In cooperation with the U.S. Army Joint Readiness Training Center and Fort Polk

Effects of Hardened Low-Water Crossings on Periphyton and Water Quality in Selected Streams at the Fort Polk Military Reservation, Louisiana, 1998–99 and 2003–04

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Cover: Low-water crossing at Little Brushy Creek at the Fort Polk Military Reservation, Louisiana, May 2003 (photograph by Dennis J. Jeffrey, U.S. Geological Survey).

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Conversion Factors, Datums, and Abbreviated Periphyton and Water-Quality Units

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

°F=(1.8×°C)+32

Vertical coordinate information is referenced to the North American Vertical Datum of 1988.

Horizontal coordinate information is referenced to the North American Datum of 1983.

Abbreviated Periphyton and Water-Quality Units

cells per square millimeter (cells/mm^2)

micrograms per liter (µg/L)

micrometer (µm)

microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C)

milligrams per liter (mg/L)

milliliter (mL)

millimeter (mm)

square millimeter (mm^2)

Effects of Hardened Low-Water Crossings on Periphyton and Water Quality in Selected Streams at the Fort Polk Military Reservation, Louisiana, 1998–99 and 2003–04

By Barbara W. Bryan[1], C. Frederick Bryan[1], John K. Lovelace[2], and Roland W. Tollett[2]

Abstract

In 2003, the U.S. Geological Survey (USGS), at the request of the U.S. Army Joint Readiness Training Center and Fort Polk, began a follow-up study to determine whether installation and modification of hardened low-water crossings had short-term (less than 1 year) or long-term (greater than 1 year) effects on periphyton or water quality in five streams at the Fort Polk Military Reservation, Louisiana. Periphyton data were statistically analyzed for possible differences between samples collected at upstream and downstream sites and before and after low-water crossings were modified on three streams, Big Brushy Creek, Tributary to East Fork of Sixmile Creek, and Tributary to Birds Creek, during 2003–04. Periphyton data also were analyzed for possible differences between samples collected at upstream and downstream sites on two streams, Tributary to Big Brushy Creek and Little Brushy Creek, during 1998–99 and 2003. Variations in periphyton communities could not be conclusively attributed to the modifications. Most of the significant changes in percent frequency of occurrence and average cell density of the 10 most frequently occurring periphyton taxa were increases at downstream sites after the hardened low-water crossing installations or modifications. However, these changes in the periphyton community are not necessarily deleterious to the community structure.

Water-quality data collected from upstream and downstream sites on the five streams during 2003–04 were analyzed for possible differences caused by the hardened crossings. Generally, average water-quality values and concentrations were similar at upstream and downstream sites. When average water-quality values or concentrations changed significantly, they almost always changed significantly at both the upstream and downstream sites. It is probable that observed variations in water quality at both upstream and downstream sites are related to differences in rainfall and streamflow during the sample-collection periods rather than an effect of the hardened low-water crossing installations or modifications, but additional study is needed.

Introduction

Streams in training areas at the Fort Polk Military Reservation, La. (hereinafter referred to as the Reservation) (fig. 1), may be affected by the installation, modification, and use of hardened low-water crossings. During 1998–99, periphyton, water quality, and stream habitat were monitored in four streams, Big Brushy Creek (BB), Tributary to East Fork of Sixmile Creek (TEF), Tributary to Big Brushy Creek (TBB), and Little Brushy Creek (LB), to determine possible effects of low-water crossings. Upstream and downstream sites were monitored before and after the crossings were hardened with interlocking concrete blocks laid over an aggregate base. Results of the study are presented in Tollett and others (2002). No substantial effects were observed during the 3-month sampling period after the hardened crossings were installed. The absence of any indication of substantial short-term (less than 1 year) effects from hardened crossing installations was, in part, due to significant effects of natural seasonal variation in the periphyton and water quality. In 2003, the U.S. Geological Survey (USGS), at the request of the U.S. Army Joint Readiness Training Center and Fort Polk, began a follow-up study to determine whether installation and modification of hardened low-water crossings had short-term (less than 1 year) or long-term (greater than 1 year) effects on periphyton or water quality in the same four streams and one additional stream, Tributary to Birds Creek (TBC), at the Reservation.

Purpose and Scope

This report documents the effects of the installation and modification of hardened low-water crossings on periphyton communities and water quality in five streams at the Reservation. Periphyton and water-quality data collected from sites located upstream and downstream from the low-water crossings during 1998–99 and 2003–04 are presented and

[1] Bryan and Associates.

[2] U.S. Geological Survey.

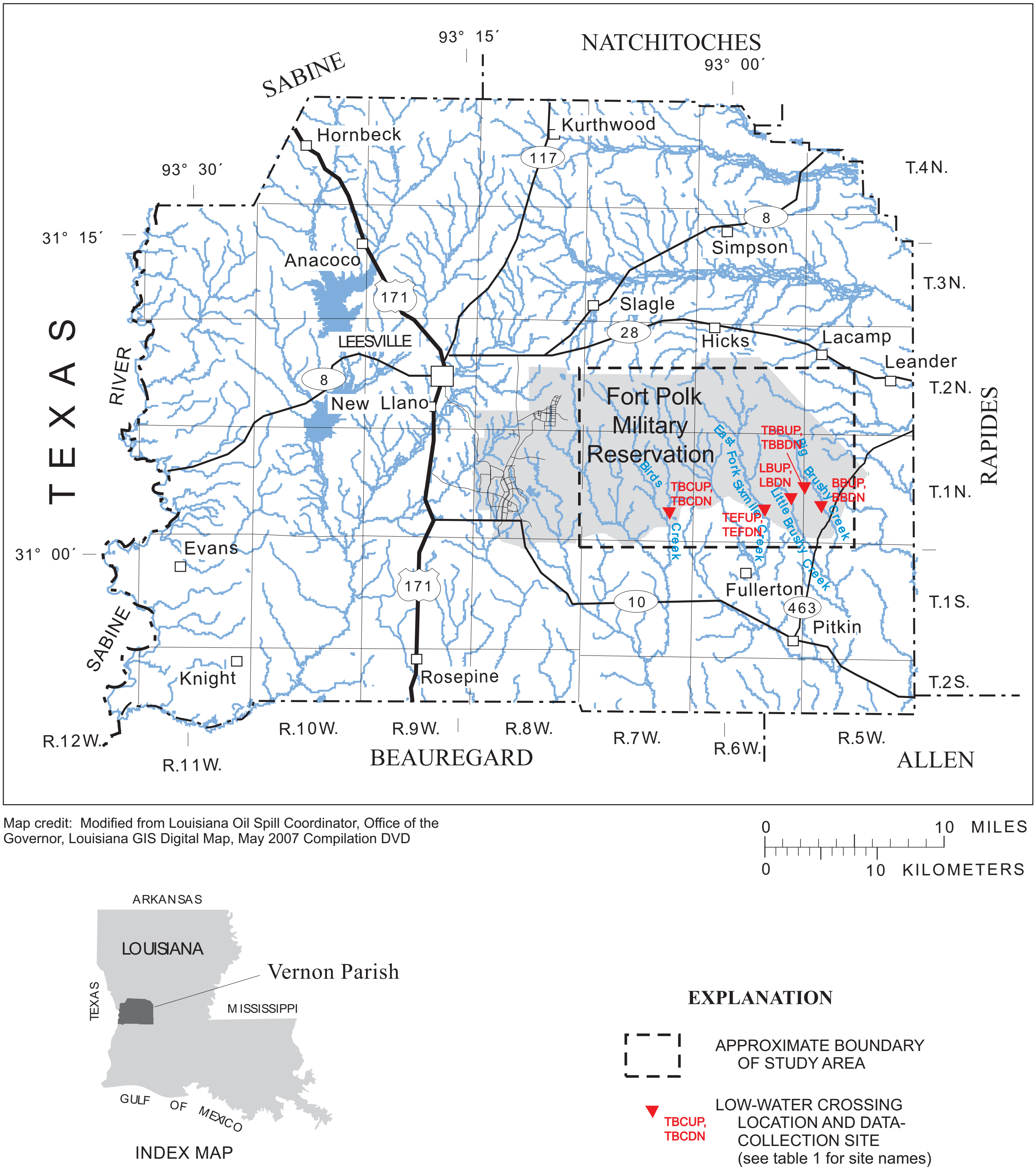

Figure 1. Location of study area, low-water crossings, and data-collection sites at the Fort Polk Military Reservation, Vernon Parish, Louisiana.

summarized. Periphyton data were statistically analyzed for possible differences between samples collected at upstream and downstream sites and before and after low-water crossings were modified on three streams, BB, TEF, and TBC, during 2003–04. Periphyton data also were analyzed for possible differences between samples collected at upstream and downstream sites on two streams, TBB and LB, during 1998–1999 and 2003. Water-quality data collected from upstream and downstream sites on the five streams during 2003–04 were analyzed for possible differences caused by the hardened crossings. Water-quality data collected from two streams, BB and TEF, were analyzed for possible differences between samples collected at upstream and downstream sites, and differences between samples collected before and after the low-water crossings were installed in 1999 and later in 2003. Data and results are presented in tables and graphs. Information presented in this report will help the U.S. Army assess the potential effects of current and future hardened low-water crossings on periphyton communities and water quality in streams draining the Reservation.

Description of Study Area

The study area is located in east-central Vernon Parish, in west-central Louisiana, on the eastern half of the Reservation (fig. 1). The land is used primarily for military training and forestry. The streams in the study area are typically small (first- and second-order) streams that drain hilly, densely forested, piney uplands. Altitudes in the study area range from about 300 to 350 ft above the North American Vertical Datum of 1988. Drainage basins in this area are characterized by loamy soils, with rapid changes in stream runoff and infiltration during heavy rainfall (Tollett and others, 2002). Basin characteristics and stream habitat for the study area are described in Tollett and others (2002).

The climate in west-central Louisiana is humid subtropical. The average annual rainfall for west-central Louisiana is 56 in., and the average annual temperature is 18 °C (Betty Wall, Louisiana Office of State Climatology, written commun., 2002).

Hardened low-water crossings installed at BB, TEF, TBB, and LB in the study area are flexible pads consisting of cabled or interlocking concrete blocks that form a hardened surface path approximately 12-ft wide. Each pad was laid along the stream bottom at right angles to the channel and on each side of the channel within the approaching roadways to a distance sufficient to prevent erosion of soil into the stream channel. Each pad was laid on a stabilized base, 12- to 24-in. thick, made of aggregate no larger than 1.5 in. in diameter. The crossings were excavated to an appropriate depth so that the top of the pad was at the natural height of the stream bottom. Dolomitic limestone was originally used as the base material for the cabled or interlocking concrete pads, and washed pea gravel was used as the interstitial filler between the individual concrete blocks (Tollett and others, 2002, p. 5). Findings by Tollett and others (2002, p. 46) indicated that dissolution of the dolomitic limestone may have altered water quality in LB, and the base material was subsequently replaced by a calcium-free aggregate. The dolomitic limestone at the low-water crossings at BB and TEF was replaced in 2003 during this study.

The hardened low-water crossing installed at TBC consists of a reinforced concrete roadway laid over a stabilized aggregate base. The crossing was excavated to an appropriate depth so that the top of the roadway is at the natural height of the stream bottom.

Methods

To determine whether additional modifications at two existing sites on BB and TEF and the installation of a hardened low-water crossing at one new site on TBC had any effects on periphyton and water quality in the streams, monthly periphyton and water-quality samples were collected upstream and downstream from each low-water crossing for a minimum of 2 months during 2003–04 before and after the modification or installation of the hardened crossing (table 1). Periphyton and water-quality samples were collected during normal flow conditions at upstream and downstream sample locations typically within 30 ft of the hardened low-water crossing. Sample locations were selected to have available submerged woody debris and similar light penetration, stream velocity, and stream geometry to facilitate comparison of results. To determine whether the modifications had any long-term effects on periphyton and water quality at two existing sites on TBB and LB, monthly periphyton and water-quality samples were collected upstream and downstream from each crossing for a minimum of 3 months during 2003 (table 1). The resulting data were analyzed and compared to data collected at the same sites during 1998–99, and analyzed for differences between upstream and downstream sites before and after modifications. Data-collection methods used during 2003–04 were consistent with those used during 1998–99, which were documented in Tollett and others (2002).

Periphyton

Periphyton samples were obtained from shallow corings made into submerged logs using a sharpened pipe, 19 mm in diameter. Periphyton samples also were obtained from glass slides (75 mm by 25 mm) that had been suspended just below the water surface in diatometers, each containing eight slides, placed near the submerged logs for a 30-day colonization period. A minimum of four cores and four slides usually were collected. Each sample was placed in a separate sample jar containing ambient stream water and preserved in 4- to 6-percent formalin solution. The samples were then sent to Bryan and Associates in Baton Rouge, La., for analysis.

Table 1. Periphyton and water-quality sampling dates and hardened low-water crossing installation and modification dates for selected streams at the Fort Polk Military Reservation, Louisiana, 2003–04.

[I, installation; M, modification]

Site name	Site abbreviation (fig. 1)	Latitude	Longitude	Hardened low-water crossing installation or modification date	Sampling date	
					Periphyton	Water quality
Big Brushy Creek upstream	BBUP	31° 02′ 31″	92° 54′ 44″	05-26-1999 (I)	[1]04-10-2003	04-10-2003
				06-17-2003 (M)	05-08-2003	05-07-2003
					06-04-2003	06-04-2003
					07-01-2003	07-01-2003
					08-05-2003	08-06-2003
					09-11-2003	09-10-2003
					11-06-2003	10-07-2003
						11-05-2003
Big Brushy Creek downstream	BBDN	31° 02′ 30″	92° 54′ 44″	05-26-1999 (I)	[1]04-10-2003	04-10-2003
				06-17-2003 (M)	05-08-2003	05-07-2003
					06-04-2003	06-04-2003
					07-01-2003	07-01-2003
					08-05-2003	08-06-2003
					09-11-2003	09-10-2003
					10-09-2003	10-07-2003
					11-06-2003	11-05-2003
Tributary to East Fork of Sixmile Creek upstream	TEFUP	31° 02′ 20″	92° 57′ 53″	06-14-1999 (I)	[1]04-10-2003	04-10-2003
				08-08-2003 (M)	05-08-2003	05-07-2003
					06-04-2003	06-04-2003
					[1]07-01-2003	07-01-2003
					08-05-2003	08-06-2003
					09-11-2003	09-10-2003
					10-09-2003	10-07-2003
					11-06-2003	11-05-2003
Tributary to East Fork of Sixmile Creek downstream	TEFDN	31° 02′ 19″	92° 57′ 53″	06-14-1999 (I)	[1]04-10-2003	04-10-2003
				08-08-2003 (M)	05-08-2003	05-07-2003
					06-04-2003	06-04-2003
					07-01-2003	07-01-2003
					08-05-2003	08-06-2003
					09-11-2003	09-10-2003
					10-09-2003	10-07-2003
					11-06-2003	11-05-2003
Tributary to Big Brushy Creek upstream	TBBUP	31° 03′ 13″	92° 55′ 22″	05-26-1999 (I)	09-11-2003	08-06-2003
					10-09-2003	09-10-2003
					11-06-2003	10-07-2003
						11-05-2003
Tributary to Big Brushy Creek downstream	TBBDN	31° 03′ 13″	92° 55′ 21″	05-26-1999 (I)	09-11-2003	08-06-2003
					10-09-2003	09-10-2003
					11-06-2003	10-07-2003
						11-05-2003

Table 1. Periphyton and water-quality sampling dates and hardened low-water crossing installation and modification dates for selected streams at the Fort Polk Military Reservation, Louisiana, 2003–04—Continued.

[I, installation; M, modification]

Site name	Site abbreviation (fig. 1)	Latitude	Longitude	Hardened low-water crossing installation or modification date	Sampling date	
					Periphyton	Water quality
Tributary to Birds Creek upstream	TBCUP	31° 02′ 05″	93° 03′ 19″	12-23-2003 (I)	[1]04-11-2003	04-11-2003
					05-08-2003	05-07-2003
					06-04-2003	06-04-2003
					07-01-2003	07-01-2003
					08-05-2003	08-06-2003
					05-10-2004	05-10-2004
					06-14-2004	06-14-2004
Tributary to Birds Creek downstream	TBCDN	31° 02′ 04″	93° 03′ 19″	12-23-2003 (I)	[1]04-11-2003	04-11-2003
					05-08-2003	05-07-2003
					06-04-2003	06-04-2003
					07-01-2003	07-01-2003
					08-05-2003	08-06-2003
					05-10-2004	05-10-2004
					06-14-2004	06-14-2004
Little Brushy Creek upstream	LBUP	31° 02′ 48″	92° 56′ 29″	10-30-1998 (I)	09-11-2003	08-06-2003
					10-09-2003	09-10-2003
					11-05-2003	10-07-2003
						11-05-2003
Little Brushy Creek downstream	LBDN	31° 02′ 47″	92° 56′ 29″	10-30-1998 (I)	09-11-2003	08-06-2003
					10-09-2003	09-10-2003
					11-05-2003	10-07-2003
						11-05-2003

[1] No slides collected.

Three samples of each substrate from each site were analyzed. Periphyton samples from wood cores were brushed with a modified short-bristled toothbrush and rinsed back into their sample jars. Glass slides were scraped with a razor blade and rinsed into their sample jars. Samples were increased to known volumes (usually 200 mL) using deionized water, subsampled with a wide-mouthed pipette into a modified Utermöhl chamber, and allowed to settle overnight before microscopic examination. Periphyton counts and identifications were made at 1,000 times magnification using Zeiss inverted microscopes. Only chloroplast-bearing algal cells and diatom frustules were counted; empty cells and frustules were omitted. Cells were counted along an average of three transects across the approximate center of the slip covering the bottom of the chamber. Cell densities were reported to the nearest 0.1 cell/mm^2 (cell per square millimeter). Fractions of cells resulted from the conversion of actual cell counts per square micrometer of substrate, determined using a microscope, to cells per square millimeter of the substrate, using the equation detailed in Tollett and others (2002, p. 10).

References used for identification and nomenclature were Prescott (1951), Patrick and Reimer (1966, 1975), Whitford and Schumacher (1973), Krammer and Lange-Bertalot (1986, 1988, 1991a, 1991b), Dillard (1989a, 1989b, 1990, 1991a, 1991b, 1993), and Cox (1996). To confirm identifications, aliquots from some of the more diverse samples were burned to remove organic matter (Clesceri and others, 1998) and sealed in Hyrax mounting medium on slides. Some taxa could not be identified to the species level, as sufficient diagnostic features were not seen; these were counted as sp. (1 morph) or spp. (greater than or equal to 2 morphs). Cells of the filamentous colonies (for example, *Oscillatoria* spp., *Mougeotia* spp., and *Ulothrix* spp.) were counted, but cell densities (cells/mm^2) of the globular colonies (for example, *Microcystis* spp. and *Gomphosphaeria* spp.) were estimated by counting cells in several large squares within the Whipple grid (the grid of a calibrated Whipple reticle), while focusing through the colony, and expanding that count by the number of squares in the grid occupied by the colony.

Methods for the calculation of percent frequency of occurrence and average cell density were from Clesceri and others (1998). The percent frequency of occurrence for each taxon for each site for each month or longer period was derived by dividing the number of times a taxon occurred by the number of samples collected at the site during the period. The overall percent frequency of occurrence of each taxon (table 2) was obtained by summing the number of times each taxon appeared in samples collected during the 2003–04 sampling period and dividing by the total number of samples. The average cell density for each taxon for each site for each month or longer period was derived by summing the cell densities of each taxon that appeared in samples collected at a site during the period and dividing the sum by the total number of samples collected at the site during the period in which the taxon appeared. The overall average cell density for each taxon (table 2) was obtained by summing the cell densities of each taxon that appeared in samples collected during the 2003–04 sampling period and dividing the sum by the total number of samples in which the taxon appeared.

Water Quality

Water-quality samples were collected at each site concurrently or within 2 days of periphyton collection using USGS field methods (Wilde and Radtke, 1998). Water samples were collected from the shallow, slow-moving streams by dipping the sample bottle just below the surface of the water near the center of flow. The mouth of the bottle was pointed upstream, as near to the center of flow as possible without disturbing the bottom sediments. Filtered samples were obtained by passing whole water through a 0.45-μm cellulose nitrate filter capsule and pouring into appropriate bottles. Filtered major inorganic ion samples were treated with nitric acid to a pH less than 2 standard units. All bottles were chilled and shipped to the USGS National Water Quality Laboratory in Lakewood, Colo.

A multiparameter water-quality meter was suspended about 1 ft below the water surface at the center of the stream for collection of water-quality data, which included specific conductance, pH, temperature, turbidity, and dissolved oxygen. Alkalinity also was determined in the field using the inflection point titration method (Wilde and Radtke, 1998). Concentrations of nutrients, major inorganic ions, total dissolved solids, iron, and manganese were determined from laboratory analysis of water samples by using methods described by Fishman and Friedman (1989).

Nutrients included dissolved ammonia (as nitrogen), dissolved nitrite (as nitrogen), dissolved ammonia plus organic nitrogen (as nitrogen), nitrite plus nitrate (as nitrogen), and dissolved phosphorus. Major inorganic ions included calcium, magnesium, sodium, potassium, sulfate, chloride, fluoride, bicarbonate, and silica. Bicarbonate was calculated from alkalinity (Wilde and Radtke, 1998).

Statistical Analysis

Data from downstream sites were first analyzed to determine changes that occurred after modifications. Data from upstream sites were then analyzed to determine whether changes at downstream sites were accompanied by statistically significant changes at the upstream site.

Percent frequency of occurrence and average cell density of 10 of the most frequently occurring periphyton taxa were used to compare streams, upstream and downstream sites, and conditions before and after low-water crossing modifications. Selected water-quality data from the streams also were used to evaluate differences in water quality. For statistical analyses, less than (<) values were replaced with values equal to one-half of the less-than value. Periphyton and water-quality data were inspected for normality. Data that were not normally distributed (Shapiro-Wilk Test statistic “W” < 0.05), were transformed using a natural logarithmic transformation ($\log_e$), and percentages were transformed using an inverse trigonometric sine transformation (ARSIN) prior to statistical analyses. Summary statistics and all linear models (One-Way Analysis of Variance [ANOVA]), with accompanying pairwise comparisons (Tukey’s Honestly Significant Differences [HSD] test), were performed using SAS 8.2 (Statistical Analysis System, 2001) and Statistix®8 (Analytical Software, 2003). Statistical analyses were considered significant when p-values were less than or equal to 0.05. Because the sample sizes were sometimes small or unequal, it is possible that average differences were not always large enough to be detected by statistical analyses.

Quality Control and Quality Assurance

Quality-control procedures for periphyton included analyses of three samples from each substrate at each site during each sampling event to provide an estimate of variance for each site and sampling event. One sample from each substrate, site, and sampling event was archived in original condition for future reference. For quality assurance, about one percent of the periphyton samples were sent to Michael Hein, Water and Air Research, Inc., Gainesville, Fla., to verify analyses. Photographs were taken of some problematic taxa and were sent to Michael Hein to confirm identification.

Quality-control water samples were collected to ensure sample-collection, sample-processing, and laboratory analytical procedures did not introduce bias into results and to determine the variability associated with collection and analysis of samples. Quality-control procedures included calibration of instruments for field measurements of pH, specific conductance, water temperature, and turbidity. The pH and specific conductance probes on the multiparameter water-quality meter and a separate pH meter (used for alkalinity titrations) and turbidity meter were checked with laboratory-grade standard solutions each day before use, following manufacturer's procedures and USGS methods (Wilde and Radtke, 1998). The temperature probe was checked prior to each sampling period against a thermometer traceable to the National Institute of Standards and Technology.

Quality-control procedures also included the collection of seven sequential replicate samples and two field-blank samples. All water-quality data collected for this report are stored in the USGS National Water Information System and are on file at the USGS office in Baton Rouge, La.

Replicate samples were collected to quality assure sample-collection methods and laboratory-analytical procedures. The relative percent difference (RPD) between constituent concentrations in a sample and the corresponding sequential replicate were calculated by multiplying 100 by the absolute value of the difference between the sample and sequential replicate concentration divided by the average of the sample and sequential replicate concentrations. The RPDs were not calculated when concentrations were estimated in the laboratory or were not detected for either the environmental or replicate sample. The RPDs between the samples and replicates for major inorganic ions in water typically were ≤5 percent (≤, less than or equal to). The RPDs for calcium, residue on evaporation, ammonia, nitrite, nitrite plus nitrate, phosphorus, and iron exceeded 5 percent for one or more sample set. The highest RPDs were for phosphorus (86 percent), nitrite (67 percent), iron (65 percent), and residue on evaporation (58 percent). These high RPDs were primarily due to relatively low concentrations of constituents in the samples and sequential replicates and did not reflect substantial water-quality differences between the samples and sequential replicates.

Field-blank samples collected at two sites were analyzed to assure that collection, preparation, processing, and analytical procedures did not contaminate the samples. Samples of inorganic-free blank water were poured at the site or passed through processing equipment at the site into appropriate bottles. The blank samples were analyzed for major inorganic ions and selected nutrients. Concentrations of major inorganic ions were less than analytical reporting limits. All nutrient concentrations were less than or equal to analytical reporting limits.

Effects of Hardened Low-Water Crossings on Periphyton

A total of 362 periphyton taxa were identified from 312 samples analyzed (table 2). Diatoms (Chrysophyta) were the most diverse group of algae, with 144 taxa identified. Green algae (Chlorophyta) ranked second, with 136 taxa. Blue-green algae (Cyanophyta) ranked third with 62 taxa (table 3). The remaining 20 taxa identified were distributed among four other plant groups. Diatom taxa outnumbered the other major divisions by at least 2.5 times in 90 percent of the samples. Green algae taxa outnumbered diatoms in <5 percent of the samples. The percent frequency of occurrence of major algal divisions in presented in table 3.

There was no significant difference in percent frequency of occurrence or cell density of taxa between substrates (slides and wood cores). Consequently, percent frequency of occurrence and cell density of all monthly samples from all substrate types for each of the 10 most frequently occurring taxa on both substrates were summed and averaged (table 4), and ANOVA's and pairwise comparisons (Tukey's HSD) were performed to check for possible differences between upstream and downstream sites. The only taxon in which the percent frequency of occurrence and cell density varied between upstream and downstream sites was *Eunotia flexuosa*, which occurred in a significantly ($p \leq 0.05$) lower percentage of the samples at BB upstream (BBUP) (table 4). Although some differences in percent frequency of occurrence or average cell density for other taxa at other upstream and downstream sites may have been larger than *Eunotia flexuosa* at BB, the wide variation in monthly values, relative to the degrees of freedom (a maximum of six samples each month) at each site precluded the finding of significant variations in the periphyton communities.

Percent frequency of occurrence and cell density (table 2) for all samples varied similarly, and 17 taxa occurred in more than 40 percent of the samples. As in the earlier study (Tollett and others, 2002), diatoms were the most frequently occurring algae (table 3), and filamentous green algae and colonial blue-green forms were numerically dominant when they occurred (fig. 2, table 2). The colonial blue-green alga, *Microcystis incerta,* was present in 60.2 percent of the samples, and the filamentous green alga, *Oedogonium* spp., was present in 43.3 percent of the samples. Although the average cell density of the four most frequently occurring diatoms ranged from 37 to 100 cells/mm^2, the combined average cell densities of the 20 most frequently occurring diatoms totaled 674.8 cells/mm^2, which was less than 8 percent of the average cell density of the most abundant blue-green alga, *Microcystis incerta*, which was 5,300 cells/mm^2. Growth habits of different algal divisions tended to be different. Diatoms typically appeared singly or in small, loosely connected groups, whereas green algae typically were species (for example, *Oedogonium* spp. and *Ulothrix* sp.) that develop long filaments. Blue-green algae were species that develop large globular (for example, *Microcystis incerta*), plate-like (for example, *Merismopedia* spp.), or filamentous (for example, *Oscillatoria* spp.) colonies. The average cell densities of blue-green algae and green algae also tended to fluctuate from month-to-month, while the diatoms occurred more consistently at most sites during the study (fig. 2).

Periphyton data from BB, TEF, and TBC collected before and after the low-water crossings were modified during 2003 were analyzed to determine whether changes may have occurred. Variations in periphyton communities could not be

Table 2. Percent frequency of occurrence and average cell density for periphyton taxa on wood cores and glass slides collected at sites upstream and downstream from low-water crossings on selected streams at the Fort Polk Military Reservation, Louisiana, 2003–04.

[sp., one morph; spp., two or more morphs; var., variety]

Taxon	Percent frequency of occurrence	Average cell density (cells per square millimeter)
Cyanophyta		
Anabaena spp.	13.4	267
Aphanocapsa delicatissima	5.1	418
Aphanocapsa elachista var. *conferta*	4.9	786
Aphanocapsa elachista var. *planctonica*	.6	130
Aphanocapsa endophytica	.3	2,160
Aphanocapsa spp.	1.9	151
Aphanothece Castagnei	.3	3,040
Aphanothece clathrata	1.0	791
Aphanothece nidulans	2.8	459
Aphanothece nidulans var. *endophytica*	.3	3.5
Aphanothece saxicola	19.5	415
Aphanothece spp.	1.6	348
Calothrix sp.	.6	68.5
Chamaesiphon spp.	1.0	2,070
Chroococcus dispersus	39.1	104
Chroococcus dispersus var. *minor*	27.9	191
Chroococcus limneticus	1.3	123
Chroococcus limneticus var. *distans*	.6	48.7
Chroococcus Prescottii	.3	100
Chroococcus turgidus	1.3	47.0
Coelosphaerium pallidum	3.5	117
Coelosphaerium spp.	17.6	1,250
Cylindrospermum spp.	1.6	149
Dactylococcopsis acicularis	.3	6.7
Dactylococcopsis sp.	.3	2.5
Fischerella spp.	.6	1,080
Gloeocapsa spp.	1.6	1,190
Gloeothece linearis	1.3	124
Gloeothece rupestris	.3	9.4
Gloeothece spp.	3.2	231
Gomphosphaeria lacustris	3.5	362
Gomphosphaeria spp.	21.5	1,560
Hapalosiphon aureus	.6	162
Hapalosiphon flexuosus	.3	202
Hapalosiphon hibernicus	.6	40.3
Hapalosiphon spp.	5.1	1,520
Johannesbaptistia pellucida	2.6	85.0
Lyngbya spp.	1.3	196
Merismopedia tenuissima	1.0	2,570
Microcystis aeruginosa	1.6	152
Microcystis incerta	60.2	5,300
Microcystis spp.	5.1	7,010
Nodularia spp.	.6	224
Nostoc spp.	3.2	1,420
Oscillatoria geminata	8.6	180
Oscillatoria lacustris	.3	19.0
Oscillatoria prolifica	.6	48.0
Oscillatoria splendida	.3	15.0
Oscillatoria spp.	24.7	384
Cyanophyta—Continued		
Oscillatoria subtilissima	0.3	47.6
Oscillatoria tenuis	1.3	456
Phormidium inundatum	.3	58.0
Phormidium spp.	19.6	184
Phormidium tenue	1.6	661
Plectonema spp.	.6	75.0
Rhabdoderma Gorskii	.6	221
Rhabdoderma sigmoidea	.3	162
Rhabdoderma sp.	1.3	135
Schizothrix spp.	1.0	1,110
Scytonema spp.	1.3	2,050
Stigonema mamillosum	.3	1,180
Symploca muscorum	.6	724
Chlorophyta		
Actinotaenium clevei	.3	.7
Actinotaenium cucurbitinum var. *longum*	.6	.2
Ankistrodesmus falcatus	.3	462
Aphanochaete repens	.3	106
Aphanochaete sp.	.3	25.0
Basal cells	9.0	5.2
Bulbochaete spp.	17.0	37.3
Carteria sp.	.3	4.0
Characium obtusum	.3	23.1
Characium Rabenhorstii	.3	.2
Characium spp.	2.6	4.5
Chlamydomonas spp.	11.2	7.6
Chlorella spp.	1.3	16.0
Chlorococcum humicola	1.0	10.3
Chlorococcum spp.	.6	28.2
Closterium acerosum	.6	.5
Closterium angustatum	.3	.4
Closterium archerianum form grande	.3	.7
Closterium cornu	.3	1.0
Closterium gracile var. *elongatum*	.3	2.6
Closterium intermedium	1.0	6.8
Closterium jenneri	1.0	2.0
Closterium juncidum	.6	.7
Closterium lineatum	.3	11.5
Closterium macilentum	.3	3.8
Closterium moniliferum	1.6	1.3
Closterium parvulum	1.3	8.8
Closterium parvulum var. *angustatum*	2.6	3.5
Closterium planum	.3	6.3
Closterium praelongum	.3	3.8
Closterium ralfsii	.3	.8
Closterium setaceum	1.3	.7
Closterium setaceum form sigmoideum	.6	3.8
Closterium spp.	7.4	2.8
Closterium toxon	1.0	6.3

Table 2. Percent frequency of occurrence and average cell density for periphyton taxa on wood cores and glass slides collected at sites upstream and downstream from low-water crossings on selected streams at the Fort Polk Military Reservation, Louisiana, 2003–04—Continued.

[sp., one morph; spp., two or more morphs; var., variety]

Taxon	Percent frequency of occur-rence	Average cell density (cells per square millimeter)
Chlorophyta—Continued		
Coelosphaerium pallidum	0.3	290
Coleochaete spp.	1.9	46.8
Cosmarium angulosum	.3	9.6
Cosmarium crenatum	.3	.7
Cosmarium cucurbitinum	.3	.3
Cosmarium exiguum	1.0	10.6
Cosmarium exiguum var. *subrectangulum*	1.0	6.8
Cosmarium margaritatum	1.0	.7
Cosmarium minimum	.9	5.8
Cosmarium minutissimum	.3	9.4
Cosmarium minutissimum var. *depressum*	.6	25.0
Cosmarium punctulatum	2.2	6.9
Cosmarium punctulatum var. *subpunctulatum*	.3	2.0
Cosmarium raciborskii	.3	2.0
Cosmarium regnellii	.3	.8
Cosmarium spp.	11.5	5.8
Cosmarium subtumidum	1.6	2.2
Cosmarium tenue	.6	27.0
Cosmarium tenue var. *minus*	1.6	7.0
Cosmarium tinctum	.3	19.0
Cosmarium tumidum	.3	.5
Cosmarium turpinii	.3	.7
Crucigenia sp.	.3	26.8
Cylindrocapsa conferta	1.0	143
Cylindrocapsa geminella	1.6	694
Cylindrocapsa spp.	8.3	115
Cylindrocystis brebissonii var. *minor*	.3	1.2
Desmidium sp.	1.0	3.3
Dicranochaete reniformis	11.2	4.0
Euastrum affine	1.0	3.0
Euastrum ansatum	.3	7.3
Euastrum binale	.3	1.1
Euastrum denticulatum	.3	.7
Euastrum didelta	.3	7.7
Euastrum insulare	.3	2.6
Euastrum insulare var. *lacustre*	.3	.2
Euastrum spp.	1.3	9.0
Euastrum trigiberrum	.3	11.2
Franceia spp.	.6	3.8
Geminella interrupta	.3	34.1
Geminella minor	1.0	18.4
Gloeocystis gigas	.3	1.7
Gloeocystis major	.3	1.8
Gloeocystis spp.	4.5	54.7
Gloeocystis vesiculosa	.6	2,200
Golenkenia sp.	.3	3.1
Gonatozygon pilosum	.3	1.0
Hormidium spp.	4.8	65.0
Hyalotheca dissiliens	.3	11.4

Taxon	Percent frequency of occur-rence	Average cell density (cells per square millimeter)
Chlorophyta—Continued		
Hyalotheca spp.	0.6	8.9
Kirchneriella contorta	.3	19.2
Kirchneriella lunaris	.3	3.1
Micrasterias denticulata var. *intermedia*	.6	5.2
Micrasterias spp.	1.3	27.0
Microspora pachyderma	.6	21.4
Microspora spp.	9.6	68.5
Mougeotia micropora	.3	26.0
Mougeotia spp.	25.0	73.0
Netrium digitus	.3	1.3
Netrium digitus var. *naegelii*	1.0	1.4
Netrium interruptum	.3	9.0
Netrium oblongum var. *cylindricum*	.3	.8
Netrium spp.	1.9	2.6
Oedogonium spp.	43.3	31.6
Oocystis spp.	9.6	24.9
Penium exiguum	.6	2.1
Penium margaritaceum	.6	2.1
Penium spp.	1.0	.7
Phymatodocis nordstedtiana form minor	.3	2.5
Pleodorina spp.	.3	256
Pleurotaenium spp.	.6	2.4
Protococcus spp.	5.1	39.1
Protoderma viride	8.0	77.3
Rhizoclonium spp.	5.4	54.9
Schroederia spp.	2.6	3.6
Selenastrum sp.	.3	19.0
Sorastrum spinulosum	.3	14.0
Sphaerocystis Schroeteri	.6	149
Sphaerocystis spp.	2.6	112
Spirogyra spp.	7.7	16.4
Spondylosium planum	4.8	9.4
Spondylosium spp.	4.8	5.3
Staurastrum alternans	6.4	11.3
Staurastrum brebissonii	.3	1.0
Staurastrum dilatatum	1.6	2.6
Staurastrum hexacerum	.3	10.2
Staurastrum margaritaceum	.3	8.0
Staurastrum punctulatum	.3	5.2
Staurastrum spp.	2.6	5.6
Stigeoclonium sp.	1.3	234
Stigonema mamillosum	.3	2,300
Tetmemorus brebissonii	2.2	7.4
Tetmemorus laevis	1.0	2.7
Tetmemorus spp.	1.0	1.1
Tetraedron regulare	.3	7.7
Ulothrix spp.	2.5	13.4
Ulothrix subconstricta	.3	55.4
Ulothrix subtilissima	1.0	25.8
Ulothrix variabilis	5.8	41.6

Table 2. Percent frequency of occurrence and average cell density for periphyton taxa on wood cores and glass slides collected at sites upstream and downstream from low-water crossings on selected streams at the Fort Polk Military Reservation, Louisiana, 2003–04—Continued.

[sp., one morph; spp., two or more morphs; var., variety]

Taxon	Percent frequency of occurrence	Average cell density (cells per square millimeter)
Chlorophyta—Continued		
Volvox spp.	0.6	145
Zygnema sp.	.3	114
Chrysophyta (Class Bacillariophyceae)		
Achnanthes clevei	1.3	15.1
Achnanthes delicatula	.6	7.0
Achnanthes exigua	2.2	21.8
Achnanthes lanceolata	8.3	15.5
Achnanthes lanceolata var. *dubia*	1.3	38.2
Achnanthes lanceolata var. *rostrata*	.3	18.8
Achnanthes linearis	.6	7.1
Achnanthes marginulata	4.8	16.3
Achnanthes minutissima	48.0	16.3
Achnanthes rosenstockii	3.8	20.2
Achnanthes sp.	.3	1.0
Amphora ovalis	.6	.3
Aulacoseira granulata	.6	.8
Aulocoseira herzogii	.3	47.0
Aulocoseira sp.	.6	7.4
Brachysira serians var. *brachysira*	78.8	100
Brachysira vitrea	41.3	13.5
Cocconeis sp.	.3	8.2
Cymbella affinis	1.6	3.4
Cymbella amphicephala	.3	.7
Cymbella cuspidata	3.5	7.2
Cymbella gracilis	1.0	7.6
Cymbella helvetica	.3	9.4
Cymbella lunata	1.0	15.0
Cymbella microcephala	.3	4.0
Cymbella minuta	1.9	14.6
Cymbella minuta var. *pseudogracilis*	.6	19.5
Cymbella spp.	3.2	6.3
Diatoma anceps	.3	1.1
Diploneis parma	.3	2.6
Encyonema gaeumannii	22.1	8.6
Encyonema minutum	1.3	1.3
Encyonema neogracile	44.6	26.9
Eunotia bidentula	2.9	9.0
Eunotia bilunaris	93.9	93.2
Eunotia diodon	55.4	15.0
Eunotia exigua	59.9	15.2
Eunotia flexuosa	76.0	45.2
Eunotia formica	39.7	24.4
Eunotia incisa	40.1	27.8
Eunotia minor	1.0	9.0
Eunotia monodon	48.7	18.8
Eunotia muscicola	6.1	4.3
Eunotia muscicola var. *tridentula*	9.0	6.0
Eunotia naegelii	73.4	37.2
Eunotia paludosa	66.3	29.0
Chrysophyta—Continued		
Eunotia pectinalis	1.0	2.8
Eunotia pectinalis var. *minor*	27.9	14.4
Eunotia pectinalis var. *undulata*	1.6	23.9
Eunotia praerupta	8.3	10.4
Eunotia praerupta var. *bidens*	.6	3.2
Eunotia serra var. *diadema*	.3	5.7
Eunotia serra var. *tetraodon*	1.6	5.7
Eunotia soleirolii	.3	2.7
Eunotia spp.	1.9	16.4
Eunotia sudetica	.3	14.2
Eunotia tenella	.3	4.8
Eunotia triodon	.3	.5
Eunotia zygodon	.3	18.9
Fragilaria capucina	11.8	20.9
Fragilaria crotonensis	.3	.2
Fragilaria delicatissima	3.5	20.6
Fragilaria exigua	.6	5.0
Fragilaria spp.	13.8	6.6
Fragilaria tenera	20.5	16.5
Fragilaria ulna	10.6	18.8
Fragilaria vaucheriae	.6	19.4
Frustulia rhomboides	66.7	48.1
Frustulia rhomboides var. *amphipleuroides*	15.4	17.5
Frustulia rhomboides var. *capitata*	53.5	65.1
Frustulia rhomboides var. *saxonica*	48.7	45.3
Frustulia vulgaris	3.2	9.9
Gomphonema affine	5.8	11.3
Gomphonema angustatum	12.5	13.0
Gomphonema angustum	32.0	24.4
Gomphonema brasiliense	8.0	16.0
Gomphonema gracile	27.6	19.9
Gomphonema minutum	2.9	18.8
Gomphonema parvulum	10.9	13.6
Gomphonema spp.	8.3	4.9
Hantzschia amphioxys	.6	12.5
Navicula angusta	11.8	16.7
Navicula bryophila	.3	184
Navicula capitata	1.0	22.6
Navicula cincta	4.2	17.2
Navicula cryptocephala	29.2	15.9
Navicula cryptotenella	21.2	8.1
Navicula exigua	.3	3.8
Navicula gottlandica	34.9	13.5
Navicula hungarica	.3	.7
Navicula ingenua	1.3	3.9
Navicula jaernefeltii	.6	5.9
Navicula lateropunctata	10.2	10.3
Navicula minima	2.6	3.7
Navicula notha	4.2	10.3

Table 2. Percent frequency of occurrence and average cell density for periphyton taxa on wood cores and glass slides collected at sites upstream and downstream from low-water crossings on selected streams at the Fort Polk Military Reservation, Louisiana, 2003–04—Continued.

[sp., one morph; spp., two or more morphs; var., variety]

Taxon	Percent frequency of occurrence	Average cell density (cells per square millimeter)
Chrysophyta—Continued		
Navicula obscura	0.3	28.4
Navicula radiosa	1.9	11.2
Navicula rhynchocephala	1.6	10.5
Navicula schroeteri var. *escambia*	1.0	20.7
Navicula spp.	15.1	11.4
Neidium apiculatum	1.6	6.2
Neidium hercynicum form substratum	.3	3.8
Neidium iridis	.3	1.9
Neidium ladogense var. *densestriatum*	2.9	4.7
Neidium spp.	.6	.7
Nitzschia acicularis	.6	5.4
Nitzschia angustata	.3	1.0
Nitzschia filiformis	1.0	18.4
Nitzschia flexoides	.6	2.7
Nitzschia frustulum	1.0	5.4
Nitzschia gracilis	1.6	16.1
Nitzschia levidensis	1.0	6.0
Nitzschia palea	3.5	10.2
Nitzschia paleacea	14.1	10.8
Nitzschia paleaeformis	1.6	21.7
Nitzschia sigmoidea	1.9	10.4
Nitzschia spp.	5.4	4.0
Pinnularia abaujensis	14.7	9.4
Pinnularia biceps	23.7	8.7
Pinnularia maior	.3	7.1
Pinnularia maior var. *transversa*	.3	.7
Pinnularia mesolepta	.6	2.1
Navicula parvula	.3	11.8
Pinnularia spp.	13.1	7.4
Pinnularia streptoraphe	.6	7.6
Pinnularia subcapitata	1.0	4.5
Rhopalodia gibberula	7.6	100
Sellophora pupula var. *rectangularis*	7.4	8.2
Stauroneis anceps	.3	1.3
Stenopterobia curvula	13.8	9.0
Surirella amphyoxis	.3	4.8
Surirella angusta	24.0	9.4
Surirella brebissonii	1.0	9.7
Surirella linearis	1.0	8.1
Chrysophyta—Continued		
Surirella minuta	1.3	2.4
Surirella roba	1.3	7.2
Surirella robusta	1.0	8.8
Surirella spp.	7.0	7.8
Surirella tenera	4.5	4.9
Synedra acus	1.6	5.0
Synedra spp.	3.5	3.5
Synedra ulna	2.9	6.1
Tabellaria flocculosa	.3	.7
Tabellaria sp.	.3	.4
Chrysophyta		
(Class Chrysophyceae)		
Derepyxis amphora	3.2	3.0
Derepysix spp.	2.6	6.0
Dinobryon spp.	2.9	2.8
Lagynion Scherffelii	5.1	12.9
(Class Cryptophyceae)		
Cryptomonas sp.	.3	3.2
(Class Xanthophyceae)		
Characiopsis sp.	1.9	.8
Chlorochromonas sp.	.6	.6
Ophiocytium desertum var. *minor*	.6	6.2
Ophiocytium spp.	1.6	9.0
Peroniella planctonica	.3	5.2
Peroniella sp.	1.0	5.6
Stipitococcus apiculatus	.3	14.4
Stipitococcus spp.	1.3	3.9
Stipitococcus vasiformis	.3	.8
Euglenophyta		
Phacus sp.	.3	.7
Trachelomonas spp.	1.0	2.9
Rhodophyta		
Batrachospermum turfosum	12.5	453
Colonial Bacterium		
Sphaerotilus sp.	17.6	96.6
Ciliata		
Unknown ciliates	21.2	5.9
Vorticella spp.	3.8	3.8

conclusively attributed to the modifications. Data analysis indicated no significant seasonal variation, a dominant factor in a previous study (Tollett and others, 2002), probably because no periphyton samples were collected during winter months.

Comparison (Tukey's HSD) of percent frequency of occurrence of the 10 most frequently occurring taxa showed that *Eunotia flexuosa* and *Frustulia rhomboides* at BB indicated significant interaction between both upstream and downstream sites, and before and after the crossing modification on BB (table 5). Comparison of average cell density of the 10 most frequently occurring taxa showed *Eunotia exigua* at BB and *Eunotia bilunaris* at TEF indicated significant interaction between both upstream and downstream sites, and before and after crossing modifications on those streams (table 5). Because of these interactions, it was not possible to conclude that the hardened low-water crossing modifications caused the differences in those taxa. For example, even though the average cell densities of *Eunotia bilunaris* at TEF were significantly lower at both upstream and downstream sites after the low-water crossings were modified, the difference cannot be assigned to the crossing

Table 3. Percent frequency of occurrence of major algal divisions in selected streams at the Fort Polk Military Reservation, Louisiana, 2003–04.

Percent frequency of occurrence	Number of taxa			
	Diatoms	Green algae	Blue-green algae	Other
Greater than or equal to 80	1	0	0	0
70–79	3	0	0	0
60–69	2	0	1	0
50–59	3	0	0	0
40–49	6	1	0	0
30–39	3	0	1	0
20–29	8	1	3	1
10–19	12	4	4	2
Less than or equal to 10	106	130	53	17
Total number of taxa	144	136	62	20

modification because of the interaction with the differences due to location (table 5). Although average cell densities of *Eunotia bilunaris* at TEF downstream (TEFDN) were significantly different before and after the modification, the average cell densities also were significantly different from average cell densities at TEF upstream (TEFUP) before and after modification.

Most of the significant changes in percent frequency of occurrence and average cell density of the 10 most frequently occurring periphyton taxa were increases at downstream sites after the hardened low-water crossing installations or modifications. However, these changes in the periphyton community are not necessarily deleterious to the community structure.

At BB, the reasons for significant differences in percent frequency of occurrence of *Eunotia flexuosa* and *Frustulia rhomboides*, as well as cell density of *Eunotia exigua,* also were inconclusive due to the interactions (table 5). However, average cell densities for *Achnanthes minutissima* were significantly low at the BB downstream (BBDN) before crossing modifications and significantly high at BBUP after the modification. Yet, average cell densities of *Achnanthes minutissima* at BBUP before the modification were similar to those at BBDN after the modification. Although the increase in average cell densities of *Achnanthes minutissima* at BBUP due to the crossing modification downstream is unlikely, it could be argued that if the canopy around the crossing was opened up because of the low-water crossing modification, then an increase in ambient sunlight could result in an increase in cell densities of the periphyton upstream, but not downstream from the crossing. Cell densities were higher, although not significantly higher, for only two other taxa (*Brachysira serians* var. *brachysira* and *Eunotia naegelii*) at BBDN after the modification. Average cell densities of the other six taxa either remained the same or were lower in density downstream after the modification (table 5).

At TEF, the highest average cell density for *Eunotia flexuosa* was at the TEFDN before crossing modifications, yet densities were similar at TEFUP and TEFDN after the stream-crossing modification (table 5). Conversely, *Frustulia rhomboides* var. *crassinervia* was significantly low in frequency of occurrence at TEFDN before the crossing was modified, although this taxon was similar in percent frequency of occurrence at TEFUP, before and after the modification, as well as at TEFDN after the modification. The percent frequency of occurrence for *Microcystis incerta* was lowest at TEFUP before the modification and appeared with similar frequency in samples from TEFDN after the modification; the percent frequency of occurrence at TEFUP after the modification was similar to that at TEFDN both before and after the crossing was modified.

At TBC, percent frequency of occurrence of *Eunotia flexuosa* was highest at TBC upstream (TBCUP) both before and after the crossing modification, and the cell density of this taxon was significantly low at TBC downstream (TBCDN) both before and after modification (table 5). Similarly, the average cell density of *Eunotia naegelii* was significantly low at TBCDN before the crossing modification and significantly high at TBCUP before the modification. Although the average cell density of *Eunotia naegelii* was significantly higher at TBCUP than at TBCDN before the modification, average cell densities for this taxon at TBCUP and TBCDN were similar after the crossing modification. Average cell densities of *Eunotia exigua* at both TBCUP and TBCDN were similar before and after the modification, but were both significantly higher after crossing modification. Conversely, the percent frequency of occurrence of *Achnanthes minutissima* was significantly lower at TBCDN than at TBCUP, both before and after modification, suggesting that the crossing modification had no effect on the taxon's frequency of occurrence.

Periphyton data collected from LB and TBB after the hardened low-water crossings were installed in 1999 and periphyton data collected in 2003 were analyzed to determine whether long-term changes may have occurred after the installation (table 6). Although periphyton samples from submerged vegetation and gravel also were collected during 1998–99, only samples from glass slides and wood cores collected during 1998–99 were used in the comparisons to 2003–04 data. Pairwise comparisons were performed on averages for percentage frequency of occurrences and cell densities of seven taxa common in both 1999 and 2003 data sets (table 6). The percent frequency of occurrence of *Eunotia bilunaris* was significantly lower at TBB downstream (TBBDN) than at TBB upstream (TBBUP) during 1999; but the percent frequency of occurrence at TBBUP during 1999 was similar to that at TBBUP and TBBDN during 2003. However, the percent frequency of occurrence *Frustulia rhomboides* var. *crassinervia* was not different at TBBUP and TBBDN for each study period, but the percent frequency of occurrences at both sites were significantly lower during 1999 than during 2003.

At LB, there was significant interaction among the factors (upstream and downstream and before and after) in the ANOVA analyses of the average percent frequency of occurrences and average cell densities of *Eunotia paludosa*. This indicates that it is inconclusive whether or not the hardened crossing modification affected either attribute of this taxon. During 1999, average cell densities of *Frustulia rhomboides*

Table 4. Percent frequency of occurrence (top row) and average cell density (bottom row) for the 10 most frequently occurring periphyton taxa in all samples collected at upstream and downstream sites on selected streams at the Fort Polk Military Reservation, Louisiana, 2003–04.

[See fig. 1 for location of site. Tributary to Big Brushy Creek and Little Brushy Creek were sampled only during autumn 2004; the remaining sites were sampled during spring, summer, and autumn 2003. Cell density is in cells per square millimeter. Analysis of variance and pairwise comparisons were done on data from samples collected within the same month. Sites with different superscripts are significantly different (p less than or equal to 0.05). var., variety]

Taxon	Big Brushy Creek (BB)		Tributary to East Fork of Sixmile Creek (TEF)		Tributary to Big Brushy Creek (TBB)		Tributary to Birds Creek (TBC)		Little Brushy Creek (LB)	
	Upstream	Down-stream	Upstream	Down-stream	Upstream	Down-stream	Upstream	Down-stream	Upstream	Down-stream
Eunotia bilunaris	94.4	82.2	100.0	97.8	100.0	94.4	94.4	97.4	87.5	94.4
	117.8	78.9	94.7	105.4	63.5	41.3	181.0	63.0	23.9	70.7
Brachysira serians brachysira	72.2	62.2	85.7	84.4	77.8	83.3	83.3	57.9	75.0	88.9
	38.0	100.0	66.2	81.0	180.8	20.5	317.0	68.8	15.5	70.8
Eunotia flexuosa	53.6[b]	69.8[ab]	100.0[a]	93.4[ab]	83.3[a]	50.0[a]	100.0[a]	71.2[ab]	81.2[a]	66.7[a]
	29.9	12.2	23.8	51.3	10.3	5.0	157.0	15.8	18.5	25.2
Eunotia naegelii	66.7	60.0	85.7	80.0	83.3	61.1	86.3	65.8	93.8	50.0
	40.4	17.5	41.1	49.2	20.7	10.8	73.3	24.3	20.4	23.1
Frustulia rhomboides	41.7	42.2	76.2	77.8	94.4	94.4	72.2	36.8	93.8	100.0
	30.2	14.3	13.8	87.5	108.9	30.6	75.0	9.0	26.0	53.4
Frustulia rhomboides var. *crassinervia*	55.6	24.4	71.4	62.2	66.7	38.9	69.4	63.2	50.0	50.0
	59.0	17.4	27.0	77.1	71.8	7.2	186.0	45.1	9.9	35.2
Eunotia paludosa	75.0	75.6	80.9	75.6	61.1	33.3	66.7	55.3	37.5	61.1
	35.4	44.3	22.3	27.8	11.9	30.9	35.6	17.1	4.1	28.5
Eunotia exigua	72.2	48.9	50.0	53.3	55.6	66.7	69.4	65.8	62.5	61.1
	15.3	17.1	8.7	7.9	8.2	7.8	24.2	18.1	7.3	33.6
Microcystis incerta	66.7	64.4	61.9	66.7	33.3	44.4	58.3	72.0	37.5	50.0
	2,371.0	3,517.0	1,423.0	4,828.0	1,198.0	475.3	2,789.0	3,854.0	557.0	53,201.0
Achnanthes minutissima	66.7	40.0	40.5	53.3	33.3	55.6	52.8	32.4	50.0	72.2
	18.3	7.0	14.0	11.8	12.6	5.0	38.9	12.4	20.0	15.2

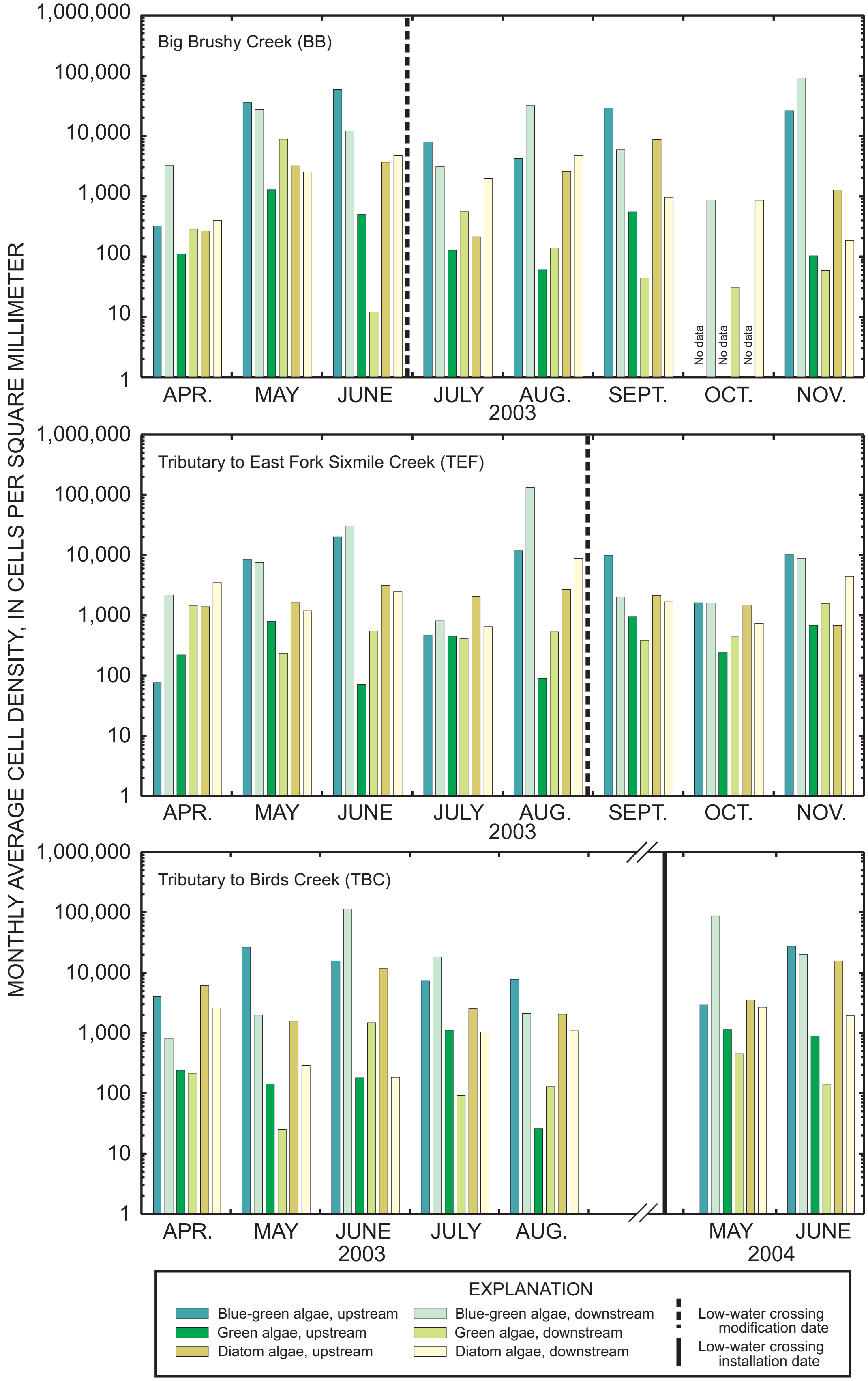

Figure 2. Monthly average cell density of blue-green, green, and diatom algae from sites upstream and downstream from hardened low-water crossings on selected streams at the Fort Polk Military Reservation, Louisiana, 2003–04. (See fig. 1 for location of site.)

Table 5. Percent frequency of occurrence (top row) and average cell density (bottom row) of the 10 most frequently occurring periphyton taxa in all samples collected before and after modification or installation of hardened low-water crossings on selected streams at the Fort Polk Military Reservation, Louisiana, 2003–04.

[See fig. 1 for location of site. Cell density is in cells per square millimeter. Averages with different superscripts are significantly different (p less than or equal to 0.05). var., variety]

Taxon	Big Brushy Creek (BB)				Tributary to East Fork Creek (TEF)				Tributary to Birds Creek (TBC)			
	Upstream		Downstream		Upstream		Downstream		Upstream		Downstream	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
Eunotia bilunaris	89.0	91.8	83.3	80.2	100.0	100.0	96.7	100.0	93.4	100.0	96.0	100.0
	104.8	81.1	127.5	33.5	[1]125.5	[1]32.8	[1]120.8	[1]76.6	126.1	226.1	153.6	18.0
Brachysira serians brachysira	55.3	70.5	44.7	73.2	80.2	94.3	73.4	94.3	50.6	91.5	51.4	83.5
	21.9	22.0	2.4	91.8	61.0	58.1	73.8	60.3	179.9	388.7	47.0	20.3
Eunotia flexuosa	[1]67.0	[1]54.2	[1]77.7	[1]43.0	100.0	89.0	93.4	78.0	100.0	100.0	71.2	67.0
	17.6	14.1	10.1	5.1	24.4[b]	16.2[b]	68.9[a]	7.8[b]	86.3[b]	171.0[ab]	8.8[c]	14.3[c]
Eunotia naegelii	61.0	62.5	61.0	56.6	86.6	77.7	80.0	77.7	90.0	83.5	56.0	75.0
	31.4	18.0	8.3	11.6	42.8	18.0	54.1	17.2	62.3[a]	49.1[ab]	2.9[c]	44.2[b]
Frustulia rhomboides	[1]33.0	[1]41.8	[1]39.0	[1]46.6	77.7	80.2	70.0	94.3	73.4	75.0	40.0	33.0
	7.6	11.3	5.4	5.4	8.1	12.4	61.1	78.6	17.7	121.8	3.3	3.2
Frustulia rhomboides var. *crassinervia*	39.0	29.0	16.7	26.8	73.6[a]	72.3[a]	53.4[b]	66.7[a]	56.8	100.0	46.6	91.0
	7.6	19.2	4.6	4.1	39.4	18.6	44.2	53.6	31.0	319.1	25.2	19.2
Eunotia paludosa	94.3	54.2	83.3	63.6	83.4	77.7	76.8	72.0	76.6	58.0	61.4	33.0
	28.9	17.4	49.9	23.8	20.7	11.0	7.4	30.0	8.3	28.0	10.2	4.2
Eunotia exigua	50.0	79.2	39.0	49.8	36.8	66.7	53.4	55.7	49.8	91.5	57.4	83.5
	[1]4.7	[1]11.0	[1]12.5	[1]6.7	2.1	6.9	3.9	4.7	8.5[b]	30.7[a]	5.2[b]	26.0[a]
Microcystis incerta	77.7	50.0	89.0	33.2	46.4[b]	72.3[a]	69.8[a]	55.3[ab]	46.6	83.5	67.8	75.0
	2,738.0	527.0	2,284.0	2,258.0	1,159.0	316.0	5,047.0	476.0	1,477.0	1,530.0	698.0	7,102.0
Achnanthes minutissima	39.0	74.8	27.7	46.8	53.4	33.3	46.6	61.0	60.0[a]	58.5[a]	36.8[b]	25.0[b]
	3.5[b]	12.9[a]	.8[c]	3.8[b]	4.8	5.7	8.5	3.0	23.9	7.9	3.9	4.7

[1] Significant interaction between location (upstream and downstream) and treatment (before and after low-water crossing modification); differences in averages could not be assigned to either location or treatment.

Table 6. Percent frequency of occurrence (top row) and average cell density (bottom row) of the seven most frequently occurring periphyton taxa collected on glass slides from sites upstream and downstream from hardened low-water crossings on selected streams at the Fort Polk Military Reservation, Louisiana, during September through October 1999 and September through November 2003.

[See fig. 1 for location of site. Averages with different superscripts are significantly different (p less than or equal to 0.05). Cell density is in cells per square millimeter. var., variety]

Taxon	Tributary to Big Brushy Creek (TBB)				Little Brushy Creek (LB)			
	Upstream		Downstream		Upstream		Downstream	
	1999	2003	1999	2003	1999	2003	1999	2003
Eunotia bilunaris	84.0[a]	100.0[a]	34.0[b]	100.0[a]	34.0	94.0	67.0	84.0
	10.6	20.0	1.6	32.0	20.1	7.2	6.2	39.3
Brachysira serians brachysira	16.5	56.0	.0	78.0	66.0	67.0	84.0	100.0
	2.5	.6	.0	1.8	34.8	2.4	28.5	14.3
Frustulia rhomboides var. *crassinervia*	50.0[b]	89.0[a]	50.0[b]	100.0[a]	83.5	100.0	16.5	100.0
	6.9	1.5	12.5	2.3	15.4[b]	29.0[a]	27.9[a]	11.4[b]
Eunotia flexuosa	100.0	78.0	83.5	89.0	100.0	77.7	100.0	77.7
	50.5	2.7	466.5	4.7	188.5	12.9	113.8	13.9
Eunotia paludosa	100.0	55.7	100.0	33.3	[1]100.0	[1]44.3	[1]83.5	[1]66.7
	221.7	1.7	175.6	6.5	[1]51.0	[1]2.3	[1]30.0	[1]20.7
Eunotia naegelii	66.5	89.0	66.5	100.0	83.5	66.7	100.0	66.7
	554.2	14.0	46.4	9.4	72.6	4.6	21.4	11.8
Achnanthes minutissima	16.5	22.0	.0	44.3	16.5	58.5	100.0	66.5
	.3	2.4	.0	2.0	11.7[b]	1.9[b]	76.4[a]	3.2[b]

[1]Significant interaction between location (upstream and downstream) and treatment (1999 and 2003) for percent frequency of occurrence and cell density: percent frequency of occurrence at upstream and downstream sites was significantly different in 1999, but similar in 2003; cell density was significantly different upstream and downstream and in 1999 and 2003. Differences in averages could not be assigned to either location or treatment.

var. *crassinervia* were significantly ($p \leq 0.05$) higher at LB downstream (LBDN), and during 2003, the average cell densities were significantly higher at LB upstream (LBUP). In contrast, the average cell density for *Achnanthes minutissima* was significantly higher at LBDN during 1999; all other averages for this taxon were similar during 1999 and 2003 at LBUP and LBDN (table 6).

Effects of Hardened Low-Water Crossings on Water Quality

Water-quality data (table 7) indicate that the sampled streams were typical of small streams in this area (Tollett and Fendick, 1998). Water-quality data from upstream and downstream sites are listed in table 7. The streams are acidic and poorly buffered, and pH ranged from 5.0 to 6.8 standard units. Field measurements of alkalinity ranged from 0.1 to 6.7 mg/L, and field measurements of specific conductance ranged from 13 to 36 μS/cm at 25 °C. Nutrient concentrations were small. Dissolved (filtered) ammonia (as nitrogen) ranged from <0.002 to 0.056 mg/L, and many results were less than detection limits. Dissolved ammonia plus organic nitrogen (as nitrogen) ranged from <0.1 to 0.4 mg/L. Dissolved nitrite plus nitrate (as nitrogen) ranged from <0.002 to 0.079 mg/L, and many results, especially from samples collected during 1999, were less than detection limits. Dissolved phosphorus (as P) ranged from <0.002 to 0.009 mg/L, and most results were less than detection limits. Calcium, magnesium, and sodium concentrations were small. Calcium ranged from 0.28 to 2.06 mg/L, magnesium ranged from 0.31 to 0.94 mg/L, and sodium ranged from 1.5 to 3.0 mg/L. Silica concentrations were large relative to other constituents measured and ranged from 7.3 to 13 mg/L.

Water-quality changes that may have resulted from original installation of the low-water crossings on BB, TEF, TBB, and LB, generally disappeared over time (figs. 3 through 8, table 8). Tollett and others (2002, p. 38–39) reported that the most pronounced changes occurred at LB, where, in 1998, calcium, magnesium, manganese, total dissolved solids, specific conductance, and alkalinity were all significantly ($p \leq 0.05$) higher at the downstream site compared with the upstream site after the low-water crossing installation in 1998. These higher values were attributed to changes in stream geometry, which caused a pool to form at LBUP, and possible dissolution of dolomitic limestone used as a base material in the low-water crossing. Tollett and others (2002) further reported that the crossing was modified in 2000, shortly after these changes were noted, to create a more natural channel, which reduced the pooling, and the limestone base material was replaced by inert gravel. By 2003, calcium concentrations at LBDN were again consistent with those at LBUP (fig. 3, table 8). Similarly to LB, increased calcium concentrations at TEFDN after the low-water crossing installation in 1999 may have resulted from the use of the dolomitic limestone. However, figure 3 shows that calcium concentrations at TEFDN were again similar to TEFUP by the time the limestone was replaced at the crossing in 2003, indicating that dissolution of the limestone probably had already slowed down or stopped.

All water-quality data were summed and averaged in 4-month groups (November, December, January, and February; March, April, May, and June; and July, August, September, and October), then statistically analyzed for seasonal differences. The only significant seasonal differences indicated were in water temperature, which was, as expected, significantly lower during the sampling period before modifications, because samples were collected only during winter months before the modifications at TEF and BB.

Water-quality data also were analyzed for significant differences between upstream and downstream sites before and after the installation of the hardened low-water crossings during 1998–99, and later, during 2003–04 (table 8). The data were grouped, summed, and averaged by upstream and downstream sites for periods referred to as before, after, and later in the text and in table 8. Average values for specific conductance and pH, and average concentrations of dissolved oxygen, dissolved solids, alkalinity, calcium, magnesium, sodium, potassium, iron, manganese, silica, sulfate, and chloride in samples were compared. Generally, average water-quality values and concentrations were similar at upstream and downstream sites. Notable exceptions were average values of specific conductance and pH, and concentrations of dissolved oxygen, alkalinity, and calcium, which often were higher at downstream sites than at upstream sites. Average iron concentrations often were higher at upstream sites than at downstream sites.

When average water-quality values or concentrations changed significantly, they almost always changed significantly at both the upstream and downstream sites. Average concentrations of alkalinity were significantly ($p \leq 0.05$) higher after the low-water crossing installation and later at upstream and downstream sites on BB and TEF. Average concentrations of iron were significantly higher after the installation and later at upstream and downstream sites on TEF and TBB. Average concentrations of silica and chloride also were significantly higher after the installation and later at upstream and downstream sites on TEF. Average values for specific conductance and concentrations of dissolved solids, calcium, sodium, potassium, silica, and sulfate increased significantly after the low-water crossing installations at TEF and TBB, but decreased significantly later to averages similar to averages before the installations. Average concentrations of dissolved oxygen were significantly lower after the installation and later at both upstream and downstream sites on TBB. Average concentrations of sodium, sulfate, and chloride were significantly lower after the installation and later at upstream and downstream sites on BB (table 8).

Monthly rainfall at Leesville, La. (fig. 1), ranged from 0.5 to 8.9 in. during the sample-collection periods (fig. 9).

Table 7. Water-quality data for sites upstream and downstream from hardened low-water crossings on selected streams at the Fort Polk Military Reservation, Louisiana, 1998–99 and 2003–04.

[See fig. 1 for location of site. Values are in milligrams per liter, except as noted. µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; -----, no data; <, less than indicated value; E, estimated value]

Date	Time	Specific conductance, field (µS/cm at 25 degrees Celsius)	pH, water, whole, field (standard units)	Temperature, air (degrees Celsius)	Temperature, water (degrees Celsius)	Turbidity, field (NTU)	Oxygen, dissolved	Nitrogen, ammonia, filtered (as N)	Nitrogen, nitrite, filtered (as N)	Nitrogen, ammonia plus organic, filtered (as N)	Nitrogen, nitrite plus nitrate, filtered (as N)	Phosphorus, filtered (as P)
Big Brushy Creek upstream (BBUP)												
12-22-1998	1100	23	6.0	2.0	14.3	-----	8.6	0.023	<0.010	0.114	0.079	<0.050
01-26-1999	1220	25	6.2	19.0	12.5	-----	9.3	<.020	.012	.132	<.050	<.004
02-24-1999	1000	21	6.1	9.5	10.1	-----	8.1	.044	<.010	.202	<.050	.004
03-23-1999	1220	22	5.6	25.0	16.0	-----	7.3	.056	<.010	.125	<.050	<.004
07-08-1999	1030	18	6.1	-----	24.1	-----	6.2	<.020	<.010	.195	.053	<.004
08-27-1999	1000	21	6.0	-----	26.9	-----	4.4	<.020	<.010	.256	<.050	<.004
10-01-1999	0915	27	5.6	22.5	17.0	-----	6.4	<.020	<.010	.259	<.050	E.003
04-10-2003	1630	22	6.2	-----	13.4	-----	7.5	.015	E.001	<.200	.005	<.002
05-07-2003	1600	21	6.1	-----	23.8	-----	-----	.021	.001	<.200	.021	<.002
06-04-2003	1430	21	6.0	29.5	23.7	20.0	6.4	.026	.002	<.200	.019	.006
07-01-2003	1200	18	5.8	31.5	23.3	15.0	7.1	.016	.002	<.200	.002	<.002
08-06-2003	0930	17	6.0	32.0	25.7	6.7	7.0	.019	<.001	<.200	.026	<.002
09-10-2003	1230	16	5.9	-----	23.6	13.0	7.5	.013	.002	<.200	.015	.004
10-07-2003	1230	16	6.0	-----	19.6	5.4	8.1	.004	<.001	<.200	.006	.003
11-05-2003	1200	16	6.0	-----	17.2	4.7	11.1	.004	.001	.300	<.002	.003
Big Brushy Creek downstream (BBDN)												
12-22-1998	1030	23	6.0	2.0	14.3	-----	8.6	<.020	<.010	.106	.075	<.050
01-26-1999	1140	26	5.7	19.0	12.5	-----	9.0	.022	<.010	.112	<.050	<.004
02-24-1999	0900	21	6.4	9.5	10.1	-----	8.4	<.020	<.010	.154	<.050	<.004
03-23-1999	1200	22	5.9	25.0	16.0	-----	7.7	.029	<.010	.119	<.050	<.004
07-08-1999	1015	18	5.5	-----	24.0	-----	6.5	<.020	<.010	.238	.051	.005
08-27-1999	0900	21	5.8	-----	27.0	-----	4.6	<.020	<.010	.239	<.050	<.004
10-01-1999	0900	27	5.5	22.5	16.9	-----	6.5	<.020	<.010	.191	<.050	<.006
04-10-2003	1600	23	6.8	-----	13.4	-----	7.7	.015	<.001	<.200	.003	<.002
05-07-2003	1530	21	6.2	-----	23.8	-----	-----	.026	.001	.200	.014	<.002
06-04-2003	1415	21	6.1	29.5	23.7	22.0	6.6	.026	.002	<.200	.024	<.002
07-01-2003	1130	18	5.8	31.5	23.3	15.0	7.2	.014	<.001	<.200	.004	<.002
08-06-2003	0900	18	6.2	32.0	25.7	7.2	7.3	.016	<.001	<.200	.026	<.002
09-10-2003	1230	16	6.0	33.0	23.7	14.0	7.8	.009	.002	.200	.012	<.002
10-07-2003	1200	17	6.1	-----	19.6	5.2	8.4	.006	<.001	<.200	.006	.003
11-05-2003	1130	17	6.1	-----	17.3	4.9	10.8	.005	.001	<.200	<.002	.003

Table 7. Water-quality data for sites upstream and downstream from hardened low-water crossings on selected streams at the Fort Polk Military Reservation, Louisiana, 1998–99 and 2003–04—Continued.

[See fig. 1 for location of site. Values are in milligrams per liter, except as noted. µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; -----, no data; <, less than indicated value; E, estimated value].

Date	Time	Specific conductance, field (µS/cm at 25 degrees Celsius)	pH, water, whole, field (standard units)	Temperature, air (degrees Celsius)	Temperature, water (degrees Celsius)	Turbidity, field (NTU)	Oxygen, dissolved	Nitrogen, ammonia, filtered (as N)	Nitrogen, nitrite, filtered (as N)	Nitrogen, ammonia plus organic, filtered (as N)	Nitrogen, nitrite plus nitrate, filtered (as N)	Phosphorus, filtered (as P)
Tributary to East Fork of Sixmile Creek upstream (TEFUP)												
12-22-1998	1030	21	5.5	1.0	-----	-----	-----	<0.020	<0.010	<0.100	0.076	<0.050
01-26-1999	1140	21	5.7	17.0	13.7	-----	9.6	<.020	<.010	.116	<.050	<.004
02-24-1999	0900	18	5.8	8.5	10.6	-----	6.0	.022	<.010	.126	<.050	<.004
03-23-1999	1200	18	5.5	23.0	16.0	-----	9.6	.034	<.010	E.091	<.050	<.004
07-08-1999	1015	19	5.7	-----	24.2	-----	5.9	<.020	<.010	.221	<.050	.004
08-27-1999	0900	18	5.6	32.0	25.3	-----	3.1	<.020	<.010	.188	<.050	<.004
10-01-1999	0900	36	5.5	22.0	18.7	-----	6.4	<.020	<.010	.339	<.050	E.003
04-10-2003	1600	18	5.5	22.0	12.2	-----	8.6	.013	<.001	.200	<.002	<.002
05-07-2003	1530	18	5.7	-----	23.2	-----	-----	<.002	<.001	<.200	.003	<.002
06-04-2003	1415	20	5.5	29.0	22.8	3.9	7.2	.016	.002	<.200	.003	<.002
07-01-2003	1130	18	5.3	27.0	22.9	4.4	7.6	.009	.002	.200	<.002	<.002
08-06-2003	0900	17	5.3	33.0	25.8	2.5	5.8	.009	<.001	<.200	.003	<.002
09-10-2003	1230	17	5.3	-----	23.2	3.7	6.5	.014	.002	.200	.004	.004
10-07-2003	1200	17	5.4	-----	19.7	2.6	6.8	.004	<.001	<.200	<.002	<.002
11-05-2003	1130	17	5.5	-----	17.2	1.8	9.2	.003	.002	<.200	<.002	.002
Tributary to East Fork of Sixmile Creek downstream (TEFDN)												
12-22-1998	1500	20	5.5	1.0	-----	-----	-----	<.020	<.010	<.100	.071	<.050
01-27-1999	0900	21	5.6	17.0	13.7	-----	9.5	.020	<.010	.142	<.050	<.004
02-25-1999	0620	18	5.6	8.5	10.6	-----	9.7	<.020	<.010	E.095	<.050	<.004
03-24-1999	0950	18	5.5	23.0	16.0	-----	9.7	.051	<.010	.108	<.050	<.004
07-07-1999	1120	18	5.9	-----	24.2	-----	5.8	<.020	<.010	.251	<.050	<.004
08-19-1999	1000	23	5.9	32.0	25.7	-----	4.3	<.020	<.010	.200	<.050	<.004
09-30-1999	1415	36	5.5	22.0	18.8	-----	6.6	<.020	<.010	.321	<.050	E.004
04-10-2003	1400	19	5.8	-----	12.0	-----	8.9	.011	<.001	<.200	<.002	<.002
05-07-2003	1630	19	5.9	-----	23.2	-----	-----	.025	.002	<.200	.019	.002
06-04-2003	1300	20	5.6	29.0	22.9	4.4	7.0	.009	.002	.200	.004	<.002
07-01-2003	0930	18	5.4	27.0	22.9	4.3	7.6	.006	.002	.300	<.002	<.002
08-06-2003	1330	18	5.5	31.0	26.3	2.8	6.2	.014	<.001	<.200	.003	<.002
09-10-2003	0930	17	5.5	-----	23.2	4.1	6.4	.018	.002	.400	.004	.009
10-07-2003	0900	16	5.5	-----	20.0	1.2	8.0	<.002	<.001	<.200	<.002	<.002
11-05-2003	0830	17	5.5	-----	17.2	2.0	8.3	.003	.002	.200	<.002	<.002

Table 7. Water-quality data for sites upstream and downstream from hardened low-water crossings on selected streams at the Fort Polk Military Reservation, Louisiana, 1998–99 and 2003–04—Continued.

[See fig. 1 for location of site. Values are in milligrams per liter, except as noted. µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; -----, no data; <, less than indicated value; E, estimated value]

Date	Time	Specific conductance, field (µS/cm at 25 degrees Celsius)	pH, water, whole, field (standard units)	Temperature, air (degrees Celsius)	Temperature, water (degrees Celsius)	Turbidity, field (NTU)	Oxygen, dissolved	Nitrogen, ammonia, filtered (as N)	Nitrogen, nitrite, filtered (as N)	Nitrogen, ammonia plus organic, filtered (as N)	Nitrogen, nitrite plus nitrate, filtered (as N)	Phosphorus, filtered (as P)
Tributary to Big Brushy Creek upstream (TBBUP)												
12-22-1998	1240	18	5.2	2.0	13.1	-----	8.7	<0.020	<0.010	0.112	0.071	<0.050
01-26-1999	1430	19	5.2	-----	14.2	-----	9.1	.031	.011	E.083	<.050	<.004
02-24-1999	1515	18	5.5	21.5	13.4	-----	8.5	<.020	<.010	E.077	<.050	<.004
03-23-1999	1425	18	5.4	25.0	16.8	-----	8.3	.043	<.010	E.082	<.050	<.004
07-07-1999	0900	19	5.3	25.8	23.6	-----	6.4	<.020	<.010	.220	<.050	<.004
08-26-1999	1300	24	5.2	-----	26.6	-----	-----	.038	<.010	.272	<.050	.004
10-01-1999	1145	30	5.7	20.5	16.9	-----	5.0	<.020	<.010	.208	<.050	E.003
08-06-2003	1100	17	5.3	32.5	25.3	2.2	6.8	.009	<.001	<.200	.003	<.002
09-10-2003	1200	17	5.1	-----	23.3	4.9	4.0	.008	<.001	<.200	<.002	.003
10-07-2003	1130	17	5.3	-----	20.2	1.0	5.8	.004	<.001	<.200	<.002	<.002
11-05-2003	1100	17	5.4	-----	17.5	3.5	7.7	.003	.002	.200	<.002	<.002
Tributary to Big Brushy Creek downstream (TBBDN)												
12-22-1998	1215	19	5.5	2.0	12.9	-----	7.5	<.020	<.010	.101	.072	<.050
01-26-1999	1445	19	5.2	-----	14.4	-----	8.8	<.020	<.010	E.093	<.050	<.004
02-24-1999	1500	18	5.6	21.5	13.7	-----	8.2	<.020	<.010	E.083	<.050	<.004
03-23-1999	1410	18	5.4	25.0	16.8	-----	8.1	.032	<.010	E.059	<.050	<.004
07-07-1999	0830	19	5.0	25.8	23.6	-----	6.4	<.020	<.010	.221	<.050	<.004
08-26-1999	1230	27	5.4	-----	26.9	-----	-----	.031	<.010	.239	<.050	.004
10-01-1999	1115	31	6.5	20.5	16.9	-----	5.6	.031	<.010	.327	<.050	E.005
08-06-2003	1030	18	5.2	33.0	25.2	2.2	6.1	.009	<.001	<.200	.004	<.002
09-10-2003	1130	17	5.2	-----	23.5	2.9	5.2	.009	.001	.200	.002	.004
10-07-2003	1100	18	5.3	-----	20.4	.5	6.4	<.002	<.001	.200	<.002	<.002
11-05-2003	1030	18	5.4	-----	17.7	3.3	8.6	.005	.001	<.200	<.002	<.002
Tributary to Birds Creek upstream (TBCUP)												
04-11-2003	1000	22	5.9	-----	12.4	-----	6.3	-----	-----	-----	-----	-----
05-07-2003	1400	24	6.0	-----	22.8	-----	-----	.023	.001	<.200	.016	<.002
06-04-2003	1100	24	5.8	28.5	22.5	15.0	5.9	.032	.002	.200	.024	<.002
07-01-2003	1400	19	5.7	-----	23.4	16.0	6.8	.022	<.001	<.200	.018	<.002
01-07-2004	0950	21	5.8	-----	6.9	4.7	11.6	.013	.001	<.200	.004	<.020
05-10-2004	1045	18	5.6	-----	19.3	8.8	7.5	.016	<.001	<.200	.007	<.002
06-14-2004	1030	20	5.3	-----	22.3	30.0	7.7	.008	.002	.400	.058	<.002

Table 7. Water-quality data for sites upstream and downstream from hardened low-water crossings on selected streams at the Fort Polk Military Reservation, Louisiana, 1998–99 and 2003–04—Continued.

[See fig. 1 for location of site. Values are in milligrams per liter, except as noted. µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; -----, no data; <, less than indicated value; E, estimated value]

Date	Time	Specific conductance, field (µS/cm at 25 degrees Celsius)	pH, water, whole, field (standard units)	Temperature, air (degrees Celsius)	Temperature, water (degrees Celsius)	Turbidity, field (NTU)	Oxygen, dissolved	Nitrogen, ammonia, filtered (as N)	Nitrogen, nitrite, filtered (as N)	Nitrogen, ammonia plus organic, filtered (as N)	Nitrogen, nitrite plus nitrate, filtered (as N)	Phosphorus, filtered (as P)
Tributary to Birds Creek downstream (TBCDN)												
04-11-2003	0930	21	5.8	-----	12.3	-----	6.4	0.008	E0.001	<0.020	0.008	<0.002
05-07-2003	1330	24	6.3	-----	22.8	-----	-----	.021	.001	<.020	.021	<.002
06-04-2003	1130	23	5.8	28.5	22.5	18.0	6.0	.025	.002	<.020	.024	<.002
07-01-2003	1330	19	5.6	30.5	23.4	16.0	6.8	.021	<.001	.300	.018	<.002
01-07-2004	0920	22	5.9	-----	6.6	6.4	12.0	.015	.001	.300	.004	<.020
05-10-2004	1030	18	5.7	-----	20.1	10.0	8.0	.004	<.001	<.200	.007	<.002
06-14-2004	1000	20	5.3	-----	22.4	30.0	7.8	.012	.002	.400	.063	.004
Little Brushy Creek upstream (LBUP)												
12-22-1998	1410	18	5.6	2.0	-----	-----	-----	<.020	<.010	<.100	.070	<.050
01-27-1999	1145	18	5.5	22.0	14.9	-----	7.8	<.020	<.010	E.099	<.050	<.004
02-25-1999	0845	16	5.8	16.0	11.8	-----	8.3	.052	<.010	.120	<.050	<.004
03-24-1999	1320	17	5.7	29.0	18.3	-----	10.2	.039	<.010	E.081	<.050	<.004
07-08-1999	0845	18	5.8	-----	22.9	-----	6.2	<.020	<.010	.215	<.050	<.004
08-26-1999	1045	17	5.6	-----	-----	-----	-----	<.020	<.010	E.092	<.050	<.004
10-01-1999	1315	22	-----	20.5	18.3	-----	7.1	<.020	<.010	.199	<.050	E.003
08-06-2003	1230	15	5.8	31.5	24.7	.8	7.1	.005	<.001	<.200	<.002	<.002
09-10-2003	1100	13	5.7	-----	22.8	2.6	7.1	.010	.002	<.200	.002	.005
10-07-2003	1030	16	5.9	-----	19.5	11.0	7.1	.012	<.001	<.200	<.002	.003
11-05-2003	1000	14	5.9	-----	17.5	2.0	12.6	.003	.001	<.200	<.002	.003
Little Brushy Creek downstream (LBDN)												
12-22-1998	1345	18	6.0	2.0	-----	-----	-----	<.020	<.010	<.100	.070	<.050
01-27-1999	1115	19	5.6	22.0	14.6	-----	8.9	<.020	<.010	E.086	<.050	<.004
02-25-1999	0815	18	6.0	16.0	11.8	-----	9.7	<.020	<.010	E.09	<.050	<.004
03-24-1999	1300	18	5.5	29.0	17.6	-----	10.2	.044	<.010	.100	<.050	<.004
07-08-1999	0815	19	6.1	-----	22.8	-----	6.3	<.020	<.010	.189	<.050	<.004
08-26-1999	0945	22	5.6	-----	25.9	-----	5.1	<.020	<.010	.188	<.050	<.004
10-01-1999	1245	25	5.4	20.5	18.4	-----	7.1	<.020	<.010	.178	<.050	E.005
08-06-2003	1200	15	5.9	31.5	25.7	-----	6.8	<.002	<.001	<.200	<.002	<.002
09-10-2003	1030	14	5.8	-----	23.3	2.8	7.2	.003	.001	<.200	<.002	.004
10-07-2003	1000	15	6.0	-----	20.4	1.8	8.6	<.002	<.001	<.200	<.002	<.002
11-05-2003	0930	15	6.0	-----	17.8	1.5	12.6	.002	.002	<.200	<.002	.003

Table 7. Water-quality data for sites upstream and downstream from hardened low-water crossings on selected streams at the Fort Polk Military Reservation, Louisiana, 1998–99 and 2003–04—Continued.

[See fig. 1 for location of site. Values are in milligrams per liter, except as noted. µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; -----, no data; <, less than indicated value; E, estimated value]

Date	Time	Calcium, filtered (as Ca)	Magnesium, filtered (as Mg)	Sodium, filtered (as Na)	Potassium, filtered (as K)	Bicarbonate, calculated (as HCO_3)	Alkalinity, field, (as $CaCO_3$)	Sulfate, filtered (as SO_4)	Chloride, filtered (as Cl)	Fluoride, filtered (as F)	Silica, filtered (as SiO_2)	Residue on evaporation at 180 degrees Celsius, filtered	Iron, filtered (as Fe)	Manganese, filtered (as Mn)
Big Brushy Creek upstream (BBUP)														
12-22-1998	1100	0.90	0.56	2.10	0.48	4.2	3.4	1.90	3.9	<0.1	9.8	27	0.175	0.045
01-26-1999	1220	.87	.56	2.30	.41	4.0	3.3	1.90	3.9	<.1	9.6	29	.146	.038
02-24-1999	1000	.68	.43	1.88	.29	-----	-----	1.00	3.2	<.1	9.1	29	.175	.026
03-23-1999	1220	.79	.51	2.05	.30	4.9	4.0	.80	3.5	<.1	9.3	29	.325	.040
07-08-1999	1030	.85	.46	1.51	.50	5.5	4.5	.80	2.5	<.1	7.9	28	.208	.035
08-27-1999	1000	.93	.48	1.79	.35	5.0	4.1	.20	3.1	<.1	8.2	29	.211	.067
10-01-1999	0915	1.04	.69	2.21	.86	5.6	4.6	2.20	3.4	<.1	8.8	38	.248	.050
04-10-2003	1630	.94	.55	2.00	.30	5.1	3.3	.80	3.1	<.1	9.8	27	.132	.024
05-07-2003	1600	.83	.50	1.80	.30	4.1	4.1	.40	3.1	<.1	9.1	28	.375	.058
06-04-2003	1430	.84	.49	1.80	.30	3.4	4.2	.60	3.1	<.1	8.5	35	.254	.046
07-01-2003	1200	.93	.49	1.70	.30	3.5	2.8	.80	2.8	<.1	11.0	41	.291	.041
08-06-2003	0930	.78	.47	1.80	.20	5.2	4.3	.30	3.1	<.1	9.1	24	.294	.041
09-10-2003	1230	.86	.48	1.60	.40	4.1	3.3	.79	2.9	<.1	8.9	25	.164	.042
10-07-2003	1230	.57	.38	1.80	.30	.9	.8	.47	3.2	<.1	9.5	19	.160	.020
11-05-2003	1200	.62	.43	1.80	.30	2.1	1.4	.40	3.1	<.1	9.8	15	.183	.031
Big Brushy Creek downstream (BBDN)														
12-22-1998	1030	.90	.56	2.10	.49	4.2	3.4	1.90	3.9	<.1	9.8	27	.192	.044
01-26-1999	1140	.88	.56	2.27	.42	4.3	3.5	1.80	4.0	<.1	9.6	29	.146	.038
02-24-1999	0900	1.02	.46	1.93	.23	-----	-----	1.10	3.3	<.1	9.5	31	.256	.029
03-23-1999	1200	.82	.51	2.06	.30	5.1	4.2	.70	3.4	<.1	9.3	23	.232	.040
07-08-1999	1015	.90	.46	1.46	.44	4.8	3.9	.80	2.4	<.1	7.7	26	.238	.035
08-27-1999	0900	.94	.47	1.72	.28	7.0	5.7	.10	2.9	<.1	8.1	27	.124	.060
10-01-1999	0900	1.10	.70	2.25	.80	4.0	3.3	2.20	3.5	<.1	8.8	37	.182	.050
04-10-2003	1600	.95	.53	2.00	.30	6.4	5.3	.90	3.2	<.1	9.8	27	.162	.024
05-07-2003	1530	.86	.50	1.90	.30	6.0	4.9	.40	3.1	<.1	8.9	28	.196	.052
06-04-2003	1415	.90	.48	1.80	.30	3.5	3.0	.60	3.1	<.1	8.6	29	.176	.043
07-01-2003	1130	.94	.49	1.70	.30	3.7	3.0	.80	2.7	<.1	11.0	48	.265	.040
08-06-2003	0900	.98	.48	1.80	.30	2.7	2.2	.40	3.1	<.1	9.3	25	.269	.039
09-10-2003	1230	.94	.47	1.60	.40	3.8	3.1	.80	2.9	<.1	9.0	24	.168	.041
10-07-2003	1200	.67	.39	1.80	.30	1.6	1.3	.53	3.2	<.1	9.4	18	.136	.019
11-05-2003	1130	.76	.42	1.70	.30	3.5	2.1	.41	3.2	<.1	9.8	17	.196	.031

Table 7. Water-quality data for sites upstream and downstream from hardened low-water crossings on selected streams at the Fort Polk Military Reservation, Louisiana, 1998–99 and 2003–04—Continued.

[See fig. 1 for location of site. Values are in milligrams per liter, except as noted. µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; -----, no data; <, less than indicated value; E, estimated value]

Date	Time	Calcium, filtered (as Ca)	Magnesium, filtered (as Mg)	Sodium, filtered (as Na)	Potassium, filtered (as K)	Bicarbonate, calculated (as HCO_3)	Alkalinity, field, (as $CaCO_3$)	Sulfate, filtered (as SO_4)	Chloride, filtered (as Cl)	Fluoride, filtered (as F)	Silica, filtered (as SiO_2)	Residue on evaporation at 180 degrees Celsius, filtered	Iron, filtered (as Fe)	Manganese, filtered (as Mn)
Tributary to East Fork of Sixmile Creek upstream (TEFUP)														
12-22-1998	1030	0.51	0.44	2.00	0.16	2.7	2.2	1.50	3.7	<0.1	10.5	25	0.114	0.037
01-26-1999	1140	.45	.42	2.16	.12	2.9	2.4	1.50	3.6	<.1	10.5	25	.114	.028
02-24-1999	0900	.42	.33	1.96	.14	2.4	2.0	1.10	3.2	<.1	9.5	20	.078	.015
03-23-1999	1200	.39	.37	1.98	.11	3.0	2.5	.80	3.6	<.1	10.2	27	.131	.021
07-08-1999	1015	.42	.36	2.02	.17	3.3	2.7	.40	3.5	<.1	9.8	25	.277	.033
08-27-1999	0900	.41	.37	2.02	.17	3.5	2.9	.20	3.4	<.1	9.0	28	.121	.075
10-01-1999	0900	.92	.92	3.00	.73	2.9	2.4	3.70	4.6	<.1	11.0	46	.191	.091
04-10-2003	1600	.37	.36	2.00	.20	2.0	1.5	.80	3.3	<.1	10.0	27	.097	.019
05-07-2003	1530	.38	.37	2.00	.20	1.5	1.1	.40	3.4	<.1	9.5	23	.147	.026
06-04-2003	1415	.43	.41	2.10	.20	1.7	1.2	.60	3.7	<.1	9.6	33	.171	.028
07-01-2003	1130	.61	.43	2.00	.20	.8	.5	.80	3.4	<.1	12.0	38	.277	.043
08-06-2003	0900	.37	.35	2.00	.10	2.4	1.7	.30	3.6	<.1	9.9	25	.161	.035
09-10-2003	1230	.44	.39	2.00	.20	1.6	1.2	.30	3.7	<.1	11.0	27	.202	.035
10-07-2003	1200	.28	.33	2.00	.10	.4	.1	.36	3.7	<.1	11.0	18	.208	.022
11-05-2003	1130	.33	.40	2.00	.20	3.1	.6	.34	3.7	<.1	11.0	15	.301	.030
Tributary to East Fork of Sixmile Creek downstream (TEFDN)														
12-22-1998	1500	.51	.44	2.01	.16	3.4	2.2	1.50	3.7	<.1	10.5	24	.116	.038
01-27-1999	0900	.45	.42	2.16	.15	3.2	2.4	1.50	3.8	<.1	10.4	24	.107	.028
02-25-1999	0620	.38	.34	1.85	.10	2.4	2.0	1.10	3.3	<.1	9.4	20	.081	.016
03-24-1999	0950	.39	.37	1.98	.12	2.9	2.5	.80	3.5	<.1	10.2	26	.131	.022
07-07-1999	1120	.69	.38	2.06	.22	4.0	2.7	.40	3.3	<.1	9.9	29	.158	.038
08-19-1999	1000	2.06	.39	2.06	.27	7.8	2.9	.30	3.4	<.1	9.1	32	.380	.077
09-30-1999	1415	1.23	.94	3.02	.96	3.8	2.4	3.80	4.7	<.1	11.0	48	.208	.096
04-10-2003	1400	.41	.35	2.00	.20	2.7	2.2	.80	3.3	<.1	10.0	23	.132	.018
05-07-2003	1630	.52	.38	2.00	.20	1.9	1.5	.40	3.4	<.1	9.5	24	.175	.027
06-04-2003	1300	.61	.44	2.00	.20	2.7	2.1	.70	3.7	<.1	9.6	47	.156	.031
07-01-2003	0930	.64	.44	2.00	.20	.4	.3	.80	3.3	<.1	12.0	33	.265	.044
08-06-2003	1330	.47	.36	2.00	.20	5.9	4.8	.30	3.6	<.1	10.0	27	.202	.039
09-10-2003	0930	.52	.40	2.00	.20	1.1	.8	.40	3.8	<.1	11.0	26	.205	.039
10-07-2003	0900	.32	.33	2.00	.10	1.0	.7	.35	3.6	<.1	11.0	29	.135	.025
11-05-2003	0830	.36	.40	2.00	.20	6.2	1.7	.34	3.6	<.1	11.0	16	.299	.034

Table 7. Water-quality data for sites upstream and downstream from hardened low-water crossings on selected streams at the Fort Polk Military Reservation, Louisiana, 1998–99 and 2003–04—Continued.

[See fig. 1 for location of site. Values are in milligrams per liter, except as noted. µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; -----, no data; <, less than indicated value; E, estimated value]

Date	Time	Calcium, filtered (as Ca)	Magnesium, filtered (as Mg)	Sodium, filtered (as Na)	Potassium, filtered (as K)	Bicarbonate, calculated (as HCO_3)	Alkalinity, field, (as $CaCO_3$)	Sulfate, filtered (as SO_4)	Chloride, filtered (as Cl)	Fluoride, filtered (as F)	Silica, filtered (as SiO_2)	Residue on evaporation at 180 degrees Celsius, filtered	Iron, filtered (as Fe)	Manganese, filtered (as Mn)
Tributary to Big Brushy Creek upstream (TBBUP)														
12-22-1998	1240	0.42	0.39	1.91	0.17	2.5	2.0	1.20	3.5	<0.1	8.8	23	0.105	0.073
01-26-1999	1430	.36	.38	2.00	.13	2.0	1.6	1.10	3.2	<.1	9.2	21	.087	.050
02-24-1999	1515	.34	.34	1.79	.13	3.4	2.8	1.00	3.0	<.1	8.7	21	.053	.037
03-23-1999	1425	.34	.35	1.84	.13	3.9	3.2	.70	3.2	<.1	8.9	23	.100	.046
07-07-1999	0900	.38	.37	2.00	.14	2.3	1.9	.20	3.3	<.1	11.1	29	.194	.096
08-26-1999	1300	.56	.47	2.05	.34	4.8	3.9	<.1	3.7	<.1	12.9	23	.598	.587
10-01-1999	1145	.60	.66	2.75	.33	4.4	3.6	2.90	4.4	<.1	12.6	34	.185	.185
08-06-2003	1100	.33	.37	2.00	.10	.5	.2	.20	3.6	<.1	12.0	25	.361	.087
09-10-2003	1200	.38	.38	2.00	.10	.5	.1	.30	3.8	<.1	12.0	25	.208	.091
10-07-2003	1130	.31	.38	2.00	.10	.3	.3	.38	3.8	<.1	13.0	27	.235	.081
11-05-2003	1100	.35	.44	2.00	.20	4.4	3.4	.32	3.6	<.1	13.0	16	.309	.103
Tributary to Big Brushy Creek downstream (TBBDN)														
12-22-1998	1215	.43	.39	1.92	.17	3.4	2.8	1.20	3.4	<.1	8.8	23	.113	.073
01-26-1999	1445	.36	.37	1.99	.14	2.7	2.2	1.10	3.3	<.1	9.2	23	.098	.053
02-24-1999	1500	.36	.35	1.83	.10	3.4	2.8	1.00	3.0	<.1	8.8	21	.058	.037
03-23-1999	1410	.34	.35	1.85	.12	3.0	2.5	.60	3.1	<.1	9.0	24	.091	.047
07-07-1999	0830	.41	.37	1.96	.15	3.4	2.8	.30	3.5	<.1	11.0	28	.234	.101
08-26-1999	1230	1.03	.50	2.08	.45	8.0	6.6	<.10	3.7	<.1	12.9	30	.561	.564
10-01-1999	1115	.72	.67	3.00	.46	3.7	3.0	2.70	4.4	<.1	12.8	34	.175	.187
08-06-2003	1030	.36	.37	2.00	.10	.5	.2	.20	3.6	<.1	12.0	27	.352	.087
09-10-2003	1130	.41	.38	2.01	.16	1.7	1.1	.28	3.8	.0	12.5	25	.197	.088
10-07-2003	1100	.34	.38	2.00	.10	.4	.3	.39	3.8	<.1	12.0	18	.162	.072
11-05-2003	1030	.47	.45	2.00	.20	6.0	3.6	.32	3.6	<.1	13.0	16	.284	.100
Tributary to Birds Creek upstream (TBCUP)														
04-11-2003	1000	-----	-----	-----	-----	2.9	2.3	-----	-----	-----	-----	-----	-----	-----
05-07-2003	1400	.83	.59	2.10	.50	4.9	4.0	.40	3.6	<.1	10.0	36	.156	.055
06-04-2003	1100	.90	.57	2.10	.60	4.5	3.6	.60	3.6	<.1	11.0	44	.309	.043
07-01-2003	1400	.76	.49	1.90	.40	3.3	2.6	.70	3.2	<.1	10.0	54	.226	.032
01-07-2004	0950	.73	.57	2.40	.40	.8	.5	1.20	4.4	<.1	12.0	22	.194	.049
05-10-2004	1045	.56	.41	2.10	.40	2.3	1.8	.55	3.6	<.1	10.0	22	.198	.026
06-14-2004	1030	.94	.54	1.50	.70	1.0	.6	1.20	2.6	<.1	7.3	-----	.362	.074

Table 7. Water-quality data for sites upstream and downstream from hardened low-water crossings on selected streams at the Fort Polk Military Reservation, Louisiana, 1998–99 and 2003–04—Continued.

[See fig. 1 for location of site. Values are in milligrams per liter, except as noted. µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; -----, no data; <, less than indicated value; E, estimated value]

Date	Time	Calcium, filtered (as Ca)	Magnesium, filtered (as Mg)	Sodium, filtered (as Na)	Potassium, filtered (as K)	Bicarbonate, calculated (as HCO_3)	Alkalinity, field, (as $CaCO_3$)	Sulfate, filtered (as SO_4)	Chloride, filtered (as Cl)	Fluoride, filtered (as F)	Silica, filtered (as SiO_2)	Residue on evaporation at 180 degrees Celsius, filtered	Iron, filtered (as Fe)	Manganese, filtered (as Mn)
Tributary to Birds Creek downstream (TBCDN)														
04-11-2003	0930	0.69	0.50	2.10	0.40	3.9	3.2	0.70	3.6	<0.10	11.0	27	0.240	0.025
05-07-2003	1330	.83	.59	2.10	.50	4.0	3.3	.40	3.6	<.10	10.0	31	.234	.055
06-04-2003	1130	.86	.57	2.10	.50	4.0	3.2	.60	3.6	<.10	11.0	39	.150	.041
07-01-2003	1330	.76	.49	1.90	.40	2.4	1.9	.70	3.2	<.10	10.0	46	.224	.031
01-07-2004	0920	.75	.55	2.40	.40	.6	.5	1.20	4.3	<.10	12.0	27	.204	.051
05-10-2004	1030	.59	.42	1.90	.40	5.0	4.0	.54	3.4	<.10	10.0	20	.160	.029
06-14-2004	1000	.99	.54	1.50	.70	1.4	1.0	1.30	2.6	<.10	7.3	-----	.368	.078
Little Brushy Creek upstream (LBUP)														
12-22-1998	1410	.40	.38	1.89	.18	3.7	3.0	.90	3.3	<.1	9.2	19	.146	.035
01-27-1999	1145	.33	.36	1.97	<.10	2.2	1.8	.90	3.3	<.1	9.1	21	.104	.017
02-25-1999	0845	.33	.31	1.82	.11	3.7	3.0	.70	3.1	<.1	8.6	21	.073	.011
03-24-1999	1320	.31	.33	1.80	.13	3.2	2.6	.50	3.1	<.1	8.8	24	.100	.012
07-08-1999	0845	.39	.40	1.93	.17	3.9	3.2	.40	3.1	<.1	9.4	25	.170	.021
08-26-1999	1045	.29	.36	1.80	.25	3.3	2.7	.20	2.9	<.1	8.8	11	.119	.015
10-01-1999	1315	.46	.48	2.22	.33	3.8	3.1	1.30	3.5	<.1	10.0	29	.171	.026
08-06-2003	1230	.31	.37	1.80	.20	2.0	1.5	.30	3.0	<.1	9.4	23	.152	.012
09-10-2003	1100	.29	.32	1.80	.20	1.6	1.3	.40	3.1	<.1	9.6	19	.111	.014
10-07-2003	1030	.28	.36	1.90	.20	.3	.3	.41	3.2	<.1	9.7	22	.099	.008
11-05-2003	1000	.30	.39	1.80	.20	1.2	1.0	.39	3.0	<.1	9.8	15	.130	.010
Little Brushy Creek downstream (LBDN)														
12-22-1998	1345	.68	.39	1.87	.18	4.4	3.6	.90	3.2	<.1	9.2	23	.147	.032
01-27-1999	1115	.61	.37	1.98	.14	3.8	3.1	.90	3.1	<.1	9.1	22	.116	.017
02-25-1999	0815	.59	.33	1.84	.11	4.9	4.0	.70	3.2	<.1	8.6	21	.071	.011
03-24-1999	1300	.68	.37	1.84	.16	4.8	3.9	.40	3.1	<.1	9.1	24	.106	.012
07-08-1999	0815	1.05	.46	1.94	.17	5.7	4.7	.40	3.1	<.1	9.4	28	.177	.020
08-26-1999	0945	1.23	.44	1.81	.20	7.1	5.8	.20	3.0	<.1	8.9	27	.099	.013
10-01-1999	1245	1.19	.52	2.22	.33	8.2	6.7	1.20	3.4	<.1	10.1	32	.161	.023
08-06-2003	1200	.36	.36	1.80	.20	3.5	2.8	.30	3.0	<.1	9.3	20	.106	.011
09-10-2003	1030	.33	.33	1.80	.20	3.4	2.5	.40	3.1	<.1	9.6	18	.094	.013
10-07-2003	1000	.32	.36	1.90	.20	2.1	1.8	.41	3.1	<.1	9.8	23	.102	.009
11-05-2003	0930	.36	.39	1.80	.20	3.5	2.4	.38	3.0	<.1	9.8	15	.134	.011

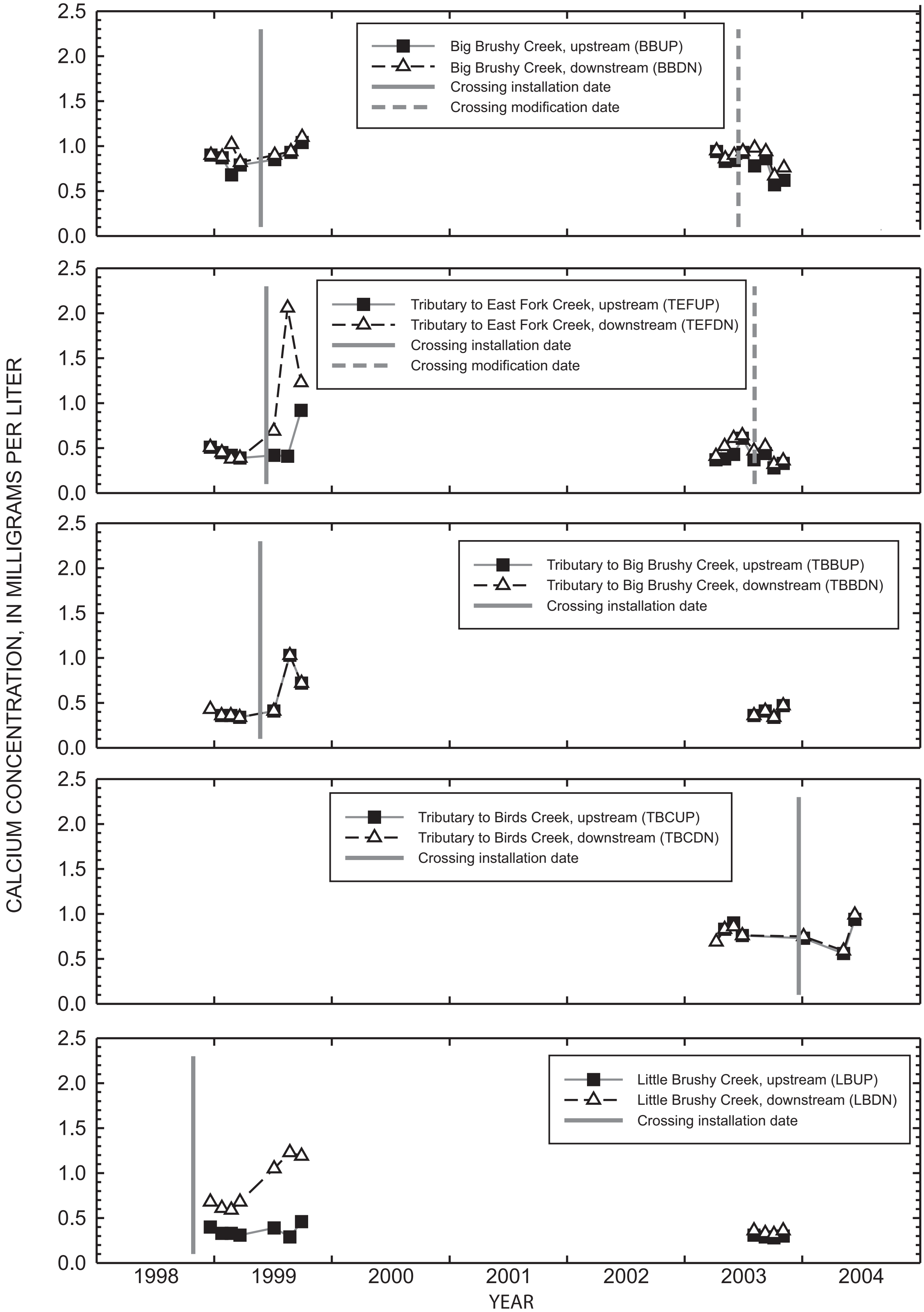

Figure 3. Calcium concentrations in water from sites upstream and downstream from hardened low-water crossings on selected streams at the Fort Polk Military Reservation, Louisiana, 1998–99 and 2003–04. (See fig. 1 for location of site.)

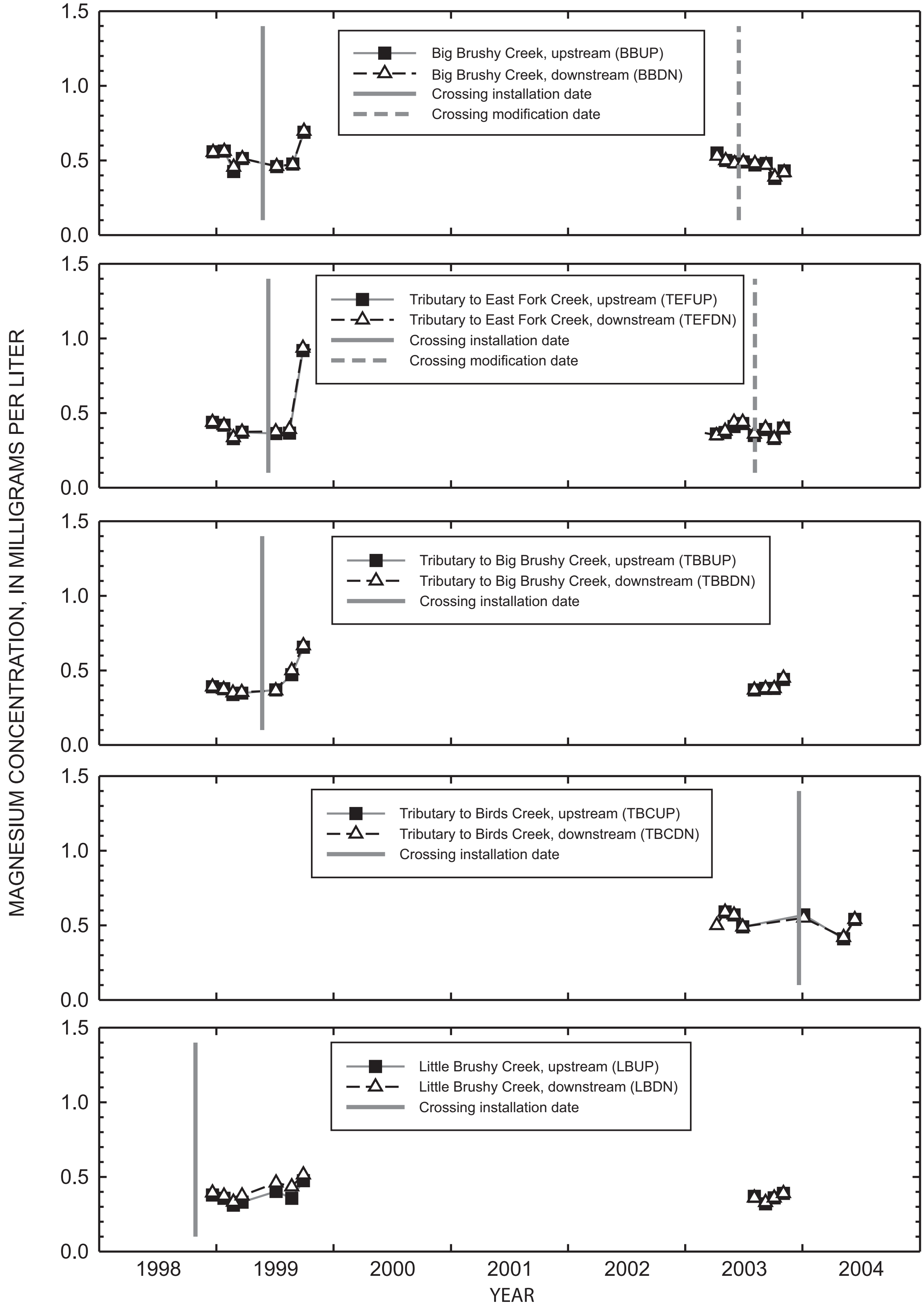

Figure 4. Magnesium concentrations in water from sites upstream and downstream from hardened low-water crossings on selected streams at the Fort Polk Military Reservation, Louisiana, 1998–99 and 2003–04. (See fig. 1 for location of site.)

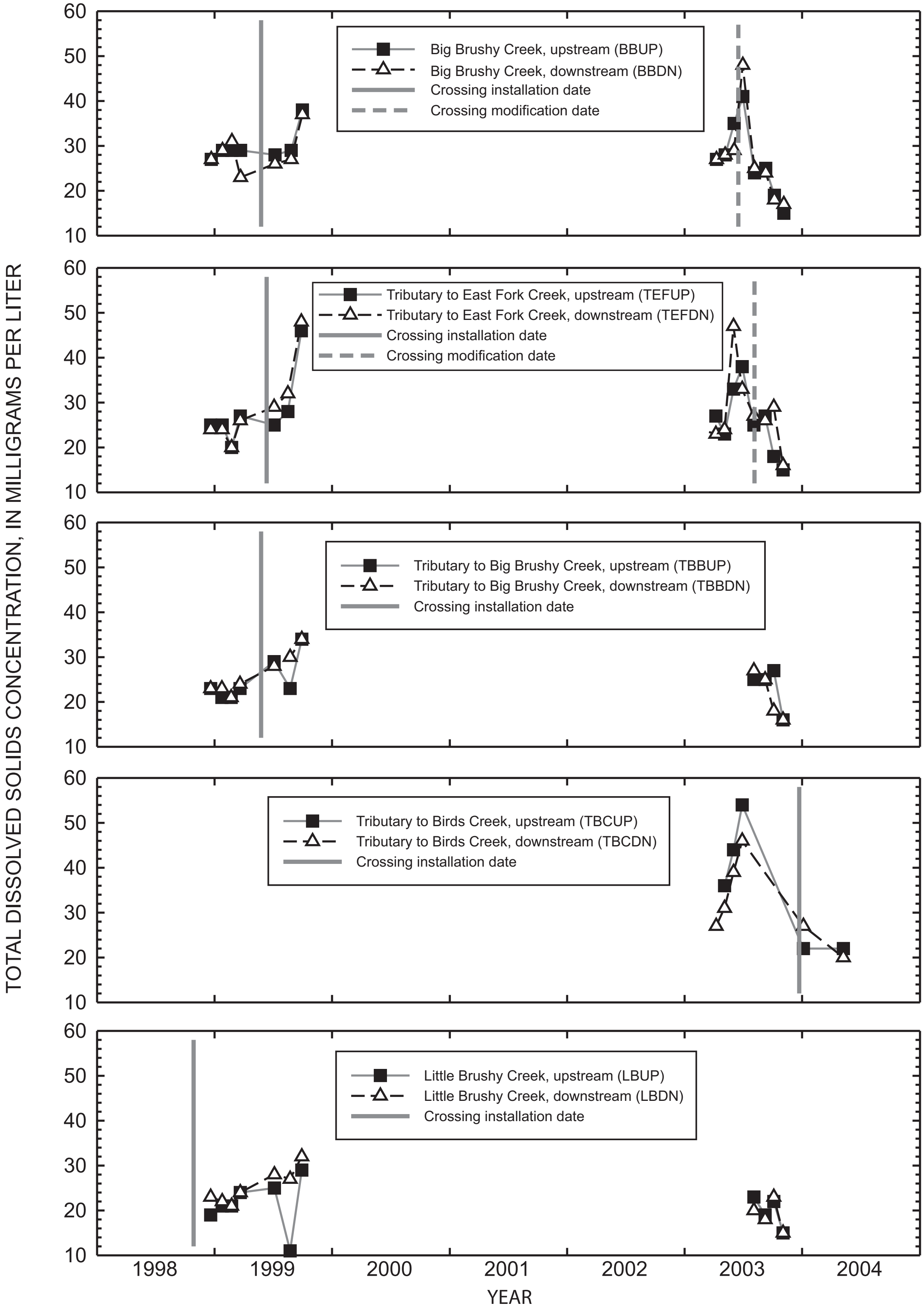

Figure 5. Concentration of total dissolved solids in water from sites upstream and downstream from hardened low-water crossings on selected streams at the Fort Polk Military Reservation, Louisiana, 1998–99 and 2003–04. (See fig. 1 for location of site.)

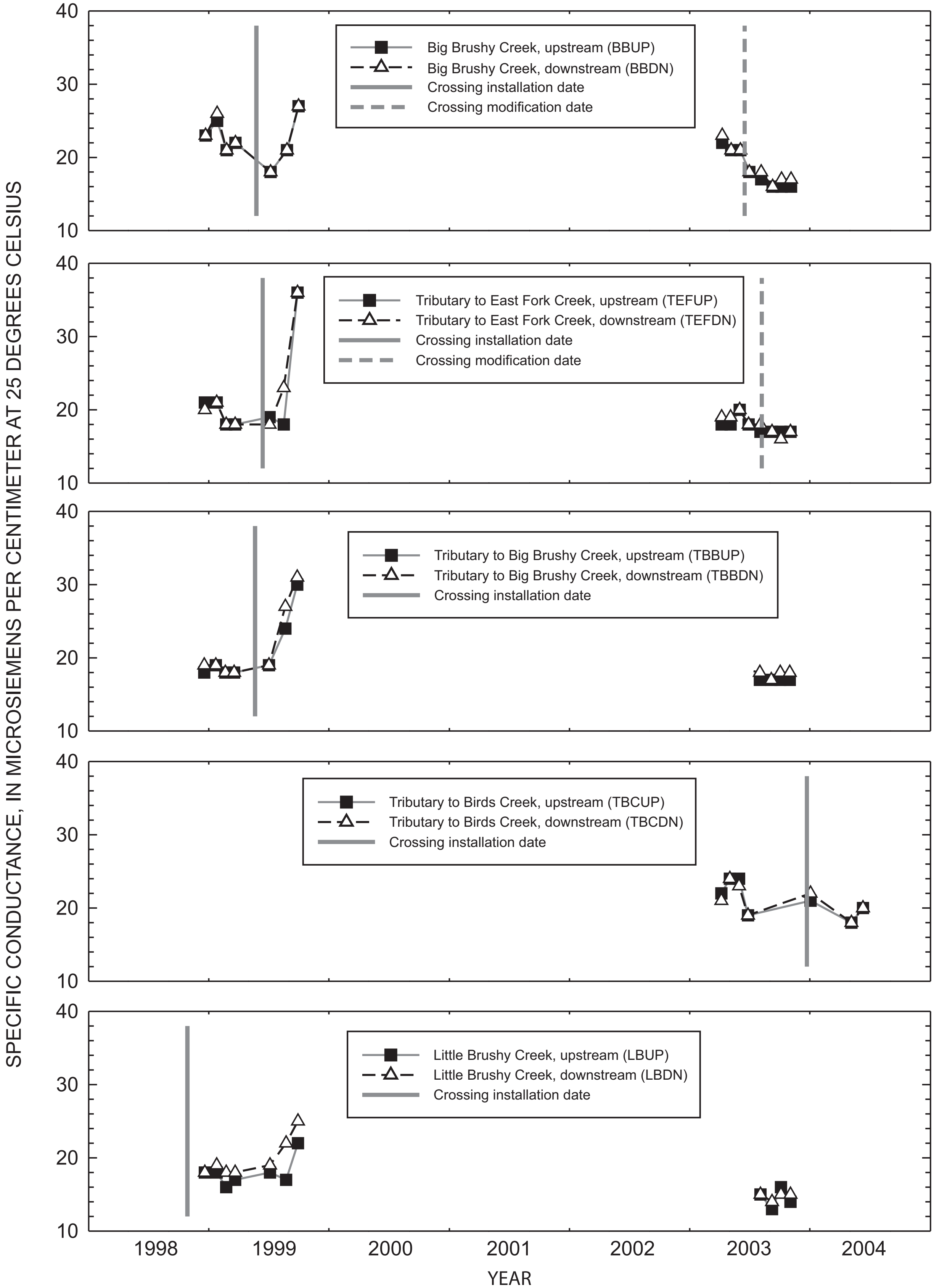

Figure 6. Specific conductance in water from sites upstream and downstream from hardened low-water crossings on selected streams at the Fort Polk Military Reservation, Louisiana, 1998–99 and 2003–04. (See fig. 1 for location of site.)

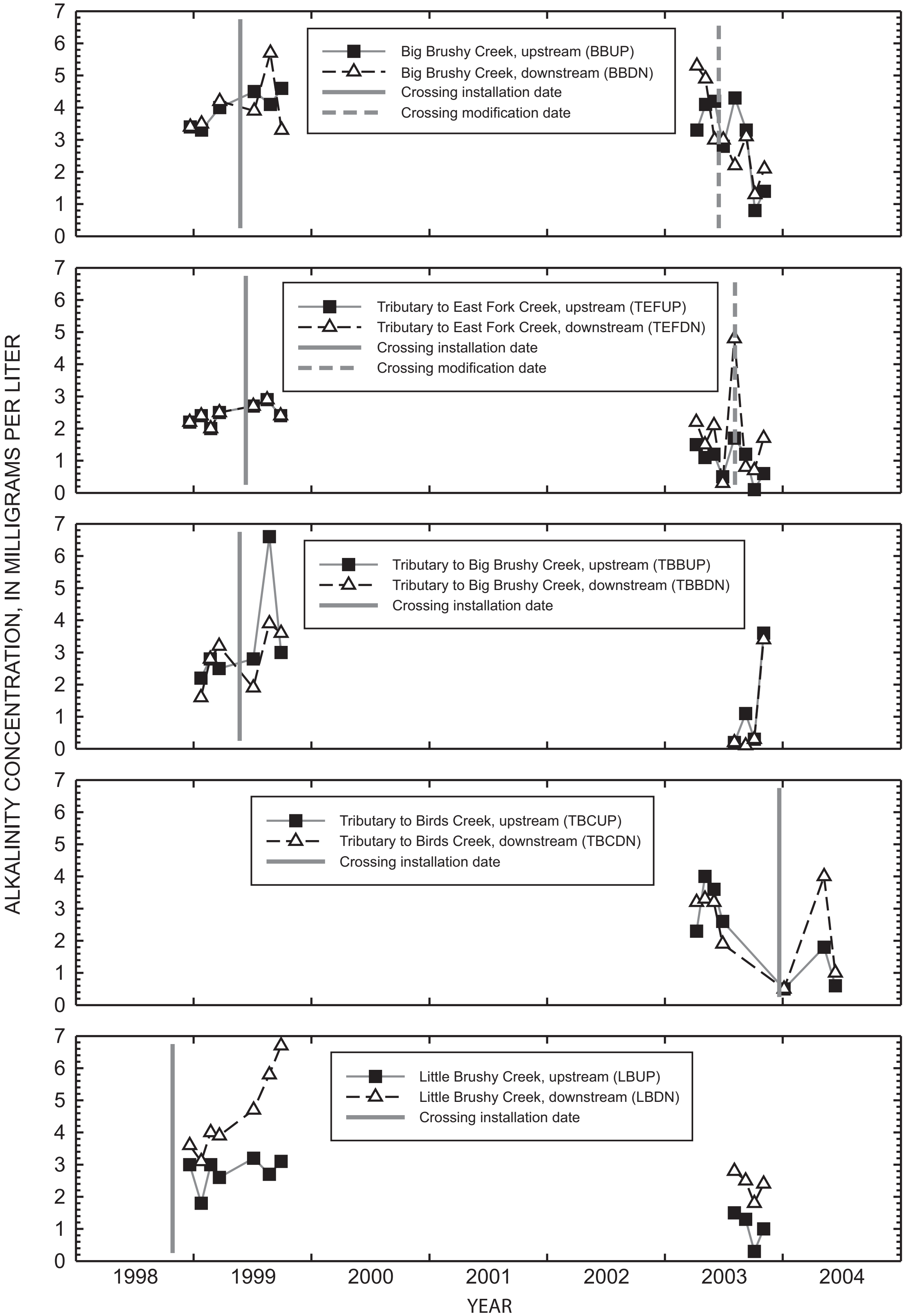

Figure 7. Alkalinity concentrations in water from sites upstream and downstream from hardened low-water crossings on selected streams at the Fort Polk Military Reservation, Louisiana, 1998–99 and 2003–04. (See fig. 1 for location of site.)

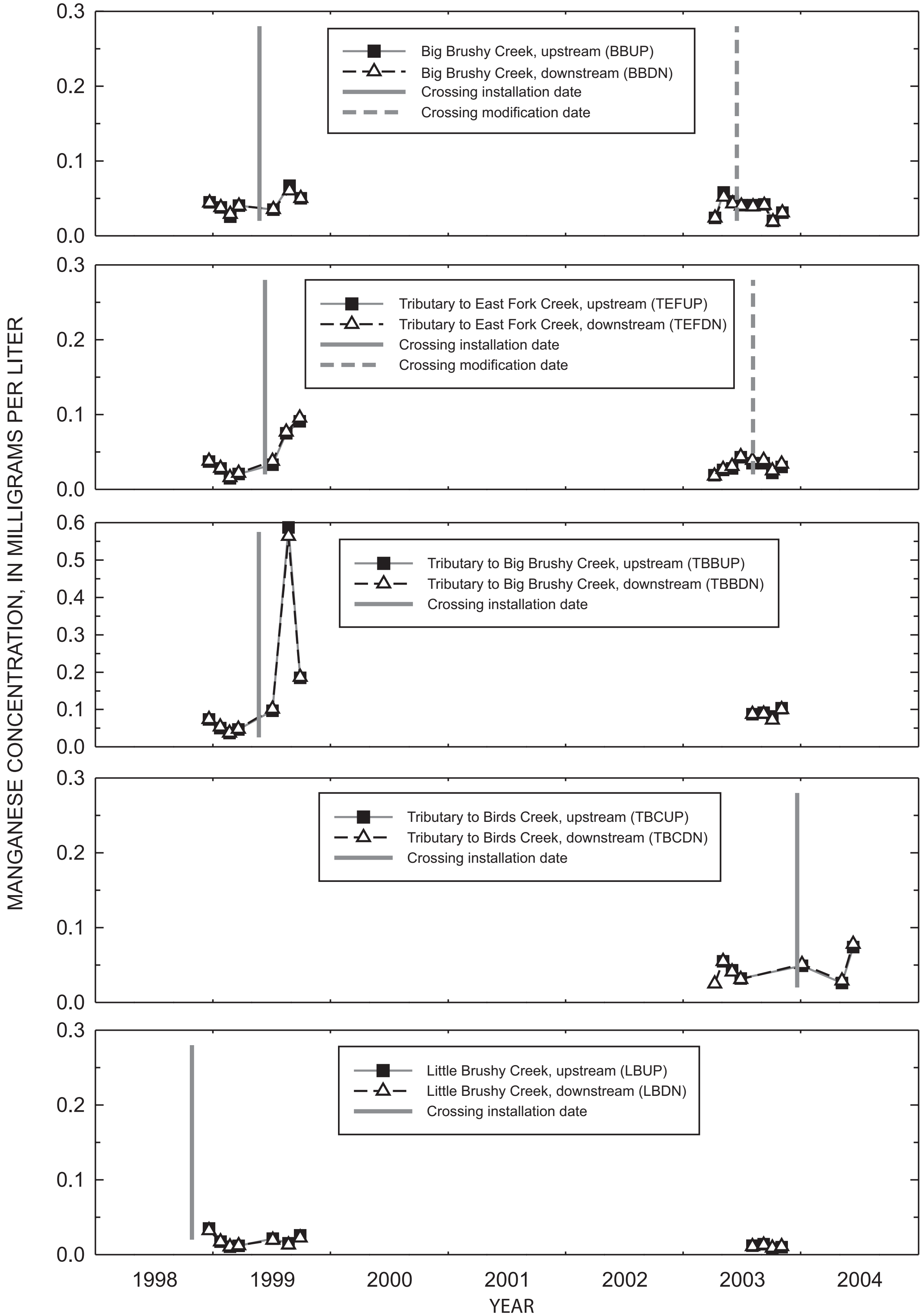

Figure 8. Manganese concentrations in water from sites upstream and downstream from hardened low-water crossings on selected streams at the Fort Polk Military Reservation, Louisiana, 1998–99 and 2003–04. (See fig. 1 for location of site.)

Table 8. Average water-quality properties at sites upstream and downstream from hardened low-water crossings on Big Brushy Creek, Tributary to East Fork of Sixmile Creek, Tributary to Birds Creek, Tributary to Big Brushy Creek, and Little Brushy Creek at the Fort Polk Military Reservation, Louisiana, 1998–99 and 2003–04.

[See fig. 1 for location of site. Before, samples collected before low-water crossing installation; After, samples collected within 1 year after hardened low-water crossing installation; Later, samples collected 5 years after hardened low-water crossing installation. Averages with different superscripts are statistically different (p less than or equal to 0.05). Units are milligrams per liter, unless indicated otherwise. µS/cm, microsiemens per centimeter]

Property or constituent	Big Brushy Creek (BB)						Tributary to East Fork Creek (TEF)						Tributary to Big Brushy Creek (TBB)					
	Upstream			Downstream			Upstream			Downstream			Upstream			Downstream		
	Before	After	Later	Before	After	Later	Before	After	Later	Before	After	Later	Before	After	Later	Before	After	Later
	Dec. 1998–Mar. 1999	July 1999–Oct. 1999	Apr. 2003–Nov. 2003	Dec. 1998–Mar. 1999	July 1999–Oct. 1999	Apr. 2003–Nov. 2003	Dec. 1998–Mar. 1999	July 1999–Oct. 1999	Apr. 2003–Nov. 2003	Dec. 1998–Mar. 1999	July 1999–Oct. 1999	Apr. 2003–Nov. 2003	Dec. 1998–Mar. 1999	July 1999–Oct. 1999	Aug. 2003–Nov. 2003	Dec. 1998–Mar. 1999	July 1999–Oct. 1999	Aug. 2003–Nov. 2003
Temperature, water (degrees Celsius)	13.2[b]	22.7[a]	21.3[a]	13.2[b]	22.6[a]	21.3[a]	13.4[b]	22.7[a]	20.9[a]	13.4[b]	22.9[a]	20.9[a]	14.4[b]	22.3[a]	21.6[a]	14.4[b]	22.4[a]	21.7[a]
Specific conductance, field (µS/cm at 25 degrees Celsius)	22.8[a]	22.0[a]	18.4[b]	23.0[a]	22.0[a]	18.9[b]	19.5[b]	24.3[a]	17.8[b]	19.2[b]	25.7[a]	18.0[b]	18.2[b]	24.3[a]	17.0[b]	18.5[b]	25.7[a]	17.8[b]
pH, whole water, field	6.0[ab]	5.9[b]	6.0[a]	6.0[ab]	5.6[b]	6.2[a]	5.6	5.6	5.4	5.5	5.8	5.6	5.3	5.4	5.3	5.4	5.6	5.3
Oxygen, dissolved	8.3[a]	5.7[b]	7.8[a]	8.4[a]	5.9[b]	7.9[a]	8.4[a]	5.1[c]	7.3[b]	9.6[a]	5.6[c]	7.5[b]	8.6[a]	5.7[b]	6.1[b]	8.2[a]	6.0[b]	6.6[b]
Residue on evaporation at 180 degrees Celsius, filtered	29	32	27	28	30	27	24[b]	33[a]	26[ab]	24[b]	36[a]	28a[b]	22[b]	29[a]	23[b]	23[b]	31[a]	22[b]
Alkalinity, field (as $CaCO_3$)	3.3[b]	4.3[ab]	4.9[a]	3.7[b]	4.3[ab]	5.1[a]	2.0[b]	2.7[a]	3.2[a]	2.5[b]	4.0[a]	3.2[a]	2.2[b]	2.7[b]	1.0[a]	2.2[b]	2.5[b]	1.3[a]
Calcium, filtered (as Ca)	.81	.94	.79	.90	.98	.88	.44[ab]	.58[a]	.40[b]	.43[ab]	1.33[a]	.48[b]	.36[b]	.51[a]	.34[b]	.37[b]	.72[a]	.40[b]
Magnesium, filtered (as Mg)	.52	.54	.47	.52	.54	.47	.39	.55	.38	.39	.57	.39	.36[b]	.50[a]	.39[b]	.37[b]	.51[a]	.40[b]
Sodium, filtered (as Na)	2.10[a]	1.80[b]	1.80[b]	2.10[a]	1.80[b]	1.80[b]	2.00[b]	2.30[a]	2.00[b]	2.00[b]	2.40[a]	2.00[b]	1.90[b]	2.30[a]	2.00[b]	1.90[b]	2.30[a]	2.00[b]
Potassium, filtered (as K)	.37[b]	.57[a]	.30[b]	.36[b]	.51[a]	.31[b]	.13[b]	.36[a]	.18[b]	.13[b]	.48[a]	.19[b]	.14[b]	.27[a]	.12[b]	.13[b]	.35[a]	.14[b]
Iron, filtered (as Fe)	205	222	232	206	196	181	109[b]	196[a]	196[a]	109[b]	249[a]	196[a]	86[b]	325[a]	278[a]	90[b]	323[a]	266[a]
Manganese, filtered (as Mn)	37	51	38	38	49	36	25[b]	66[a]	30[b]	26[b]	70[a]	32[b]	51[b]	289[a]	90[b]	53[b]	284[a]	86[b]
Silica, filtered (as SiO_2)	9.4[a]	8.3[b]	9.6[a]	9.6[a]	8.2[b]	9.5[a]	10.2	10.0	10.0	10.1	10.0	10.5	8.9[b]	12.2[a]	12.5[a]	8.9[b]	12.3[a]	12.4[a]
Sulfate, filtered (as SO_4)	1.40[a]	1.10[ab]	.60[b]	1.40[a]	1.00[ab]	.60[b]	1.20[ab]	1.40[a]	.50[b]	1.20[ab]	1.50[a]	.50[b]	1.00[b]	1.60[a]	.30[b]	1.00[ab]	1.50[a]	.30[b]
Chloride, filtered (as Cl)	3.6[a]	3.0[b]	3.0b	3.6[a]	2.9[b]	3.1[b]	3.5	3.8	3.6	3.6	3.8	3.5	3.2[b]	3.8[a]	3.7[a]	3.2[b]	3.8[a]	3.7[a]

Table 8. Average water-quality properties at sites upstream and downstream from hardened low-water crossings on Big Brushy Creek, Tributary to East Fork of Sixmile Creek, Tributary to Birds Creek, Tributary to Big Brushy Creek, and Little Brushy Creek at the Fort Polk Military Reservation, Louisiana, 1998–99 and 2003–04—Continued.

[See fig. 1 for location of site. Before, samples collected before low-water crossing installation; After, samples collected within 1 year after hardened low-water crossing installation; Later, samples collected 5 years after hardened low-water crossing installation. Averages with different superscripts are statistically different (p less than or equal to 0.05). Units are milligrams per liter, unless indicated otherwise. µS/cm, microsiemens per centimeter]

Property or constituent	Tributary to Birds Creek (TBC)				Little Brushy Creek (LB)			
	Upstream		Downstream		Upstream		Downstream	
	Before	After	Before	After	After	Later	After	Later
	May 2003–July 2003	Jan. 2004–June 2004	May 2003–July 2003	Jan. 2004–June 2004	Dec. 1998–Oct. 1999	Sept. 2003–Nov. 2003	Dec. 1998–Oct. 1999	Sept. 2003–Nov. 2003
Temperature, water (degrees Celsius)	20.3[a]	16.2[b]	19.2[a]	18.1[b]	17.4[a]	21.8[a]	17.4[a]	21.8[a]
Specific conductance, field (µS/cm at 25 degrees Celsius)	22.2	19.7	22.7	19.8	18.0[a]	14.5[b]	19.8[a]	14.8[b]
pH, whole water, field	5.8	5.6	6.0	5.6	5.7	5.8	5.7	5.9
Oxygen, dissolved	6.7[b]	8.9[a]	6.6[b]	8.6[a]	8.2	8.8	7.8	8.8
Residue on evaporation at 180 degrees Celsius, filtered	45[a]	20[b]	32[a]	27[b]	21	20	25	19
Alkalinity, field (as $CaCO_3$)	5.3[a]	3.7[b]	5.0[a]	3.8[b]	2.8[b]	3.8[a]	4.7[a]	3.8[a]
Calcium, filtered (as Ca)	.83	.74	.79	.77	.36[b]	.30[b]	.86[a]	.34[b]
Magnesium, filtered (as Mg)	.55	.51	.55	.50	.37	.36	.41	.3[6]
Sodium, filtered (as Na)	2.00	2.00	2.10	1.90	1.90	1.80	1.90	1.80
Potassium, filtered (as K)	.50	.50	.47	.48	.17	.20	1.80	2.00
Iron, filtered (as Fe)	230	251	208	239	126	123	125	109
Manganese, filtered (as Mn)	43	50	40	47	20[a]	11[b]	18[a]	11[b]
Silica, filtered (as SiO_2)	10.3	9.8	10.7	9.8	9.1[a]	9.6[b]	9.2[a]	9.6[b]
Sulfate, filtered (as SO_4)	.57[b]	.98[a]	.57[b]	.94[a]	.70[a]	.38[b]	.67[a]	.37[b]
Chloride, filtered (as Cl)	3.5	3.5	3.6	3.4	3.2	3.1	3.2	3.0

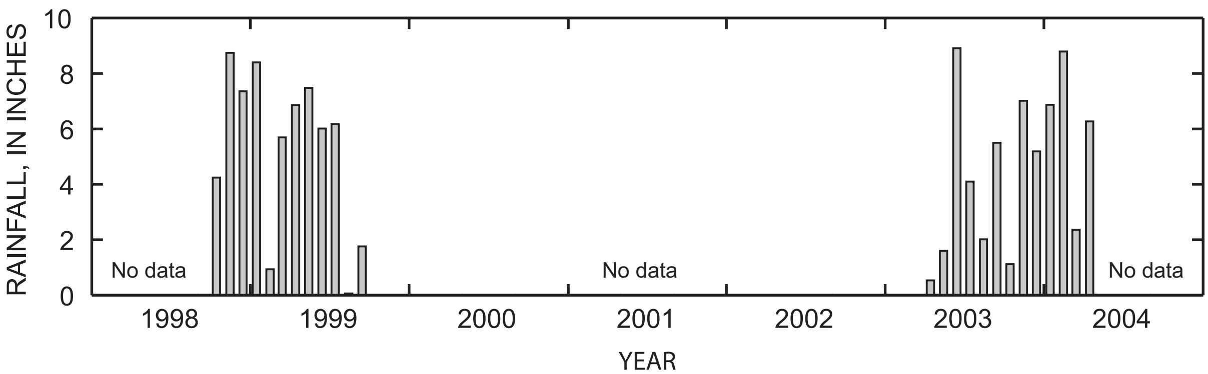

Figure 9. Monthly rainfall at Leesville, Louisiana, during periphyton and water-quality data collection at selected streams at the Fort Polk Military Reservation, Louisiana, October 1998 through September 1999 and April 2003 through April 2004 (Betty Wall, Louisiana Office of State Climatology, written commun., 2004).

It is probable that observed variations in water quality at both upstream and downstream sites are related to differences in rainfall and streamflow during the sample-collection periods rather than an effect of the hardened low-water crossing installations or modifications, but additional study is needed.

Summary

In 2003, the U.S. Geological Survey (USGS), at the request of the U.S. Army Joint Readiness Training Center and Fort Polk, began a follow-up study to determine whether installation and modification of hardened low-water crossings had short-term (less than 1 year) or long-term (greater than 1 year) effects on periphyton or water quality in five streams at the Fort Polk Military Reservation, Louisiana. Periphyton data were statistically analyzed for possible differences between samples collected at upstream and downstream sites and before and after low-water crossings were modified on three streams, Big Brushy Creek (BB), Tributary to East Fork of Sixmile Creek (TEF), and Tributary to Birds Creek (TBC), during 2003–04. Periphyton data also were analyzed for possible differences between samples collected at upstream and downstream sites on two streams, Tributary to Big Brushy Creek (TBB) and Little Brushy Creek (LB), during 1998–1999 and 2003. Water-quality data collected from upstream and downstream sites on all five streams during 2003–04 were analyzed for possible differences caused by the hardened crossings. Water-quality data collected from two streams, BB and TEF, were analyzed for possible differences between samples collected at upstream and downstream sites, and differences between samples collected before and after the low-water crossings were installed in 1999 and later, in 2003.

A total of 362 periphyton taxa were identified from 312 samples analyzed. Diatoms (Chrysophyta) were the most diverse group of algae, with 144 taxa identified. Green algae (Chlorophyta) ranked second, with 136 taxa. Blue-green algae (Cyanophyta) ranked third with 62 taxa. The remaining 20 taxa identified were distributed amongst four other plant groups, including red algae (Rhodophyta), filamentous bacteria, and other golden brown algae (within three Classes of the Division, Chrysophyta). Diatom taxa outnumbered the other major divisions by at least 2.5 times in 90 percent of the samples. Green algae taxa outnumbered diatoms in less than 5 percent of the samples.

Percent frequency of occurrence and cell density across all samples varied similarly and 17 taxa occurred in more than 40 percent of the samples. Diatoms were the most frequently occurring algae, and filamentous green algae and colonial blue-green forms were numerically dominant when they occurred. The colonial blue-green alga, *Microcystis incerta,* was present in 60.2 percent of the samples, and the filamentous green alga, *Oedogonium* spp., was present in 43.3 percent of the samples. The average cell densities of blue-green algae and green algae tended to fluctuate from month-to-month, while the diatoms occurred more consistently at most sites during the study.

Variations in periphyton communities in samples collected before and after the low-water crossings were modified during 2003 could not be conclusively attributed to the modifications. Data analysis indicated no significant seasonal variation, a dominant factor in a previous study, probably because no periphyton samples were collected during winter months. In addition, there was no significant difference in percent frequency of occurrence or cell density of taxa between substrates (slides and wood cores).

Comparison of percent frequency of occurrence and average cell density of the 10 most frequently occurring taxa showed that four diatom taxa, *Eunotia binularis*, *Eunotia flexuosa*, *Frustulia rhomboides*, and *Eunotia exigua*, indicated significant interaction between upstream and downstream sites, and before and after crossing modifications at BB, TEF,

and TBC. Because of these interactions, it was not possible to conclude that the hardened low-water crossing modifications caused the differences in those taxa. Periphyton data collected from TBB and LB during 1998–99 and 2003 also were analyzed to determine whether long-term changes may have occurred after the installation of the hardened low-water crossings during 1998–99.

Most of the significant changes in percent frequency of occurrence and average cell density of the 10 most frequently occurring periphyton taxa were increases at downstream sites after the hardened low-water crossing installations or modifications. However, these changes in the periphyton community are not necessarily deleterious to the community structure.

Water-quality data collected from upstream and downstream sites on the five streams during 2003–04 were analyzed for possible differences caused by the hardened crossings. Water-quality data collected from two streams, BB and TEF, were analyzed for possible differences between samples collected at upstream and downstream sites and differences between samples collected before and after the low-water crossings were installed in 1999 and later, in 2003.

The streams are acidic and poorly buffered, and pH ranged from 5.0 to 6.8 standard units. Field measurements of alkalinity ranged from 0.1 to 6.7 mg/L, and field measurements of specific conductance ranged from 13 to 36 μS/cm. Nutrient concentrations were small. Dissolved ammonia (as nitrogen) ranged from less than 0.002 to 0.056 mg/L, and many results were below detection limits. Dissolved ammonia plus organic nitrogen (as nitrogen) ranged from less than 0.1 to 0.4 mg/L. Dissolved nitrite plus nitrate (as nitrogen) ranged from less than 0.002 to 0.079 mg/L, and many results, especially from samples collected during 1999, were below detection limits. Dissolved phosphorus (as P) ranged from less than 0.002 to 0.009 mg/L, and most results were below detection limits. Calcium, magnesium, and sodium concentrations were small. Calcium ranged from 0.28 to 2.06 mg/L, magnesium ranged from 0.31 to 0.94 mg/L, and sodium ranged from 1.5 to 3.0 mg/L. Silica concentrations were large relative to other constituents measured and ranged from 7.3 to 13 mg/L. All analyzed water-quality properties and constituents were typical of small streams in this area.

Water-quality changes that may have resulted from original installation of the low-water crossings on BB, TEF, TBB, and LB, generally disappeared over time. Increased calcium concentrations at the downstream site on TEF after the low-water crossing installation in 1999 may have resulted from the use of dolomitic limestone. However, calcium concentrations at the downstream site on TEF were consistent with those at the upstream site by the time the limestone was replaced at the crossing in 2003, indicating that dissolution of the limestone probably had already slowed down or stopped.

Water-quality data also were analyzed for significant differences between upstream and downstream sites before and after the installation of the hardened low-water crossings during 1998–99, and later, during 2003–04. Generally, average water-quality values and concentrations were similar at upstream and downstream sites. When average water-quality values or concentrations changed significantly, they almost always changed significantly at both the upstream and downstream sites. It is probable that observed variations in water quality at both upstream and downstream sites are related to differences in rainfall and stream flow during the sample-collection periods rather than an effect of the hardened low-water crossing installations or modifications, but additional study is needed.

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