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Assessment of Stream Conditions and Trends in Biological and Water-Chemistry Data From Selected Streams in Chester County, Pennsylvania, 1981-97

by Andrew G. Reif

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In cooperation with
CHESTER COUNTY WATER RESOURCES AUTHORITY

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CONVERSION FACTORS AND ABBREVIATIONS

Multiply	By	To obtain
inch (in.)	2.54	centimeter
foot (ft)	0.3048	meter
square mile (mi^2)	2.590	square kilometer
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
degree Fahrenheit (°F)	°C = 5/9 (°F-32)	degree Celsius

Abbreviated water-quality units used in this report

micrograms per gram (µg/g)

micrograms per kilogram (µg/kg)

milligram per liter (mg/L)

millimeter (mm)

micron (µm)

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ABSTRACT

Biological, chemical, and physical data were collected from a network of 43 sites in Chester County, Pa., from 1981 to 1997. The goal of the network is to assess stream conditions and determine trends in benthic-macroinvertebrate and water-chemistry data. Most sites in the network were assessed as nonimpacted or slightly impacted on the basis of biological metric analysis of benthic-macroinvertebrate data. Sites assessed as impacted were affected by habitat degradation, organic pollution, or toxins. Analysis of calculated biological metrics indicates that most sites were assessed as nonimpacted or slightly impacted between 1981 and 1997. Sites in the Pigeon, French, Pickering, and upper East Branch Brandywine Creek Basins generally were assessed as nonimpacted with stable physical and chemical data through the 17-year period. Sites in the Darby, Crum, Ridley, Valley, and lower East Branch Brandywine Creek Basins are being degraded from the reference conditions, primarily because of habitat alteration. The areas with the poorest stream quality were sites with greater than 50 percent agricultural land use, sites with greater than 10 percent impervious surface, and sites affected by wastewater-treatment plant discharges. These sites are being degraded by erosion, sedimentation, and nutrient enrichment. Trend analysis indicates that calculated biological metrics at most sites improved or remained unchanged between 1981 and 1997. Trend analysis on chemical constituents indicated that concentrations of nitrate and chloride were increasing, and concentrations of phosphorus and ammonia were unchanged or declining across Chester County from 1981 to 1997. The highest concentrations of ammonia and chloride were at locations affected by wastewater-treatment plant discharges. Concentrations of pesticides and other organic compounds in stream-bottom sediments decreased between 1983 and 1997 but these compounds still are present at low concentrations throughout Chester County.

INTRODUCTION

The Chester County Water Resources Authority (CCWRA) and the U.S. Geological Survey (USGS) established a long-term stream-quality monitoring network in 1970. The goal of the network is to assess the quality of streams in Chester County, Pa., and to further the understanding of stream changes in response to urbanization using benthic-macroinvertebrate data (Lium, 1977). Benthic macroinvertebrates are aquatic insects and other invertebrates that live on the stream bottom. They are useful in evaluating stream quality because their habitat preference and low mobility cause them to be affected directly by water quality, physical conditions, and riparian habitat. By evaluating the diversity and community structure of benthic-macroinvertebrate populations, a determination of stream quality can be made.

Samples of benthic macroinvertebrates and stream water for the Stream Conditions of Chester County Biological Monitoring Network have been collected annually from up to 51 sites since 1970. Samples of stream-bottom sediment have been collected twice at most sampling sites and have been analyzed for metals and pesticides. This database represents one of the longest nearly continuous water-quality data sets in the country. Data from 1970 to 1980 were analyzed for trends in benthic-macroinvertebrate diversity by Moore (1987).

The streams included in the network drain nearly 95 percent of the county (fig. 1). Valley Creek, Pickering Creek, Stony Run, Pigeon Creek, and French Creek are tributaries to the Schuylkill River. Darby, Crum, Ridley, and Chester Creeks are tributaries to the Delaware River. Buck Run, Doe Run, Indian Run, and Valley Creek (also called West Valley Creek) are tributaries to the Brandywine Creek. Red Clay, White Clay, and Brandywine Creeks are tributaries to the Christina River, itself a tributary to the Delaware River.

Big Elk Creek flows into the Chesapeake Bay. Octoraro Creek is a tributary to the Susquehanna River. All streams sampled originate within the boundaries of Chester County, except for the headwaters of the West Branch Brandywine, French, and Octoraro Creeks. The Octoraro Creek forms part of the western border of the county, and its headwaters lie in both Chester and Lancaster Counties (fig. 1).

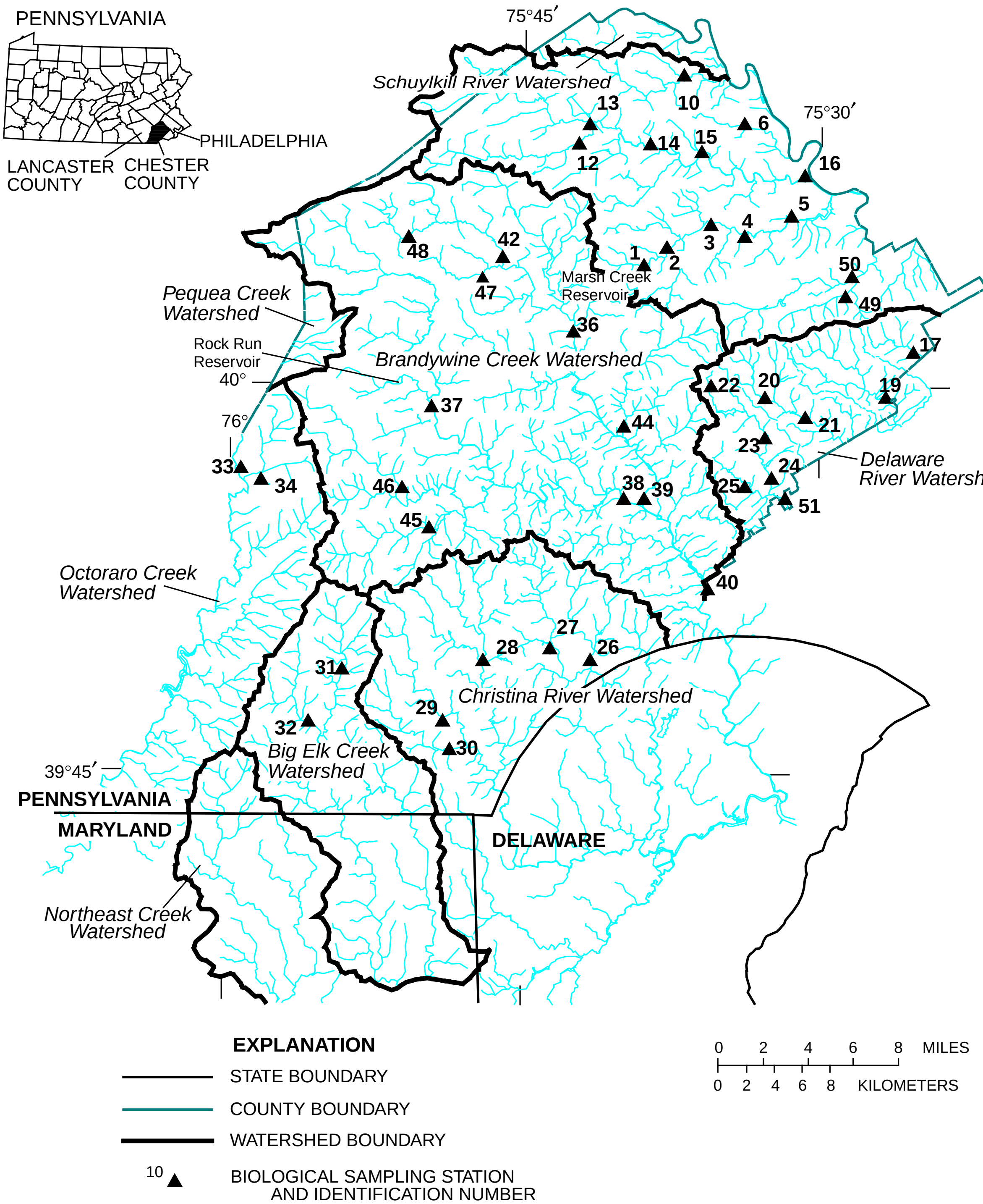

Figure 1. Biological sampling sites and major drainage basin divides in Chester County, Pennsylvania, and surrounding area.

Purpose and Scope

This report evaluates chemical, biological, and field data collected from 1981 to 1997 as part of the Stream Conditions of Chester County Biological Monitoring Network. Stream-quality conditions were assessed by analyzing benthic-macroinvertebrate communities. Trends in benthic-macroinvertebrate diversity were analyzed to evaluate changes in stream quality over time. Chemical data were evaluated for trends and relations between chemical and benthic-macroinvertebrate data. The results of this report will allow Chester County government agencies to identify streams or reaches of streams that are biologically stressed and will allow them to assess the effects of past environmental and land-use practices. This information also will assist Chester County and its municipalities in future land-use and resource-management decisions in support of Chester County's Landscapes Program (Chester County, 1996) and other related programs.

Description of Network and Previous Investigations

This investigation began in the fall of 1969 with a reconnaissance of Chester County to determine the general conditions of streams and land-use patterns. In 1970, the reconnaissance served as a guide to establishing a chemical and biological stream-quality network of 50 sites in 13 stream basins. The sites were established on the basis of equal cumulative square miles of drainage area within each basin (Lium, 1977). The sites also were established away from any known point source of pollution so that the water quality of the overall stream could be assessed. Twelve sites were added and 9 sites were discontinued between 1972 and 1982. Forty-three sites were sampled between 1981 and 1997. The locations of the 43 sampling sites are shown in figure 1, and drainage areas and periods of record are listed in table 1. This network of sampling sites and the biological, physical, and chemical data collected at these sites between 1981 and 1997 are the basis for this investigation.

The physical, chemical, and biological data, which this investigation is based on, are contained in three USGS data reports. Complete analytical and biological results are given by Moore (1989) for 1969-80, by Reif (1999) for 1981-94, and by Reif (2000) for 1995-97. The physical and chemical data for the 1974-97 water years[1] also have been published in the USGS annual water-resources data reports for Pennsylvania (U.S. Geological Survey, 1975-98).

Lium (1977) developed a biotic index that used a 10-point rating scale to assess the environmental conditions at the 50 sites on the basis of data published in his 1976 report (Lium, 1976). The ratings developed by Lium indicated most streams studied were experiencing nutrient enrichment and (or) sediment deposition. In 1967-68, a study was conducted by Miller and others (1971) in the Pickering and East Branch Brandywine Creek Basins to document the present hydrologic conditions of these two small basins prior to urbanization.

Moore (1987) evaluated the physical, chemical, and biological data collected as part of the Stream Conditions of Chester County program from 1969 to 1980. This study showed statistically valid upward trends in Brillouin's diversity index during 1970-80 at 27 sites, which indicate improved environmental quality. Both Lium (1977) and Moore (1987) observed that total dissolved solids correlated significantly with the biotic index and the diversity index.

A report by Sloto (1987) evaluated the effects of urbanization on the water resources of four basins in eastern Chester County. This study showed those basins with the largest increase in urbanization also had the greatest upward change in benthic-macroinvertebrate diversity. Sloto attributed this to decreased pesticide use in urbanizing basins and to the burial and (or) flushing of older pesticides.

Hardy and others (1995) examined land-use changes and concentrations of organochlorine compounds in stream-bottom sediment in relation to the trends in diversity indices of benthic-macroinvertebrate communities. This report showed upward trends in benthic-macroinvertebrate community diversities were associated with increases in residential land use and decreases in agricultural

[1] The 12-month period October 1 through September 30. The water year is designated by the calendar year in which it ends.

Table 1. *U.S. Geological Survey station identification numbers, site numbers, names, drainage areas, and period of record of sites in the Stream Conditions of Chester County Biological Monitoring Network, Pennsylvania, 1981-97*

[—, no data]

U.S. Geological Survey station identification number	Site number (fig. 1)	Name	Drainage area (square miles)	Period of record		
				Biological	Chemical	Bottom sediment
		Schuylkill River Basin				
01472080	10	Pigeon Creek near Parker Ford	12.00	1970-97	1969-97	1985,1996
01472109	6	Stony Run near Spring City	2.00	1970-96	1969-96	1985,1996
01472138	13	French Creek near Coventryville	19.90	1970-97	1969-97	1986,1997
01472140	12	South Branch French Creek at Coventryville	12.40	1970-97	1969-97	1985,1997
01472154	14	French Creek near Pughtown	46.10	1970-97	1969-97	1985,1997
01472157	[1] 15	French Creek near Phoenixville	59.10	1970-97	1969-97	1994
014721612	16	French Creek at Railroad Bridge at Phoenixville	70.70	1980-97	1970-97	1985,1994
01472170	1	Pickering Creek near Eagle	3.09	1970-96	1969-96	1987,1996
01472174	2	Pickering Creek near Chester Springs	5.98	1970-95	1969-95	1986
014721854	3	Pickering Creek at Merlin	21.20	1970-97	1969-97	1986,1997
014721884	4	Pickering Creek at Charlestown Road at Charlestown	27.50	1972-96	1969-96	1985
01472190	5	Pickering Creek near Phoenixville	31.40	1970-97	1969-97	1986,1994
01473167	49	Little Valley Creek at Howellville	6.45	1973-96	1970-96	1986,87,93
01473168	50	Valley Creek near Valley Forge	12.70	1973-96	1970-96	1985,1993
		Delaware River Basin				
01475300	17	Darby Creek at Waterloo Mills near Devon	5.15	1970-96	1969-96	1996
01475840	19	Crum Creek at Whitehorse	10.10	1970-96	1969-96	1986,1996
01476430	20	Ridley Creek at Goshenville	4.22	1970-96	1969-96	1985
01476435	21	Ridley Creek at Dutton Mill near West Chester	9.71	1970-96	1969-96	1986
01476790	22	East Branch Chester Creek at Green Hill	.63	1970-97	1969-97	1986,1997
01476830	23	East Branch Chester Creek at Milltown	5.77	1970-96	1969-96	1986,1996
01476835	24	East Branch Chester Creek at Westtown	10.40	1970-97	1969-97	1985,1994
01476840	25	Goose Creek Tributary to East Branch Chester Creek near West Chester	4.28	1975-82 1988-97	1970-82 1988-97	1988,1993
01476848	51	East Branch Chester Creek below Goose Creek near West Chester	19.20	1983-97	1970-97	1986,1994
		Brandywine Creek Basin				
01480434	37	West Branch Brandywine Creek at Rock Run	37.30	1970-96	1970-96	—
01480629	46	Buck Run at Doe Run	22.60	1973-97	1971-97	1985,1995
01480632	[1] 45	Doe Run at Springdell	11.80	1973-97	1971-97	1986
01480640	38	West Branch Brandywine Creek at Wawaset	134.00	1970-97	1970-97	1985,1993
01480648	48	East Branch Brandywine Creek near Cupola	5.98	1973-95	1971-95	1986
01480653	42	East Branch Brandywine Creek at Glenmoore	16.50	1973-95	1971-95	1985
01480656	47	Indian Run near Springton	4.26	1974-95	1971-95	1986,1995
01480700	36	East Branch Brandywine Creek near Downingtown	60.60	1970-96	1970-96	1985
01480903	44	Valley Creek[2] at Mullsteins Meadows near Downingtown	16.10	1973-97	1971-97	1985,1995
01480950	39	East Branch Brandywine Creek at Wawaset	123.00	1979-97	1970-97	1986,1993
01481030	40	Brandywine Creek near Chadds Ford	291.00	1972-97	1970-97	1985,1997
		Red Clay and White Clay Creek Basins				
01479680	27	West Branch Red Clay Creek at Kennett Square	9.79	1970-97	1970-97	1983,86,93
01479800	26	East Branch Red Clay Creek near Five Point	10.20	1970-97	1970-97	1985,1993
01478120	28	East Branch White Clay Creek at Avondale	11.30	1970-97	1970-97	1985,1993
01478190	29	Middle Branch White Clay Creek at Wickerton	9.94	1970-97	1970-97	1986,1993
01478220	30	West Branch White Clay Creek near Chesterville	9.92	1970-97	1970-97	1985,1993

__Table 1.__ U.S. Geological Survey station identification numbers, site numbers, names, drainage areas, and period of record of sites in the Stream Conditions of Chester County Biological Monitoring Network, Pennsylvania, 1981-97 —Continued

[—, no data]

U.S. Geological Survey station identification number	Site number (fig. 1)	Name	Drainage area (square miles)	Period of record		
				Biological	Chemical	Bottom sediment
		Big Elk and Octoraro Creek Basins				
01494900	31	East Branch Big Elk Creek at Elkview	11.10	1970-97	1970-97	1986,1994
01494950	32	West Branch Big Elk Creek near Oxford	10.00	1970-96	1970-96	1985,1994
01578340	33	East Branch Octoraro Creek at Christiana	11.80	1970-97	1970-97	1994
01578343	34	Valley Creek near Atglen	10.50	1970-96	1970-96	1985

[1] Reference reach.
[2] Also called West Valley Creek.

land use. It also described an association between low community diversity values and concentrations of organochlorine compounds above 45 μg/kg in stream-bottom material. Data collected as part of the Stream Conditions of Chester County program were used in this report.

Description of Study Area

Chester County is a 760-mi^2 area in southeastern Pennsylvania near Philadelphia (fig. 1). It lies in the Piedmont Physiographic Province of the Appalachian Highlands. The topography of the area is characterized by gently rolling hills underlain by deeply weathered crystalline rock. The streams included in this study drain nearly 95 percent of Chester County. The largest basin is the Brandywine Creek Basin, which drains 38 percent (290 mi^2) of the county. The eastern part of the county is more developed; the southern and western parts of the county contain more farm and pasture land. Major crops are hay, corn, vegetables, and mushrooms. Dairy farms and nurseries also are prevalent in the area.

Chester County has undergone and continues to experience rapid population growth. The county's population nearly doubled between 1960 and 1995, increasing from 210,600 to 412,000. Population projections indicate the county will have 489,000 residents by 2020 (Chester County, 1996). In response to this rapid urbanization, open space and farmland have been converted to residential and commercial land. Farmland in the county decreased from 47 percent in 1974 to 37 percent in 1992. The percentage of developed land is projected to increase from 23 percent in 1990 to 38 percent in 2020 (Chester County, 1996).

Climate

The study area has a humid, modified continental climate characterized by warm summers and moderately cold winters. The normal (1961-90) mean annual temperature at Phoenixville is 51.7°F. The normal (1961-90) mean temperature for January, the coldest month, is 28°F, and the normal mean temperature for July, the warmest month, is 73.8°F. The normal (1961-90) annual precipitation at Phoenixville is 42.56 in. (Owenby and Ezell, 1992). Precipitation is distributed about evenly throughout the year; slightly more occurs during the warmer months because of localized thunderstorms.

Hydrologic Conditions

The water-chemistry and biological conditions that exist during a particular year are conditional on the hydrological conditions that were present. Extremely low or high flow conditions can be a major factor controlling the benthic-macroinvertebrate community at a site.

Between 1981 and 1997, there were several years when hydrologic conditions may have had a large effect on the benthic-macroinvertebrate communities sampled. Annual mean discharges were 25 percent below average during the years 1981, 1985, 1986, 1992, and 1995. During these years, adverse conditions may have been present because of low-flow conditions. Under low-flow conditions, water temperatures are higher, chemical constituents can be concentrated, and algal growth can increase; these changes can cause wide fluctuations in dissolved oxygen concentrations. Flows greater than 25 percent of the mean were recorded in 1984, 1994, 1996, and 1997. High flows can cause a disruption of the bottom habitat that can adversely affect benthic-macroinvertebrate communities.

Acknowledgments

The cooperation of the Chester County Board of Commissioners, the Chester County Water Resources Authority, Chester County Planning Commission, and the Chester County Health Department is gratefully acknowledged. Special thanks are extended to David C. Yaeck, Irene B. Brooks, and Janet L. Bowers, Executive Directors of the Chester County Water Resources Authority, for their interest throughout the program's history. Many colleagues, all USGS personnel except Dr. Richard McLean, have provided valuable information and comments for this report. These include Dr. J. Kent Crawford and Dr. Richard McLean for their guidance; Michael D. Bilger, Dr. Martin Gurtz, and Ronald A. Sloto for the review of the manuscript; and Kim L. Otto, Joanne Koch, and Terriann Preston for their technical and editorial input.

SAMPLING AND ANALYTICAL METHODS

Field Measurements

Dissolved oxygen, pH, water temperature, specific conductance, alkalinity, and streamflow were measured at each site once a year in the fall. Field meters were calibrated prior to each use, and records of each meter's performance are kept with the meter and recorded on each field data sheet. Calibration standards for pH and specific conductance were obtained from the USGS laboratory in Ocala, Fla.

Chemical Analysis

Samples for chemical analysis were collected at the same time as the biological samples by use of techniques described by Brown and others (1970, p. 5). Chemical samples collected from 1981 to 1984 were analyzed at the USGS National Water-Quality Laboratory in Atlanta, Ga. Chemical samples collected from 1985 to 1997 were analyzed at the USGS National Water-Quality Laboratory in Arvada, Colo. Water samples were analyzed for nutrients, major ions, and selected metals. Quality-control samples consisting of replicates and field blanks were collected to provide quantitative information on the precision and bias of the overall field and laboratory process. Constituent concentrations in field blanks almost always were less than the minimum reporting levels and replicate samples generally were within 10 percent. These results indicate no systematic bias and good precision in the reported water-quality data.

Stream-bottom sediment samples were collected from 1985 through 1987 and from 1993 through 1994. Most sites were sampled once during each period. Samples of stream-bottom sediment were collected from depositional areas where water depth was less than 2 ft. Samples were collected by hand from the top 6 to 12 in. of stream-bottom sediment with a polyethylene scoop and washed through a 2-mm polyethylene sieve with native water. The sample was homogenized in a polyethylene basin and transferred to clean glass or polyethylene containers and placed on ice for shipment to the USGS laboratory.

Samples of stream-bottom sediment were analyzed for selected metals, pesticides, gross polychlorinated biphenyls (PCB), and gross polychlorinated naphthalenes (PCN). Analyses for selected metals included arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, and zinc. Metal concentrations were determined by atomic absorption spectrometry (Fishman and Friedman, 1989). Analyses for organochlorine insecticides included aldrin, chlordane, DDD, DDE, DDT, dieldrin, endosulfan, endrin, heptachlor, heptachlor epoxide, lindane, methoxychlor, mirex, perthane, and toxaphene. Concentrations of organochlorine pesticides, PCB, and PCN were determined by gas chromatography using a flame photometric detector (Wershaw and others, 1987). Concentrations of total carbon were determined by the induction furnace method (Wershaw and others, 1987). All results are reported as dry weights.

Biological Analysis

Biological samples consisted of benthic macroinvertebrates collected annually from October through November. During each visit, benthic macroinvertebrates were sampled by collecting 10 rocks (45-90 mm in diameter) at random from a riffle area (Lium, 1974). All organisms that were dislodged or washed off the rocks were collected in the sampler or with a sieve with a 210-µm mesh. All invertebrates from the rocks were composited in a container and stored in 70 percent ethanol for later identification. A complete description of the sampling technique is described by Moore (1987, p. 7). Benthic-macroinvertebrate samples collected from 1980 to 1997 were identified at the USGS office in Malvern, Pa. Benthic macroinvertebrates were identified to the lowest taxonomic level possible. A systematic checklist of taxa reported is presented in appendix 1. A reference collection of identified organisms is maintained at the USGS, Water Resources Division, Malvern, Pa. Unusual taxa were confirmed by expert taxonomists. A list of taxonomic references on which the identifications were based is given in table 2. Taxa richness, modified Hilsenhoff's Biotic Index (HBI), Ephemeroptera, Plecoptera, Trichoptera (EPT) taxa richness, and percentage EPT were calculated for each benthic-macroinvertebrate sample (tables 14-56, pages 51-72).

Table 2. *List of taxonomic references used to identify benthic-macroinvertebrate samples*

Taxonomic group	Reference
Turbellaria, Nemertea, Nematoda, Gastropoda, Bivalvia, Annelida, Crustacea, Arachnida	Pennak, 1989, Peckarsky and others, 1990
Ephemeroptera, Plecoptera, Megaloptera, Neuroptera, Lepidoptera, Coleoptera, Diptera	Brigham and others, 1982, Peckarsky and others, 1990; Merritt and Cummins, 1996
Trichoptera	Wiggins, 1996

STREAM-QUALITY ASSESSMENT AND TRENDS

Biological Metrics Evaluation

The analysis of overall stream quality on the basis of benthic-macroinvertebrate sampling uses various biological metrics. Numerous biological metrics commonly are used to describe benthic-macroinvertebrate communities including taxa richness, EPT taxa richness, percent EPT taxa, and the HBI. Each biological metric evaluates a different aspect of the invertebrate community and how it relates to overall stream quality. By examining all these biological metrics together, an evaluation of the overall stream quality can be made. A complete listing of the biological metrics calculated for each site is presented in tables 14-56 (pages 51-72). Benthic-macroinvertebrate data from 1981 to 1997 were used in the assessments. Data prior to 1981 were used only as a historical reference. The biological metrics used are described below.

Taxa richness is a measure of the number of distinct taxonomic groups (taxa) in a collection. Richness measures the overall diversity of the biological community sampled. Taxa richness tends to decrease with decreasing stream quality (Weber, 1973; Resh and Grodhaus, 1983). The availability of adequate food, habitat, and niche space to support a variety of taxa is an indication of a healthy biological community and typically is reflected in increasing taxa richness (Plafkin and others, 1989).

EPT taxa richness is the total number of taxa within the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). **Percentage EPT individuals** is the total number of EPT individuals divided by the total number of individuals in the sample. These three orders of insects generally are considered "pollution sensitive" and their presence is associated with good stream quality (Lenat, 1988). EPT taxa richness and (or) the percentage EPT individuals increase with improving stream quality.

Hilsenhoff's biotic index (HBI) is based on the sensitivity of organisms to stream-quality conditions. The HBI uses assigned tolerance values that range from 0 to 10. A zero value is assigned to organisms least tolerant of organic pollution, and a 10 is assigned to organisms most tolerant of organic pollution. Species intermediate in their tolerance of organic pollution were assigned intermediate values

(Hilsenhoff, 1982). The HBI is calculated by multiplying the number of individuals of each taxon by its assigned tolerance value, summing these products, and dividing by the total number of individuals. Tolerance values are from the genus- and species-level biotic index developed by the State of New York (Bode, 1991). HBI values from 0 to 4.5 have been associated with nonimpacted sites, 4.51 to 6.50 have been associated with slightly impacted sites, 6.51 to 8.50 have been associated with moderately impacted sites, and 8.51 to 10.00 are associated with severely impacted sites (Bode, 1993).

Stream-Quality Assessment Criteria

Streams in the network were assessed as nonimpacted, slightly impacted, moderately impacted, or severely impacted on the basis of calculated biological metric values (table 3). Each biological metric assesses a different part of the benthic-macroinvertebrate community structure to produce an overall assessment of stream-quality conditions.

Table 3. *Stream-quality assessment criteria for Chester County, Pennsylvania, streams (adapted from Bode, 1993)*

[EPT, Ephemeroptera, Plecoptera, and Trichoptera; HBI, Hilsenhoff's biotic index; >, greater than]

Stream-quality assessment	Taxa richness	EPT taxa richness	HBI
Nonimpacted	>30	>10	0 - 4.50
Slightly impacted	21 - 30	6 -10	4.51 - 6.50
Moderately impacted	11 - 20	2 -5	6.51 - 8.50
Severely impacted	0 - 10	0 - 1	8.51 - 10

Nonimpacted: Biological metrics indicate excellent stream conditions. The benthic-macroinvertebrate community is balanced and diverse. The community is dominated by "pollution sensitive" and facultative groups including mayflies, stoneflies, and caddisflies. "Pollution tolerant" groups may be present but are not dominant. Water-quality and habitat conditions are not limiting the benthic-macroinvertebrate community. Nonimpacted sites include pristine habitats and those receiving inputs that minimally affect the benthic-macroinvertebrate community.

Slightly Impacted: Biological metrics indicate good stream conditions. The benthic-macroinvertebrate community is less diverse than at nonimpacted sites but still contains mayflies, caddisflies, and possibly some stoneflies. The community structure typically is dominated by a few taxa including caddisflies, Elmidae (riffle beetles), and chironomids. Water-quality and physical conditions are affecting the benthic-macroinvertebrate community. Slightly impacted sites commonly receive some wastewater inputs and (or) agricultural / urban runoff.

Moderately Impacted: Biological metrics indicate fair stream conditions. The benthic-macroinvertebrate community is disturbed and noticeably altered from a nonimpacted site. Mayflies and stoneflies are rare, and caddisfly taxa may be limited. The benthic-macroinvertebrate community is dominated by "pollution tolerant" and facultative organisms including chironomids and oligochaetes (aquatic earthworms). One or a few groups usually dominate the community. Stream-quality conditions are major factors affecting the benthic-macroinvertebrate community. Moderately impacted sites commonly receive heavy wastewater inputs and (or) agricultural / urban runoff.

Severely Impacted: Biological metrics indicate poor stream quality. The benthic-macroinvertebrate community is limited with poor diversity. Mayflies, stoneflies, and caddisflies are rare, and the community usually is dominated by chironomids and aquatic earthworms. The community may have low numbers of individuals or very high numbers of a few taxa. Severely impacted sites commonly receive inputs of a toxin or have extremely low concentrations of dissolved oxygen. Stream-quality conditions are severely affecting the benthic-macroinvertebrate community. Severely impacted sites commonly receive heavy wastewater inputs, agricultural / urban runoff, and possibly toxic substances.

Reference Reaches

Reference reaches are sites that represent good stream conditions in a particular area. Reference sites are considered those minimally affected by anthropogenic impacts. These sites have stable habitat, non-toxic water chemistry, and healthy biological conditions. Other sites with similar stream characteristics can be compared to the reference reach to determine impacts. The sites were selected on the basis of historical data that indicated good stream quality. Two sites were selected to represent reference conditions in areas of agricultural and nonagricultural land use.

French Creek near Phoenixville (site 15) was chosen as the reference site for the Schuylkill River Basin, Delaware River Basin, and East Branch Brandywine Creek Basin. This site has a diverse and stable benthic-macroinvertebrate community, stable habitat, and consistent chemical data. It receives no direct discharges and has a stable land use that is low in impervious surface and low in intense agricultural lands. Doe Run at Springdell (site 45) was chosen as the reference site for the West Branch Brandywine, Red Clay, White Clay, Big Elk, and Octoraro Creek Basins. Areas minimally affected by human activities are difficult to find in these basins. Although this site is affected by anthropogenic impacts, including agricultural activities, it represents stable stream conditions in the area.

Assessment of Stream Quality Using Benthic-Macroinvertebrate Data

Schuylkill River Basin

Streams sampled in the Schuylkill River Basin include Pigeon Creek, Stony Run, French Creek, Pickering Creek, Little Valley Creek, and Valley Creek. The Schuylkill River Basin drains the northern part of the county, including the Boroughs of Phoenixville and Spring City. Land use in the basin is dominated by a mix of agriculture, forested, and residential areas. Assessments of stream conditions, on the basis of macroinvertebrate criteria, are presented in table 4.

Table 4. *Assessment of stream conditions on the basis of median values of taxa richness, EPT taxa richness, and HBI for sites in the Schuylkill River Basin, Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, and Trichoptera; HBI, Hilsenhoff's biotic index; Assessment based on values presented in tables 14-27]

U.S. Geological Survey station identification number	Site number	Taxa richness	EPT taxa richness	HBI
		Pigeon Creek		
01472080	10	Nonimpacted	Nonimpacted	Nonimpacted
		Stony Run		
01472109	6	Nonimpacted	Nonimpacted	Slightly impacted
		French Creek		
01472138	13	Nonimpacted	Nonimpacted	Slightly impacted
01472140	12	Nonimpacted	Nonimpacted	Nonimpacted
01472154	14	Nonimpacted	Nonimpacted	Nonimpacted
01472157	15	Nonimpacted	Nonimpacted	Nonimpacted
014721612	16	Slightly impacted	Slightly impacted	Slightly impacted
		Pickering Creek		
01472170	1	Slightly impacted	Nonimpacted	Slightly impacted
01472174	2	Slightly impacted	Nonimpacted	Nonimpacted
014721854	3	Nonimpacted	Nonimpacted	Slightly impacted
014721884	4	Nonimpacted	Nonimpacted	Slightly impacted
01472190	5	Nonimpacted	Nonimpacted	Slightly impacted
		Valley Creek Basin		
01473167	49	Moderately impacted	Slightly impacted	Nonimpacted
01473168	50	Slightly impacted	Slightly impacted	Slightly impacted

Pigeon Creek

Pigeon Creek near Parker Ford (site 10) was sampled annually from 1981 through 1997. Pigeon Creek has a drainage area of 12.0 mi^2 and is approximately 24 ft wide at site 10. The predominant land-use categories at site 10 are agriculture (36 percent), forested (36 percent), and residential (25 percent) (Delaware Valley Regional Planning Commission, 1997).

Pigeon Creek was assessed as nonimpacted on the basis of calculated biological metrics (table 4). The benthic-macroinvertebrate data collected at this site indicate a diverse and stable benthic-macroinvertebrate community with numerous “pollution sensitive” organisms. The physical and chemical data collected in conjunction with the benthic-macroinvertebrate samples indicate stable physical, chemical, and biological conditions with no adverse effects of habitat alteration, siltation, or nutrient enrichment. Samples of stream-bottom sediment collected in 1985 contained no detectable concentrations of pesticides or PCBs. Taxa richness and the number of EPT taxa increased in 1987 and remained higher through 1997 (table 14, page 51), but there were no changes in measured habitat or chemical data to explain the increase in taxa. This site had similar numbers of taxa and EPT taxa but slightly larger HBI values (median = 4.28, indicating a less healthy benthic-macroinvertebrate community) when compared to the reference site. The increased HBI values were the result of occasionally high numbers of chironomids, which can be an indication of degraded stream conditions (Plafkin and others, 1989) (fig. 2).

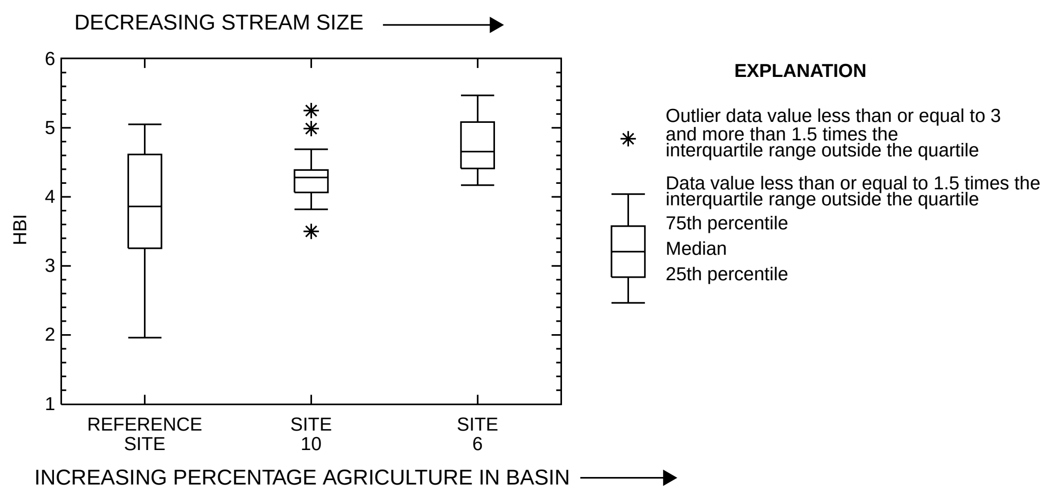

Figure 2. Range of Hilsenhoff’s biotic index (HBI) values from reference site (site 15), Pigeon Creek (site 10), and Stony Run (site 6), Chester County, Pennsylvania, 1981-97.

Stony Run

Stony Run near Spring City (site 6) was sampled annually from 1981 through 1996. Stony Run is a small headwater stream with a drainage area of 2.0 mi^2 at site 6. The stream is approximately 6 ft wide. The predominant land-use categories at site 6 are agriculture (63 percent), residential (22 percent), and forested (11 percent) (Delaware Valley Regional Planning Commission, 1997).

Stony Run was assessed as nonimpacted on the basis of median values of taxa richness and EPT taxa richness and as slightly impacted on the basis of the HBI index (table 4). The benthic macroinvertebrates collected at this site had consistent numbers of taxa but increasing numbers of EPT taxa and slightly decreasing HBI values after 1988 (table 15, page 51). The benthic-macroinver-tebrate community after 1988 also contained lower numbers of gastropods (snails) and aquatic earthworms than prior to 1988, which generally decreased the HBI values. The decreasing HBI values and increasing numbers of EPT taxa—both indications of improved stream quality—occurred in conjunction with decreasing concentrations of ammonia, phosphorus, sodium, potassium, and chloride and a reduction in siltation. The improved chemical conditions and increased diversity in benthic-macroinvertebrate communities occurred after 1988.

The benthic-macroinvertebrate community was diverse with large numbers of mayflies, caddisflies, and riffle beetles and a small but consistent population of stoneflies, which are indications of good stream quality. The invertebrate community also contained occasionally large numbers of “pollution tolerant” organisms, which can be an indication of degraded stream quality. This large number of “pollution tolerant” organisms caused the HBI values to indicate slightly impacted conditions (table 4). The benthic-macroinvertebrate community contained similar taxa richness numbers but reduced EPT taxa richness and increased HBI values when compared to the reference site. The difference in biological metrics between site 6 and the reference site corresponds to the large percentage of agriculture in the basin and the small stream size at site 6 (fig. 2). Agriculture in a basin can cause increased sediment and pesticide loads that can negatively affect benthic macroinvertebrates. Minshall and others (1985) and Grubaugh and others (1996) have shown that small streams (first and second order) have reduced taxa richness when compared to larger streams (fourth and fifth order streams).

French Creek

Five sampling sites were on French Creek (sites 12-16) between Coventryville in the headwaters and Phoenixville near the confluence with the Schuylkill River. The drainage area of French Creek at the most downstream location (site 16) is 70.7 mi^2. The stream is approximately 15 ft wide at site 12 and is 50 ft wide at site 16. The predominant land-use categories at site 16 are forested (47 percent), agriculture (35 percent), and residential (13 percent) (Delaware Valley Regional Planning Commission, 1997). The sites were sampled annually from 1981 through 1997.

French Creek from Coventryville to above Phoenixville (sites 12-15) was assessed as nonimpacted on the basis of calculated biological metrics, except site 13, which was assessed as slightly impacted on the basis of HBI values (table 4). The benthic-macroinvertebrate data collected from these sites indicate a diverse and stable benthic-macroinvertebrate community with numerous “pollution sensitive” organisms including a large and diverse stonefly population. The physical and chemical data collected in conjunction with the benthic-macroinvertebrate samples indicate no adverse effects of habitat alteration, siltation, or nutrient enrichment and stable water-chemistry conditions. These sites had similar biological metric values when compared to the reference site, which is in the basin (site 15).

The benthic-macroinvertebrate community at site 16 was degraded compared with those at upstream sites. Site 16 is near the confluence with the Schuylkill River and is downstream of the Borough of Phoenixville. The area immediately upstream of the site is an old heavy industrial area that is being converted to a light industrial / business area. The benthic-macroinvertebrate data collected from this site had lower taxa richness, fewer EPT taxa (fig. 3), and higher HBI values than the other sites on French Creek. Site 16 was assessed as slightly impacted on the basis of all three biological metrics (table 4). Although this site was assessed as slightly impacted, it has improved since 1982. Taxa richness and EPT taxa richness have increased and HBI values have decreased from 1981 to 1997, although they were variable (table 20, page 54). Decreases in concentrations of ions and metals at the site after 1982 correspond to the increased diversity in the benthic-macroinvertebrate community (fig. 4).

Pickering Creek

Five sampling sites were on Pickering Creek (sites 1-5). Predominant land use at site 5 is agriculture (42 percent), forested (36 percent), and residential (17 percent) (Delaware Valley Regional Planning Commission, 1997). The drainage area of Pickering Creek at site 5 is 31.4 mi^2. The stream is approximately 15 ft wide at site 1 and is 50 ft wide at site 5. The sites were sampled annually from 1981 through 1997.

The Pickering Creek sites were all assessed as nonimpacted or slightly impacted on the basis of calculated biological metrics (table 4). The benthic-macroinvertebrate data collected from these sites indicate a diverse but variable benthic-macroinvertebrate community with numerous “pollution sensitive” organisms including large and diverse stonefly and mayfly populations. Large populations of

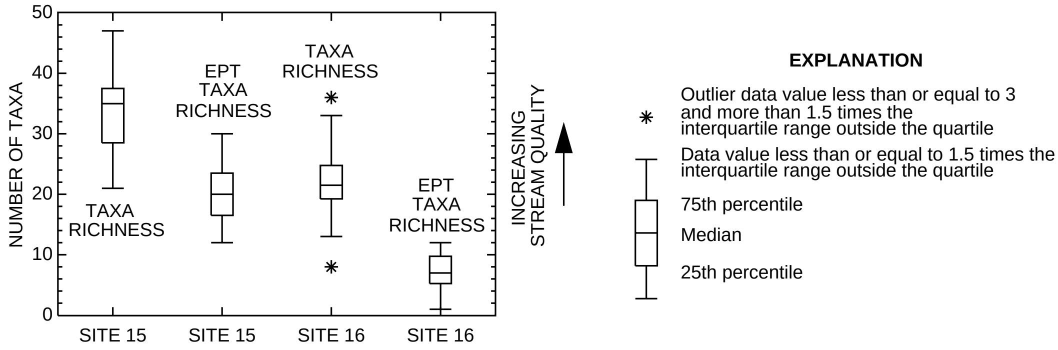

Figure 3. Taxa richness and Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa richness from French Creek near Phoenixville (site 15) and French Creek at Phoenixville (site 16), Chester County, Pennsylvania, 1981-97.

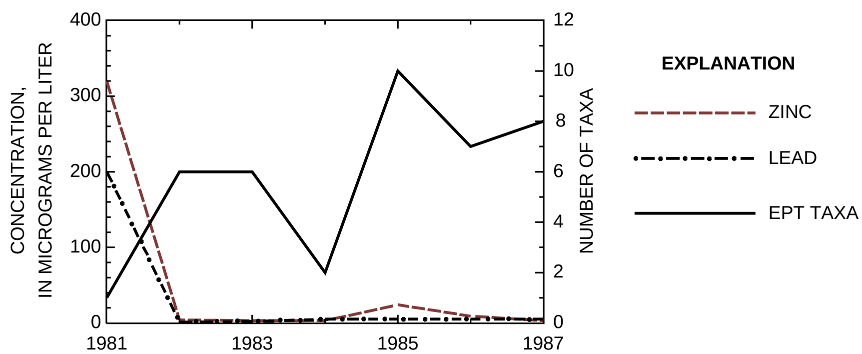

Figure 4. Concentrations of zinc and lead and number of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa from French Creek at Phoenixville (site 16), Chester County, Pennsylvania, 1981-87.

“pollution tolerant” organisms occasionally were present in the downstream sites. Biological metrics indicated steady or slightly improving stream conditions in Pickering Creek from 1986 to 1997 (tables 21-25, pages 54-56). Physical and chemical data collected in conjunction with the benthic-macroinvertebrate samples also indicate stable habitat and consistent water chemistry that support the stable benthic-macroinvertebrate community.

All sites in the basin had concentrations of ammonia that were elevated over the reference site from 1983 to 1984. The ammonia concentrations declined in 1985 and remained lower throughout the study period. Sites 1-4 had increased numbers of taxa after 1985 when the lower ammonia concentrations were measured (fig. 5).

The most upstream sites (sites 1 and 2) had reduced numbers of taxa and EPT taxa when compared to the other sites in the basin and the reference site but still contained numerous “pollution sensitive” organisms. The reduced numbers of taxa at sites 1 and 2 may be because of limited habitat, food, and flow in headwater streams and not related directly to degraded stream conditions. Minshall and others (1985) and Grubaugh and others (1996) have shown that taxa richness decreases as stream size decreases. Taxa richness and EPT taxa richness increased with increasing stream size; sites 4 and 5 have numbers of taxa similar to the reference site (fig. 6). Both sites had low summer flow and variable stream bottoms.

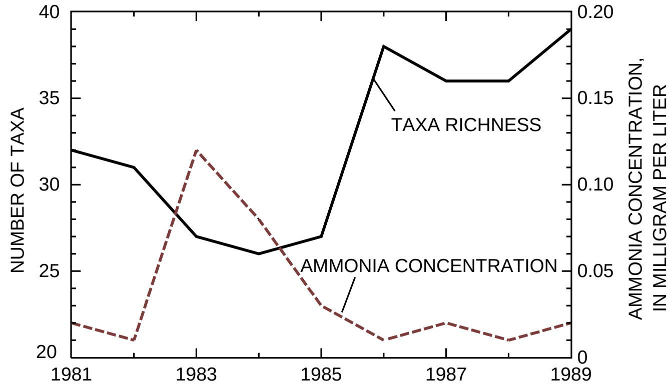

Figure 5. Taxa richness and ammonia concentration at Pickering Creek at Charlestown (site 4), Chester County, Pennsylvania, 1981-89.

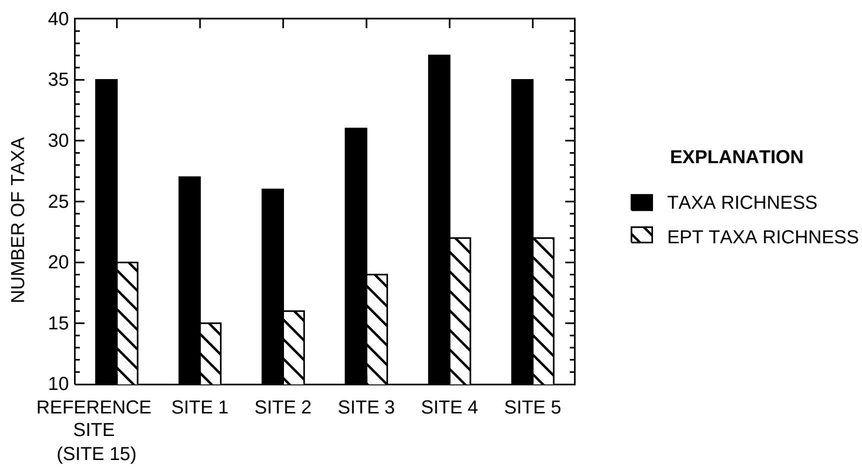

Figure 6. Median values of taxa richness and Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa richness from sites in Pickering Creek Basin and the reference site, Chester County, Pennsylvania, 1981-97.

Valley Creek

Two sampling sites were in the Valley Creek Basin. Site 49 is on Little Valley Creek near its confluence with Valley Creek, and site 50 is on Valley Creek upstream of Little Valley Creek. Little Valley Creek is 11 ft wide at site 49 and has a drainage area of 6.45 mi^2. Valley Creek is 32 ft wide at site 50 and has a drainage area of 12.7 mi^2. The predominant land-use categories at site 50 are forested (33 percent), residential (28 percent), commercial (10 percent), parking / transportation (6 percent), and agriculture (10 percent) (Delaware Valley Regional Planning Commission, 1997). The basin contains major highways and business areas with 9 percent impervious surface at site 50. The sites were sampled annually from 1981 through 1996.

The benthic-macroinvertebrate communities collected from these sites have relatively low but consistent numbers of total taxa and EPT taxa. Site 49 was assessed as moderately impacted on the basis of taxa richness, slightly impacted on the basis of EPT taxa richness, and nonimpacted on the basis of HBI (table 4). Although the number of taxa was low at site 49, the percent of EPT taxa was above 50 percent, which indicates good stream conditions (table 26, page 57). Physical and chemical data from this site indicate low nutrient enrichment and stable water chemistry that correspond to the stable benthic-macroinvertebrate community found there.

Site 50 was assessed as slightly impacted on the basis of calculated biological metrics (table 4). Site 50 had values of taxa richness and EPT taxa richness similar to those at site 49, but the community at site 50 contains higher numbers of “pollution tolerant” organisms including chironomids, tipulids (crane flies), and Turbellaria (flatworms) (fig. 7). The physical and chemical data collected in conjunction with the benthic-macroinvertebrate samples indicate low nitrate concentrations (less than 3.0 mg/L) at both sites but occasional ammonia concentrations above 0.10 mg/L at site 50. Site 50 also had degraded habitat caused by siltation. The benthic-macroinvertebrate community was consistent and did not respond to small changes in the water chemistry at this site.

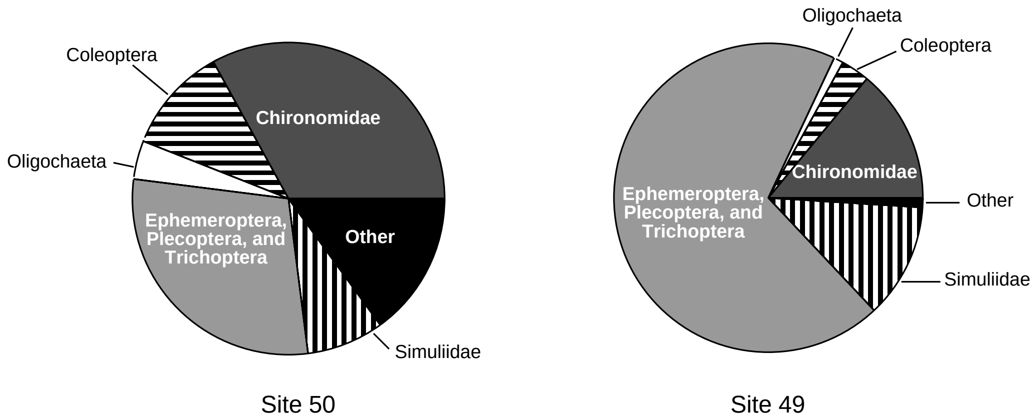

Figure 7. Community composition of benthic-macroinvertebrate communities in Valley Creek (site 50) and Little Valley Creek (site 49), Chester County, Pennsylvania, 1994.

Valley and Little Valley Creeks are limestone streams with naturally high conductance and alkalinity. The low numbers of taxa and EPT taxa that indicate the streams are slightly to moderately impacted may be because the basins have greater than 10 percent impervious surfaces and (or) because of naturally high conductance and alkalinity found in limestone streams. A limestone reference stream was not available in the area for comparison. Site 49 was affected by PCB contamination from the Paoli Rail Yard Superfund Site in the 1970s and 1980s, although recently collected samples of stream-bottom sediment contained low concentrations of PCBs.

Sites in the Schuylkill River Basin are varied in land use from agricultural in Pigeon Creek and Stony Run to forested/residential in French and Pickering Creeks to urban/residential in Valley and Little Valley Creeks. In general, these streams were nonimpacted or slightly impacted and had stable benthic-macroinvertebrate communities and water chemistry; nitrate concentrations generally were less than 4.0 mg/L and phosphorus concentrations were less than the U.S. Environmental Protection Agency (USEPA) desired goal of 0.1 mg/L (U.S. Environmental Protection Agency, 1994b). Samples of stream-bottom sediment contained concentrations of chlordane and dieldrin above the threshold effect concentration in the 1980s but decreased to below the threshold effect concentration in the 1990s. Concentrations below the threshold effect concentration have little or no biological effect on the majority of benthic organisms (MacDonald and others, 2000).

Delaware River Basin

Streams sampled in the Delaware River Basin include Darby, Crum, Ridley, East Branch Chester, and Goose Creeks. The Delaware River Basin drains a small part of eastern Chester County including the Boroughs of Malvern and West Chester. The streams are small headwater streams in a suburban setting. Land use in the basin is dominated by a mix of residential, urban, and forested areas. Assessments of stream quality, on the basis of benthic-macroinvertebrate data, are presented in table 5.

Table 5. *Assessment of stream quality on the basis of median values of taxa richness, EPT taxa richness and HBI for sites in the Delaware River Basin, Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, and Trichoptera; HBI, Hilsenhoff's biotic index; Assessment based on values presented in tables 28-36]

U.S. Geological Survey station identification number	Site number	Taxa richness	EPT taxa richness	HBI
		Darby Creek		
01475300	17	Slightly impacted	Nonimpacted	Slightly impacted
		Crum Creek		
01475840	19	Nonimpacted	Nonimpacted	Slightly impacted
		Ridley Creek		
01476430	20	Slightly impacted	Nonimpacted	Slightly impacted
01476435	21	Slightly impacted	Nonimpacted	Slightly impacted
		Chester Creek Basin		
01476790	22	Slightly impacted	Slightly impacted	Nonimpacted
01476830	23	Slightly impacted	Nonimpacted	Slightly impacted
01476835	24	Slightly impacted	Nonimpacted	Slightly impacted
01476840	25	Moderately impacted	Moderately impacted	Slightly impacted
01476848	51	Slightly impacted	Slightly impacted	Slightly impacted

Darby Creek

Site 17, Darby Creek at Waterloo Mills near Devon, was sampled annually from 1981 to 1996. Darby Creek is a small headwater stream at site 17 with a drainage area of 5.15 mi^2. The stream is approximately 20 ft wide, and the predominant land-use categories at site 17 are residential (71 percent), forested (12 percent), and agriculture (6 percent) (Delaware Valley Regional Planning Commission, 1997).

Site 17 was assessed as nonimpacted or slightly impacted on the basis of calculated biological metrics (table 5). The benthic macroinvertebrates collected from this site were highly variable in total number of individuals and taxa richness (table 28, page 58) but consistently contained "pollution sensitive" organisms including mayflies and caddisflies but few stoneflies. The number of "pollution sensitive" organisms generally were declining and highly variable since 1989. Physical and chemical data from this site indicate low nutrient concentrations and stable water chemistry but unstable substrate and flow fluctuations. The lack of stable substrate and susceptibility to flow fluctuation, potentially from increased peak streamflows caused by urbanization, is the most likely cause of the variable communities. Darby Creek is one of two basins sampled that has over 10-percent impervious surface and over 30-percent urbanized areas. This level of impervious surface can cause the degraded conditions present at this site (Schueler, 1995).

Crum Creek

Crum Creek at Whitehorse (site 19) was sampled annually from 1981 through 1996. Crum Creek is a small headwater stream in Chester County with a drainage area of 10.1 mi^2 at site 19. The stream is approximately 20 ft wide at this site. The predominant land-use categories at site 19 are residential (41 percent), forested (27 percent), and agriculture (17 percent) (Delaware Valley Regional Planning Commission, 1997).

Crum Creek was assessed as nonimpacted or slightly impacted on the basis of the calculated biological metrics (table 5). The benthic macroinvertebrates collected from this site had a mix of "pollution sensitive" organisms and occasionally large populations of "pollution tolerant" organisms. Water-chemistry data from this site do not suggest a direct cause for the increased numbers of "pollution tolerant" taxa. Chloride concentrations were increasing but nutrient concentrations were low and the other water-chemistry constituents measured were consistent. Habitat information indicates heavy sediment on the stream bottom is degrading the habitat and may be causing the slightly impacted benthic-macroinvertebrate communities.

Ridley Creek

Two sampling sites in the Ridley Creek Basin (sites 20 and 21) were sampled annually from 1981 through 1996. Ridley Creek is a small headwater stream in Chester County with a drainage area of 9.71 mi^2 at site 21. The stream is approximately 10 ft wide at site 20 and is 22 ft wide at site 21. The predominant land-use categories at site 21 are residential (46 percent), forested (22 percent), and agriculture (21 percent) (Delaware Valley Regional Planning Commission, 1997).

Both sites on Ridley Creek were assessed as nonimpacted or slightly impacted on the basis of calculated biological metrics (table 5). The benthic-macroinvertebrate community at site 20 contained highly variable values for total individuals and relatively low taxa richness (table 30, page 59). Between 1988 and 1994, EPT taxa richness decreased and HBI values increased indicating degraded stream quality. Water chemistry did not change between 1988 and 1994, but this site is a small headwater stream and is subject to unstable physical conditions and heavy siltation. The variable macroinvertebrate communities at site 20 may be because of these variable habitat conditions.

Site 21 had a more consistent community of "pollution sensitive" organisms and taxa richness comparable to site 20, but it also had larger populations of "pollution tolerant" organisms (fig. 8). There were no trends in taxa richness or HBI values at site 21 since 1981. Site 21 had stable habitat conditions that allowed it to support a more consistent macroinvertebrate community than site 20.

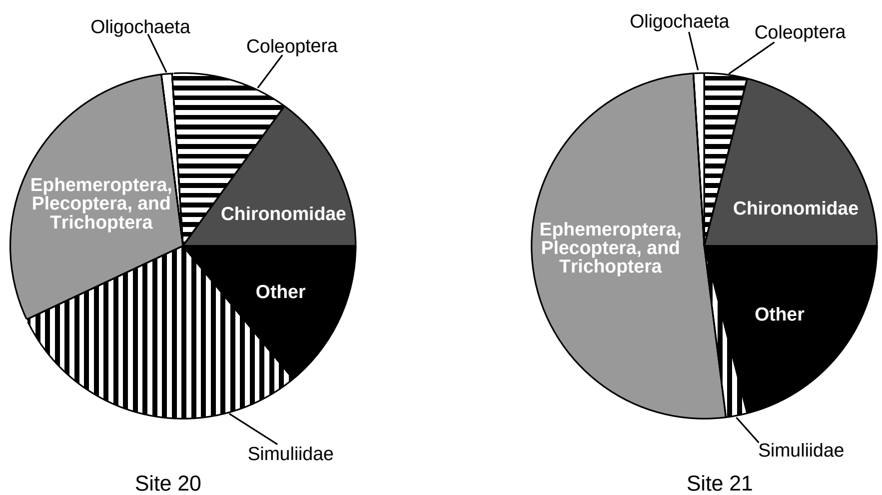

Figure 8. Community composition of benthic-macroinvertebrate communities at sites 20 and 21 on Ridley Creek, Chester County, Pennsylvania, 1996.

East Branch Chester Creek

Five sites in the East Branch Chester Creek Basin were sampled annually between 1981 and 1997. Sites 22, 23, 24, and 51 are on the East Branch Chester Creek, and site 25 is on Goose Creek, which is a tributary to the East Branch Chester Creek. Drainage areas range in size from 0.63 mi^2 at site 22 to 19.2 mi^2 at site 51. The stream is approximately 7 ft wide at site 22 and is 25 ft wide at site 51. The predominant land-use categories at site 51 are residential (50 percent), forested (18 percent), and agriculture (12 percent) (Delaware Valley Regional Planning Commission, 1997).

Sites 22 and 23 were assessed as slightly impacted on the basis of two of the three biological metrics (table 5). Benthic-macroinvertebrate data from site 22 indicate low taxa richness, but approximately 50 percent of the taxa are EPT taxa, which is an indication of good stream quality (table 32, page 60). Benthic-macroinvertebrate data from site 23 have variable taxa numbers but increasing HBI values after 1987 (table 33, page 60). Both sites had reduced taxa richness and EPT taxa richness and higher HBI values than the reference site. The reduced taxa numbers are typical of a small headwater stream and not necessarily degraded stream conditions. The elevated HBI values were caused by higher numbers of "pollution tolerant" organisms including flatworms, aquatic worms, chironomids, and crane flies. These organisms along with heavy algal growth on the stream bottom are an indication of organic enrichment. Physical and chemical data indicate increasing concentrations of sodium, chloride, and calcium after 1987 when the HBI values at site 23 were increasing.

A major event in 1989-91 at site 22 caused a sharp reduction in EPT taxa and a sharp increase in HBI values (table 32, page 60). The benthic-macroinvertebrate community was affected negatively by an increase in dissolved manganese concentrations and manganese precipitate on the stream bottom. The manganese was from a ground-water airstripper that was discharging into the stream above site 22. When the airstripper was shut off, the benthic macroinvertebrates recovered (fig. 9). Site 23 was not affected by the manganese because it is downstream of a small reservoir that may have acted as a buffer.

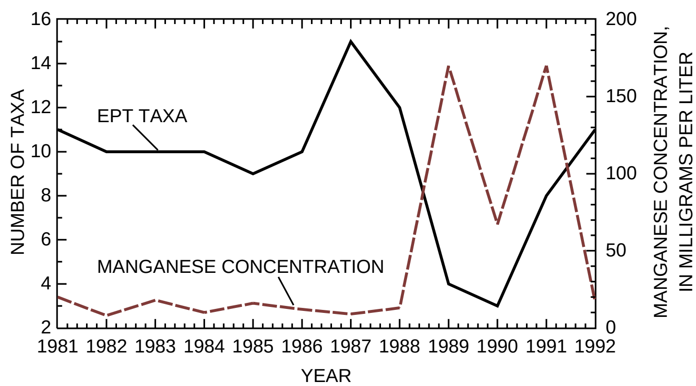

Figure 9. Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa and manganese concentrations from East Branch Chester Creek at Greenhill (site 22), Chester County, Pennsylvania, 1981-92.

Site 24 was assessed as slightly impacted on the basis of two of the three biological metrics (table 5). Benthic-macroinvertebrate data from site 24 indicate a variable benthic-macroinvertebrate community along with variable water chemistry. This site was distinctly different from the reference site in benthic-macroinvertebrate community structure and nutrient water chemistry (figs. 10 and 11). The numbers of "pollution tolerant" organisms, including aquatic worms, chironomids, and black flies, and the concentrations of ammonia and phosphorus occasionally were high, indicating an unstable chemical and biological environment. Phosphorus concentrations were above the USEPA recommended limit of 0.10 mg/L. A small wastewater-treatment plant upstream of this site is degrading the stream quality at this site.

Site 25 is on Goose Creek, a tributary to the East Branch Chester Creek, and site 51 is on East Branch Chester Creek below Goose Creek. Both sites were moderately or slightly impacted on the basis of all three calculated biological metrics (table 5). These sites are downstream of a discharge from a wastewater-treatment plant, and the benthic-macroinvertebrate community is affected by organic pollution. The benthic-macroinvertebrate community and water chemistry were improved greatly between 1982 and 1988 after an upgrade in the wastewater-treatment plant. Taxa richness and EPT taxa richness increased and HBI values decreased (table 35, page 61); concentrations of nutrients and ions all decreased in 1988. The benthic-macroinvertebrate community, however, was different substantially from the reference site. It was dominated by "pollution tolerant" organisms including flatworms, aquatic worms, chironomids, and

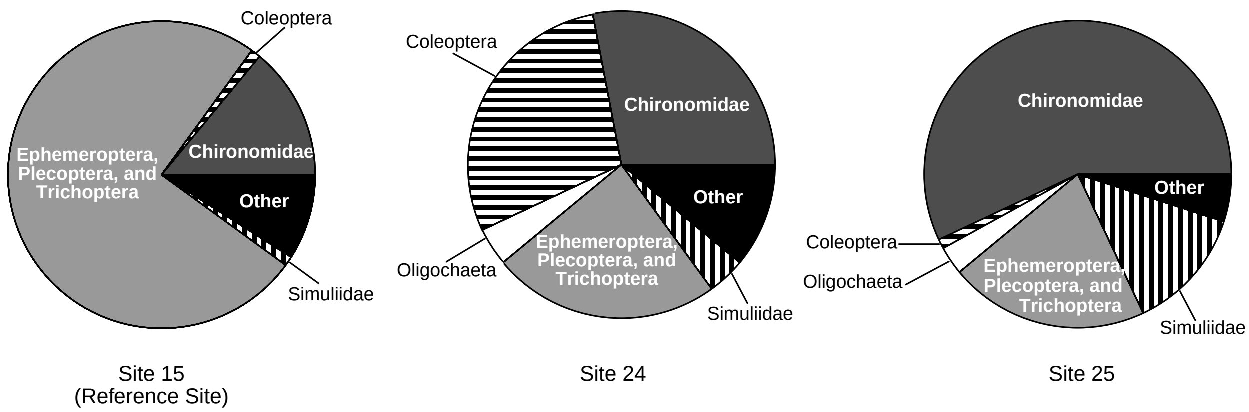

Figure 10. Community composition of benthic-macroinvertebrate communities from the reference site (site 15), East Branch Chester Creek at Westtown (site 24), and Goose Creek (site 25), Chester County, Pennsylvania, 1995.

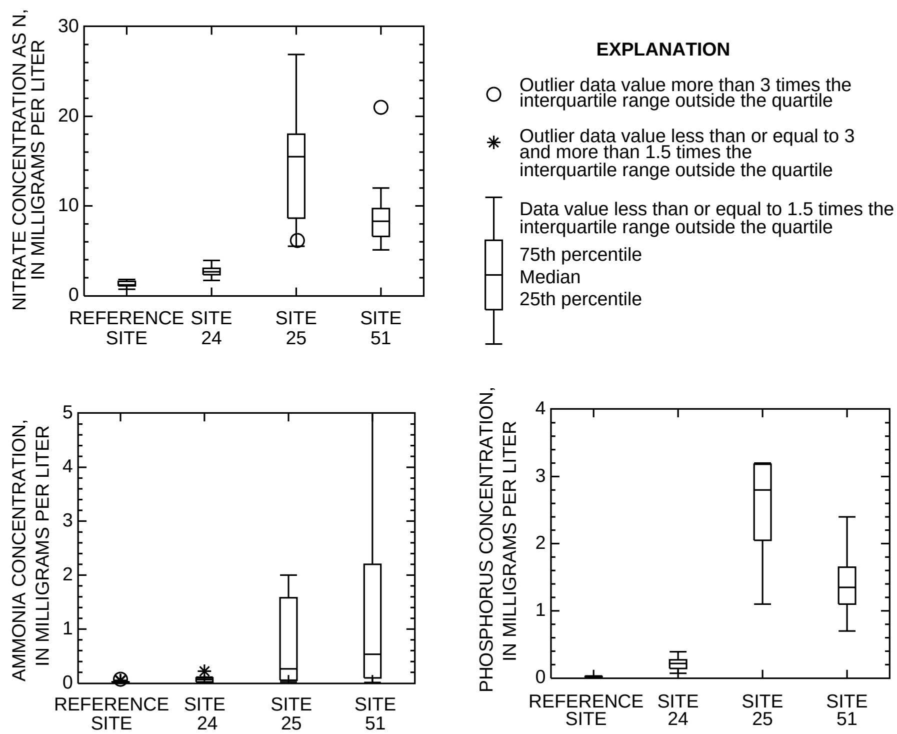

Figure 11. Concentrations of nitrate, ammonia, and phosphorus from the reference site (site 15), East Branch Chester Creek at Westtown (site 24), Goose Creek (site 25), and East Branch Chester Creek below Goose Creek (site 51), Chester County, Pennsylvania, 1981-97.

crane flies (fig. 10). Nitrate concentrations at sites 25 and 51 consistently were above the USEPA drinking water standard of 10 mg/L, and phosphorus concentrations were 10 times the recommended limit of 0.10 mg/L. Concentrations of ammonia and major ions were elevated over other sites in the basin (fig. 11). The degraded stream quality created by the discharges from the wastewater-treatment plant is limiting the benthic macroinvertebrates in Goose Creek and East Branch Chester Creek below Goose Creek.

Sites in the Delaware River Basin are mostly suburban streams; residential land use is dominant in the basin. Most streams were degraded in taxa richness and HBI values when compared to the reference site. Sites have specific problems that cause them to be degraded, ranging from altered habitat to the effects of discharges from wastewater-treatment plants. Discharges from a wastewater-treatment plant have a negative effect on Goose Creek and the East Branch Chester Creek below Westtown. The percent impervious surface is above 10 percent in Darby Creek and is above 5 percent in Crum, Ridley, and Chester Creeks. Stream degradation is likely to occur when percent impervious reaches 10 to 20 percent in the basin (Schueler, 1995). Samples of stream-bottom sediment contained concentrations of chlordane, DDT, and PCBs above the threshold effect concentration in the 1980s, but concentrations of these compounds decreased to below the threshold effect concentration in the 1990s. Concentrations below the threshold effect concentration have little or no biological effect on the majority of benthic organisms (MacDonald and others, 2000). The concentrations were highest in samples from Goose Creek and East Branch Chester Creek below Goose Creek.

Brandywine Creek Basin

Streams sampled in the Brandywine Creek Basin were the West Branch Brandywine Creek, Buck Run, Doe Run, East Branch Brandywine Creek, Indian Run, West Valley Creek, and the main stem Brandywine Creek. The Brandywine Creek Basin drains the center of the county and includes the Boroughs of Coatesville, Downingtown, and West Chester. Land use in the basin is dominated by a mix of agriculture, forested, and residential areas. Assessments of stream quality, on the basis of benthic-macroinvertebrate criteria, are presented in table 6.

Table 6. *Assessment of stream quality on the basis of median values of taxa richness, EPT taxa richness, and HBI for sites in the Brandywine Creek Basin, Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, and Trichoptera; HBI, Hilsenhoff's biotic index; Assessment based on values presented in tables 37-47]

U.S. Geological Survey station identification number	Site number	Taxa richness	EPT taxa richness	HBI
		West Branch Brandywine Creek		
01480434	37	Nonimpacted	Nonimpacted	Slightly impacted
01480640	38	Slightly impacted	Nonimpacted	Slightly impacted
		Buck Run		
01480629	46	Slightly impacted	Nonimpacted	Slightly impacted
		Doe Run		
01480632	45	Slightly impacted	Nonimpacted	Slightly impacted
		East Branch Brandywine Creek		
01480648	48	Nonimpacted	Nonimpacted	Slightly impacted
01480653	42	Nonimpacted	Nonimpacted	Nonimpacted
01480700	36	Nonimpacted	Nonimpacted	Slightly impacted
01480950	39	Nonimpacted	Nonimpacted	Nonimpacted
		Indian Run		
01480656	47	Nonimpacted	Nonimpacted	Nonimpacted
		West Valley Creek		
01480903	44	Slightly impacted	Nonimpacted	Nonimpacted
		Main Stem Brandywine Creek		
01481030	40	Nonimpacted	Nonimpacted	Slightly impacted

West Branch Brandywine Creek

Four sampling sites were in the West Branch Brandywine Creek Basin—two on the West Branch Brandywine Creek (sites 37 and 38), one on Buck Run (site 46), and one on Doe Run (site 45). Drainage areas range from 11.8 mi^2 at site 45 to 134 mi^2 at site 38. The stream is approximately 40 ft wide at site 37 and is 55 ft wide at site 38. The predominant land-use categories at site 38 are agriculture (50 percent), forested (29 percent), and residential (14 percent) (Delaware Valley Regional Planning Commission, 1997). These sites were sampled annually from 1981 through 1997.

Sites 37 and 38 were assessed as nonimpacted or slightly impacted on the basis of calculated biological metrics (table 6). The benthic-macroinvertebrate community at these sites was diverse with a large number of “pollution sensitive” organisms, which are indications of good stream conditions. “Pollution tolerant” organisms were present in occasionally high numbers (where 57 percent of individuals were midges in 1991) , particularly at site 37, indicating some disturbance. Site 37 had consistent taxa richness and EPT taxa richness (table 37, page 62) along with consistent water chemistry since 1981. Site 38 had an increase in taxa richness in 1989 (table 40, page 64) that corresponds to a decrease in phosphorus concentrations at the same time. Concentrations of phosphorus decreased from above the USEPA recommended level of 0.1 mg/L in 1990 to 0.04 mg/L in 1994; taxa richness rose from 23 to 37 (fig. 12). Other chemical constituents were stable over the period of record. Sites 37 and 38 had increased taxa richness and EPT taxa richness when compared to the reference site but also have slightly higher HBI values.

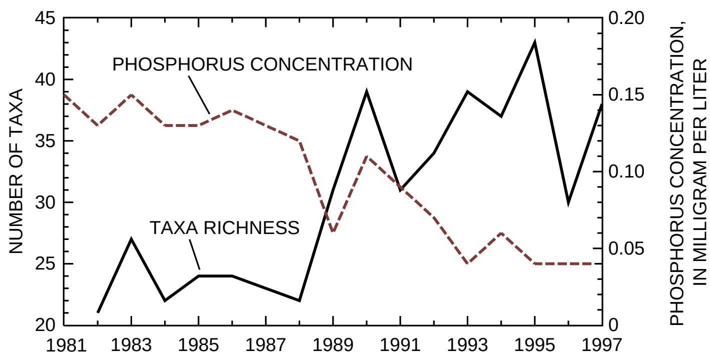

Figure 12. Taxa richness and phosphorus concentrations from West Branch Brandywine Creek at Wawaset (site 38), Chester County, Pennsylvania, 1981-97.

Buck Run (site 46) and Doe Run (site 45) were assessed as slightly impacted on the basis of median values of taxa richness and HBI and were assessed as nonimpacted on the basis of EPT taxa richness (table 6). The benthic-macroinvertebrate community at both sites was diverse with large numbers of mayflies, caddisflies, and riffle beetles, which are indications of good stream quality. “Pollution tolerant” organisms occasionally were present in high numbers, indicating some disturbance. Both sites had an increase in EPT taxa richness and a decrease in HBI values around 1986 (tables 38 and 39, page 63) that correspond to a decrease in concentrations of phosphorus similar to that noted at site 38. Since 1986, the benthic-macroinvertebrate, habitat, and chemical data indicate stable conditions at both sites. Site 45 is the reference site for the western and southern part of the county.

The sites in the West Branch Brandywine Creek had diverse benthic-macroinvertebrate communities that increased in taxa richness and EPT taxa richness (fig. 13) and decreased in HBI values over time. Water chemistry generally was stable with slightly increasing concentrations of nitrate and major ions and decreasing concentrations of ammonia and phosphorus. Samples of stream-bottom sediment generally contained pesticide concentrations that were below the threshold effect concentration and were decreasing over time. Habitat was fairly stable, although siltation was a problem at most sites. The West Branch

Brandywine Creek is affected by agricultural and urban runoff and discharges from wastewater-treatment plants but benthic-macroinvertebrate communities and water chemistry were stable, indicating good overall stream conditions.

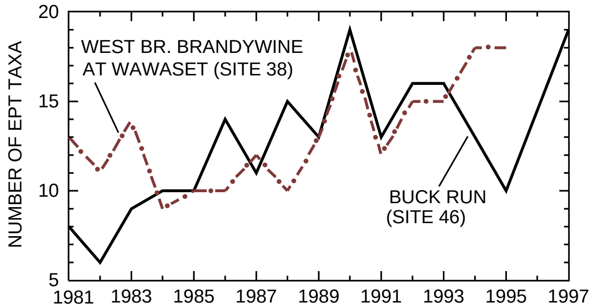

Figure 13. Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa richness from Buck Run (site 46) and West Branch Brandywine Creek at Wawaset (site 38), Chester County, Pennsylvania, 1981-97.

East Branch Brandywine Creek

Six sampling sites were in the East Branch Brandywine Creek Basin—four sites on the East Branch Brandywine Creek (sites 48, 42, 36, and 39), one site on Indian Run (site 47), and one site on West Valley Creek (site 44). Drainage areas range in size from 4.26 mi^2 at site 47 to 123 mi^2 at site 39. The stream ranges in size from approximately 15 ft wide at site 48 to 52 ft wide at site 39. The predominant land-use categories at site 39 are forested (34 percent), agriculture (30 percent), and residential (26 percent) (Delaware Valley Regional Planning Commission, 1997). These sites were sampled annually from 1981 through 1997.

Sites 42 and 48 are on the upper East Branch Brandywine Creek. Site 47 is on Indian Run, a tributary to the upper East Branch Brandywine Creek. These sites were assessed as nonimpacted on the basis of calculated biological metrics except for site 48, which was assessed as slightly impacted on the basis of median values of HBI (table 6). The benthic-macroinvertebrate community at all of these sites was diverse with large numbers of “pollution sensitive” organisms and low populations of “pollution tolerant” organisms. Sites 42 and 47 have had consistent benthic-macroinvertebrate communities and stable habitat. Water-chemistry data indicate low but increasing concentrations of nitrate and major ions and decreasing concentrations of phosphorus and ammonia. These sites had biological metric values and chemical concentrations similar to the reference site.

Site 48 is in the headwaters and had varied benthic-macroinvertebrate, physical, and chemical data. The benthic-macroinvertebrate community at site 48 was variable with occasionally large numbers of individuals (table 41, page 64). Chemical data indicate occasionally increased ammonia concentration and increasing concentrations of nitrate and major ions. East Branch Brandywine Creek at site 48 is a small headwater stream (5.98-mi^2 drainage area), and the variable benthic-macroinvertebrate communities may be because of the inconsistent water chemistry and shifting stream bottom noted at this site.

Sites 36, 39, and 44 are on the lower East Branch Brandywine Creek. These sites were assessed as nonimpacted or slightly impacted on the basis of median values of the biological metrics measured (table 6). The invertebrate communities at all of these sites were diverse with large numbers of mayflies, caddisflies, and riffle beetles, which indicate good stream quality. Although sites 39 and 44 were assessed as nonimpacted or slightly impacted, their water chemistry and benthic-macroinvertebrates communities have been inconsistent.

Concentrations of ammonia and phosphorus at site 39 were elevated over the reference site and sites upstream on the East Branch Brandywine Creek from 1981 to 1985. Concentrations decreased after 1986 and EPT taxa richness increased from 1986 to 1991 (table 46, page 67). EPT taxa richness declined after 1991 without any associated change in measured water chemistry.

Site 44 had very variable metric numbers with large changes year to year (table 45, page 66). “Pollution tolerant” organisms occasionally are present in relatively high numbers and dense growths of algae were always present. These indicate possible organic enrichment. Chemical data indicate consistent water chemistry. Biological metric values at site 44 indicate degraded stream quality when compared to the reference site (fig. 14). Ground-water discharge from limestone formations along with nutrient enrichment may be factors in the reduced taxa at site 44. Site 44 is immediately downstream from Broad Run, which has an increased nutrient load because of a small wastewater-treatment discharge and ground-water discharge from unsewered parts of the West Valley Creek Basin (Senior and others, 1997).

Sites in the upper part of the East Branch Brandywine Creek (sites 42 and 47) had consistent macroinvertebrate communities that were assessed as nonimpacted (table 6). Sites in the lower part of the East Branch Brandywine Creek (sites 36, 44, and 39) had lower taxa richness and EPT taxa richness and

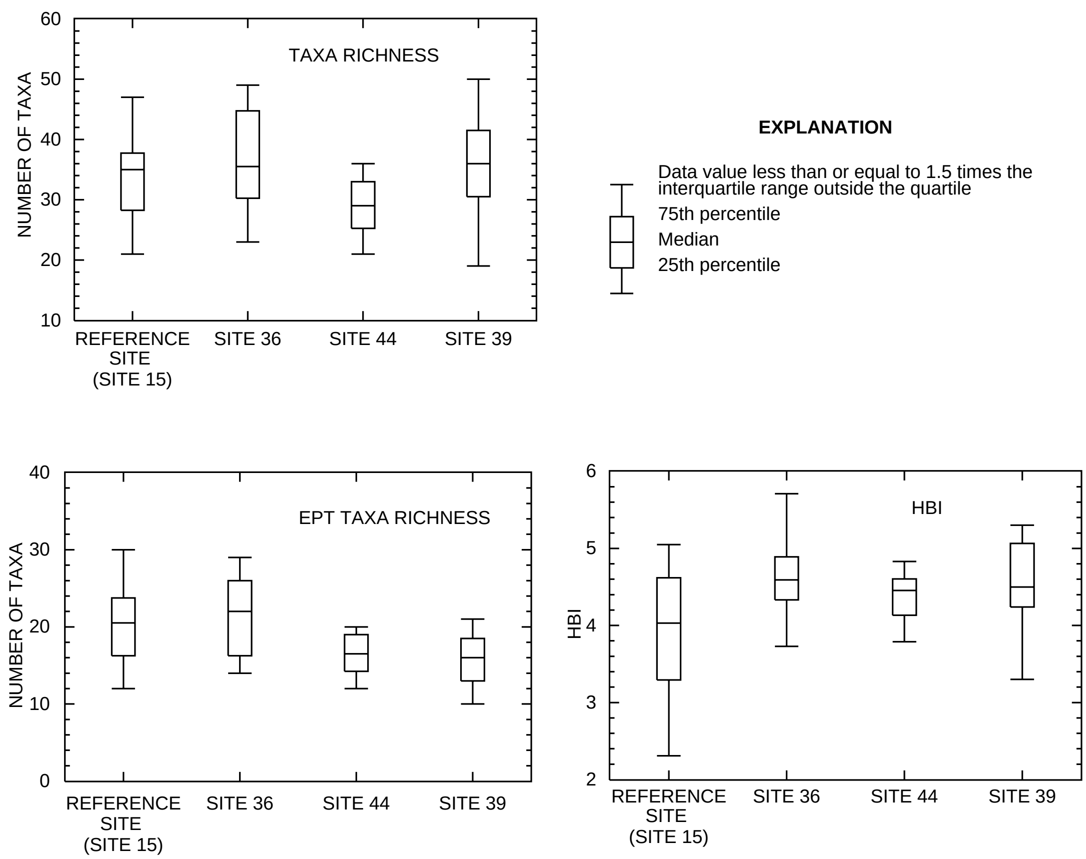

Figure 14. Taxa richness, Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa richness, and Hilsenhoff’s biotic index (HBI) values from reference site (site 15), East Branch Brandywine Creek near Downingtown (site 36), West Valley Creek (site 44), and East Branch Brandywine Creek at Wawaset (site 39), Chester County, Pennsylvania, 1981-97.

higher HBI values from 1981 to 1987. After 1987, sites in the lower East Branch Brandywine Creek had increasing taxa richness and EPT taxa richness and decreasing HBI values; sites in the upper East Branch Brandywine Creek remained unchanged. By the mid 1990s, the sites on the upper and lower parts of the East Branch Brandywine Creek had similar biological metrics (fig. 15). Samples of stream-bottom sediment generally contained pesticide concentrations that were below the threshold effect concentration and were decreasing over time.

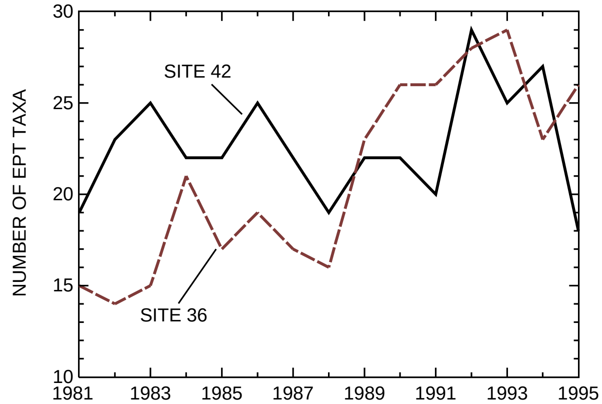

Figure 15. Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa richness from site 42 and site 36 on the East Branch Brandywine Creek, Chester County, Pennsylvania, 1981-95.

Main Stem Brandywine Creek

The site on the main stem Brandywine Creek is near Chadds Ford (site 40). The drainage area at site 40 is 291 mi^2. This site is the largest in the Stream Conditions of Chester County Biological Monitoring Network. The stream is 100 ft wide and less than 2 ft deep at the sampling site. The predominant land-use categories at site 40 are agriculture (39 percent), forested (31 percent), and residential (21 percent) (Delaware Valley Regional Planning Commission, 1997). This site was sampled annually from 1981 through 1995 and in 1997.

The main stem Brandywine Creek was assessed as nonimpacted on the basis of median values of taxa richness and EPT taxa richness and as slightly impacted on the basis of HBI values (table 6). Taxa richness and EPT taxa richness increased and HBI values decreased starting around 1987 (table 47). Site 40 had a decrease in concentrations of ammonia and phosphorus associated with improved stream conditions similar to that measured in the East and West Branch Brandywine Creeks. The benthic-macroinvertebrate community at this site was diverse with large numbers of “pollution sensitive” organisms including mayflies, caddisflies, and riffle beetles, which are indications of good stream quality. “Pollution tolerant” organisms are present but in relatively low numbers. This site had similar taxa richness and EPT taxa richness but slightly increased HBI values when compared to the reference site. This site receives a mix of agricultural, urban, and wastewater-treatment plant discharges but contains a benthic-macroinvertebrate community that indicates good stream conditions. Most inputs that could impair water quality are far enough upstream to be attenuated at the main stem Brandywine Creek site. Water-quality conditions at this site also may be buffered by large acreages of wetland immediately upstream from the sampling location.

Red Clay and White Clay Creek Basins

Streams sampled in the Red Clay and White Clay Creek Basins were the East Branch Red Clay Creek, West Branch Red Clay Creek, East Branch White Clay Creek, Middle Branch White Clay Creek, and the West Branch White Clay Creek. The Red Clay and White Clay Creek Basins drain the south-central part of the county, including the boroughs of Kennett Square, Avondale, and West Grove. Land use in both basins is dominated by a mix of agriculture (including mushroom farming), residential, and forested areas. Assessments of stream quality, on the basis of benthic-macroinvertebrate criteria, are presented in table 7.

Table 7. *Assessment of stream quality on the basis of median values of taxa richness, EPT taxa richness, and HBI for sites in the Red Clay and White Clay Creek Basins, Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, and Trichoptera; HBI, Hilsenhoff's biotic index; Assessment based on values presented in tables 48-52]

U.S. Geological Survey station identification number	Site number	Taxa richness	EPT taxa richness	HBI
		Red Clay Creek		
01479680	27	Moderately impacted	Moderately impacted	Slightly impacted
01479800	26	Moderately impacted	Moderately impacted	Slightly impacted
		White Clay Creek		
01478120	28	Slightly impacted	Slightly impacted	Slightly impacted
01478190	29	Slightly impacted	Nonimpacted	Slightly impacted
01478220	30	Slightly impacted	Nonimpacted	Slightly impacted

Red Clay Creek

Two sampling sites were in the Red Clay Creek Basin—one on the West Branch (site 27) and one on the East Branch (site 26). The drainage areas are approximately 10 mi^2, and the stream is approximately 17 ft wide at both sites. The predominant land-use categories in the entire basin are agriculture (50 percent), residential (21 percent), and forested (20 percent) (Delaware Valley Regional Planning Commission, 1997). The agricultural land use in the basin includes a large mushroom-producing area in the central and western parts of the basin and surrounding the Borough of Kennett Square. Water quality in the Red Clay Creek Basin has been affected by the use of fertilizers and pesticides related to general agriculture and the mushroom industry. Spent compost may contain potential contaminants including organochlorine and organophosphorus insecticides and heavy metals. The basin also has potential contaminants, including PCBs, associated with industrial and commercial land use (Sloto, 1987). The sites were sampled annually from 1981 through 1997.

Sites in the Red Clay Creek Basin had benthic-macroinvertebrate communities with few EPT taxa and HBI values elevated over reference sites and sites in surrounding basins (fig. 16). Both sites were assessed as slightly or moderately impacted on the basis of calculated biological metrics (table 7). Dominant taxa were "pollution tolerant" organisms including chironomids, aquatic worms, and crane flies (fig. 17). Field observations have noted that heavy siltation and algal growth are degrading the physical habitat at both sites. Chemical data indicate steady concentrations of nutrients and major ions but at levels elevated over the reference site. Samples of stream-bottom sediment collected in the mid-1980s at both sites contained concentrations of DDT and PCBs above the threshold effect concentration (table 13). Concentrations above the threshold effect concentration are likely to cause changes in the composition of benthic-macroinvertebrate communities (MacDonald and others, 2000).

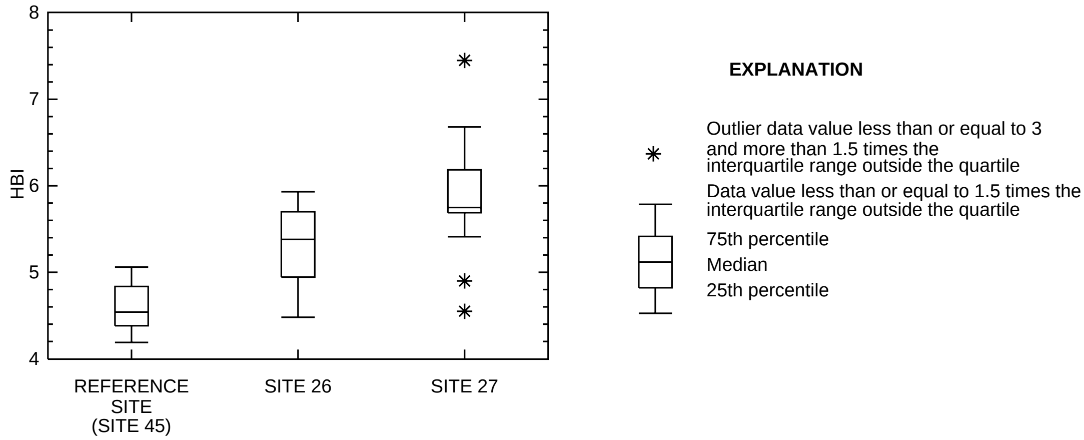

Figure 16. Hilsenhoff's biotic index (HBI) values from reference site (site 45), East Branch Red Clay Creek (site 26), and West Branch Red Clay Creek (site 27), Chester County, Pennsylvania, 1981-97.

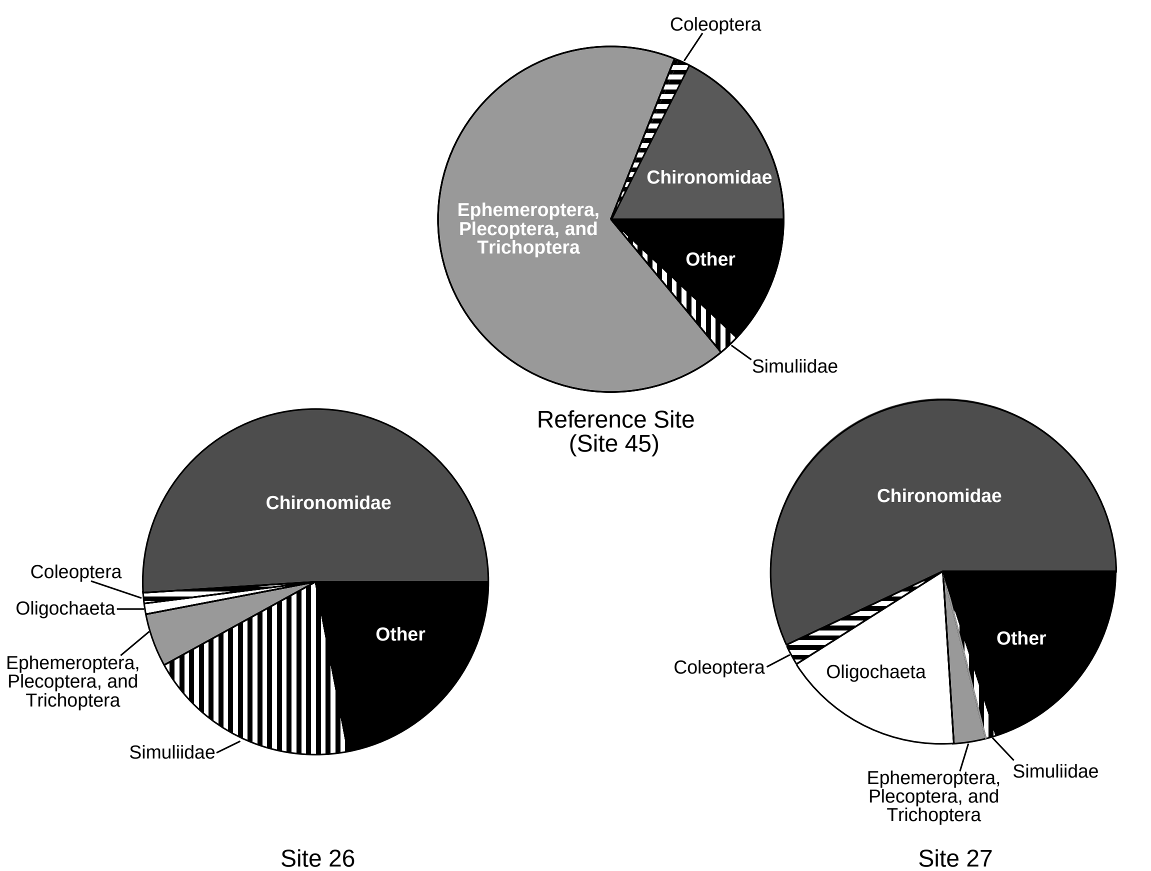

Figure 17. Community composition of benthic-macroinvertebrate communities from the reference site (site 45), East Branch Red Clay Creek (site 26), and West Branch Red Clay Creek (site 27), Chester County, Pennsylvania, 1994.

Although biological metrics indicated slightly or moderately impacted conditions at both sites, stream conditions have been improving over time. Taxa richness and EPT taxa richness have increased and HBI values at site 26 decreased after 1993 (tables 48 and 49, page 68). Stream-bottom sediment data indicate pesticide and PCB contamination was reduced between 1983 and 1993 (table 13). The improvement in benthic-macroinvertebrate communities is most likely because of the decrease in the toxicity of stream sediments. Despite the improvement, both sites have benthic-macroinvertebrate communities that differ greatly from the reference conditions (figs. 16 and 18). These sites are subject to urban and agricultural runoff and habitat degradation because of siltation.

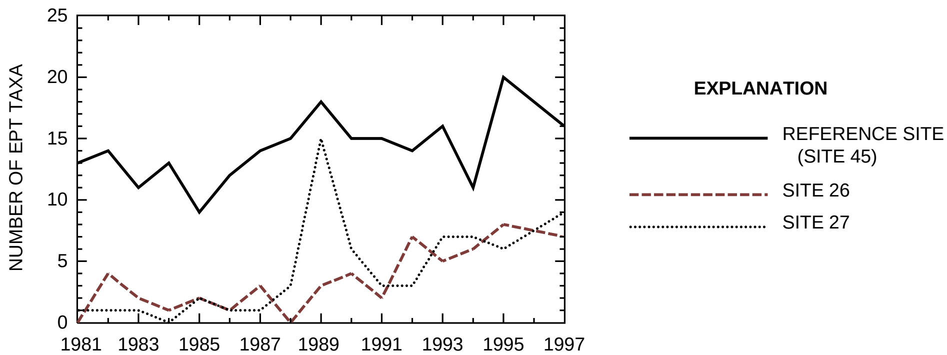

Figure 18. Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa richness from reference site (site 45), East Branch Red Clay Creek (site 26), and West Branch Red Clay Creek (site 27), Chester County, Pennsylvania, 1981-97.

White Clay Creek

Three sampling sites were in the White Clay Creek Basin—one on the East Branch (site 28), one on the Middle Branch (site 29), and one on the West Branch (site 30). The drainage area at each site is approximately 10 mi^2. The stream sites are approximately 20 to 35 ft wide. The predominant land-use categories at the three sites sampled are agriculture (61 percent), forested (22 percent), and residential (13 percent) (Delaware Valley Regional Planning Commission, 1997). The sites were sampled annually from 1981 through 1995 and 1997.

The three sites in the White Clay Creek Basin were assessed as nonimpacted or slightly impacted on the basis of calculated biological metrics (table 7). All sites had benthic-macroinvertebrate communities that had relatively high numbers of “pollution tolerant” organisms compared to the reference site, including chironomids, flatworms, and crane flies. Between 1981 and 1997, these sites had an increase in taxa richness and EPT taxa richness (tables 50-52, page 69-70), which is an indication of improved stream conditions (fig. 19). Biological metrics indicated that stream conditions improved in an east to west direction within the basin (fig. 20). The biological metrics at site 30 on the West Branch White Clay Creek consistently indicated better stream conditions when compared to site 28 on the East Branch. Water-chemistry data have a pattern similar to the benthic-macroinvertebrate data. Concentrations of nutrients and major ions decreased in an east to west direction in the basin; the East Branch is elevated over the reference site and the West and Middle Branches. Site 28 is in the Borough of Avondale and receives localized urban runoff and agricultural runoff. Sites 29 and 30 are away from any direct urban influences.

The sites in the Red and White Clay Creek Basins had benthic-macroinvertebrate communities that indicate improved stream conditions from 1981 to 1997. These sites, however, were degraded from the reference conditions. Biological metrics indicate improved stream conditions in an east to west direction in the White Clay Creek Basin (fig. 21). Water chemistry generally was stable with slightly increasing concentrations of nitrates and major ions along with decreasing concentrations of ammonia and

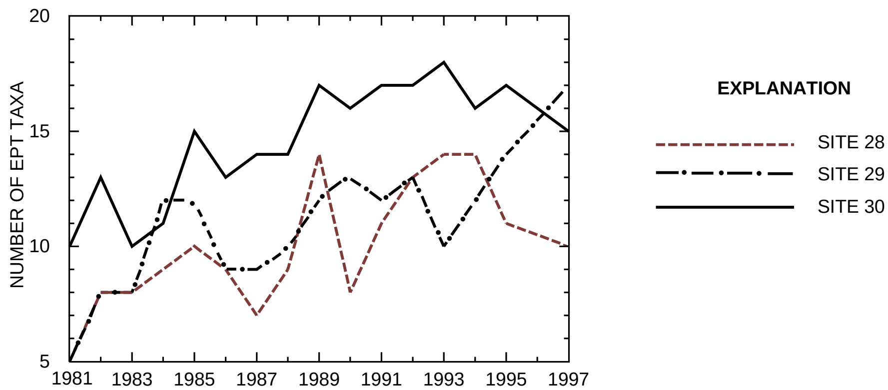

Figure 19. Numbers of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa from East Branch White Clay Creek (site 28), Middle Branch White Clay Creek (site 29), and West Branch White Clay Creek (site 30), Chester County, Pennsylvania, 1981-97.

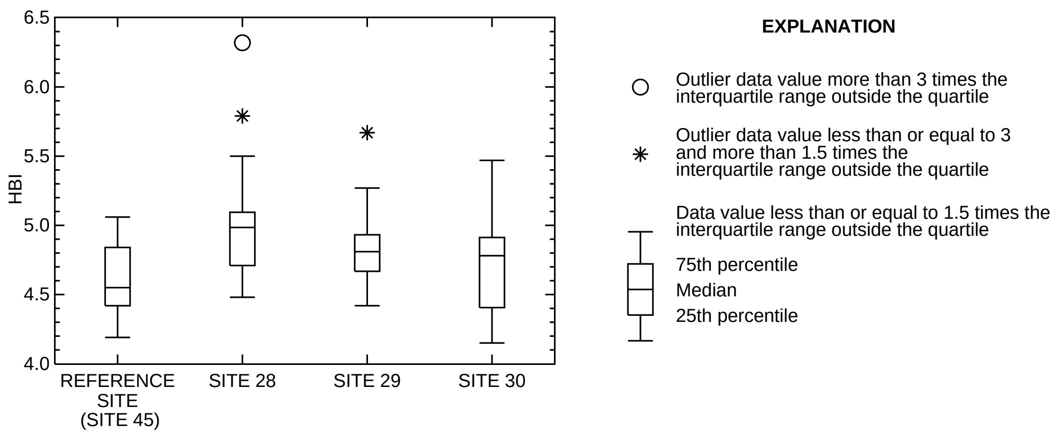

Figure 20. Hilsenhoff's biotic index (HBI) values for the reference site (site 45), East Branch White Clay Creek (site 28), Middle Branch White Clay Creek (site 29), and West Branch White Clay Creek (site 30), Chester County, Pennsylvania, 1981-97.

phosphorus. Although water chemistry was stable and similar to the reference conditions, the stream bottom was subjected to heavy siltation at sites 26, 27, and 28. These sites receive runoff from urban and agricultural areas including heavy mushroom farming.

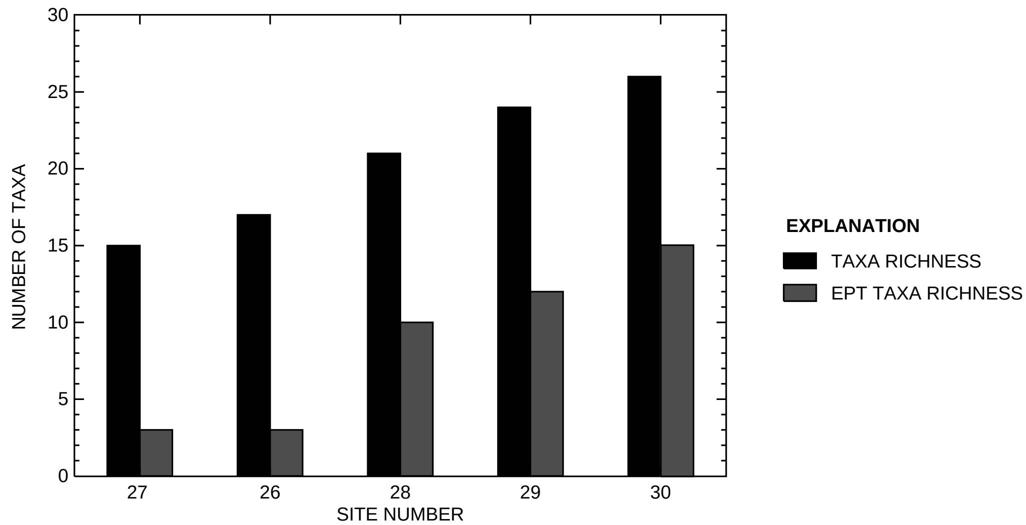

Figure 21. Median values of taxa richness and Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa richness from sampling sites in the Red Clay and White Clay Creek Basins, Chester County, Pennsylvania, 1981-97.

Big Elk and Octoraro Creek Basins

Streams sampled in the Big Elk Creek Basin were the East Branch and West Branch Big Elk Creek. The Big Elk Creek Basin drains the southwest part of Chester County including the borough of Oxford. Streams sampled in the Octoraro Creek Basin were East Branch Octoraro Creek and Valley Creek. The Octoraro Creek Basin drains the southwestern part of the county and includes the boroughs of Parkesburg and Atglen. Land use in the basin is dominated by a mix of agriculture and forested areas. Assessments of stream quality, on the basis of benthic-macroinvertebrate criteria, are presented in table 8.

Table 8. *Assessment of stream quality on the basis of median values of taxa richness, EPT taxa richness, and HBI for sites in the Big Elk and Octoraro Creek Basins, Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, and Trichoptera; HBI, Hilsenhoff’s biotic index; Assessment based on values presented in tables 53-56]

U.S. Geological Survey station identification number	Site number	Taxa richness	EPT taxa richness	HBI
		Big Elk Creek		
01494900	31	Slightly impacted	Nonimpacted	Slightly impacted
01494950	32	Slightly impacted	Nonimpacted	Slightly impacted
		Octoraro Creek		
01578340	33	Slightly impacted	Nonimpacted	Slightly impacted
01578343	34	Slightly impacted	Nonimpacted	Slightly impacted

Big Elk Creek

Two sampling sites were in the Big Elk Creek Basin—one on the East Branch (site 31) and one on the West Branch (site 32). The drainage area of each site is approximately 10 mi^2. The stream is approximately 18 ft wide at site 31 and is 30 ft wide at site 32. The predominant land-use categories in the basin are agriculture (68 percent), forested (15 percent), and residential (12 percent) (Delaware Valley Regional Planning Commission, 1997). These sites were sampled annually from 1981 through 1997.

Both sites in the Big Elk Creek Basin were assessed as slightly impacted on the basis of median values of taxa richness and HBI and as nonimpacted on the basis of EPT taxa richness (table 8). Through 1993, both sites had taxa richness and EPT taxa richness values similar to the reference site but higher HBI values because of a relatively high number of "pollution tolerant" organisms (compared to the reference site) including chironomids and crane flies (fig. 22). These sites had increased concentrations of nutrients and major ions and heavier sedimentation when compared to the reference site. The degraded chemical and physical conditions are affecting the benthic-macroinvertebrate communities negatively in the Big Elk Creek Basin.

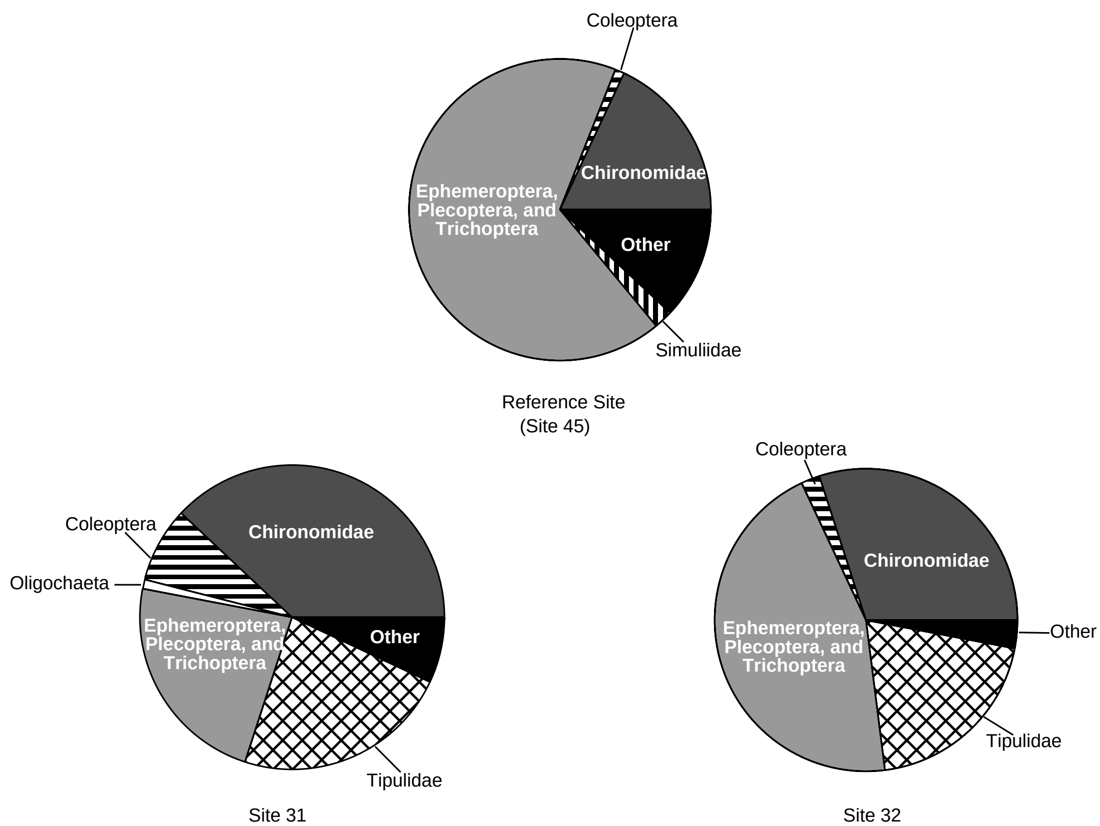

Figure 22. Community composition of reference site (site 45), East Branch Big Elk Creek (site 31), and West Branch Big Elk Creek (site 32), Chester County, Pennsylvania, 1993.

Both sites had a decrease in taxa richness and EPT taxa richness starting in 1994. The decrease in organisms was most noticeable at site 31 where EPT taxa richness declined from 13 in 1992 to 3 in 1996 (fig. 23). Analysis of physical and chemical data did not reveal any change in the habitat or water chemistry at these sites to explain the decrease in taxa. The sudden drop in taxa from all groups of benthic macroinvertebrates may be caused by some factor not measured in the physical or chemical sampling, such as pesticide contamination.

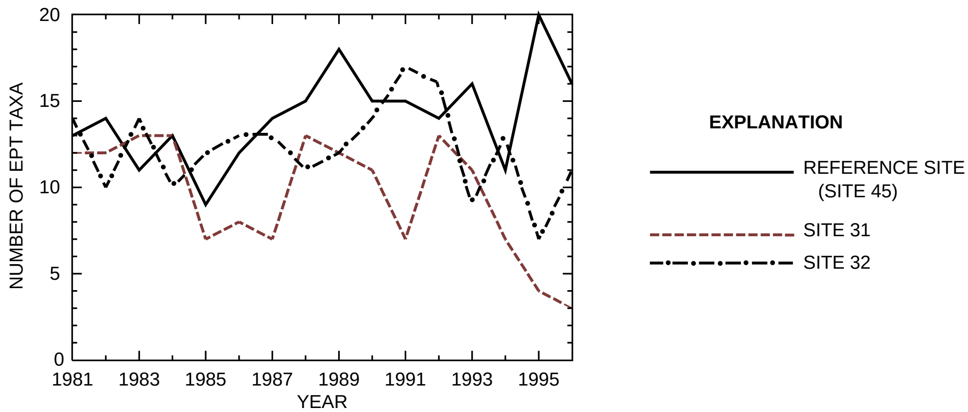

Figure 23. Number of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa from the reference site (site 45), East Branch Big Elk Creek (site 31), and West Branch Big Elk Creek (site 32), Chester County, Pennsylvania, 1981-96.

East Branch Octoraro Creek

Two sampling sites were in the East Branch Octoraro Creek Basin—one on the East Branch Octoraro Creek (site 33) and one on Valley Creek (site 34). The drainage area of both sites is approximately 10 mi^2. The stream is approximately 21 ft wide at site 34 and is 55 ft wide at site 33. The predominant land-use categories at site 33 are agriculture (69 percent), forested (15 percent), and residential (11 percent) (Delaware Valley Regional Planning Commission, 1997; Lancaster County, 2002). These sites were sampled annually from 1981 through 1997.

Both sampling sites were assessed as nonimpacted or slightly impacted on the basis of calculated biological metrics (table 8). The benthic-macroinvertebrate community at site 33 occasionally had high numbers of “pollution tolerant” organisms including chironomids, black flies, aquatic worms, and crane flies, but this number was offset by a large population of “pollution sensitive” organisms. These year-to-year differences in community composition are reflected in widely fluctuating values of the HBI (fig. 24). Taxa richness and EPT taxa richness were stable since 1982 (tables 55 and 56, pages 71-72). Physical and chemical data indicate increasing concentrations of nitrate and major ions and decreasing concentrations of ammonia and phosphorus at these sites. The nitrate concentrations increased from 5.10 mg/L in 1981 to 9.0 mg/L in 1997 (fig. 25). Heavy agriculture in the basin is the most likely source of the nutrient enrichment. Despite the increased concentrations of nitrate, the benthic-macroinvertebrate data indicate improved stream quality. The improved stream quality most likely is related to the decreased ammonia concentrations, which can lead to increased concentrations of dissolved oxygen.

Site 34 had very inconsistent benthic-macroinvertebrate and water-chemistry data from 1981 to 1997. Site 34 had a benthic-macroinvertebrate community with occasionally high numbers of “pollution tolerant” organisms including chironomids, black flies, worms, and crane flies. Biological metrics were variable, indicating inconsistent stream conditions (table 56, page 72). Water chemistry at site 34 also was highly variable; concentrations of nutrients and major ions were elevated over reference conditions. Nitrate concentrations increased and phosphorus concentrations decreased since 1981 in a pattern similar to the East Branch Octoraro Creek (fig. 25). However, ammonia concentrations increased at site 34 from 0.050 mg/L in 1981 to a maximum of 0.34 mg/L in 1994. An increase in ammonia can lead to a decrease in

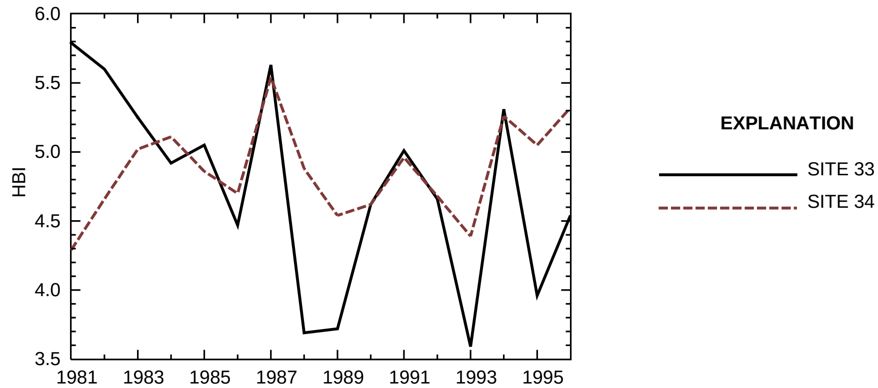

Figure 24. Hilsenhoff's biotic index (HBI) values from East Branch Octoraro Creek (site 33) and Valley Creek (site 34), Chester County, Pennsylvania, 1981-96.

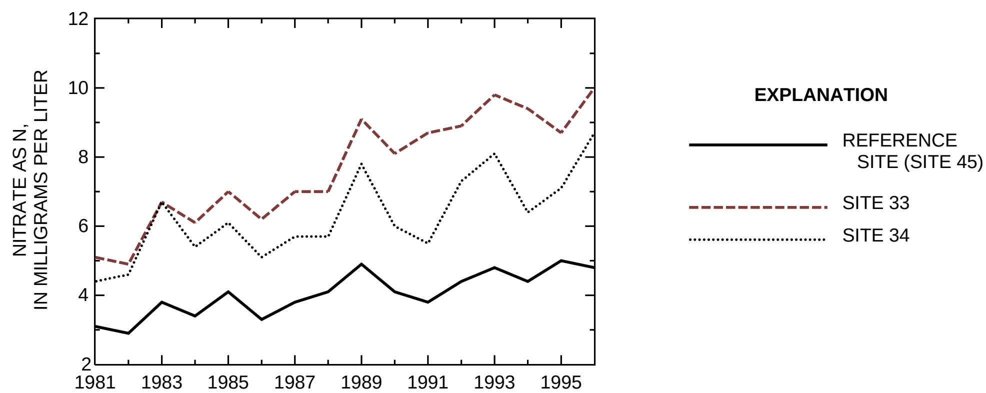

Figure 25. Nitrate concentrations from the reference site (site 45), East Branch Octoraro Creek (site 33), and Valley Creek (site 34), Chester County, Pennsylvania, 1981-96.

dissolved oxygen, which can affect the benthic-macroinvertebrate communities negatively. The physical habitat at the site was stable, but the stream bottom was subjected to heavy sedimentation. Nutrient enrichment, including elevated concentrations of ammonia, are most likely from heavy agriculture and a small wastewater-treatment plant that discharges into the stream upstream of the site.

The sites in the East Branch Octoraro Creek Basin had water chemistry and benthic-macroinvertebrate community structure that was different from reference conditions. Both streams had higher concentrations of nutrients and major ions, and the concentration of nitrate has been increasing since 1981. The benthic-macroinvertebrate community contained increased numbers of "pollution tolerant" organisms compared to the reference site, indicating degraded stream conditions. Although both sites differ from the reference conditions, the calculated biological metrics indicate improving stream quality at site 33 on the East Branch Octoraro Creek and declining stream quality at site 34 on Valley Creek. Nitrate concentrations at site 33 were higher than site 34, but concentrations of ammonia and phosphorus were lower. The difference in nutrient concentrations may be because of discharge from a wastewater-treatment plant that affects site 34.

Summary of Stream-Quality Conditions

Benthic-macroinvertebrate samples collected in Chester County from 1981 to 1997 indicate nonimpacted or slightly impacted conditions at most of the 43 sites sampled. Sites in the Pigeon, French, Pickering, and upper East Branch Brandywine Creek Basins generally were assessed as nonimpacted with stable physical and chemical data. These sites receive minimal disturbance. Sites in the Darby, Crum, Ridley, Valley, and lower East Branch Brandywine Creek Basins are being degraded compared with reference conditions, possibly resulting from habitat alteration.

Sites in the West Branch Brandywine, Red Clay, White Clay, Big Elk, and Octoraro Creek Basins had benthic-macroinvertebrate communities that indicated a degradation in stream conditions from reference conditions. These basins have more agricultural land, which can cause increased concentrations of nutrients and major ions and increased sedimentation. Sites near discharges from wastewater-treatment plants have benthic-macroinvertebrate communities that indicate the poorest stream conditions.

Along with general patterns in benthic-macroinvertebrate communities, the community structure shows incidents of dramatic changes. Examples of these include a significant change in taxa richness, EPT taxa richness, and HBI values between 1989 and 1991 at site 22 and between 1993 and 1996 at site 31. The degraded stream quality at site 22 was caused by an increase in manganese concentrations from a malfunctioning ground-water air stripper discharging into the stream. The benthic macroinvertebrates at site 22 recovered when the air stripper was shut off. The degraded stream quality at site 31 could not be attributed to any measured change in physical or chemical conditions.

Trend Analysis

Biological organisms usually are found in nature in a nonrandom distribution. This nonrandom distribution is a result of habitat and behavior requirements of the individual organisms (Greeson and others, 1977). Nonparametric statistical methods are suggested for the detection of trends in stream-quality data because of the problems of skewness and serial correlation (Hirsch and others, 1982). The Mann-Kendall test for trend, a nonparametric, distribution-free statistical test for monotonic trend with time, was used to detect trends in taxa richness, EPT taxa richness, and HBI at each site. The Mann-Kendall test for trend also was used to detect trends in specific conductance and concentrations of nitrate, ammonia, and phosphorus at each site.

Mann-Kendall Test for Trend in Biological Metrics

The Mann-Kendall test for trend was used to detect trends in taxa richness, EPT taxa richness, and HBI from 1981 through 1997 at each of the 43 sampling sites. This statistical technique was used by Moore (1987) and Hardy and others (1995) to evaluate trends in values of Brillouin's diversity index from sites in the Stream Conditions of Chester County Biological Monitoring Network. The results of the trend test are presented in table 9. Trends were considered significant if the p value was greater than 90 percent.

Table 9. *Mann-Kendall test of taxa richness, EPT taxa richness, and HBI from selected streams in Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, and Trichoptera; HBI, Hilsenhoff's biotic index; p>90, trends were considered significant if the p value was greater than 90 percent]

Basin	Number of sites	Taxa richness[1]		EPT taxa richness[2]		HBI[3]	
		Positive trends (p>90)	Negative trends (p>90)	Positive trends (p>90)	Negative trends (p>90)	Positive trends (p>90)	Negative trends (p>90)
Schuylkill River Basin	14	5	0	6	0	1	3
Delaware River Basin	9	1	0	1	1	3	2
Brandywine Creek Basin	11	4	0	5	1	0	3
Red / White Clay Creek Basins	5	5	0	5	0	0	0
Big Elk / Octoraro Creek Basins	4	1	1	1	1	0	2

[1] Positive trend for taxa richness indicates improving biological community.
[2] Positive trend for EPT taxa richness indicates improving biological community.
[3] Negative trend for HBI indicates improving biological community.

Trends in biological metrics from the 43 sites in Chester County indicate unchanged or improving stream conditions at most sites between 1981 and 1997. Positive trends were measured at 37 percent of the sites for taxa richness and at 42 percent of the sites for EPT taxa richness. One site had a decreasing trend in taxa richness and three sites had decreasing trends in EPT taxa richness. Decreasing trends in HBI were measured at 27 percent of the sites and positive trends at 9 percent of the sites. Increasing taxa richness and decreasing HBI are indications of improved stream quality. Significant trends in these biological metrics indicate values that are changing in one direction over time. Temporary changes in stream quality may occur within the time period and not be reflected in a significant trend.

The improvement in stream conditions may be the result of various factors, including upgrading and eliminating wastewater-treatment plants, reducing organochlorine pesticide use, changing land use from agriculture to suburban, and improving farm-management procedures. These factors have improved the water chemistry and reduced the toxicity and amount of sediment reaching the stream bottom.

The basins that showed the most consistent improvement in biological metric values were Red Clay and White Clay Creeks. All five sites in the basins had significant increases in taxa richness and EPT taxa richness from 1981 to 1997. Although the trends in taxa richness and EPT taxa richness are indicating better stream conditions in these basins, the samples from the Red Clay Creek Basin have low taxa richness and EPT taxa richness and high HBI values compared to other sites in Chester County. The HBI at the Red Clay Creek sites had no significant trend from 1981 to 1997, despite the increase in total taxa and EPT taxa; these patterns suggest that the communities are still dominated by “pollution tolerant” organisms. These streams are in an area where mushroom farming is common and, therefore, have high concentrations of nutrients and heavy sedimentation. Decreasing toxicity of bottom sediments may be one factor for the observed changes in biological communities.

Mann-Kendall Test For Trend in Chemical Constituents

Samples of stream water were collected in conjunction with each benthic-macroinvertebrate sample. Concentrations of nutrients, major ions, and dissolved metals were determined. Changing concentrations of these constituents over time is a factor affecting the benthic-macroinvertebrate communities. The Mann-Kendall test for trend was calculated to evaluate trends in specific conductance and concentrations of nitrate, ammonia, and phosphorus (table 10). The constituents were chosen because they were analyzed over the complete period of record, they are found in concentrations that could affect the benthic-macroinvertebrate community, and they are associated with common water-quality problems in Chester County.

Table 10. *Mann-Kendall test of specific conductance and concentrations of nitrate, ammonia, and phosphorus from selected streams in Chester County, Pennsylvania, 1981-97*

[Positive trends indicate deteriorating water-quality conditions; p>90, trends were considered significant if the p value was greater than 90 percent]

Basin	Number of sites	Specific conductance		Nitrate		Ammonia		Phosphorus	
		Sites with positive trends (p>90)	Sites with negative trends (p>90)	Sites with positive trends (p>90)	Sites with negative trends (p>90)	Sites with positive trends (p>90)	Sites with negative trends (p>90)	Sites with positive trends (p>90)	Sites with negative trends (p>90)
Schuylkill River Basin	14	10	0	1	1	0	4	0	2
Delaware River Basin	9	7	1	1	1	0	2	1	3
Brandywine Creek Basin	11	10	0	8	1	0	3	0	4
Red / White Clay Creek Basins	5	5	0	2	0	0	1	0	3
Big Elk / Octoraro Creek Basins	4	4	0	4	0	1	3	0	1

Specific conductance

Specific conductance is the capacity of water to conduct an electrical current at 25°C. Specific conductance is a measure of the total inorganic dissolved solids in the water. Charged ions such as chloride, potassium, and sodium dissolved in the water will increase the conductance. These ions are non-toxic to aquatic life at concentrations found in Chester County streams. Sources of ions in surface water include ground-water discharges, wastewater-treatment and septic discharges, and overland runoff.

Specific conductance values increased at 36 of the 43 sites sampled from 1981 to 1997 (table 10). The increasing values were measured throughout Chester County in areas of different land use and in various size basins (fig. 26). Specific conductance is an indirect measurement of dissolved ions. Increasing specific conductance may be related to increased runoff from impervious surfaces and wastewater-treatment and septic discharges. The only site with a decreasing trend in specific conductance was Goose Creek in the East Branch Chester Creek Basin. This site is below the discharge of a wastewater-treatment plant upgraded in the mid 1980s. Although the conductance was declining at this site, it was two to four times higher than at other sites in the Delaware River Basin and had the highest median conductance of all sites sampled from 1981 to 1997. There is little relation between specific conductance trends and trends in the biological metrics calculated for this study. Although specific conductance is a good measure of general water-quality contamination, it has limited value for isolating causes for trends of biological communities.

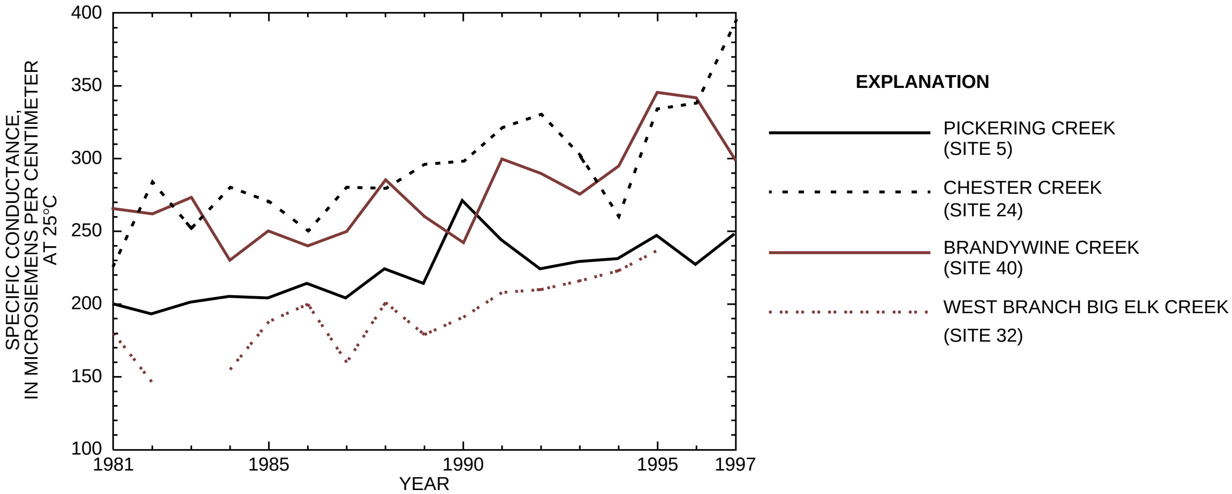

Figure 26. Specific conductance from selected sites in Chester County, Pennsylvania, 1981-97.

Nutrients

Nutrients (nitrogen and phosphorus compounds) are naturally occurring compounds needed for plant growth and commonly are found in elevated concentrations above background levels because of human activities. Nutrient sources include commercial fertilizers and manure, wastewater-treatment discharges, septic systems, and atmospheric deposition. Elevated nutrient concentrations can cause increased plant growth in the stream that can alter benthic-macroinvertebrate communities and cause low concentrations of dissolved oxygen (hypoxia) that can be fatal to aquatic organisms.

Nitrate.—Nitrate is the primary form of nitrogen dissolved in stream water. Nitrate is non-toxic to aquatic life at concentrations found in Chester County streams, but high concentrations can cause increased algal growth, which decays and results in low concentrations of dissolved oxygen. Degraded benthic-macroinvertebrate communities in high nitrate conditions are caused by the low concentrations of dissolved oxygen and not the high nitrate concentrations. Areas with increasing trends in nitrate concentrations are likely to have decreasing concentrations of dissolved oxygen that may result in degraded benthic-macroinvertebrate communities. A drinking-water standard of 10 mg/L has been established for nitrate, although concentrations above 0.3 mg/L can cause increased plant productivity, which can lead to low concentrations of dissolved oxygen and decreased benthic-macroinvertebrate diversity (U.S. Environmental Protection Agency, 1994a).

Increasing trends in nitrate concentrations were measured at 16 of 43 sites between 1981 and 1997. Three sites had decreasing trends in nitrate and 24 sites had no significant trends (table 10). The sites with increasing trends in nitrate concentrations are concentrated in the central and western parts of Chester County where agricultural land use is higher than in the Schuylkill and Delaware River Basins (fig. 27). Nitrate concentrations also follow an east to west pattern; the highest concentrations are in the Octoraro Creek Basin (fig. 28). Elevated nitrate concentrations (above 10 mg/L) also are common at sites

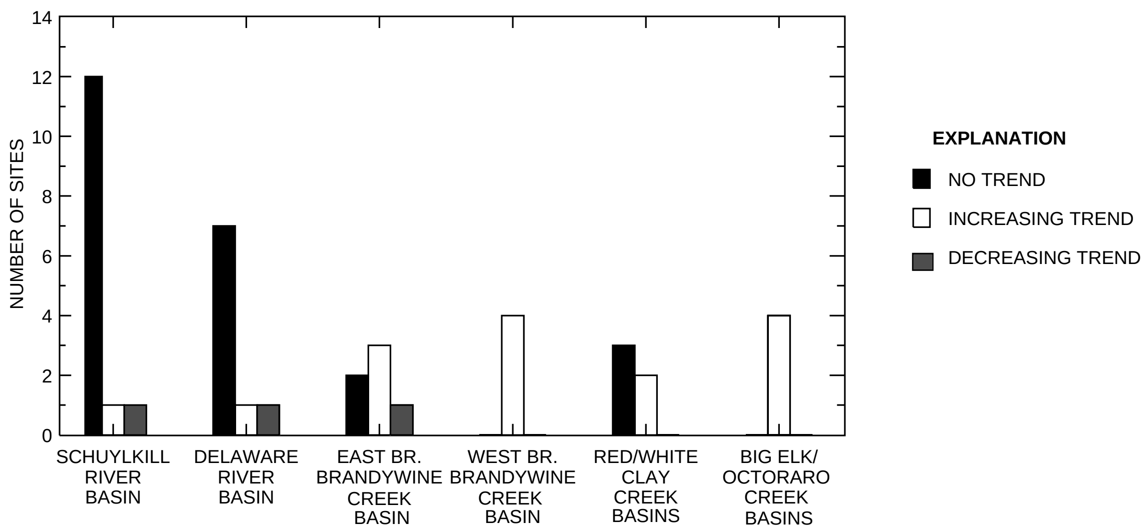

Figure 27. Results of Mann-Kendall test for trend in nitrate from selected sites in various basins, Chester County, Pennsylvania, 1981-97.

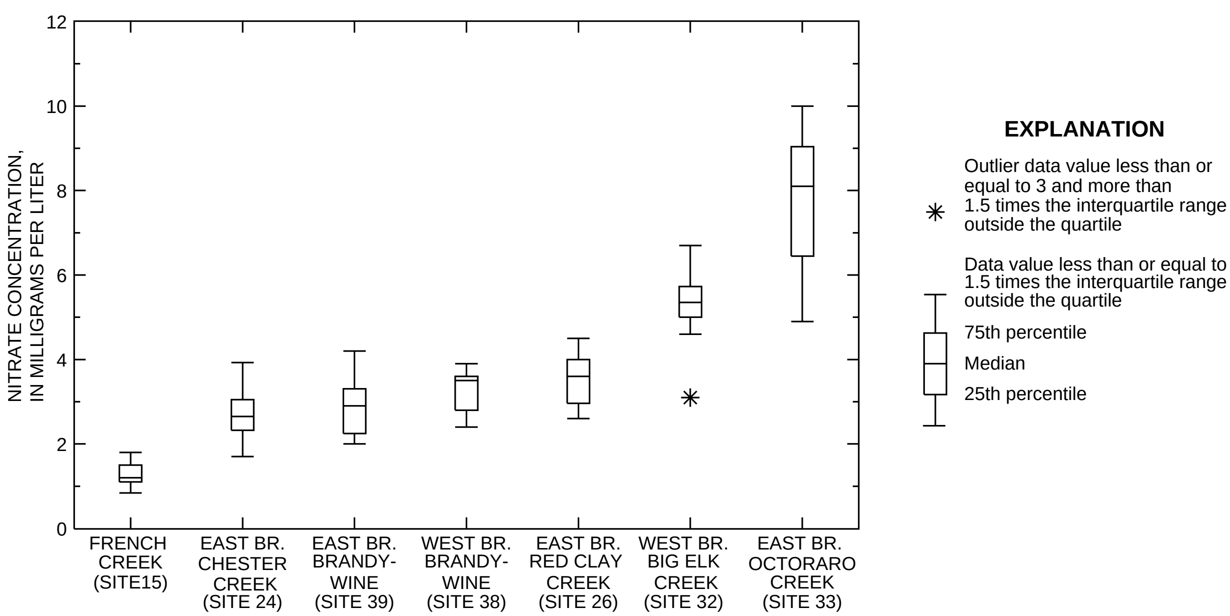

Figure 28. Nitrate concentrations from selected sites in Chester County, Pennsylvania, 1981-97.

downstream of wastewater-treatment plant discharges in all basins. Nitrate concentrations downstream of wastewater-treatment plants also are related to the conversion of ammonia to nitrate. The conversion of ammonia to nitrate decreases the toxicity to the benthic macroinvertebrates but does not decrease the potential for eutrophication.

Ammonia and phosphorus.—Ammonia is a dissolved form of nitrogen that, at high concentrations, is toxic to aquatic organisms. The USEPA has set an aquatic-life criteria in surface waters of 0.07 to 2.1 mg/L ammonia-nitrogen depending on water temperature and pH (U.S. Environmental Protection Agency, 1986). Although no national criterion has been established, the USEPA recommends that concentrations of total phosphorus not exceed 0.1 mg/L in flowing waters for the prevention of nuisance plant growth (U.S. Environmental Protection Agency, 1994b). Excess phosphorus can cause increased plant production that can lead to low concentrations of dissolved oxygen and degraded habitat that can cause decreased benthic-macroinvertebrate diversity.

A decreasing trend in the concentration of ammonia was measured at 13 of 43 sites (table 10) between 1981 and 1997. Phosphorus concentrations also had a decreasing trend at 13 of 43 sites during the same time period (table 10). The decreasing trends were found in all basins in areas of various land use. Concentrations of ammonia and phosphorus are elevated above reference conditions in heavy agricultural areas and near wastewater-treatment discharges. Improvements in wastewater-treatment, restrictions on phosphate detergents, and reduced agricultural runoff have decreased the phosphorus concentrations throughout Chester County. Ammonia concentrations also have decreased as a result of upgrades to wastewater-treatment plants. Upon oxidation, ammonia is converted to nitrate, which is less toxic to benthic macroinvertebrates. Sampling sites that were not in agricultural areas or near wastewater-treatment discharges had low concentrations of ammonia and phosphorus in 1981 that remained low through 1997.

Increasing trends in specific conductance were measured from all basins in the county across various land uses. Trends in nutrient concentrations follow more of a spatial pattern related to land use. Nutrient concentrations in the Schuylkill and Delaware River Basins generally are unchanged except in areas affected by discharges from wastewater-treatment plants. Most sites in these basins had relatively low concentrations of nitrate, ammonia, and phosphorus in the early 1980s, and the concentrations of these constituents have remained consistent over time. The sites near discharges from wastewater-treatment plants have decreasing concentrations of nutrients, but the concentrations are still elevated over reference conditions. Nutrient concentrations in the Brandywine, Red Clay, White Clay, Big Elk, and Octoraro Creek Basins generally are higher and more variable than in the eastern part of the county.

Nitrate concentrations generally are increasing, but concentrations of ammonia and phosphorus are decreasing. Decreasing phosphorus concentrations are likely the result of upgrades in wastewater-treatment plants, restrictions on phosphate detergents, and reduced fertilizer runoff. Increasing nitrate and decreasing ammonia concentrations are likely the result of improved wastewater-treatment processes that convert ammonia to nitrate. As a result, the toxicity to aquatic life has decreased, but the concentrations of total nitrogen have remained the same. Elevated concentrations of nutrients can cause algal blooms that can result in low concentrations of dissolved oxygen and poor habitat conditions that can cause decreased benthic-macroinvertebrate communities.

Dissolved-oxygen concentrations have been measured at three continuous monitoring stations in the Brandywine Creek Basin since 1972. Data from these monitoring stations indicate the concentrations of minimum dissolved oxygen have increased over time. In 1997, there only were 3 days when the minimum concentration of dissolved oxygen was below 5.0 mg/L on the East Branch Brandywine Creek below Downingtown compared to 103 days in 1981. This increase in minimum dissolved-oxygen concentrations is a major factor for the improvement in benthic-macroinvertebrate communities throughout Chester County between 1981 and 1997.

Stream-Bottom Sediment Samples

Metals, trace elements, and organic contaminants may accumulate and become concentrated in stream-bottom sediments. The concentration of these substances in the stream-bottom sediments can exceed those of the overlying water by an order of magnitude (Horowitz, 1991). Concentrations of organic contaminants, trace elements, and metals in stream-bottom sediments may occur naturally from the local geology or be related to human influences. Bottom-dwelling and bottom-feeding organisms provide a pathway for contaminants to enter the food web (Hem, 1985; Horowitz, 1991).

Sampling for selected metals and trace elements was conducted during the period 1993 to 1997 at 36 of the 43 sites, and for organic contaminants during 1983 to 1997 at all 43 sites. Information gathered from stream-bottom sediment sampling was used to help assess the benthic-macroinvertebrate samples and provide data that can be used to examine trends in sediment quality. Sampling locations at each site were selected in depositional areas. Depositional areas contain fine-grained particles that usually are associated with high concentrations of organic compounds, metals, and trace elements (Horowitz, 1991). Samples were collected by hand from the top 6 to 12 in. of sediment according to the methods of Wershaw and others (1987, p. 7-8). The sample was homogenized by mixing and transferred to clean glass or polyethylene containers and placed on ice for shipment to the USGS National Water-Quality Laboratory in Arvada, Colo. Metal concentrations were determined by atomic absorption spectrometry (Fishman and Friedman, 1989). Concentrations of organochlorine and organophosphorus pesticides and PCB were determined by gas chromatography using a flame photometric detector (Wershaw and others, 1987). All results are reported as dry weights.

Selected Metals and Trace Elements

Metals and trace elements in small quantities are needed for normal plant and animal development. However, some metals and trace elements, such as mercury and arsenic, can be toxic at low concentrations (Meade, 1995). Metals and trace elements in stream-bottom sediments come from natural as well as artificial sources. Natural sources are from rock weathering, soil erosion, and the dissolution of salts. Artificial sources include wastewater discharges, industrial activities, mining, and agriculture.

Samples for analysis of metals and trace elements were collected once from stream-bottom sediment at 36 of the 43 sites between 1993 and 1997. Sites 2, 16, 20, 21, 34, 36, and 37 were not sampled. Statistics for arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, and zinc are presented in table 11. Metals and trace elements were evaluated by use of guidelines developed by MacDonald and others (2000). These sediment-quality guidelines include the threshold effect concentration. Concentrations below the threshold effect concentration are unlikely to cause harmful effects (MacDonald and others, 2000).

Table 11. *Occurrence of selected trace elements in samples of stream-bottom sediment collected in Chester County, Pennsylvania, 1984-97*

[μg/g, microgram per gram]

Constituent	Number of samples	Percentage of samples with detectable concentrations	Range of detected concentrations (μg/g)	Threshold effect concentration[1]	Percentage of samples with concentration greater than threshold effect concentration
Arsenic	35	86	1.0 - 6.0	9.79	0
Cadmium	36	5.6	1.0	.99	8.3
Chromium	36	100	1.0 - 50	43.4	8.3
Copper	36	86	10 - 42	31.6	2.8
Lead	36	83	10 - 80	35.8	17
Mercury	36	86	.01 - .76	.18	11
Zinc	36	100	7.0 - 170	121	5.6

[1] A level of sediment contamination below which harmful effects are unlikely to be observed (MacDonald and others, 2000).

Arsenic, chromium, copper, lead, mercury, and zinc were detected in more than 83 percent of the samples. Cadmium was detected in less than 6 percent of the samples. The percentage of samples exceeding the threshold effect concentration was below 10 percent for arsenic, cadmium, chromium, copper, and zinc and between 10 and 17 percent for lead and mercury (table 11).

Arsenic

Arsenic is a trace element on the USEPA Priority Pollutants list (U.S. Environmental Protection Agency, 1994b). Arsenic occurs naturally and is used in industrial processes including bronze production, pesticides, transistors, and treated lumber (Weast, 1983). Arsenic was detected in 86 percent of 35 samples (table 11); concentrations ranged from 1.0 to 6.0 µg/g, which are below the threshold effect concentration (9.79 µg/g). The highest detected arsenic concentration (6.0 µg/g) was at site 49 on Little Valley Creek. These data suggest arsenic is not affecting benthic-macroinvertebrate communities adversely in Chester County.

Cadmium

Cadmium is a toxic trace element on the USEPA Priority Pollutants list (U.S. Environmental Protection Agency, 1994b). Cadmium is used for electroplating, solder, batteries, and pigments (Weast, 1983). Cadmium was detected in 3 of the 36 (8 percent) samples collected (table 11). The concentration of cadmium detected in the samples was 1 µg/g, which is slightly above the threshold effect concentration. These samples were collected from Little Valley Creek (site 49), Valley Creek (site 50), and East Branch Chester Creek (site 25). Cadmium concentrations measured in the stream-bottom sediments do not appear to be affecting the benthic-macroinvertebrate communities in Chester County.

Chromium

Chromium is a toxic trace element on the USEPA Priority Pollutants list (U.S. Environmental Protection Agency, 1994b). Chromium is used in steel production and fabrication, leather tanning, and in glass and textiles (Weast, 1983). Chromium was detected in all 36 samples collected. Detected concentrations ranged from 1.0 to 50 µg/g. Chromium concentrations exceeded the threshold effect concentration of 43.4 µg/g in 8 percent of the 36 samples (table 11). The highest concentrations (50 µg/g) were at site 1 on Pickering Creek, site 38 on West Branch Brandywine Creek, and site 33 on East Branch Octoraro Creek. Benthic-macroinvertebrate communities at these sites were either nonimpacted or slightly impacted. So, although chromium is ubiquitous in Chester County streams, it does not appear to be a factor in the impairment of benthic-macroinvertebrate communities.

Copper

Copper is a toxic trace element on the USEPA Priority Pollutants list (U.S. Environmental Protection Agency, 1994b). Copper is used by the electrical industry and in algicides and insecticides (Weast, 1983). Copper was detected in 31 of the 36 (86 percent) samples collected. Detected concentrations ranged from 10 to 42 µg/g. Copper concentrations exceeded the threshold effect concentration of 31.6 µg/g in 2.8 percent of the 36 samples (table 11). The highest concentration (42 µg/g) was at site 25 on East Branch Chester Creek.

Lead

Lead is a widely dispersed naturally occurring metal on the USEPA Priority Pollutants list (U.S. Environmental Protection Agency, 1994b). Lead is used for batteries, plumbing, and insecticides (Weast, 1983). Lead was detected in 30 of the 36 (83 percent) samples collected. Detected concentrations ranged from 10 to 80 µg/g. Lead concentrations exceeded the threshold effect concentration of 35.8 µg/g in 17 percent of the 36 samples (table 11). Sites that exceeded the threshold effect concentration were primarily in the Schuylkill River Basin (sites 14, 16, and 50). The highest concentration (80 µg/g) was at site 16 on French Creek. This site was judged to be slightly impacted. Lead may be a contributing factor to these impacts.

Mercury

Mercury is a toxic trace element on the USEPA Priority Pollutants list (U.S. Environmental Protection Agency, 1994b). Mercury has been used widely in industrial products and processes and pesticides and will bioaccumulate in stream organisms (Hem, 1985). Mercury was detected in 31 of 36 (86 percent) samples collected and concentrations ranged from 0.01 to 0.76 µg/g. Mercury concentrations exceeded the threshold effect concentration of 0.18 µg/g in 11 percent of 36 samples (table 11). Sites that exceeded the threshold effect concentration were in the East Branch Chester Creek (site 24, 25, and 51) and West Branch Brandywine Creek Basins (site 46). The highest concentration (0.76 µg/g) was at site 25 on Goose Creek. The biological community in Goose Creek was judged to be moderately impacted. Mercury may be a causative factor to this impairment.

Zinc

Zinc is a trace element that occurs naturally in the Earth's crust and is on the USEPA Priority Pollutants list (U.S. Environmental Protection Agency, 1994b). Zinc is important to the normal development of animals but is toxic in higher concentrations (Weast, 1983). Zinc was detected in all 36 samples collected. Concentrations ranged from 7 to 170 µg/g and exceeded the threshold effect concentration of 120 µg/g in only two samples, Goose Creek (site 25) and East Branch Chester Creek (site 27) (table 11). Zinc concentrations most likely are not causing biological impairments in Chester County streams.

In general, background metal and trace-element concentrations in samples of stream-bottom sediment collected throughout Chester County were not a water-quality problem. Sites with concentrations of metals or trace elements above the threshold effect concentration were in the French Creek Basin (sites 14 and 16), Pickering Creek (site 1), Valley Creek (site 50), East Branch Chester Creek (sites 22, 25, and 51), Brandywine Creek (sites 38, 40, and 46), and the Octoraro Creek (site 33) (fig. 29). Background concentrations of ground water in the northeastern part of the county indicate the elevated concentrations, above background levels, of metals and trace elements at sites in the French, Pickering, and Valley Creeks may be from natural sources (Sloto, 1987). The elevated concentrations at sites 22, 25, and 40 may be affected by natural sources and past and present industrial activities or wastewater discharges near those sites.

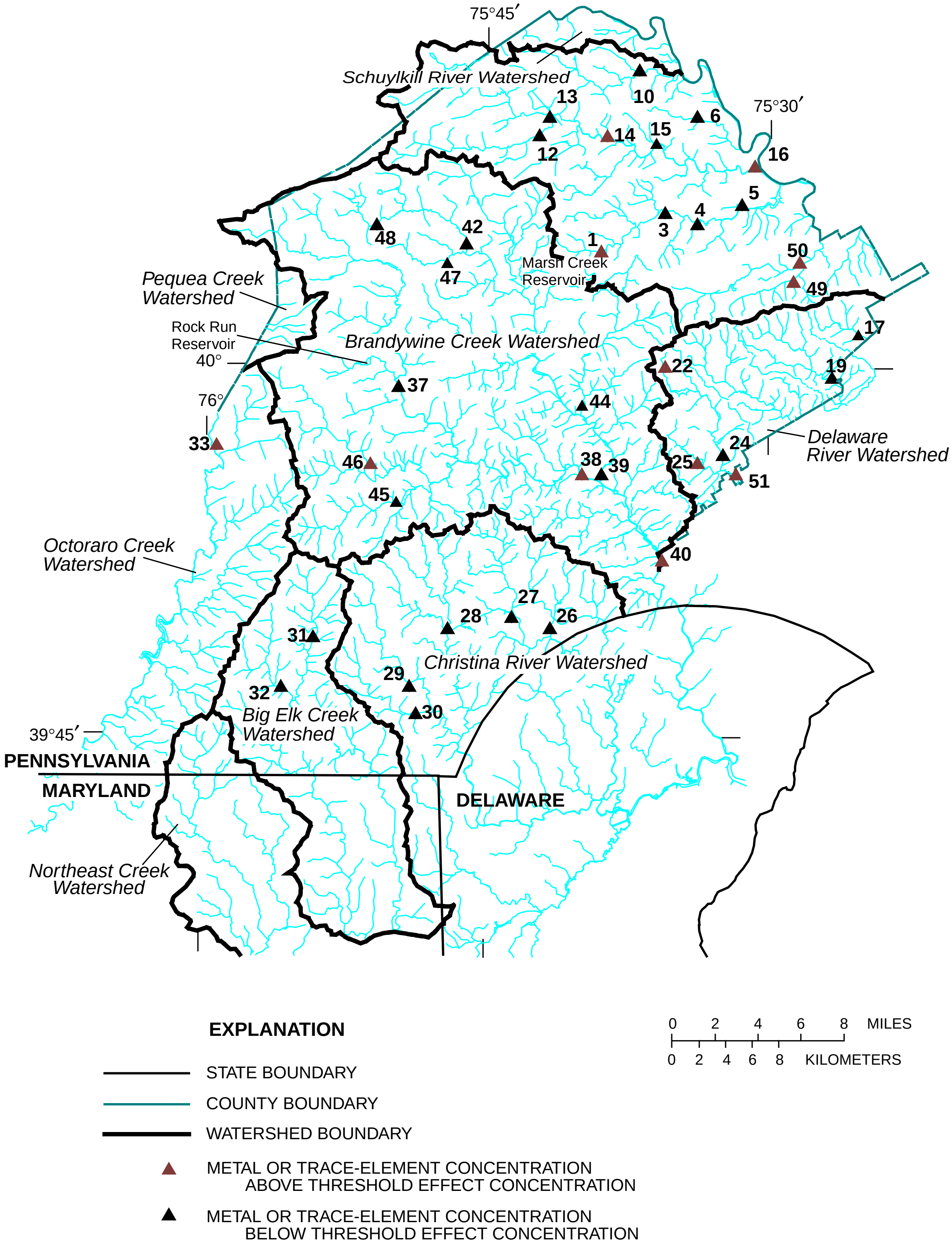

Figure 29. Sampling sites with metal or trace-element concentration above the threshold effect concentration, Chester County, Pennsylvania.

Organochlorine Insecticides and Polychlorinated Biphenyls

Organochlorine insecticides are used in agriculture and urban areas to control insects. PCBs have been used in electrical transformers, plasticizers, and flame retardants. These compounds have low solubility in water, are persistent in the environment, and are bioaccumulated by many organisms. Each of these compounds can impair aquatic organisms living in or on the stream bottom.

Samples of stream-bottom sediment were collected from the 43 sites in the study area from 1983 through 1997 and analyzed for organochlorine insecticides and gross PCBs. Most sites were sampled twice, once between 1983 and 1989 and once between 1993 and 1997. Of the 15 organochlorine insecticides analyzed, 14 were detected. PCBs were detected in 55 of 82 samples collected. The most frequently detected compounds were chlordane, dieldrin, DDD, DDE, DDT, and PCBs (table 12).

Table 12. *Occurrence of selected organochlorine insecticides and polychlorinated biphenyls in samples of stream-bottom sediment collected at 43 sites in Chester County, Pennsylvania, 1984-97*

[µg/kg, micrograms per kilogram]

Constituent	Number of samples	Percentage of samples with detectable concentrations	Percentage of sites with detectable concentra-tions	Range of detected concentrations (µg/kg)	Threshold effect concentra-tion[1] (µg/kg)	Percentage of samples with concentration greater than threshold effect concentration	Percentage of sites with concentration greater than threshold effect concentration
Chlordane	80	61	70	1.0 - 110	3.24	42	56
DDT	79	53	70	.10 - 61	4.16	6	7
DDD	79	75	93	.10 - 260	4.88	4	5
DDE	77	88	95	.10 - 22	3.16	5	9
Dieldrin	80	64	77	.10 - 5.4	1.90	8	14
PCB	82	67	74	1.0 - 15,000	59.8	10	12

[1] A level of sediment contamination below which harmful effects are unlikely to be observed (MacDonald and others, 2000).

Chlordane

Chlordane is a synthetic organic compound used as an insecticide around the foundations of buildings for termite and ant control until the mid-1980s (U.S. Environmental Protection Agency, 1990). Chlordane is on the USEPA Priority Pollutants list (U.S. Environmental Protection Agency, 1994b).

Chlordane was detected in 61 percent of the 80 samples collected. Concentrations of chlordane ranged from 1.0 to 110 µg / kg and exceeded the threshold effect concentration of 3.24 µg / kg in 42 percent of the samples from 56 percent of the sites (table 12). Sites that exceeded the threshold effect concentration were on Stony Run (site 6), French Creek (sites 13 and 16), Little Valley Creek (site 49), Darby Creek (site 17), East Branch Chester Creek (sites 22, 25, and 51), Brandywine Creek (sites 39 and 46), and East Branch Big Elk Creek (site 31). The highest concentration (110 µg / kg) was at site 51 on East Branch Chester Creek in 1986 (table 13). Thirty-six sites were sampled once between 1983 and 1987 and once between 1993 and 1997. Of these 36 paired sites, chlordane was detected in 61 percent of samples collected between 1983 and 1987 and in 69 percent of samples collected between 1993 and 1997 (fig. 30). The 36 sites had a median concentration of 5 mg / kg with a maximum concentration of 110 mg / kg in 1983-87 and a median concentration of 5 mg / kg with a maximum concentration of 32 mg / kg in 1993-97 (fig. 31). This result indicates elevated chlordane concentrations are less common, but low level chlordane concentrations are persistent throughout Chester County.

Table 13. *Concentrations of organochlorine insecticides and gross polychlorinated biphenyls greater than the threshold effect concentration[1] from stream-bottom sediment samples collected in Chester County, Pennsylvania, 1983-97*

[All concentrations are in micrograms per kilogram; —, concentration did not exceed or equal threshold effect concentration[1]; PCB, gross polychlorinated biphenyls]

U.S. Geological Survey station identification number	Site number	Year	Chlordane	DDT	DDD	DDE	Dieldrin	PCB
			Schuylkill River Basin					
01472109	6	1985	6.0	—	—	—	—	—
		1996	10		—	—	—	—
01472138	13	1997	12	—	—	—	—	—
01472140	12	1985	—	—	—	—	4.8	—
01472154	14	1985	6.0	—	—	—	—	—
014721612	16	1985	5.0	—	—	—	5.4	—
		1994	24	—	—	—	—	—
01473167	49	1986	—	—	—	—	—	15,000
		1987	13	—	—	—	—	540
		1993	5.0	—	—	—	—	—
01473168	50	1985	5.0	—	—	—	—	—
		1993	5.0	—		10	—	—
			Delaware River Basin					
01475300	17	1986	—	—	—	—	2.7	95
		1996	14	—	—	—	2.0	—
01475840	19	1986	7.0	—	—	—	—	—
			6.0	—	—	—	—	—
01476430	20	1985	7.0	—	—	—	—	—
01476790	22	1986	30	—	—	—	—	—
		1997	32	—	—	—	3.9	—
01476830	23	1996	7.0	—	—	—	—	—
01476835	24	1985	7.0	—	—	—	—	—
		1994	6.0	—	—	—	—	—
01476840	25	1988	51	13	7.5	—	—	120
		1993	10	12	—	—	—	—
01476848	51	1986	110	—	5.0	—	—	73
			Brandywine Creek Basin					
01480629	46	1995	9.0	—	—	—	—	—
01480632	45	1986	4.0	—	—	—	—	—
01480640	38	1993	4.0	—	—	—	—	—
01480903	44	1985	4.0	—	—	—	—	—
		1995	5.0	—	—	—	—	—
01480950	39	1986	32	—	—	4.1	3.2	—
01481030	40	1997	5.4	—	—	—	—	—
			Red Clay/White Cay Creek Basins					
01478120	28	1985	—	—	6.3	—	—	—
01479680	27	1983	—	15	260	—	2.5	5,600
		1986	—	—	—	—	—	1,400
		1993	7.0	27	23	20	—	550
01479800	26	1985	5.0	61	36	22	—	—
			Big Elk/Octoraro Creek Basins					
01494900	31	1986	29	—	—	7.4	—	—
01578343	33	1986	4.0		—	4.8	—	—
		1994	5.0	—	—	—	—	—

[1] A level of sediment contamination below which harmful effects are unlikely to be observed (MacDonald and others, 2000).

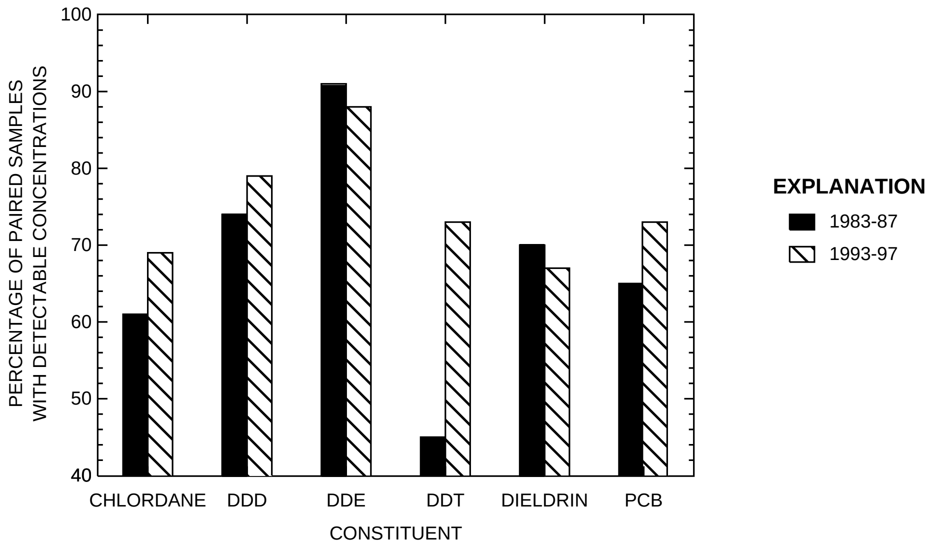

Figure 30. Percentage of stream-bottom sediment samples with detectable concentrations of selected pesticides and PCB from selected streams in Chester County, Pennsylvania, 1983-97.

DDT

DDT is the common name for a mixture of compounds in which the main component is 1,1,1,-trichloro-2,2-bis (p-chlorophenyl) ethane. DDT was banned in 1973 but because of its widespread use and chemical stability it still is detectable (Ware, 1989). DDT was detected in 53 percent of the 79 samples collected (table 12). The concentrations of DDT ranged from 0.1 to 61 µg / kg and exceeded the threshold effect concentration of 4.16 µg / kg in 6 percent of the samples and from 7 percent of the sites (table 12). Sites that exceeded the threshold effect concentration were on East Branch Chester Creek (site 25) and Red Clay Creek (sites 26 and 27). The highest concentration (61 µg / kg) was at site 26 on East Branch Red Clay Creek in 1985 (table 13). Thirty-three sites were sampled once between 1983 and 1987 and once between 1993 and 1997. Of these 33 paired sites, DDT was detected in 45 percent of samples collected between 1983 and 1987 and in 73 percent of samples collected between 1993 and 1997 (fig. 30). The 33 sites had a median concentration of 1.30 µg / kg with a maximum concentration of 61 µg / kg in 1983-87 and a median concentration of 0.6 µg / kg with a maximum concentration of 27 µg / kg in 1993-97 (fig. 31). High concentrations of DDT were less common in the samples collected during the 1990s, but low concentrations are persistent throughout Chester County.

At sites where DDT was detected, the DDE / DDT ratio was greater than 1 at 57 percent of sites sampled between 1983 and 1987 and at 71 percent of sites sampled between 1993 and 1997, indicating long-term degradation of the DDT to DDE. The reduction in DDT concentrations may be from degradation, downstream movement of contaminated sediments, and influx of less contaminated sediments.

DDD

DDD is an insecticide and is also a breakdown product of DDT. DDD was banned in 1973 but because of its widespread use and chemical stability still is detectable (Ware, 1989). DDD was detected in 75 percent of the 79 samples collected (table 12). The concentration of DDD ranged from 0.1 to 260 µg / kg and exceeded the threshold effect concentration of 4.88 µg / kg in 4 percent of the samples and from 5 percent of the sites (table 12). Sites that exceeded the lowest effects concentration were on East Branch Chester Creek (sites 25 and 51), East Branch White Clay Creek (site 28), and Red Clay Creek (sites 26 and

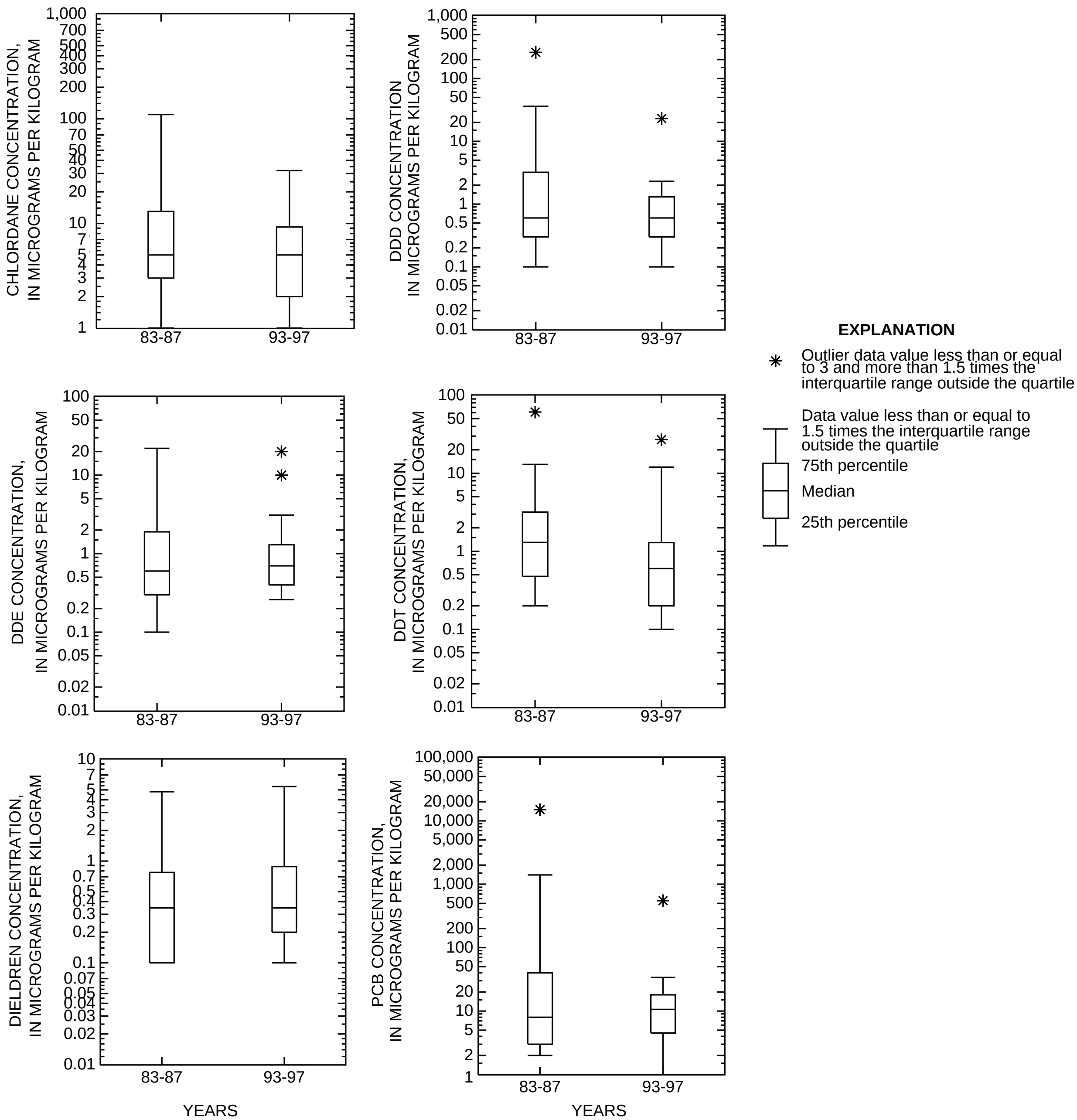

Figure 31. Concentrations of pesticides and PCBs in stream-bottom sediment samples from selected streams in Chester County, Pennsylvania, 1983-97.

27). The highest concentration (260 µg / kg) was at site 27 on West Branch Red Clay Creek in 1983 (table 13). Thirty-four sites were sampled once between 1983 and 1987 and once between 1993 and 1997. Of these 34 paired sites, DDD was detected in 74 percent of samples collected between 1983 and 1987 and in 79 percent of samples collected between 1993 and 1997 (fig. 30). The 34 sites had a median concentration of 0.8 µg / kg with a maximum concentration of 260 µg / kg in 1983-87 and a median concentration of 0.6 µg / kg with a maximum concentration of 23 µg / kg in 1993-97 (fig. 31). These concentrations are an indication that although DDD is persistent in stream-bottom sediments throughout Chester County, the concentrations are decreasing over time.

DDE

DDE is not produced as a pesticide but is a breakdown product of DDT. DDE was detected in 88 percent of the 77 samples collected (table 12). The detectable concentration of DDE ranged from 0.1 to 22 µg / kg and exceeded the threshold effect concentration of 3.16 µg / kg in 5 percent of the samples and from 9 percent of the sites (table 12). Sites that exceeded the threshold effect concentration were on Valley Creek (site 50), East Branch Brandywine Creek (site 39), Red Clay Creek (sites 26 and 27), East Branch Big Elk Creek (site 31), and East Branch Octoraro Creek (site 33). The highest concentration (22 µg / kg) was at site 26 on East Branch Red Clay Creek in 1985 (table 13). Thirty-three sites were sampled once between 1983 and 1987 and once between 1993 and 1997. Of these 33 paired sites, DDE was detected in 91 percent of samples collected between 1983 and 1987 and in 88 percent of samples collected between 1993 and 1997 (fig. 30). The 33 sites had a median concentration of 0.6 µg / kg with a maximum concentration of 22 µg / kg in 1983-87 and a median concentration of 0.7 µg / kg with a maximum concentration of 20 µg / kg in 1993-97 (fig. 31). High concentrations of DDE were less common in the samples collected during the 1990s, but low concentrations are persistent throughout Chester County.

Dieldrin

Dieldrin is an isomer of endrin and has been used as a contact insecticide. All uses of dieldrin were prohibited by the USEPA in 1986 (Ware, 1989). Dieldrin was detected in 64 percent of the 80 samples collected (table 12). The concentrations of dieldrin ranged from 0.1 to 5.4 µg / kg (table 12) and exceeded the threshold effect concentration of 1.90 µg / kg in 8 percent of the samples from 14 percent of the sites (table 13). Sites that exceeded the threshold effect concentration were on French Creek (sites 12 and 16), Darby Creek (site 17), East Branch Chester Creek (site 22), East Branch Brandywine Creek (site 39), and West Branch Red Clay Creek (site 27). The highest concentration (5.4 µg / kg) was at site 16 on French Creek in 1985 (table 13). Thirty-three sites were sampled once between 1983 and 1987 and once between 1993 and 1997. Of these 33 paired sites, dieldrin was detected in 70 percent of samples collected between 1983 and 1987 and in 67 percent of samples collected between 1993 and 1997 (fig. 30). The 33 sites had a median detectable concentration of 0.35 µg / kg with a maximum concentration of 4.8 µg / kg in 1983-87 and a median detectable concentration of 0.35 µg / kg with a maximum concentration of 5.4 µg / kg in 1993-97 (fig. 31). This result indicates concentrations of chlordane in stream-bottom sediments did not change between the 1980s and the 1990s. It still is widespread throughout Chester County in low concentrations in drainage basins of various sizes and among various land uses.

PCBs

PCBs are a group of compounds commonly used in electrical transformers and lubricants. PCBs have been banned in the United States since 1977, but because of their high stability, they still persist in the environment (Tigler and others, 1990). PCBs were detected in 67 percent of 82 samples of stream-bottom sediment collected between 1983 and 1997 (table 12). The concentrations of PCBs ranged from 1.0 to 15,000 µg / kg and exceeded the threshold effect concentration of 59.8 µg / kg in 10 percent of the samples and from 12 percent of the sites (table 12). The highest concentrations of PCBs were at sites 27 and 49 where the concentration of PCBs was 5,600 µg / kg and 15,000 µg / kg, respectively (table 13). Thirty-seven sites were sampled once between 1983-87 and once between 1993-97. Of these 37 paired sites, PCB was detected in 65 percent of samples collected between 1983 and 1987 and in 73 percent of samples collected between 1993 and 1997 (fig. 30). The 37 sites had a median detectable concentration of 8.00 µg / kg with a maximum concentration of 15,000 µg / kg in 1983-87 and a median detectable concentration of 9.40 µg / kg with a maximum concentration of 550 µg / kg in 1993-97 (fig. 31). Although maximum concentrations are declining over time, low concentrations did not change between the 1980s and the 1990s. It still is widespread throughout Chester County in low concentrations in drainage basins of various sizes and among various land uses.

The high concentration at site 27, West Branch Red Clay Creek at Kennett Square, was because of contamination from a landfill fire, and at site 49, Little Valley Creek at Howellville, the high concentration was caused by runoff from the Paoli Train Yard Superfund Site. The concentration of PCBs has dropped dramatically at both sites after the source of the PCBs was contained. The contaminated sediment has washed downstream or been buried by less contaminated sediments.

Overall, the concentrations of organochlorine insecticides and PCBs in stream-bottom sediments has decreased across Chester County between 1983 and 1997. This reduction is because of the limitations and restriction on the uses of these substances and decreased agricultural land use in the county. The compounds in the sediments are degrading, being washed downstream, and mixing and being buried with sediment containing lower concentrations of these substances. Many of these compounds, however, are stable and will remain in the stream system for many years. The concentrations of most compounds detected do not pose a serious threat to the aquatic life on the stream bottom.

SUMMARY

Water-chemistry, bottom-sediment chemistry, and benthic-macroinvertebrate data were collected by the U.S. Geological Survey, in cooperation with the Chester County Water Resources Authority at 43 sites from 1981 to 1997 as part of the Stream Conditions of Chester County Biological Monitoring Network. Stream-quality conditions were assessed using biological metrics to evaluate benthic-macroinvertebrate communities. Trends in benthic-macroinvertebrate diversity and water chemistry were analyzed to evaluate changes in stream conditions over time. Chemical and benthic-macroinvertebrate data were compared to find relations between water chemistry and benthic-macroinvertebrate communities.

The 43 sites sampled in Chester County from 1981 to 1997 have varied benthic-macroinvertebrate communities that are related to many factors including land use, point discharges, and natural stream conditions. Although the streams each have unique combinations of these factors, some general patterns in the data are present. Sites in the Pigeon, French, Pickering, and East Branch Brandywine Creeks generally have consistent benthic-macroinvertebrate communities that indicate good stream conditions. Benthic-macroinvertebrate communities in the Darby, Crum, Ridley, and Valley Creek Basins are being degraded from the reference conditions. The degraded benthic-macroinvertebrate communities are associated with habitat alteration probably caused by increased urban areas and impervious surfaces in these basins. Sites in the West Branch Brandywine and White Clay Creek Basins have benthic-macroinvertebrate communities that indicate some degradation in stream conditions because of sedimentation but good overall stream conditions. Benthic-macroinvertebrate communities in the Red Clay, Big Elk, and Octoraro Creek Basins are being degraded from the reference conditions by increased nutrient concentrations (which may result in low dissolved-oxygen concentrations) and by heavy sedimentation caused by agricultural land use and construction activities. Sites in the Red Clay Creek have benthic-macroinvertebrate communities that indicate improving but still highly degraded stream conditions when compared to reference conditions.

Trend analysis of biological-metric values indicates most sites in the Stream Conditions of Chester County Biological Monitoring program have increased in diversity or have remained unchanged between 1981 and 1997. This improvement was likely because of various factors including upgrading and eliminating wastewater-treatment plants, decreasing agricultural land use, and improving farm management procedures. Upgrades in sewage-treatment plants have resulted in improved water quality by decreasing concentrations of ammonia and phosphorus. This improvement has lead to less toxic and better oxygenated waters. The decrease in agricultural lands and improved farm-management procedures have reduced sediment loads and organochlorine pesticide concentrations. The basins that showed the greatest improvement in diversity were basins that had very low diversities in the past. These areas, however, are affected by wastewater discharges, pesticides, and nutrient enrichment and still have the poorest stream condition in the network.

Trend analysis on chemical constituents indicates concentrations of nitrate and chloride are increasing and concentrations of phosphorus and ammonia are unchanged or declining across Chester County. Elevated concentrations of nitrate and phosphorus generally were in basins that were above 50 percent agricultural land use or were affected by wastewater discharges. The highest concentrations of ammonia and chloride were associated with wastewater-treatment plant discharges. The median concentration of nutrients in the county generally was low in areas with agricultural land use below 35 percent and high in areas of wastewater-treatment plant discharge and where agricultural land use is above 50 percent. Although the nutrient concentrations are low (below 2 mg/L) or moderate (below 5.0 mg/L) in most of Chester County, the upward trends in nitrate concentrations could lead to degraded stream-quality conditions associated with nutrient enrichment in the future.

Background metal and trace-element concentrations in samples of stream-bottom sediment collected throughout Chester County were not a stream-quality problem. The concentrations of pesticides and other organic compounds in stream-bottom sediments have decreased across Chester County between 1983 and 1997. This reduction is because of limitations and restriction on the uses of these substances. The compounds in the sediments are degrading, being washed downstream, and mixing and being buried with sediment containing lower concentrations of these substances. Many of these compounds, however, are very stable and will remain in the stream system for many years. The concentrations of most compounds detected do not pose a serious threat to the aquatic life on the stream bottom.

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Table 14. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from Pigeon Creek near Parker Ford (site 10), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	2,785	33	18	69	4.46
1982	1,691	30	18	63	4.32
1983	969	24	18	83	4.24
1984	1,492	29	18	74	4.28
1985	1,032	21	13	69	4.99
1986	1,133	24	16	84	4.28
1987	2,098	39	20	56	4.14
1988	2,397	31	22	70	4.22
1989	2,270	40	23	67	3.82
1990	1,947	32	20	77	3.50
1991	1,705	34	21	75	4.29
1992	440	30	16	72	4.69
1993	1,161	35	22	51	4.30
1994	1,599	41	26	58	4.16
1995	930	39	23	58	3.99
1996	1,685	40	22	22	5.25
1997	1,918	36	25	58	5.23
Median	1,685	33	20	69	4.28

Table 15. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from Stony Run near Spring City (site 6), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera; —, no data]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	2,760	32	14	40	5.14
1982	1,265	27	15	67	4.39
1983	2,082	37	16	42	5.21
1984	998	26	12	60	4.56
1985	550	26	12	32	5.47
1986	651	38	16	67	4.71
1987	1,467	34	15	42	5.25
1988	816	24	15	65	4.72
1989	2,122	35	16	55	4.60
1990	2,129	37	16	66	4.53
1991	1,489	35	18	61	4.47
1992	671	29	14	70	4.17
1993	993	24	13	77	4.39
1994	1,010	36	18	60	4.72
1995	744	39	19	68	4.25
1996	1,860	34	18	39	4.91
1997	—	—	—	—	—
Median	1,138	34	16	60	4.66

Table 16. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from French Creek near Coventryville (site 13), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera; —, no data]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	1,542	42	28	72	3.88
1982	2,380	34	22	44	4.47
1983	1,615	37	26	79	4.25
1984	1,295	27	20	76	4.51
1985	535	36	19	39	4.83
1986	1,395	31	20	48	4.89
1987	1,338	31	21	30	5.10
1988	1,846	31	21	55	4.71
1989	1,643	51	24	38	4.56
1990	1,507	46	25	47	4.56
1991	597	35	19	41	4.69
1992	573	29	16	59	4.30
1993	732	38	20	58	4.52
1994	1,029	32	17	49	4.83
1995	414	34	18	44	4.60
1996	—	—	—	—	—
1997	1,080	32	19	53	4.60
Median	1,317	34	20	49	4.58

Table 17. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from South Branch French Creek at Coventryville (site 12), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera; —, no data]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	1,197	32	13	75	4.13
1982	2,649	33	12	54	4.50
1983	1,697	31	12	89	3.88
1984	1,563	26	12	74	4.44
1985	785	32	24	71	4.17
1986	1,312	39	26	82	3.66
1987	2,014	40	26	59	4.50
1988	3,070	40	27	75	4.11
1989	2,447	41	24	79	3.70
1990	643	36	26	66	3.40
1991	1,737	43	27	83	3.94
1992	1,336	48	31	69	3.78
1993	1,432	42	24	63	4.30
1994	565	29	20	65	4.34
1995	585	32	16	51	4.32
1996	—	—	—	—	—
1997	1,527	32	18	75	4.66
Median	1,480	35	24	73	4.15

Table 18. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from French Creek near Pughtown (site 14), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera; —, no data]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	1,760	35	20	76	4.18
1982	1,543	29	20	68	5.05
1983	1,432	40	20	84	4.29
1984	1,716	31	20	78	4.64
1985	421	24	18	81	4.27
1986	1,416	32	21	63	4.58
1987	1,331	31	17	23	5.44
1988	2,589	33	25	65	4.20
1989	1,489	38	23	78	3.86
1990	747	35	22	73	3.95
1991	1,545	36	23	61	4.54
1992	1,025	40	27	66	4.43
1993	765	34	21	77	3.99
1994	1,212	40	24	84	4.15
1995	388	34	23	68	4.33
1996	—	—	—	—	—
1997	800	33	20	79	3.86
Median	1,374	34	21	74	4.28

Table 19. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from French Creek near Phoenixville (site 15), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	3,427	32	20	91	1.96
1982	548	22	16	66	4.61
1983	1,141	28	17	87	2.31
1984	821	29	21	58	4.20
1985	226	30	16	73	3.81
1986	712	36	18	66	3.39
1987	600	35	20	29	5.05
1988	2,496	41	22	85	3.53
1989	203	35	18	39	4.91
1990	271	38	12	27	4.55
1991	1,254	38	24	85	4.80
1992	825	45	24	53	4.30
1993	587	34	23	80	3.12
1994	1,045	47	30	73	3.86
1995	281	35	23	74	3.24
1996	198	21	14	40	4.62
1997	1,677	37	23	87	3.26
Median	712	35	20	76	3.86

Table 20. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT taxa richness, and Hilsenhoff's biotic index from French Creek at Railroad Bridge at Phoenixville (site 16), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera; <, less than; —, no data]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	240	8	1	<1	6.13
1982	619	20	6	8	8.24
1983	343	24	7	4	7.52
1984	2,247	18	3	<1	6.48
1985	72	21	11	50	5.08
1986	605	21	8	44	4.98
1987	489	25	10	23	5.35
1988	1,340	20	8	70	4.75
1989	270	36	12	13	6.39
1990	113	22	5	5	7.09
1991	727	24	8	19	5.52
1992	115	13	1	2	6.30
1993	985	33	14	42	5.00
1994	656	22	9	28	5.36
1995	90	19	9	51	4.94
1996	—	—	—	—	—
1997	1,234	26	13	47	5.08
Median	547	22	7	19	5.44

Table 21. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from Pickering Creek near Eagle (site 1), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera; —, no data]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	1,301	23	13	40	5.12
1982	2,643	22	13	24	5.36
1983	2,715	31	16	63	5.01
1984	1,537	23	13	77	5.13
1985	765	31	12	59	5.09
1986	1,102	32	17	69	4.81
1987	1,431	25	14	72	5.18
1988	2,728	29	16	60	4.60
1989	1,088	32	17	53	4.71
1990	1,000	23	16	60	4.91
1991	725	29	16	72	4.78
1992	328	21	13	77	4.14
1993	872	26	12	53	5.29
1994	560	27	15	31	5.23
1995	533	23	12	40	5.28
1996	757	28	16	50	4.31
1997	—	—	—	—	—
Median	1,044	27	15	59	5.05

Table 22. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from Pickering Creek near Chester Springs (site 2), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera; —, no data]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	747	20	12	33	4.70
1982	1,084	26	14	59	3.69
1983	526	24	16	77	3.78
1984	1,350	21	16	85	3.73
1985	595	28	11	82	4.24
1986	488	30	19	58	3.99
1987	170	18	13	91	3.08
1988	1,340	24	15	86	3.62
1989	1,076	35	18	70	4.19
1990	502	32	18	68	3.97
1991	766	39	23	77	3.97
1992	295	35	16	65	4.25
1993	219	21	12	72	4.37
1994	871	39	23	49	4.40
1995	223	26	14	41	4.51
1996	—	—	—	—	—
1997	—	—	—	—	—
Median	595	26	16	70	3.99

Table 23. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from Pickering Creek at Merlin (site 3), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera; —, no data]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	1,757	27	17	48	4.83
1982	2,123	30	19	65	4.81
1983	935	25	17	77	4.47
1984	2,005	24	18	62	5.08
1985	912	39	22	79	4.31
1986	1,049	36	19	32	5.02
1987	1,396	38	23	37	5.51
1988	1,047	24	15	50	4.42
1989	1,015	45	24	44	4.64
1990	430	29	17	45	4.13
1991	956	33	20	28	5.29
1992	1,522	44	22	47	3.58
1993	939	30	15	51	4.75
1994	780	31	17	37	4.93
1995	457	31	15	55	4.15
1996	—	—	—	—	—
1997	1,463	41	22	33	4.72
Median	1,031	31	19	48	4.73

Table 24. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from Pickering Creek at Charlestown Road at Charlestown (site 4), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera; —, no data]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	3,611	32	21	54	4.92
1982	1,887	31	23	78	4.65
1983	1,316	27	19	69	4.77
1984	1,943	26	16	81	4.49
1985	557	27	18	84	4.28
1986	2,593	38	22	56	4.89
1987	2,312	36	24	91	3.95
1988	4,090	36	21	62	4.65
1989	1,147	39	22	56	4.65
1990	1,684	37	20	67	5.01
1991	1,514	34	19	72	4.70
1992	2,247	46	23	59	4.89
1993	2,535	48	28	66	4.53
1994	1,310	40	23	78	4.40
1995	811	42	21	53	4.48
1996	1,325	37	21	74	4.56
1997	—	—	—	—	—
Median	1,786	37	22	68	4.65

Table 25. *Values of total individuals, taxa richness, EPT individuals, percentage of EPT taxa richness, and Hilsenhoff's biotic index from Pickering Creek near Phoenixville (site 5), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	2,081	32	22	48	5.02
1982	3,232	39	24	65	4.85
1983	2,183	38	22	79	4.31
1984	1,513	32	23	80	3.98
1985	438	30	18	83	4.03
1986	1,150	40	21	46	4.43
1987	2,029	39	24	65	4.59
1988	2,651	28	17	71	5.09
1989	373	34	19	67	4.58
1990	948	30	19	83	4.99
1991	3,066	42	24	49	4.66
1992	1,775	47	27	55	4.80
1993	1,259	36	20	80	5.04
1994	1,177	29	17	75	5.01
1995	872	35	24	63	4.74
1996	418	26	17	42	4.77
1997	1,530	36	23	78	4.18
Median	1,513	35	22	67	4.74

Table 26. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from Little Valley Creek at Howellville (site 49), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera; —, no data]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	2,871	20	8	56	4.75
1982	2,454	21	9	61	4.59
1983	1,231	18	7	80	3.67
1984	1,218	17	6	75	3.45
1985	551	20	7	80	3.91
1986	1,102	17	7	66	4.46
1987	1,357	15	7	70	3.46
1988	1,375	20	10	71	3.68
1989	346	17	7	68	3.66
1990	518	15	10	52	3.44
1991	481	14	8	39	4.63
1992	913	19	7	63	4.07
1993	804	16	7	41	4.56
1994	1,068	15	7	64	3.98
1995	395	22	10	39	4.24
1996	113	16	8	38	4.50
1997	—	—	—	—	—
Median	991	17	7	64	4.03

Table 27. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from Valley Creek near Valley Forge (site 50), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera; —, no data]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	2,183	20	6	32	5.47
1982	3,144	20	7	44	5.43
1983	1,745	16	6	55	5.08
1984	2,073	21	8	28	5.51
1985	1,354	19	6	23	5.69
1986	1,820	19	8	44	5.00
1987	1,625	22	8	34	5.10
1988	2,278	15	6	37	5.57
1989	1,046	22	7	26	5.25
1990	1,557	19	7	39	5.07
1991	1,020	21	8	25	4.99
1992	1,848	23	9	27	5.07
1993	1,307	22	8	25	5.10
1994	1,561	23	9	25	5.05
1995	1,032	18	5	46	4.59
1996	870	23	8	15	4.70
1997	—	—	—	—	—
Median	1,593	21	8	30	5.08

Table 28. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from Darby Creek at Waterloo Mills near Devon (site 17), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera; —, no data]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	524	23	10	45	4.88
1982	215	20	9	44	4.60
1983	403	28	11	76	4.35
1984	1,208	28	13	66	4.68
1985	968	26	13	61	4.87
1986	706	26	12	71	4.16
1987	1,115	27	11	57	4.27
1988	2,008	24	13	42	5.06
1989	1,165	39	18	56	4.24
1990	450	19	12	55	4.38
1991	1,352	24	10	36	5.06
1992	918	35	12	40	4.77
1993	369	19	8	82	4.29
1994	883	29	14	55	5.28
1995	463	25	9	6	7.12
1996	256	20	10	21	4.62
1997	—	—	—	—	—
Median	795	28	13	56	4.60

Table 29. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from Crum Creek at Whitehorse (site 19), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera; —, no data]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	992	38	16	56	4.89
1982	1,636	35	16	53	5.27
1983	525	30	16	34	4.88
1984	1,222	26	12	74	4.98
1985	568	28	14	43	5.20
1986	907	28	16	67	5.27
1987	1,285	33	18	53	4.92
1988	2,028	24	14	29	5.56
1989	1,644	38	20	48	5.53
1990	1,117	37	18	50	5.04
1991	1,789	36	18	30	5.29
1992	1,881	32	19	36	5.74
1993	538	25	13	42	5.12
1994	1,240	32	16	46	5.22
1995	603	33	15	20	5.69
1996	886	29	14	21	5.17
1997	—	—	—	—	—
Median	1,170	32	16	44	5.21

Table 30. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from Ridley Creek at Goshenville (site 20), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera; —, no data]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	241	27	10	37	4.78
1982	1,345	29	15	75	4.46
1983	855	22	9	53	4.35
1984	1,688	21	13	60	4.48
1985	722	19	11	37	4.97
1986	980	26	12	67	4.40
1987	1,881	30	12	51	4.79
1988	1,660	26	13	51	4.94
1989	767	26	9	31	5.29
1990	757	30	11	17	5.28
1991	547	20	5	41	5.16
1992	1,297	31	9	18	5.35
1993	511	24	7	18	4.97
1994	572	26	9	35	4.96
1995	412	25	12	32	4.27
1996	201	19	7	30	4.64
1997	—	—	—	—	—
Median	762	26	11	37	4.87

Table 31. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from Ridley Creek at Dutton Mill near West Chester (site 21), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera; —, no data]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	1,407	33	20	67	4.64
1982	1,578	27	16	59	4.77
1983	1,697	32	16	70	4.21
1984	3,842	26	16	66	4.61
1985	1,617	27	14	60	4.59
1986	1,629	30	13	49	4.68
1987	1,198	27	14	51	4.43
1988	2,446	25	16	72	4.18
1989	1,347	29	12	37	4.86
1990	2,813	39	17	59	4.48
1991	1,509	21	10	41	5.03
1992	1,391	32	16	54	4.62
1993	1,467	36	17	56	4.62
1994	1,322	28	14	60	4.67
1995	915	36	16	58	4.65
1996	633	34	16	51	4.69
1997	—	—	—	—	—
Median	1,488	30	16	58	4.63

Table 32. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from East Branch Chester Creek at Green Hill (site 22), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera; <, less than; —, no data]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	323	25	11	74	3.37
1982	464	20	10	79	3.66
1983	319	22	11	81	3.15
1984	519	21	10	83	2.94
1985	247	13	9	76	3.20
1986	338	21	10	75	3.54
1987	1,304	32	15	52	5.31
1988	1,014	19	12	62	3.72
1989	231	22	4	5	8.05
1990	425	16	3	<1	6.14
1991	505	23	8	10	6.48
1992	451	19	11	65	4.82
1993	106	15	10	54	4.66
1994	294	23	10	39	4.57
1995	331	22	11	77	3.97
1996	—	—	—	—	—
1997	250	17	9	72	4.16
Median	335	21	10	64	4.06

Table 33. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from East Branch Chester Creek at Milltown (site 23), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera; —, no data]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	1,371	28	11	56	5.09
1982	1,700	27	11	58	5.16
1983	1,247	31	11	53	5.01
1984	1,085	29	14	71	5.09
1985	991	25	12	53	4.36
1986	518	19	10	53	4.02
1987	2,252	31	14	68	4.46
1988	2,477	24	14	44	5.03
1989	4,174	33	14	25	5.89
1990	2,625	33	16	36	5.45
1991	1,731	26	14	37	5.34
1992	2,926	38	14	29	5.43
1993	693	20	11	17	5.47
1994	2,643	30	13	25	5.70
1995	281	25	10	31	5.71
1996	1,594	29	10	30	5.64
1997	—	—	—	—	—
Median	1,647	29	13	41	5.25

Table 34. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from East Branch Chester Creek at Westtown (site 24), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	1,783	28	13	41	5.23
1982	3,535	22	10	32	4.63
1983	2,250	30	15	64	4.77
1984	2,424	30	15	65	4.99
1985	1,365	25	12	14	5.05
1986	1,026	19	10	71	4.41
1987	2,592	29	12	35	4.91
1988	1,677	22	11	41	4.80
1989	1,518	27	8	16	6.26
1990	3,187	33	11	37	5.64
1991	1,808	27	13	44	4.86
1992	2,471	24	11	24	5.17
1993	643	24	9	41	4.65
1994	767	24	13	34	4.94
1995	464	26	10	24	5.34
1996	1,386	30	13	54	4.74
1997	1,291	26	12	55	4.65
Median	1,677	26	12	41	4.91

Table 35. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from Goose Creek Tributary to East Branch Chester Creek near West Chester (site 25), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera; <, less than; —, no data]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	356	9	3	2	6.00
1982	9,644	8	3	<1	5.29
1983	—	—	—	—	—
1984	—	—	—	—	—
1985	—	—	—	—	—
1986	—	—	—	—	—
1987	—	—	—	—	—
1988	587	12	5	29	5.08
1989	3,091	17	4	<1	5.95
1990	1,111	20	6	3	5.67
1991	2,108	17	6	2	5.60
1992	1,095	20	6	23	5.45
1993	765	16	3	32	5.67
1994	671	11	4	27	5.05
1995	1,868	18	5	21	5.59
1996	1,298	19	5	58	4.99
1997	1,320	12	5	69	4.82
Median	1,205	17	5	12	5.52

Table 36. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from East Branch Chester Creek below Goose Creek near West Chester (site 51), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera; <, less than; —, no data]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	—	—	—	—	—
1982	—	—	—	—	—
1983	2,869	22	5	3	7.33
1984	2,874	22	6	22	5.87
1985	4,236	19	2	<1	7.05
1986	1,514	23	6	42	5.25
1987	12,174	20	4	7	7.63
1988	3,963	17	6	49	5.65
1989	926	28	7	40	6.20
1990	3,033	31	10	52	4.95
1991	3,951	27	11	52	5.18
1992	3,046	26	12	33	4.99
1993	1,169	28	11	20	5.83
1994	2,093	32	11	42	4.85
1995	589	22	8	34	4.61
1996	—	—	—	—	—
1997	2,219	18	7	68	4.59
Median	2,872	23	7	37	5.45

Table 37. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from West Branch Brandywine Creek at Rock Run (site 37), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera; —, no data]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	551	29	19	67	3.98
1982	1,086	31	21	63	4.58
1983	1,241	31	19	87	5.22
1984	1,052	30	20	78	4.93
1985	1,711	32	19	63	4.88
1986	646	34	19	73	4.21
1987	1,278	36	21	53	4.86
1988	1,182	28	16	85	5.26
1989	1,399	37	19	58	4.85
1990	1,020	29	21	73	4.88
1991	1,793	38	23	33	5.10
1992	1,376	38	22	58	4.60
1993	665	31	18	53	4.74
1994	1,471	32	18	53	5.16
1995	440	36	18	46	4.67
1996	511	27	17	74	4.03
1997	—	—	—	—	—
Median	1,134	32	19	63	4.85

Table 38. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from Buck Run at Doe Run (site 46), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera; —, no data]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	1,026	19	8	72	5.03
1982	1,647	16	6	74	5.20
1983	1,846	17	9	88	5.43
1984	2,272	21	10	68	5.07
1985	1,091	21	10	47	4.55
1986	1,769	23	14	80	4.96
1987	1,644	25	11	61	5.33
1988	2,070	24	15	68	4.90
1989	1,353	32	13	83	5.08
1990	1,804	39	19	58	5.12
1991	1,756	26	13	83	5.15
1992	1,432	34	16	77	4.50
1993	1,403	31	16	69	4.90
1994	2,602	24	13	73	4.71
1995	674	27	10	45	4.43
1996	—	—	—	—	—
1997	1,405	31	15	52	4.83
Median	1,646	25	13	71	4.99

Table 39. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from Doe Run at Springdell (site 45), Chester County, Pennsylvania, 1981-97*

{EPT, Ephemeroptera, Plecoptera, Trichoptera; —, no data]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	1,133	24	13	58	4.37
1982	1,620	25	14	37	4.84
1983	1,405	23	11	69	4.82
1984	1,608	22	13	62	4.55
1985	974	20	9	71	4.42
1986	774	19	12	66	4.96
1987	1,617	26	13	62	5.06
1988	1,818	22	15	72	4.62
1989	1,430	34	18	79	4.21
1990	1,752	25	15	62	4.91
1991	1,392	29	15	49	4.51
1992	1,195	23	14	54	4.68
1993	1,229	32	16	76	4.53
1994	1,300	23	11	67	4.51
1995	820	32	20	49	4.22
1996	—	—	—	—	—
1997	1,078	26	16	52	4.19
Median	1,346	25	14	62	4.54

Table 40. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from West Branch Brandywine Creek at Wawaset (site 38), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	598	31	15	82	4.48
1982	1,655	21	13	75	4.79
1983	1,110	27	14	78	4.74
1984	1,402	22	9	37	4.90
1985	1,085	24	11	27	5.27
1986	769	24	12	66	4.38
1987	402	23	13	55	4.61
1988	1,939	22	13	84	4.40
1989	1,631	31	15	46	4.75
1990	1,532	39	22	69	4.16
1991	1,418	31	17	70	3.88
1992	1,041	34	18	41	4.70
1993	764	39	20	52	4.37
1994	1,005	37	23	82	4.23
1995	547	43	22	63	4.03
1996	861	30	14	54	4.81
1997	1,476	38	21	56	4.62
Median	1,085	30	13	61	4.61

Table 41. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from East Branch Brandywine Creek near Cupola (site 48), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera; —, no data]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	1,310	43	24	59	4.83
1982	2,529	35	20	61	4.99
1983	733	32	16	65	4.39
1984	1,652	24	14	71	4.29
1985	689	28	13	48	4.65
1986	895	33	18	48	4.20
1987	1,139	31	14	31	5.06
1988	1,984	32	15	33	4.78
1989	3,846	46	24	42	4.73
1990	538	25	14	26	4.86
1991	926	37	21	30	4.94
1992	610	25	11	51	4.34
1993	2,016	49	24	13	5.83
1994	973	31	14	33	4.90
1995	648	35	20	29	4.35
1996	—	—	—	—	—
1997	—	—	—	—	—
Median	973	32	16	42	4.78

Table 42. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from East Branch Brandywine Creek at Glenmoore (site 42), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera; —, no data]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	752	36	19	83	3.84
1982	1,708	47	23	60	4.43
1983	1,338	45	25	70	4.33
1984	1,008	36	23	73	4.45
1985	1,361	43	22	63	4.43
1986	723	48	25	77	4.09
1987	1,435	36	22	67	4.25
1988	1,671	33	19	60	4.58
1989	2,617	46	22	45	4.50
1990	973	41	22	46	4.78
1991	1,825	42	20	49	4.48
1992	1,330	50	29	39	4.08
1993	1,554	48	25	53	3.81
1994	1,378	47	27	58	4.70
1995	625	34	18	30	4.78
1996	—	—	—	—	—
1997	—	—	—	—	—
Median	1,361	43	22	58	4.43

Table 43. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from Indian Run near Springton (site 47), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera; —, no data]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	1,050	37	23	60	3.70
1982	1,883	40	24	51	4.06
1983	1,165	38	22	79	2.97
1984	1,027	33	21	74	3.54
1985	729	29	20	68	3.79
1986	688	34	25	82	2.94
1987	640	35	19	46	4.32
1988	787	29	21	75	3.28
1989	1,288	32	18	54	4.06
1990	840	32	20	42	4.16
1991	589	31	21	55	3.97
1992	440	25	17	63	3.66
1993	770	34	22	53	3.80
1994	1,232	34	20	53	4.20
1995	647	33	19	45	4.11
1996	—	—	—	—	—
1997	—	—	—	—	—
Median	787	33	21	55	3.80

Table 44. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from East Branch Brandywine Creek near Downingtown (site 36), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera; —, no data]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	2,450	28	15	68	4.50
1982	11,821	23	14	12	5.71
1983	2,848	31	15	56	4.68
1984	5,962	33	21	20	5.39
1985	1,866	30	18	58	4.92
1986	2,232	31	20	41	4.69
1987	2,179	31	18	50	4.80
1988	1,499	24	16	65	4.69
1989	2,207	41	23	37	4.96
1990	2,488	46	26	66	4.40
1991	1,398	41	26	60	4.44
1992	2,426	46	28	46	4.50
1993	1,896	49	29	77	3.75
1994	1,022	38	23	80	4.19
1995	1,508	41	26	66	4.31
1996	1,347	49	27	49	3.73
1997	—	—	—	—	—
Median	2,193	36	22	57	4.59

Table 45. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from West Valley Creek at Mullsteins Meadow near Downingtown (site 44), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera; —, no data]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	2,812	33	19	58	4.50
1982	1,556	33	17	71	4.68
1983	1,918	26	16	76	4.22
1984	1,475	25	15	70	4.41
1985	2,091	33	18	52	4.41
1986	1,079	24	12	70	4.83
1987	2,352	33	19	64	4.55
1988	2,626	22	15	75	4.61
1989	1,105	30	16	76	3.79
1990	1,100	28	14	81	4.04
1991	1,499	21	13	51	4.58
1992	1,380	28	18	52	4.08
1993	1,179	36	20	60	4.12
1994	1,163	27	14	55	4.50
1995	1,327	34	19	47	4.17
1996	—	—	—	—	
1997	3,137	36	20	49	4.72
Median	1,487	29	17	62	4.45

Table 46. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from East Branch Brandywine Creek at Wawaset (site 39), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	641	31	13	44	5.21
1982	2,825	36	11	32	5.07
1983	771	36	13	45	5.06
1984	2,999	42	17	40	5.11
1985	699	27	13	44	4.82
1986	2,583	44	20	56	4.34
1987	1,115	40	17	60	4.50
1988	1,357	28	16	76	4.41
1989	2,698	40	19	57	4.33
1990	3,793	44	21	63	3.98
1991	11,771	50	21	89	3.30
1992	1,354	19	10	49	4.46
1993	1,701	33	13	61	3.91
1994	792	41	18	36	5.30
1995	307	33	14	59	4.60
1996	880	32	15	33	5.06
1997	2,123	30	16	69	4.15
Median	1,354	36	16	56	4.50

Table 47. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from Brandywine Creek near Chadds Ford (site 40), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera; —, no data]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	651	23	11	53	4.67
1982	1,673	30	15	52	4.83
1983	1,009	32	17	52	4.76
1984	1,446	24	12	37	5.03
1985	993	25	14	52	4.78
1986	428	36	15	48	4.76
1987	1,046	37	21	36	5.11
1988	1,824	25	16	66	4.63
1989	2,155	37	19	56	3.95
1990	1,702	31	19	46	4.26
1991	2,380	31	18	39	4.72
1992	1,835	29	17	63	3.96
1993	1,142	36	21	58	4.31
1994	1,424	32	21	79	4.42
1995	1,208	33	16	67	4.11
1996	—	—	—	—	—
1997	3,000	41	22	58	4.13
Median	1,435	32	17	52	4.65

***Table 48**. Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from West Branch Red Clay Creek at Kennett Square (site 27), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera; <, less than]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	211	11	1	<1	5.70
1982	777	13	1	<1	6.16
1983	84	11	1	5	5.93
1984	468	10	0	0	5.75
1985	326	18	2	2	5.88
1986	107	10	1	<1	5.68
1987	267	15	1	<1	6.68
1988	546	17	3	1	5.71
1989	758	33	15	40	4.90
1990	1,843	26	6	4	5.75
1991	424	14	3	6	7.45
1992	410	14	3	43	4.55
1993	834	28	7	9	6.37
1994	922	24	7	3	6.21
1995	323	22	6	14	5.41
1996	178	15	6	15	5.75
1997	790	26	9	15	5.94
Median	424	15	3	4	5.75

***Table 49.** Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from East Branch Red Clay Creek near Five Point (site 26), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera; <, less than]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	1,055	14	0	0	5.64
1982	285	16	4	15	5.70
1983	577	17	2	74	4.48
1984	2,375	12	1	<1	5.88
1985	627	16	2	<1	5.70
1986	34	10	1	2	4.91
1987	577	17	3	3	5.37
1988	920	11	0	0	5.36
1989	545	17	3	<1	5.38
1990	2,652	19	4	<1	5.78
1991	700	15	2	<1	5.40
1992	1,0534	26	7	1	5.67
1993	761	23	5	10	5.93
1994	998	21	6	5	5.22
1995	514	22	8	49	4.58
1996	1,240	22	7	29	4.98
1997	1,213	17	7	40	4.59
Median	761	17	3	2	5.38

Table 50. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from East Branch White Clay Creek at Avondale (site 28), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera; —, no data]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	836	18	5	28	5.50
1982	1,295	23	8	34	5.79
1983	1,368	18	8	72	4.64
1984	932	16	9	24	5.03
1985	1,007	22	10	35	4.94
1986	1,026	19	10	28	4.64
1987	4,223	19	7	8	6.32
1988	2,624	19	9	28	4.92
1989	1,797	29	14	48	4.57
1990	1,492	20	8	30	4.93
1991	2,007	19	11	29	4.92
1992	2,514	29	13	33	5.07
1993	2,090	27	14	23	5.03
1994	1,779	28	14	24	5.08
1995	1,543	28	11	21	5.10
1996	—	—	—	—	—
1997	1,717	24	10	36	4.48
Median	1,630	21	10	29	4.98

Table 51. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from Middle Branch White Clay Creek at Wickerton (site 29), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera; —, no data]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	780	16	5	21	5.67
1982	1,697	19	8	70	4.63
1983	833	17	8	69	4.42
1984	1,742	19	12	52	4.75
1985	1,265	25	12	33	4.85
1986	898	24	10	53	4.54
1987	1,314	23	9	32	4.79
1988	3,440	21	9	59	4.85
1989	1,438	26	12	42	5.27
1990	2,008	29	13	44	4.96
1991	2,464	24	12	52	4.79
1992	1,458	32	13	56	4.83
1993	829	19	10	73	4.65
1994	1,912	24	12	52	4.72
1995	1,841	28	14	38	5.03
1996	—	—	—	—	—
1997	1,371	29	17	54	4.83
Median	1,448	24	12	52	4.81

Table 52. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from West Branch White Clay Creek near Chesterville (site 30), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera; —, no data]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	1,216	22	10	53	4.89
1982	2,270	23	13	80	5.47
1983	794	23	10	31	4.77
1984	1,232	23	11	74	4.96
1985	836	29	15	40	4.94
1986	1,079	24	13	71	4.34
1987	1,665	24	14	65	4.40
1988	2,065	23	14	81	4.58
1989	1,114	34	17	57	4.63
1990	1,794	29	16	64	4.85
1991	1,438	27	17	59	4.92
1992	1,472	34	17	59	4.36
1993	1,270	33	18	38	4.83
1994	1,027	25	16	50	4.15
1995	637	30	17	39	4.79
1996	—	—	—	—	—
1997	1,470	27	15	53	4.42
Median	1,251	26	15	58	4.78

Table 53. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from East Branch Big Elk Creek at Elkview (site 31), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	846	25	12	29	5.52
1982	1,416	26	12	29	5.26
1983	1,171	23	13	60	5.14
1984	1,216	25	13	59	5.42
1985	546	22	7	29	5.36
1986	851	20	8	41	5.33
1987	1,638	21	7	4	6.42
1988	1,357	26	13	39	4.97
1989	1,722	26	12	33	5.37
1990	1,387	23	11	16	5.32
1991	810	15	7	16	5.50
1992	755	26	13	28	5.02
1993	948	26	11	23	4.83
1994	553	17	7	27	5.30
1995	124	14	4	13	6.23
1996	71	11	3	20	4.96
1997	529	13	4	2	4.76
Median	851	23	11	28	5.32

Table 54. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from West Branch Big Elk Creek near Oxford (site 32), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera; —, no data]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	1,517	30	14	75	4.83
1982	2,458	26	10	73	5.13
1983	1,203	28	14	51	5.16
1984	1,875	23	10	81	4.97
1985	1,124	21	12	53	4.98
1986	1,402	24	13	69	4.51
1987	1,309	22	13	38	5.30
1988	2,245	20	11	55	4.85
1989	1,533	25	12	68	4.77
1990	1,536	27	14	51	4.94
1991	2,733	32	17	52	4.87
1992	752	27	16	45	4.93
1993	424	18	9	45	4.40
1994	1,587	29	13	58	4.84
1995	85	15	7	19	3.84
1996	290	20	11	36	4.63
1997	—	—	—	—	—
Median	1,460	25	13	52	4.86

Table 55. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from East Branch Octoraro Creek at Christiana (site 33), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	978	18	7	45	5.82
1982	1,670	24	11	56	5.60
1983	856	25	9	75	5.25
1984	1,518	21	12	45	5.07
1985	593	25	11	67	5.05
1986	1,110	27	11	52	4.66
1987	1,421	27	11	40	5.80
1988	1,953	20	9	76	4.19
1989	2,083	30	12	73	4.05
1990	1,419	33	15	58	4.62
1991	1,476	28	14	47	5.01
1992	1,268	23	10	42	4.66
1993	558	22	11	56	3.59
1994	2,194	31	15	27	5.31
1995	719	26	13	64	3.96
1996	847	25	8	57	4.54
1997	1,478	29	14	64	4.42
Median	1,419	25	11	56	4.66

Table 56. *Values of total individuals, taxa richness, EPT taxa richness, percentage of EPT individuals, and Hilsenhoff's biotic index from Valley Creek near Atglen (site 34), Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, Trichoptera; —, no data]

Year	Total individuals	Taxa richness	EPT taxa richness	Percentage of EPT individuals	Hilsenhoff's biotic index
1981	2,173	21	11	62	4.29
1982	2,478	32	14	61	4.66
1983	930	23	13	72	5.02
1984	2,239	30	15	40	5.11
1985	962	28	15	72	4.86
1986	783	23	13	47	4.70
1987	2,316	31	15	46	5.54
1988	2,916	24	13	62	4.88
1989	3,051	39	19	68	4.54
1990	1,262	28	14	55	4.62
1991	3,201	32	14	43	4.96
1992	1,788	27	12	34	4.68
1993	825	18	6	50	4.39
1994	2,936	23	8	17	5.26
1995	460	21	10	45	5.05
1996	1,855	31	13	31	5.32
1997	—	—	—	—	—
Median	2,014	28	13	49	4.87

APPENDIX 1. SYSTEMATIC CHECKLIST OF TAXA REPORTED FROM THE STREAM CONDITIONS OF CHESTER COUNTY BIOLOGICAL MONITORING NETWORK, CHESTER COUNTY, PENNSYLVANIA

Hydrozoa (Hydroids)
- Hydra sp.

Platyhelminthes (Flatworms)
- Planariidae

Nematoda (Round Worms)

Nemertea (Proboscis worms)
- Prostoma sp.

Gastropoda (Snails)
- Amnicola sp.
- Campeloma sp.
- Ferrissia sp.
- Goniobasis sp.
- Gyraulus sp.
- Helisoma sp.
- Lymnaea sp.
- Menetus sp.
- Physa sp.
- Planorbula sp.

Bivalvia (Clams)
- Musculium sp.
- Pisidium sp.
- Sphaerium sp.

Annelida (Segmented worms)
- Erpobdella sp.
- Helobdella sp.
- Hirudinea
- Lumbriculidae
- Naididae
- Oligochaeta
- Polychaeta
- Sabellidae
- Tubificidae

Cladocera (Water fleas)

Cyclopoida (Copepods)
- Cyclopidae

Podacopa (Seed shrimps)

Isopoda (Sow bugs)
- Caecidotea sp.
- Lirceus sp.

Amphipoda (Scuds)
- Crangonyx sp.
- Gammarus sp.
- Hyallela azteca

Decapoda (Crayfish)

- Cambarus sp.
- Orconectes sp.
- Procambarus sp.

Arachnida (Water mites)

- Acarina

Ephemeroptera (Mayflies)

- Ameletus sp.
- Anthopotamus sp.
- Baetis sp.
- Caenis sp.
- Centroptilum sp.
- Epeorus sp.
- Ephemera sp.
- Ephemerella sp.
- Eurylophlebia sp.
- Habrophlebia sp.
- Heptagenia sp.
- Isonychia sp.
- Paraleptophlebia sp.
- Potamanthus sp.
- Serratella sp.
- Siphlonurus sp.
- Stenacron sp.
- Stenonema sp.
- Tricorythodes sp.

Odonata (Dragonflies and Damselflies)

- Aeshna sp.
- Amphiagrion sp.
- Argia sp.
- Boyeria sp.
- Calopteryx sp.
- Enallagma sp.
- Gomphus sp.
- Hetaerina sp.
- Ischnura sp.
- Lanthus sp.
- Macromia sp.
- Nehalennia sp.
- Ophiogomphus sp.
- Stylogomphus sp.

Plecoptera (Stoneflies)

- Acroneuria sp.
- Agnetina sp.
- Allocapnia sp.
- Belonuria sp.
- Hastaperla sp.
- Isoperla sp.
- Leuctra sp.
- Neoperla sp.
- (Neo)phasganophora sp.
- Paracapnia sp.
- Paragnetina sp.
- Paraleuctra sp.
- Paranemoura sp.
- Peltoperla sp.
- Strophopteryx sp.
- Taeniopteryx sp.

Hemiptera (Bugs)

- Gerris sp.
- Mesovelia sp.
- Metrobates sp.
- Microvelia sp.
- Rhagovelia sp.
- Rheumatobates sp.
- Sigara sp.
- Trepobates sp.
- Trichocorixa sp.

Megaloptera (Alderflies and Dobsonflies)

- Chauliodes sp.
- Corydalus sp.
- Nigronia sp.
- Sialis sp.

Neuroptera (Spongillaflies)

- Climacia sp.
- Climacia areolaris
- Sisyridae

Lepidoptera (Butterflies and Moths)

- Archanara sp.
- Nymphula sp.
- Petrophila sp.
- Synclita sp.

Trichoptera (Caddisflies)

- Agraylea sp.
- Anisocentropus pyraloides
- Apatania sp.
- Brachycentrus sp.
- Ceraclea sp.
- Cheumatopsyche sp.
- Chimarra sp.
- Culoptila sp.
- Cyrnellus sp.
- Diplectrona sp.
- Dolophilodes sp.
- Glossosoma sp.
- Goera sp.
- Helicopsyche sp.
- Hydatophylax sp.
- Hydropsyche sp.
- Hydroptila sp.
- Lepidostoma sp.
- Leucotrichia sp.
- Lype sp.
- Macronema sp.
- Micrasema sp.
- Molanna sp.
- Mystacides sp.
- Nectopsyche sp.
- Neophylax sp.
- Neureclipsis sp.
- Nyctiophylax sp.
- Ochrotrichia sp.
- Oecetis sp.
- Parapsyche sp.
- Phylocentropus sp.
- Polycentropus sp.
- Potamyia sp.
- Protoptila sp.
- Psilotreta sp.
- Psychomyia sp.
- Rhyacophila sp.
- Rhyacophila fuscula
- Stactobiella sp.
- Symphitopsyche sp.
- Triaenodes sp.
- Wormaldia sp.

Coleoptera (Beetles)

- Agabus sp.
- Anchytarsus bicolor
- Ancyronyx sp.
- Ancyronyx variegata
- Berosus sp.
- Chrysomelidae
- Curculionidae
- Dineutus sp.
- Dubiraphia sp.
- Ectopria sp.
- Ectopria nervosa
- Helichus sp.
- Helophorus sp.
- Hydrobius sp.
- Hydrochara sp.
- Hygrotus sp.
- Laccophilus sp.
- Limnebius sp.
- Macronychus sp.
- Macronychus glabratus
- Microcylloepus sp.
- Optioservus sp.
- Oulimnius sp.
- Promoresia sp.
- Psephenus sp.
- Stenelmis sp.

Diptera (Flies)

- Antocha sp.
- Atherix sp.
- Blepharoceridae
- Ceratopogonidae (Heleidae)
- Chaoborus sp.
- Chelifera sp.
- Chironomidae
- Clinocera sp.
- Dicranota sp.
- Dixa sp.
- Ephydridae
- Helius sp.
- Hemerodromia sp.
- Hexatoma sp.
- Limnophora sp.
- Muscidae
- Prosimulium sp.
- Simulium sp.
- Stratiomys sp.
- Syrphidae
- Tabanus sp.
- Telmatoscopus sp.
- Tipula sp.