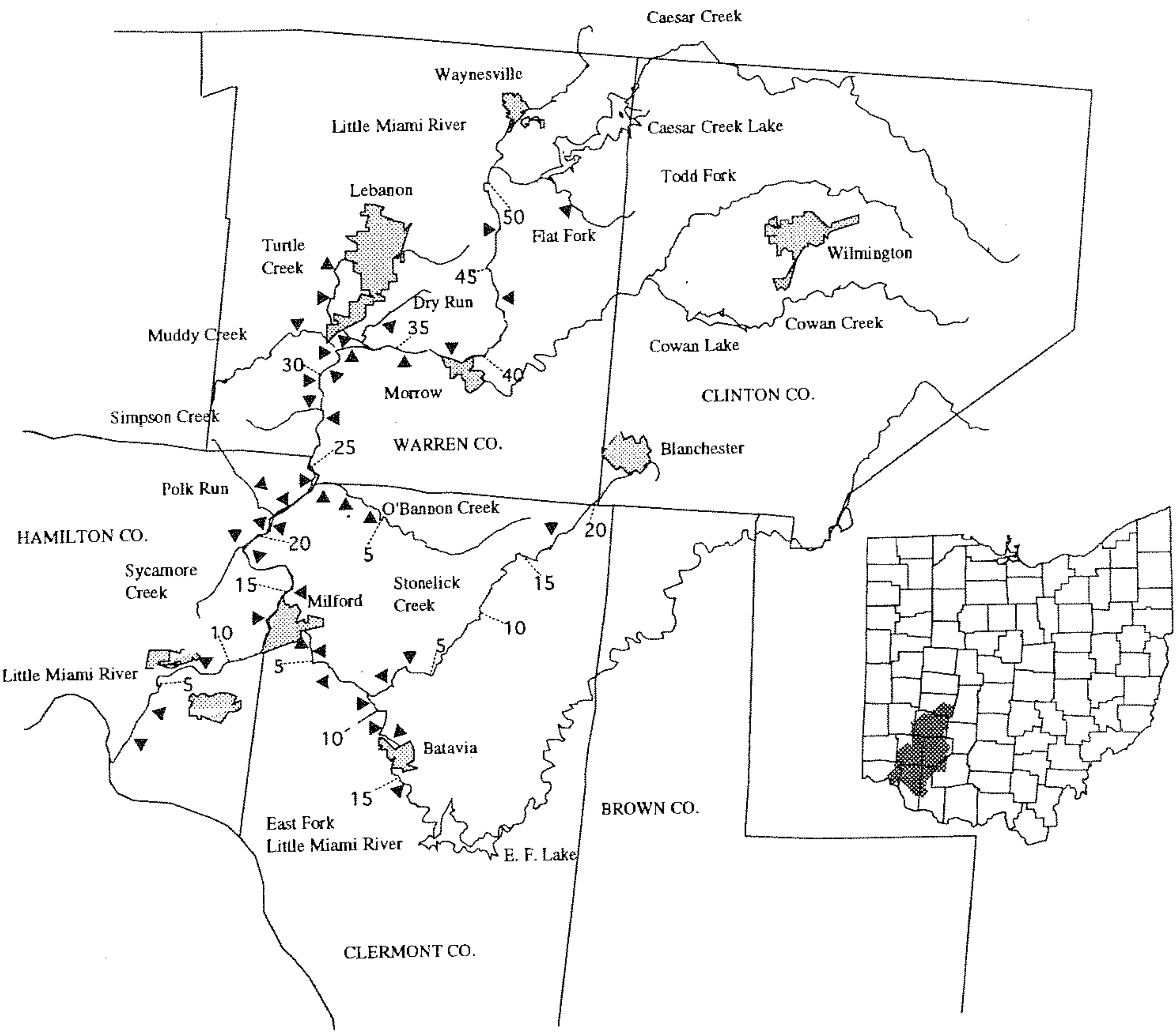


Figure 3. The lower portion of the Little Miami River study area showing principal streams and tributaries, population centers, and pollution sources.

Table 5. List of sampling locations (effluent sample - E; conventional water chemistry - C; organic water chemistry - CO; sediment metals chemistry - S; sediment organics - SO; datasonde - D; modeling - M; flow [USGS - Q, manual - QM]; macroinvertebrates - B; fish - F; and fish tissue - FT) in the Little Miami River study area, 1993. Italics denote effluent mixing zone sampling locations.

Stream RM	Type of Sampling	Latitude/Longitude	Landmark	USGS Quad.Map
Little Miami River				
102.10	F	39°48'52"/83°39'20"	Ust. S.R. 42	S. Charleston
101.50	B	39°49'14"/83°39'36"	Clifton Rd. near S. Charleston	S. Charleston
101.30	C,CO	39°49'23"/83°39'40"	Clifton Rd. near S. Charleston	S. Charleston
98.98	C,S,SO	39°49'57"/83°41'40"	Dolly Varden Rd.	S. Charleston
98.80	B	39°49'47"/83°41'51"	Dst. Dolly Varden Rd.	S. Charleston
98.30	F	39°49'59"/83°41'40"	Dst. Dolly Varden Rd.	S. Charleston
92.20	F	39°48'21"/83°46'54"	Pitchin Rd.	Clifton
89.20	B	39°47'37"/83°49'22"	Ust. S.R. 72	Clifton
89.12	C	39°47'36"/83°49'28"	S.R. 72	Clifton
85.40	F	39°46'57"/83°52'30"	Grinnel Rd.	Yellow Spr.
85.38	C,CO,S,SO,M,D	39°46'57"/83°52'32"	Ust. Yellow Springs. Cr., Grinnel Rd.	Yellow Spr.
85.30	B	39°46'55"/83°52'34"	Grinnel Rd.	Yellow Spr.
83.63	M,D	39°46'02"/83°53'38"	Dst. Yellow Springs Creek	Yellow Spr.
83.14	C,CO,D	39°45'51"/83°54'06"	Dst. Yellow Sp. Cr., Jacoby Rd.	Yellow Spr.
83.10	B,F,FT	39°45'50"/83°54'15"	Dst. Yellow Sp. Cr., Jacoby Rd.	Yellow Spr.
80.63	C,Q	39°44'54"/83°55'53"	U.S. Rt 68	Xenia
80.60	B	39°44'52"/83°55'50"	U.S. Rt 68	Xenia
77.30	F	39°43'12"/83°58'00"	Ust. Xenia Ford Rd. WWTP	Xenia
77.00	*C,B,F*	*39°42'58"/83°58'12"*	*Xenia Ford Rd. WWTP mixing zone*	*Xenia*
76.80	F	39°42'51"/83°58'15"	Dst. Xenia Ford Rd. WWTP	Xenia
76.70	B	39°42'48"/83°58'22"	Dst. Xenia Ford Rd. WWTP	Xenia
76.43	C,CO,S,SO,D	39°42'35"/83°58'32"	Ust. Shawnee Cr., dst Xenia Fd. WWTP	Xenia
74.60	B	39°42'13"/83°59'57"	U.S. Rt. 35	Xenia
74.50	F	39°42'04"/83°59'57"	U.S. Rt. 35	Xenia
74.46	C	39°42'05"/83°59'58"	U.S. Rt. 35	Xenia
73.16	M,D	39°41'55"/84°01'10"	Ust. Beaver Cr. confluence	Bellbrook
72.30	C,CO,S,SO,M,D,B	39°41'29"/84°01'43"	Indian Ripple Rd.	Bellbrook
71.80	F	39°41'12"/84°01'56"	Dst. Indian Ripple Rd. at park	Bellbrook
71.70	M	39°41'04"/84°02'09"	Ust. single island	Bellbrook
70.97	M	39°40'35"/84°02'32"	Dst. unnamed tributary	Bellbrook
70.45	M,D	39°40'11"/84°02'38"	Ust. twin islands	Bellbrook
66.56	C	39°37'58"/84°03'05"	Lower Bellbrook Rd.	Bellbrook
65.60	B	39°37'14"/84°03'01"	S.R. 725	Waynesville
64.70	F	39°36'59"/84°01'57"	Ust. Greene Co. Sugar Cr. WWTP	Waynesville
64.40	*C,CO,B,F,FT*	*39°36'58"/84°01'42"*	*Greene Co. Sugar Cr. WWTP mix. zone*	*Waynesville*
64.28	C,CO,S,SO	39°36'57"/84°01'36"	Dst. Greene Co. Sugar Cr. WWTP	Waynesville
64.20	B,F,FT	39°36'57"/84°01'37"	Dst. Greene Co. Sugar Cr. WWTP	Waynesville
63.73	M,D	39°36'42"/84°00'59"	Ust. Glady Run	Waynesville

Table 5. (continued)

Stream RM	Type of Sampling	Latitude/Longitude	Landmark	USGS Quad. Map
Little Miami River, cont.				
63.40	F	39°36'12"/84°00'59"	Ust. Spring Valley Roadside Park	Waynesville
63.28	C,S,SO,M,D	39°36'20"/84°00'50"	Spring Valley Roadside Park	Waynesville
63.00	B	39°36'05"/84°00'49"	U.S. 42	Waynesville
53.50	F,FT	39°31'17"/84°05'30"	Dst. Waynesville WWTP	Waynesville
53.20	C,B	39°30'59"/84°05'36"	Dst. Waynesville WWTP	Waynesville
53.00	D	39°30'54"/84°05'41"	Dst. Waynesville WWTP	Waynesville
47.50	C,B,F	39°27'08"/84°05'54"	Oregonia Rd.	Oregonia
44.20	F	39°24'43"/84°06'14"	Ust. S.R. 350	Oregonia
43.76	C,CO,S,SO,D	39°24'23"/84°05'03"	S.R. 350, near Fort Ancient	Oregonia
43.70	B	39°24'22"/84°06'03"	Dst. S.R. 350, canoe access	Oregonia
38.66	C	39°21'25"/84°07'44"	S.R. 123	So. Lebanon
38.60	B,F,FT	39°21'22"/84°07'53"	Dst. S.R. 123	So. Lebanon
35.98	C,CO,S,SO,D	39°20'48"/84°10'26"	Stubbs Mill Rd.	So. Lebanon
35.90	B	39°21'48"/84°10'29"	Dst. Stubbs Mill Rd.	So. Lebanon
35.50	F	39°21'52"/84°11'02"	Dst. Stubbs Mill Rd.	So. Lebanon
32.95	C,M,D,QM	39°22'07"/84°13'31"	S.R. 48	So. Lebanon
32.90	B,F	39°22'06"/84°13'33"	Dst. S.R. 48	So. Lebanon
32.12	*E*	*39°22'06"/84°14'25"*	*Lebanon WWTP effluent*	*So. Lebanon*
32.10	*C,B,F,FT*	*39°21'57"/84°14'22"*	*Lebanon WWTP mixing zone*	*So. Lebanon*
32.00	B	39°21'54"/84°14'30"	Dst. Lebanon WWTP	So. Lebanon
31.96	C,CO,S,SO	39°21'53"/84°14'31"	Ust. Muddy Cr.	So. Lebanon
31.90	F,FT	39°21'51"/84°14'35"	Dst. Lebanon WWTP	So. Lebanon
30.72	C,M,D	39°23'07"/84°15'33"	Grandin Rd.	So. Lebanon
30.70	B	39°23'07"/84°15'32"	Grandin Rd.	So. Lebanon
29.46	C	39°20'23"/84°15'23"	Ust. Union Run, Dst. Kings Mill	Mason
29.20	M,D,B	39°20'12"/84°15'16"	End of Kings Mill Rd.	Mason
28.30	F	39°19'36"/84°15'09"	Ust. Foster-Maineville Rd.	Mason
28.20	M,D	39°19'17"/84°15'09"	Foster-Maineville Rd., ust. Simpson Cr.	Mason
28.00	C,CO,S,SO,QM,B	39°19'05"/84°15'05"	Dst. Simpson Cr.	Mason
27.90	F,FT	39°19'05"/84°15'06"	Dst. Simpson Cr.	Mason
27.56	M,D	39°18'46"/84°15'15"	0.58 mi. dst. Simpson Cr.	Mason
26.65	D	39°18'07"/84°15'24"	Adjacent Davis Rd.	Mason
25.24	M,D	39°16'60"/84°15'55"	Loveland Castle	Mason
24.50	M,D	39°16'36"/84°15'28"	Ust. of Loveland	Mason
24.10	C,CO,S,SO,QM	39°16'17"/84°15'34"	Ust. confluence of O'Bannon Cr.	Mason
23.90	B,F	39°16'07"/84°15'40"	Dst. O'Bannon Cr.; Loveland	Mason
22.20	*C,CO,B*	*39°15'04"/84°17'11"*	*Tote's mixing zone*	*Mason*
22.10	F	39°15'04"/84°17'05"	Dst. Tote's	Mason
21.81	M,D	39°15'05"/84°17'17"	Ust. Polk Run WWTP	Mason
21.80	*E*	*39°15'02"/84°17'22"*	*Polk Run WWTP eff.*	*Mason*

Table 5. (continued)

Stream RM	Type of Sampling	Latitude/Longitude	Landmark	USGS Quad. Map
Little Miami River, cont.				
21.50	F	39°14'58"/84°17'30"	Dst. Polk Run	Mason
21.45	C,M,D	39°14'48"/84°17'42"	Branch Hill-Guinea Rd.	Madeira
21.40	B	39°14'47"/84°17'43"	Dst. Polk Run	Madeira
20.90	F	39°14'15"/84°17'50"	Ust. and dst. I-275	Madeira
20.88	M,D	39°14'18"/84°17'52"	Dst. I-275	Madeira
20.60	C,QM,B	39°14'06"/84°17'28"	Lake Isabella Park canoe access	Madeira
19.23	M,D	39°13'31"/84°19'04"	Remington Rd.	Madeira
18.90	B	39°13'18"/84°19'05"	Dst. Sycamore Creek	Madeira
18.50	F,FT	39°12'47"/84°18'49"	Ust. Camargo Rd.	Madeira
18.14	C,CO	39°12'38"/84°18'44"	Camargo Rd.	Madeira
18.10	M,D	39°12'38"/84°12'05"	Dst. Carmago Rd.	Madeira
17.06	M,D,QM	39°12'38"/84°17'37"	Ust. RR bridge near Miamiville	Madeira
15.00	M,D	39°11'41"/84°16'53"	End of Lincoln St.; Camp Dennison	Madeira
13.30	F	39°10'50"/84°17'26"	Milford, OH; dst. Indian Hill WTP	Madeira
13.10	B	39°10'19"/84°17'44"	Ust. Wooster Pike	Madeira
13.07	C,Q	39°10'18"/84°17'55"	Wooster Pike	Madeira
8.80	B	39°08'10"/84°20'29"	Avoca Park	Madeira
8.30	F	39°08'11"/84°21'01"	Ust. and dst. Newtown Rd.	Madeira
8.14	C	39°08'13"/84°21'11"	Newtown Rd.	Madeira
8.00	F,FT	39°08'15"/84°21'16"	Dst. Newtown Rd., adj. Bass Island	Maderia
3.50	C,CO,S,SO,D,F,FT	39°06'36"/84°23'44"	Beechmont Ave.	Newport
3.40	B	39°06'30"/84°24'14"	Dst. Beechmont Ave.	Newport
1.60	B,F	39°05'07"/84°25'11"	Kellogg Ave.	Newport
1.45	C,CO,D	39°05'07"/84°25'17"	Kellogg Ave.	Newport
0.40	B	39°04'33"/84°25'52"	Ust. mouth	Newport
0.20	F	39°04'29"/84°25'51"	Ust. mouth	Newport
Yellow Springs Creek				
0.50	B,F	39°47'30"/83°52'49"	Ust. Yellow Springs WWTP	Yellow Spri.
0.44	C,M,D	39°47'28"/83°52'47"	Ust. Yellow Springs WWTP	Yellow Spr.
0.43	*E,B,F*	*39°47'27"/83°52'46"*	*Yellow Springs WWTP eff./mix. zone*	*Yellow Spr.*
0.42	*C*	*39°47'23"/83°52'42"*	*Yellow Springs WWTP mixing zone*	*Yellow Spr.*
0.30	B,F	39°47'12"/83°52'39"	Dst. Yellow Springs WWTP	Yellow Spr.
0.23	M,D	39°47'12"/83°52'38"	Dst. Yellow Springs WWTP	Yellow Spr.
0.10	C,CO,S,SO,M,D	39°47'10"/83°52'40"	Grinnel Rd.	Yellow Spr.
Oldtown Creek				
0.40	B	39°43'52"/83°56'07"	Dst. Brush Row Rd.	Xenia
0.10	C,CO,S,SO,F	39°44'18"/83°47'10"	Near mouth, near U.S. 68	Xenia

Table 5. (continued)

Stream RM	Type of Sampling	Latitude/Longitude	Landmark	USGS Quad. Map
South Fork Massies Creek				
2.10	B	39°44'17"/83°45'58"	Dst. Weimer Rd.	Cedarville
1.10	B,F	39°44'09"/83°56'08"	Adj. quarry	Cedarville
Massies Creek				
0.30	B,F	39°44'10"/83°56'10"	Ust. U.S. 68	Xenia
0.25	C	39°44'08"/83°56'10"	U.S. 68	Xenia
Beaver Creek				
1.60	B,F	39°42'46"/84°01'24"	Dayton-Xenia Rd.	Bellbrook
1.57	C,S,SO	39°42'50"/84°01'16"	Dayton-Xenia Rd.	Bellbrook
1.13	M,D	39°42'37"/84°01'41"	Ust. Little Beaver Cr.	Bellbrook
1.04	C,S,SO	39°42'31"/84°01'41"	Dst. Little Beaver Cr., at U.S. 35	Bellbrook
0.50	B,F	39°42'12"/84°01'36"	Ust. Greene Co. Beaver Cr. WWTP	Bellbrook
0.41	M,D	39°42'06"/84°01'39"	Ust. Greene Co. Beaver Cr. WWTP	Bellbrook
0.40	*E*	*39°42'00"/84°01'40"*	*Greene Co. Beaver Cr. WWTP eff.*	*Bellbrook*
0.39	*C,B,F*	*39°42'01"/84°01'39"*	*Greene Co. Beaver Cr. WWTP mix. zone*	*Bellbrook*
0.30	F	39°41'54"/84°01'10"	Dst. Greene Co. Beaver Cr. WWTP	Bellbrook
0.20	C,CO,S,SO,B	39°41'53"/84°01'37"	Dst. Greene Co. Beaver Cr. WWTP	Bellbrook
0.01	M,D	39°41'45"/84°01'30"	At mouth	Bellbrook
Little Beaver Creek				
4.70	B,F	39°43'31"/84°06'13"	Ust. Mont. Co. E. Regional WWTP	Bellbrook
4.62	C,S,SO	39°43'35"/84°06'13"	Ust. Mont. Co. E. Regional WWTP	Bellbrook
4.57	*C,B,F*	*39°43'39"/84°06'12"*	*Mont. Co. E. Reg. WWTP mix. zone*	*Bellbrook*
4.53	C,CO,S,SO	39°43'41"/84°06'12"	Dst. Mont. Co. E. Regional WWTP	Bellbrook
4.40	B,F	39°43'38"/84°06'13"	Dst. Mont. Co. E. Regional WWTP	Bellbrook
2.10	F	39°43'23"/84°03'37"	North Fairfield Rd.	Bellbrook
2.00	B	39°43'21"/84°03'34"	North Fairfield Rd.	Bellbrook
1.95	C	39°43'22"/84°03'30"	North Fairfield Rd.	Bellbrook
0.10	B	39°42'36"/84°01'44"	Factory Rd.	Bellbrook
0.05	C,M,D	39°42'36"/84°01'43"	Factory Rd.	Bellbrook
Glady Run				
4.90	B,F	39°39'29"/83°58'57"	Ust. Xenia Glady Run WWTP swale	Xenia
4.82	C,S,SO,M	39°39'27"/83°58'00"	Ust. Xenia Glady Run WWTP swale	Xenia
4.75	C,CO,S,SO	39°39'26"/83°58'02"	Dst. Xenia Glady Run swale	Xenia
4.70	B,F	39°39'23"/83°58'05"	Dst. Xenia Glady Run swale	Xenia
4.08	M,D	39°39'01"/83°58'32"	Hedges Rd.	Xenia
2.08	M,D	39°37'58"/83°59'45"	Schnebly Rd. (north crossing)	Xenia
1.10	M,D	39°37'24"/84°00'20"	Schnebly Rd. (south crossing)	Waynesville
0.60	C,M,D	39°37'02"/84°00'37"	S.R. 725	Waynesville
0.30	B,F	39°37'01"/84°00'38"	Dst. S.R. 725	Waynesville

Table 5. (continued)

Stream RM	Type of Sampling	Latitude/Longitude	Landmark	USGS Quad. Map
Glady Run WWTP Swale				
0.30	B,F	39°39'39"/83°57'49"	Ust. Xenia Glady Run WWTP	Xenia
0.21	M,D	39°39'36"/83°57'52"	Ust. Xenia Glady Run WWTP	Xenia
0.20	*E,F*	*39°39'34"/83°57'54"*	*Xenia Glady Run WWTP eff./mix. zone*	*Xenia*
0.10	F	39°39'28"/83°57'54"	Ust. mouth	Xenia
0.01	M,D	39°39'26"/83°58'02"	At mouth	Xenia
Tributary to Glady Run				
0.01	M	39°37'02"/84°00'38"	At mouth (ust. from S.R. 725)	Waynesville
Mill Run				
0.59	C	39°32'30"/84°03'52"	U.S. Rt. 42	Waynesville
Newman Run				
0.30	B,F	39°31'06"/84°05'54"	Ust. S.R. 42	Waynesville
0.27	C,S,SO	39°31'04"/84°05'53"	Adj. Pekin-Waynesville Rd.	Waynesville
Anderson Fork				
5.00	B,F,	39°33'57"/83°54'08"	Ust. Old Winchester Trail	N. Burlington
4.90	C,CO,S,SO	39°33'59"/83°54'10"	Old Winchester Trail	N. Burlington
Flat Fork				
1.70	C,CO,S,SO,B,F	39°28'26"/84°02'46"	Oregonia Rd.	Oregonia
Caesar Creek				
16.52	C,CO,S,SO	39°37'26"/83°57'53"	Spring Valley Paintersville Rd.	N. Burlington
16.50	B,F	39°35'53"/83°57'58"	Spring Valley Paintersville Rd.	N. Burlington
0.15	C	39°29'34"/84°06'06"	Corwin Rd.	Oregonia
0.10	B,F	39°29'34"/84°06'07"	Dst. Corwin Rd., ust mouth	Oregonia
Dry Run				
1.80	B,F	39°23'02"/84°12'13"	Snook Rd.	Lebanon
1.79	C,CO,S,SO	39°23'01"/84°12'15"	Snook Rd.	Lebanon
Turtle Creek				
6.30	B,F	39°25'55"/84°13'26"	Ust. Glosser Rd.	Lebanon
6.23	C,CO,S,SO	39°25'53"/84°13'31"	Glosser Rd.	Lebanon
5.00	C	39°25'28"/84°14'28"	McClure Rd.	Lebanon
4.70	F	39°25'18"/84°14'37"	McClure Rd.	Lebanon
4.30	B	39°24'54"/84°14'23"	Dst. U.S. 42	Lebanon
0.70	C,S,SO,D	39°22'22"/84°13'47"	Mason Rd.	S. Lebanon
0.60	B,F	39°22'19"/84°13'45"	Ust. Cincinnati Milacron	S. Lebanon
0.58	*C,CO,S,SO*	39°22'18"/84°13'44"	*Cincinnati Milacron diffuser mix. zone*	*S. Lebanon*
0.57	D	39°22'19"/84°13'43"	Dst. Cincinnati Milacron diffuser	S. Lebanon
0.52	C,S,SO	39°22'19"/84°13'35"	S.R. 48	S. Lebanon
0.50	*B,F*	*39°22'18"/84°13'38"*	*Dst. Cincinnati Milacron diffuser*	*S. Lebanon*
0.40	B,F	39°22'19"/84°13'36"	Ust. S.R. 48	S. Lebanon
0.10	B,F	39°22'13"/84°13'12"	Ust. mouth	S. Lebanon
0.01	C,S,SO,D	39°22'11"/84°13'12"	At mouth, dst. Dry Run	S. Lebanon

Table 5. (continued)

Stream RM	Type of Sampling	Latitude/Longitude	Landmark	USGS Quad. Map
Muddy Creek				
3.50	M,D	39°22'18"/84°17'18"	S.R. 741, ust. Mason WWTP	Mason
3.24	*E*	*39°22'29"/84°17'05"*	*Mason WWTP eff.*	*Mason/Monroe*
2.50	C,CO,M,D,B	39°22'26"/84°16'30"	Mason-Morrow Rd.	Mason
1.60	F	39°22'37"/84°15'44"	Mason-Morrow Rd.	Mason
Simpson Creek				
0.15	M,D	39°19'17"/84°15'19"	Ust. Warren Co. Lower LMR WWTP	Mason
0.14	*E*	*39°19'17"/84°15'19"*	*Warren Co. Lower LMR WWTP eff.*	*Mason*
0.01	M,D	39°19'14"/84°15'12"	At mouth	Mason
O'Bannon Creek				
4.37	M	39°14'57"/84°12'05"	Gibson Rd.	S. Lebanon
2.57	*E*	*39°15'35"/84°13'20"*	*Clerm. Co. O'Bannon Cr. WWTP eff.*	*S. Lebanon*
0.26	M,D,QM	39°16'07"/84°15'21"	S.R. 48	Mason
Polk Run				
1.71	M	39°14'56"/84°17'37"	Loveland Rd.	Mason
Sycamore Creek				
0.50	B	39°13'24"/84°19'35"	Ust. Ham. Co. Sycamore Cr. WWTP	Madeira
0.40	C,S,SO,F	39°13'33"/84°19'28"	Ust. Ham. Co. Sycamore Cr. WWTP	Madeira
0.27	M,D,QM	39°13'29"/84°19'25"	Ust. Ham. Co. Sycamore Cr. WWTP	Madeira
0.26	*E,B,F*	*39°13'30"/84°19'26"*	*Sycamore Cr. WWTP mixing zone*	*Madeira*
0.25	*C*	*39°13'30"/84°19'25"*	*Sycamore Cr. WWTP mixing zone*	*Madeira*
0.20	F	39°13'13"/84°19'10"	Dst. Sycamore Cr. WWTP	Madeira
0.10	B	39°13'30"/84°19'15"	Dst. Sycamore Cr. WWTP	Madeira
0.05	C,CO,S,SO,M,D	39°13'32"/84°19'10"	Dst. Sycamore Cr. WWTP, near mouth	Madeira
Stonelick Creek				
20.00	F	39°15'23"/84°00'45"	Dst. Woodville-Mainville Rd.	Pleasant Plain
17.70	B	39°14'04"/84°02'30"	SR 133 and Martin Rd.	Newtonsville
16.74	C CO	39°13'33"/84°03'07"	S.R. 133	Newtonsville
16.70	F	39°13'33"/84°03'08"	S.R. 133, Stonelick Lake	Newtonsville
3.10	C,CO,F	39°08'21"/84°11'07"	Dst. Lick Fork	Goshen
2.90	B	39°08'12"/84°11'14"	Dst. Lick Fork	Goshen
1.20	F	39°07'16"/84°12'06"	U.S. Rt. 50	Batavia
1.00	C,CO,S,SO,B	39°07'21"/84°11'57"	U.S. Rt. 50	Batavia
East Fork Little Miami River				
15.60	C,CO,S,SO	39°03'36"/84°10'32"	S.R. 222	Batavia
15.50	B,F	39°03'45"/84°10'46"	Dst. S.R. 222	Batavia
13.35	*C,S,SO*	*39°04'55"/84°10'37"*	*Batavia WWTP mixing zone*	*Batavia*
13.30	B	39°05'04"/84°10'41"	Dst. Batavia WWTP	Batavia
12.70	B,F	39°05'20"/84°11'03"	Dst. Batavia WWTP, ust. ODNR access	Batavia
12.59	*C,S,SO*	*39°05'20"/84°11'18"*	*Clerm. Co. Mid. E.Fk. WWTP mix. zone*	*Batavia*
12.40	F	39°05'21"/84°11'25"	Dst. Clerm. Co. Middle E.Fk. WWTP	Batavia
9.20	B,F	39°07'02"/84°12'30"	Ust. Olive Branch-Stonelick Rd.	Batavia
9.10	C	39°07'08"/84°12'42"	Olive Branch-Stonelick Rd.	Batavia
6.70	B	39°08'08"/84°14'12"	Roundbottom Rd.	Goshen
6.60	F	39°08'17"/84°14'26"	Roundbottom Rd.	Goshen

Table 5. (continued)

Stream RM	Type of Sampling	Latitude/Longitude	Landmark	USGS Quad. Map
East Fork Little Miami River, cont.				
6.57	C,D	39°08'13"/84°14'17"	Roundbottom Rd.	Goshen
4.85	C,S,SO	39°08'51"/84°15'31"	Dst. Clerm. Co. Lower E.F. WWTP trib.	Madeira
4.70	B,F	39°08'54"/84°15'30"	Dst. Lower E.F. WWTP trib.	Madeira
4.30	D	39°09'17"/84°15'32"	Dst. Clerm. Co. Lower E.F. WWTP trib.	Madeira
4.00	C	39°10'17"/84°17'53"	S.R. 50 entrance to I-275	Madeira
2.50	D	39°10'01"/84°16'17"	I-275	Madeira
1.90	B	39°09'40"/84°16'48"	Dst. I-275	Maderia
1.70	F	39°09'42"/84°16'55"	Ust. Milford WWTP	Maderia
1.40	F	39°09'49"/84°17'05"	Dst. Milford WWTP	Maderia
0.80	B	39°09'23"/84°16'50"	South Milford Rd.	Madeira
0.77	C,CO,S,SO	39°09'20"/84°17'30"	Cleveland Ave., near Terrace Park C.C.	Madeira

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) for aquatic habitat assessment. Chemical, physical and biological sampling locations are listed in Table 4 .

Determining Use Attainment Status

The attainment status of aquatic life uses (*i.e.,* FULL, PARTIAL, and **NON**) is determined by using the biological criteria codified in the Ohio Water Quality Standards (WQS; Ohio Administrative Code [OAC] 3745-1-07, Table 7-17). The biological community performance measures which are 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 1988). 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 at least 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 metrics used to determine the QHEI score which generally ranges from 20 to 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. Scores greater than 75 frequently typify habitat conditions which have the ability to support exceptional warmwater faunas.

Macroinvertebrate Community Assessment

Macroinvertebrate assemblages were sampled quantitatively using multiple-plate artificial substrate samplers (modified Hester/Dendy [Plate 6]) 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 developmental 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 ICI scale of 0 to 60. For the qualitative collections in the Ottawa River 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. Use of the QCTV in evaluating sites in the Little Miami River study area was restricted to relative comparisons between sites with no direct attempt to interpret quality of the sites or aquatic life use attainment status.

Fish Community Assessment

Fish assemblages were sampled using wading or boat method pulsed DC electrofishing gear (Plate 6). The wading method was used at a frequency of one or two samples at each site. The boat method was used at a frequency of two or three samples at each site. The specific electrofishing method and the number of samples for each sampling location are listed in Table 12.

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 (Fig. 4). 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 also expressed as ADV/mile to normalize comparisons between segments 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 the principal arbiter of aquatic life use attainment and impairment (partial and non-attainment). The rationale for using the biological criteria in the role of principal arbiter 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 1991a; 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, biomonitoring results, land use data, and the biological response signatures (Yoder and Rankin 1995) within the biological data itself. Thus the assignment of principal causes and sources of impairment in this report do not represent a true "cause and effect" analysis, but rather represent the association of impairments (based on response indicators) with stressor and exposure indicators whose links with the biosurvey data are based on previous research or experience with analogous situations and impacts. The reliability of the identification of probable causes and sources is increased where many such prior associations have been identified. The process is similar to making a medical diagnosis in which a doctor relies on multiple lines of evidence concerning patient health. Such diagnoses are based on previous research which experimentally or statistically linked symptoms and test results to specific diseases or pathologies. Thus a doctor relies on previous experience in interpreting symptoms (*i.e.*, multiple lines from test results) to establish a diagnosis, potential causes and/or sources of the malady, a prognosis, and a strategy for alleviating the symptoms of the disease or condition. As in medical science, where the ultimate arbiter of success is the eventual recovery and the well-being of the patient, the ultimate measure of success in water resource management is 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) here we are referring to the process for identifying biological integrity and causes/sources associated with observed impairment, not whether human health and ecosystem health are analogous concepts.

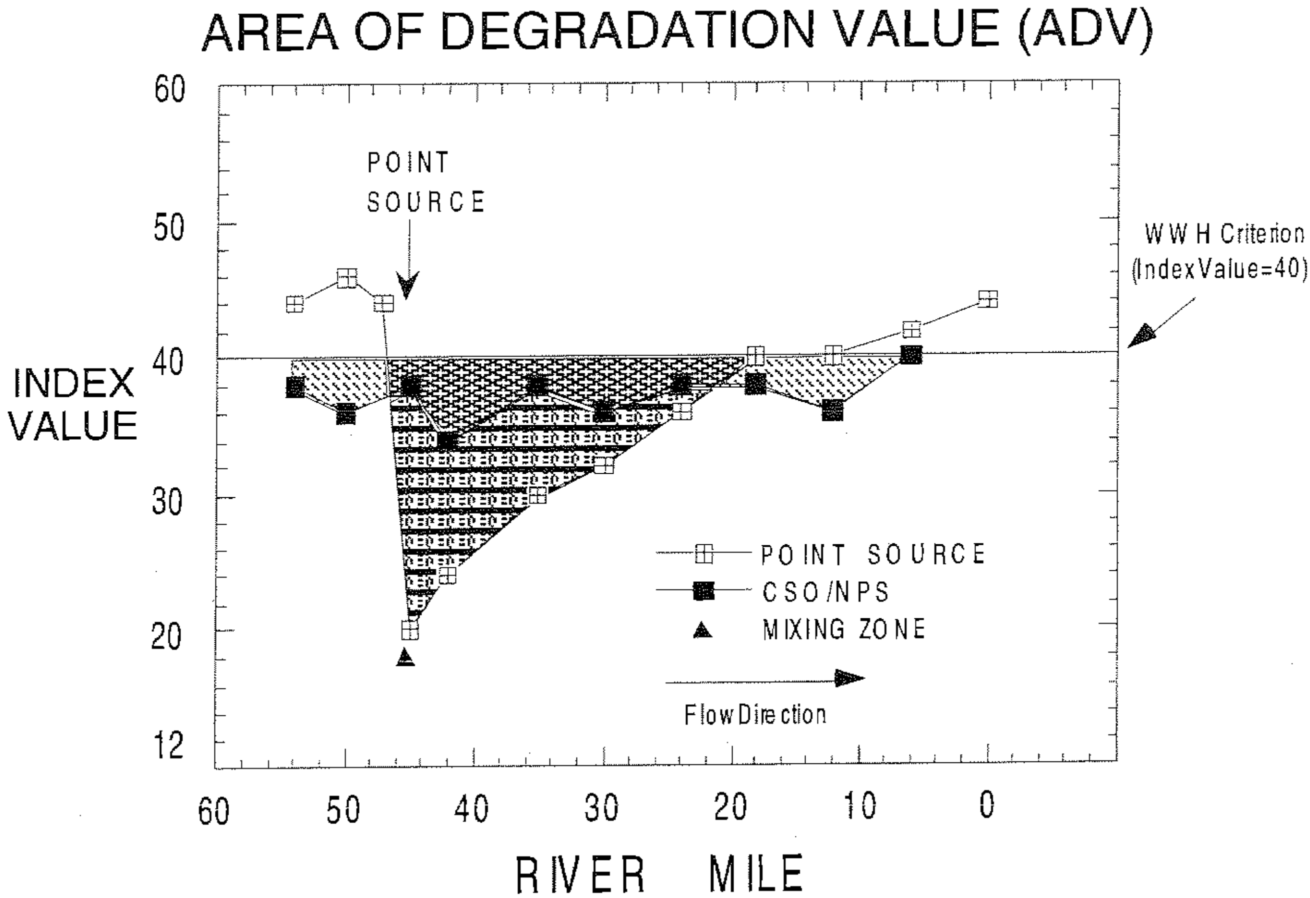


Figure 4. Graphic illustration of the Area of Degradation Value (ADV) based on the ecoregion biocriterion (WWH in this example). The index value trend line indicated by the unfilled boxes and solid shading (area of departure) represents a typical response to a point source impact (mixing zone appears as a 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: 1979 - 1993 (Plates 11-12; Figures 5 - 25; Tables A-1 - A-2c)

Gilroy Ditch - South Charleston WWTP

- Initially constructed in 1938 and later expanded in 1969, the South Charleston WWTP utilizes secondary treatment which includes aeration, primary and secondary settling, chlorination, and aerobic sludge digestion. Flow equalization was added in 1990 along with additional clarifiers. The facility discharges to Gilroy Ditch at a design flow of 0.24 MGD. The latest census estimated the population at 1600 with a population equivalent of 2400. Separate sewers service 98-99% of the village with three lift stations, one with an overflow (outfall 002). Excessive flow to the WWTP due to inflow and infiltration is a major problem. South Charleston is in the process of obtaining finances for a recommended WWTP upgrade to address deficiencies within the existing sewer system.

- Average annual discharge flow from the WWTP from 1983 through 1993 ranged from 0.121 to 0.380 MGD. The average during 1992-93 was 0.210 MGD. Flow during the years 1987 and 1989-91 exceeded the design capacity of 0.24 MGD indicating that the plant was hydraulically overloaded. The hydraulic overloads in 1990 and 1991 may have been caused by above normal amounts of precipitation (USGS 1991, 1992).

- Total suspended solids (TSS) loadings (50th percentile values) showed gradual reductions over a 15 year span (1979-1993) and averaged 9.69 kg/day.

- Annual median (50th percentile) ammonia-N values for 1987-1993 (data is available only since 1987) exhibited a steady reduction with the most dramatic decline occurring after 1989 (Figure 5). Third quarter (July 1 - September 30) loadings exhibited a similar pattern for the same four years.

- Annual 5-day biochemical oxygen demand (BOD_5) loadings (50th percentile) ranged from 11.7-34.4 kg/day and demonstrated variability during 1979-1993 with no discernable trend. Annual median loadings in 1993 ($CBOD_5$ reported 1987-1993) were double those during the two previous years which corresponded to values reported during 1979-1989.

Massies Creek - Cedarville WWTP

- Constructed in 1952 and upgraded in 1971 (new plant), the Cedarville WWTP is a secondary treatment plant utilizing contact stabilization and chlorination. The collection system consists of separate sanitary sewers throughout 100% of the service area. Two lift stations with bypasses exist, but the frequency of overflows is unknown. The bypasses should be eliminated via an impending upgrade of the WWTP. Design capacity is 0.480 MGD and the discharge is to Massies Creek. The population averages 3,800 during June - September, but seasonally increases to 4800 when Cedarville College is in session.

- In 1967 the plant was recognized as being "seriously overloaded" with peak flows exceeding design flows by greater than 50%. In 1974 U.S EPA recommended adoption of a regular program of solids wasting in order to avoid the discharge of solids to Massies Creek. In 1984 Ohio EPA reiterated the need for an upgrade at the WWTP. A Municipal Compliance Plan for upgrading the facility was approved by Ohio EPA in 1988.

- In 1991 notice of violation (NOV) letters were sent to Cedarville for failure to submit required monthly operating reports (MOR) by the required date. Sludge management is a problem and is presently stored in the sludge lagoon for indefinite time periods. When the design capacity of the

WWTP is exceeded, biosolids are subsequently bypassed to Massies Creek. Detailed plans for a WWTP upgrade were to be submitted by November 15, 1993.

- Average annual flows reported in 1983 were 0.339 MGD and 0.340 MGD in 1993. Within a 10 year period flow values fluctuated between 0.255 - 0.431MGD. Discharge volume in 1989 and 1990 exceeded other years and was likely influenced by above normal precipitation. However, average flow data indicates that design capacity is not exceeded.

- Average annual ammonia-N loadings remained relatively stable from 1977-1981, but nearly doubled in 1982 and further increased in 1983 and 1984. Ammonia-N loadings then declined to 50% of the 1983 and 1984 values and stabilized to an annual average of 1.10 - 3.40 through 1992. In 1993 the highest annual average since 1976 was reported (7.36 kg/day), a further indication of WWTP problems (Figures 6-7).

- Average annual suspended solids demonstrated a pattern similar to ammonia-N in the early 1970s (Figure 7) In the late 1970s and early 1980s loadings increased by nearly 43% increasing to 52% by 1993.

- BOD_5 remained in the range of 12 to 14 kg/day from 1979 to 1987 and increased to nearly 39% during 1988-1990 (Figure 6). $CBOD_5$ loadings increased during 1991-1993 by 300% (3.89 to 26.8 kg/day) with the most significant increase in 1993.

- Bioassay testing showed acute toxicity to both fathead minnow *(Pimephales promelas)* and water fleas *(Ceriodaphnia dubia)* in August and September 1993.

Yellow Springs Creek - Yellow Springs WWTP

- Constructed in 1961, the Yellow Springs WWTP has secondary treatment consisting of extended aeration, secondary clarification, chlorination, and aerobic sludge digestion. An upgrade to the WWTP in July 1988 resulted in a design capacity of 0.600 MGD. The service area consists of separate sewers with 90% of the area sewered. The most recent census estimates the population at 3772 with a population equivalent of 3973 and only stagnant growth predicted. The WWTP's effluent flows through a series of cascading, high gradient falls in Camp Glen Helen (Plate 11) before splitting into several channels that enter Yellow Springs Creek over a 100 meter segment. One lift station with an overflow was reported, however, these should rarely occur due to the recent upgrades. Elimination of the lift station overflow is planned with the future upgrade of the WWTP. An upgrade to the internal bypass was recently approved which should provide more accurate conduit flow data and prevent solids washouts during high flows. Industrial input from Vernay Labs, Inc. (print shop), Yellow Springs Instruments (electronic instruments), and Antioch Publishing Co. comprises 2-4% of the WWTP inflow.

- The annual average flow over a 10-year period (1983-1993) has increased 2.5 times, but was much higher in 1980, 1990, and 1992. The volume of flow from the WWTP has shown a high degree of year-to-year variability.

- Median total suspended solids during 1979-1988 averaged 49.5 kg/day and declined to 25.5 kg/day after 1989 (Figure 8).

- BOD_5 loadings during 1979-1988 were variable averaging 65.8 kg/day. The highest values occurred during 1980-1988 with an average median value of 58.2 kg/day. Differences between the median and 95th percentile values indicated a high degree of variability in the final effluent quality.

- Median and 95th percentile ammonia-N loadings fluctuated widely (0.12-22.0 kg/day) over a nine-year period (1979-1988). Marked reductions in median values occurred during 1989-1992. Median and 95th percentile ammonia-N loadings varied widely and suggest a high degree of variability in WWTP efficiency. Values for ammonia-N during 1989-1993 were the lowest recorded since 1984.

Little Miami River - Xenia Ford Road WWTP

- Constructed in 1969 and upgraded in 1988, the Xenia-Ford Road plant is an advanced secondary WWTP consisting of secondary clarifiers, flow equalization, final clarification and dechlorination. The WWTP discharges directly to the Little Miami River with a design capacity of 3.600 MGD. Nearly 100% of the service area is sewered with separate sewers. Industrial contributions to the WWTP is approximately 0.05% of the inflow. The latest population census estimate is 25,000 with no reported population equivalent. One relatively inactive overflow exists at the equalization basin. Various efforts are on-going to reduce inflow/infiltration to the WWTP. The city has occasionally pumped from a manhole directly to Shawnee Creek during heavy rainfall events although this practice has been reduced.

- Conduit flows reported during 1983-1993 remained relatively stable with an annual average of 2.820 MGD. This average is approximately 43% below the design flow of 3.600 MGD.

- Ammonia-N loadings fluctuated during 1979-1988 at an annual average of 71.2 kg/day for the median value (Figure 10). The annual median loading decreased to 5.02 kg/day following a plant upgrade in 1988.

- Recent bioassay test results include acute toxicity to *Ceriodaphnia dubia* in the first day effluent grab sample in March 1992, effluent and receiving water samples were not acutely toxic in June 1992, and 5% mortality to fathead minnow *(Pimephales promelas)* in April 1993.

Little Beaver Creek - Montgomery County Eastern Regional WWTP

- Constructed in 1953 and expanded in 1958 and 1970, the Montgomery County Eastern Regional WWTP is a secondary treatment plant consisting of secondary clarification and activated sludge. A major 1988 modification included flow equalization tanks, secondary clarifiers, aerated channels, dechlorination, and post-aeration. Forty-two (42) overflows were also eliminated. The WWTP has a design flow of 13.0 MGD and discharges to Little Beaver Creek. The plant is served by separate sewers with 100% of the service area sewered. However, the extent of inflow/infiltration has not been quantified. The collection system contains 17 lift stations with no reported overflows or bypasses. The population is reported at 120,000 with saturated growth. The plant receives a 15% industrial input consisting of wastewater from General Motors-Delco (automotive parts manufacturer), Kodak Co., and a dairy.

- Average annual flows at this facility varied by nearly 1.500 MGD during 1983-1993 (7.560-14.90 MGD) which persisted after the addition of flow equalization in 1988. Average annual flow in 1991 and possibly 1992 were well above design capacity with reported flows of 14.90 and 22.20 MGD, respectively.

- Ammonia-N loadings exhibited a gradual reduction during 1979-1985 when loadings increased slightly during the next two years (Figure 9). Loadings were significantly reduced in 1988 due to a WWTP upgrade. Median ammonia-N averaged 8.62 kg/day during 1991-1993.

- BOD_5 loadings in the late 1970s and mid-1980s fluctuated between 650-1500 kg/day. $CBOD_5$ loadings declined from 605 kg/day to 250 kg/day during 1986-1993. With the exception of 1992, $CBOD_5$ during 1988-1993 remained in the 200 kg/day range.

- Median copper loadings ranged from 0.571-1.280 kg/day during 1979-1993 with no discernable trends. Values in 1993 were approximately the same as the prior 14 years.

- Recent bioassay test results reveal the following: 20% mortality to *Ceriodaphnia dubia* and no acute toxicity to fathead minnows was evident in 75% and 100% strength effluent in a U.S. EPA test in 1988; no adverse effects to either fathead minnows or *Ceriodaphnia dubia* in a 1990 Montgomery Co. test; no acute toxicity in a May 1993 Ohio EPA test; both the effluent and receiving water exhibited acute toxicity in April 1993 (chronic toxicity testing was recommended); and bioassay test results submitted by Montgomery Co. revealed six of 11 tests failed.

Beaver Creek - Greene County Beaver Creek WWTP

- Constructed in 1965 and upgraded in 1988, the Beaver Creek plant is a secondary plant served by separate sewers within 100% of the service area. The plant is equipped to perform basic secondary treatment processes utilizing secondary clarifiers, extended aeration tanks, and chlorination. Plans have been approved for ultraviolet light disinfection. The population is estimated at 32,784 (no equivalent population reported) with rapid growth predicted for the area. The plant discharges to Beaver Creek and has a design capacity of 4.600 MGD. A WWTP expansion is planned to handle excessive flows which have recently exceeded the design capacity. Industrial inputs are estimated at 2% and consist of significant flows from Elano (metal cleaner) and lesser contributions from Universal Technologies (transparency manufacturer), Kray International (govt. research facility), and JBK Manufacturing (pipe bending).

- Annual average flow during 1983-1993 increased 45% with the most substantial increases occurring during 1988-1993 (3.890 to 5.450 MGD). Design capacity was reached in 1991 and surpassed in 1992 and 1993.

- Loadings of ammonia-N increased during 1979-1981, but then declined during 1981-1987 (Figure 10). Even more dramatic reductions occurred in 1988 (following a plant upgrade) and again during 1991-1993 (median values of 25.78 and 5.67 kg/day, respectively).

- Median BOD_5 loads during 1976-1987 increased from 79 kg/day to 689 kg/day. Loadings of $CBOD_5$ decreased from 175 kg/day to 42 kg/day during 1987-1993.

- Bioassay test results showed the following: a composite sample was toxic to 50% of the *Ceriodaphnia dubia* after a 48 hr. exposure in March 1989; no acute toxicity to either species in any sample was evident in January 1989; and test results submitted by Greene Co. revealed three failures out of four tests.

Little Miami River - Greene County Sugar Creek WWTP

- Constructed in 1977 with a major modification in 1987, the Sugar Creek WWTP is a secondary treatment plant consisting of pre-aeration, secondary clarifiers, aerobic sludge digestion, and chlorination. Chlorination in the effluent is reportedly being replaced by ultraviolet light. The plant has a design capacity of 4.900 MGD and discharges directly to the Little Miami River. The collection system consists of separate sewers and 100% of the service area is sewered. Seven lift stations exist with no reported overflows or bypasses. Plans have been drafted to eliminate the lift stations in Montgomery County. Industrial inputs comprise <10% of the inflow with the most significant inputs from Dimco Gray (machine shop) and Union Camp (cardboard corrugator). Minor industrial contributors include Finishing Touch (furniture stripper), Marble Molders (sink-top manufacturers), and N/R labs (shampoo manufacturer).

- Average annual conduit flow during 1983-1993 increased by nearly 2 MGD (3.770 to 5.600

MGD; nearly 1 MGD/five years). The design capacity was exceeded beginning in 1990 and was nearly surpassed by 1 MGD in 1993.

- Median annual ammonia-N loadings varied widely ranging from 45 to 154 kg/day (Figure 10). Reductions in ammonia-N ensued during 1988-1990 (from 11 to 7 kg/day, respectively) a result of the WWTP upgrade in 1987. However, a substantial increase (300-600%) in loadings from 7.3 kg/day to 47 kg/day occurred between 1991 and 1993.

- Bioassay tests showed the following: no acute toxicity was observed in April 1989; no acute toxicity was observed in October 1992 (grab samples of 001 outfall) - *Ceriodaphnia dubia* was adversely affected (50%) in the mixing zone which was likely due to chlorine toxicity; no acute toxicity was observed in grab and composite samples during October 1992.

Glady Run Swale - Xenia-Glady Run WWTP

- Constructed in 1959 with a major modification in 1988, the Xenia-Glady Run WWTP is an advanced secondary treatment plant consisting of activated sludge, settling, and anaerobic digestion. The WWTP has a design capacity of 2.600 MGD and discharges to Glady Run (in the past a drainage swale to Glady Run received the final effluent). Glady Run has since merged with the swale, thus adding increased flow and greater dilution for the effluent. The estimated population is 25,000. The collection system serves 100% of the service area. There is one fairly inactive overflow from an equalization basin. Inflow from Bob Evans Co. occasionally creates blockages in the sewer line. Approximately 9% of the inflow consists of industrial wastewater all of which are classified as minor industrial users.

- Average annual WWTP flow during 1983-1986 was fairly stable (1.940-2.000 MGD), but exhibited an increase of nearly 60% during 1987-1993. Effluent flow is presently within 5% of design capacity.

- Median ammonia-N loadings during 1979-1988 averaged 70.1 kg/day (Figure 11). Marked reductions in ammonia-N loadings occurred after the 1988 WWTP upgrade resulting in an average median value of only 0.98 kg/day during 1989-1993.

- One bioassay test in February 1989 showed no acute toxicity to either test species in any sample.

Little Miami River - Waynesville WWTP

- Constructed in 1962 with a major modification in 1983, the Waynesville WWTP is a secondary treatment plant consisting of flow equalization, fixed film reactor (RBC), extended aeration, lime stabilization, and chlorination. Plans for ultraviolet light disinfection in lieu of chlorination are being evaluated. The WWTP discharges to the Little Miami River and has a design flow of 0.710 MGD with no reported overflows or bypasses. The population is 1,969 with moderate to rapid growth predicted for the area. The service area has separate sewers and 100% of the area is sewered. Industrial contributions from a minor industrial user comprises <1% of the inflow.

- Average annual conduit flow data during 1983-1993 shows a gradual increase from 0.271 to 0.492 MGD, an increase of 82% over 10 years. The facility is operating at less than 70% of the design capacity.

- Average annual loadings for BOD_5 during 1983-1987 increased nearly 2.5 times over the five year span. Loadings of $CBOD_5$ increased during 1988-1993 with annual median values ranging from 4.44 to 5.30 kg/day.

- With a few exceptions, median annual ammonia-N loadings exhibited reductions of nearly 600%

during 1983-1993 (Figure 11). Median loadings increased from 0.088 kg/day in 1991 to 0.715 kg/day in 1993.

- Bioassay tests showed the following results: no acute toxicity to either test species in any sample was evident in July 1993; <20% toxicity to fathead minnows was detected in a composite sample collected in September 1993; a September 14, 1993 grab sample revealed toxicity to 10% of the fathead minnows and 20% of *Ceriodaphnia dubia* and 5% of *Ceriodaphnia dubia* in a composite sample.

Turtle Creek - Cincinnati Milacron

- Cincinnati Milacron manufactures printed circuit boards and generates industrial wastewater. The treatment of process wastewater consists of ion exchange (added in 1993) and pH control (outfall 001). Sanitary wastewater (outfall 002) is treated with extended aeration and ultraviolet light disinfection. The total wastewater design flow capacity is 0.088 MGD (combined wastewater volume). Both outfalls currently discharge intermittently to Turtle Creek through a three outlet diffuser installed in 1993. The diffuser's plume occupies approximately one-third of Turtle Creek's width. For the past 6-7 years Cincinnati Milacron has operated on a 9-10 hours/day and five day/week production schedule. Occasional weekend work is performed, but no wastewater containing metals is produced. A higher volume of wastewater will soon be produced on tuesdays and thursdays due to the electrolysis copper line being iu operation simultaneously with the copper electroplating line. Copper concentrations averaged 57 ug/l and nickel concentrations averaged 60 ug/l in outfall 002 during 1990-1993. These concentrations are 2-3 times higher than in the water drawn from their wells.

- Sanitary wastewater flow (002) remained the same (0.012 MGD) from 1979-1981, decreased from 1982-1989, then markedly increased from 1990-1993 (Figure 12). Process wastewater flow (001) increased gradually during 1976-1980 from 0.15 to 0.22 MGD. During 1981-1983 flows decreased to 0.05 MGD, but doubled during 1984-1987 (Figure 13). Effluent volume then gradually declined to an average of 0.07 MGD during 1989-1993.

- Annual average copper levels at outfall 001 averaged 0.972 kg/day during 1979-1982 and remained steady until 1988. Loadings decreased from an average of 0.791 to 0.099 kg/day in 1993. Third quarter, average annual copper loadings at 001 ((Figure 13) for years 1979-1987 fluctuated within a range of 0525-1.130 kg/day. Between 1988 and 1993 average loadings declined further from 0.401-0.046 kg/day, respectively.

- In April 1990 the OEPA issued a Director's "Findings and Orders" to initiate a biomonitoring program by December 1991. A Toxicity Reduction Evaluation (TRE) plan was discussed.

- Bioassay tests performed by Ohio EPA, Cincinnati Milacron, and others showed the following: 100% mortality to fathead minnows and *Ceriodaphnia dubia/affinis* was observed in 100% effluent in a 1983 Ohio EPA test; chronic toxicity to both test organisms was observed in a 1984 Battelle test; toxicity related to copper concentrations in the effluent were reported in 1987 by Wright State University ; acute toxicity to *Ceriodaphnia dubia* was observed in a 1992 Cincinnati Milacron test; acute toxicity to both fathead minnows and *Ceriodaphnia dubia* was observed in May 1993 no toxicity was observed from the 002 outfall; acute toxicity to both test organisms was observed in a combined outfall sample in July 1993 with toxicity persisting in the mixing zone; a definitive test (employed when sufficient mortality or other adverse effects allow determination of a median lethal concentration or median effect concentration) indicated acute toxicity to both test organisms in October 1993; all 21 tests submitted by Cincinnati Milacron were considered as failing (*i.e.*, >20% mortality observed).

Muddy Creek - Mason WWTP

- Constructed in 1962 and a major upgrade in 1989, the Mason WWTP is a secondary treatment plant consisting of an oxidation ditch, final settling, and ultraviolet light disinfection. The collection system is separate and serves 85% of the service area (population of 11,000). The WWTP discharges to Muddy Creek with a design flow of 2.500 MGD. Excessive inflow and infiltration have resulted in the need for flow equalization basins along with new pretreatment, clarifiers, a sludge press, and sludge digester. The lack of sludge removal is also a problem. Construction on some of these processes has been initiated while other projects are currently in review. While the collection system has a fairly active overflow to Muddy Creek, construction is underway to eliminate the overflow. Industrial inputs comprise approximately 47% of the total inflow volume.

- A Consent Order signed in June 1991 contains a schedule for Mason to upgrade the plant to meet final table NPDES permit limits and eliminate the separate sewer overflow by September 1995. Imminent requirements include handling and disposing of sludge in accordance with an approved sludge management plan and infiltration/inflow reduction.

- Annual average conduit flow over the past 10 years (1983-1993) increased by nearly 150%. Flow values were approaching design capacity in 1993.

- Annual median ammonia-N loadings during 1981-1993 were variable ranging from 0.15 to 21.5 kg/day with no obvious trends (Figure 14). The disparity between median and 95th percentile values indicate instability in treatment efficiency which remained apparent after the 1989 plant upgrade.

- The median annual suspended solids loading during 1985-1989 was 26.9 kg/day. Loadings increased during 1991-1993 with an average of 48.3 kg/day. Again, considerable variability occurred between the median and 95th percentile values.

- BOD_5 loadings during 1979-1993 showed no recognizable pattern with values ranging between 145 kg/day in 1981 to 5.37 kg/day in 1993. Loadings in 1992 and 1993 were below those of previous years.

- Bioassay tests showed the following: no acute toxicity to either species was evident in any sample in November 1992 or January 1993 and no acute toxicity was detected in the effluent and 5% mortality to *Ceriodaphnia dubia* occurred in mixing zone in March 1993.

Little Miami River - Lebanon WWTP

- Constructed as a new facility in 1987, the Lebanon WWTP is a secondary treatment plant with counter-current aeration, plastic media sludge drying beds, and chlorination. This facility replaced the original Lebanon WWTP which discharged to Turtle Creek. The collection system is separate with 60% of the service area sewered (population is 12,500). The discharge is to the Little Miami River with a design capacity of 3.000 MGD. Two lift stations exist with no reported bypasses or overflows. Industrial inputs comprise 30-35% of the inflow with the most significant contribution from Fuji Tech, Inc. The WWTP flow is presently operating at the design capacity.

- Annual average flow during 1983-1993 increased 3.5 times and reached design capacity in 1990. The flow doubled in 1988 and nearly doubled again in 1993 to 3.460 MGD. Design capacity was exceeded in three different years (1990, 1992 and 1993).

- Annual median ammonia-N loadings during 1979-1987 (old WWTP) were sporadic and averaged 29.1 kg/day (Figure 15). By 1988 (new WWTP) median loadings diminished significantly to an average of 3.23 kg/day during 1988-1993.

- Bioassay tests in April and May 1990 and April 1993 revealed no acute toxicity.

Simpson Creek - Warren County Lower Little Miami WWTP

- Constructed in 1981 and upgraded in 1992, the Lower Little Miami WWTP is a secondary treatment plant consisting of vertical loop reactor extended aeration, secondary clarification, and chlorination/dechlorination. The collection system is separate with 100% of the service area sewered (population is 12,500 with a population equivalent of 14,873). The WWTP discharges to Simpson Creek with a plant design capacity of 3.640 MGD. An upgrade and expansion was recently completed; however, the facility is already in the design phase to double capacity.

- Seventeen (17) lift stations exist with no reported overflows or bypasses. The plant receives approximately 6% industrial flows from one significant user, OTC (semi-conductor devices), and seasonally variable quantities of sanitary wastewater from the Kings Island Amusement Park.

- Annual average conduit flow increased nearly 300% during 1983-1993. Flow volume increased steadily from 1983 to 1991 with values ranging from 0.770 to 2.540 MGD, respectively. Following the upgrade in 1992, flow volume declined slightly to 2.220 MGD in 1993, well below the design capacity.

- Annual median ammonia-N loadings during 1981-1991 exhibited, for the most part, a gradual increase in loadings to Simpson Creek (Figure 15). Differences between the median and 95th percentiles were apparent even in 1992; however reported values for both were less than 2.0 kg/day in 1993.

- Bioassay tests showed the following: acute toxicity was evident in a first day grab of the effluent, but no acute toxicity was evident in the second day grab in March 1990; acute toxicity to *Ceriodaphnia dubia* after a 48 hour exposure in April 1990; no acute toxicity was evident to fathead minnows, but 10% toxicity to *Ceriodaphnia dubia* in a day-1 effluent grab occurred after a 48 hour exposure in May 1990; and test results submitted by Warren Co. revealed only two of 12 test failures.

O'Bannon Creek - Clermont County O'Bannon Creek WWTP

- Constructed in 1984, the O'Bannon Creek WWTP is a secondary treatment plant consisting of two stage aeration, rapid sand filters, and chlorination. The collection system is separate with 80% of the service area sewered (population is 11,400) with moderate to high growth predicted. The WWTP discharge is to O'Bannon Creek with a plant design capacity of 1.200 MGD. Occasional bypasses and overflows have been reported. Inflow/infiltration is significant at the WWTP and a plan is being developed to address this problem. Plans include flow equalization and parallel aeration.

- Average annual conduit flow mostly increased during 1984-1990 ranging between 0.949 to 1.380 MGD. Flow volume decreased somewhat during 1991-1993 averaging 1.200 MGD. Design capacity was exceeded by average annual flows in six of nine years.

- Ammonia-N loadings (median and 95th percentiles) demonstrated significant deviations in 1984 and 1985 were nearly equal during 1986-1990 and significantly lower (Figure 15). Data for one or both percentiles was missing for the period 1991-1993.

- Bioassay results revealed no toxicity in November 1992 or March 1993.

Little Miami R. (via U.T.) - Hamilton County MSD Polk Run WWTP

- Constructed in 1970 with a major modification in 1988 (new plant), the Polk Run WWTP is an advanced secondary treatment plant consisting of secondary clarification and chlorination/dechlorination. The 1988 upgrade and expansion increased the design capacity from 1.0 to 6.0 MGD. The 6.0 MGD design capacity is expected to be reached within the next two years and another expansion is being planned to meet the rapid growth projected for the area. The collection system is separate with 50% of the service area sewered (population is unreported). The facility discharges to an unnamed tributary of the Little Miami River approximately 50 feet upstream from the mainstem. Industrial flow from one minor user (Donisi Glass) accounts for approximately 5% of the inflow. The plant has seven lift stations with reported bypasses at four pump stations (Glen Lake and Harper Ave., Bears Run, and Polk Run). A plant bypass (due mostly to infiltration/inflow resulting from a heavy rainfall) in May 1990 discharged approximately one million gallons of wastewater.

- Polk Run is extending its service lines to cover annexed areas in the Twenty Mile area. The Taylor Street sewer replacement is designed to alleviate the inflow/infiltration problems. The Director's Findings & Orders require the identification of all sanitary sewer overflows by June 22, 1993. An order to require elimination of sanitary sewer overflows is pending.

- The average annual conduit flow from 1989-1993 ranged from 2.810 to 4.100 MGD and did not exceed the design capacity.

- Bioassay tests showed the following: acute toxicity was evident to *Ceriodaphnia dubia* in all effluent samples in March 1993 - acute toxicity (100% mortality) persisted into the mixing zone; the effluent and mixing zone were acutely toxic in May 1993 - 10-20% mortality to *Ceriodaphnia dubia* in grabs and composite samples and 85% mortality occurred in the mixing zone.

Sycamore Creek - Hamilton County MSD Sycamore Creek WWTP

- Constructed in phases (1954, 1970) and upgraded in 1988 and 1991, the Sycamore Creek WWTP is a secondary treatment plant with rapid sand filters and chlorination. The construction of dechlorination facilities was scheduled for completion in August 1994. The collection system is separate with 70% of the service area sewered (population is 30,000). The plant has a design capacity of 6.0 MGD and discharges to Sycamore Creek near the mouth. Industrial contributions amount to only 1% of the inflow. There are three lift stations each with bypasses and one with an overflow. A Consent Order has been issued to address the sanitary sewer overflows, mercury exceedences, and the extension of service to unsewered areas.

- Average annual conduit flow during 1983-1993 varied from 5.530 to 7.510 MGD. Since 1984, the average annual flow has exceeded the design capacity of 6.0 MGD.

- Ammonia-N loadings (median values) increased during 1979-1989 from 95 to 175 kg/day and 95th percentile values followed a similar pattern (Figure 16). Loading reductions in 1989 and 1991 illustrates the improvement in effluent quality brought about by the 1988 and 1991 facility upgrades.

- BOD_5 loadings were also significantly reduced subsequent to the 1988 and 1991 plant upgrades.

- Total suspended solids loadings (median and 95th percentile values) fluctuated significantly during 1979-1990 indicating considerable variability in effluent quality. Similar to ammonia-N and BOD_5, total suspended solids loadings decreased markedly during 1991-1993 due to the plant upgrades.

- Bioassay tests showed the following: no acute toxicity was evident to *Ceriodaphnia dubia* except in the mixing zone (100% mortality) in March 1990; no acute toxicity was evident in April 1990;

no acute toxicity was evident in the effluent, but acute toxicity was observed in Sycamore Creek in April 1990; test results submitted by Hamilton Co. revealed four of seven test failures.

Little Miami River - Totes, Inc.

- Totes, Inc. manufactures latex boots utilizing various processes (i.e., latex dips, mold cleaning, mixing/curing and compounding). Production is on a 24 hour shift, five days/week, 52 weeks/year. Wastewater volume is approximated at 0.029 MGD and consists of non-contact cooling water, second-stage chlorination, wash treatment tank, and stormwater. The treatment processes consists of activated sludge, settling, sand filters, and chlorination.

East Fork Little Miami River - Batavia WWTP

- Constructed in 1955, the Batavia WWTP is a secondary treatment plant consisting of secondary settling, activated sludge, anaerobic digesters, and chlorination. The collection system is separate with three lift stations and no reported overflows or bypasses. The WWTP discharges to the East Fork Little Miami River with a design capacity of 0.24 MGD. The population served is 1,700 and stagnant growth is predicted. Industrial contributions are minor and include Cincinnati Chemical Processing (chemical manufacturer).

- Inflow/infiltration is a problem resulting in overflows during storm events and plant overloads. Problems also occur with the sludge digesters which periodically are inoperable.

- Average annual conduit flow during 1984-1987 increased (excepting 1986) from 0.193 to 1.680 MGD. Conduit flow increased incrementally during 1988-1992, but then declined to 0.332 MGD. Average flows during 1989-1993 (0.264-0.608 MGD) exceeded the design capacity of 0.24 MGD.

- Annual ammonia-N loadings (median values) during 1979-1988 varied, but remained below 10 kg/day (Figure 19). Annual nitrate-N loadings (median values) declined in 1980 and 1981, but increased steadily until 1991 and remained at the 1980 levels in 1992 and 1993.

- Annual total suspended solids loadings (median values) generally increased during 1982-1988. TSS loadings from 1989-1993, however, declined to levels below those observed over the previous 10 years. Significant departures between median and 95th percentile values occurred reflecting inconsistent treatment efficiency.

East Fork Little Miami River - Clermont County Middle East Fork Regional WWTP

- Constructed in 1973 and a major modification in 1981, the Middle East Fork Regional WWTP is a secondary treatment plant with secondary clarification, anaerobic digestion, and chlorination. A phase II upgrade (*i.e.*, new clarifiers) is also in progress (70% complete). The collection system is separate with 50% of the service area sewered. There are 11 lift stations with three bypasses and a moderate inflow/infiltration problem. The population served is 10,031 and the design capacity of the current upgrade is 7.0 MGD. Industries contribute 15% of the inflow with the most significant input from Ford Transmission followed by Sun Chemical, U.S. Precision Lens, and two poultry processors.

- Average annual conduit flows ranged from 1.730 to 2.100 MGD in 1983-1987, averaged 2.400 MGD from 1988-1992, and was 2.190 MGD in 1993. The reported flow data indicates the WWTP is operating well below design capacity.

- Ammonia-N loadings (median values) fluctuated during 1979-1993 with the highest loading years occurring during 1984-1986 (Figure 17). Differences between the median and 95th percentiles were considerable particularly from 1987-1993. Loadings were lowest during 1989-1992 and remained near 7.0 kg/day in 1993.

East Fork Little Miami River - Clermont County Lower East Fork WWTP

- Constructed in 1979 and upgrade in 1992 (RBC trains and flow equalization were added), the Lower East Fork WWTP is a tertiary treatment plant with rapid sand filters, secondary clarifiers, aerobic digestion, and chlorination. Disinfection by ultraviolet light is being evaluated as an alternative to chlorination. Occasional nuisance odors from the sludge holding and digestion tanks continue to be a problem and the use of ferric chloride is being investigated. The collection system is separate and contains 29 lift stations, 11 with bypasses (several are active) and five with overflows. A number of overflows impact the Shayler Creek subbasin, some of which is due to vandalism and debris which blocks flow within the collection system. The service area is 60% sewered and serves a population of 39,449 (population equivalent of 50,000). Rapid growth, however, is predicted for the area. The plant has a design capacity of 7.0 MGD, discharges to the East Fork Little Miami River, and receives and industrial input of 2.1 %.

- Infiltration/inflow is excessive and high flows to the plant are a problem. Some of this is a result of instream inceptor sewer alignments in which the harsh conditions result in structural failures and stream water enters the sewer.

- Average annual conduit flow decreased by more than one MGD (4.710-6.060 MGD) during 1983-1988, but increased during 1989-1991(average = 4.25 MGD). The annual average flow for the 10 year period were below the design capacity of 7.0 MGD.

- Annual ammonia-N loadings (median values) demonstrated a steady reduction from 1980 through 1985, but increased to the highest levels during 1986-1991. Loadings declined markedly, however, following the WWTP upgrade in 1992- 1993.

- Bioassay tests showed the following: only slight acute toxicity was evident to fathead minnows and no toxicity was evident for *Ceriodaphnia dubia* in February 1993 and acute toxicity was evident in the effluent in April 1993 with 100% mortality to *Ceriodaphnia dubia.*

East Fork Little Miami River - Milford WWTP

- Constructed in 1961 and upgraded in 1989 (new plant), the Milford WWTP is a secondary treatment plant consisting of two oxidation ditches, sludge press, sludge drying beds, post-aeration, and chlorination/dechlorination. The facility discharges to the East Fork Little Miami River and receives no industrial wastewater. The collection system contains two combined sewer overflows at Mill and Main Streets (outfall 002) and upstream U.S. Rt. 50 (outfall 003). Recent discharges for these two CSOs are listed in Table A-2c. The WWTP design capacity is 0.750 MGD. Administrative Orders (AO) were issued by U.S. EPA in 1987 requiring Milford to attain compliance with their NPDES permit.

- Average annual conduit flow increased by nearly 46% during 1983-1993 (0.472-0.687 MGD), but remained below the design capacity of 0.750 MGD.

- Annual BOD_5 loadings (median values) demonstrated variability during 1979-1987 with values ranging from 58 to 70 kg/day (Figure 18). Steady reductions in BOD_5/$CBOD_5$ values from 43 to 5.44 kg/day occurred during 1988-1993. Differences between median and 95th percentile values demonstrate variability in effluent quality and treatment efficiency.

- Annual ammonia-N loadings (median values) demonstrated variability during 1979-1987 with significant reductions in ammonia-N loadings occurring from 1988-1993. Loadings for 50th and 95th percentile varied mostly from 1984-1986 and 1989.

- Annual total suspended solids loadings (50th percentile) fluctuated considerably with no discernable trends from 1979-1988. Substantial reductions occurred during 1989-1993 (except in 1991). Differences between median and 95th percentile values demonstrate variability in effluent quality and treatment efficiency.

Conduit Flow (001 Outfall)

- The amount of treated, wastewater effluent discharged to the Little Miami River increased between 1983 and 1993 as the result of the upgraded larger capacity WWTPs. The cumulative total average annual flow (001 conduit outfall) for five (5) WWTPs increased 60% from 7.545 MGD in 1983 to 12.134 MGD in 1993 (Figure 20). Two of the five entities accounted for most of the increase (*i.e.*, increased flow from the Greene Co. Sugar Creek and Lebanon WWTPs were 1.83 and 2.479 MGD, respectively).

- During 1993, the total cumulative third quarter effluent flow to the watershed from 24 dischargers was 50.5 MGD with it divided relatively equally between the upper and lower halves of the watershed (Figure 21). From July 1 - September 30, 1993, nine (9) WWTPs discharged a total of 22.74 MGD to the upper half and 15 entities discharged 27.8 MGD of effluent to the lower watershed (Figures 22-23).

Ammonia-N Loadings

- The 1993 annual total average ammonia-N loading from 19 dischargers to the Little Miami River watershed was 183.75 kg/day (Figure 24). The largest contributor was the Greene County Sugar Creek WWTP (33.5%) followed by the Clermont County Middle East Fork WWTP (8.5%), Lebanon WWTP (7.8%), and Montgomery County Eastern Regional WWTP (7.5%). Due primarily to increased nitrification at the facilities during the warmer months, the total third quarter (July 1 - September 30, 1993) average ammonia-N loading decreased to 113.78 kg/day (Figure 25). The largest contributors during those months were the Greene County Sugar Creek WWTP (28.3%) and Montgomery County Eastern Regional WWTP (17.5%) followed by the Lebanon WWTP (9.1%), Cedarville WWTP (7.4%), and Clermont County Lower East Fork WWTP (6.9%).

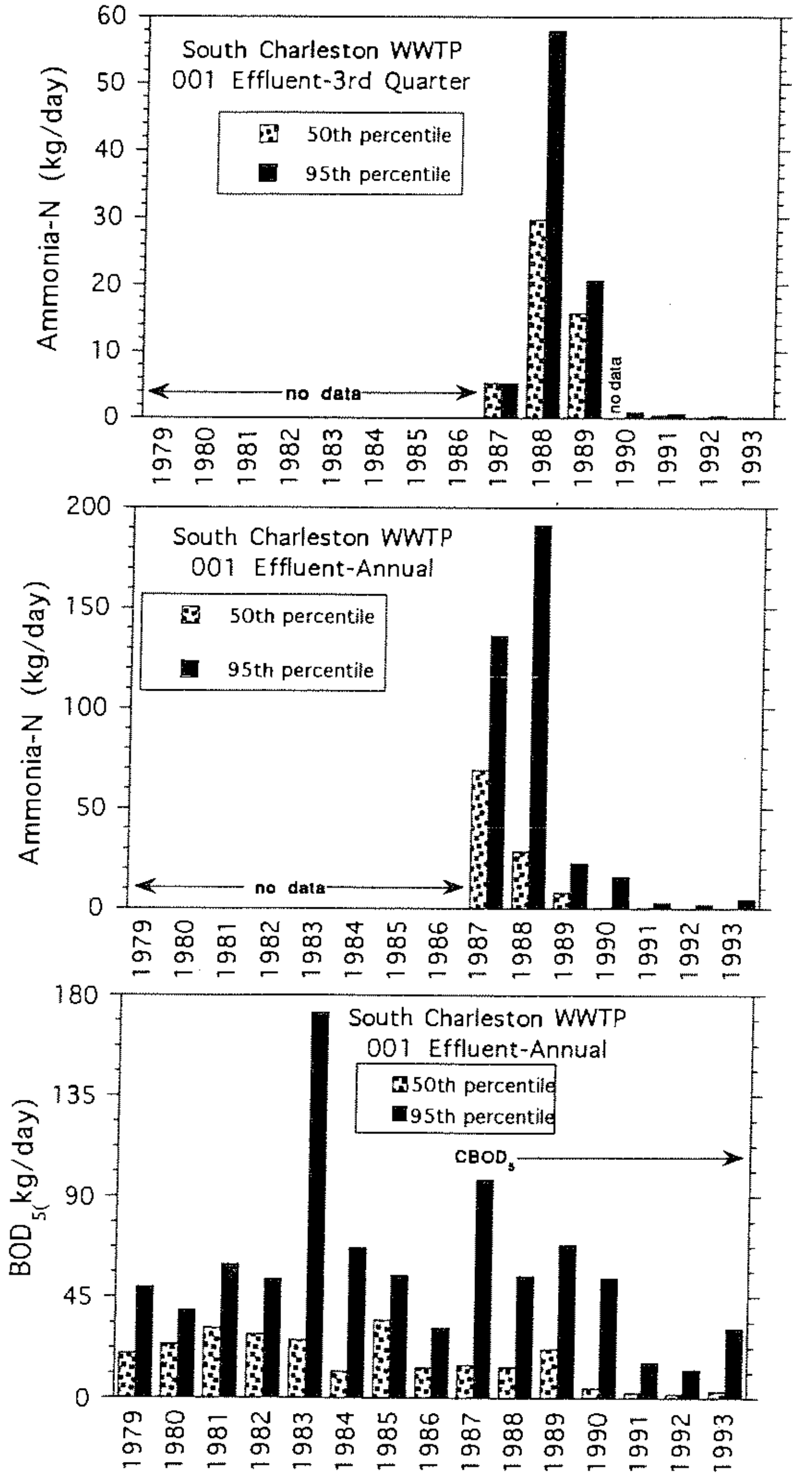


Figure 5. Median and 95th percentile loadings (kg/day) of ammonia-N (third quarter and annual) and BOD_5 (annual) from the South Charleston WWTP (001 outfall).

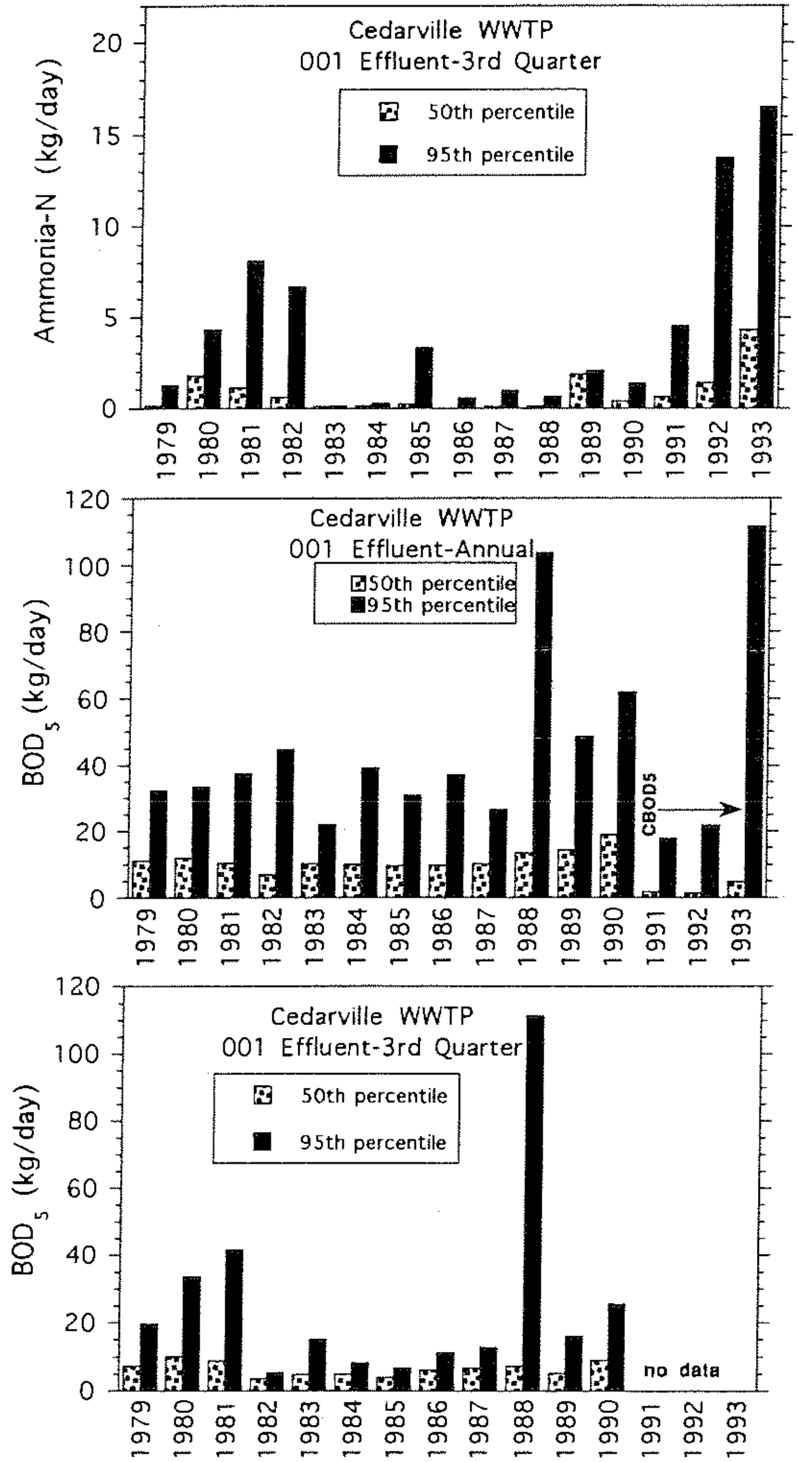


Figure 6. Median and 95th percentile annual loadings (kg/day) of ammonia-N (third quarter) and BOD_5 (third quarter and annual) from the Cedarville WWTP (001 outfall).

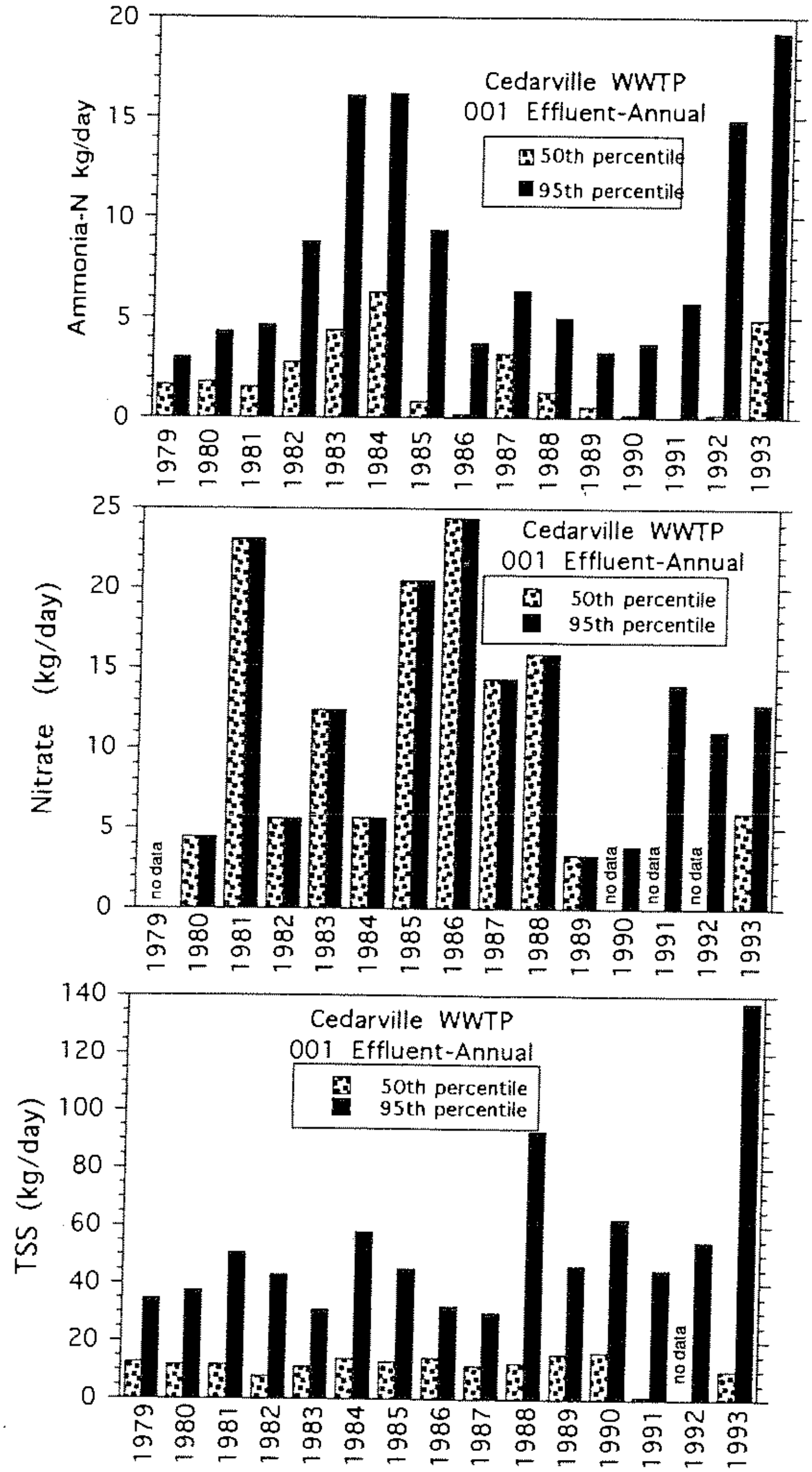


Figure 7. Median and 95th percentile annual loadings (kg/day) of ammonia-N, nitrate, and total suspended solids (TSS) from the Cedarville WWTP (001 outfall).

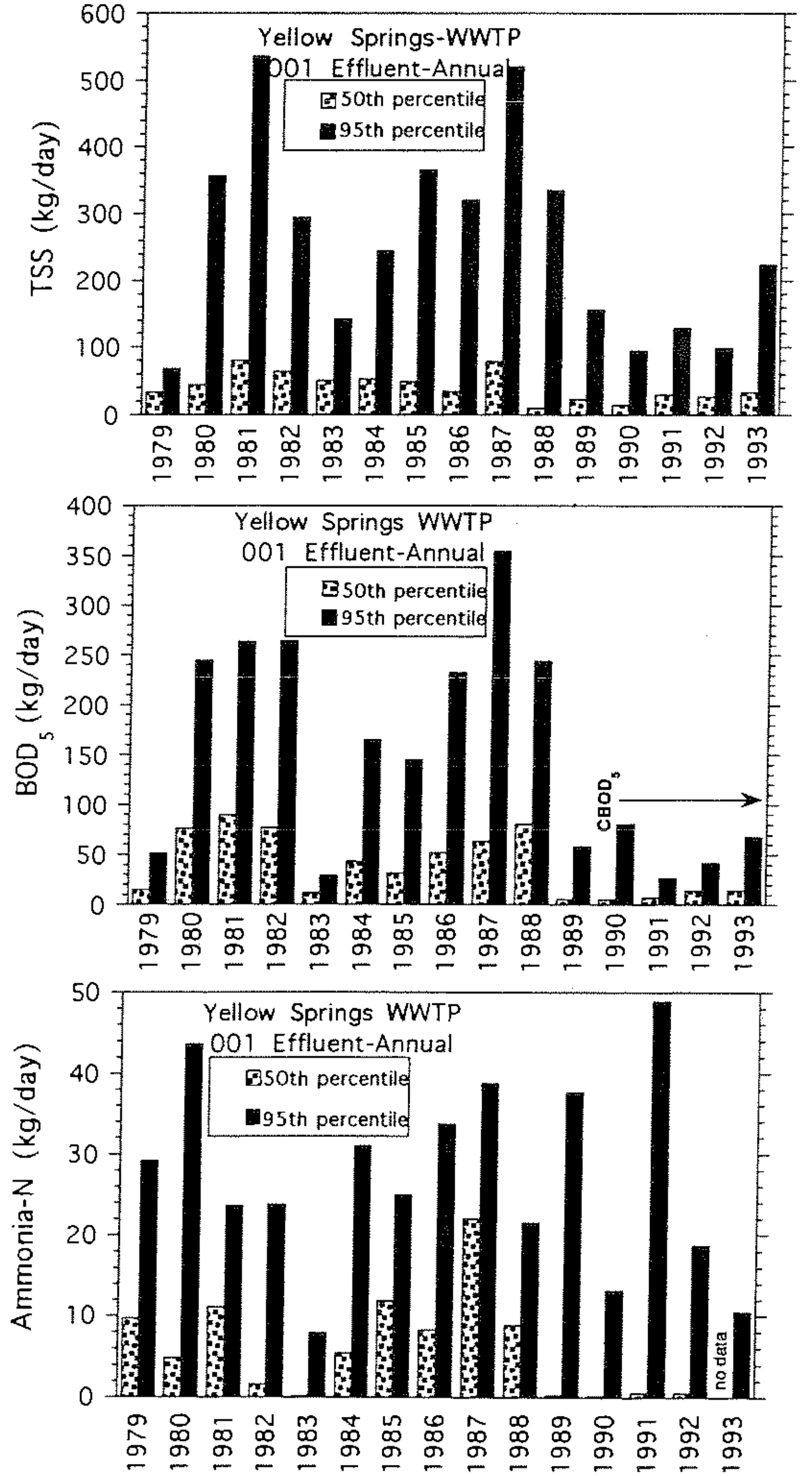


Figure 8. Median and 95th percentile annual loadings (kg/day) of total suspended solids (TSS), BOD_5, and ammonia-N from the Yellow Springs WWTP (001 outfall).

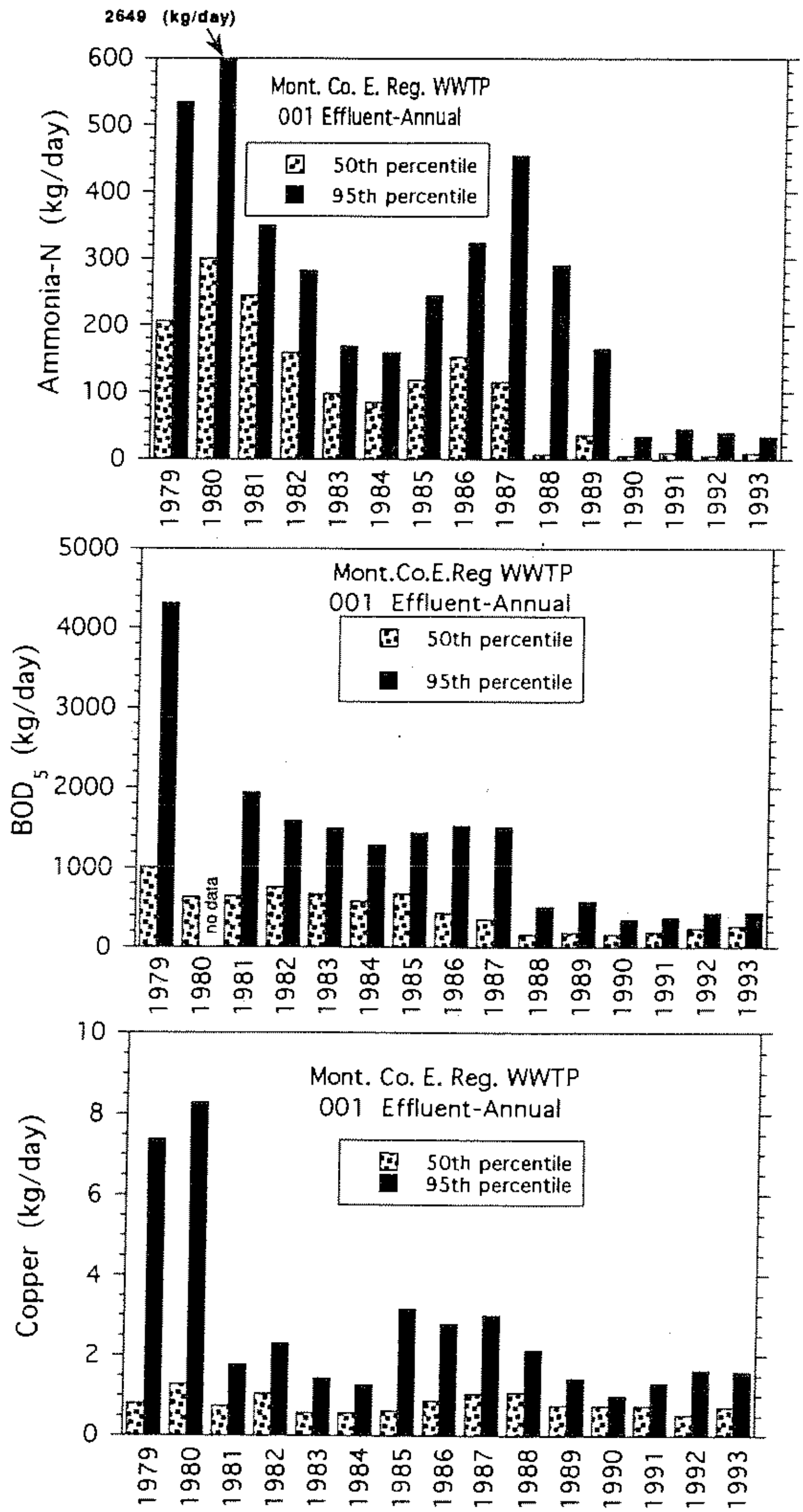


Figure 9. Median and 95th percentile annual loadings (kg/day) of ammonia-N, BOD_5, and copper from the Montgomery Co. E. Regional WWTP (001 outfall).

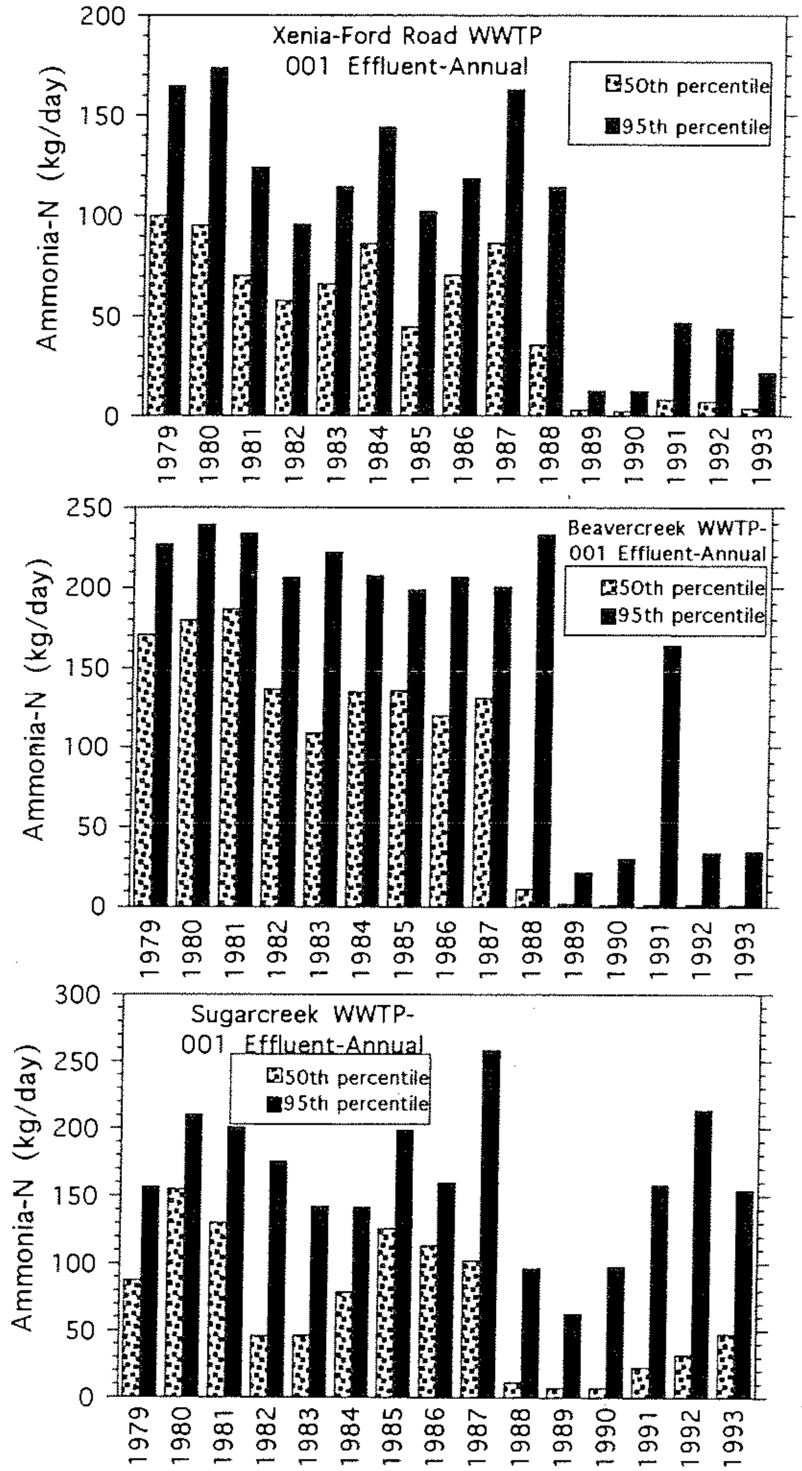


Figure 10. Median and 95th percentile annual loadings (kg/day) of ammonia-N from the Xenia-Ford Rd., Greene Co. Beaver Creek, and Greene Co. Sugar Creek WWTPs (001 outfall).

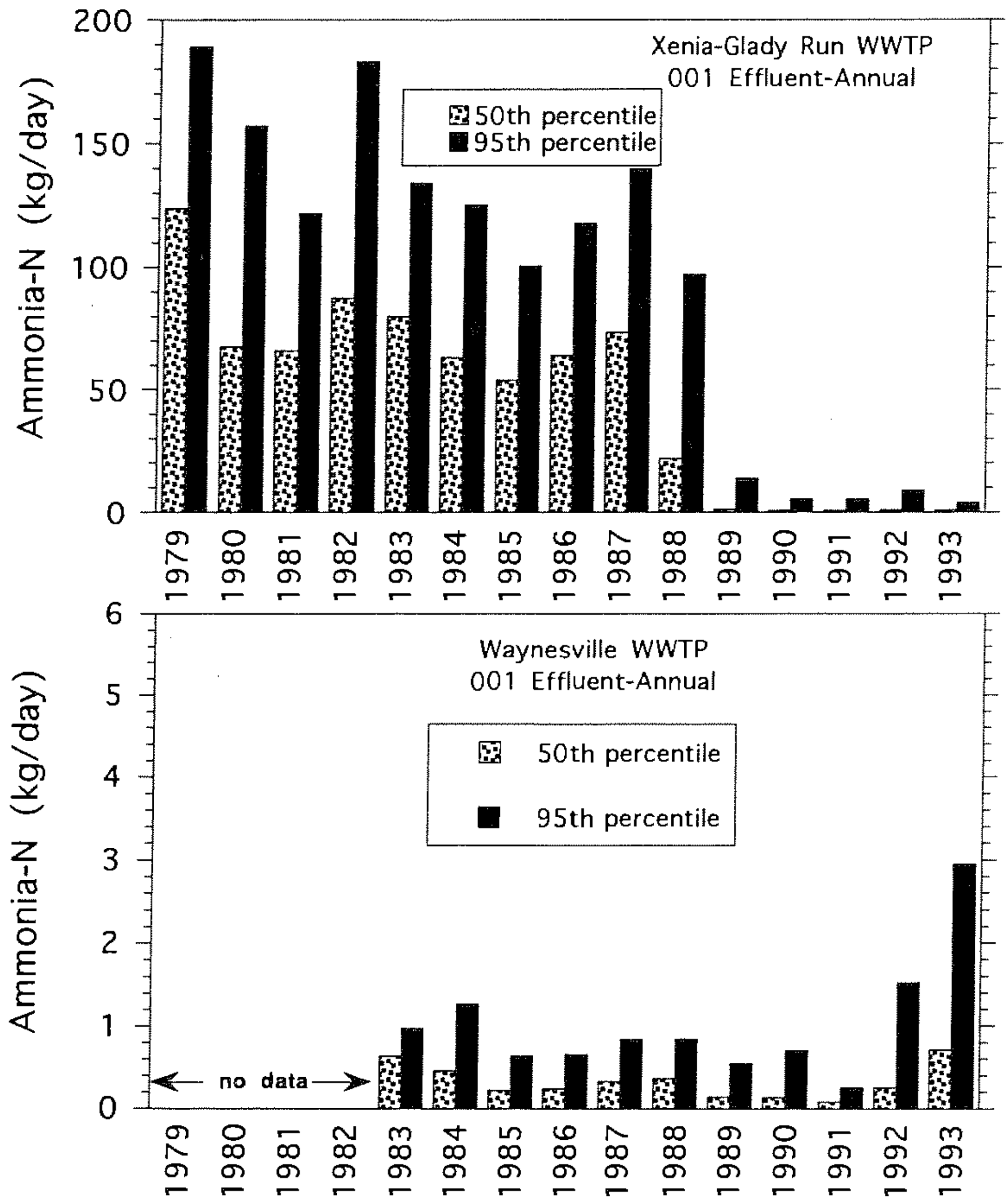
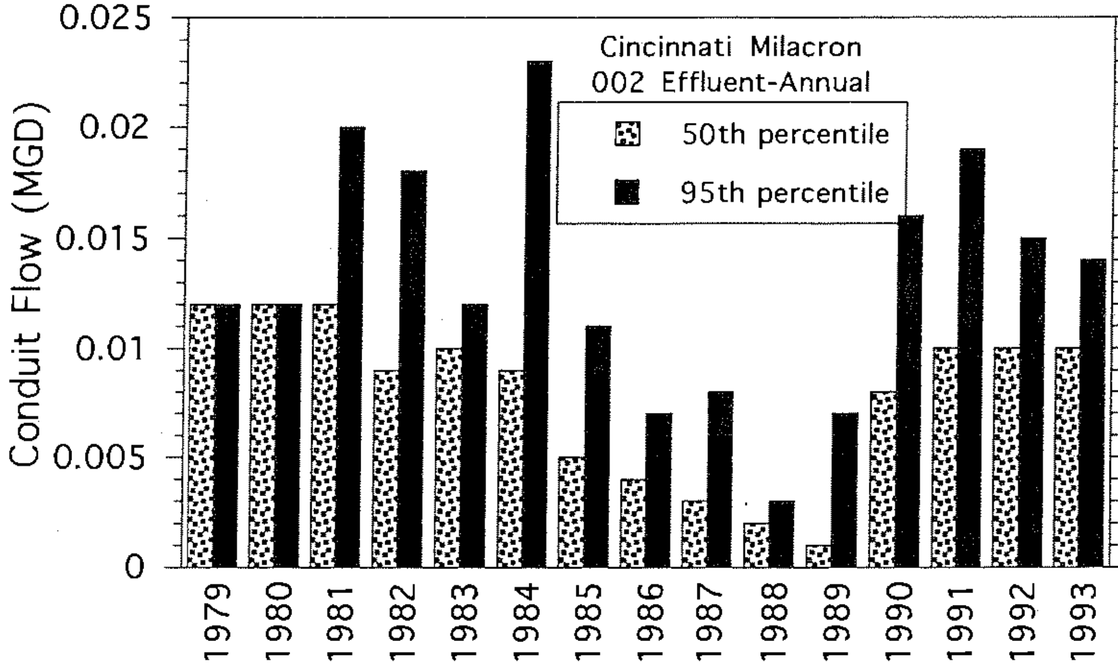


Figure 11. Median and 95th percentile annual loadings (kg/day) of ammonia-N from the Xenia-Glady Run and Waynesville WWTPs (001 outfall).



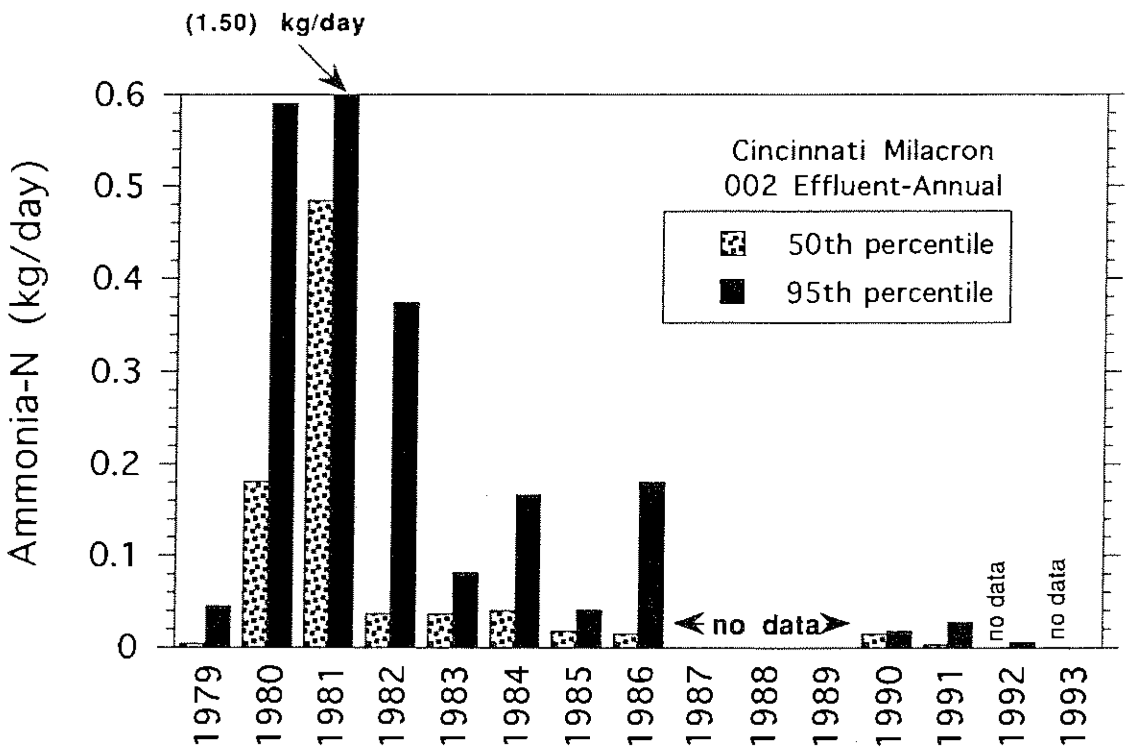


Figure 12. Median and 95th percentile annual loadings of flow (MGD) and ammonia-N (kg/day) from Cincinnati Milacron (002 outfall).

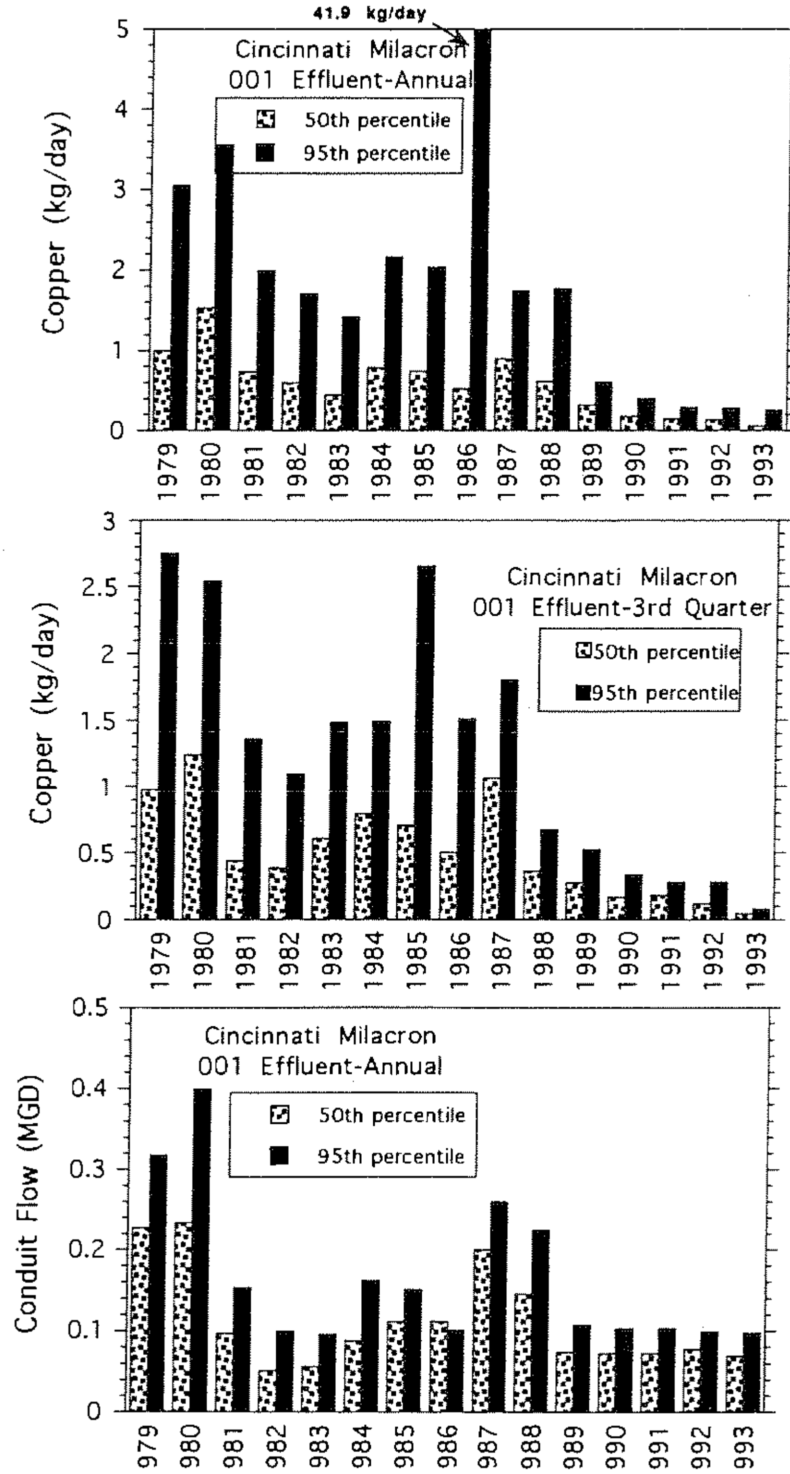


Figure 13. Median and 95th percentile annual loadings of total copper (kg/day, annual and third quarter) and conduit flow (MGD) for Cincinnati Milacron (outfall 001).

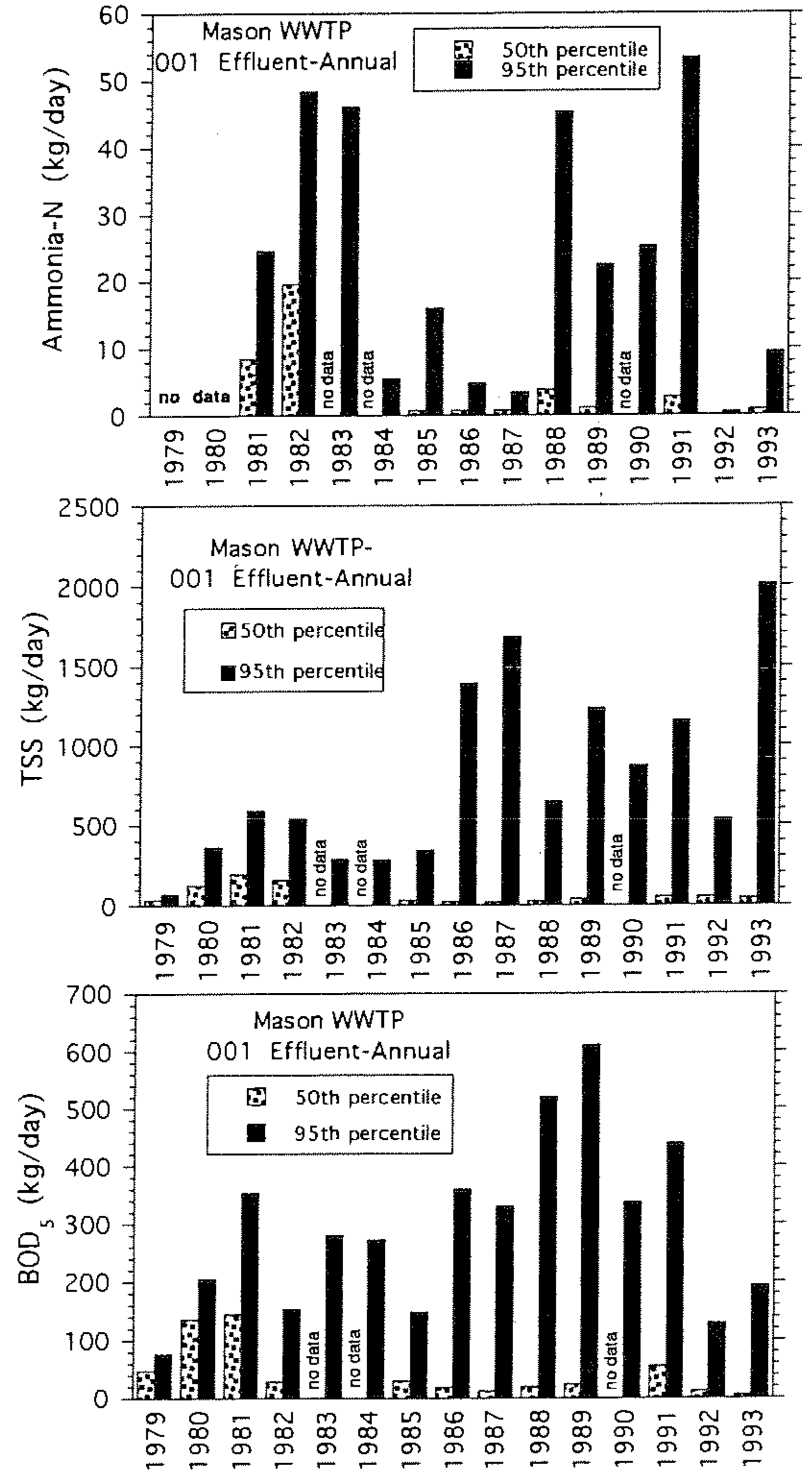


Figure 14. Median and 95th percentile annual loadings (kg/day) of ammonia-N, total suspended solids (TSS), and BOD_5 from the Mason WWTP (outfall 001).

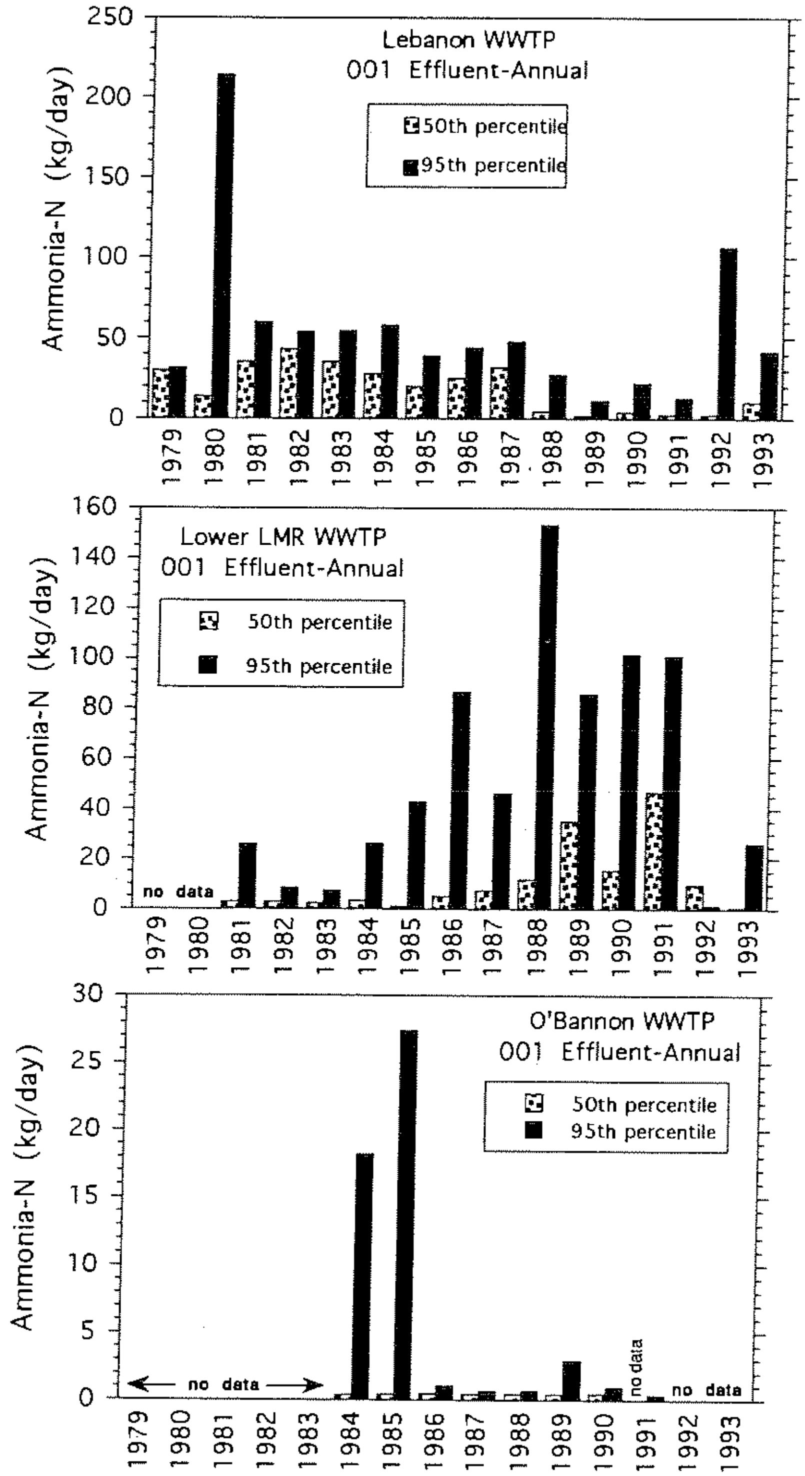


Figure 15. Median and 95th percentile annual loadings (kg/day) of ammonia-N from the Lebanon, Warren Co. Lower LMR, and O'Bannon WWTPs (001 outfall).

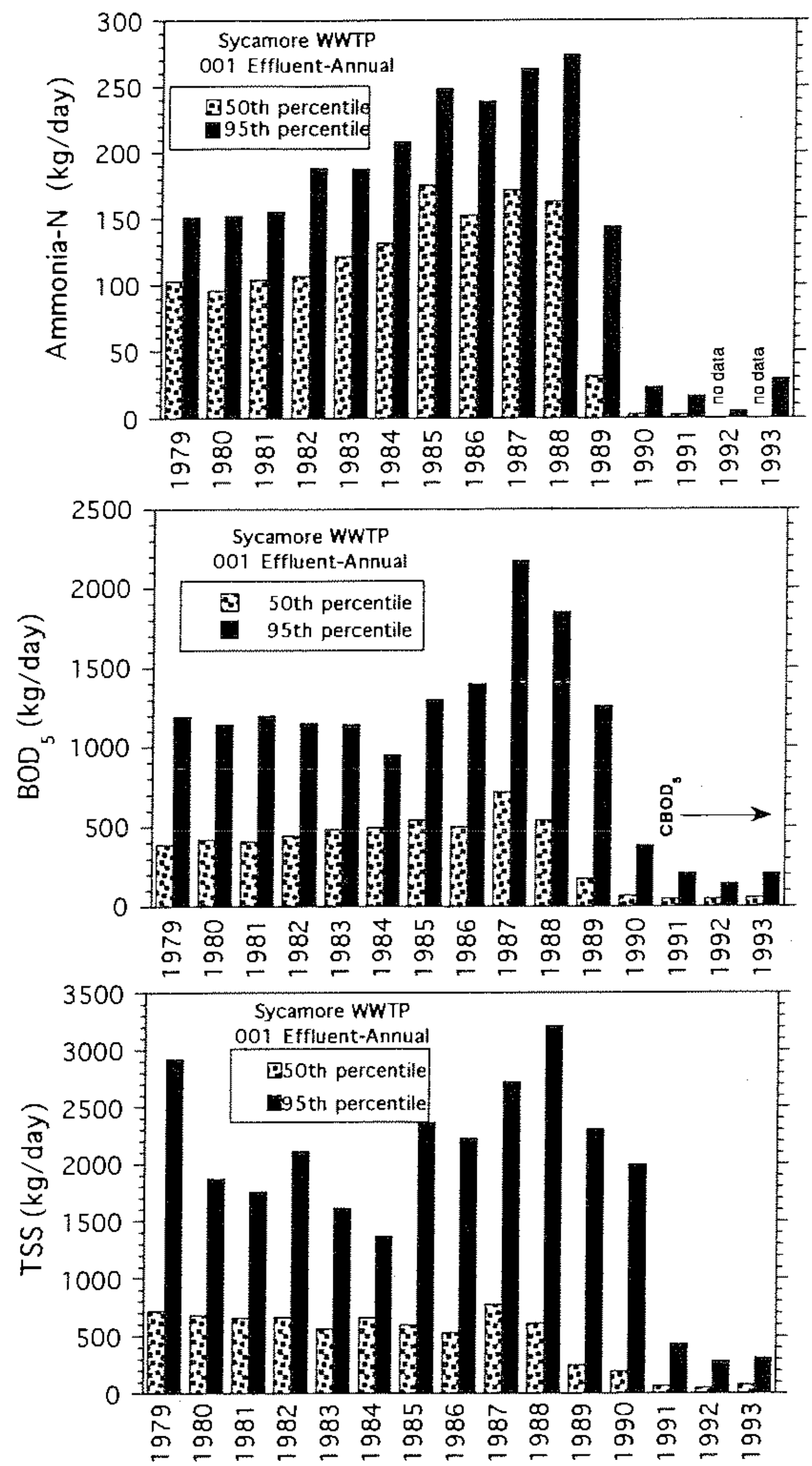
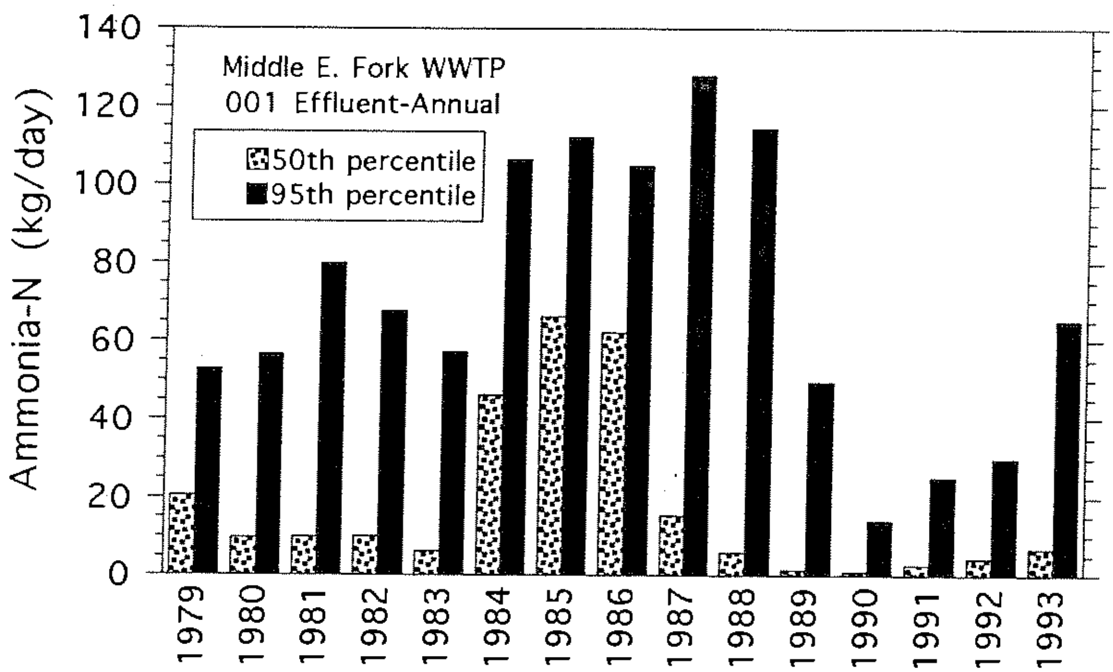


Figure 16. Median and 95th percentile annual loadings (kg/day) of ammonia-N, BOD_5, and total suspended solids (TSS) from the Sycamore Creek WWTP (001 outfall).



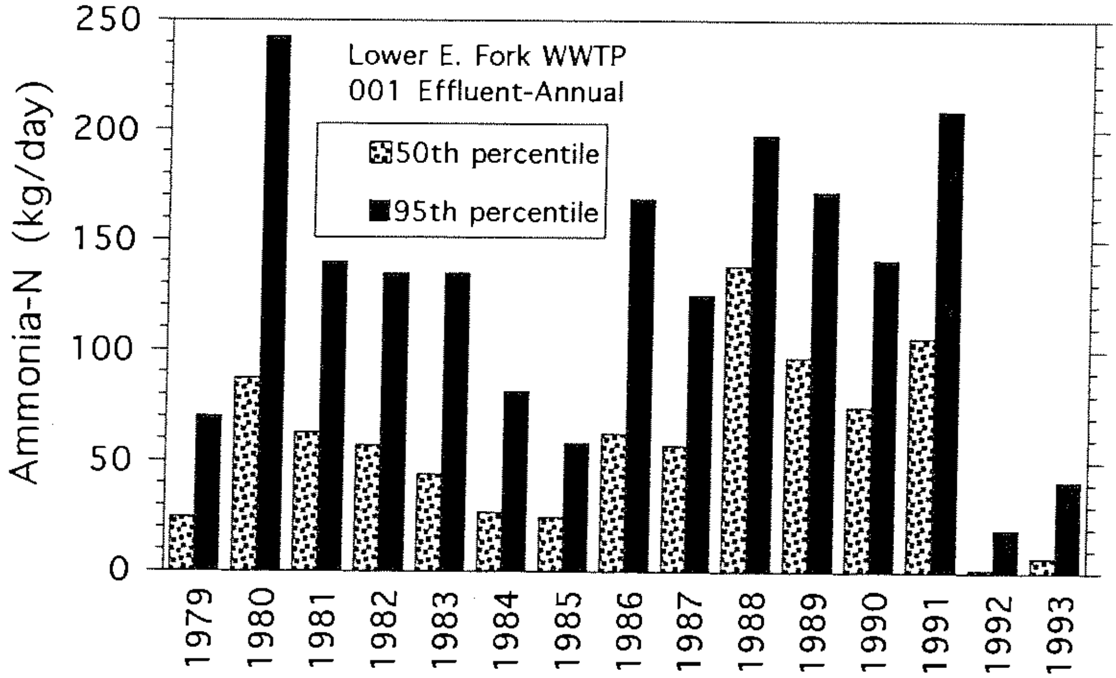


Figure 17. Median and 95th percentile annual loadings (kg/day) of ammonia-N from the Clermont Co. Middle and Lower East Fork WWTPs (001 outfall).

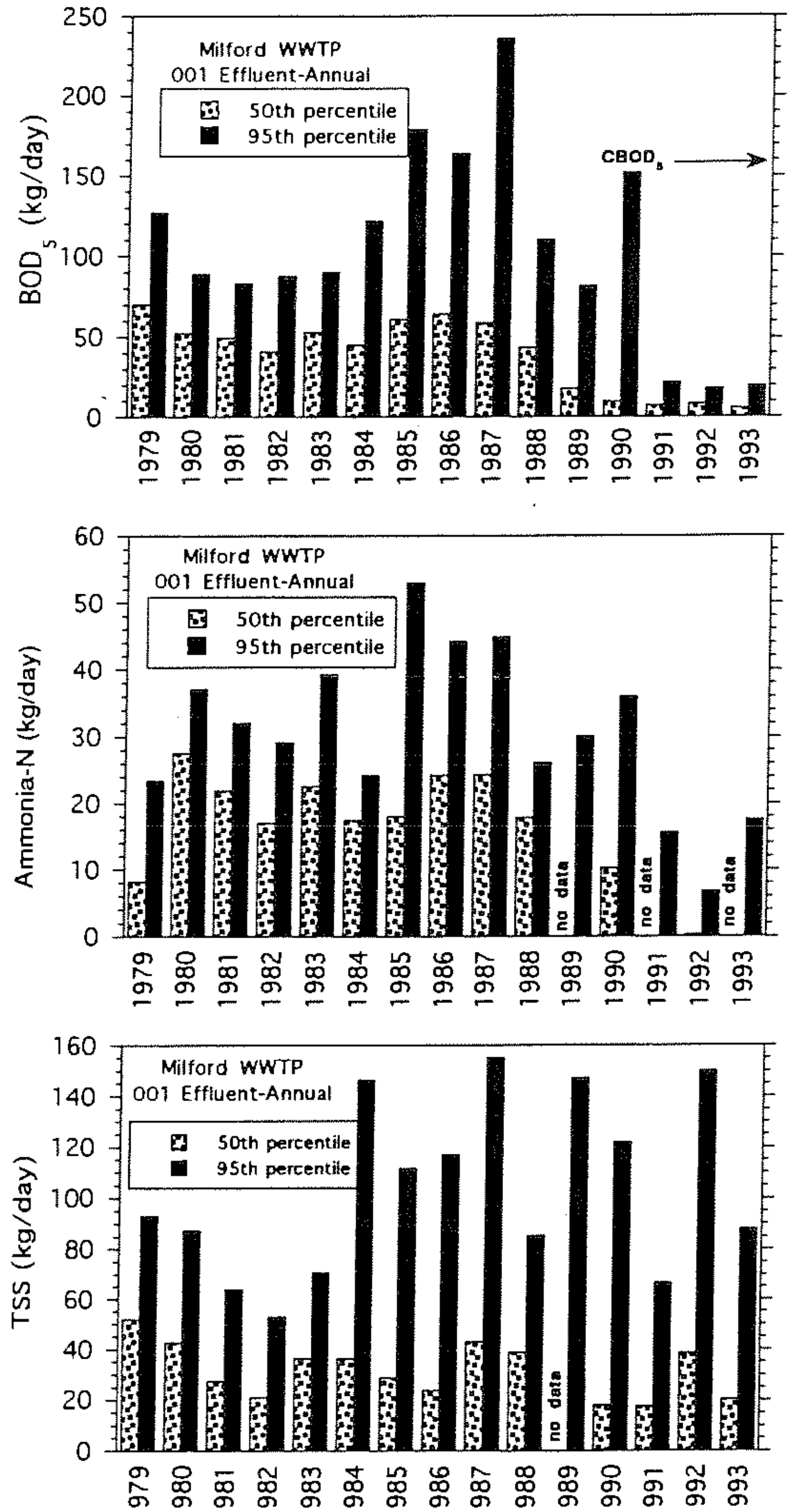


Figure 18. Median and 95th percentile annual loadings (kg/day) of BOD_5, ammonia-N, and total suspended solids (TSS) from the Milford WWTP (001 outfall).

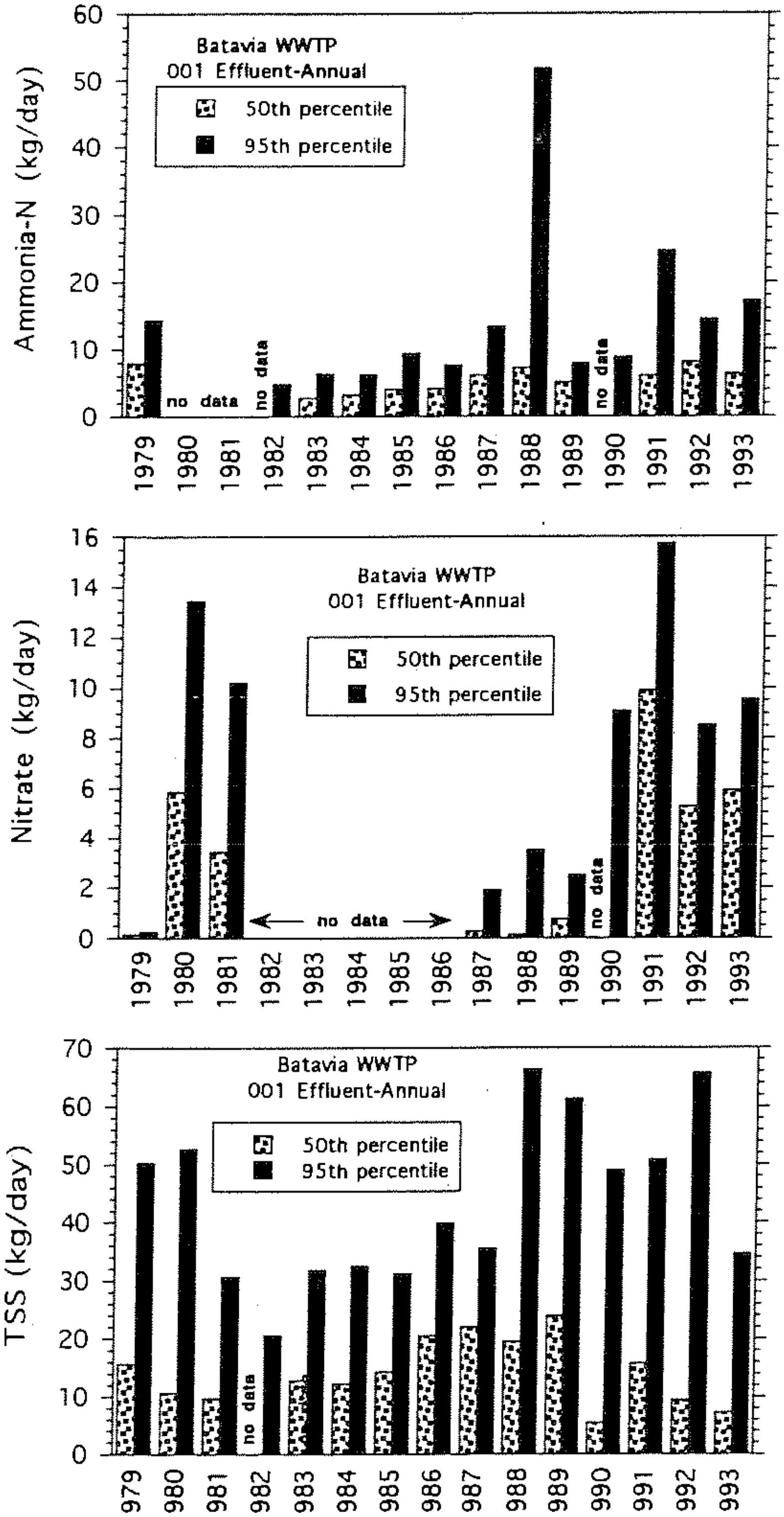


Figure 19. Median and 95th percentile annual loadings (kg/day) of ammonia-N, nitrate, and total suspended solids (TSS) from the Batavia WWTP (001 outfall).

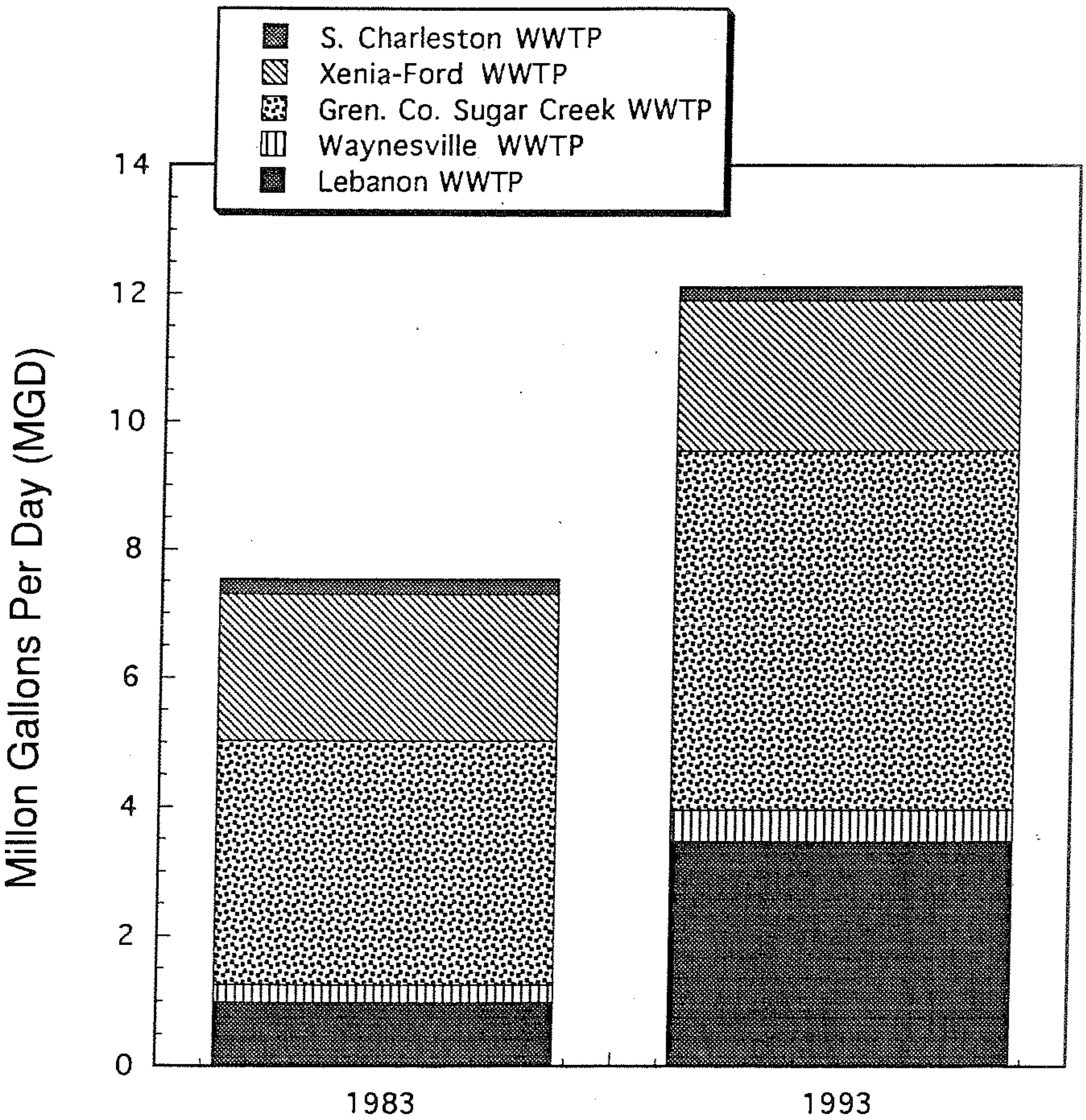


Figure 20. Stacked bar graphs comparing the 1983 and 1993 total cumulative average annual effluent flow (MGD, 001 outfall) from 5 dischargers located in the Little Miami River watershed. The total cumulative volume from the 5 WWTPs increased from 7.545 MGD in 1983 to 12.134 MGD in 1993.

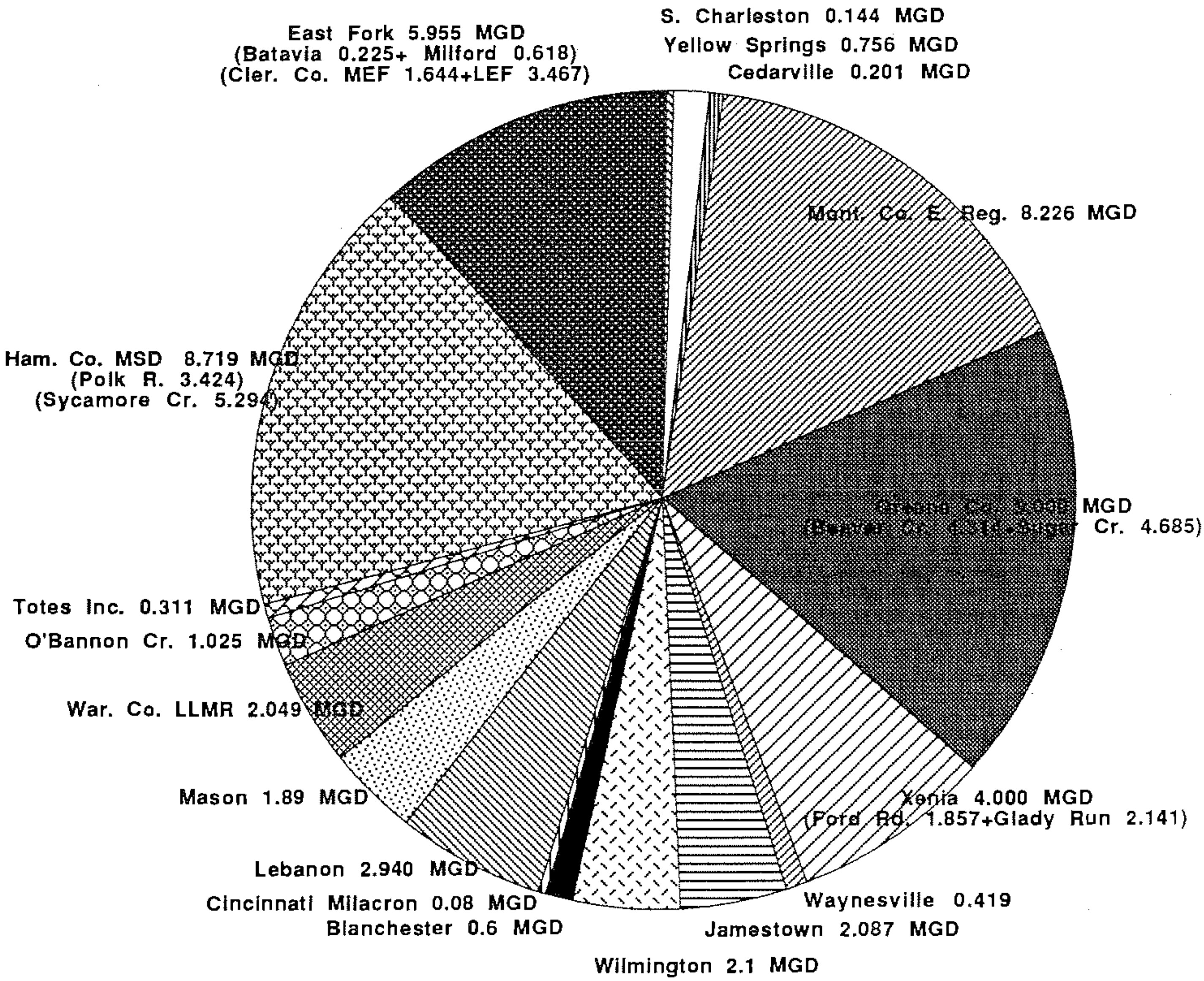


Figure 21. Pie graph of the total average third quarter 1993 conduit flow (MGD, 001 outfall) from 24 dischargers located throughout the Little Miami River watershed. The total cumulative volume is 50.5 MGD.

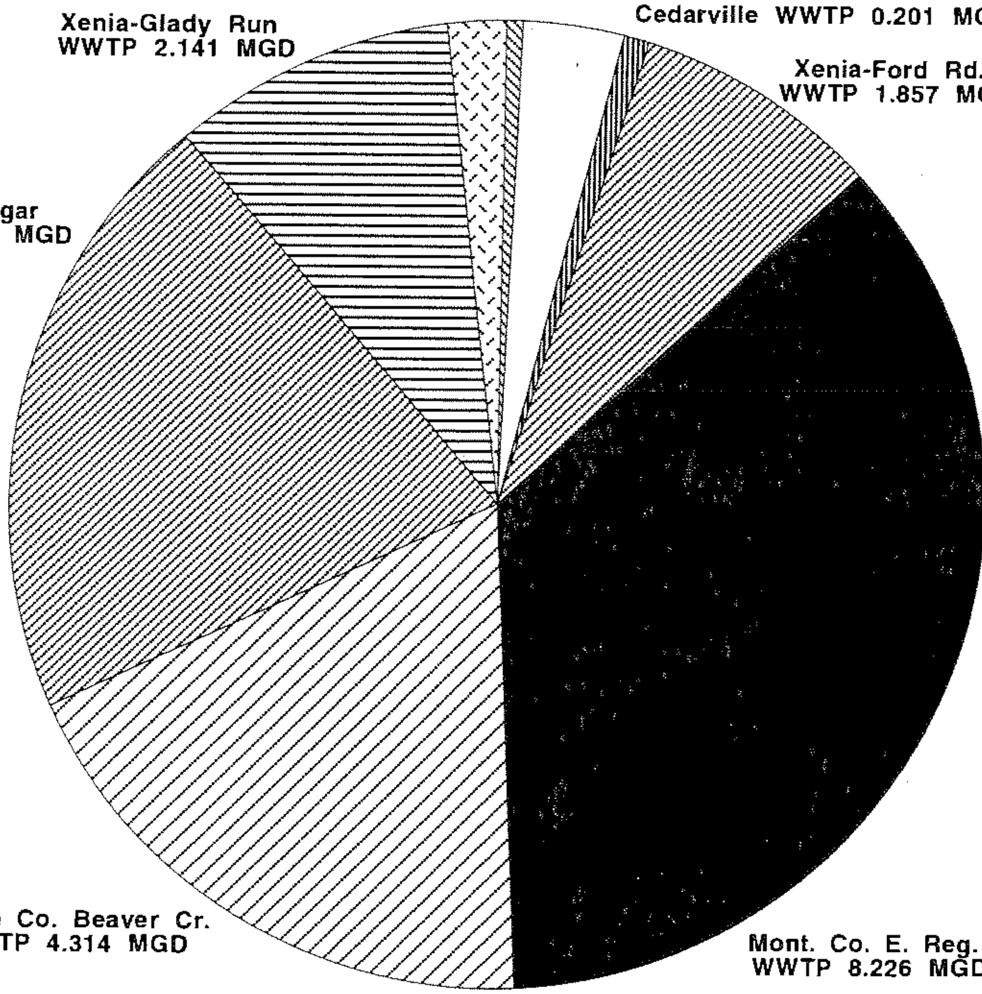


Figure 22. Pie graph of the total average third quarter 1993 conduit flow (MGD, 001 outfall) from 9 dischargers located in the upper half of the Little Miami River watershed. The total cumulative volume is 22.74 MGD.

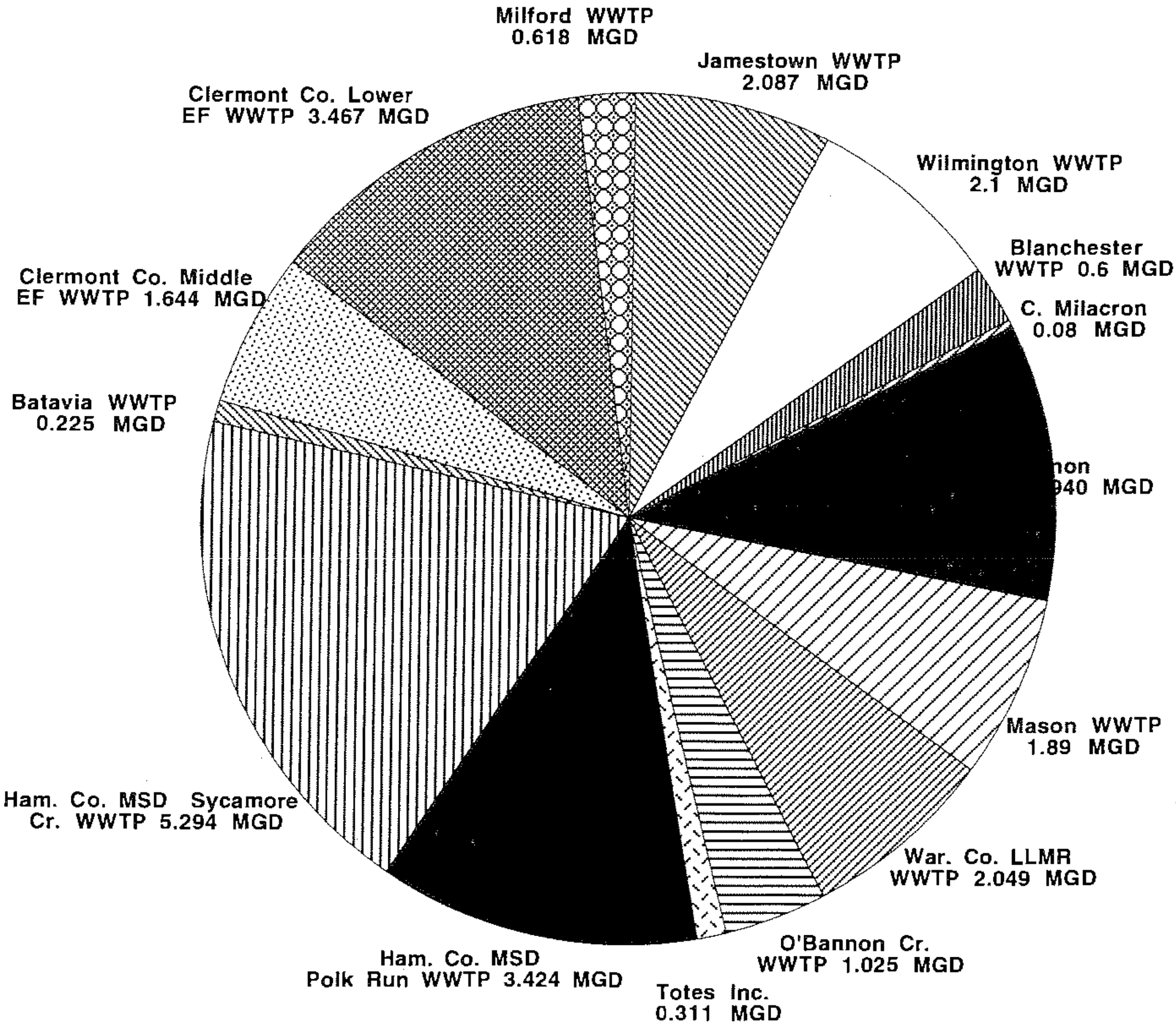


Figure 23. Pie graph of the total average third quarter 1993 conduit flow (MGD, 001 outfall) from 15 dischargers located in the lower half of the Little Miami River watershed. The total cumulative volume is 27.8 MGD.

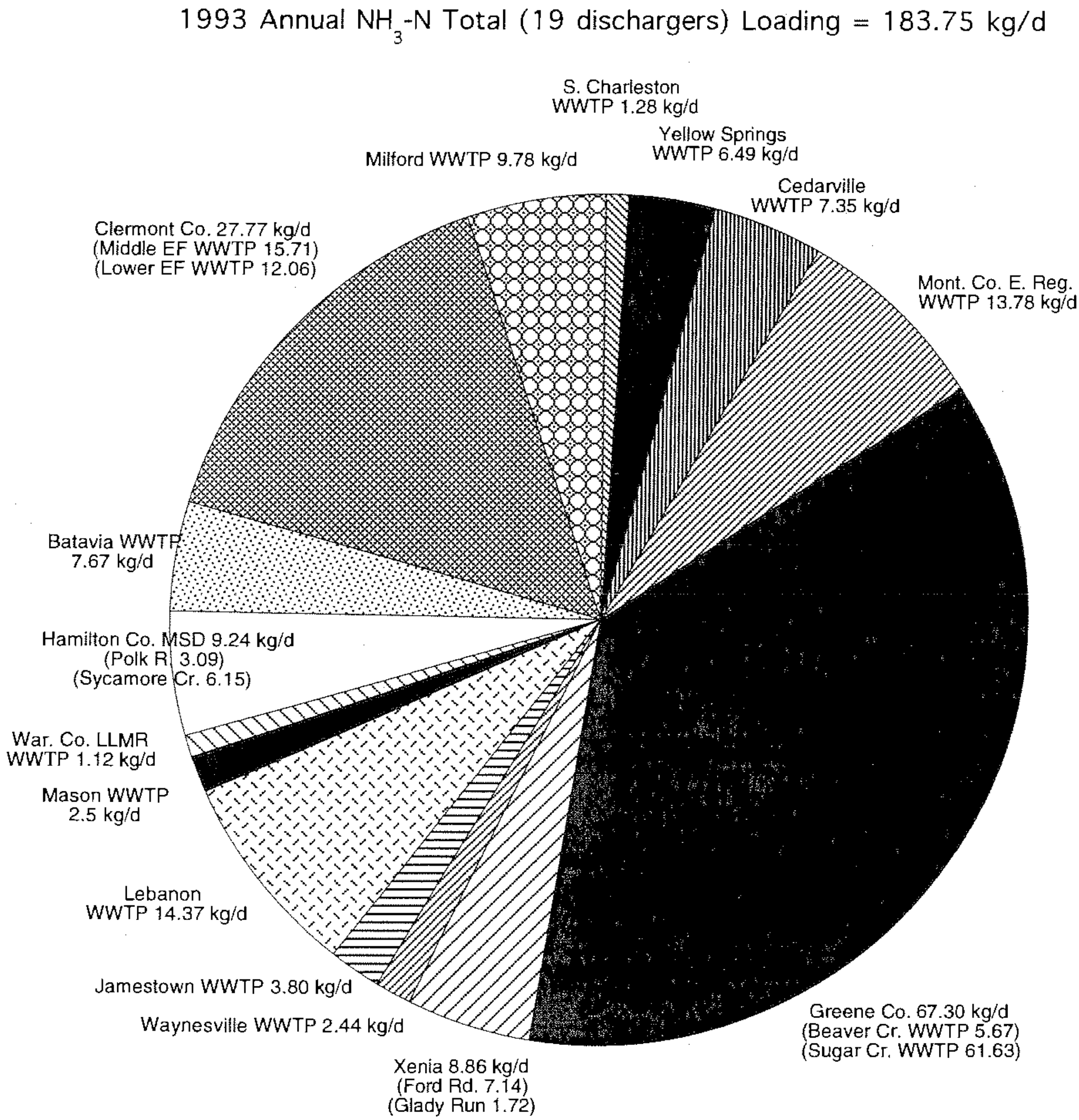


Figure 24. Pie graph of the total average annual 1993 ammonia-N (kg/day) loadings (001 outfall) for 19 dischargers within the Little Miami River watershed.

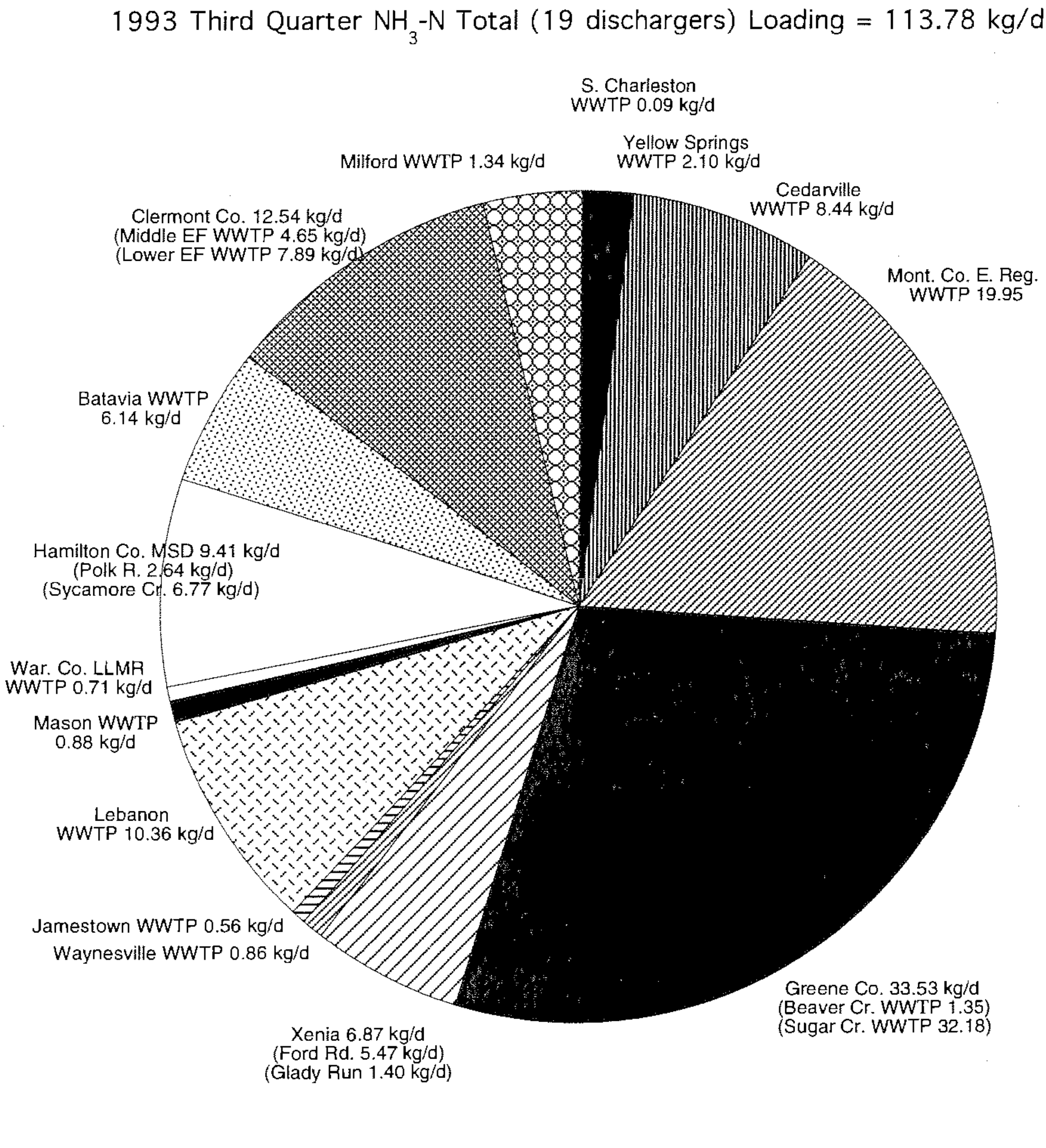


Figure 25. Pie graph of the total average third quarter (1993) ammonia-N (kg/day) loadings (001 outfall) for 19 dischargers within the Little Miami River watershed.

Spills, Overflows, and Unauthorized Releases

- Pollutant discharges from spills, overflows, permit violations, and other unauthorized releases are a significant source of lethal and sublethal stresses for aquatic communities in the Little Miami River watershed. Approximately 1500 incidents have been recorded by the Ohio EPA Emergency Response Section during the 10 year period between from 1983 to 1993. During the 10 year period, 241 of the most significant events (*i.e.*, releases greater than 100 gallons or could have exhibited an acutely toxic impact to surface water) cumulatively released more than 78,393,659 gallons and 48,326 pounds of pollutants (Appendix Table A-1).

- Sewage releases through unauthorized bypasses, SSOs, and CSOs events, was the leading spill pollutant discharged to the Little Miami River by volume (76,916,405 gallons = 98.1%) and frequency (127 events = 53%). The largest source of sewage spills was the Clermont County Sewer Department which had 86 spills (36%) of the significant releases. Fifteen (15) of the 86 spills released more than 1,000,000 gallons and 55 spills exceeded 100,000 gallons. The Hamilton County Metropolitan Sewer District (MSD) had the next highest rate of release with 14 discharges to the Little Miami River. Eight of the events were in excess of 1,000,000 gallons. Since 1989, the total quantity of sewage released to the watershed has declined and both Clermont and Hamilton Counties have shown marked improvement in attempting to comply with the Clean Water Act. Also point source related, the second highest spill type was industrial and other types of wastewater which discharged 1,268,620 gallons (1.6%) and 47,876 pounds (99.1%) of pollutants.

- Agricultural related spills (*i.e.*, fertilizer, pesticides, herbicides and manure) accounted for 9% (21 events) of the most significant spills. By volume, fertilizer and other agricultural products/chemicals accounted for more than 122,730 gallons and 450 pounds of pollutants.

- Petroleum related spills released 45,040 gallons and accounted for 22% (52 events) of the most significant spills. Diesel fuel was the most common petroleum contaminant spilled. Airborne Express in Clinton County had 16 spill events recorded, but only 6 listed a quantity, all of which were recorded as significant. The other spill reports failed to report any quantities. Jet Fuel "A" , urea, and monomethyl diethyleneglycol were the primary spill contaminants released by Airborn Express and detected in Cowan and Lytle creeks.

- Chemical spills released 40,864 gallons (< 0.1%) of pollutants and accounted for 13% (32 events) of the significant spills during the 10 year period. The General Motors Delco plant in Montgomery County had 29 spill events recorded during this time frame, unfortunately no volume of discharge was given to many of the spills. Therefore, the true volume and associated impacts are under-estimated. Elevated concentrations of hexavalent chromium is a characteristic water quality violation from the G.M.-Delco facility. Pre-treatment violations for hexavalent chromium and zinc are also common in wastewater discharged from the G.M.-Delco plant to the Montgomery County Eastern Regional WWTP.

- The Ohio Attorney General issued the Montgomery County Eastern Regional WWTP (which discharges to Little Beaver Creek) an eighteen count complaint for injunctive relief and civil penalties for violations of water quality (Chapter 6111 of the Ohio Revised Code). The case was settled in April 1992 with Montgomery County agreeing to pay $50,000 in Civil penalties.

Sanitary Sewer Overflows (SSOs)

- The Little Miami River watershed also receives periodic discharges of untreated sewage and other pollutants through SSOs within the Hamilton County Metropolitan Sewer District's Sycamore Creek and Polk Run WWTP systems (Plate 13). The Hamilton Co. MSD has recently installed new sewer lines with sealed lids within the Sycamore Creek basin to reduce the number of overflows. Sanitary Sewer Overflows (SSO) also enter the mainstem via the Beechmont interceptor gate. When the Ohio River reaches 42 feet the interceptor gate must be closed to prevent flooding of the sewer system. Sewage then backs up in the lines north of Beechmont Avenue and discharges through CSO's and the SSO's within the Little Miami River. The periodic discharge of raw sewage and other pollutants to the mainstem and tributaries contribute to the Partial and NON attainment recorded in the Little Miami River within Hamilton and Clermont Counties.

Combined Sewer Overflows (CSOs)

- In addition to SSO discharges, the lower 13 miles of the Little Miami River also receives periodic discharges of untreated wastewater from 55 identified Combined Sewer Overflows (CSO) within southern Hamilton and Clermont Counties (Plate 13). The two most upstream CSOs are located in the City of Milford and 53 structures are located within the Hamilton County Metropolitan Sewer District (MSD) (Appendix Tables 2a-c). Five of the CSOs discharge directly to the mainstem, 48 structures are located within the Duck Creek basin, and two discharge to Clough Creek. The periodic discharge of raw sewage and other pollutants to the mainstem and tributaries through these CSOs also contribute to the Partial and **NON** attainment recorded downstream from Milford.

- Milford's two CSO structures are located near the US 50 bridge and discharge intermittently through a 27" pipe at RM 13.0 (CSO #002) and a 54" pipe at RM 13.1 (CSO #003). Monitoring data collected during the last three years reveals the CSOs discharged more frequently (59 events) and a larger total volume (90.3 million gallons [MG]) in 1990 due to the high amounts of rain. Both structures, however, discharged considerably lower amounts during the subsequent years with more normal rainfall amounts (14.8 MG, 16 events in 1992 and 16.7 MG through 18 events in 1993). Throughout the three year period, the structures discharged a cumulative total of 121.8 MG during 93 events.

- Within the Hamilton Co. MSD, 13 of the 53 CSOs have been recently monitored (Appendix Tables 2a-b) as part of a 12 month study. Data collected from the 13 structures during October 1993 through February 1994 show they discharged 295 times and released more than 232.2 MG (cumulative total). The data also shows that 70% (170.6 MG) of the total discharge came from one structure (CSO #549) located at Williams Road and Duck Creek. Rainfall events greater than .08" have been shown to be the threshold of CSO occurrences. CSO # 656 is also suspected to be a major contributor to the total flow due to its position next to a major trunk sewer.

Wild Animal Kills

- Pollution discharges from spills frequently result in toxic impacts to fish and other aquatic life. Water Pollution, Fish Kill, and Stream Litter Investigations Reports (ODNR 1983 - 1990, Division of Wildlife unpublished data) from the same 11 year period (1983 through 1993) lists 49 incidents within the Little Miami River watershed that killed a total of 58,590 wild animals. The leading cause was agricultural related activities (primarily manure runoff from animal husbandry operations and fertilizer spills) which accounted for 37.3% of the total kill followed by chemical/industrial sources (primarily petroleum products and chemicals; 26.7%), public services (primarily municipal sewage; 21.7%), and unknown causes (14.3%). By county, the highest number of incidents occurred in Greene (13), Clinton (12), and Clermont (11) followed by Montgomery (4), Warren (4), Clark (2), and Hamilton (2).

- All but three of kills occurred in tributaries as opposed to the mainstem. Sub-basins (tributaries and their tributaries) with the highest number of kill incidents were: Todds Fork basin (12) in Clinton Co.; East Fork basin (8) in Clermont Co.; Shawnee Creek basin (6) in Greene Co.; Caesar Creek basin (6) in Greene Co. and Clinton Co.; and the Little Beaver Creek basin (3) in Greene Co.and Montgomery Co. Single kills in the Little Miami River were reported for in Clark, Warren, and Clermont counties.

Fluvial Sediment

- Fluvial sediment, a widely recognized pollutant, is sediment that is suspended in, transported, or deposited by water (Hindall 1989). Fluvial sediment data from the Little Miami River at Milford between 1977 and 1986 shows a mean annual suspended sediment discharge of 474,000 tons. Per square mile of watershed, the Little Miami River had the third highest rate (394 tons/year/square mile) of the 10 streams reported with daily data between 1977 and 1986 (Hindall 1989). It had the highest rate for the four large rivers within the Ohio River basin. Major sources includes soil erosion from new sediment from agricultural fields and construction sites, but can also include re-suspension and downstream export of existing deposits within the main channel. Severely eroding banks can also contribute significant amounts, especially during extended periods of high flow (Plate 12 and 14).

Chemical Water Quality (Plates 6,10-13; Figs. 26-66, Tables 5-6,A4-A6)

Little Miami River

- Flows in the Little Miami River from May through September 1993 remained above the $Q_7 10$ values, but exhibited general declining trends (with the exception of several rain events) in both the upper and lower halves (Figures 26-27).

- The minimum day time dissolved oxygen (D.O.) concentrations (grab samples) in the Little Miami River remained above 6.0 mg/l (EWH minimum water quality criterion) at most locations, but was measured below the standard upstream from Clifton (RM 101.30 - 89.12), and downstream from the Lebanon WWTP (Figure 28a, Table 6). The lower levels appear to be caused by excessive fecal contamination, possibly from a commercial manure/composting operation's stormwater runoff. Minimum values increased slightly downstream from Gilroy Ditch (S. Charleston WWTP), but remained below 6.0 mg/l. Channelization, uncontrolled livestock access, and secondary effects of these activities (i.e., low flows) are the principal sources associated with the lower than expected concentrations.

- Datasonde continuous monitors also recorded D.O. levels below 6.0 mg/l in the mainstem during August 31-September 2, 1993 in a 2.5 mile segment (RM 26.65-29.20) extending downstream from Muddy Creek to downstream from Simpson Creek (Figure 28b, Table A-6). The majority of the below standard oxygen values were recorded at night when respiration exceeds photosynthesis. Excessive nutrient loadings from the Lebanon, Mason, and Warren Co. Lower Little Miami River WWTPs may be contributing to the D.O. exceedences.

- An exceptionally high $CBOD_5$ value (53.0 mg/l) was recorded in Tote's mixing zone (RM 22.20) on September 8, 1993 (Figure 29). Zinc concentrations (1010 µg/l) also exceeded the final acute value (FAV) and phosphorus levels were above the WQS guideline the same day (Figure 32, Table 6). Field notes indicate that the discharge on this day was white and very foamy.

- Ammonia-N concentrations were elevated in some mixing zone samples, but there were no exceedences of any chronic or maximum criterion detected elsewhere in the Little Miami River mainstem (Figure 30).

- The average and maximum nitrate+nitrite-N values in the upper half of Little Miami River were higher than in the lower half possibly due to a greater influence of agriculture (Figure 31). The highest values, however, were recorded at RM 98.98, downstream from the South Charleston WWTP discharge to Gilroy Ditch.

- Maximum phosphorus levels at four ambient mainstem sites (RMs 74.46, 63.28, 28.00, 1.45) were higher than the WQS guideline of 1.0 mg/l (Figure 32, Table 6). The highest average

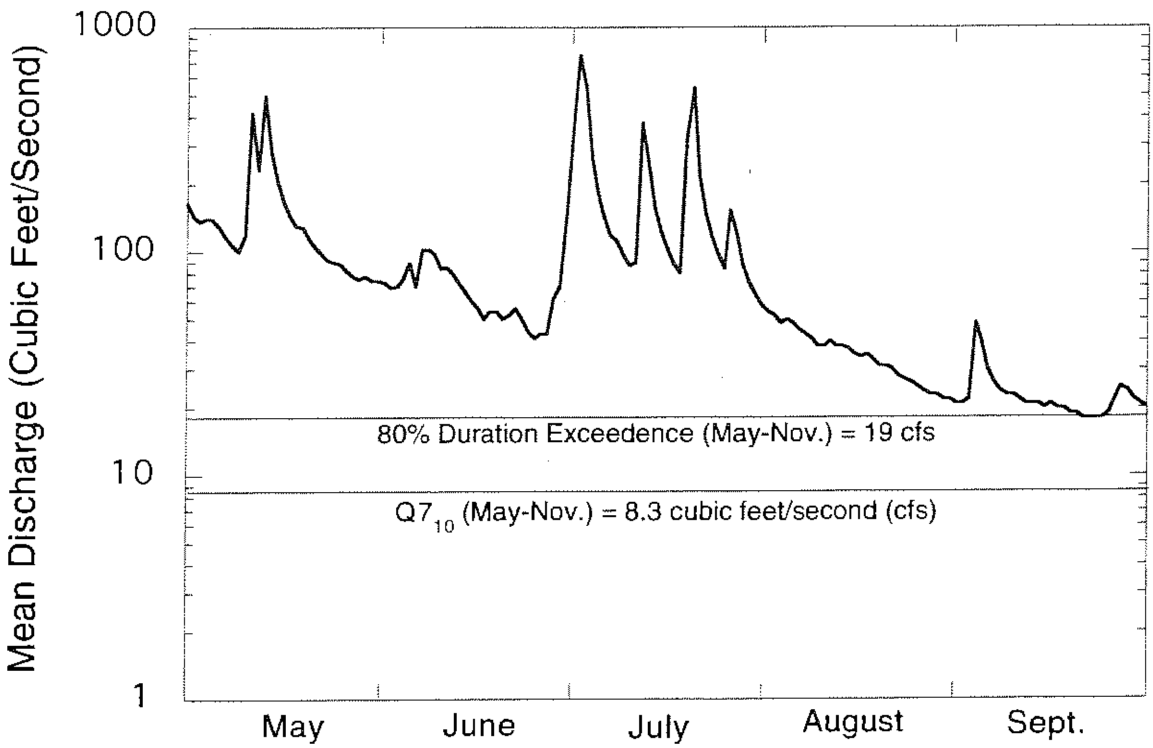


Figure 26. May through September, 1993, flow hydrograph for the upper Little Miami River near Oldtown, Greene Co.(RM 80.63). Low flow conditions ($Q7_{10}$ [8.3 cubic feet/second (cfs)] and 80% duration exceedence flow [19 cfs]) are based on the USGS gage station #03240000. Period of record: 1952 until present.

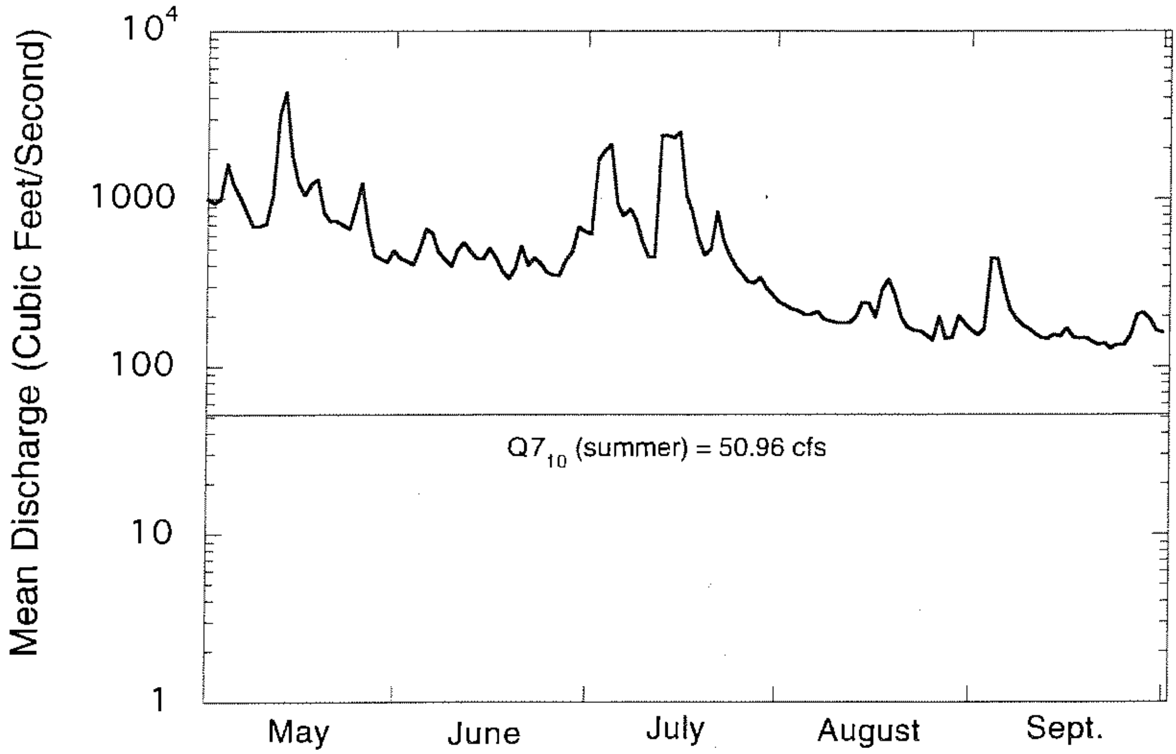
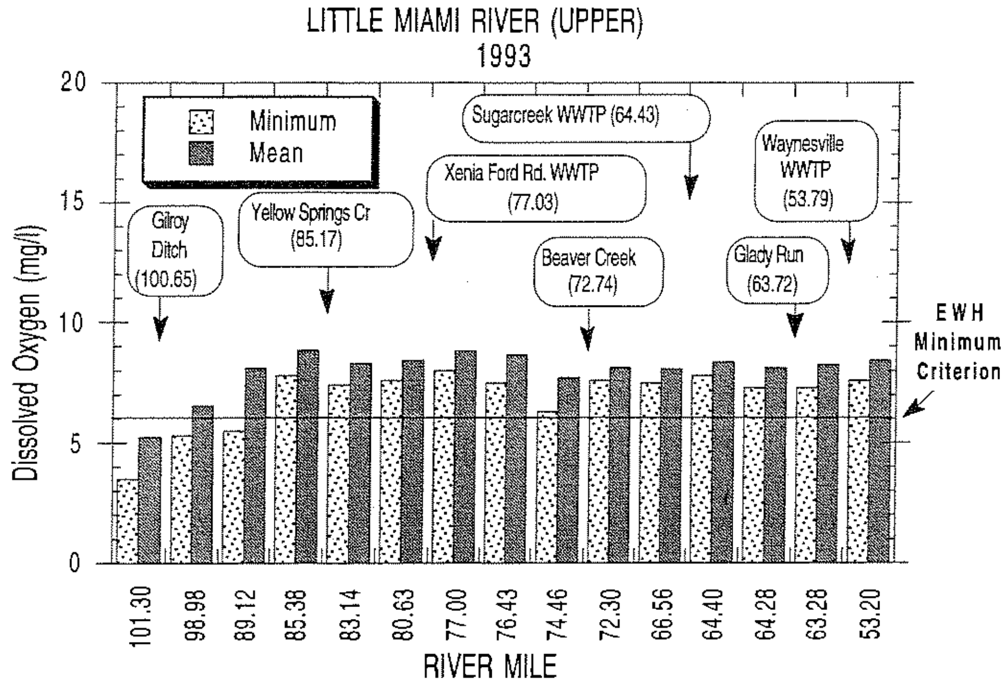


Figure 27. May through September, 1993, flow hydrograph for the lower Little Miami River near Milford, Clermont Co. (RM 13.07). Low flow conditions ($Q7_{10}$ [50.96 cubic feet/second (cfs)] is based on the USGS gage station #03245500. Period of record: 1938 until present. Eighty percent duration exceedence data is not available.



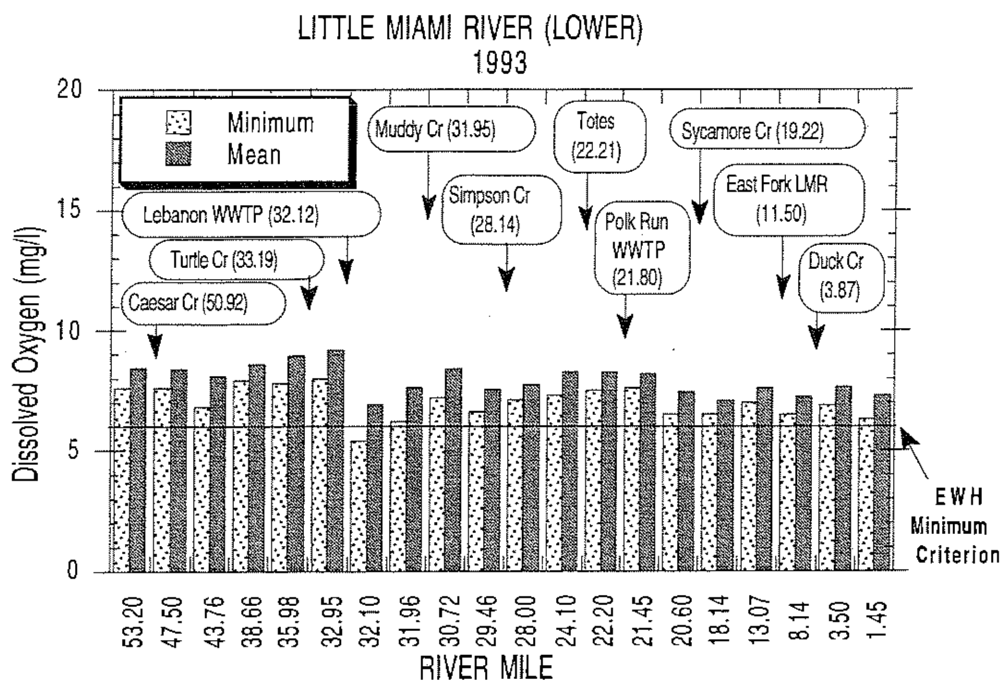
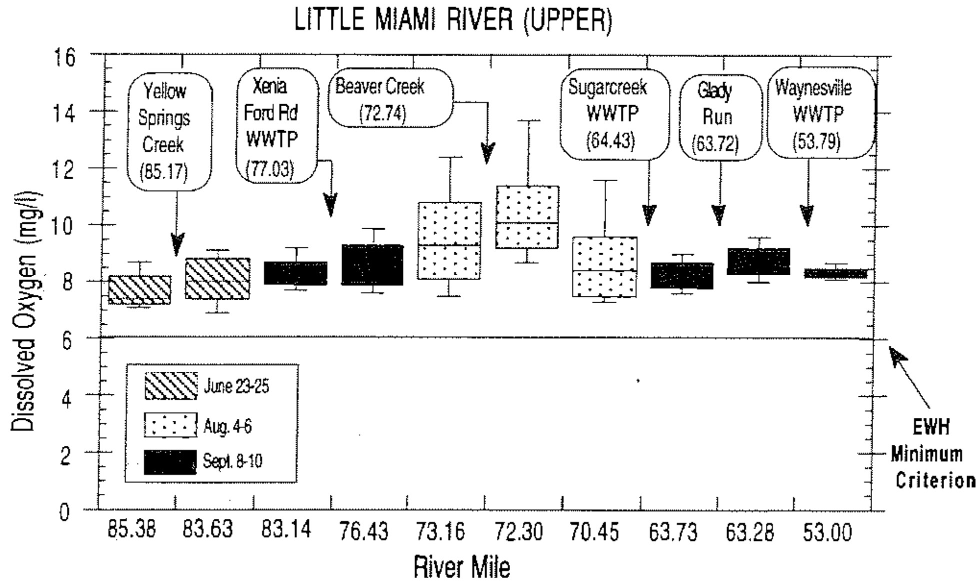


Figure 28a. Longitudinal summary of dissolved oxygen concentrations (minimum and mean values, daytime grab samples) in the upper and lower Little Miami River during the 1993 survey. Mixing zone values are shown for RMs 77.00, 64.40, 32.10, and 22.20.



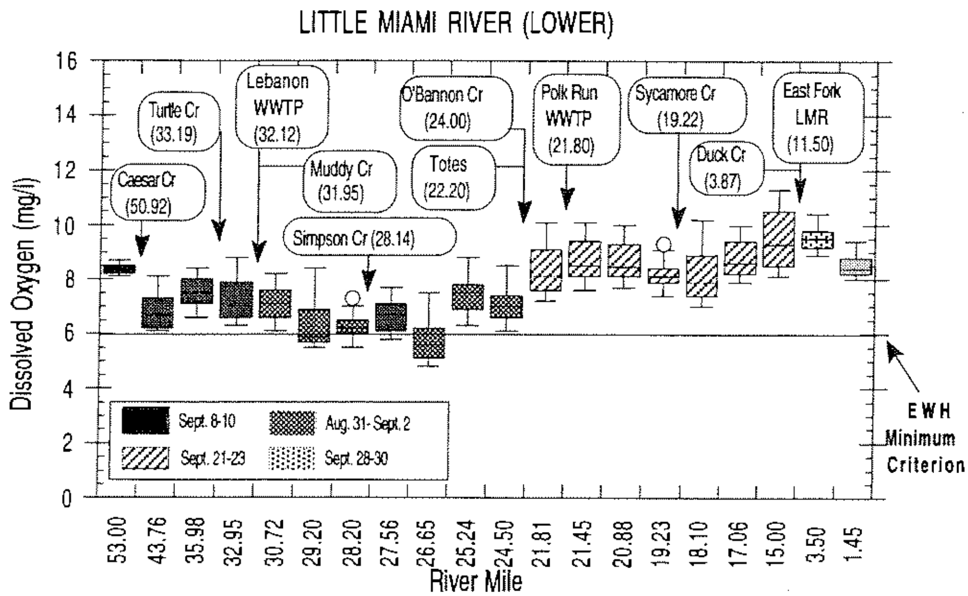


Figure 28b. Longitudinal summary of dissolved oxygen concentrations recorded with Datasonde continuous monitors in the upper and lower Little Miami River during the 1993 survey.

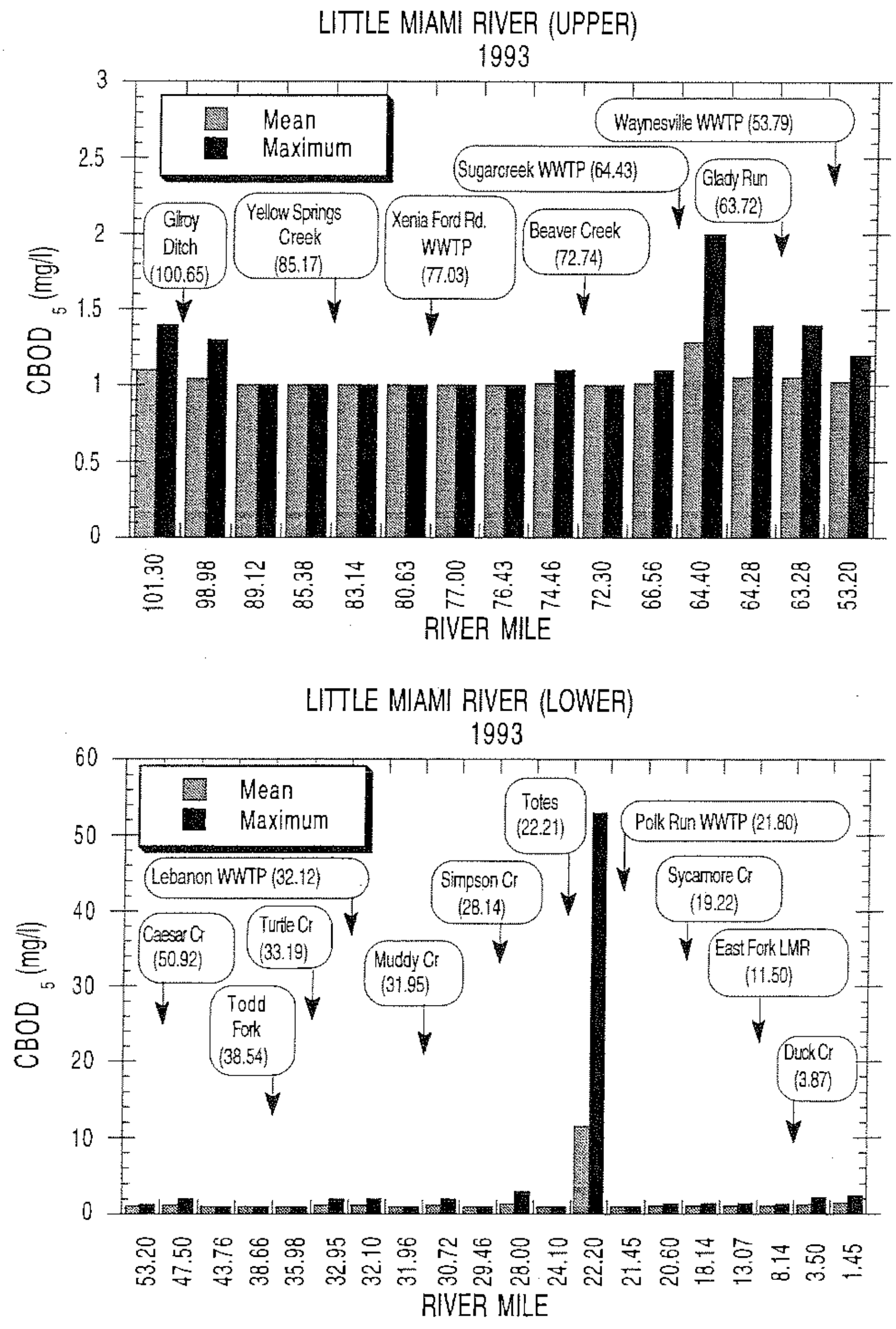


Figure 29. Longitudinal summary of $CBOD_5$ concentrations (mean and maximum values) in the upper and lower Little Miami River during the 1993 survey. Mixing zone values are shown for RMs 77.00, 64.40, 32.10, and 22.20.

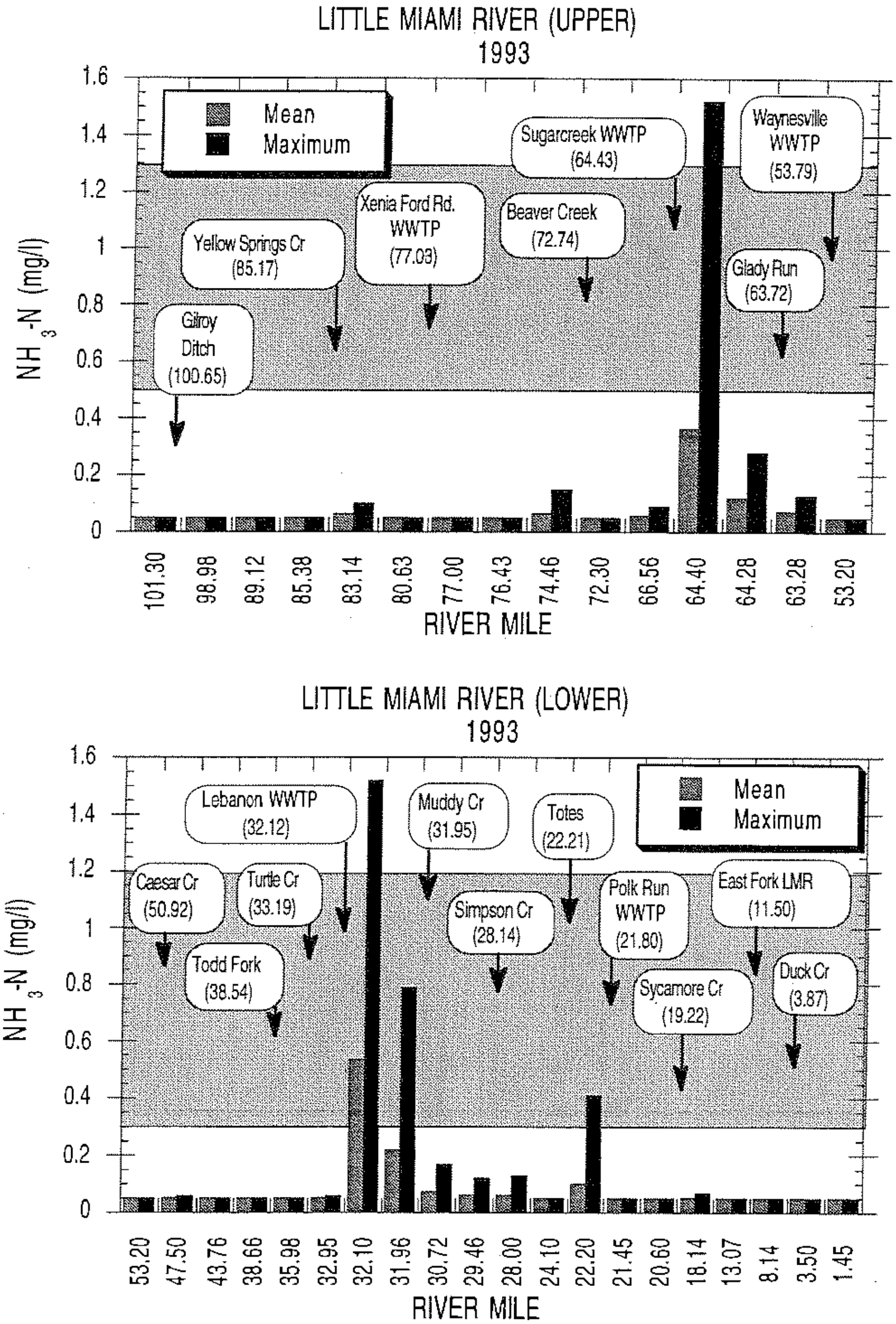


Figure 30. Longitudinal summary of ammonia-N concentrations (mean and maximum values) in the upper and lower Little Miami River during the 1993 survey *(shaded area is the ammonia-N water quality criteria range between the 25th and 90th percentile pH and temperature recorded during sample collection)*. The criteria does not apply for the mixing zone values shown for RMs 77.00, 64.40, 32.10, and 22.20.

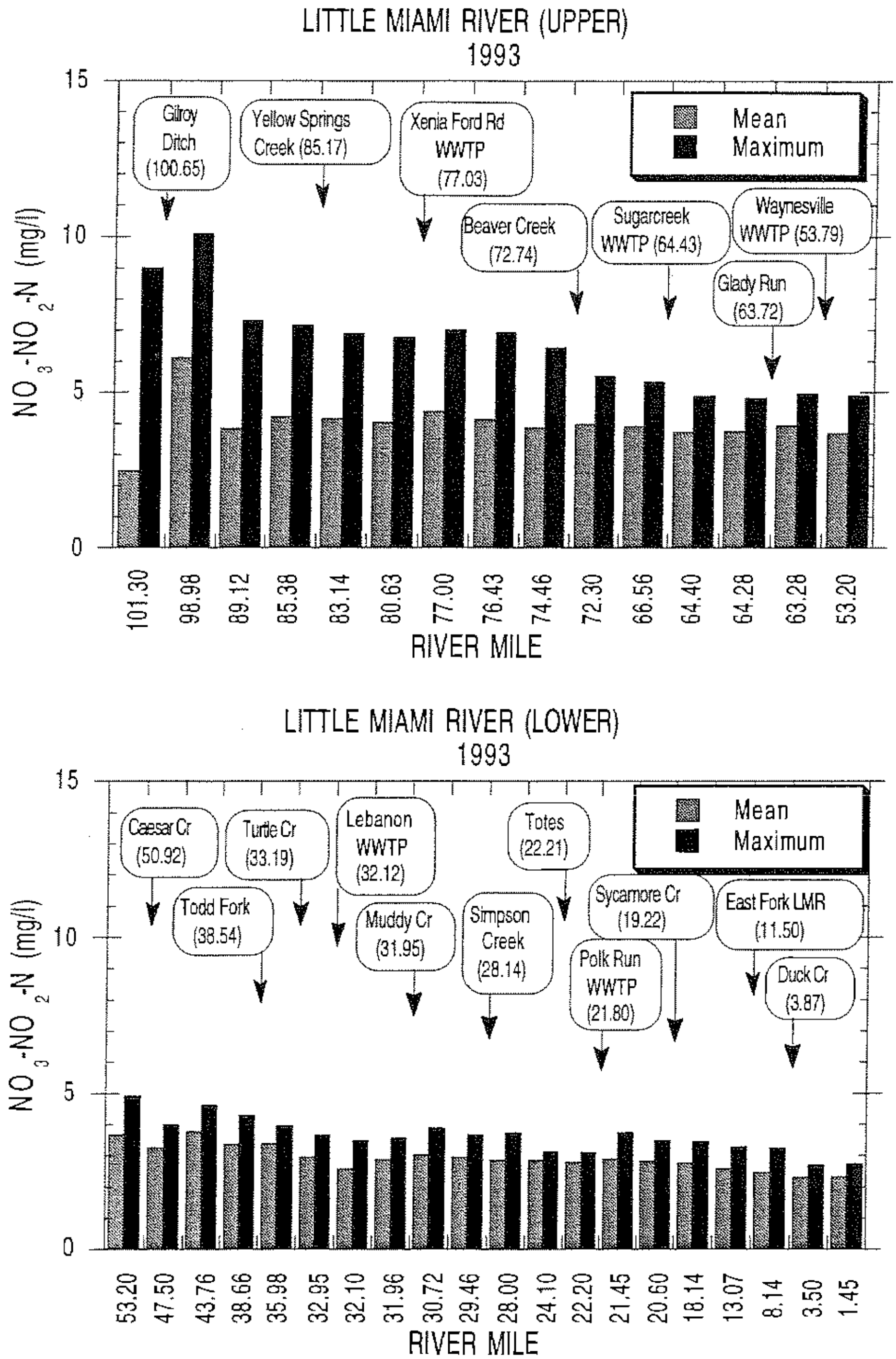


Figure 31. Longitudinal summary of nitrate+nitrite-N concentrations (mean and maximum values) in the upper and lower Little Miami River during the 1993 survey. Mixing zone values are shown for RMs 77.00, 64.40, 32.10, and 22.20.

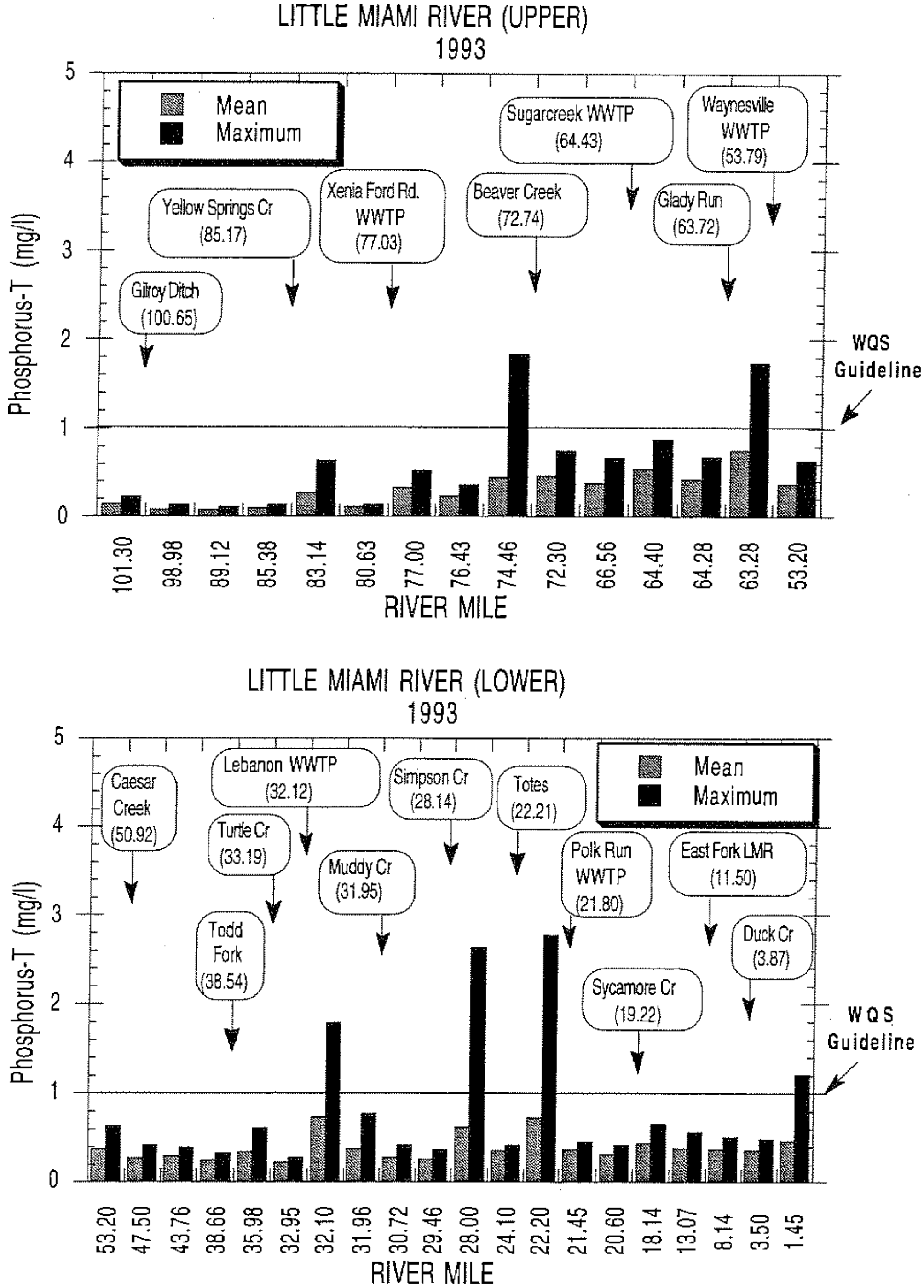
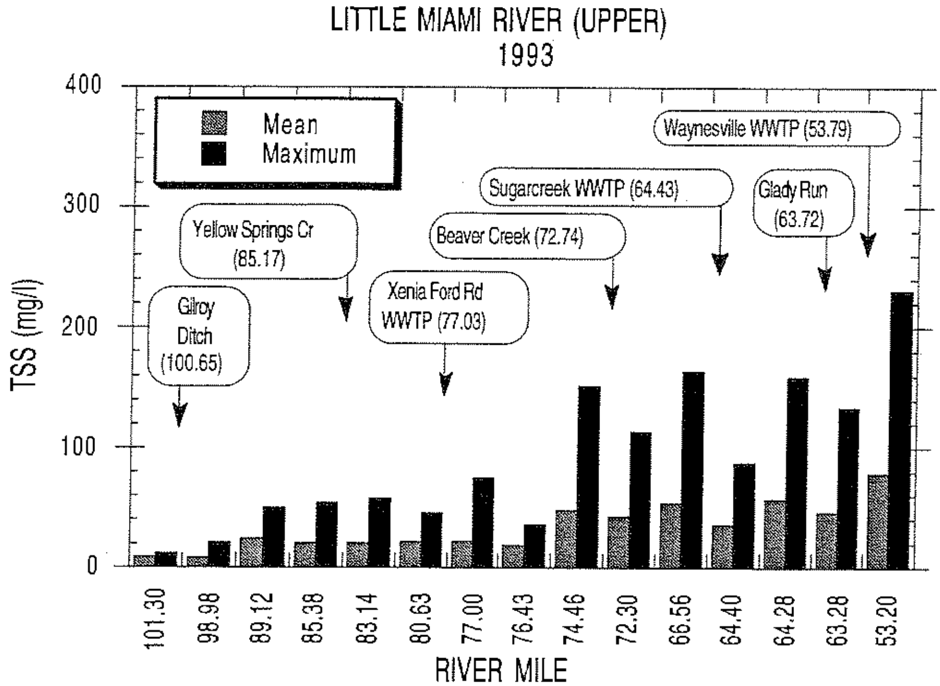


Figure 32. Longitudinal summary of total phosphorus concentrations (mean and maximum values) in the upper and lower Little Miami River during the 1993 survey. Mixing zone values are shown for RMs 77.00, 64.40, 32.10, and 22.20.



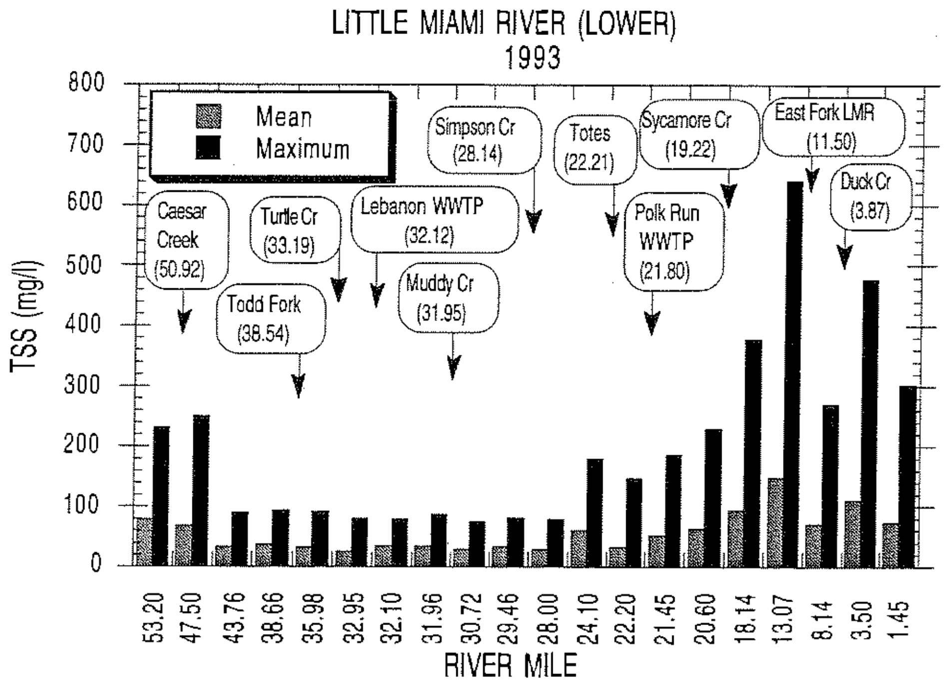


Figure 33. Longitudinal summary of total suspended solids concentrations (mean and maximum values) in the upper and lower Little Miami River during the 1993 survey. Mixing zone values are shown for RMs 77.00, 64.40, 32.10, and 22.20.

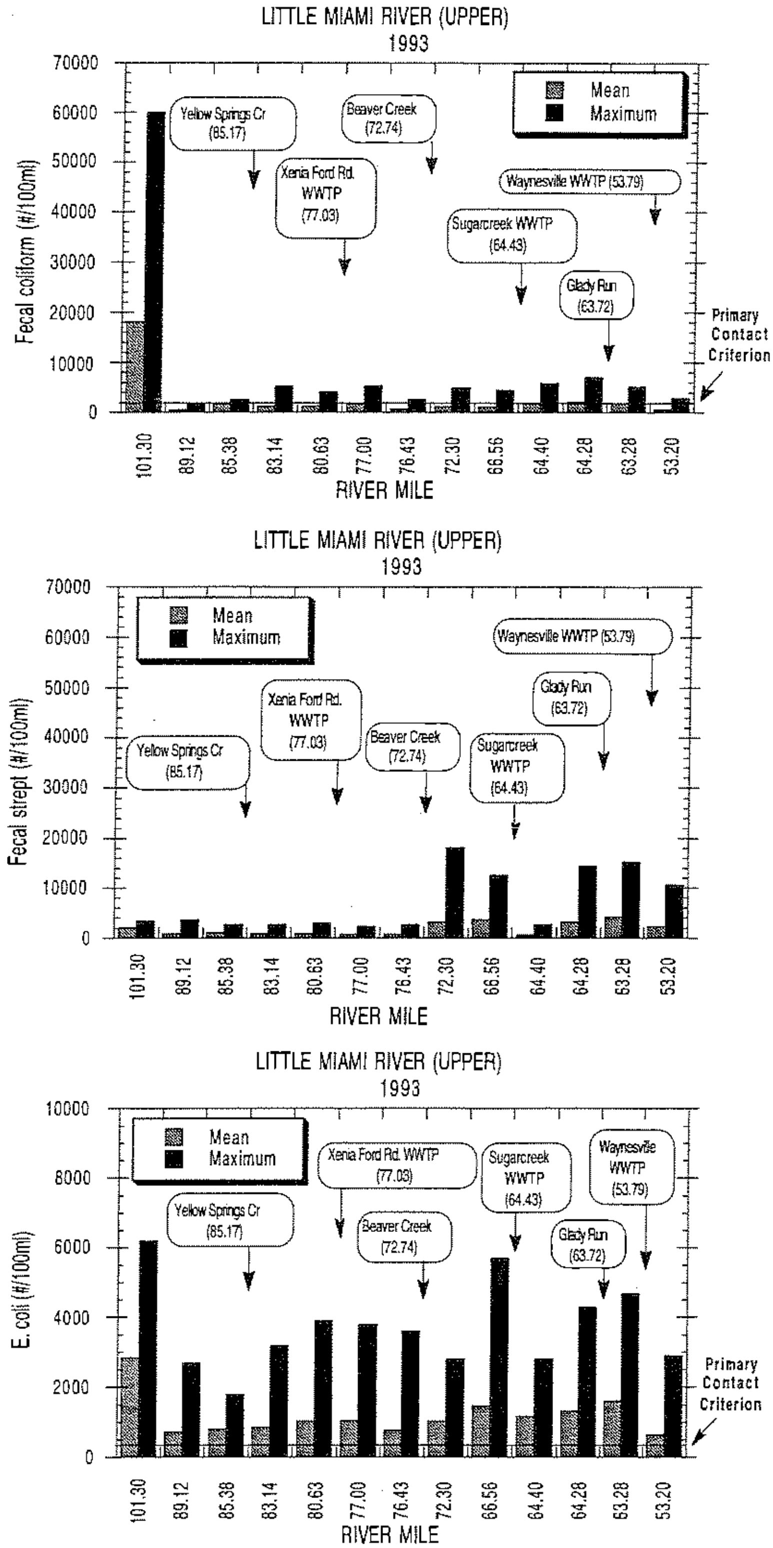


Figure 34. Longitudinal summary of fecal coliform, fecal strept, and *E. coli* concentrations (mean and maximum counts) in the upper Little Miami River during the 1993 survey. Mixing zone values are shown for RMs 77.00 and 64.40.

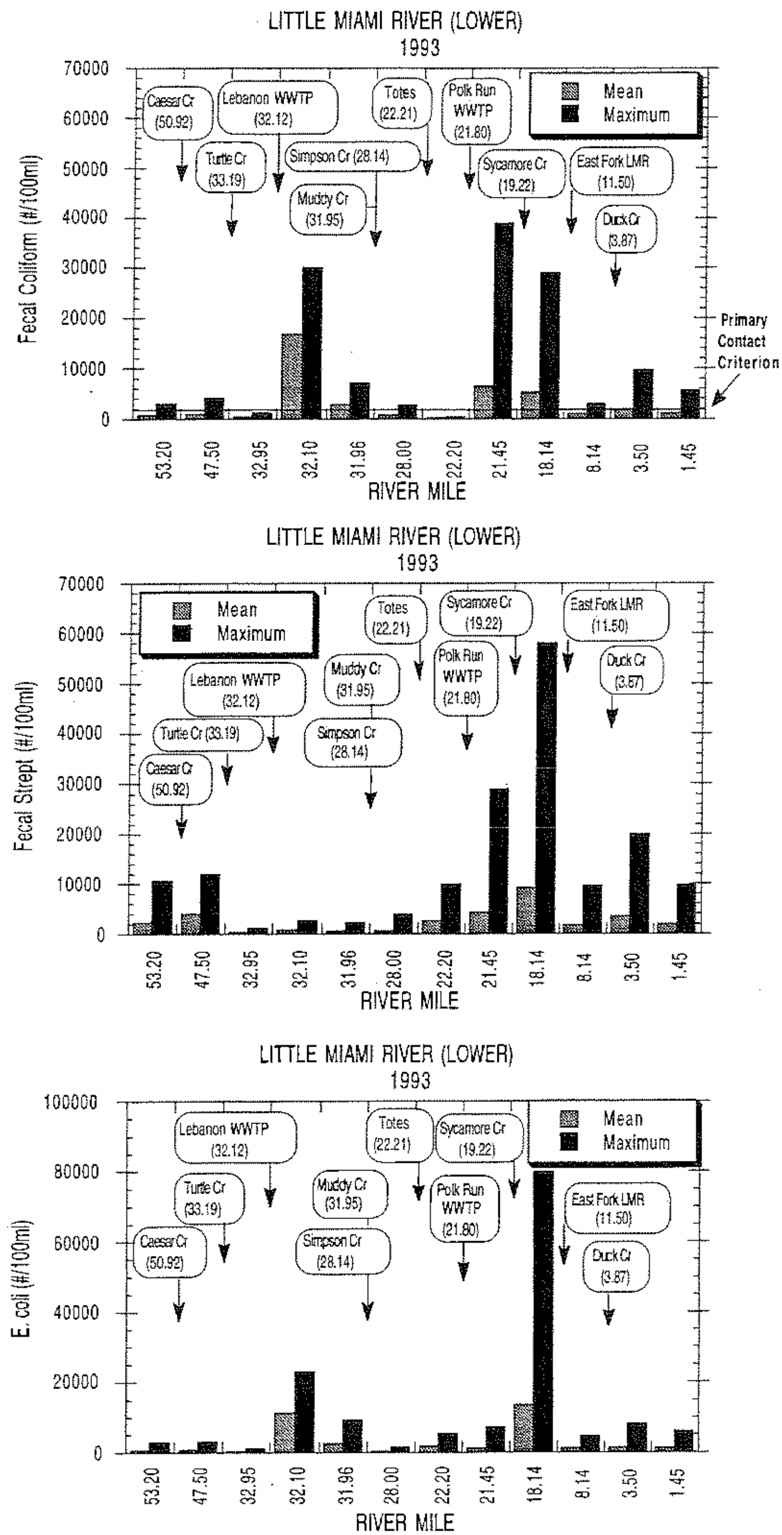


Figure 35. Longitudinal summary of fecal coliform, fecal strept, and *E. coli* concentrations (mean and maximum counts) in the lower Little Miami River during the 1993 survey. Mixing zone values are shown for RMs 32.10 and 22.20.

phosphorus concentration (0.76 mg/l) in the mainstem was recorded downstream from Glady Run (RM 63.28).

- Most (91%) of the high total suspended solids (TSS) concentrations were recorded during periods of heavy rain and high flows between July 13-15 (Figure 26-27,33). TSS were highest in the lower mainstem (RMs 18.14 - 1.45) and increased substantially downstream from Sycamore Creek (RM 19.22) to Milford (RM 13.07). Suspended sediment from excessive soil erosion appeared to be the primary source contributing to the high TSS concentrations in the lower mainstem.

- Almost every non-mixing zone sampling site on the mainstem had numerous exceedences of the primary contact recreation criterion due to elevated fecal coliform and *E. coli* counts (Figures 34-35, Table 6). The highest fecal coliform concentrations of the study area were recorded at Clifton Road (RM 101.30). Runoff from a manure composting operation and livestock pasturing near S. Charleston are likely responsible for the consistently higher fecal coliform levels at this site. The highest fecal concentrations (non-mixing zone) in the lower mainstem were recorded downstream from the Polk Run WWTP (RM 21.45) and Sycamore Creek (RM 18.14; Hamilton Co. Sycamore Creek WWTP). This segment receives untreated and partially treated sewage discharges from combined sewer (CSOs), sanitary sewer overflows (SSOs), and leaking sewer lines in tributaries. The high fecal values at RM 18.14 in particular may be a reflection of the combined impact of SSOs, the MSD Sycamore Creek WWTP, and sewer line leaks and replacement in the Sycamore Creek watershed.

- All mainstem sites sampled for organic compounds revealed exceedences of various water quality criteria (Table 6, A-5). Several exceedences of water quality criteria for selected pesticides occurred immediately downstream from WWTPs, although these same compounds were detected in upstream areas as well. Previous usage of organochlorine pesticides for agricultural purposes may also account for the compounds which were detected in the water column.

- Other mainstem water quality exceedences included a copper value of 137 µg/l at S.R. 72 (RM 89.12), a cadmium value of 6.4 µg/l at S.R. 48 (RM 32.95), and a mercury value of 1.8 µg/l downstream from Simpson Creek (RM 28.00).

Yellow Springs Creek

- All average and minimum dissolved oxygen values (daytime grabs and Datasonde) recorded in Yellow Springs Creek were above the 6.0 mg/l EWH water quality criteria (Figures 36a-36b, Tables 6, A-4, A-6).

- Ammonia-N levels markedly increased in Yellow Springs Creek downstream from the Yellow Springs WWTP. The mixing zone (RM 0.42) samples contained one highly elevated ammonia-N concentration and phosphorus levels frequently above 1.0 mg/l (Figures 37-38). One ammonia-N value also exceeded the chronic aquatic criterion (CAC) downstream from the WWTP (RM 0.10, Figure 37, Table 6). The quality of the effluent is improved as it flows over the high gradient cascading falls before entering Yellow Springs Creek.

- Moderate to high nitrate+nitrite-N concentrations were recorded at all sites reflecting a combined impact of nutrient loading from non-point agricultural runoff, other upstream point sources, and the WWTP (Figure 37). Longitudinally, TSS concentrations remained similar (Figure 38).

- Numerous exceedences of the primary contact recreation criteria for fecal coliform and *E. coli* were recorded both upstream (RM 0.44) and downstream (RM 0.10) of the Yellow Springs WWTP (Figure 39, Table 6). Fecal strept concentrations were also elevated at these sites. Overflows from a lift station upstream and agricultural runoff may account for the elevated fecal bacteria levels at the upstream site.

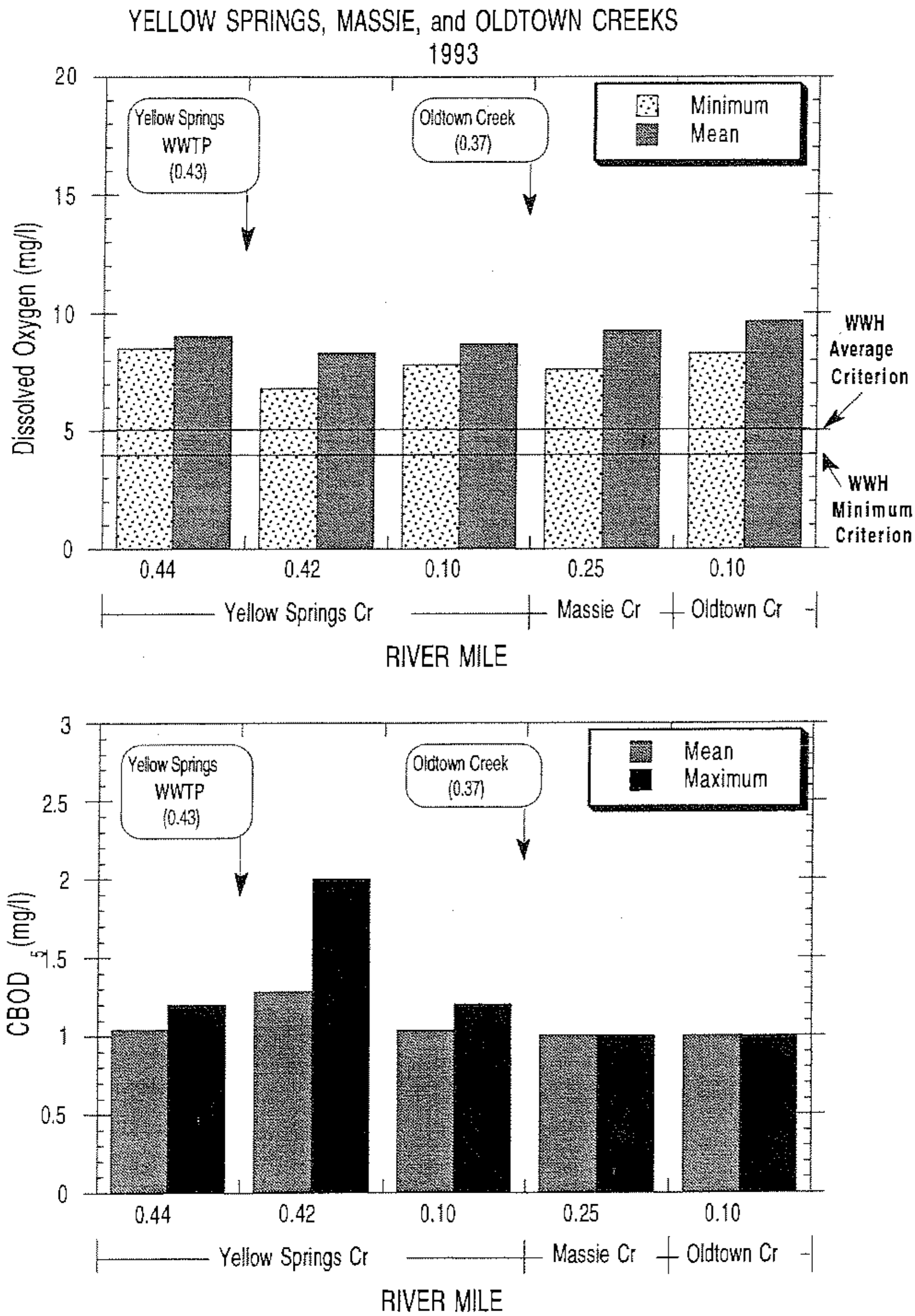


Figure 36a. Daytime grab dissolved oxygen concentrations (minimum and mean values) and $CBOD_5$ concentrations (mean and maximum values) in Yellow Springs, Massies, and Oldtown creeks during the 1993 survey. Mixing zone values are shown for RM 0.42.

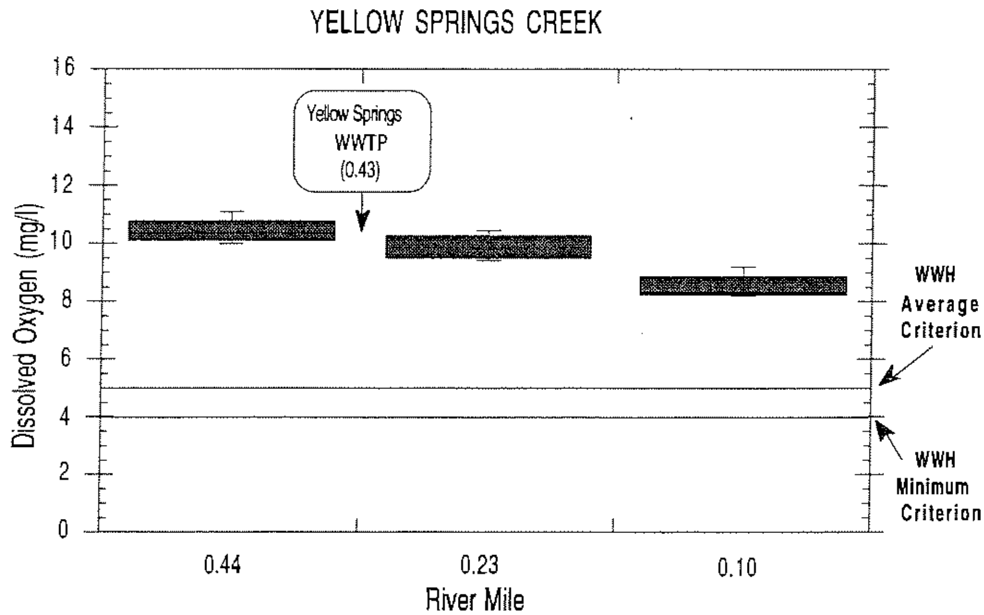


Figure 36b. Box and whisker plots of dissolved oxygen concentrations recorded with Datasonde continuous monitors in Yellow Springs Creek from September 29 - 30, 1993.

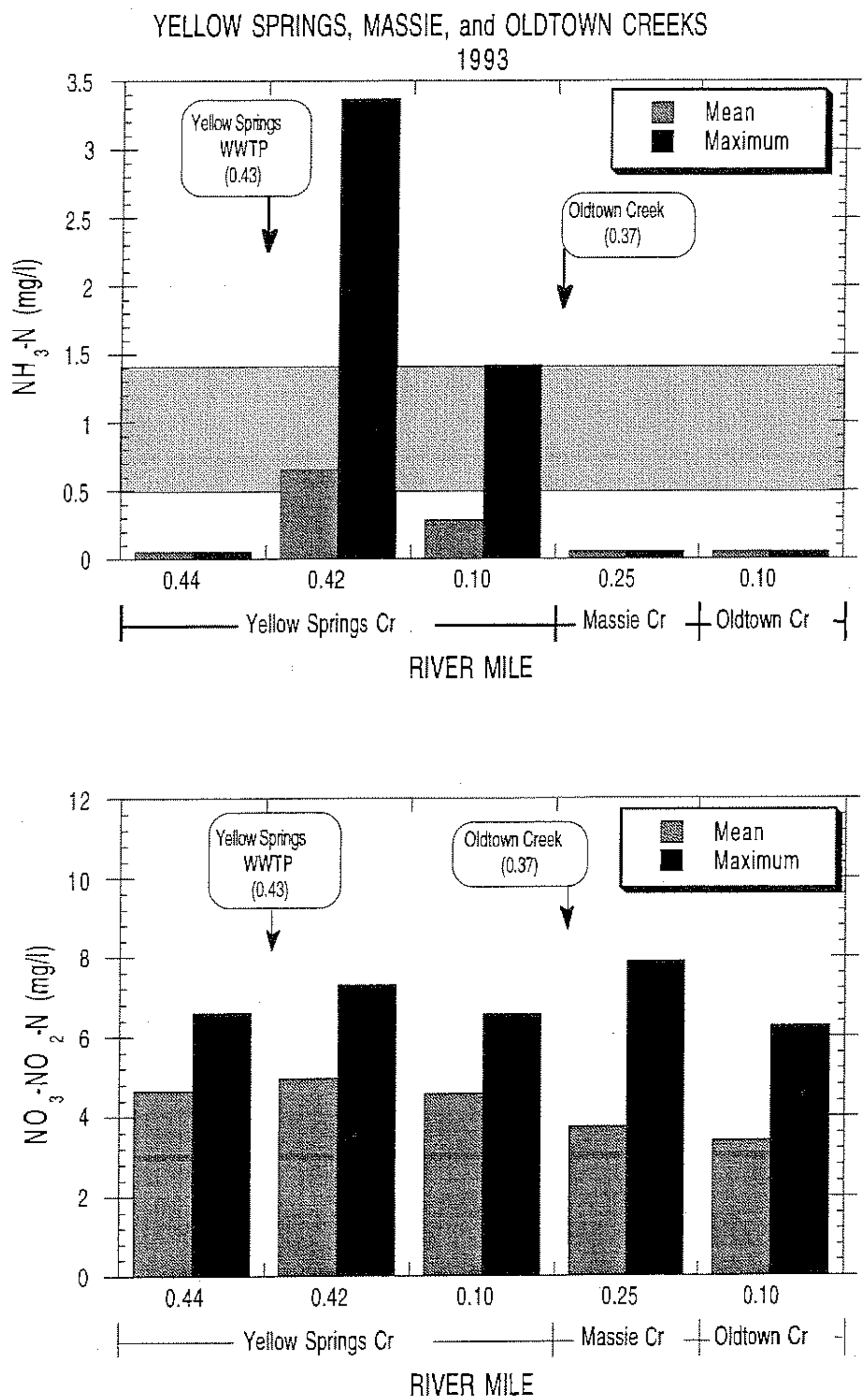


Figure 37. Longitudinal summary (mean and maximum values) of ammonia-N and nitrate+nitrite-N concentrations in Yellow Springs Creek, Massies Creek and Oldtown Creek during the 1993 survey (*shaded area is the ammonia-N water quality criteria range between the 25th and 90th percentile pH and temperature recorded during sample collection*). The criteria does not apply for the ammonia-N mixing zone values shown for RM 0.42.

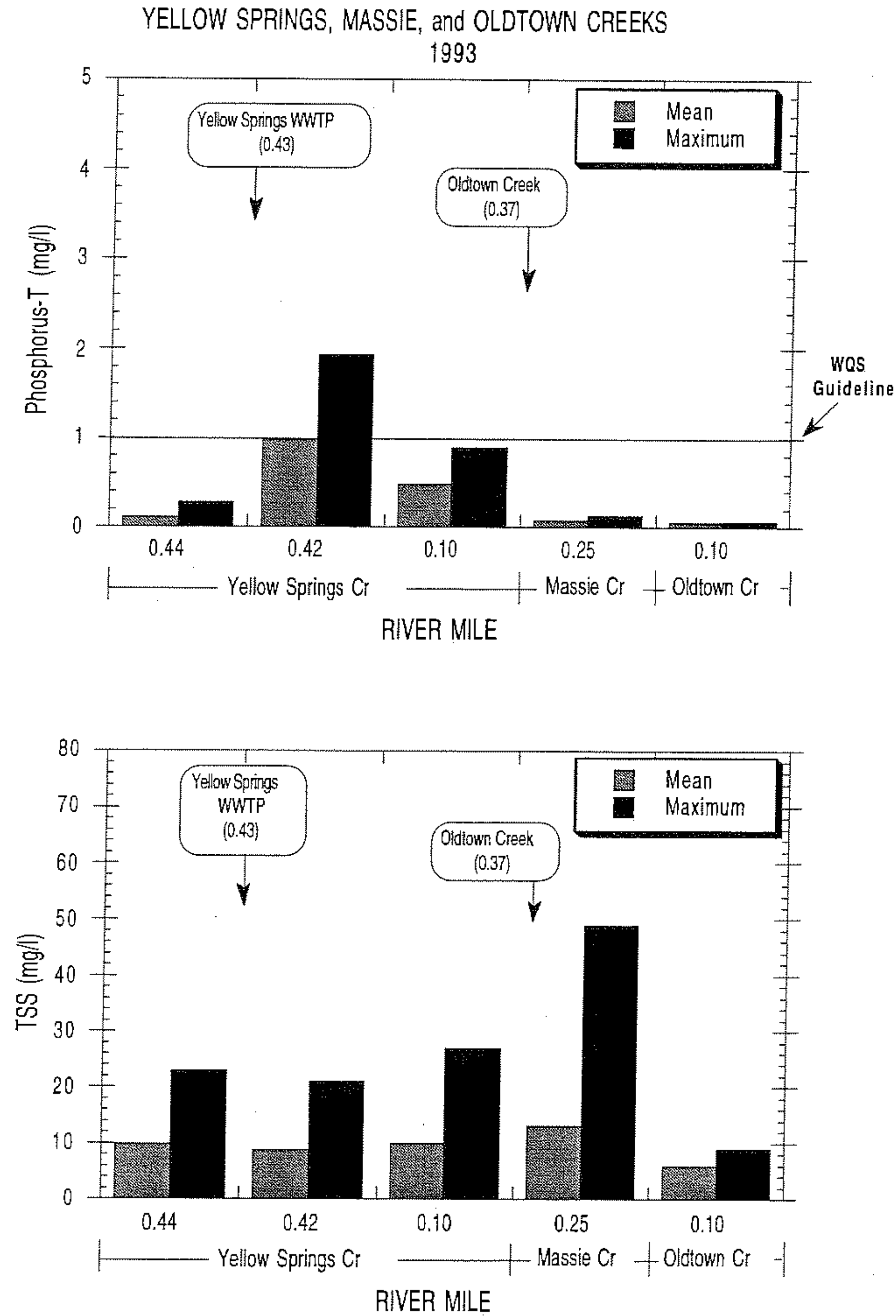


Figure 38. Longitudinal summary (mean and maximum values) of total phosphorus and total suspended solids concentrations in Yellow Springs Creek (mixing zone value shown for RM 0.42), Massies Creek and Oldtown Creek during the 1993 survey.

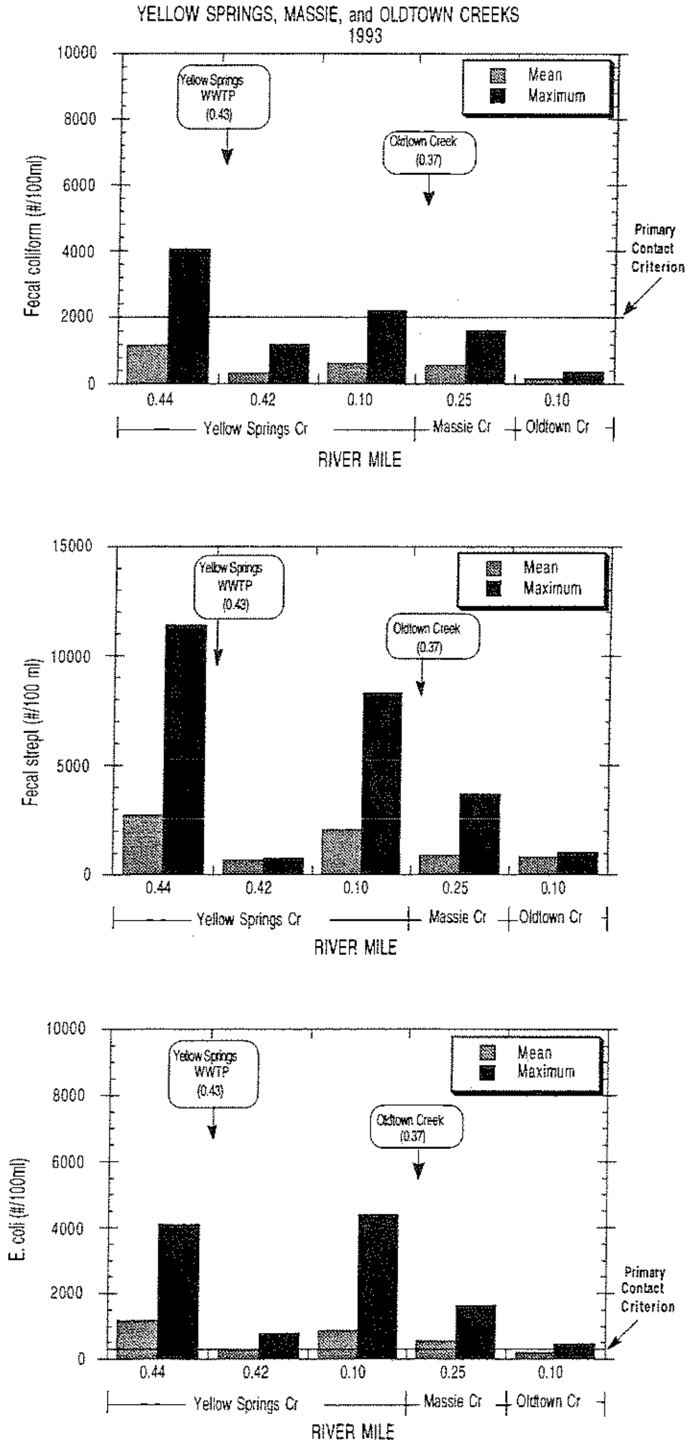


Figure 39. Longitudinal summary (mean and maximum values) of fecal coliform, fecal strep, and *E. coli* counts in Yellow Springs Creek (mixing zone value shown for RM 0.42), Massies Creek and Oldtown Creek during the 1993 survey.

- Organic sampling at RM 0.1 also detected low concentrations of organochlorine pesticides and volatile organic compounds (Table A-5). Only dieldrin exceeded water quality criteria.

Oldtown Creek

- Oldtown Creek had general good water quality with markedly lower concentrations of ammonia-N, total phosphorus, and fecal counts than Yellow Springs Creek (Figures 36a-39, Tables 6, A-4, A-5). Several *E. coli* counts exceeded the primary contact recreation criteria near the mouth. Low concentrations of organochlorine pesticides were also detected in one sample. No other parameters were elevated at RM 0.10.

Massies Creek

- Water quality in Massies Creek at U.S. 68 (RM 0.25) was also good and similar to Oldtown Creek except for moderate to high nitrate+nitrite-N levels and several exceedences of the primary contact recreation criteria for fecal coliform and *E. coli* (Figures 36a-39, Tables 6, A-4). The maximum TSS concentration recorded (49 mg/l) coincided with the higher flows experienced during the second week of the survey (Figure 38).

Beaver Creek

- Dissolved oxygen concentrations measured in Beaver Creek (daytime grabs and Datasonde) were above the WWH water quality criteria at all four locations (Figures 40a-40b, Table A-6).

- Ammonia-N levels at all sites were very low. Longitudinally, nitrate+nitrite-N concentrations in Beaver Creek increased downstream of the Little Beaver Creek (due to levels discharged by the Montgomery Co. Eastern Regional WWTP), peaked in the Greene Co. Beaver Creek WWTP mixing zone (RM 0.39) and remained in the moderate to high range downstream from both WWTPs (RM 0.20, Figure 41).

- Further evidence of nutrient enrichment is shown by phosphorus levels which follow the same general longitudinal pattern as nitrate+nitrite-N. Phosphorus values frequently exceeded the WQS guideline of 1.0 mg/l. (Figure 42, Table 6).•Turbidity levels in Beaver Creek were consistently higher at RM 1.57 than downstream from the confluence of Little Beaver Creek (Figure 42). Poor soil erosion control at upstream development sites likely account for the increased suspended sediment levels. Little Beaver Creek's flow, however, is dominated by WWTP effluent which contains very low amounts of solids when the plant is efficiently operating.

- Fecal bacteria counts in Beaver Creek detected frequent exceedences of the *E. coli* secondary contact recreation criterion at all sites and one fecal coliform exceedence of the secondary contact recreation criterion upstream from both major WWTPs (RM 1.57, Figure 43, Table 6).

- Organochlorine pesticides and volatile organic compounds were detected in water samples immediately downstream of the Beaver Creek WWTP (RM 0.20). Several exceedences of water quality criteria for endrin, dieldrin, and endosulfan II were observed (Tables 6, A-5).

Little Beaver Creek

- Similar to Beaver Creek, minimum dissolved oxygen values (daytime grabs or Datasonde) in Little Beaver Creek did not drop below WWH water quality criteria (Figures 40a-40b,Tables 6, A-6).

- Ammonia-N concentrations increased downstream from the Montgomery Co. Eastern Regional WWTP, but remained below WWH water quality criteria (Figure 41). Nutrient enrichment from the WWTP is also apparent in the sustained, elevated nitrate+nitrite-N and phosphorus concentrations downstream from the WWTP (Figures 41-42, Table 6).

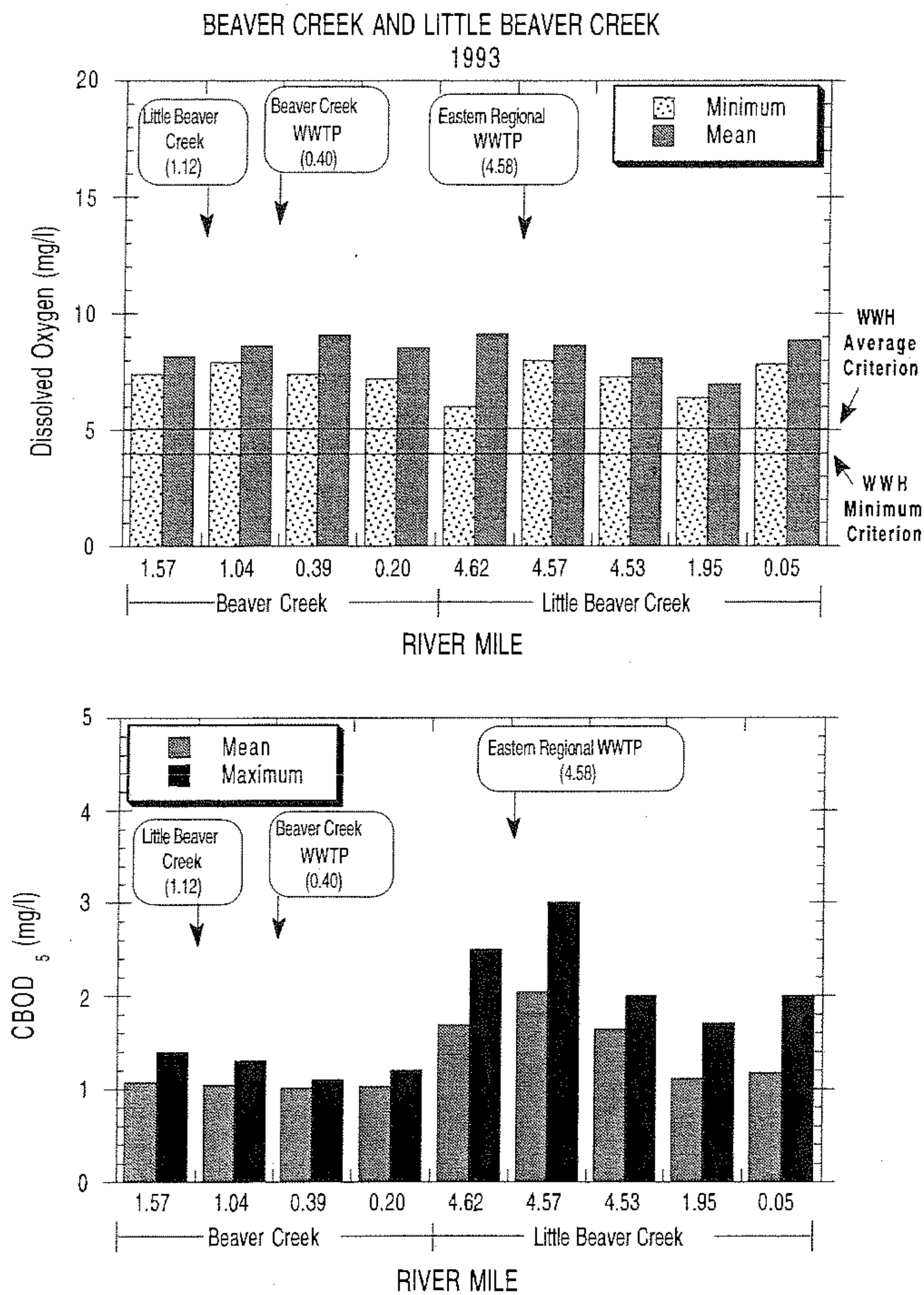


Figure 40a. Longitudinal summary of dissolved oxygen (daytime grab mean and minimum values) and $CBOD_5$ (mean and maximum) concentrations in Beaver Creek and Little Beaver Creek during the 1993 survey. Mixing zone values are shown for RMs 0.39 and 4.57.

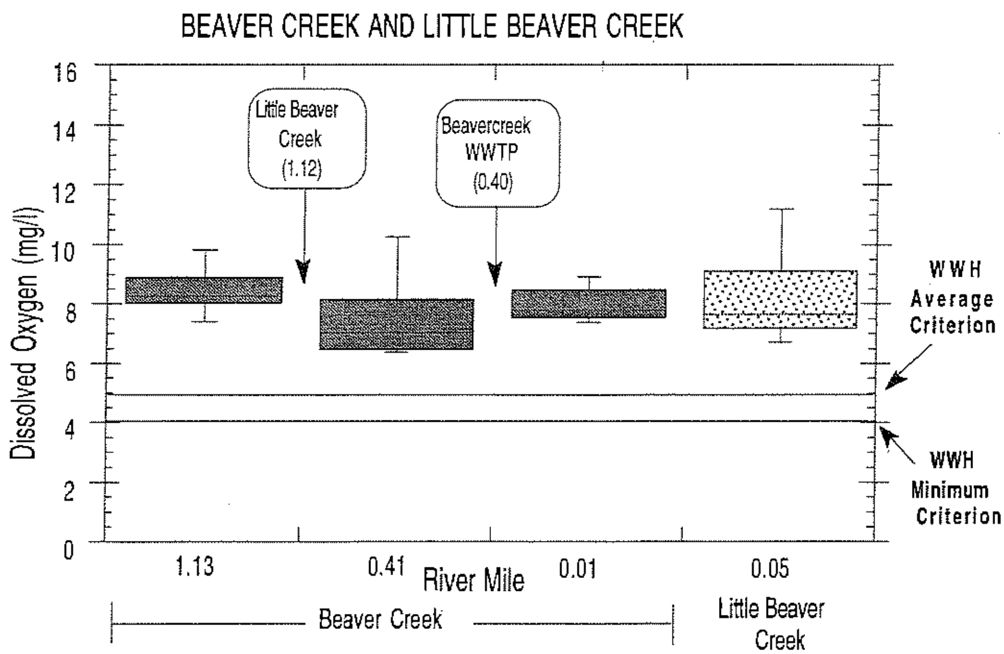


Figure 40b. Longitudinal summary of dissolved oxygen (box and whisker plots) concentrations recorded by Datasonde continuous monitors in Beaver Creek and Little Beaver Creek from August 4-6, 1993.

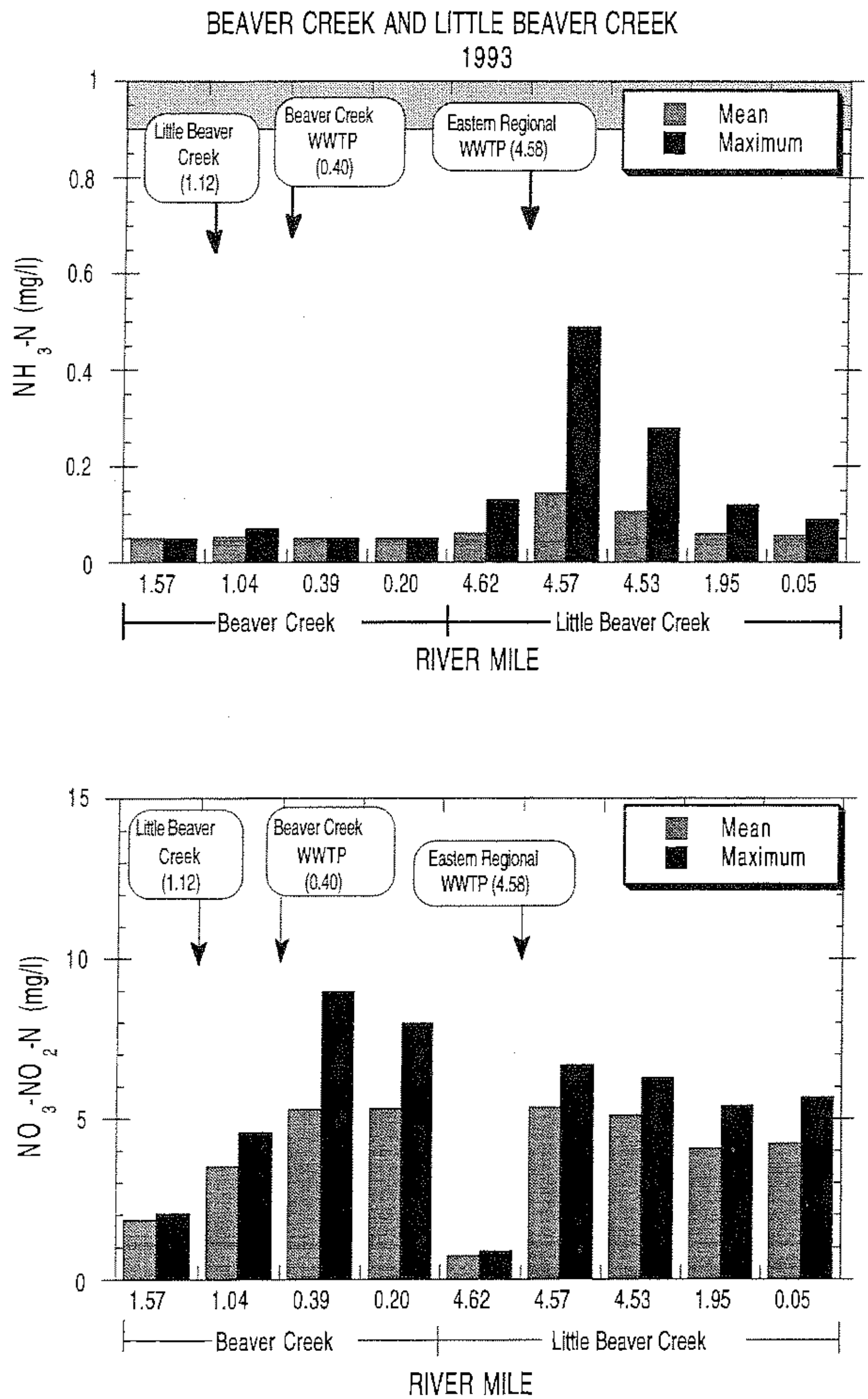


Figure 41. Longitudinal summary of ammonia-N and nitrate+nitrite-N concentrations (mean and maximum values) in Beaver Creek and Little Beaver Creek during the 1993 survey (*shaded area is the ammonia-N water quality criteria range between the 25th and 90th percentile pH and temperature recorded during sample collection*). The ammonia-N criteria does not apply to the mixing zone values shown for RMs 0.39 and 4.57.

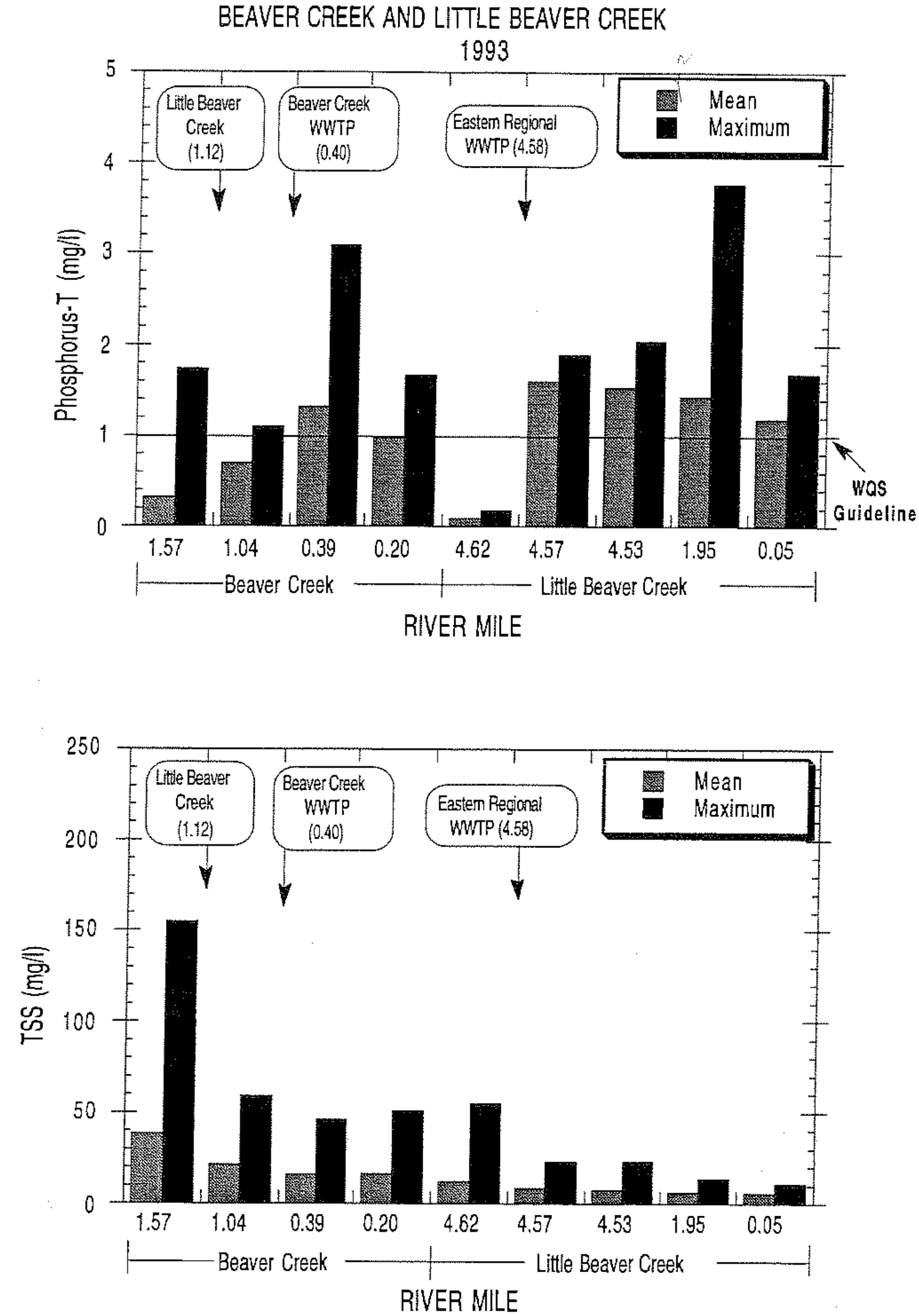


Figure 42. Longitudinal summary of total phosphorus and total suspended solids concentrations (mean and maximum values) in Beaver Creek and Little Beaver Creek during the 1993 survey. Mixing zone values shown for RMs 0.39 and 4.57.

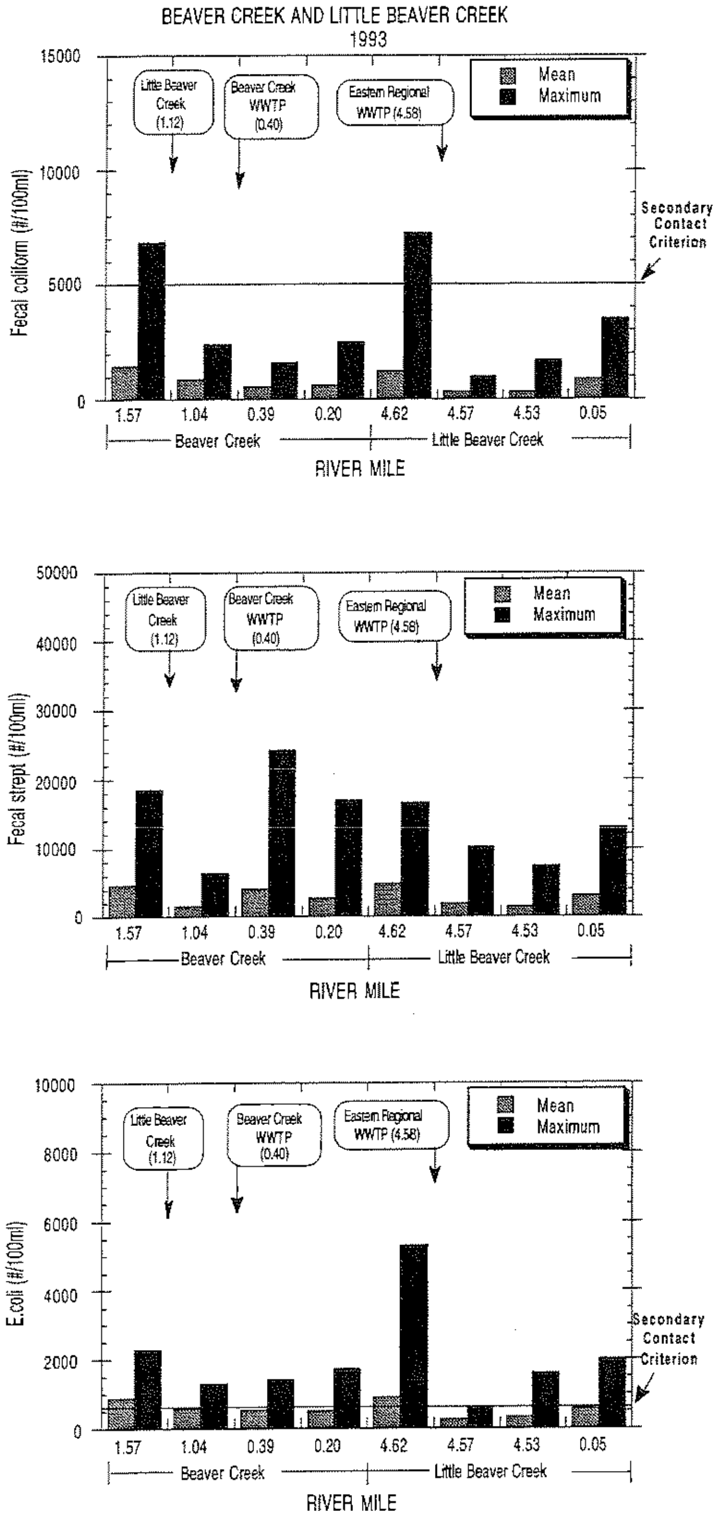
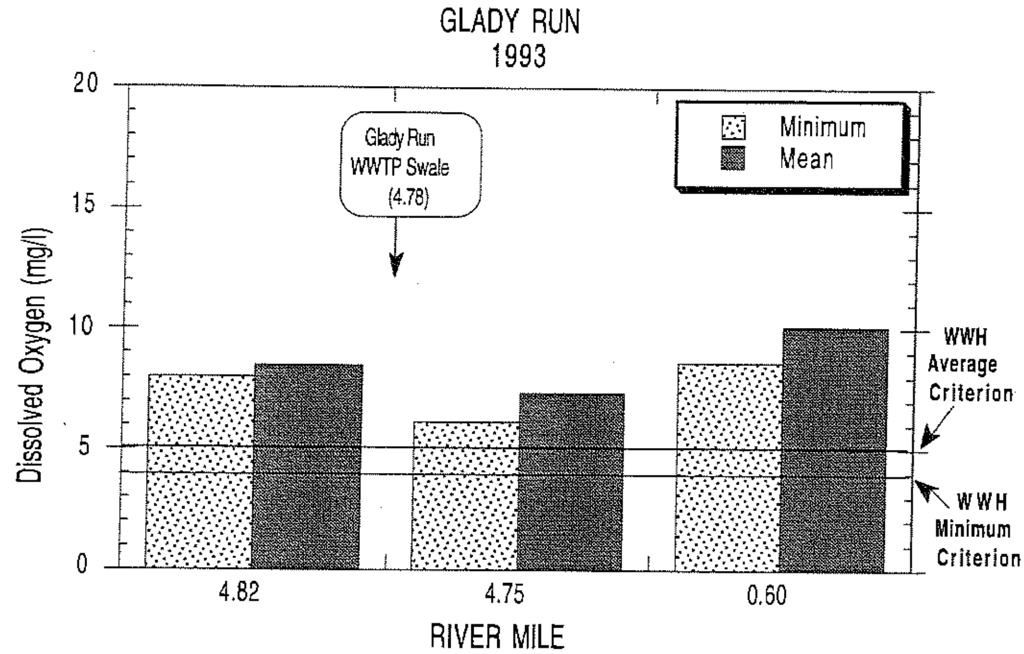


Figure 43. Longitudinal summary of fecal coliform, fecal strep, and *E. coli* concentrations (mean and maximum values) in Beaver Creek and Little Beaver Creek during the 1993 survey. Mixing zone values shown for RMs 0.39 and 4.57.



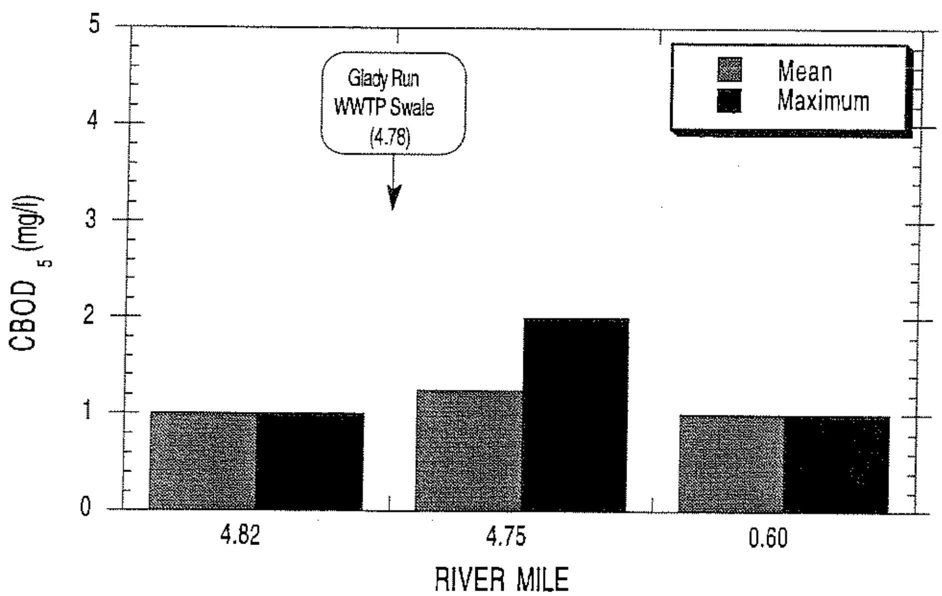


Figure 44a. Longitudinal summary of dissolved oxygen (daytime grab mean and minimum values) and $CBOD_5$ (mean and maximum values) concentrations in Glady Run during the 1993 survey.

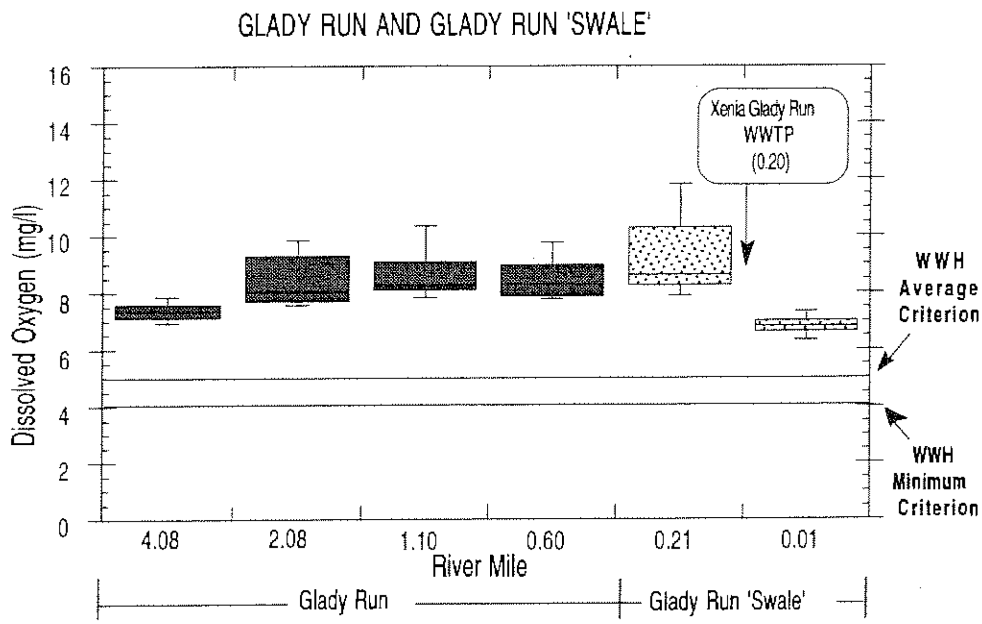


Figure 44b. Longitudinal summary of dissolved oxygen concentrations (box and whisker plots) recorded with Datasonde continuous monitors in Glady Run and Glady Run "Swale" from September 8-10, 1993.

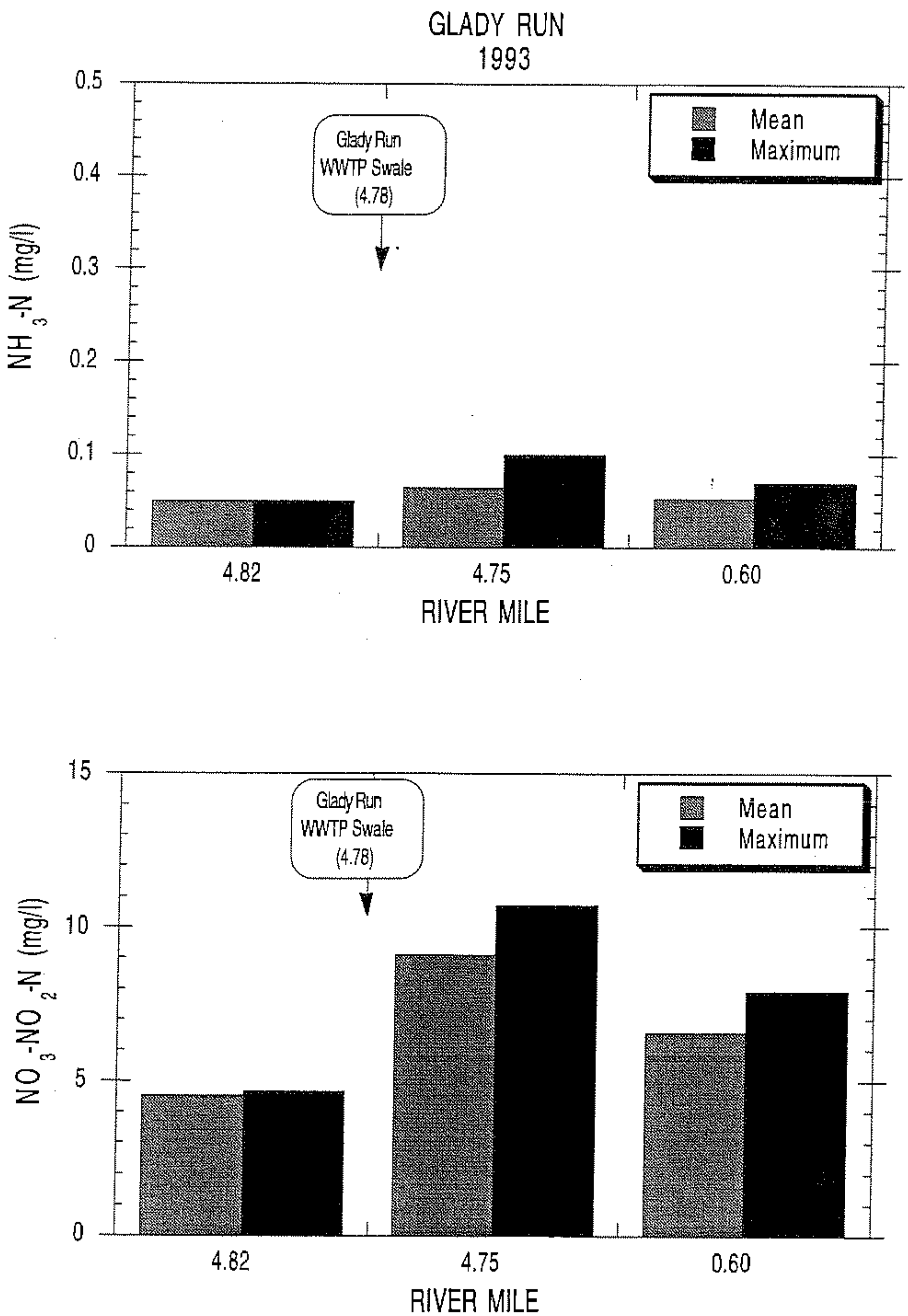


Figure 45. Longitudinal summary of ammonia-N and nitrate+nitrite-N concentrations (mean and maximum values) in Glady Run during the 1993 survey.

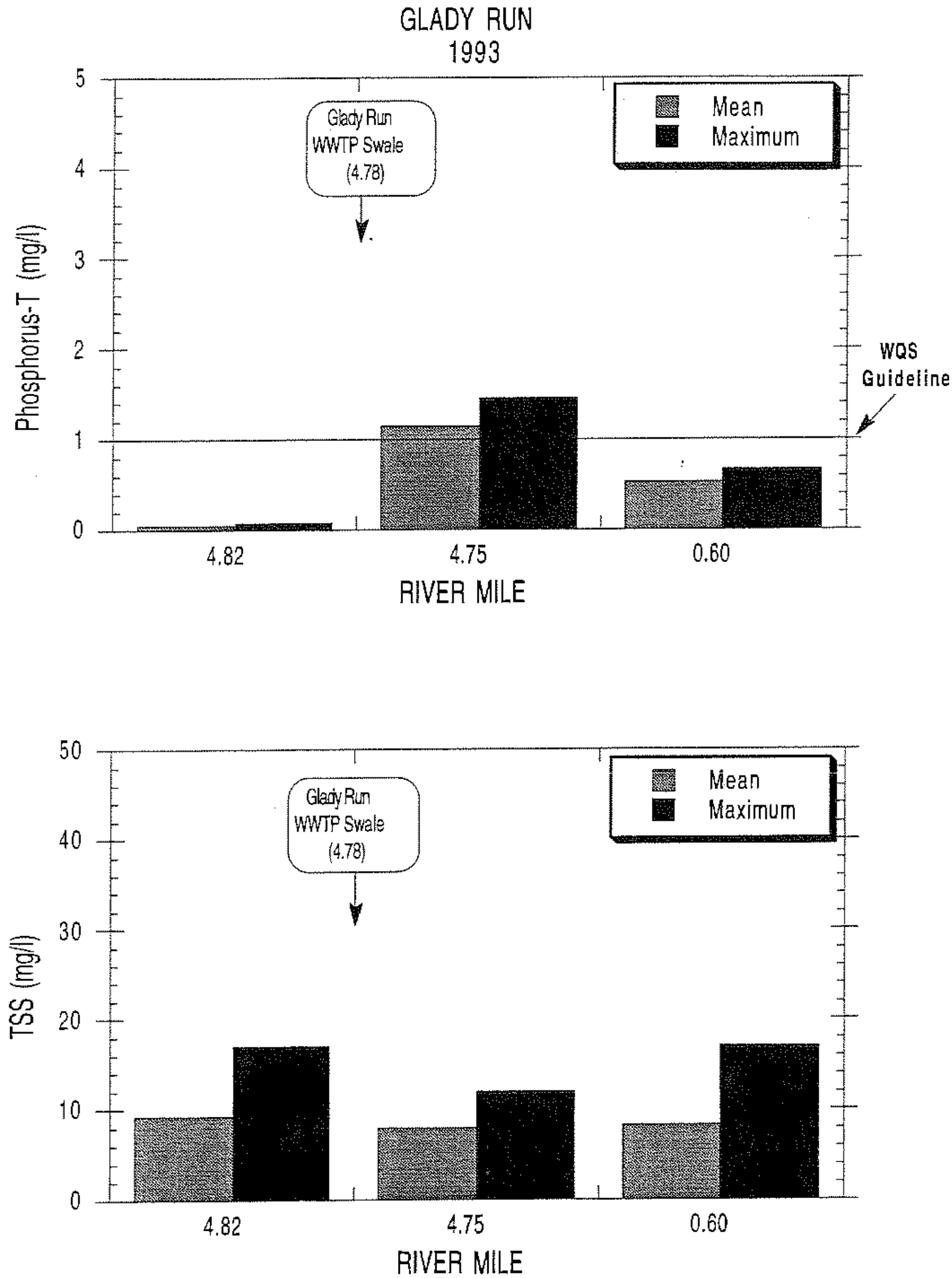


Figure 46. Longitudinal summary of total phosphorus and total suspended solids (TSS) concentrations (mean and maximum values) in Glady Run during the 1993 survey.

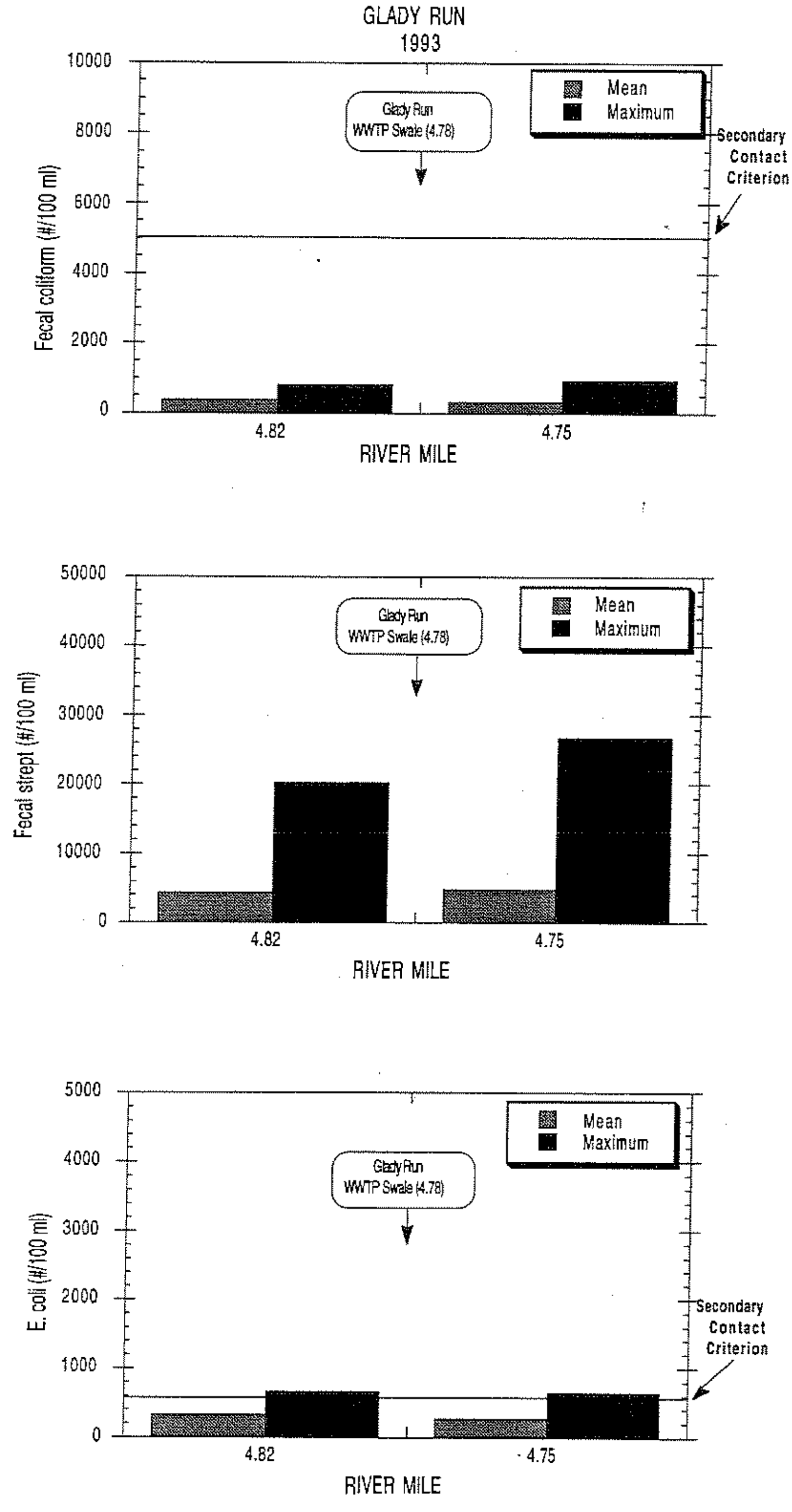


Figure 47. Longitudinal summary of fecal coliform, fecal strep, and *E. coli* counts (mean and maximum values) in Glady Run during the 1993 survey.

- Fecal coliform counts upstream from the WWTP (RM 4.62) exceeded the secondary contact recreation criterion on one occasion. *E. coli* counts frequently exceeded secondary contact recreation criterion at all sites. Most high fecal coliform and TSS values recorded in both Beaver Creek and Little Beaver Creek occurred on June 29, a day after localized heavy rains. Elevated levels of fecal coliform and TSS are most common after rain events, reflecting contributions from nonpoint urban and agricultural stormwater runoff (Figures 42-43, Table 6).

- Organic sampling downstream from the Montgomery Co. Eastern Regional WWTP (RM 4.53) detected the presence of organochlorine pesticides and volatile organic compounds. Several pesticide concentrations exceeded water quality criteria (Tables 6, A-5).

Glady Run and Glady Run Swale

- Glady Run has recently changed course to intercept the Glady Run swale upstream from the Xenia Glady Run WWTP. The swale was previously an unnamed tributary to Glady Run to which the Xenia Glady Run WWTP discharges. Further investigation revealed that subsequent to the dismantling of the railroad between Glady Run and the Glady Run swale, Glady Run has eroded through the old railroad grade to capture the swale upstream from the WWTP.

- Datasonde continuous monitors detected a marked decline in dissolved oxygen levels in the Glady Run swale downstream of the Xenia Glady Run WWTP (RM 0.01). However, dissolved oxygen values in both Glady Run and the swale remained above the WWH water quality criteria (Figure 44b, Table A-6). Daytime grab dissolved oxygen values in Glady Run downstream from the swale (RM 4.75) also showed a slight decline (Figure 44a).

- Most ammonia-N concentrations were below the minimum detection limit in both streams. Nutrient enrichment from the Xenia-Glady Run WWTP increased nitrate+nitrite-N and phosphorus concentrations significantly increased in Glady Run downstream of the swale, and remained moderately to highly elevated to RM 0.60 (Figures 45-46, Table 6,A-4).

- Fecal coliform counts remained well below the secondary contact criterion both upstream and downstream from the Glady Run swale (RMs 4.82-4.75). *E. coli* counts, however, exceeded the criterion once at both sites and suggest human fecal contamination. An elevated fecal strep count also suggests potential contributions from non-point agricultural runoff (Figure 47, Table 6).

- Organic samples taken in Glady Run at RM 4.75 downstream of the mouth of the swale revealed various organochlorine pesticides and low levels of volatile organic compounds (Table A-5). Several concentrations of pesticides exceeded water quality criteria (Table 6).

Anderson Fork

- Water samples from one site in Anderson Fork (RM 4.90) revealed good water quality with concentrations of most parameters well within water quality criteria. A daytime grab dissolved oxygen value, however, dropped below the EWH minimum water quality criterion (Figure 48, Table 6). $CBOD_5$ and ammonia-N concentrations were below the minimum detection limits. Elevated nitrite nitrate-N and TSS concentrations were recorded on July 15 after heavy rains in the area. Dieldrin and endosulfan II concentrations also exceeded water quality criteria (Table 6, A-5).

Caesar Creek

- Water samples collected at the upstream Caesar Creek site (RM 16.52) had one daytime grab dissolved oxygen value below 6.0 mg/l and one phosphorus value above 1.0 mg/l (Figures 48-49, Table 6). This was the only location in the study area where no organic compounds were

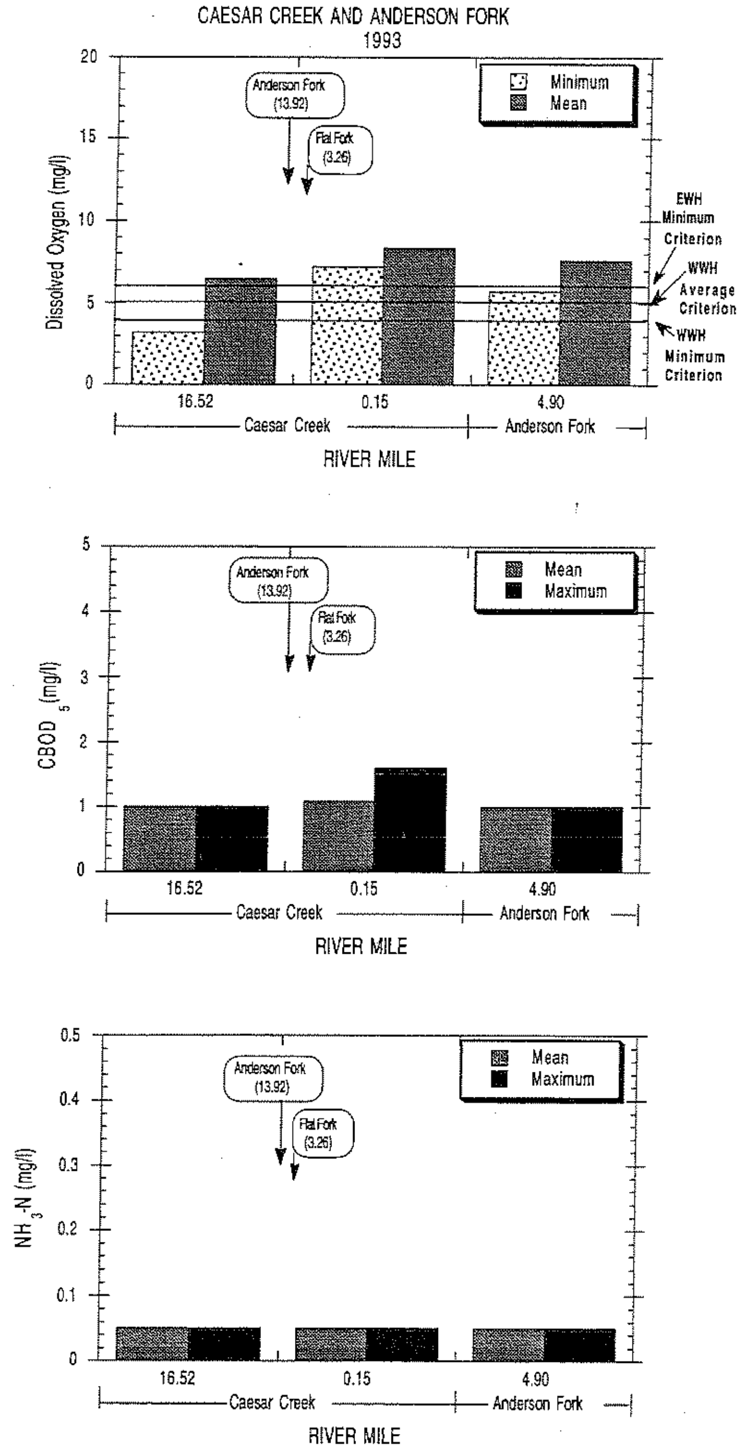


Figure 48. Longitudinal summary of dissolved oxygen (daytime grab mean and minimum values), $CBOD_5$, and ammonia-N(mean and maximum values) concentrations in Caesar Creek and Anderson Fork during the 1993 survey.

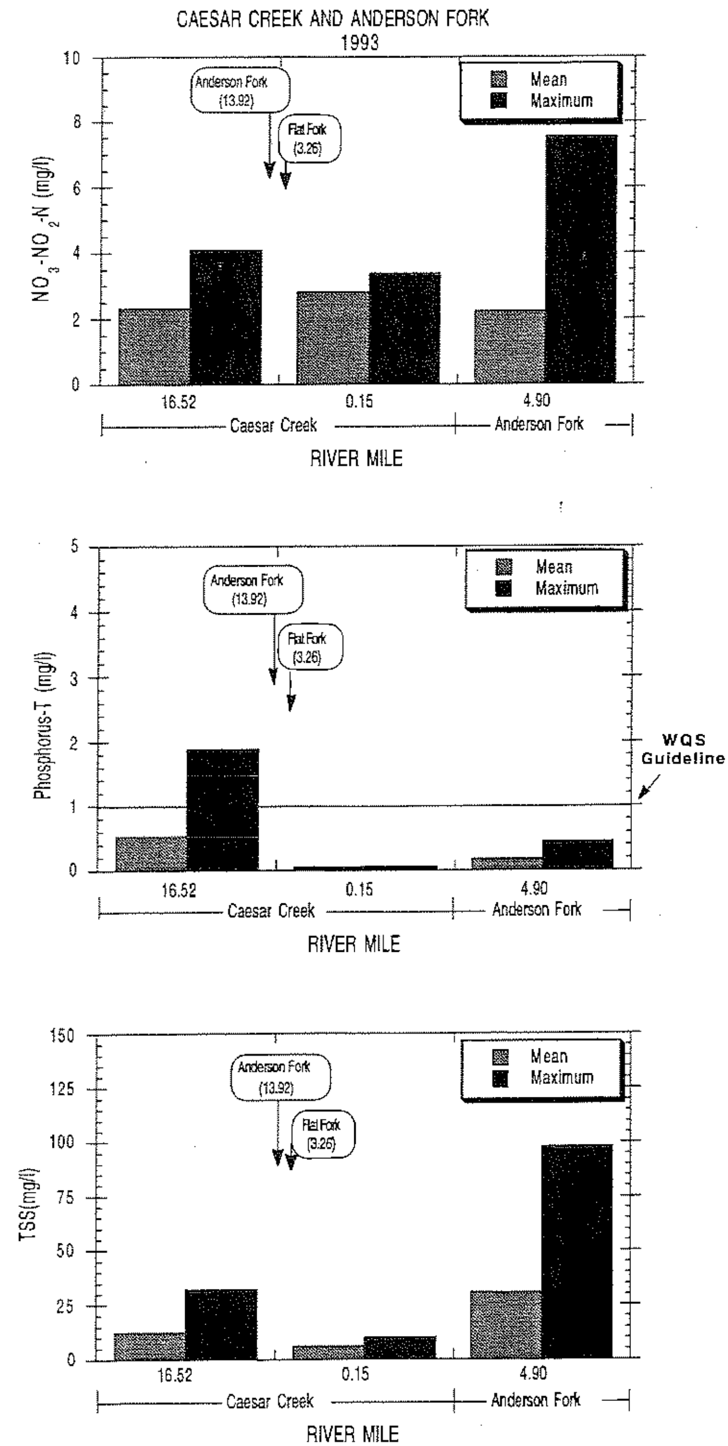


Figure 49. Longitudinal summary of nitrate+nitrite-N, total phosphorus, and total suspended solids (TSS) concentrations (mean and maximum values) in Caesar Creek and Anderson Fork during the 1993 survey.

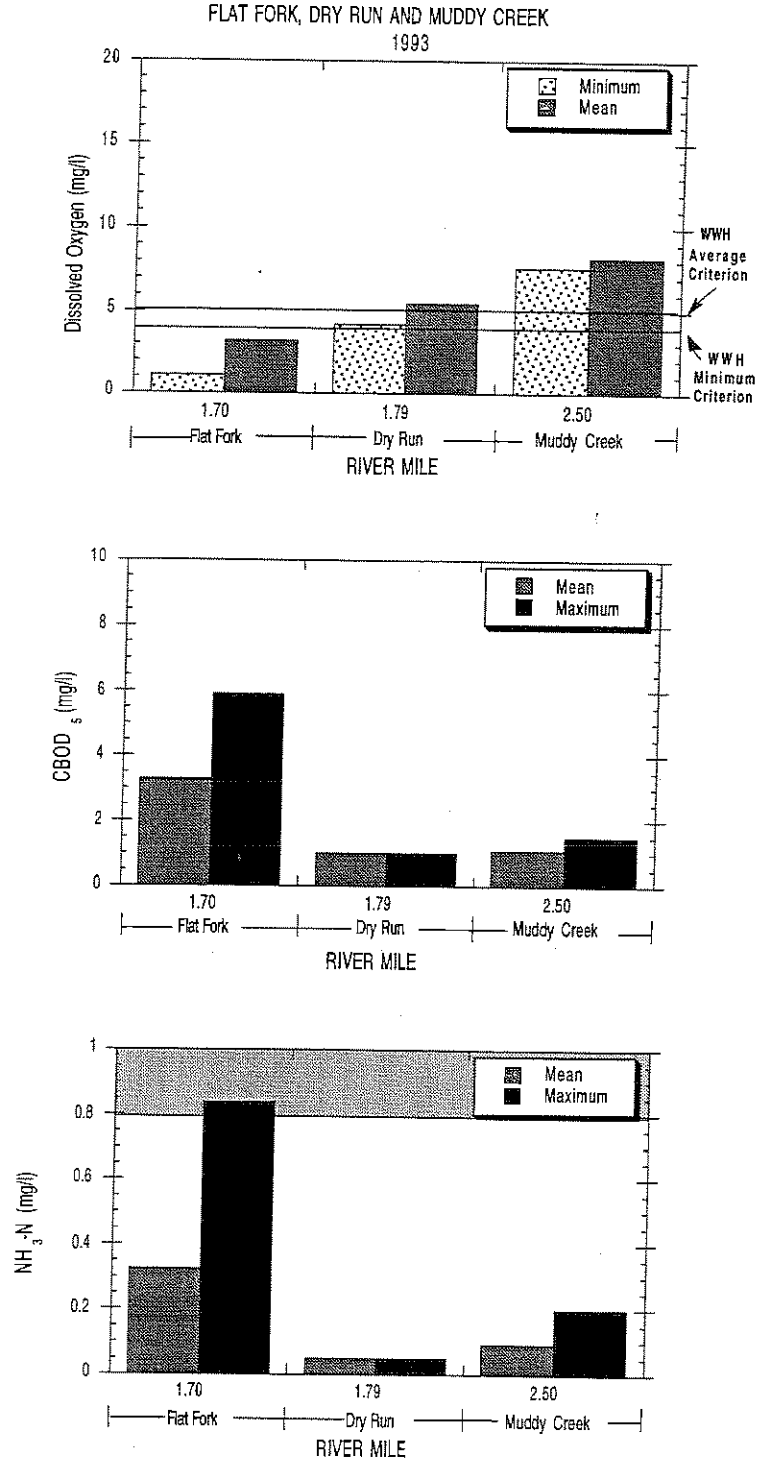


Figure 50. Longitudinal summary of dissolved oxygen (daytime grab minimum and mean values), $CBOD_5$, and ammonia-N (mean and maximum) concentrations in Flat Fork, Dry Run and Muddy Creek during the 1993 survey (*shaded area is the ammonia-N water quality criteria range between the 25th and 90th percentile pH and temperature recorded during sample collection*).

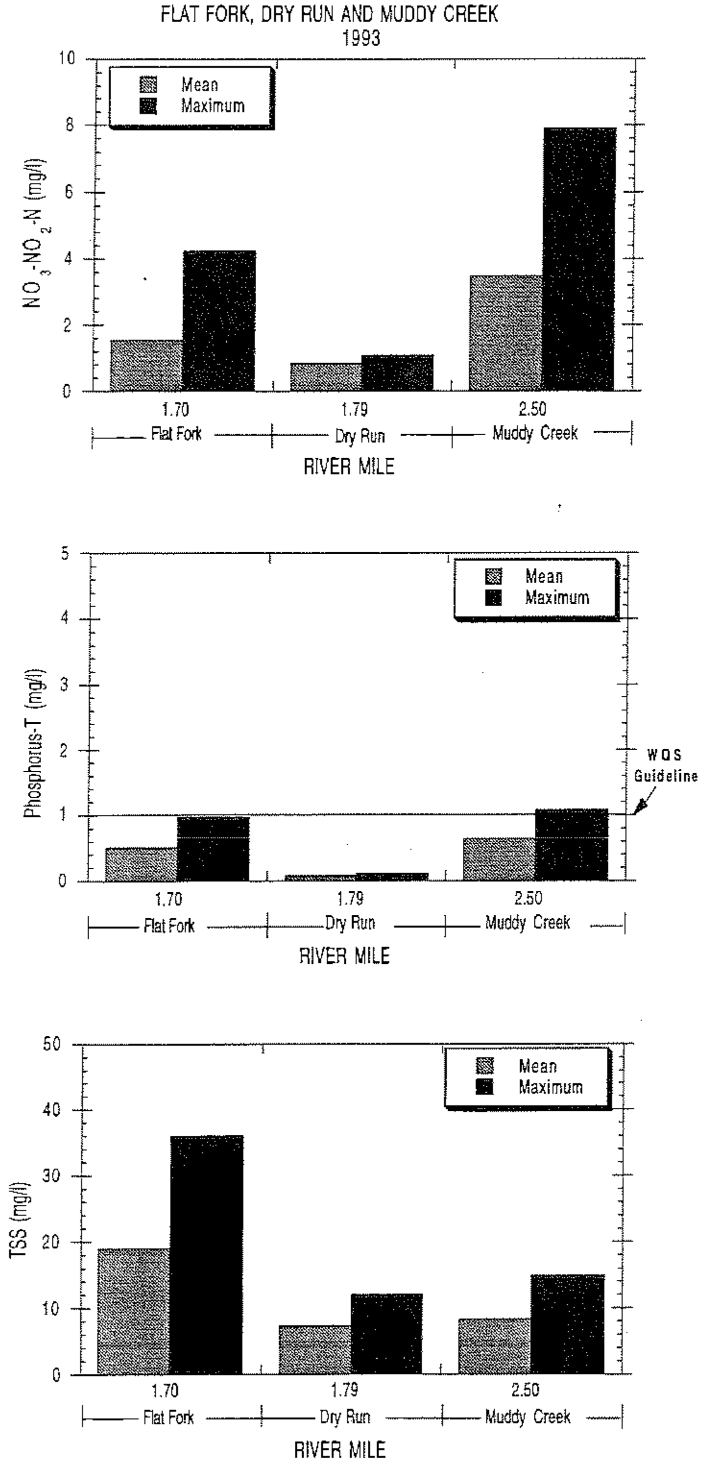


Figure 51. Longitudinal summary of nitrate+nitrite-N, total phosphorus, and total suspended solids (TSS) concentrations (mean and maximum values) in Flat Fork, Dry Run and Muddy Creek during the 1993 survey.

detected in the water column (Tables A-3 and A-5). Both locations in Caesar Creek (RMs 16.52 and 0.15) had higher average concentrations of nitrate+nitrite-N than the Anderson Fork site, but lower maximum values (Figure 49).

Flat Fork

- Low daytime grab dissolved oxygen values and moderate to high concentrations of $CBOD_5$, ammonia-N, TSS, fecal coliform, and *E. coli* in Flat Fork (RM 1.70) indicate degraded water quality. Various organochlorine pesticides, including dieldrin and endrin, were also detected (Figures 50-51, Tables 6, A-5). The sources of impact appear related to agricultural activities, the predominant land use within the watershed.

Dry Run

- Dry Run, a small tributary to Turtle Creek, had better water quality than Flat Fork. However, one daytime grab dissolved oxygen violation was detected at RM 1.7 (Figures 50-51, Table 6). Low flow conditions may have caused the below standard concentration.

Muddy Creek

- Water samples from Muddy Creek were collected at RM 2.50, approximately 0.7 miles downstream from the Mason WWTP. Sampling detected moderate to high levels of nitrate+nitrite-N and phosphorus (Figure 51). Dissolved oxygen values remained above the WWH minimum of 4.0 mg/l for all grab and datasonde samples. The 24 hour average concentrations for the 45 hourly values recorded by datasonde continuous monitors also remained above the 5.0 mg/l 24 hour average criterion (Figures 50 & 52a, Tables 6 & A-6).

- Frequent exceedences of the fecal coliform and *E. coli* primary contact recreation criteria and for residual chlorine were detected. Organic water column sampling also detected exceedences for dieldrin and endrin (*i.e.*, concentrations above detection limits are exceedences; Table 6, A-5). An extremely elevated copper value (486 µg/l) in excess of the final acute value (FAV) was recorded at RM 2.50 on August 26 (Table 6). All other copper levels recorded at this location, however, were below the minimum detection limit.

Turtle Creek

- Although no flow measurements were taken, visual observations in Turtle Creek suggest flows downstream from Mason Road (RM 0.70) were substantially lower in 1993 than during previous sampling years (1989-1992; the sites upstream and downstream from Cincinnati Milacron were sampled each year). The significantly lower water levels suggests localized dewatering of Turtle Creek has occurred. The source of the dewatering is unknown, but possibly includes well water withdrawals) and/or quarrying. This situation requires further investigation.

- In May of 1993, Cincinnati Milacron changed their discharge configuration to Turtle Creek from a high gradient, cascading falls (similar to the Yellow Springs Creek WWTP discharge) to an instream multi-port diffuser (Plate 11). During the summer of 1993, numerous chemical criteria exceedences were detected within and downstream from the diffuser mixing zone (RM 0.58-0.52, Figures 52a-56, Table 6). Copper levels consistently exceeded the final acute value (FAV) from the mixing zone to State Route 48 (RM 0.58-0.52), but declined by RM 0.01. One elevated mercury concentration (1.35 µg/l) was also recorded in the mixing zone. Ambient chemical concentrations downstream from the Cincinnati Milacron effluent may have been higher than predicted due to less dilution caused by the lower flows in Turtle Creek during 1993.

- Dissolved oxygen levels in Turtle Creek were detected below 4.0 mg/l both upstream and downstream from Cincinnati Milacron (RMs 5.0-0.1). Below standard values were detected in daytime grab samples between RMs 5.0-0.7 and by datasonde continuous monitors from

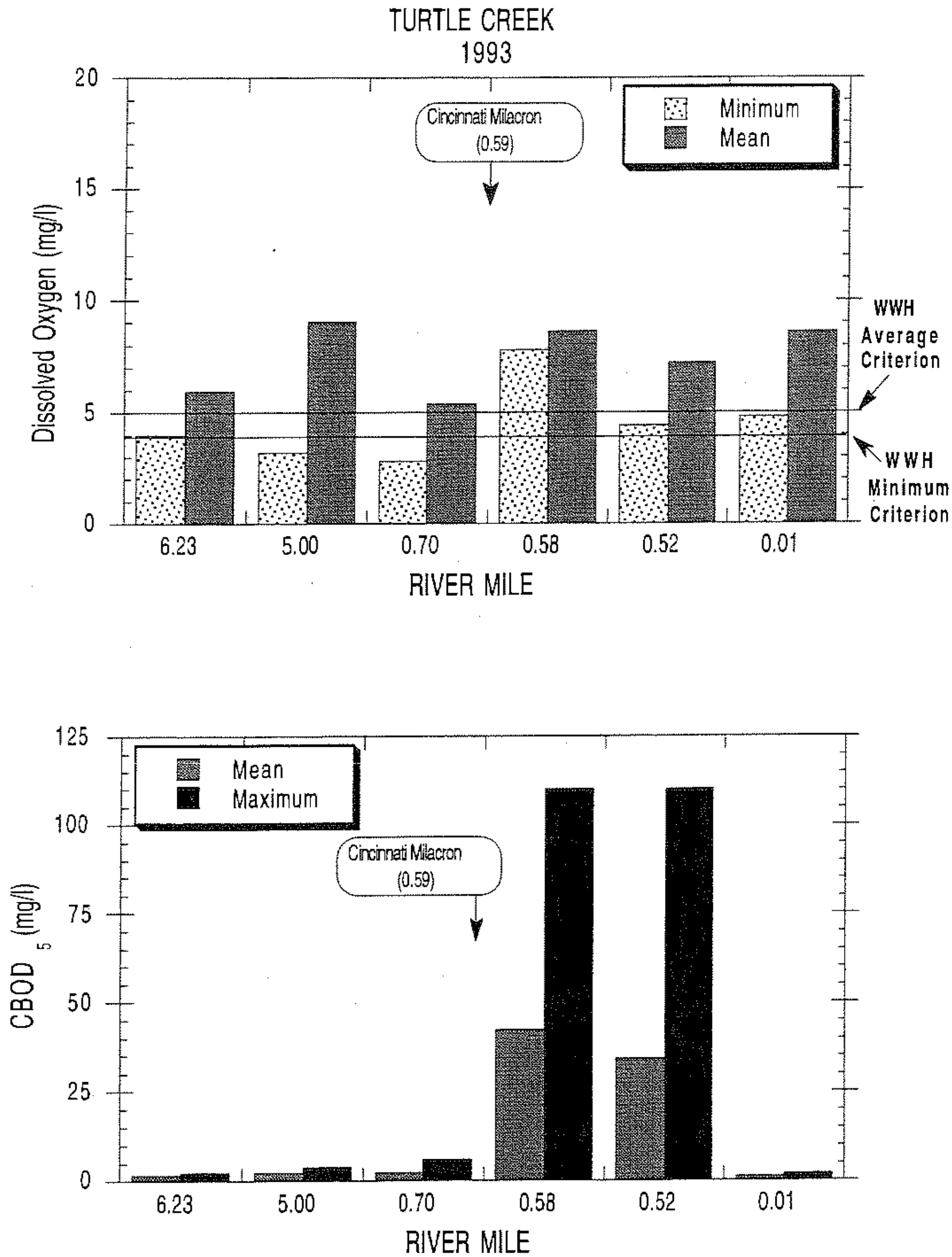


Figure 52a. Longitudinal summary of dissolved oxygen (daytime grab minimum and mean values) and $CBOD_5$ (mean and maximum values) concentrations in Turtle Creek during the 1993 survey. The Cincinnati Milacron diffuser mixing zone values are shown for RM 0.58.

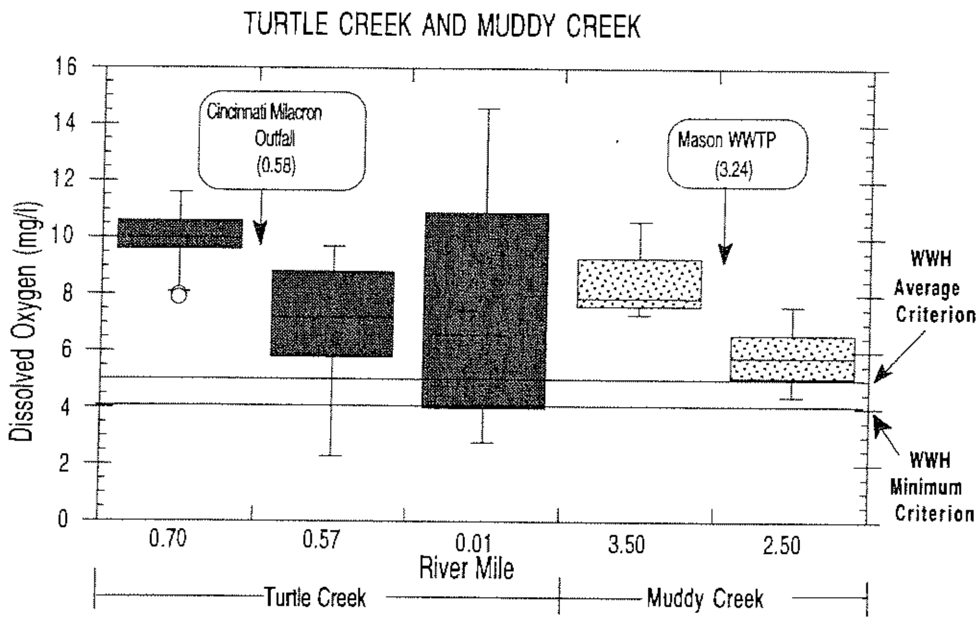


Figure 52b. Longitudinal summary (box and whisker plots) of dissolved oxygen concentrations recorded with Datasonde continuous monitors in Turtle Creek from September 28-October 1, 1993 and in Muddy Creek from August 31-September 2, 1993.

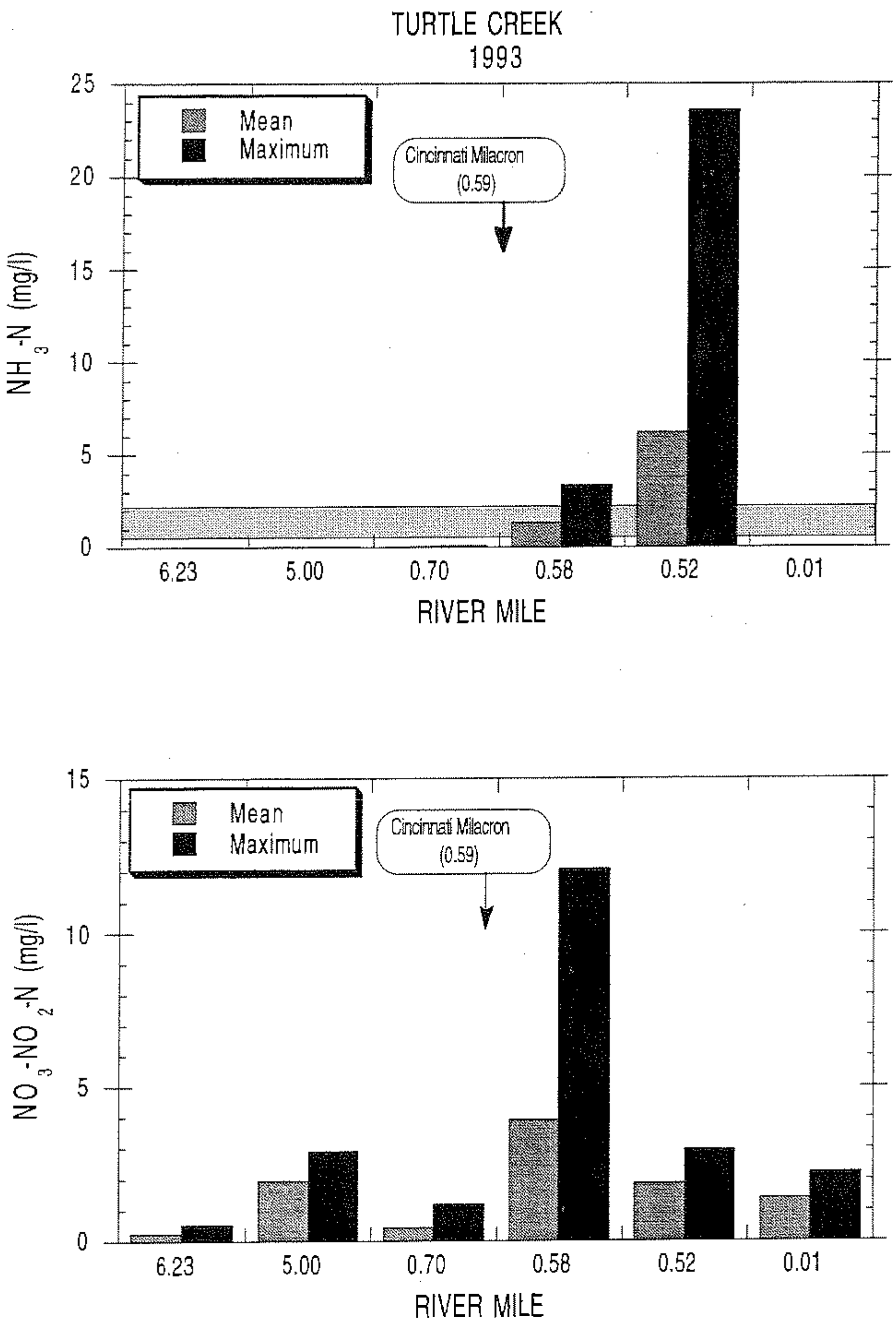
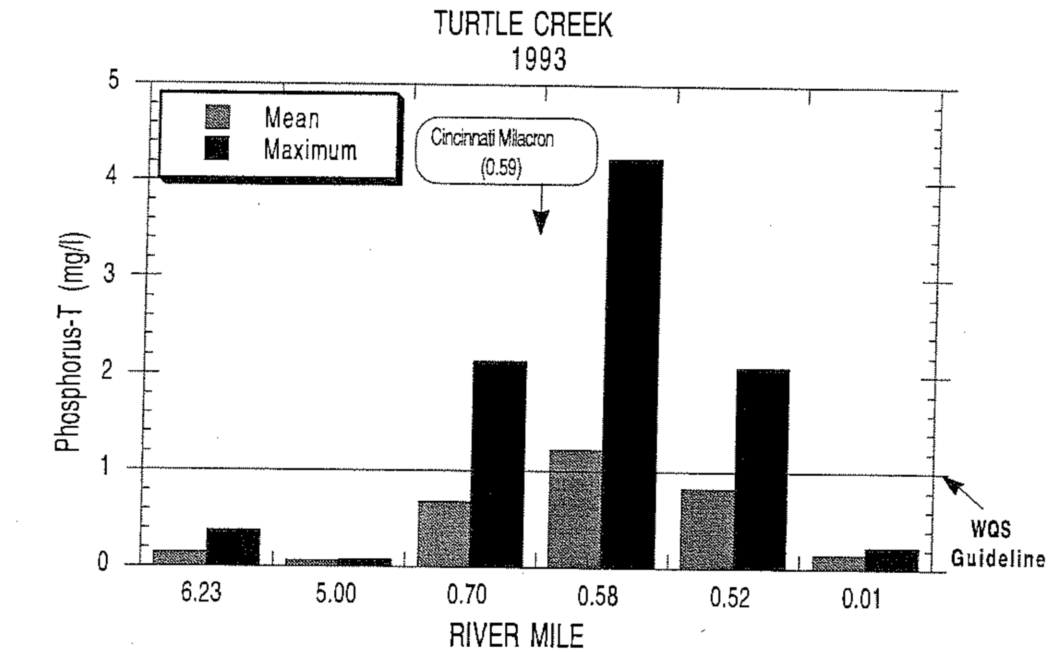


Figure 53. Longitudinal summary of ammonia-N and nitrate+nitrite-N concentrations (mean and maximum values) in Turtle Creek during the 1993 survey (*shaded area is the ammonia-N water quality criteria range between the 25th and 90th percentile pH and temperature recorded during sample collection*). The Cincinnati Milacron diffuser mixing zone values are shown for RM 0.58.



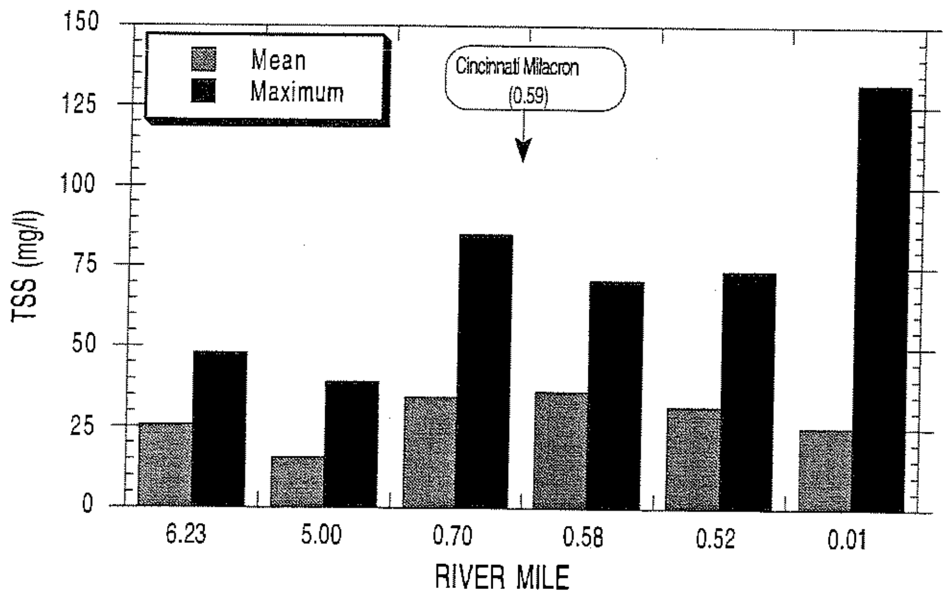


Figure 54. Longitudinal summary of total phosphorus and total suspended solids TSS) concentrations (mean and maximum values) in Turtle Creek during the 1993 survey. The Cincinnati Milacron diffuser mixing zone values are shown for RM 0.58.

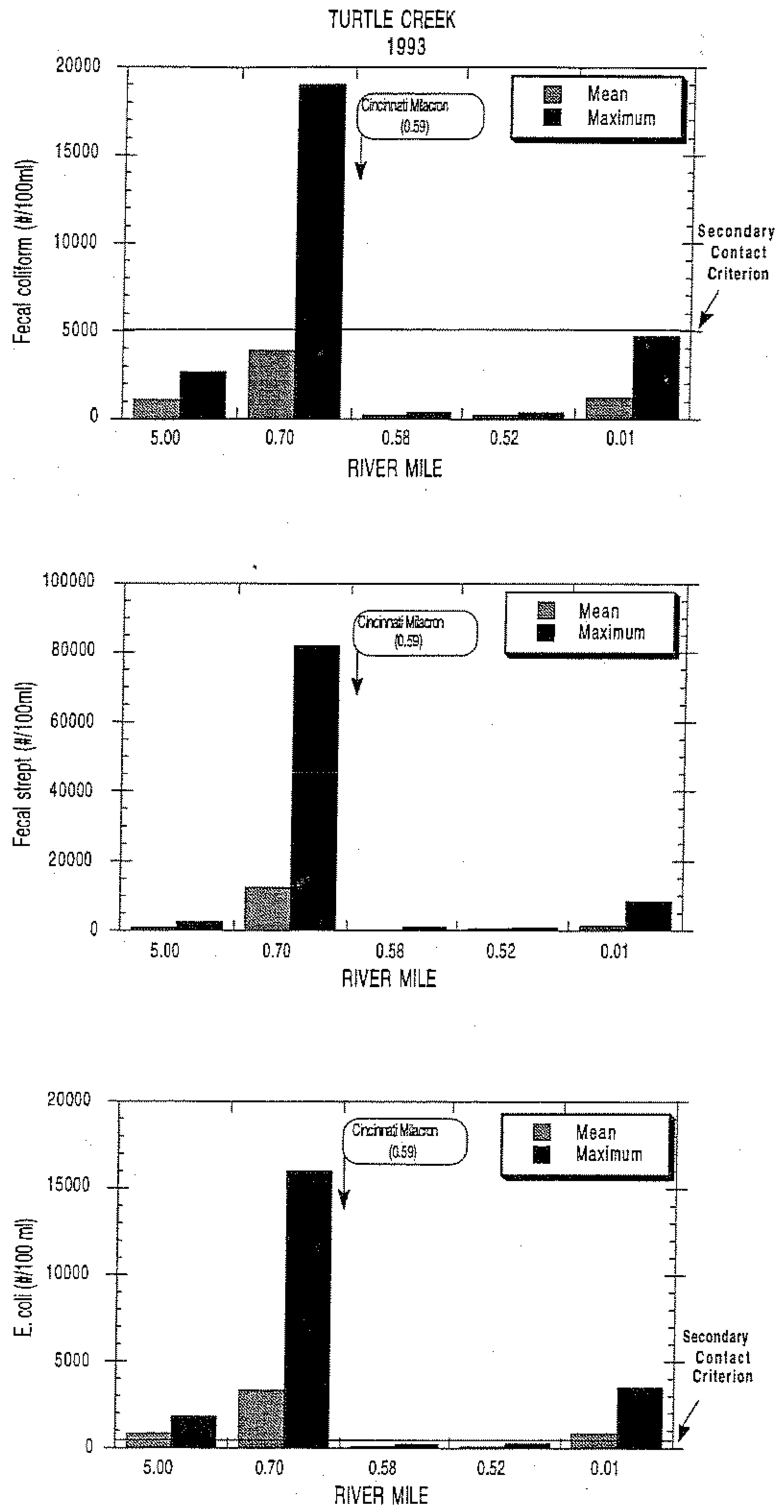
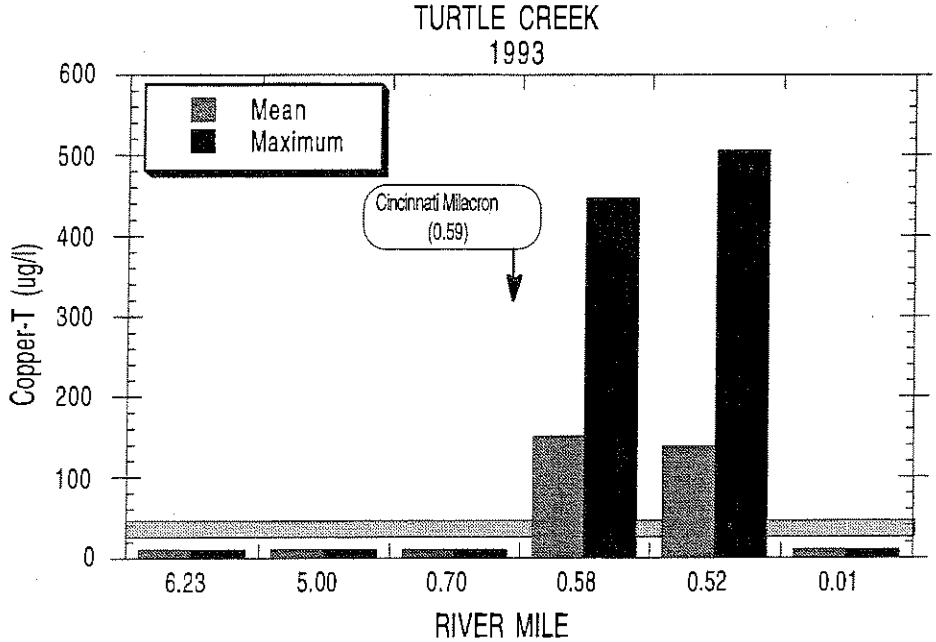


Figure 55. Longitudinal summary of fecal coliform, fecal strept and E. coli concentrations (mean and maximum values) in Turtle Creek during the 1993 survey. The Cincinnati Milacron diffuser mixing zone values are shown for RM 0.58.



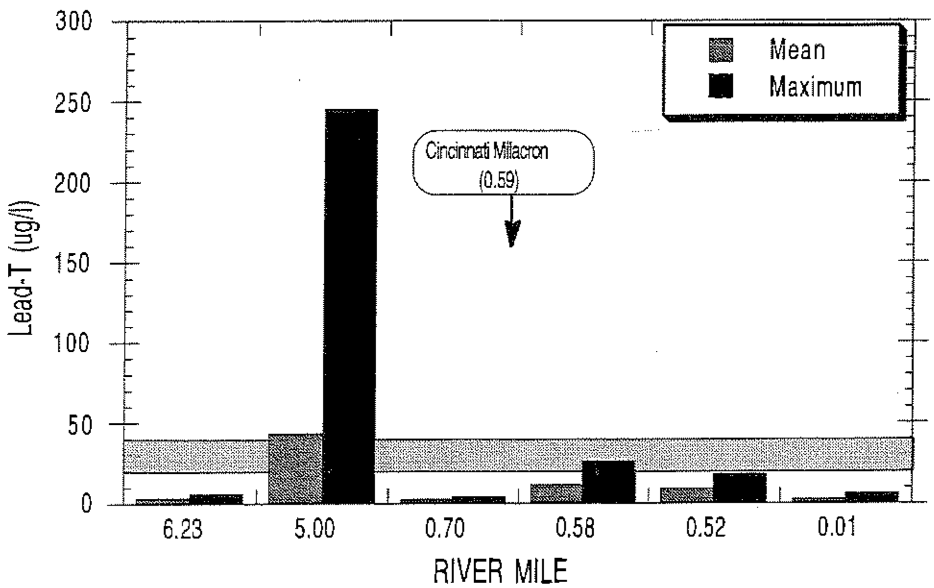


Figure 56. Longitudinal summary of copper and lead concentrations (mean and maximum values) in Turtle Creek during the 1993 survey (*shaded area is the water quality criteria range between the 25th and 90th percentile hardness recorded during sample collection*). The Cincinnati Milacron diffuser mixing zone values are shown for RM 0.58.

Cincinnati Milacron to the mouth (RMs 0.57-0.01, Figures 52a-52b, Table 6, A-6). The 24 hour continuous data also revealed a larger diel fluctuation (*i.e.,* the difference between day and night values) in D.O. concentrations downstream from the industrial discharge. The minimum to maximum difference increased from 3.7 mg/l at Mason-Morrow Road to 7.4-11.8 mg/l downstream from the industry (the first and third largest range in datasonde values of the 55 locations monitored throughout the study area). The larger variation between day and night values is indicative of excessive algal production which is the result of nutrient enrichment.

- Exceptionally high $CBOD_5$ values were also recorded downstream from the diffuser (RMs 0.58 and RM 0.52, Figure 52a). Ammonia-N concentrations were also elevated in the mixing zone and frequently exceeded water quality criteria downstream at RM 0.52 (Table 6, Figure 53). Water samples also indicated elevated levels of total dissolved solids, chemical oxygen demand (COD), total organic carbon (TOC), chlorides, and phosphorus (Figure 54, Tables 6, A-4).

- Except for lead, chemical sampling sites upstream from Cincinnati Milacron generally had fewer elevated concentrations than sites downstream. Concentrations of $CBOD_5$, ammonia-N, and nitrate+nitrite-N at the three upstream sites (RMs 6.23, 5.00, and 0.70) were consistently low throughout the survey. Phosphorus levels at RM 0.70 increased above the WQS guideline of 1.0 mg/l on one occasion (Figures 52a-56).

- The *E. coli* secondary contact recreation criterion was frequently exceeded at RMs 5.00, 0.70, and 0.01. The highest bacterial counts of fecal coliform, fecal strep, and *E. coli* in Turtle Creek during the survey occurred on July 14 during a high flow event. The values were highest at RM 0.70, upstream from the industrial discharge (Figure 55, Table 6).

- A total of 10 and 11 organochlorine pesticides, semi-volatile, and volatile organic compounds were detected in Turtle Creek at Glosser Road and the Cincinnati Milacron diffuser mixing zone, respectively (RMs 6.23 and 0.58, Tables 6, A-5). Notable differences included the presence of benzene, bromoform, and phthalates at RM 0.58 and toluene and dieldren at RM 6.23.

Sycamore Creek

- No dissolved oxygen violations were detected in Sycamore Creek, but Datasonde continuous monitors documented a sharp decline downstream from the Hamilton Co. MSD Sycamore Creek WWTP (RM 0.05, Figures 57a-57b, Table A-6). The 24-hour continuous monitors also detected a large diel swing in D.O. values (9.3 mg/l, the second largest minimum to maximum range in the study area) at RM 0.27 indicating the presence of excessive nutrient loadings upstream from the WWTP as well. Sludge deposits were observed downstream from the WWTP, but were not evident immediately upstream.

- Low $CBOD_5$ and ammonia-N concentrations were recorded at all three sampling locations. Nutrient loadings from the Hamilton Co. MSD Sycamore Creek WWTP were indicated by elevated nitrate+nitrite-N and phosphorus levels within and downstream from the mixing zone (RM 0.25-0.05). Total suspended solids concentrations remained fairly constant throughout the stream (Figures 57a, 58).

- Elevated counts of fecal coliform, fecal strept, and *E. coli* bacteria were recorded both upstream and downstream from the WWTP. Sanitary sewer overflows (SSOs) and leaking sewer lines upstream from the WWTP are the likely sources of the elevated fecal bacteria counts recorded at RM 0.40 (Figure 59, Table 6).

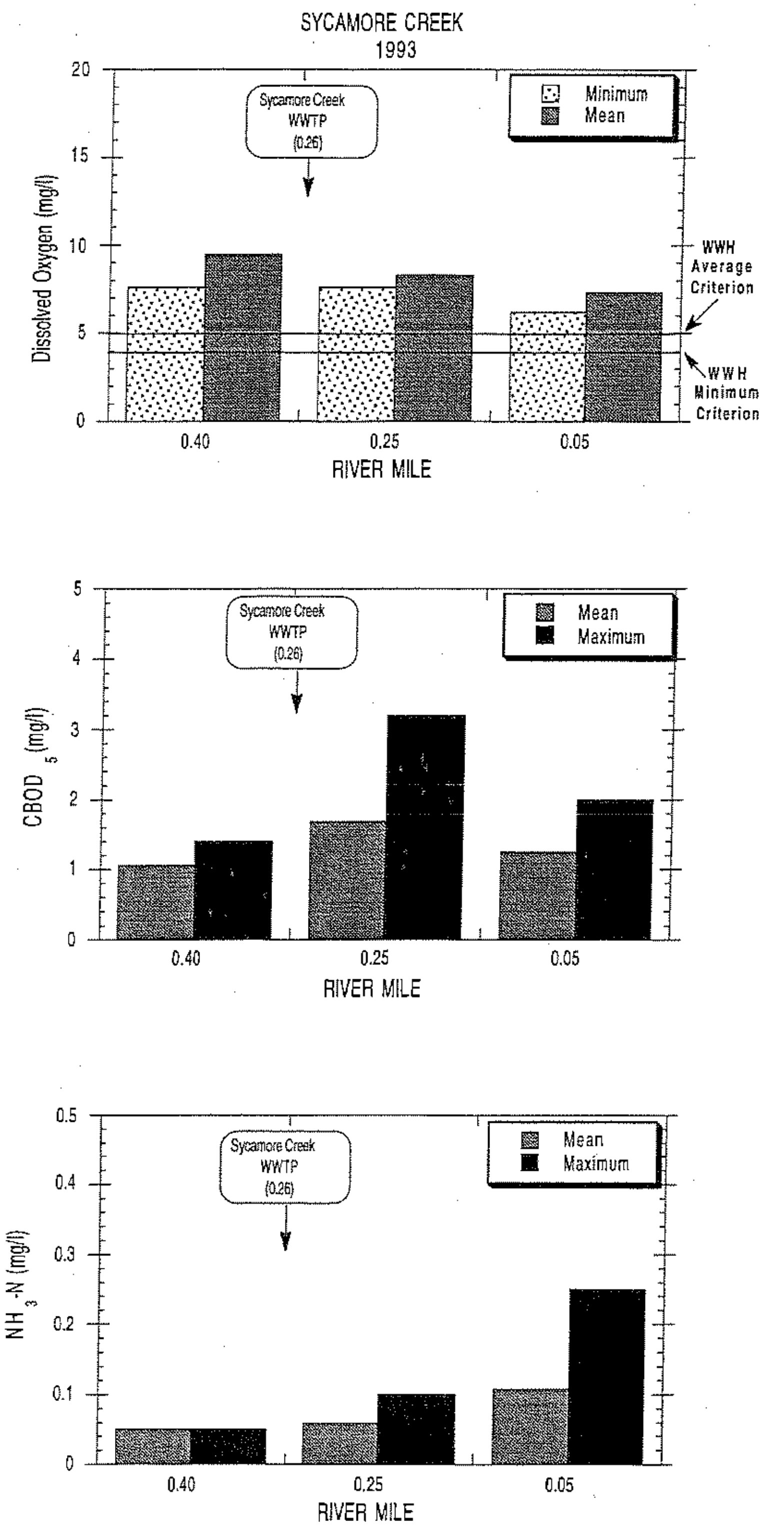


Figure 57a. Longitudinal summary of dissolved oxygen (daytime grab minimum and mean values), $CBOD_5$, and ammonia-N (mean and maximum values) concentrations in Sycamore Creek during the 1993 survey. Mixing zone values are shown for RM 0.25.

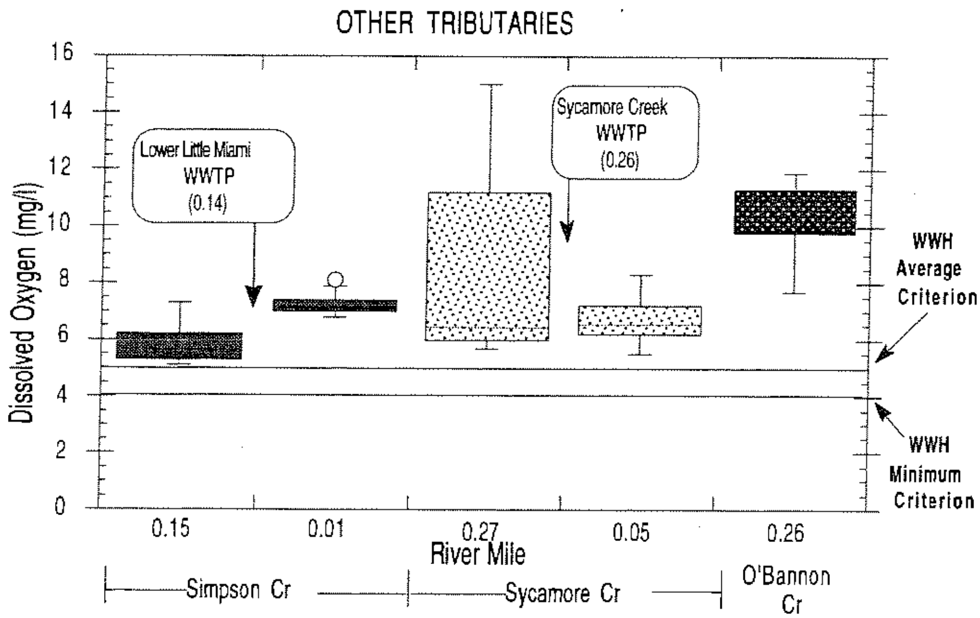


Figure 57b. Longitudinal summary (box and whisker plots) of dissolved oxygen concentrations recorded with Datasonde continuous monitors in Simpson Creek from August 31-September 2, 1993 and in Sycamore and O'Bannon creeks from September 21-23, 1993.

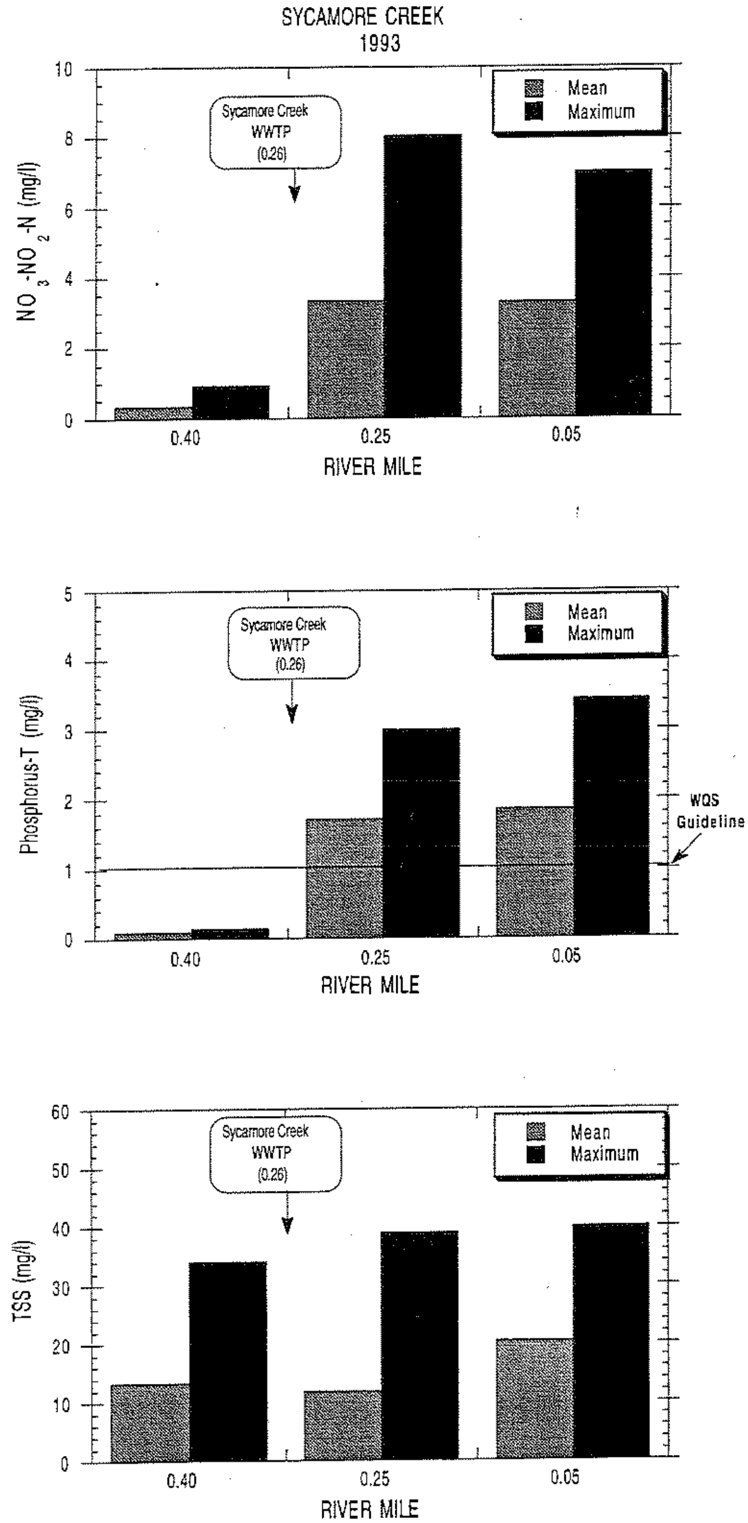


Figure 58. Longitudinal summary of nitrate+nitrite-N, total phosphorus, and total suspended solids (TSS) concentrations (mean and maximum values) in Sycamore Creek during the 1993 survey. Mixing zone values are shown for RM 0.25.

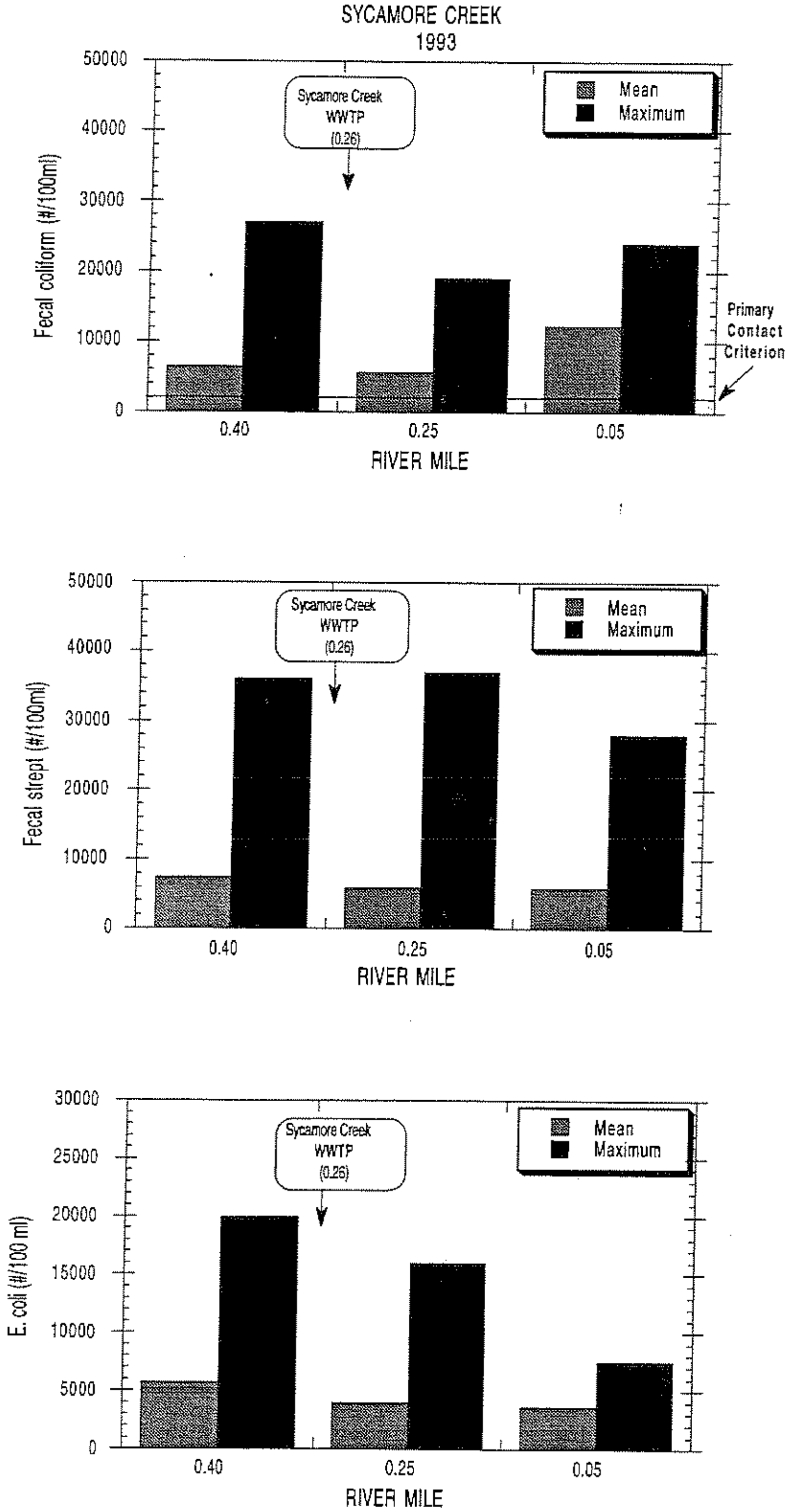


Figure 59. Longitudinal summary of fecal coliform, fecal strep, and *E. coli* concentrations (mean and maximum values) in Sycamore Creek during the 1993 survey. Mixing zone values are shown for RM 0.25.

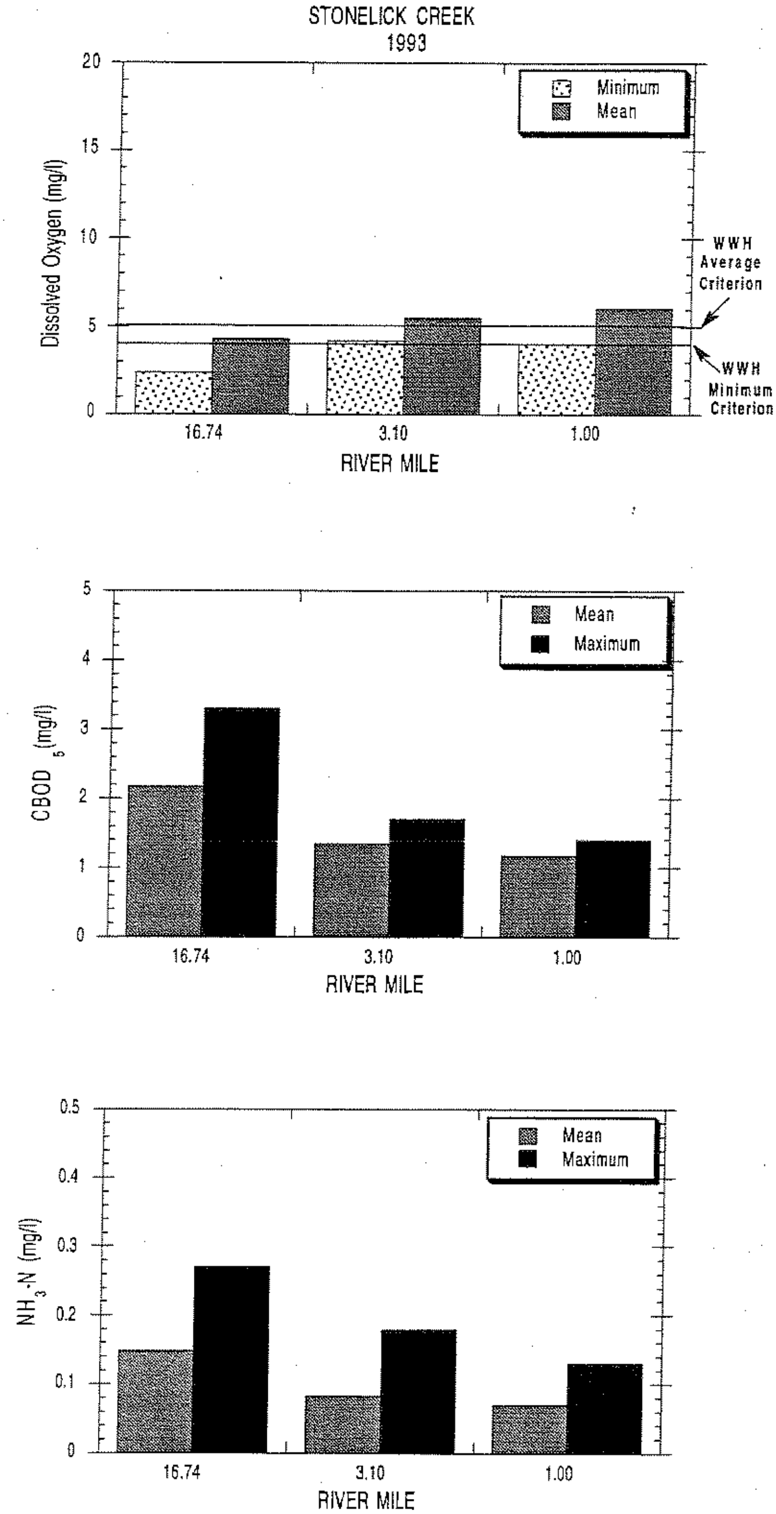


Figure 60. Longitudinal summary of dissolved oxygen (daytime grab minimum and mean values), $CBOD_5$, and ammonia-N (mean and minimum values) concentrations in Stonelick Creek during the 1993 survey.

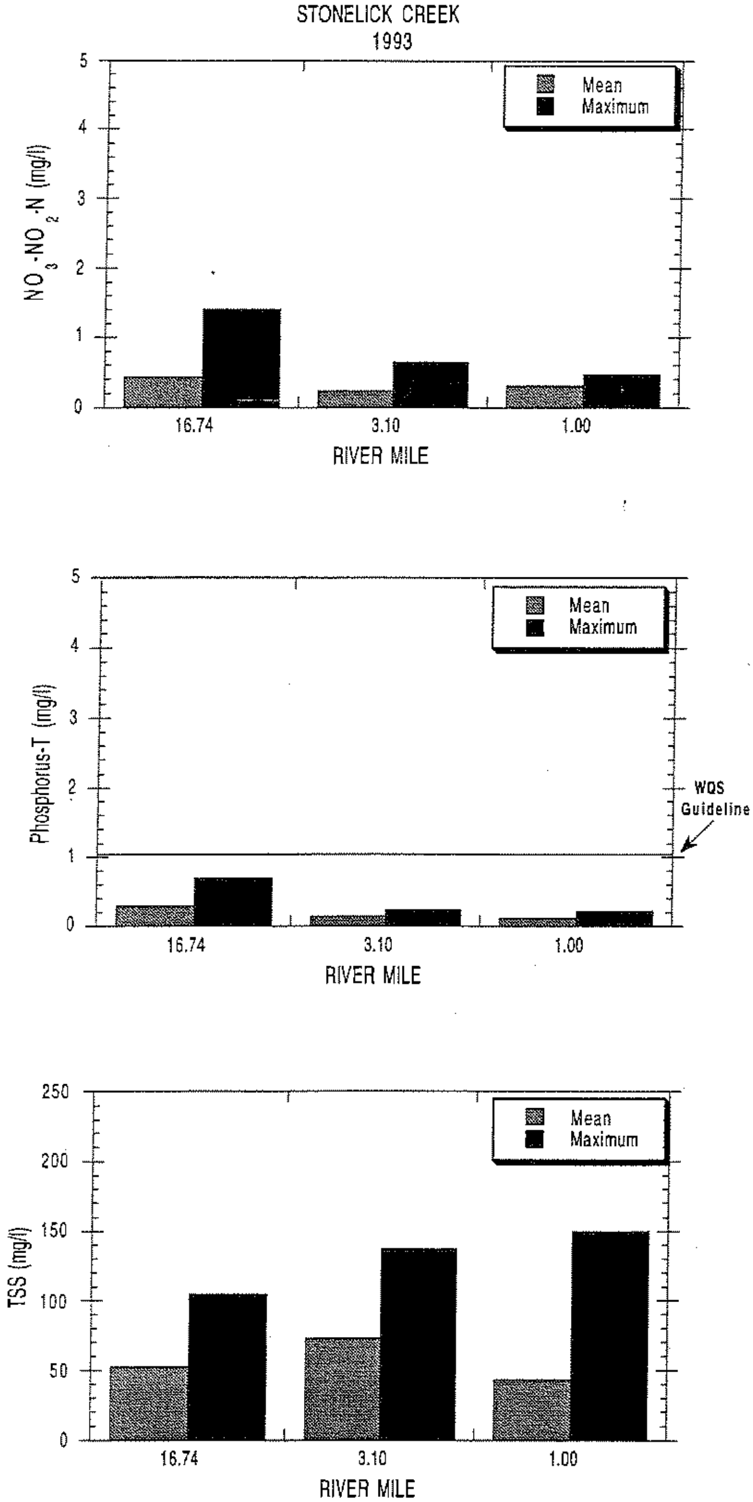


Figure 61. Longitudinal summary of nitrate+nitrite-N, total phosphorus, and total suspended solids (TSS) concentrations (mean and maximum values) in Stonelick Creek during the 1993 survey.

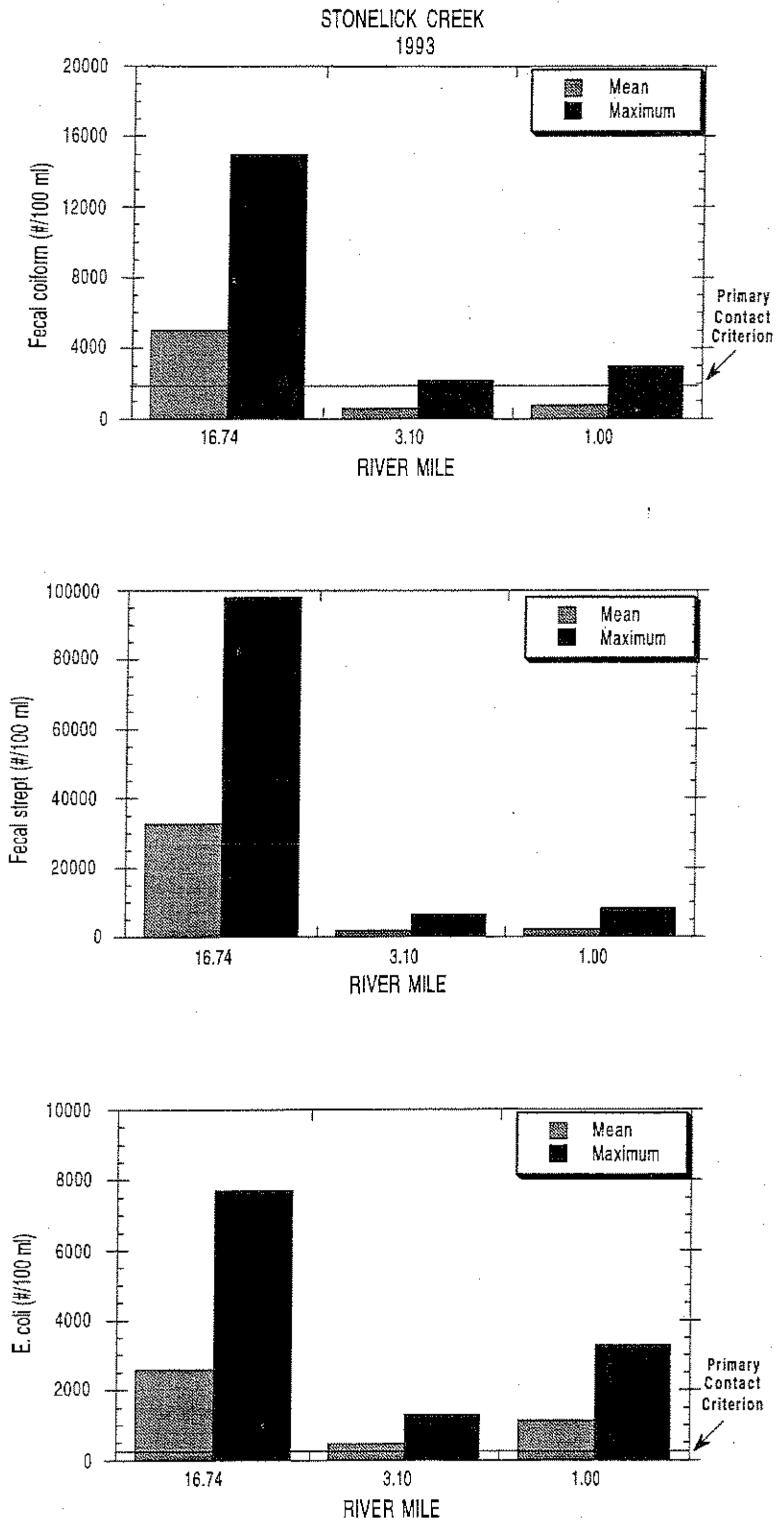


Figure 62. Longitudinal summary of fecal coliform, fecal strep, and *E. coli* concentrations (mean and maximum values) in Stonelick Creek during the 1993 survey.

- A total of 12 organochlorine pesticides and volatile organic compounds were detected in water samples collected downstream from the WWTP. Concentrations of four different pesticides exceeded water quality criteria (Tables 6, A-5). The water column was not tested for organic compounds in Sycamore Creek upstream from the WWTP.

Stonelick Creek

- Daytime grab D.O. concentrations declined to less than 4.0 mg/l only at the upstream sampling location within the impoundment influence of Stonelick Lake (RM 16.74, Figure 60, Table 6).

- Concentrations of $CBOD_5$, ammonia-N, nitrate+nitrite-N, and phosphorus were highest at RM 16.74, but remained relatively low throughout the creek (Figures 60,61).

- Fecal coliform, fecal strep, and *E. coli* bacteria counts were highest in the upper end of Stonelick Lake (RM 16.74). The highest values were recorded during high flows on July 15, 1993 (Figure 62, Table 6). Fecal bacteria counts on all other days were relatively low, indicating the source is predominantly nonpoint i origin (Table A-4).

- A total of 7 to 9 organochlorine pesticides and volatile organic compounds were detected at each of the three sampling locations (Table A-5). Organochlorine pesticide concentrations exceeded water quality criteria at all three sites (Table 6). Low levels of volatile organic compounds were also detected at RM 16.74 and RM 3.10 (Table A-5).

- One water sampled collected from Stonelick Lake contained a slightly elevated lead concentration (5 µg/l) that exceeded the chronic water quality criterion (Table 6). The hardness was unusually low (63 mg/l) which contributed to this low value being an exceedence.

East Fork Little Miami River

- Stream flows in the East Fork near Batavia from May through September 1993 followed an overall pattern of declining values (Figure 63a). However, lower than normal flows of less than 30 cfs ($Q_{7,10}$ = 30 cfs) were recorded during the last two weeks of July. Stream flow in the East Fork is regulated by releases from the Harsha Reservoir (East Fork Lake).

- Daytime grab D.O. values at two sites in the East Fork (RMs 9.10 and 0.77) were below the minimum EWH water quality criterion of 6.0 mg/l on one day (Figure 63b, Table 6). A below standard value was also measured in the Batavia WWTP mixing zone (RM 13.35). Datasonde continuous samplers set at RMs 6.57, 4.30, and 2.50 recorded dissolved oxygen concentrations well above 6.0 mg/l during September 28 - October 1, 1993 (Figure 63c, Table A-6). Lower D.O. values, however, may have occurred during late July when low flow values were below the $Q_{7,10}$ flow of 30 cfs.

- $CBOD_5$ concentrations were generally low, but showed a slight increase downstream from the Clermont Co. Lower East Fork Regional WWTP outfall (RM 4.85, Figure 63b).

- The majority of ammonia-N concentrations recorded in the East Fork were at or below the minimum detection limit of 0.05 mg/l (Table A-4). Ammonia-N concentrations were frequently elevated in the Batavia WWTP mixing zone (RM 13.35, Figure 64).

- Nitrate+nitrite-N and total phosphorus concentrations increased in the Batavia WWTP mixing zone (RM 13.35), peaked in the Middle East Fork WWTP mixing zone (RM 12.59), and were also elevated downstream from the Clermont Co. Lower East Fork Regional WWTP. Lower concentrations reflecting background conditions were recorded between RMs 9.10 - 6.57 and RMs 4.00 - 0.77 (Figures 64-65, Table 6).

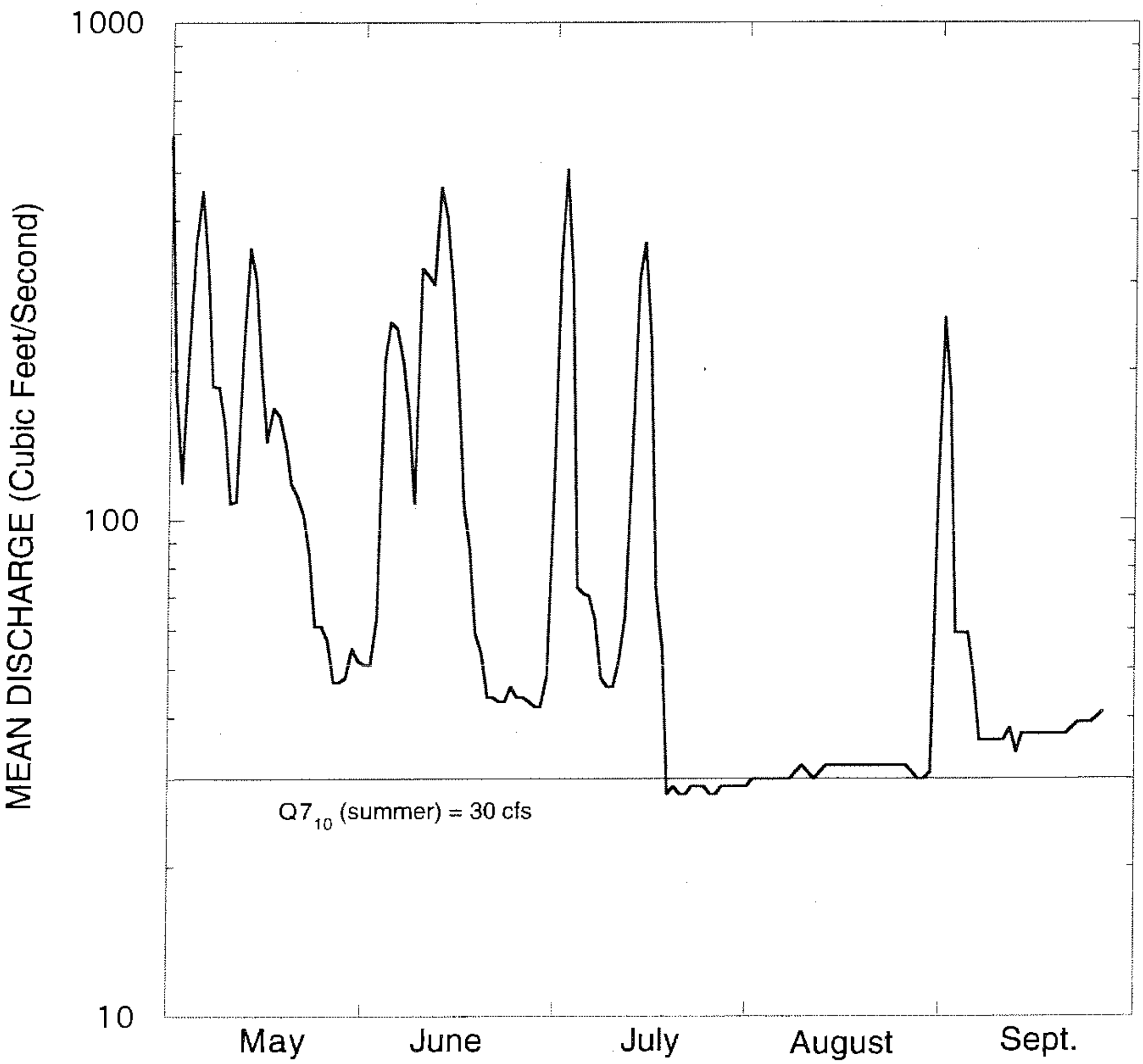
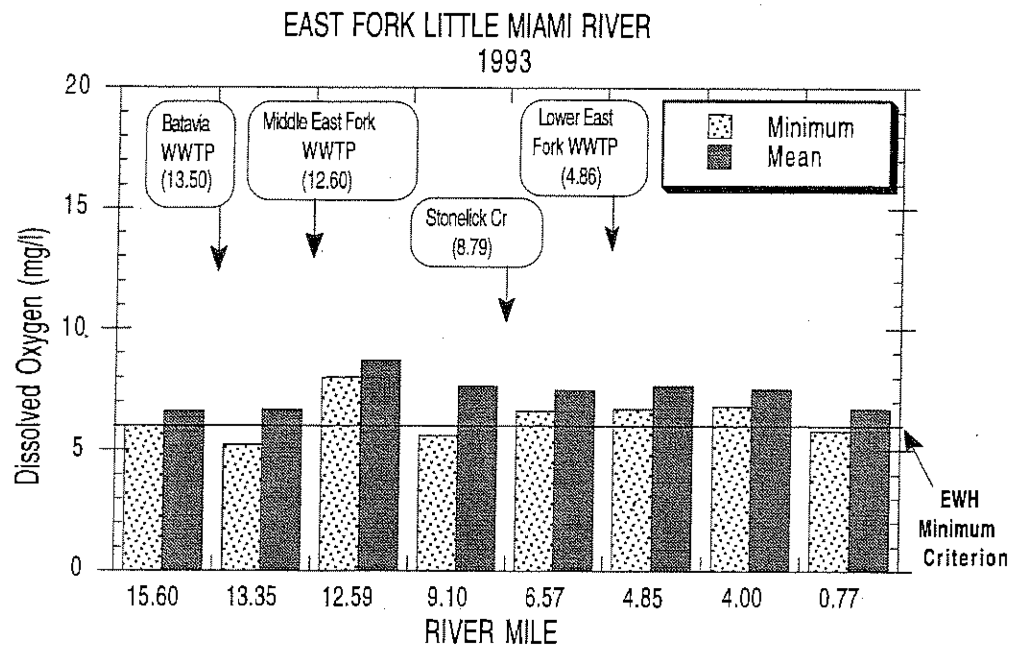


Figure 63a. May through September, 1993, flow hydrograph for the East Fork Little Miami River near Batavia, Clermont Co. (RM 15.6). Low flow conditions ($Q7_{10}$ [30 cubic feet/second (cfs)] is based on the USGS gage station #03247050. Period of record: 1965 until present. Eighty percent duration exceedence data is not available.



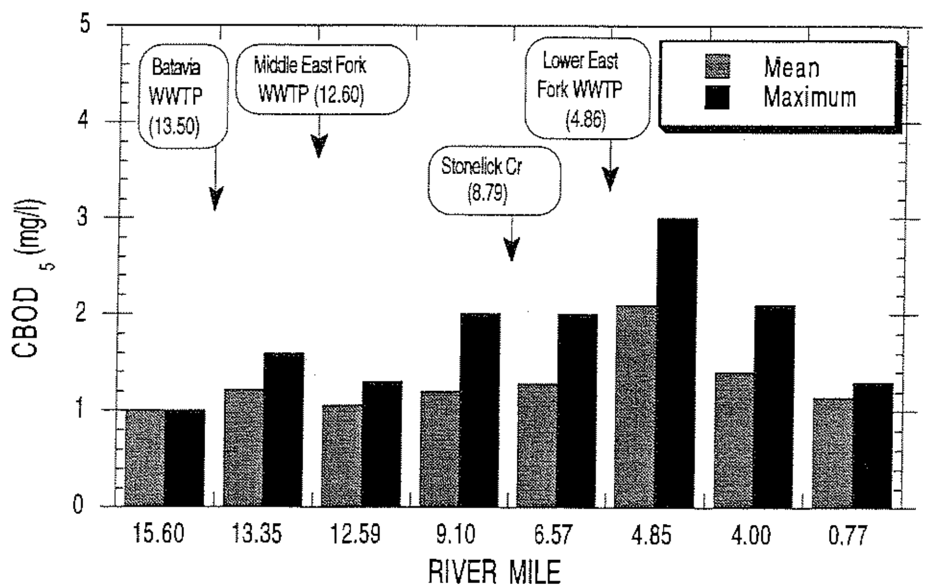


Figure 63b. Longitudinal summary of dissolved oxygen (daytime grabs) and $CBOD_5$ concentrations (mean and maximum values) in the East Fork Little Miami River during the 1993 survey. Mixing zone values are shown for RMs 13.35 and 12.59.

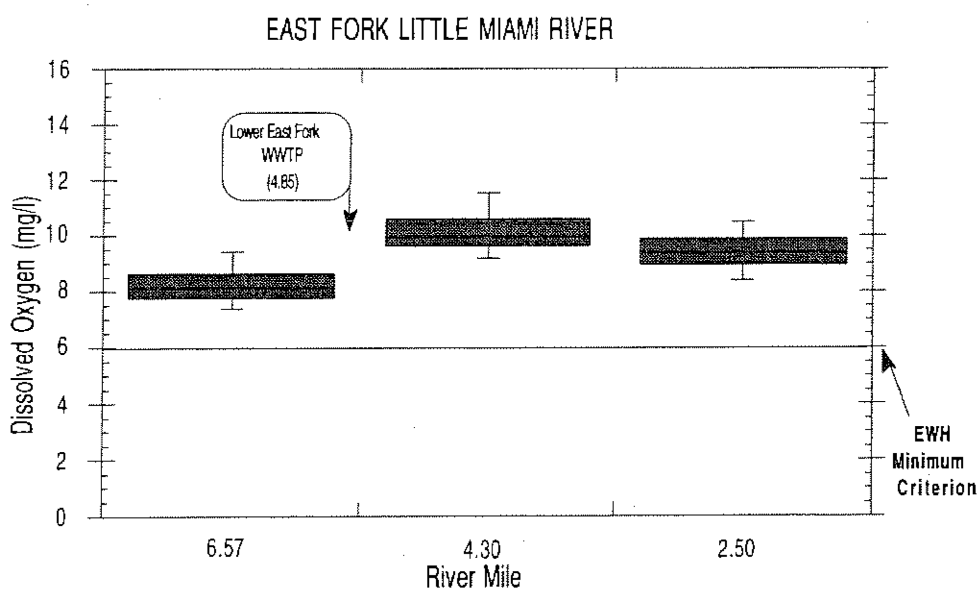


Figure 63c. Longitudinal summary (box and whisker plots) of dissolved oxygen concentrations recorded with Datasonde continuous monitors in the East Fork Little Miami River during from September 28 - October 1, 1993.

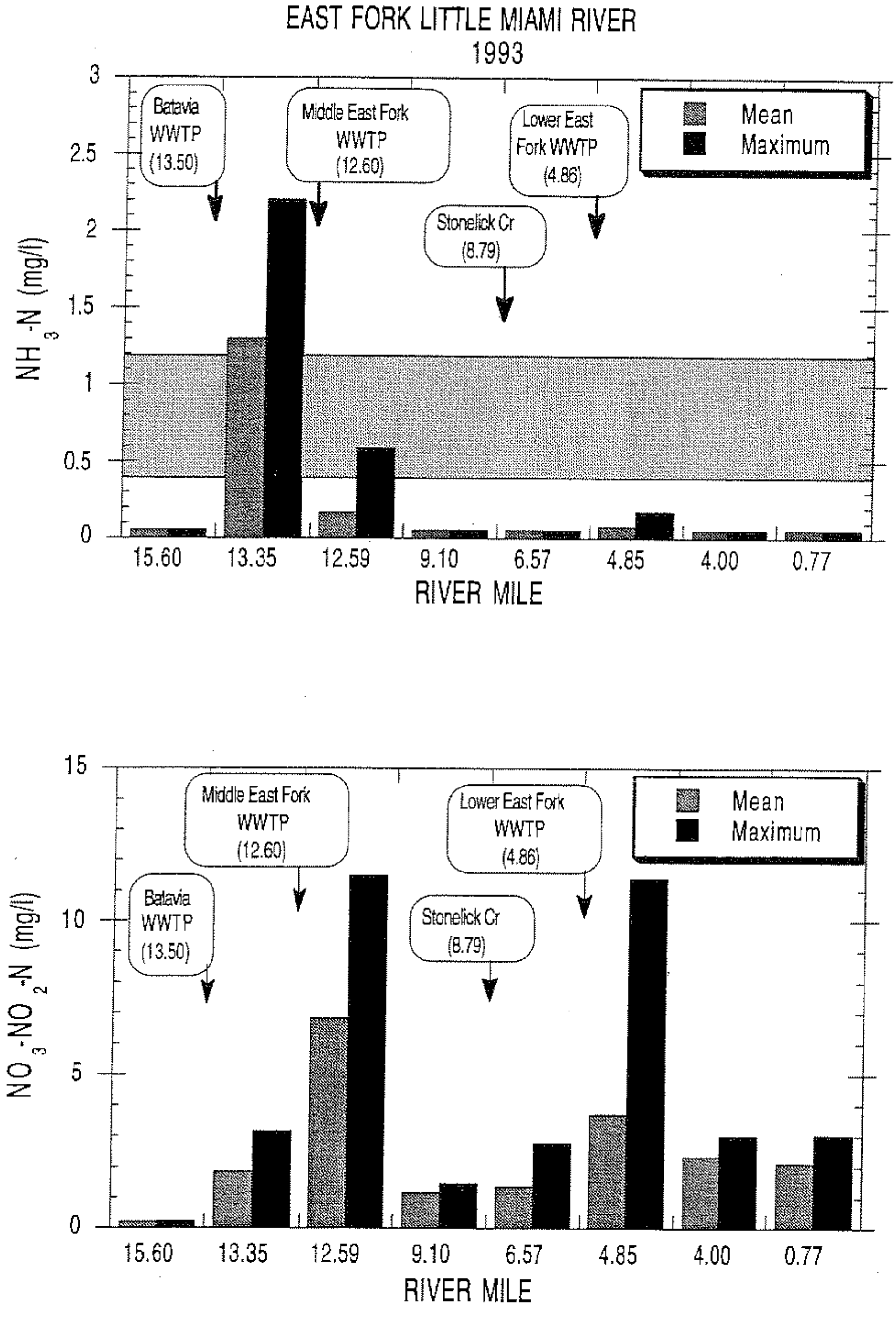


Figure 64. Longitudinal summary of ammonia-N and nitrate+nitrite-N concentrations in the East Fork Little Miami River during the 1993 survey *(shaded area is the ammonia- -N water quality criteria range between the 25th and 90th percentile pH and temperature recorded during sample collection).* The criteria does not apply for mixing zone values shown for RM 13.35 and 12.59.

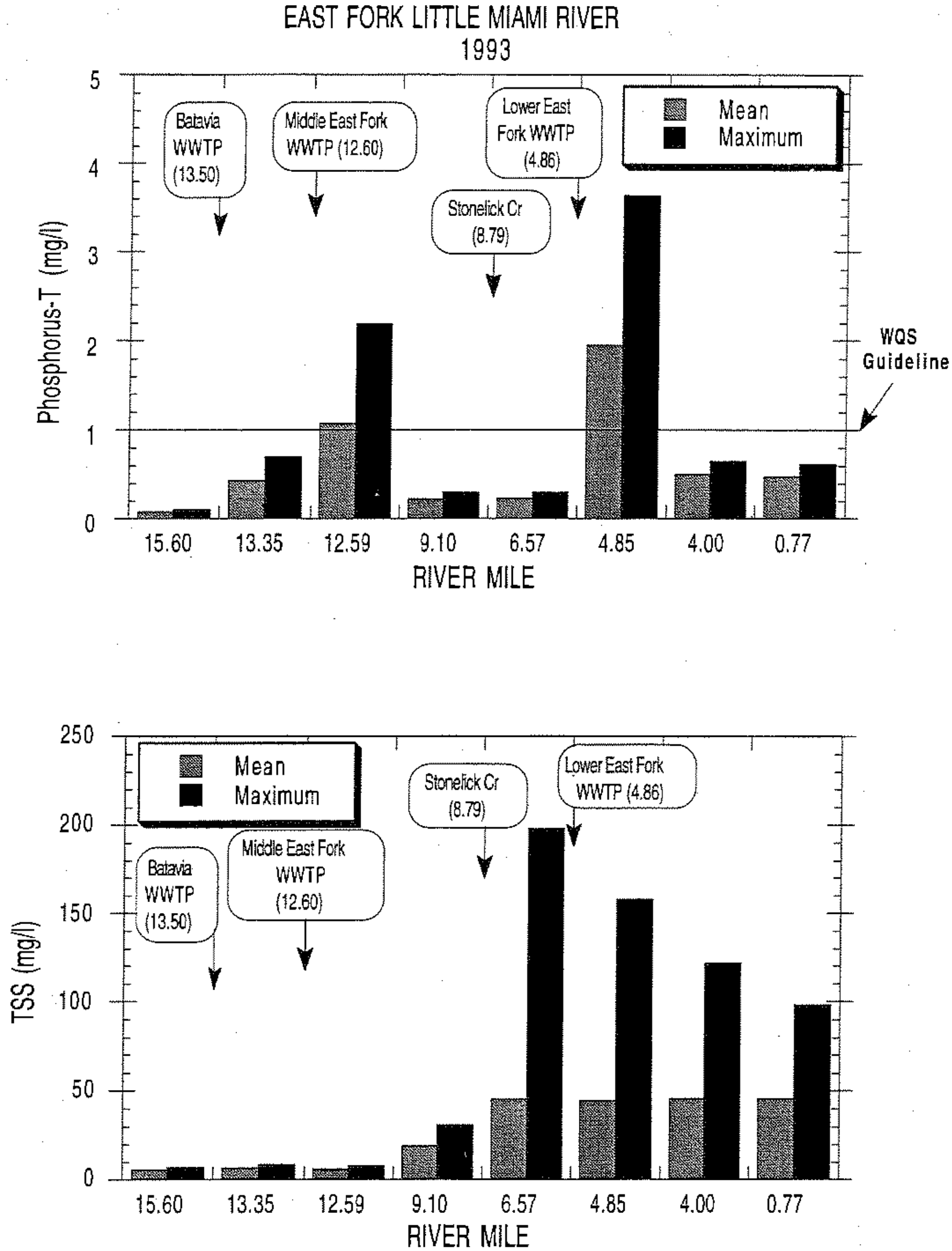


Figure 65. Longitudinal summary (mean and maximum values) of total phosphorus and total suspended solids (TSS) concentrations in the East Fork Little Miami River during the 1993 survey. Mixing zone values are shown for RMs 13.35 and 12.59.

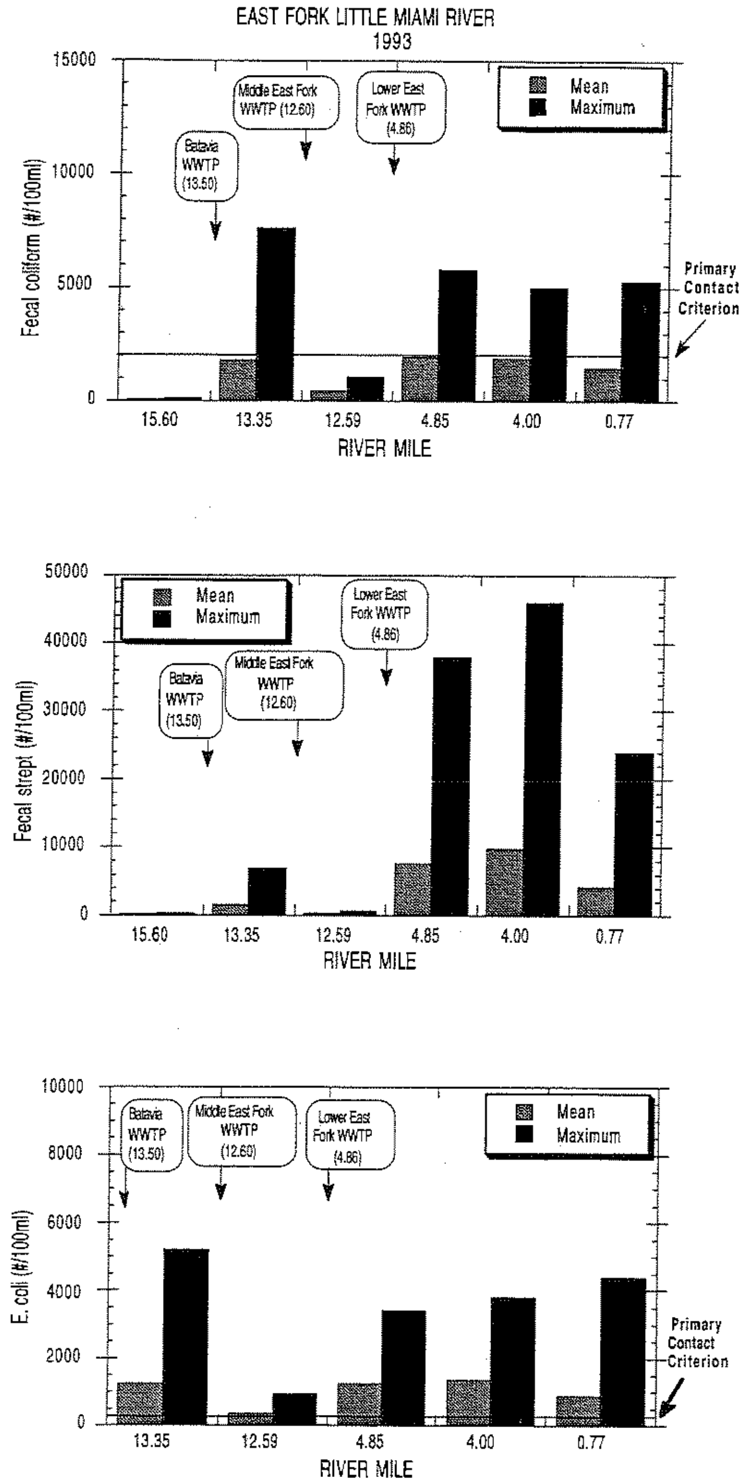


Figure 66. Longitudinal summary (mean and maximum values of fecal coliform, fecal strept, and *E. coli* concentrations in the East Fork Little Miami River during the 1993 survey. Mixing zone values are shown for RMs 13.35 and 12.59.

Table 6. Exceedences of Ohio EPA Exceptional Warmwater Habitat and Warmwater Habitat criteria (OAC 3745-1) for chemical/physical water parameters measured in grab samples taken from the Little Miami River study area during 1993 (units are µg/l for metals and organics, # colonies/100ml for fecal coliform and *E. coli*, µmhos/cm for conductivity, °C for temperature, and mg/l for all other parameters). Mixing zone samples are shown in *italics*.

Stream	River Mile	Parameter (value)
Little Miami River	101.30	Dissolved Oxygen (5.1‡‡‡, 3.5‡‡‡, 4.2‡‡‡); Fecal coliform (3800◊◊, >60000◊◊, 6820◊◊, 2100◊◊); E.coli (2400◊◊, 1050◊◊, 6200◊◊, 1700◊◊); Dieldrin (0.002#, 0.004#, 0.003#)
	98.98	Dissolved Oxygen (5.6‡‡‡, 5.6‡‡‡, 5.3‡‡‡)
	89.12	Dissolved Oxygen (5.5‡‡‡); Fecal coliform (1600◊, 1130◊); E.coli (230◊, 560◊◊, 1100◊◊, 2700◊◊, 420◊◊); Copper (137***)
	85.38	Fecal coliform (2800◊◊, 2500◊◊); E.coli (1800◊◊, 580◊◊); Dieldrin (0.002#)
	83.14	Fecal coliform (5400◊◊); E.coli (140◊, 3200◊◊); Dieldrin (0.002#, 0.006#*); Endrin (0.004*)
	80.63	Fecal coliform (1400◊, 3700◊◊, 4200◊◊); E.coli (1500◊◊, 3900◊◊, 1600◊◊)
	76.43	Fecal coliform (1300◊, 2800◊◊); E.coli (270◊, 140◊, 1000◊◊, 3600◊◊, 400◊◊); Dieldrin (0.007#*); Bis (2-ethylhexyl) phthalate (18.5*)
	74.46	Residual Chlorine (0.08**); Phosphorus (1.84†)
	72.30	Fecal coliform (2000◊, 1700◊, 5000◊◊); E.coli (220◊, 130◊, 1430◊◊, 2800◊◊, 2500◊◊); Dieldrin (0.005#, 0.003#, 0.004#); Endosulfan II (0.005*, 0.006*); Endrin (0.004*)
	66.56	Fecal coliform (3400◊◊, 4650◊◊); E.coli (130◊, 260◊, 5700◊◊, 3650◊◊, 420◊◊); Iron (6600Δ)

Table 6. Continued.

Stream	River Mile	Parameter (value)
Little Miami River	64.28	Fecal coliform (6180[◊◊], 7090[◊◊]); E.coli (210[◊], 3550[◊◊], 4300[◊◊], 900[◊◊], 305[◊◊]); Dieldrin (0.003[#], 0.003[#]); Endrin (0.008*); Bis (2-ethylhexyl) phthalate (98.7[#*]); Iron (5810[Δ], 7340[Δ])
	63.28	Phosphorus (1.29[†], 1.74[†]); Fecal coliform (5200[◊◊], 4600[◊◊]); E.coli (180[◊], 4700[◊◊], 4200[◊◊], 420[◊◊]); Iron (6850[Δ])
	53.20	Fecal coliform (3000[◊◊]); E.coli (170[◊], 2900[◊◊]); Iron (8000[Δ], 8280[Δ])
	47.50	Fecal coliform (1600[◊], 4200[◊◊]); E.coli (240[◊], 3200[◊◊], 1200[◊◊]); Iron (10500[Δ])
	43.76	Dieldrin (0.005[#], 0.005[#]); Endosulfan II (0.005*); Endrin (0.003*, 0.004*, 0.003*)
	35.98	Dieldrin (0.005[#]); Endosulfan II (0.004*, 0.005*); Endrin (0.003*, 0.006*); gamma-Hexachlorocyclohexane (0.012*)
	32.95	Fecal coliform (1300[◊]); E.coli (320[◊◊], 1300[◊◊]); Cadmium (6.4*)
	32.10	*Phosphorus (1.79[†], 1.23[†])*
	31.96	Fecal coliform (2800[◊◊], 2700[◊◊], 7180[◊◊], 4550[◊◊]); E.coli (240[◊], 1000[◊◊], 1300[◊◊], 3400[◊◊], 9270[◊◊]); Dieldrin (0.005[#], 0.006[#*], 0.010[#*]); Endrin (0.009*, 0.008*)

Table 6. Continued.

Stream	River Mile	Parameter (value)
Little Miami River	28.00	Temperature (27.9*, 28.1*); Residual Chlorine (0.09**, 0.12**, 0.09**, 0.07**, 0.11**, 0.05**); Phosphorus (2.63†); Mercury (1.8**); Fecal coliform (2800◊◊); E.coli (480◊◊, 1700◊◊); Dieldrin (0.005#, 0.003#, 0.006#*); Endrin (0.004*); Methoxychlor (0.040*)
	24.10	Dieldrin (0.003#, 0.002#); Endrin (0.005*)
	22.20	*Phosphorus (2.77†);* *Zinc (1010***)*
	21.45	Temperature (28.0*); Fecal coliform (39000◊◊); E.coli (130◊, 330◊◊, 7100◊◊);
	18.14	Fecal coliform (1300◊, 29000◊◊); E.coli (180◊, 510◊◊, >80000◊◊, 510◊◊, 390◊◊); Dieldrin (0.004#, 0.005#); Endrin (0.003*); Endosulfan II (0.004*); Iron (20900Δ)
	13.07	Temperature (28.0*); Iron (15700Δ)
	8.14	Fecal coliform (3000◊◊, 2500◊◊); E.coli (230◊, 370◊◊, 4700◊◊, 2000◊◊); Iron (10200Δ)
	3.50	Temperature (28.0*); Fecal coliform (9730◊◊); E.coli (140◊, 210◊, 210◊, 420◊◊, 8000◊◊, 360◊◊); Dieldrin (0.002#, 0.003#); Endosulfan II (0.006*, 0.006*); Iron (15200Δ)

Table 6. Continued.

Stream	River Mile	Parameter (value)
Little Miami River	28.00	Temperature (27.9*, 28.1*); Residual Chlorine (0.09**, 0.12**, 0.09**, 0.07**, 0.11**, 0.05**); Phosphorus (2.63†); Mercury (1.8**); Fecal coliform (2800◊◊); E.coli (480◊◊, 1700◊◊); Dieldrin (0.005#, 0.003#, 0.006#*); Endrin (0.004*); Methoxychlor (0.040*)
	24.10	Dieldrin (0.003#, 0.002#); Endrin (0.005*)
	22.20	*Phosphorus (2.77†);* *Zinc (1010***)*
	21.45	Temperature (28.0*); Fecal coliform (39000◊◊); E.coli (130◊, 330◊◊, 7100◊◊);
	18.14	Fecal coliform (1300◊, 29000◊◊); E.coli (180◊, 510◊◊, >80000◊◊, 510◊◊, 390◊◊); Dieldrin (0.004#, 0.005#); Endrin (0.003*); Endosulfan II (0.004*); Iron (20900Δ)
	13.07	Temperature (28.0*); Iron (15700Δ)
	8.14	Fecal coliform (3000◊◊, 2500◊◊); E.coli (230◊, 370◊◊, 4700◊◊, 2000◊◊); Iron (10200Δ)
	3.50	Temperature (28.0*); Fecal coliform (9730◊◊); E.coli (140◊, 210◊, 210◊, 420◊◊, 8000◊◊, 360◊◊); Dieldrin (0.002#, 0.003#); Endosulfan II (0.006*, 0.006*); Iron (15200Δ)

Table 6. Continued.

Stream	River Mile	Parameter (value)
Little Miami River	1.45	Temperature (28.0*, 28.5*); Phosphorus (1.21†); Fecal coliform (5600◊◊); E.coli (270◊, 430◊◊, 6000◊◊, 390◊◊); Dieldrin (0.002#, 0.004#); Endosulfan II (0.006*, 0.006*); Iron (10100Δ)
Yellow Springs Creek	0.44	Fecal coliform (4050◊◊, 2600◊◊); E.coli (190◊, 140◊, 4100◊◊, 1400◊◊)
	0.42	*Phosphorus (1.07†, 1.93†, 1.24†)*
	0.10	Ammonia-N (1.42*); Fecal coliform (1240◊, 2200◊◊); E.coli (4400◊◊, 580◊◊); Dieldrin (0.003#, 0.003#, 0.004#)
Oldtown Creek	0.10	E.coli (170◊, 140◊, 460◊◊); Dieldrin (0.002#)
Massies Creek	0.25	Fecal coliform (1210◊, 1620◊); E.coli (160◊, 1630◊◊, 910◊◊, 470◊◊, 540◊◊)
Beaver Creek	1.57	Phosphorus (1.74†); Fecal coliform (6820◊◊◊); E.coli (2300◊◊◊, 2100◊◊◊, 630◊◊◊); Iron (5290Δ)
	1.04	Phosphorus (1.10†); E.coli (1300◊◊◊, 1010◊◊◊, 650◊◊◊)
	0.39	*Phosphorus (3.09†, 1.22†, 1.27†, 1.07†, 1.89†)*
	0.20	Phosphorus (1.01†, 1.26†, 1.19†, 1.67†); E. coli (1700◊◊◊, 1200◊◊◊) Dieldrin (0.002#, 0.005#, 0.002#); Endosulfan II (0.006*, 0.011*); Endrin (0.005*)

Table 6. Continued.

Stream	River Mile	Parameter (value)
Little Beaver Creek	4.62	Temperature (28.8*); Fecal coliform (7270◊◊◊); E. coli (5300◊◊◊)
	4.57	*Phosphorus (1.01†, 1.28†, 1.72†, 1.78†, 1.89†, 1.64†, 1.86†)*
	4.53	Phosphorus (1.23†, 1.35†, 1.62†, 2.04†, 1.68†, 1.82†); E. coli (1600◊◊◊); Dieldrin (0.011#*, 0.012#*); Endosulfan I (0.006*); Endrin (0.008*, 0.006*); Heptachlor (0.014#*, 0.016#*); gamma-Hexachlorocyclohexane (0.011*, 0.023*)
	1.95	Phosphorus (3.77†, 1.15†, 1.20†, 1.12†, 1.45†)
	0.05	Phosphorus (1.68†, 1.56†, 1.15†, 1.07†, 1.44†); E. coli (2000◊◊◊, 610◊◊◊)
Glady Run	4.82	E. coli (660◊◊◊)
	4.75	Residual chlorine (0.16**, 0.15**, 0.10**, 0.24**, 0.14**, 0.10**); Phosphorus (1.05†, 1.38†, 1.33†, 1.46†); E. coli (640◊◊◊); Dieldrin (0.015#*, 0.013#*, 0.008#*); Endosulfan II (0.005*); Heptachlor (0.031#*, 0.012#*); gamma-Hexachlorocyclohexane (0.067*, 0.034*, 0.049*); Endrin (0.009*)
	4.08	Phosphorus (1.28†, 1.32†)
Glady Run Swale	0.01	Phosphorus (1.72†, 1.64†)
Anderson Fork	4.90	Dissolved Oxygen (5.7‡‡‡); Dieldrin (0.005#, 0.006#*); Endosulfan II (0.005*)
Caesar Creek	16.52	Dissolved Oxygen (3.2‡‡‡); Phosphorus (1.89†)
	0.15	Temperature (28.0*)

Table 6. Continued.

Stream	River Mile	Parameter (value)
Flat Fork	1.70	Dissolved Oxygen (2.9‡‡, 1.1‡‡); Fecal coliform (1320◊); E. coli (210◊, 1130◊◊); Dieldrin (0.007#*); Endrin (0.004*)
Dry Run	1.79	Dissolved Oxygen (4.2‡)
Turtle Creek	6.23	Temperature (28.1*); Dissolved Oxygen (4.0‡); Dieldrin (0.004#); Endosulfan II (0.005*)
	5.00	Temperature (29.0*); Dissolved Oxygen (4.8‡, 3.2‡‡); E. coli (1400◊◊◊, 1800◊◊◊, 800◊◊◊); Lead (245*Δ)
	0.70	Dissolved Oxygen (2.8‡‡, 3.2‡‡, 4.2‡); Phosphorus (2.14†); Fecal coliform (19000◊◊◊); E. coli (3200◊◊◊, 16000◊◊◊)
	0.58	*Phosphorus (4.24†, 1.31†);* *Copper (447***, 128***, 374***, 43***)*
	0.52	Dissolved Oxygen (4.4‡); Conductivity (3900*, 2890*); Total Dissolved Solids (1530*, 1690*, 2370*, 1760*); Ammonia-N (3.33*, 8.91*, 23.60**); Phosphorus (2.09†); Copper (506***Δ, 111**, 135**, 50*)
	0.01	Dissolved Oxygen (4.8‡); E. coli (790◊◊◊, 3500◊◊◊)
Muddy Creek	2.50	Residual Chlorine (0.09**, 0.07**, 0.14**); Phosphorus (1.08†); Fecal coliform (1430◊, 4200◊◊); E. coli (190◊, 310◊◊, 780◊◊, 480◊◊, 300◊◊); Copper (486***); Dieldrin (0.005#); Endrin (0.006*)

Table 6. Continued.

Stream	River Mile	Parameter (value)
Simpson Creek	0.01	Phosphorus (1.63†)
Stonelick Creek	16.74	Dissolved Oxygen (4.2‡, 2.4‡‡, 4.4‡); Fecal coliform (15000◊◊); E. coli (7700◊◊); Lead (5*); Dieldrin (0.002#); Iron (6900Δ)
	3.10	Dissolved Oxygen (4.8‡, 4.2‡); Fecal coliform (2200◊◊); E. coli (1300◊◊); Dieldrin (0.002#, 0.003#); Aldrin (0.005#); Endosulfan II (0.005*)
	1.00	Dissolved Oxygen (4.0‡); Fecal coliform (3000◊◊); E. coli (3300◊◊); Dieldrin (0.004#, 0.004#); Endosulfan II (0.004*)
Sycamore Creek	0.40	Fecal coliform (27000◊◊, 11000◊◊); E. coli (300◊◊, 20000◊◊, 8000◊◊, 150◊)
	0.25	*Phosphorus (1.92†, 1.41†, 3.00†, 1.92†, 2.97†)*
	0.05	Phosphorus (2.83†, 2.90†, 3.43†, 2.43†, 2.22†); Fecal coliform (1650◊, 1280◊, 17000◊◊, 8640◊◊, 24000◊◊, 21000◊◊); E. coli (765◊◊, 6000◊◊, 7200◊◊, 7500◊◊, 220◊, 230◊); Dieldrin (0.005#, 0.005#); Endosulfan I (0.005*, 0.006*); Endrin (0.004*, 0.005*); gamma-Hexachlorocyclohexane (0.012*)
O'Bannon Creek	0.26	Phosphorus (2.25†)
East Fork	15.60	Temperature (28.0*); Dieldrin (0.004#, 0.003#); Bis (2-ethylhexyl) phthalate (10.6*)
	12.59	*Phosphorus (1.29†, 1.10†, 2.19†)*

Table 6. Continued.

Stream	River Mile	Parameter (value)
East Fork	9.10	Temperature (29.5**, 28.5*); Dissolved Oxygen (5.6‡‡‡)
	6.57	Temperature (29.6**, 28.5*); Iron (6990Δ)
	4.85	Phosphorus (1.49†, 3.09†, 2.30†, 3.64†)
	4.00	Temperature (29.9**); Fecal coliform (5000◊◊, 3900◊◊); E. coli (2700◊◊, 3800◊◊, 160◊); Iron (5750Δ)
	0.77	Temperature (27.9*); Dissolved Oxygen (5.8‡‡‡) Fecal coliform (5300◊◊, 2500◊◊); E. coli (460◊◊, 4400◊◊, 130◊, 200◊); Dieldrin (0.003#); Endrin (0.006*)

* exceedence of numerical criteria for prevention of chronic toxicity (Chronic Aquatic Concentration [CAC]).
** exceedence of numerical criteria for prevention of acute toxicity (Acute Aquatic Concentration [AAC]).
*** exceedence of numerical criteria for prevention of lethality (Final Acute Value [FAV]).
# exceedence of numerical criteria for human health 30-day average.
‡ exceedence of the average warmwater habitat dissolved oxygen (D.O.) criterion (5.0 mg/l).
‡‡ exceedence of the minimum warmwater habitat dissolved oxygen (D.O.) criterion (4.0 mg/l).
‡‡‡ exceedence of the exceptional warmwater habitat minimum dissolved oxygen (D.O.) criterion (6.0 mg/l).
◊ exceedence of the average Primary Contact Recreation criterion (fecal coliform 1000/100ml; E. coli 126/100ml).
◊◊ exceedence of the maximum Primary Contact Recreation criterion (fecal coliform 2000/100ml; E. coli 298/100ml).
◊◊◊ exceedence of the maximum Secondary Contact Recreation criterion (fecal coliform 5000/100ml; E. coli 576/100ml).
† exceedence of WQS guideline for daily average phosphorus (1 mg/l).
Δ exceedence of agricultural water supply 30-day average (copper 500 μg/l; lead 100 μg/l; iron 5000 μg/l).

NOTE: Iron exceeded 1.0 mg/l (the CAC) in 130 of 392 (33%) non-mixing zone samples in the study area.

- Total suspended solids concentrations increased markedly in the lower reaches of the East Fork downstream from Stonelick Creek (RMs 6.57 - 0.77, Figure 65). Similar to other tributaries, the maximum concentrations occurred on July 15 during elevated flow conditions following heavy rainfall. Soil erosion from agricultural fields and construction sites were the likely sources of the increased TSS.

- Elevated fecal coliform, fecal strep, and *E. coli* bacteria counts were recorded at RMs 13.35, 4.85, 4.00, and 0.77 (Figure 66, Table 6). The highest counts again generally occurred on July 15 during high flows.

- Two sites (RMs 15.60 and 0.77) were sampled for organics. Results revealed exceedences of water quality criteria for dieldrin at both sites, endrin at RM 0.77, and one semi-volatile compound (bis [2-ethylhexyl] phthalate) at RM 15.60 (Table 6,A-5). Overall, the results showed no appreciable differences in the number of compounds detected at the upstream site compared to the four downstream sites.

Chemical Sediment Quality (Tables 6-8, A-7,A-8a)

- During the summer of 1993 sediment samples were collected from 39 locations in the study area to assess levels of contaminants present in stream sediments in the Little Miami River and tributaries. Whenever possible, composite samples of the channel cross-section were collected. All samples were analyzed for heavy metals, pesticides, polychlorinated biphenyls (PCBs), and semi-volatile and volatile organic compounds. Sediment levels were classified according to a scheme developed by Kelly and Hite (1984).

Little Miami River

- Sediment results for heavy metals from 12 sites in the Little Miami River mainstem showed only one site, Beechmont Avenue (RM 3.50), with highly elevated concentrations (lead = 87.8 mg/kg, Table 7). The highly elevated lead level was attributed to urban runoff and combined sewer overflow (CSO) discharges to Duck Creek. Elevated lead levels also appeared downstream from the Warren Co. Lower LMR WWTP (Simpson Creek, RM 28.00). Other elevated heavy metals included arsenic at Dolly Varden Rd. (RM 98.98) and zinc at Beechmont Avenue (RM 3.50). *Mercury* analyses (conducted at only two mainstem sites) showed a non-elevated concentration (0.053 mg/kg) downstream from Simpson Creek (RM 28.0), but an extremely elevated level (0.485 mg/kg) at Beechmont Avenue (RM 3.5). Beechmont Avenue was the only site at which more than one elevated heavy metal was detected. Values at all of the other sediment sampling sites were indicative of either slightly or non-elevated concentrations.

- Sediment scans for priority pollutants detected one or more semi-volatile compounds at all 12 mainstem sites. Similar to the heavy metals, Beechmont Avenue (RM 3.50) contained the highest number of pesticides (4) and polycyclic aromatic hydrocarbons (9 PAHs; Tables 8, A-8a). Probable sources of the contaminants are in the Duck Creek subbasin and include the Norwood/Duck Creek landfill, urban runoff, spills, and numerous CSOs. The landfill is closed, but has been exposed by erosion along Duck Creek. Sediments at Spring Valley (RM 63.28) contained the second highest quantity of PAHs (6) in the mainstem. Indian Ripple Rd. (RM 72.30) data included two PAH compounds. PAH compounds were not detected at the other nine mainstem sites. The most frequently detected organic compounds were bis (2-ethylhexyl) phthalate, benzo [B&K] fluoranthene, and fluoranthene.

- One or more pesticides were detected at all 12 mainstem sites (Table 8). Dieldrin was the most frequently detected pesticide occurring at nine (9) locations. It was the only pesticide found at a highly elevated concentration (Dolly Varden Rd., RM 98.98). Other locations contained non to slightly elevated values. The summed total of DDT compounds (total of 4,4'-DDE, 4,4'-DDD and 4,4'-DDT-sum of DDT and metabolites) was the second most frequently detected pesticide, but most values were non-elevated. No polychlorinated biphenyl (PCB) compounds were detected.

Tributaries

- Sediment analyses for heavy metals at 27 tributary sites showed elevated levels of zinc in Oldtown Creek (RM 0.10) and Turtle Creek (RM 6.23) and an elevated arsenic value in Turtle Creek (RM 0.52, Table 7).

- Sediment in Sycamore Creek (RM 0.05; downstream the Sycamore WWTP) contained the highest number and concentrations of PAHs of the 27 tributary sampling sites (Table A-8a). Thirteen (13) PAH compounds and one volatile organic compound (toluene) were detected. Turtle Creek (RM 6.23) near Lebanon yielded the second highest number of organic compounds (8). Four semi-volatile organic compounds were detected in Glady Run (RM 4.75) and Beaver Creek (RM 0.20). The most commonly detected organic compounds in tributaries were bis (2-ethylhexyl) phthalate, fluoranthene, and benzo [B&K] fluoranthene.

- Pesticide analyses showed non-elevated levels with dieldrin and endosulfan II the most frequently detected. Only one stream, Flat Fork, had a slightly elevated concentration of dieldrin. Non-elevated levels of PCBs were detected at three sites.

Table 7. Concentrations of heavy metals in sediments of the Little Miami River study area, 1993. (All parameter concentrations, excluding aluminum and nickel, were ranked based on a stream sediment classification system described by Kelly and Hite [1984]. The Kelly and Hite classification system addresses relative concentrations, but does not directly assess toxicity.)

Stream River Mile	As	Cu	Cd	Cr	Fe	Pb	Ni	Zn	Hg
			Sediment Concentration (mg/kg dry weight)						
Little Miami River									
98.98	*11.5*[c]	11.7[a]	0.265[a]	13.0[a]	14900[a]	10.5[a]	6.8[a]	*81.7*[b]	-
85.38	5.0[a]	14.4[a]	0.317[a]	12.9[a]	17600[a]	13.5[a]	7.1[a]	61.4[a]	-
76.43	4.4[a]	7.1[a]	0.165[a]	5.8[a]	9690[a]	4.8[a]	2.2[a]	28.5[a]	-
72.30	4.9[a]	17.4[a]	0.302[a]	13.5[a]	12600[a]	17.7[a]	5.2[a]	65.6[a]	-
64.28	5.2[a]	18.6[a]	0.353[a]	12.4[a]	16400[a]	17.6[a]	6.0[a]	77.9[a]	-
63.28	7.8[a]	13.8[a]	0.210[a]	13.0[a]	13900[a]	13.1[a]	7.4[a]	60.4[a]	-
43.76	4.9[a]	9.9[a]	0.155[a]	10.8[a]	10900[a]	10.9[a]	4.3[a]	44.9[a]	-
35.98	4.6[a]	10.3[a]	0.140[a]	10.5[a]	13400[a]	10.2[a]	5.1[a]	42.3[a]	-
31.96	*9.8*[b]	13.9[a]	0.119[a]	14.8[a]	*19700*[b]	11.5[a]	8.7[a]	53.9[a]	-
28.00	5.6[a]	13.3[a]	0.152[a]	8.9[a]	7480[a]	*42.9*[c]	4.2[a]	47.6[a]	0.053[a]
24.10	5.6[a]	13.2[a]	0.183[a]	12.6[a]	15500[a]	13.6[a]	7.5[a]	60.1[a]	-
3.50	*10.5*[b]	*41.8*[b]	0.628[a]	*18.6*[b]	15400[a]	***87.8***[d]	11.6[a]	*129.0*[c]	***0.485***[e]
Yellow Springs Creek									
0.10	*8.1*[b]	29.3[a]	0.372[a]	15.7[a]	16900[a]	23.3[a]	7.7[a]	*96.7*[b]	-
Oldtown Creek									
0.10	6.7[a]	14.1[a]	0.240[a]	13.3[a]	16500[a]	14.2[a]	5.7[a]	*114.0*[c]	-

Table 7. Continued.

Stream River Mile	As	Cu	Cd	Cr	Fe	Pb	Ni	Zn	Hg
			Sediment Concentration (mg/kg dry weight)						
Glady Run									
4.82	10.2[a]	16.0[a]	0.314[a]	*20.2*[b]	*18600*[b]	15.2[a]	9.0[a]	77.8[a]	-
4.75	6.5[a]	*44.7*[b]	0.322[a]	13.2[a]	11800[a]	40.2[a]	7.5[a]	*84.8*[b]	0.0613[a]
Anderson Fork									
4.90	4.5[a]	8.9[a]	0.133[a]	10.5[a]	10700[a]	7.8[a]	6.0[a]	34.0[a]	<0.0137[a]
Newman Run									
0.27	*10.7*[b]	20.7[a]	0.269[a]	*19.8*[b]	*24700*[c]	18.9[a]	10.2[a]	*92.9*[b]	-
Caesar Creek									
16.52	3.7[a]	7.6[a]	0.156[a]	9.8[a]	10100[a]	6.6[a]	5.2[a]	42.9[a]	-
Flat Fork									
1.70	*11.7*[c]	17.2[a]	0.258[a]	*17.5*[b]	*26400*[c]	17.1[a]	9.1[a]	-	-
Dry Run									
1.79	*8.8*[b]	16.6[a]	0.167[a]	*18.8*[b]	*18200*[b]	16.7[a]	10.0[a]	78.3[a]	-
Stonelick Creek									
1.0	5.8[a]	14.8[a]	0.173[a]	*18.1*[b]	*20500*[b]	13.5[a]	6.20[a]	55.3[a]	-
Turtle Creek									
6.23	*10.9*[b]	20.9[a]	0.369[a]	*19.3*[b]	*22400*[b]	40.4[a]	8.04[a]	*140.0*[c]	-
0.70	7.37[a]	12.2[a]	0.160[a]	11.2[a]	5940[a]	36.8[a]	5.49[a]	74.9[a]	-
0.58	6.86[a]	16.2[a]	0.051[a]	15.4[a]	*23900*[c]	28.2[a]	11.4[a]	56.1[a]	-
0.52	*12.5*[c]	24.9[a]	0.245[a]	14.5[a]	15500[a]	36.9[a]	10.4[a]	64.0[a]	0.0377[a]
0.01	6.98[a]	15.6[a]	0.183[a]	*18.5*[b]	16800[a]	18.5[a]	5.52[a]	66.5[a]	-
Sycamore Creek									
0.40	*9.91*[b]	11.4[a]	0.179[a]	15.0[a]	*22000*[b]	17.5[a]	5.56[a]	54.7[a]	-
0.05	7.0[a]	20.9[a]	0.349[a]	15.1[a]	*24300*[c]	25.5[a]	7.77[a]	*82.3*[b]	0.0321[a]
East Fork Little Miami River									
15.60	3.3[a]	8.0[a]	0.147[a]	8.0[a]	11400[a]	12.1[a]	4.40[a]	42.4[a]	-
13.35	2.5[a]	5.5[a]	0.061[a]	8.0[a]	11100[a]	11.5[a]	3.70[a]	23.0[a]	-
12.59	1.9[a]	7.2[a]	0.072[a]	7.2[a]	10100[a]	11.8[a]	3.82[a]	43.8[a]	-
4.85	3.1[a]	10.4[a]	0.125[a]	10.3[a]	14500[a]	9.2[a]	5.27[a]	34.3[a]	0.0148[a]
0.77	5.1[a]	15.6[a]	0.157[a]	14.2[a]	*19200*[b]	17.6[a]	8.42[a]	54.6[a]	-

a Non-elevated.
b Slightly elevated.
c Elevated.
d Highly elevated.
e Extremely elevated.

Table 8. Concentration (µg/kg) of pesticides in the sediments of the Little Miami River study area during1993.[1,2,3]

Stream Location	River Mile	*Hepta-chlor	*Aldrin	Dieldrin	*Endo-sulfan II	*Endosulfan sulfate	DDT Total
Little Miami River							
Dolly Vardin Rd.	98.98	-	3.89	**20.71d**	-	-	-
Grinnel Rd.	85.38	-	-	*4.43*[b]	-	-	-
ust. Shawnee Ck.	76.43	-	-	-	0.76	-	-
Indian Ripple Rd.	72.30	-	-	*5.38*[b]	-	-	2.86[a]
dst. Sugarcrk WWTP	64.28	-	-	2.76[a]	-	-	-
SpringValley Rd. Park	63.28	-	-	-	-	-	2.34[a]
S.R 350/Ft. Ancient	43.76	-	-	1.26[a]	-	-	2.19[a]
Stubbs Mill Rd.	35.98	-	-	2.73[a]	-	-	2.73[a]
ust. Muddy Cr.	31.96	-	-	-	-	-	2.08[a]
dst. Simpson Cr.	28.00	-	-	1.68[a]	-	-	-
ust. conf. O'Bannon Cr	24.10	-	-	0.73[a]	-	-	-
Beechmont Ave.	3.500	-	1.52	*4.26*[b]	7.79	-	*12.73*[c]
Yellow Springs Creek							
Grinnel Rd.	0.10	-	-	2.80[a]	0.85	-	-
Oldtown Creek							
near mouth, U.S. 68	0.10	-	-	1.48[a]	-	-	-
Beaver Creek							
Dayton-Xenia Rd.	1.57	-	-	0.96[a]	1.27	-	-
dst. little Bvrcrk @ U.S 35	1.04	-	1.12	-	4.51	-	-
dst. Beaver Cr. WWTP	0.20	-	-	1.09[a]	-	-	-
Little Beaver Creek							
ust. Mnt Co.E.Reg. WWTP	4.62	-	-	-	0.65	-	3.36[a]
dst. Mnt Co.E.Reg. WWTP	4.53	-	-	1.74[a]	-	-	3.41[a]
Glady Run							
ust. Xenia Glady Rn Swale	4.82	-	-	-	-	-	-
dst. Xenia Glady Rn Swale	4.75	-	-	1.83[a]	-	-	-
Anderson Fork							
Old Winchester Trail	4.90	-	-	0.74[a]	-	-	-
Newman Run							
Adj. Pekin-Waynsvle Rd.	0.27	-	-	-	-	-	-
Caesar Creek							
Paintersville Rd.	16.52	-	-	-	-	-	-
Flat Fork							
Oregonia Rd.	1.70	-	-	*3.49*[b]	-	-	-

Table 8. Continued.

Location	River Mile	Hepta-chlor	*Aldrin	Dieldrin	*Endo-sulfan II	*Endosulfan sulfate	DDT Total
Dry Run							
Snook Rd.	1.79	-	-	3.19[a]	-	-	-
Turtle Creek							
Glosser Rd.	6.23	-	-	-	-	-	4.48[a]
Mason Rd.	0.70	-	-	1.03[a]	1.05	-	-
Cin.Milacron Mix Zone	0.58	-	-	-	-	-	-
S.R. 48	0.52	-	-	-	0.63	-	-
mouth, dst. Dry Run	0.01	-	-	3.43[a]	-	-	-
Stonelick Creek							
U.S.Rt. 50	1.00	-	-	-	-	-	-
Sycamore Creek							
ust. Sycamore Cr. WWTP	0.40	-	-	1.70[a]	-	-	-
dst. Sycamore Cr. WWTP	0.05	-	0.93	2.29[a]	-	-	-
East Fork Little Miami River							
S.R. 222	15.60	-	-	-	-	-	-
Batavia WWTP mix zone	13.35	-	-	-	-	-	-
Middle E. FWWTPmix zone	12.59	-	-	-	-	-	-
dst. Lower E. F. WWTP	04.85	-	-	-	-	-	-
Cleveland Ave.	00.77	-	-	-	-		

1 All concentrations were ranked on a stream sediment classification system described by Kelly and Hite (1984). The system addresses relative concentrations, but does not directly assess toxicity.

a Non-elevated.

b *Slightly elevated.*

c *Elevated.*

d **Highly elevated.**

e **Extremely elevated.**

* Not evaluated by Kelly and Hite (1984).

2 No PCB's detected in sediment samples.

3 Sum DDT is total of 4,4'-DDE, 4,4'-DDT, 4,4'-DDD.

Fish Tissue (Table A-8b)

- Chemical analyses of 34 fish tissue samples for selected metals, pesticides, and PCBs showed relatively little chemical contamination of fish throughout the Little Miami River mainstem (based on cumulative data from a total of eight (8) species and 11 locations between RM 83.1 and RM 3.5, Table A-8b). All detected concentrations from seven (7) sport species (composite fillet samples) and common carp (composite whole body) were below U.S. FDA Action Levels (Appendix Table A-8b; Estenik and Smith 1992). No pesticides or PCBs were detected in composite fillet samples of smallmouth bass, sauger, and channel catfish at RM 31.9; spotted bass and sauger at RM 18.5; smallmouth bass and freshwater drum at RM 8.0; and smallmouth bass at RM 3.5. Chlordane, a historical insecticide used for termite control, was not detected in any of the 34 mainstem tissue samples.

- A total of seven (7) pesticides and their derivatives were detected. Similar to the water and sediment scans, dieldrin was the most frequently occurring pesticide with a detection rate of 76.5%. This rate is higher than the statewide detection rate of 48.1% report by Estenik and Smith (1992). The highest dieldrin concentration, 68.7 ug/kg, was found in a whole body sample of common carp from Jacoby Road (RM 83.1). The second most frequently detected organic compound was 4,4'-DDE with a detection rate of 73.5% (compared with a 60.5% statewide rate of detection). The whole body common carp sample from Beechmont Avenue (RM 3.5) contained the only detected concentration of 4,4'-DDT (suggests a recent exposure), the highest levels of 4,4'-DDE and 4,4'-DDD (total DDT = 183.3 ug/kg), and all seven (7) of the detected pesticides and derivatives. It was also the only sample containing mirex and methoxychlor, two rarely detected pesticides in Ohio. Heptachlor epoxide was detected in 29.4% of the samples compared to a statewide detection rate of 15.6%.

- The total PCB detection rate in the mainstem was considerably lower than the reported statewide rate of 97.6%. PCB-1260, the most resilient PCB and the only PCB mixture detected, occurred above detection in 64.7% of the Little Miami River samples. Slightly elevated (*i.e.*, $>50 \leq 300$ ug/kg) concentrations of PCB's were detected in two of two (2 of 2) white bass samples (*i.e.*, locations), one of three (1 of 3) freshwater drum samples, and three of six (3 of 6) channel catfish samples. Whole body composite values for eight (8) common carp samples were slightly elevated at six (6) locations, elevated (*i.e.*, $>300 \leq 1000$ ug/kg) at one location, and highly elevated (*i.e.*, $>1000<50000$ ug/kg) at Beechmont Avenue.

- The highest mercury concentration (0.7 ug/g) occurred in spotted bass fillets collected downstream from the confluence of Sycamore Creek (RM 18.5). This value is below the U.S. FDA criteria of 1.0 ug/g, but greater than the extremely elevated status Kelly and Hite (1984) report for sediment concentrations. It represents the highest concentration recorded to date in the Ohio EPA statewide database and may be related to the recurring mercury exceedences at the Sycamore Creek WWTP. The value also appears highly elevated when compared to studies conducted by the U.S. EPA where mercury was detected in 92% of the fish tissue samples analyzed (maximum value = 1.80 ppm, mean = 0.26 ppm, median = 0.17 ppm; J. Estenik pers. comm). Concentrations of cadmium and lead (maximum values = 0.046 and 1.88 ug/g, respectively) appeared low throughout the mainstem compared to sediment criteria.

Physical Habitat for Aquatic Life (Plates 1-6, 12; Figures 67-68; Tables 9-10)

Little Miami River

- Throughout most of its 105 mile length, the Little Miami River is free-flowing with a natural pool-run-riffle morphology (Plates 1-4). The mainstem has an average gradient of 6.5 feet/mile and flows through a series of broad floodplains and constricted valleys. The river has a complex geologic history with sections occupying pre-, inter-, and post-glacial valleys (Stansbery and Lafferty 1979). As a cross-boundary stream which flows from the E. Cornbelt Plains ecoregion into the Interior Plateau ecoregion, the Little Miami River contains diverse physical attributes and some of the highest quality riverine habitat found in Ohio.

- Physical habitats are predominantly natural with less than four percent of the mainstem directly affected by impoundments or channelization. The longest modified segment, the lower three miles, is inundated by the Markland Dam on the Ohio River. Two shorter sections are impounded by dams in the upper half of the mainstem. The tallest dam (approximately 35 feet high) is located at Clifton Mill (RM 89.3) and a small low head dam is located near Waynesville (RM 55.3). An old dam at Foster was removed.

- Flows in the Little Miami River are becoming increasingly regulated, particularly during low flows. The East Fork and Caesar Creek contain large flood control reservoirs with regulated releases and approximately 50 MGD (77 cfs) of municipal wastewater effluent are discharged in the watershed(third quarter of 1993). Due to increasing suburban development throughout the watershed many of the WWTPs have requested increased design flows. The lowest recorded stream flows (lowest daily mean) for the two operating USGS gaging stations on the upper and lower mainstem, respectively, are 3.5 cfs near Oldtown (September 2, 1988; RM 82.3) and 27 cfs near Milford (September 18, 1954; RM 12.9).

Upper Mainstem - South Charleston to Waynesville

- As the Little Miami River flows from South Charleston to Waynesville the mainstem changes from a small spring-fed creek into a moderately large river. Excluding mixing zones, all of the fish sampling locations contained alternating series of pools, riffles and runs. Substrates were predominated by sand and gravel, but generally contained more than four types of material. Shallow water depths and low turbidity levels made substrates visible at most sites upstream from Waynesville.

- Based on similar QHEI scores, four relatively homogenous segments of physical habitats were identified in the upper half of the mainstem (Table 9). In the most upstream segment, located between U.S. Rt. 42 and Pitchin Road, the stream flows through gently rolling agricultural land and the QHEI scores from three sites ranged from 62.0 to 75.0 (mean = 68.5). The quality of habitat improved downstream from Clifton where the mainstem descends through a steep gradient, constricted gorge. The QHEI value at Grinnel Road was 87.0, the highest value recorded in the mainstem (Figure 67). Downstream from the gorge from Jacoby Road to Spring Valley, the river valley widens into a broad flood plain where it retains good to exceptional quality physical habitats (QHEI range = 62.5-78.0; mean = 73.0).

- The QHEI matrix analysis illustrates the overwhelming predominance of positive warmwater habitat attributes throughout the upper half of the mainstem (Table 10). Five sampling locations (three between Clifton Gorge and Xenia Ford Road, U.S. Rt. 35, and upstream of the Sugar Creek WWTP) contained 9-10 warmwater habitat attributes with no influence from modified habitat attributes. Severely eroding banks, however, were observed on the mainstem where agricultural activities have eliminated woody riparian vegetation (Plate 12).

Lower Mainstem - Oregonia to the Ohio River

- The lower half of the Little Miami River mainstem flows into and through the Interior Plateau ecoregion and also contains a diverse mixture of aquatic habitats in the free-flowing segments. Similar to the upper half, most sampling locations contained a good mixture of pool, riffle, and run habitats. Pools in the lower mainstem are typically longer and wider than in the upper half, but are interspersed with well defined riffle/run complexes. Pool sizes varied from less than 100 meters to more than 800 meters in length, usually exceeded 30 meters in width, and had water depths from 0.5- 2.0 meters. The size of the riffle-run complexes varied from less than 50 meters to more than 200 meters in length. Substrates throughout were predominated by sand, gravel and fragmented slabs of limestone. However, heavy silt deposits were observed in most of the large pools. Large, vegetated gravel/boulder bars, islands, and high flow channels (all positive warmwater habitat attributes) were common in the lower mainstem. Dense patches of water-willow and lizard tail (two pollution sensitive macrophytes) were also common on bars and along the channel margins downstream from Oregonia (Plate 4).

- Only two relatively homogenous segments of habitat were identified between Oregonia and the Ohio River (Table 9). The upstream segment includes the 18 free-flowing sites and the downstream segment contains the two sites which are impounded by the Ohio River backwater effect. The mean QHEI score of 77.6 in the free-flowing segment is indicative of very good to exceptional habitat quality. QHEI scores at the two impounded sites were considerably lower (QHEI = 57.5 at RM 28.2 and 63.5 at RM 22.1; Figure 67). Two other locations, RM 47.5 at Oregonia and RM 8.4 located upstream from Bass Island near Newtown, were predominantly pooled, but contained short lengths of run habitat. QHEI scores from nine locations were greater than or equal to 80 and indicative of exceptional quality habitat. The total number of warmwater habitat attributes ranged from seven to nine (7-9) and were higher than the number of modified habitat attributes at all of the free-flowing sites. Higher numbers of modified attributes were recorded at the two predominantly pooled sites (RM 28.2 and RM 22.1).

- The diversity of habitat declined markedly in the lower three miles of the mainstem due to the impoundment effect by the Markland Dam on Ohio River. The two sampling locations had the lowest QHEI values on the mainstem (50 and 51). Typical of Ohio River backwater areas, these sites consisted of uniformly deep pooled habitat with soft hardpan and silt substrates and slow current. In contrast to the free-flowing mainstem, the total number of modified habitat attributes ranged from seven to eight and outnumbered the warmwater habitat attributes (only 4 were observed). Flotsam in the form of urban trash and debris from stormwater (Plate 13) noticeably increased in the backwater segment. The last outside bend of the mainstem, near the confluence with the Ohio River, had a severely eroding bank.

Yellow Springs Creek

- Yellow Springs Creek had wide, wooded riparian zones and QHEI scores (range = 73.5 - 80.0) indicative of very good to exceptional quality physical habitat. Instream habitats contained pools interspersed by riffle-run complexes, clear water, and substrates predominated by cobble, gravel, and sand (Plate 5). A few sludge deposits, however, were observed downstream from the Yellow Springs Creek WWTP. This tributary had a high number of warmwater habitat attributes (8 or 9 per site) and few or no modified habitat influences.

Oldtown Creek

- Near its confluence with Massies Creek, Oldtown Creek meanders through a wooded floodplain and contains exceptional quality physical habitat (QHEI = 82.5). The natural channel contained pools interspersed by riffles and runs, a predominantly loose (not embedded) gravel substrate, and abundant instream cover. A channelized segment, however, was located immediately upstream adjacent to an abandoned railroad grade.

South Fork of Massies Creek

- At RM 1.1, the South Fork flows through a wooded strip adjacent to a quarry and contains relatively good stream morphology, despite historical channel modifications. Instream habitats consisted of alternating series of pools and riffles with substrates predominated by limestone bedrock and cobble sized fragments. This section of the stream had good riparian cover, stable banks, and diverse aquatic habitats including deep pools. Upstream from the wooded segment, the South Fork flows through an open field and appeared to have been recently channelized. The QHEI scored 66.5 an indication that the WWH use is appropriate.

Massies Creek

- Massies Creek was evaluated downstream from the confluence of Old Town Creek (RM 0.3). This section of the stream may have been previously modified during bridge construction and contained primarily pooled habitat. The QHEI scored 67.5, similar to the South Fork. Hardpan and gravel were the predominant substrates. The site exhibited seven warmwater habitat attributes and four modified habitat attributes, including sparse amounts of instream cover.

Beaver Creek

- The quality of physical habitats in Beaver Creek improved downstream from the confluence of Little Beaver Creek possibly due to increased flows from an upstream WWTP (Plate 11). QHEI scores increased from 54.5 upstream of Little Beaver Creek to 74.0 and 70.5, respectively, upstream and downstream from the Greene Co. Beavercreek WWTP (the mixing zone QHEI was 64.0).

Little Beaver Creek

- Throughout its length, Little Beaver Creek is a headwater tributary based on drainage area, but contains instream habitats more similar to larger streams due to the large volume of flow discharged by the Montgomery Co. Eastern Regional WWTP (3rd quarter 1993 mean daily discharge = 12.7 cfs; Figure 22, Plate 11). QHEI scores were indicative of good quality habitat at four of the sampling locations (QHEIs = 67.5-76.0), but poor quality habitat was evident downstream from the WWTP due to a shallow, uniform channel with little instream cover (QHEI = 48.5).

Glady Run

- Glady Run was sampled upstream and downstream from the WWTP swale and downstream from St.Rt. 725 near the mouth. QHEI scores increased from 54.0 upstream from the WWTP swale to 69.0 near the mouth. The lower score at upstream site was due primarily to a lack of flow caused the diversion of most of the Glady Run flow into the swale upstream from the WWTP.

Glady Run Swale

- The WWTP tributary (the swale) to Glady Run was also sampled at three locations, upstream from the WWTP, downstream from the diversion of Glady Run, the WWTP mixing zone, and near the mouth. The tributary appeared to have been channelized throughout the segment and exhibited considerable recovery downstream from the old railroad grade (RM 0.1). QHEI scores increased from 49-53 upstream from the WWTP and in the mixing zone to 66 near the mouth. The swale contained a low diversity of substrate types at all three locations and was dominated by sand and small gravel.

Newman Run

- Newman Run is a small headwater tributary which joins the Little Miami River upstream from Waynesville. It contained good quality physical habitat (QHEI = 76.0) in early July, but became mostly dry by September due to a lack of surface water flow. Substrates were dominated by limestone fragments and gravel.

Anderson Fork

- Anderson Fork, a tributary of Caesar Creek, contained good quality physical habitat as indicated by a QHEI score of 75.0 (Table 10). The site had an average width of seven meters and alternating series of riffles, runs, and pools. One pool was particularly extensive and deep (>1 meter). Typical of small streams within the Eastern Corn Belt Plains ecoregion, the predominant substrates were cobble and gravel.

Flat Fork

- By the middle of August, aquatic habitats in Flat Fork (a headwater tributary of Caesar Creek) were reduced to isolated, shallow pools due to a lack of surface water flow. The QHEI scored a 50.0 suggesting marginal WWH. Although technically in the Eastern Corn Belt Plain, aquatic habitats in Flat Fork were more typical of Ohio's southwestern Interior Plateau streams. The most common substrate types were limestone bedrock and cobble size fragments.

Caesar Creek

- Caesar Creek contained very good to exceptional quality physical habitats both upstream and downstream from the reservoir. The QHEI increased from 76.0 upstream from the reservoir to 81.5 near the mouth. Silt-free substrates comprised of sand, gravel, and cobble were the predominant types. Both locations contained eight (8) warmwater habitat attributes and only one to two (1-2) modified habitat attributes. Water willow patches were observed only at the site near the mouth.

Dry Run

- Dry Run contained relatively poor habitat for a reference site. While the channel exhibited a predominance of limestone bedrock fragments, it was very shallow with a maximum depth of less than 40 cm. The QHEI score reflected the relatively low quality (54.5) for a WWH stream due principally to poor to fair development, moderate to heavy silt deposits, moderately embedded substrates, low to no sinuosity, narrow riparian corridors, and sparse amounts of instream cover.

Turtle Creek

- Longitudinally, QHEI scores were similar ranging from 68.0 to 75.5 (mean = 69.8; Figure 68, Plate 5). Substrates were predominated by sand and gravel near the mouth and at McClure Road (RM 4.7), cobble and hardpan at Glosser Road (RM 6.3), limestone slabs and gravel downstream from Mason-Morrow Road (RM 0.7), boulder and cobble sized limestone slabs at the two sampling locations between Cincinnati Milacron and SR 48 (RM 0.5 and 0.4), and a mixture of sand and gravel near the mouth (RM 0.1). Deep pools were present at all locations except RM 0.5 and 0.4. Water depths were considerably lower downstream from RM 0.7 in 1993 than during the previous four years. Low flow (0.050 cfs) was recorded at Mason-Morrow Road. However, on June 30, 1988 during a severe drought, flows were higher suggesting an external impact in 1993. The number of warmwater habitat attributes was considerably higher than the number of modified habitat attributes at RM 0.6 (7 compared to 2), but only slightly higher or equal to the number of modified habitat attributes at the other locations. Black, mucky sediment deposits observed in a pool upstream from Glosser Road suggested possible sewage contamination.

Muddy Creek

- Muddy Creek contained very good quality physical habitat at RM 1.6 (QHEI = 78.0) as characterized by a predominantly gravel substrate, a diverse mixture of cover, deep pools, and well defined riffle-run complexes. Physical habitats in the lower section of Muddy Creek were more typical of a wadeable size stream as opposed to smaller headwater tributaries due to the augmenting flow from the Mason WWTP.

Stonelick Creek

- Typical of Interior Plateau streams, the three free-flowing sites in Stonelick Creek contained good to very good quality physical habitat as evidenced by QHEIs of 69.0 - 78.0 (Plate 5). Substrates were comprised of limestone bedrock, bedrock fragments, and gravel. The quality of habitat was markedly lower (QHEI = 48.0) in the upper end of Stonelick Lake, reflecting the effect of the impoundment. This site contained soft and highly embedded substrates, a thick layer of silt and organic muck, and no flow or riffle-run habitats. The site did, however, contain abundant instream cover, a wooded riparian zone, and a high degree of channel sinuosity.

Sycamore Creek

- Physical habitat was evaluated at the three adjacent sampling locations. QHEI scores were similar and ranged from 70.5 - 76.0. Deep pools were absent in the Sycamore Creek WWTP mixing zone, but present both upstream and downstream from the WWTP discharge.

East Fork Little Miami River

- With a 500 square mile watershed (28.5% of the Little Miami River watershed), the East Fork of the Little Miami River is the largest mainstem tributary. Physical habitats were evaluated at the eight fish sampling locations downstream from East Fork Lake (Plate 5). QHEI scores suggest two relatively homogenous segments, RM 15.5 - 6.6 and RM 4.7 - 1.4 (Figure 67). The upstream segment exhibited the highest QHEI scores (mean = 85.9, range 83.5 - 87.0) indicating higher quality than the lower segment (mean = 68.0, range = 65.0 - 70.5; Figure 68). The three upstream locations (RMs 15.5 - 12.4) contained eight to nine (8-9) warmwater habitat attributes and no modified habitat influences.

- Aquatic habitats in the East Fork were similar to those found in the lower half of the Little Miami River within the Interior Plateau ecoregion. Habitat typically consisted of large pools interspersed by high gradient, fast flowing riffle-run complexes. The pools were generally more than 100 meters in length, 50 to 80 meters wide, and 0.3 to >1.0 meter deep. Riffle-run complexes were approximately 65 to 100 meters in length, 10 to 33 meters wide, and <1.0 meter deep. Substrates in the upper segment were predominated by limestone bedrock, bedrock fragments (boulder and cobble sized slabs), and gravel. Dense patches of water-willow were common along the channel margins and numerous sand, gravel, and rock bars. Within the lower five miles, however, pools became deeper, substrates were predominated by smaller sizes (gravel, sand, hardpan, and silt), and the large riffle-run complexes were replaced by smaller riffles and runs. Severely eroding banks also appeared to be more common in the lower segment due to increased riparian encroachment. Dense patches of water-willow were also noticeably lacking on gravel bars downstream from the Clermont Co. Lower East Fork WWTP suggesting a possible toxic impact to these pollution sensitive macrophytes.

Table 9. Mean 1993 Qualitative Habitat Evaluation Index (QHEI) scores for homogenous segments of the Little Miami River and East Fork.

Stream **Segment Description**	Sampling Location (RM)	QHEI	**Segment Mean QHEI**
Upper Little Miami River			
SR42 to Pitchin Road (RM 102.1 - 92.2)			
	102.1	62.0	**68.5**
	98.3	75.0	
	92.2	68.5	
Clifton Gorge at Grinnel Road (RM 85.4)			
	85.4	87.0	**87.0**
Jacoby Road to Spring Valley (RM 83.1 - 63.4)			
	83.1	76.5	**73.0**
	77.3	78.0	
	77.0	*63.5*	
	76.8	76.0	
	74.5	77.5	
	71.8	77.5	
	64.7	73.0	
	64.4	*62.5*	
	64.2	74.0	
	63.4	71.0	
Waynesville (RM 53.5)			
	53.5	65.0	**65.0**
Lower Little Miami River			
Oregonia to SR 125 (RM 47.5 - 3.5)			
	47.5	76.5	**77.6**
	44.2	83.5	
	38.6	83.5	
	35.5	76.5	
	32.9	74.0	
	32.1	*77.0*	
	31.9	86.5	
	28.2	57.5	

Table 9. Continued.

Stream Segment Description	Sampling Location (RM)	QHEI	Segment Mean QHEI
Oregonia to SR 125, continued (RM 47.5 - 3.5)			
	27.9	80.0	**77.6**
	23.9	82.5	
	22.1	63.5	
	21.5	84.0	
	20.9	80.0	
	18.5	72.5	
	13.3	86.5	
	8.3	73.0	
	8.0	82.0	
	3.5	77.5	
Kellogg Avenue to the Ohio River (RM 1.6 - 0.2)			
	1.6	51.0	**50.5**
	0.2	50.0	
East Fork Little Miami River			
SR 222 to Roundbottom Rd. (RM 15.5 - 6.6)			
	15.5	86.0	**85.9**
	12.7	83.5	
	12.4	87.0	
	9.2	86.0	
	6.6	87.0	
Dst. Clermont Co. Lower E.F. WWTP Trib. to Dst. Milford WWTP (RM 4.7 - 1.4)			
	4.7	68.5	**68.0**
	1.7	70.5	
	1.4	65.0	

Table 10. Qualitative Habitat Evaluation Index (QHEI) matrix showing modified and warmwater habitat characteristics for fish sampling sites in the Little Miami River study area.

Key QHEI Components

			WWH Attributes											MWH Attributes: High Influence						MWH Attributes: Moderate Influence														
River Mile	QHEI	Gradient (ft/mile)	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 Embeddedness	Max Depth > 40 cm	Low/No Riffle Embeddedness	Total WWH Attributes	Channelized or No Recovery	Silt/Muck Substrates	Low Sinuosity	Sparse/No Cover	Max Depth < 40 cm (WD,HW)	Total H.I. MWH Attributes	Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low/No Sinuosity	Only 1-2 Cover Types	Intermittent & Poor Pools	No Fast Current	High/Moderate Embeddedness	Ext./Moderate Riffle Embed.	No Riffle	Total M.I. MWH Attributes	MWH H.I./WWH Ratio	MWH M.I./WWH Ratio
(11-001) – Little Miami River																																		
Year: 93																																		
102.1	62.0	6.9	■	■		■	■	■			■		6						0		▲			▲				▲	▲	▲		5	.14	.86
98.3	75.0	8.3	■	■		■	■	■		■	■	■	8						0					▲	▲			▲				3	.11	.44
92.2	68.5	5.5	■	■	■	■	■	■	■	■	■	■	10						0									▲				1	.09	.18
85.4	87.0	4.9	■	■	■	■	■	■	■	■	■	■	10						0													0	.09	.09
83.1	76.5	25.0	■	■		■	■	■	■	■	■	■	9						0													0	.10	.10
77.3	78.0	5.1	■	■		■	■	■	■	■	■	■	9						0													0	.10	.10
77.0	63.5	5.1	■	■		■	■	■		■	■		7						0				▲	▲	▲			▲			▲	5	.13	.75
76.8	76.0	5.1	■	■		■	■	■	■	■	■	■	9						0							▲						1	.10	.20
74.5	77.5	5.3	■	■		■	■	■	■	■	■	■	9						0													0	.10	.10
71.8	77.5	4.7	■	■		■	■	■	■	■	■	■	9				●		1					▲								1	.20	.30
64.7	73.0	2.6	■	■		■	■	■	■	■	■	■	9						0													0	.10	.10
64.4	62.5	2.6	■	■		■		■	■		■		6				●		1					▲	▲				▲	▲		4	.29	.86
64.2	74.0	2.6	■	■		■	■	■	■		■		7						0										▲	▲		2	.13	.38
63.4	71.0	2.6	■	■		■	■	■	■		■		7						0					▲	▲				▲	▲		4	.13	.63
53.5	65.0	3.2	■			■	■	■	■		■		6		●				1		▲			▲					▲	▲		4	.29	.86
47.5	76.5	5.6	■	■		■	■	■	■		■	■	8						0		▲								▲			2	.11	.33
44.2	83.5	4.5	■	■		■	■	■	■	■	■	■	9						0		▲											1	.10	.20
38.6	83.5	4.2	■	■		■	■	■	■	■	■	■	9						0													0	.10	.10
35.5	76.5	7.5	■	■		■	■	■	■	■	■	■	9				●		1		▲			▲	▲							3	.20	.50
32.9	74.0	2.7	■	■		■	■	■	■	■	■	■	9		●		●		2		▲			▲					▲			3	.30	.60
32.1	77.0	2.7	■	■		■		■	■	■	■	■	8				●		1		▲				▲							2	.22	.44
31.9	86.5	2.7	■	■		■	■	■	■	■	■	■	9						0													0	.10	.10
28.3	57.5	3.5	■	■				■			■		4		●				1		▲			▲	▲			▲	▲		▲	6	.40	1.60
27.9	80.0	4.9	■	■		■	■	■	■	■	■	■	9						0		▲					▲						2	.10	.30
23.9	82.5	3.9	■	■		■		■	■	■	■	■	8						0						▲							1	.11	.22
22.1	63.5	4.6	■	■				■		■	■		5				●		1		▲			▲	▲			▲			▲	5	.33	1.17
21.5	84.0	3.8	■	■		■		■	■	■	■	■	8						0						▲							1	.11	.22
20.9	80.0	3.8	■	■		■	■	■	■	■	■	■	9						0		▲			▲								2	.10	.30
18.5	72.5	6.5	■	■		■		■	■	■	■	■	8				●		1		▲				▲							2	.22	.44
13.3	86.5	5.5	■	■		■	■	■	■	■	■		8						0											▲		1	.11	.22
8.3	73.0	3.9	■	■				■	■	■	■	■	7						0		▲			▲	▲			▲	▲			5	.13	.75
8.0	82.0	3.9	■	■		■	■	■	■	■	■		9						0		▲								▲	▲		3	.10	.40
3.5	77.5	.1	■	■		■	■	■	■		■		7						0										▲	▲		2	.13	.38

Table 10. Continued.

Key
QHEI
Components

River Mile	QHEI	Gradient (ft/mile)	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 Embeddedness	Max Depth > 40 cm	Low/No Riffle Embeddedness	Total WWH Attributes	MWH Attributes, High Influence: Channelized or No Recovery	Silt/Muck Substrates	Low Sinuosity	Sparse/No Cover	Max Depth < 40 cm (WD,HW)	Total H.I. MWH Attributes	MWH Attributes, Moderate Influence: Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low/No Sinuosity	Only 1-2 Cover Types	Intermittent & Poor Pools	No Fast Current	High/Moderate Embeddedness	Ext./Moderate Riffle Embed.	No Riffle	Total M.I. MWH Attributes	MWH H.I./WWH Ratio	MWH M.I./WWH Ratio
1.6	51.0	.1	■				■	■			■		4		●				1		▲		▲	▲				▲	▲		▲	6	.40	1.60
.2	50.0	.1	■				■	■			■		4		●		●		2		▲		▲	▲				▲	▲		▲	6	.60	1.80
(11-007) – Sycamore Creek																																		
Year: 93																																		
.4	76.0	13.8	■	■		■		■		■	■	■	7						0				▲		▲			▲				3	.13	.50
.2	70.5	13.8	■	■	■	■		■	■		■		7						0					▲	▲	▲			▲	▲		5	.13	.75
.1	75.0	13.8	■	■		■	■	■	■		■		7						0										▲	▲		2	.13	.38
(11-020) – Muddy Creek																																		
Year: 93																																		
1.6	78.0	15.3	■	■		■	■	■	■		■		7						0		▲								▲	▲		3	.13	.50
(11-021) – Turtle Creek																																		
Year: 93																																		
6.3	69.5	10.3	■	■		■	■	■			■		6						0		▲		▲					▲	▲	▲		5	.14	.86
4.7	69.5	7.5	■	■		■	■	■			■		6						0		▲			▲				▲	▲	▲		5	.14	.86
.6	75.5	20.8	■	■		■	■	■			■	■	7						0									▲	▲			2	.13	.38
.5	68.0	20.8	■					■		■	■	■	5						0					▲	▲	▲		▲				4	.17	.83
.4	68.0	20.8	■	■		■		■			■		5						0					▲	▲			▲	▲	▲		5	.17	1.00
.1	68.5	5.2	■	■		■	■	■			■		6						0		▲							▲	▲	▲		4	.14	.71
(11-030) – Newman Run																																		
Year: 93																																		
.3	76.0	41.6	■	■		■	■	■		■	■	■	8						0		▲							▲				2	.11	.33
(11-032) – Glady Run																																		
Year: 93																																		
4.9	54.0	9.5	■				■	■			■		4		●				1		▲			▲				▲	▲	▲	▲	6	.40	1.60
4.7	66.0	40.0	■	■		■	■	■	■		■		7						0										▲	▲		2	.13	.38
.3	69.0	5.6	■	■		■	■	■	■		■		7						0										▲	▲		2	.13	.38

Table 10. Continued.

Key QHEI Components

River Mile	QHEI	Gradient (ft/mile)	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 Embeddedness	Max Depth > 40 cm	Low/No Riffle Embeddedness	Total WWH Attributes	MWH Attributes, High Influence: Channelized or No Recovery	Silt/Muck Substrates	Low Sinuosity	Sparse/No Cover	Max Depth < 40 cm (WD,HW)	Total H.I. MWH Attributes	MWH Attributes, Moderate Influence: Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low/No Sinuosity	Only 1-2 Cover Types	Intermittent & Poor Pools	No Fast Current	High/Moderate Embeddedness	Ext./Moderate Riffle Embed.	No Riffle	Total M.I. MWH Attributes	MWH H.I./WWH Ratio	MWH M.I./WWH Ratio
(11-035) – Beaver Creek																																		
Year: 93																																		
1.6	54.5	5.2	■	■				■			■		4		●		●		2		▲		▲	▲	▲			▲	▲	▲		7	.60	2.00
.5	74.0	15.3	■	■	■	■		■	■		■		7						0						▲				▲	▲		3	.13	.50
.3	64.0	7.2	■	■	■			■	■		■		6				●		1					▲	▲	▲			▲	▲		5	.29	1.00
.3	70.5	7.2	■	■	■	■		■	■		■		7						0					▲	▲				▲	▲		4	.13	.63
(11-036) – Little Beaver Creek																																		
Year: 93																																		
4.7	67.5	16.1		■		■		■	■		■		5			●	●		2	▲				▲	▲				▲	▲		5	.50	1.33
4.5	72.0	10.6		■	■	■		■	■	■	■		7			●			1	▲					▲					▲		3	.25	.63
4.4	48.5	10.6		■							■		2	●		●	●		3	▲				▲	▲			▲	▲	▲		6	1.33	3.33
2.1	76.0	12.3	■	■	■	■	■	■	■		■		8						0	▲				▲					▲	▲		4	.11	.56
.1	70.5	15.3		■				■	■		■		4						0	▲				▲	▲				▲	▲		5	.20	1.20
(11-040) – Yellow Springs Creek																																		
Year: 93																																		
.5	80.0	31.2	■	■		■	■	■		■	■	■	8						0									▲				1	.11	.22
.4	73.5	31.2	■	■		■	■	■	■	■	■	■	9				●		1													0	.20	.20
.3	79.0	31.2	■	■		■	■	■	■	■	■	■	9						0													0	.10	.10
(11-050) – Glady Run WWTP Swale																																		
Year: 93																																		
.3	53.0	24.3		■				■			■		3			●	●		2	▲	▲			▲	▲			▲	▲	▲		7	.75	2.50
.2	49.0	24.3		■	■					■	■		4	●		●	●		3	▲			▲	▲	▲			▲		▲	▲	7	.80	2.20
.1	66.0	24.3		■	■	■		■		■	■	■	7			●			1	▲			▲	▲	▲			▲				5	.25	.88
(11-100) – East Fork Little Miami River																																		
Year: 93																																		
15.5	86.0	10.9	■	■		■	■	■	■	■	■	■	9						0													0	.10	.10
12.7	83.5	7.5	■			■	■	■	■	■	■	■	8						0													0	.11	.11
12.4	87.0	7.5	■	■		■	■	■	■	■	■	■	9						0													0	.10	.10
9.2	89.0	5.7	■	■		■	■	■	■	■	■	■	9						0						▲							1	.10	.20
6.6	87.0	4.5	■	■		■	■	■	■	■	■	■	9						0		▲				▲							2	.10	.30
4.7	68.5	4.5	■	■				■	■		■		5						0		▲			▲	▲				▲	▲		5	.17	1.00
1.7	70.5	3.5	■	■		■	■	■	■		■		7						0				▲						▲	▲		3	.13	.50
1.4	65.0	3.5	■			■	■	■			■	■	6		●				1		▲		▲	▲				▲	▲			5	.29	1.00

Table 10. Continued.

Key QHEI Components

			WWH Attributes											MWH Attributes: High Influence						MWH Attributes: Moderate Influence														
River Mile	QHEI	Gradient (ft/mile)	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 Embeddedness	Max Depth > 40 cm	Low/No Riffle Embeddedness	Total WWH Attributes	Channelized or No Recovery	Silt/Muck Substrates	Low Sinuosity	Sparse/No Cover	Max Depth < 40 cm (WD,HW)	Total H.I. MWH Attributes	Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low/No Sinuosity	Only 1-2 Cover Types	Intermittent & Poor Pools	No Fast Current	High/Moderate Embeddedness	Ext./Moderate Riffle Embed.	No Riffle	Total M.I. MWH Attributes	MWH H.I./WWH Ratio	MWH M.I./WWH Ratio
(11-300) – Caesar Creek																																		
Year: 93																																		
16.5	76.0	5.2	■	■		■	■	■		■	■	■	8						0									▲				1	.11	.22
.1	81.5	8.2	■	■	■	■	■	■			■	■	8						0									▲	▲			2	.11	.33
(11-301) – Flat Fork																																		
Year: 93																																		
1.7	50.0	31.2	■	■				■		■			4			●	●	●	3					▲	▲			▲			▲	4	.80	1.60
(11-400) – Massies Creek																																		
Year: 93																																		
.3	67.5	18.1	■	■		■		■		■	■	■	7				●		1				▲		▲			▲				3	.25	.63
(11-401) – Oldtown Creek																																		
Year: 93																																		
.1	82.5	17.2	■	■		■	■	■	■	■	■	■	9						0													0	.10	.10
(11-404) – South Fork Massies Creek																																		
Year: 93																																		
1.1	66.5	5.5		■		■		■		■	■	■	6			●			1	▲					▲			▲				3	.29	.71
(11-107) – Stonelick Creek																																		
Year: 93																																		
20.0	69.0	18.1	■	■	■	■		■				■	7			●			2						▲			▲	▲			3	.38	.75
16.7	48.0	.1	■				■	■			■		4		●				1		▲		▲	▲				▲	▲		▲	6	.40	1.60
3.1	73.5	18.5	■	■		■		■			■	■	6						0		▲				▲			▲	▲			4	.14	.71
1.2	78.0	7.5	■	■		■	■	■		■	■	■	8						0									▲				1	.11	.22

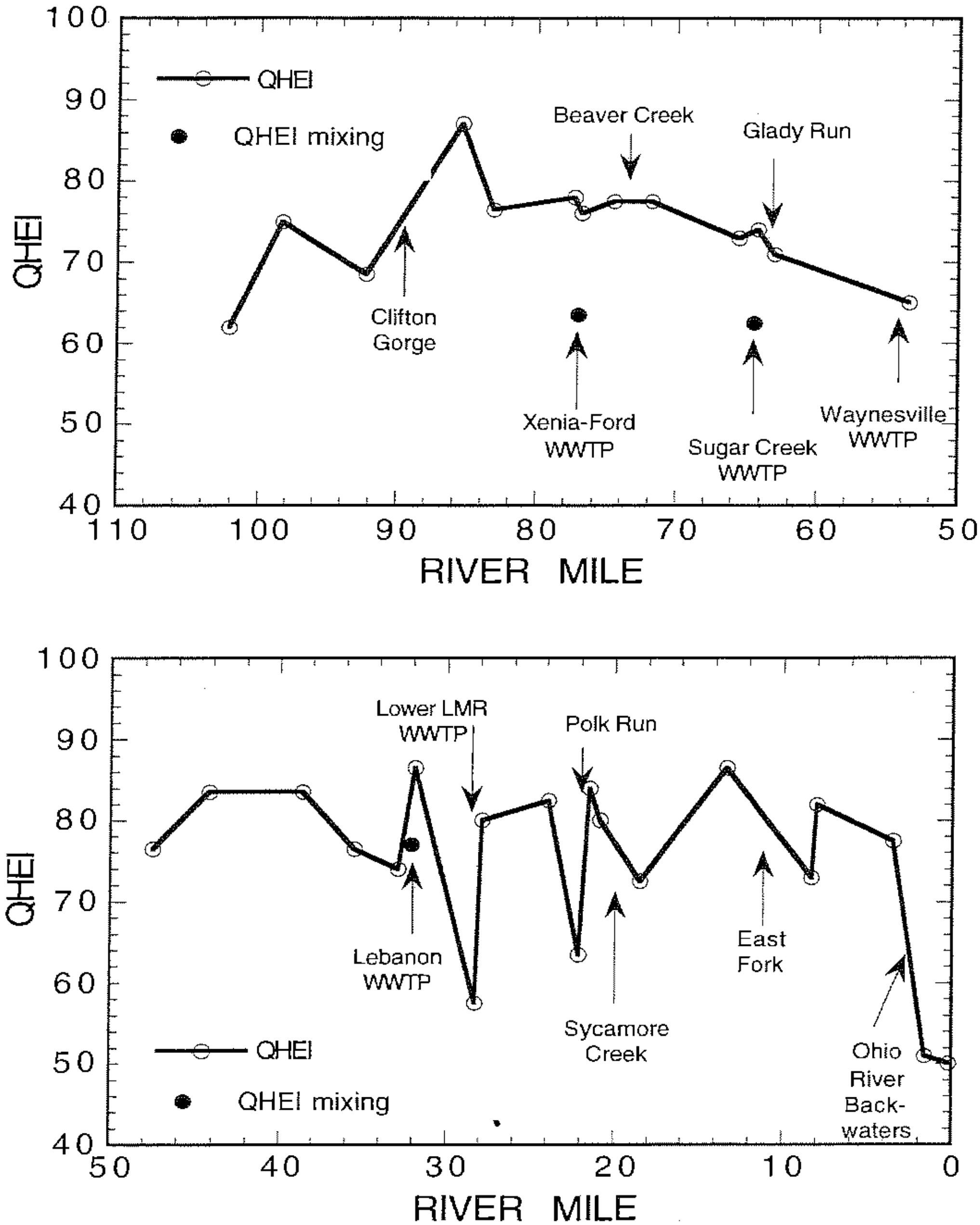


Figure 67. Longitudinal trend of the Qualitative Habitat Evaluation Index (QHEI) in the upper half (Top Graph) and lower half (Bottom Graph) of the Little Miami River mainstem during 1993.

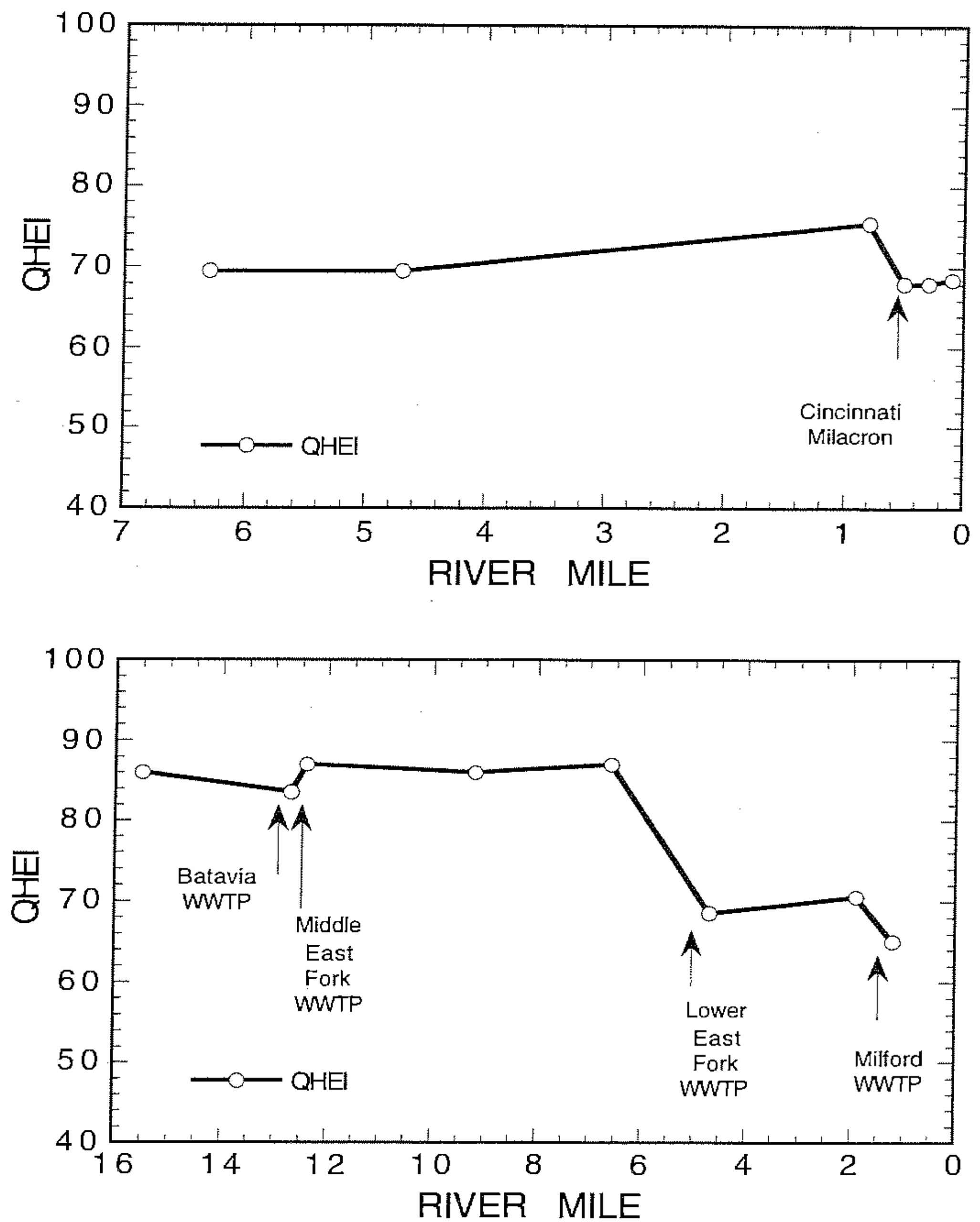


Figure 68. Longitudinal trend of the Qualitative Habitat Evaluation Index (QHEI) in Turtle Creek (Top Graph) and the East Fork of the Little Miami River (Bottom Graph) during 1993.

Macroinvertebrate Assemblages (Plate 6-7,9; Figure 1,69-70; Table 5,11,A-9,A-10)
Little Miami River

- Macroinvertebrate assemblages were sampled and evaluated at 35 sites in the Little Miami River during the 1993 survey. Narrative evaluations of the assemblages ranged from good to exceptional quality in the free flowing section to only fair quality within the Ohio River backwaters (Table 11). Invertebrate Community Index (ICI) scores, excluding mixing zone and slow current affected stations, ranged from a low of 40 (downstream from the Waynesville WWTP, RM 53.2) to a high of 58 (downstream from the I 275 bridge, RM 20.6, Figure 69).

- A total of 236 macroinvertebrate taxa were collected from the Little Miami River by the Ohio EPA in 1993. A cumulative total of 321 taxa were collected throughout the watershed by Ohio EPA (349 total taxa with the additional 28 unionid taxa reported by Hoggarth [1992]). By sampling location, the highest cumulative total number of macroinvertebrates collected in the Little Miami River mainstem (86) occurred at SR 48 (RM 32.9, Figure 1). This location also had the highest cumulative total number (27) of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) taxa (*i.e.,* EPT taxa) in the mainstem. The mainstem at RM 32.9 contained the second most diverse macroinvertebrate assemblage found in the study area. The highest number (90 taxa) occurred in the East Fork at RM 6.7 (Table A-10).

- Macroinvertebrate taxa collected in the Little Miami River that are indicative of high quality streams in Ohio included mayflies from the family Baetidae (species formerly in *Pseudocloeon)* at RMs 101.5 and 72.3; stoneflies of the *Agnetina capitata* complex at 10 stations between RM 47.5 and 8.8, the *Neoperla clymene* complex at 9 locations from RM 43.7 to 18.9, and the genus *Leuctra sp.* at RM 80.6; the caddisfly species *Psychomyia flavida* at 8 stations from RM 76.7 to 29.2 and the genus *Protoptila* at RM 32.0; and the midges of the *Rheotanytarsus distinctissimus* group at 5 sites from RM 85.3 to 35.9 and *Sublettea coffmani* at 7 locations between RMs 83.3 and 64.4. A new macroinvertebrate taxa, the riffle beetle *Microcylloepus pusillus*, was collected for the first time at RMs 53.2, 43.7, and 32.0 (*i.e.,* the first Ohio EPA records for this taxon in an Ohio stream).

- Hoggarth (1992) reports a total of 30 Unionidae (freshwater mussels) species, including two state endangered species (*Quadrula nodulata* , the wartyback mussel at SR 48 [RM 23.9] and Newtown Road [RM 8.2] and *Villosa fabalis*, the rayed bean mussel at SR 123 [RM 38.7]), that inhabit the Little Miami River (Plate 7). The highest numbers of mussel species in the mainstem were collected at RM 23.9 (18 species) and RMs 36.0 and 42.0 (17 species each, Figure 1). Longitudinally within the Little Miami River, the mussel survey found a gradual increase in the number of upper mainstem mussel species from 1 species near South Charleston (RMs 103.0-99.0) to 12 species in the Clifton Gorge (RMs 85.4-80.8) followed by a marked decline of only 3 to 8 species at most locations between Xenia and Waynesville (RMs 80.8-53.8, Hoggarth 1992). Mussel populations within the lower half increased to 12 to 17 species in the segment extending from downstream of Waynesville to South Lebanon (RMs 51.2-33.2), declined to 9 species downstream from Muddy Creek (RM 31.2), increased to 13 to 18 species between Simpson Creek and I-275 (RMs 28.3-20.9), but decrease to only 4 to 12 species between I-275 and Bass Island (RMs 19.3-8.0). No mussel species were collected at Beechmont or Kellogg avenues (RM 3.5-1.6).

- Zebra mussels *(Dreissena polymorpha)* were collected from the Little Miami River at Milford (RM 13.1) for the first time during the 1993 survey. Approximately 125 individuals were attached to a set of artificial substrates retrieved from a calm area in the river with non-detectable current. The introduced species was not found by qualitative sampling at this station, however, or at any other location within the basin. The scarcity of zebra mussels in the basin may be because they have only recently been introduced and have not had time to disperse. Zebra mussels can clog water intake pipes and kill native unionid mussels by physically attaching to their shells and interfering with their ability to feed, reproduce, and remain anchored in the substrates. The species can be introduced to new waters via transportation on boats and trailers from infested lakes and rivers.

Upper Mainstem: South Charleston to Waynesville

- Macroinvertebrate communities sampled upstream (RM 101.5) and downstream (RM 98.8) from Gilroy Ditch (RM 100.65) were evaluated as exceptional with no apparent impact from the South Charleston WWTP (Gilroy Ditch RM 1.4) or a feedlot near the mouth of Gilroy Ditch that have historically caused impairment (Figure 69). Macroinvertebrate communities remained indicative of exceptional quality downstream to U.S. 68 (RM 80.6). Compared to the results at Dolly Varden Road (RM 98.8), assemblages at Grinnel Rd. (RM 85.3) and U.S. Rt. 68 (RM 80.6) showed some indication of impact due to decreases in the ICIs (50 to 46), fewer total taxa (78 compared to 59 to 64), and higher percentages of tolerant taxa (1.2% compared to 8.2 and 7.1%; Tables A-9 and A-10). The most notable difference upstream and downstream from the confluence of Yellow Springs Creek was a large increase in the density of macroinvertebrates (from 557 individuals per square foot at RM 85.3 to 1081 organisms per square foot at RM 83.1), an indication of nutrient enrichment, most likely from the Yellow Springs Creek WWTP.

- The ICI and total cumulative number of taxa showed further declines downstream from the Xenia Ford Road WWTP (RM 77.05) indicating a change from exceptional to very good quality. Results of qualitative sampling within the mixing zone (RM 77.0) indicated a good quality assemblage (Table 11). The sample contained 12 EPT taxa (compared to 18 EPT taxa at RM 80.6 and 15 at RM 76.7) and the predominant organisms shifted from a diverse mixture of hydropsychid caddisflies, mayflies, and midges (at RM 80.6 and 76.7) to only midges (Table A-10). The total density of macroinvertebrates showed another significant increase from 1488 individuals per square foot at RM 80.6 to 2855 organisms per square foot downstream from the WWTP (RM 76.7). These types of community changes are indicative of increased organic or nutrient loadings as opposed to a more severe impact from acute toxicity. Sampling results from the next two stations downstream (RMs 74.6 and 72.3) remained indicative of exceptional quality. Downstream, sampling results showed an increase in the ICI score and cumulative total number of taxa at RM 72.3, but subsequent declines in both the ICI and taxa richness took place between Bellbrook and Waynesville (RMs 65.6 to 53.2). The highest densities of macroinvertebrates in the mainstem were collected downstream from the Xenia Ford Road WWTP and Beaver Creek which receives effluent from the Montgomery Co. Eastern Regional WWTP and Greene Co. Beavercreek WWTP.

- The ICI increased slightly from the very good range (44 at RM 65.6) upstream from the Greene County Sugar Creek WWTP to the exceptional range (46 at RM 64.2) downstream, however, the cumulative total number of species and number of qualitative EPT taxa showed the opposite trend and decreased (67 to 57 and 16 to 11, respectively). Sampling results from within the WWTP mixing zone were also indicative of an impaired community. Narratively, the ICI was indicative of only a good quality macroinvertebrate assemblage due to a high percentages of tolerant taxa (22.6%) and other dipteran and non-insects and a lower percentage and number of mayflies (Table A-9). Additionally, the majority of hydropsychid caddisflies in the mixing zone sample had severely "burned" gills; this is a condition associated with chlorine pollution (Simpson 1980). The impairment found within the mixing zone was more indicative of enrichment and chlorine impacts as apposed to acute toxicity. Downstream at Spring Valley (RM 63.0), the ICI remained a 46 (exceptional range), but the cumulative total number of taxa declined to 53, the lowest value in the free-flowing mainstem (Table A-10).

- The ICI declined to the good range (40 at RM 53.2) and the total number of taxa remained 53 at the next station located downstream from the Waynesville WWTP. The ICI declined due to a lower number of mayfly taxa and a markedly lower percentage of *Tanytarsini* midges (declined from 40.1 to 4.8% and remained below the expected range for over 17.3 miles). While these results may have been influenced by suboptimal current velocity over the artificial substrates, water quality impacts are likely because of the abnormally low proportion of *Tanytarsini* midges were also found throughout the next 17.3 miles of the mainstem (RMs 53.2 to 35.9).

Lower Mainstem: Oregonia to the Ohio River

- Narratively, macroinvertebrate communities in the lower free-flowing Little Miami River ranged from very good to exceptional quality, except for one mixing zone station. Communities within the impounded Ohio River backwaters, however, were evaluated as only fair quality (Table 11). Samples affected by slow current speed (RMs 47.5, 35.9, 22.2, 13.1, and 1.6) were evaluated using the qualitative and quantitative results.

- ICI values increased from 48 at Ft. Ancient (RM 43.7) to 56 at South Lebanon (RMs 32.9-32.0), decreased slightly (52-50) between Kings Mill and Loveland (but remained exceptional, RMs 30.7-23.9), increased to the highest mainstem value (58) at I-275, then declined to 52 upstream from Bass Island (RM 8.8) and 42 at Beechmont Avenue (RM 3.5, Figure 69, Table 11). Downstream from Waynesville, densities of macroinvertebrates decreased to values less than 500 organisms per square foot in the mainstem to Morrow, but then increased back to over 1,000 organisms per square foot at most locations from downstream of Turtle Creek to Beechmont Avenue (RMs 32.9-3.4).

- Macroinvertebrate results from the Lebanon WWTP mixing zone (RM 32.1) were indicative of only a good quality assemblage (ICI=34) due partially to very high percentages of tolerant taxa and other dipteran and non-insects. These structural changes and relatively high numbers of qualitative EPT taxa (11), cumulative total taxa (69), and density of organisms (1,161 per foot squared) suggest nutrient enrichment associated impacts as apposed to acute toxicity.

- The ICI significantly declined from 52 at RM 8.8 to 42 at Beechmont Avenue (RM 3.4), one of the largest changes in the study area. The decline was due primarily to an increase in the tolerant taxa Oligochaeta (segmented worms) and an increase in several facultative (pollution intermediate) taxa of midges, possibly caused by CSO discharges and urban runoff from the Cincinnati area.

- The ICI score from the Ohio River backwaters (RMs 1.6) was substantially below the Interior Plateau's warmwater biocriterion (30). Ecologically, the Ohio River backwaters are most similar to the Lake Erie river mouths which are evaluated by an interim biocriterion of 22. The ICI value of 12, however, is even significantly below that value. The communities in the Little Miami River were predominated by the facultative midge taxa *Glyptotendipes (Phytotendipes) sp.* and *Dicrotendipes lucifer*. A cumulative total of only seven (7) mayfly and caddisfly taxa were collected at the two impounded stations compared to 12 to 19 taxa at most free-flowing locations. The primary cause(s) of the depressed community was probably due to lower habitat quality (*i.e.*, slow current speed and fine particle size substrates) combined with CSO and urban runoff impacts from Cincinnati.

Yellow Springs Creek

- Macroinvertebrate samples from upstream (RM 0.5) and downstream (RM 0.3) the Yellow Springs Creek WWTP were evaluated as exceptional (ICI=46) and showed no evidence impact. Two intolerant stonefly taxa, *Leuctra* and *Paragnetina media* , were collected at both stations. Community performance within the mixing zone, however, declined to the good (ICI=36) range due primarily to structural changes. The results did not suggest acutely toxic conditions, but more of an impact associated with nutrients.

Oldtown Creek

- The macroinvertebrate community sampled downstream from Brush Row Road (RM 0.4) was evaluated as good (ICI=38). This station had a relatively taxa rich caddisfly community, with ten total taxa, and midge community, with 30 total taxa. Six coolwater taxa were found to inhabit this station which indicates some groundwater recharge in this stream. These six (6) taxa were the caddisfly species *Hydropsyche (H.) slossonae* and midges of the genera *Zavrelimyia*, *Parametriocnemus*, and *Micropsectra* , and the species *Polypedilum (P) aviceps* and *Paratanytarus n. sp. 1.*

South Fork Massies Creek

- Macroinvertebrate communities sampled in South Fork Massies Creek, using qualitative methods, were evaluated as exceptional (RM 2.1) and very good (RM 1.1). The upstream station was channelized with grass banks, agricultural fields on both sides, but contained good riffle development, however, heavy silt covered most substrates. The downstream station had forested banks, good riffle-pool development, and only slight amounts of siltation. The proposed channel deepening in this area would severely degrade the ability of these two sites to support high quality macroinvertebrate communities by turning this area into a big pool.

Massies Creek

- The qualitative macroinvertebrate sample from Massies Creek was indicative of a good quality assemblage, however, the total number of qualitative and EPT taxa were relatively low (33 and 9, respectively). The taxa present were indicative of non-impacted communities, however. The substrates were heavily embedded with marl which may be causing the lower taxa richness by physically reducing suitable attachment sites and microhabitats for macroinvertebrates.

Beaver Creek

- ICI scores in Beaver Creek were exceptional (48) both upstream and downstream from the confluence of Little Beaver Creek, suggesting no far-field impact from the Montgomery Co. E. Regional WWTP. Downstream from the Greene Co. Beavercreek WWTP, however, the mixing zone (RM 0.4) ICI declined to the good range (36) due to a lower number of mayfly taxa, lower percentage of caddisfly taxa, and an increase in other dipteran and non-insect taxa (especially midges of the *Cricotopus tremulus* and *Rheotanytarsus exiguus* groups). Acute toxicity, however, was not indicated. Also suggesting an impact, the qualitative sample further downstream (RM 0.2) was indicative of only a fair quality macroinvertebrate assemblage. A comparison of the qualitative results from upstream of the WWTP (RM 0.5) to downstream (RM 0.2) shows a declines in the total numbers of all taxa and EPT taxa (53 to 35 and 9 to 6, respectively).

Little Beaver Creek

- The macroinvertebrate community in Little Beaver Creek was severely impacted by the Montgomery County Eastern Regional WWTP discharge. The ICI markedly declined from a 40 (good) at RM 4.7 to 4 (poor) within the mixing zone. The mixing zone station was predominated by pollution tolerant Oligochaets (segmented worms), Turbellaria (flatworms), the midge *Polypedilum (P.) illinoense* , and a blackfly *Simulium sp.* The mixing zone sample contained no mayflies or stoneflies and low numbers of only one caddisfly. The degree of impact was indicative of an acutely toxic response by macroinvertebrates to the WWTP effluent. The community sampled at RM 4.4 by qualitative methods was essentially identical to the mixing zone community and was likewise evaluated as poor. The ICI gradually increased to the fair range (20) at North Fairfield Road (RM 2.0) and the good range (38) near the mouth (RM 0.1).

Glady Run

- Macroinvertebrates in Glady Run upstream from the Glady Run Swale (RM 4.9) were indicative of a good quality assemblage (ICI=36). The fauna included 10 cool-water macroinvertebrate taxa indicative of groundwater flow from springs. They were (the stonefly *Amphinemura delosa*, the caddisfly *Diplectrona modesta*, and the midges *Meropelopia sp.*, *Zavrelimyia sp.*, *Prodiamesa olivacea*, *Parametriocnemus sp.*, *Thienemanniella partita*, *Polypedilum (P.) albicorne*, *Micropsectra sp.*, and *Paratanytarsus n. sp. 1)*.

- The macroinvertebrate community performance downstream (RM 4.7) from Glady Run Swale declined to the fair range (ICI=28) due primarily to compositional and structural changes. The number of coolwater taxa declined to only four midge taxa. The community remained fair (ICI=24) near the mouth (RM 0.3). Isopods (aquatic sow bugs) were one of the most numerous taxa in both the quantitative and qualitative samples.

Glady Run Swale

- A fair quality community was collected from Glady Run Swale upstream from the Xenia-Glady Run WWTP discharge possibly due to channelization. The number of qualitative EPT taxa (3) was below the expectations for a good community, but overall the community supports the conclusion that Glady Run Swale has permanent flow; at least through August.

Newman Run

- A very limited macroinvertebrate community was collected from Newman Run during severe drought (intermittent flow) conditions in late August. Newman Run contained one of the lowest total number of qualitative taxa (11) in the study area. The assemblage was predominated by Isopods, aquatic sow bugs. Based on the fish community results, which were indicative of exceptional quality in early July, the limited macroinvertebrate results were due more to the drought than poor water quality.

Anderson Fork

- The macroinvertebrate community performance in Anderson Fork (RM 5.0) was evaluated as good. The artificial substrate sample was affected by slow current speed, but the number of qualitative sample EPT (11) was indicative of a good benthic community.

Flat Fork

- Qualitative sampling in Flat Fork during intermittent flow yielded a very limited macroinvertebrate community indicative of only marginally fair quality. The assemblage was dominated by water boatmen and snails. An abundance of leeches were also observed by the fish crew while electrofishing.

Caesar Creek

- The macroinvertebrate community performance in Caesar Creek (RM 16.5) upstream from Caesar Creek Reservoir was evaluated as very good. The artificial substrate sample was affected by slow current speed, but the number of qualitative EPT taxa (15) met the expected range for a very good community. The Asiatic clam *(Corbicula fluminea)*, midges, and riffle beetle larvae were the predominant benthic taxa in the stream channel.

- The quality of the macroinvertebrate community declined to only fair downstream from the reservoir. The qualitative EPT declined from 15 to eight (8), which slightly deviates from the expected range for a good quality community.

Dry Run

- A fair quality macroinvertebrate community was collected from Dry Run during intermittent flow in late August. The qualitative number of EPT taxa (4) deviated slightly from the expected range of a good community. The fauna included two intolerant taxa, the stonefly *Acroneuria evoluta* and caddisfly taxa *Helichopsyche borealis*. The quantitative sample was affected by slow current speed, thus was not used as the primary assessment.

Turtle Creek

- ICI values in Turtle Creek ranged from a high of 36 at RM 4.3 to a low of 16 upstream from Dry Run near the mouth (Figure 70). Narratively, the quality of macroinvertebrate communities was marginally good at three locations (RMs 6.3, 0.6, and 0.5), good at one location (RM 4.3), and fair near the mouth (RM 0.1, Table 11). Flows were low throughout most of the sample colonization period; based on an inspection conducted two weeks into colonization. The quantitative sample at RM 0.6 was affected by slow current speed. No significant change was detected between assemblages upstream and immediately downstream from the Cincinnati Milacron discharge, however, the community at RM 0.1 was impacted by enrichment. Sample density increased to 2,583 organisms per square foot compared to a density of 149 organisms at RM 0.5. The most numerous taxa included two pollution tolerant taxa, Oligochaets (segmented worms) and *Dicrotendipes fumidus* (midge).

Muddy Creek

- A macroinvertebrate community indicative of good (ICI=34) quality was collected from Muddy Creek at RM 2.5. The percentage of other dipterans and non-insects, however, strongly deviated from the expected range for a good community suggesting organic or nutrient enrichment from the Mason WWTP which discharges approximately three quarters of a mile upstream. A strong effluent odor and black sludge deposits along the channel margins were present at the sampling site.

Sycamore Creek

- Sycamore Creek contained only fair quality midge dominated communities both upstream and downstream from the Hamilton Co. MSD Sycamore Creek WWTP. The mixing zone supported an improved assemblage indicative of good quality (ICI=32), however, four ICI metrics only scored a "two" and no qualitative EPT taxa were collected. The results also show the continuation of rather severe impacts upstream from the WWTP. Upstream sewer overflows may be the principle source of the impact. Negative attributes of the assemblage downstream from the WWTP included high percentages of other dipteran and non-insects and tolerant taxa which strongly deviated from the expected (*i.e.,* the ICI metric scored a zero).

Stonelick Creek

- Stonelick Creek's macroinvertebrates improved from fair quality (ICI=24) upstream from Stonelick Lake to good quality in the lower three miles (ICI = 32 and 36). The number of qualitative EPT taxa (5) upstream from the Lake (RM 17.7) deviated slightly from the expected range for a good community, possibly impacted by the drought. The stream flow continued to be low downstream from the lake (RMs 2.9 and 1.0), but community performance improved to the good range and the pollution sensitive stonefly, *Agnetina capitata* complex, was collected at both stations. The number of qualitative EPT taxa collected (17) at RM 0.1 is typical of exceptional quality stream communities.

East Fork Little Miami River

- The lower 15.5 miles of the East Fork supports a diverse aquatic macroinvertebrate fauna. Cumulatively, a total of 163 macroinvertebrate taxa were collected from the eight (8) sites downstream from the reservoir (Ohio EPA collections). The total cumulative number of taxa collected by site ranged from a Little Miami River watershed high of 90 taxa collected at Roundbottom Road (RM 6.7) to 50 taxa downstream from the Milford WWTP (RM 0.8, Table 11, A-10). The highest number of qualitative and cumulative EPT taxa (24 and 27, respectively) within the study area was also collected in the East Fork at the ODNR canoe access (RM 12.7), immediately upstream from the Clermont Co. Middle East Fork WWTP. Pollution sensitive taxa collected that are indicative of high quality streams in Ohio included the mayfly Baetidae (formerly in *Pseudocloeon)* at six (6) stations; the stonefly taxa *Acroneuria evoluta* at one (1) station, *Agnetina capitata* complex at all eight (8) stations, and *Neoperla clymene* complex at three (3) stations; the caddisfly taxa *Psychomyia flava* at four (4) stations, *Leucotrichia pictipes* at three (3) stations, and *Protoptila sp.* at six (6) stations; and the midge taxa *Synorthocladius semivirens* at one (1) station. The combination of high ICI scores and a diverse macroinvertebrate fauna makes the East Fork of the Little Miami River one of Ohio's highest quality streams.

- The macroinvertebrate community samples from the East Fork of the Little Miami River ranged from exceptional to very good quality based on ICI scores (Table 11). The highest ICI value (54) was recorded at three of the four most upstream stations (RMs 15.5, 12.7, and 9.2) and the lowest value (44) occurred downstream from the Clermont County Lower East Fork WWTP (RM 4.7, Figure 70). Longitudinally, the density of macroinvertebrates doubled downstream from the Batavia WWTP (872 to 1649 organisms per square foot), decreased back to background levels (716 -746 organisms per square foot) upstream and downstream from the Clermont Co. Lower East Fork WWTP, but increased again by Milford (1366-1904 organisms per square foot, Table 11).

- The ICI declined 8 units immediately downstream from the Batavia WWTP (RM 13.3) due to structural changes caused by an increase in two filter feeding taxa; the midge *Rheotanytarsus exiguus* group and the caddisfly *Cheumatopsyche* sp., but increased back to 54 one half mile downstream (RM 12.7). The community shift suggests an increase in fine particulate organic matter from the Batavia WWTP, possibly in the form of algae from higher nutrient levels.

- The ICI remained high (54) downstream to Olive Branch Stonelick Road (RM 9.2), but declined to 46 at Perintown (RM 6.7) due to a higher percentage of other dipteran and non-insects and lower percentages of Tanytarsini and caddisflies. The ICI declined further to a 44 (the lowest score) downstream from the Lower East Fork Regional WWTP (RM 4.9) due to a high percentage of tolerant taxa and fewer mayfly taxa. These types of changes were relatively minor and were probably caused by some source of mild organic enrichment.

- Although the ICI increased at the last two downstream stations (upstream and downstream from the Milford WWTP, RMs 1.9 and 0.8), the number of pollution sensitive taxa declined to one (1) taxa (*Agnetina capitata* complex) compared to a minimum of three (3) taxa at the other six (6) upstream stations.

- Hoggarth (1992) reported 22 species of Unionidae (freshwater mussels) as inhabiting the East Fork. The fauna included two state endangered species, *Villosa fabalis* (the rayed bean mussel) and *Villosa lienosa* (the little spectaclecase mussel), upstream from the East Fork Lake.

Table 11. Summary of macroinvertebrate data collected from artificial substrates (quantitative) and natural substrates (qualitative) in the Little Miami River study area from July through September, 1993. Mixing zone samples are denoted by *Italics*.

Stream River Mile	Density (#/ft2)	Quant. Taxa	*Quantitative Evaluation* Qual. Taxa	Qual. EPT[a]	Total Taxa	ICI	Evaluation
Little Miami River							
101.5	-	-	53	13	-	-	Exceptional
98.8	757	41	62	14	78	50	Exceptional
89.2	-	-	61	19	-	-	Exceptional
85.3	557	40	40	12	59	46	Exceptional
83.1	1081	38	51	18	67	48	Exceptional
80.6	1488	35	48	18	64	46	Exceptional
77.0	-	-	*54*	*12*	-	-	*Good*
76.7	2855	36	32	15	54	44ns	Very Good
74.6	-	-	57	18	-	-	Exceptional
72.3	2622	46	54	13	74	52	Exceptional
65.6	1507	33	55	16	67	44ns	Very Good
64.4	*1601*	*47*	*44*	*13*	*65*	*38*	*Good*
64.2	1339	37	38	11	57	46	Exceptional
63.0	854	31	42	12	53	46	Exceptional
53.2	293	29	45	14	53	40*	Good
47.5	458	45	46	11	71	[34]c	Very Good
43.7	406	44	42	12	66	48	Exceptional
38.6	390	45	42	16	61	50	Exceptional
35.9	79	44	55	11	80	[34]c	Very Good
32.9	1285	50	63	17	86	56	Exceptional
32.1	*1161*	*49*	*39*	*11*	*69*	*34*	*Good*
32.0	1723	44	58	17	78	56	Exceptional
30.7	1916	42	48	15	67	52	Exceptional
29.2	2098	40	68	19	80	52	Exceptional
28.0	-	-	53	18	-	-	Exceptional
23.9	1061	47	64	18	82	50	Exceptional
22.2	292	46	53	13	71	[32]c	Very Good
21.4	987	51	47	14	73	56	Exceptional
20.6	1068	45	55	19	70	58	Exceptional
18.9	-	-	49	15	-	-	Very Good
13.1	442	38	35	13	55	[32]c	Very Good
8.8	1347	29	47	16	57	52	Exceptional
3.4	1485	48	61	14	80	42ns	Very Good
1.6	626	21	22	4	35	[12]c	Fair
0.4	-	-	24	5	-	-	Fair
Yellow Springs Creek							
0.5	303	32	45	11	62	46	Exceptional
0.44	*154*	*39*	*37*	*9*	*60*	*36*	*Good*
0.3	253	50	46	12	74	46	Exceptional

Table 11. Continued.

Stream River Mile	Density (#/ft²)	Quantitative Evaluation Quant. Taxa	Qual. Taxa	Qual. EPT[a]	Total Taxa	ICI	Evaluation
Old Town Creek							
0.4	302	35	49	13	69	38	Good
Beaver Creek							
1.6	326	40	35	8	56	48	Exceptional
0.5	1579	40	53	9	69	48	Exceptional
0.4	*1621*	*38*	*29*	*5*	*49*	*36*	*Good*
0.2	-	-	35	6	-	-	Fair
Little Beaver Creek							
4.7	1757	40	37	9	55	40	Good
4.57	*4713*	*11*	*10*	*0*	*14*	<u>*4*</u>	*Poor*
4.4	-	-	18	1	-	-	Poor
2.0	281	28	16	1	34	20*	Fair
0.1	747	33	45	6	58	38	Good
Glady Run							
4.9	229	35	28	6	51	36	Good
4.7	341	39	31	2	56	28*	Fair
0.3	283	37	42	6	66	24*	Fair
Anderson Fork							
5.0	189	37	48	11	72	[30][c]	Good
Caesar Creek							
16.5	122	27	63	15	74	[24][c]	Very Good
0.1	-	-	36	8	-	-	Fair
Dry Run							
1.8	211	15	26	4	29	[8][c]	Fair
Turtle Creek							
6.3	62	33	38	5	55	26[ns]	Marg. Good
4.3	231	41	50	6	70	36	Good
0.6	211	29	39	5	53	[22][c]	Marg. Good
0.5	149	39	41	5	59	26	Marg. Good
0.1	2583	32	42	7	56	16*	Fair
Muddy Creek							
2.5	903	36	36	4	58	34	Good
Sycamore Creek							
0.5	-	-	30	7	-	-	Fair
0.26	*215*	*38*	*24*	*3*	*43*	*32*	*Good*
0.1	406	31	36	7	50	20*	Fair

Table 11. Continued.

Stream River Mile	Density (#/ft2)	Quant. Taxa	*Quantitative Evaluation* Qual. Taxa	Qual. EPT[a]	Total Taxa	ICI	Evaluation
Stonelick Creek							
17.7	76	29	26	5	45	24*	Fair
2.9	401	29	38	12	56	32	Good
1.0	164	27	46	17	60	36	Good
East Fork Little Miami River							
15.5	872	42	71	21	85	54	Exceptional
13.3	1649	30	65	20	76	46	Exceptional
12.7	1433	51	61	24	81	54	Exceptional
9.2	1381	42	64	19	82	54	Exceptional
6.7	716	62	57	17	90	46	Exceptional
4.7	746	44	64	18	85	44	Very Good
1.9	1366	53	56	14	78	48	Exceptional
0.8	1904	39	61	13	50	50	Exceptional

Stream River Mile	No. Qual. Taxa	QCTV[b]	*Qualitative Evaluation* Qual. EPT[a]	Relative Density	Predominant Organisms	Narrative Evaluation[d]
Little Miami River						
101.5	53	37.9	13	Low	Hydropsychids, riffle beetles, baetid mayflies	Exceptional
89.2	61	38.1	19	Moderate	Hydropsychids, mayflies	Exceptional
77.0	*54*	*37.9*	*12*	*Moderate*	*Midges*	*Good*
74.6	57	38.9	18	Moderate	Hydropsychids, *Isonychia*, midges	Exceptional
47.5	46	38.8	11	Moderate	Mayflies, hydropsychids, clams & snails	V. Good
35.9	55	38.9	11	Moderate	Hydropsychids, mayflies, snails	V. Good
28.0	53	40.8	18	Moderate	Hydropsychids, baetid mayflies	Exceptional
22.2	53	38.1	13	Low	River snails, mayflies	V. Good
18.9	49	38.9	15	Moderate	Hydropsychids, mayflies	V. Good
13.1	35	38.6	13	High	Hydropsychids, riffle beetles, mayflies	V. Good

Table 11. Continued.

Stream River Mile	No. Qual. Taxa	QCTV[b]	*Qualitative Evaluation* Qual. EPT[a]	Relative Density	Predominant Organisms	Narrative Evaluation[d]
Little Miami River						
0.4	24	35.1	5	Moderate	Midges	Fair
South Fork Massies Creek						
2.1	49	38.9	16	Moderate	Mayflies, hydropsychids, midges	Exceptional
1.1	39	40.6	13	Low-Mod.	Hydropsychids, mayflies	V. Good
Massies Creek						
0.3	33	40.0	9	Low-Mod.	Caddisflies, mayflies, midges	Good
Beaver Creek						
0.2	35	34.9	6	Moderate	Midges	Fair
Little Beaver Creek						
4.4	18	23.2	1	Mod.-High	Midges, flatworms, blackflies	Poor
Glady Run Swale						
0.3	35	35.1	3	Moderate	Blackflies, segmented worms, midges	Fair
Newman Run						
0.3	11	38.9	4	Low	Sow bugs	Fair
Anderson Fork						
5.0	48	38.6	11	High	Caddisflies, *Isonychia*, riffle beetles	Good
Flat Fork						
1.7	19	27.1	2	Moderate	Water boatmen, snails	Low Fair
Ceasar Creek						
16.5	63	37.9	15	Moderate	Asiatic clams, midges, riffle beetles	V. Good
0.1	36	38.6	8	Mod.-High	Damselflies, river snails, riffle beetles	Fair

Table 11. Continued.

Stream River Mile	No. Qual. Taxa	QCTV[b]	Qual. EPT[a]	Relative Density	Predominant Organisms	Narrative Evaluation[d]
			Qualitative Evaluation			
Dry Run						
1.8	26	36.1	4	Low	Midges, snails, beetles	Fair
Turtle Creek						
0.6	39	32.5	5	Moderate	Riffle beetles, midges, heptageniids	Marg. Good
Sycamore Creek						
0.5	30	35.1	7	Low	Midges	Fair

Ecoregion Biocriteria: Invertebrate Community Index (ICI)

	WWH	EWH
Eastern Corn Belt Plains (ECBP)	36	46
Interior Plateau (IP)	30	46

a EPT = total Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) taxa.

b Qualitative Community Tolerance Value calculated as the median of the weighted ICI for each taxon.

c The quantitative sample was effected by slow current speed, evaluation was based primarily on the qualitative sample.

d A qualitative narrative evaluation based on best professional judgement is used when quantitative data is not available to calculate the Invertebrate Community Index (ICI) scores.

* Significant departure from ecoregion biocriteria (>4 ICI units); poor and very poor results are underlined.

ns Nonsignificant departure from biocriterion (≤4 ICI units).

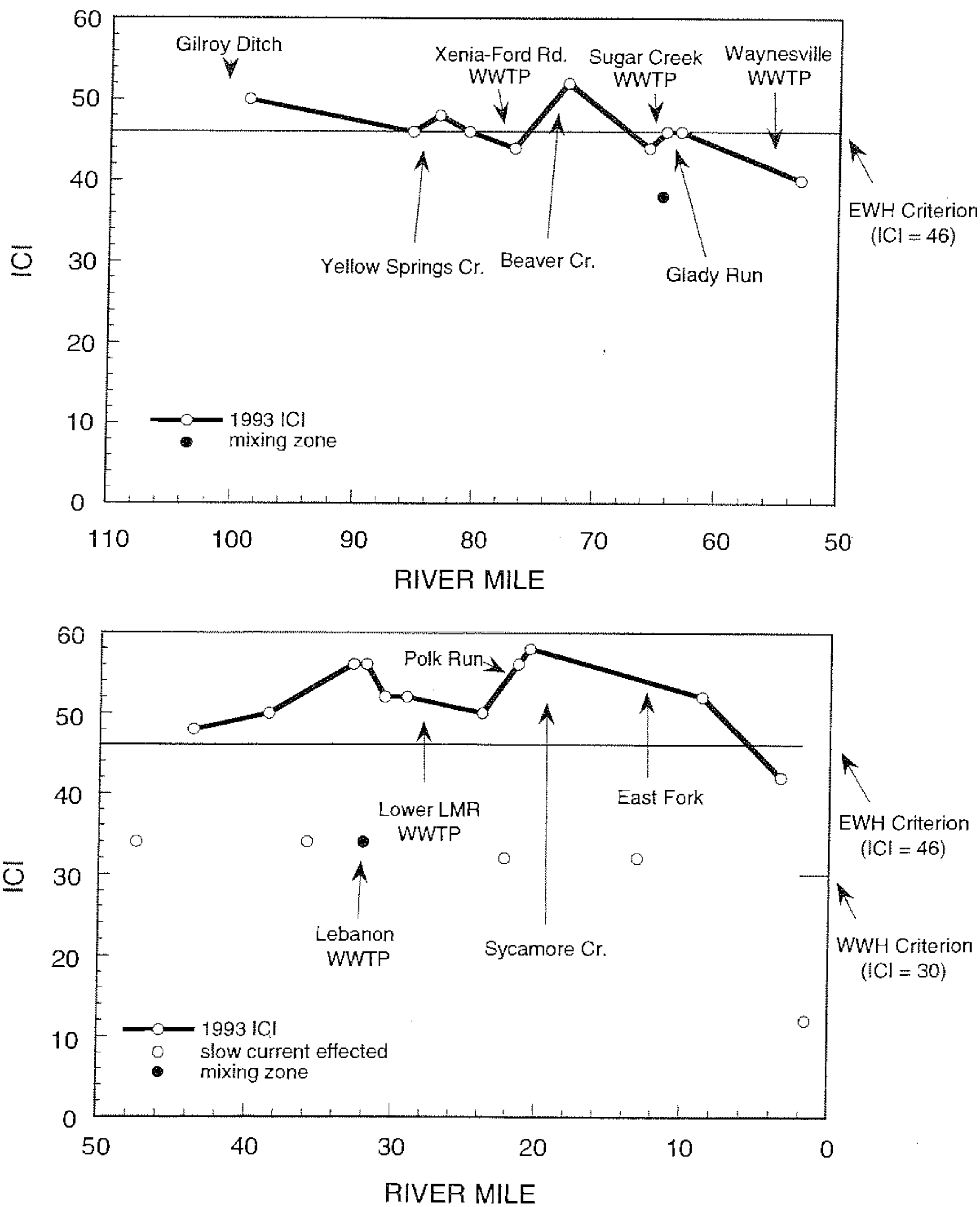
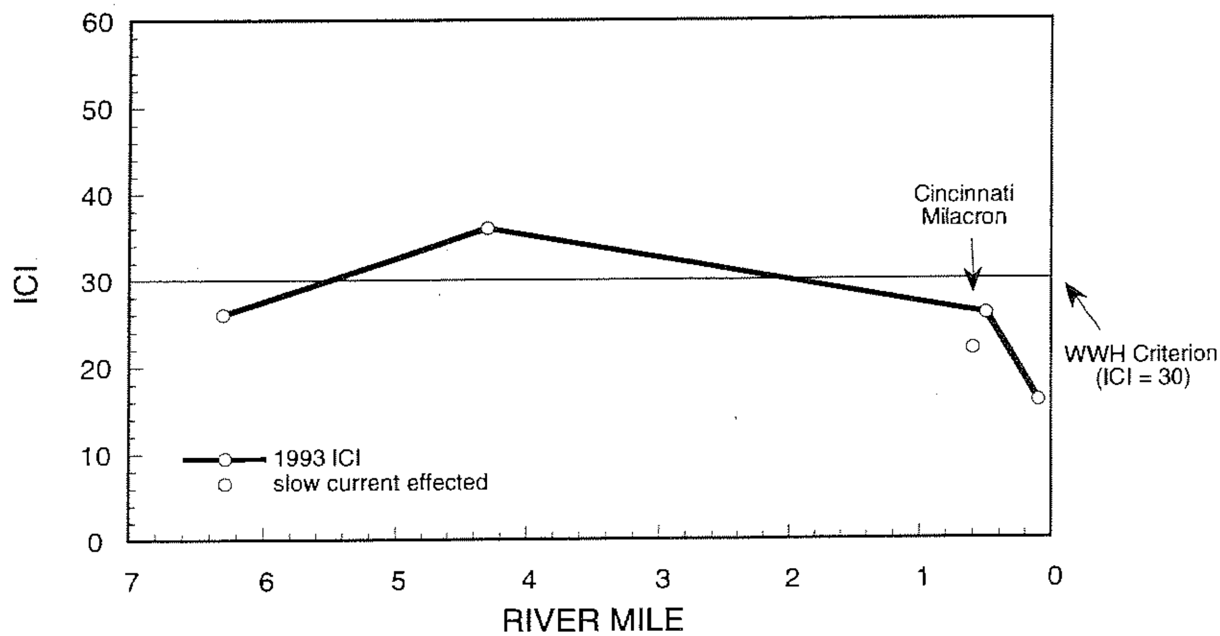


Figure 69. Longitudinal trend of the Invertebrate Community Index (ICI) in the upper half (Top Graph) and lower half (bottom graph) of the Little Miami River during 1993.



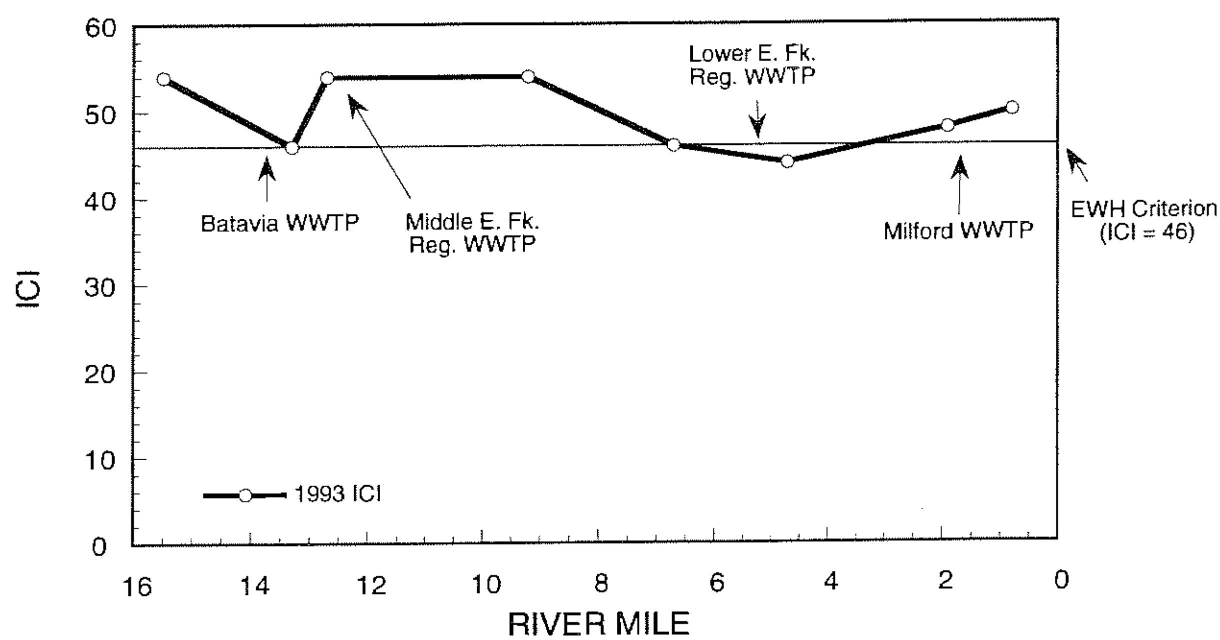


Figure 70. Longitudinal trend of the Invertebrate Community Index (ICI) in Turtle Creek (top graph) and the East Fork Little Miami River (bottom graph) during 1993.

Fish Assemblages (Plates 2, 6-10; Figures 71-81; Tables 1,5,12, A-8b, A-11, A-12)
Little Miami River

- Electrofishing at 35 locations throughout the Little Miami River yielded a total cumulative catch of 33,139 fish comprised of 83 species and 10 hybrids (82 species were collected during the intensive survey and one additional species, the grass carp, was collected during a November blue sucker survey). The mainstem catch included three (3) fish species which are listed as endangered in Ohio (ODNR 1992). A single tonguetied minnow was collected from the Clifton gorge area (RM 85.4), 42 mountain madtoms were captured at Newtown (RM 8.0) and one individual at RM 3.5, and seven blue suckers were captured also at RM 3.5, the first riffle upstream from the Ohio River (Plate 7). The collection of blue suckers is particularly significant because it was the first reported from the watershed and included a variety of sizes from young-of-the-year to large adults. Evidence of the successful reproduction by blue suckers in Ohio has not been documented for approximately 50 years. Despite numerous statewide fish sampling efforts since 1978, only a few large specimens have been collected from one other location in the lower Scioto River. An American eel, a now rare species which was once common in Ohio (Trautman 1981) was also collected in the mainstem at Morrow. The American eel is a long lived catadromus species which is spawned at sea, but which lives most of their adult life in freshwater. Dams on the Ohio and the Mississippi Rivers have impeded migration which has greatly reduced the number of eels observed in Ohio's rivers and streams.

- Mean MIwb values were indicative of very good to exceptional quality fish assemblages at 25 locations (74%), good to marginally good quality at seven locations (21%), and fair quality at two locations (6%). IBI values were indicative of exceptional to very good quality fish assemblages at 17 locations (49%) and good to marginally good assemblages at 10 locations (29%), and fair quality at eight locations (23%). Excluding mixing zone samples, MIwb and IBI values collectively attained (including nonsignificant departures) EWH criteria at 50% of the sampling locations.

Upper Little Miami River: South Charleston to Waynesville

- A total of 16,638 fish comprised of 61 species were collected from the upper half of the LMR located in the Eastern Corn Belt Plains (ECBP) ecoregion. The total cumulative catch was numerically dominated by central stonerollers (19.4%) and white suckers (11.3%). The predominant species by weight were common carp (28.8%), black redhorse (16.9%), white sucker (12.4%), and golden redhorse (12.2%). The total number of fish species collected at sites increased from 14-21 species downstream from South Charleston to 21-38 species between Clifton and Waynesville.

- Between South Charleston and Clifton (RM 102.1-92.2), IBI values were indicative of only fair fish assemblages due to very low numbers of headwater, sensitive, and intolerant species; low percentages of insectivores and top carnivores; and high percentages of tolerant species (Table 12,A-11). MIwb scores were indicative of marginally good quality (i.e., also did not attain EWH biocriterion). The average percent and relative number of fish with deformities, erosion, lesions/ulcers, and tumors (DELT anomalies) remained relatively low throughout the reach (ranged from 0.0-0.6% and 0.0-3.8 fish per 0.3 km, respectively; Figure 75-77b). Fish assemblages throughout the reach may have been impacted by a large fish kill in 1992 caused by manure runoff from a composting industry in South Charleston. The mainstem is also impacted by agricultural activities including unrestricted livestock access, channelization, and intensive row crop cultivation.

- Compositionally, mainstem fish assemblages improved between Clifton and the Narrows (RM 85.4-72.5) to very good to exceptional quality (*i.e.,* IBI and MIwb values attained EWH biocriteria), however, the incidence of DELT anomalies also increased apparently due to effluent quality and the increasing cumulative volume (mean values ranged from 0.3-4.13% and 3.0-51.8 fish per km; Table 12, A-11; Figure 71, 75-77b).

- Downstream from Bellbrook (RM 64.7) and at Spring Valley (RM 63.4), however, both IBI and MIwb values declined to the marginally good to good range downstream (*i.e.,* met only WWH biocriteria), but attained EWH downstream from the Sugar Creek WWTP mixing zone (RM 64.2 also contained the highest total number of fish species within the upper half of the mainstem). The IBI declined further to the fair range downstream from the Waynesville WWTP (RM 53.5), but the MIwb increased to very good. Compositional changes, such as marked increases in the relative abundance of common carp (a highly tolerant fish species) downstream from Bellbrook suggests impacts from pollutant loadings as apposed to lower habitat quality. The relative number and weight of carp increased from 3.3-14.0 fish per km and 4.9-24.7 kg per km between Clifton and the Narrows to 17.3-81.0 fish per km and 35.2-171.2 kg per km between Bellbrook and Waynesville (Table A-12). Higher incidences of DELT anomalies within the segment were also indicative of chemical impacts. The average percent and relative number of fish with DELT anomalies increased to 4.1-9.3% and 18.7-38.0 fish per km (excluding mixing zones) between Bellbrook and Waynesville. The highest incidences of DELT anomalies by sample ranged from 5.3-11.7 % and 22.6-55.5 fish per km between RMs 64.7 and 53.5 (Table A-11, Figure 75).

- The higher than normal incidences of DELT anomalies in the upper half of the mainstem is an indication of stressed fish communities. Elevated DELT levels in Ohio streams typically occur in association with marginal dissolved oxygen concentrations and chemical toxicity. Figures 76a - 77b show a positive relationship between DELT anomalies and the cumulative volume of effluent discharged to the upper half of the mainstem. There is also a direct relationship between anomalies and mean total phosphorus concentrations, a common constituent of municipal WWTP effluent. The types of impacts to fish assemblages throughout the upper half are primarily indicative of excessive nutrient enrichment with an assimilation sag extending from downstream Bellbrook to Oregonia. Although relatively good effluent quality is discharged by most of the WWTPs, the cumulative pollutant load continues to exceed the assimilative capacity of the upper mainstem. The largest mainstem diurnal swings in dissolved oxygen concentrations (4.3-5.0 mg/l difference between maximum and minimum diel values) between RMs 73.2 and 70.5, due to high algal growth, is additional evidence indicative of high nutrient levels (Table A-6).

- Fish sampling results from the mixing zones (first 100 meters downstream from the 001 outfalls) of the Xenia-Ford Road and Greene County Sugar Creek WWTPs showed no evidence of acute toxicity or avoidance and were indicative (respectively) of good to exceptional and fair to very good quality fish assemblages. Twenty one (21) and 29 species, respectively, were collected within 100 m of the outfalls. High levels of DELT anomalies, however, were found on fish captured in the Xenia-Ford Road WWTP mixing zone (4.0-4.2% and 40.0-61.7 per km).

- Fish assemblages throughout the upper mainstem contained a relatively low percentage of top carnivore fish such as smallmouth bass and rock bass (Table A-11). The highest value (11%) was recorded upstream from Xenia at Jacoby Road (RM 83.1) during the early August sample. This sample was the only one where the IBI metric scored a "5" which is indicative of expected values for reference sites. Although not markedly higher, percentages decreased downstream from the Xenia-Ford Road WWTP enough to score a "1" (value strongly deviates from the expected) in all but one sample (RM 64.2) at the next eight sites (RM 76.8-53.5).

Lower Little Miami River: Oregonia to the Ohio River

- A total of 16,500 fish comprised of 69 species and seven (7) hybrids were collected from the Little Miami River between Oregonia and the Ohio River within the Interior Plateau ecoregion. The total cumulative catch from 20 locations was numerically dominated by gizzard shad (27.7%), golden redhorse (11.3%), and emerald shiner (10.2%). By weight, the predominate species were common carp (24.5%), golden redhorse (17.1%), and shorthead redhorse (12.0%). The highest total number of fish species collected 41 fish species (50 % of the total number collected from the 102 mile mainstem) adjacent to Bass Island RM 8.0) downstream from Newtown Road

- Longitudinally, mean IBI and MIwb values exhibited slight recovery from upstream impacts by Oregonia and FULL attainment of EWH biocriteria at nine (9) of the next 11 locations sampled between Fort Ancient and I-275 (RMs 44.2-20.9, Figure 72, Table 12). The two sampling locations where one or both fish indices did not attain EWH (upstream from Simpson Creek [RM 28.3] and downstream of Tote's [RM 22.1]) contained only large pool habitat. The lack of swift flowing habitat which is preferred by shorthead redhorse and other pollution sensitive species may have been responsible for the lower than expected values, however, thick sediment deposits from excessive soil erosion may also be responsible. The mean percent and relative number of DELT anomalies between Oregonia and I-275 (excluding the Lebanon WWTP mixing zone sample) ranged from 1.0-4.8% and 2.7-27.2 fish per km (Table A-11, Figure 75, 78-80b). Longitudinally, the highest incidences were recorded at Oregonia (RM 47.5) and downstream from the Lebanon WWTP and Muddy Creek (RM 31.9-28.2). Overall, the incidences of DELT anomalies on fish in the lower half of the mainstem also appear to show positive relationships to the amount of effluent and total phosphorus concentrations (Figure 78-80b).

- The only mixing zone sample in the lower mainstem was conducted immediately downstream from the Lebanon WWTP (RM 32.1). Sampling results at RM 32.1 yielded 21 cumulative species (including several large sport fish) and there was no evidence of acute toxicity through avoidance. Fish assemblages within the mixing zone did, however, have a high number of DELT anomalies (mean values = 6.1% and 40.3 fish per km).

- The IBI decreased downstream from Sycamore Creek and failed to meet the EHW biocriterion at all seven sampling locations in the lower 18.5 miles of the mainstem. IBI scores were indicative of fair to good fish assemblages. IBI metrics which showed the greatest departure from background reference conditions included lower than normal numbers of sunfish and intolerant species combined with low percentages of top carnivores, and generally higher than expected percentages of omnivorous species and DELT anomalies. The MIwb also decreased downstream from Sycamore Creek and did not meet EWH biocriterion at Milford (RM 13.3, despite excellent habitat) or upstream from Bass Island (RM 8.3), but increased back to the exceptional range at Bass Island and Beechmont Avenue (RMs 8.0 and 3.5). The mean percent and relative number of DELT anomalies on fish captured downstream from Sycamore Creek to Beechmont Avenue (RMs 18.5-3.5) ranged from 1.9-5.0% and 8.7-20.7 fish per km. The highest incidences occurred downstream from Sycamore Creek (RM 18.5). The impairment to fish assemblages within the segment is likely due to a combination of causes and sources. Longitudinally, changes include lower dissolved oxygen levels (due to the assimilation of upstream discharges of organic and nutrients) and higher concentrations of total suspended solids. Fecal bacteria counts also increased within the segment. Possible sources of nutrients and other pollutants include the cumulative WWTP discharges between Lebanon and I-275, pollutant loads from Sycamore Creek, CSO discharges in Milford, WWTP loads from the East Fork, and additional CSO and landfill leachate from Duck Creek. Urban runoff also contributes pollutants to the river throughout the segment.

- IBI and MIwb values from the lower two impounded miles of the river were indicative of only fair quality fish assemblages. These two sites, however, were sampled only during the day and may have scored higher if sampled during the night.

Yellow Springs Creek

- A total of 2,428 fish comprised of 23 species were collected from the three adjacent sampling locations in Yellow Springs Creek which bracketed the Yellow Springs WWTP (RM 0.5 - 0.3). Fish assemblages showed no impact from the 001 effluent, IBI scores attained EWH criterion both upstream and downstream from the discharge and in the mixing zone. The most numerically abundant species were creek chubs (18.5%), greenside darters (13.4%), rainbow darters (12.7%), white suckers (12.4%), and central stonerollers (11.9%). No DELT anomalies were observed on fish during the six samples.

Oldtown Creek

- A total of 1,370 fish comprised of 21 species were collected from Oldtown Creek near the mouth (RM 0.1) during early July (a second sample was not collected due to the extreme drought conditions). The IBI score of 56 (the highest value in the 1993 study area) was indicative of an exceptional quality headwater fish community. Numerically dominant species were central stonerollers (41%), followed by creek chubs (12.3%), and mottled sculpins (12.0%). River chubs (7.4%) were also common. The reference site sampled, however, was not representative of the long channelized stretch upstream and adjacent to the old railroad grade. No DELT anomalies were observed during the July sample.

South Fork Massies Creek

- A total of 331 fish comprised of 15 species were collected from a wooded segment of the South Fork of Massies Creek adjacent to the quarry (RM 1.1). Despite relatively good physical habitat (pool-riffle-run sequences) the fish assemblage was indicative of only fair quality. The IBI scored a 30, considerably lower than the WWH biocriterion for headwater streams within the ECBP (40). Two highly tolerant species, creek chubs and bluntnose minnows, were numerically dominant and represented over half of the fish caught. The catch did include, however, several creek chubsuckers and a brook stickleback which are uncommon Ohio fish species. Downstream effects of upstream channel modifications may be impacting this site. A local land owner reported that even the wooded section had been historically modified.

Massies Creek

- The two samples from Massies Creek at the confluence of Oldtown Creek (RM 0.3) yielded a total catch of 1,379 fish comprised of 25 species. The catch was representative of a very good fish assemblage, MIwb and IBI scores exceeded the WWH biocriteria and were in the nonsignificant departure ranges of EWH criteria. Numerically dominant species were central stonerollers (29.4%), northern hog suckers (17.9%), and greenside darters (13.7%). By weight, the catch was predominantly composed of northern hog suckers (40.9%), black redhorse (18.3%), and central stonerollers (12.6%). Only two fish were collected with a DELT anomaly (mean = 0.15% DELT) (Table A-11).

Beaver Creek

- A total of 3,054 fish comprised of 28 species were collected from the four sampling locations in Beaver Creek (RMs 1.6-0.3). IBI scores were indicative of only fair quality fish assemblages at the three full length sampling locations, but a marginally good quality assemblage was present in the mixing zone of the Beaver Creek WWTP. MIwb scores increased from the fair range at the upstream control site to the good range downstream from Little Beaver Creek and upstream from the Greene Co. Beaver Creek WWTP (RM 0.5). MIwb values decreased to the marginally good range at both locations downstream from the WWTP. Downstream from Little Beaver Creek, dominant fish species shifted from creek chubs and white suckers to central stonerollers, white suckers, green sunfish, common carp, northern hog suckers, and black redhorse. Fish assemblages captured in the Beaver Creek WWTP mixing zone showed no evidence of acute toxicity. The most common species in the mixing zone species were northern hog suckers, central stonerollers, blacknose dace, and greenside darters. Immediately downstream from the WWTP, however, no black redhorse were collected and the relative weight of fish declined from 47.2 kg/km (RM 0.5) to 15.7 kg/km (0.3). The catch did include five (5) pollution sensitive species, the rainbow darter, mottled sculpin, greenside darter, longear sunfish, and northern hog sucker. Dominant species downstream from the mixing zone included creek chubs, green sunfish, blacknose dace, white suckers, common carp, and northern hog suckers. A total of 29 fish with a DELT anomaly were collected in the stream, three upstream from Little Beaver Creek, 16 downstream from Little Beaver Creek, and 10 downstream from the Beaver Creek WWTP. The mean percent of DELT anomalies increased from 0.5% (RM 1.6) to 2.2% downstream from Little Beaver Creek (RM 0.5), but decreased to 0.6 - 1.0% downstream from the WWTP.

Little Beaver Creek

- A total of 2,841 fish comprised of 24 species and three hybrids were collected from the five sampling locations in Little Beaver Creek (RMs 4.7-0.1). Narratively, fish assemblages exhibited slight recovery from poor quality upstream and downstream from the Montgomery Co. East WWTP (RMs 4.7-4.4) to fair quality in the lower two miles (RMs 2.1-0.1, Table 12). The highest relative number of fish in the tributary was recorded in the mixing zone, suggesting no acute toxicity or avoidance. The relative abundance of predominant species numerically shifted from green sunfish, central stonerollers, creek chubs, and bluntnose minnows at RM 4.7 to northern hog suckers, green sunfish, white suckers, and creek chubs at RM 0.1. A total of 46 fish with a DELT anomaly were collected throughout the tributary, however, with 44 of them occurring downstream from the Montgomery Co. East Regional WWTP (cumulative total from the four sites). The highest number (24) and most severe anomalies (*i.e.*, heavy vs. light) were recorded at North Fairfield Road (RM 2.1).

Glady Run

- A total of the 3,506 fish comprised of 22 species (including brook stickleback and southern redbelly dace) were captured in Glady Run. The headwater tributary supported only fair quality fish assemblages upstream and immediately downstream from the WWTP swale, but a good assemblage near the mouth. The total cumulative number of fish species markedly increased from five to eight (5-8) species near the swale (RM 4.9-4.7) to 20 species downstream from SR 725 (RM 0.3). The relative number of fish collected markedly increased downstream from the WWTP due partially to improved habitat from additional flow. Only one fish captured in Glady Run had a DELT anomaly. Southern redbelly dace, one of Ohio's declining fish species, was very abundant downstream from the WWTP swale (229 were collected at RM 4.7).

Glady Run Swale

- Fish sampling (single pass) at the three sites in Glady Run Swale yielded 1,942 fish comprised of 12 species. Fish assemblages in small tributary improved from poor to good quality downstream from the Xenia-Glady Run WWTP. The mixing zone contained a fair quality fish community with no evidence of avoidance or acute toxicity. Similar to Glady Run, only one fish with a DELT anomaly was observed. Although QHEI values were relatively low at all three sites (53.0-48.5) due to previous channelization, the lower section downstream from the railroad grade appeared to have recovered the most.

Newman Run

- A total of 559 fish comprised of 15 species were collected in Newman Run in early July, before the drought. The July sample had an IBI score of 54 (the second highest value in the study area) which is indicative of an exceptional quality headwater fish community. The community was well balanced and numerically dominated by mottled sculpins (31.5%), rainbow darters (19.3%), central stonerollers (12.9%), creek chubs (11.5%), and small white suckers (10.2%). No DELT anomalies were observed in the catch.

Anderson Fork

- During the August sample, a total of 956 fish comprised of 26 species were collected from the Caesar Creek tributary upstream from the Old Winchester Trail bridge. Similar to Newman Run, the IBI also scored a 54 in Anderson Fork (RM 5.0). The MIwb (10.0) was also indicative of an exceptional quality fish assemblage. Both IBI and the MIwb scores exceeded EWH biocriteria. The most abundant fish species in the stream were central stonerollers (33.6%) and northern hog suckers (9.1%). By weight, the catch was dominated by northern hog suckers (35.2%), black redhorse (18.3%), central stonerollers (10.1%), an common carp (10.0%). The incidence of DELT anomalies was low at 0.1%.

Flat Fork

- Flat Fork had intermittent flow regime and was mostly dry when sampled in August. The isolated pools contained only 6 fish species, dominated numerically by green sunfish (84.9%). Although the QHEI (50) reflected sub-optimal physical habitat, such conditions typically occur in small southwestern streams with limestone bedrock. The IBI scored in the poor range (24), considerably lower than expected and indicative of a rather severe impact. Algae was present suggesting nutrient enriched conditions and low D.O. levels. The source of pollutants is unknown, but may be agriculturally related. The abundance of leeches further suggests possible organic enrichment.

Caesar Creek

- A total of 1,361 fish comprised of 36 species were collected from the two sampling locations. Upstream from the reservoir (RM 16.5), the fish assemblage in Caesar Creek was indicative of very good (IBI) to exceptional (MIwb) quality. Downstream from the lake (RM 0.1), the IBI increased to the exceptional range, but the MIwb decreased to the good range. A predominance of shallow water habitat may have been the reason for considerably lower relative number and weight of fish captured near the mouth. Compositionally, the downstream assemblage (dominated by longear sunfish, northern hog suckers, and golden redhorse) by was more indicative of a high quality stream than the upstream assemblage (gizzard shad, common carp, and northern hog suckers) possibly due to lake influences. The total number of fish species , however, declined from 30 at RM 16.5 to 23 at RM 0.1. The incidence of DELT anomalies was slightly higher at RM 16.5 (0.5%) than at RM 0.1 (0.0%).

Dry Run

- Only 450 fish comprised of 8 species were collected from Dry Run (RM 1.8). The IBI scored a 34 and did not meet the ecoregional expectation for a headwater stream. The percent DELT anomalies was the only metric to score a "5". Suggesting rather severe impairment, a low number of sensitive species and high percentages of tolerant fishes and omnivores caused these three metrics to score a "1". Other fair habitat quality, the cause of impairment is unknown.

Turtle Creek

- A total of 10,603 fish of 40 species were collected from the six sampling locations in Turtle Creek (RMs 6.3-0.1). IBI scores were indicative of marginally good to exceptional fish assemblages and exceeded the WWH criterion of 40 at all locations (except for a 39 at RM 4.7 which is a nonsignificant departure, Table 12, Figure 73). MIwb scores exceeded the 8.1 WWH criterion at five (5) locations, but were significantly lower (6.7) in the shallow segment downstream from Cincinnati Milacron (RM 0.4). The low score may have been caused entirely by the lack of a deep pool. The mean percent DELT anomalies was lower downstream (0.0-0.1%) from the industrial discharger than upstream (0.3-0.7%). The highest percentages of tolerant fish species also occurred in the upper reach downstream from Lebanon.

Muddy Creek

- A total of 1,468 fish of 21 species were collected at RM 1.6 during August. Despite the abundance of common carp (82.2% of the total relative weight of 111 kg/.3 km), the IBI (46) exceeded the WWH criterion (40) for a headwater stream and was indicative of very good quality. Central stonerollers were numerically dominant and represented 74.4% of the catch. The percent of fish with DELT anomalies was slightly elevated (0.5%). Black sludge deposits were observed in the deep pools.

Sycamore Creek

- A total of 2,864 fish comprised of 27 species were collected from the three adjacent locations sampled during the survey. Central stonerollers, creek chubs, and juvenile white suckers were the dominant species. IBI and MIwb scores did not meet WWH criteria upstream from the Sycamore Creek WWTP, but were within the area of nonsignificant departure downstream from the facility. The number of fish species captured increased from 18 at RM 0.4 to 25 at RM 0.2). A total 832 fish comprised of 11 species, including fantail darters, were collected from the shallow WWTP mixing zone suggesting no acute toxicity. Zero to one intolerant species caused the metric to score a "1" at all three sites during both samples. The mean percentage of fish with DELT anomalies increased from 0.1% upstream from the WWTP to 0.8% downstream. Thick black sludge deposits were observed in the large pool downstream from the WWTP. Despite good cover, longear sunfish and other pool dwelling species were noticeably lacking in the large pool upstream from the WWTP.

Stonelick Creek

- A total of 2,662 fish comprised of 42 species and two (2) hybrids were collected from four locations. Fish assemblages were sampled at three free-flowing locations and one impounded location within the upper section of Stonelick Lake. The quality of fish assemblages improved from fair upstream from the lake to good to exceptional downstream (Table 12). IBI and MIwb scores did not attain in Stonelick Lake or its headwaters, but met or exceeded WWH criteria at both locations in the lower 3 miles. The mean number of fish species was only 8.0-11.0 at the two upstream sites, but increased to 27.5-36.0 at the downstream two sites. The assemblage at RM 1.2 was very diverse with a cumulative total of 39 fish species. The mean percentage of fish with DELT anomalies was 0.0% in the headwaters (RM 20.0), 0.7% in the upper end of the lake (RM 16.7), 0.5% downstream at RM 3.1, and 1.0% at U.S. 50 (RM 1.2).

East Fork Little Miami River

- A total of 4,357 fish comprised of 55 species and five (5) hybrids were collected from eight sites in the lower 16 miles downstream from the East Fork Lake (RMs 15.5-1.4). Numerically, the total catch was well balanced and dominated by central stonerollers (10.0%), longear sunfish (8.6%), emerald shiners (7.7%), and gizzard shad (7.6%). Distribution by weight, however, was more typically skewed and dominated by common carp (37.0%) and golden redhorse (9.1%). Mean MIwb scores were indicative of very good to exceptional fish assemblages (mean = 10.1, range 9.4-11.1) due to high numbers, biomass, and diversity of fish at all eight locations.

- Mean IBI values were representative of only marginally good to very good quality fish assemblages, suggesting more significant changes between the sampling locations. All eight (8) The five IBI values that did meet EWH below 50 and further suggest only marginal attainment. Longitudinally, both fish indices met EWH expectations (or nonsignificant departure) from upstream of Batavia (RM 15.5) downstream to Olive Branch Stonelick Creek Road (RM 9.2), but dropped into partial attainment at Perintown (RM 6.6) due to a slight decrease in the IBI.

- The percentages of top carnivores in the East Fork markedly declined from 26 - 27% upstream from Batavia (RM 15.5) to only 2-13% (mean = 6.6%) at all seven locations from one or more WWTPs. The total relative number (density) of rock bass, smallmouth bass, and spotted bass combined (the three most abundant game species) declined from 167 per km at RM 15.5 to 26 per km at RM 12.7. Downstream densities remained low (6-61/km) to the mouth. The cause of decline is unknown, but may be related to the quality of WWTP discharges. The decline is indicative of an impact to fish assemblages in the mainstem.

- A higher than normal incidence of external DELT anomalies was found at all eight sampling locations (Table A-11, Figure 81). The percent occurrence of DELT anomalies increased downstream from Batavia. The actual number of fish weighed with an anomaly increased from 4-5 fish at the two sampling locations upstream from the Middle Fork WWTP to 13-16 fish downstream to Round Bottom Road to 7-16 fish downstream from the Lower East Fork WWTP.

- Some of the declines in the lower five miles of the mainstem may have been due to changes in physical habitat as reflected by lower QHEI scores.

Table 12. Fish community summaries for 84 locations in the Little Miami River study area based on pulsed D.C. electrofishing catches during June through October, 1993. The number of samples collected at each location is listed with the sampling method. Relative number and weight are per km for boat sites and 0.3 km for wading sites. Mixing zone samples are denoted by italics.

Stream RM	Sampling Method*	Mean # Species	Total # Species	Mean Relative Number	Mean Relative Weight(kg)	QHEI	Mean Index of Biotic Integrity	Mean Modified Index of Well-Being	Narrative Evaluation
Little Miami River									
102.1	Wading-2	13.0	14	2,494	NA	62.0	33*	NA	Fair
98.3	Wading-2	19.5	21	1,696	35.3	75.0	35*	7.8ns	Fair-M.Good
92.2	Wading-2	17.5	19	689	17.0	68.5	35*	7.9ns	Fair-M.Good
85.4	Wading-2	27.0	30	1,027	27.5	87.0	47ns	9.0ns	Very Good
83.1	Boat-3	22.3	24	1,180	106.2	76.5	45ns	10.1	V.G.-Except.
77.3	Boat-2	27.0	30	1,452	129.1	78.0	48	10.3	Exceptional
77.0	*Boat-3*	*16.0*	*21*	*1,260*	*368.8*	*63.5*	*42*	*10.1*	*Good-Except.*
76.8	Boat-3	26.3	32	979	114.1	76.0	49	10.1	Exceptional
74.5	Boat-2	30.5	35	1,262	141.2	77.5	48	10.5	Exceptional
71.8	Boat-2	27.0	30	624	85.6	77.5	52	9.9	Exceptional
64.7	Boat-3	23.3	31	553	160.9	73.0	41*	9.0*	M.G.-Good
64.4	*Boat-3*	*20.0*	*29*	*1,513*	*62.8*	*62.5*	*33*	*9.2*	*Fair-V.Good*
64.2	Boat-3	29.7	38	684	175.3	74.0	46ns	9.6	V.G.-Except.
63.4	Boat-2	24.0	26	452	235.7	71.0	39*	8.5*	M.G.-Good
53.5	Boat-3	22.0	32	211	96.4	65.0	33*	9.3ns	Fair-V.Good
47.5	Boat-3	24.3	35	331	116.7	76.5	39*	9.3ns	Good-V.G.
44.2	Boat-3	28.0	37	454	104.2	83.5	49	9.8	Exceptional
38.6	Boat-3	23.7	37	537	223.5	83.5	47ns	10.0	V.G.-Except.
35.5	Boat-3	26.0	36	536	179.4	76.5	49	10.2	Exceptional
32.9	Boat-3	24.3	39	378	128.7	74.0	47ns	9.3ns	Very Good
32.1	*Boat-3*	*14.3*	*21*	*670*	*360.4*	*77.0*	*37*	*9.6*	*M.G.-Except.*
31.9	Boat-3	31.3	38	828	248.4	86.5	48	11.0	Exceptional
28.3	Boat-3	17.7	25	328	163.7	57.5	34*	9.0*	M.G.-Good
27.9	Boat-3	27.7	35	814	263.2	80.0	50	10.7	Exceptional
23.9	Boat-3	23.3	33	652	201.5	82.5	47ns	10.2	V.G.-Except.
22.1	Boat-3	19.0	29	444	76.9	63.5	46ns	8.7*	V.G.-Good
21.5	Boat-3	26.0	36	719	173.6	84.0	49	10.4	Exceptional
20.9	Boat-3	22.0	34	360	142.6	80.0	45ns	9.6	V.G.-Except.
18.5	Boat-3	21.7	36	431	129.9	72.5	40*	9.3ns	Good-V.G.
13.3	Boat-3	23.3	36	1,119	170.7	86.5	35*	8.8*	M.G.-Good
8.3	Boat-3	21.0	34	431	114.2	73.0	33*	8.9*	Fair-Good
8.0	Boat-2	33.0	41	714	150.0	82.0	43*	10.1	Good-Except.
3.5	Boat-3	26.7	37	853	222.0	77.5	40*	9.9	Good-Except.
1.6	Boat-3	12.7	20	605	35.8	51.0	33*	7.4*	Fair
0.2	Boat-3	13.3	21	529	26.4	50.0	29*	7.3*	Fair
Yellow Springs Creek									
0.5	Wading-2	18.0	20	870	NA	80.0	48	NA	Very Good
0.43	*Wading-2*	*14.0*	*16*	*1,358*	*NA*	*73.5*	*51*	*NA*	*Exceptional*
0.3	Wading-2	18.0	21	1,305	NA	79.0	50	NA	Exceptional

Table 12. Continued.

Stream RM	Sampling Method	Mean # Species	Total # Species	Mean Relative Number	Mean Relative Weight(kg)	QHEI	Biotic Integrity	Mean Index of Index of Well-Being	Mean Modified Narrative Evaluation
Oldtown Creek									
0.1	Wading-1	21.0	21	2,055	15.3	82.5	56	8.8	Exceptional
South Fork Massies Creek									
1.1	Wading-1	15	15	662	NA	66.5	30*	NA	Fair
Massies Creek									
0.3	Wading-2	23.0	25	1,034	17.3	67.5	46	9.0	Very Good
Beaver Creek									
1.6	Wading-2	15.5	18	885	17.6	54.5	28*	6.8*	Fair
0.5	Wading-2	20.5	22	860	47.2	74.0	32*	8.7	Fair-Good
0.39	*Wading-2*	*12.0*	*14*	*1,089*	*13.7*	*64.0*	*37*	*8.0*	*Marg. Good*
0.3	Wading-2	16.5	19	832	15.7	70.5	32*	7.9ns	Fair-M.G.
Little Beaver Creek									
4.7	Wading-2	8.5	10	563	NA	67.5	26*	NA	Poor
4.57	*Wading-2*	*7.0*	*9*	*958*	*NA*	*72.0*	*23*	*NA*	*Poor*
4.4	Wading-2	10.0	13	530	NA	48.5	24*	NA	Poor
2.1	Wading-2	15.0	18	532	16.0	76.0	31*	NA	Fair
0.1	Wading-2	15.0	20	303	15.9	70.5	33*	7.0*	Fair
Glady Run									
4.9	Wading-1	5.0	5	180	NA	54.0	34*	NA	Fair
4.7	Wading-2	7.0	8	1,511	NA	66.0	33*	NA	Fair
0.3	Wading-2	16.0	20	1,692	NA		40	NA	Good
Glady Run Swale									
0.3	Wading-1	6.0	6	534	NA	53.0	24*	NA	Poor
0.2	*Wading-1*	*3.0*	*3*	*750*	*NA*	*49.0*	*28*	*NA*	*Fair*
0.1	Wading-1	10.0	10	3,278	NA	48.5	40	NA	Good
Newman Run									
0.3	Wading-1	15.0	15	1,118	NA	76.0	54	NA	Exceptional
Anderson Fork									
5.0	Wading-1	26.0	26	1,434	40.8	75.0	54	10.0	Exceptional
Flat Fork									
1.7	Wading-1	6.0	6	358	NA	50.0	24*	NA	Poor
Caesar Creek									
16.5	Wading-1	30.0	30	1,598	81.3	76.0	46ns	9.5	V.G.-Except.
0.1	Wading-1	23.0	23	476	16.1	81.5	50	8.7	Except.-Good

Table 12. Continued.

Stream RM	Sampling Method	Mean # Species	Total # Species	Mean Relative Number	Mean Relative Weight(kg)	QHEI	Mean Index of Biotic Integrity	Mean Modified Index of Well-Being	Narrative Evaluation
Dry Run									
1.8	Wading-1	8.0	8	900	NA	54.5	34*	NA	Fair
Turtle Creek									
6.3	Wading-2	19.5	21	2,358	14.0	69.5	43	NA	Good
4.7	Wading-2	24.5	27	2,492	45.0	69.5	39ns	8.5	M.G.-Good
0.6	Wading-2	25.5	28	1,156	45.6	75.5	50	10.1	Exceptional
0.5	Wading-2	17.0	21	1,245	5.8	68.0	41	8.3	Good
0.4	Wading-2	18.5	24	1,138	2.2	68.0	41	6.7*	Good-Fair
0.1	Wading-2	27.5	33	1,122	21.5	68.5	46	8.9	Very Good
Muddy Creek									
1.6	Wading-1	21.0	21	2,936	111.3	78.0	46	NA	Very Good
Stonelick Creek									
20.0	Wading-1	11.0	11	570	NA	69.0	30*	NA	Fair
16.7	Boat-1	8.0	8	562	97.2	48.0	30*	7.5*	Fair
3.1	Wading-2	27.5	31	769	33.6	73.5	45	8.8	Good
1.2	Wading-2	36.0	39	832	95.4	78.0	49	10.4	V.G.-Except.
Sycamore Creek									
0.4	Wading-2	14.5	18	1,546	4.4	76.0	34*	6.6*	Fair
0.26	*Wading-2*	*8.0*	*11*	*2,080*	*3.5*	*70.5*	*29*	*6.6*	*Fair*
0.2	Wading-2	19.5	25	365	11.2	75.0	38ns	7.7ns	Marg. Good
East Fork Little Miami River									
15.5	Boat-2	21.5	26	638	137.5	86.0	45ns	9.4ns	Very Good
12.7	Boat-2	31.5	35	583	170.7	83.5	47ns	10.5	V.G.-Except.
12.4	Boat-2	33.5	41	731	221.1	87.0	47ns	11.1	V.G.-Except.
9.2	Boat-2	32.0	39	617	162.4	86.0	44ns	10.4	V.G.-Except.
6.6	Boat-2	28.0	35	429	108.6	87.0	42*	9.4ns	Good-V.G.
4.7	Boat-2	30.0	37	515	58.5	68.5	44ns	10.1	V.G.-Except.
1.7	Boat-2	30.0	34	556	101.8	70.5	36*	10.2	M.G.-Except.
1.4	Boat-2	27.5	33	288	133.5	65.0	39*	10.0	Good-Except.

	Eastern Corn Belt Plains (ECBP)			*Interior Plateau (IP)*		
INDEX - Site Type	**WWH**	**EWH**	**MWH**	**WWH**	**EWH**	**MWH**
IBI - Headwaters	**40**	**50**	**24**	**40**	**50**	**24**
IBI - Wading	**40**	**50**	**24**	**40**	**50**	**24**
IBI - Boat	**42**	**48**	**24**	**38**	**48**	**24**
Mod. Iwb - Wading	**8.3**	**9.4**	**6.2**	**8.1**	**9.4**	**6.2**
Mod. Iwb - Boat	**8.5**	**9.6**	**5.8**	**8.7**	**9.6**	**5.8**

* Significant departure from ecoregional biological criterion (>4 IBI or >0.5 Iwb units); underlined values are in the poor and very poor range.

ns Nonsignificant departure from biocriterion (≤4 IBI units or ≤ 0.5 MIwb units)

a Narrative evaluation is based on both MIwb and IBI scores.

NA Headwater site; MIwb is not applicable.

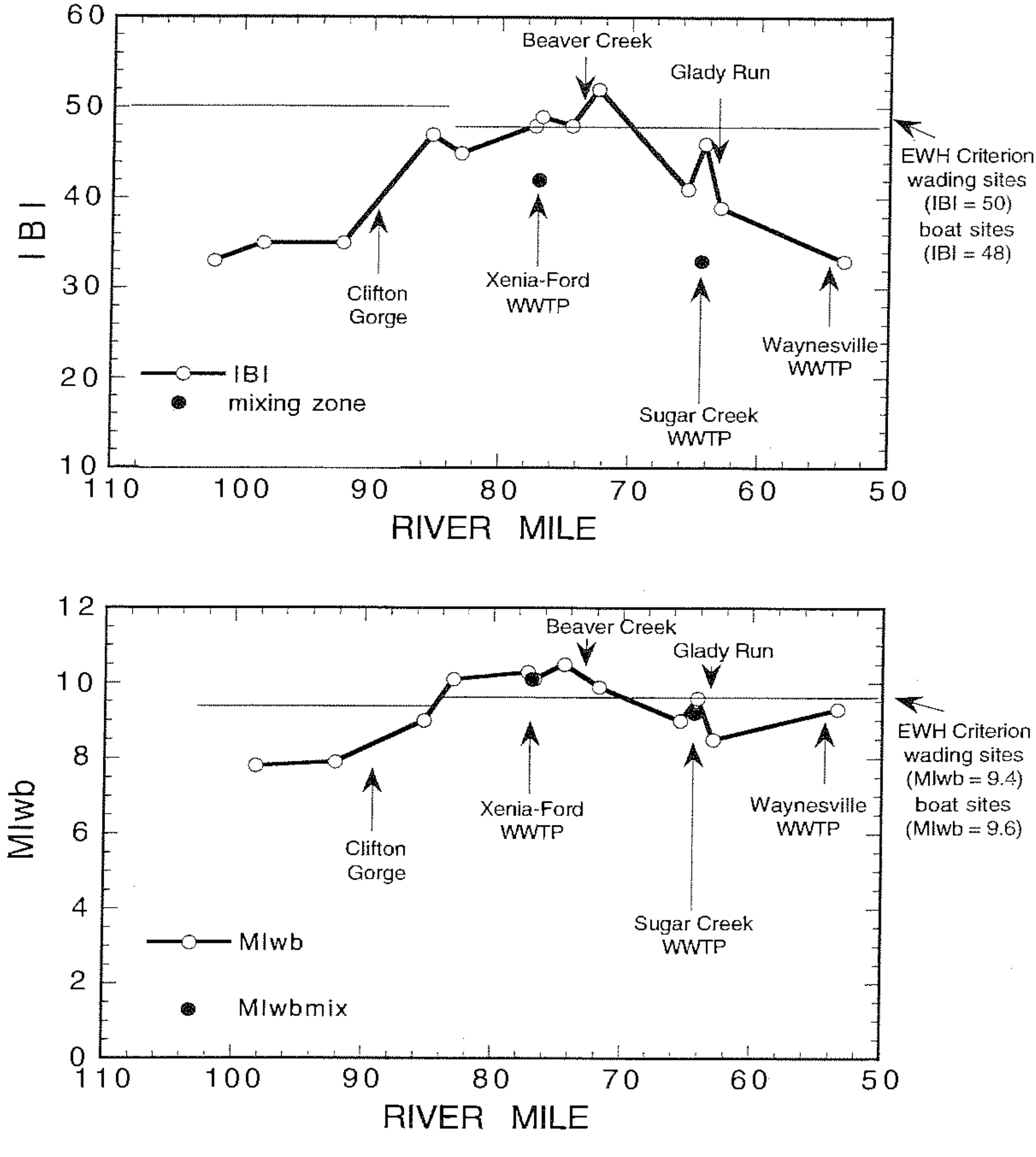


Figure 71. Longitudinal trend of the Index of Biotic Integrity (IBI; Top Graph) and the Modified Index of Well-Being (MIwb; Bottom Graph) in the upper half of the Little Miami River during 1993.

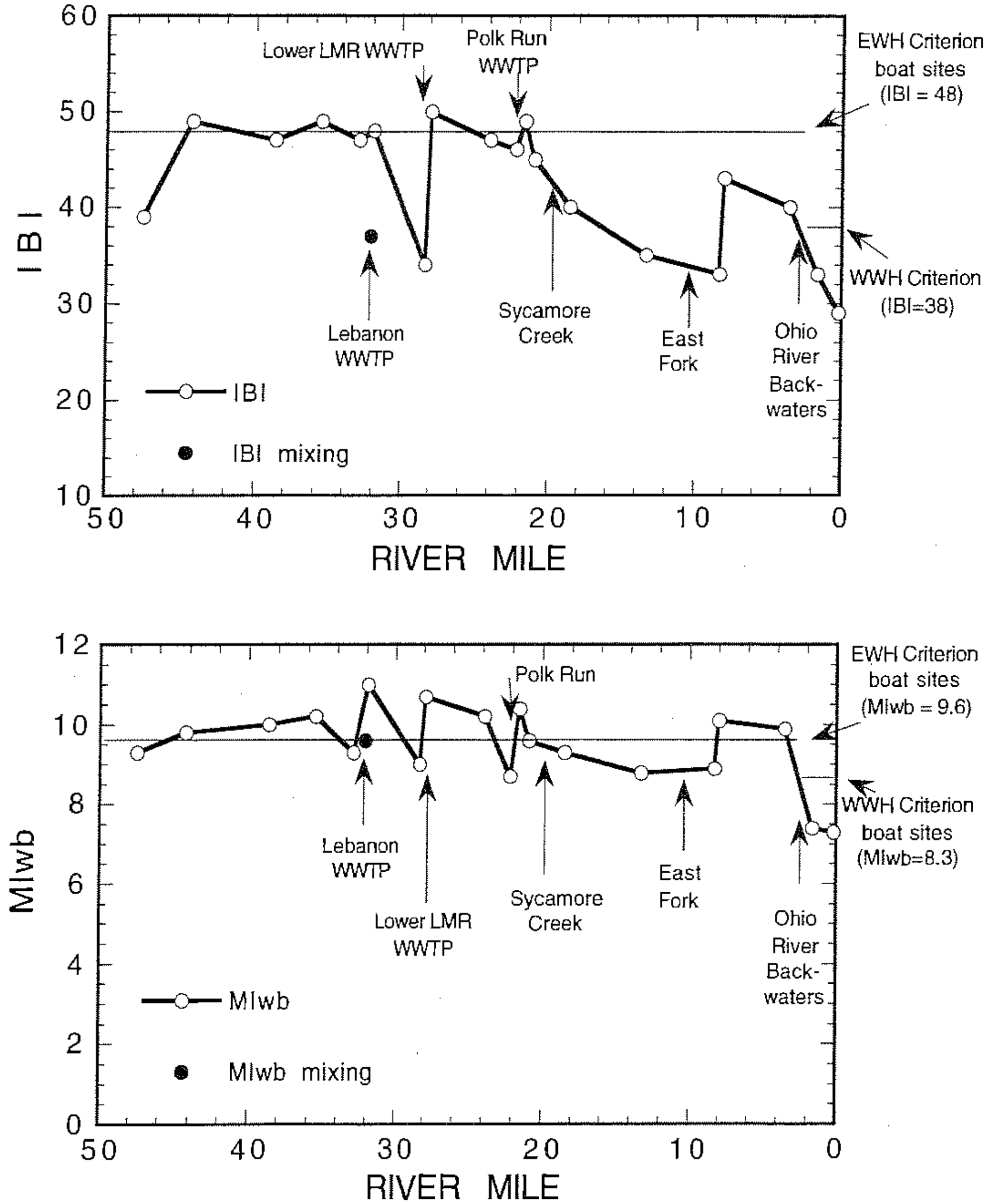
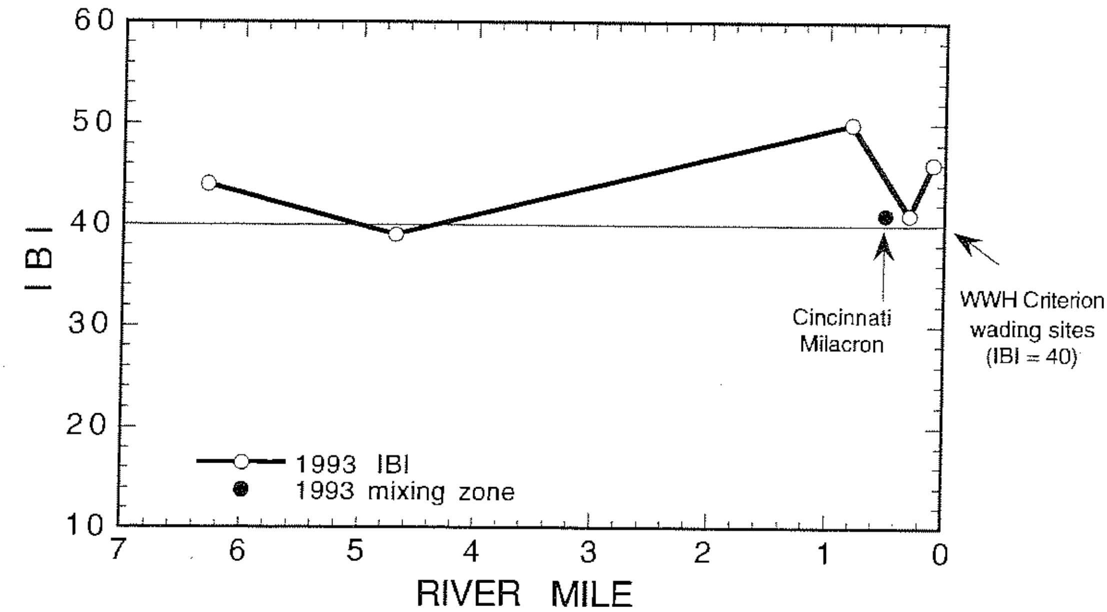


Figure 72. Longitudinal trend of the Index of Biotic Integrity (IBI; upper graph) and the Modified Index of Well-Being (MIwb; lower graph) in the lower half of the Little Miami River during 1993.



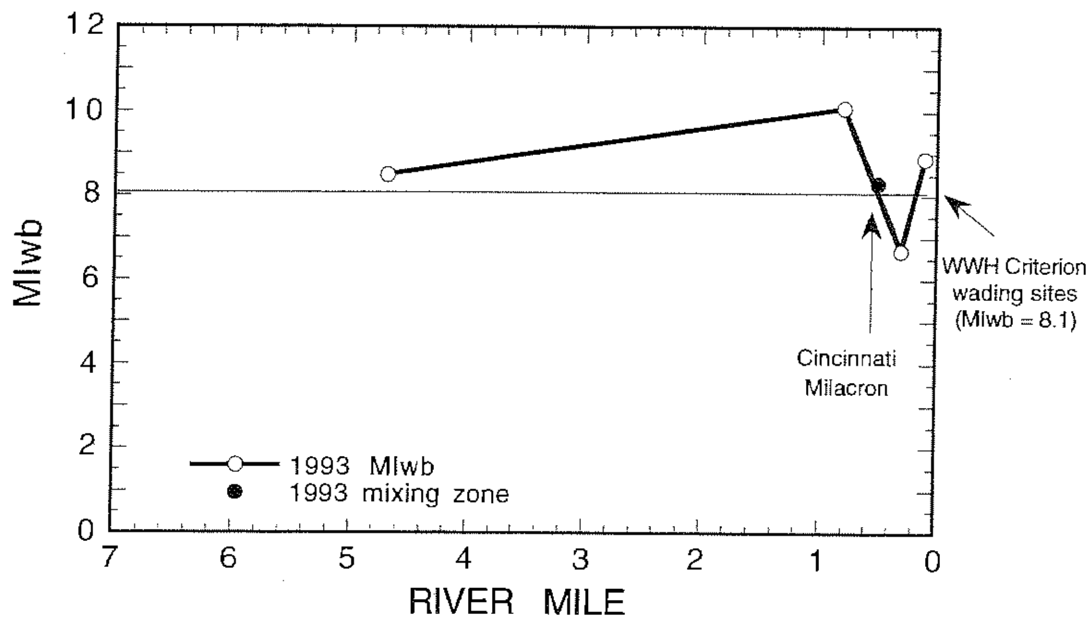


Figure 73. Longitudinal trend of the Index of Biotic Integrity (IBI; Top Graph) and the Modified Index of Well-Being (MIwb; Bottom Graph) in Turtle Creek during 1993.

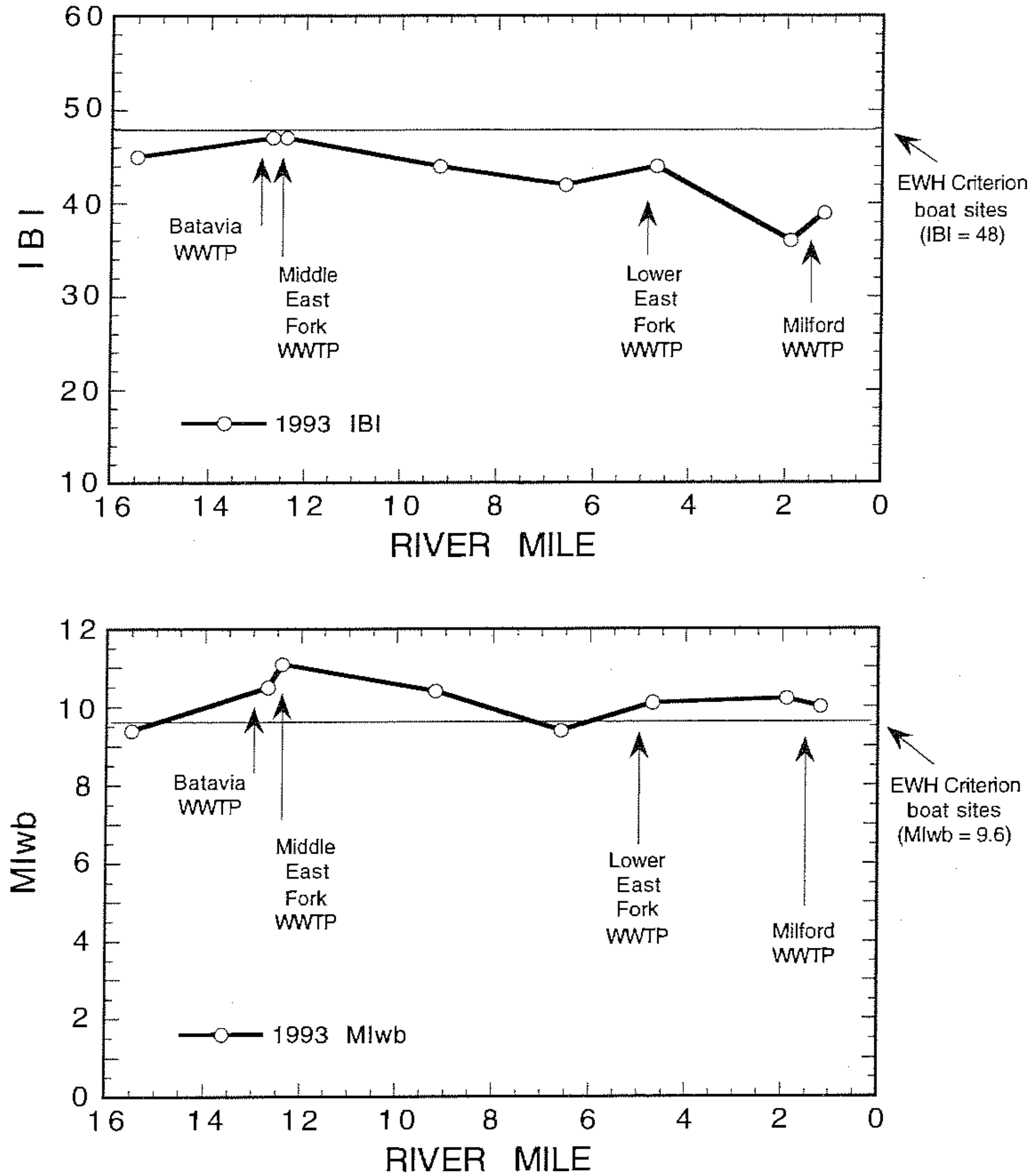


Figure 74. Longitudinal trend of the Index of Biotic Integrity (IBI; Top Graph) and the Modified Index of Well-Being (MIwb; Bottom Graph) in the East Fork of the Little Miami River during 1993.

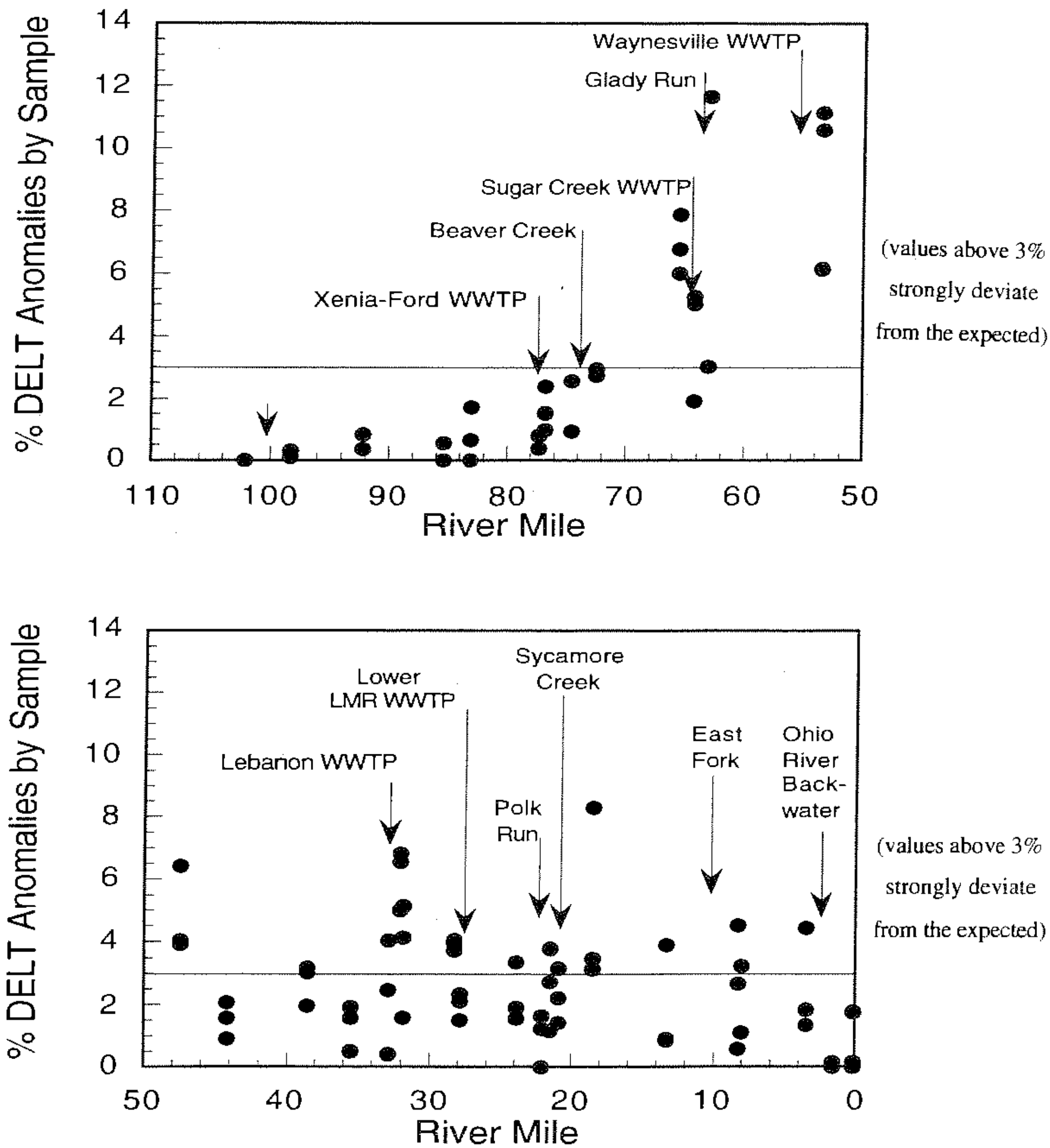


Figure 75. Longitudinal scatter plots of the percentages of fish with DELT (deformities, eroded fins, lesions, and tumors) external anomalies by sample in the upper half (Top Graph) and lower half (Bottom Graph) of the Little Miami River during 1993.

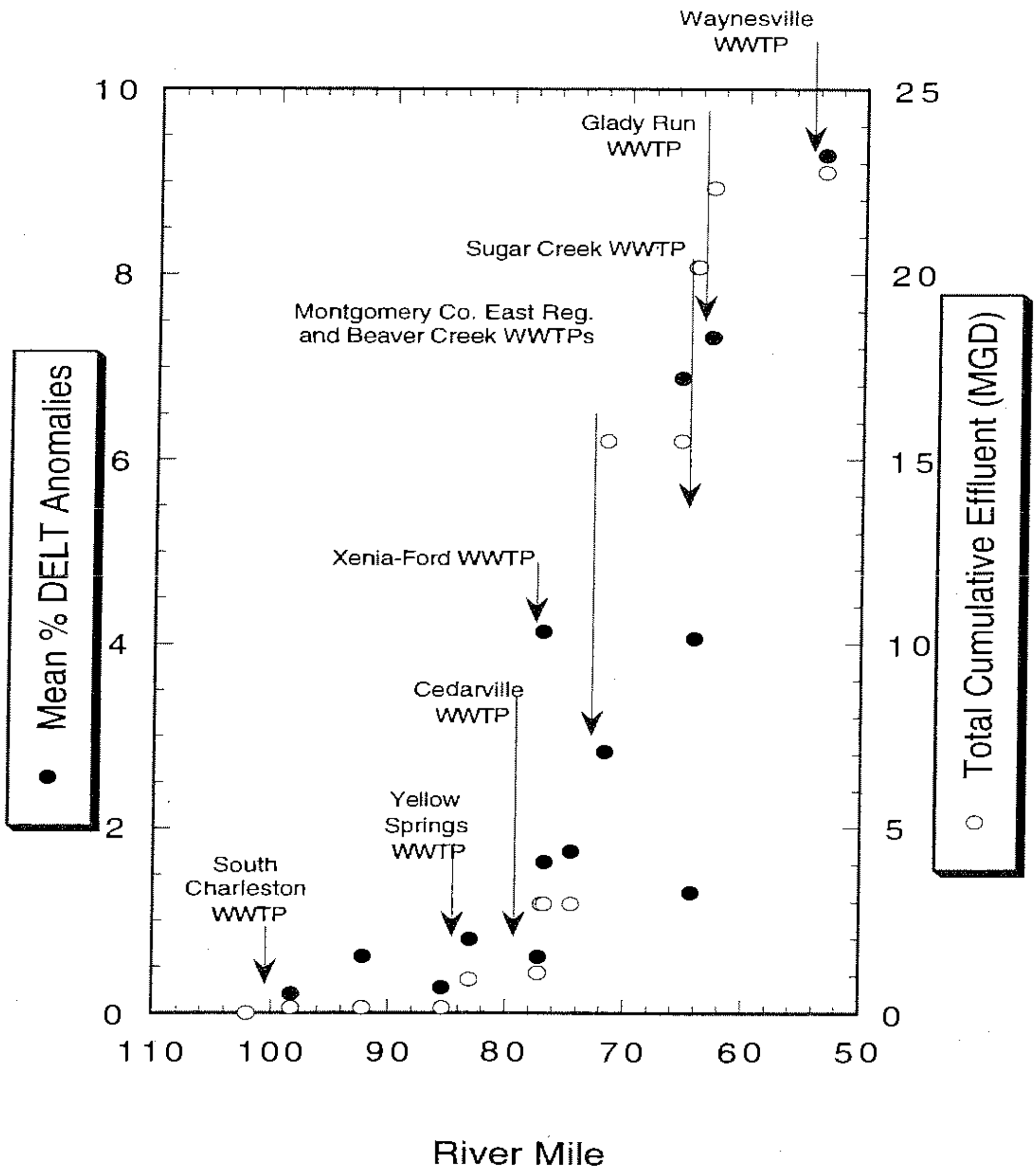


Figure 76a. Longitudinal scatter plots of the mean percentage of fish with DELT (deformities, eroded fins, lesions, and tumors) external anomalies and total cumulative effluent (3rd quarter mean million gallons per day) in the upper half of the Little Miami River during 1993.

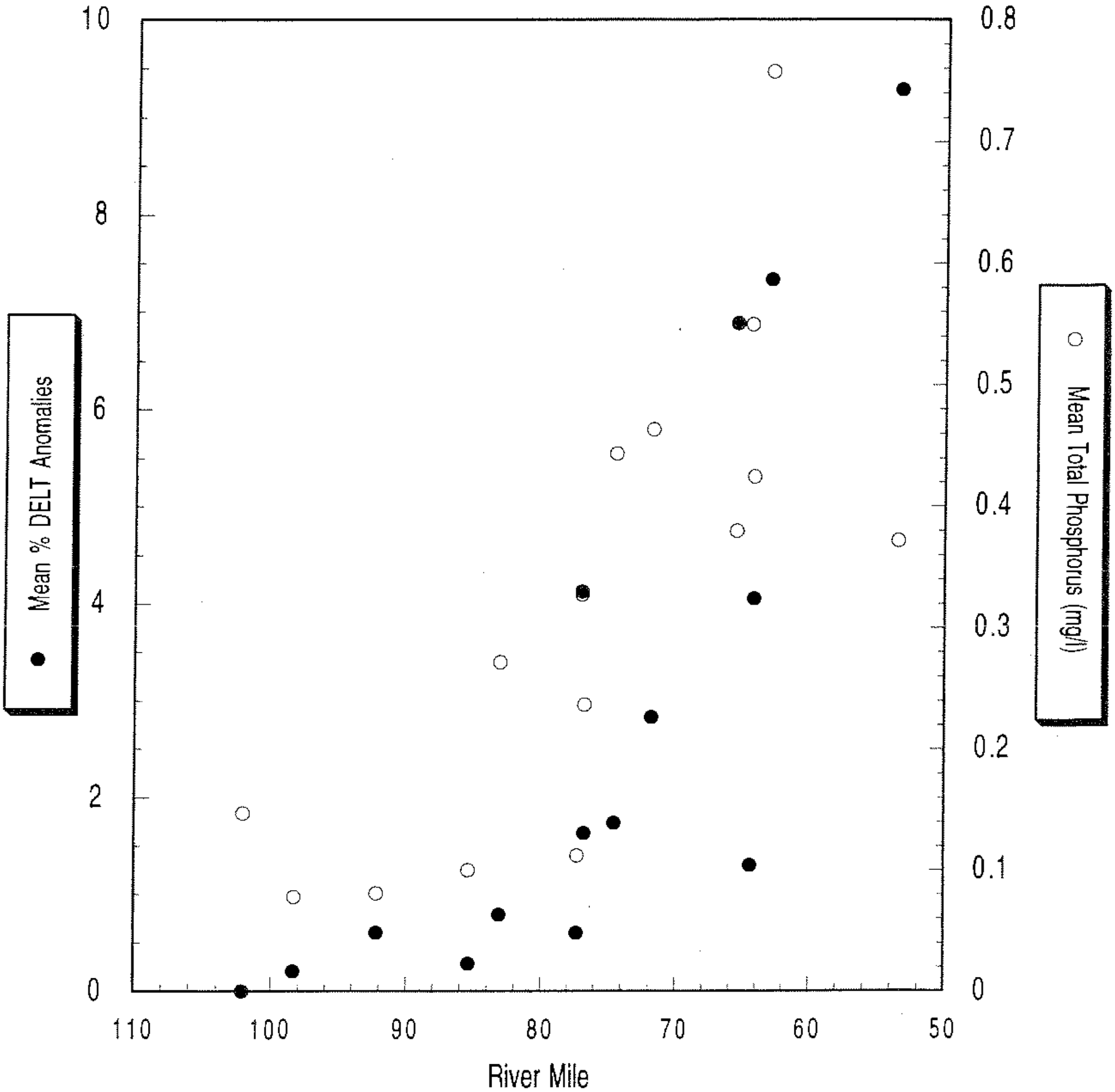


Figure 76b. Longitudinal scatter plots of the mean percentage of fish with DELT (deformities, eroded fins, lesions, and tumors) external anomalies and average total phosphorus concentrations (mg/l) in the upper half of the Little Miami River during 1993.

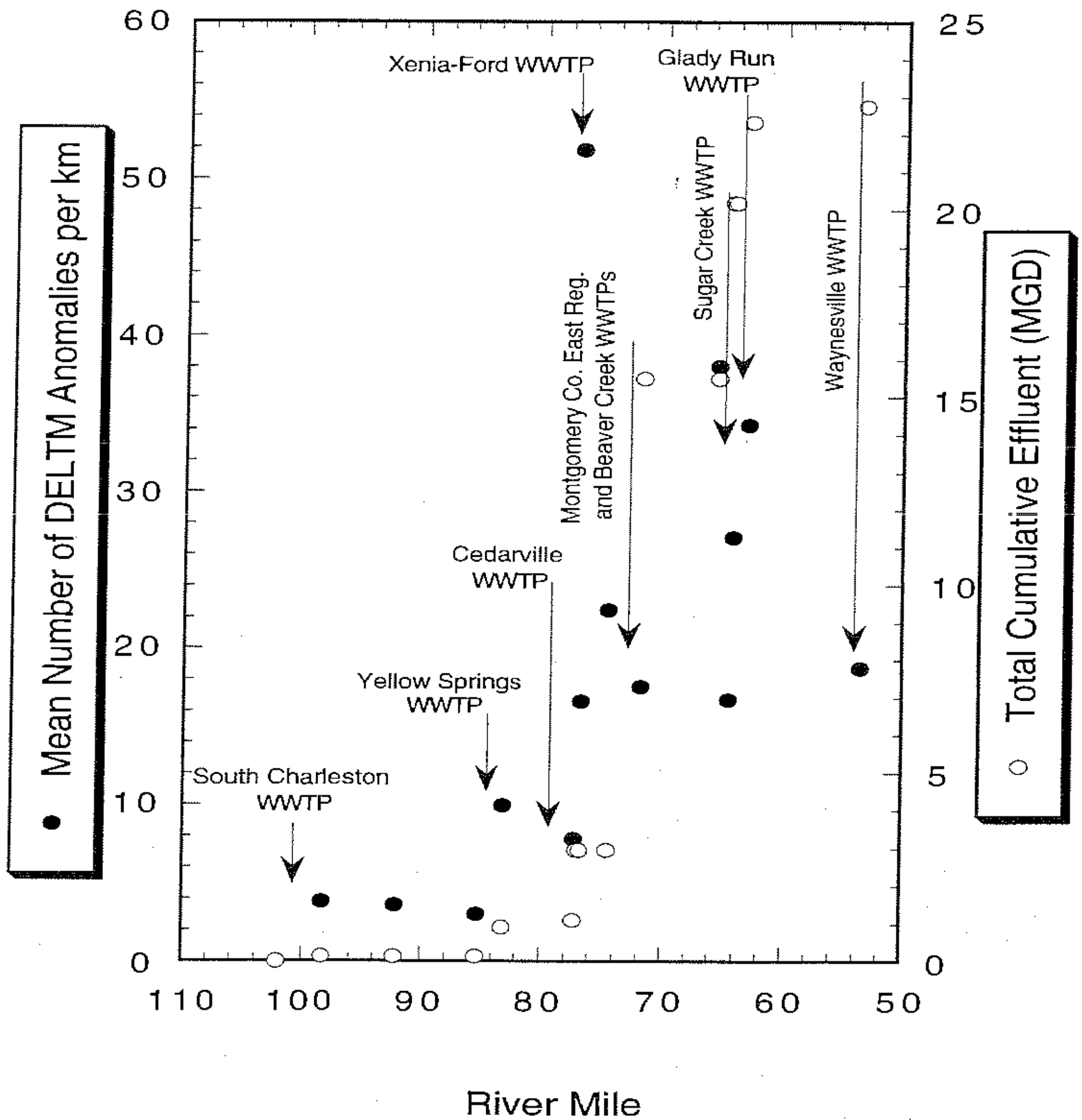


Figure 77a. Longitudinal scatter plots of the mean number of fish with DELT (deformities, eroded fins, lesions, and tumors) external anomalies and total cumulative effluent (3rd quarter mean million gallons per day) in the upper half of the Little Miami River during 1993.

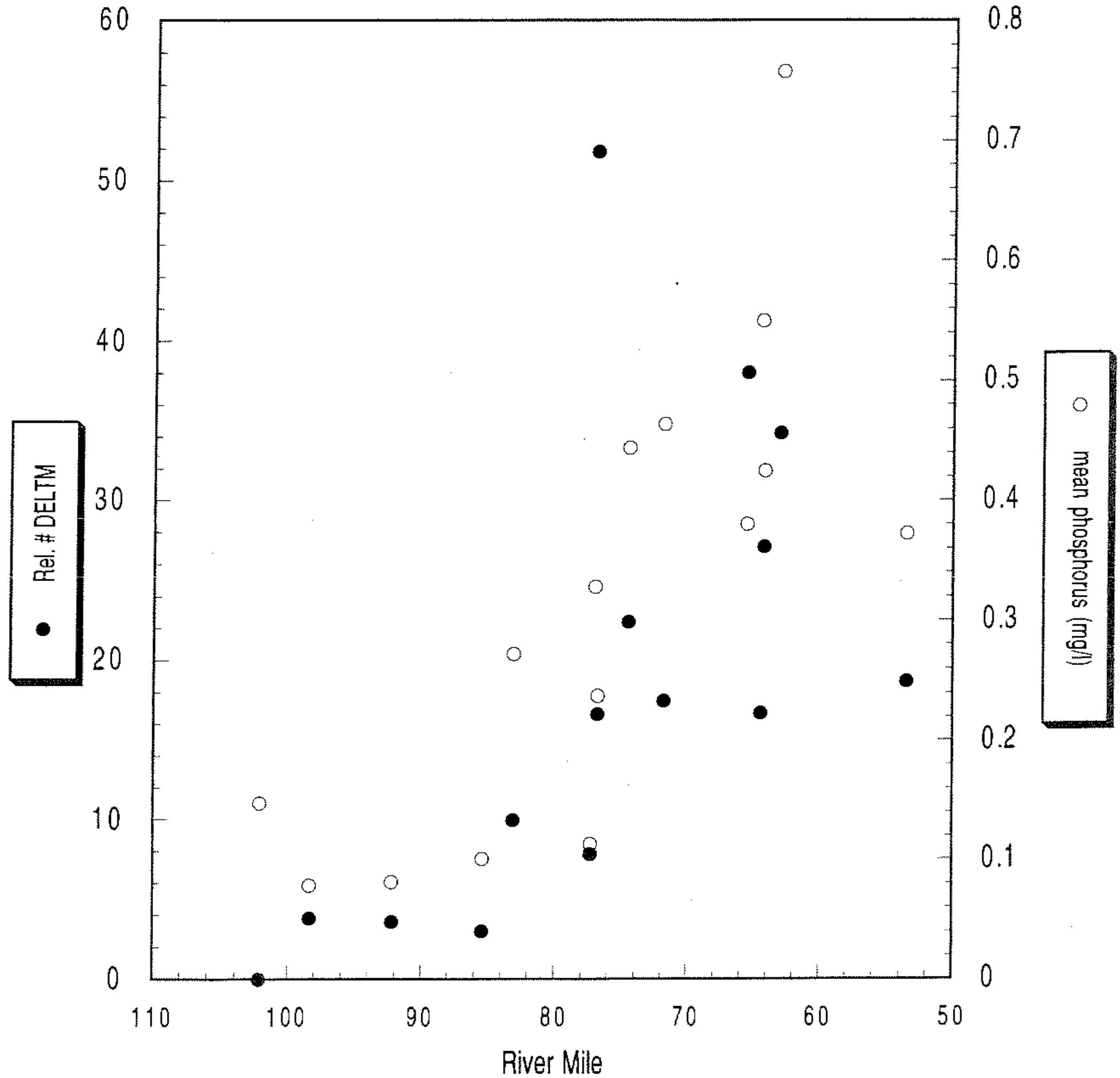


Figure 77b. Longitudinal scatter plots of the mean number of fish with DELT (deformities, eroded fins, lesions, and tumors) external anomalies and average total phosphorus concentrations (mg/l) in the upper half of the Little Miami River during 1993.

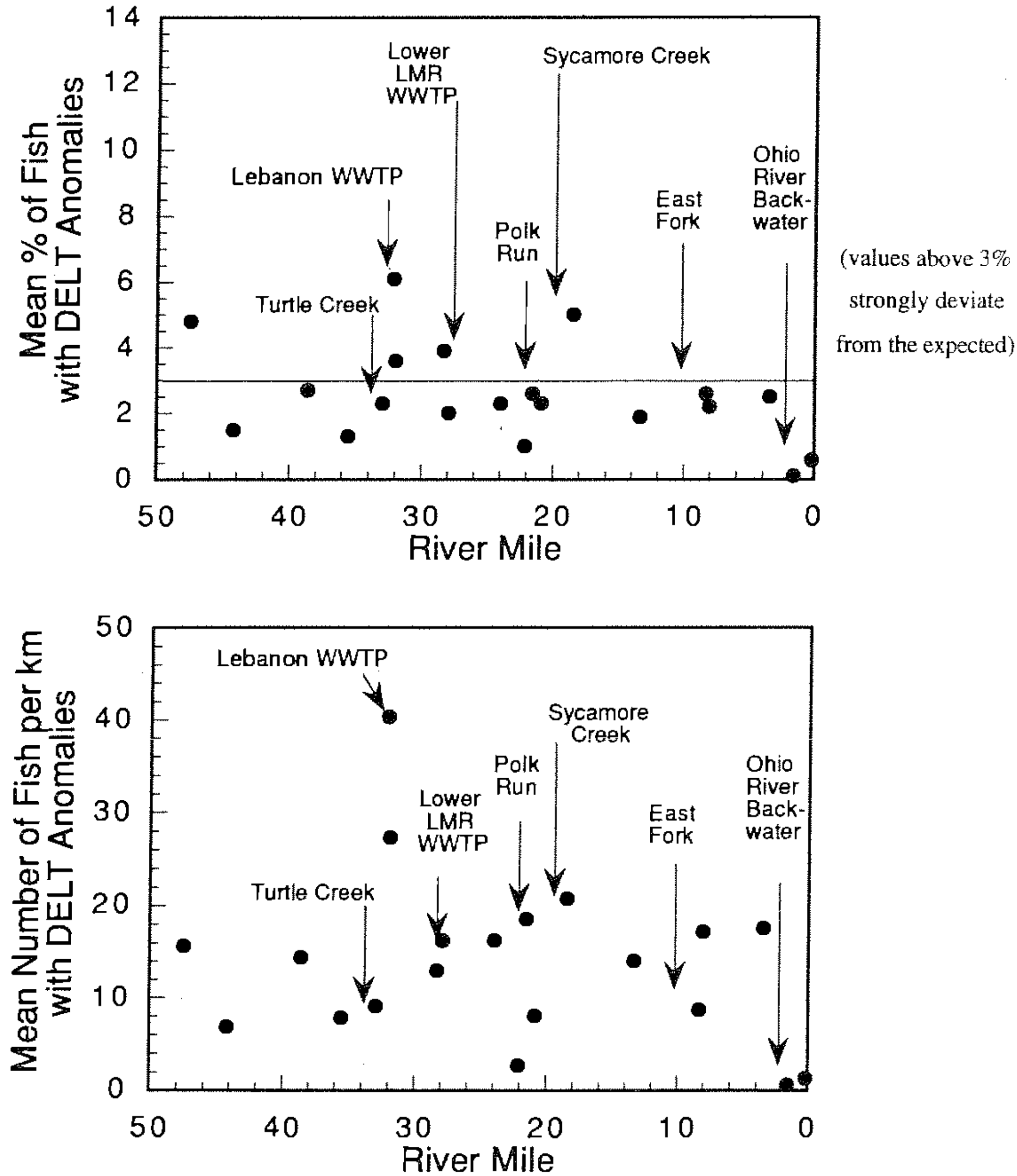


Figure 78 Longitudinal scatter plot of the mean percent occurrence of DELT anomalies (upper graph) and the mean relative number of fish (#/km) with DELT (deformities, eroded fins, lesions, and tumors) external anomalies (lower graph) by location in the lower half of the Little Miami River during 1993.

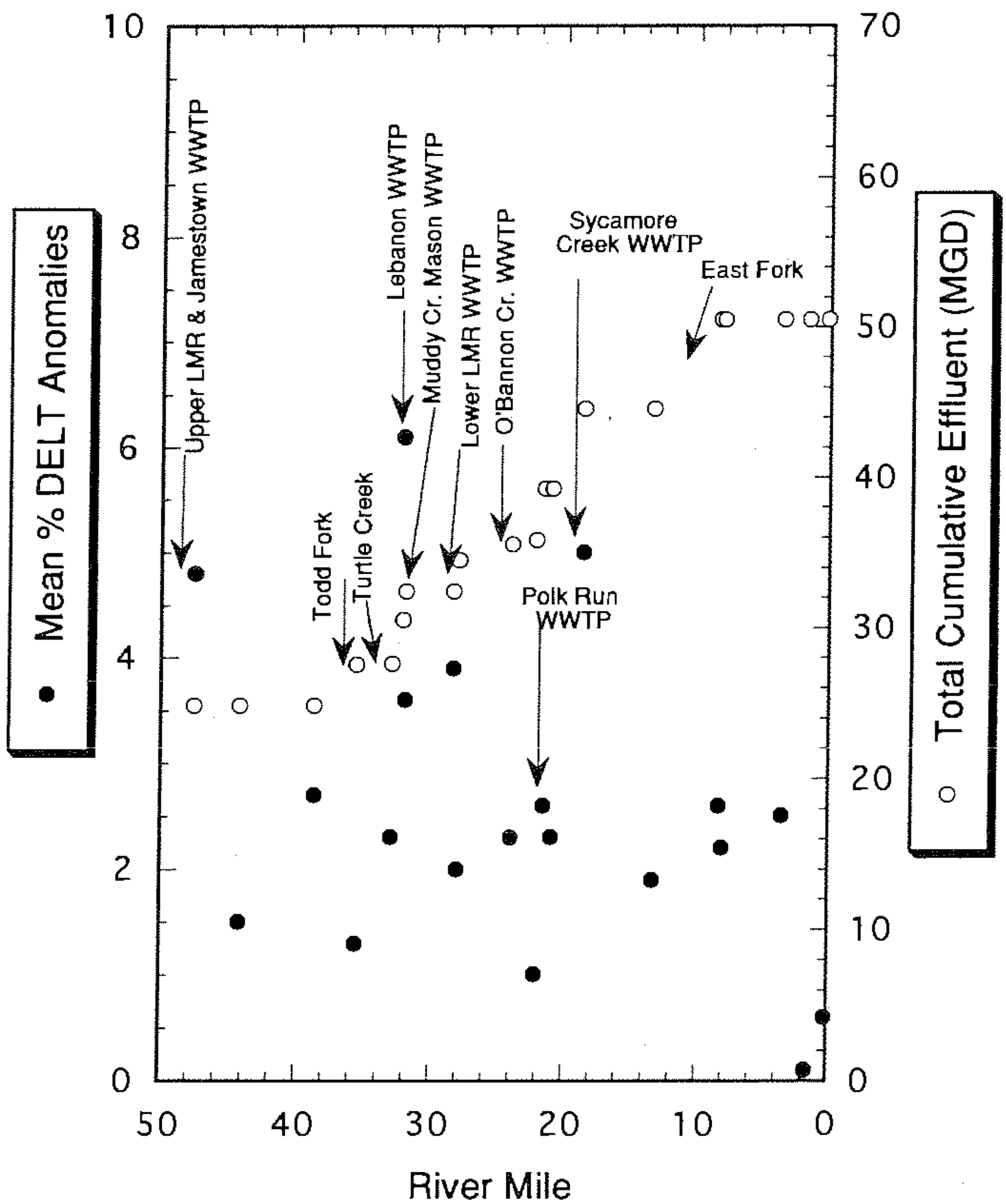


Figure 79a. Longitudinal scatter plots of the mean percentages of fish with DELT (deformities, eroded fins, lesions, and tumors) external anomalies and total cumulative effluent (3rd quarter mean million gallons per day) in the lower half of the Little Miami River during 1993.

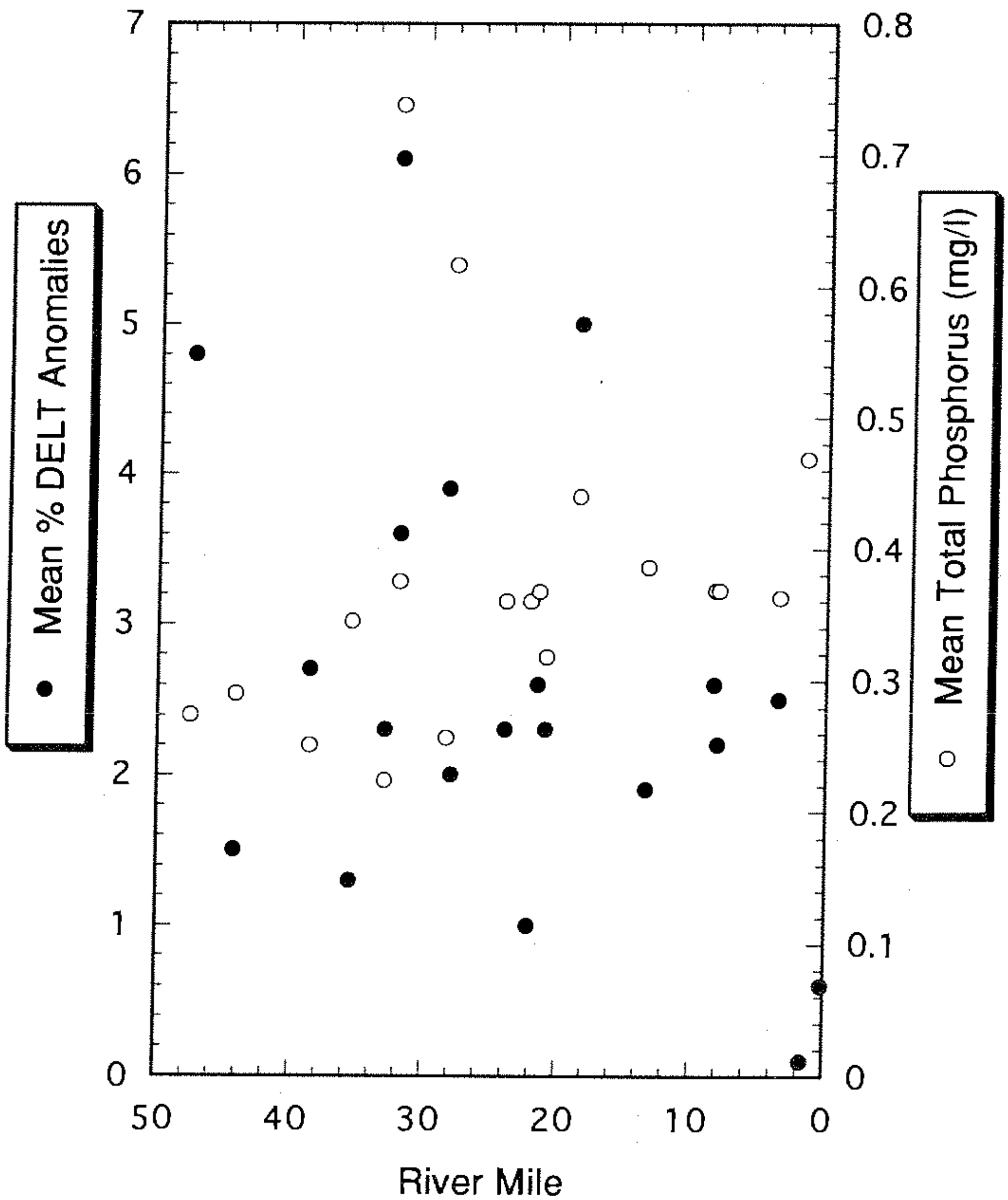


Figure 79b. Longitudinal scatter plots of the mean percentage of fish with DELT (deformities, eroded fins, lesions, and tumors) external anomalies and average total phosphorus concentrations (mg/l) in the lower half of the Little Miami River during 1993.

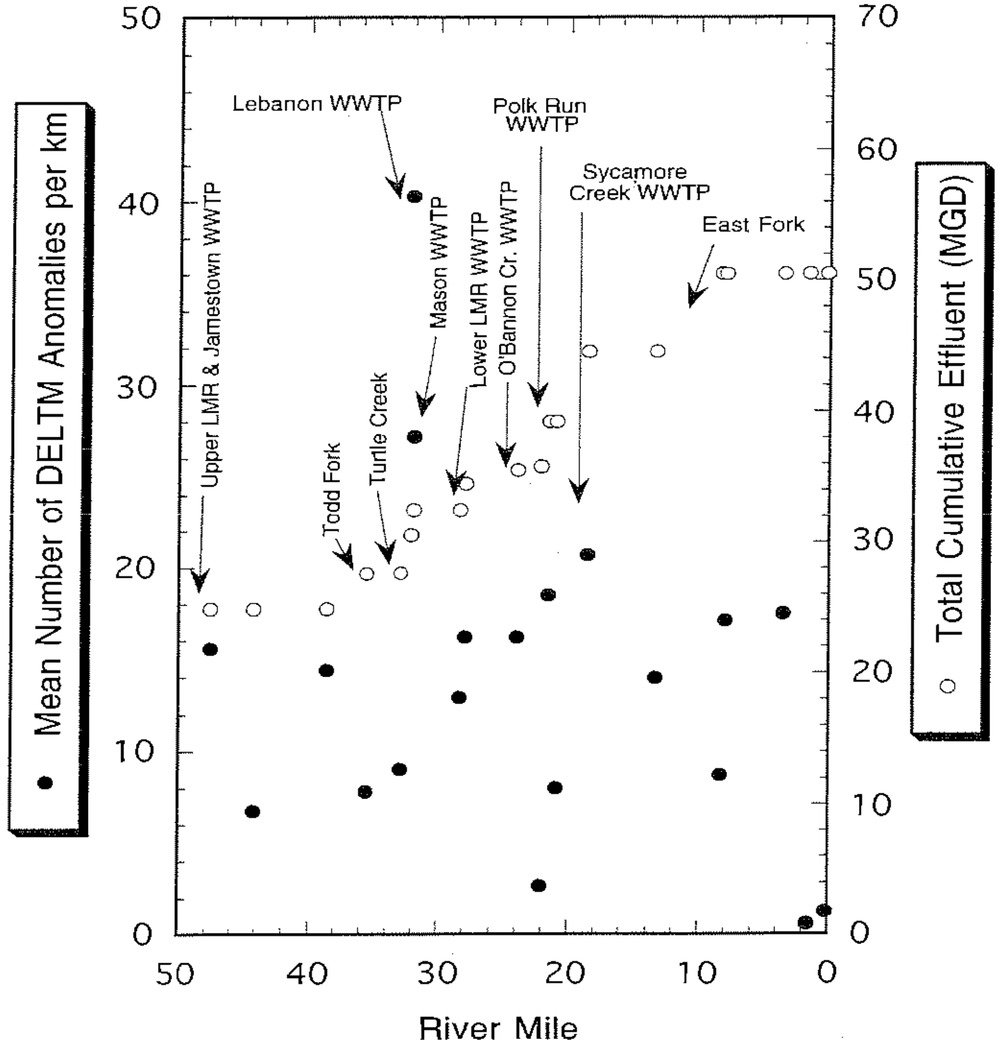


Figure 80a. Longitudinal scatter plots of the mean number of fish with DELT (deformities, eroded fins, lesions, and tumors) external anomalies and total cumulative effluent (3rd quarter mean million gallons per day) in the lower half of the Little Miami River during 1993.

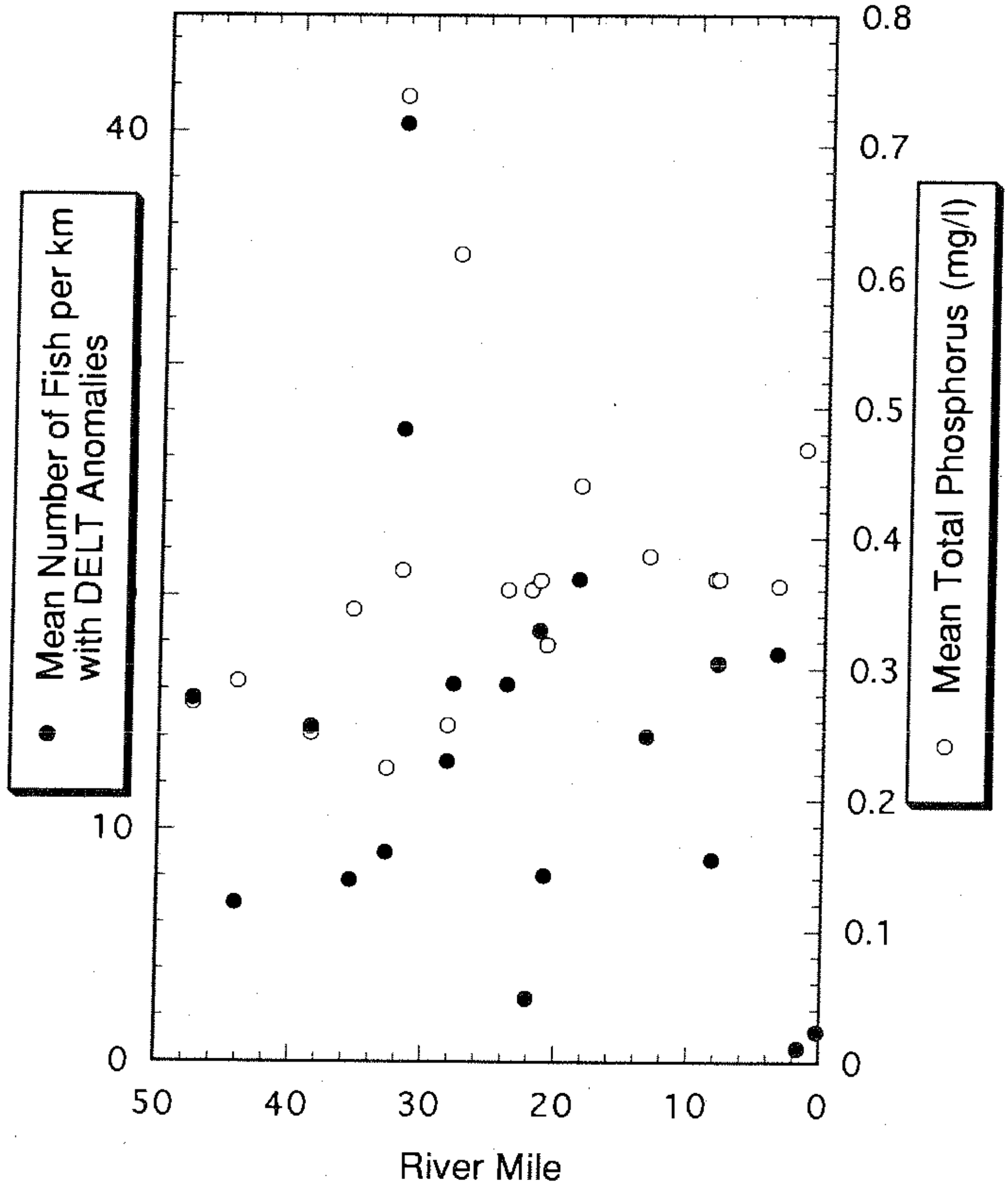
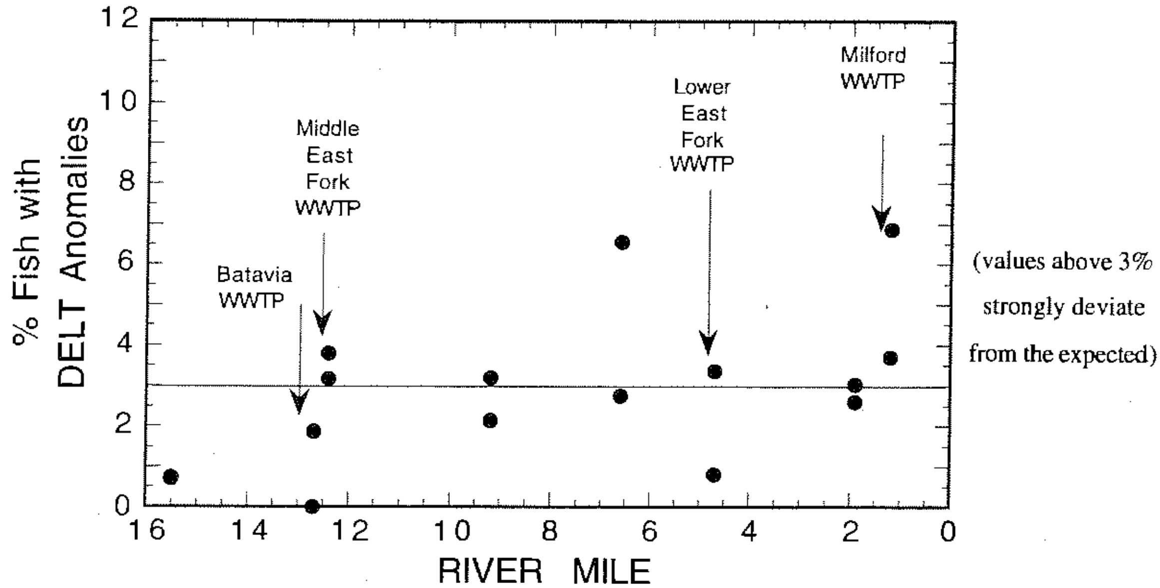


Figure 80b. Longitudinal scatter plots of the mean number of fish with DELT (deformities, eroded fins, lesions, and tumors) external anomalies and average total phosphorus concentrations (mg/l) in the lower half of the Little Miami River during 1993.



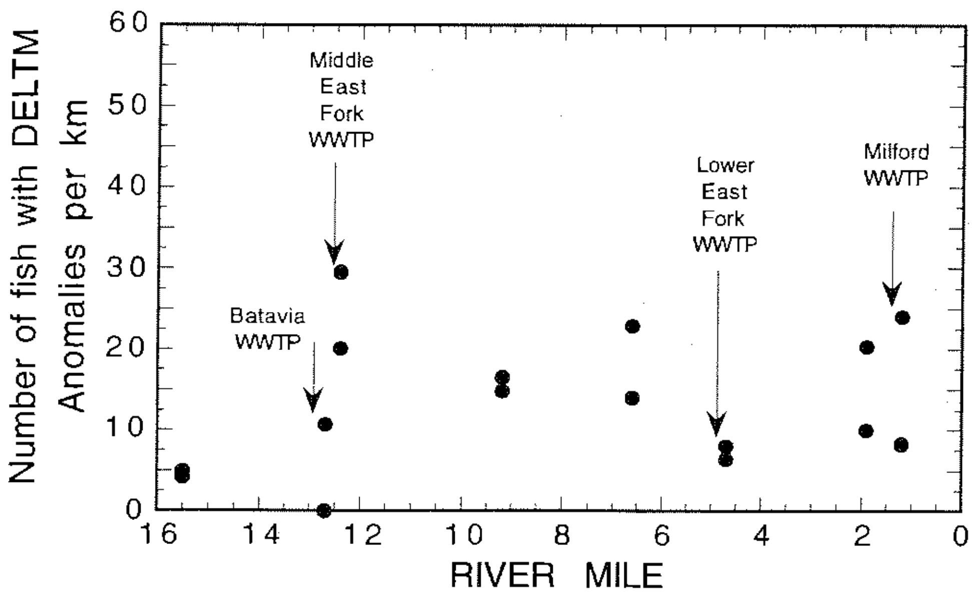


Figure 81. Longitudinal scatter plot of the percentage of DELT anomalies by sample (Upper Graph) and the relative number of fish (#/km) with DELT (deformities, eroded fins, lesions, and tumors) external anomalies (Lower Graph) in the East Fork of the Little Miami River during 1993.

TREND ASSESSMENT: 1983 - 1993

Chemical Water Quality Changes (Figures 82-96)

Little Miami River

- Since 1975, ambient chemical monitoring has been conducted in the Little Miami River near Xenia (RM 80.63) as part of the National Ambient Water Quality Monitoring Network (NAWQMN). Box plots of monthly data for six parameters are summarized in Figures 82 and 83. Throughout the nineteen year period, only one recorded dissolved oxygen concentration (daytime grab in July 1977) was below the EWH minimum criterion of 6 mg/l. Ammonia-N concentrations in earlier years (1975-1982) were elevated, but generally decreased to below the minimum detection limit in later years (1983-1993). Moderate to high levels of nitrate+nitrite-N have been recorded at the site throughout the period reflecting the predominantly agricultural land use within the upper basin. However, nitrate+nitrite-N values generally increased as ammonia-N levels decreased in the mid to late 1970s, possibly due to increased nitrification at the South Charleston WWTP. Most phosphorus concentrations recorded at the site have remained below the WQS guideline of 1.0 mg/l. High concentrations of total suspended solids (TSS) and high fecal coliform counts have tended to coinçide with high flow events due to increased nonpoint source runoff from the agricultural land use.

- Ohio EPA conducted an intensive biological and water quality study of the Little Miami River mainstem in 1983 and a comparison of 1983 and 1993 mean chemical results are presented in Figures 84-88. Daytime grab dissolved oxygen concentrations have remained similar throughout the mainstem with the exception of lower values recorded downstream of Gilroy Ditch in 1993 (Figure 84). D.O. values in the headwater region (RM 101.30) were below the EWH minimum criterion in 1983 and 1993.

- Mean ammonia-N concentrations recorded in 1993 were consistently low throughout most of the mainstem (Figure 85). In the upper half of the Little Miami River, lower concentrations were evident downstream of Gilroy Ditch (South Charleston WWTP, RM 98.98) and downstream from Beaver Creek (RMs 72.30 and 66.56). In the lower half, mean concentrations downstream from Sycamore Creek (RM 18.14) have also decreased since 1983. However, concentrations downstream from the Lebanon and Mason WWTPs have increased slightly.

- Mean nitrate+nitrite-N concentrations have increased since 1983 at most locations in the upper half with the largest increase recorded downstream from Gilroy Ditch (Figure 86). Concentrations in the lower half have remained more similar at most locations.

- Mean phosphorus concentrations in the upper half have decreased downstream from Gilroy Ditch, but increased slightly downstream from Yellow Springs Creek (Figure 87). Values also decreased downstream from the Xenia Ford Road WWTP and the confluence of Beaver Creek, but remain higher in 1993 than background levels upstream from Clifton. Total phosphorus concentrations decreased at most locations in the lower mainstem except for downstream from the Warren Co. Lower LMR WWTP (Simpson Creek).

- Mean fecal coliform counts were generally below the Primary Contact Recreation (PCR) criterion in both 1983 and 1993. Mean concentrations downstream from Sycamore Creek (RM 18.14) exceeded the primary contact criterion both years (Figure 88).

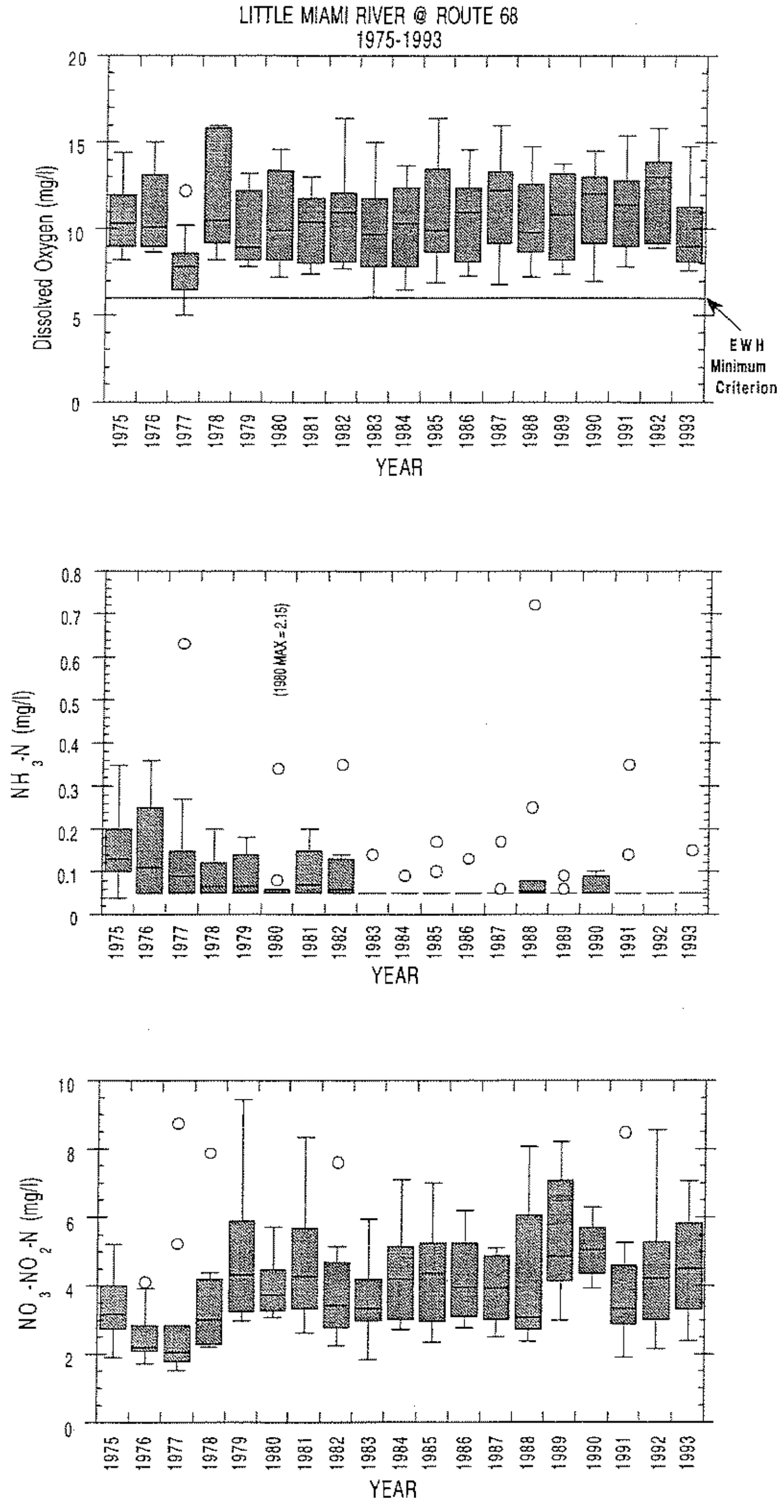


Figure 82. Longitudinal trends of dissolved oxygen (daytime grabs), ammonia-N, and nitrate+nitrite-N in the upper Little Miami River at SR 68 (RM 80.63) from 1975-1993.

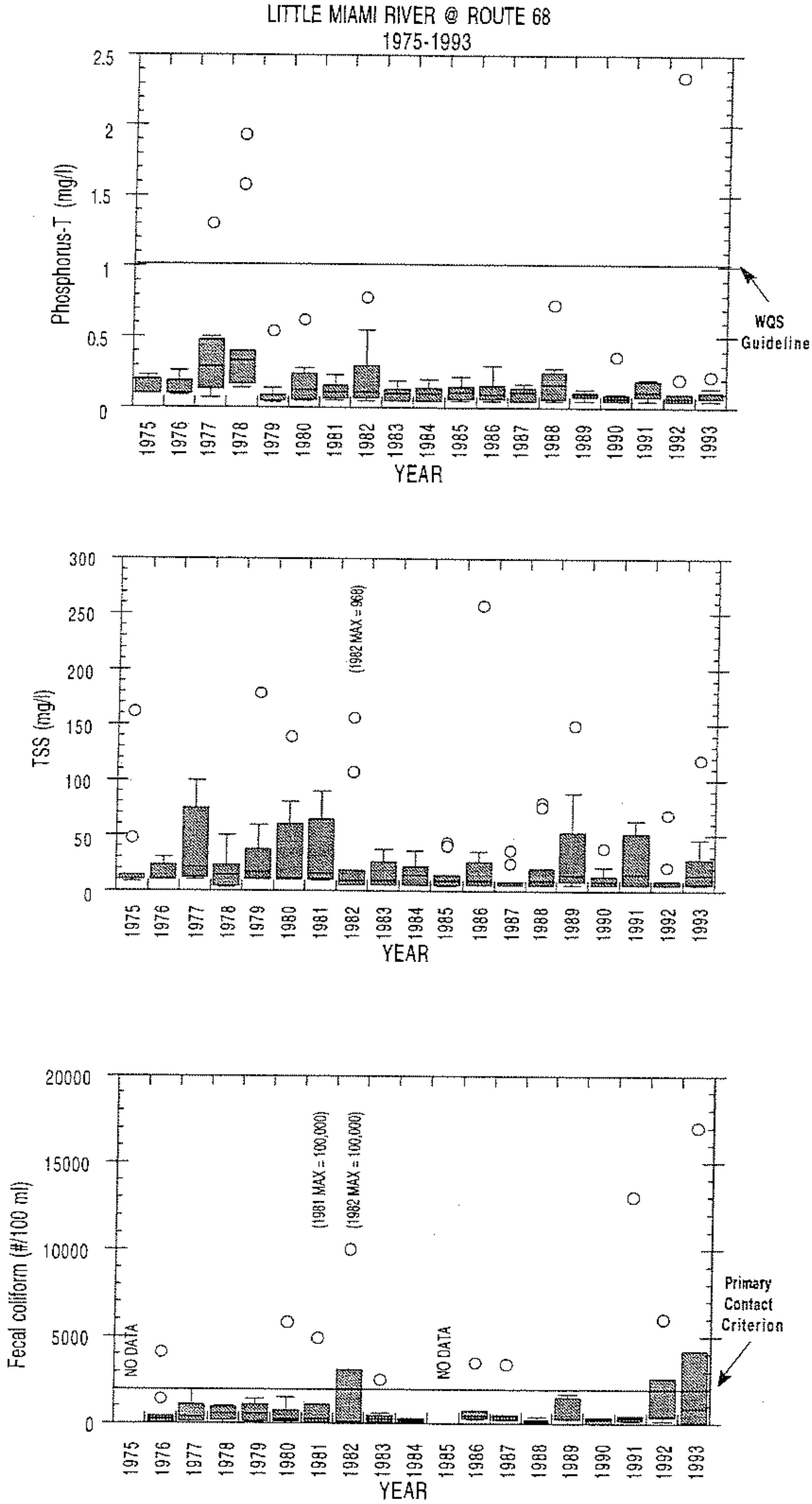
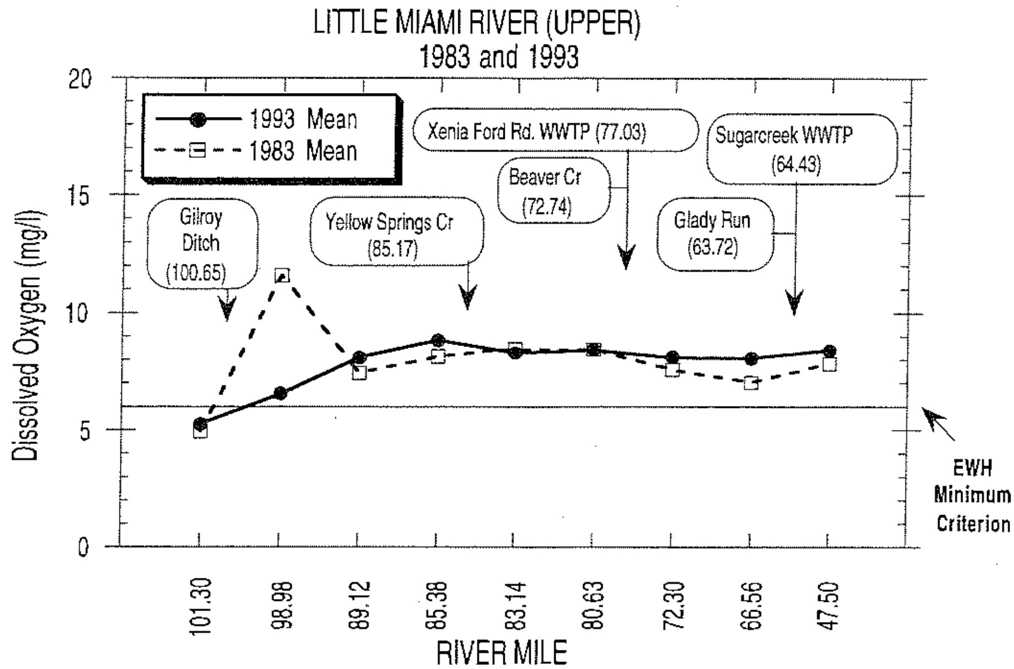


Figure 83. Longitudinal trend of total phosphorus, total suspended solids (TSS) and fecal coliform in the Little Miami River at State Route 68 (river mile 80.63) from 1975-1993.



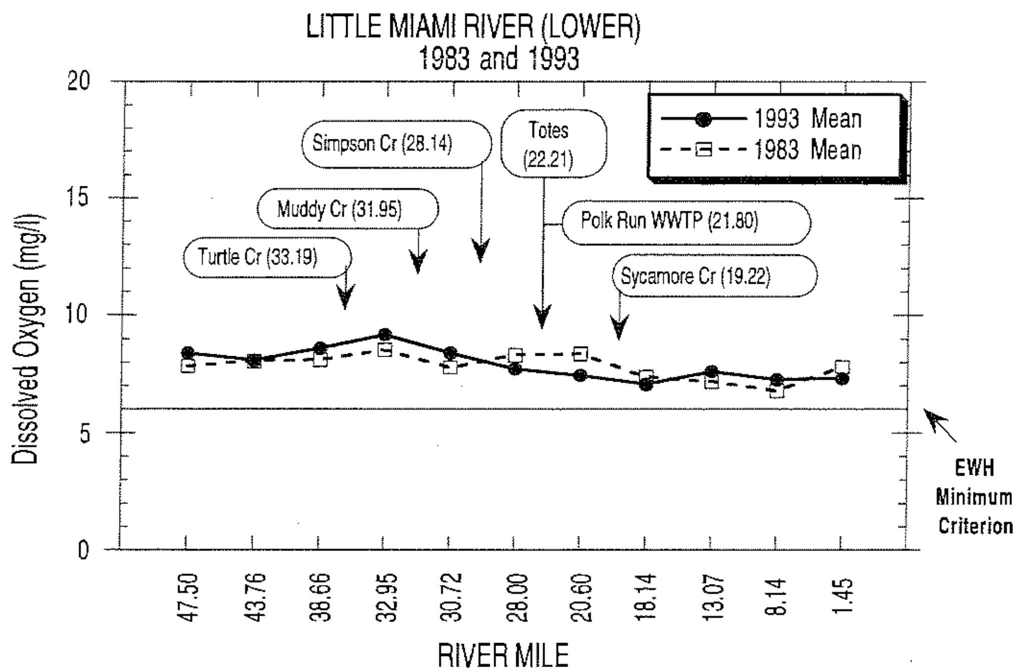


Figure 84. Longitudinal trend of mean dissolved oxygen (daytime grabs) in the upper and lower Little Miami River in 1983 and 1993.

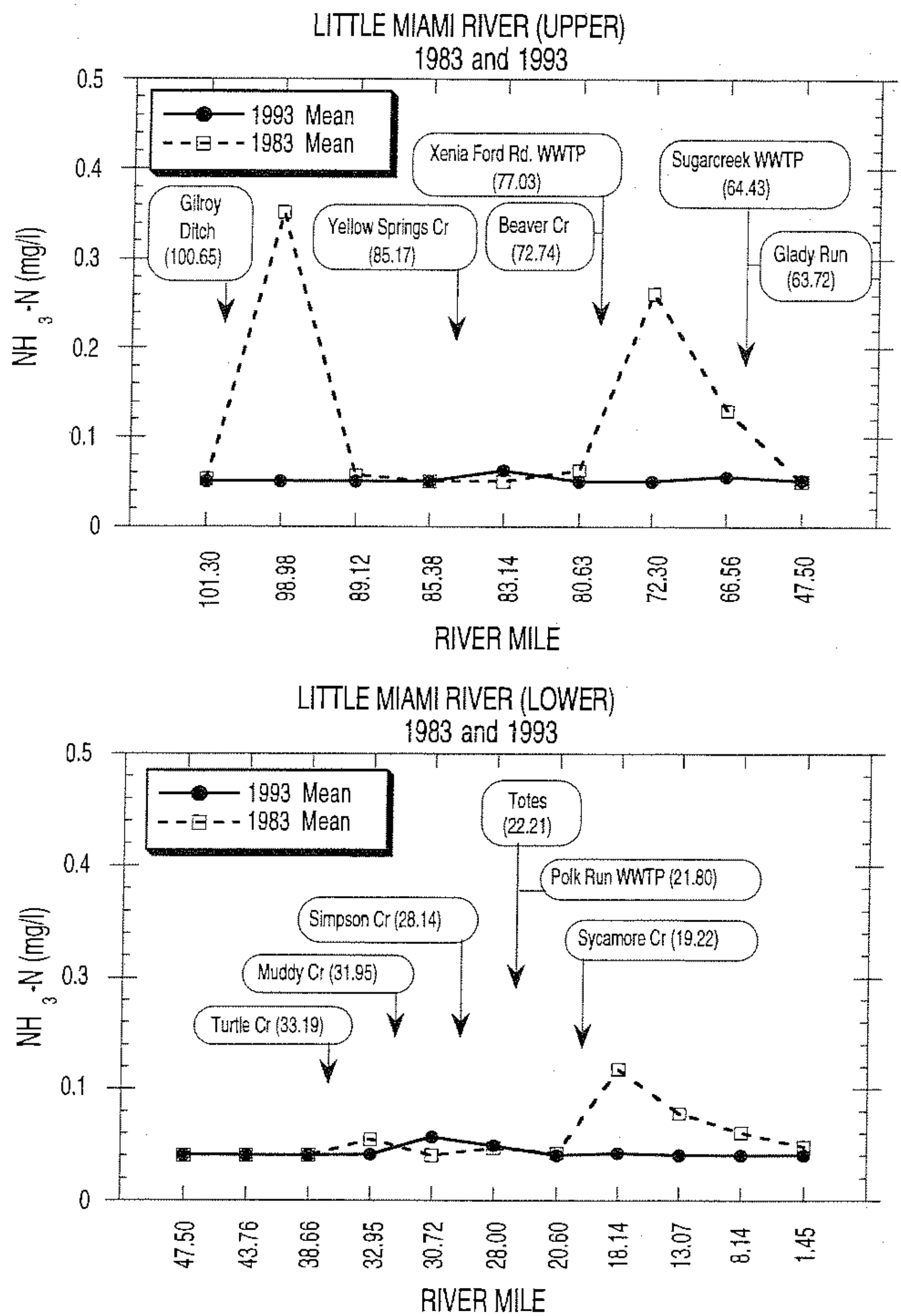


Figure 85. Longitudinal trend of mean ammonia-N in the upper and lower Little Miami River in 1983 and 1993.

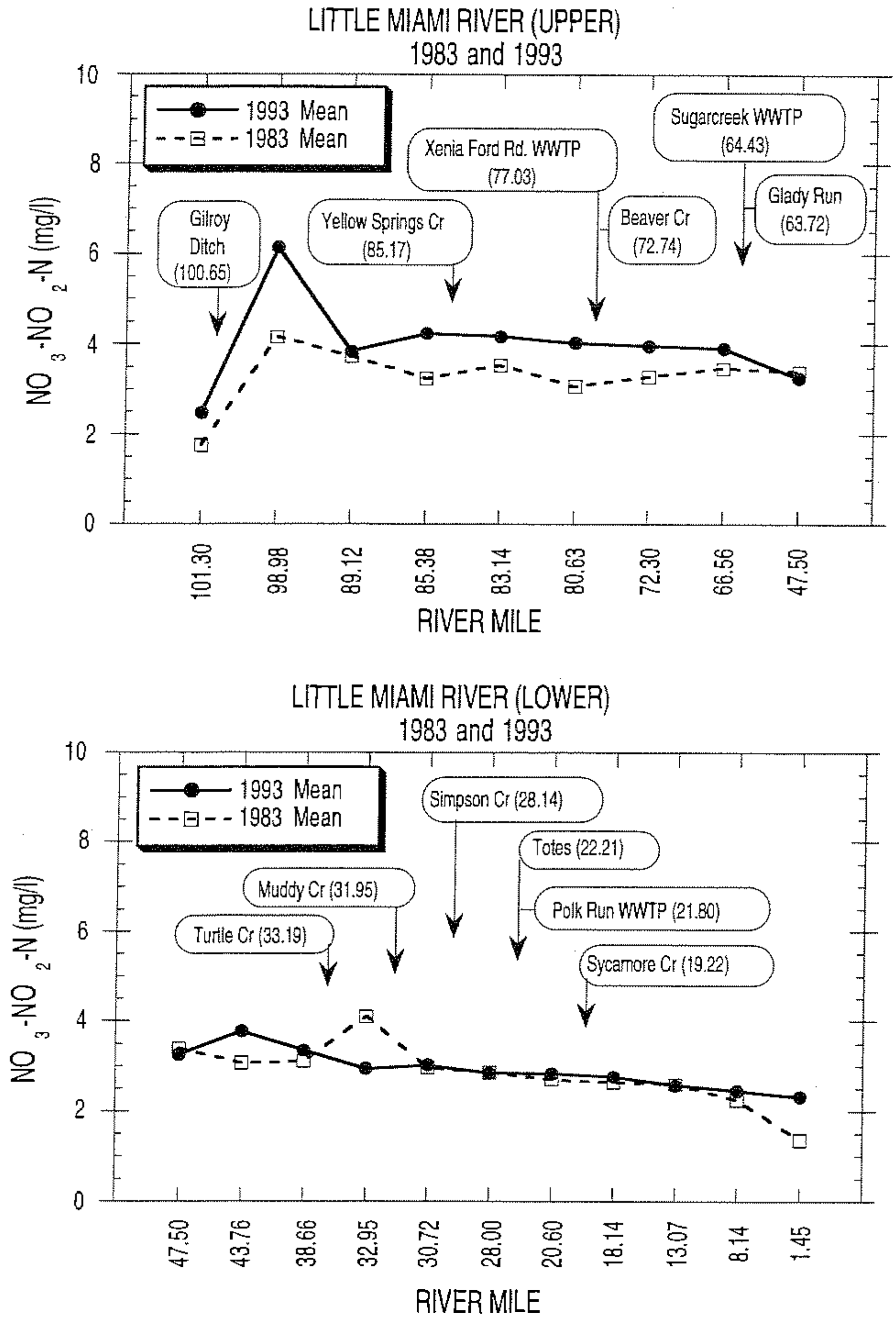


Figure 86. Longitudinal trend of mean nitrate+nitrite-N in the upper and lower Little Miami River in 1983 and 1993.

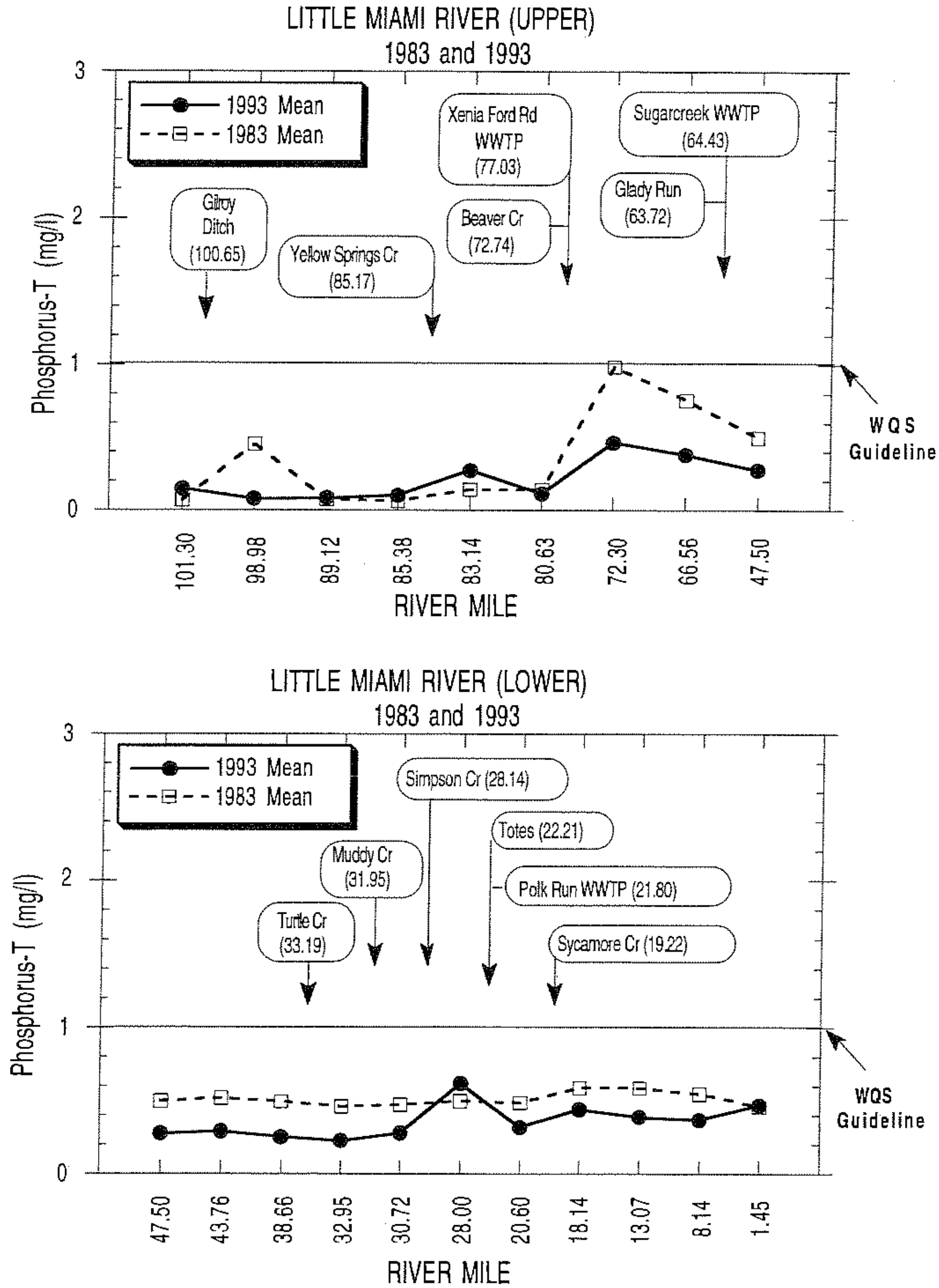
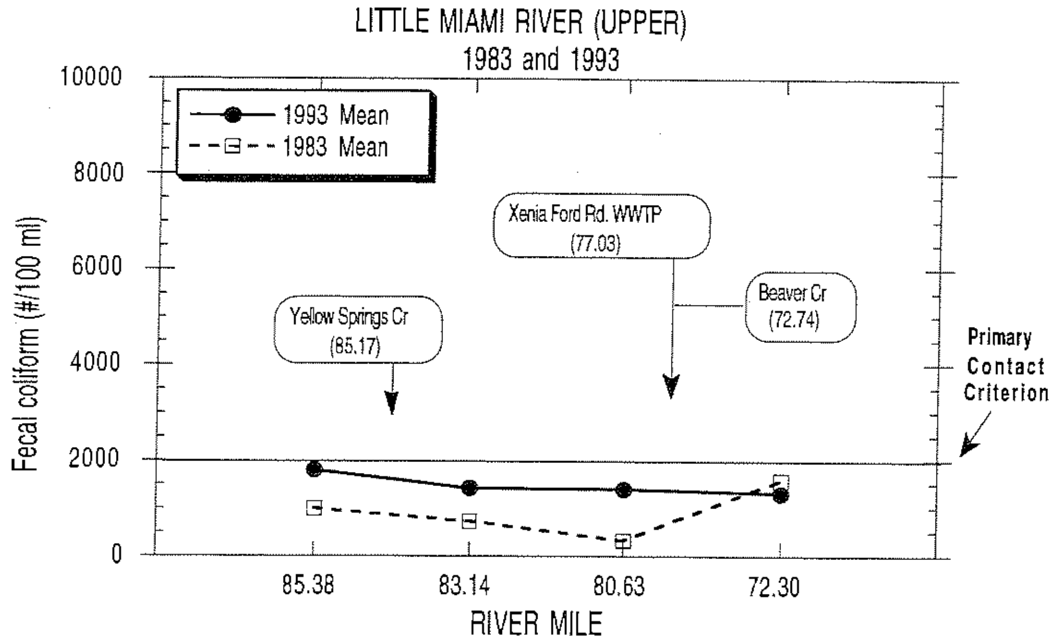


Figure 87. Longitudinal trend of mean total phosphorus in the upper and lower Little Miami River in 1983 and 1993.



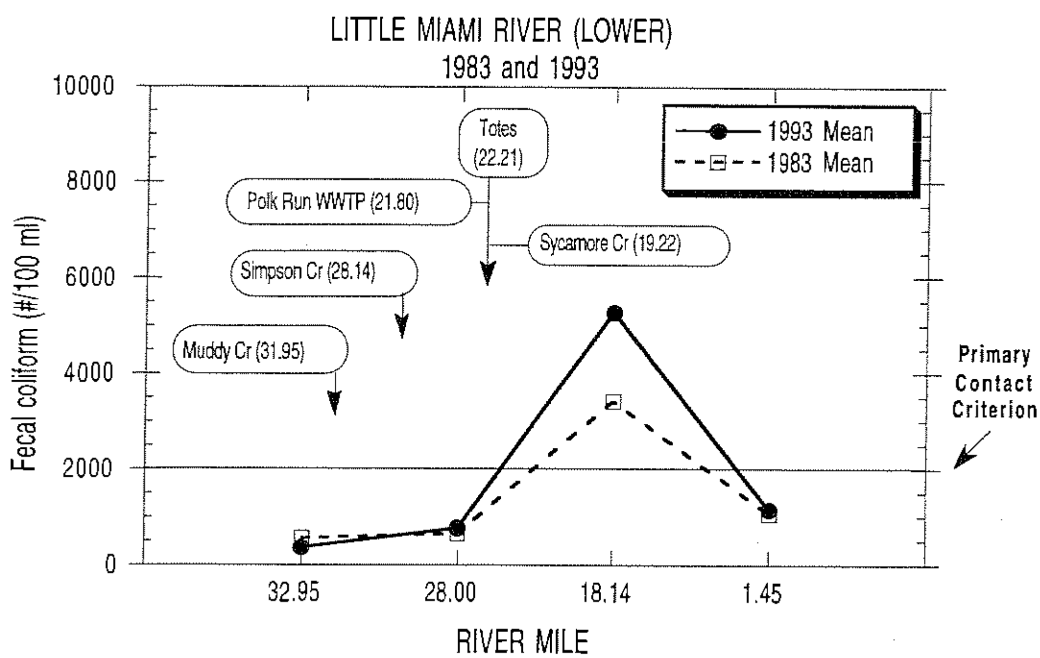


Figure 88. Longitudinal trend of mean fecal coliform in the upper and lower Little Miami River in 1983 and 1993.

Little Beaver Creek

- A comparison of 1982 and 1993 mean water chemistry results for five parameters from two locations (RMs 1.95 and 0.05) are shown in Figures 89 and 90. Due likely to improved treatment at Montgomery County Eastern Regional WWTP, the 1993 data shows increased dissolved oxygen and nitrate+nitrite-N levels and decreased ammonia-N concentrations. Mean phosphorus concentrations also markedly decreased in 1993, but remained above the WQS guideline (1.0 mg/l) demonstrating the continued nutrient loading from the Montgomery County Eastern Regional WWTP. Although now measured as CBOD5, BOD5 levels have markedly declined since 1982. The conversion of the 1993 $CBOD_5$ values near 1.0 mg/l would yield a very similar trend in BOD_5 (Figure 89).

Turtle Creek

- Mean results from comparable sites (RMs 6.23, 0.70, and 0.52) in the 1983 and 1993 surveys of Turtle Creek are given in Figures 91 through 93. Turtle Creek in the vicinity of Cincinnati Milacron was also sampled extensively for metals in 1989. Mean copper and lead results from 1989 are presented in Figure 93.

- The 1993 results show slightly lower mean dissolved oxygen concentrations at RMs 6.23 and 0.52, but a markedly lower level at RM 0.70, the area upstream from the industrial discharge where dewatering was suspected in 1993. Values did, however, remained above the WWH average criterion (5.0 mg/l) at all three sites (Figure 91).

- Mean ammonia-N levels in 1993 remained similar to the 1983 concentrations between RMs 6.23 and 0.70, but markedly increased to critically high values downstream from Cincinnati Milacron (RM 0.52, Figure 91). The 1993 mean concentration of nitrate+nitrite-N was similar at the upstream site and markedly lower between RMs 0.70 and 0.52 (Figure 92). Total phosphorus was similar to slightly higher between RMs 6.23 and 0.70 and markedly lower downstream from Cincinnati Milacron. The 1993 mean phosphorus levels at RMs 0.70 and 0.52 approached the WQS guideline (Figure 92).

- The mean concentrations of copper has remained highly elevated immediately downstream from Cincinnati Milacron since 1983 (Figure 93). While mean concentrations recorded in the mixing zone (RM 0.58) in 1993 were lower than 1989, 1993 levels were more highly elevated than the 1989 value at RM 0.52. Mean lead concentrations recorded in 1989 and 1993 in the mixing zone were comparable, but the 1993 value again exceeded 1989 concentration at RM 0.52 (Figure 93).

East Fork Little Miami River

- The 1993 mean dissolved oxygen values were similar to the 1982 values between RMs 9.10 and 0.77, but were considerably lower downstream from the reservoir at RM 15.60 (Figure 94). The 1993 trend remained fairly constant and above the EWH minimum water quality criterion throughout the lower mainstem. Although now measured as CBOD5, BOD5 levels have apparently declined since 1982. The conversion of the 1993 $CBOD_5$ values near 1.0 mg/l would yield a very similar trend in BOD_5 (Figure 94).

- The 1993 mean ammonia-N concentrations were below the minimum detection limit (0.05 mg/l) at all four sites. In 1982, concentrations were detected at most locations. Mean nitrate+nitrite-N levels were relatively constant throughout the mainstem in 1982, but demonstrated an increasing trend downstream from the WWTPs in 1993 (Figure 95). Mean phosphorus concentrations in 1982 and 1993 were very similar. Values in both years peaked at RM 0.77, but remained below 1.0 mg/l (Figure 96). Mean total suspended solids concentrations were somewhat more elevated in 1993 and increased longitudinally during both years (Figure 96). Fecal coliform counts in 1982 and 1993 also showed higher values near the mouth than upstream from Batavia, but the 1993 value at RM 0.77 was markedly lower in 1993. Mean 1993 concentrations remained below the primary contact recreation criterion at both locations (Figure 96).

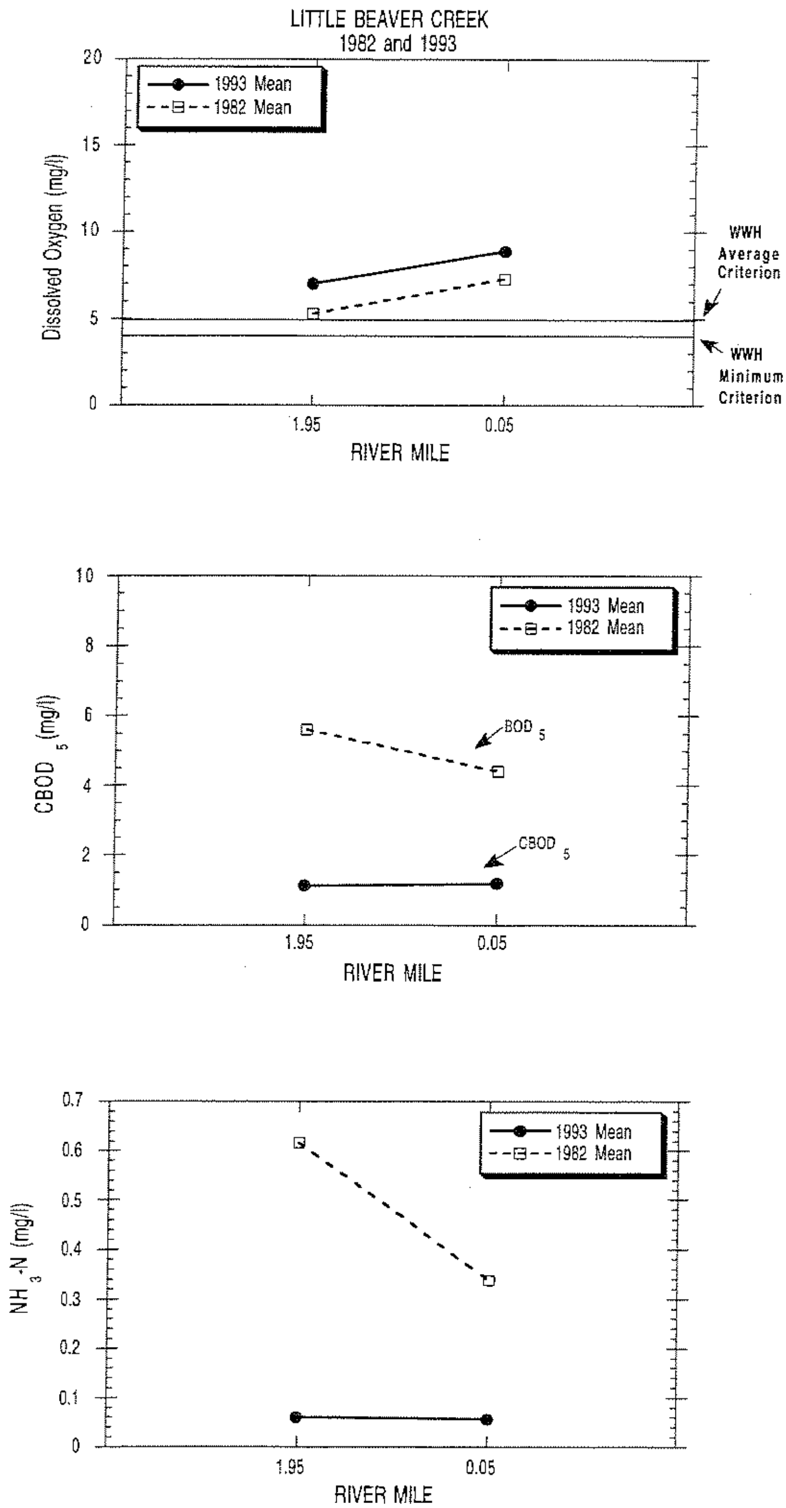


Figure 89. Longitudinal trend of mean dissolved oxygen (daytime grabs), (C)BOD$_5$, and ammonia-N in Little Beaver Creek in 1982 and 1993.

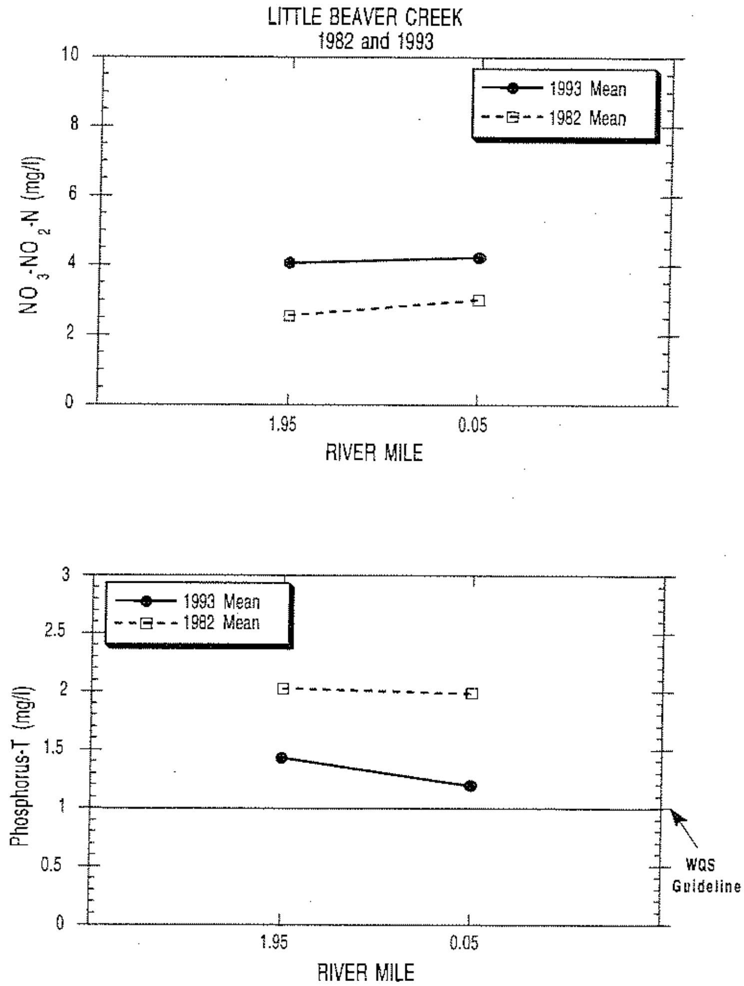


Figure 90. Longitudinal trend of mean nitrate+nitrite-N and total phosphorus in Little Beaver Creek in 1982 and 1993.

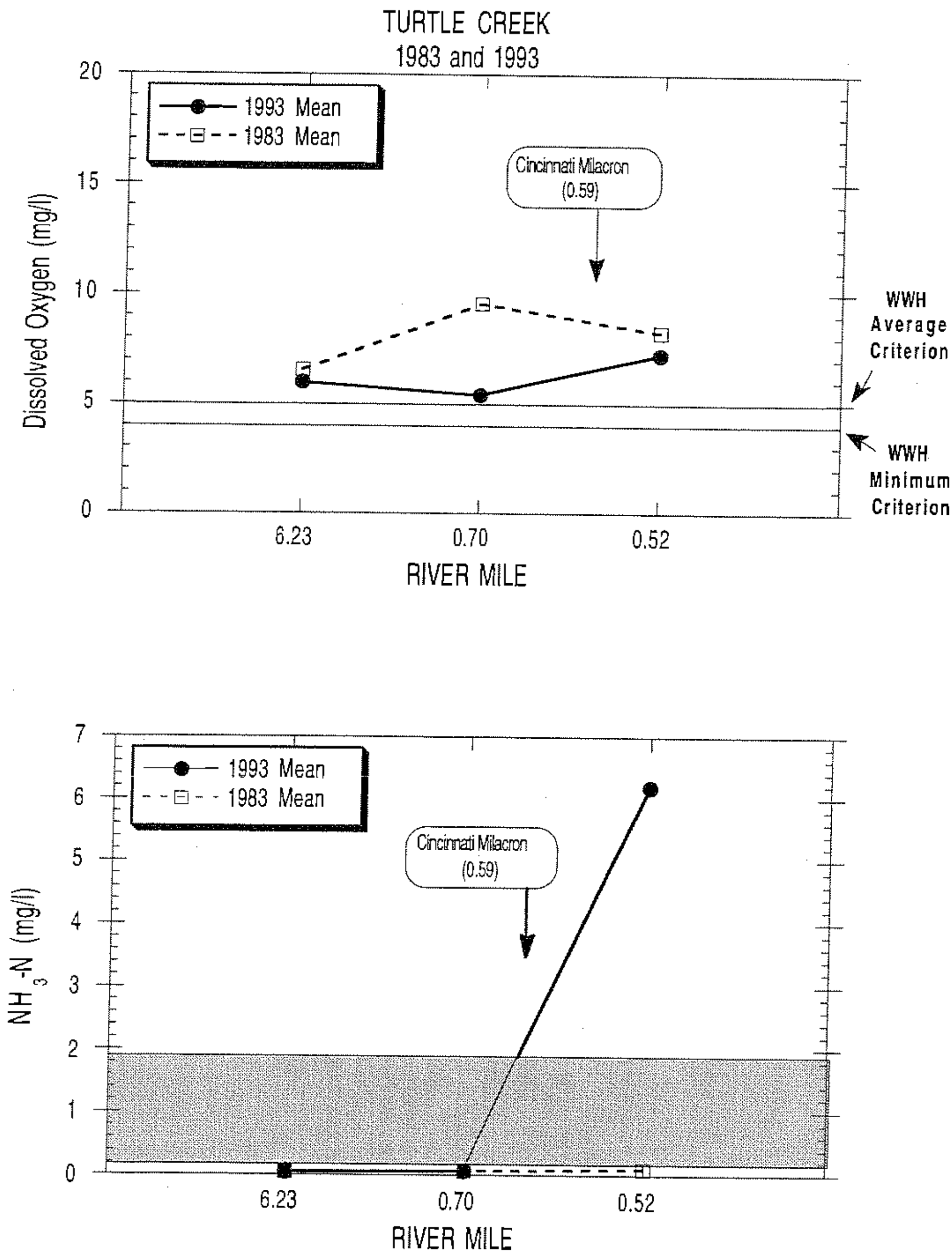


Figure 91. Longitudinal trends of mean dissolved oxygen (daytime grabs) and ammonia-N in Turtle Creek in 1983 and 1993 (*shaded area is the ammonia-N water quality criteria range between the 25th and 90th percentile hardness recorded during sample collection*).

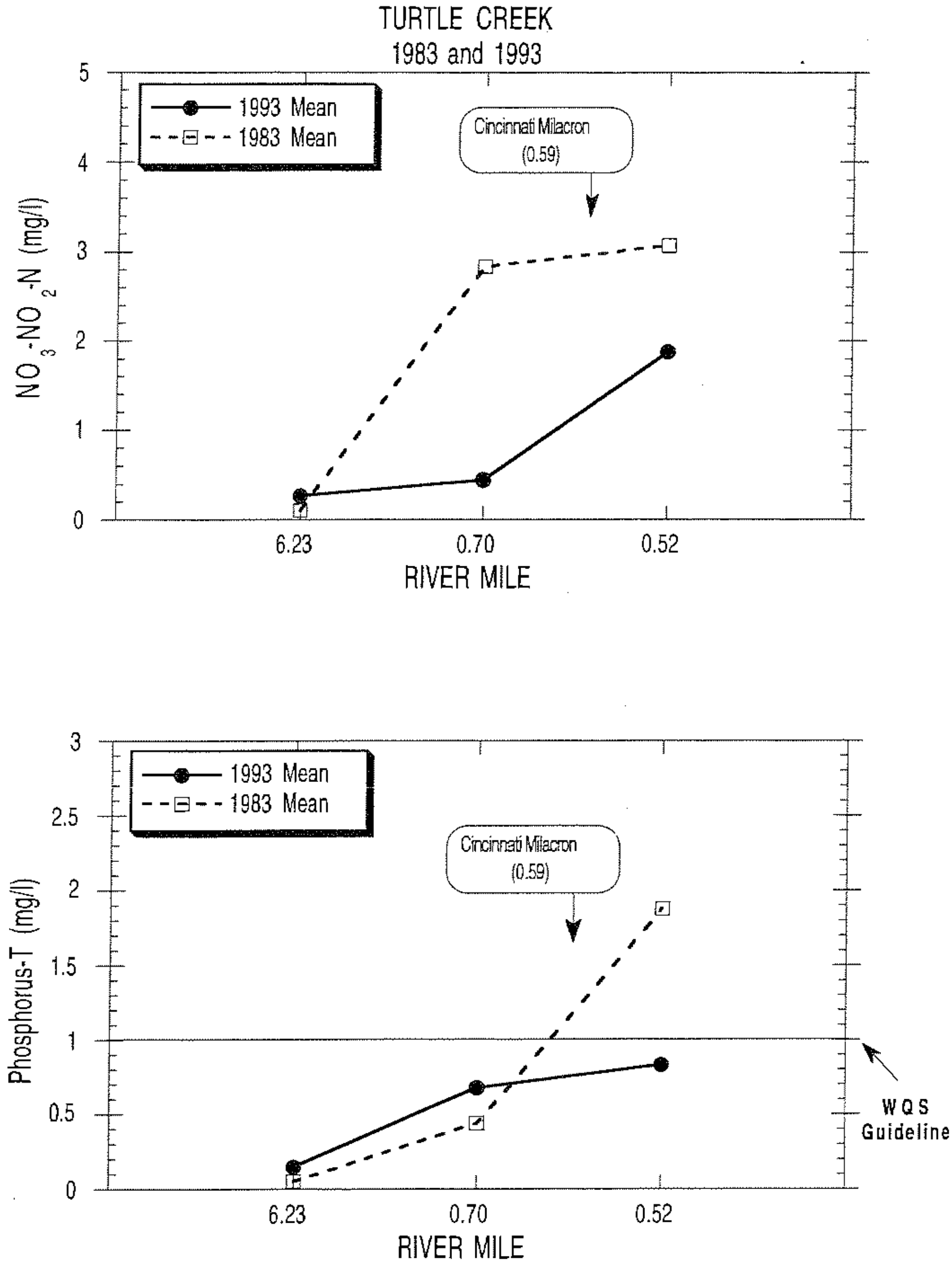
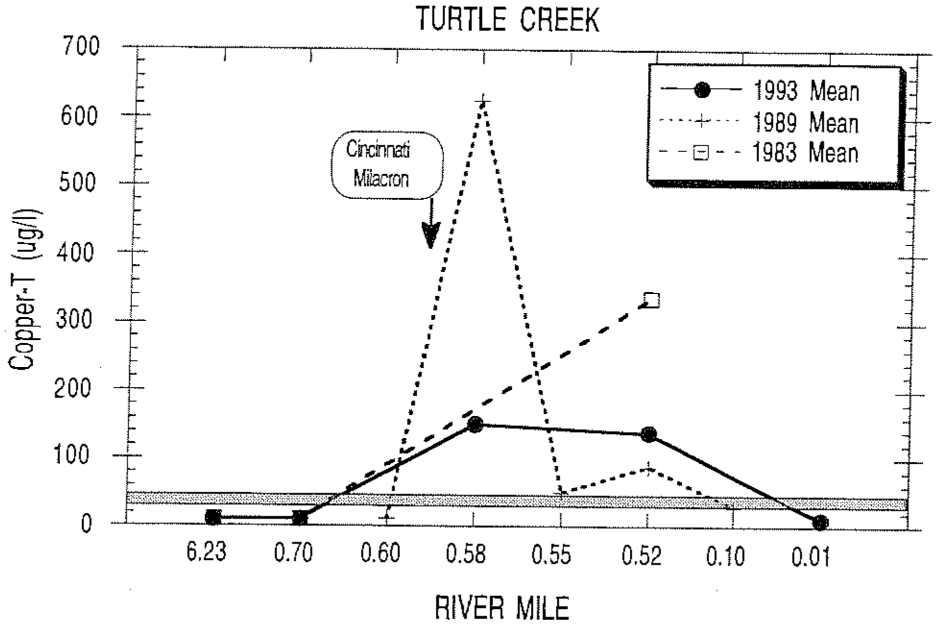


Figure 92. Longitudinal trend of mean nitrate+nitrite-N and total phosphorus in Turtle Creek in 1983 and 1993.



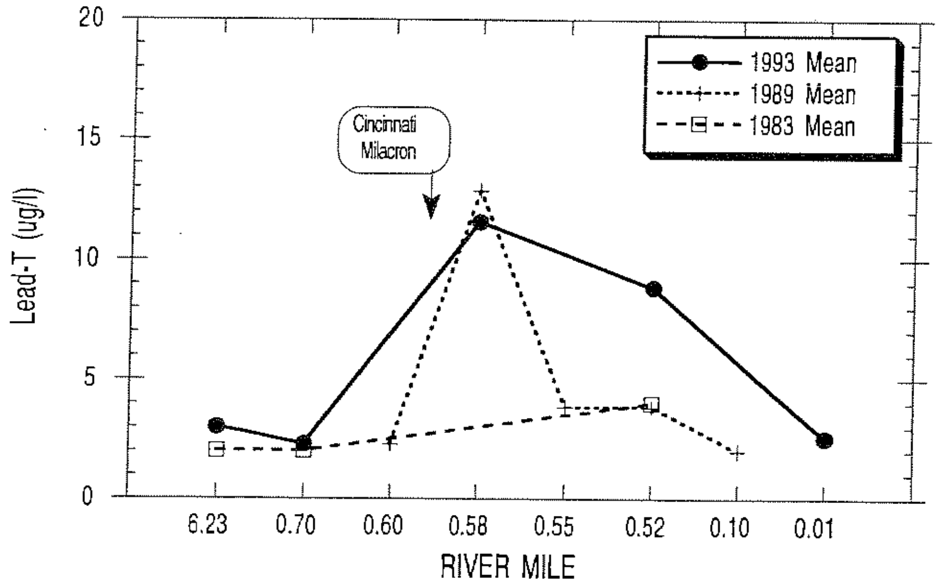
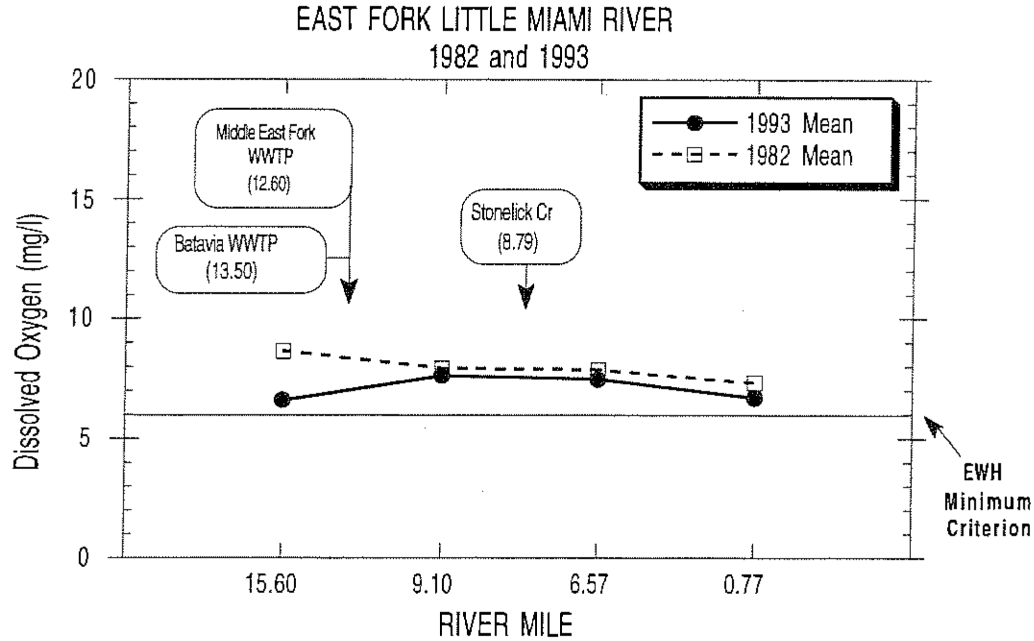


Figure 93. Longitudinal trend of mean copper and lead concentrations in Turtle Creek in 1983, 1989 and 1993 (*shaded area is the water quality criteria range between the 25th and 90th percentile hardness recorded during sample collection*).



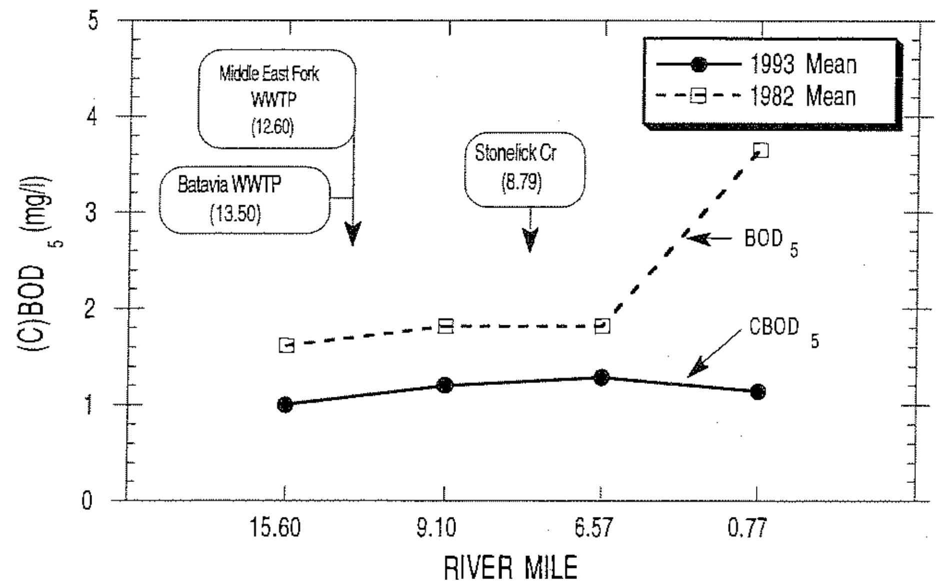


Figure 94. Longitudinal trend of mean dissolved oxygen (daytime grabs) and (C)BOD_5 in the East Fork Little Miami River in 1982 and 1993.

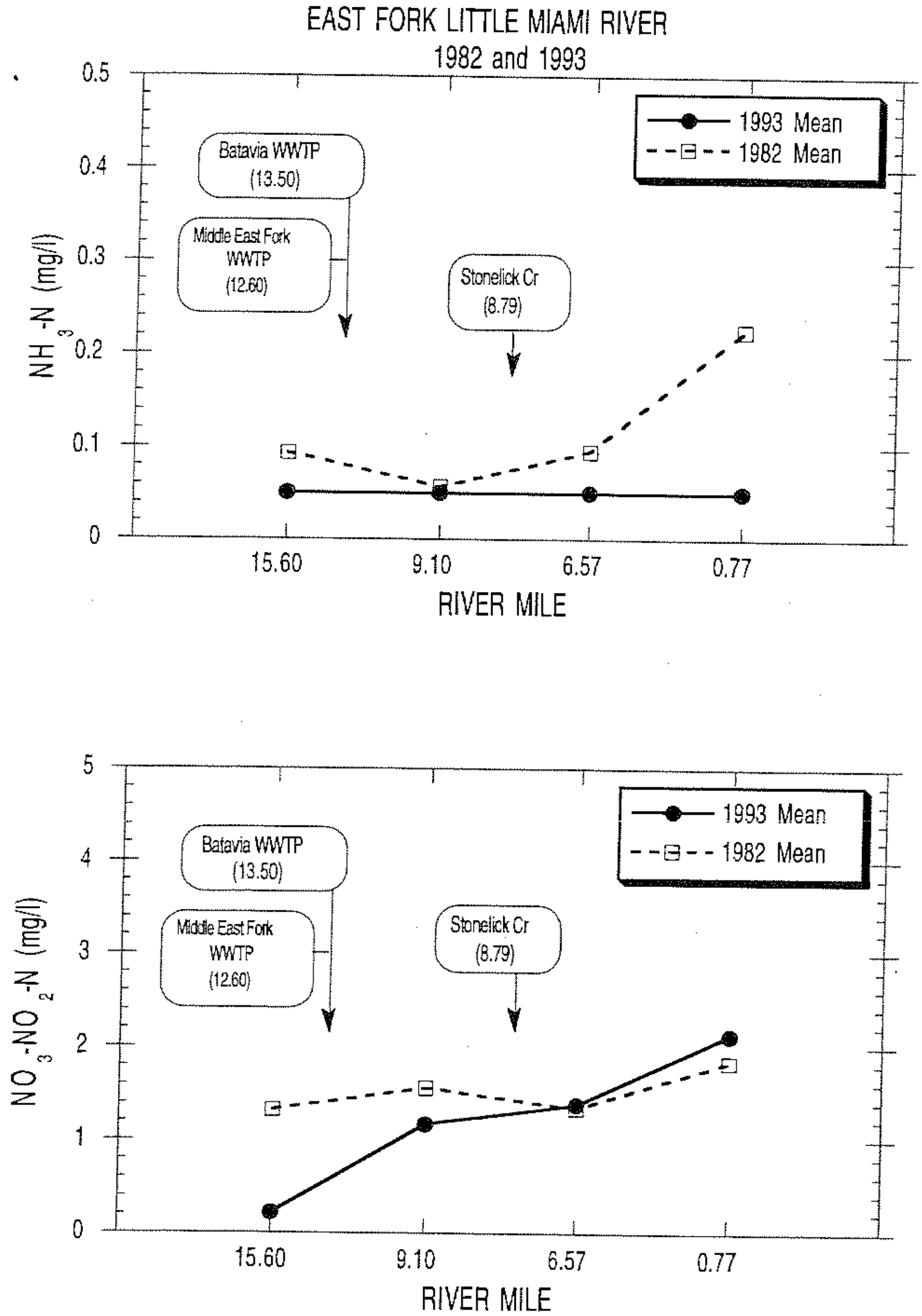


Figure 95. Longitudinal trend of mean concentrations of ammonia-N and nitrate-nitrite-N in the East Fork Little Miami River in 1982 and 1993.

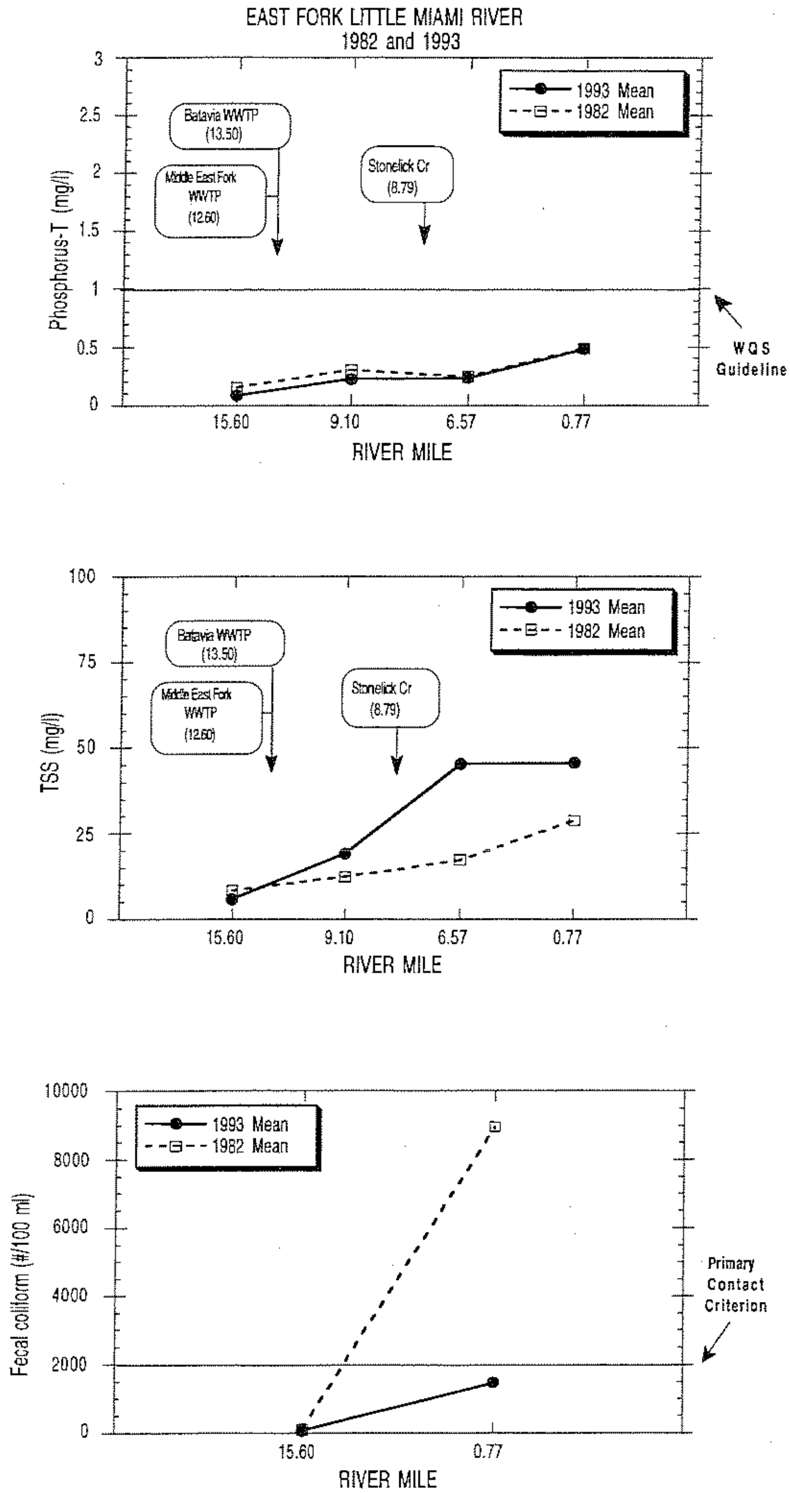


Figure 96. Longitudinal average concentrations of total phosphorus, total suspended solids (TSS), and fecal coliform in the East Fork Little Miami River in 1982 and 1993.

Biological and Aquatic Life Use Attainment Changes (Figures 97-107; Tables 3, 13)

Little Miami River

- Over the last decade, significant improvements have been made in restoring the chemical and biological integrity of the Little Miami River mainstem. From 1983 to 1993, the number of miles in FULL EWH attainment has increased from 1.5 to 40.9 while the number of miles in NON attainment decreased from 45.4 to 3.0 in 1993 (Table 13). Complete recovery had not occurred by 1993, however, because 58.2 miles were in only PARTIAL attainment due primarily to impacted fish assemblages.

- The most significant improvements (*i.e.*, FULL EWH attainment) have occurred in Greene, southern Warren, and northern Hamilton/Clermont Counties due to the improved treatment of sewage by county and municipal wastewater treatment plants (WWTPs). Since 1983, the aquatic life attainment status has improved (*e.g.*, **NON** to Partial, Partial to FULL) at all 11 of the similarly sampled segments within the upper half of the mainstem, but only six of the 13 previously PARTIAL or **NON** attaining segments within the lower half (Table 3). Comparisons of the biological indices (ICI, MIwb, and IBI) and Area of Degradation (ADV) values from 1983 to 1993 for similarly sampled segments also show the greatest improvements have occurred within the upper half of the Little Miami River mainstem (Tables 3 and 13). The mean difference between 1983 and 1993 ICI scores was significantly (> 4 units) higher in the upper half (13.8 units; range 2 to 32) than in the lower half (5.8 units; range -2 to 18). Also indicating considerable improvement in macroinvertebrate assemblages, ADV values for the ICI markedly declined 5,637 units in the upper half. and in the lower half. The ICI's ADV value declined less (326 units) in the lower half. During 1993, the ICI's ADV value in the lower mainstem was also significantly higher (*i.e.*, more impacted) than in the upper half (743 vs. 44 ADV units, respectively). The mean difference between MIwb scores was also higher in the upper half (1.0 units; range -0.3 to 2.1) than in the lower half (0.5 units; range -0.7 to 1.7 [> 0.5 MIwb units is considered a significant difference]). ADV values for the MIwb declined 1,765 units in the upper half and 370 units in the lower half. The MIwb's ADV value during 1993 was only slightly higher in the upper half (320) than the lower half (255). The mean difference between 1983 and 1993 IBI scores was only slightly higher in the upper half (2.8 units; range -4 to 13) than in the lower half (1.6 units; range -8 to 9 [> 4 IBI units is considered a significant difference]). ADV values for the IBI declined 1,671 units in the upper half and 317 units in the lower half. The 1993 ADV values remain high in the mainstem in both the upper half (2,412) and in the lower half (1,632) indicating fish assemblages are still impacted in portions of both 50 mile segments. Overall, the 1993 ADV values per mile in both the upper and lower mainstem remained relatively high (46.3 and 32.6, respectively). Also indicating improvement, the number of fish species collected in the Little Miami River increased from 71 in 1983 to 83 in 1993.

LMR: Upstream from Clifton (RM 102.1 - 89.2)

- Since 1983, the EWH attainment status in the three commonly sampled segments have improved from **NON** to PARTIAL attainment (Table 3). Macroinvertebrate assemblages have significantly improved upstream from Clifton. ICI values at all three locations improved from the fair to good range in 1983 to the exceptional range in 1993 (Table 11, Figure 97). Fish assemblages, however, have improved less with IBI scores remaining in the fair range and MIwb values indicative of only marginally good assemblages (Table 12, Figure 101). The 1993 PARTIAL attainment of EWH appeared due to a combination causes and sources including low dissolved oxygen levels; extremely high fecal bacteria counts; manure runoff from a commercial composting operation (Paygro was the source of a large fish kill in 1992); high nitrate-nitrite concentrations downstream from Gilroy Ditch; NPDES exceedences at the South Charleston WWTP; and physical habitat degradation from agricultural runoff, riparian encroachment, channelization, and uncontrolled livestock access (Table 2, A-3). The improvements in biological performance are primarily attributed to the improvements completed at the South Charleston WWTP in 1990. Incidences of DELT anomalies have decreased slightly in this upper reach since 1983 (Figure 102).

LMR: Clifton to the Narrows (RM 85.4 - 71.8)

- Since 1983, the EWH attainment status in the five commonly sampled segments have improved from PARTIAL to FULL attainment (Table 3). Macroinvertebrate and fish communities throughout the segment were indicative of exceptional quality with the exception of several locations with very good index scores (Tables 11-12, Figure 97, 101). The incidences of DELT anomalies, however, have also increased and appears to be positively correlated to the cumulative quantity and/or quality of effluent discharged by the series of municipal and county WWTPs (Figure 102). Ongoing sewage and chemical spills in Shawnee Creek and other areas also contribute pollutants and have caused fish kills. Similar to the chemical sampling, macroinvertebrate assemblages were also annually sampled in the Little Miami River at RM 80.0 from 1977 to 1979 and at RM 80.6 from 1983 to 1993. Results show the quality of macroinvertebrate assemblages has improved from high fair to low good from 1977 to 1983, to very good in 1984, and exceptional quality from 1989 to 1993 (Figure 98).

LMR: Bellbrook to Oregonia (RM 65.6 - 47.5)

- Since 1983, three similarly sampled segments have improved from **NON** to PARTIAL attainment and one site has remained PARTIAL (Table 3). The incidence of fish with external DELT anomalies within this segment has increased since 1983. This segment had some of the highest percentages and relative numbers of DELTs recorded during the 1993 survey. The primary cause and sources of impacts appears to be from a high volume of effluent and excessive nutrient loads cumulatively discharged by WWTPs. Urban and agricultural runoff, spills, and NPDES exceedences may also be contributing to the total pollutant loadings (Table 2, A-1, A-3).

LMR: Fort Ancient to I-275 (RM 44.2 - 20.6)

- Eight of the nine commonly sampled segments within this reach improved to FULL attainment in 1993. Only two of the sites attained EWH criteria during the 1983 survey. The one segment that did not improve, remained PARTIAL in 1993 possibly due to the lack of swift-water habitat within the fish sampling location. The segment receives WWTP effluent from a number of municipalities and small industries. Ambient chemical and bacterial exceedences were detected along with a number of NPDES exceedences (Table 6, A-3). Spills were also reported in several tributaries, particularly within the Todd Fork basin. Similar to the Bellbrook to Oregonia reach, cumulative pollutant loadings from dischargers within this reach may contribute to the PARTIAL attainment recorded downstream. Similar to areas within the upper half, tremendous residential and commercial growth has occurred locally within this portion of the watershed (e.g., Mason area).

LMR: Sycamore Creek to the Ohio River (RM 18.9 - 0.2)

- In contrast to most of the mainstem, the attainment status in five similarly sampled segments downstream from Sycamore Creek have not improved (remained PARTIAL) since 1983 (Table 3). ICI and MIwb scores have not significantly changed at the three similarly sampled locations. The IBI, however, remained similar between Remington and Milford, but decreased (8 units) downstream from the confluence of the East Fork near Newtown. MIwb and IBI have declined slightly at the two similarly sampled sites in the Ohio River backwaters since 1983. In addition to upstream point source discharges, this segment receives additional pollutant loadings from point source discharger(s) in Sycamore Creek and the East Fork; CSO and SSO discharges, landfill leechate, and urban runoff. Contaminated sediments were detected near the mouth of Sycamore Creek and in the mainstem at Beechmont Avenue (RM 3.5).

Yellow Springs Creek

- Since 1983, macroinvertebrate assemblages have remained exceptional quality both upstream and downstream from the Yellow Springs WWTP. A mild and relatively minor enrichment effect was detected, however, downstream from the facility in 1993. Fish assemblages in Yellow Springs Creek have significantly improved since 1983. During the 10 year period, fish assemblages have improved from fair to exceptional quality downstream from the WWTP.

Oldtown Creek

- Biological sampling in the lower reach of Oldtown Creek during 1993 showed improved macroinvertebrate and fish assemblages. Macroinvertebrate sampling yielded 13 qualitative EPT taxa in 1993 compared to seven in 1983. The IBI value increased from 45 to 56 (*i.e.*, good to exceptional quality) near the mouth (RM 0.1).

Massies Creek

- The 1993 biological results from Massies Creek were similar to the 1983 results. Ten qualitative EPT taxa were collected in 1983 compared to nine in 1993. The 1993 MIwb and IBI scores were slightly higher than in 1983 (8.8 increased to 9.0 and 45 increased to 46, respectively).

Beaver Creek

- Since 1983, the aquatic life use attainment status in Beaver Creek has shown no significant change downstream from Little Beaver Creek or the Greene County Beaver Creek WWTP. The length of stream in PARTIAL attainment of WWH has remained at 0.4 miles. The number of qualitative EPT taxa upstream and downstream from the Greene County Beaver Creek WWTP has remained similar since 1983 with a decline from very good (EPT=13) upstream to fair (EPT=4) downstream. The IBI has also shown little change at RMs 0.5 or 0.3 since 1983. The MIwb has increased upstream from the Beaver Creek WWTP (7.7 to 8.7 at RM 0.5), but decreased downstream from the facility (from 8.6 to 7.9 at RM 0.2 - 0.3). The mean number of fish species collected, however, has increased at both locations (15.5 to 20.5 species at RM 0.5 and 15.0 to 16.5 species at RMs 0.2 -0.3).

Little Beaver Creek

- The WWH aquatic life use attainment status in Little Beaver Creek has slightly improved since 1982. The number of miles in NON attainment has decreased from 4.2 to 2.1 while the number of miles in PARTIAL attainment has increased from 0.0 to 0.7 in 1993. Macroinvertebrate communities in Little Beaver Creek have improved since 1982, but remain severely to moderately degraded between the Montgomery County Eastern Regional WWTP discharge and the mouth. The number of fish species collected in 1993 was only slightly higher upstream from the WWTP (6.0 species at RM 5.0 in 1982, 8.5 species at RM 4.7 in 1993), but markedly higher near the mouth (1.0 species at RM 0.2 in 1982, 15.0 species at RM 0.1 in 1993). The 1993 IBI values, however, improved only slightly from 28 at RM 4.7 to 33 at RMs 2.1 and 0.1. Narratively, fish assemblages were only fair quality at the mouth. Little Beaver Creek has also been recently affected by spills and fish kills.

Glady Run

- Since 1983, the macroinvertebrate communities in Glady Run have remained similar with a fair community present downstream from the Xenia-Glady Run WWTP (RM 4.1) and a slightly better assemblage farther downstream (RM 0.6). Macroinvertebrates remained impacted near the mouth in 1993. The sampling location near the mouth of Glady Run (RM 0.3), however, was the only location in the tributary with a good fish community. Fish assemblages have also remained similar upstream from the Glady Run WWTP, but have improved downstream from the WWTP near the mouth. The mean number of fish species collected at RM 0.3 has increased from 7.3 in 1983 to 16.0 in 1993.

Newman Run

- The macroinvertebrate community in Newman Run was limited by intermittent flow conditions in 1983 and 1993. A total of five (5) qualitative EPT which slightly deviates from the expected range for a good community was collected both years. The fish community was sampled only once in 1993 due to severe drought conditions. The IBI scored a 54 (exceptional) in 1993 compared to a 47 (very good) in 1983 using a backpack shocker. The mean number of fish species collected in 1993 (15), however, was slightly lower than in 1983 (18).

Anderson Fork

- Since 1984, the fish community in Anderson Fork has remained exceptional. MIwb and IBI scores, respectively, were 10.0 and 51 in 1984 and a 10.0 and 54 in 1993.

Caesar Creek

- Since 1983, the number of EPT taxa (8) collected in Caesar Creek near the mouth (RM 0.1) has remained similar. This lower than expected number may be due to fluctuating flow releases from the reservoir. MIwb and IBI scores near the mouth, however, were higher in 1993 than in 1983 (respectively, a 7.9 and 46 in 1983 and a 8.7 and 50 in 1993), suggesting an improved fish community. Although Caesar Creek was not sampled upstream from the reservoir prior to 1993, the 1993 quality of macroinvertebrate and fish assemblages in Caesar Creek from upstream to downstream from the reservoir, respectively, declined from very good to fair and very good/exceptional to exceptional/good (Table 11-12).

Dry Run

- Similar to 1983, the macroinvertebrate community in Dry Run (RM 1.8) in 1993 was also limited by intermittent flow conditions. The 1993 community contained a slightly lower than expected number of qualitative EPT taxa (4). A decrease in IBI values from a 40 in 1983 to a 34 in 1993 is indicative of a moderately severe impact to the headwater fish community at the reference location (RM 1.8). The quality of physical habitat appears to have been impacted possibly by excessive sedimentation. The QHEI score decreased from 67.0 in 1983 to 54.5 in 1993. Drought conditions may have also impacted aquatic communities in 1993.

Turtle Creek

- From 1983 to 1993, the number of miles in FULL attainment of the WWH aquatic life use designation has increased from 1.6 to 5.9 miles (Table 13). The number of miles in **NON** attainment has decreased from 4.0 in 1983 to 0.0 in 1993. More recent monitoring, however, shows that the current attainment status downstream from Cincinnati Milacron has decreased from FULL in 1992 to PARTIAL in 1993.

- Macroinvertebrate communities in the upper reach of Turtle Creek have significantly improved since the Lebanon WWTP relocated to the Little Miami River in 1987 (Figure 99). Sampling stations upstream (RM 0.6) and downstream (RM 0.5) from Cincinnati Milacron have been sampled six (6) times from 1983 to 1993 (Figure 100). Communities have generally improved from 1983 to 1989, but subsequently declined to the fair range. This declining trend has occurred both upstream and downstream from the industrial discharge and may be due to a reduction in flow caused by some unknown source. There may also be an unknown intermittent source of turbid water discharged into the stream between Glosser Road (RM 6.3) and the next upstream bridge (West Road).

- MIwb and IBI values have also improved throughout Turtle Creek since 1983 (Figure 105-106). Both fish community indices longitudinally increase to their highest values at RM 0.6 then decline downstream from Cincinnati Milacron (RM 0.4). MIwb and IBI values increased the most between 1982 and 1989, but have subsequently shown a general declining trend. Since 1983, the mean incidence of DELT anomalies has decreased from 4.8 to 0.1% near the mouth (RM 0.1) and from 0.9 to 0.2% at McClure Road (RM 4.7), but increased slightly at Glosser Road (RM 6.3, 0.1 to 0.4%) and at Mason Road (RM 0.6, 0.4 to 0.7%). No DELT anomalies were observed immediately downstream from Cincinnati Milacron (RM 0.5 - 0.4) during the 1983 or 1993 surveys.

Muddy Creek

- Macroinvertebrate communities in Muddy Creek downstream from the Mason WWTP (RM 2.5) have improved since 1981-1983 when they were evaluated as fair (EPT=5) due to organic loadings from the WWTP. Since 1989, the macroinvertebrate assemblage at RM 2.5 has been in the marginally good to good range (ICI=28, EPT=8 in 1989; ICI=32, EPT=12 in 1991). The communities, however, were stressed by organic enrichment (*i.e.*, ICI metrics for other diptera/non-insects and for tolerant taxa strongly deviated from the expected range for a good community in 1989 and 1991). The ICI in 1993 continued to increase due to a reduction in the percentage of tolerant taxa (9.1% compared to 40.0% in 1991), but a decrease in the number of qualitative EPT from 12 in 1991 to four (4) suggests a decline in water quality. The fish community in Muddy Creek at RM 1.6 has shown considerable improvement since 1981. The IBI has increased from 15 to 46.

Sycamore Creek

- Since 1983, the aquatic life use attainment status in the lower half mile of Sycamore Creek has shown only a slight improvement downstream from Hamilton Co. MSD Sycamore Creek WWTP. The number of miles in PARTIAL attainment of WWH has increased from 0.0 to 0.3 while the number of poor to very poor miles have decreased from 0.6 to 0.1 miles.

- The macroinvertebrate community downstream from the Hamilton County Sycamore Creek WWTP (RM 0.1) has improved from poor quality in 1983 to fair to good quality in 1993. The community upstream (RM 0.6) from the WWTP was evaluated as fair (EPT=4) in 1983 and in 1993. The number of qualitative EPT taxa, however, increased slightly to seven in 1993, suggesting a slight improvement. Community degradation from sewage overflows and sewer line construction (Ohio EPA 1992) remain the primary factors for not attaining the biocriterion for WWH upstream from the WWTP. The fish assemblage downstream from the Sycamore Creek WWTP has shown considerable improvement since 1983. MIwb and IBI scores, respectively, at RM 0.2 increased from a 5.2 and 26 in 1983 to 7.7 and 38 in 1993. MIwb and IBI values upstream from the WWTP (RM 0.4), however, have shown little change scoring a 6.9 and 27 in 1983 and 6.6 and 34 in 1993. Streams within the Sycamore Creek basin contain gravity fed sewer lines and have been impacted by instream channel modifications, urban runoff, and sewer overflows (OEPA 1992b). Sewerline improvements have been recently made by the Hamilton Co. MSD to reduce infiltration into the sewers during high flows which caused frequent overflows.

Stonelick Creek

- Since 1984, the macroinvertebrate community at RM 1.0 has remained good quality with an ICI score of 36. Fish communities in the headwaters of Stonelick Creek (RM 20.0) have remained impacted (*i.e.*, fair quality and [NON] attainment) since 1982 due presumably to nonpoint sources. The IBI scored a 28 at RM 19.0 in 1982 and a 30 at RM 20.0 in 1993. MIwb and IBI scores downstream from the lake have decreased at RM 3.1 which scored a 10.4 and 54, respectively, in 1987 and a 8.8 and a 45 in 1993, but increased at RM 1.2 from a 8.4 and 43 in 1982 and a 7.9 and 41 in 1984 to a 10.4 and 49 in 1993.

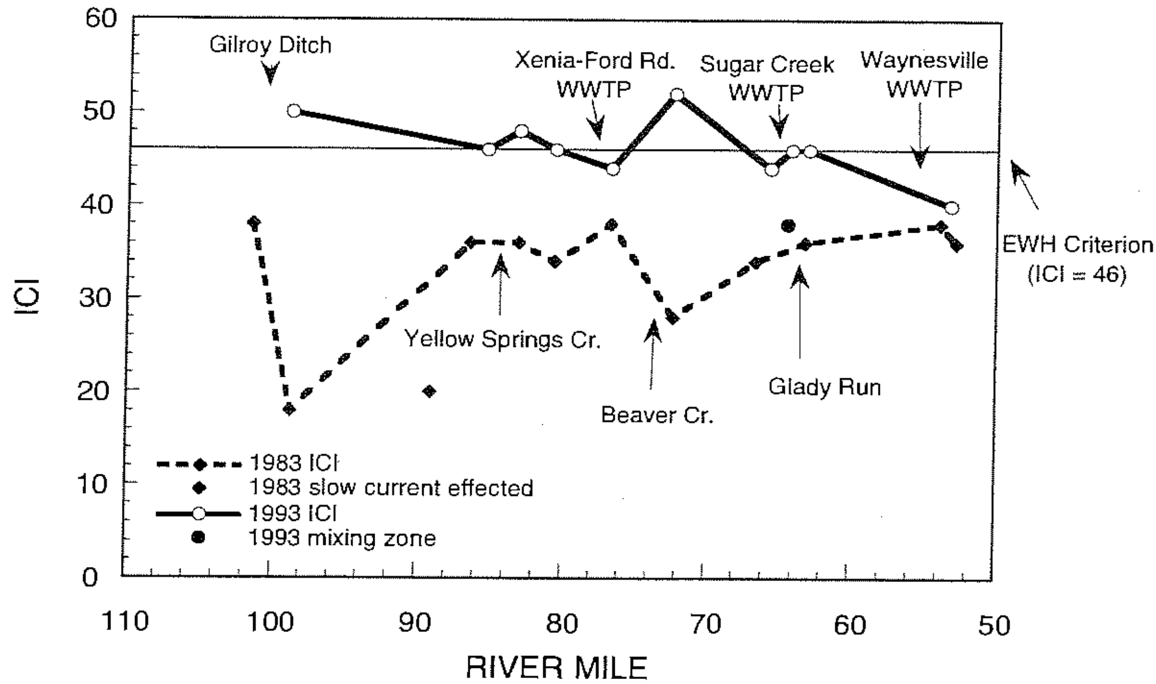
East Fork Little Miami River

- The 1993 results show the aquatic life attainment status within the East Fork has deteriorated since 1982 due primarily to lower IBI scores (Table 3). The number of miles in FULL attainment of EWH has decreased from 10.0 in 1982 to 7.1 in 1993, while the number of miles in PARTIAL attainment increased from 4.8 to 7.8 (Table 13). Since 1982, the use attainment status in commonly sampled segments upstream and downstream from Batavia have improved from PARTIAL to FULL (RM 15.5 - 12.7); the reach downstream from the Clermont County Middle East Fork WWTP to Stonelick Creek has remained FULL (RM 12.4-9.1); the site at Perintown has decreased from FULL to PARTIAL (RM 6.7-6.6); downstream from the Clermont Co. Lower E.F. WWTP has improved from PARTIAL to FULL, but also shown evidence of more impact (RM 4.7-4.1); the segment upstream from the Milford WWTP has remained PARTIAL (RM 2.4-

1.7); and the segment downstream from the Milford WWTP has decreased from FULL to PARTIAL (RM 1.4-0.8).

- Macroinvertebrate communities in the East Fork Little Miami River downstream from East Fork Lake have remained very good to exceptional quality since 1982, but exhibited signs of both improvement and impact (Figure 99). Compared to the 1982 values, the 1993 ICI scores have increased in four segments, but decreased in three segments (mean increase of +1.8 units; range -6 to +8, Table 3). The largest ICI decreases occurred from Perintown to downstream from the Lower East Fork WWTP (RMs 6.7-4.7).

- Compared to the 1982 values, the 1993 IBI values have declined in four segments and increased in three segments (mean decrease of -1.4 units; range -5 to +7, Table 3). IBI values were slightly lower at RM 15.5, higher downstream from the Batavia WWTP, similar downstream from the Middle and Lower East Fork WWTPs, but lower than in 1982 at the other four locations. Since 1982, the MIwb values have increased in six segments and decreased in only one segment (mean increase of +0.7 units; range -0.2 to +1.9, Table 3). MIwb scores were slightly higher upstream from Batavia, considerably higher downstream from the Batavia and Middle East Fork WWTPs, similar in Perintown and downstream from the Lower East Fork WWTP, and slightly higher upstream and downstream from the Milford WWTP. The mean relative number of the three most common game fish in the lower 13 miles of the East Fork declined from 59 per km in 1982 to 26 per km in 1993.



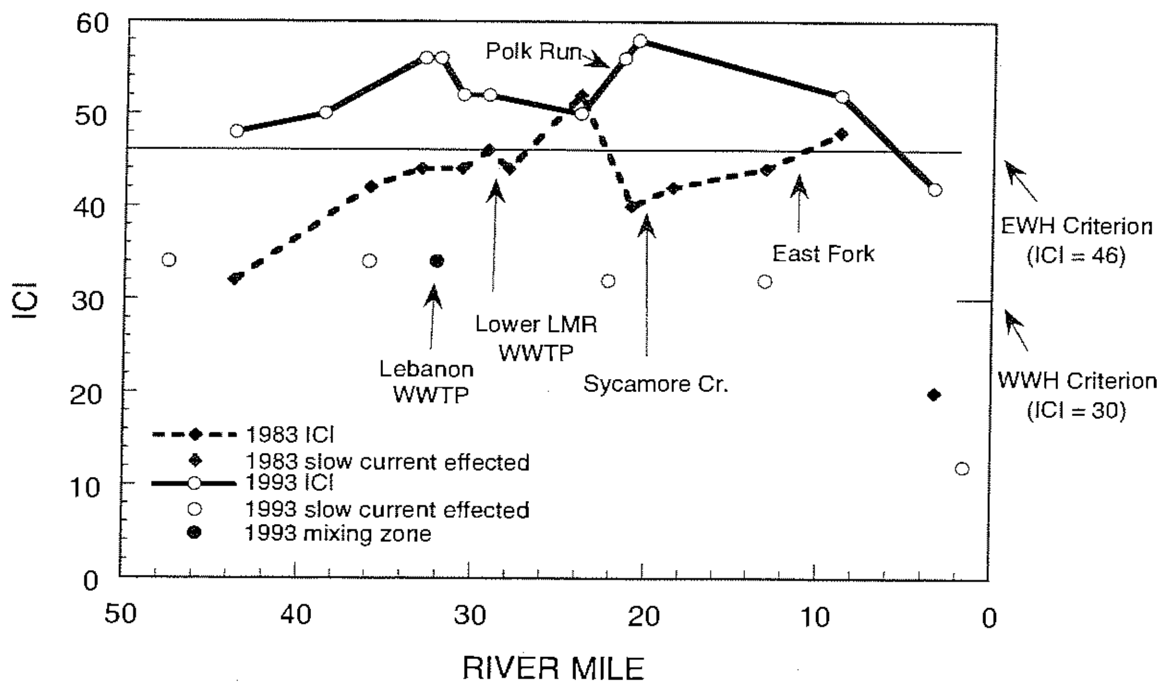


Figure 97. Longitudinal trend of the Invertebrate Community Index (ICI) from 1983 to 1993 in the upper half (Top Graph) and lower half (Bottom Graph) of the Little Miami River.

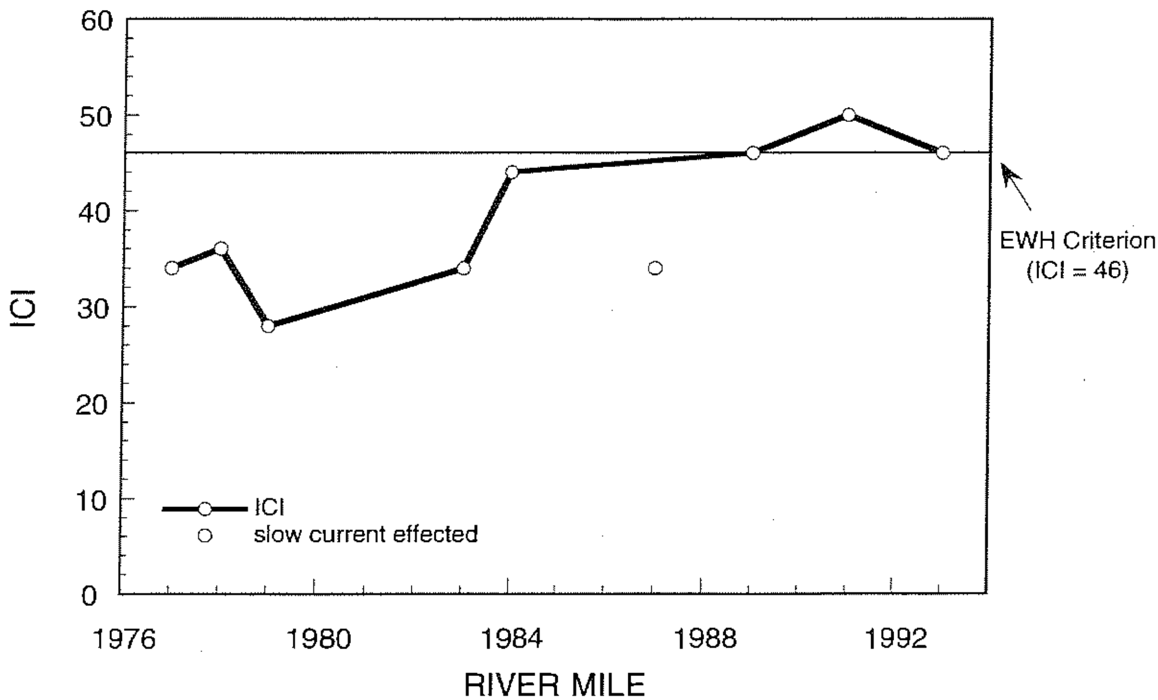


Figure 98. Historical trend of the Invertebrate Community Index (ICI) from 1977 to 1993 in the upper Little Miami River at Oldtown (RM 80.0, 80.6).

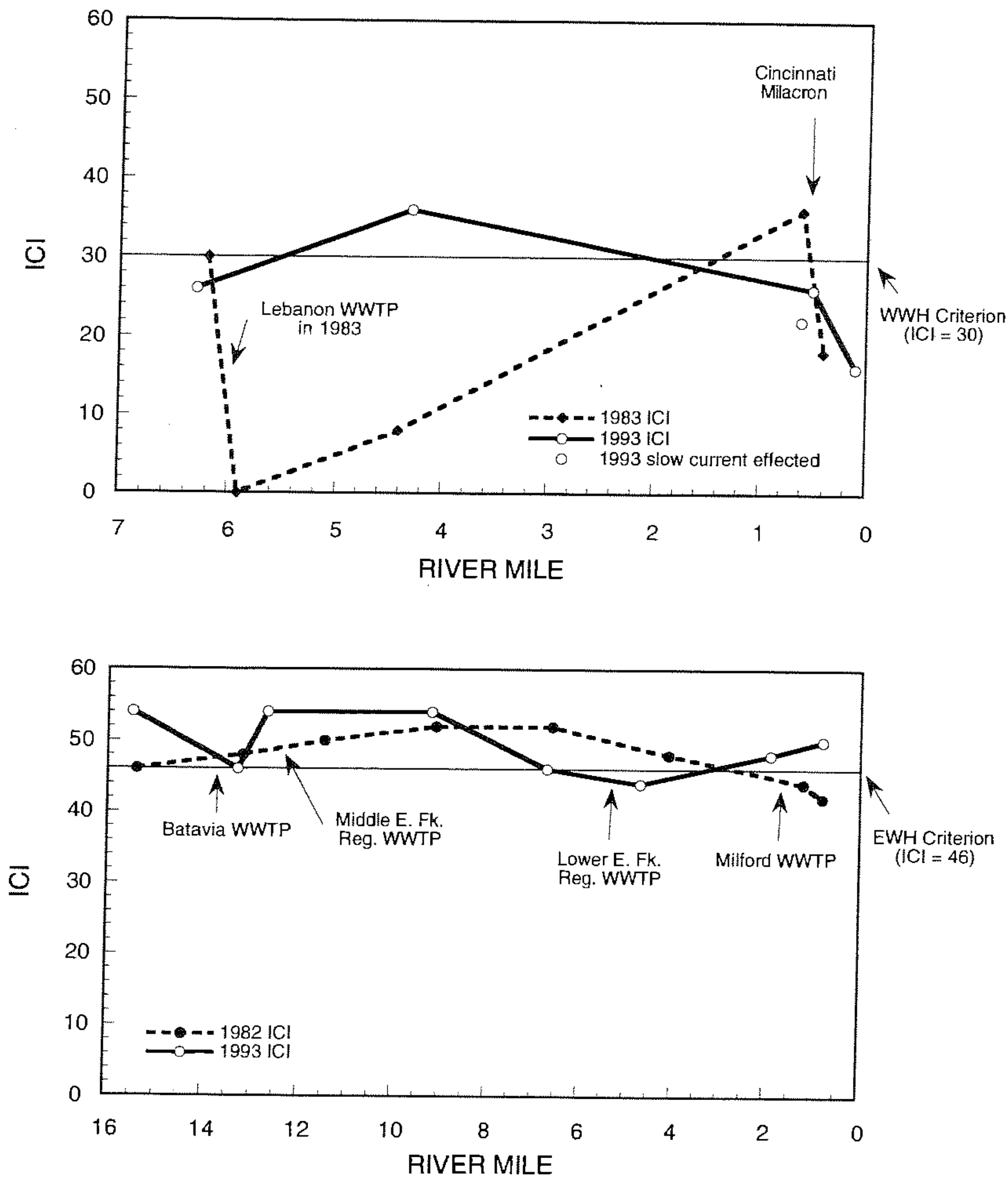


Figure 99. Longitudinal trend of the Invertebrate Community Index (ICI) from 1983 to 1993 in Turtle Creek (Upper Graph) and from 1982 to 1993 in the East Fork Little Miami River (Bottom Graph).

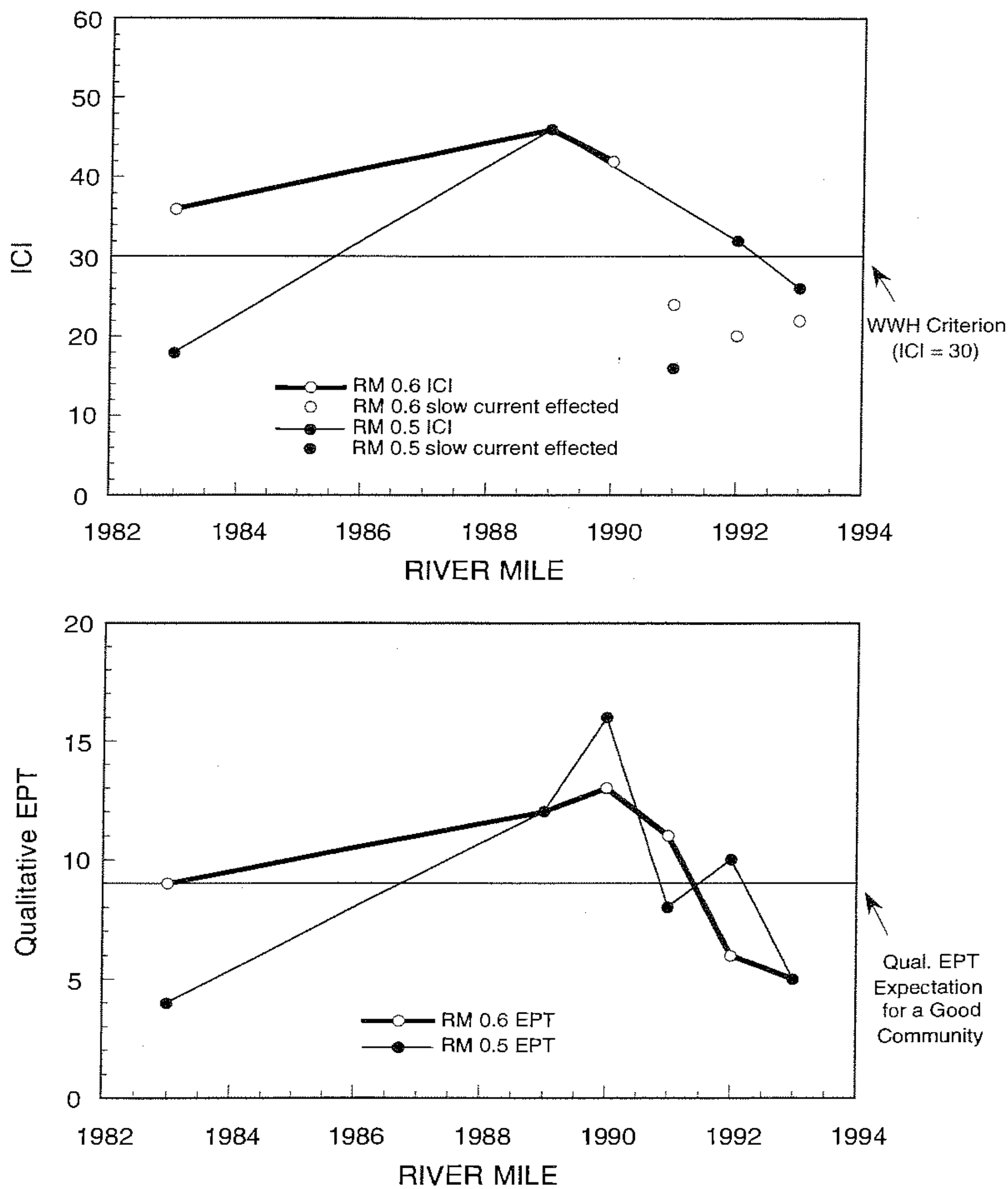


Figure 100. Historical trend of the Invertebrate Community Index (ICI; Top Graph) and qualitative number of mayfly (Ephemeroptera), stonefly (Plecoptera), and caddisfly (Trichoptera) taxa (EPT; Bottom Graph) from 1983 to 1993 in Turtle Creek upstream (RM 0.6) and downstream (RM 0.5) from Cincinnati Milacron.

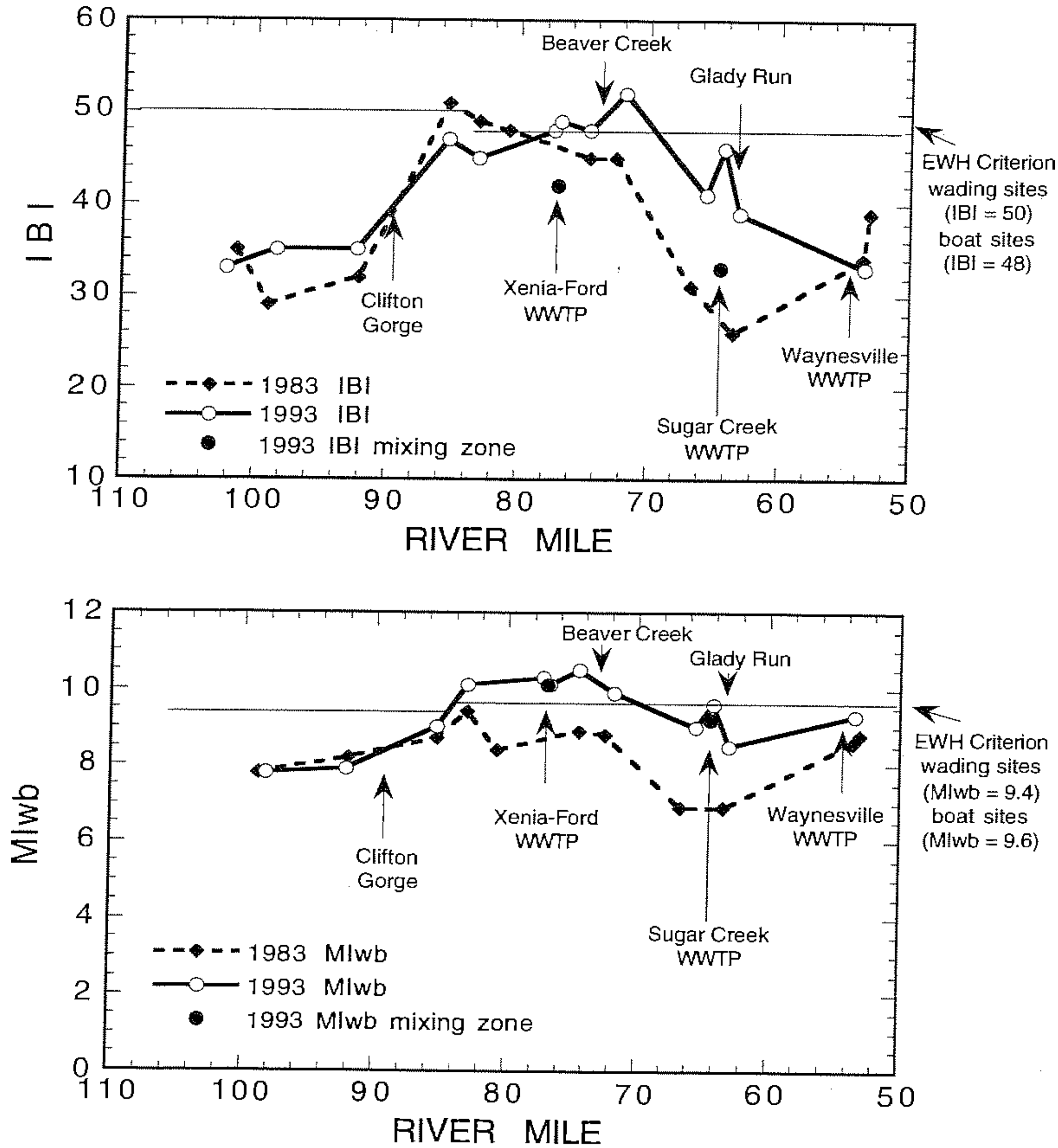


Figure 101. Longitudinal trends of the Index of Biotic Integrity (IBI; Top Graph) and the Modified Index of Well-Being (MIwb; Bottom Graph) in the upper half of the Little Miami River during 1983 and 1993.

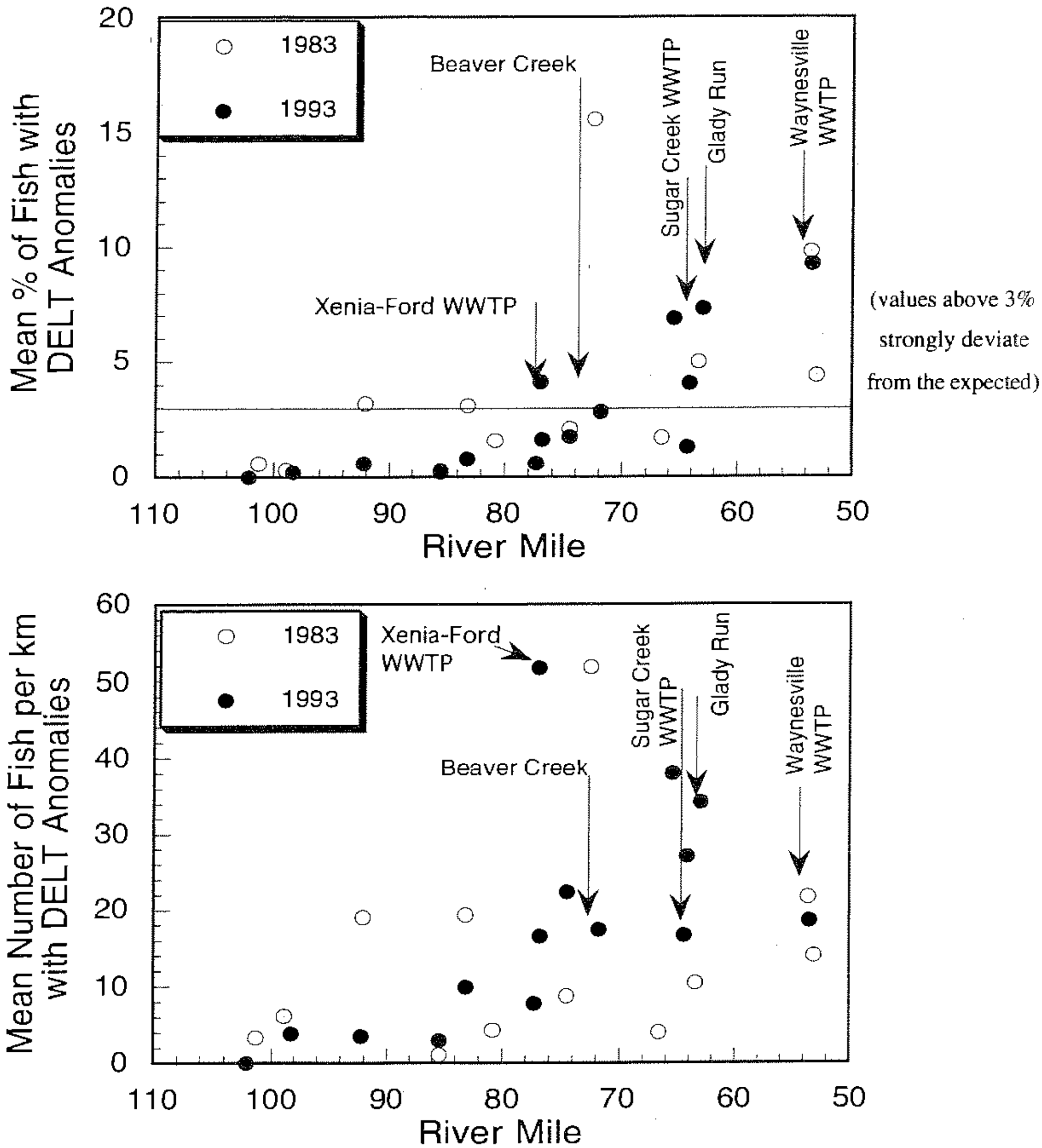


Figure 102. Longitudinal scatter plots of the mean percent (Top Graph) and number per kilometer (Bottom Graph) of fish with external DELT anomalies in the upper half of the Little Miami River during 1983 and 1993.

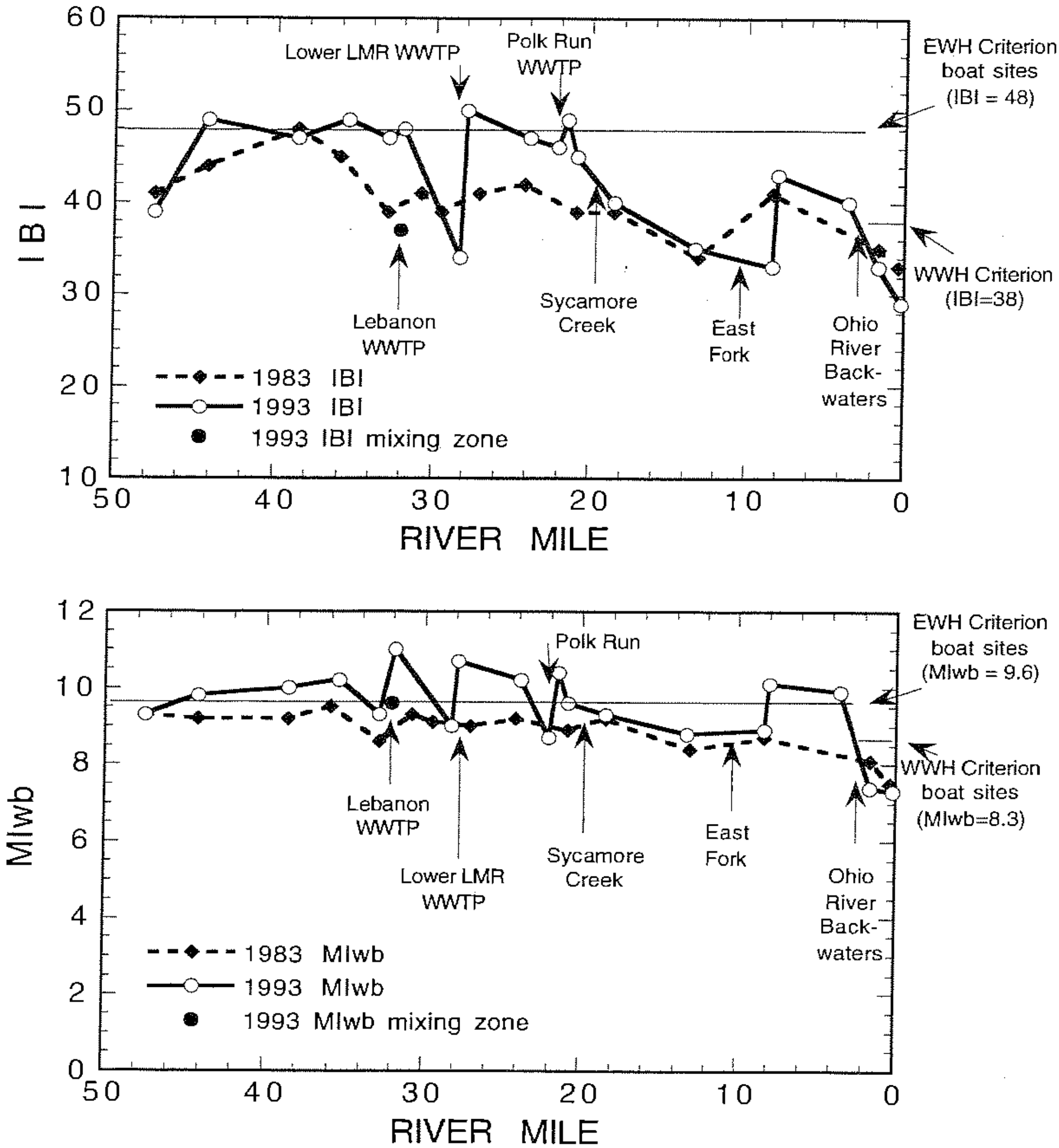
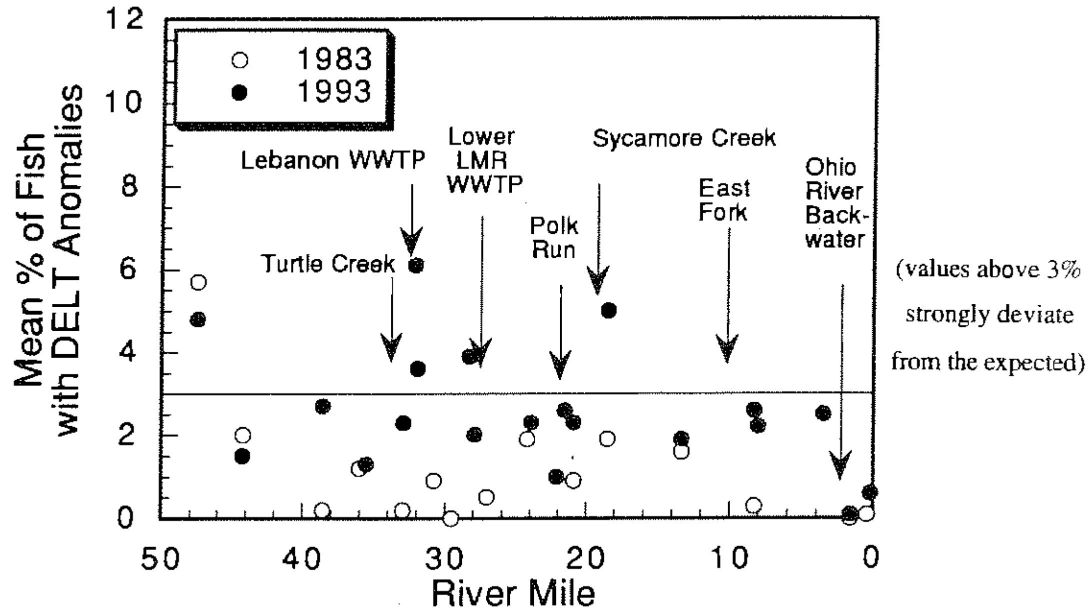


Figure 103. Longitudinal trends of the Index of Biotic Integrity (IBI; Top Graph) and the Modified Index of Well-Being (MIwb;Bottom Graph) in the lower half of the Little Miami River during 1983 and 1993.



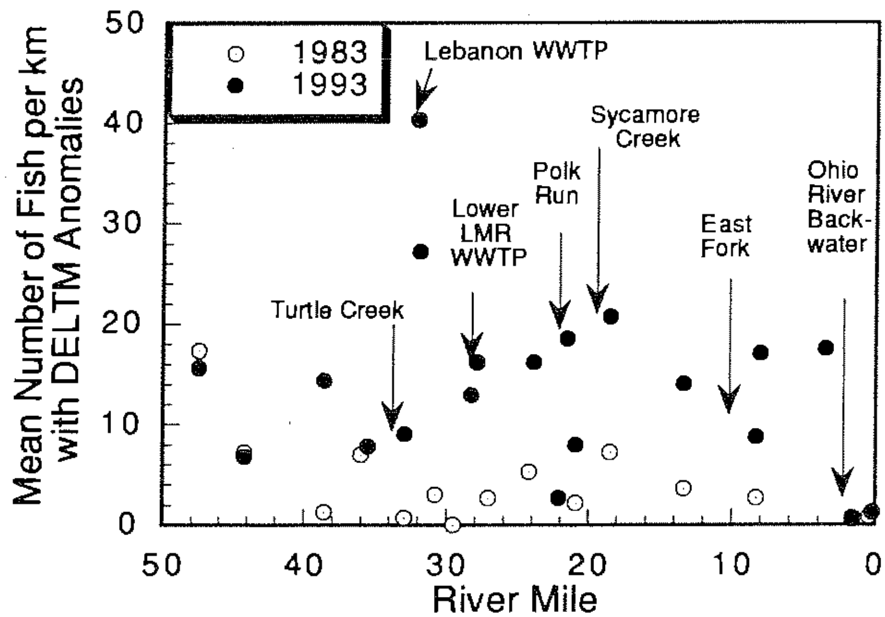


Figure 104. Longitudinal scatter plots of the mean percentage (Top Graph) and number per km (Bottom Graph) of fish with external DELT anomalies in the lower half of the Little Miami River during 1983 and 1993.

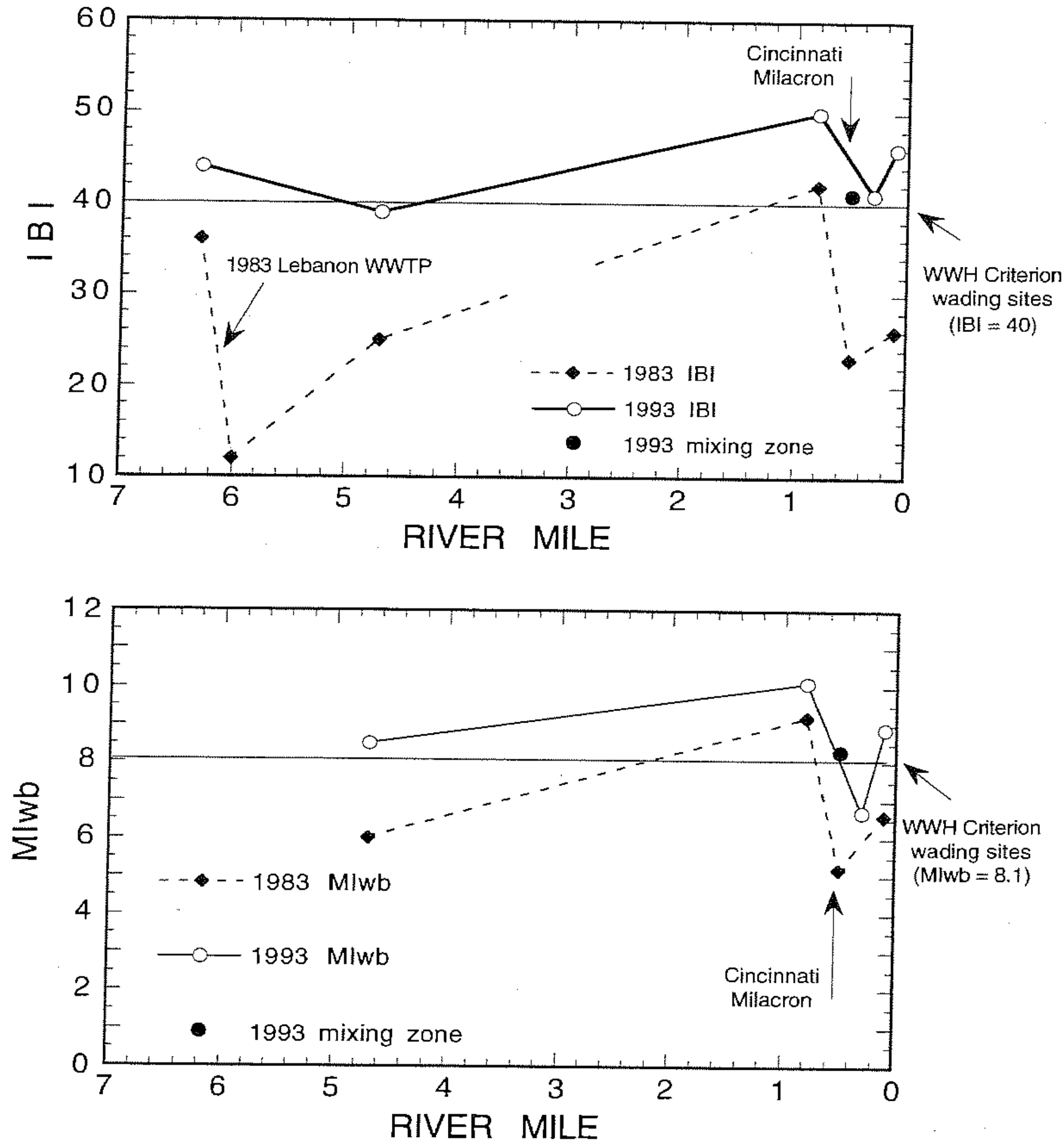
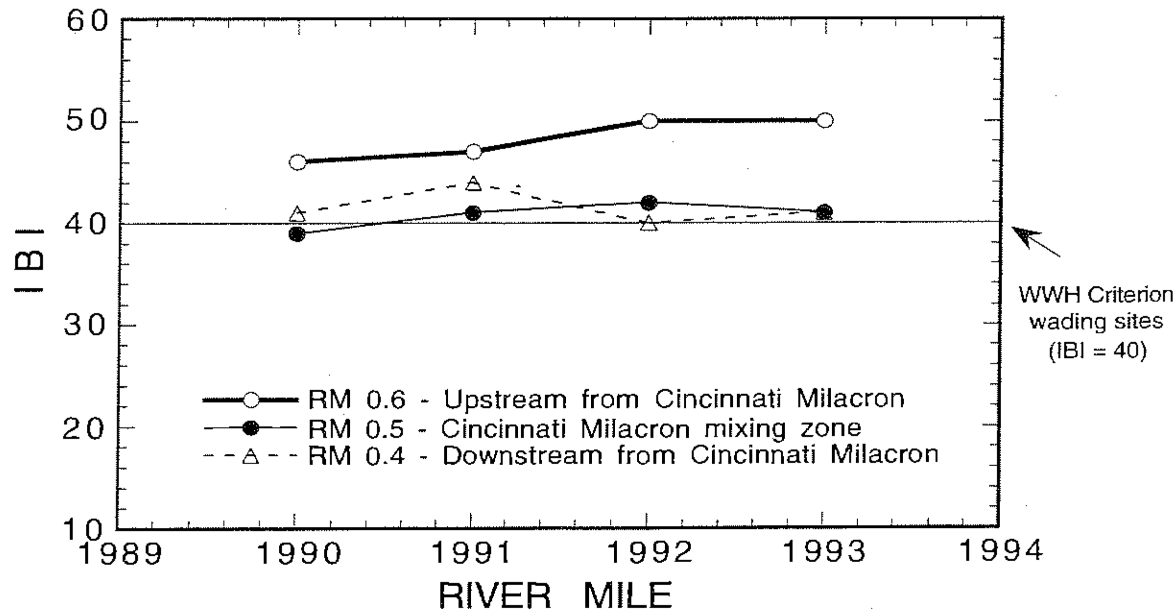


Figure 105. Longitudinal trends of the Index of Biotic Integrity (IBI; Top Graph) and the Modified Index of Well-Being (MIwb; Bottom Graph) in Turtle Creek during 1983 and 1993.



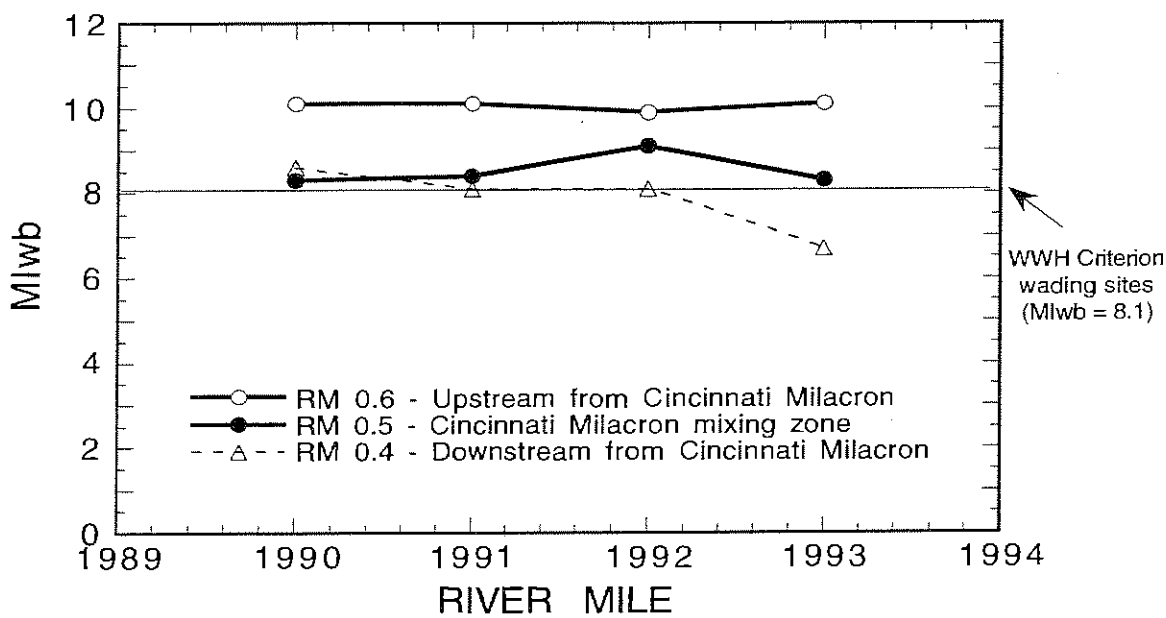


Figure 106. Temporal trends of the Index of Biotic Integrity (IBI; Top Graph) and the Modified Index of Well-Being (MIwb; Bottom Graph) in Turtle Creek from 1990 to 1993.

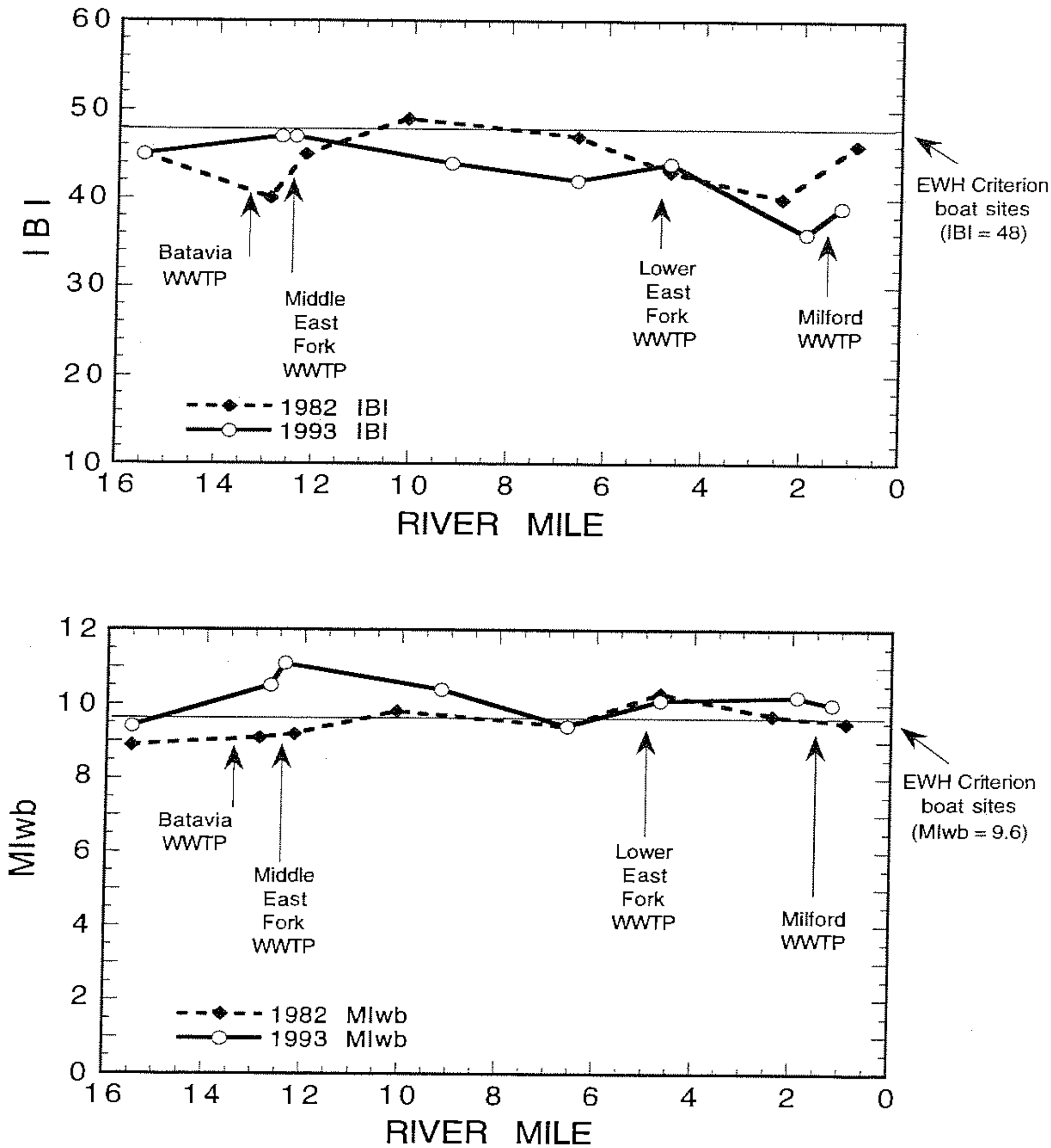


Figure 107. Longitudinal trends of the Index of Biotic Integrity (IBI; Top Graph) and the Modified Index of Well-Being (MIwb; Bottom Graph) in the East Fork of the Little Miami River during 1982 and 1993.

Table 13. Comparison of Area of Degradation (ADV) statistics for the Little Miami River mainstem and selected tributaries in the study area originally sampled in 1982-83 and resampled in 1993 (calculated using the ecoregion biocriterion as the background community performance).

Stream Index	Upper RM	Lower RM	Mini- mum	Maxi- mum	ADV	**ADV/ Mile**	P-VP ADV	Miles FULL	PARTIAL	NON	Poor-VP
Upper Little Miami River (1993)											
IBI			33	52	2412	**46.3**	0				
MIwb	102.1	50.0	7.8	10.5	320	**6.1**	0	19.5	32.6	0.0	0.0
ICI			40	52	44	**0.8**	0				
Lower Little Miami River (1993)											
IBI			29	50	1632	**32.6**	0				
MIwb	50.0	0.0	7.3	11.0	255	**5.1**	0	21.4	25.6	3.0	0.3
ICI			12	58	743	**14.9**	0				
Upper Little Miami River (1983)											
IBI			26	51	4083	**84.7**	0				
MIwb	101.4	50.0	6.9	9.4	2085	**45.5**	0	0.0	15.5	35.9	0.0
ICI			18	38	568	**116.9**	0				
Lower Little Miami River (1983)											
IBI			33	48	1949	**39.0**	0				
MIwb	50.0	0.0	7.5	9.5	625	**12.5**	0	1.5	39.0	9.5	0.0
ICI			20	52	1069	**21.4**	0				
Beaver Creek (1993)											
IBI			32	37	12	**60.0**	0				
MIwb	0.5	0.3	7.9	8.7	0	**0**	0	0.0	0.4	0.0	0.0
ICI			48	48	0	**0**	0				
Beaver Creek (1983)											
IBI			31	33	18	**60.0**	0				
MIwb	0.5	0.2	7.7	8.6	0	**0**	0	0.0	0.4	0.0	0.0
ICI			30	42	2	**6.7**	0				
Little Beaver Creek (1993)											
IBI			12	33	359	**78.0**	39				
MIwb	4.7	0.1	7.0	7.0	30	**300.0**	0	0.0	0.7	4.3	2.1
ICI			2	40	619	**134.6**	73				
Little Beaver Creek (1982)											
IBI			12	33	795	**165.6**	371				
MIwb	5.0	0.1	12.0	0.0	-	**-**	-	0.0	0.0	5.0	4.2
ICI			0	30	1240	**253.1**	330				

Table 13. Continued.

Stream Index	Upper RM	Lower RM	Mini-mum	Maxi-mum	ADV	**ADV/ Mile**	P-VP ADV	Miles FULL	PARTIAL	NON	Poor-VP
Turtle Creek (1993)											
IBI			39	50	0	**0**	0				
MIwb	6.3	0.1	6.7	10.1	5	**1.1**	0	5.9	0.4	0.0	0.0
ICI			16	36	47	**7.6**	0				
Turtle Creek (1983)											
IBI			12	42	470	**75.8**	145				
MIwb	6.3	0.1	5.2	9.2	165	**35.9**	1	1.6	0.7	4.0	2.9
ICI			0	36	625	**102.5**	139				
Sycamore Creek (1993)											
IBI			12	38	30	**150.0**	15				
MIwb	0.5	0.1	0.0	7.7	5	**25.0**	0	0.0	0.3	0.3	0.1
ICI			20	32	10	**25.0**	0				
Sycamore Creek (1983)											
IBI			26	27	56	**186.7**	2				
MIwb	0.6	0.1	5.2	6.9	15	**50.0**	1	0.0	0.0	0.6	0.6
ICI			0	30	70	**140.0**	18				
East Fork Little Miami River (1993)											
IBI			36	47	221	**15.7**	0				
MIwb	15.5	0.8	9.3	11.1	0	**0**	0	7.1	7.8	0.0	0.0
ICI			44	54	0	**0**	0				
East Fork Little Miami River (1982)											
IBI			40	49	102	**6.9**	0				
MIwb	15.5	0.8	8.9	10.3	5	**0.3**	0	10.0	4.8	0.0	0.0
ICI			42	52	0	**0**	0				

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