SURFACE-WATER AND STREAMBED-SEDIMENT QUALITY OF STREAMS DRAINING SURFACE-MINED LAND RECLAIMED WITH SEWAGE SLUDGE, FULTON COUNTY, ILLINOIS, 1972-89

By Richard H. Coupe and Jo A. Macy

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CONVERSION FACTORS AND ABBREVIATIONS

Multiply	By	To obtain
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
acre	0.4047	hectare
pound (lb)	453.6	gram
gallon (gal)	3.785	liter

Abbreviated water-quality units used in this report:

milligram per kilogram (mg/kg)

microgram per gram (μg/g)

microgram per kilogram (μg/kg)

micrometer (μm)

milligram per liter (mg/L)

SURFACE-WATER AND STREAMBED-SEDIMENT QUALITY OF STREAMS

DRAINING SURFACE-MINED LAND RECLAIMED WITH SEWAGE SLUDGE,

FULTON COUNTY, ILLINOIS, 1972-89

by Richard H. Coupe and Jo A. Macy

ABSTRACT

Sewage sludge from the Chicago area has been used from 1971 through 1989 to reclaim surface-mined land in Fulton County, Ill. The sludge contains substantial amounts of nutrients and significant amounts of toxic organic compounds. Because of the concern of the fate of these toxins, the U.S. Geological Survey in cooperation with the Metropolitan Water Reclamation District of Greater Chicago began an analysis of historical data in 1989 to compare the quality of water and streambed sediments from streams in a 15,528-acre area in the county to determine whether the application of sludge is adversely affecting the quality of surface water.

Surface-water-quality and streambed-quality data were collected at four sites in Fulton County, Ill. These data were analyzed to determine changes in water quality over time. The data-collection program was not designed to determine the effects of specific factors on water quality. However, it is possible to isolate the major factors affecting water quality by comparing water quality and trends in water quality at similar sites with different land uses.

Trend analyses of surface-water-quality data indicate that sludge application is affecting the quality of stream water by increasing the concentrations of nitrite plus nitrate and kjeldahl nitrogen. However, the concentrations of these constituents in Evelyn Branch (the stream draining the sludge-application fields) are lower than the concentrations at the site upstream from the project area on Big Creek (the stream transecting the project area). In fact, the median concentrations of these constituents decrease from the upstream site on Big Creek to the site on Big Creek downstream from the confluence with the stream draining the sludge-application fields.

There were few detections of organic compounds in the streambed sediments in Evelyn Branch, and the median concentrations of organic compounds were smaller than those in Big Creek upstream from the project area. This would indicate that the application of sludge is not affecting the streambed quality with respect to these constituents. Trend analyses of streambed chemical constituents over time did not indicate that application of sludge has adversely affected streambed quality. On the other hand, the available data cannot show that adverse effects of sludge application on streambed quality have not

occurred. A refinement of the sampling scheme would be necessary to rule out the possibility of present and future adverse effects of sludge applications on streambed quality.

INTRODUCTION

The Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) has been operating a sewage-sludge recycling and surface-mine reclamation project on 15,528 acres in Fulton County, Ill., since 1971. Sludge from the Chicago area is transported to Fulton County and is used as a soil conditioner; supernate from the liquid sludge is used as an irrigant on hayfields in the project area. Sludge contains substantial quantities of nutrients, and its incorporation into deficient soil helps to recondition the soil (Patterson and others, 1982). Analyses indicate that sludge from the Chicago area can contain high concentrations of some hydrophobic compounds, such as polychlorinated biphenyls (PCB's) and pesticides. The fate of these constituents, some of which are known toxins, is of concern to local residents, public-health officials, and others.

In 1989, the U.S. Geological Survey (USGS) in cooperation with the MWRDGC began an analysis of historical data to compare the quality of water and streambed sediments from streams in the project area and to determine, if possible, whether the application of sludge as a soil conditioner is adversely affecting the quality of water in the streams. Several factors could affect water quality, but the major factor in the study area is runoff from large amounts of surface-mined land (U.S. Environmental Protection Agency, 1981). Additional anthropogenic factors may include faulty septic systems, road salting during the winter, effluent from sewage-treatment plants, and annual field plowing. Statistical and trend analyses were used to determine if sludge application or other factors have affected constituent concentrations significantly.

The historical data-collection program was not specifically designed to identify specific factors that affect water quality and to what degree; however, it is possible to isolate the major factors affecting water quality by comparing water quality and trends in water quality among similar sites with different land uses. Analysis of streambed-sediment quality can be used to determine long-term changes in water quality, especially if the streams contain hydrophobic compounds that accumulate in the sediments (Helsel and Koltun, 1986, p. 1).

Purpose and Scope

This report presents the results of statistical and trend analyses on surface-water-quality and streambed-sediment-quality data at four surface-water sites in Fulton County, Ill., from 1972 through 1989. Water-quality data for these sites were evaluated for monotonic trends; streambed-sediment-quality data at these sites also were evaluated for monotonic trends and for differences in the mean values of constituent concentrations among the sites. The results are presented in tabular form.

Description of Project Area

The 15,528-acre project area (fig. 1) was surface mined for coal from the 1920's until the early 1960's. Before mining, bedrock in the project area consisted of alternating layers of coal, limestone, shale, and sandstone. Overlying the bedrock were glacial drift and loess. During mining, all the material overlying the coal was stripped, mixed, and redeposited, leaving an unsorted, uncompacted mixture of clay, silt, sand, and large blocks of bedrock (Patterson, 1982; and Patterson and others, 1982). Surface mining left rough unreclaimed areas of hills, ridges, and valleys composed of displaced overburden, as well as steep valley walls along surface-mine lakes and drainage channels.

In 1970, the MWRDGC (then known as the Metropolitan Sanitary District of Greater Chicago) began acquiring and recontouring surface-mined land near Bryant and St. David, Fulton County, Ill. (Patterson and others, 1982). During recontouring, some of the hills and ridges were formed into gentle slopes, and berms were constructed to form four storage basins for sludge. These storage basins form a prominent mound near the center of the project area (fig. 2). The storage basins have not received any shipments of sludge since March 1983 and are gradually being cleaned.

The project area includes 45 sludge-application fields and 18 hayfields (fig. 2). Most of the numerous small lakes and retention basins (which total 1,200 acres) are not shown in figure 2. The sludge-application fields have been bermed and sloped to drain into field runoff-retention basins (Zenz and others, 1976, p. 2233). The hayfields are closed drainage basins that have been contoured to prevent surface runoff from entering the streams draining the project area. Because of previous surface-mining activities, the soils on most of the sludge-application fields and on all of the hayfields are relatively impervious and nondraining or poorly draining (U.S. Environmental Protection Agency, 1981). These impervious soils minimize the movement of any contaminants downward through the unsaturated zone.

Water in the retention basins is released to the receiving stream. Before water from the retention basins is released, the water is sampled to determine pH, total suspended solids (TSS), and fecal coliform bacteria. If the values and concentrations of these water-quality characteristics are within the Illinois Environmental Protection Agency (IEPA) water-quality standards, then the water in the retention basin can be released into a receiving stream. If pH and the concentrations of TSS and fecal coliforms are not within the IEPA standards, then the water cannot be released and must be either (1) resampled at a later date for compliance with standards, (2) treated and then released, or (3) pumped back onto the fields.

Big Creek, the major stream draining the project area (figs. 1 and 2), flows southwesterly to Spoon River (fig. 1). Slug Run and Evelyn Branch (fig. 2) are tributaries to Big Creek. Evelyn Branch flows out of Lake Evelyn--a manmade lake that was created by an earthen dam across Evelyn Branch. A 48-in. inside-diameter pipe open at the surface of the lake leads down and then through the base of the dam, allowing water to discharge from the

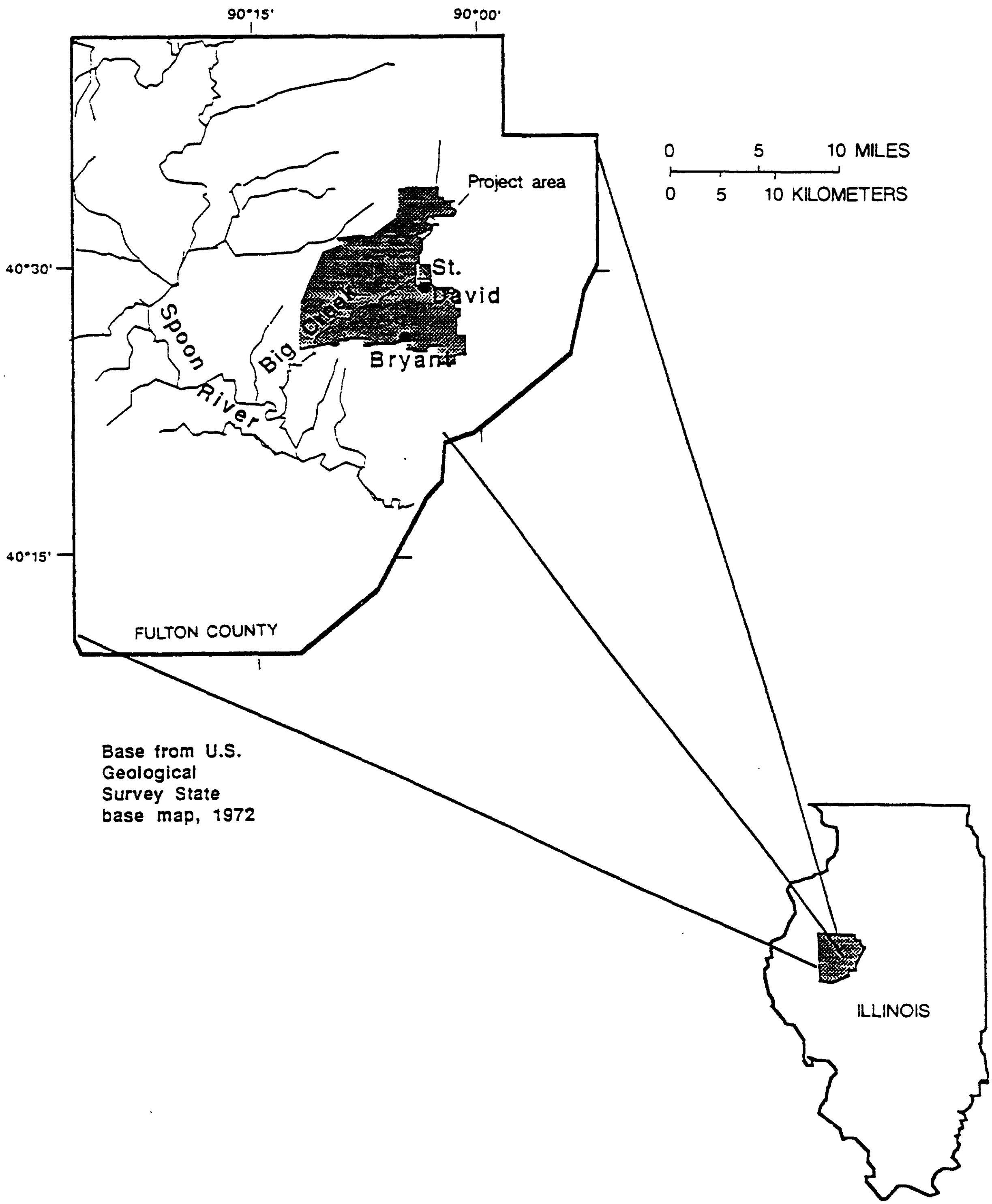

Figure 1.--Location of project area.

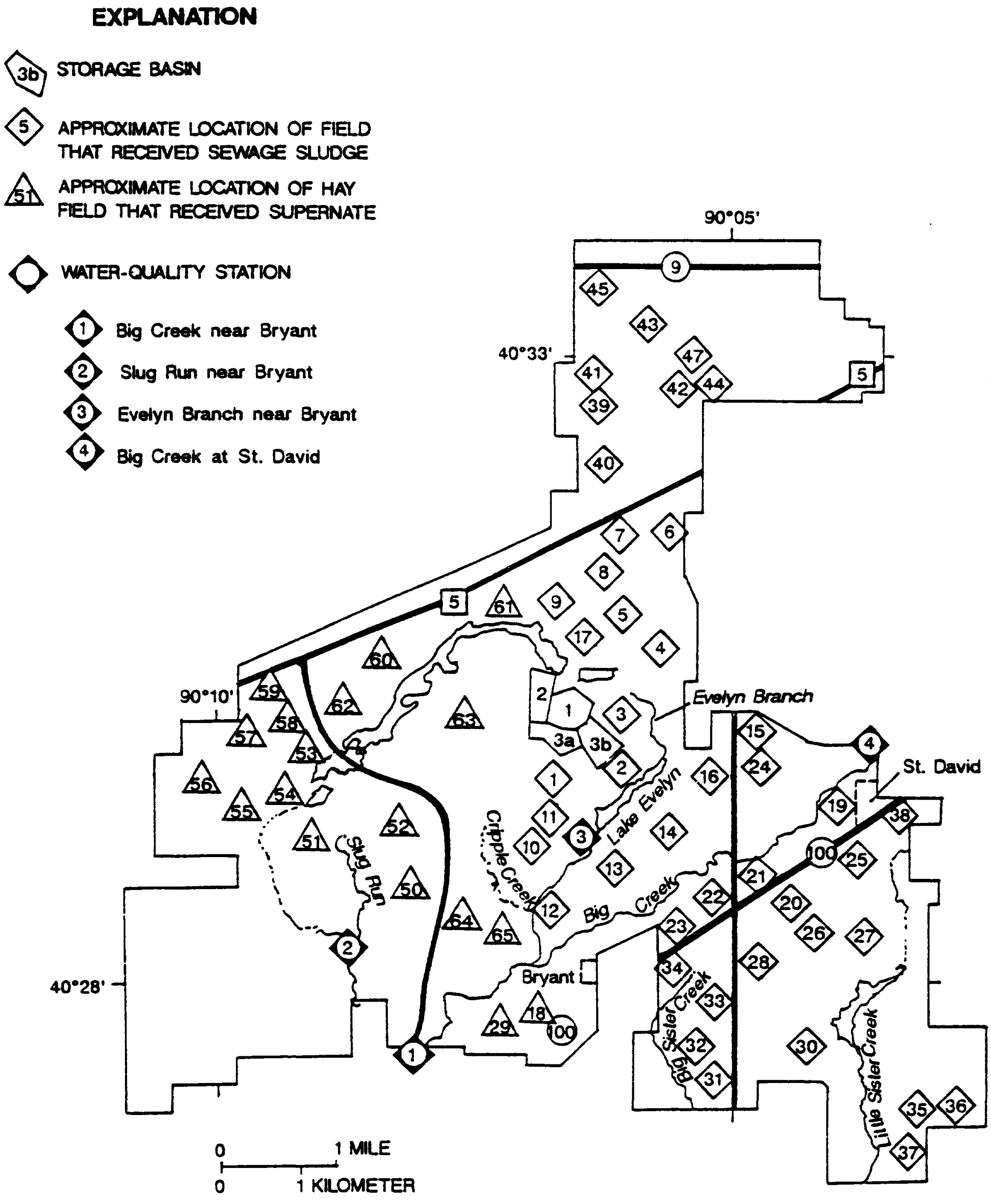

Figure 2.--Locations of the data-collection sites and sludge-holding basins and the approximate locations of the fields that received sewage sludge and hayfields that received supernate.

lake and making Evelyn Branch below Lake Evelyn the outfall from Lake Evelyn. South of State Highway 100, the project area is drained by two tributaries of the Illinois River--Big Sister and Little Sister Creeks (fig. 2).

Many of the lakes in the project area are connected by pipes or drainage channels, forming several interconnected reservoirs that discharge into either Evelyn Branch or Slug Run. These reservoirs are hydraulically connected to the shallow ground-water system, and their surfaces are continuous with the water table. Details on the hydrologic environment at the study site are given in Patterson and others (1982, p. 3).

Sludge Application

The term "sludge", as used in this report, refers to a solid, semisolid, or semifluid mixture resulting from sewage treatment. The water content of the sludge was about 95 percent during 1971-83. Shipments of sludge from the Chicago area to the project area were stopped in March 1983. In 1986, shipments of dewatered, centrifuged, and lagooned sludge, which is approximately 70 percent solids, were resumed. Since 1986, the sludge has been transported to the project area and delivered directly to sludge-application fields.

In 1971, the sludge was barged down the Illinois River and pumped into four storage basins in the project area (fig. 2) (Patterson, 1982, p. 1). The solids in the sludge settled out during storage and left a solids-free supernate above the sludge layer. Before 1977, the supernate was shipped back to sewage-treatment plants in Chicago. In 1977, the MWRDGC began pumping the supernate from the storage basins directly onto the hayfields. The supernate was applied at a rate necessary to supply a maximum of 120 lb of available nitrogen per acre per year. This is equivalent to about 234,000 gal of supernate (5 percent solids concentration) being applied per acre per year.

Initially, sludge in the storage basins was sprayed onto the sludge-application fields through a pressurized nozzle. The nozzle opening was at least 2 in. in diameter to prevent clogging. This method of application, which caused volatilization of malodors, was phased out by 1977. In 1977, the sludge was injected into the soil with a field disk that was equipped with a manifold that distributed the sludge to each disk blade (Peterson and others, 1982). The total amount of sludge applied to fields in the project area during 1972-89 is shown in figure 3; the mean and maximum sludge-application rates during 1972-89 (Pietz, 1990) are shown in figure 4.

A statistical summary of chemical analyses of sludge sampled from June 1979 through September 1989 is in table 1; analyses for earlier periods can be found in Patterson (1982, p. 21) and Patterson and others (1982, p. 5). The percentile rankings of the nutrients and trace metals indicate substantial variability in the concentration of the constituents (table 1). The median concentrations of nitrogen ammonia, nitrogen ammonia plus organic, nitrite plus nitrate, and phosphorus were 3,400, 24,000, 35, and 16,000 mg/kg, respectively. Median concentrations of copper, lead, manganese, zinc, and iron were 1,200, 710, 480, 2,700, and 32,000 μg/g, respectively. The median

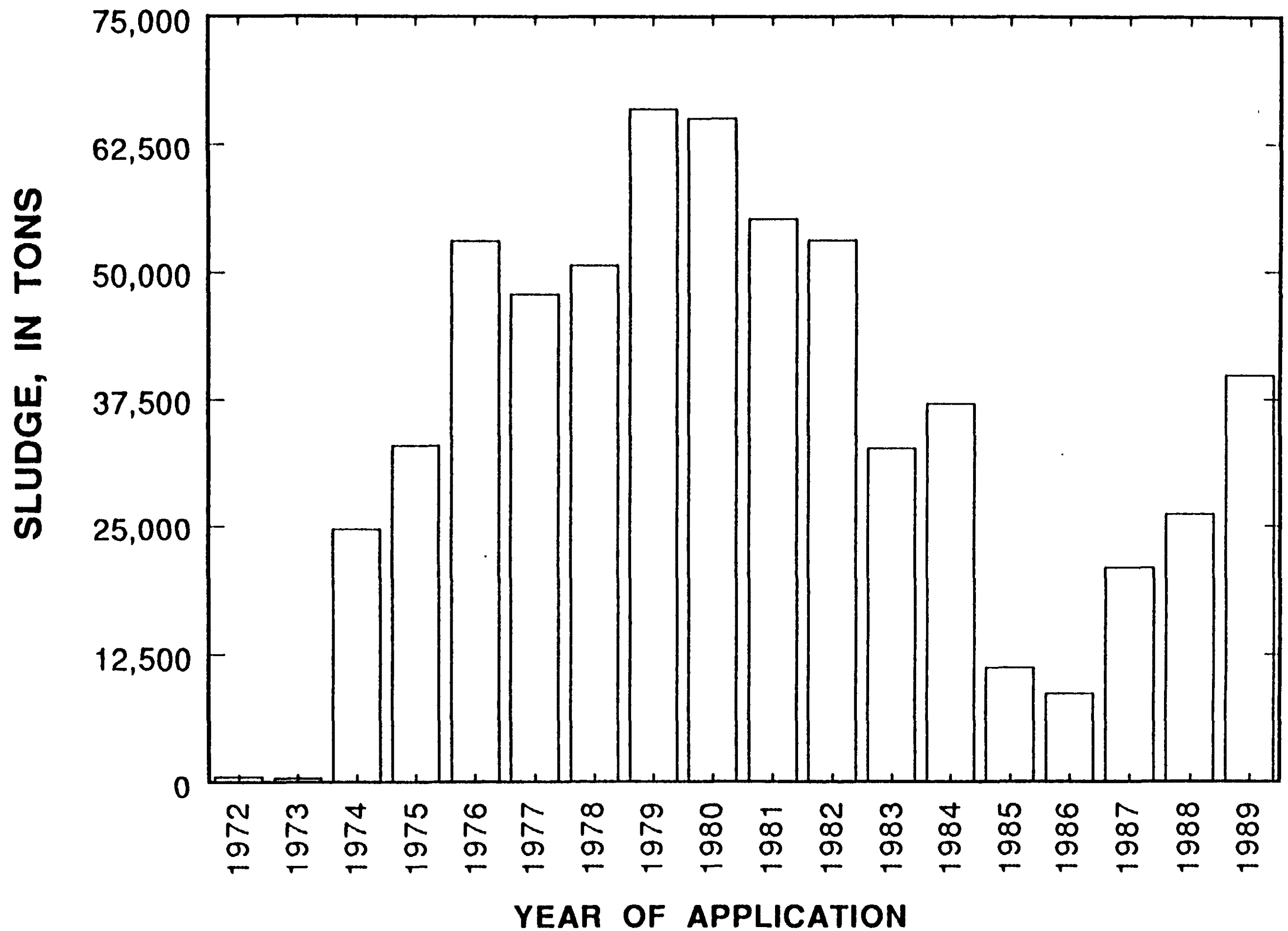

Figure 3.--Total sludge applied annually to the fields in the project area, 1972-89.

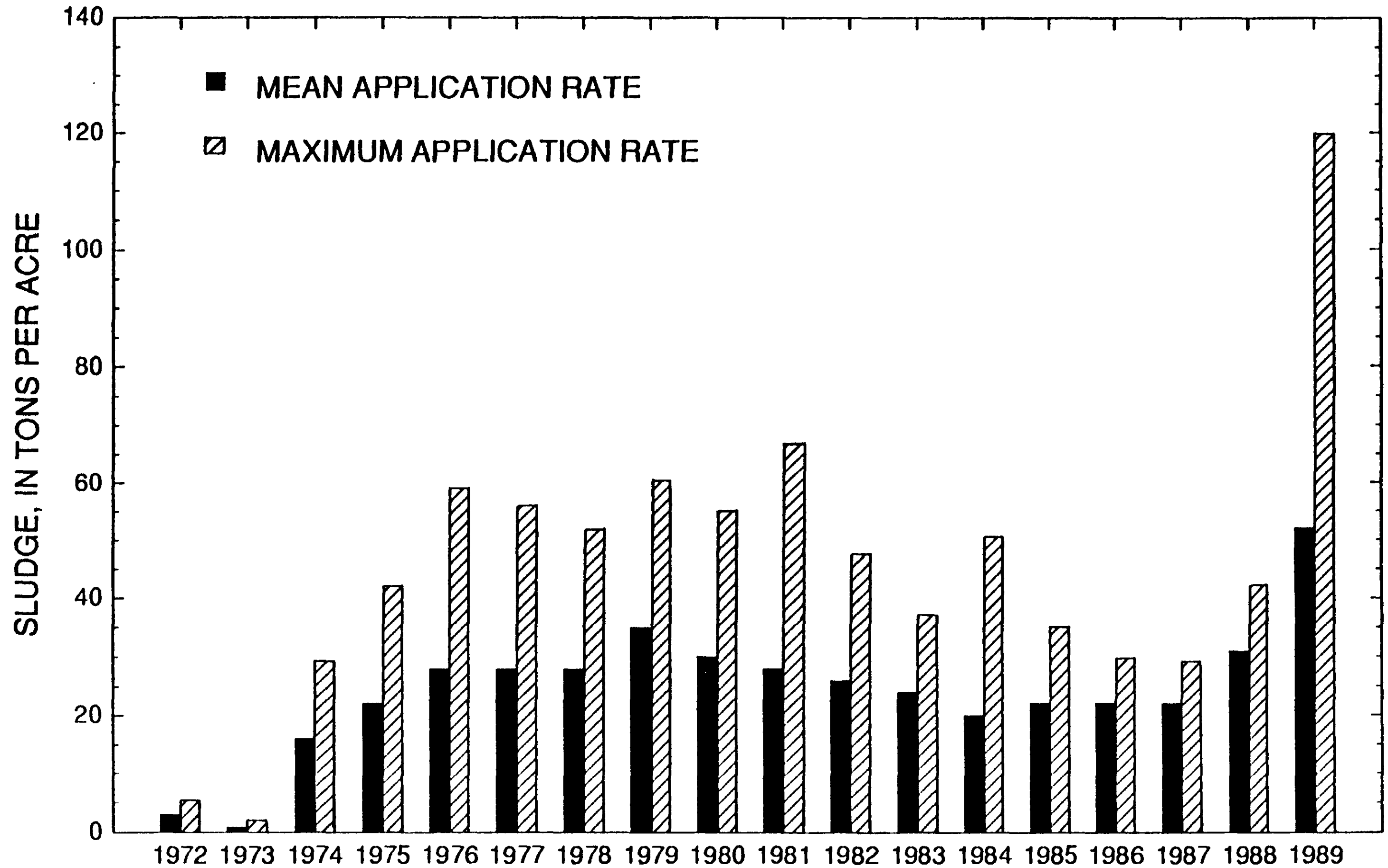

Figure 4.--Sludge-application rates in the project area, 1972-89.

Table 1.--Summary statistics of chemical analyses of sludge used to reclaim land in Fulton County, Illinois, 1979-89

[mg/kg, milligram per kilogram; µg/g, microgram per gram; µg/kg, microgram per kilogram; <, less than]

Note.--Multiple detection limits during the period of record may result in various values flagged with a "<".

Water-quality constituent	Unit	Descriptive statistics: Number of samples	Maximum	Minimum	Mean	Percentage of samples in which values were less than or equal to those shown: 95	75	50 (Median)	25	5
Nitrogen, ammonia	mg/kg as N	39	67,000	7.8	9,190	36,000	15,000	3,400	176	9.1
Nitrogen, ammonia plus organic	mg/kg as N	35	1,520,000	2,500	144,000	900,000	168,000	24,000	11,000	6,180
Nitrogen, nitrite plus nitrate	mg/kg as N	39	1,900	<2.0	160	990	190	35	5.0	<2.0
Phosphorus, total	mg/kg as P	33	140,000	64	33,000	126,000	55,000	16,000	7,800	1,630
Arsenic	µg/g as As	38	49	<1.0	11.3*	38	14	9.0	<1.0	<1.0
Cadmium	µg/g as Cd	39	3,700	4.0	308	1,600	250	150	62	10
Chromium	µg/g as Cr	37	45,000	<1.0	3,190*	12,000	2,600	1,500	510	<1.0
Cobalt	µg/g as Co	39	1,200	<10	70.6*	310	40	20	<50	<10
Copper	µg/g as Cu	38	22,000	1.0	1,870	7,940	1,700	1,200	462	8.6
Lead	µg/g as Pb	39	13,000	20	1,120	4,300	1,000	710	290	70
Manganese	µg/g as Mn	35	8,100	7.0	916	4,820	990	480	330	10
Zinc	µg/g as Zn	39	52,000	6.0	4,920	28,000	4,300	2,700	820	20
Iron	µg/g as Fe	38	380,000	700	45,400	181,000	42,800	32,000	19,000	4,120
2,4-Dimethylphenol	µg/kg	36	<1.0	<.1	--	<1.0	<.1	<.1	<.1	<.1
Polychlorinated naphthalenes	µg/kg	35	<5,000	<1.0	--	<100	<5.0	<1.0	<1.0	<1.0
Aldrin	µg/kg	39	<500	<.1	--	<10	<.2	<.1	<.1	<.1
Lindane	µg/kg	41	4.0	<.1	--	<500	<.2	<.1	<.1	<.1
Chlordane	µg/kg	41	1,800	<1.0	393*	1,300	560	150	<10	<1.0
DDD[1]	µg/kg	41	300	<.1	54.5*	240	66	5.2	<.2	<.1
DDE[2]	µg/kg	39	360	<.1	45.1*	300	52	<100	<.1	<.1
DDT[3]	µg/kg	39	140	<.1	--	120	<10	<.1	<.1	<.1
Dieldrin	µg/kg	41	73	<.1	16.9*	65	31	3.3	<1.0	<.1
Endosulfan	µg/kg	38	<5,000	<.1	--	<100	<.2	<.1	<.1	<.1
Endrin	µg/kg	41	5.5	<.1	--	.4	<.2	<.1	<.1	<.1
Ethion	µg/kg	35	.4	<.1	--	<10	<.1	<.1	<.1	<.1

Table 1.--Summary statistics of chemical analyses of sludge used to reclaim land in Fulton County, Illinois, 1979-89--Continued

Water-quality constituent	Unit	Descriptive statistics: Number of samples	Maximum	Minimum	Mean	Percentage of samples in which values were less than or equal to those shown: 95	75	50 (Median)	25	5
Toxaphene	µg/kg	41	<10,000	<1.0	--	<1,000	<10	<10	<10	<1.0
Heptachlor	µg/kg	40	47	<.1	--	6.0	<.2	<.1	<.1	<.1
Heptachlor epoxide	µg/kg	41	53	<.1	--	21	<.2	<.1	<.1	<.1
Methoxychlor	µg/kg	40	2.1	<.1	--	<13	<1.0	<.1	<.1	<.1
PCB	µg/kg	40	800,000	<1.0	24,700*	20,000	7,000	2,000	570	<1.0
Malathion	µg/kg	35	13	<.1	--	5.2	<.1	<.1	<.1	<.1
Parathion	µg/kg	35	<10	<.1	--	<10	<.1	<.1	<.1	<.1
Diazinon	µg/kg	35	240	<.1	34.9*	180	40	<1.0	<.1	<.1
Methyl parathion	µg/kg	35	1.0	<.1	--	<10	<.1	<.1	<.1	<.1
2,4-Dichlorophenoxy-acetic acid	µg/kg	40	<1.0	<.1	--	<1.0	<.1	<.1	<.1	<.1
2,4,5-Trichlorophenoxy-acetic acid	µg/kg	40	<1.0	<.1	--	<1.0	<.1	<.1	<.1	<.1
Mirex	µg/kg	36	33	<.1	--	.1	<.2	<.1	<.1	<.1
Silvex	µg/kg	40	<1.0	<.1	--	<1.0	<.1	<.1	<.1	<.1
Trithion	µg/kg	35	<10	<.1	--	<10	<.1	<.1	<.1	<.1
Methyl Trithion	µg/kg	35	<20	<.1	--	<10	<.1	<.1	<.1	<.1
Mercury	µg/g as Hg	37	14	<.01	2.90*	12	4.4	.8	.1	<.01
Perthane	µg/kg	37	140	<.1	--	27	<4.0	<1.0	<1.0	<.1

* Value is estimated by use of a log-probability regression to predict the values of data below the detection limit.
[1] 1,1Dichloro-2,2-bis(p-chlorophenyl) ethane.
[2] Dichlorodiphenyldichloroethylene.
[3] Dichloro diphenyl trichloroethane.

Beginning in January 1980, water samples collected for metal analyses were filtered through a membrane filter, 0.45-µm pore size, and the constituent concentration was reported as dissolved (Hem, 1985, p. 60). As a result of this change, the analyses for metals are divided into two groups--total metals from January 1972 through December 1979 and dissolved metals from January 1980 through September 1989.

Streambed-sediment samples were collected by USGS personnel once a year during 1975-89 at Slug Run near Bryant and Evelyn Branch near Bryant and during 1975-85 at Big Creek at St. David and Big Creek near Bryant. Samples were analyzed for 15 constituents, including trace metals, herbicides, insecticides, and nutrients. Streambed-sediment samples were analyzed at the USGS National Water Quality Laboratory in Arvada, Colo. These analyses were published in the USGS annual water-data reports for Illinois through 1989 (U.S. Geological Survey, 1976-90).

Streamflow-gaging stations at the four sites were operated by the USGS, and the data were published in the USGS annual water-data reports for Illinois. Daily streamflow data are available for the entire period of record (1972-89) for Big Creek near Bryant and Evelyn Branch near Bryant. Streamflow-data collection was discontinued at Big Creek at St. David in December 1985. Data collection at Slug Run near Bryant began in January 1975.

Surface-Water Quality

The major cations in the surface-water samples were sodium, calcium, and magnesium; the major anions were chloride, sulfate, and carbonate plus bicarbonate reported as alkalinity in milligrams per liter of $CaCO_3$. This combination of major ions is typical of waters draining areas that have been extensively surface mined. During surface mining, pyrite and marcasite are brought to the surface and are subjected to weathering, producing sulfuric acid. The sulfuric acid reacts with limestone (calcium carbonate); as a result, dolomite (calcium magnesium carbonate), calcite, magnesium, sulfate, and bicarbonate go into solution (Brabets, 1984). When surface-mined land is leveled and tilled for agricultural use, additional materials are exposed to weathering and the process is accelerated.

Summary Statistics

The median concentrations of nutrients in Big Creek decreased between Big Creek at St. David and Big Creek near Bryant. The median concentrations of nitrogen ammonia, kjeldahl nitrogen (KJD), nitrite plus nitrate (NO_2+NO_3), and total phosphorus were higher at Big Creek at St. David (the most upstream site) than at Big Creek near Bryant (table 2). These decreases can be attributed to the cleansing and diluting that occurs in the 6.5-mi reach between the two sites (U.S. Environmental Protection Agency, 1981, p. III-19). The median concentrations of these constituents in Slug Run near Bryant and Evelyn Branch near Bryant are small when compared to those at the two Big Creek sites. Summary statistics for selected surface-water-quality constituents analyzed for at the four sites are given in tables 10-13 (at the end of the report).

Table 2.--Median concentrations of selected water-quality constituents in surface water at four sites in Fulton County, Illinois

[<, less than. All figures are concentrations in milligrams per liter]

Period of record is 1972-89 except for total calcium, magnesium, and sodium (1972-79) and dissolved calcium, magnesium, and sodium (1980-89).

Constituent	Sampling site (downstream-order number) Big Creek at St. David (05570350)	Evelyn Branch near Bryant (05570360)	Big Creek near Bryant (05570370)	Slug Run near Bryant (05570380)
Nitrogen, ammonia	0.5	<0.1	0.3	<0.1
Nitrogen, kjeldahl	1.5	1.0	1.1	.4
Nitrogen, nitrite plus nitrate	2.7	.4	2.1	.09
Phosphorus, total	.93	.09	.55	.09
Chloride	37	18	32	11
Sulfate	317	646	419	747
Alkalinity as $CaCO_3$	250	275	260	272
Calcium, total	124	145	140	200
Calcium, dissolved	112	114	131	183
Magnesium, total	55	100	68	133
Magnesium, dissolved	49	100	61	129
Sodium, total	68	180	80	76
Sodium, dissolved	51	129	57	62

Of the major anions (table 2) chloride, sulfate, and carbonate plus bicarbonate reported as alkalinity in milligrams of $CaCO_3$, only chloride decreased in median concentration from Big Creek at St. David to Big Creek near Bryant. Among all four sampling sites, median concentrations of chloride ranged from 11 to 37 mg/L, median alkalinity values ranged from 250 to 275 mg/L, and median concentrations of sulfate ranged from 317 to 747 mg/L. The concentrations of sulfate and alkalinity generally were higher in Evelyn Branch near Bryant than at Big Creek at St. David; thus, concentrations at Big Creek near Bryant were higher than the concentrations at Big Creek at St. David. The median concentrations of sulfate and alkalinity at Slug Run near Bryant were similar to those in Evelyn Branch near Bryant. Concentrations were probably higher in these basins because of the combination of a large proportion of surface-mined land and the leveling and tillage operations for agriculture. The high concentrations of sulfate in water from Evelyn Branch near Bryant, Big Creek near Bryant, and Slug Run near Bryant are indicative of mine drainage.

Median concentrations of the major cations generally increased between Big Creek at St. David and Big Creek near Bryant (table 2). The concentrations of these constituents generally are higher in Evelyn Branch near Bryant than in Big Creek at St. David; thus, concentrations at Big Creek near Bryant were higher than the concentrations at Big Creek at St. David.

The median concentrations of total calcium at the four sites ranged from 124 to 200 mg/L, and the median concentrations of magnesium ranged from 55 to 133 mg/L (table 2). The higher concentrations of calcium and magnesium (table 2) in Evelyn Branch near Bryant and Slug Run near Bryant are indicative of mine drainage. The median concentrations of total sodium were similar (less than or equal to 80 mg/L) at each of the sites except Evelyn Branch near Bryant, where the median concentration was 180 mg/L (table 2). This elevated concentration at Evelyn Branch also was observed by Patterson (1982) who attributed it to the construction of the storage basins, which increased the availability of sodium by exposing large amounts of sodium-rich mine spoil to weathering.

The site at Evelyn Branch near Bryant represents 50 percent of the increase in drainage area between the two Big Creek sites. The large concentrations of sulfate, calcium, magnesium, and sodium at Evelyn Branch near Bryant caused the concentrations of these constituents at Big Creek near Bryant to be higher than at Big Creek at St. David. The median concentrations of sulfate, calcium, and magnesium were higher in Slug Run than in Evelyn Branch.

The trace metals analyzed for and the percentages of observations above the MDL are listed in table 3. Percentages of observations above the MDL were less than 10 percent for cadmium, chromium, zinc, and selenium, and they were similar at each site. The percentages of observations above the MDL for total aluminum were higher at both Big Creek sites than at either Evelyn Branch or Slug Run. The source of the aluminum in Big Creek is not known; the possible sources include the natural weathering of sedimentary rocks and soils, acidic mine drainage, and the addition of aluminum sulfate in water-treatment processes (Hem, 1985, p. 73). The percentages of observations above the MDL for mercury and lead concentrations are higher than the percentages for the other metals. Percentages of mercury and lead differ little among the four sites. The concentrations of total copper exceeded the MDL in 38 percent of the samples collected at Evelyn Branch near Bryant. Almost all of the total copper concentrations above the MDL at Evelyn Branch near Bryant were in samples collected in 1972, 1976, and 1977 (fig. 5). Only 12, 14, and 5 percent of the samples collected at Big Creek at St. David, Big Creek near Bryant, and Slug Run near Bryant, respectively, exceeded the MDL for total copper.

Trends

Trends, as used in this report, refer to a monotonic change in concentrations, either gradual or abrupt, in a given period of time. The Seasonal Kendall test, set up for 12 seasons (each month as a season), was used to test for trends in the surface-water-quality data (Hirsch and others, 1982, p. 117). For the purposes of this report, a trend was considered statistically significant for $\rho \leq 0.05$ (where ρ is the probability that a trend resulted from chance arrangement of the data rather than an actual change in concentration). Table 4 lists the computed ρ for each constituent concentration. The trend slope is listed as the percentage of change per year of the median concentration.

concentrations of arsenic, cadmium, chromium, and cobalt were 9.0, 150, 1,500, and 20 µg/g, respectively. Of the synthetic organic compounds analyzed for (table 1), only chlordane, 1,1-Dichloro-2,2-bis(p-chlorophenyl) ethane (DDD), dieldrin, and PCB's had median concentrations above the minimum detection level (MDL)--150, 5.2, 3.3, and 2,000 µg/kg, respectively.

SURFACE-WATER AND STREAMBED-SEDIMENT QUALITY

Water-quality samples were collected at four sites in the project area--Big Creek at St. David (downstream order number 05570350), Evelyn Branch near Bryant (05570360), Big Creek near Bryant (05570370), and Slug Run near Bryant (05570380) (fig. 2). These four sites are a subnetwork of a larger MWRDGC water-quality-monitoring network within the study area; however, these four sites were the only sites in the study area where streamflow data have been collected.

Water quality at three of these sites is affected by different land uses. Big Creek at St. David drains an area outside of the study area (fig. 1) that includes mines, urban land, and factories. Water quality at this site is likely to be only minimally affected by the sludge-application operations in the project area. The fields north of County Highway 5 (fig. 2) eventually drain into Big Creek upstream from the sampling site at St. David. Evelyn Branch near Bryant drains an area that has been extensively surface mined and where sludge is being used to recondition the soil. Slug Run near Bryant drains an area that has been extensively surface mined; however, sludge has not been used to recondition the soil. Water quality at the fourth site, Big Creek near Byrant, represents a composite of streamflow from Evelyn Branch near Bryant and Big Creek at St. David and is, thus, of little value in relating water quality to land use.

The MWRDGC collected and analyzed water-quality samples monthly from the four sites listed above from January 1972 through December 1981 (Dr. Richard Pietz, Metropolitan Water Reclamation District of Greater Chicago, written commun., 1990). The samples were analyzed for 29 water-quality constituents and physical properties including major anions and cations, nutrients, trace metals, pH, and specific conductance. The MWRDGC water-quality sampling frequency during 1982-89 was three times per year during the sludge-application season (April through November)--twice immediately following rainfall and once during a drier period. Monthly samples were collected and analyzed for fecal coliform bacteria from January 1972 through December 1981. Collection of samples for dissolved solids (DS) analyses began in August 1974.

Water samples for analyses of total organic carbon (TOC) were collected every 6 weeks by USGS personnel from January 1975 through September 1989, except at Big Creek at St. David where sampling was discontinued after 1985. Collections of these samples were independent of the MWRDGC sampling program. The TOC samples were analyzed at the USGS National Water Quality Laboratory in Arvada, Colo.

Table 3.--Trace metals analyzed for and the percentage of observations above the minimum detection limit

[MDL, minimum detection limit; mg/L, milligram per liter; µg/L, microgram per liter. Period of record: total, January 1972-December 1979; dissolved, January 1980-September 1989]

	Sampling site (downstream-order number)								
	Big Creek at St. David (05570350)		Evelyn Branch near Bryant (05570360)		Big Creek near Bryant (05570370)		Slug Run near Bryant (05570380)		
Constituent	Number of samples	Percent above MDL	Number of samples	Percent above MDL	Number of samples	Percent above MDL	Number of samples	Percent above MDL	Minimum detection limit
Cadmium:									
Total	95	4	96	1	95	9	94	2	0.02 mg/L
Dissolved	48	0	48	2	48	0	48	2	.02 mg/L
Chromium:									
Total	95	1	95	4	95	3	93	6	.02 mg/L
Dissolved	48	6	48	6	48	0	48	6	.02 mg/L
Copper:									
Total	95	12	86	38	95	14	94	5	.02 mg/L
Dissolved	48	6	48	6	48	6	48	2	.02 mg/L
Lead:									
Total	95	57	96	53	95	49	93	55	.02 mg/L
Dissolved	48	15	48	13	48	15	48	27	.02 mg/L
Nickel:									
Total	95	4	95	3	95	4	93	8	.10 mg/L
Dissolved	48	2	48	6	48	8	48	10	.10 mg/L
Zinc:									
Total	95	3	95	3	95	4	94	3	.10 mg/L
Dissolved	48	2	48	4	48	0	48	0	.10 mg/L
Aluminum:									
Total	92	27	86	5	92	22	89	9	1.0 mg/L
Dissolved	48	0	48	0	48	0	48	0	1.0 mg/L
Selenium:									
Total	65	0	70	0	66	0	63	0	.10 mg/L
Dissolved	48	6	47	6	48	8	48	8	.10 mg/L
Mercury:									
Total	95	17	95	27	94	28	92	30	.10 µg/L
Dissolved	48	33	48	31	48	46	48	40	.10 µg/L

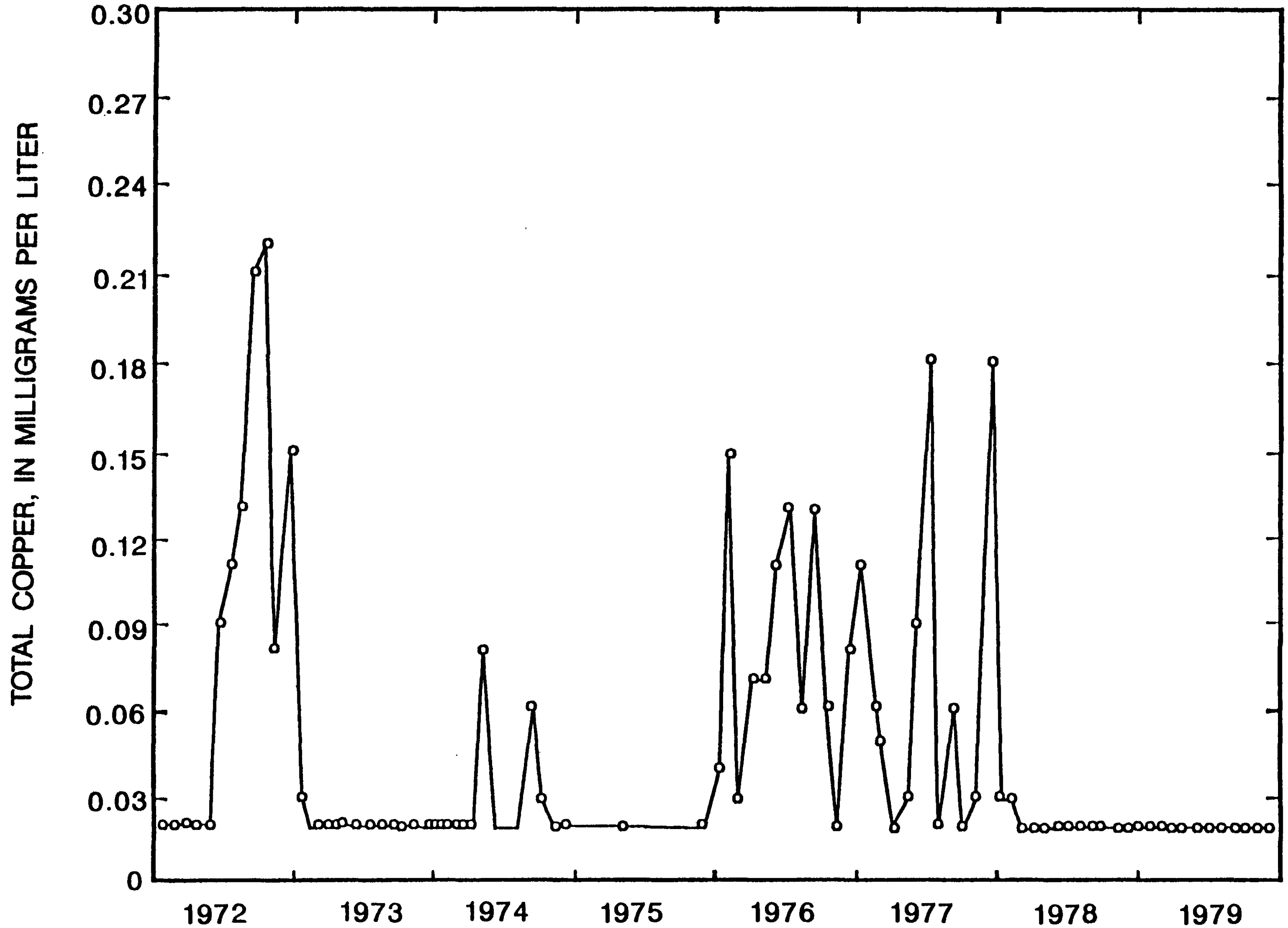

Figure 5.--Trends of instantaneous concentrations of total copper at Evelyn Branch near Bryant, 1972-80.

Table 4.--Results of the Seasonal Kendall test for each constituent, by site

[mg/L, milligram per liter; col/100mL, colonies per 100 milliliters; µS/cm, microsiemen per centimeter at 25 degrees Celsius; -, negative slope; +, positive slope; --, not determined]

ρ is the probability that a trend resulted from a chance arrangement of the data. A trend is considered statistically significant if $\rho \leq 0.05$.

The Seasonal Kendall test was applied to data collected during 1972-81 except for total metals, which were collected during 1972-79 and total organic carbon, which was collected during January 1975-September 1989. Collection of dissolved solids data began in August 1974.

	Concentration		Flow-adjusted concentration		
Site	ρ	Trend slope (percent)	ρ	Trend slope (percent)	Seasonal median
		Nitrogen, ammonia (mg/L)			
Big Creek at St. David	0.00	(-)	--	--	0.6
Evelyn Branch near Bryant	.00	(-)	--	--	.1
Big Creek near Bryant	.00	(-)	--	--	.3
Slug Run near Bryant	.00	(-)	--	--	.1
		Nitrogen, kjeldahl (mg/L)			
Big Creek at St. David	.22	-2.1	--	--	1.7
Evelyn Branch near Bryant	.00	(+)	--	--	1.1
Big Creek near Bryant	.21	(-)	--	--	1.2
Slug Run near Bryant	.41	(+)	0.00	(-)	.4
		Nitrogen, nitrite plus nitrate (mg/L)			
Big Creek at St. David	.69	.5	--	--	2.7
Evelyn Branch near Bryant	.03	(+)	--	--	.47
Big Creek near Bryant	.89	-.19	.21	1.7	2.1
Slug Run near Bryant	.33	(-)	.39	-4.4	.09
		Phosphorus, total (mg/L)			
Big Creek at St. David	.02	5.1	1.0	-.1	.95
Evelyn Branch near Bryant	.18	-2.2	--	--	.09
Big Creek near Bryant	.02	5.7	.82	.3	.56
Slug Run near Bryant	.00	-7.4	.58	-4.4	.09

Table 4.--Results of the Seasonal Kendall test for each constituent, by site--Continued

Site	Concentration		Flow-adjusted concentration		Seasonal median
	ρ	Trend slope (percent)	ρ	Trend slope (percent)	
		Chloride (mg/L)			
Big Creek at St. David	0.00	3.5	0.05	2.2	38
Evelyn Branch near Bryant	.00	5.2	.00	3.6	19
Big Creek near Bryant	.00	3.5	.04	2.6	32
Slug Run near Bryant	.09	1.8	--	--	11
		Sulfate (mg/L)			
Big Creek at St. David	.06	3.8	.17	1.5	314
Evelyn Branch near Bryant	.05	3.1	.14	2.4	646
Big Creek near Bryant	.03	2.9	--	--	414
Slug Run near Bryant	.00	5.8	.18	-2.8	720
		Alkalinity (mg/L as $CaCO_3$)			
Big Creek at St. David	.00	-2.0	.57	-.2	250
Evelyn Branch near Bryant	.06	-.93	--	--	275
Big Creek near Bryant	.02	-1.1	--	--	266
Slug Run near Bryant	.40	.42	.25	.87	272
		Calcium, total (mg/L)			
Big Creek at St. David	.07	2.2	.07	1.7	125
Evelyn Branch near Bryant	.80	.17	--	--	143
Big Creek near Bryant	.91	-.07	--	--	140
Slug Run near Bryant	.82	.30	.02	-3.3	200
		Magnesium, total (mg/L)			
Big Creek at St. David	.02	-3.1	.19	-1.3	55
Evelyn Branch near Bryant	.00	-2.7	.00	-2.9	101
Big Creek near Bryant	.05	-2.9	.52	-1.4	68
Slug Run near Bryant	.19	-1.3	1.0	.02	134

Table 4.--Results of the Seasonal Kendall test for each constituent, by site--Continued

Site	Concentration ρ	Concentration Trend slope (percent)	Flow-adjusted concentration ρ	Flow-adjusted concentration Trend slope (percent)	Seasonal median
		Sodium, total (mg/L)			
Big Creek at St. David	0.15	1.5	0.79	-0.48	68
Evelyn Branch near Bryant	.21	-1.9	.00	-3.4	184
Big Creek near Bryant	.41	.87	.03	-1.7	81
Slug Run near Bryant	.06	1.8	.00	7.2	76
		Potassium, total (mg/L)			
Big Creek at St. David	.00	2.7	.26	-1.6	5
Evelyn Branch near Bryant	.18	.0	.94	-.6	8
Big Creek near Bryant	.02	.5	.20	-.89	5
Slug Run near Bryant	.48	.0	.87	-.3	6
		Iron, total (mg/L)			
Big Creek at St. David	.11	-3.0	--	--	1.1
Evelyn Branch near Bryant	.28	.0	--	--	.2
Big Creek near Bryant	.13	-2.7	.15	4.6	1.0
Slug Run near Bryant	.33	1.0	--	--	.6
		Manganese, total (mg/L)			
Big Creek at St. David	.00	-4.6	--	--	.51
Evelyn Branch near Bryant	.19	-2.5	--	--	.20
Big Creek near Bryant	.00	-5.9	--	--	.55
Slug Run near Bryant	.00	-4.1	--	--	.49
		Aluminum, total (mg/L)			
Big Creek at St. David	.11	(-)	--	--	1.0
Evelyn Branch near Bryant	.38	(+)	--	--	1.0
Big Creek near Bryant	.046	(-)	--	--	1.0
Slug Run near Bryant	1.0	.0	--	--	1.0

Table 4.--Results of the Seasonal Kendall test for each constituent, by site--Continued

Site	Concentration ρ	Concentration Trend slope (percent)	Flow-adjusted concentration ρ	Flow-adjusted concentration Trend slope (percent)	Seasonal median
		Copper, total (mg/L)			
Big Creek at St. David	0.00	(-)	--	--	0.02
Evelyn Branch near Bryant	.24	(-)	--	--	.02
Big Creek near Bryant	.00	(-)	--	--	.02
Slug Run near Bryant	.00	(-)	--	--	.02
		Lead, total (mg/L)			
Big Creek at St. David	.27	(-)	--	--	.03
Evelyn Branch near Bryant	.15	(-)	--	--	.03
Big Creek near Bryant	.02	(-)	--	--	.03
Slug Run near Bryant	.90	(-)	--	--	.03
		Mercury, total (μg/L)			
Big Creek at St. David	.00	(-)	--	--	.1
Evelyn Branch near Bryant	.02	(-)	--	--	.1
Big Creek near Bryant	.02	(-)	--	--	.1
Slug Run near Bryant	.15	(-)	--	--	.1
		Fecal coliform (col/100mL)			
Big Creek at St. David	.00	-40	0.00	-29	2,545
Evelyn Branch near Bryant	.73	0	.86	.5	10
Big Creek near Bryant	.00	31	.00	-20	700
Slug Run near Bryant	.11	-10	--	--	195
		Total organic carbon (mg/L)			
Big Creek at St. David	.00	-7.0	.00	-7.1	6.0
Evelyn Branch near Bryant	.05	-1.6	--	--	6.9
Big Creek near Bryant	.11	-1.3	.47	.6	5.9
Slug Run near Bryant	.00	-4.2	.00	-2.5	5.1

Table 4.--Results of the Seasonal Kendall test for each constituent, by site--Continued

Site	Concentration ρ	Concentration Trend slope (percent)	Flow-adjusted concentration ρ	Flow-adjusted concentration Trend slope (percent)	Seasonal median
Specific conductance (μS/cm)					
Big Creek at St. David	0.61	0.45	0.89	-0.18	1,010
Evelyn Branch near Bryant	.23	-.78	.11	1.0	1,600
Big Creek near Bryant	.85	.00	--	--	1,200
Slug Run near Bryant	.38	.39	.00	5.4	1,600
pH					
Big Creek at St. David	.01	-.31	--	--	7.9
Evelyn Branch near Bryant	.31	-.02	--	--	8.0
Big Creek near Bryant	.13	-.19	.03	-.25	8.0
Slug Run near Bryant	.57	.00	--	--	8.0
Dissolved solids (mg/L)					
Big Creek at St. David	.08	-2.1	.05	-2.2	924
Evelyn Branch near Bryant	.08	-1.6	.01	-2.0	1,628
Big Creek near Bryant	.30	-1.1	.10	-1.2	1,113
Slug Run near Bryant	.78	.46	.91	-.31	1,770
Total suspended solids (mg/L)					
Big Creek at St. David	.05	-5.4	.97	-.37	37
Evelyn Branch near Bryant	.06	-4.2	.06	-3.8	12
Big Creek near Bryant	.09	-4.1	1.0	.2	26
Slug Run near Bryant	.10	-7.5	.12	-6.2	11

A flow-adjustment procedure, as outlined in Hirsch and others (1982, p. 119), was used to remove the effects of flow on the concentration data before the Seasonal Kendall test was applied. The equations used to characterize the correlation between stream discharge and the chemical constituents are from Smith and others (1982, p. 9). Changes in water quality are indicated by positive or negative trends in concentration. Trends in the flow-adjusted concentrations (FAC) indicate that a change in the process that delivers that constituent to the stream occurred. If the relation between constituent concentration and flow was poor ($\rho \geq 0.1$, where ρ is the probability that the relation occurred by a chance arrangement of the data), the flow-adjustment procedure was not used, and only trends in concentration were reported. If more than 10 percent of the reported values for a constituent were below the MDL, no attempt was made to adjust the constituent concentration for flow. In these cases, trends in concentration were considered indicative of a change in the process delivering that constituent to the stream.

The procedures for collecting samples changed considerably in January 1982; thus, the pre- and post-1982 data are not considered to be a continuous set. The Seasonal Kendall test was not used on data collected after 1981. In January 1980, a change in the way samples were processed for metal analysis possibly affected valid statistical comparison. Therefore, trend analyses for metals were limited to data collected from January 1972 through December 1979.

For many of the constituents, more than 5 percent of the data set are censored--that is, reported as less than the MDL. If more than 5 percent of the data are censored, the magnitude of the slope estimator is likely to be in error (Hirsch and others, 1991). Therefore, for these constituents, the slope estimate is not listed; only the direction of the slope, + or -, is indicated (table 4). It should also be noted that results of the trend test apply only to concentrations above the MDL. No information is obtained from the trend test about the status of trends for concentrations at or below the MDL.

Some trace metals analyzed for (cadmium, chromium, nickel, and zinc; tables 10-13) but not listed in table 4 had less than 10 percent of their values at or above the detection limit; therefore, a Seasonal Kendall test was not applied to these trace-metal data.

The Seasonal Kendall test will indicate trends, but it will not indicate a causal mechanism for those trends unless the study that generates the data is specifically designed to indicate a causal mechanism. The MWRDGC data-collection program was not designed to determine the effects of individual factors affecting the water quality in the project area, so the causal mechanism for the trends could not be determined; however, a comparison of trends in water quality at sites where land-use patterns differ could possibly isolate the major factors influencing water quality.

The Slug Run near Bryant site has a drainage area that was 90 percent surfaced mined before 1962 (Brabets, 1984). Trends in water quality at this site would not be expected to be the result of any land-use changes. As the near-surface mine spoil weathers and decreases in chemical reactivity, negative trends in some constituents might be expected.

Evelyn Branch near Bryant represents a drainage basin in which the amount of surface-mined land is similar to that in Slug Run; however, in the Evelyn Branch basin, land reclamation has been ongoing since 1972. Trends at this site would be expected because the land use has undergone changes over time. The cause of the trends could be related to the disturbance of the land during the leveling and tilling operations that periodically expose additional mine spoil to weathering. These trends might manifest as increased concentrations of those constituents that are typical in waters draining surface-mined land. It also is possible that decreased concentrations of these same constituents might occur as a result of the reclamation efforts. In addition, trends in concentrations of constituents that are found in abundance in the sludge used to reclaim the surface-mined land, such as metals and nutrients, could be expected to be positive.

Big Creek at St. David represents an area in which surface mining was still active in 1980; urbanization, industrialization, and changes in agricultural practices might have contributed to trends in water quality. Trends in water quality at the Big Creek near Bryant site could result from a combination of those at Big Creek at St. David and Evelyn Branch near Bryant, inasmuch as they are both upstream from Big Creek near Bryant.

In addition to the trends in water quality that could be attributed to land-use changes within drainage basins, some trends at all sites could be due to regional or national changes in the environment that affect the chemistry of the project-area streams. Such changes may include the reduction in the use of leaded fuels, precipitation, changing wind patterns, global climate change, the increased use of road salts, or the increased use of fertilizers and agricultural chemicals.

Trends in constituent concentrations were used to determine if there has been a change in the process of delivery of that constituent to the streams. If the correlation between concentration and flow was significant, only the FAC was used to determine if a trend was present. If a significant correlation between concentration and discharge could not be determined, trends in unadjusted concentration were used.

Constituents from the three sites that are independent of one another were tested for trends (table 5). Trends in water quality in Big Creek at St. David represent changes in water quality attributable to sources upstream from the project area, such as improvements in sewage-treatment capabilities or changes in urbanization, industrialization, upstream mine drainage, and farming. Trends in water quality in Evelyn Branch near Bryant represent changes in water quality attributable to activities within the project area, such as the construction of the sludge-holding basins, the leveling and tilling of the agricultural fields, project-area mine drainage, and the application of sludge. Trends in water quality in Slug Run near Bryant represent changes in water quality from sources similar to those in the Evelyn Branch basin, excluding the application of sludge.

The concentrations of nitrogen ammonia had a decreasing trend at all three sites. The concentrations in Slug Run and Evelyn Branch are low compared to those at the Big Creek site. The concentrations of nitrite plus

Table 5.--Trends in selected properties and constituents in surface water at three study sites

[P, positive trend in concentration; N, negative trend in concentration; -, no trend]

Constituent	Sampling site (downstream-order number)		
	Big Creek at St. David (05570350)	Evelyn Branch near Bryant (05570360)	Slug Run near Bryant (05570380)
Nutrients			
Nitrogen, ammonia	N	N	N
Nitrogen, kjeldahl	-	P	N
Nitrogen, nitrite plus nitrate	-	P	-
Phosphorus, total	-	-	-
Major anions			
Chloride	P	P	-
Sulfate	-	-	-
Alkalinity[1]	-	-	-
Major cations			
Calcium	-	-	N
Magnesium	-	N	-
Sodium	-	N	P
Potassium	-	-	-
Iron	-	-	-
Manganese	N	-	N
Trace metals			
Copper	N	-	N
Lead	-	N	-
Aluminum	-	N	-
Mercury	N	N	-
Other properties and constituents			
Fecal coliform	N	-	-
Total organic carbon	N	N	N
Specific conductance	-	-	P
pH	N	-	-
Dissolved solids	N	N	-
Total suspended solids	-	-	-

[1]Carbonate plus bicarbonate reported as alkalinity in milligrams per liter of $CaCO_3$.

nitrate increased in Evelyn Branch. This was noted in a report by the U.S. Environmental Protection Agency (1981), but no single factor was associated with the increase. TOC concentrations were decreasing at all three sites.

The concentrations of KJD increased in Evelyn Branch. KJD measures both nitrogen ammonia and organic nitrogen. If nitrogen ammonia decreased in Evelyn Branch and KJD increased, then organic nitrogen must have increased. Organic nitrogen in a stream is derived from both the inflow of nitrogenous debris from a watershed and from normal biological activities in the stream. Anthropogenic sources of nitrogenous debris include sludge and farm runoff.

Trends in magnesium, sodium, and TDS were negative in Evelyn Branch. These trends can probably be attributed to the completion of the weathering process that occurred when the storage basins were constructed and the land was leveled for agricultural purposes.

The concentration of chloride increased in Big Creek and Evelyn Branch. The sources and causes for this increase are not clear. Smith and others (1987) tested for trends in chloride concentration in data collected during 1974-81 from more than 300 sites nationwide. Trends at nearly all of the sites in the Midwest were positive and significantly associated with the heavy use of road salt (Smith and others, 1987, p. 7).

Except for KJD and nitrite plus nitrate, no trends in the measured surface-water-quality constituents could be directly attributed to the application of sludge in the project area. Trends in KJD and nitrite plus nitrate were positive in Evelyn Branch, although the median concentrations of these constituents were lower than at either of the Big Creek sites (table 2). The detection of trends in KJD and in nitrite plus nitrate in only Evelyn Branch indicates that sludge application may be affecting the surface-water quality in the project area; however, for statistical validation of the effects of sludge application, it would be necessary to refine the sampling scheme.

Streambed-Sediment Quality

Streambed sediment can be used to determine long-term changes in water quality (Helsel and Koltun, 1986, p. 1). Discharges of contaminants from the runoff-retention basins are short term and irregular and could be missed by a routine surface-water-sampling program; however, streambed sediment can be used to detect these discharges if the discharges contain hydrophobic compounds that would tend to accumulate in the sediments. Chemical analyses (table 1) show that the sludge contains high concentrations of some hydrophobic compounds, such as dieldrin, chlordane, PCB's, and DDD. If runoff from the sludge-application fields was affecting the quality of surface waters in the project area, it would be expected that these hydrophobic compounds would be present in the sediments at Evelyn Branch near Bryant and that the magnitude of the concentrations in Evelyn Branch would be different from those at Big Creek at St. David or Slug Run near Bryant.

Summary Statistics

The median concentrations of nitrite plus nitrate in streambed sediment were similar at all four sites (table 6). Before 1977, when sludge was applied to the fields with a pressurized nozzle, the concentrations of nitrite plus nitrate in streambed sediment ranged from 15 to 35 mg/kg (fig. 6). When this method of application was discontinued in 1977, the concentrations of nitrite plus nitrate in streambed sediments decreased dramatically (fig. 6).

The median concentrations of ammonia plus organic nitrogen in streambed sediments in Evelyn Branch near Bryant (1,450 mg/kg) and Slug Run near Bryant (1,400 mg/kg) were higher than the median concentrations at Big Creek at St. David (1,000 mg/kg) and Big Creek near Bryant (850 mg/kg) (table 6). The median concentrations of phosphorus in streambed sediments at Big Creek at St. David (1,400 mg/kg) and Big Creek near Bryant (1,045 mg/kg) were higher than the median concentrations at Evelyn Branch (445 mg/kg) and Slug Run (480 mg/kg) (table 6).

The median concentration of manganese in streambed sediment at Slug Run near Bryant (1,200 µg/g) was higher than at Big Creek at St. David (620 µg/g), Evelyn Branch near Bryant (860 µg/g) and Big Creek near Bryant (810 µg/g) (table 6). The median concentration of iron in streambed sediments at Big Creek at St. David (5,700 µg/g) was less than at Evelyn Branch (9,100 µg/g), Big Creek near Bryant (15,500 µg/g), and Slug Run near Bryant (13,500 µg/g).

At Evelyn Branch near Bryant, the maximum concentrations of many constituents were much higher than the maximum concentrations at the other three sites (table 6). Most of the maximum concentrations at Evelyn Branch are from the same sample collected in July 1979 (table 7). A sample collected in September 1979 did not contain such unusually high concentrations of constituents. If this one analysis was removed, the resulting maximum values would be more typical of the other sites.

Dieldrin, an insecticide used on corn, was detected in greater than 50 percent of the samples collected, and it was detected in samples from all four sites. The median concentrations of dieldrin in streambed sediments at Big Creek at St. David (1.8 µg/kg) and Big Creek near Bryant (2.5 µg/kg) were higher than the median concentrations in samples collected at Evelyn Branch near Bryant (0.3 µg/kg) and Slug Run near Bryant (1.2 µg/kg) (table 6). PCB's were not detected in any sample collected from either Evelyn Branch or Slug Run. Every sample from Big Creek at both sites contained detectable quantities of chlordane and DDD, except for one sample at Big Creek near Bryant that did not contain a detectable level of DDD. Chlordane was not detected in any sample from Evelyn Branch near Bryant, and only one DDD concentration was greater than the MDL. At Slug Run near Bryant, DDD and chlordane were each detected only once.

The analyses of the sludge used to reclaim the project area (table 1) indicate that there can be substantial amounts of dieldrin, PCB's, DDD, and chlordane in the sludge. If the sludge was affecting the streambed-sediment quality, then detection of these constituents in streambed sediment would be

Table 6.---Maximum and median concentrations of selected constituents in streambed sediments at four sites in Fulton County, Illinois, 1975-89

[mg/kg, milligram per kilogram; µg/g, microgram per gram; µg/kg, microgram per kilogram; <, less than]

Constituent	Sampling site (downstream-order number) Big Creek near St. David (05570350)	Evelyn Branch near Bryant (05570360)	Big Creek near Bryant (05570370)	Slug Run near Bryant (05570380)
Nitrogen, nitrite plus nitrate (mg/kg):				
Maximum	34	35	30	28
Median	3.0	2.1	3.8	5.0
Nitrogen, ammonia plus organic (mg/kg):				
Maximum	4,800	170,000	3,900	4,200
Median	1,000	1,450	850	1,400
Phosphorus, total (mg/kg):				
Maximum	3,400	1,600	2,800	1,700
Median	1,400	445	1,045	480
Arsenic (µg/g):				
Maximum	28	26	19	19
Median	<1.0	8.0	<1.0	<1.0
Cadmium (µg/g):				
Maximum	4.0	320	3.0	1.0
Median	<10	1.0	<10	<10
Chromium (µg/g):				
Maximum	100	3,400	110	26
Median	9.0	9.0	4.0	9.0
Copper (µg/g):				
Maximum	57	2,200	170	14
Median	9.0	7.0	7.0	10
Iron (µg/g):				
Maximum	21,000	71,000	27,000	31,000
Median	5,700	9,100	15,500	13,500
Lead (µg/g):				
Maximum	30	1,400	400	30
Median	19	20	20	20
Manganese (µg/g):				
Maximum	1,500	2,700	1,100	1,700
Median	620	860	810	1,200
Mercury (µg/g):				
Maximum	.06	2.1	.1	.07
Median	<.01	<.01	<.01	.005
Zinc (µg/g):				
Maximum	700	4,900	120	160
Median	47	50	68	50
Chlordane (µg/kg):				
Maximum	56	1.0	11	1.0
Median	9.0	<1.0	6	<1.0
DDD[1] (µg/kg):				
Maximum	7.2	1.5	2.2	.7
Median	2.7	<.1	1.0	<.1
Dieldrin (µg/kg):				
Maximum	8.7	3.4	6.4	4.2
Median	1.8	.3	2.5	1.2
Diazinon (µg/kg):				
Maximum	1.5	<10.0	1.4	3.3
Median	<.1	<.1	.7	<.1
PCB[2] (µg/kg):				
Maximum	44	<1.0	19	<1.0
Median	5.0	<1.0	2.0	<1.0

[1]1,1Dichloro-2,2-bis(p-chlorophenyl) ethane.
[2]Polychlorinated biphenyls.

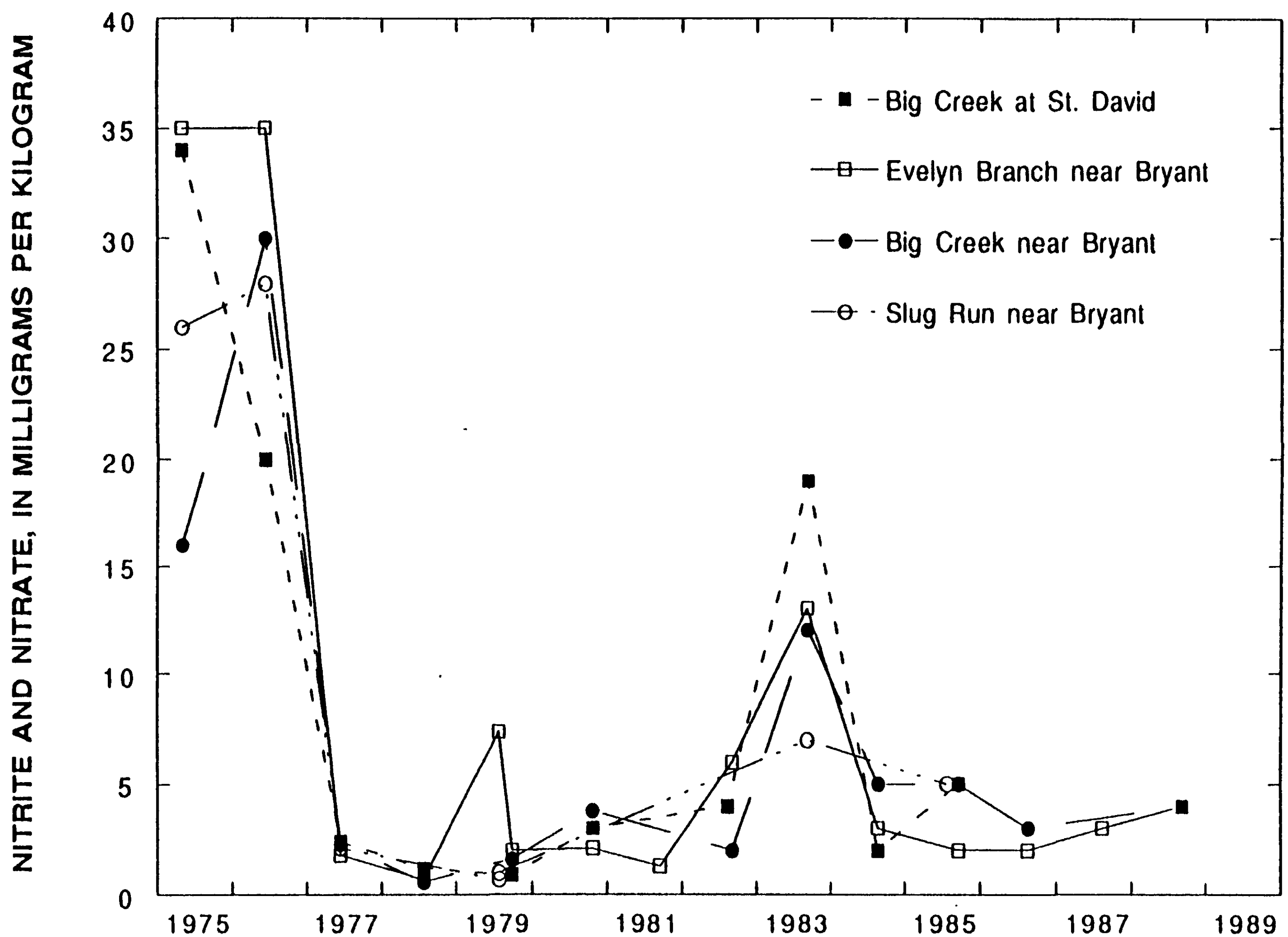

Figure 6.--Trends of instantaneous concentrations of nitrite plus nitrate in streambed sediment at four sites in Fulton County, Illinois, 1975-88.

Table 7.--Constituent concentrations in streambed sediment from Evelyn Branch near Bryant, July and September 1979

[mg/kg, milligram per kilogram; µg/g, microgram per gram; < less than]

Constituent	Concentration	
	July 26, 1979	September 28, 1979
Nitrogen, nitrite plus nitrate (mg/kg as N)	7.4	2.0
Nitrogen, ammonia (mg/kg as N)	297	27
Nitrogen, ammonia plus organic (mg/kg as N)	170,000	4,700
Nitrogen (mg/kg as N)	170,000	4,700
Phosphorus, total (mg/kg as P)	1,300	410
Arsenic (µg/g as As)	16	0
Cadmium (µg/g as Cd)	320	<10
Chromium (µg/g as Cr)	3,400	10
Cobalt (µg/g as Co)	70	<10
Copper (µg/g as Cu)	2,200	10
Iron (µg/g as Fe)	71,000	16,000
Lead (µg/g as Pb)	1,400	<10
Manganese (µg/g as Mn)	530	780
Mercury (µg/g as Hg)	2.1	0
Zinc (µg/g as Zn)	4,900	50

expected at Evelyn Branch near Bryant, the site that drains the sludge-application fields. The fact that neither PCB's nor chlordane was detected, that DDD was detected only once, and that the concentration of dieldrin found in Evelyn Branch was much lower than concentrations found in Big Creek indicate that, with respect to these constituents, the application of sludge is not affecting the streambed quality in Evelyn Branch.

A statistical test on the distribution of the means of constituent concentrations was done to determine if the distribution of a constituent concentration was significantly different between stations. If the process of the delivery of a constituent to the streambed sediment is different at one station than at the others, then the differences between mean values should be statistically significant. For example, the mean concentrations of those constituents that accumulate in the streambed sediment as a result of urbanization would be expected to be different at Big Creek at St. David than at Evelyn Branch near Bryant or Slug Run near Bryant. Mean concentrations of those constituents related to the applications of sludge would be statistically different at Evelyn Branch near Bryant compared to the other sites if the sludge was affecting the streambed-sediment quality.

The Kruskal-Wallis nonparametric test was used on the streambed-sediment-quality data to test the null hypothesis (H_0)--that the means of the constituent concentration are identical among sites. The only assumptions for this test are (1) all samples are random samples and (2) the samples are independent of one another (Conover, 1980, p. 230). A significance level of $\alpha \leq 0.05$ was used to test H_0. This test was not used on the data collected at Big Creek near Bryant because this site is downstream from both Evelyn Branch near Bryant and Big Creek at St. David; therefore, the constituent concentrations at this site are affected by the concentrations at the upstream sites.

The Kruskal-Wallis test indicated that, for the inorganics and metals, means of only phosphorus and manganese were statistically different among the sites. Although the Kruskal-Wallis test does not indicate which mean is different, the median phosphorus concentration of 1,400 mg/kg at Big Creek at St. David is nearly three times the median concentrations at either Evelyn Branch near Bryant or Slug Run near Bryant (table 6). These differences are shown in figure 7 by use of boxplots. At Slug Run near Bryant, the median manganese concentration, 1,200 μg/g, was almost 50 percent higher than at any other site.

The Kruskal-Wallis test indicated that the mean concentrations of the organics--chlordane, DDD, dieldrin, and PCB--were statistically different. Nearly all of the samples collected at Big Creek at St. David contained detectable concentrations of these constituents. At Evelyn Branch near Bryant and Slug Run near Bryant, there were few detections of chlordane and DDD and no detections of PCB's. Table 8 is a list of constituents that were analyzed for, but for which no concentrations were above the MDL at any site. Summary statistics for selected streambed-sediment constituents analyzed for are given in tables 14-17 (at the end of the report).

Trends

For most of the streambed-quality constituents, substantial amounts of data were censored (reported concentration at the MDL). Hirsch and others (1991) list two methods for testing for trends when censored data are used. The first method, a parametric approach, involves linear regression to estimate values below the MDL. The second method, a nonparametric approach, involves the Seasonal Kendall test to estimate trends above the MDL. According to Hirsch and others (1991), there is a slight advantage to use of a nonparametric test when the data depart slightly from normality, and there are large advantages when data depart a great deal from normality. Streambed-quality data can be expected to depart from normal. Therefore, the Seasonal Kendall test with one season (one sample per year) was used to test for trends on the streambed data for those constituents for which four or more concentrations were above the MDL. Trends were considered significant at $\rho \leq 0.05$.

Because of changing analytical techniques, some constituents were analyzed at multiple MDL's. Hirsch and others (1991) outlined a method for the computation of trends by use of the Seasonal Kendall test under these circumstances.

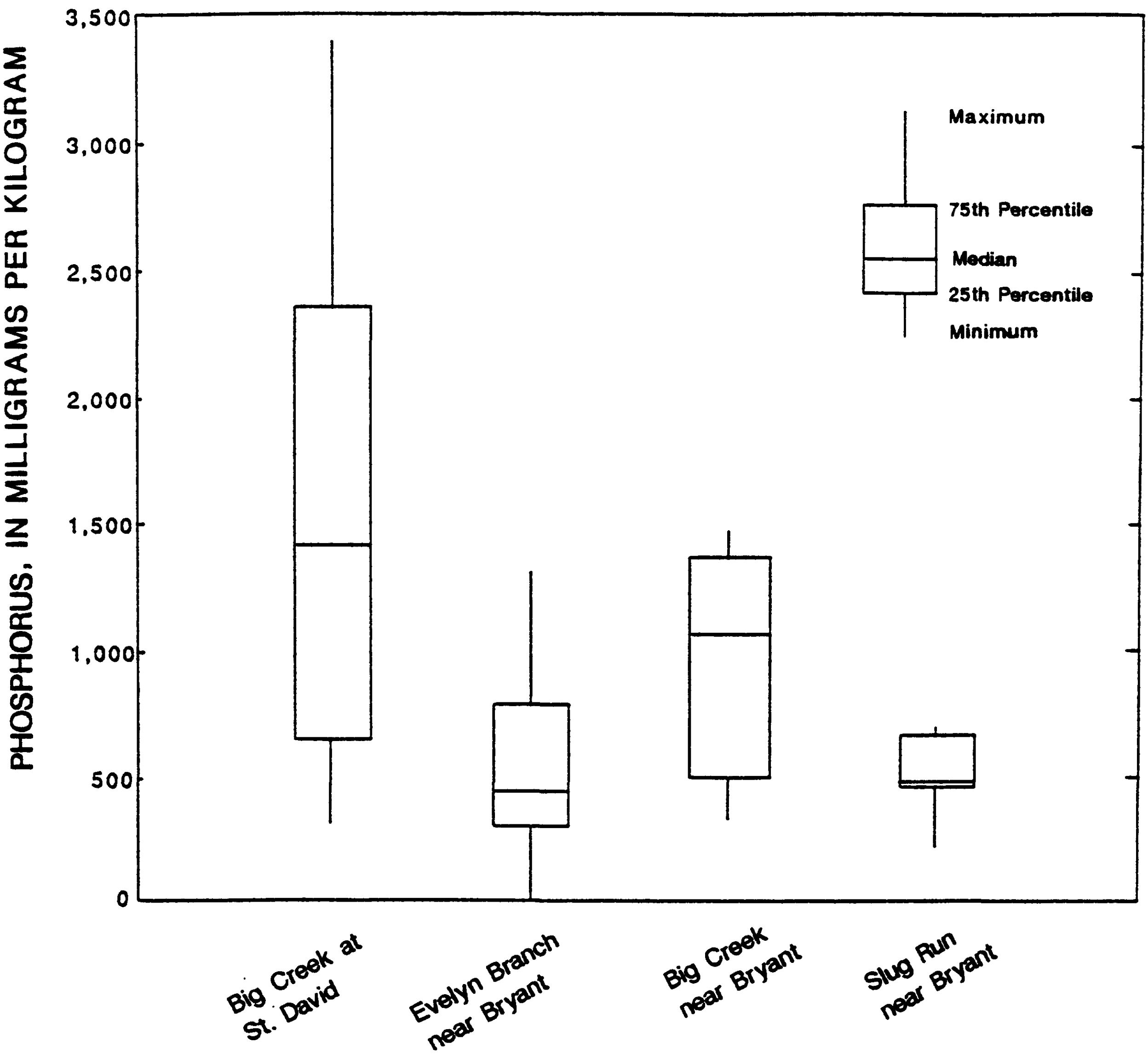

Figure 7.--Boxplots of phosphorus concentrations in streambed sediments at four sites in Fulton County, Illinois, 1975-89.

Table 8.--Streambed-sediment constituents undetected in analyses of samples from all sites

[µg/kg, microgram per kilogram; MDL, minimum detection limit. More than one MDL indicates a change in detection limits during the period of data collection]

Constituent	Number of samples	MDL
2,4-Dimethylphenol (µg/kg)	22	1.0, 0.1, 0.0
Gross polychlorinated naphthalenes (µg/kg)	23	1.0
Endosulfan (µg/kg)	23	0.1
Endrin (µg/kg)	23	0.1
Ethion (µg/kg)	23	0.1
Toxaphene (µg/kg)	23	10.0, 1.0
Methoxychlor (µg/kg)	21	0.1
Malathion (µg/kg)	23	1.0, 0.1
Parathion (µg/kg)	23	1.0, 0.1
Methyl parathion (µg/kg)	23	1.0, 0.1
2,4-Dichlorophenoxyacetic acid (µg/kg)	22	1.0, 0.1, 0.0
2,4,5-Trichlorophenoxyacetic acid (µg/kg)	22	1.0, 0.1, 0.0
Mirex (µg/kg)	23	0.1
Silvex (µg/kg)	22	1.0, 0.1, 0.0
Trithion (µg/kg)	23	0.1
Methyl trithion (µg/kg)	23	0.1
Perthane (µg/kg)	23	1.0, 0.1

In these cases, all values below the largest MDL are set equal to the largest MDL. For the streambed-quality data, the largest MDL sometimes was greater than most of the measured concentrations. To set all of the values below the largest MDL equal to that MDL would substantially increase the amount of censored data and restrict the evaluation of trends to ranges of concentrations that are rarely observed. Therefore, no attempt was made to apply the Seasonal Kendall test to those constituents analyzed at multiple MDL's. Additionally, MDL's for a few constituents were greater than the median of the measured values because of changes in the analytical methods. Trends were not computed for these constituents. Only the direction (+ or -) of the trend is reported for those constituents where data sets include greater than 5 percent censored values. The interpretation of the results from the trend test is restricted to concentrations above the MDL. No information is obtained from the test about the status of trends for concentrations below the MDL. The results are listed in table 9. Trend tests for lindane and heptachlor were unnecessary because concentrations of these constituents were either at or below the MDL at all sites.

Table 9.--Results of the Seasonal Kendall test for streambed constituents, by site

[mg/kg, milligram per kilogram; µg/g, microgram per gram; µg/kg, microgram per kilogram; -, negative slope; +, positive slope; <, less than; --, too few values above the minimum detection limit]

ρ is the probability that a trend resulted from a chance arrangement of the data. A trend is considered statistically significant if ρ ≤ 0.05.

The Seasonal Kendall test was used on the data collected from 1975-89 at Evelyn Branch near Bryant and Big Creek near Bryant, and from 1975-85 at Big Creek at St. David and Slug Run near Bryant.

Site	ρ	Trend slope (percent)	Number of seasons	Median
	Nitrogen, ammonia (mg/kg)			
Big Creek at St. David	0.15	-15.1	10	16.5
Evelyn Branch near Byrant	.58	-4.8	14	21
Big Creek near Bryant	.43	-2.1	13	8.7
Slug Run near Bryant	.04	-29.3	7	8.8
	Nitrogen, ammonia plus organic (mg/kg)			
Big Creek at St. David	.37	-8.4	10	995
Evelyn Branch near Bryant	1.00	.0	14	1,450
Big Creek near Bryant	.58	-5.2	13	850
Slug Run near Bryant	.76	5.0	7	1,400
	Phosphorus, total (mg/kg)			
Big Creek at St. David	.05	17.3	10	1,350
Evelyn Branch near Bryant	.39	4.3	13	610
Big Creek near Bryant	.24	4.2	12	1,045
Slug Run near Bryant	.09	20.8	7	480
	Arsenic (µg/g)			
Big Creek at St. David	1.00	.0	10	1
Evelyn Branch near Bryant	.78	.0	14	8
Big Creek near Bryant	.26	(+)	13	8
Slug Run near Bryant	.35	(-)	7	1

Table 9.--Results of the Seasonal Kendall test for streambed constituents, by site--Continued

Site	ρ	Trend slope (percent)	Number of seasons	Median
		Iron (µg/g)		
Big Creek at St. David	0.92	0.7	10	5,643
Evelyn Branch near Bryant	.70	2.3	14	9,100
Big Creek near Bryant	.67	2.7	13	15,000
Slug Run near Bryant	.54	10.5	7	10,000
		Lead (µg/g)		
Big Creek at St. David	.31	(+)	10	17
Evelyn Branch near Bryant	.95	.0	14	20
Big Creek near Bryant	.15	(+)	13	20
Slug Run near Bryant	.12	(+)	7	20
		Manganese (µg/g)		
Big Creek at St. David	.06	16.5	10	600
Evelyn Branch near Bryant	.81	2.1	13	930
Big Creek near Bryant	.95	-.3	12	800
Slug Run near Bryant	1.00	.0	7	1,200
		Zinc (µg/g)		
Big Creek at St. David	.59	-7.1	10	46
Evelyn Branch near Bryant	.55	1.9	14	57.5
Big Creek near Bryant	.46	4.0	13	65
Slug Run near Bryant	.05	-15.2	7	50
		Chlordane (µg/kg)		
Big Creek at St. David	.52	-8	10	10
Evelyn Branch near Bryant	--	--	13	<.1
Big Creek near Bryant	1.0	(+)	12	<.1
Slug Run near Bryant	--	--	6	<.1
		DDD[1] (µg/kg)		
Big Creek at St. David	.07	-15	10	2.75
Evelyn Branch near Bryant	--	--	13	<.1
Big Creek near Bryant	.83	-2	12	<.1
Slug Run near Bryant	--	--	6	<.1

Table 9.--Results of the Seasonal Kendall test for streambed constituents, by site--Continued

Site	ρ	Trend slope (percent)	Number of seasons	Median
	DDE[2] (µg/kg)			
Big Creek at St. David	0.26	(+)	10	<.1
Evelyn Branch near Bryant	--	--	13	<.1
Big Creek near Bryant	.08	(+)	12	<.1
Slug Run near Bryant	--	--	6	<.1
	DDT[3] (µg/kg)			
Big Creek at St. David	.5	(0)	10	<.1
Evelyn Branch near Bryant	--	--	13	<.1
Big Creek near Bryant	.06	(+)	12	<.1
Slug Run near Bryant	--	--	6	.55
	Diazinon (µg/kg)			
Big Creek at St. David	.22	(+)	10	<.1
Evelyn Branch near Bryant	--	--	12	<.1
Big Creek near Bryant	.14	(+)	12	.7
Slug Run near Bryant	--	--	6	<.05
	Dieldrin (µg/kg)			
Big Creek at St. David	.11	(-)	10	2.45
Evelyn Branch near Bryant	.03	(-)	13	.3
Big Creek near Bryant	.68	-1.2	12	2.5
Slug Run near Bryant	1.00	-2.9	6	1.15
	PCB[4] (µg/kg)			
Big Creek at St. David	.52	-8	10	6.0
Evelyn Branch near Bryant	--	--	14	<.1
Big Creek near Bryant	.33	(+)	12	2.0
Slug Run near Bryant	--	--	6	<.1

[1]1,1Dichloro-2,2-bis(p-chlorophenyl) ethane.
[2]Dichlorodiphenyldichloroethylene.
[3]Dichloro diphenyl trichloroethane.
[4]Polychlorinated biphenyls.

Slug Run near Bryant had a negative trend in nitrogen ammonia; this corresponded with the negative trend observed in nitrogen ammonia in the water column. The positive trend in phosphorus in streambed sediments in Big Creek at St. David corresponded to the positive trend in phosphorus in samples from the water column collected at this site. The trend in zinc concentration was negative at Slug Run near Bryant, and the trend for dieldrin was negative at Evelyn Branch near Bryant.

Trend analyses on the streambed constituents that were measured did not indicate any adverse effects that could be attributed to the application of sludge; however, it cannot be stated from the existing data that there have been no adverse effects from sludge application. A refinement of the sampling scheme would be necessary to rule out the possibility of adverse effects. Of particular concern is Evelyn Branch near Bryant, the site that could be expected to show the effects of sludge application. The streambed sediment collected at this site for analyses is collected below the outfall of Lake Evelyn. Discharge through the outfall is from the surface of the lake; thus, Lake Evelyn could be functioning as a filter because solids and the sorbed hydrophobic compounds have a chance to settle to the lake bottom. The sediment from the bottom of Lake Evelyn could be expected to resuspend during high flows, which normally occur during April or May. Streambed samples were always collected in late summer (July, August, or September).

SUMMARY AND CONCLUSIONS

Sewage sludge from the Chicago area has been used to reclaim surface-mined land in Fulton County, Ill., since 1971. Sludge contains substantial quantities of nutrients but may also contain some toxins. Analyses of the sludge indicate that it contains significant amounts of organic compounds such as dieldrin, PCB's, chlordane, and DDD. The fate of these toxins is of concern to local residents, public-health officials, and others. In 1989, the U.S. Geological Survey in cooperation with the Metropolitan Water Reclamation District of Greater Chicago began an analysis of historical data to compare the quality of water and streambed sediments from streams in the project area and to determine whether the application of sludge is adversely affecting the quality of surface water in a 15,528-acre area in the county.

Surface-water-quality and streambed-quality data were collected at four sites: (1) Big Creek at St. David (upstream from the project area and the quality of water is influenced by mining, urban land, and manufacturing); (2) Evelyn Branch near Bryant (drains an area almost completely surface mined and a large area has been reclaimed by sludge application); (3) Big Creek near Bryant (downstream from the confluence of Evelyn Branch and Big Creek); and (4) Slug Run near Bryant (an area where more than 90 percent of the land has been surface mined, but no reclamation has been done). These data were analyzed to determine changes in water quality. The data-collection program was not designed to determine which of many compounding factors are affecting water quality. However, it is possible to isolate the major factors affecting water quality by comparing water quality and trends in water quality at similar sites where land uses differ.

Nutrient concentrations in Big Creek decreased between Big Creek at St. David and Big Creek near Bryant because of the cleansing and diluting that occurs between the two sites. Median concentrations at Big Creek at St. David and Big Creek near Bryant for nitrite plus nitrate were 2.7 and 2.1 mg/L, respectively, and 0.5 and 0.3 mg/L for KJD, respectively. Sulfate, bicarbonate, calcium, magnesium, and sodium concentrations are larger in Evelyn Branch than at Big Creek at St. David, causing an increase in these constituents at Big Creek near Bryant.

The Seasonal-Kendall test was used to test for trends on flow-adjusted surface-water-quality data. Magnesium, sodium, and dissolved solids had negative (decreasing concentration with time) trends in Evelyn Branch. Chloride had a positive (increasing concentration with time) trend in Big Creek and Evelyn Branch. Kjeldahl nitrogen and nitrite plus nitrate had positive trends in Evelyn Branch. Evelyn Branch is the stream draining the sludge-application fields. No trends in these constituents were detected at the other sites, suggesting that sludge application may be affecting the quality of water in Evelyn Branch, although the median concentrations of these constituents were lower in Evelyn Branch than in Big Creek.

On the basis of streambed-quality data, mean concentrations of phosphorus, manganese, chlordane, DDD, dieldrin, and PCB's were statistically different among sites. The median phosphorus concentration of 1,400 mg/kg at Big Creek at St. David is nearly three times the median concentration at Evelyn Branch or Slug Run. The median concentration of 1,200 µg/g of manganese at Slug Run near Bryant is almost 50 percent larger than at the other sites. Nearly all of the streambed-sediment samples from Big Creek at St. David had detectable concentrations of chlordane, DDD, and PCB's. Few samples had detectable concentrations of these constituents in Evelyn Branch or Slug Run.

The median concentration of dieldrin in the streambed at Evelyn Branch was 0.3 µg/kg--much lower than the median concentrations at Big Creek at St. David and Big Creek near Bryant (1.8 and 2.5 µg/kg, respectively). PCB's and chlordane were not detected, and only one value above the MDL for DDD in the streambed sediment was detected at Evelyn Branch near Bryant. The low frequency of detections of these constituents in Evelyn Branch, the stream most likely to see any effects of sludge applications, indicates that, for these constituents, sludge application is not affecting the quality of the streambed.

Trend analyses on the streambed constituents did not indicate any adverse effects that could be related to the application of sludge. However, the available data are not adequate to determine whether the quality of the streambed has been adversely affected by sludge application. A refinement of the sampling scheme would be necessary to rule out the possibility of present and future adverse effects.

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TABLES 10-17

Table 10.--Summary statistics for selected surface-water-quality constituents and physical properties at Big Creek at St. David (05570350), 1972-89

[µS/cm, microsiemen per centimeter at 25 degrees Celsius; mg/L, milligram per liter; col/100mL, colonies per 100 milliliters; µg/L, microgram per liter; <, less than; --, not determined]

Water-quality constituent	Descriptive statistics				Percentage of samples in which values were less than or equal to those shown				
	Number of samples	Maximum	Minimum	Mean	95	75	50 (Median)	25	5
Specific conductivity (µS/cm)	143	2,100	96	1,010	1,450	1,170	1,000	850	576
pH (standard unit)	143	8.5	6.2	7.8	8.3	8.1	7.9	7.6	7.2
Nitrogen, ammonia (mg/L as N)	143	6.7	<.10	.98*	3.1	1.3	.50	.20	<.10
Nitrogen, kjeldahl (mg/L as N)	143	16	.10	2.0	4.0	2.4	1.5	1.0	.44
Nitrogen, nitrite plus nitrate (mg/L as N)	143	13.5	.01	2.9	5.3	3.5	2.7	2.0	1.0
Phosphorus, total (mg/L as P)	139	3.8	.02	1.1	2.7	1.6	.93	.56	.16
Chloride (mg/L as Cl)	143	148	.50	40	80	46	37	29	20
Sulfate (mg/L as SO_4)	143	1,030	64	330	597	426	317	219	119
Coliform fecal (col/100mL)	110	200,000	0	12,900	77,800	13,200	1,950	182	10
Suspended solids (mg/L)	110	1,470	3.0	89	290	81	37	17	5.5
Dissolved solids (mg/L)	111	2,250	412	894	1,390	1,050	870	733	488
Alkalinity (mg/L as $CaCO_3$)	143	1,030	121	259	438	275	250	220	154
Calcium, dissolved (mg/L as Ca)	48	199	60	113	195	130	112	83	63
Calcium, total (mg/L as Ca)	95	228	57	127	200	146	124	100	83
Magnesium, dissolved (mg/L as Mg)	48	75	24	47	71	54	49	40	28
Magnesium, total (mg/L as Mg)	95	103	28	56	81	64	55	48	35
Sodium, total (mg/L as Na)	95	178	10	70	111	81	68	53	38
Sodium, dissolved (mg/L as Na)	48	140	3.0	54	110	69	51	37	14
Potassium, dissolved (mg/L as K)	48	12.4	1.0	5.1	10.9	6.1	5.0	3.0	1.9
Potassium, total (mg/L as K)	94	9.0	1.3	4.9	7.0	6.0	5.0	4.0	3.0
Cadmium, dissolved (mg/L as Cd)	48	<.02	<.02	--	<.02	<.02	<.02	<.02	<.02
Cadmium, total (mg/L as Cd)	95	.40	<.02	--	<.02	<.02	<.02	<.02	<.02
Chromium, dissolved (mg/L as Cr)	48	.03	<.02	--	.03	<.02	<.02	<.02	<.02
Chromium, total (mg/L as Cr)	95	.06	<.02	--	<.02	<.02	<.02	<.02	<.02
Copper, dissolved (mg/L as Cu)	48	.05	<.02	--	.03	<.02	<.02	<.02	<.02
Copper, total (mg/L as Cu)	95	.21	<.02	.02*	.08	<.02	<.02	<.02	<.02
Iron, total (mg/L as Fe)	95	11	<.10	1.4*	3.1	1.7	1.1	.70	<.10
Iron, dissolved (mg/L as Fe)	48	1.1	<.10	.20*	.60	.20	<.10	<.10	<.10
Lead, dissolved (mg/L as Pb)	48	.10	<.02	.02*	.10	.02	<.02	<.02	<.02
Lead, total (mg/L as Pb)	95	.20	<.02	.04*	.12	.06	.03	<.02	<.02

Table 10.--Summary statistics for selected surface-water-quality constituents and physical properties at Big Creek at St. David (05570350), 1972-89--Continued

Water-quality constituent	Descriptive statistics				Percentage of samples in which values were less than or equal to those shown				
	Number of samples	Maximum	Minimum	Mean	95	75	50 (Median)	25	5
Manganese, total (mg/L as Mn)	95	18	0.05	0.71	0.81	0.66	0.51	0.41	0.26
Manganese, dissolved (mg/L as Mn)	48	.70	.07	.32	.61	.43	.28	.21	.09
Nickel, dissolved (mg/l as Ni)	48	.20	<.10	--	<.10	<.10	<.10	<.10	<.10
Nickel, total (mg/L as Ni)	95	.20	<.10	--	<.10	<.10	<.10	<.10	<.10
Zinc, dissolved (mg/L as Zn)	48	.30	<.10	--	<.10	<.10	<.10	<.10	<.10
Zinc, total (mg/L as Zn)	95	6.0	<.10	--	<.10	<.10	<.10	<.10	<.10
Aluminum, Total (mg/L as Al)	92	21	<1.0	1.4*	4.0	2.0	<1.0	<1.0	<1.0
Aluminum, dissolved (mg/L as Al)	48	<1.0	<1.0	--	<1.0	<1.0	<1.0	<1.0	<1.0
Selenium, dissolved (mg/L as Se)	48	.30	<.10	--	.20	<.10	<.10	<.10	<.10
Selenium, total (mg/L as Se)	65	<.10	<.10	--	<.10	<.10	<.10	<.10	<.10
Mercury, dissolved (µg/L as Hg)	48	.70	<.10	.16*	.50	.20	<.10	<.10	<.10
Mercury, total (µg/L as Hg)	95	.60	<.10	.11*	.40	<.10	<.10	<.10	<.10

*Value is estimated by use of a log-probability regression to predict the values of data below the detection limit.

Table 11.--Summary statistics for selected surface-water-quality constituents and physical properties at Evelyn Branch near Bryant (055700360), 1972-89

[µS/cm, microsiemen per centimeter at 25 degrees Celsius; mg/L, milligram per liter; col/100mL, colonies per 100 milliliters; µg/L, microgram per liter; <, less than; --, not determined]

Water-quality constituent	Descriptive statistics				Percentage of samples in which values were less than or equal to those shown				
	Number of samples	Maximum	Minimum	Mean	95	75	50 (Median)	25	5
Specific conductivity (µS/cm)	143	2,900	145	1,580	2,100	1,820	1,550	1,400	900
pH (standard unit)	144	10	6.8	8.02	8.6	8.2	8.1	7.8	7.2
Nitrogen, ammonia (mg/L as N)	144	1.4	<.10	.22*	.80	.30	<.10	<.10	<.10
Nitrogen, kjeldahl (mg/L as N)	144	3.4	<.10	1.08*	2.0	1.3	1.0	.70	<.10
Nitrogen, nitrite plus nitrate (mg/L as N)	144	4.3	<.01	.78*	2.6	1.2	.37	.05	<.01
Phosphorus, total (mg/L as P)	143	1.8	0	.12	.26	.12	.09	.05	.01
Chloride (mg/L as Cl)	143	220	8.0	22	36	22	18	14	11
Sulfate (mg/L as SO_4)	143	1,290	21	633	1,050	833	646	426	227
Coliform fecal (col/100mL)	117	480	0	16	56	12	4.0	0	0
Suspended solids (mg/L)	109	444	1.0	17	38	18	11	6.0	1.5
Dissolved solids (mg/L)	107	2,290	746	1,430	2,030	1,720	1,420	1,100	847
Alkalinity (mg/L as $CaCO_3$)	143	900	15	283	416	335	275	225	142
Calcium, dissolved (mg/L as Ca)	48	210	55	116	176	141	114	86	69
Calcium, total (mg/L as Ca)	96	350	54	145	211	165	144	120	85
Magnesium, dissolved (mg/L as Mg)	48	150	69	100	133	114	100	85	73
Magnesium, total (mg/L as Mg)	96	188	41	103	142	112	100	91	71
Sodium, total (mg/L as Na)	96	360	25	184	271	220	180	146	99
Sodium, dissolved (mg/L as Na)	48	230	4.0	117	218	160	129	73	16
Potassium, dissolved (mg/L as K)	48	15	1.0	6.5	10	8.0	7.2	5.2	1.4
Potassium, total (mg/L as K)	95	12	1.0	7.8	10	9.0	8.0	7.0	5.8
Cadmium, dissolved (mg/L as Cd)	48	.03	<.02	<.02	<.02	<.02	<.02	<.02	<.02
Cadmium, total (mg/L as Cd)	96	.03	<.02	--	<.02	<.02	<.02	<.02	<.02
Chromium, dissolved (mg/L as Cr)	48	.04	<.02	--	.03	<.02	<.02	<.02	<.02
Chromium, total (mg/L as Cr)	95	.04	<.02	--	.02	<.02	<.02	<.02	<.02
Copper, dissolved (mg/L as Cu)	48	.31	<.02	--	<.04	<.02	<.02	<.02	<.02
Copper, total (mg/L as Cu)	86	.22	<.02	.04*	.15	<.06	<.02	<.02	<.02
Iron, total (mg/L as Fe)	96	6.0	<.10	.45*	2.0	.40	.20	.10	<.10
Iron, dissolved (mg/L as Fe)	48	1.4	<.10	.15*	.50	.20	<.10	<.10	<.10
Lead, dissolved (mg/L as Pb)	48	.10	<.02	.01*	.10	<.02	<.02	<.02	<.02
Lead, total (mg/L as Pb)	96	.79	<.02	.05*	.13	.05	.03	<.02	<.02

Table 11.--Summary statistics for selected surface-water-quality constituents and physical properties at Evelyn Branch near Bryant (055700360), 1972-89--Continued

Water-quality constituent	Descriptive statistics				Percentage of samples in which values were less than or equal to those shown				
	Number of samples	Maximum	Minimum	Mean	95	75	50 (Median)	25	5
Manganese, total (mg/L as Mn)	96	.88	0.05	0.24	0.57	0.32	0.20	0.11	0.08
Manganese, dissolved (mg/L as Mn)	48	.56	<.02	.16*	.41	.20	.11	.05	<.02
Nickel, dissolved (mg/L as Ni)	48	.20	<.10	.04*	.20	<.10	<.10	<.10	<.10
Nickel, total (mg/L as Ni)	95	.30	<.10	--	<.10	<.10	<.10	<.10	<.10
Zinc, dissolved (mg/L as Zn)	48	.20	<.10	--	<.10	<.10	<.10	<.10	<.10
Zinc, total (mg/L as Zn)	95	.20	<.10	--	<.10	<.10	<.10	<.10	<.10
Aluminum, total (mg/L as Al)	86	3.0	<1.0	.34*	1.0	<1.0	<1.0	<1.0	<1.0
Aluminum, dissolved (mg/L as Al)	48	<1.0	<1.0	--	<1.0	<1.0	<1.0	<1.0	<1.0
Selenium, dissolved (mg/L as Se)	47	.20	<.10	--	.20	<.10	<.10	<.10	<.10
Selenium, total (mg/L as Se)	70	.10	<.10	--	<.10	<.10	<.10	<.10	<.10
Mercury, dissolved (μg/L as Hg)	48	1.3	<.10	.16*	.40	.20	<.10	<.10	<.10
Mercury, total (μg/L as Hg)	95	1.2	<.10	.13*	.40	.20	<.10	<.10	<.10

*Value is estimated by use of a log-probability regression to predict the values of data below the detection limit.

Table 12.--Summary statistics for selected surface-water-quality constituents and physical properties at Big Creek near Bryant (05570370), 1972-89

[μS/cm, microsiemen per centimeter at 25 degrees Celsius; mg/L, milligram per liter; col/100mL, colonies per 100 milliliters; μg/L, microgram per liter; <, less than; --, not determined]

Water-quality constituent	Descriptive statistics				Percentage of samples in which values were less than or equal to those shown				
	Number of samples	Maximum	Minimum	Mean	95	75	50 (Median)	25	5
Specific conductivity (μS/cm)	143	9,000	100	1,190	1,650	1,350	1,150	1,000	579
pH (standard unit)	143	8.7	6.9	7.9	8.4	8.1	8.0	7.8	7.2
Nitrogen, ammonia (mg/L as N)	143	5.3	<.10	.48*	1.4	.70	.30	<.10	<.10
Nitrogen, kjeldahl (mg/L as N)	143	5.7	<.10	1.2*	2.3	1.5	1.1	.70	<.10
Nitrogen, nitrite plus nitrate (mg/L as N)	143	9.4	.01	2.2	3.8	2.9	2.1	1.5	.32
Phosphorus, total (mg/L as P)	141	3.0	.02	.68	1.7	.86	.55	.37	.16
Chloride (mg/L as Cl)	143	303	3.0	35	63	40	32	24	14
Sulfate (mg/L as SO_4)	143	1,070	16	430	712	545	419	310	154
Coliform fecal (col/100mL)	110	90,000	0	5,310	32,500	3,820	635	107	20
Suspended solids (mg/L)	105	1,830	3.0	87	319	74	35	12	5.3
Dissolved solids (mg/L)	110	2,610	470	1,060	1,660	1,200	1,030	870	603
Alkalinity (mg/L as $CaCO_3$)	142	1,250	115	270	387	286	260	233	177
Calcium, dissolved (mg/L as Ca)	48	214	65	133	210	151	131	110	70
Calcium, total (mg/L as Ca)	95	325	79	148	213	165	140	125	99
Magnesium, dissolved (mg/L as Mg)	48	96	25	62	87	70	61	55	35
Magnesium, total (mg/L as Mg)	95	127	38	69	98	78	68	58	42
Sodium, total (mg/L as Na)	95	183	13	82	122	97	80	63	49
Sodium, dissolved (mg/L as Na)	48	110	4.0	59	106	79	57	38	14
Potassium, dissolved (mg/L as K)	48	12	1.0	5.2	10.3	6.5	5.0	3.0	2.0
Potassium, total (mg/L as K)	94	8.0	1.0	5.1	7.4	6.0	5.0	4.0	3.0
Cadmium, dissolved (mg/L as Cd)	48	<.02	<.02	--	<.02	<.02	<.02	<.02	<.02
Cadmium, total (mg/L as Cd)	95	.80	<.02	--	.05	<.02	<.02	<.02	<.02
Chromium, dissolved (mg/L as Cr)	48	<.02	<.02	--	<.02	<.02	<.02	<.02	<.02
Chromium, total (mg/L as Cr)	95	.07	<.02	--	<.02	<.02	<.02	<.02	<.02
Copper, dissolved (mg/L as Cu)	48	.04	<.02	--	.03	<.02	<.02	<.02	<.02
Copper, total (mg/L as Cu)	95	.57	<.02	.02*	.09	<.02	<.02	<.02	<.02
Iron, total (mg/L as Fe)	95	12	.10	1.4	4.2	1.5	1.0	.70	.26
Iron, dissolved (mg/L as Fe)	48	1.2	<.10	.16*	.60	.20	<.10	<.10	<.10
Lead, dissolved (mg/L as Pb)	48	.10	<.02	.01*	.05	<.02	<.02	<.02	<.02
Lead, total (mg/L as Pb)	95	.30	<.02	.04*	.14	.05	.02	<.02	<.02

Table 12.--Summary statistics for selected surface-water-quality constituents and physical properties at Big Creek near Bryant (05570370), 1972-89--Continued

Water-quality constituent	Descriptive statistics				Percentage of samples in which values were less than or equal to those shown				
	Number of samples	Maximum	Minimum	Mean	95	75	50 (Median)	25	5
Manganese, total (mg/L as Mn)	95	17	0.05	0.71	0.88	0.71	0.54	0.40	0.24
Manganese, dissolved (mg/L as Mn)	48	.79	.08	.35	.70	.51	.28	.20	.10
Nickel, dissolved (mg/L as Ni)	48	.20	<.10	--	.20	<.10	<.10	<.10	<.10
Nickel, total (mg/L as Ni)	95	.50	<.10	--	<.10	<.10	<.10	<.10	<.10
Zinc, dissolved (mg/L as Zn)	48	<.10	<.10	--	<.10	<.10	<.10	<.10	<.10
Zinc, total (mg/L as Zn)	95	6.0	<.10	--	<.10	<.10	<.10	<.10	<.10
Aluminum, total (mg/L as Al)	92	20	<1.0	1.1*	4.0	<1.0	<1.0	<1.0	<1.0
Aluminum, dissolved (mg/L as Al)	48	<1.0	<1.0	--	<1.0	<1.0	<1.0	<1.0	<1.0
Selenium, dissolved (mg/L as Se)	48	.30	<.10	--	.20	<.10	<.10	<.10	<.10
Selenium, total (mg/L as Se)	66	<.10	<.10	--	<.10	<.10	<.10	<.10	<.10
Mercury, dissolved (µg/L as Hg)	48	.60	<.10	.24*	.60	.30	<.10	<.10	<.10
Mercury, total (µg/L as Hg)	94	.70	<.10	.14*	.40	.20	<.10	<.10	<.10

*Value is estimated by use of a log-probability regression to predict the values of data below the detection limit.

Table 13.--Summary statistics for selected surface-water-quality constituents and physical properties at Slug Run near Bryant (05570380), 1972-89

[µS/cm, microsiemen per centimeter at 25 degrees Celsius; mg/L, milligram per liter; col/100mL, colonies per 100 milliliters; µg/L, microgram per liter; <, less than; --, not determined]

Water-quality constituent	Descriptive statistics: Number of samples	Maximum	Minimum	Mean	Percentage of samples in which values were less than or equal to those shown: 95	75	50 (Median)	25	5
Specific conductivity (µS/cm)	142	2,600	150	1,570	2,200	1,800	1,600	1,380	843
pH (standard unit)	142	8.7	7.2	8.0	8.4	8.2	8.0	7.8	7.4
Nitrogen, ammonia (mg/L as N)	142	3.3	<.10	.16*	.50	.20	<.10	<.10	<.10
Nitrogen, kjeldahl (mg/L as N)	142	5.7	<.10	.59*	1.6	.70	.40	.20	<.10
Nitrogen, nitrite plus nitrate (mg/L as N)	142	1.0	<.01	.12*	.36	.13	.09	.05	<.01
Phosphorus, total (mg/L as P)	142	2.0	0	.12	.31	.13	.09	.04	0
Chloride (mg/L as Cl)	142	56	4.0	13	27	14	11	10	8.0
Sulfate (mg/L as SO_4)	142	2,150	35	725	1,310	891	747	493	189
Coliform fecal (col/100mL)	110	2,900	0	317	1,300	370	130	27	0
Suspended solids (mg/L)	98	1,460	1.0	36	72	27	11	6.0	2.0
Dissolved solids (mg/L)	109	3,320	17	1,560	2,170	1,820	1,590	1,320	746
Alkalinity (mg/L as $CaCO_3$)	142	520	129	278	370	308	272	242	200
Calcium, dissolved (mg/L as Ca)	48	290	88	182	240	204	183	155	120
Calcium, total (mg/L as Ca)	94	610	40	204	282	230	200	165	132
Magnesium, dissolved (mg/L as Mg)	48	162	49	126	161	140	129	114	81
Magnesium, total (mg/L as Mg)	94	240	10	134	192	149	133	116	89
Sodium, total (mg/L as Na)	94	145	9.4	76	104	86	76	66	45
Sodium, dissolved (mg/L as Na)	48	96	1.0	55	94	73	62	34	8.4
Potassium, dissolved (mg/L as K)	48	10	<1.0	4.9*	8.0	6.0	5.0	2.3	<1.0
Potassium, total (mg/L as K)	93	8.9	3.8	6.2	8.0	7.0	6.0	5.6	4.5
Cadmium, dissolved (mg/L as Cd)	48	.03	<.02	--	<.02	<.02	<.02	<.02	<.02
Cadmium, total (mg/L as Cd)	94	.03	<.02	--	<.02	<.02	<.02	<.02	<.02
Chromium, dissolved (mg/L as Cr)	48	.08	<.02	--	.03	<.02	<.02	<.02	<.02
Chromium, total (mg/L as Cr)	93	.06	<.02	.01*	.03	<.02	<.02	<.02	<.02
Copper, dissolved (mg/L as Cu)	48	.05	<.02	--	<.02	<.02	<.02	<.02	<.02
Copper, total (mg/L as Cu)	94	.20	<.02	--	.03	<.02	<.02	<.02	<.02
Iron, total (mg/L as Fe)	93	4.8	<.10	.68*	1.6	.80	.50	.30	<.10
Iron, dissolved (mg/L as Fe)	48	.60	<.10	.16*	.40	.20	<.10	<.10	<.10
Lead, dissolved (mg/L as Pb)	48	.10	<.02	.03*	.10	.03	<.02	<.02	<.02
Lead, total (mg/L as Pb)	93	.46	<.02	.05*	.14	.06	.03	<.02	<.02

Table 13.--Summary statistics for selected surface-water-quality constituents and physical properties at Slug Run near Bryant (05570380), 1972-89--Continued

Water-quality constituent	Descriptive statistics				Percentage of samples in which values were less than or equal to those shown				
	Number of samples	Maximum	Minimum	Mean	95	75	50 (Median)	25	5
Manganese, total (mg/L as Mn)	93	1.3	0.14	0.54	1.0	0.74	0.49	0.33	0.20
Manganese, dissolved (mg/L as Mn)	48	1.7	.03	.34	1.0	.39	.27	.19	.07
Nickel, dissolved (mg/L as Ni)	48	.20	<.10	.20*	.20	<.10	<.10	<.10	<.10
Nickel, total (mg/L as Ni)	93	.30	<.10	.11*	.20	<.10	<.10	<.10	<.10
Zinc, dissolved (mg/L as Zn)	48	<.10	<.10	--	<.10	<.10	<.10	<.10	<.10
Zinc, total (mg/L as Zn)	94	.30	<.10	--	<.10	<.10	<.10	<.10	<.10
Aluminum, total (mg/L as Al)	89	2.3	<1.0	1.1*	2.0	<1.0	<1.0	<1.0	<1.0
Aluminum, dissolved (mg/L as Al)	48	<1.0	<1.0	--	<1.0	<1.0	<1.0	<1.0	<1.0
Selenium, dissolved (mg/L as Se)	48	.30	<.10	--	.20	.10	<.10	<.10	<.10
Selenium, total (mg/L as Se)	63	<.10	<.10	--	<.10	<.10	<.10	<.10	<.10
Mercury, dissolved (µg/L as Hg)	48	1.1	<.10	.21*	.50	.30	<.10	<.10	<.10
Mercury, total (µg/L as Hg)	92	.78	<.10	.15*	.50	.20	<.10	<.10	<.10

*Value is estimated by use of a log-probability regression to predict the values of data below the detection limit.

Table 14.--Summary statistics for selected streambed-sediment-quality constituents at Big Creek at St. David (05570350), 1975-85

[mg/kg, milligram per kilogram; µg/g, microgram per gram; µg/kg, microgram per kilogram; <, less than; --, not determined]

Water-quality constituent	Descriptive statistics: Number of samples	Maximum	Minimum	Mean	Percentage of samples in which values were less than or equal to those shown: 95	75	50 (Median)	25	5
Nitrogen, ammonia (mg/kg as N)	10	40	2.6	19	40	33	16	7.4	2.6
Nitrogen, ammonia plus organic (mg/kg as N)	11	4,800	0	1,410	4,800	2,100	1,000	500	0
Nitrogen, nitrite plus nitrate (mg/kg as N)	10	34	<2.0	9.0*	34	19	3.0	1.2	.90
Phosphorus, total (mg/kg as P)	11	3,400	320	1,580	3,400	2,700	1,400	560	320
Arsenic (µg/g as As)	10	28	<1.0	--	28	11	<1.0	<1.0	<1.0
Cadmium (µg/g as Cd)	11	4.0	<1.0	1.7*	4.0	2.0	<10.0	<10.0	<10.0
Chromium, total (µg/g as Cr)	11	100	<10.0	17*	100	10	9.0	4.0	4.0
Cobalt (µg/g as Co)	11	20	<10.0	10*	20	20	6.0	<10.0	<10.0
Copper (µg/g as Cu)	11	57	<1.0	12*	57	10	9.0	<10.0	<10.0
Lead, total (µg/g as Pb)	11	30	<10.0	16*	30	20	20	<10.0	<10.0
Manganese (µg/g as Mn)	11	1,500	69	692	1,500	880	620	410	69
Zinc (µg/g as Zn)	11	700	4.0	106	700	60	50	30	4.0
Iron (µg/g as Fe)	11	21,000	170	9,610	21,000	15,000	5,700	4,500	170
Aldrin (µg/kg)	11	<.10	<.10	--	<.10	<.10	<.10	<.10	<.10
Lindane (µg/kg)	11	.10	<.10	--	.10	<.10	<.10	<.10	<.10
Chlordane (µg/kg)	11	56	0	15	56	24	9.0	7.0	0
DDD[1] (µg/kg)	11	7.2	<.10	3.0*	7.2	5.2	2.7	1.3	1.2
DDE[2] (µg/kg)	11	3.0	<.10	--	3.0	.70	<.10	<.10	<.10
DDT[3] (µg/kg)	11	.30	<.10	--	.30	.10	<.10	<.10	<.10
Dieldrin (µg/kg)	11	8.7	<.10	3.5*	8.7	7.5	1.8	1.1	.20
Heptachlor (µg/kg)	11	.10	<.10	--	.10	<.10	<.10	<.10	<.10
Heptachlor epoxide (µg/kg)	11	.90	<.10	--	.90	.60	<.10	<.10	<.10
PCB (µg/kg)	11	44	0	13	44	24	5.0	3.0	0
Diazinon (µg/kg)	11	1.5	<.10	--	1.5	.20	<.10	<.10	<.10
Mercury (µg/g as Hg)	11	.06	<.01	--	.06	.05	<.01	<.01	<.01

*Value is estimated by use of a log-probability regresion to predict the values of data below the detection limit.

[1]1, 1Dichloro-s, 2-bis (p-chlorophenyl) ethane.

[2]Dichlorodiphenyldichloroethylene.

[3]Dichloro diphenyl trichloroethane.

Table 15.--Summary statistics for selected streambed-sediment-quality constituents at Evelyn Branch near Bryant (05570360), 1975-89

[mg/kg, milligram per kilogram; µg/g, microgram per gram; µg/kg, microgram per kilogram; <, less than; --, not determined]

Water-quality constituent	Descriptive statistics: Number of samples	Maximum	Minimum	Mean	Percentage of samples in which values were less than or equal to those shown: 95	75	50 (Median)	25	5
Nitrogen, ammonia (mg/kg as N)	16	300	4.8	48	300	51	21	11	4.8
Nitrogen, ammonia plus organic (mg/kg as N)	16	170,000	0	12,300	170,000	2,900	1,450	902	0
Nitrogen, nitrite plus nitrate (mg/kg as N)	16	35	<2.0	7.4*	35	6.0	2.1	.70	<2.0
Phosphorus, total (mg/kg as P)	16	1,600	40	626	1,600	840	480	300	40
Arsenic (µg/g as As)	16	26	<1.0	8.4*	26	12	8.0	<1.0	<1.0
Cadmium (µg/g as Cd)	16	320	<1.0	22*	320	2.0	1.0	<10.0	<1.0
Chromium, total (µg/g as Cr)	15	3,400	<10.0	241*	3,400	10	9.0	2.0	<10.0
Cobalt (µg/g as Co)	16	120	<10.0	23*	120	20	10	9.0	<10.0
Copper (µg/g as Cu)	16	2,200	<10.0	159*	2,200	10	7.0	<10.0	<10.0
Lead, total (µg/g as Pb)	16	1,400	<10.0	116*	1,400	30	20	10	<10.0
Manganese (µg/g as Mn)	15	2,700	350	1,020	2,700	1,300	860	600	350
Zinc (µg/g as Zn)	16	4,900	10	354	4,900	85	55	22	10
Iron (µg/g as Fe)	16	71,000	1,000	13,800	71,000	15,500	9,100	4,420	1,000
Aldrin (µg/kg)	14	.30	<.10	--	.30	<.10	<.10	<.10	<.10
Lindane (µg/kg)	14	<.10	<.10	--	<.10	<.10	<.10	<.10	<.10
Chlordane (µg/kg)	14	1.0	<1.0	--	1.0	<1.0	<1.0	<1.0	<1.0
DDD[1] (µg/kg)	14	1.5	<.10	--	<.10	<.10	<.10	<.10	<.10
DDE[2] (µg/kg)	14	.20	<.10	--	<.10	<.10	<.10	<.10	<.10
DDT[3] (µg/kg)	14	.40	<.10	--	.40	<.10	<.10	<.10	<.10
Dieldrin (µg/kg)	14	3.4	<.10	.71*	3.4	1.2	.30	<.10	<.10
Heptachlor (µg/kg)	14	.10	<.10	--	.10	<.10	<.10	<.10	<.10
Heptachlor epoxide (µg/kg)	14	.50	<.10	.10*	.50	.10	<.10	<.10	<.10
PCB (µg/kg)	14	<1.0	<1.0	--	<1.0	<1.0	<1.0	<1.0	<1.0
Diazinon (µg/kg)	13	<10.0	<.10	--	<10.0	<.10	<.10	<.10	<.10
Mercury (µg/g as Hg)	16	2.1	<.01	--	2.1	.01	<.01	<.01	<.01

* Value is estimated by use of a log-probability regression to predict the values of data below the detection limit.
[1] 1,1Dichloro-2,2-bis(p-chlorophenyl) ethane.
[2] Dichlorodiphenyldichloroethylene.
[3] Dichloro diphenyl trichloroethane.

Table 16.--Summary statistics for selected streambed-sediment-quality constituents at Big Creek near Bryant (05570370), 1979-89

[mg/kg, milligram per kilogram; µg/g, microgram per gram; µg/kg, microgram per kilogram; <, less than; --, not determined]

Water-quality constituent	Number of samples	Descriptive statistics: Maximum	Minimum	Mean	Percentage of samples in which values were less than or equal to those shown: 95	75	50 (Median)	25	5
Nitrogen, ammonia (mg/kg as N)	13	45	1.4	18	45	30	8.7	7.7	1.4
Nitrogen, ammonia plus organic (mg/kg as N)	13	3,900	0	1,350	3,900	2,350	850	505	0
Nitrogen, nitrite plus nitrate (mg/kg as N)	13	30	<2.0	6.7*	30	5.0	3.8	1.6	<10.0
Phosphorus, total (mg/kg as P)	12	2,800	320	1,060	2,800	1,370	1,040	452	320
Arsenic (µg/g as As)	14	19	<1.0	8.8*	19	12	<1.0	<1.0	<1.0
Cadmium (µg/g as Cd)	14	3.0	<1.0	1.3*	3.0	1.0	<10.0	<10.0	<10.0
Chromium, total (µg/g as Cr)	14	110	<10.0	18*	110	20	4.0	<10.0	<10.0
Cobalt (µg/g as Co)	14	120	<10.0	18*	120	10	10	10	<10.0
Copper (µg/g as Cu)	13	170	<10.0	23*	170	10	7.0	<10.0	<10.0
Lead, total (µg/g as Pb)	14	400	<10.0	47*	400	20	20	10	10
Manganese (µg/g as Mn)	13	1,100	470	813	1,100	950	810	680	470
Zinc (µg/g as Zn)	14	120	22	68	120	100	67	37	22
Iron (µg/g as Fe)	14	27,000	2,000	13,300	27,000	18,700	15,500	6,070	2,000
Aldrin (µg/kg)	13	<.10	<.10	--	<.10	<.10	<.10	<.10	<.10
Lindane (µg/kg)	13	.40	<.10	--	.40	.10	<.10	<.10	<.10
Chlordane (µg/kg)	13	11	2.0	5.6	11	6.5	6.0	3.5	2.0
DDD[1] (µg/kg)	13	2.2	<.10	1.0*	2.2	1.4	1.0	.70	<.10
DDE[2] (µg/kg)	13	.80	<.10	.27*	.80	.30	<.10	<.10	<.10
DDT[3] (µg/kg)	13	1.8	<.10	--	1.8	.20	<.10	<.10	<.10
Dieldrin (µg/kg)	13	6.4	1.2	2.8	6.4	3.3	2.5	1.8	1.2
Heptachlor (µg/kg)	13	<.10	<.10	--	<.10	<.10	<.10	<.10	<.10
Heptachlor epoxide (µg/kg)	13	1.0	<.10	.29*	1.0	.30	.30	.10	<.10
PCB (µg/kg)	13	19	<1.0	4.2*	19	6.0	2.0	1.0	<1.0
Diazinon (µg/kg)	13	1.4	<.20	.69*	1.4	1.1	.70	<.20	<.20
Mercury (µg/g as Hg)	14	.10	<.01	.02*	.10	.03	<.01	<.01	<.01

* Value is estimated by use of a log-probability regression to predict the values of data below the detection limit.
[1] 1,1Dichloro-2,2-bis(p-chlorophenyl) ethane.
[2] Dichlorodiphenyldichloroethylene.
[3] Dichloro diphenyl trichloroethane.

Table 17.--Summary statistics for selected streambed-sediment-quality constituents at Slug Run near Bryant (05570380), 1975-85

[mg/kg, milligram per kilogram; µg/g, microgram per gram; µg/kg, microgram per kilogram; <, less than; --, not determined]

Water-quality constituent	Descriptive statistics				Percentage of samples in which values were less than or equal to those shown				
	Number of samples	Maximum	Minimum	Mean	95	75	50 (Median)	25	5
Nitrogen, ammonia (mg/kg as N)	7	34	3.3	17	34	33	8.8	7.4	3.3
Nitrogen, ammonia plus organic (mg/kg as N)	7	4,200	860	1,730	4,200	1,900	1,400	880	860
Nitrogen, nitrite plus nitrate (mg/kg as N)	7	28	.70	10	28	26	5.0	1.0	.70
Phosphorus, total (mg/kg as P)	7	1,700	210	656	1,700	680	480	410	210
Arsenic (µg/g as As)	8	19	<1.0	--	19	10	<1.0	<1.0	<1.0
Cadmium (µg/g as Cd)	8	1.0	<1.0	--	1.0	<10.0	<10.0	<10.0	<10.0
Chromium, total (µg/g as Cr)	8	26	<10.0	9.9*	26	10	9.0	4.0	4.0
Cobalt (µg/g as Co)	8	20	<10.0	11*	20	10	10.0	<10.0	<10.0
Copper (µg/g as Cu)	8	10	<10.0	8.8*	10	10	10	6.0	6.0
Lead, total (µg/g as Pb)	8	30	<10.0	22*	30	30	20	<10.0	<10.0
Manganese (µg/g as Mn)	8	1,700	880	1,200	1,700	1,350	1,200	987	880
Zinc (µg/g as Zn)	8	160	30	67	160	97	50	35	30
Iron (µg/g as Fe)	8	31,000	5,000	15,100	31,000	24,700	13,500	5,850	5,000
Aldrin (µg/kg)	6	.20	<.10	--	.20	.10	<.10	<.10	<.10
Lindane (µg/kg)	6	<.10	<.10	--	<.10	<.10	<.10	<.10	<.10
Chlordane (µg/kg)	6	1.0	<1.0	--	1.0	<1.0	<1.0	<1.0	<1.0
DDD[1] (µg/kg)	6	.70	<.10	--	.70	<.10	<.10	<.10	<.10
DDE[2] (µg/kg)	6	.70	<.10	--	.70	<.10	<.10	<.10	<.10
DDT[3] (µg/kg)	6	1.7	<.10	--	1.7	1.0	<.10	<.10	<.10
Dieldrin (µg/kg)	6	4.2	0	1.6	4.2	2.8	1.1	.45	0
Heptachlor (µg/kg)	6	<.10	<.10	--	<.10	<.10	<.10	<.10	<.10
Heptachlor epoxide (µg/kg)	6	.40	<.10	--	.40	.30	<.10	<.10	<.10
PCB (µg/kg)	6	<1.0	<1.0	--	<1.0	<1.0	<1.0	<1.0	<1.0
Diazinon (µg/kg)	6	3.3	<.10	--	3.3	<.10	<.10	<.10	<.10
Mercury (µg/g as Hg)	8	.07	0	.02	.07	.05	.005	0	0

* Value is estimated by use of a log-probability regression to predict the values of data below the detection limit.

[1] 1,1Dichloro-2,2-bis(p-chlorophenyl) ethane.

[2] Dichlorodiphenyldichloroethylene.

[3] Dichloro diphenyl trichloroethane.