Occurrence of Phosphorus, Other Nutrients, and Triazine Herbicides in Water From the Hillsdale Lake Basin, Northeast Kansas, May 1994 Through May 1995

By JAMES E. PUTNAM

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CONVERSION FACTORS

Multiply	By	To obtain
cubic foot	28.32	liter
acre	4,047	square meter
acre-foot	1,233	cubic meter
cubic foot per second	0.02832	cubic meter per second
foot	0.3048	meter
inch	2.54	centimeter
mile	1.609	kilometer
square mile	2.590	square kilometer
square mile	259.0	hectare
Abbreviated water-quality units:		
gram (g)	0.03527	ounce
hectare (ha)	2.471	acre
kilogram (kg)	2.205	pound
kilogram per day (kg/d)	2.205	pound per day
kilogram per hectare per year [(kg/ha)/yr]	0.8924	pound per acre per year
kilogram per year (kg/yr)	2.205	pound per year
liter (L)	0.2642	gallon
microgram per liter (µg/L)	1.0	part per billion
micrometer (µm)	0.00003937	inch
milligram (mg)	0.0000353	ounce
milligram per liter (mg/L)	1.0	part per million
milliliter (mL)	0.0338	ounce, fluid

Temperature can be converted to degrees Celsius (°C) or degrees Fahrenheit (°F) by the equations:

$$°C = 5/9\ (°F-32)$$
$$°F = 9/5\ (°C) + 32.$$

Occurrence of Phosphorus, Other Nutrients, and Triazine Herbicides in Water from the Hillsdale Lake Basin, Northeast Kansas, May 1994 Through May 1995

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Abstract

An investigation of the occurrence of phosphorus, other nutrients, and triazine herbicides in water samples from the Hillsdale Lake Basin in northeast Kansas was conducted from May 1994 through May 1995. Point-source and non-point-source contributions of these water-quality constituents were estimated by conducting synoptic sampling at 48 sites in the basin during five periods of low-flow conditions. Samples were collected for the determination of nutrients, including total phosphorus as phosphorus, dissolved orthophosphate as phosphorus, total nitrite plus nitrate as nitrogen, and total ammonia plus organic nitrogen as nitrogen, and for selected triazine herbicides.

On the basis of criteria developed by the Kansas Department of Health and Environment, the Hillsdale Water-Quality Protection Project established a goal to maintain water quality in the tributaries of the Hillsdale Lake Basin at a mean annual low-flow total phosphorus concentration of 0.05 mg/L (milligram per liter). The mean low-flow total phosphorus concentration of water samples collected in the Big Bull Creek (which includes drainage from Martin Creek), Rock Creek, Little Bull Creek, Wade Branch, and Smith Branch subbasins during low-flow conditions ranged from 0.05 to 4.9 mg/L during this study. Of the 44 sites sampled during low flow, 95 percent had low-flow total phosphorus concentrations larger than the 0.05-mg/L criterion. Discharges from wastewater-treatment plants located in Big Bull Creek and Martin Creek subbasins and the Little Bull Creek subbasin affected nutrient concentrations. Nutrient concentrations in water samples collected from the subbasins not affected by point-source discharges generally were smaller than those in the Big Bull Creek and Little Bull Creek subbasins.

Estimated annual low-flow phosphorus loads computed at sampling sites located at the outlet of the subbasins show that the Big Bull Creek subbasin, which includes drainage from the Martin Creek subbasin, had the largest estimated annual low-flow load, 2,740 kg/yr (kilograms per year). Rock Creek, Little Bull Creek, Wade Branch, and Smith Branch subbasins contributed less annual low-flow phosphorus load, 175, 161, 234, and 22 kg/yr, respectively.

With the exception of the Smith Branch subbasin, the largest triazine herbicide concentrations occurred in water samples collected during May 1994 and May 1995. During May 1994, 10 of 17 sampling sites in the Big Bull Creek and Martin Creek subbasins, 5 of 6 sites in the Rock Creek subbasin, and 4 of 10 sites in the Little Bull Creek subbasin had triazine herbicide concentrations in water larger than the U. S. Environmental Protection Agency's Maximum Contaminant Level (MCL), which is an annual mean of 3.0 µg/L (micrograms per liter) for atrazine in drinking water. During May 1995, 7 of 19 sites in the Big Bull Creek and Martin Creek subbasins, 5 of 6 sites in the Rock Creek subbasin, 1 of 12 sites in

the Little Bull Creek subbasin, and 2 of 4 sites in the Wade Branch subbasin had samples with triazine herbicide concentrations larger than the MCL. Water samples collected in the Rock Creek subbasin had the largest mean triazine herbicide concentrations during May 1994 and May 1995, 6.4 and 4.5 µg/L, respectively.

INTRODUCTION

The Hillsdale Lake Basin is a 144-square-mile area located in Douglas, Franklin, Johnson, and Miami Counties of northeast Kansas (fig. 1). Hillsdale Lake, completed in 1982, was among the last of the Federal reservoirs built in Kansas. As early as 1985, concerns existed that water quality in Hillsdale Lake may be adversely affected by urbanization and agricultural activities from point and nonpoint sources of nutrients and herbicides within the basin. Water samples collected by the U.S. Army Corps of Engineers from 1976–95 at sites in the Big Bull Creek, Martin Creek, and Little Bull Creek drainage basins, as well as in the lake, indicated that existing phosphorus concentrations may lead to water-quality problems in Hillsdale Lake (Garland Kersh, U.S. Army Corps of Engineers, written commun., 1995). A study completed by the Kansas Department of Health and Environment (KDHE) in 1994 indicated the need for reduction in annual phosphorus loads by 28 to 45 percent (Carney, 1994).

In 1992, the Hillsdale Water-Quality Protection Project was initiated within the basin to establish long-term protection of the lake and drainage area. Specifically, the goal of the Hillsdale Water-Quality Protection Project as determined by KDHE is to maintain an annual mean total phosphorus concentration of 0.06 mg/L or less in Hillsdale Lake (Carney, 1994). Additionally, the phosphorus in tributary streams is to be limited to an annual mean concentration of 0.10 mg/L, a low-flow mean concentration of 0.05 mg/L, and a runoff mean concentration of 0.40 mg/L.

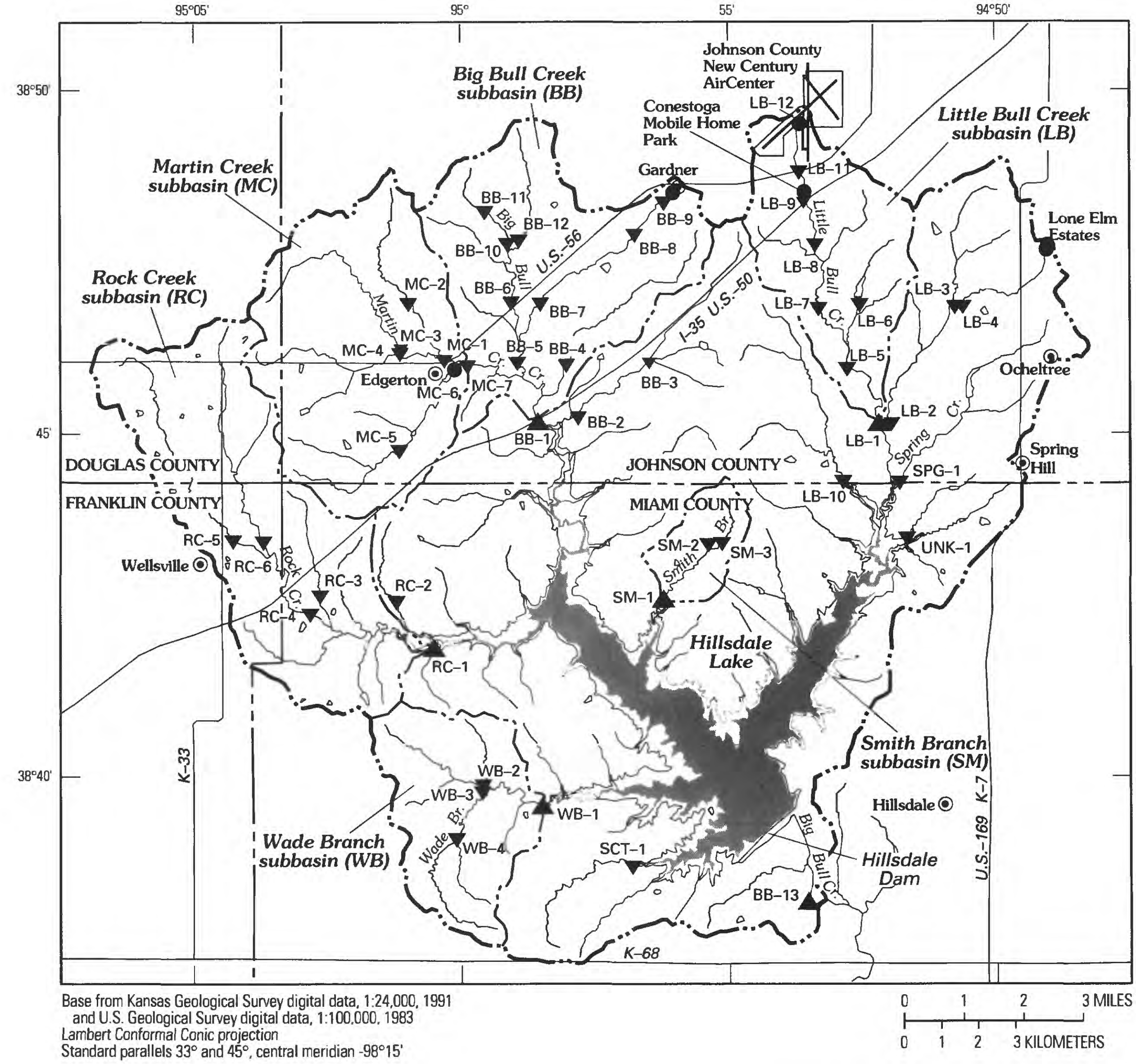
The U.S. Geological Survey (USGS) conducted a water-quality study from May 1994 through May 1995 in cooperation with the Hillsdale Lake Region Resource Conservation and Development Council, the Kansas Department of Health and Environment, and the U.S. Environmental Protection Agency (USEPA) to assess low-flow distribution of nutrient and triazine herbicide concentrations and nutrient loads in the basin. Objectives of the study were to: (1) identify areas within the selected subbasins where nutrient and triazine herbicide concentrations exceed the criteria established by the Hillsdale Water-Quality Protection Project or exceed Maximum Contaminant Levels (MCLs) in drinking water established by the USEPA (U.S. Environmental Protection Agency, 1992), (2) document locations of point-source discharges of nutrients and areas of major nonpoint-source contributions of nutrients and triazine herbicides, and (3) identify relative contribution of subbasins to nutrient loading of Hillsdale Lake during low flow. The study involved the collection of water samples at 48 sites in the Hillsdale Lake Basin for the determination of nutrient concentrations of total phosphorus as phosphorus, dissolved orthophosphate as phosphorus, total nitrite plus nitrate as nitrogen, and total ammonia plus organic nitrogen as nitrogen and for the determination of triazine herbicides.

This report describes the results of the study. It provides improved understanding of the low-flow distribution of nutrient and triazine herbicide concentrations and nutrient loads in the Hillsdale Lake Basin.

Description of Study Area

The Hillsdale Lake Basin encompasses approximately 92,160 acres in parts of Douglas, Franklin, Johnson, and Miami Counties. Five major streams contribute flow directly to Hillsdale Lake—Big Bull Creek, Rock Creek, Little Bull Creek, Wade Branch, and Smith Branch (fig. 1). Most of the study area lies within the Dissected Till Plains physiographic section and partly in the Osage Cuestas division of the Osage Plains physiographic section (Schoewe, 1949). The area consists of gently rolling uplands, with hilly areas along the streams, and is underlain by Pennsylvania-age shale and limestone (O'Connor, 1971). Soils in the study area are of the Polo-Oska type, consisting of moderately sloping and sloping soils that have a loamy or clayey subsoil (Plinsky and others, 1979). About 50 percent of the lake's drainage area is grassland, 35 percent cropland, with the remainder used as animal holding areas (feedlots), pasture, or considered urban and residential areas (Keith Macedo, Hillsdale Water-Quality Protection Project, oral commun., 1995).

Several point sources of nutrients are located in the Big Bull Creek, Martin Creek (a tributary of Big Bull Creek), and Little Bull Creek drainage basins. Wastewater-treatment plants are located at Gardner and Edg-



Base from Kansas Geological Survey digital data, 1:24,000, 1991
and U.S. Geological Survey digital data, 1:100,000, 1983
Lambert Conformal Conic projection
Standard parallels 33° and 45°, central meridian -98°15'

EXPLANATION

Extent of lake at conservation-pool level

Boundary of Hillsdale Lake Basin

Boundary of sampled subbasin

SAMPLING SITES

BB-1 ▲ **Streamflow-gaging station and synoptic sampling site**—Site identification corresponds to that used in table 6

WB-4 ▼ **Synoptic sampling site**—Site identification corresponds to that used in table 6

MC-6 ● **Point source and synoptic sampling site**—Site identification corresponds to that used in table 6

● **Point source**—No sample

Figure 1. Location of Hillsdale Lake in northeast Kansas and selected sampling sites in the Hillsdale Lake Basin.

erton in the Big Bull Creek and Martin Creek Basins. Sampling site BB–9 is located downstream from the Gardner wastewater-treatment plant, and site MC–6 is located at the Edgerton wastewater-treatment plant discharge point. The Johnson County New Century AirCenter wastewater-treatment plant, the Conestoga Mobile Home Park lagoon, and the Lone Elm Estates lagoon are located in the Little Bull Creek Basin. Samples were collected at the discharge point of the Johnson County New Century AirCenter wastewater-treatment plant (site LB–12) and downstream from the Conestoga Mobile Home Park lagoon and Lone Elm Estates lagoon at sites LB–9 and LB–4, respectively (fig. 1).

Total precipitation in the 14-county area surrounding the study area during May 1994 through May 1995 was 43.41 inches compared to the total long-term (1961–90) mean of 41.55 inches (National Oceanic and Atmospheric Administration, 1994–95). Precipitation in the 14-county area was below normal during the May 1994 and March 1995 sampling periods. Above-normal precipitation during November 1994 and May 1995 (table 1) affected some samples collected during these periods due to localized overland runoff in the study area.

Table 1. Monthly precipitation from May 1994 through May 1995 and mean monthly precipitation in east-central Kansas for 1961–90

[Data from National Oceanic and Atmospheric Administration, 1994–95]

Month	Precipitation, in inches	Mean monthly precipitation (1961–90), in inches
	1994	
May	1.37	4.70
June	4.46	5.54
July	3.61	3.56
August	5.10	3.84
September	2.56	4.35
October	2.58	3.23
November	3.79	2.16
December	1.29	1.39
	1995	
January	1.03	1.05
February	.48	1.04
March	2.07	2.69
April	3.40	3.30
May	11.67	4.70

Acknowledgments

Appreciation is extended to the Hillsdale Water-Quality Protection Project personnel who helped with project coordination and sample collection. Financial and technical support also was provided by the USEPA who supplied sample containers, preservatives, and nutrient analyses. Appreciation is extended to the landowners in the study area who allowed access to sampling sites on their land. Planning and technical support by the Johnson County Environmental Department (JCED), KDHE, the U.S. Army Corps of Engineers (USACOE), the U.S. Natural Resource Conservation Service (NRCS), and the State Conservation Commission (SCC) also is acknowledged.

DATA COLLECTION AND ANALYSIS METHODS

For the purpose of sample collection and data interpretation, the Hillsdale Lake drainage basin was divided into the Big Bull Creek (BB), Martin Creek (MC), Rock Creek (RC), Little Bull Creek (LB), Wade Branch (WB), and Smith Branch (SM) subbasins. The Big Bull Creek subbasin (BB) includes drainage from the Martin Creek (MC) subbasin, the combination of which is referred to as the Big Bull Creek subbasin for the remainder of this report. Sampling sites BB–2, BB–3, LB–3, and LB–4 are located outside of identified subbasins (fig. 1).

Streamflow-gaging stations installed by the USGS for this study are located on Big Bull Creek near Edgerton (site BB–1), drainage area 28.7 square miles; Rock Creek near Wellsville (site RC–1), drainage area 15.8 square miles; and Little Bull Creek near Spring Hill (site LB–1), drainage area 8.81 square miles. A streamflow-gaging station (site BB–13), drainage area 147 square miles, is located on Big Bull Creek downstream from Hillsdale Dam. Two partial-record streamflow-gaging stations (crest-stage gages) are located on Wade Branch (site WB–1), drainage area 7.6 square miles, and Smith Branch (site SM–1), drainage area 2.2 square miles.

Streamflow Data Collection

Stream discharge was defined using data collected at streamflow-gaging stations located at sites BB–1, RC–1, LB–1, and BB–13 and at partial-record gages at sites WB–1 and SM–1 (fig. 1). Stage-discharge relationships (Kennedy, 1984) for these sites were developed using streamflow measurements made throughout the year (Buchanan and Somers, 1969).

Discharge hydrographs for the streamflow-gaging stations, sites BB–1, RC–1, and LB–1, are shown in figure 2. The sampling dates for samples collected at these sites are labeled on the hydrographs to show streamflow conditions at subbasin outlet sites during sample collection. To estimate a representative low-flow discharge (base flow), two analyses were performed. Flow-duration curves were developed for sites BB–1, RC–1, and LB–1 and are shown in figure 3. Flow-duration curves give the percentage of time specified discharges are equaled or exceeded in a given period. Duration curves are not reliable for short periods of record but were used in conjunction with discharge hydrographs to estimate a representative low-flow discharge for sites BB–1, RC–1, and LB–1. A reasonable estimate for low-flow discharge for each streamflow site was made by considering the median discharge (50 percent) from the flow-duration curves and the low-flow parts of the hydrograph. Base flow of a stream changes throughout the year due to increases (or decreases) of ground-water contributions. Using the flow-duration curves and stream hydrographs as a guide, a representative low-flow discharge was selected for each site and is indicated by a line on the stream hydrographs (fig. 2).

It is important to put into perspective the amount of time streamflow in the Big Bull Creek, Rock Creek, and Little Bull Creek subbasins was at low flow compared to periods affected by runoff. Low-flow periods account for only a small amount of the total streamflow in these subbasins. Low-flow discharge for site BB–1 was selected as 2 cubic feet per second (fig. 2). The number of days during the study period (May 1, 1994, through May 31, 1995) when the daily mean streamflow at this gaging station was less than or equal to 2 cubic feet per second was 245 days or 62 percent of the 396 days in the study period (Geiger and others, 1995; Putnam and others, 1996). The total flow at site BB–1 during these low-flow periods was 513 acre-feet. The total flow during the study period was 23,082 acre-feet. Low flow occurred on many days, but it represents only 2.2 percent of the total flow during the study period. Using a similar analysis, low flow in the Little Bull Creek subbasin represented only 6.7 percent of the total flow during the study period.

Sampling sites MC–6 and MC–7 in the Big Bull Creek subbasin were not sampled during May 1994, although they were sampled during the remainder of the study. There was no flow at sites BB–12, BB–11, BB–10, BB–6, MC–4, MC–3, MC–2, MC–1, MC–5, BB–4, BB–3, BB–2 during the August 1994 sampling. The sites at BB–12, BB–10, and MC–2 did not have flowing water during the November 1994 sampling period. None of the sampling sites in the Rock Creek subbasin were flowing during the August 1994 sampling period. Sampling sites RC–3 and RC–2 also had no flow during the November 1994 sampling. There was no flow at site LB–4 in the Little Bull Creek subbasin during the August 1994 sampling period. Sites LB–12 and LB–11 were not sampled during May 1994. Site LB–12 is located downstream from a point source; this site and a site downstream, LB–11, were added and sampled during the remainder of the study. There was no flow in Wade Branch and Smith Branch subbasins during the August 1994 sampling period. There also was no flowing water at site SM–3 during the November 1994 sampling period. Instantaneous discharges determined for each site at the time of sampling are listed in table 6 at the end of this report.

Sample Collection and Analysis

Point-source and nonpoint-source contributions of nutrients and selected triazine herbicides were estimated by conducting synoptic sampling at 48 sites during low-flow conditions. Low-flow samples were collected in an attempt to show the effects of point-source discharges and to facilitate between-site comparison. The drainage area of each sampling site was approximately 4 square miles. Sites were selected to represent all major tributaries draining to Hillsdale Lake. Samples collected during synoptic sampling gave a "snapshot" in time of water-quality constituents in each subbasin. Samples were generally collected at different times of the year to describe seasonal variability. The location of the sampling sites is shown in figure 1. Samples for determination of nutrients and herbicides were collected May 23–26, 1994, August 15–17, 1994, October 31–November 3, 1994, March 7–10, 1995, and May 9–12, 1995. For the remainder of this report, these sampling periods will be referred to as May 1994, August 1994, November 1994, March 1995, and May 1995.

Onsite determinations of specific conductance, pH, water temperature, and dissolved oxygen were made at

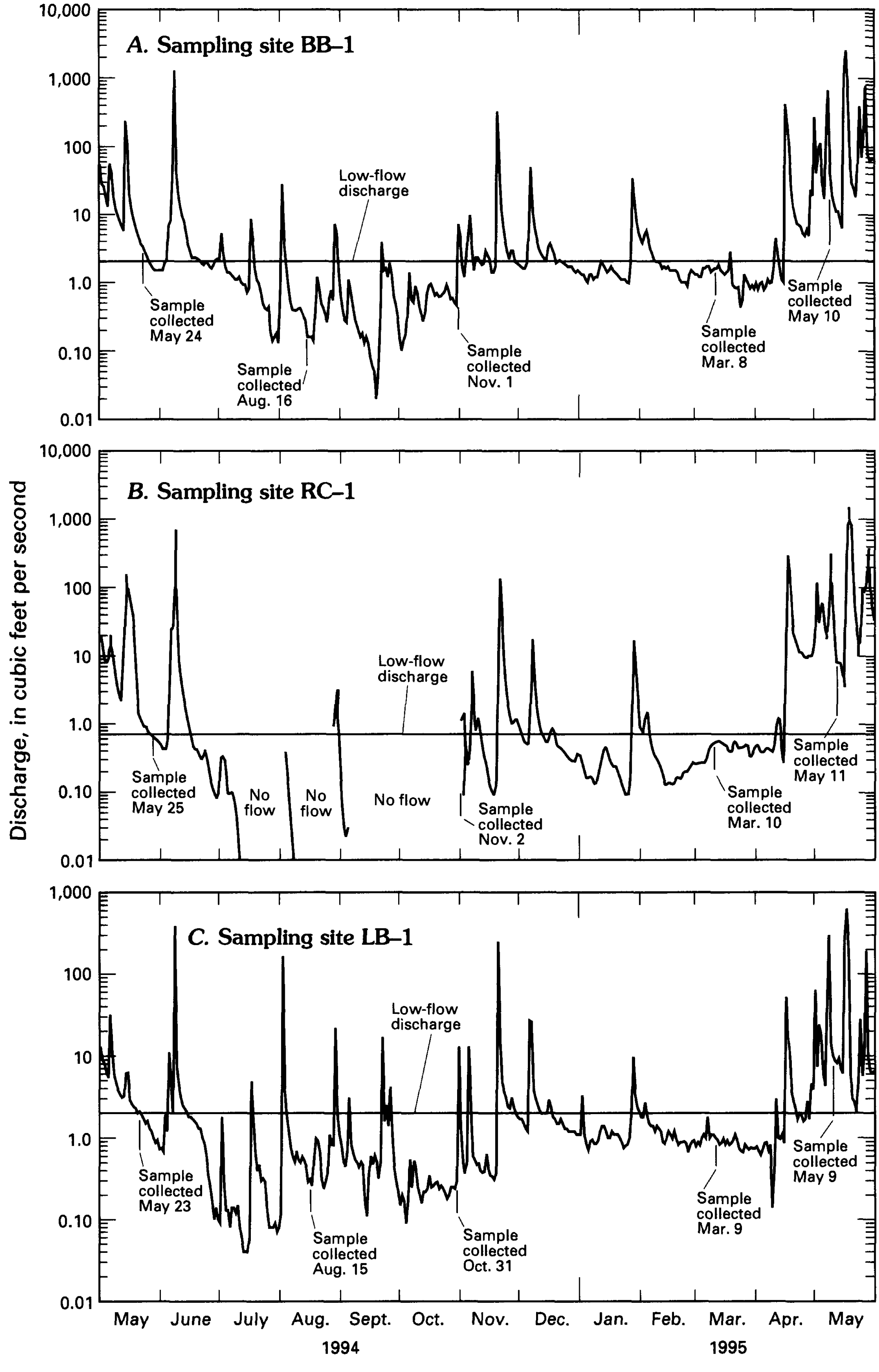
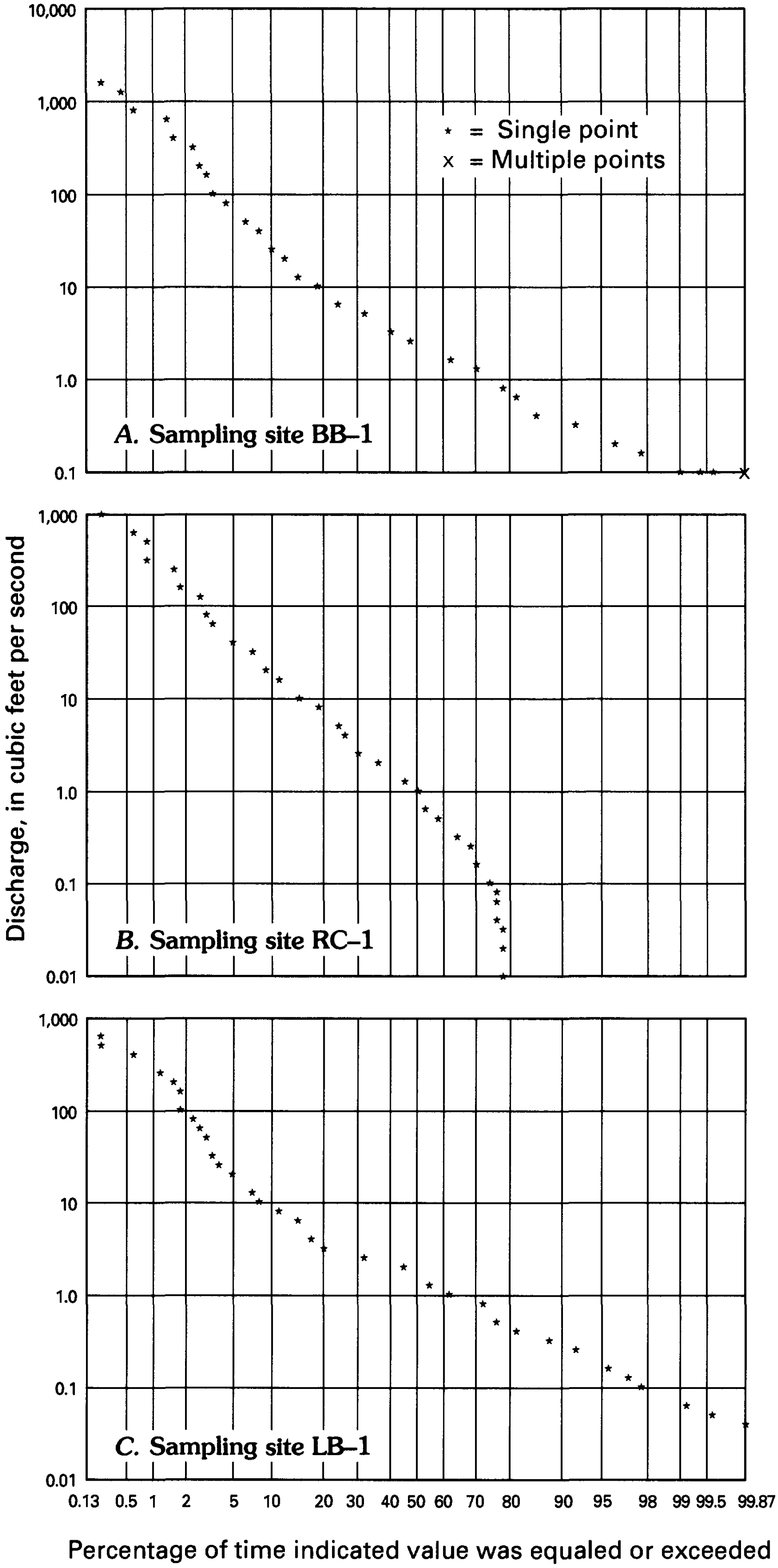


Figure 2. Stream discharge for (*A*) Big Bull Creek near Edgerton (sampling site BB–1), (*B*) Rock Creek near Wellsville (sampling site RC–1), and (*C*) Little Bull Creek near Spring Hill (sampling site LB–1), May 1994–May 1995.



PERCENTAGE OF TIME VALUE EQUALED OR EXCEEDED	DATA VALUE
95.0	0.22
90.0	.31
85.0	.44
80.0	.62
75.0	.87
70.0	1.20
65.0	1.20
60.0	1.70
55.0	1.70
50.0	1.70
45.0	2.93
40.0	3.58
35.0	4.11
30.0	5.40
25.0	6.68
20.0	8.45
15.0	13.5
10.0	26.2
5.0	73.0

PERCENTAGE OF TIME VALUE EQUALED OR EXCEEDED	DATA VALUE
95.0	0
90.0	0
85.0	0
80.0	0
75.0	.08
70.0	.16
65.0	.23
60.0	.33
55.0	.46
50.0	.66
45.0	1.30
40.0	1.30
35.0	1.90
30.0	1.90
25.0	4.12
20.0	7.02
15.0	10.1
10.0	17.4
5.0	43.8

PERCENTAGE OF TIME VALUE EQUALED OR EXCEEDED	DATA VALUE
95.0	0.17
90.0	.23
85.0	.31
80.0	.42
75.0	.56
70.0	.75
65.0	.75
60.0	1.00
55.0	1.30
50.0	1.30
45.0	1.80
40.0	1.80
35.0	1.80
30.0	2.40
25.0	2.40
20.0	3.61
15.0	5.09
10.0	8.65
5.0	20.3

Figure 3. Flow-duration curves for (*A*) Big Bull Creek near Edgerton (sampling site BB–1), (*B*) Rock Creek near Wellsville (sampling site RC–1), and (*C*) Little Bull Creek near Spring Hill (sampling site LB–1), May 1994–May 1995.

all sampling sites. Water samples were collected from the centroid of the streams using a dip method (Shelton, 1994). If the stream was wide enough, an equal-width-increment dip sample was collected (Shelton, 1994). Sample bottles were rinsed three times with stream water prior to sample collection. All samples were processed and preserved onsite. Water samples for the determination of total phosphorus as phosphorus, total nitrite plus nitrate as nitrogen, total ammonia as nitrogen, and total ammonia plus organic nitrogen as nitrogen concentrations were collected in USEPA-supplied containers, preserved with 2 mL of sulfuric acid to inhibit bacterial growth, and chilled at 4 °C. Water samples for the determination of dissolved orthophosphate and triazine herbicide concentrations were collected in 1-L Teflon bottles. An aliquot for the determination of dissolved orthophosphate concentration was withdrawn from each Teflon bottle, filtered through a cellulose acetate, 0.45-µm porosity filter into a 125-mL polyethylene bottle, and chilled at 4 °C. Another aliquot for the determination of triazine herbicide concentration was withdrawn from each 1-L bottle, filtered through a 0.70-µm porosity, baked glass-fiber filter, transferred into 125-mL amber glass bottles, and chilled to 4 °C.

Samples for the determination of nutrients including total phosphorus as phosphorus, dissolved orthophosphate as phosphorus, total nitrite plus nitrate as nitrogen, total ammonia as nitrogen, and total ammonia plus organic nitrogen as nitrogen were analyzed at the USEPA laboratory in Kansas City, Kansas. Water samples for the determination of concentrations of triazine herbicides were analyzed by enzyme-linked immunosorbent assay (ELISA), with selected samples confirmed by gas chromatography/mass spectrometry (GC/MS) at the USGS laboratory in Lawrence, Kansas (Thurman and others, 1990). Although the ELISA method is sensitive to the presence of atrazine (0.10-µg/L detection level), the method is not totally specific to atrazine; other triazine compounds such as ametryn, prometon, prometryn, and propazine may be detected. Therefore, results of ELISA methods were reported as concentrations of triazine herbicides even though only small concentrations, if any, of these other triazine compounds were detected in water samples by GC/MS analyses. Results of chemical analyses are shown in table 6 at the end of this report.

Quality Assurance

Analytical quality-assurance samples for this study included replicate samples collected at random sites. The precision and reproducibility of the analytical method can be evaluated by comparison of duplicate analyses of these randomly selected stream samples. Replicate samples were collected from at least two sampling sites during each sampling period. Results of these duplicate analyses are shown throughout table 6 and are labeled as "dup." Comparison of these analyses show that both the sample processing techniques and analytical methods gave reproducible results.

Blank water samples also were included as part of the quality-assurance data collection. Results of the blank water analyses, QA–1 and QA–2, are shown at the end of table 6. A bottle blank tests the cleanliness of sample bottles used, and the equipment blank evaluates the equipment used during sample processing. Blank water samples evaluate the probability of the analytical methods producing a false positive result. All blank water samples for dissolved nutrient constituents and triazine herbicides gave results less than detection limits. However, total nutrient analyses from several sampling periods had nutrient concentrations greater than the detection limits. The inorganic blank water used for the Hillsdale study was also used in another study during this same period (same lot and bottle number), and results of quality-assurance analyses showed no problems. Therefore, it is unlikely that contaminated blank water caused the concentrations greater than the detection limits. Sample-collection bottles and caps were packaged separately, and it is possible that these bottles contained particulate matter that was not thoroughly rinsed with blank water during processing. Moreover, the replicate samples analyzed show that the processing and analytical methods used gave reproducible results. Therefore, it was not considered necessary to adjust the nutrient data on the basis of the false positive results of the blank water analyses.

Computation of Water-Quality Constituent Loads

Transport of nutrients in a stream is a function of constituent concentration and stream discharge (volume). Analysis of nutrient loads computed at sampling sites may show contributions of contaminants from point or nonpoint sources as well as the fate of the constituent mass. For example, a decrease in total nutrient loads between sampling sites may be caused by the uptake of the nutrients by aquatic vegetation or deposition of the nutrients in streambed material. Streamflow and concentration data were used to compute total loads of constituents at outlet sites of the subbasins and other selected sampling sites within the subbasins. Nutrient loads were computed in kilograms per day.

Daily nutrient loads were estimated using the following equation:

$$\text{Daily nutrient load (kg/d)} = [\text{discharge (ft}^3\text{/s)}] \times (86{,}400 \text{ seconds per day}) \times (\text{nutrient concentration, mg/L}) \times (1 \text{ g}/1{,}000 \text{ mg}) \times (1 \text{ kg}/1{,}000 \text{ g}). \quad (1)$$

Annual nutrient loads (in kilograms per year) were estimated using daily load estimates.

Comparisons of nutrient loads among subbasins are complicated by differences in subbasin drainage areas and streamflow volumes. Computation of transport rate for each subbasin outlet site results in the quantity of constituent load per unit drainage area. Transport rate (in kilograms per hectare per year) is computed by dividing annual load (in kilograms per year) by subbasin drainage area (in hectares). An example of the use of equation 1 is shown in the section "Nutrient Loads."

SOURCES AND TRANSPORT OF NUTRIENTS AND HERBICIDES

An understanding of the sources and transport of nutrients and herbicides in a stream basin can help explain the resulting constituent concentrations and loads in streams. Constituent concentrations and loads within the Hillsdale Lake Basin are primarily affected by land use.

Sources

Land-use related discharges from point and nonpoint sources contribute nutrients and herbicides to the streams. Point-source contamination originates from specific locations such as wastewater-treatment plants and industrial outflows. Nonpoint-source contamination does not originate from any specific location—an example is runoff from cropland and animal holding areas (U.S. Environmental Protection Agency, 1994).

Phosphorus is essential for the synthesis of energy in the cells of plants and animals and can have a direct effect on the production of phytoplankton populations, an important component of the food chain. Phosphorus is a component of sewage and is always present in animal metabolic waste (Hem, 1985, p.126), and according to Hammer (1986), only 20 to 30 percent of the total phosphorus from domestic waste is removed by conventional wastewater-treatment processes. Therefore, it is common to see relatively large concentrations of total phosphorus directly downstream from treatment plants (point sources). Hem (1985, p. 128) notes that particulate forms of phosphorus constitute about 95 percent of the total phosphorus in stream water; however, the predominant form of phosphorus found in many samples in the Big Bull Creek subbasin was orthophosphate (table 6). Generally, dissolved orthophosphate results from the biological oxidation of phosphorus during the wastewater-treatment process.

Nonpoint sources of particulate phosphorus are animal holding areas (feedlots) and phosphorus fertilizers applied to cropland. If animal holding areas are located in close proximity to the stream or if cattle have direct access to the stream, water quality may be adversely affected during low flow by the leaching of phosphorus through the soil and into streams.

Nitrogen is important to all ecosystems because of its role in the synthesis and maintenance of protein, which is a major constituent of living substances (Reid and Wood, 1976). Common forms of nitrogen in stream water are nitrite and nitrate, ammonia, and organic nitrogen. Wastewater-treatment plants are major point-source contributors of nitrogen constituents. Nitrogen in wastewater results from human waste, nitrogen-containing organic compounds, and industrial waste. The wastewater-treatment process converts the organic nitrogen to ammonia. A secondary treatment process biologically converts ammonia to nitrite and nitrate. The predominant form of nitrogen in water from wastewater-treatment plant discharge is dependent on the treatment process.

Cropland and animal feedlots also are nonpoint sources of nitrogen nutrients. Organic nitrogen and nitrate are common in animal wastes, and ammonia is used as a fertilizer.

Triazine herbicides are used in agricultural areas to control weed growth on cropland. The herbicides are generally applied to fields in the early spring prior to planting.

Transport

Phosphorus and nitrogen nutrients are transported to rivers in both a particulate phase and the dissolved phase. Particulate and soluble forms of phosphorus and nitrogen from nonpoint sources of contamination, such as cropland and feedlots, are transported to rivers in a water and soil mixture during runoff. Particulate phosphorous and nitrogen tend to adhere to sediment particles and may be deposited on streambanks and as bed material as streamflow decreases. Some loss of nutrient load from upstream sites to downstream sites may be explained by this phenomenon. Part of the total phosphorus and the dissolved constituents of phosphorus (dissolved orthophosphate) and nitrogen (ammonia and nitrate) from point sources are available for uptake by aquatic vegetation, such as rooted vegetation, periphyton, and free-floating algae. Therefore, nutrient loads may decrease between point-source discharges and downstream sites as nutrients are consumed by aquatic vegetation.

Triazine herbicides are applied to fields in the early spring, and concentrations larger than the MCL may occur in streams after late-spring and early-summer rains with subsequent return to preplanting concentrations by harvest periods. Thurman and others (1991) described this flushing of the herbicides as pulses in response to late-spring and early-summer rainfall. According to Squillace and Thurman (1992), triazine herbicides such as atrazine may be transported in both the suspended phase (on sediment particles) and the dissolved phase. They note that the triazine herbicides may be sorbed on sediment particles and slowly released back to the dissolved phase in the river. The herbicide water samples collected for this study were filtered, assuming that the herbicides in the streams were in the dissolved phase.

OCCURRENCE OF PHOSPHORUS AND OTHER NUTRIENTS

Large concentrations of phosphorus and nitrogen may adversely affect the quality of the water in streams and lakes. Because both phosphorus and nitrogen are essential to plant growth, these constituents may contribute to algal blooms in lakes. Dense, rapidly growing algal blooms may lead to depleted oxygen in lake water, odor and taste problems in drinking water, and loss of some fish species. Elevated levels of free ammonia, common downstream from wastewater-treatment plants, is toxic to fish. Therefore, it is important to assess the occurrence of nutrient contamination so that concentrations of these constituents can be managed.

Nutrient Concentrations

Results of analyses for total phosphorus as phosphorus, dissolved orthophosphate as phosphorus, total nitrite plus nitrate as nitrogen, and total ammonia plus organic nitrogen as nitrogen are discussed in this report. A statistical summary of nutrient concentrations in water samples collected from all sampling sites is shown in table 2. For those samples with constituent concentration less than detection limits, one-half of the detection limit was used for constituent concentration when computing the mean constituent concentrations. Runoff-affected samples collected during November 1994 in the Little Bull Creek subbasin and collected during May 1995 in all subbasins were not used in the mean low-flow concentrations shown in figure 4. Mean low-flow total phosphorus concentrations ranged from 0.05 (site LB–3) to 4.9 mg/L (site BB–9) (table 6). Of the 44 sites sampled during low flow, 95 percent of the sites had mean low-flow total phosphorus concentrations larger than the 0.05-mg/L criterion proposed by the Hillsdale Water-Quality Protection Project (fig. 4). In fact, nearly 32 percent of the sites sampled during low flow had mean low-flow total phosphorus concentrations larger than the runoff mean concentration of 0.40 mg/L (fig. 4).

Of the five sampled subbasins in the study area, the Big Bull Creek subbasin, which includes drainage from the Martin Creek subbasin, had the largest mean total phosphorus, mean dissolved orthophosphate, and mean total ammonia plus organic nitrogen concentrations, 1.3, 0.80, and 3.7 mg/L, respectively (table 2). The maximum nitrite plus nitrate concentrations in water samples collected from the Big Bull Creek subbasin, 11.5 and 11.7 mg/L, occurred in water samples from site BB–9 during the May 1994 and August 1994 sampling periods and exceeded the Kansas and Federal MCL of 10 mg/L (Kansas Department of Health and Environment, 1994; U.S. Environmental Protection Agency, 1992). Site BB–9 is affected by discharge from the Gardner wastewater-treatment plant located approximately 0.75 mile upstream. The Little Bull Creek subbasin had the largest mean total nitrite plus nitrate concentration, 2.8 mg/L. The maximum nitrite plus nitrate concentration in the Little Bull Creek

Table 2. Statistical summary of nutrient concentrations in water samples collected from all sampling sites in the Hillsdale Lake Basin, northeast Kansas, May 1994–May 1995

[Concentrations are in milligrams per liter. <, less than]

Subbasin (fig. 1)	Number of samples analyzed	Total phosphorus concentration			Dissolved orthophosphate concentration			Total nitrite plus nitrate as nitrogen concentration			Total ammonia plus organic nitrogen, as nitrogen concentration		
		Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean
Big Bull Creek[1]	78	8.1	0.03	1.3	4.3	<0.01	0.80	11.7	<0.03	2.3	43	0.50	3.7
Rock Creek	22	1.4	.07	.33	.30	.01	.06	3.9	<.03	.83	15	.60	1.7
Little Bull Creek	57	1.2	<.02	.34	.63	.02	.17	17.7	<.03	2.8	4.3	.19	1.7
Wade Branch	16	1.1	<.02	.28	.34	.01	.05	1.4	.19	.72	4.1	.06	.75
Smith Branch	11	.35	<.02	.11	.12	<.01	.03	1.2	<.03	.71	.89	.18	.51

[1]Includes Martin Creek subbasin drainage.

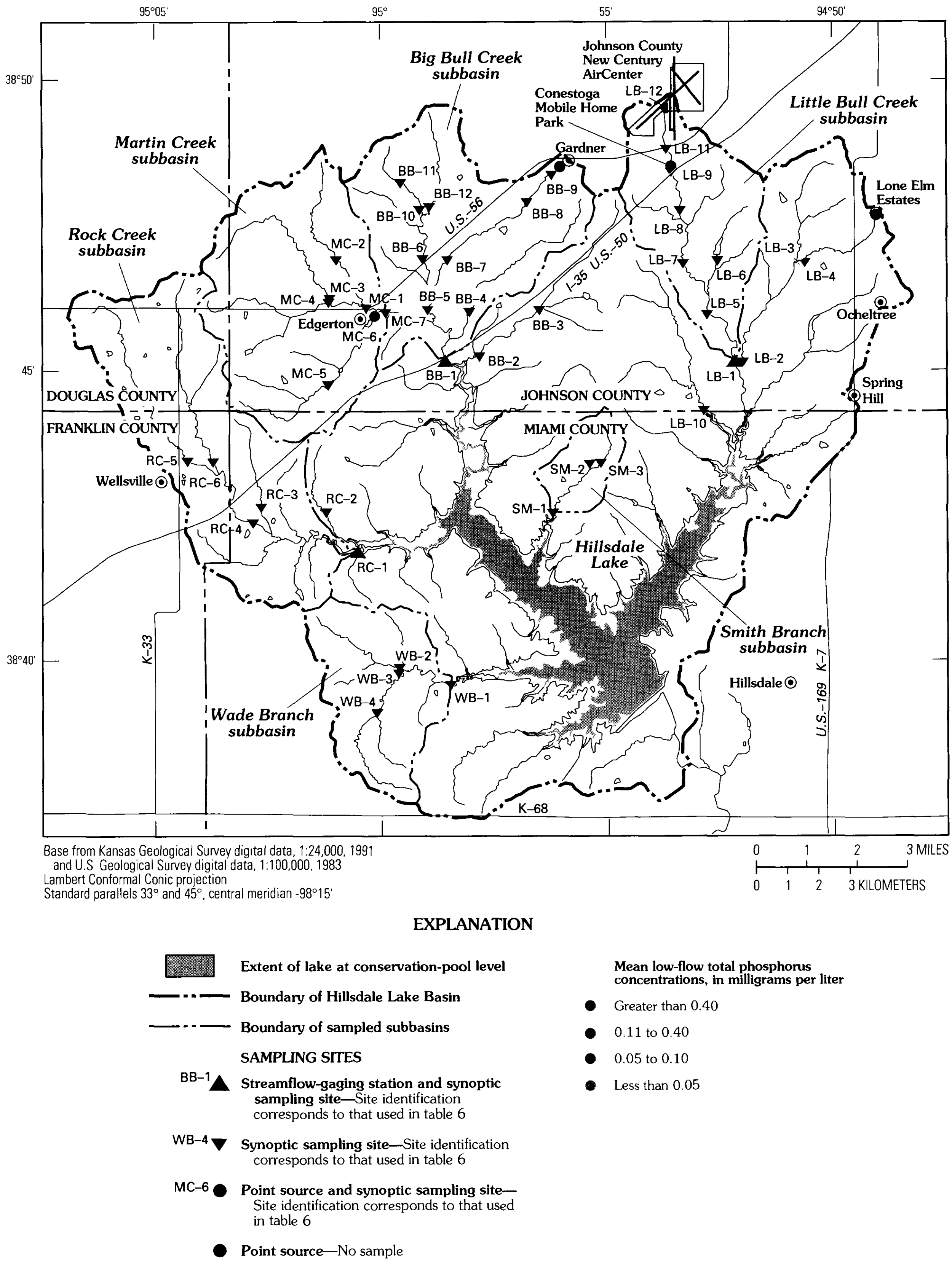


Figure 4. Mean low-flow total phosphorus concentrations at selected sampling sites, May 1994–March 1995. Runoff-affected samples from the Little Bull Creek subbasin are not included.

subbasin, 17.7 mg/L, during August 1994 also exceeded the Kansas and Federal MCL of 10 mg/L. This water sample was collected at site LB–12, which is affected by discharge from the Johnson County New Century AirCenter wastewater-treatment plant, located approximately 0.75 mile upstream.

The wastewater-treatment plants located in the Big Bull Creek subbasin affect nutrient concentrations during low flow. Sampling sites are located downstream from the Gardner wastewater-treatment plant (site BB–9) and the Edgerton wastewater-treatment plant (site MC–6). The graph in figure 5 shows that the largest total phosphorus and dissolved orthophosphate concentrations occurred in water samples collected at site BB–9 during all sampling periods. The relatively large total phosphorus and nitrogen-containing nutrient concentrations at site MC–6 during the August 1994 and November 1994 sampling periods reflect discharge from the wastewater-treatment plant at Edgerton. The largest nitrogen-containing nutrient concentrations, total nitrite plus nitrate and ammonia plus organic nitrogen, occurred at site BB–9 during all sampling periods (fig. 6). The nutrient concentrations generally decreased from upstream to downstream as streamflow increased and diluted the constituent concentration and, to some degree, as a loss of the particulate forms of the constituents (total phosphorus) to streambed material. For example, figure 5 shows the decrease of total phosphorus concentration between the point source (site BB–9) and site BB–7 during all sampling periods except November 1994. Variability in streamflow and the fact that some water samples were not collected on the same day in the Big Bull Creek subbasin accounted for the variability of constituent concentrations during sample collection in November 1994.

Nutrient concentrations in the Little Bull Creek subbasin are shown in figures 7 and 8. The mean total phosphorus and dissolved orthophosphate concentrations in this subbasin were 0.34 and 0.17 mg/L, respectively (table 2). The mean total nitrite plus nitrate and mean total ammonia plus organic nitrogen concentrations were 2.8 and 1.7 mg/L, respectively (table 2). Sampling sites downstream from the three point sources in this subbasin are located at sites LB–12, LB–9, and LB–4. Nutrient constituents common in wastewater were found in water samples collected at site LB–12. However, the nutrient concentrations at this point source were less than those found at the point-source-dominated site BB–9 in the Big Bull Creek subbasin. For example, the total phosphorus and dissolved orthophosphate concentrations in water samples collected at site LB–12 during August 1994 were 0.78 and 0.49 mg/L, respectively (table 6). The total phosphorus and dissolved orthophosphate concentrations in water samples collected at site BB–9 during August 1994 were 5.0 and 4.3 mg/L, respectively (table 6). Furthermore, with the exception of the nitrite plus nitrate concentrations, the mean total phosphorus, dissolved orthophosphate, and total ammonia plus organic nitrogen concentrations in water samples were much larger in the Big Bull Creek subbasin than those in the Little Bull Creek subbasin (table 2).

Another difference between the Big Bull Creek and Little Bull Creek subbasin is seen in a comparison of the nitrogen nutrient concentrations shown in figures 6 and 8. The dominant nitrogen nutrient constituent downstream from the point source in the Big Bull Creek subbasin (site BB–9) was total ammonia plus organic nitrogen (fig. 6) and that downstream from the wastewater-treatment plant in the Little Bull Creek subbasin (site LB–12) was nitrite plus nitrate, except during August 1994 and November 1994 (fig. 8). The mean total nitrite plus nitrate and total ammonia plus nitrogen concentrations in water from site BB–9 were 7.3 and 20 mg/L, respectively. The mean total nitrite plus nitrate and total ammonia plus organic nitrogen concentrations in water from site LB–12 (August 1994 through May 1995) were 10.7 and 2.0 mg/L, respectively. The differences in constituent concentrations found downstream from the wastewater-treatment plants in the subbasins reflect the differences in treatment processes.

Nutrient concentrations for the subbasins not affected by point sources, the Rock Creek, Wade Branch, and Smith Branch subbasins, are shown in figures 9–14. A summary of nutrient constituent concentrations for these subbasins is shown in table 2. Because of the absence of point-source discharges, it is believed that nutrient concentrations in streams of these subbasins are from nonpoint sources. These subbasins do not contribute water with substantial nutrient concentrations to the Hillsdale Lake Basin; however, nearly all sites in these subbasins had total phosphorus concentrations larger than the mean annual low-flow concentration criterion proposed by the Hillsdale Water-Quality Protection Project (0.05 mg/L). For example, the mean total phosphorus concentration in the Wade Branch subbasin (0.28 mg/L) is more than five times the 0.05-mg/L criterion. Moreover, of the 16 water samples collected from the Wade Branch

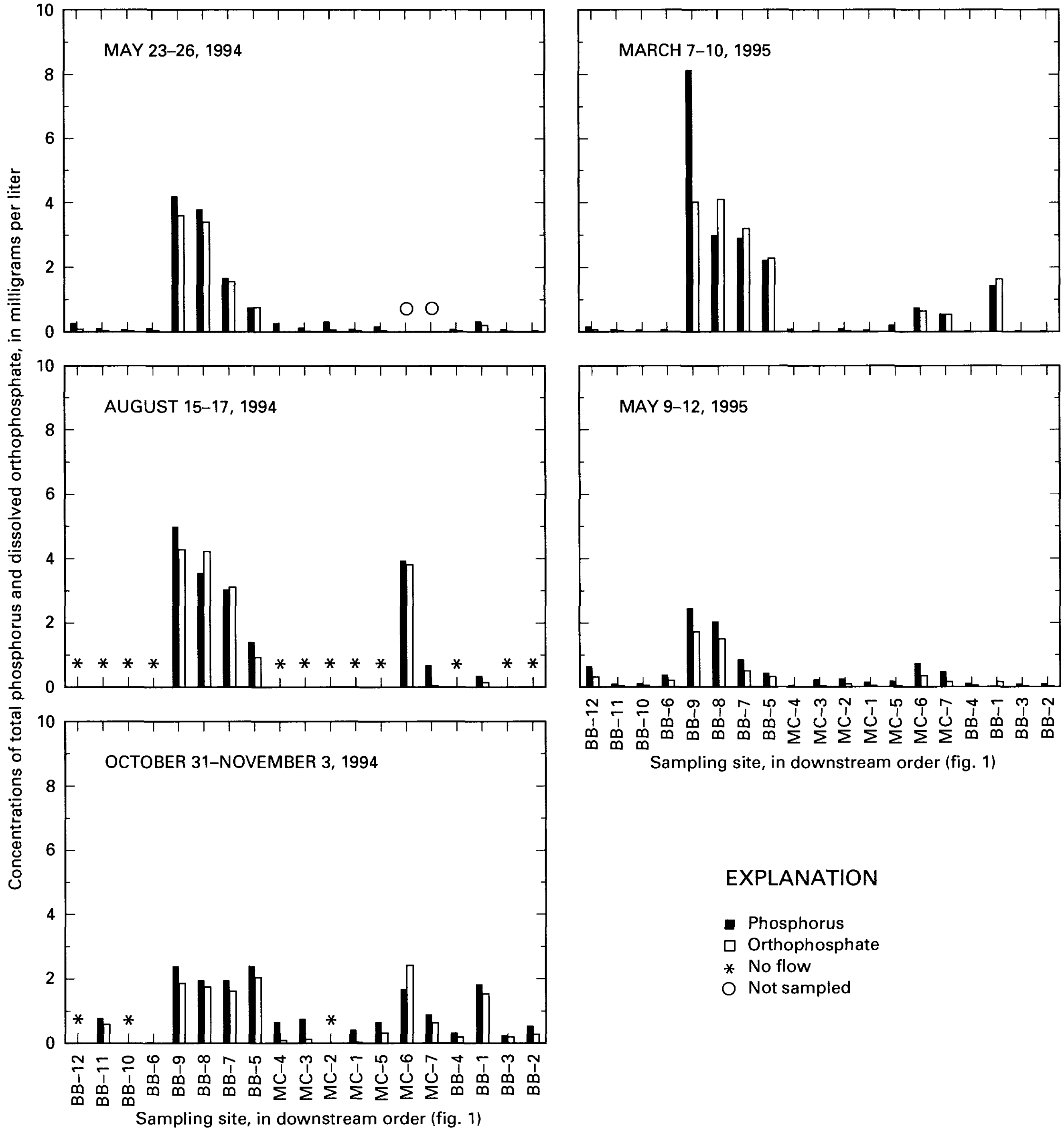


Figure 5. Concentrations of total phosphorus and dissolved orthophosphate in Big Bull Creek (BB) and Martin Creek (MC) subbasins, May 1994–May 1995.

subbasin, 12 exceeded the 0.05-mg/L criterion for total phosphorus (table 6). During May 1994, water samples collected at site RC–3 in the Rock Creek subbasin had larger total phosphorus and total ammonia plus organic concentrations than other sites sampled during this period. Samples collected at this site were probably affected by some nonpoint source in the area.

Figure 15 shows mean low-flow total phosphorus concentrations for samples collected in the five subbasins in relation to the 0.05-mg/L criterion

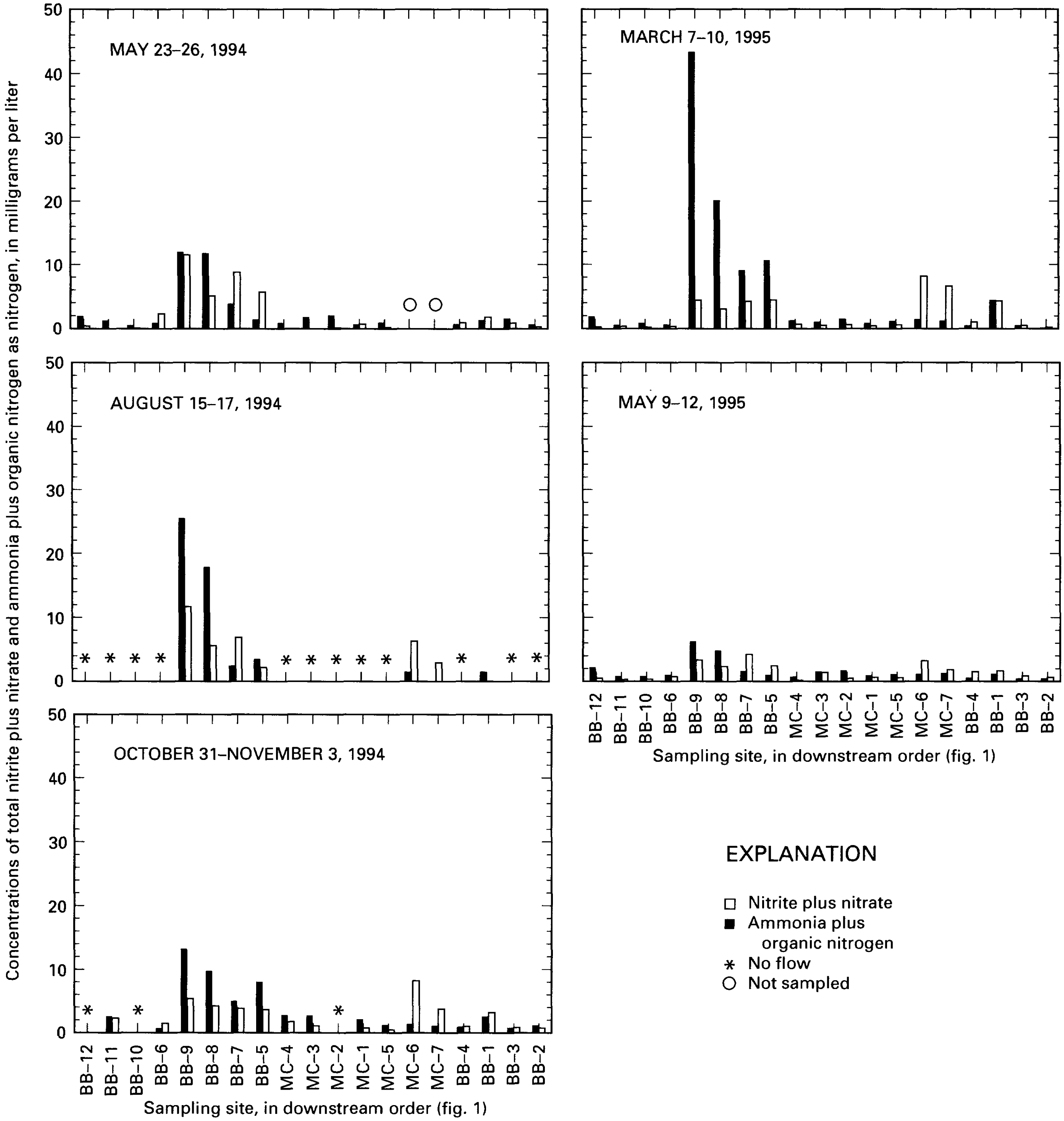


Figure 6. Concentrations of total nitrite plus nitrate and ammonia plus organic nitrogen as nitrogen in Big Bull Creek (BB) and Martin Creek (MC) subbasins, May 1994–May 1995.

established by the Hillsdale Water-Quality Protection Project. Managing and controlling the point-source discharges in the subbasins alone apparently would not decrease the nutrient concentrations in the Hillsdale Basin to the proposed criterion.

Although a rigorous analysis of seasonal variation of nutrient concentrations among subbasins cannot be performed due to the limited data set, some comparisons can be made. Box plots showing total phosphorus data for water samples collected from all sampled

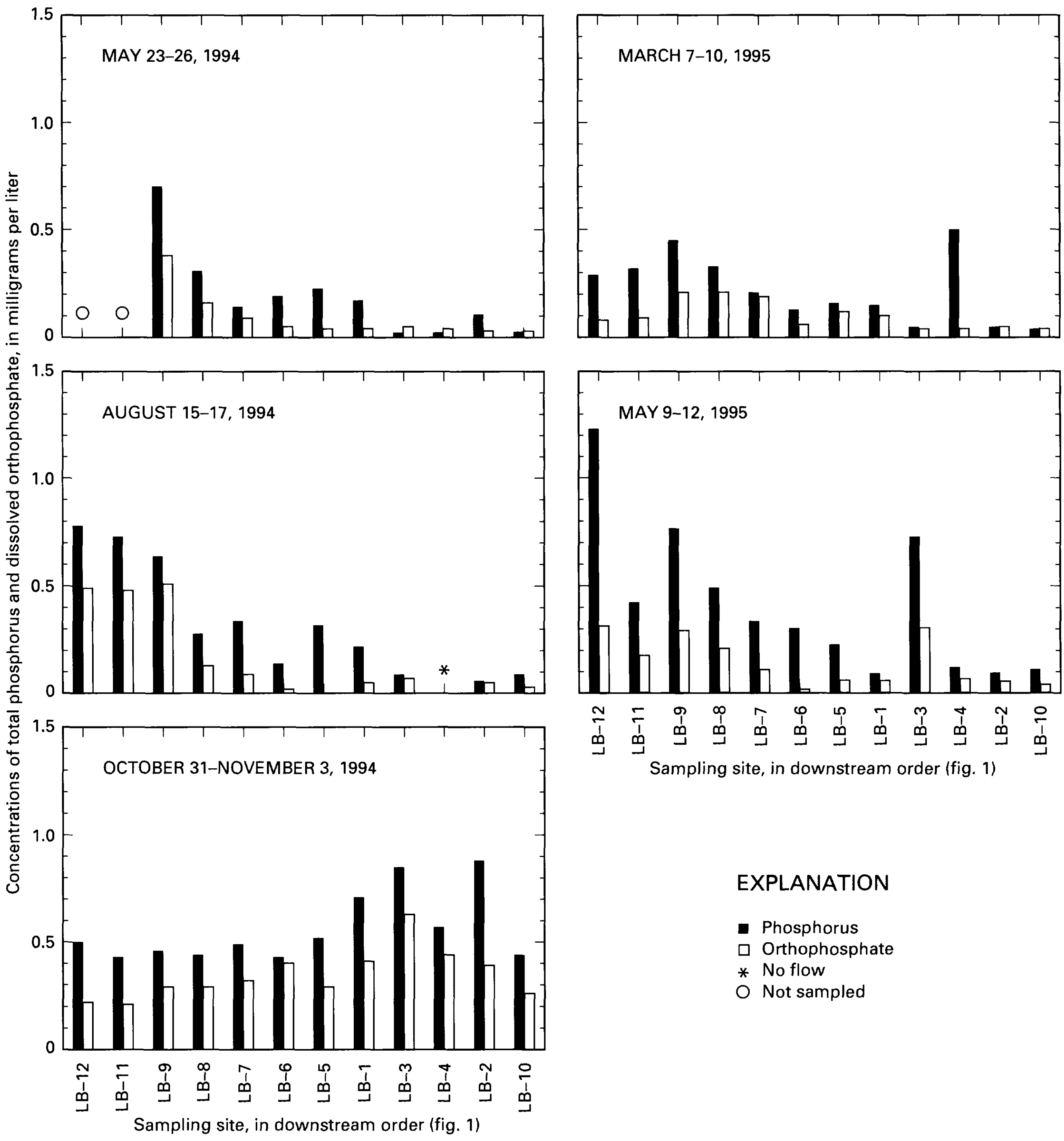


Figure 7. Concentrations of total phosphorus and dissolved orthophosphate in Little Bull Creek (LB) subbasin, May 1994–May 1995.

subbasins during May 1994, August 1994, November 1994, and March 1995 are shown in figure 16*A*. The median total phosphorus concentration during August 1994 shows the effect of the point sources in the Big Bull Creek and Little Bull Creek subbasins. None of the streams in the Rock Creek, Wade Branch, and Smith Branch subbasins were flowing during the August 1994 sampling period. Therefore, the majority of sites sampled during August 1994 were affected by point-source discharges. The November 1994 sample had the largest median total phosphorus concentration because many of the sampling sites,

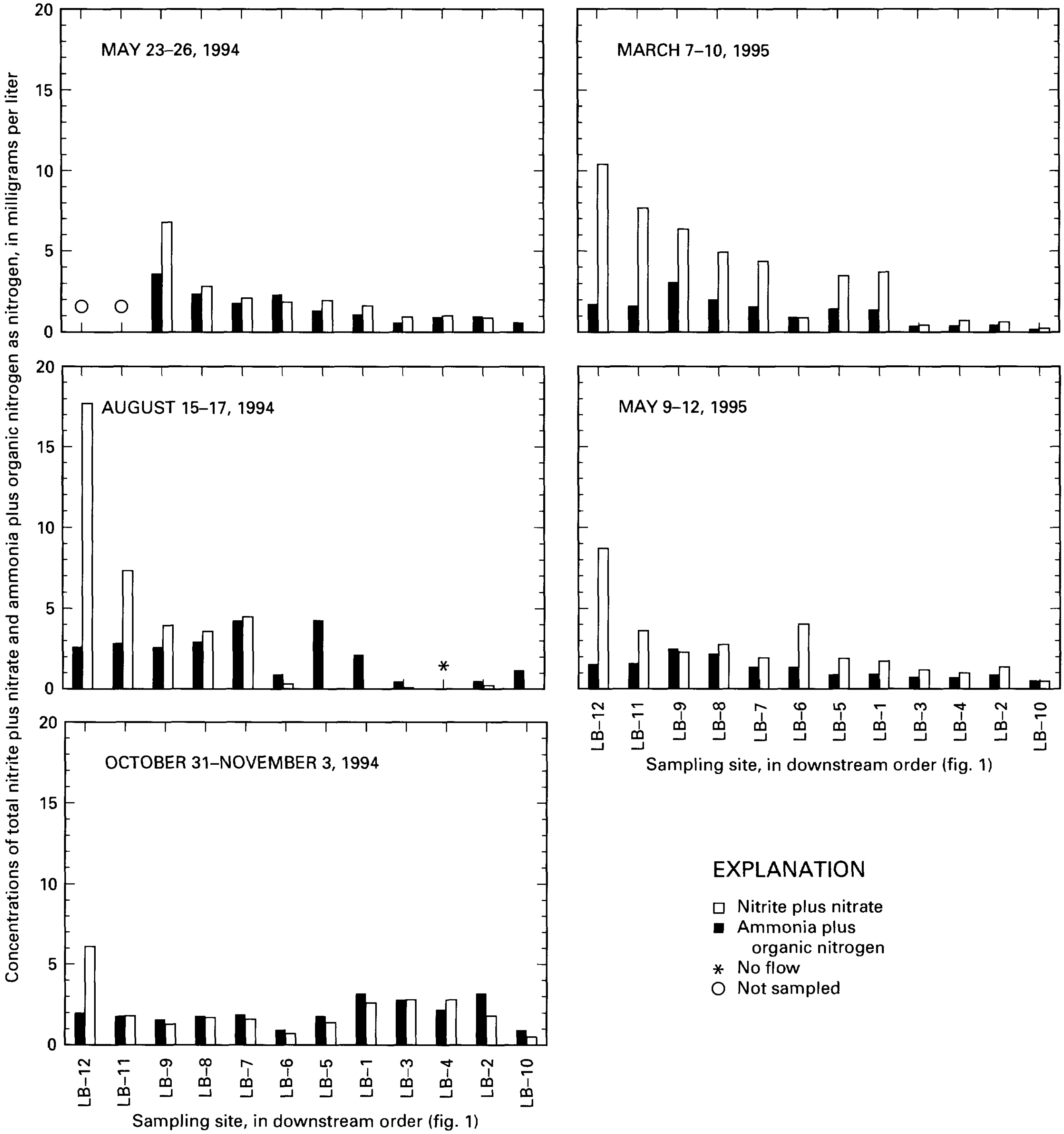


Figure 8. Concentrations of total nitrite plus nitrate and ammonia plus organic nitrogen as nitrogen in Little Bull Creek (LB) subbasin, May 1994–May 1995.

especially those in the Little Bull Creek subbasin, were affected by runoff from nonpoint sources. The mean streamflow in the Little Bull Creek subbasin during the November 1994 sampling period was 14.9 cubic feet per second, whereas that for May 1994, August 1994, and March 1995 was 0.77, 0.25, and 0.52 cubic feet per second, respectively. Samples collected at site LB–3 show the effect of runoff on constituent concentrations. The total phosphorus concentration at site LB–3, a sampling site not affected by the point sources, was 0.02 mg/L during May 1994, whereas the November 1994 sample at this site had a total phosphorus concen-

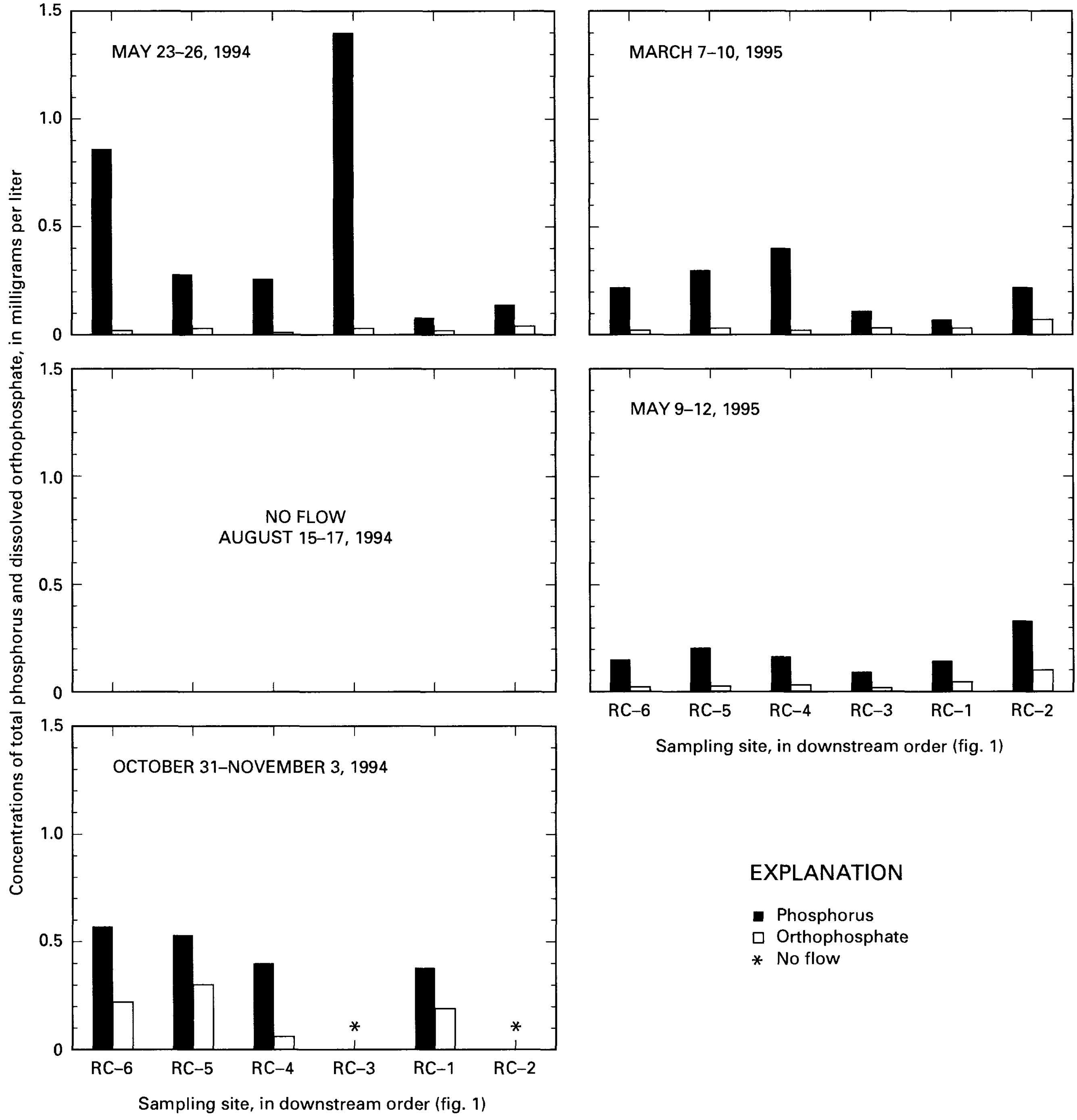


Figure 9. Concentrations of total phosphorus and dissolved orthophosphate in Rock Creek (RC) subbasin, May 1994–May 1995.

tration of 0.85 mg/L. Although runoff in the Little Bull Creek subbasin was minor, it does point out the effect on water quality of nonpoint-source contributions during runoff.

Figure 16*B* shows box plots of total phosphorus concentrations in water samples collected from the Big Bull Creek subbasin. The largest total phosphorus concentrations occurred during August 1994. Many of the sites in the Big Bull Creek subbasin had no flow during the August 1994 sampling period; of the 19 sites visited, only 7 had flowing water. As the nonpoint-source tributaries dry up, the point sources dominate the stream system, resulting in larger median total phosphorus concentrations.

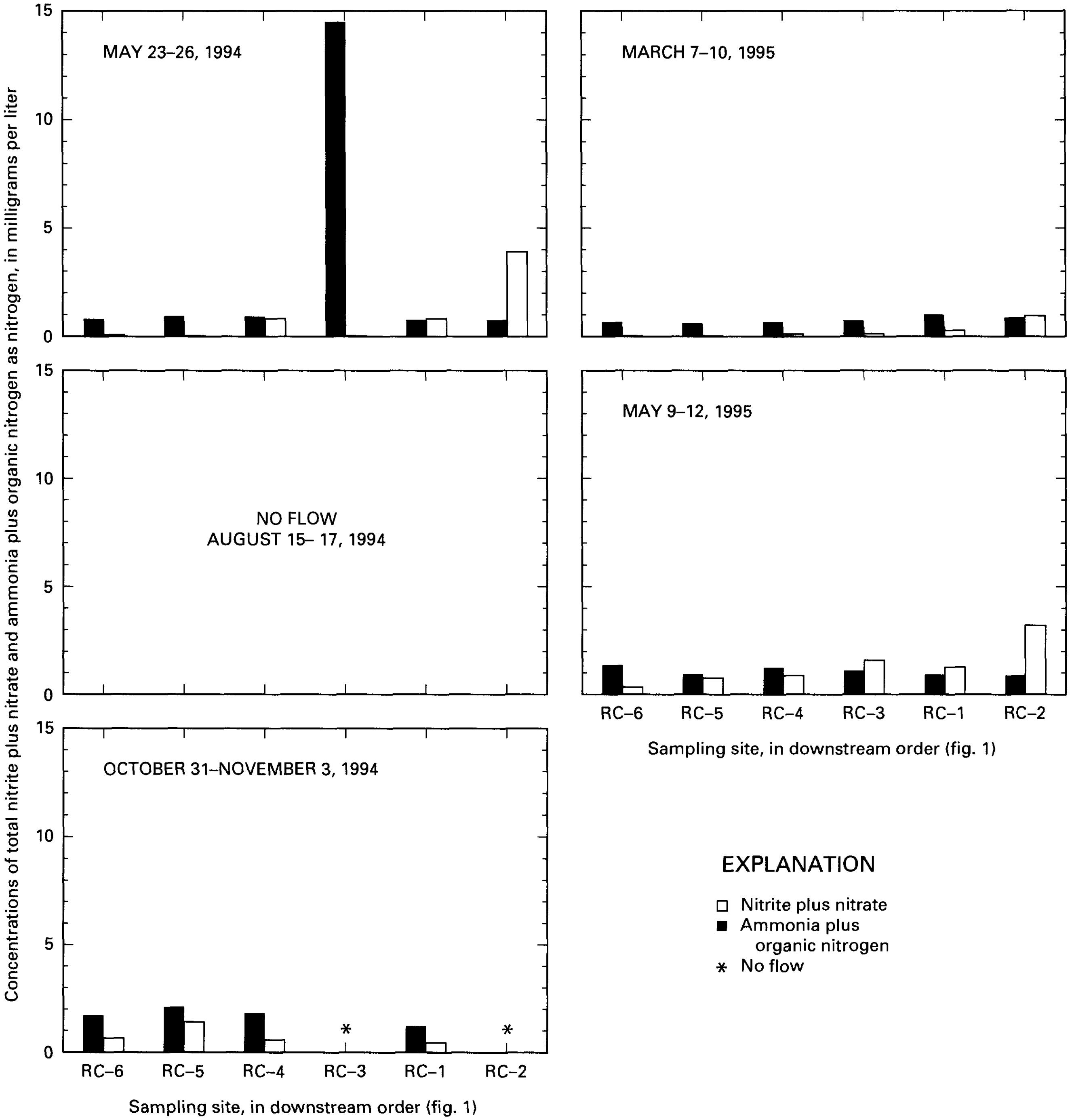


Figure 10. Concentrations of total nitrite plus nitrate and ammonia plus organic nitrogen as nitrogen in Rock Creek (RC) subbasin, May 1994–May 1995.

Nutrient Loads

Results of this study focus on nutrient loads during low flow. More information concerning point-source and nonpoint-source phosphorus loading to Hillsdale Lake is reported by Holt (1996).

Mean low-flow nutrient loads computed for the outlet sampling sites in the subbasins are listed in table 3. Figure 17 shows mean low-flow total phosphorus loads for selected sampling sites in the Hillsdale Basin. All sampling periods, except those periods affected by runoff (all samples collected during May 1995 and those collected during November 1994 in the

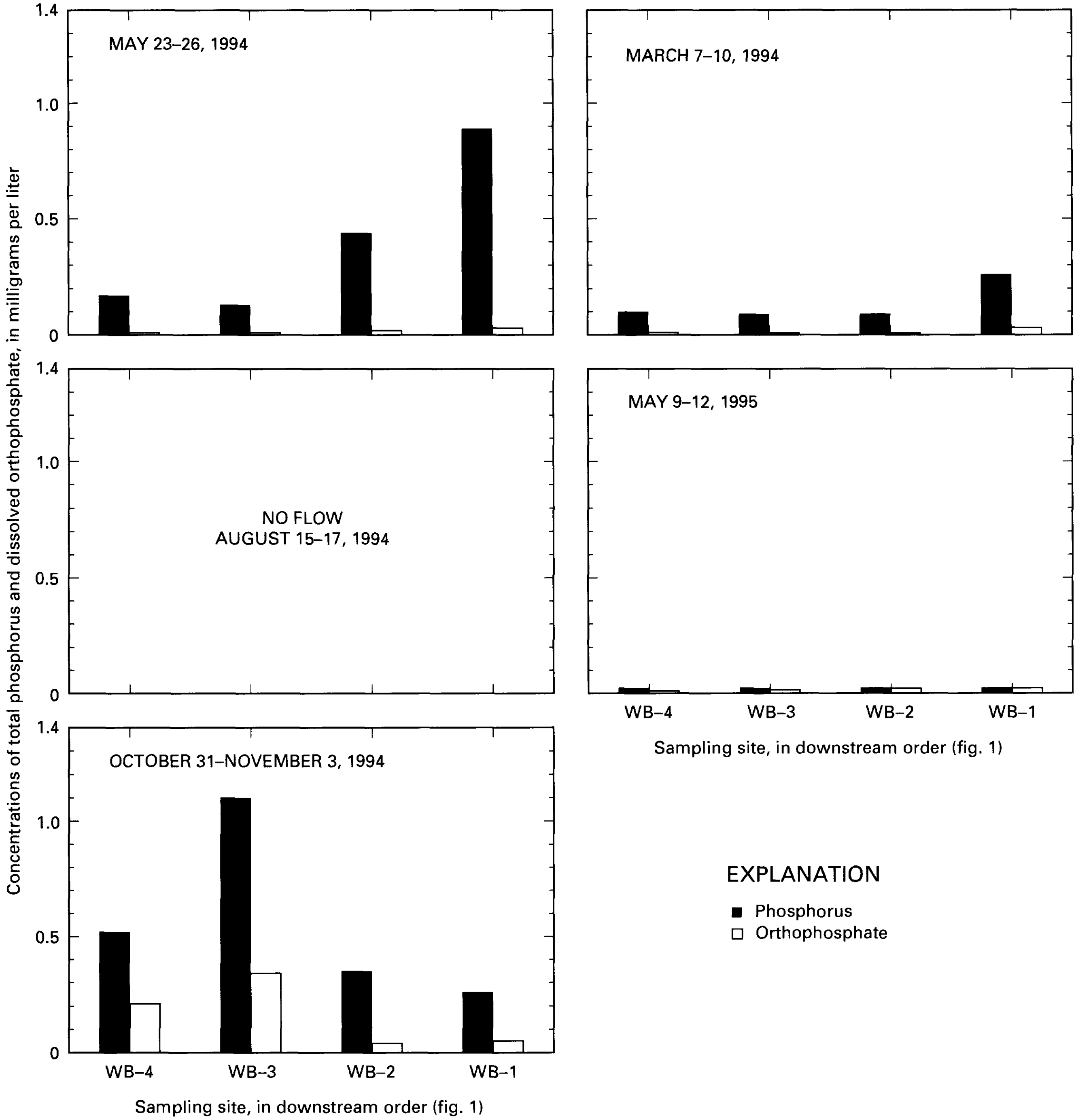


Figure 11. *Concentrations of total phosphorus and dissolved orthophosphate in Wade Branch (WB) subbasin, May 1994–May 1995.*

Little Bull Creek subbasin), were used in the low-flow mean load computation. The discharge hydrographs and flow-duration curves (figs. 2 and 3) for sites BB–1, RC–1, and LB–1 were used to determine which samples were affected by runoff. The instantaneous discharge measured at site BB–1 during May 1994, August 1994, November 1994, and March 1994 was at (or near) the low-flow discharge shown in figure 2. The instantaneous discharge measured at this site during May 1995 (16.2 cubic feet per second) indicates a runoff-affected period. Therefore, data for this period (May 1995) were not used to compute low-flow

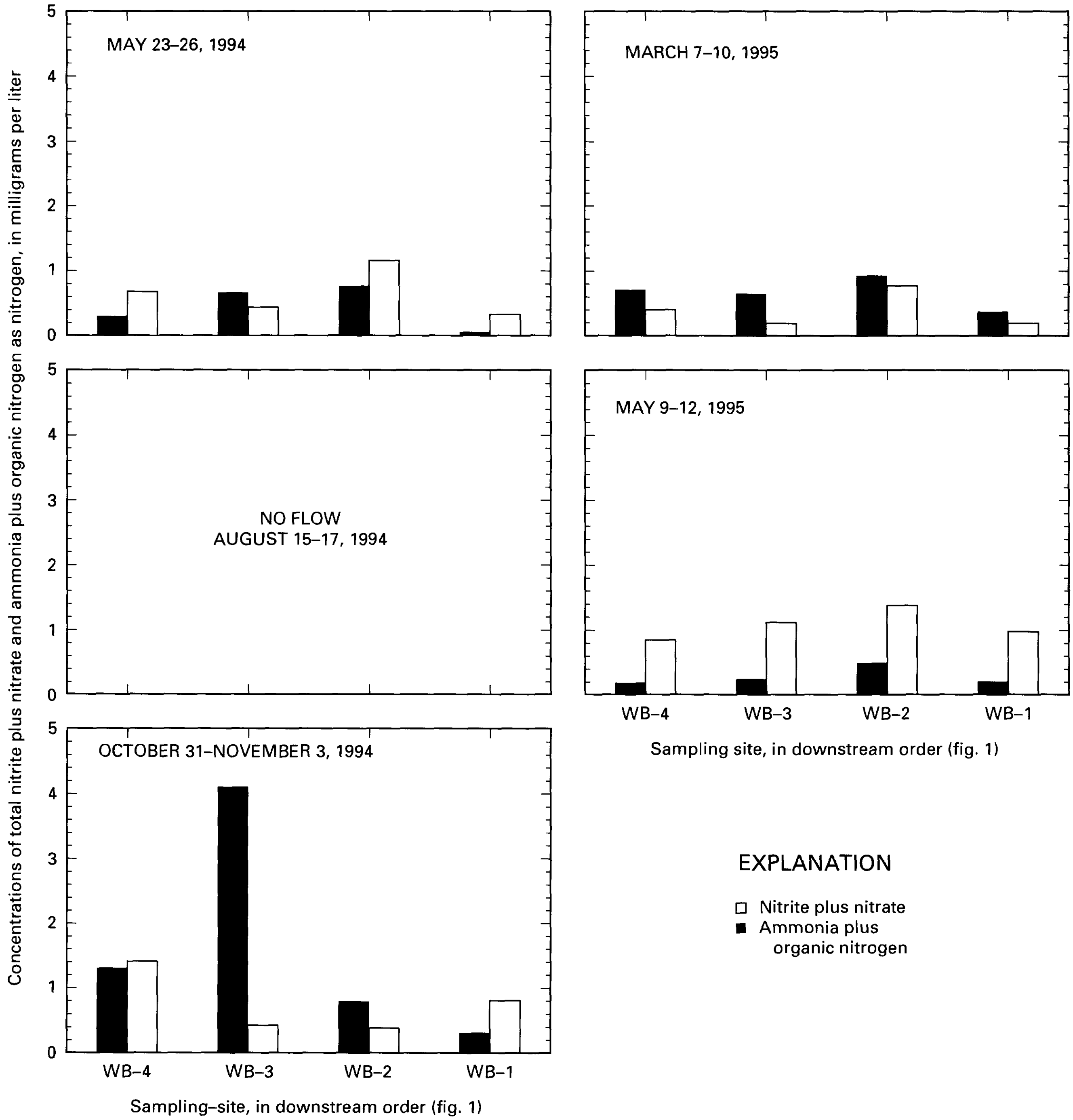


Figure 12. Concentrations of total nitrite plus nitrate and ammonia plus organic nitrogen as nitrogen in Wade Branch (WB) subbasin, May 1994–May 1995.

nutrient load statistics shown in table 3. Similar analysis indicates that samples collected at sites RC–1 and LB–1 during May 1995 and those collected during November 1994 at site LB–1 were affected by runoff.

No discharge hydrographs or flow-duration curves were computed for sites WB–1 and SM–1 because continuous discharge records were not collected for these sites. As a result of the analysis of the discharge measurements made at sites WB–1 and SM–1 and comparison with runoff at site RC–1 (located near sites WB–1 and SM–1), a reasonable assumption was made that samples collected at sites WB–1 and SM–1 during May 1995 were also affected by runoff. Therefore,

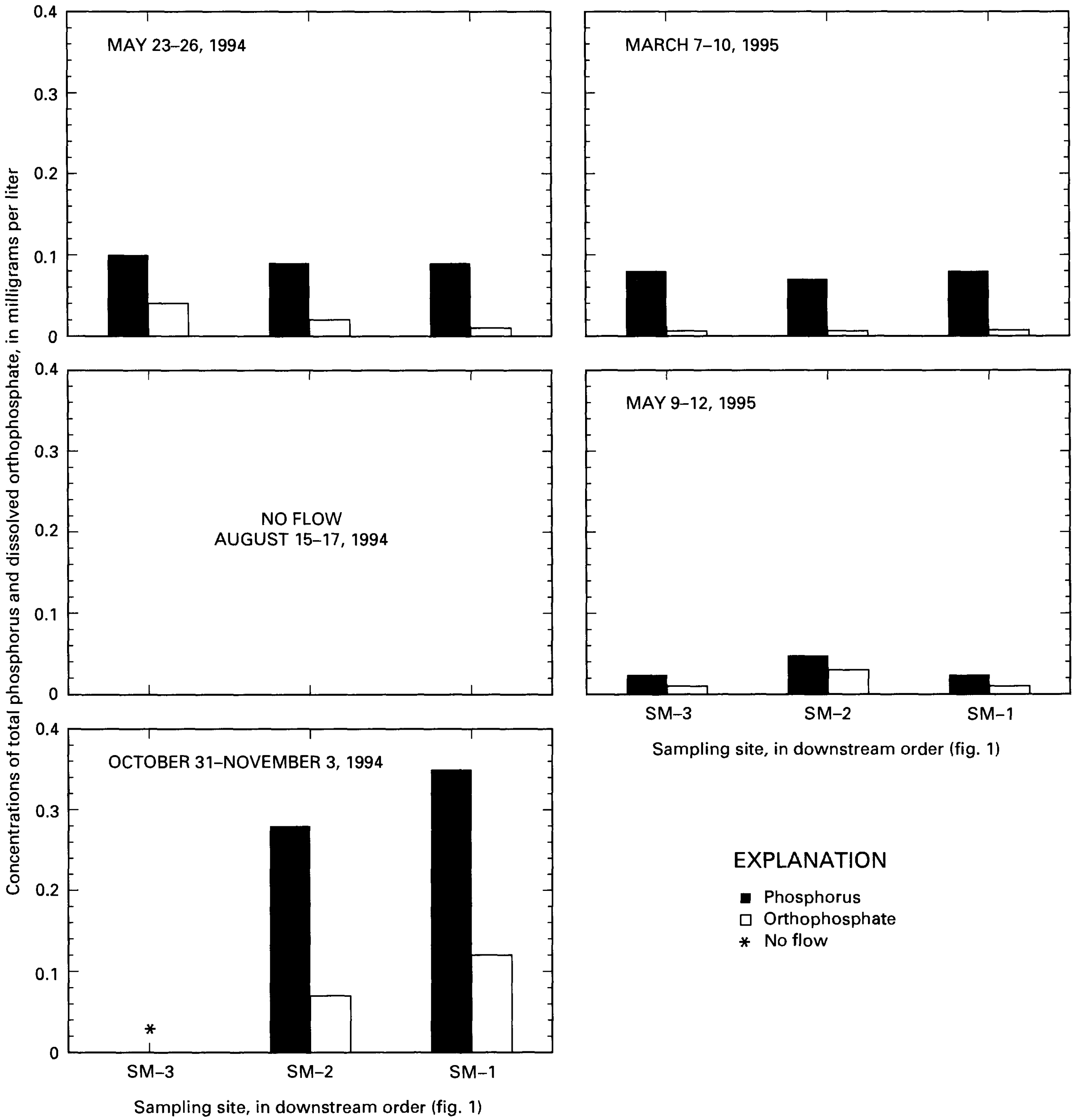


Figure 13. Concentrations of total phosphorus and dissolved orthophosphate in Smith Branch (SM) subbasin, May 1994–May 1995.

these samples were not used for computation of the low-flow nutrient statistics shown in table 3.

Equation 1 was used to compute low-flow nutrient loads for the subbasin outlet sites listed in table 3. For example, the discharge measured at site RC–1 during May 1994 was 0.92 cubic foot per second. The total phosphorus concentration for the sample collected was 0.08 mg/L. Using equation 1, the low-flow total phosphorus load at site RC–1 during May 1994 was 0.18 kg/d. Low-flow nutrient loads for the remaining samples collected (except those during runoff periods) were used to compute mean low-flow total phosphorus loads.

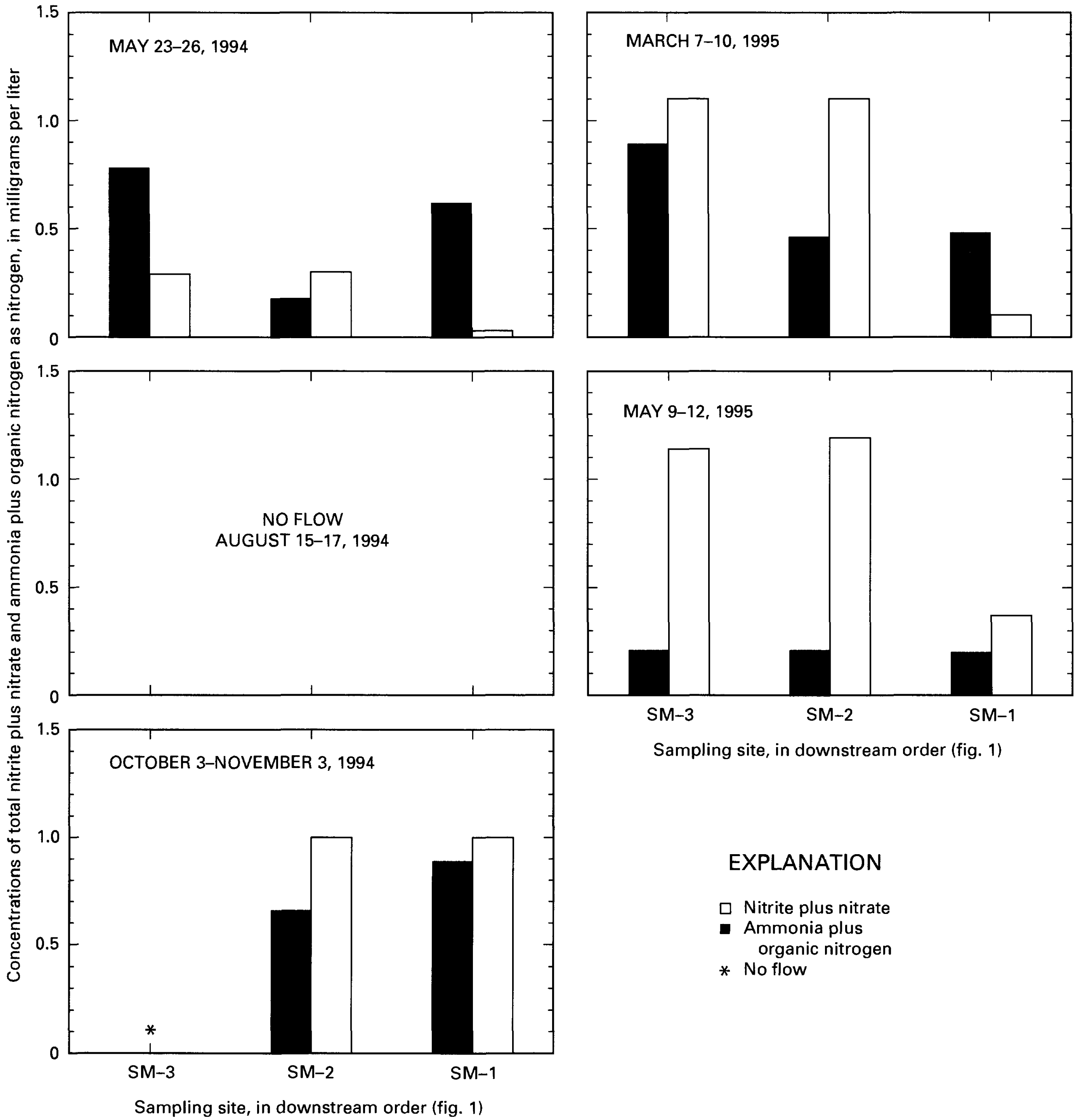


Figure 14. Concentrations of total nitrite plus nitrate and ammonia plus organic nitrogen as nitrogen in Smith Branch (SM) subbasin, May 1994–May 1995.

The largest mean nutrient loads occurred at the outlet sampling site in the Big Bull Creek subbasin, site BB–1 (table 3). In the Big Bull Creek subbasin, the largest nutrient loads generally occurred downstream from point sources. Stream discharge and nutrient loads for the Big Bull Creek subbasin are shown in figures 18 and 19. The total phosphorus and dissolved orthophosphate loads were relatively large at site BB–1 during the November 1994 and May 1995 sampling periods. Minor runoff occurred just prior to or during collection of these samples, thereby increasing the nonpoint-source component of the measured load at site BB–1. Also, some sites were not sampled on the same day the during the November 1994 sampling,

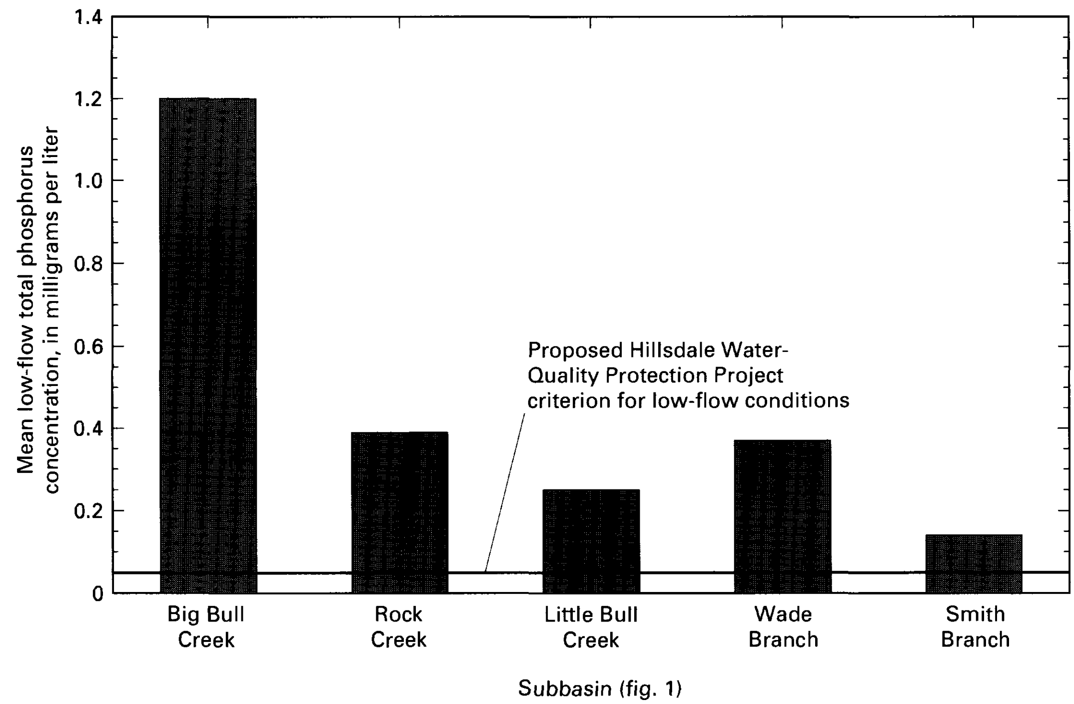


Figure 15. Mean low-flow total phosphorus concentrations in selected subbasins and proposed Hillsdale Water-Quality Protection Project criterion for low-flow conditions, May 1994–March 1995. Runoff-affected samples collected during November 1994 from the Little Bull Creek subbasin are not included.

which increased load variability because of variations in streamflow. An example of point-source discharges and the effect on the Big Bull Creek subbasin is shown in figure 18 during the May 1994, August 1994, March 1995, and May 1995 sampling periods. The total phosphorus and dissolved orthophosphate loads generally decreased between sites BB–9 (immediately downstream from a point-source discharge) and BB–7 and were much smaller at the subbasin outlet site, site BB–1, during May 1994 and August 1994. Nitrogen nutrient loads shown in figure 19 varied in a similar manner. As discussed earlier in this report, nutrients are utilized by aquatic vegetation in the stream, and deposition of some particulate phosphorus onto bed material may occur, thereby decreasing nutrient loads between point sources and downstream sites.

Sites BB–12, BB–11, BB–10, BB–6, MC–4, MC–3, MC–2, MC–5, BB–4, BB–3, and BB–2 are located in areas not affected by point sources of nutrients. The mean total phosphorus load computed for the May 1995 sampling period at these sites was 0.52 kg/d. By comparison, the computed total phosphorus load downstream from the wastewater-treatment plant in the Martin Creek subbasin, site MC–6, was 5.0 kg/d during May 1995. The total phosphorus load computed for site BB–9 downstream from the Gardner wastewater-treatment plant was 9.0 kg/d during the May 1995 sampling period. This comparison points out the effects of point sources on total phosphorus loads within the Big Bull Creek and Martin Creek subbasins during low flow.

Mean nutrient loads in the Little Bull Creek subbasin are smaller than those in the Big Bull Creek subbasin. The low-flow mean total phosphorus and dissolved orthophosphate loads computed for the outlet site, LB–1, in the Little Bull Creek subbasin were 0.44 and 0.16 kg/d, respectively (table 3). The nitrite plus nitrate and total ammonia plus organic nitrogen loads, 5.9 and 3.4 kg/d, respectively (table 3), demonstrated the effect of point-source discharges on the Little Bull Creek subbasin. Nutrient loads for the Little Bull Creek subbasin are shown in figures 20 and 21. During May 1994, the largest total phosphorus loads occurred at site LB–9 (fig. 20), and during August 1994, the largest nitrite plus nitrate loads occurred at site LB–12 (fig. 21). Both sites are downstream from point-source discharges.

Mean low-flow nutrient loads at the outlet sites of the Rock Creek, Wade Branch, and Smith Branch subbasins are listed in table 3. Because of the smaller streamflow and the fact that there are no point sources located in these subbasins, the mean low-flow nutrient

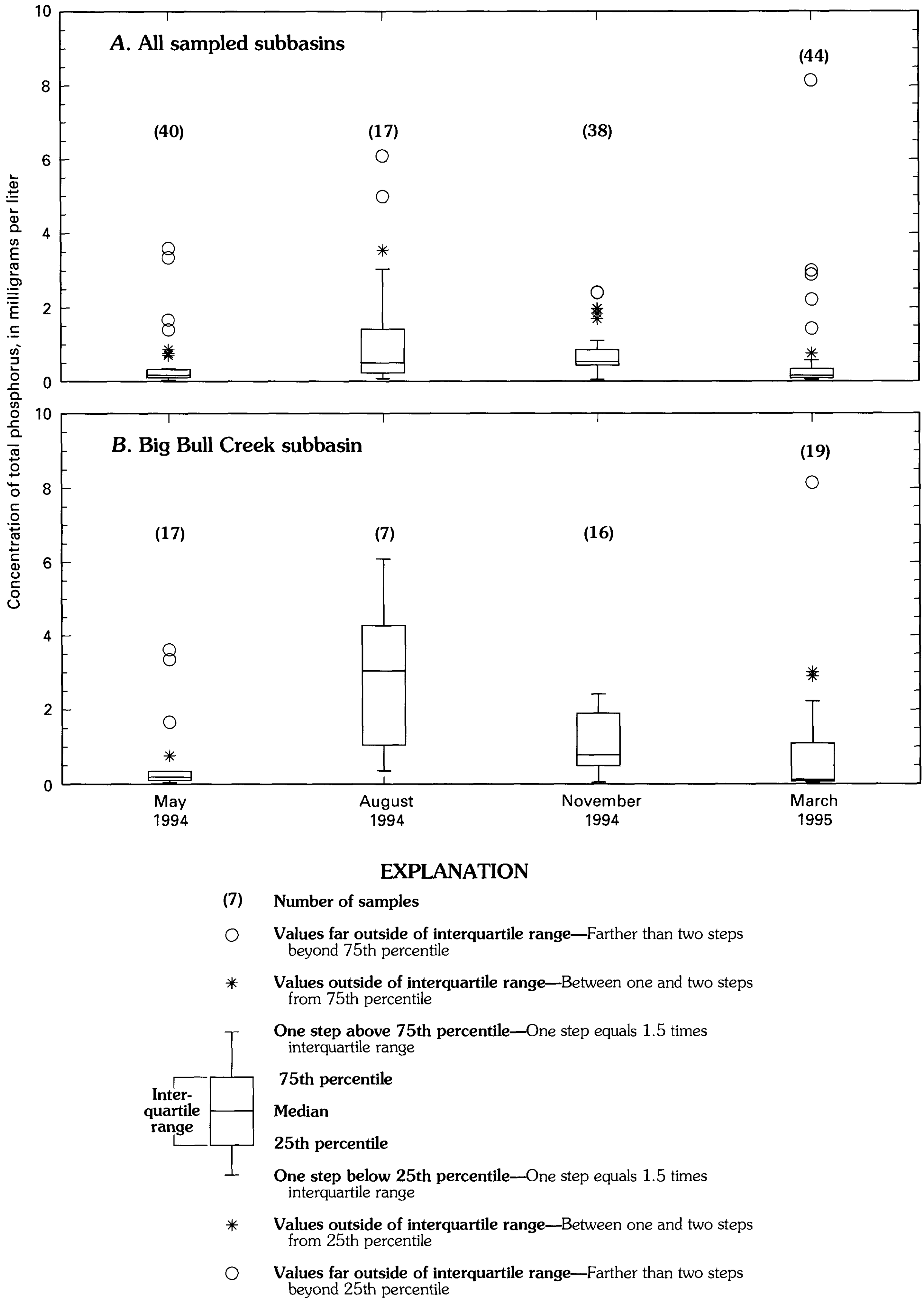


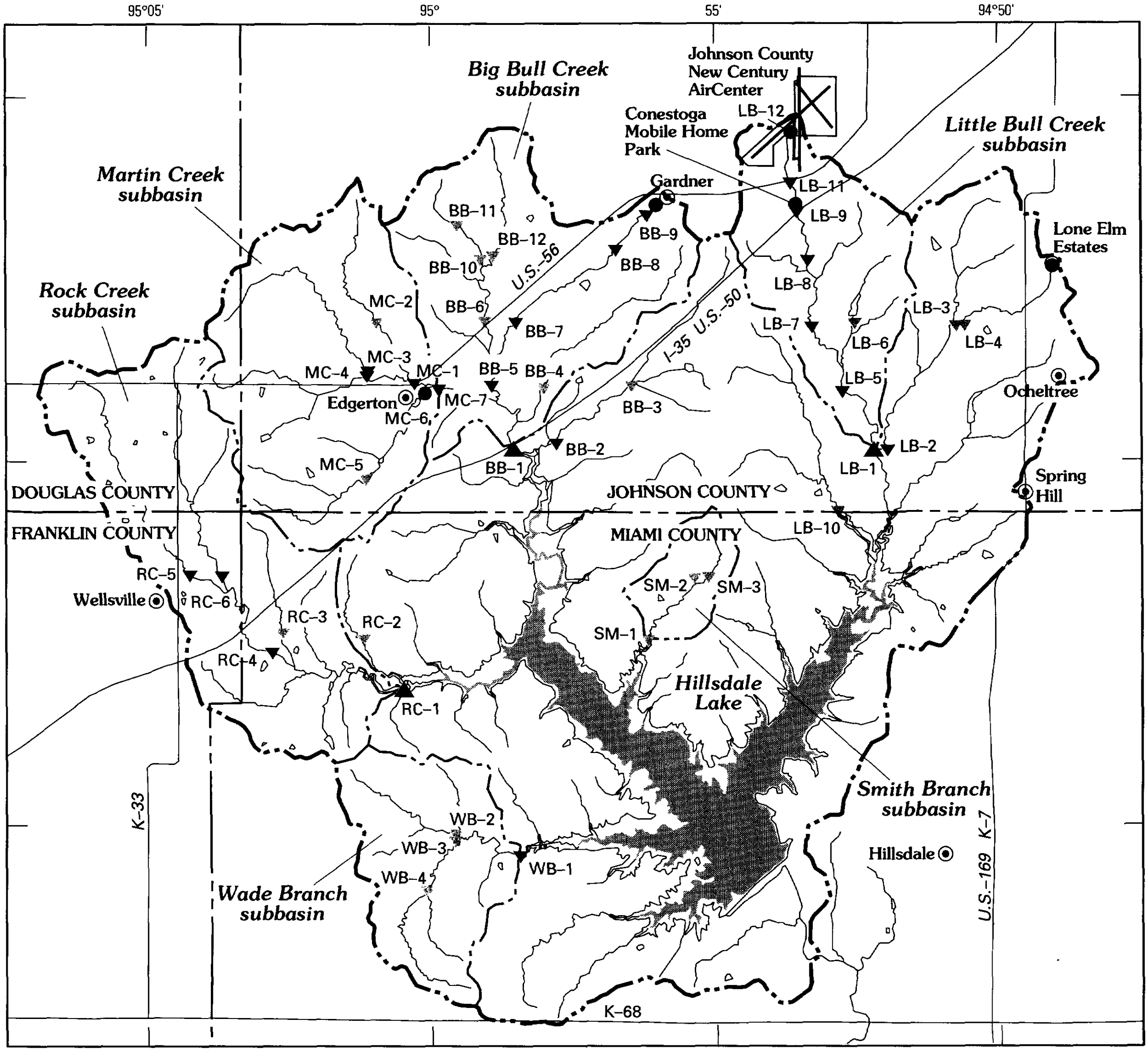
Figure 16. Total phosphorus concentrations in water samples from (*A*) all sampled subbasins and from (*B*) Big Bull Creek subbasin, May 1994–March 1995.

Table 3. Statistical summary of low-flow nutrient loads computed for subbasin outlet sampling sites in Hillsdale Lake Basin, northeast Kansas, May 1994–March 1995

[Loads are in kilograms per day. <, less than]

Subbasin (fig. 1)	Number of samples	Total phosphorus load			Dissolved orthophosphate load			Total nitrite plus nitrate as nitrogen load			Total ammonia plus organic nitrogen load as nitrogen		
		Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean
Big Bull Creek[1] (site BB–1)	4	22	0.17	7.5	18	0.07	6.5	37	0.04	16	31	0.78	14
Rock Creek (site RC–1)	4	1.2	.06	.48	.62	.02	.23	1.8	.22	1.1	3.9	.83	2.1
Little Bull Creek[2] (site LB–1)	3	.83	.09	.44	.27	.02	.16	10	<.01	5.9	5.4	.86	3.4
Wade Branch (site WB–1)	4	1.6	.02	.64	.05	<.01	.03	.59	.08	.30	.44	.03	.19
Smith Branch (site SM–1)	4	.09	.03	.07	.01	.01	.01	.29	<.01	.12	.61	.06	.38

[1]Includes Martin Creek subbasin drainage.
[2]Runoff-affected samples collected during November 1994 from the Little Bull Creek subbasin are not included.



Base from Kansas Geological Survey digital data, 1:24,000, 1991
and U.S. Geological Survey digital data, 1:100,000, 1983
Lambert Conformal Conic projection
Standard parallels 33° and 45°, central meridian -98°15'

0 1 2 3 MILES

0 1 2 3 KILOMETERS

EXPLANATION

Extent of lake at conservation-pool level

Boundary of Hillsdale Lake Basin

Boundary of sampled subbasins

SAMPLING SITES

BB-1 ▲ **Streamflow-gaging station and synoptic sampling site**—Site identification corresponds to that used in table 6

WB-4 ▼ **Synoptic sampling site**—Site identification corresponds to that used in table 6

MC-6 ● **Point source and synoptic sampling site**—Site identification corresponds to that used in table 6

● **Point source**—No sample

Mean low-flow phosphorus loads, in kilograms per day

- Greater than 1.0
- 0.51 to 1.0
- 0.10 to 0.50
- Less than 0.10

Figure 17. Mean low-flow total phosphorus loads computed for selected sampling sites, May 1994–March 1995. Runoff-affected samples collected during November 1994 from the Little Bull Creek subbasin are not included.

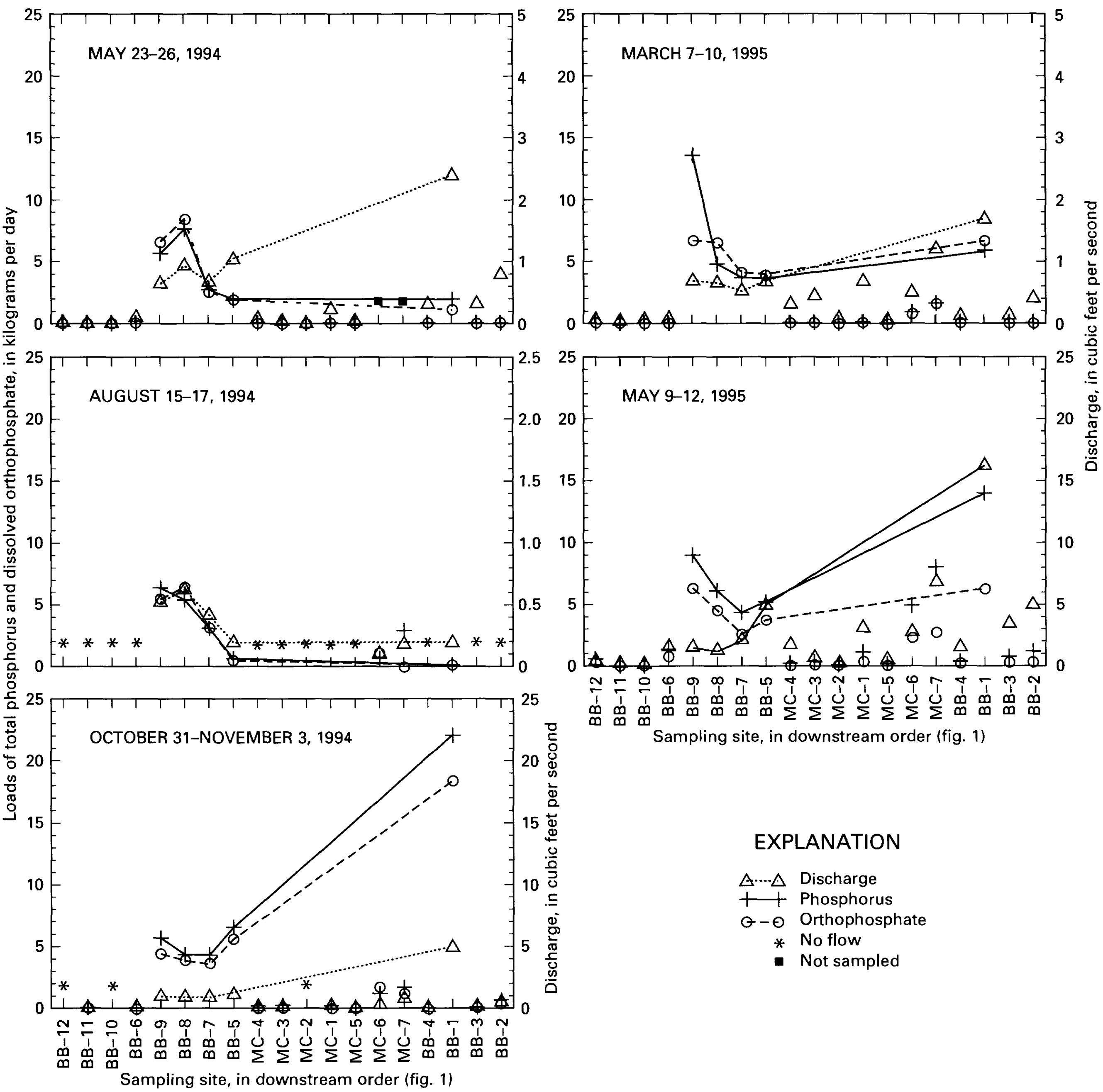


Figure 18. Stream discharge and loads of total phosphorus and dissolved orthophosphate in Big Bull Creek (BB) and Martin Creek (MC) subbasins, May 1994–May 1995.

loads were generally much smaller than those in the Big Bull Creek subbasin. Mean low-flow total phosphorus loads at the outlets of the Rock Creek, Wade Branch, and Smith Branch subbasins were 0.48, 0.64, and 0.07 kg/d, respectively (table 3). By comparison, the mean low-flow total phosphorus load at site BB–1 was 7.5 kg/d.

Runoff can cause substantial increases in nutrient loads in the subbasins, and at times the nutrient loads at sites not affected by point-source discharges may be larger than at those sites affected by point-source discharges. For example, during the March 1995 sampling period, the total phosphorus load at site LB–2 was 0.06 kg/d. The total phosphorus load computed at this site during a runoff period, November 1994, was

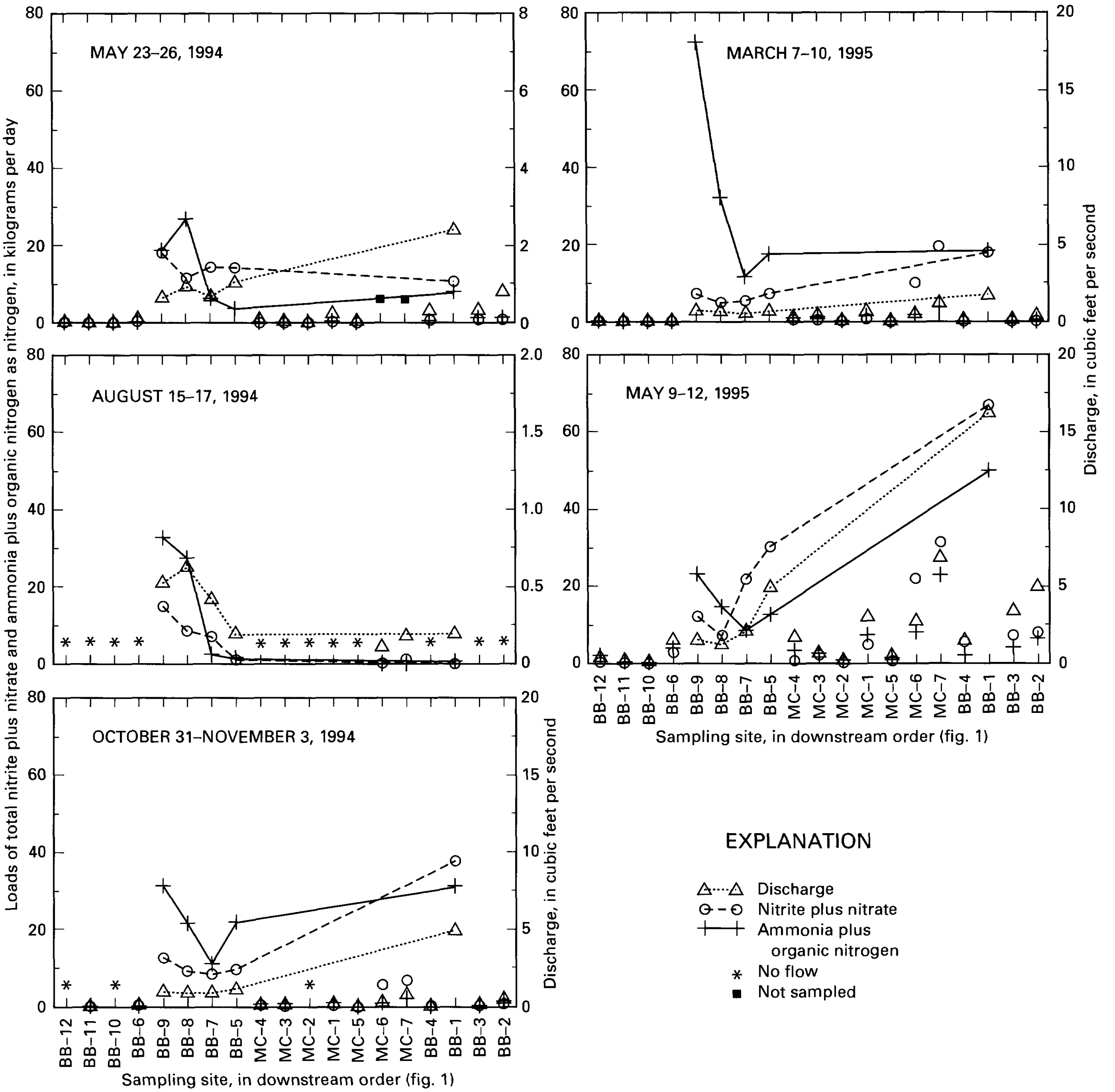


Figure 19. Stream discharge and loads of total nitrite plus nitrate and ammonia plus organic nitrogen as nitrogen in Big Bull Creek (BB) and Martin Creek (MC) subbasins, May 1994–May 1995.

46 kg/d. By comparison, the total phosphorus load computed at site LB–12, downstream from a point source, during the November 1994 sampling period was 1.8 kg/d. The effects of runoff on nutrient loads in the Little Bull Creek subbasin are reflected in the variability of the nutrient loads shown in figures 20 and 21. For example, during November 1994, the total phosphorus and dissolved orthophosphate loads at the outlet site of the Little Bull Creek subbasin (site LB–1) were 54 and 31 kg/d, respectively. The nitrogen nutrient loads also were large at this site (fig. 21). By comparison, the total phosphorus and dissolved orthophosphate loads at site LB–12, the site downstream from the point source, were 1.8 and 0.81 kg/d, respectively.

It is impossible to make accurate projections of annual low-flow nutrient loads from the subbasins with

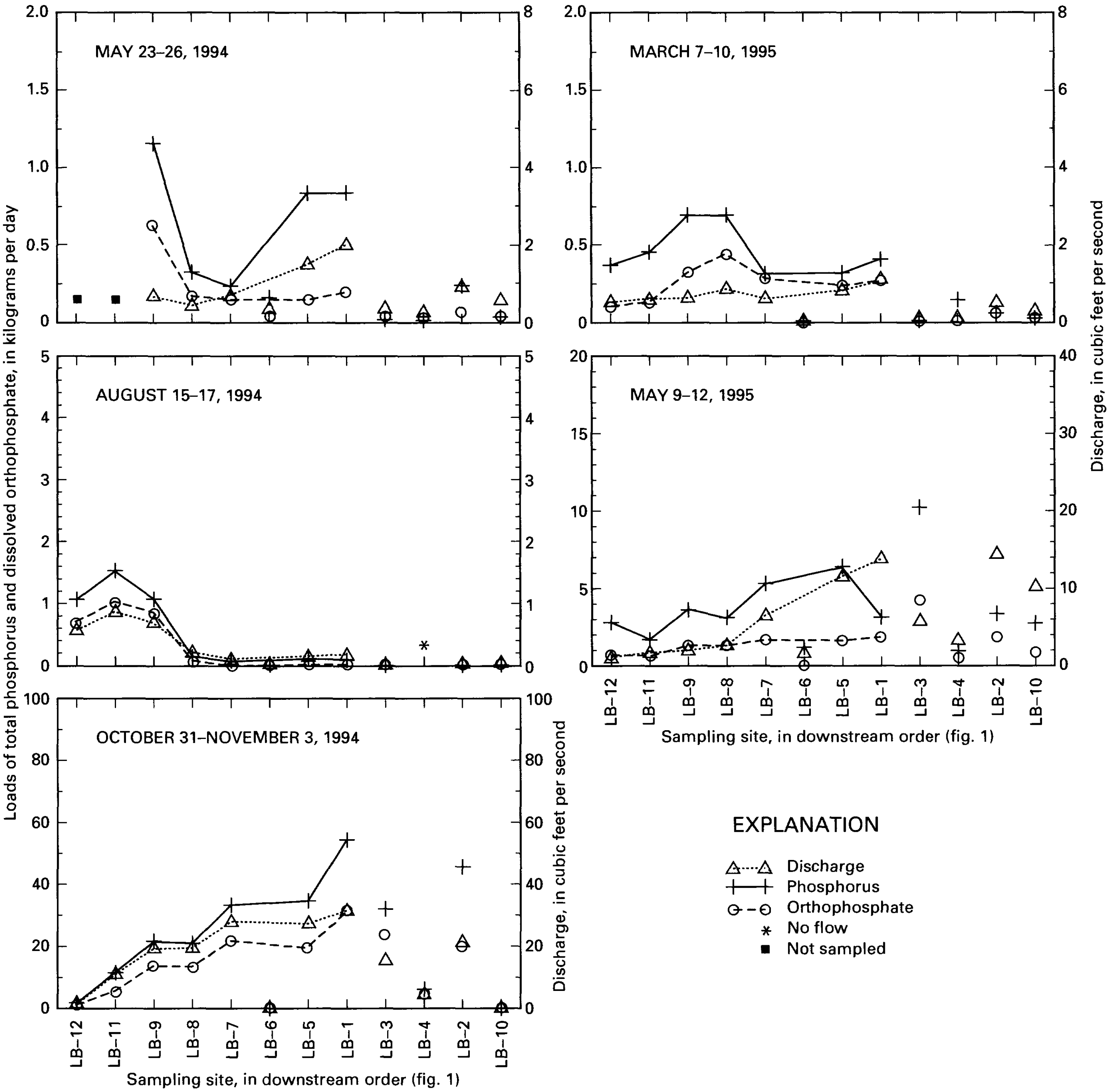


Figure 20. Stream discharge and loads of total phosphorus and dissolved orthophosphate in Little Bull Creek (LB) subbasin, May 1994–May 1995.

this limited data set. The computed annual low-flow total phosphorus loads are estimations and should only be used for subbasin comparisons in a relative manner.

Mean low-flow total phosphorus loads at the outlet sampling site for each subbasin were computed using a mean total phosphorus concentration, the mean instantaneous discharge (streamflow) measured during sample collection, and equation 1. To compute annual low-flow total phosphorus loads for each subbasin, the number of days during the study period when low flow occurred needs to be determined. For example, representative low-flow discharge estimated for site LB–1 from flow-duration curves and streamflow hydrographs was 2 cubic feet per second (fig. 2). The number of days during the study period when the mean daily discharge was less than or equal to 2 cubic feet per second was 297 (Geiger and others, 1995; Putnam and others, 1996). There was no way to determine the

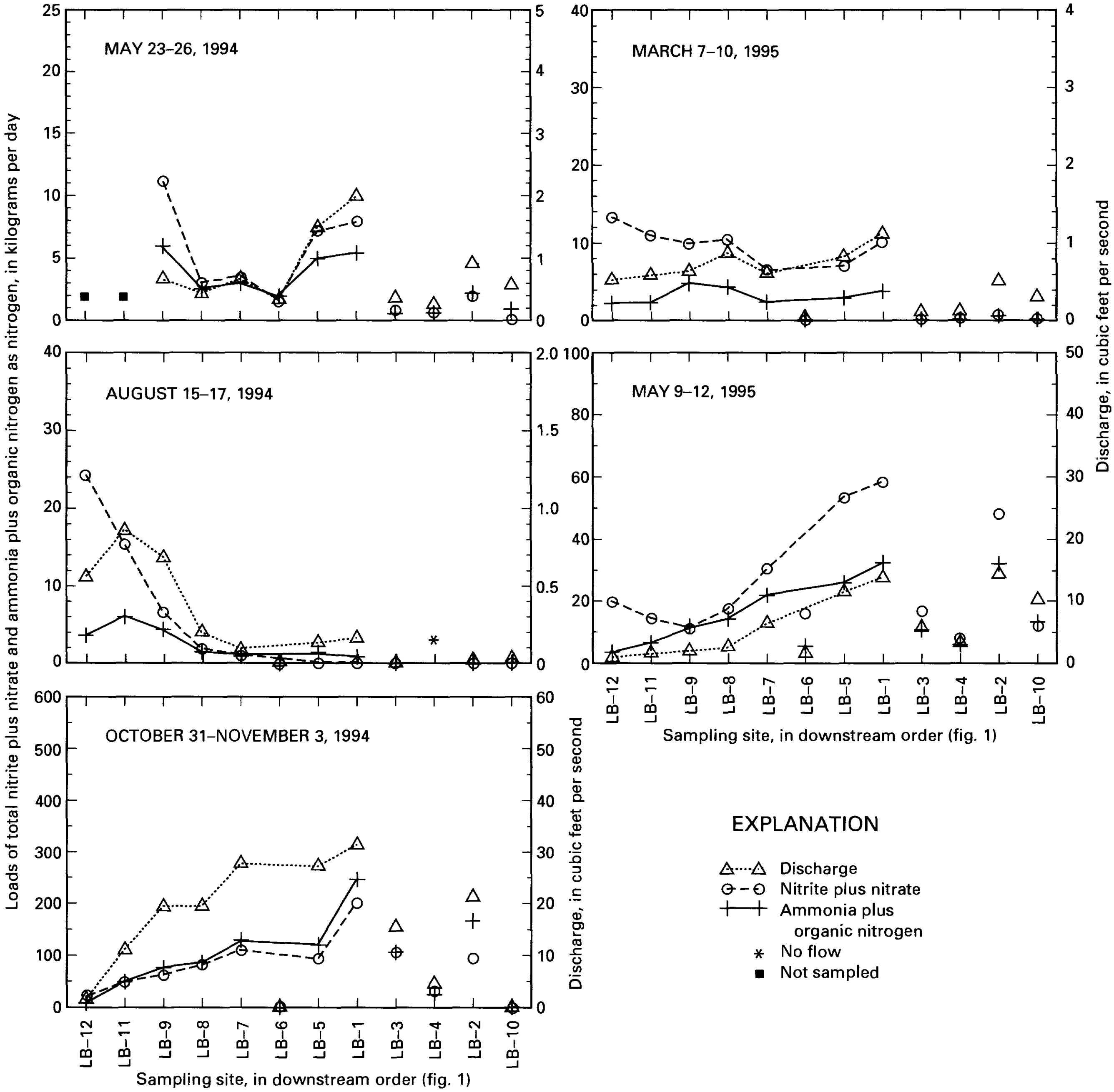


Figure 21. Stream discharge and loads of total nitrite plus nitrate and ammonia plus organic nitrogen as nitrogen in Little Bull Creek (LB) subbasin, May 1994–May 1995.

number of low-flow days for the outlet sites in the Wade Branch (site WB–1) and Smith Branch (SM–1) subbasins because continuous streamflow data were not collected. To include the Wade Branch and Smith Branch subbasins in this analysis, it was assumed that the low flow occurred every day during the study period. Therefore, annual low-flow total phosphorus loads for each subbasin were computed by multiplying the mean low-flow total phosphorus load (table 3) by 365 days. Distribution of the total phosphorus load over the entire drainage area for each subbasin (transport rate) can be computed by dividing the estimated annual low-flow phosphorus load by the drainage area (in hectares). Results of these computations are summarized in table 4.

The annual low-flow phosphorus load analysis indicates that the Big Bull Creek subbasin, which includes drainage from the Martin Creek subbasin, contributed the largest annual low-flow phosphorus load, 2,740 kg/yr (table 4). The remaining subbasins contributed far less annual phosphorus load during low flow (table 4). In fact, the Little Bull Creek subbasin and the Rock Creek subbasin, a subbasin not affected by point sources, had similar annual low-flow phosphorus loads. The point sources in the Little Bull Creek subbasin appeared to have less effect on phosphorus loads than those point sources in the Big Bull Creek subbasin. Comparison of the load per hectare (transport rate) for each subbasin also shows that the Big Bull Creek subbasin had the largest phosphorus contribution per unit drainage area. Wade Branch subbasin, a subbasin with no point sources of total phosphorus, had the second largest transport rate, 0.12 (kg/ha)/yr. This indicates the presence of nonpoint-source contributions of total phosphorus in the subbasin.

OCCURRENCE OF TRIAZINE HERBICIDES

Triazine herbicides are commonly used in agricultural areas to control weeds on cropland. The MCL for atrazine in drinking water is an annual mean of 3.0 μg/L. On the basis of GC/MS analyses, the dominant triazine herbicide found in the Hillsdale Lake Basin was atrazine. The largest mean triazine herbicide concentrations were found in water samples collected during May 1994 and May 1995 because herbicide application occurred just prior to these periods. Figures 22 and 23 show triazine herbicide concentrations at selected sites during May 1994 and May 1995. Triazine herbicide concentrations generally were small during the August 1994, November 1994, and March 1995 sampling periods. Mean triazine herbicide concentrations in all of the subbasins are summarized in table 5.

Table 4. Estimated mean annual low-flow total phosphorus loads in water from subbasin outlet sampling sites in Hillsdale Lake Basin, northeast Kansas, May 1994–March 1995

[Units of measurement: kg/yr, kilograms per year; ha, hectares; (kg/ha)/yr, kilograms per hectare]

Subbasin (fig. 1)	Estimated annual low-flow total phosphorus load (kg/yr)	Drainage area (ha)	Total phosphorus transport rate (kg/ha)/yr
Big Bull Creek[1] (site BB–1)	2,740	7,430	0.37
Rock Creek (site RC–1)	175	4,090	.04
Little Bull Creek[2] (site LB–1)	161	2,280	.07
Wade Branch (site WB–1)	234	1,970	.12
Smith Branch (site SM–1)	22	570	.04

[1]Includes Martin Creek subbasin drainage.

[2]Runoff-affected samples collected during November 1994 from the Little Bull Creek subbasin are not included.

Big Bull Creek and Martin Creek Subbasins

Graphs of triazine herbicide concentrations in the Big Bull Creek subbasin are shown in figure 24. Triazine herbicide concentrations in water samples collected from this subbasin ranged from less than 0.10 μg/L (site BB–4 during November 1994 and sites MC–4, MC–3, BB–4, BB–3, and BB–2 during March 1995) to 15 μg/L (site BB–11 during May 1994). During May 1994, 10 of 17 sites sampled had triazine herbicide concentrations larger than the MCL for atrazine, annual mean of 3.0 μg/L. Triazine herbicide concentrations in water at all sites during November 1994 and March 1995 were less than the MCL. During the May 1995 sampling period, 7 of the 19 sites sampled had triazine herbicide concentrations larger than the MCL.

Rock Creek Subbasin

Triazine herbicide concentrations for the Rock Creek subbasin are shown in figure 25. There was no flow at all of the sampling sites during the August 1994 sampling period. Triazine herbicide concentrations in water samples collected from this subbasin ranged from less than 0.10 μg/L (sites RC–5 and RC–2 during March 1995) to 8.2 μg/L at site RC–5 during May 1995. The largest herbicide concentrations were detected in samples collected during May 1994 and May 1995. During May 1994, five of six sites sampled had triazine herbicide concentrations larger than the MCL for atrazine, annual mean of 3.0 μg/L. Analyses of samples collected during November 1994 and March 1995 show that all sites had triazine herbicide concentrations less than the MCL. During May 1995,

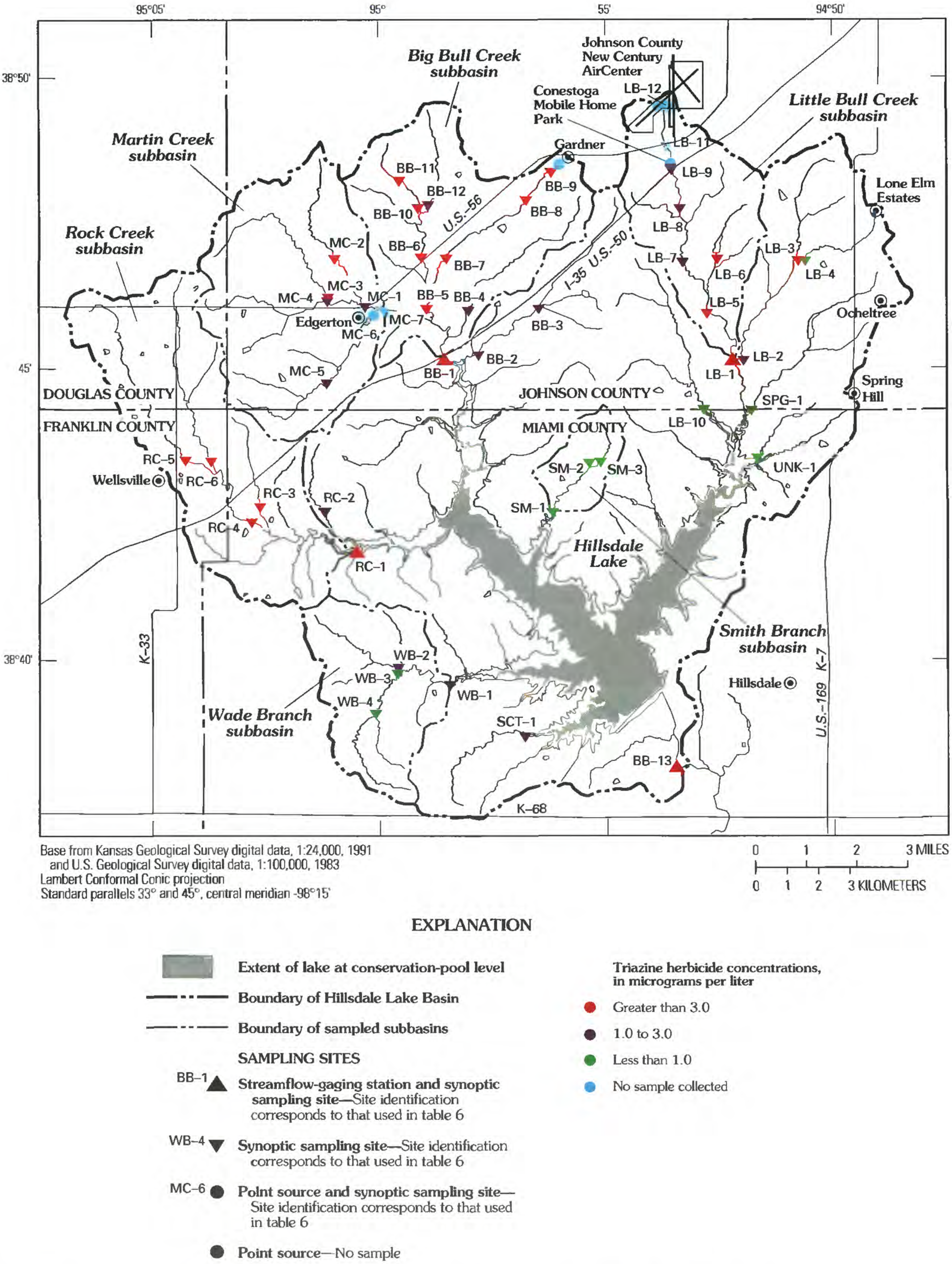


Figure 22. Concentrations of triazine herbicides at selected sampling sites, May 23–26, 1994.

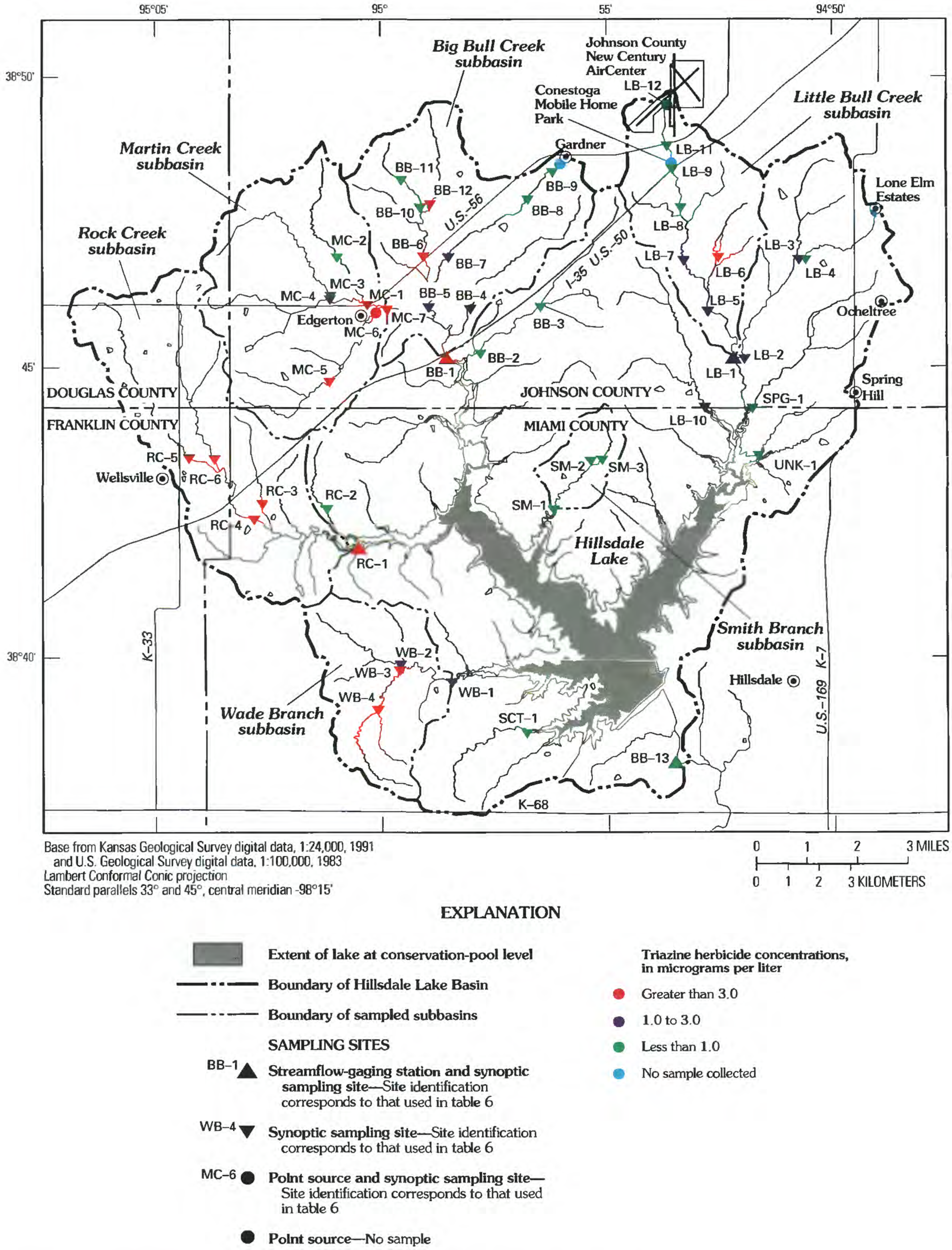


Figure 23. Concentrations of triazine herbicides at selected sampling sites, May 9–12, 1995.

Table 5. Mean concentrations of triazine herbicides in water samples collected from Hillsdale Lake Basin, northeast Kansas, May 1994–May 1995

[Values are mean triazine herbicide concentrations in micrograms per liter. <, less than]

Sampling period	Subbasin (fig. 1)				
	Big Bull Creek[1]	Rock Creek	Little Bull Creek	Wade Branch	Smith Branch
May 1994	4.5	6.4	3.1	1.2	0.44
August 1994	2.3	(2)	1.9	(2)	(2)
November 1994	.72	.22	.52	1.6	.16
March 1995	.50	.16	.98	<.10	<.10
May 1995	3.0	4.4	1.6	3.2	<.10

[1]Includes Martin Creek subbasin drainage.
[2]No flow during sampling.

five of six sites sampled had concentrations of triazine herbicide in water larger than the MCL. Rock Creek subbasin had the largest mean triazine herbicide concentrations during May 1994 and May 1995 (see table 5).

Little Bull Creek Subbasin

Triazine herbicide concentrations in water samples collected from the Little Bull Creek subbasin are shown in figure 26. Triazine herbicide concentrations in water samples collected from this subbasin ranged from 0.10 μg/L at sites LB–6 and LB–10 during November 1994 to 8.7 μg/L at site LB–6 during May 1994. During May 1994, 4 of 10 sites sampled in the Little Bull Creek subbasin had triazine herbicide concentrations larger than the MCL for atrazine, annual mean of 3.0 μg/L. Only 1 of 11 sites sampled during August 1994 had triazine herbicide concentrations larger than the MCL. Water samples analyzed for the November 1994 and March 1995 sampling periods had no triazine herbicide concentrations larger than the MCL. During May 1995, only 1 of 12 sites sampled had triazine herbicide concentrations larger than the MCL.

Wade Branch and Smith Branch Subbasins

Triazine herbicide concentrations for the Wade Branch subbasin are shown in figure 27. There was no flow in the Wade Branch subbasin during the August 1994 sampling period. Triazine herbicide concentrations in water samples collected from this subbasin ranged from less than 0.10 μg/L at all sites during March 1995 to 4.8 μg/L at site WB–4 during May 1995. Water samples collected during May 1994 and March 1995 had triazine herbicide concentrations less than the MCL for atrazine, annual mean of 3.0 μg/L. During November 1994, one of four sites sampled had triazine herbicide concentrations larger than the MCL, and during May 1995, two of four sites had triazine herbicide concentrations larger than the MCL. Analyses from samples collected at all sites in the Smith Branch subbasin show that all water samples had triazine herbicide concentrations less than the 3.0-μg/L MCL for atrazine.

Miscellaneous Sampling Sites

Water samples for the determination of triazine herbicide concentrations were collected downstream from Hillsdale Lake at site BB–13 (fig. 1). This site is located 1,850 feet downstream from Hillsdale Dam, and it is assumed that samples collected at this site are representative of water from Hillsdale Lake. Triazine herbicide concentrations in water samples collected at this site exceeded the value of the MCL for atrazine not only during May 1994 but also during August 1994 and March 1995 (fig. 28). The triazine herbicide concentration in water from site BB–13 during November 1994 was 2.6 μg/L. These data show that herbicides were transported to Hillsdale Lake and may remain at concentrations larger than the value of the MCL throughout the year.

Samples for triazine herbicide analysis also were collected at sites SPG–1, UNK–1, and SCT–1 (fig. 1). These sites all had concentrations less than the value of the MCL for atrazine in water. The largest triazine herbicide concentration, 2.4 μg/L, was found in samples collected from site SCT–1 during May 1994.

Triazine herbicide concentration data collected for this study should only be used as a guide for indicating problem areas in the Hillsdale Lake Basin. Triazine herbicide loads are not presented because the loads were very small. For example, using equation 1 and an appropriate conversion factor for concentration, the daily triazine herbicide load at site BB–12 (uppermost sampling site in Big Bull Creek subbasin) during March 1995 was 0.002 kg/d. The triazine herbicide concentration for this sample was 15.0 μg/L, one of the

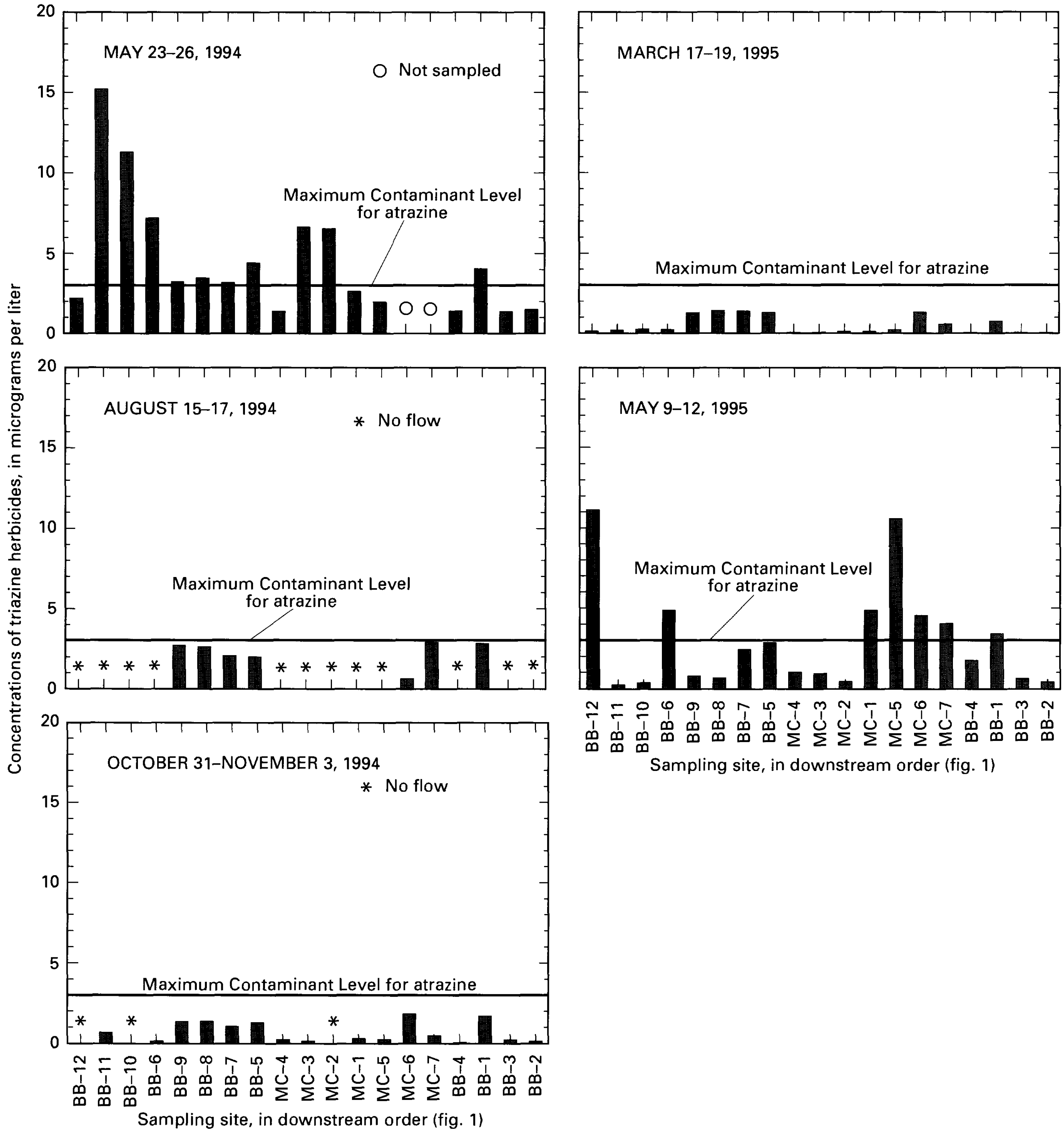


Figure 24. Concentrations of triazine herbicides in Big Bull Creek (BB) and Martin Creek (MC) subbasins, May 1994–May 1995.

largest concentrations of all samples collected. The triazine herbicide load at the outlet site of Big Bull Creek subbasin, site BB–1, during March 1995 was 0.06 kg/d. It can be assumed that transport of herbicides into Hillsdale Lake was minor during low flow.

SUMMARY AND CONCLUSIONS

An investigation of the occurrence of phosphorus, other nutrients, and triazine herbicides in water samples from the Hillsdale Lake Basin in northeast Kansas was conducted from May 1994 through May 1995.

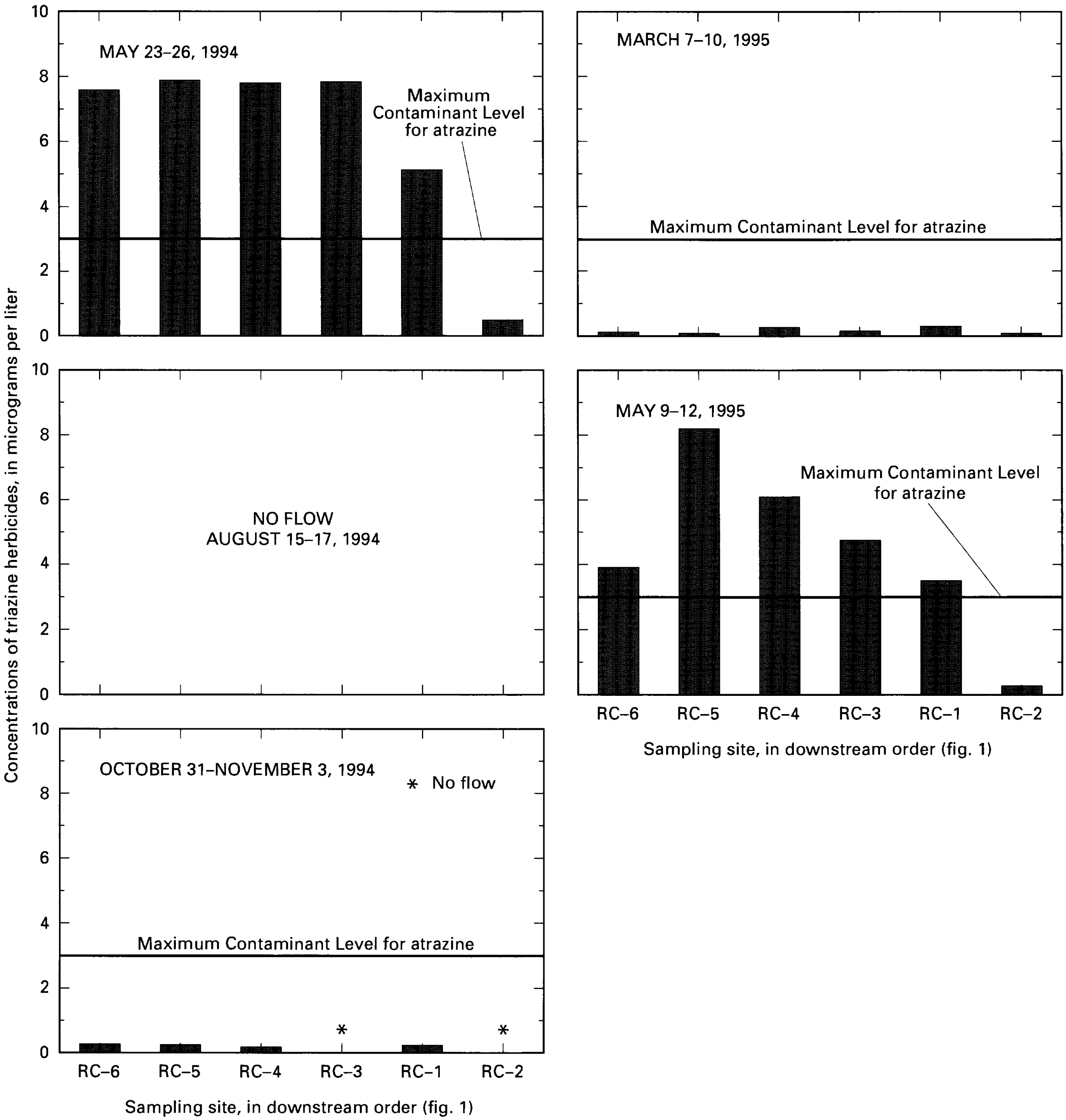


Figure 25. Concentrations of triazine herbicides in Rock Creek (RC) subbasin, May 1994–May 1995.

Point-source and nonpoint-source contributions of the water-quality constituents were estimated by conducting synoptic sampling at 48 sites in the basin during five low-flow periods. Samples for the determination of nutrients, including total phosphorus as phosphorus, dissolved orthophosphate as phosphorus, total nitrite plus nitrate as nitrogen, and total ammonia plus organic nitrogen as nitrogen, and for triazine herbicides were collected.

Discussed in this report were results of constituent concentrations and loads for samples collected during low flow. Low flow occurred during many days in the Hillsdale Basin but accounted for only a small percentage of total flow for the year. Therefore, contributions of constituent loads to Hillsdale Lake are probably

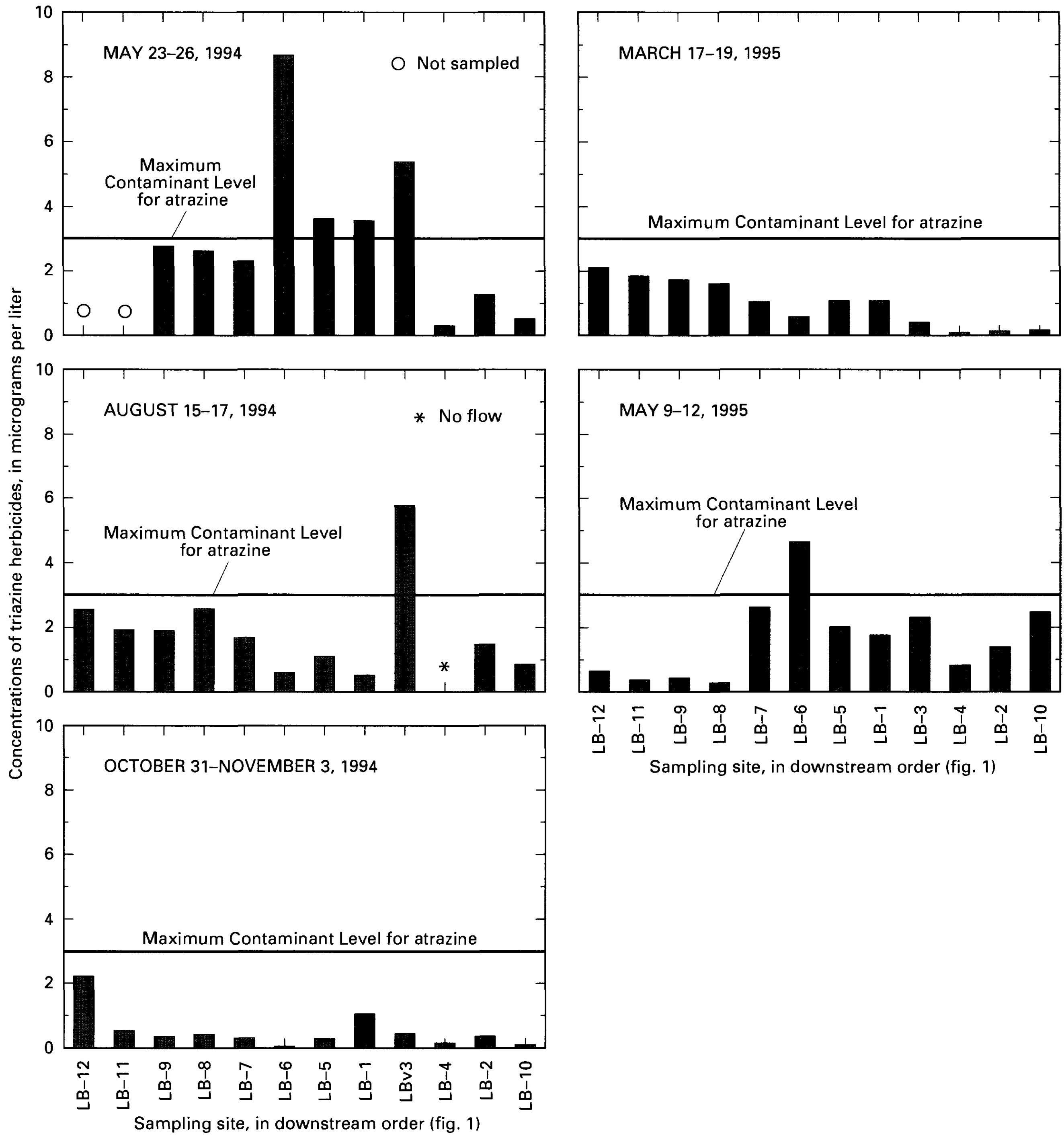


Figure 26. Concentrations of triazine herbicides in Little Bull Creek (LB) subbasin, May 1994–May 1995.

minimal during low flow compared to loads contributed during runoff-affected periods.

Total phosphorus concentrations routinely exceeded the 0.05-mg/L annual low-flow criterion proposed by the Hillsdale Water-Quality Protection Project. Of the 44 sites sampled during low flow, 95 percent of the sites had low-flow total phosphorus concentrations larger than the 0.05-mg/L criterion. In fact, nearly 32 percent of the sites sampled during low flow had mean low-flow total phosphorus concentrations larger than the criterion established for runoff mean concentration, 0.40 mg/L. The largest mean low-flow total phosphorus concentration occurred at site BB–9 in the Big Bull Creek subbasin, 4.9 mg/L.

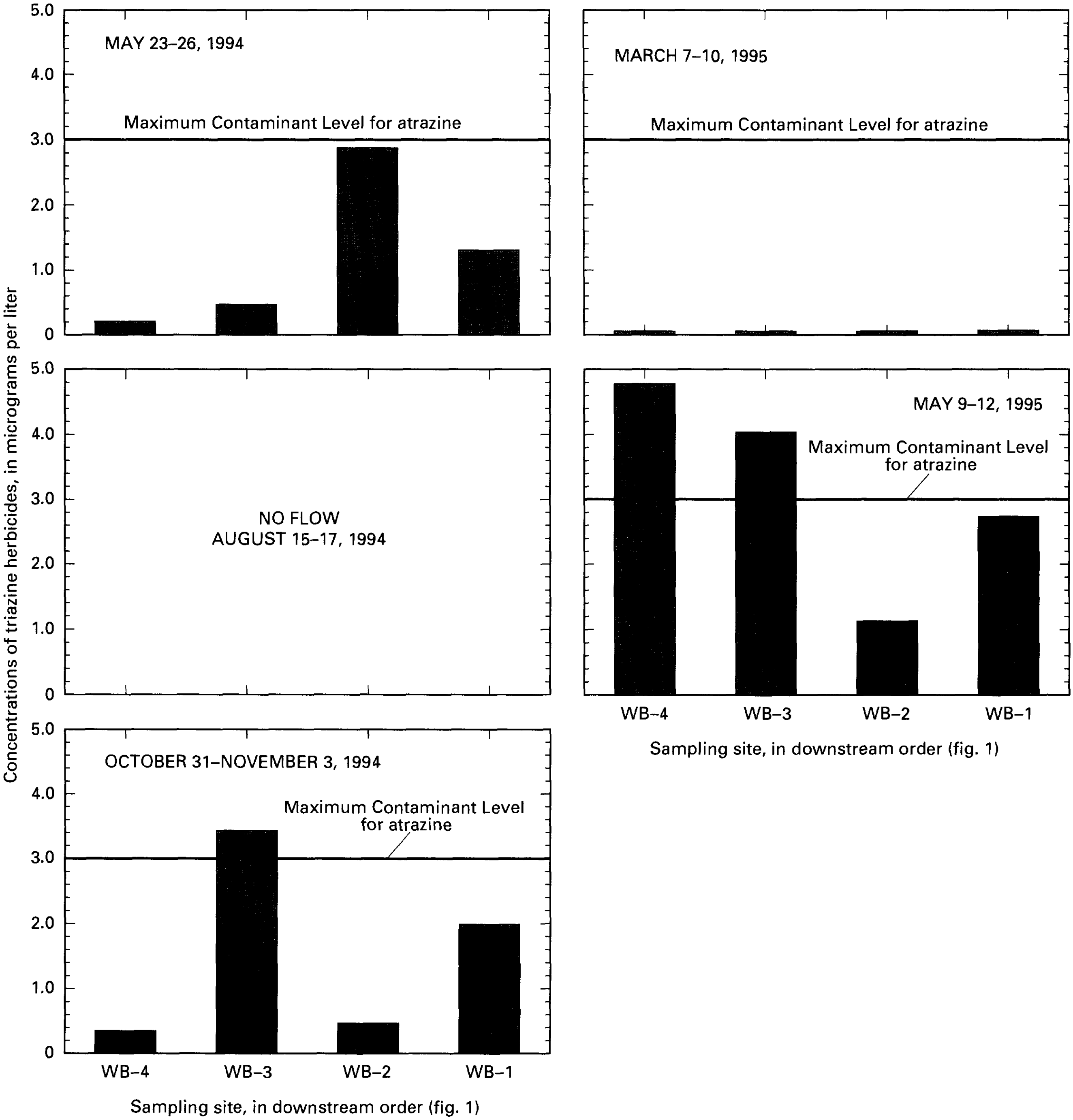


Figure 27. Concentrations of triazine herbicides in Wade Branch (WB) subbasin, May 1994–May 1995.

Total phosphorus concentrations in the Rock Creek, Wade Branch, and Smith Branch subbasins were small; however, nearly all water samples collected in these subbasins had total phosphorus concentrations larger than the 0.05-mg/L criterion. Methods and techniques for managing the nonpoint sources of nutrients will need to be considered in order to achieve the total phosphorus criterion proposed by the Hillsdale Water-Quality Protection Project.

There appeared to be no significant seasonal variations in nutrient concentrations among subbasins, except during periods of very low flow. In the Big Bull Creek subbasin, the largest median total phosphorus concentrations occurred during August 1994. During this low-flow period, many of the tributaries in the non-

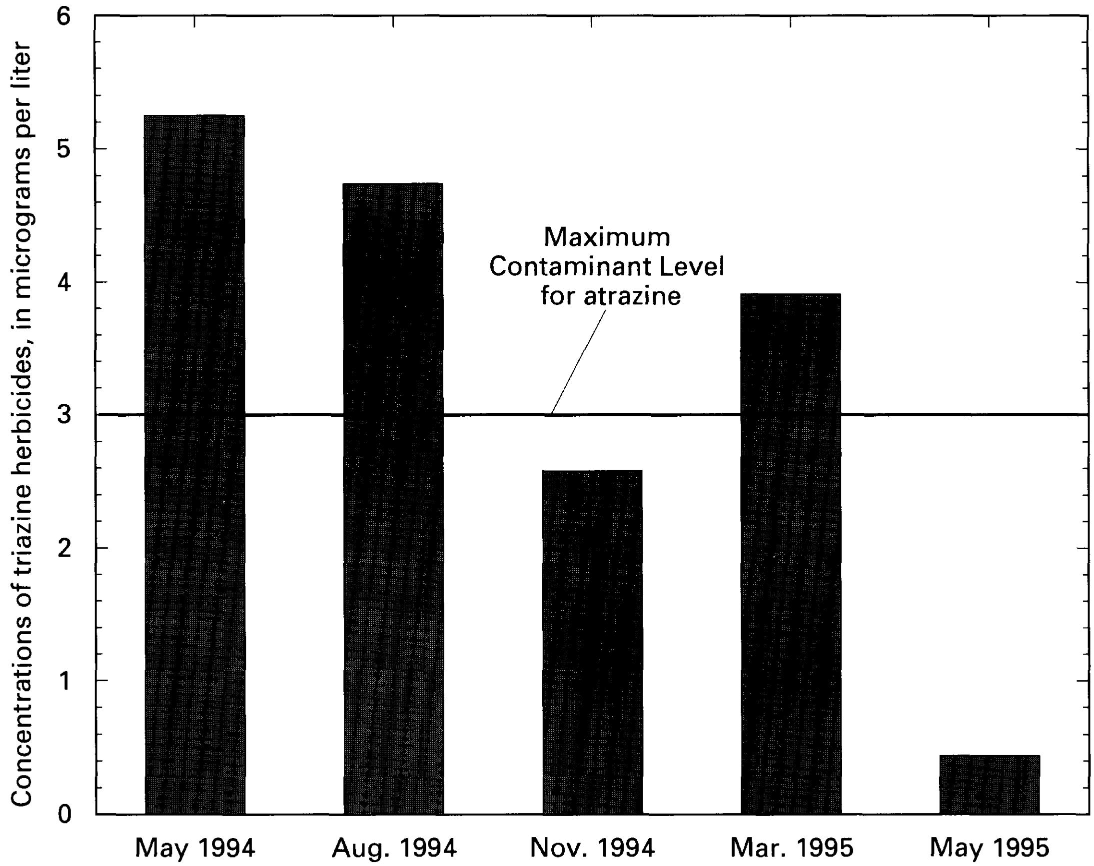


Figure 28. Concentrations of triazine herbicides at sampling site BB–13, located downstream from Hillsdale Dam, May 1994–May 1995.

point-source subbasin were not flowing. As the non-point-source tributaries dry up, the point sources dominate the stream system, resulting in larger total phosphorus concentrations.

The Big Bull Creek subbasin had the largest mean total phosphorus, nitrite plus nitrate, and total ammonia loads. The mean low-flow total phosphorus load for all sampling periods at the Big Bull Creek outlet site (site BB–1) was 7.5 kg/d. Mean low-flow total phosphorus loads in the Rock Creek, Little Bull Creek, Wade Branch, and Smith Branch subbasins were less than 1.0 kg/d. Because of the absence of point-source discharges, it is believed that nutrients in the Rock Creek, Wade Branch, and Smith Branch subbasins were contributed by nonpoint sources. Runoff can cause substantial increases in nutrient loads in the subbasins, and at times, sites not affected by point-source discharges had nutrient loads greater than those affected by point-source discharges.

Annual low-flow phosphorus load analysis indicated that the Big Bull Creek subbasin, which includes drainage from the Martin Creek subbasin, contributes the largest annual low-flow phosphorus load, 2,740 kg/yr. The remaining subbasins contribute far less annual phosphorus load during low flow. The Little Bull Creek subbasin and the Wade Branch subbasin, a subbasin not affected by point-source discharges, had similar annual low-flow phosphorus loads, 161 and 175 kg/yr, respectively. Point-source discharges appeared to have less effect on phosphorus loads in the Little Bull Creek subbasin than in the Big Bull Creek subbasin. Comparison of the total phosphorus transport rate (kilograms per hectare per year) for each subbasin showed that the Big Bull Creek subbasin had the largest phosphorus contribution per unit drainage area, 0.37 (kg/ha)/yr. Wade Branch subbasin, a subbasin with no point sources, had the second largest transport rate, 0.12 (kg/ha)/yr. This indicates the presence of nonpoint-source contributions of total phosphorus in this subbasin.

The largest mean triazine herbicide concentrations in water samples occurred during the May 1994 and 1995 sampling periods because herbicides were applied prior to these periods. During May 1994, 10 of the 17 sites sampled in the Big Bull Creek subbasin had triazine herbicide concentrations larger than the MCL for atrazine (annual mean of 3.0 μg/L). In the Rock Creek subbasin, five of the six sites sampled during May 1994 had triazine herbicide concentrations larger than the MCL for atrazine. In the Little Bull Creek subbasin, 4 of the 10 sites sampled during May 1994 had triazine herbicide concentrations larger than the MCL. During May 1995, 7 of 19 sites sampled in the Big Bull Creek subbasin had triazine herbicide concentrations larger than the MCL for atrazine. The Rock Creek subbasin had triazine herbicide concentrations larger than the MCL in water from five of the six sites sampled during May 1995. In the Little Bull Creek subbasin, 1 of the 12 sites sampled during May 1995 had triazine herbicide concentrations larger than the MCL for atrazine, and the Wade Branch subbasin had concentrations larger than the MCL at two of the four sites sampled. Water samples collected during May 1994 and May 1995 in the Rock Creek subbasin had the largest mean triazine herbicide concentrations.

Water samples for determination of triazine herbicides also were collected at site BB–13, located downstream from Hillsdale Dam. Triazine herbicide concentrations in water samples collected at this site exceeded the MCL not only during May 1994 but also during August 1994 and March 1995. The triazine herbicide concentration in water from this site during November 1994 was 2.6 μg/L. The lake appears to store the herbicides, and it takes some time for the herbicides to move through the lake. The data show that herbicides are transported to Hillsdale Lake and remained at concentrations larger than the MCL throughout the year.

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Table 6. Results of chemical analyses of water samples collected from the Hillsdale Lake Basin, northeast Kansas, May 1994–May 1995

[ft^3/s, cubic foot per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mm, millimeters; Hg, mercury; mg/L, milligrams per liter; µm, micrometer; ELISA, enzyme-linked immunosorbent assay; µg/L, microgram per liter; herbicides filtered through 0.70-µm glass-fiber filters; --, no data; dup, duplicate sample; <, less than; number in parentheses is U.S. Geological Survey WATSTORE parameter code]

Downstream order and map reference number (fig. 1)	U.S. Geological Survey identification number	Date (month-day-year)	Time (24-hour)	Discharge, instantaneous (ft^3/s) (00061)	Specific conductance (µS/cm) (00095)	Field pH (standard units) (00400)	Temperature, water (°C) (00010)	Barometric pressure (mm of Hg) (00025)	Oxygen, dissolved (mg/L) (00300)
			Big Bull and Martin Creek subbasins						
BB–12	384750094585500	05–24–94	1055	0.02	407	7.4	23.0	733	4.3
		08–16–94	0930	NO FLOW	--	--	--	--	--
		11–01–94	---	NO FLOW	--	--	--	--	--
		03–07–95	1510	.06	390	7.9	2.5	750	15.0
		05–10–95	1105	.40	330	7.0	14.5	731	6.2
BB–11	384815094593300	05–24–94	1140	<.01	687	7.6	9.5	733	3.5
		08–16–94	0935	NO FLOW	--	--	--	--	--
		11–01–94	1255	.03	397	7.2	12.0	734	7.1
		03–07–95	1445	.04	760	7.6	2.5	750	14.5
		05–10–95	1025	.20	473	7.1	14.0	731	8.2
BB–10	384747094590800	05–24–94	1115	<.01	571	7.7	18.0	733	5.0
		08–16–94	0940	NO FLOW	--	--	--	--	--
		11–01–94	1145	NO FLOW	--	--	--	--	--
		03–07–95	1525	.06	570	7.7	2.5	750	14.4
		05–10–95	1050	.12	401	7.4	14.0	731	8.6
BB–6	384656094590400	05–24–94	1245	.10	540	7.2	21.0	733	7.2
		08–16–94	1355	NO FLOW	--	--	--	--	--
		11–01–94	1140	.11	660	8.1	13.0	745	10.7
		03–08–95	1005	.08	473	7.9	1.5	759	15.2
		05–10–95	1000	1.53	384	7.2	15.0	731	7.4

Table 6. Results of chemical analyses of water samples collected from the Hillsdale Lake Basin, northeast Kansas, May 1994–May 1995—Continued

Down-stream order and map reference number (fig. 1)	U.S. Geological Survey identification number	Date (month-day-year)	Time (24-hour)	Discharge, instan-taneous (ft^3/s) (00061)	Specific conduct-ance (µS/cm) (00095)	Field pH (standard units) (00400)	Temp-erature, water (°C) (00010)	Baro-metric pressure (mm of Hg) (00025)	Oxygen, dissolved (mg/L) (00300)
Big Bull and Martin Creek subbasins—Continued									
BB–9	384823094561200	05–24–94	1025	0.64	911	7.1	19.0	733	3.1
		08–16–94	1350	.52	972	7.1	22.5	738	2.3
		11–01–94	1000	.97	794	7.4	16.5	745	4.2
		03–08–95	1520	.68	1,170	7.3	10.0	755	4.6
		05–10–95	0920	1.50	810	7.0	15.0	731	4.1
BB–8	384753094564600	05–24–94	1000	.93	905	7.4	19.0	733	3.9
		08–16–94	1250	.63	884	7.4	23.0	738	3.6
		11–01–94	1040	.90	818	7.7	15.0	745	4.0
		03–08–95	1500	.65	975	7.6	10.0	755	6.2
		05–10–95	0940	1.23	769	7.2	14.0	731	5.3
BB–7	384652094583000	05–24–94	1255	.67	836	7.6	23.0	735	5.5
		08–16–94	1315	.42	890	7.5	22.0	738	7.1
		11–01–94	1100	.90	561	7.7	10.0	745	8.1
		03–08–95	1030	.52	1,230	7.7	1.0	759	13.8
		05–10–95	1400	2.10	613	7.4	14.0	736	8.7
BB–5	384603094585700	05–24–94	1315	1.03	743	7.5	22.0	735	5.1
		08–16–94	1420	.20	920	7.6	24.5	738	3.3
		11–01–94	1510	1.11	609	7.4	10.0	735	7.1
		03–08–95	1110	.67	928	8.1	1.0	759	14.5
		05–10–95	1455	4.92	517	7.3	15.0	736	8.1
MC–4	384612095010900	05–25–94	1215	.08	310	8.4	27.5	730	10.7
		08–16–94	0915	NO FLOW	--	--	--	--	--
		11–02–94	0905	.11	279	7.2	8.5	728	5.9
		03–07–95	1230	.31	483	7.6	1.5	750	13.8
		05–10–95	1520	1.71	237	7.5	16.0	736	9.8

Table 6. Results of chemical analyses of water samples collected from the Hillsdale Lake Basin, northeast Kansas, May 1994–May 1995—Continued

Down-stream order and map reference number (fig. 1)	U.S. Geological Survey identification number	Date (month-day-year)	Time (24-hour)	Discharge, instantaneous (ft^3/s) (00061)	Specific conductance (µS/cm) (00095)	Field pH (standard units) (00400)	Temperature, water (°C) (00010)	Barometric pressure (mm of Hg) (00025)	Oxygen, dissolved (mg/L) (00300)
			Big Bull and Martin Creek subbasins—Continued						
MC–3	384615095010800	05–25–94	1200	0.04	551	7.7	25.5	730	7.0
		08–16–94	0920	NO FLOW	--	--	--	--	--
		11–02–94	0930	.13	294	7.2	9.5	728	7.9
		03–07–95	1250	.44	432	7.8	1.0	750	14.5
		05–10–95	1540	.68	296	7.3	15.5	736	9.0
MC–2	384655095005900	05–25–94	1020	<.01	670	7.2	20.5	730	7.5
		08–16–94	0925	NO FLOW	--	--	--	--	--
		11–02–94	--	NO FLOW	--	--	--	--	--
		03–07–95	1350	.08	555	7.9	2.0	750	14.6
		05–10–95	1555	.21	209	7.3	15.5	736	9.0
MC–1	384605095001900	05–25–94	1015	.23	540	7.5	21.5	730	8.0
		08–16–94	1015	NO FLOW	--	--	--	--	--
		11–02–94	1005	.20	376	7.4	10.0	728	5.6
		03–07–95	1150	.67	535	7.6	1.5	750	15.3
		05–11–95	0905	3.04	342	7.1	13.5	737	8.6
MC–5	384446095011000	05–25–94	1100	.04	312	7.4	22.5	730	9.1
		08–16–94	1000	NO FLOW	--	--	--	--	--
		11–02–94	1105	<.01	473	7.6	13.5	730	6.4
		03–07–95	1415	.05	392	7.8	1.5	750	15.5
		05–11–95	0935	.50	249	7.3	14.0	737	10.4
MC–6	384600094595300	08–16–94	1030	.11	1,140	7.1	22.5	738	5.2
		11–02–94	0945	.29	940	7.1	13.0	728	4.9
		03–07–95	1030	.50	488	7.5	2.5	750	12.8
		05–11–95	1015	2.76	313	7.1	16.5	737	7.8

Table 6. Results of chemical analyses of water samples collected from the Hillsdale Lake Basin, northeast Kansas, May 1994–May 1995—Continued

Downstream order and map reference number (fig. 1)	U.S. Geological Survey identification number	Date (month-day-year)	Time (24-hour)	Discharge, instantaneous (ft^3/s) (00061)	Specific conductance (µS/cm) (00095)	Field pH (standard units) (00400)	Temperature, water (°C) (00010)	Barometric pressure (mm of Hg) (00025)	Oxygen, dissolved (mg/L) (00300)
			Big Bull and Martin Creek subbasins—Continued						
MC–7	384557095000800	08–16–94	1100	0.18	867	7.5	23.5	738	7.2
		11–02–94	1020	.77	630	7.3	10.0	728	5.4
		03–07–95	1130	1.20	673	7.4	2.0	--	13.3
		05–11–95	0935	6.84	357	7.0	14.5	737	7.6
BB–4	384601094580200	05–24–94	1355	.31	487	7.8	24.0	735	7.6
		08–16–94	1210	NO FLOW	--	--	--	--	--
		11–01–94	1340	.04	433	7.5	13.0	735	8.6
		03–08–95	1140	.12	534	7.7	2.0	759	17.2
		05–10–95	1435	1.49	422	7.4	14.0	736	10.6
BB–1	06914950	05–25–94	0915	2.37	596	7.2	21.0	730	6.4
		dup	0930	2.37	596	7.2	21.0	730	6.4
		08–16–94	1520	.20	495	7.7	25.5	738	6.4
		dup	1525	.20	495	7.7	25.5	738	6.4
		11–01–94	1540	4.89	878	7.7	10.0	734	7.2
		03–08–95	1405	1.68	793	8.3	3.0	756	16.0
		dup	1410	1.68	793	8.3	3.0	756	16.0
		05–10–95	1145	16.2	412	7.1	15.5	731	7.6
		dup	1150	16.2	412	7.1	15.5	731	7.6
BB–3	384600094563000	05–24–94	1410	.32	551	7.9	23.5	735	9.1

Table 6. Results of chemical analyses of water samples collected from the Hillsdale Lake Basin, northeast Kansas, May 1994–May 1995—Continued

Downstream order and map reference number (fig. 1)	U.S. Geological Survey identification number	Date (month-day-year)	Time (24-hour)	Discharge, instantaneous (ft^3/s) (00061)	Specific conductance (µS/cm) (00095)	Field pH (standard units) (00400)	Temperature, water (°C) (00010)	Barometric pressure (mm of Hg) (00025)	Oxygen, dissolved (mg/L) (00300)
				Big Bull and Martin Creek subbasins—Continued					
BB–3	384600094563000	08–16–94	1245	NO FLOW	--	--	--	--	--
		11–01–94	1400	0.15	480	7.9	11.5	735	9.7
		03–08–95	1210	.13	1,000	7.7	2.5	758	15.0
		05–10–95	1320	3.40	443	7.5	14.0	731	10.1
BB–2	384515094574900	05–24–94	1435	.79	542	7.9	23.0	735	7.9
		08–16–94	1255	NO FLOW	--	--	--	--	--
		11–01–94	1420	.50	494	7.9	10.5	735	7.4
		dup	1445	.50	494	7.9	10.5	735	7.4
		03–08–95	1230	.40	637	8.0	2.0	758	16.0
		05–10–95	1255	4.97	456	7.4	14.0	736	9.5
BB–13	06915000	05–26–94	1340	908	287	7.5	17.0	732	11.0
		08–17–94	1010	24.2	287	7.3	25.5	740	6.3
		11–03–94	1125	5.66	256	8.0	14.5	736	8.7
		03–10–95	1315	16	293	7.9	7.0	--	13.2
		05–12–95	1105	1.84	298	7.1	14.5	734	7.1
				Rock Creek subbasin					
RC–6	384326095034300	05–25–94	1515	.05	390	6.9	21.0	732	4.8
		08–16–94	1540	NO FLOW	--	--	--	--	--
		11–02–94	1300	.13	252	7.3	11.0	730	4.6
		03–10–95	0910	.18	467	7.7	1.0	747	12.6
		05–11–95	1140	1.10	219	7.0	13.5	737	9.0

Table 6. Results of chemical analyses of water samples collected from the Hillsdale Lake Basin, northeast Kansas, May 1994–May 1995—Continued

Downstream order and map reference number (fig. 1)	U.S. Geological Survey identification number	Date (month-day-year)	Time (24-hour)	Discharge, instantaneous (ft^3/s) (00061)	Specific conductance (µS/cm) (00095)	Field pH (standard units) (00400)	Temperature, water (°C) (00010)	Barometric pressure (mm of Hg) (00025)	Oxygen, dissolved (mg/L) (00300)
			Rock Creek subbasin—Continued						
RC–5	384327095041300	05–25–94	1520	0.15	299	6.8	20.5	732	5.4
		08–16–94	1545	NO FLOW	--	--	--	--	--
		11–02–94	1315	.35	215	7.6	11.0	730	7.7
		03–10–95	0930	.18	382	7.7	1.0	747	12.4
		05–11–95	1130	1.42	215	7.2	14.0	737	9.5
RC–4	384223095025000	05–25–94	1630	.30	402	7.9	26.5	732	10.8
		08–16–94	1550	NO FLOW	--	--	--	--	--
		11–02–94	1135	.25	278	7.7	11.0	730	7.6
		03–10–95	1025	.34	480	7.9	5.0	747	13.5
		05–11–95	1105	3.47	277	7.2	14.5	737	8.7
RC–3	384232095024100	05–25–94	1610	<.01	546	7.3	31.5	732	.80
		08–16–94	1555	NO FLOW	--	--	--	--	--
		11–02–94	--	NO FLOW	--	--	--	--	--
		03–10–95	1045	<.01	350	7.6	2.0	757	14.6
		05–11–95	1200	.17	392	7.4	15.5	737	11.3
RC–1	06914960	05–25–94	1305	.92	486	7.6	21.5	733	8.5
		dup	1310	.92	486	7.6	21.5	733	8.5
		08–16–94	1605	NO FLOW	--	--	--	--	--
		11–02–94	1345	1.34	339	7.8	10.0	730	7.6
		dup	1350	1.34	339	7.8	10.0	730	7.6
		03–10–95	1000	.34	525	7.7	2.5	747	12.9
		05–11–95	1255	7.15	370	7.4	14.5	737	9.6

Table 6. Results of chemical analyses of water samples collected from the Hillsdale Lake Basin, northeast Kansas, May 1994–May 1995—Continued

Down-stream order and map reference number (fig. 1)	U.S. Geological Survey identification number	Date (month-day-year)	Time (24-hour)	Discharge, instantaneous (ft^3/s) (00061)	Specific conductance (µS/cm) (00095)	Field pH (standard units) (00400)	Temperature, water (°C) (00010)	Barometric pressure (mm of Hg) (00025)	Oxygen, dissolved (mg/L) (00300)
				Rock Creek subbasin—Continued					
RC–2	384234095010600	05–25–94	1350	0.07	538	7.5	22.0	733	9.0
		08–16–94	1600	NO FLOW	--	--	--	--	--
		11–02–94	--	NO FLOW	--	--	--	--	--
		03–10–95	1055	.04	573	7.6	4.5	747	13.5
		05–11–95	1240	.57	491	7.5	15.5	737	10.7
				Little Bull Creek subbasin					
LB–12	384932094533900	08–15–94	1015	.56	2,160	7.7	28.5	739	11.2
		10–31–94	0925	1.50	2,210	7.8	20.5	740	9.2
		03–09–95	0930	.52	2,490	7.9	12.5	750	13.8
		05–09–95	0950	.93	1,030	7.5	18.0	731	9.9
LB–11	384850094534000	08–15–94	1040	.86	2,100	7.8	20.0	739	7.6
		10–31–94	1025	11.0	482	8.2	11.5	740	10.6
		03–09–95	1000	.58	2,480	8.0	2.0	750	16.4
		05–09–95	1010	1.63	671	7.5	16.0	671	8.7
LB–9	384826094533300	05–23–94	1705	.67	1,420	8.4	27.5	738	11.0
		08–15–94	1245	.68	1,990	8.7	21.0	739	7.2
		dup	1250	.68	1,990	8.7	21.0	739	7.2
		10–31–94	1055	19.3	383	8.2	10.0	740	10.9
		03–09–95	1030	.63	2,270	8.2	2.0	750	16.8
		dup	1035	.63	2,270	8.2	2.0	750	16.8
		05–09–95	1030	1.93	637	7.5	15.5	731	8.3
		dup	1250	1.93	652	7.6	17.5	730	8.5

Table 6. Results of chemical analyses of water samples collected from the Hillsdale Lake Basin, northeast Kansas, May 1994–May 1995—Continued

Down-stream order and map reference number (fig. 1)	U.S. Geological Survey identification number	Date (month-day-year)	Time (24-hour)	Discharge, instan-taneous (ft^3/s) (00061)	Specific conduct-ance (µS/cm) (00095)	Field pH (standard units) (00400)	Temp-erature, water (°C) (00010)	Baro-metric pressure (mm of Hg) (00025)	Oxygen, dissolved (mg/L) (00300)
			Little Bull Creek subbasin—Continued						
LB–8	384746094532200	05–23–94	1640	0.43	1,240	8.3	28.0	738	9.6
		08–15–94	1140	.20	1,680	8.0	22.5	739	9.7
		10–31–94	1225	19.4	379	8.4	10.5	740	10.1
		dup	1230	19.4	379	8.4	10.5	740	10.1
		03–09–95	1500	.86	2,130	8.8	5.0	750	24.5
		05–09–95	1140	2.60	580	7.4	17.0	731	8.9
LB–7	384651094531800	05–23–94	1530	.67	982	8.1	24.0	738	11.5
		08–15–94	1340	.09	1,610	8.4	21.5	742	9.4
		10–31–94	1320	27.7	350	8.2	10.0	740	9.5
		03–09–95	1520	.61	2,280	8.3	4.0	750	18.5
		05–09–95	1105	6.43	433	7.4	15.0	731	9.0
LB–6	384654094523200	05–23–94	1435	.34	221	7.5	24.5	738	6.5
		08–15–94	1355	.01	256	7.4	19.5	742	6.3
		10–31–94	1340	.01	427	7.3	10.5	740	8.2
		03–09–95	1535	.04	240	7.5	4.5	749	16.9
		05–09–95	1120	1.61	240	7.3	17.0	731	8.5
LB–5	384558094524600	05–23–94	1500	1.49	622	7.8	22.5	738	8.5
		08–15–94	1500	.13	870	8.6	26.0	739	11.0
		10–31–94	1505	27.2	356	8.0	11.0	740	9.9
		03–09–95	1630	.82	2,000	8.0	4.5	747	18.1
		05–09–95	1510	11.5	428	7.4	18.0	726	8.8

Table 6. Results of chemical analyses of water samples collected from the Hillsdale Lake Basin, northeast Kansas, May 1994–May 1995—Continued

Down-stream order and map reference number (fig. 1)	U.S. Geological Survey identification number	Date (month-day-year)	Time (24-hour)	Discharge, instantaneous (ft^3/s) (00061)	Specific conductance (µS/cm) (00095)	Field pH (standard units) (00400)	Temperature, water (°C) (00010)	Barometric pressure (mm of Hg) (00025)	Oxygen, dissolved (mg/L) (00300)
			Little Bull Creek subbasin—Continued						
LB–1	06914990	05–23–94	1140	1.99	536	7.4	20.0	740	6.1
		08–15–94	1545	.16	570	7.7	23.0	734	7.0
		10–31–94	1540	31.3	793	8.0	11.0	740	11.2
		03–09–95	1235	1.11	1,900	7.9	3.0	750	18.0
		05–09–95	1425	13.8	451	7.3	18.0	730	8.7
LB–3	384652094504500	05–23–94	1400	.36	444	7.8	21.0	740	9.3
		08–15–94	1415	<.01	397	7.4	18.5	739	5.9
		10–31–94	1415	15.4	210	7.8	10.0	740	10.1
		03–09–95	1340	.11	371	7.9	4.0	747	20.5
		05–09–95	1350	5.73	337	7.2	17.0	726	9.0
LB–4	384652094503600	05–23–94	1330	.26	514	7.6	21.0	740	6.7
		08–15–94	1005	NO FLOW	--	--	--	--	--
		10–31–94	1425	4.46	271	7.9	10.0	740	9.9
		03–09–95	1610	.12	720	7.7	3.5	747	19.7
		05–09–95	1405	3.28	376	7.3	17.0	726	8.7
LB–2	384509094515900	05–23–94	1130	.91	490	7.5	19.0	740	6.2
		08–15–94	1520	.02	525	7.5	21.5	739	5.9
		10–31–94	1555	21.2	371	8.0	11.0	740	10.4
		03–09–95	1245	.51	526	7.7	2.0	750	17.5
		05–09–95	1445	14.4	394	7.4	18.0	730	8.8

Table 6. Results of chemical analyses of water samples collected from the Hillsdale Lake Basin, northeast Kansas, May 1994–May 1995—Continued

Downstream order and map reference number (fig. 1)	U.S. Geological Survey identification number	Date (month-day-year)	Time (24-hour)	Discharge, instantaneous (ft^3/s) (00061)	Specific conductance (µS/cm) (00095)	Field pH (standard units) (00400)	Temperature, water (°C) (00010)	Barometric pressure (mm of Hg) (00025)	Oxygen, dissolved (mg/L) (00300)
				Little Bull Creek subbasin—Continued					
LB–10	384419094525100	05–23–94	1600	0.57	531	7.6	21.5	738	6.7
		08–15–94	1610	.03	490	7.6	24.0	742	7.0
		11–03–94	0935	<.01	444	7.7	14.5	735	.90
		03–09–95	1310	.30	567	7.6	4.5	750	17.7
		05–09–95	1545	10.2	415	7.3	17.5	726	8.8
				Wade Branch subbasin					
WB–4	383906095000600	05–26–94	1215	.22	539	7.6	19.0	732	10.2
		08–15–94	1610	NO FLOW	--	--	--	--	--
		11–03–94	1425	<.01	586	7.7	19.0	735	7.6
		03–10–95	1125	.16	562	7.6	7.5	747	12.2
		05–11–95	1325	1.36	469	7.5	14.0	737	10.6
WB–3	383947094593700	05–26–94	1150	.22	467	8.1	23.0	732	9.8
		08–16–94	1615	NO FLOW	--	--	--	--	--
		11–03–94	1350	<.01	487	7.8	18.5	735	6.5
		03–10–95	1140	.29	324	7.9	8.5	747	14.8
		05–11–95	1340	2.08	486	7.5	14.5	737	10.2
WB–2	383953094593600	05–26–94	1135	.07	520	7.7	18.5	732	8.5
		08–16–94	1620	NO FLOW	--	--	--	--	--
		11–03–94	1405	.01	379	7.6	17.0	735	5.2
		03–10–95	1145	.07	540	7.7	6.5	747	13.2
		05–11–95	1355	.96	444	7.7	14.5	737	11.8

Table 6. Results of chemical analyses of water samples collected from the Hillsdale Lake Basin, northeast Kansas, May 1994–May 1995—Continued

Down-stream order and map reference number (fig. 1)	U.S. Geological Survey identification number	Date (month-day-year)	Time (24-hour)	Discharge, instan-taneous (ft^3/s) (00061)	Specific conduct-ance (μS/cm) (00095)	Field pH (standard units) (00400)	Temp-erature, water (°C) (00010)	Baro-metric pressure (mm of Hg) (00025)	Oxygen, dissolved (mg/L) (00300)
			Wade Branch subbasin—Continued						
WB–1	06914980	05–26–94	1240	0.73	502	7.6	21.0	732	7.0
		08–16–94	1625	NO FLOW	--	--	--	--	--
		11–03–94	1245	.04	379	7.6	16.0	735	6.0
		03–10–95	1200	.49	504	7.6	4.5	747	13.2
		05–11–95	1415	4.77	456	7.6	14.5	737	10.2
			Smith Branch subbasin						
SM–3	384323094550700	05–26–94	1045	.05	589	7.6	15.5	732	8.4
		08–15–94	1530	NO FLOW	--	--	--	--	--
		11–02–94	--	NO FLOW	--	--	--	--	--
		03–08–95	1620	.04	567	7.3	7.0	755	12.0
		05–12–95	1010	.27	498	7.9	12.0	734	12.7
SM–2	384324094552300	05–26–94	1100	.02	644	7.5	15.0	732	9.1
		08–15–94	1535	NO FLOW	--	--	--	--	--
		11–02–94	1515	<.01	658	7.5	14.0	728	5.4
		03–08–95	1550	.01	600	7.8	3.5	755	16.2
		05–12–95	0945	.34	553	7.6	11.0	734	10.7
SM–1	06914970	05–26–94	0955	.40	512	7.6	17.0	732	6.9
		08–15–94	1525	NO FLOW	--	--	--	--	--
		11–02–94	1425	.03	368	7.6	13.0	727	7.0
		03–08–95	1640	.40	519	7.9	1.0	--	15.4
		05–12–95	0925	2.12	472	7.5	11.5	734	10.4

Table 6. Results of chemical analyses of water samples collected from the Hillsdale Lake Basin, northeast Kansas, May 1994–May 1995—Continued

Down-stream order and map reference number (fig. 1)	U.S. Geological Survey identification number	Date (month-day-year)	Time (24-hour)	Discharge, instan-taneous (ft^3/s) (00061)	Specific conduct-ance (µS/cm) (00095)	Field pH (standard units) (00400)	Temp-erature, water (°C) (00010)	Baro-metric pressure (mm of Hg) (00025)	Oxygen, dissolved (mg/L) (00300)
				Miscellaneous sampling sites					
SPG–1	384418094514800	05–23–94	1215	0.47	542	7.5	20.0	740	9.1
		08–17–94	1300	.12	527	7.6	24.0	740	10.8
		11–03–94	1005	.36	489	7.7	13.0	735	7.5
		03–09–95	1340	.34	599	7.6	5.5	750	16.8
		05-09-95	1620	12.5	458	7.4	17.0	726	8.8
UNK–1	384317094513500	05–26–94	1505	.07	553	7.8	21.5	732	10.0
		08–15–94	1635	.08	544	7.7	23.0	740	10.3
		11–03–94	1035	1.18	531	8.1	14.5	734	9.2
		03–09–95	1425	.47	509	7.8	4.5	750	16.6
		05–09–95	1640	9.48	462	7.4	18.5	726	8.7
SCT–1	383842094564900	05–26–94	1320	.15	504	7.9	23.5	732	10.4
		08–16–94	1630	NO FLOW	--	--	--	--	.65
		11–03–94	1220	.01	319	8.0	18.0	735	8.0
		03–10–95	1235	.30	524	7.8	5.0	--	14.5
		05–11–95	1510	2.15	498	7.6	14.5	737	10.1
				Blank water samples					
[1]QA–1	06914980	05–26–94	0945	--	--	--	--	--	--
		08–17–94	1500	--	--	--	--	--	--
		11–03–94	1520	--	--	--	--	--	--
		03–07–95	1030	--	--	--	--	--	--
		05–09–95	0925	--	--	--	--	--	--
[2]QA–2	06914980	05–26–94	1000	--	--	--	--	--	--
		08–17–94	1505	--	--	--	--	--	--
		11–03–94	1500	--	--	--	--	--	--
		03–07–95	1050	--	--	--	--	--	--
		05–09–95	0930	--	--	--	--	--	--

Table 6. Results of chemical analyses of water samples collected from the Hillsdale Lake Basin, northeast Kansas, May 1994–May 1995—Continued

Down-stream order and map reference number (fig. 1)	Date (month-day-year)	Oxygen, dissolved (percent saturation) (00301)	Phos-phorus, total (mg/L as P) (00665)	Phos-phorus ortho, filtered 0.45-μm (mg/L as P) (00671)	Nitrogen, nitrite plus nitrate, total (mg/L as N) (00630)	Nitrogen, ammonia (mg/L as N) (00610)	Nitrogen, ammonia plus organic nitrogen, total (mg/L as N) (00625)	Triazine, screen (ELISA) water, filtered, recover-able, as atrazine (μg/L) (34756)
Big Bull and Martin Creek subbasins								
BB–12	05–24–94	53	0.28	0.08	0.42	0.31	2.0	2.2
	08–16–94	--	--	--	--	--	--	--
	11–01–94	--	--	--	--	--	--	--
	03–07–95	111	.17	.06	.29	<.02	1.9	.13
	05–10–95	63	.65	.31	.53	.35	2.2	11
BB–11	05–24–94	32	.12	.03	<.03	.13	1.3	15
	08–16–94	--	--	--	--	--	--	--
	11–01–94	68	.79	.59	2.3	<.02	2.6	.70
	03–07–95	108	.08	.04	.36	<.02	.63	.19
	05–10–95	83	.11	.04	.35	.03	.88	.26
BB–10	05–24–94	55	.08	.03	.08	.04	.55	11
	08–16–94	--	--	--	--	--	--	--
	11–01–94	--	--	--	--	--	--	--
	03–07–95	107	.07	.01	.25	.14	.89	.26
	05–10–95	88	.12	.04	.38	.06	.86	.39
BB–6	05–24–94	84	.12	.05	2.3	<.02	.92	7.2
	08–16–94	--	--	--	--	--	--	--
	11–01–94	104	.04	.01	1.5	.05	.73	.14
	03–08–95	109	.08	<.01	.36	<.02	.66	.23
	05–10–95	76	.38	.20	.78	.09	1.1	4.9

Table 6. Results of chemical analyses of water samples collected from the Hillsdale Lake Basin, northeast Kansas, May 1994–May 1995—Continued

Down-stream order and map reference number (fig. 1)	Date (month-day-year)	Oxygen, dissolved (percent saturation) (00301)	Phos-phorus, total (mg/L as P) (00665)	Phos-phorus ortho, filtered 0.45-μm (mg/L as P) (00671)	Nitrogen, nitrite plus nitrate, total (mg/L as N) (00630)	Nitrogen, ammonia (mg/L as N) (00610)	Nitrogen, ammonia plus organic nitrogen, total (mg/L as N) (00625)	Triazine, screen (ELISA) water, filtered, recover-able, as atrazine (μg/L) (34756)
Big Bull and Martin Creek subbasins—Continued								
BB–9	05–24–94	35	4.2	3.6	11.5	6.5	12	3.2
	08–16–94	27	5.0	4.3	11.7	13.8	26	2.7
	11–01–94	44	2.4	1.9	5.3	4.8	13	1.4
	03–08–95	41	8.1	4.0	4.4	15.9	43	1.3
	05–10–95	42	2.5	1.7	3.4	3.0	6.3	.81
BB–8	05–24–94	44	3.7	3.4	5.1	7.8	12	3.5
	08–16–94	43	3.5	4.2	5.6	11.4	18	2.6
	11–01–94	41	2.0	1.7	4.2	4.9	9.8	1.4
	03–08–95	56	3.0	4.1	3.1	14.2	20	1.4
	05–10–95	54	2.0	1.5	2.4	3.3	4.9	.68
BB–7	05–24–94	67	1.7	1.6	8.8	2.0	3.9	3.2
	08–16–94	85	3.0	3.1	6.9	.22	2.5	2.1
	11–01–94	74	2.0	1.6	3.8	2.3	5.0	1.1
	03–08–95	97	2.9	3.2	4.2	9.3	9.1	1.4
	05–10–95	88	.85	.50	4.2	.88	1.7	2.5
BB–5	05–24–94	60	.76	.76	5.7	.14	1.5	4.4
	08–16–94	41	1.4	.92	2.2	.26	3.5	2.0
	11–01–94	65	2.4	2.0	3.6	3.4	8.0	1.3
	03–08–95	102	2.2	2.3	4.5	7.4	11	1.3
	5–10–95	82	.44	.31	2.5	.20	1.1	2.9

Table 6. Results of chemical analyses of water samples collected from the Hillsdale Lake Basin, northeast Kansas, May 1994–May 1995—Continued

Down-stream order and map reference number (fig. 1)	Date (month-day-year)	Oxygen, dissolved (percent saturation) (00301)	Phos-phorus, total (mg/L as P) (00665)	Phos-phorus ortho, filtered 0.45-μm (mg/L as P) (00671)	Nitrogen, nitrite plus nitrate, total (mg/L as N) (00630)	Nitrogen, ammonia (mg/L as N) (00610)	Nitrogen, ammonia plus organic nitrogen, total (mg/L as N) (00625)	Triazine, screen (ELISA) water, filtered, recover-able, as atrazine (μg/L) (34756)
Big Bull and Martin Creek subbasins—Continued								
MC–4	05–25–94	142	0.28	0.01	<0.03	<0.02	0.92	1.4
	08–16–94	--	--	--	--	--	--	--
	11–02–94	53	.67	.09	1.7	.13	2.8	.25
	03–07–95	100	.10	<.01	.70	<.02	1.3	<.10
	05–10–95	104	.07	<.01	.20	.03	.83	1.0
MC–3	05–25–94	89	.13	.02	.03	.14	1.8	6.6
	08–16–94	--	--	--	--	--	--	--
	11–02–94	72	.76	.12	1.0	0.06	2.7	.16
	03–07–95	103	.06	<.01	.55	<.02	1.1	<.10
	05–10–95	94	.23	.03	1.4	.10	1.6	.95
MC–2	05–25–94	87	.32	.06	.15	.18	2.1	6.5
	08–16–94	--	--	--	--	--	--	--
	11–02–94	--	--	--	--	--	--	--
	03–07–95	107	.10	.03	.63	<.02	1.6	.12
	05–10–95	94	.26	.09	.51	.17	1.8	.46
MC–1	05–25–94	94	.10	.04	.73	.03	.67	2.6
	08–16–94	--	--	--	--	--	--	--
	11–02–94	52	.43	.04	.74	.06	2.1	.31
	03–07–95	111	.07	.01	.43	<.02	.92	.12
	05–11–95	86	.16	.04	.66	.11	1.0	4.9

Table 6. Results of chemical analyses of water samples collected from the Hillsdale Lake Basin, northeast Kansas, May 1994–May 1995—Continued

Downstream order and map reference number (fig. 1)	Date (month-day-year)	Oxygen, dissolved (percent saturation) (00301)	Phosphorus, total (mg/L as P) (00665)	Phosphorus ortho, filtered 0.45-µm (mg/L as P) (00671)	Nitrogen, nitrite plus nitrate, total (mg/L as N) (00630)	Nitrogen, ammonia (mg/L as N) (00610)	Nitrogen, ammonia plus organic nitrogen, total (mg/L as N) (00625)	Triazine, screen (ELISA) water, filtered, recover-able, as atrazine (µg/L) (34756)
Big Bull and Martin Creek subbasins—Continued								
MC–5	05–25–94	110	0.18	0.04	0.21	0.05	0.99	2.0
	08–16–94	--	--	--	--	--	--	--
	11–02–94	64	.66	.32	.41	.05	1.2	.26
	03–07–95	113	.22	<.01	.62	<.02	1.2	.21
	05–11–95	105	.19	.04	.64	.03	1.2	11
MC–6	08–16–94	62	3.8	3.6	6.1	.03	1.5	.70
	11–02–94	49	1.7	2.4	8.1	.16	1.4	1.9
	03–07–95	95	.75	.64	8.1	.03	1.5	1.3
	05–11–95	81	.74	.34	3.3	.27	1.2	4.6
MC–7	08–16–94	88	.68	.28	.04	.03	2.9	2.9
	11–02–94	50	.90	.63	3.7	<.02	1.2	.49
	03–07–95	--	.56	.54	6.7	<.02	1.3	.58
	05–11–95	77	.48	.16	1.9	.30	1.4	4.1
BB–4	05–24–94	94	.09	.04	.92	.03	.72	1.4
	08–16–94	--	--	--	--	--	--	--
	11–01–94	85	.34	.19	.98	.05	1.0	<.10
	03–08–95	126	.04	<.01	1.0	<.02	.50	<.10
	05–10–95	107	.12	.05	1.5	<.02	.60	1.8

Table 6. Results of chemical analyses of water samples collected from the Hillsdale Lake Basin, northeast Kansas, May 1994–May 1995—Continued

Down-stream order and map reference number (fig. 1)	Date (month-day-year)	Oxygen, dissolved (percent saturation) (00301)	Phos-phorus, total (mg/L as P) (00665)	Phos-phorus ortho, filtered 0.45-µm (mg/L as P) (00671)	Nitrogen, nitrite plus nitrate, total (mg/L as N) (00630)	Nitrogen, ammonia (mg/L as N) (00610)	Nitrogen, ammonia plus organic nitrogen, total (mg/L as N) (00625)	Triazine, screen (ELISA) water, filtered, recover-able, as atrazine (µg/L) (34756)
Big Bull and Martin Creek subbasins—Continued								
BB–1	05–25–94	76	0.34	0.20	1.8	<0.02	1.4	4.0
	dup	76	.33	.19	1.8	<.02	1.3	4.7
	08–16–94	80	.35	.14	.08	<.02	1.6	2.8
	dup	80	.29	.14	.08	<.02	1.4	2.9
	11–01–94	66	1.8	1.5	3.1	.73	2.6	1.7
	03–08–95	121	1.4	1.6	4.3	2.0	4.5	.76
	dup	121	1.3	1.7	4.2	2.0	4.5	--
	05–10–95	79	.35	.16	1.7	.12	1.2	3.4
	dup	79	.32	.16	1.6	.17	1.3	3.5
BB–3	05–24–94	111	.09	.03	.84	<.02	1.6	1.4
	08–16–94	--	--	--	--	--	--	--
	11–01–94	93	.25	.20	.77	.06	.83	.25
	03–08–95	111	.04	<.01	.48	<.02	.53	<.10
	05–10–95	102	.09	.03	.87	<.02	.51	.65
BB–2	05–24–94	95	.03	.03	.32	<.02	.70	1.5
	08–16–94	--	--	--	--	--	--	--
	11–01–94	69	.55	.27	.71	.08	1.2	.15
	dup	69	.50	.27	.66	.06	1.2	.19
	03–08–95	116	.04	<.01	.24	<.02	.17	<.10
	05–10–95	96	.10	.02	.66	<.02	.54	.43

Table 6. Results of chemical analyses of water samples collected from the Hillsdale Lake Basin, northeast Kansas, May 1994–May 1995—Continued

Down-stream order and map reference number (fig. 1)	Date (month-day-year)	Oxygen, dissolved (percent saturation) (00301)	Phos-phorus, total (mg/L as P) (00665)	Phos-phorus ortho, filtered 0.45-μm (mg/L as P) (00671)	Nitrogen, nitrite plus nitrate, total (mg/L as N) (00630)	Nitrogen, ammonia (mg/L as N) (00610)	Nitrogen, ammonia plus organic nitrogen, total (mg/L as N) (00625)	Triazine, screen (ELISA) water, filtered, recover-able, as atrazine (μg/L) (34756)
			Big Bull and Martin Creek subbasins—Continued					
BB–13	05–26–94	118	--	--	--	--	--	5.2
	08–17–94	79	--	--	--	--	--	4.7
	11–03–94	88	0.11	0.02	0.62	<0.02	0.50	2.6
	03–10–95	108	--	--	--	--	--	3.9
	05–12–95	72	--	--	--	--	--	.44
			Rock Creek subbasin					
RC–6	05–25–94	56	.86	.02	.08	.08	.80	7.6
	08–16–94	--	--	--	--	--	--	--
	11–02–94	44	.57	.22	.65	.04	1.7	.26
	03–10–95	91	.22	.02	<.03	<.02	.67	.12
	05–11–95	89	.15	.02	.33	.18	1.3	3.9
RC–5	05–25–94	62	.28	.03	<.03	<.02	.94	7.9
	08–16–94	--	--	--	--	--	--	--
	11–02–94	73	.53	.30	1.4	.07	2.1	.24
	03–10–95	90	.30	.03	<.03	<.02	.60	<.10
	05–11–95	95	.20	.02	.75	<.02	.93	8.2
RC–4	05–25–94	140	.26	.01	.82	<.02	.92	7.8
	08–16–94	--	--	--	--	--	--	--
	11–02–94	72	.40	.06	.57	.04	1.8	.17
	03–10–95	108	.40	.02	.10	<.02	.67	.27
	05–11–95	88	.16	.03	.86	.05	1.2	6.1

Table 6. Results of chemical analyses of water samples collected from the Hillsdale Lake Basin, northeast Kansas, May 1994–May 1995—Continued

Downstream order and map reference number (fig. 1)	Date (month-day-year)	Oxygen, dissolved (percent saturation) (00301)	Phosphorus, total (mg/L as P) (00665)	Phosphorus ortho, filtered 0.45-µm (mg/L as P) (00671)	Nitrogen, nitrite plus nitrate, total (mg/L as N) (00630)	Nitrogen, ammonia (mg/L as N) (00610)	Nitrogen, ammonia plus organic nitrogen, total (mg/L as N) (00625)	Triazine, screen (ELISA) water, filtered, recover-able, as atrazine (µg/L) (34756)
				Rock Creek subbasin—Continued				
RC–3	05–25–94	11	1.4	0.03	<0.03	8.4	15	7.8
	08–16–94	--	--	--	--	--	--	--
	11–02–94	--	--	--	--	--	--	--
	03–10–95	106	.11	.03	.13	<.02	.73	.16
	05–11–95	117	.09	.01	1.6	<.02	1.1	4.7
RC–1	05–25–94	100	.08	.02	.82	<.02	.76	5.1
	dup	100	.11	.02	.82	<.02	.99	5.9
	08–16–94	--	--	--	--	--	--	--
	11–02–94	70	.38	.19	.44	.04	1.2	.22
	dup	70	.42	.19	.46	.05	1.2	.23
	03–10–95	97	.07	.03	.27	<.02	1.0	.30
	05–11–95	98	.14	.04	1.2	.06	.91	3.5
RC–2	05–25–94	108	.14	.04	3.9	<.02	.75	2.5
	08–16–94	--	--	--	--	--	--	--
	11–02–94	--	--	--	--	--	--	--
	03–10–95	106	.22	.07	.95	<.02	.87	<.10
	05–11–95	111	.33	.10	3.2	.06	.87	.27
				Little Bull Creek subbasin				
LB–12	08–15–94	150	.78	.49	17.7	.36	2.6	2.5
	10–31–94	106	.50	.22	6.1	.04	2.0	2.2
	03–09–95	133	.29	.08	10.4	<.02	1.7	2.1
	05–09–95	109	1.2	.31	8.7	.04	1.5	.64

Table 6. Results of chemical analyses of water samples collected from the Hillsdale Lake Basin, northeast Kansas, May 1994–May 1995—Continued

Down-stream order and map reference number (fig. 1)	Date (month-day-year)	Oxygen, dissolved (percent saturation) (00301)	Phos-phorus, total (mg/L as P) (00665)	Phos-phorus ortho, filtered 0.45-µm (mg/L as P) (00671)	Nitrogen, nitrite plus nitrate, total (mg/L as N) (00630)	Nitrogen, ammonia (mg/L as N) (00610)	Nitrogen, ammonia plus organic nitrogen, total (mg/L as N) (00625)	Triazine, screen (ELISA) water, filtered, recover-able, as atrazine (µg/L) (34756)
				Little Bull Creek subbasin—Continued				
LB–11	08–15–94	87	0.73	0.48	7.3	0.06	2.9	1.9
	10–31–94	100	.43	.21	1.8	.11	1.8	.54
	03–09–95	121	.32	.09	7.7	<.02	1.6	1.8
	05–09–95	93	.42	.17	3.6	.17	1.6	.37
LB–9	05–23–94	144	.70	.38	6.8	.22	3.6	2.8
	08–15–94	84	.64	.51	3.9	.08	2.6	--
	dup	84	.63	.51	4.0	.09	2.8	1.9
	10–31–94	100	.46	.29	1.3	.03	1.6	.36
	03–09–95	124	.45	.21	6.3	.43	3.1	1.7
	dup	124	.48	.21	6.2	.42	3.0	--
	05–09–95	87	.77	.29	2.3	.27	2.5	.43
	dup	93	.67	.29	2.5	.26	2.7	.39
LB–8	05–23–94	128	.31	.16	2.8	.09	2.4	2.6
	08–15–94	116	.28	.13	3.6	.12	3.0	2.6
	10–31–94	93	.44	.29	1.7	.02	1.8	.42
	dup	93	.47	.28	1.8	.03	1.7	.40
	03–09–95	197	.33	.21	4.9	.10	2.0	1.6
	05–09–95	97	.49	.21	2.8	.27	2.2	.28
LB–7	05–23–94	141	.14	.09	2.1	.05	1.8	2.3
	08–15–94	110	.34	.09	4.5	.04	4.3	1.7
	10–31–94	87	.49	.32	1.6	.13	1.9	.32

Table 6. Results of chemical analyses of water samples collected from the Hillsdale Lake Basin, northeast Kansas, May 1994–May 1995—Continued

Down-stream order and map reference number (fig. 1)	Date (month-day-year)	Oxygen, dissolved (percent saturation) (00301)	Phos-phorus, total (mg/L as P) (00665)	Phos-phorus ortho, filtered 0.45-μm (mg/L as P) (00671)	Nitrogen, nitrite plus nitrate, total (mg/L as N) (00630)	Nitrogen, ammonia (mg/L as N) (00610)	Nitrogen, ammonia plus organic nitrogen, total (mg/L as N) (00625)	Triazine, screen (ELISA) water, filtered, recover-able, as atrazine (μg/L) (34756)
				Little Bull Creek subbasin—Continued				
LB–7	03–09–95	144	0.21	0.19	4.4	<0.02	1.6	1.0
	05–09–95	93	.34	.11	1.9	.15	1.4	2.6
LB–6	05–23–94	81	.19	.05	1.8	.04	2.3	8.7
	08–15–94	71	.14	.02	.31	.09	.92	.60
	10–31–94	76	.43	.40	.70	<.02	.96	<.10
	03–09–95	132	.13	.06	.89	<.02	.94	.57
	05–09–95	92	.30	.02	4.0	.18	1.4	4.6
LB–5	05–23–94	102	.23	.04	2.0	<.02	1.4	3.6
	08–15–94	140	.32	.05	<.03	.09	4.3	1.1
	10–31–94	93	.51	.29	1.4	.13	1.8	.29
	03–09–95	143	.16	.12	3.5	.05	1.5	1.1
	05–09–95	99	.23	.06	1.9	.12	.92	2.0
LB–1	05–23–94	68	.17	.04	1.6	.03	1.1	3.6
	08–15–94	85	.22	.05	<.03	.07	2.2	.52
	10–31–94	105	.71	.41	2.6	.02	3.2	1.0
	03–09–95	137	.15	.10	3.7	.13	1.4	1.1
	05–09–95	96	.09	.05	1.7	.07	.96	1.8
LB–3	05–23–94	108	<.02	.05	.94	<.02	.62	5.4
	08–15–94	65	.09	.07	.08	<.02	.47	5.8
	10–31–94	92	.85	.63	2.8	.28	2.8	.45
	03–09–95	159	.05	.04	.42	<.02	.38	.41
	05–09–95	98	.30	.06	1.2	.09	.76	2.3

Table 6. Results of chemical analyses of water samples collected from the Hillsdale Lake Basin, northeast Kansas, May 1994–May 1995—Continued

Down-stream order and map reference number (fig. 1)	Date (month-day-year)	Oxygen, dissolved (percent saturation) (00301)	Phos-phorus, total (mg/L as P) (00665)	Phos-phorus ortho, filtered 0.45-µm (mg/L as P) (00671)	Nitrogen, nitrite plus nitrate, total (mg/L as N) (00630)	Nitrogen, ammonia (mg/L as N) (00610)	Nitrogen, ammonia plus organic nitrogen, total (mg/L as N) (00625)	Triazine, screen (ELISA) water, filtered, recover-able, as atrazine (µg/L) (34756)
Little Bull Creek subbasin—Continued								
LB–4	05–23–94	77	<0.02	0.04	1.0	0.07	0.96	0.30
	08–15–94	--	--	--	--	--	--	--
	10–31–94	90	.57	.44	2.8	<.02	2.2	.16
	03–09–95	152	.50	.04	.71	<.02	.41	<.10
	05–09–95	94	.12	.06	.99	.06	.73	.83
LB–2	05–23–94	69	.11	.03	.89	.10	.99	1.3
	08–15–94	69	.06	.05	.21	<.02	.50	1.5
	10–31–94	97	.88	.39	1.7	.17	3.2	.37
	03–09–95	129	.05	.05	.62	<.02	.47	.13
	05–09–95	97	.10	.05	1.4	.13	.91	1.4
LB–10	05–23–94	79	.03	.03	<.03	<.02	.64	.52
	08–15–94	85	.09	.03	<.03	.03	1.2	.86
	11–03–94	9	.44	.26	.50	.07	.94	<.10
	03–09–95	140	.04	.04	.24	<.02	.19	.16
	05–09–95	97	.11	.04	.48	<.02	.53	2.5
Wade Branch subbasin								
WB–4	05–26–94	115	.17	.01	.68	<.02	.30	.21
	08–15–94	--	--	--	--	--	--	--
	11–03–94	85	.52	.21	1.4	.06	1.3	.35
	03–10–95	103	.10	.01	.40	<.02	.71	<.10
	05–11–95	106	<.02	.01	.84	<.02	.18	4.8

Table 6. Results of chemical analyses of water samples collected from the Hillsdale Lake Basin, northeast Kansas, May 1994–May 1995—Continued

Down-stream order and map reference number (fig. 1)	Date (month-day-year)	Oxygen, dissolved (percent saturation) (00301)	Phos-phorus, total (mg/L as P) (00665)	Phos-phorus ortho, filtered 0.45-μm (mg/L as P) (00671)	Nitrogen, nitrite plus nitrate, total (mg/L as N) (00630)	Nitrogen, ammonia (mg/L as N) (00610)	Nitrogen, ammonia plus organic nitrogen, total (mg/L as N) (00625)	Triazine, screen (ELISA) water, filtered, recover-able, as atrazine (μg/L) (34756)
				Wade Branch subbasin—Continued				
WB-3	05-26-94	119	0.13	0.01	0.44	<0.02	0.67	0.47
	08-16-94	--	--	--	--	--	--	--
	11-03-94	72	1.1	.34	.42	.22	4.1	3.4
	03-10-95	128	.09	.01	.19	<.02	.65	<.10
	05-11-95	103	<.02	.02	1.1	<.02	.24	4.0
WB-2	05-26-94	95	.44	.02	1.2	.03	7.77	2.9
	08-16-94	--	--	--	--	--	--	--
	11-03-94	56	.35	.04	.38	.04	.79	.47
	03-10-95	110	.09	.01	.77	<.02	.93	<.10
	05-11-95	119	<.02	.02	1.4	<.02	.49	1.1
WB-1	05-26-94	81	.89	.03	.33	.04	.06	1.3
	08-16-94	--	--	--	--	--	--	--
	11-03-94	63	.26	.05	.80	.04	.31	2.0
	03-10-95	105	.26	.03	.19	<.02	.37	<.10
	05-11-95	104	<.02	.02	.97	<.02	.20	2.7
				Smith Branch subbasin				
SM-3	05-26-94	88	.10	.04	.29	.17	.78	.13
	08-15-94	--	--	--	--	--	--	--
	11-02-94	--	--	--	--	--	--	--
	03-08-95	99	.08	<.01	1.1	<.02	.89	<.10
	05-12-95	122	<.02	.01	1.1	<.02	.21	<.10

Table 6. Results of chemical analyses of water samples collected from the Hillsdale Lake Basin, northeast Kansas, May 1994–May 1995—Continued

Down-stream order and map reference number (fig. 1)	Date (month-day-year)	Oxygen, dissolved (percent saturation) (00301)	Phos-phorus, total (mg/L as P) (00665)	Phos-phorus ortho, filtered 0.45-µm (mg/L as P) (00671)	Nitrogen, nitrite plus nitrate, total (mg/L as N) (00630)	Nitrogen, ammonia (mg/L as N) (00610)	Nitrogen, ammonia plus organic nitrogen, total (mg/L as N) (00625)	Triazine, screen (ELISA) water, filtered, recover-able, as atrazine (µg/L) (34756)
			Smith Branch subbasin—Continued					
SM–2	05–26–94	94	0.09	0.02	0.30	<0.02	0.18	0.74
	08–15–94	--	--	--	--	--	--	--
	11–02–94	55	.28	.07	1.0	.02	.66	.21
	03–08–95	122	.07	<.01	1.1	.05	.46	<.10
	05–12–95	102	.05	.03	1.2	<.02	.21	.14
SM–1	05–26–94	74	.09	.01	<.03	.05	.62	.44
	08–15–94	--	--	--	--	--	--	--
	11–02–94	70	.35	.12	1.0	.03	.89	.12
	03–08–95	--	.08	.01	.30	<.02	.48	<.10
	05–12–95	100	<.02	.01	.37	<.02	.20	<.10
			Miscellaneous sampling sites					
SPG–1	05–23–94	104	.08	.02	.45	<.02	.25	.20
	08–17–94	132	--	--	--	--	--	.11
	11–03–94	74	.28	.07	.58	.02	.45	<.10
	03–09–95	136	--	--	--	--	--	<.10
	05–09–95	96	--	--	--	--	--	.51
UNK–1	05–26–94	118	--	--	--	--	--	<.10
	08–15–94	124	--	--	--	--	--	--
	11–03–94	94	--	--	--	--	--	<.10
	03–09–95	130	--	--	--	--	--	<.10
	05–09–95	98	--	--	--	--	--	<.10

Table 6. Results of chemical analyses of water samples collected from the Hillsdale Lake Basin, northeast Kansas, May 1994–May 1995—Continued

Down-stream order and map reference number (fig. 1)	Date (month-day-year)	Oxygen, dissolved (percent saturation) (00301)	Phos-phorus, total (mg/L as P) (00665)	Phos-phorus ortho, filtered 0.45-µm (mg/L as P) (00671)	Nitrogen, nitrite plus nitrate, total (mg/L as N) (00630)	Nitrogen, ammonia (mg/L as N) (00610)	Nitrogen, ammonia plus organic nitrogen, total (mg/L as N) (00625)	Triazine, screen (ELISA) water, filtered, recover-able, as atrazine (µg/L) (34756)
			Miscellaneous sampling sites—Continued					
SCT–1	05–26–94	129	--	--	--	--	--	2.4
	08–16–94	--	--	--	--	--	--	--
	11–03–94	88	--	--	--	--	--	.65
	03–10–95	--	--	--	--	--	--	.14
	05–11–95	103	--	--	--	--	--	.24
			Blank water samples					
[1]QA–1	05–26–94	--	0.45	<0.01	<0.03	<0.02	<0.05	<.10
	08–17–94	--	<.02	<.01	<.03	<.02	<.08	<.10
	11–03–94	--	.24	<.01	.40	<.02	.08	--
	03–07–95	--	.03	<.01	.25	<.02	.26	<.10
	05–09–95	--	<.02	<.01	<.03	<.02	<.08	<.10
[2]QA–2	05–26–94	--	.47	<.01	<.03	<.02	<.08	<.10
	08–17–94	--	.04	<.01	<.03	<.02	<.08	--
	11–03–94	--	.03	<.01	.41	<.02	<.08	<.10
	03–07–95	--	.04	<.01	<.03	<.02	.17	<.10
	05–09–95	--	<.02	<.01	<.03	<.02	.10	<.10

[1]Bottle blank using certified inorganic and organic blank water.
[2]Equipment blank using certified inorganic and organic blank water.

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