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HYDROLOGIC AND WATER-QUALITY CHARACTERISTICS FOR CALF CREEK NEAR SILVER HILL, ARKANSAS, AND SELECTED BUFFALO RIVER SITES, 2001-2002

Scientific Investigations Report 2004-5007

U.S. Department of the Interior
U.S. Geological Survey

Cover: Photograph of Calf Creek near Silver Hill, Arkansas. Photograph by W. Reed Green, U.S. Geological Survey.

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By Joel M. Galloway and W. Reed Green

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U.S. DEPARTMENT OF THE INTERIOR
GALE A. NORTON, Secretary

U.S. GEOLOGICAL SURVEY
Charles G. Groat, Director

For additional information
write to:

District Chief
U.S. Geological Survey, WRD
401 Hardin Road
Little Rock, Arkansas 72211

Copies of this report can be
purchased from:

U.S. Geological Survey
Branch of Information Services
Box 25286
Denver Federal Center
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By Joel M. Galloway and W. Reed Green

ABSTRACT

The Buffalo River and its tributary, Calf Creek, are in the White River Basin in the Ozark Plateaus physiographic province in north-central Arkansas. A better understanding of the hydrology and water quality of Calf Creek is of interest to many, including the National Park Service, which administers the Buffalo National River, to evaluate its effect on the hydrology and water quality of the Buffalo River.

The streamflow and water-quality characteristics of Calf Creek near Silver Hill, Arkansas, were compared to two sites on the Buffalo River upstream (near Boxley, Arkansas) and downstream (near St. Joe, Arkansas) from the confluence of Calf Creek for calendar years 2001 and 2002. Annual and seasonal loads were estimated for Calf Creek for nutrients, dissolved organic carbon, and suspended sediment and compared with loads at sites on the Buffalo River. Flow-weighted concentrations and yields were computed from estimated annual loads for comparison with other developed and undeveloped basins.

Streamflow varied annually and seasonally at the three sites. The Buffalo River near St. Joe had the largest annual mean streamflow (805 to 1,360 cubic feet per second for 2001 and 2002) compared to the Buffalo River near Boxley (106 and 152 cubic feet per second for 2001 and 2002) and Calf Creek (39 and 80 cubic feet per second for 2001 and 2002).

Concentrations of nutrients, suspended sediment, and fecal indicator bacteria generally were greater in samples from Calf Creek than in samples collected from both Buffalo River sites. Bacteria and suspended-sediment concentrations were greater in samples collected during high-flow events at all three sites. The Buffalo River near Boxley had the lowest concentrations for nutrients, suspended sediment, and fecal indicator bacteria.

Estimated annual loads of the nutrients, suspended sediment, and organic carbon for 2001 and 2002 demonstrated substantial variability between the three sites and through time. Estimated loads for nutrients at the Buffalo River near St. Joe were 7 to 27 times the median loads estimated for Calf Creek and suspended sediment loads were as much as 120 times greater. Dissolved organic carbon loads were 16 to 20 times greater at the Buffalo River near St. Joe than for Calf Creek. The Buffalo River near Boxley had the smallest annual loads for all constituents except for suspended sediment, which were slightly greater than suspended sediment loads estimated for Calf Creek. Higher loads would be expected at the Buffalo River near St. Joe because of the larger basin area and larger volume of streamflow. Likewise, estimated loads for all three sites were greater during seasons that had greater streamflow than during seasons with more frequent periods of base-flow conditions. The highest daily loads occurred in the fall and winter of 2001 and the winter and spring of 2002.

Flow-weighted concentrations generally were higher for Calf Creek than concentrations for the two sites on the Buffalo River and for typical flow-weighted concentrations found in undeveloped basins. However, the flow-weighted concentrations were lower than concentrations in a developed basin.

Annual yields calculated for Calf Creek were higher than the two sites on the Buffalo River and sites that are representative of undeveloped basins but lower than a site representative of a developed basin. The Buffalo River near Boxley had yields that were less than the yields typical of undeveloped basins.

INTRODUCTION

The Buffalo River and its tributary, Calf Creek, are in the White River Basin in the Ozark Plateaus physiographic province (Fenneman, 1938) in north-central Arkansas (fig. 1). The Buffalo River is a 150-mile long free-flowing stream known for its scenic beauty and for canoeing, fishing, and other recreational activities. Eleven percent of the Buffalo River Basin and less than 4 percent of the Calf Creek Basin near its confluence with the Buffalo River lie within the boundaries of the Buffalo National River. Outside the boundary of the Buffalo National River, agricultural activities such as animal production and logging have increased over the past 30 years, especially in the middle portion of the Buffalo River Basin (U.S. Department of Agriculture, 1995). Previous investigations indicated that nutrient and fecal-indicator bacteria concentrations and loads were elevated in Calf Creek and nearby Bear Creek (fig. 1) (Mott, 1997; Petersen and others, 1998; 2002; Steele and Mott, 1998). Nutrient enrichment in the Buffalo River can contribute to excessive algal growth and the reduction of dissolved oxygen in the stream, which can be unfavorable for aesthetics and detrimental to the aquatic health of the stream. Bacteria increase in the stream can pose a threat to humans that commonly come in contact with the waters for recreation. A better understanding of the hydrology and water quality of Calf Creek is of interest to many, including the National Park Service, which administers the Buffalo National River, to evaluate its effect on the hydrology and water quality of the Buffalo River.

Description of Study Area

The Buffalo River (fig. 1) originates north of Fallsville, Arkansas, in the Boston Mountains and flows eastward into the Ozark Plateaus to the White River. The drainage area of the Buffalo River at its mouth is 1,340 square miles (Sullavan, 1974). The drainage area upstream from the Buffalo River near Boxley streamflow gaging station (07055646) is approximately 57 square miles and upstream from the Buffalo River near St. Joe gaging station (07056000) is 829 square miles (Porter and others, 2002). Land use in the Buffalo River Basin is primarily a mixture of forest and pasture. Approximately 13 percent of the land is agricultural (mostly pasture) upstream from the Buffalo River near St. Joe. Only approximately 4 percent of the land is used for agriculture upstream from the Buffalo River near Boxley (Davis and Bell, 1998).

Calf Creek lies in the middle reach of the Buffalo River Basin and originates near Witts Spring, Arkansas, flowing northward to empty into the Buffalo River (fig. 1). The Calf Creek drainage area is about 49.6 square miles at its mouth or about 6 percent of the Buffalo River drainage area at its confluence with Calf Creek. Land use in the Calf Creek Basin includes forest (56 percent), and pasture and hay (39 percent) (Vogelmann and others, 2001). A part of the Calf Creek Basin (3.5 percent) is included in the Buffalo National River boundary. The basin shares a boundary to the east with Bear Creek, a larger tributary to the Buffalo River with a drainage area of 91.6 square miles.

Purpose and Scope

The purpose of this report is to describe and compare the hydrologic and water-quality characteristics of Calf Creek near Silver Hill, Arkansas, to sites on the Buffalo River upstream and downstream from the confluence of Calf Creek. Stream stage was measured continuously to compute streamflow, and water-quality samples were collected monthly and during selected high-flow events from January 2001 to March 2003. Results for calendar years 2001 and 2002 are described in this report. Water samples were analyzed for several field parameters and constituents, including specific conductance, dissolved oxygen, water temperature, pH, alkalinity, fecal indicator bacteria, nutrients, organic carbon, and suspended sediment. Annual and seasonal loads were estimated for Calf Creek for nutrients, dissolved organic carbon, and suspended sediment and compared with loads for sites on the Buffalo River upstream and downstream from its confluence with Calf Creek. Flow-weighted concentrations and yields were calculated from estimated annual loads for comparison with other developed and undeveloped basins.

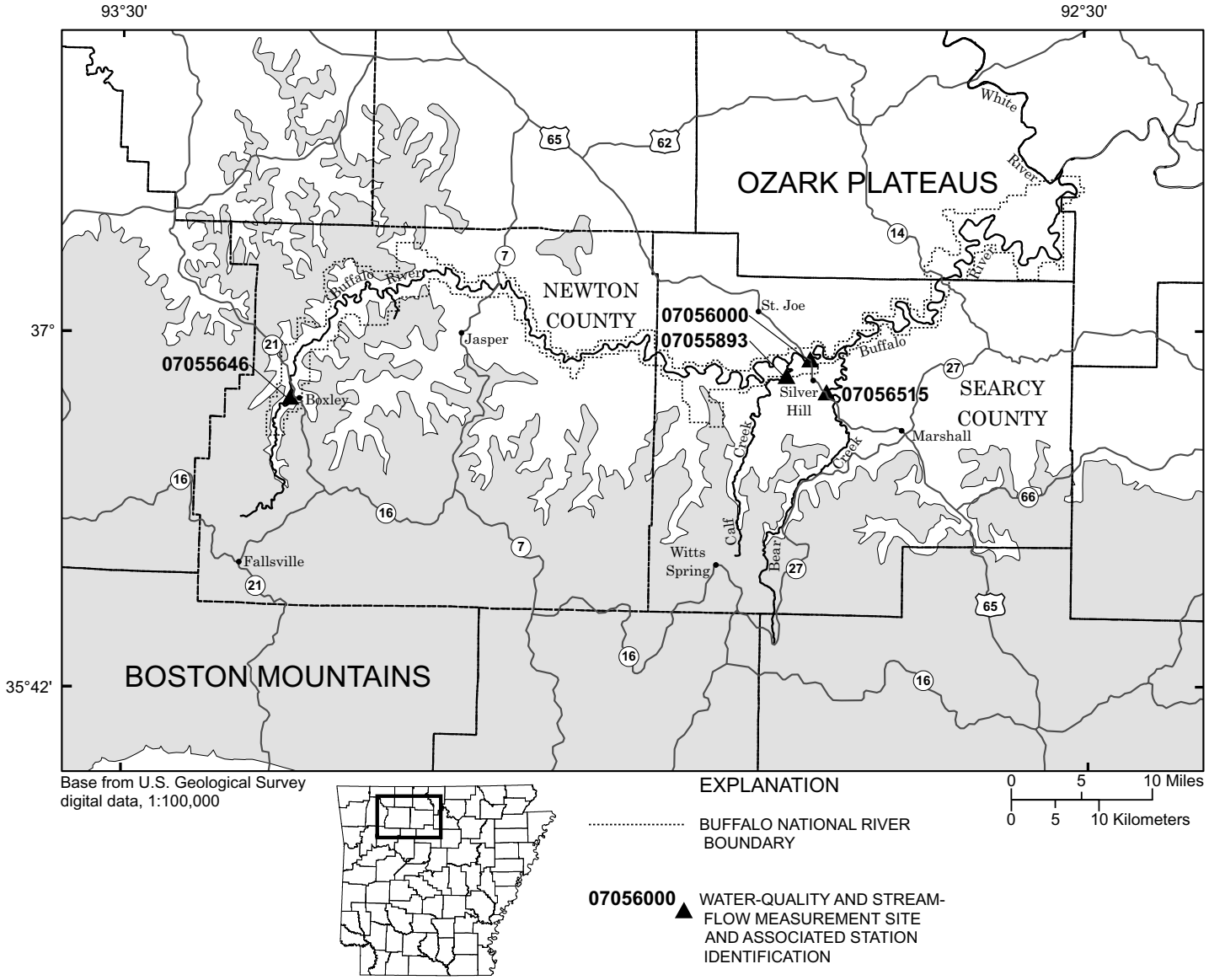

Figure 1. Locations of Calf Creek and Buffalo River sites.

METHODS

Stream stage was measured continuously at a site on Calf Creek near Silver Hill (07055893) and two sites on the Buffalo River (fig. 1). Stage and instantaneous discharge were measured to compute the continuous streamflow from stage-discharge rating curves using methods described in Rantz and others (1982). Because stage was not measured on January 1-17, 2001, at the Calf Creek site, the daily mean streamflow was estimated using a hydrograph comparison with a nearby gaging station on Bear Creek near Silver Hill (07056515) (fig. 1) for estimates of load during this period.

Water-quality samples were collected from a fixed sampling site at Calf Creek from January 2001 to March 2003. Samples were collected monthly and during high-flow events resulting in 12 samples collected during high-flow events and 16 samples collected during base-flow conditions. Samples were collected from fixed sampling sites at the Buffalo River near Boxley (07055646) from April 1994 to present and at the Buffalo River near St. Joe (07056000) from April 1974 to present. Nine samples collected at the Buffalo River near Boxley were associated with high-flow events and 11 samples were collected during base-flow conditions during calendar years 2001 and 2002. Seventeen samples collected at the Buffalo River near St. Joe were associated with high-flow events and 14 samples were collected during base-flow conditions during calendar years 2001 and 2002.

Water-quality samples were collected by equal-width increment methods using depth-integrated samplers and processed using protocols described in Wilde and others (1998a, 1998b, 1998c, 1999a, and 1999b) and Meyers and Wilde (1999). Samples were analyzed for nutrients (total ammonia plus organic nitrogen, dissolved nitrite plus nitrate, total nitrogen, dissolved phosphorus, dissolved orthophosphorus, and total phosphorus), fecal indicator bacteria (fecal coliform, fecal streptococci, and E. *coli*), dissolved organic carbon, and suspended sediment. Field parameters, including water temperature, dissolved-oxygen concentration, pH, specific conductance, and alkalinity also were collected with each sample following protocols described in Wilde and Radke (1998). Nutrient and dissolved organic carbon analyses were conducted at the USGS National Water-Quality Laboratory in Denver, Colorado, following procedures described in Fishman (1993). Samples were analyzed for fecal indicator bacteria in the field by USGS personnel, following procedures described in Meyers and Wilde (1999). Suspended sediment analyses were conducted at the USGS laboratory at the Rolla, Missouri District office following procedures described in Guy (1969).

The resulting water-quality and streamflow data were analyzed using several statistical and graphical techniques. Boxplots were used to compare concentrations of selected water-quality constituents among sites for data collected during calendar years 2001 and 2002. Concentrations reported as less than a laboratory reporting limit were converted to one-half the reporting limit for preparation of boxplots, calculation of total nitrogen concentrations (the sum of nitrite plus nitrate and ammonia plus organic nitrogen), and statistical analyses. The Wilcoxon rank sum test (Helsel and Hirsch, 1992) was used to test for differences in selected water-quality constituents between sites.

Streamflow was separated using the Base Flow Index (BFI) hydrograph separation computer program to identify base-flow and surface-runoff components (Wahl and Wahl, 1995). The BFI program is based on the Institute of Hydrology method of base-flow separation, which divides the water year into increments and identifies the minimum flow for each increment. A 2-day increment was used for Calf Creek and Buffalo River near Boxley, and a 5-day increment was used for the Buffalo River near St. Joe because it has a larger drainage area. Minimums are compared to adjacent minimums to determine turning points on the base-flow hydrograph. If 90 percent of a given minimum is less than both adjacent minimums, then that minimum is a turning point. Straight lines are drawn between the turning points to define the base-flow hydrograph (Wahl and Wahl, 1995). The area beneath the hydrograph is the estimate of the volume of base flow for the period. The ratio of the base-flow volume to total-flow volume is the base-flow index.

Water-quality samples were separated into those collected under base-flow or high-flow conditions. Base-flow water-quality samples were collected on days when the estimated base-flow component was greater than or equal to 70 percent of the total daily mean flow. High-flow samples were defined as water-quality samples collected on days when the surface-runoff component was greater than 30 percent of the total daily mean flow.

Water-quality constituent loads and yields were calculated from concentrations and streamflow measured at each site from January 2001 to March 2003. Constituent load (L) is a function of the volumetric rate (Q) of water passing a point in the stream and the constituent concentration (C) within the water. Regression methods used to estimate constituent loads use the natural logarithm (ln) transformed relation between Q and C to estimate daily C (or L) of the constituent (Cohn and others, 1989; Cohn and others, 1992; Cohn, 1995). The regression method can account for non-normal data distributions, seasonal and long-term cycles, censored data, biases associated with using logarithmic transformations, and serial correlations of the residuals (Cohn, 1995). The regression method uses discrete water-quality samples often collected over several years and a daily streamflow hydrograph. A typical log-linear regression model for estimating load can be expressed as:

$$\ln(L) = \beta_o + \beta_1 \ln(Q) + \beta_2 \ln(Q^2) + \beta_3 T + \beta_4 T^2 + \beta_5 \sin(2\pi T) + \beta_6 \cos(2\pi T) \quad (1)$$

where L represents the constituent load,
β_0 represents the regression constant,
β_1, β_2, β_3, β_4, β_5, and β_6 represent regression coefficients,
Q represents daily streamflow discharge, and
T represents decimal time.

However, seasonality and time were not included in the regression analysis described in this report because the period of data collection was too short (2 years) to describe or identify seasonal or temporal trends in the data for the regression model. Therefore, only the relations between natural logarithmic-transformed L and Q were used to estimate annual and seasonal constituent loads:

$$\ln(L) = \beta_o + \beta_1 \ln(Q) \quad (2)$$

Transforming the results of the model from logarithmic space to real space was accomplished using two methods; an adjusted maximum likelihood estimator (AMLE) (Cohn, 1995) and a least absolute deviation (LAD). The AMLE method was used if the constituent had censored values and the LAD method was used to transform the results if censored values were not included in the data or if outliers in the residuals were present. The S-LOADEST computer program (David Lorenz, U.S. Geological Survey, written commun., 2003) was used to estimate annual and seasonal constituent loads at the three sites for calendar years 2001 and 2002.

Annual yields (pounds per square mile) also were computed from estimated annual loads at each site. The yield was calculated by simply dividing the annual load (pounds per year) by the drainage area contributing flow at the location of the sampling site (square miles).

Flow-weighted concentrations were computed from the loads derived from the monthly samples. Flow-weighted concentrations were calculated by dividing the annual load by annual mean flow, and applying appropriate conversion factors for dimensional units:

$$C_{FW} = \left[\frac{L}{Q_{Annual}}\right] \times 5.08 \times 10^{-4} \quad (3)$$

where C_{FW} represents the flow-weighted concentrations, in milligrams per liter,
L represents the annual constituent load in pounds per year, and
Q_{Annual} represents the mean annual streamflow, in cubic feet per second.

HYDROLOGIC CHARACTERISTICS

The streamflow for Calf Creek near Silver Hill varies seasonally and annually (fig. 2). The annual mean streamflow for calendar years 2001 and 2002 was 39.3 and 79.6 cubic feet per second (ft^3/s), respectively (table 1). Daily mean streamflow ranged from 1.2 to 2,970 ft^3/s for the period. The highest daily mean flows were generally in the months of January through May and the lowest daily mean flows generally occurred in the months of July through October.

Streamflow for the Buffalo River near Boxley and near St. Joe also varied seasonally and annually (figs. 3 and 4, table 1). The mean annual streamflow for the Buffalo River near Boxley was 106 and 152 ft^3/s for calendar years 2001 and 2002, respectively. Buffalo River near St. Joe, located approximately 73 river miles downstream, had mean annual streamflows of 805 and 1,360 ft^3/s for 2001 and 2002, respectively. Daily mean streamflow ranged from 0.23 to 4,690 ft^3/s for the Buffalo River near Boxley and from 20 to 45,800 ft^3/s for the Buffalo River near St. Joe for 2001 to 2002. Additional summary statistics for January 2001 to December 2002 for all of the sites are reported in Porter and others (2002) and Brossett and Evans (2003).

The streamflow for Calf Creek and the two Buffalo River sites demonstrated a considerable amount of base flow that varied seasonally. The base flow at Calf Creek comprised approximately 34 to 35 percent of the total mean annual streamflow in 2001 and 2002, respectively. In 2001, the base flow comprised 84 to 97 percent of the total mean monthly streamflow during April to June and less than 18 percent of the total mean monthly streamflow in December. In 2002, the base flow comprised 91 to 98 percent of total mean monthly streamflow during September to November and less than 17 percent of the total mean monthly streamflow in January. The base flow comprised 25 to 28 percent of the total mean annual streamflow at the Buffalo River near Boxley and 35 percent of the total mean annual streamflow near St. Joe. Both sites had similar seasonal trends compared to Calf Creek.

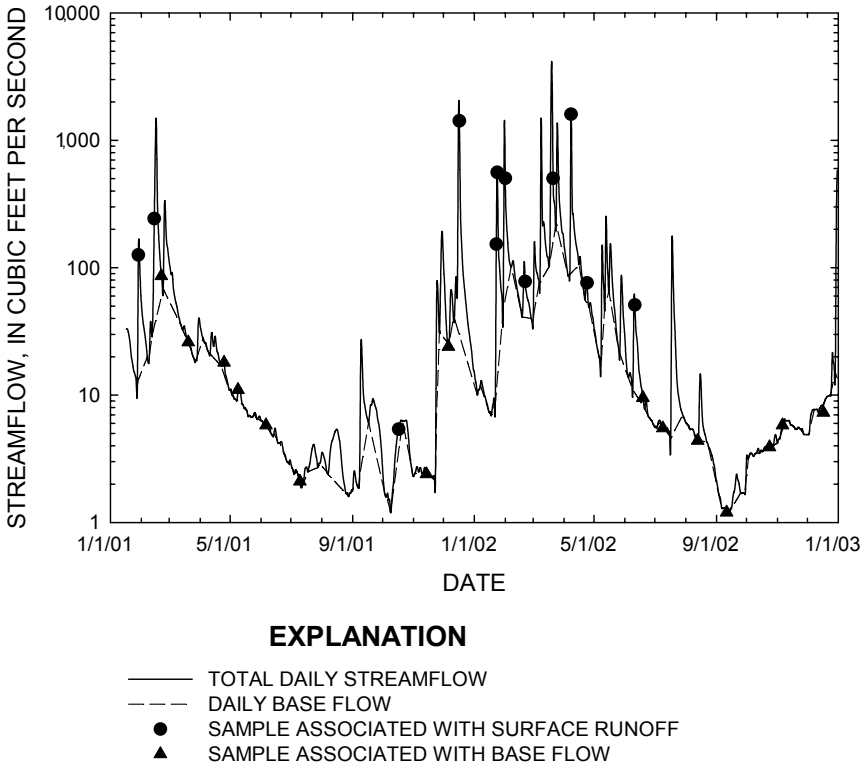

Figure 2. Daily base flow and total daily streamflow and water-quality sample times during calendar years 2001 and 2002 for Calf Creek near Silver Hill, Arkansas.

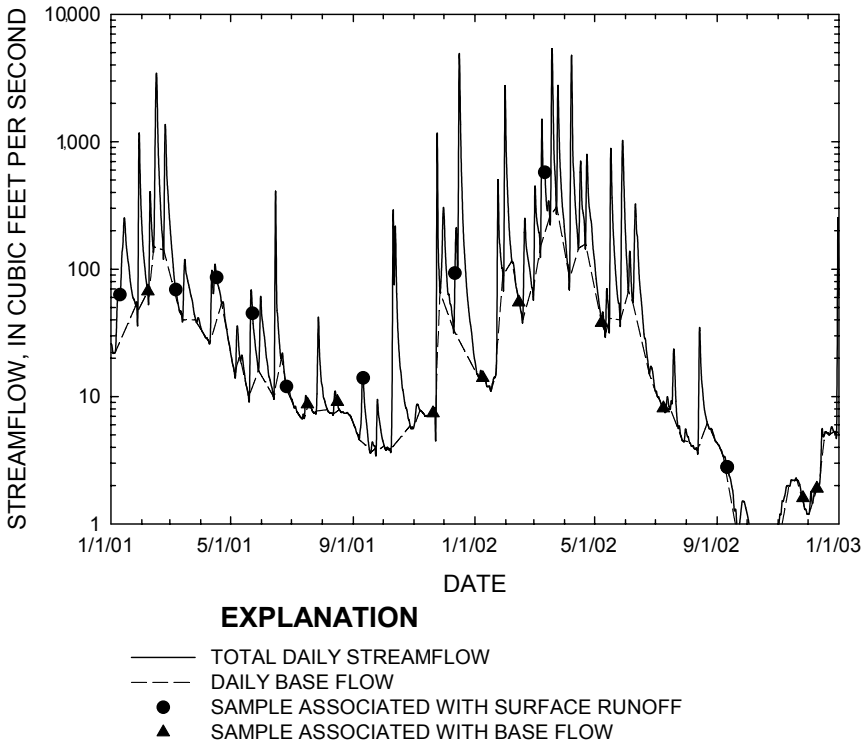

Figure 3. Daily base flow and total daily streamflow and water-quality sample times during calendar years 2001 and 2002 for Buffalo River near Boxley, Arkansas.

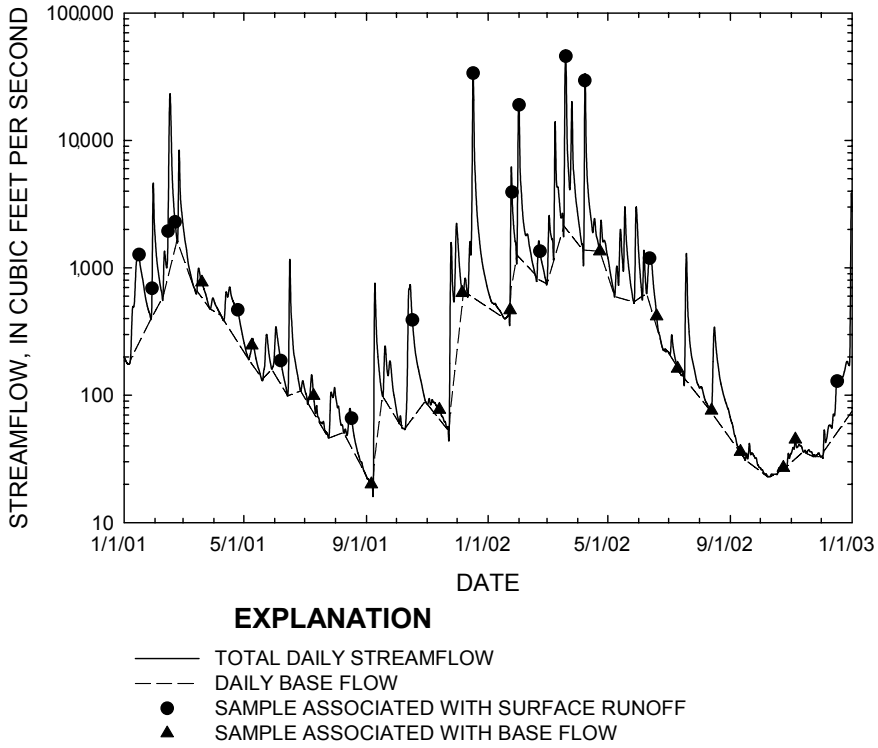

Figure 4. Daily base flow and total daily streamflow and water-quality sample times during calendar years 2001 and 2002 for Buffalo River near St. Joe, Arkansas.

Table 1. Annual and monthly streamflow statistics for Calf Creek near Silver Hill, and Buffalo River near Boxley and St. Joe, Arkansas, calendar years 2001-2002

[Values are in cubic feet per second; e, estimated]

Station		January	February	March	April	May	June	July	August	September	October	November	December	Annual
							2001							
Calf Creek	Mean	35.1e	181	42.3	23.1	8.34	4.69	2.78	3.20	7.08	3.66	22.2	149	39.3
	Median	25.0e	71.5	35.0	22.5	7.90	4.80	2.70	3.10	6.65	3.00	2.50	56.0	7.50
	Maximum	132e	1,420	110	35.0	11.0	6.30	4.10	5.40	24.0	6.30	182	1,420	1,420
	Minimum	2.10e	18.0	18.0	11.0	6.50	2.90	1.90	1.60	1.80	1.20	2.20	16.0	1.20
Buffalo River near Boxley	Mean	137	530	75.2	49.4	24.4	35.0	10.34	8.13	6.09	30.93	68.11	326	106
	Median	66	248	62.0	38.0	20.0	18.5	8.1	7.50	5.40	7.7	7.5	81	24
	Maximum	925	3,120	232	104	65.0	400	42.0	12.0	14.0	290	1,020	3,590	3,590
	Minimum	22.0	61.0	38.0	25.0	9.90	10.0	6.70	6.50	3.60	3.80	5.90	21.0	3.60
Buffalo River near St. Joe	Mean	775	3,640	882	493	201	229	83.0	52.7	148	191	299	2,880	805
	Median	509	1,860	740	480	197	172	83.0	51.0	125	115	85.0	1,110	218
	Maximum	4,350	23,200	2,180	704	300	1,120	145	99.0	569	734	2,120	33,700	33,700
	Minimum	175	592	477	287	132	99.0	46.0	24.0	20.0	54.0	53.0	606	20.0
							2002							
Calf Creek	Mean	87.6	99.6	456	164	63.3	15.7	17.0	5.29	1.62	3.75	5.52	34.5	79.6
	Median	11.0	71.0	215	103	49.0	12.0	6.30	5.00	1.70	3.70	5.50	8.30	9.50
	Maximum	1,260	503	2,970	1,600	244	52.0	122	14.0	2.40	4.90	6.50	581	2,970
	Minimum	6.90	37.0	39.0	40.0	17.0	5.80	4.60	2.30	1.20	3.20	4.20	4.90	1.20
Buffalo River near Boxley	Mean	126	173	748	473	175	80.1	8.78	7.20	2.29	0.47	1.75	11.3	152
	Median	15.0	106	381	255	67.0	60.5	8.50	5.10	2.00	0.34	1.85	5.00	12.0
	Maximum	2,320	1,250	4,330	4,690	1,010	326	21.0	30.0	4.30	1.20	2.30	238	4,690
	Minimum	11.0	40.0	69.0	84.0	31.0	12.0	4.50	3.80	0.82	0.23	0.73	1.20	0.23
Buffalo River near St. Joe	Mean	1,270	2,320	6,800	3,435	1,200	643	251	125	38.7	26.2	36.8	201	1,360
	Median	519	1,360	3,650	1,990	1,000	614	186	102	35.0	26.0	36.0	112	271
	Maximum	10,300	19,000	45,800	29,500	2,910	1,330	1,270	342	66.0	35.0	45.0	3,120	45,800
	Minimum	398	778	749	1,310	539	221	119	71.0	27.0	23.0	33.0	33.0	23.0

WATER-QUALITY CHARACTERISTICS

Water-quality data for the sites on Calf Creek and the Buffalo River are described below in terms of concentrations, loads, flow-weighted concentrations, and yields. Considerable differences were indicated between the sites and individual samples. Calf Creek generally had the greatest concentrations, flow-weighted concentrations, and yields, while the Buffalo River near St. Joe had the highest loads.

Concentrations

Concentrations of water-quality constituents in samples collected from Calf Creek generally were greater than in samples from both sites on the Buffalo River in 2001 and 2002 (appendix). The median nutrient concentrations in Calf Creek were significantly higher ($p < 0.05$) than the Buffalo River near St. Joe and near Boxley for nitrite plus nitrate, total nitrogen (fig. 5), and total phosphorus (fig. 6) for all of the samples. However, the 90th percentile of the total phosphorus concentrations for the Buffalo River near St. Joe was substantially greater than the 90th percentile for the other two sites for samples collected during base-flow conditions. In general, the median nutrient concentrations in samples collected during base-flow conditions were slightly less than median nutrient concentrations for all of the samples, although a strong relation between the concentrations and streamflow was not evident (appendix). Concentrations of total ammonia plus organic nitrogen were not significantly different between Calf Creek and the Buffalo River near St. Joe and concentrations in samples from the Buffalo River near Boxley were all near or below laboratory reporting limits (appendix).

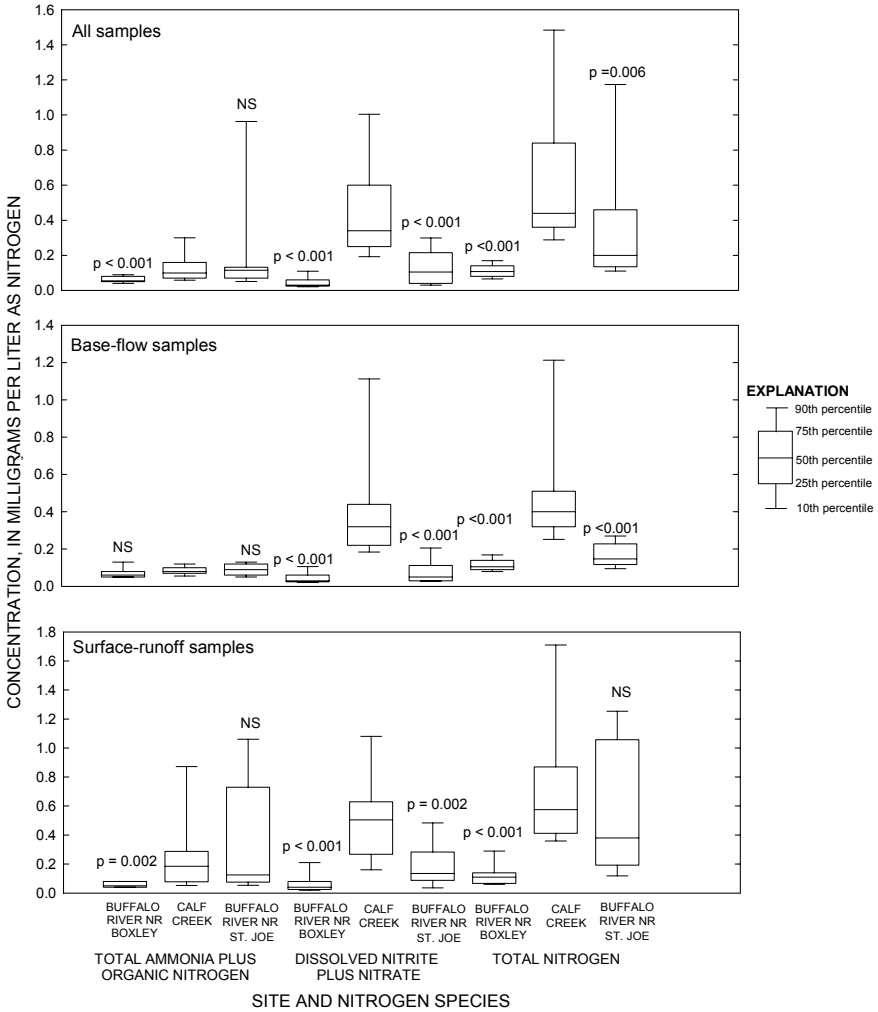

Figure 5. Distribution of nitrogen concentrations for Calf Creek near Silver Hill and the Buffalo River near Boxley and St. Joe, Arkansas, 2001-2002. The p-value is the probability that the median concentrations between the Calf Creek site and the Buffalo River sites are equal. NS indicates the probability exceeds 0.05.

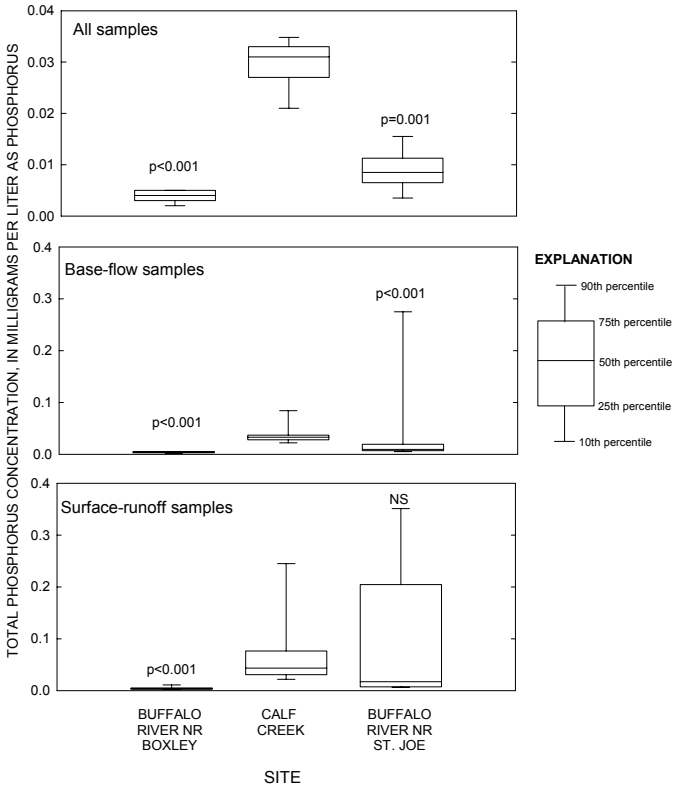

Figure 6. Distribution of total phosphorus concentrations for Calf Creek near Silver Hill and the Buffalo River near Boxley and St. Joe, Arkansas, 2001-2002. The p-value is the probability that the median concentrations between the Calf Creek site and the Buffalo River sites are equal. NS indicates the probability exceeds 0.05.

Fecal indicator bacteria concentrations in samples collected from all three sites varied substantially (fig. 7). Calf Creek had the highest concentrations of bacteria with median values for all samples ranging from 50 (*E. coli*) to 86 colonies per 100 milliliters (fecal streptococci). The Buffalo River near Boxley had the lowest concentrations with median values ranging from 8 (*E. coli*) to 15 colonies per 100 milliliters (fecal streptococci). Concentrations from base-flow samples generally had lower concentrations of fecal indicator bacteria with a range of 1 to 190 colonies per 100 milliliters compared to high-flow event samples that had concentrations with a range of 1 to 7,300 colonies per 100 milliliters (appendix) at all the sites. Sources of fecal indicator bacteria can include untreated municipal wastewater-treatment effluents; septic tanks; animal wastes from feedlots, barnyards, and pastures; and manure application areas. Higher concentrations of fecal indicator bacteria in high-flow samples from Calf Creek may reflect the higher percentage of pastureland in the basin, providing a source of nonpoint contamination during high-flow events.

Dissolved organic carbon concentrations in samples from Calf Creek and the Buffalo River near St. Joe were similar (fig. 8). However, samples associated with base-flow conditions at Calf Creek had significantly lower concentrations than samples collected from the Buffalo River near St. Joe. Samples from the Buffalo River near Boxley were not analyzed for dissolved organic carbon.

Suspended-sediment concentrations for Calf Creek were significantly higher than for the two Buffalo River sites (fig. 9). Although Calf Creek had the highest median concentrations, the Buffalo River near St. Joe had the highest measured concentrations during high-flow events. The Buffalo River near Boxley had the lowest concentrations ranging from 1 to 11 mg/L, which could be because fewer high-flow event samples were collected at the site and most of the high-flow samples were collected on the fall of the peak streamflow during high-flow events. Suspended-sediment concentrations generally are highest during the rise in streamflow during high-flow events. Similar to the bacteria concentrations, higher concentrations of suspended sediment for Calf Creek may be related to the higher percentage of agricultural activity in the basin.

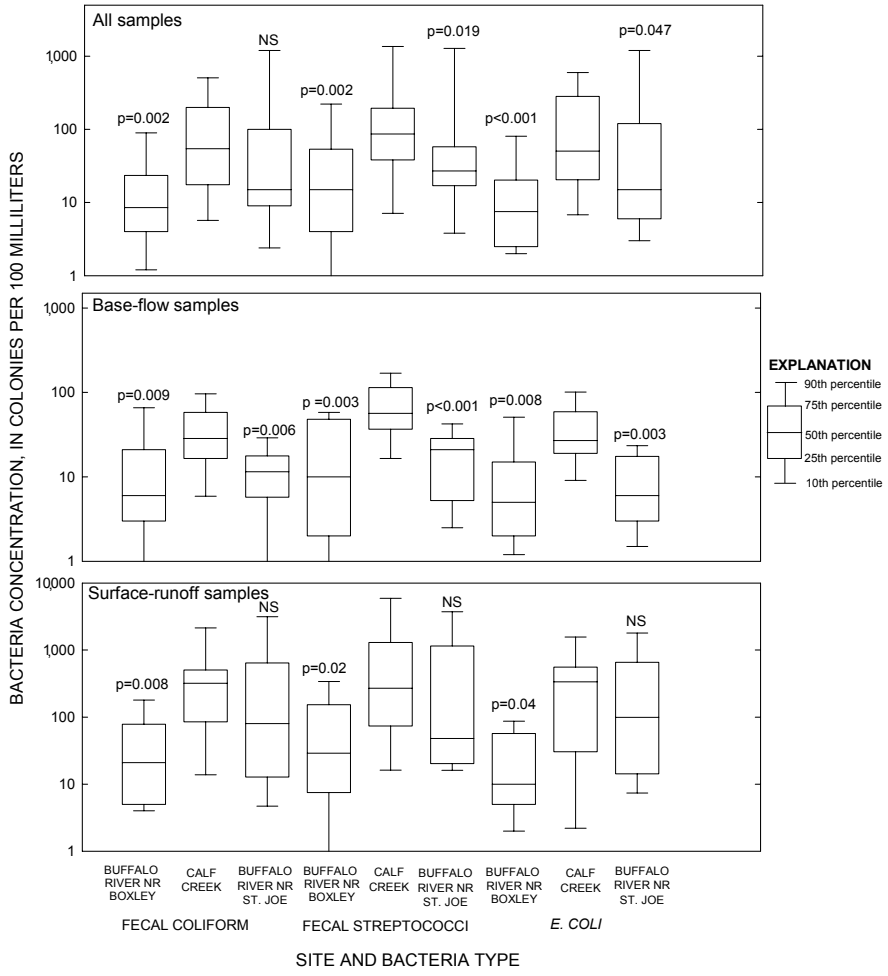

Figure 7. Distribution of bacteria concentrations for Calf Creek near Silver Hill and the Buffalo River near Boxley and St. Joe, Arkansas, 2001-2002. The p-value is the probability that the median concentrations between the Calf Creek site and the Buffalo River sites are equal. NS indicates the probability exceeds 0.05.

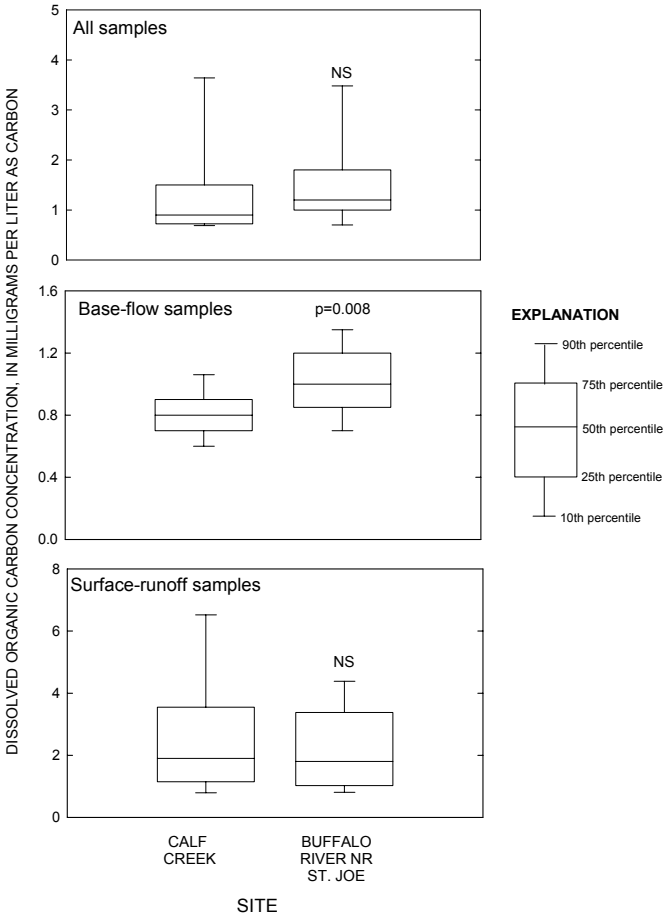

Figure 8. Distribution of dissolved organic carbon for Calf Creek near Silver Hill and the Buffalo River near St. Joe, Arkansas, 2001-2002. The p-value is the probability that the median concentrations between the Calf Creek site and the Buffalo River site are equal. NS indicates the probability exceeds 0.05.

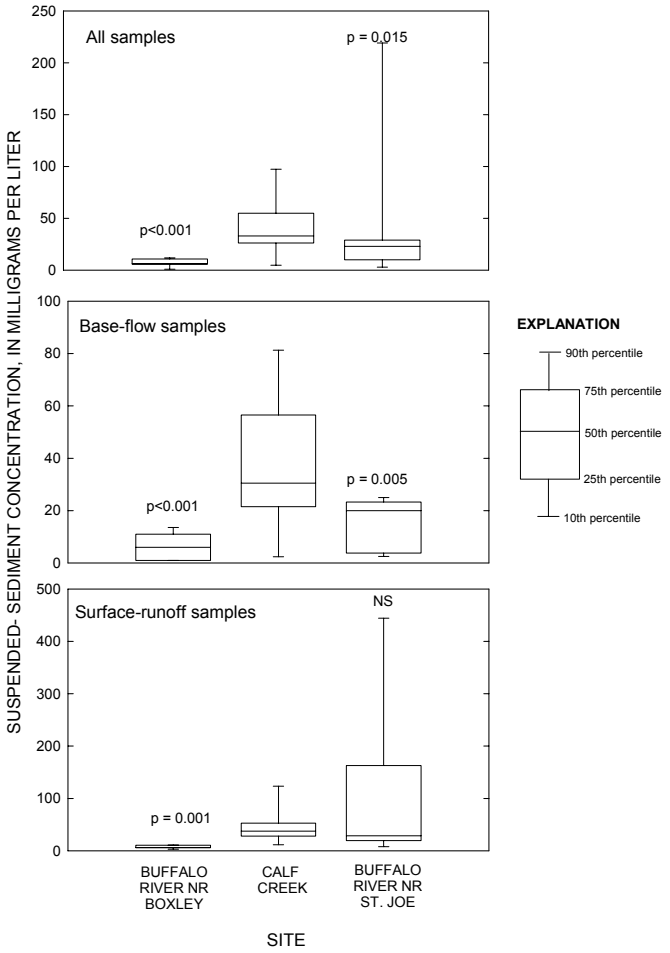

Figure 9. Distribution of suspended-sediment concentrations for Calf Creek near Silver Hill and the Buffalo River near Boxley and St.Joe, Arkansas, 2001-2002. The p-value is the probability that the median concentrations between the Calf Creek site and the Buffalo River sites are equal. NS indicates the probability exceeds 0.05.

Loads

Constituent loads for nutrients, dissolved organic carbon, and suspended sediment were estimated using regression models (table 2). Estimated loads for 2001 and 2002 showed substantial variability among the three sites and through time (table 3). The Buffalo River near St. Joe had estimated annual loads for nutrients and suspended sediment that were at least an order of magnitude higher than the other two sites. Higher loads would be expected at the Buffalo River near St. Joe because of the higher volume of streamflow. Likewise, estimated loads were higher during seasons that had higher values for streamflow from high-flow events than during seasons with more frequent periods of base-flow conditions for all three sites.

Table 2. Regression models applied to estimate constituent loads

[Water-quality data collected between January 2001 and March 2003. Regression model described by the equation $\ln(L) = \beta_o + \beta_1 \ln(Q)$, where L is load, Q is discharge, β_o is a regression constant, and β_1 is a regression coefficient; --, not calculated]

Constituent	Site	Number of samples	Regression constant (β_o)	Regression coefficient (β_1)	Coefficient of determination (R^2)
Total ammonia plus organic nitrogen	Calf Creek	27	-5.21	1.24	96.2
	Buffalo River near Boxley	20	-5.92	0.99	97.1
	Buffalo River near St. Joe	30	-1.89	1.31	94.9
Nitrite plus nitrate	Calf Creek	27	-3.94	1.06	93.1
	Buffalo River near Boxley	20	-6.41	1.03	84.4
	Buffalo River near St. Joe	30	2.22	1.27	93.8
Total nitrogen	Calf Creek	27	-3.64	1.12	95.7
	Buffalo River near Boxley	20	-5.50	1.00	93.5
	Buffalo River near St. Joe	30	-1.25	1.32	97.4
Dissolved phosphorus	Calf Creek	27	-6.59	1.04	97.7
	Buffalo River near Boxley	--	--	--	--
	Buffalo River near St. Joe	30	-5.12	1.26	95.6
Orthophosphorus	Calf Creek	27	-6.78	1.04	95.3
	Buffalo River near Boxley	--	--	--	--
	Buffalo River near St. Joe	--	--	--	--
Total phosphorus	Calf Creek	27	-6.31	1.16	96.3
	Buffalo River near Boxley	20	-8.83	1.04	94.2
	Buffalo River near St. Joe	30	-4.03	1.48	92.7
Dissolved organic carbon	Calf Creek	28	-3.21	1.28	98.1
	Buffalo River near Boxley	--	--	--	--
	Buffalo River near St. Joe	31	0.36	1.20	97.7
Suspended sediment	Calf Creek	28	0.15	1.04	80.4
	Buffalo River near Boxley	20	-1.61	1.30	87.9
	Buffalo River near St. Joe	31	3.02	1.53	93.8

Table 3. Annual nitrogen, phosphorus, dissolved organic carbon, and suspended-sediment loads and yields for Calf Creek near Silver Hill and Buffalo River near Boxley and St. Joe, Arkansas, 2001-2002

[Loads and yields were rounded to two significant figures, lbs/yr, pounds per year; lbs/yr/mi^2, pounds per year per square mile; --, not calculated]

Constituent	Calf Creek		Buffalo River near Boxley		Buffalo River near St. Joe	
	Load (lbs/yr)	Yield (lbs/yr/mi^2)	Load (lbs/yr)	Yield (lbs/yr/mi^2)	Load (lbs/yr)	Yield (lbs/yr/mi^2)
2001						
Total ammonia plus organic nitrogen	18,000	400	16,000	280	490,000	590
Nitrite plus nitrate	39,000	870	11,000	200	330,000	400
Total nitrogen	59,000	1,300	24,000	420	880,000	1,100
Dissolved phosphorus	2,400	52	--	--	17,000	21
Orthophosphorus	2,100	46	--	--	--	--
Total phosphorus	4,300	95	960	17	95,000	120
Dissolved organic carbon	170,000	3,800	--	--	3,400,000	4,100
Suspended sediment	3,000,000	67,000	4,000,000	71,000	170,000,000	200,000
2002						
Total ammonia plus organic nitrogen	42,000	940	23,000	400	960,000	1,200
Nitrite plus nitrate	82,000	1,800	16,000	290	640,000	770
Total nitrogen	130,000	2,900	34,000	590	1,700,000	2,100
Dissolved phosphorus	4,800	110	--	--	32,000	39
Orthophosphorus	4,300	96	--	--	--	--
Total phosphorus	9,400	210	1,400	24	190,000	230
Dissolved organic carbon	410,000	9,000	--	--	6,400,000	7,700
Suspended sediment	5,900,000	130,000	6,300,000	110,000	360,000,000	430,000

Annual

In general, estimated loads for the three sites were greater in 2002 than in 2001 (table 3), which could be attributed to greater streamflow in 2002 (table 1). The annual nutrient loads estimated for the Buffalo River near St. Joe were 7 to 27 times the annual loads estimated for Calf Creek. The total phosphorus and total ammonia plus organic nitrogen loads had the greatest differences between sites with values for the Buffalo River near St. Joe more than 20 times greater than those estimated for Calf Creek for 2001 and 2002. Estimated loads for nitrite plus nitrate were 7 times greater and dissolved phosphorus were approximately 8 times greater for the Buffalo River near St. Joe than for Calf Creek for 2001 and 2002. Calf Creek had lower estimated loads for suspended sediment than the Buffalo River near St. Joe and Buffalo River near Boxley. Suspended-sediment loads estimated for the Buffalo River near St. Joe were 57 times the estimated loads at Calf Creek for 2001 and 61 times the estimated load at Calf Creek for 2002. Estimated loads of dissolved organic carbon were 20 times greater at the Buffalo River near St. Joe than Calf Creek for 2001 and 16 times greater for 2002. The larger nutrient and suspended-sediment loads estimated at the Buffalo River near St. Joe can be attributed to a larger basin area and larger volume of streamflow than Calf Creek. Although the annual streamflow for the Buffalo River near Boxley was greater than Calf Creek and less than the Buffalo River near St. Joe, it had the lowest values for estimated annual loads for all the constituents except suspended sediment, which had loads slightly greater than Calf Creek.

Seasonal

The seasonal distribution of the loads differed between 2001 and 2002 (table 4; fig. 10) due to higher rainfall and streamflow in the spring (April through June) of 2002 and in the fall (October through December) of 2001 (table 1).The estimated seasonal loads for all the sites show similar patterns for the period. For 2001, the highest loads occurred in the winter (January through March) and the fall. In 2002, the summer (July through September) and fall seasons generally had the smallest estimated loads, and the highest loads were in the winter and spring.

Table 4. Seasonal nitrogen, phosphorus, dissolved organic carbon, and suspended-sediment loads for Calf Creek near Silver Hill and Buffalo River near Boxley and St. Joe, Arkansas, 2001-2002

[Values are loads in pounds per day; winter defined as January through March, spring defined as April through June, summer defined as July through September, and fall defined as October through December; values were rounded to two significant figures; --, not calculated]

Constituent	Site	Winter	Spring	Summer	Fall
	2001				
Total ammonia plus organic nitrogen	Calf Creek	100	7.5	2.2	83
	Buffalo River near Boxley	98	15	3.4	59
	Buffalo River near St. Joe	2,900	240	55	2,200
Nitrite plus nitrate	Calf Creek	230	28	10	170
	Buffalo River near Boxley	71	11	2.4	42
	Buffalo River near St. Joe	2,000	180	42	1,500
Total nitrogen	Calf Creek	350	35	11	260
	Buffalo River near Boxley	150	23	5.2	87
	Buffalo River near St. Joe	5,200	420	95	4,000
Dissolved phosphorus	Calf Creek	14	1.8	0.64	10
	Buffalo River near Boxley	--	--	--	--
	Buffalo River near St. Joe	100	11	2.7	74
Orthophosphorus	Calf Creek	12	1.5	0.54	8.8
	Buffalo River near Boxley	--	--	--	--
	Buffalo River near St. Joe	--	--	--	--
Total phosphorus	Calf Creek	25	2.6	0.85	19
	Buffalo River near Boxley	6.0	0.85	0.18	4
	Buffalo River near St. Joe	560	41	8.9	440
Dissolved organic carbon	Calf Creek	990	74	22	800
	Buffalo River near Boxley	--	--	--	--
	Buffalo River near St. Joe	20,000	2,300	570	14,000
Suspended sediment	Calf Creek	17,000	2,700	1,000	12,000
	Buffalo River near Boxley	25,000	2,000	270	17,000
	Buffalo River near St. Joe	960,000	43,000	7,800	850,000
	2002				
Total ammonia plus organic nitrogen	Calf Creek	350	97	5.9	14
	Buffalo River near Boxley	150	100	2.5	1.9
	Buffalo River near St. Joe	7,500	3,000	97	79
Nitrite plus nitrate	Calf Creek	630	220	20	32
	Buffalo River near Boxley	100	74	1.7	1.3
	Buffalo River near St. Joe	4,900	2,000	73	57
Total nitrogen	Calf Creek	1,000	330	26	47
	Buffalo River near Boxley	220	150	3.9	2.8
	Buffalo River near St. Joe	13,000	5,300	170	140
Dissolved phosphorus	Calf Creek	37	13	1.2	1.9
	Buffalo River near Boxley	--	--	--	--
	Buffalo River near St. Joe	250	100	4.5	3.3
Orthophosphorus	Calf Creek	33	12	1.1	1.7
	Buffalo River near Boxley	--	--	--	--
	Buffalo River near St. Joe	--	--	--	--
Total phosphorus	Calf Creek	75	24	1.9	3.4
	Buffalo River near Boxley	9.0	6.2	0.13	0.10
	Buffalo River near St. Joe	1,500	570	16	14
Dissolved organic carbon	Calf Creek	3,400	940	58	130
	Buffalo River near Boxley	--	--	--	--
	Buffalo River near St. Joe	48,000	21,000	940	680
Suspended sediment	Calf Creek	44,000	17,000	1,900	2,600
	Buffalo River near Boxley	42,000	26,000	190	250
	Buffalo River near St. Joe	2,900,000	1,000,000	16,000	18,000

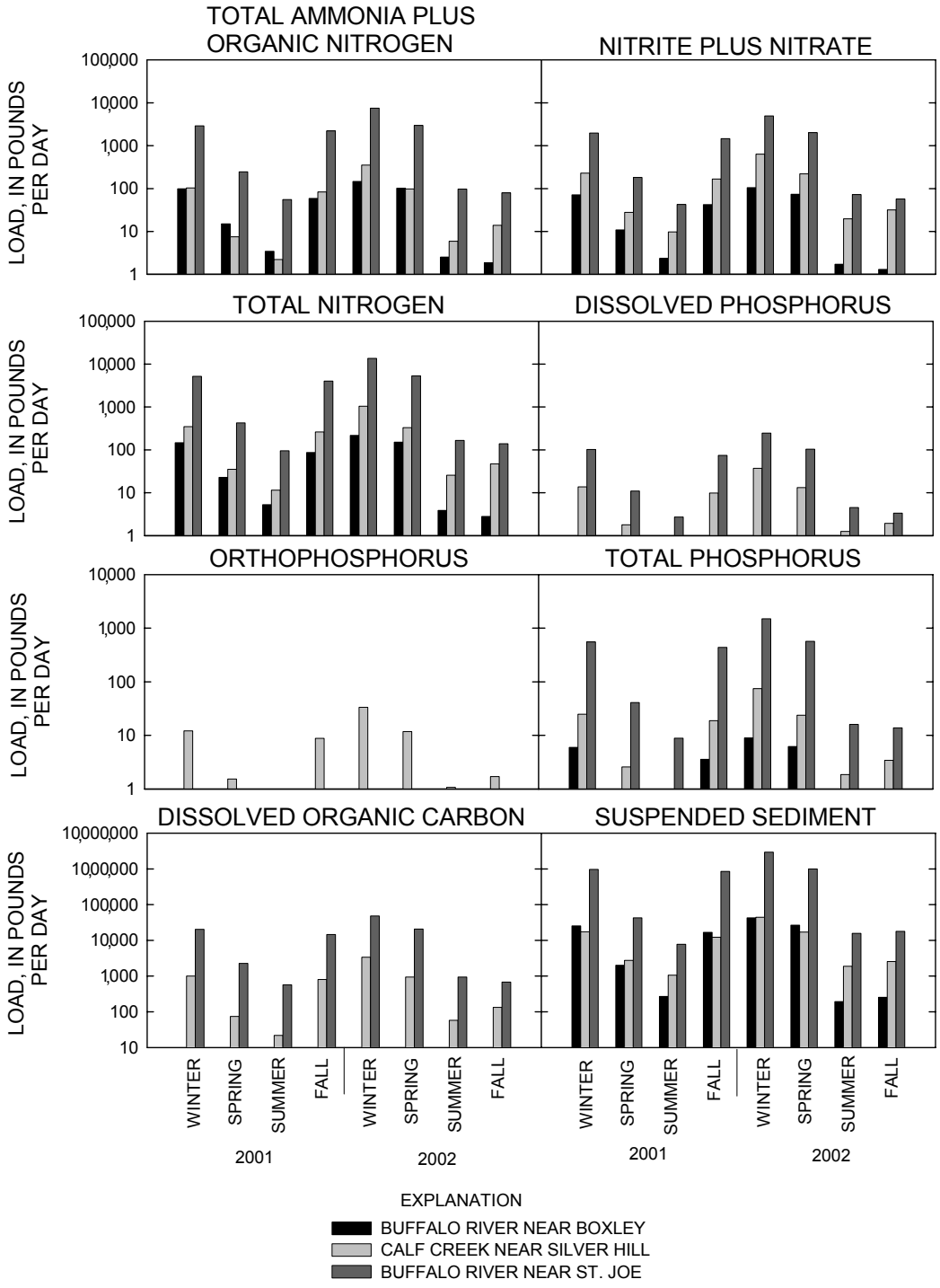

Figure 10. Seasonal loads of nutrients, dissolved organic carbon, and suspended sediment for Calf Creek near Silver Hill and the Buffalo River near Boxley and St. Joe, Arkansas, 2001-2002.

Flow-Weighted Concentrations

Annual flow-weighted concentrations were computed for Calf Creek and the two Buffalo River sites (table 5). The flow-weighted concentrations for the three sites also were compared to the flow-weighted concentrations of 82 undeveloped basins throughout the Nation (Clark and others, 2000; Petersen and others, 2002), including two basins in the Ozark Plateaus—North Sylamore Creek and Paddy Creek. The flow-weighted concentrations also were compared to flow-weighted concentrations at Bear Creek, a tributary to the Buffalo river adjacent to Calf Creek (fig. 1), and to flow-weighted concentrations for a site on the Illinois River near Siloam Springs, Arkansas (Petersen and others, 2002). The Illinois River represents a developed basin that is affected by both point and non-point sources of contamination (Green and Haggard, 2001).

The flow-weighted concentrations for Calf Creek and the Buffalo River were determined from loads estimated using water-quality data collected at fixed intervals. These data were a subset of the water-quality data used to estimate annual and seasonal loads in tables 3 and 4. Data associated with high-flow events were omitted because the data for the undeveloped basins (Clark and others, 2000) generally included little high-flow event data. The flow-weighted concentrations for the Illinois River were calculated from loads computed from data that included some high-flow event data (Green and Haggard, 2001).

Flow-weighted concentrations for Calf Creek generally were higher than the flow-weighted concentrations computed for both of the Buffalo River sites. Nitrite plus nitrate flow-weighted concentrations for Calf Creek were approximately 2.5 times higher than the flow-weighted concentrations for the Buffalo River near St. Joe and 10 to 13 times higher than the flow-weighted concentrations computed for the Buffalo River near Boxley for 2001 and 2002. Total nitrogen flow-weighted concentrations for Calf Creek were similar to the flow-weighted concentrations computed for the Buffalo River near St. Joe and were 8 to 9 times the flow-weighted concentrations for the Buffalo River near Boxley for 2001 and 2002. The Buffalo River near St. Joe had similar flow-weighted concentrations of total phosphorus as Calf Creek, and the flow-weighted concentrations of total phosphorus computed for the Buffalo River near Boxley were small (less than 0.01 mg/L).

Flow-weighted concentrations for Calf Creek generally were higher than all the other sites in the comparison with the exception of the Illinois River (table 5). Nitrite plus nitrate flow-weighted concentrations for Calf Creek were approximately 7 times the median concentration for the undeveloped basins. Total nitrogen flow-weighted concentrations for Calf

Table 5. Flow-weighted concentrations for Calf Creek, two Buffalo River sites, and selected other stream basins

[Values are in milligrams per liter. Buffalo River, Bear Creek, and Calf Creek concentrations are calculated from fixed interval sampling data. Values for undeveloped basins, North Sylamore Creek and Paddy Creek, are from Clark and others (2000). Values for the Illinois River are from Green and Haggard (2001) and for the Buffalo River and Bear Creek for years 1999 and 2000 are from Petersen and others (2002).
--, not available; <, less than].

	Dissolved nitrite plus nitrate	Total nitrogen	Dissolved ortho-phosphorus	Total phosphorus
Calf Creek - 2001	0.61	0.90	0.03	0.06
Calf Creek - 2002	0.67	1.01	0.03	0.06
Buffalo River near Boxley - 2001	0.06	0.11	--	<0.01
Buffalo River near Boxley - 2002	0.05	0.11	--	<0.01
Buffalo River near St. Joe - 1999	0.35	0.75	--	0.05
Buffalo River near St. Joe - 2000	0.39	0.93	--	0.06
Buffalo River near St. Joe - 2001	0.24	0.52	--	0.04
Buffalo River near St. Joe - 2002	0.28	0.60	--	0.04
Undeveloped basin median (1990-1995)	0.09	0.26	0.01	0.02
Undeveloped basin 75th percentile (1990-1995)	0.21	0.50	0.01	0.04
North Sylamore Creek, Arkansas - undeveloped (1990-1995)	0.10	0.23	<0.01	0.03
Paddy Creek, Missouri - undeveloped (1990-1995)	0.04	<0.20	<0.01	0.04
Bear Creek -1999	0.46	0.82	0.03	0.09
Bear Creek -2000	0.46	0.88	0.04	0.13
Illinois River, Arkansas - developed (1997-1998)	2.4	3.4	0.22	0.40

Creek were 3 to 4 times higher than the median concentration for the undeveloped basins. Calf Creek had values for the flow-weighted concentrations of total phosphorus that were slightly higher than the 75th percentile of flow-weighted concentrations for the undeveloped basins. The total phosphorus flow-weighted concentrations for the Illinois River were approximately 7 times the concentrations found at Calf Creek. The Buffalo River near St. Joe had flow-weighted concentrations of nitrogen and phosphorus computed for 2001 and 2002 that were similar to the 75th percentile of the flow-weighted concentrations for the undeveloped basins. Flow-weighted concentrations of nitrogen and phosphorus for the Buffalo River near Boxley generally were lower than the median flow-weighted concentration for the undeveloped basins.

Yields

Annual yields (annual load divided by drainage area) for Calf Creek were higher than yields for both of the Buffalo River sites for 2001 and 2002 (table 3). Although the estimated loads for the Buffalo River near St. Joe were considerably greater than estimated loads for Calf Creek, the annual yields of nitrite plus nitrate and dissolved phosphorus for Calf Creek were approximately 2 times greater than that of the Buffalo River near St. Joe in 2001 and 2002. Total phosphorus and total nitrogen yields were similar between Calf Creek and the Buffalo River near St. Joe. Compared to the Buffalo River near Boxley, yields computed for 2001 and 2002 for Calf Creek were approximately 4.4 to 6.2 times greater for nitrite plus nitrate, 5.6 to 8.8 times greater for total phosphorus, and 3.1 to 4.9 times greater for total nitrogen.

Annual yields for Calf Creek and the Buffalo River were compared to the yields of the 82 undeveloped basins throughout the Nation, including two streams in the Ozark Plateaus (Clark and others, 2000; table 6). The yields also were compared to Bear Creek (Petersen and others, 2002) and the Illinois River near Siloam Springs, Arkansas (Green and Haggard, 2001). For comparison, the yields for Calf Creek and the Buffalo River were determined from loads calculated using water-quality data collected at fixed time intervals. These data were a subset of the water-quality data used to calculate the annual loads and yields in table 3 and seasonal loads in table 4. Data associated with high-flow events were omitted because the data for the undeveloped basins (Clark and others, 2000) generally did not include high-flow event data. The yields for the Illinois River were calculated from loads computed from

Table 6. Yields for Calf Creek, two Buffalo River sites, and selected other stream basins

[Values are in pounds per year per square mile. Buffalo River, Bear Creek, and Calf Creek yields are calculated from fixed time interval sampling data. Values for undeveloped basins, North Sylamore Creek and Paddy Creek, are from Clark and others (2000). Values for the Illinois River are from Green and Haggard (2001) and for the Buffalo River and Bear Creek for years 1999 and 2000 are from Petersen and others (2002). --, not available]

	Dissolved nitrite plus nitrate	Total nitrogen	Dissolved orthophosphorus	Total phosphorus
Calf Creek - 2001	1,000	1,500	53	97
Calf Creek - 2002	2,300	3,500	110	210
Buffalo River near Boxley - 2001	200	420	--	17
Buffalo River near Boxley - 2002	290	590	--	24
Buffalo River near St. Joe - 1999	700	1,500	--	97
Buffalo River near St. Joe - 2000	660	1,600	--	100
Buffalo River near St. Joe - 2001	460	1,000	--	73
Buffalo River near St. Joe - 2002	910	1,900	--	140
Undeveloped basin median (1990-1995)	150	490	16	49
Undeveloped basin 75th percentile (1990-1995)	500	1,300	27	69
North Sylamore Creek, Arkansas - undeveloped (1990-1995)	170	390	7	43
Paddy Creek, Missouri - undeveloped (1990-1995)	80	360	9	74
Bear Creek -1999	610	1,100	44	120
Bear Creek -2000	700	1,400	61	190
Illinois River, Arkansas - developed (1997-1998)	5,900	8,600	540	960

data that included some high-flow event data (Green and Haggard, 2001).

The annual yields calculated for Calf Creek were considerably higher compared to the other selected sites except for the Illinois River (table 6). Nitrite plus nitrate yields for Calf Creek were approximately 7 to 15 times the median yield for undeveloped basins and total phosphorus yields were 2 to 4 times greater than the median yield for undeveloped basins. The total nitrogen and dissolved orthophosphorus yields were both 3 to 7 times greater than the median yield for undeveloped basins. The Buffalo River near Boxley generally had the lowest yields except for yields computed for Paddy Creek, Missouri. Yields calculated for the Buffalo River near Boxley with respect to nitrite plus nitrate were 1.3 to 1.9 times greater than the median yield for undeveloped basins, and total phosphorus yields were approximately 1/3 to 1/2 of the median yield for undeveloped basins.

SUMMARY

The Buffalo River and its tributary, Calf Creek, are in the White River Basin in the Ozark Plateau physiographic province in north-central Arkansas. A better understanding of the hydrology and water quality of Calf Creek is of interest to many, including the National Park Service, who administers the Buffalo National River, to evaluate its effect on the hydrology and water quality of the Buffalo River.

The hydrologic and water-quality characteristics of Calf Creek near Silver Hill, Arkansas, were compared to two sites on the Buffalo River upstream (near Boxley, Arkansas) and downstream (near St. Joe, Arkansas) from the confluence of Calf Creek for calendar years 2001 and 2002. Stage was measured continuously to compute streamflow, and water-quality samples were collected monthly and during selected high-flow events from January 2001 to March 2003. Annual and seasonal loads were estimated for Calf Creek for nutrients, dissolved organic carbon, and suspended sediment and compared with loads and yields at the sites on the Buffalo River. Flow-weighted concentrations and yields were computed from estimated annual loads for comparison with other developed and undeveloped basins.

Streamflow for Calf Creek and the two sites on the Buffalo River varied annually and seasonally. The Buffalo River near St. Joe had the largest annual mean streamflow (805 to 1,360 ft^3/s for 2001 and 2002) compared to the Buffalo River near Boxley (106 and 152 ft^3/s for 2001 and 2002) and Calf Creek (39.3 and 79.6 ft^3/s for 2001 and 2002). The highest mean daily streamflows were generally in the months of January through May and the lowest in the months of July through October.

Concentrations of nutrients, suspended sediment, and fecal indicator bacteria generally were greater in samples from Calf Creek than in samples collected from both Buffalo River sites. Bacteria and suspended-sediment concentrations were higher in samples collected during high-flow events at all three sites. The Buffalo River near Boxley had the lowest concentrations for nutrients, suspended sediment, and fecal indicator bacteria.

Estimated loads of the nutrients, suspended sediment, and organic carbon for 2001 and 2002 demonstrated substantial variability among the three sites and through time. Estimated loads for nutrients at the Buffalo River near St. Joe were 7 to 27 times the median loads calculated for Calf Creek. Suspended-sediment loads for the Buffalo River near St. Joe were up to 61 times greater than estimated loads for Calf Creek and dissolved organic carbon loads were 16 to 20 times greater. The Buffalo River near Boxley had the least annual loads for all constituents except for suspended sediment, which were slightly greater than suspended-sediment loads estimated for Calf Creek. Higher loads would be expected at the Buffalo River near St. Joe because of the larger basin area and larger volume of streamflow. Likewise, estimated loads for all three sites were higher during seasons that had higher streamflow from high-flow events than during seasons with more frequent periods of base-flow conditions. The highest daily loads occurred in the fall and winter of 2001 and the winter and spring of 2002.

Flow-weighted concentrations generally were higher for Calf Creek than concentrations for the two sites on the Buffalo River and for typical flow-weighted concentrations found in undeveloped basins. Nitrite plus nitrate flow-weighted concentrations for Calf Creek were 7 times higher and total nitrogen flow-weighted concentrations were 3 to 4 times higher than the median concentration for the undeveloped basins. Total phosphorus flow-weighted concentrations for Calf Creek and the Buffalo River near St. Joe were slightly higher than the 75th percentile of concentrations for the undeveloped basins. The Buffalo River near Boxley had flow-weighted concentrations of

nitrogen and phosphorus that were lower than the median concentration of the undeveloped basins.

Annual yields computed for Calf Creek were higher than yields computed for the two sites on the Buffalo River and sites that are representative of undeveloped basins. Nitrite plus nitrate yields for Calf Creek were approximately 2 times greater than yields for the Buffalo River near St. Joe, 4.4 to 6.2 times greater than yields for the Buffalo River near Boxley for 2001 and 2002, and 7 to 15 times greater than the median yield for the undeveloped basins. Annual yields of total nitrogen for 2001 and 2002 for Calf Creek were similar to the yields for the Buffalo River near St. Joe, 3.1 to 4.9 times greater than yields for the Buffalo River near Boxley, and 2 to 4 times greater than the median yield for undeveloped basins. All of the computed yields were less than yields for a developed basin.

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APPENDIX

Appendix—Water-quality data for Calf Creek near Silver Hill, Buffalo River near Boxley, and Buffalo River near St. Joe, Arkansas

[Five digit numbers in parentheses are U.S. Environmental Protection Agency STORET data management system parameter codes, ft^3/s, cubic feet per second; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus; C, carbon; mL, milliliters; --, no data; E, estimated; <, less than]

Date	Time	Discharge, instantaneous (ft^3/s) (00061)	Oxygen, dissolved (mg/L) (00300)	Oxygen, dissolved (percent saturation) (00300)	pH, field standard units (00400)	Specific conductance (µS/cm) (00095)	Temperature (°C) (00010)	Acid neutralizing capacity, field (mg/L as $CaCO_3$) (00410)	Solids, residue at 180 °C dissolved (mg/L) (70300)	Ammonia, dissolved (mg/L as N) (00608)	Ammonia plus organic nitrogen, dissolved (mg/L as N) (00623)	Ammonia plus organic nitrogen, total (mg/L as N) (00625)	Nitrogen, dissolved (mg/L as N) (00602)	Nitrite plus nitrate, dissolved (mg/L as N) (00631)
Calf Creek near Silver Hill, Arkansas														
1/29/2001	1715	304	10.6	95	7.9	162	9.9	56	102	<0.04	0.36	1.1	1	0.64
2/14/2001	0745	193	10.3	91	7.2	264	10.1	110	155	<.04	0.13	0.28	1.4	1.26
2/21/2001	0930	88	10.8	96	7.8	236	10.1	95	132	<.04	E.07	0.1	--	1.37
3/20/2001	1115	37	11.2	99	8.6	256	9.8	107	128	<.04	<.10	0.12	--	0.39
4/25/2001	0925	19	7.4	70	7.8	272	13	121	156	<.04	E.09	0.1	--	0.34
5/9/2001	1000	8	10.3	104	8.1	287	16.1	122	174	E.03	E.08	E.07	--	0.35
6/6/2001	1405	5.7	10.8	125	8.1	285	21.8	100	166	E.03	0.12	E.07	0.33	0.22
7/10/2001	1045	3	9	101	7.8	333	20.4	152	192	E.03	E.07	0.12	--	0.2
10/17/2001	1040	6.7	8.8	84	7.5	389	13.8	171	208	<.04	E.08	E.07	--	0.52
11/14/2001	0915	1.9	9.4	89	7.5	365	13	178	200	<.04	E.06	E.08	--	0.28
12/6/2001	0930	23	10	100	7.7	327	15.6	144	188	<.04	E.08	0.1	--	0.94
12/17/2001	1615	824	8.3	80	8.2	200	12.7	97	124	<.04	0.14	0.29	0.34	0.21
1/23/2002	1055	2.7	11.4	106	7.5	309	11.3	137	172	<.04	<.10	<.10	--	0.51
1/24/2002	1815	137	10.9	94	7.7	163	8.7	63	98	<.04	0.19	0.34	0.69	0.5
2/1/2002	1410	420	11.5	103	7.3	185	10.2	89	--	E.02	0.12	0.22	0.78	0.66
2/21/2002	1145	77	15.8	140	7.6	244	10.1	105	140	<.04	<.10	E.10	--	0.32
3/21/2002	1515	459	7.3	66	7.8	217	11.5	98	129	<.04	E.07	0.15	--	0.6
4/8/2002	1715		9.8	95	7.8	172	13.8	80	95	<.04	0.19	0.21	0.33	0.14
4/24/2002	0745	80	8.3	84	7.8	332	15.8	162	189	<.04	E.08	E.06	--	0.32
6/11/2002	1615	45	11.4	139	7.8	246	24.6	108	139	E.03	E.10	0.16	--	0.25
6/19/2002	1100	10	7.5	85	7.5	271	20.8	129	153	<.04	E.06	E.05	--	0.16
7/9/2002	1245	5.8	12.8	154	7.8	332	24.9	148	173	<.04	E.07	E.08	--	0.2
8/13/2002	1130	4.2	9.8	115	7.7	307	23.7	138	185	<.04	E.10	E.07	--	0.27
9/11/2002	1240	1.1	10.4	121	7.6	319	22.9	148	181	<.04	E.09	0.11	--	0.29
10/24/2002	0900	--	7	69	7.8	344	15.4	165	189	<.04	E.05	E.06	--	0.32
11/6/2002	0830	--	9.6	92	7.6	361	12.8	165	199	<.04	E.06	E.07	--	0.44
12/17/2002	1130	--	12.1	122	8	327	15.2	145	200	<.04	E.08	E.06	--	0.82
1/14/2003	0930	--	10.4	88	7.7	270	7.9	114	154	--	--	--	--	--

Appendix—Water-quality data for Calf Creek near Silver Hill, Buffalo River near Boxley, and Buffalo River near St. Joe, Arkansas—Continued

[Five digit numbers in parentheses are U.S. Environmental Protection Agency STORET data management system parameter codes, ft^3/s, cubic feet per second; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus; C, carbon; mL, milliliters; --, no data; E, estimated; <, less than]

Date	Time	Nitrite, dissolved (mg/L as N) (00613)	Nitrogen, total (mg/L as N) (00600)	Phos-phorus, dissolved (mg/L as P) (00666)	Ortho-phosphorus, dissolved (mg/L as P) (00671)	Phos-phorus, total (mg/L as P) (00665)	Organic carbon, dissolved (mg/L as C) (00681)	E. coli (colonies per 100 mL) (31633)	Fecal coliform (colonies per 100 mL) (31625)	Fecal strepto-cocci (colonies per 100 mL) (31673)	Sediment, suspended (mg/L) (80154)
Calf Creek near Silver Hill, Arkansas											
1/29/2001	1715	E.004	1.8	0.097	0.08	0.31	7.6	E1,900	E2,800	7,100	129
2/14/2001	0745	<.006	1.5	0.015	E.01	0.037	3.4	780	470	1,400	40
2/21/2001	0930	0.012	1.5	0.028	0.03	0.034	1	140	60	52	26
3/20/2001	1115	<.006	0.51	0.017	E.01	0.018	0.9	E7	<1	E6	30
4/25/2001	0925	E.003	0.44	0.023	E.02	0.027	0.8	68	53	45	36
5/9/2001	1000	E.004	--	0.024	0.06	0.028	0.7	E18	23	39	31
6/6/2001	1405	E.003	--	0.024	E.01	0.03	0.9	E13	E12	61	57
7/10/2001	1045	<.006	0.32	0.02	0.02	0.023	0.8	53	56	93	68
10/17/2001	1040	<.008	--	0.03	0.03	0.03	1	20	39	190	110
11/14/2001	0915	<.008	--	0.024	E.01	0.024	0.7	27	29	160	96
12/6/2001	0930	<.008	1	0.032	0.03	0.036	1.2	26	46	98	75
12/17/2001	1615	<.008	0.5	0.032	0.03	0.053	4	330	290	550	29
1/23/2002	1055	<.008	--	0.026	0.03	0.025	0.7	E5	E3	E3	55
1/24/2002	1815	<.008	0.84	0.04	0.03	0.093	3.6	490	510	3,200	46
2/1/2002	1410	<.008	0.88	0.034	0.03	0.082	2.3	340	620	330	45
2/21/2002	1145	<.008	--	0.023	0.02	0.033	1.3	77	100	55	28
3/21/2002	1515	<.008	0.75	0.031	0.02	0.06	1.5	E62	E80	E47	28
4/8/2002	1715	<.008	0.35	0.025	0.02	E.05	3.1	580	490	1,000	35
4/24/2002	0745	<.008	--	0.017	0.02	0.02	1.1	380	350	210	27
6/11/2002	1615	<.008	0.41	0.028	0.02	0.037	1.5	<1	120	130	5
6/19/2002	1100	<.008	--	0.027	0.02	0.031	0.9	25	E16	28	21
7/9/2002	1245	<.008	--	0.026	0.02	0.031	0.8	E10	E18	36	30
8/13/2002	1130	<.008	--	0.027	0.02	0.031	0.8	>84	<16	>120	23
9/11/2002	1240	<.008	0.4	0.029	0.02	0.033	0.6	31	65	160	20
10/24/2002	0900	<.008	--	0.03	0.03	0.034	0.7	61	E170	190	36
11/6/2002	0830	<.008	--	0.027	0.02	0.033	0.7	48	59	80	55
12/17/2002	1130	<.008	--	0.028	0.02	0.03	0.6	27	E18	45	3
1/14/2003	0930	--	--	--	--	--	0.9	22	28	E21	1

Appendix—Water-quality data for Calf Creek near Silver Hill, Buffalo River near Boxley, and Buffalo River near St. Joe, Arkansas

[Five digit numbers in parentheses are U.S. Environmental Protection Agency STORET data management system parameter codes, ft^3/s, cubic feet per second; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus; C, carbon; mL, milliliters; --, no data; E, estimated; <, less than]

Date	Time	Discharge, instantaneous (ft^3/s) (00061)	Oxygen, dissolved (mg/L) (00300)	Oxygen, dissolved (percent saturation) (00300)	pH, field standard units (00400)	Specific conductance (µS/cm) (00095)	Temperature (°C) (00010)	Acid neutralizing capacity, field (mg/L as CaCO3) (00410)	Solids, residue at 180 °C dissolved (mg/L) (70300)	Ammonia, dissolved (mg/L as N) (00608)	Ammonia plus organic nitrogen, dissolved (mg/L as N) (00623)	Ammonia plus organic nitrogen, total (mg/L as N) (00625)	Nitrogen, dissolved (mg/L as N) (00602)	Nitrite plus nitrate, dissolved (mg/L as N) (00631)
Buffalo River near Boxley, Arkansas														
1/10/2001	1000	64	13.2	98	7	64	2.7	--	36	<0.04	E0.06	<0.08	--	0.1
2/7/2001	1315	66	11.9	100	7.9	59	6.9	--	40	<.04	<.10	E.06	--	0.11
3/7/2001	1045	69	12.3	104	7.9	61	7.8	--	38	<.04	<.10	E.05	--	0.06
4/17/2001	1135	86	11	104	6.7	58	12.6	--	45	<.04	<.10	<.08	--	<.05
5/23/2001	1515	42	9.2	103	8.1	77	19.8	--	41	<.04	<.10	<.08	--	E.03
6/26/2001	1000	12	7.5	85	8.1	112	21.1	--	64	<.04	<.10	<.08	--	E.02
7/17/2001	1000	8.8	7.5	86	7.5	142	21.4	--	87	<.04	<.10	E.08	--	0.06
8/16/2001	1320	8.8	7	88	7.2	149	25.5	--	43	<.04	E.05	E.06	--	E.03
9/11/2001	1145	14	8.6	96	8.1	161	19.2	--	89	<.04	<.10	0.08	--	0.21
11/20/2001	1130	7.4	7.7	70	8.5	128	10.8	--	--	<.04	--	0.14	--	<.05
12/12/2001	1215	40	10.2	91	7.5	59	9.2	--	--	<.04	--	<.10	--	<.05
1/9/2002	1125	14	13	104	7.9	69	4.9	--	--	<.04	--	<.10	--	E.03
2/14/2002	0930	56	12.7	101	7.5	55	4.8	--	--	<.04	--	E.08	--	<.05
3/12/2002	1245	560	11.3	98	7.4	50	8.1	--	--	<.04	--	E.08	--	0.06
5/8/2002	1050	38	9.3	100	7.7	71	17.6	--	--	<.04	--	E.09	--	<.05
7/9/2002	1050	8	6.6	79	7.3	118	23.6	--	--	<.04	--	E.07	--	E.02
9/11/2002	0755	2.9	7.8	88	7	163	20.6	--	--	<.04	--	E.08	--	E.04
11/26/2002	1215	--	11.4	96	8.1	182	7.4	--	--	<.04	--	<.10	--	E.05
12/10/2002	1150	--	11.4	96	7.5	177	7.3	--	--	<.04	--	E.05	--	0.09
1/14/2003	1500	--	11.4	96	8	89	7.7	--	--	<.04	--	<.10	--	<.06

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Date	Time	Nitrite, dissolved (mg/L as N) (00613)	Nitrogen, total (mg/L as N) (00600)	Phos-phorus, dissolved (mg/L as P) (00666)	Ortho-phos-phorus, dissolved (mg/L as P) (00671)	Phos-phorus, total (mg/L as P) (00665)	Organic carbon, dissolved (mg/L as C) (00681)	E. coli (colonies per 100 mL) (31633)	Fecal coliform (colonies per 100 mL) (31625)	Fecal strepto-cocci (colonies per 100 mL) (31673)	Sediment, suspended (mg/L) (80154)
Buffalo River near Boxley, Arkansas											
1/10/2001	1000	<.006	--	<.006	<.02	<.004	--	E5	E5	E7	6
2/7/2001	1315	<.006	--	<.006	<.02	E.003	--	E2	E7	<1	6
3/7/2001	1045	<.006	--	<.006	<.02	E.003	--	E2	E4	E1	6
4/17/2001	1135	<.006	--	<.006	<.02	0.005	--	E6	E5	E9	6
5/23/2001	1515	<.006	--	<.006	<.02	E.002	--	E5	E10	29	9
6/26/2001	1000	0.007	--	<.006	<.02	E.003	--	E10	24	49	11
7/17/2001	1000	E.003	--	<.006	<.02	<.004	--	59	77	59	9
8/16/2001	1320	<.006	--	<.006	<.02	0.004	--	E9	22	E22	14
9/11/2001	1145	<.006	0.3	<.006	<.02	0.005	--	83	E180	340	10
11/20/2001	1130	<.008	--	--	<.02	E.002	--	<10	<16	<10	11
12/12/2001	1215	<.008	--	--	<.02	E.004	--	E87	66	66	6
1/9/2002	1125	<.008	--	--	<.02	E.003	--	E15	E3	E3	6
2/14/2002	0930	<.008	--	--	<.02	0.004	--	E1	E4	E2	6
3/12/2002	1245	<.008	--	--	<.02	0.011	--	21	21	E8	11
5/8/2002	1050	<.008	--	--	<.02	0.005	--	E4	E6	48	10
7/9/2002	1050	<.008	--	--	E.01	0.004	--	18	21	55	12
9/11/2002	0755	<.008	--	--	<.02	0.005	--	31	91	240	3
11/26/2002	1215	<.008	--	--	<.02	0.005	--	E2	E1	E10	1
12/10/2002	1150	<.008	--	--	<.02	0.005	--	E5	E4	20	1
1/14/2003	1500	<.008	--	--	<.02	0.005	--	E2	E1	E1	1

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Date	Time	Discharge, instantaneous (ft^3/s) (00061)	Oxygen, dissolved (mg/L) (00300)	Oxygen, dissolved (percent saturation) (00300)	pH, field standard units (00400)	Specific conductance (µS/cm) (00095)	Temperature (°C) (00010)	Acid neutralizing capacity, field (mg/L as $CaCO_3$) (00410)	Solids, residue at 180 °C dissolved (mg/L) (70300)	Ammonia, dissolved (mg/L as N) (00608)	Ammonia plus organic nitrogen, dissolved (mg/L as N) (00623)	Ammonia plus organic nitrogen, total (mg/L as N) (00625)	Nitrogen, dissolved (mg/L as N) (00602)	Nitrite plus nitrate, dissolved (mg/L as N) (00631)
Buffalo River near St. Joe, Arkansas														
1/16/2001	1400	1,240	9.4	77	8.4	152	6.4	68	83	<0.04	<.10	<0.08	--	0.29
1/29/2001	1815	774	11.8	99	8	183	7.1	71	102	<.04	0.2	0.81	0.56	0.37
2/14/2001	0645	1,590	10.6	91	8	146	8.7	64	86	<.04	<.10	0.13	--	0.3
2/21/2001	0815	2,240	10.6	92	7.6	156	9.4	68	84	<.04	E.06	0.12	--	0.75
3/20/2001	1300	750	11.8	107	8.3	172	11	74	100	<.04	<.10	0.1	--	0.15
4/25/2001	0815	477	7	71	7	176	16.2	79	--	<.04	E.09	0.13	--	E.04
5/9/2001	1100	244	8.5	94	8.1	210	20.7	95	130	<.04	E.09	0.12	--	0.1
6/7/2001	0740	176	8.2	99	7.5	202	24	94	--	<.04	E.07	E.07	--	0.05
7/10/2001	1145	94	6.4	84	8	219	28.6	99	132	<.04	E.09	0.14	--	E.04
8/17/2001	0710	94	5.2	64	7.5	236	24.8	145	69	<.04	E.08	0.09	--	<.05
9/6/2001	0945	21	6.6	81	8.1	241	25.8	109	144	<.04	E.10	0.11	--	E.03
10/17/2001	1140	388	9.2	90	7.7	237	15.3	108	136	<.04	E.08	0.12	--	0.08
11/13/2001	1515	77	11.6	115	7.8	253	15.2	125	142	<.04	E.06	E.06	--	E.03
12/6/2001	0845	639	9.3	91	7.4	191	14.4	92	108	<.04	E.07	E.08	--	0.2
12/17/2001	1730	35,000	10.2	95	8	88	11.4	41	62	<.04	0.18	1	0.41	0.23
1/23/2002	1130	268	11.7	104	7.5	226	9.2	101	132	<.04	<.10	<.10	--	0.21
1/25/2002	0900	3,800	9.8	82	8	140	7.7	61	82	<.04	0.18	0.29	0.44	0.26
2/1/2002	1325	15,900	9.8	85	6.9	100	9.1	50	--	E.02	0.2	0.49	0.44	0.24
2/22/2002	0845	1,380	11.4	97	7.6	172	8.9	80	92	0.09	<.10	E.06	--	0.13
3/20/2002	0810	51,500	8.5	76	7.5	89	10.8	5	62	<.04	0.14	0.98	0.28	0.14
4/8/2002	1500	44,200	11.2	102	7.6	81	10.8	33	49	<.04	0.21	1.2	0.32	0.11
4/23/2002	1445	1,360	10.2	109	8.3	177	18.8	87	105	<.04	E.07	E.05	--	0.05
6/12/2002	1000	1,190	8	95	7.9	203	23.2	103	117	E.03	E.10	0.12	--	0.11
6/19/2002	1145	407	7.4	84	8.1	209	21	107	119	<.04	E.08	E.07	--	0.05
7/10/2002	0715	139	5.7	72	7.9	231	27.6	109	130	<.04	E.09	0.12	--	E.04
8/13/2002	1015	70	6.8	84	7.9	225	26.6	103	135	<.04	E.10	E.09	--	E.03
9/11/2002	1040	36	7.3	88	7.7	232	25	111	122	<.04	E.07	0.12	--	<.05
10/24/2002	0805	--	7.7	77	7.9	264	15.7	131	142	<.04	<.10	E.06	--	E.05
11/5/2002	1215	--	11.4	110	7.7	260	12.7	129	152	<.04	E.07	E.09	--	E.06
12/17/2002	1210	--	10.2	95	8.2	256	11.5	121	149	<.04	E.06	E.07	--	0.13
1/14/2003	1015	--	10.9	87	7.7	207	6.2	84	121	--	--	--	--	--

Appendix—Water-quality data for Calf Creek near Silver Hill, Buffalo River near Boxley, and Buffalo River near St. Joe, Arkansas

[Five digit numbers in parentheses are U.S. Environmental Protection Agency STORET data management system parameter codes, ft^3/s, cubic feet per second; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus; C, carbon; mL, milliliters; --, no data; E, estimated; <, less than]

Date	Time	Nitrite, dissolved (mg/L as N) (00613)	Nitrogen, total (mg/L as N) (00600)	Phos-phorus, dissolved (mg/L as P) (00666)	Ortho-phosphorus, dissolved (mg/L as P) (00671)	Phos-phorus, total (mg/L as P) (00665)	Organic carbon, dissolved (mg/L as C) (00681)	E. coli (colonies per 100 mL) (31633)	Fecal coliform (colonies per 100 mL) (31625)	Fecal strepto-cocci (colonies per 100 mL) (31673)	Sediment, suspended (mg/L) (80154)
Buffalo River near St. Joe, Arkansas											
1/16/2001	1400	<.006	--	E.005	<0.02	0.008	1.3	E6	E4	E17	21
1/29/2001	1815	E.003	1.2	0.042	0.04	0.28	3.3	1,700	2,000	7,300	172
2/14/2001	0645	<.006	0.43	E.004	<.02	0.019	1.4	240	210	260	28
2/21/2001	0815	0.009	0.87	0.006	<.02	0.02	1	120	52	58	33
3/20/2001	1300	<.006	0.25	<.006	<.02	0.005	1	<1	E2	E2	20
4/25/2001	0815	<.006	--	E.003	<.02	0.007	0.9	78	110	27	16
5/9/2001	1100	E.003	0.22	E.003	<.02	0.008	1	E4	E10	21	19
6/7/2001	0740	<.006	--	<.006	<.02	0.009	1.1	E14	E12	38	22
7/10/2001	1145	E.003	--	<.006	<.02	0.008	1.2	E11	E13	21	23
8/17/2001	0710	<.006	--	<.006	<.02	0.007	1.9	E9	E5	35	29
9/6/2001	0945	<.006	--	E.003	<.02	0.007	1.4	27	29	E18	23
10/17/2001	1140	<.008	0.2	E.004	<.02	0.007	1.8	28	51	29	24
11/13/2001	1515	<.008	--	<.004	<.02	E.003	0.9	E2	E1	E3	24
12/6/2001	0845	<.008	--	0.005	<.02	0.012	1.2	E17	26	53	23
12/17/2001	1730	<.008	1.2	0.025	E.01	0.23	4.8	1,300	5,800	1,200	231
1/23/2002	1130	<.008	--	E.003	<.02	0.004	0.7	E3	E1	E3	25
1/25/2002	0900	<.008	0.55	0.01	<.02	0.058	3.5	190	E230	1,000	54
2/1/2002	1325	<.008	0.73	0.013	<.02	0.128	3.4	290	780	880	136
2/22/2002	0845	<.008	--	0.004	<.02	0.01	0.9	E15	E15	E14	19
3/20/2002	0810	<.008	1.1	0.023	0.02	0.33	3.3	780	1,300	1,300	430
4/8/2002	1500	<.008	1.3	0.029	0.02	0.4	4.2	2,000	100	2,200	478
4/23/2002	1445	<.008	--	<.004	<.02	0.008	1	7	13	21	25
6/12/2002	1000	<.008	0.23	0.007	E.02	0.015	1.8	40	60	E17	10
6/19/2002	1145	<.008	--	E.003	<.02	0.009	1.2	E19	E9	30	20
7/10/2002	0715	<.008	--	E.003	<.02	0.014	1.3	E13	E10	32	5
8/13/2002	1015	<.008	--	0.005	<.02	0.017	1	<6	29	<12	3
9/11/2002	1040	<.008	--	E.004	<.02	0.011	1.1	5	7	27	3
10/24/2002	0805	<.008	--	0.006	<.02	0.011	0.7	3	E13	7	4
11/5/2002	1215	<.008	--	0.004	<.02	0.009	0.7	E20	E15	28	2
12/17/2002	1210	<.008	--	E.003	<.02	0.005	0.6	E8	E8	E18	3
1/14/2003	1015	--	--	--	--	--	1	E5	E9	E10	3

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