Water Quality, Fish Tissue, and Bed Sediment Monitoring in Waterbodies of Fort Chaffee Maneuver Training Center, Arkansas, 2002-2004

Prepared in cooperation with the
ARKANSAS ARMY NATIONAL GUARD

Scientific Investigations Report 2004-5273

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

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Front cover:
A- Vache Grasse Creek near Lavaca, Arkansas
B - Big Creek at Potato Hill Road (near Charleston), Fort Chaffee, Arkansas
C - U.S. Geological Survey employee servicing a water-quality monitor at Vache Grasse Creek near Lavaca, Arkansas

All photographs by David A. Freiwald, U.S. Geological Survey.

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Contents

Figures

Tables

Water Quality, Fish Tissue, and Bed Sediment Monitoring in Waterbodies of Fort Chaffee Maneuver Training Center, Arkansas, 2002-2004

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Abstract

The Fort Chaffee Maneuver Training Center is a facility used to train as many as 50,000 Arkansas National Guardsmen each year. Due to the nature of ongoing training and also to a poor understanding of environmental procedures that were practiced in the World War II era, areas within Fort Chaffee have the potential to be sources of a large number of contaminants. Because some streams flow on to Fort Chaffee, there is also the potential for sources that are off post to affect environmental conditions on post. This study evaluates constituent concentrations in water, fish tissue, and bed sediment collected from waterbodies on Fort Chaffee between September 2002 and July 2004. Constituent concentrations detected in the three media and measured at nine stream sites and four lake sites were compared to national and regional criteria when available. Two of the larger streams, Big and Vache Grasse Creeks, were sampled at multiple sites. All three sampled media were analyzed for insecticides, PCBs, explosives, and trace elements. Additionally, water samples were analyzed for nutrients and herbicides.

The different constituents detected in the three sample media (water, fish tissue, and bed sediment) indicate that land-use activities both on and off post are influencing environmental conditions. Contaminants such as explosives that were sometimes detected in water samples have an obvious relation to military training; however, the occurrence and locations of some nutrients, insecticides, and trace elements suggest that land use both on and off post also could be influencing environmental conditions to some degree.

Constituent concentrations at sites on Vache Grasse Creek, and particularly the most upstream site, which was located immediately downstream from an off-post wastewater-treatment facility, indicate that environmental conditions were being influenced by an off-post source. The most upstream site on Vache Grasse Creek had both the highest number of detections and the highest concentrations detected of all sites sampled. Event-mean storm concentrations and storm loads calculated from storm-flow samples at two sites each for Big and Vache Grasse Creeks indicate that storm loads were highest at the two Vache Grasse Creek sites for 24 of the 25 constituents detected. Further evaluation by normalizing storm loads at Big Creek to storm loads at Vache Grasse Creek by stream flow indicate that event loads at Vache Grasse Creek were about two or more times higher than those on Big Creek for 15 of the 25 constituents measured. Low concentrations of arsenic and lead were detected in water samples, but all detections for the two trace elements occurred in samples collected at the upstream site on Vache Grasse Creek. The nickel concentration in fish livers collected from the upstream site on Vache Grasse Creek was 45 percent higher than the median of a national study of 145 sites. Mercury concentrations in edible fish tissue, which are a widespread concern in the United States, exceeded an USEPA criterion for methylmercury of 300 µg/kg in four of nine samples; however, concentrations are typical of mercury concentrations in fish tissues for the State of Arkansas.

Constituent concentrations at some sites indicate that environmental conditions are being influenced by on-post activities. Of the 55 (excluding total organic carbon) organic constituents analyzed in water samples, only 10 were detected above the minimum detection limit but four of those were explosives. Bed-sediment samples from one site located on Grayson Creek, and nearest the administrative and residential (cantonment) area, had detections for arsenic, copper, lead, manganese, nickel, and zinc that were above background concentrations, and concentrations for arsenic and nickel at this site exceeded lowest effect level criteria established by the U.S. Environmental Protection Agency. The site on Grayson Creek also had the only detections of DDT metabolites in bed sediment.

Concentrations of some trace elements in all media sampled for this study could also have a relation to on-post activities or conditions. Some trace elements detected may result from the combined effects of sedimentation (a possible consequence of soil erosion resulting from training activities and an extensive road system) and trace element concentrations in soils in western Arkansas. Regarding sedimentation (and soil erosion), turbidity data collected at the most downstream site on Vache Grasse Creek, and observations of substantial sediment deposition in both Vache Grasse and Big Creeks indicate that turbidity and associated sedimentation is a chronic problem that is impairing the ecological integrity of Fort Chaffee streams. Trace element concentrations at some sites may be related to this chronic sedimentation and the associated redox potential of the aquatic environments sampled.

Introduction

The Fort Chaffee Maneuver Training Center (Fort Chaffee), a facility for the Arkansas Army National Guard (ANG) since 1997, covers approximately 65,000 acres and is located in western Arkansas just east of the city of Fort Smith (fig. 1) in the Arkansas River Valley and Ouachita Mountains physiographic provinces (Fenneman, 1938). A rich military history is associated with Fort Chaffee. Fort Chaffee was established in 1941 under a Department of Army directive during World War II (WWII) and served as a training and housing facility for several U.S. Army armored and infantry divisions. From 1943 to 1946, the facility was used to house about 3,000 German prisoners of war. Because many of the buildings constructed in the 1940's are still standing, Fort Chaffee also has served as the setting for two movies set in the WWII era. On two occasions, once in the 1970's and once in the 1980's, Fort Chaffee was used as a refugee camp. More recently, Fort Chaffee has served as a test site for the Joint Readiness Training Center and as a location for the U.S. Army Training and Doctrine Command. In addition to being used for training, much of Fort Chaffee is important to area sportsmen. The Fort Chaffee Wildlife Management Area offers hunting and fishing opportunities in western Arkansas (U.S. Department of Defense, 2000).

As many as 50,000 soldiers may undergo training at Fort Chaffee annually, and a large part of Fort Chaffee is used for some aspect of military training (U.S. Department of Defense, 2000). Training activities include small arms firing (ranges), artillery ordnance, and equipment and personnel maneuvers. Because of the nature of ongoing training (lead and other metals contained in ammunition lodged in the landscape, explosive and phosphorus compounds associated with some ordnances, disruption of the landscape by exploding ordnances, associated pesticide use, and sedimentation from an extensive road system) and a poor understanding of environmental procedures during the WWII era, areas within Fort Chaffee have the potential to be sources of a large number of contaminants. Another concern is that because some streams flow on to Fort Chaffee, there is also the potential for sources that are off post to affect environmental conditions on post. To address these concerns, the U.S. Geological Survey (USGS), in cooperation with the ANG, conducted a study to document concentrations from September 2002 to July 2004 for various chemical compounds in three media collected from waterbodies on Fort Chaffee—water, fish tissue, and bed sediment. This information is necessary before contaminant sources can be identified and managed in a manner that will minimize risk of future contamination and exposure.

Purpose and Scope

The purpose of this report is to provide data from September 2002 to July 2004 for contaminants in the water, fish tissue, and bed sediment of Fort Chaffee's streams and lakes. The three sampled media were analyzed for insecticides, polychlorinated binphenyls (PCBs), explosives, and trace elements. Additionally, water samples were analyzed for field parameters (water temperature, dissolved oxygen, specific conductance, and pH), total dissolved and suspended solids, fecal coliform bacteria, total organic carbon, nutrients, and herbicides, and bed sediments were analyzed for total organic carbon. Constituent concentrations detected in the three media and measured at the nine stream sites and four lake sites were compared to national and regional criteria, which can be used as a reference for the extent of contamination. One stream site was continuously monitored for three water-quality parameters—specific conductance, turbidity, and temperature. These continuous data were evaluated for relations to changes in streamflow conditions using stage as a surrogate for streamflow.

Description of Study Area

The area contained within Fort Chaffee is intermixed forest and grasslands (fig. 1). The ANG has implemented an extensive burning program in some areas where training is most intense (such as the training/ordnance-impact area) to control vegetation that can fuel wildfires started with ordnance explosions (Sabrina Kirkpatrick, Arkansas National Guard Natural and Cultural Resource Manager, oral commun., January 2004). As a result, much of Fort Chaffee is open grassland with sparse forest intermixed. Conversely, because livestock grazing is no longer a part of the land use, some areas that were once pasture and are not periodically burned are now in different stages of forest succession. Coalbeds have been documented in the Vache Grasse Creek drainage (Lamb, 1978), much of which is contained within Fort Chaffee, and mining scars in forested areas adjacent to the stream indicate that coal may have been mined there at one time.

Soils found in Fort Chaffee are the weathered remnants of the Hartshorn and McAlester Formations (Haley and others, 1993), which are composed generally of clay, siltstone, and well indurated sandstone. In addition to bridges, an extensive road system also consists of low-water crossings for tanks and other artillery vehicles. Road use and maintenance, and a soil dominated by clay, results in a high potential for soil erosion and subsequent stream sediment deposition.

Acknowledgments

Thanks are extended to Amanda Riggs and Sabrina Kirkpatrick, Fort Chaffee Environmental Branch, who assisted the authors with locating sampling sites and with field sampling. Appreciation also is extended to U.S. Geological Survey (USGS) personnel Chris O'Dell, Bill Baldwin, and Brian Clark for assistance during round-the-clock sampling events.

Methods

Chemical constituent data for this study were collected from September 2002 through July 2004. Water samples were collected at 13 sites—9 stream sites and 4 lake sites —and bed sediment samples were collected at 8 streams sites and 4 lake sites (table 1; fig. 1). Two of the larger streams, Big and Vache Grasse Creeks, were sampled at multiple sites.

Fish tissue samples were collected at nine sites—the five stream sites with the largest drainage areas and the four lake sites. Field parameters (dissolved oxygen, pH, specific conductance, and water temperature) were measured on every sampling occasion (appendixes 1 and 2). One stream site was continuously monitored for three water-quality parameters—specific conductance, turbidity, and temperature—from November 2003 through July 2004. Continuous monitoring equipment was calibrated according to USGS protocols (Wagner and others, 2000).

All chemical analyses were performed by Severn Trent Laboratories (STL) in Arvada, Colorado, using laboratory methods and quality assurance/quality control (QA/QC) procedures approved by the U.S. Environmental Protection Agency (USEPA) (U.S. Environmental Protection Agency, 1983; 1986a; 1986b). Laboratory QA/QC that are associated with USEPA methods include duplicate analysis, matrix spikes, method blanks, and surrogate analyses. For all three media, constituent concentrations that were between the minimum detection limit (MDL, the minimum concentration of a substance that can be measured and reported with 99 percent confidence that the concentration is greater than zero) and the reporting limit (RL, a value higher than the MDL and also the lowest level at which measurements become quantitatively meaningful) were estimated by the analytical laboratory and were reported as estimated values. Fecal coliform bacteria were identified and enumerated in the field by USGS following USGS procedures (Wilde and Ratke, 1998).

Table 1. Sampling site information for sites at Fort Chaffee, Arkansas, 2002 through 2004.

[FF, fish fillet; FL, fish liver; S, bed sediment; W, water]

Site name	Abbreviated name and site identifier (fig. 1)	Station identification number	Latitude[1]	Longitude[1]	Sample media
Big Creek tributary at Burnville Road	Big Creek Site 1 (BC1)	07250673	35° 11’37"	94° 09’42"	S, W
Big Creek at Potato Hill Road	Big Creek Site 2 (BC2)	07250686	35° 15’40"	94° 06’29"	FF, FL, S, W
Big Creek tributary at range 87 bypass	Big Creek Site 3 (BC3)	07250688	35° 15’53"	94° 06’17"	S, W
Big Creek at Bloomer	Big Creek Site 4 (BC4)	07250700	35° 17’34"	94° 07’58"	FF, FL, S, W
Christmas Knob Lake	Christmas Knob Lake (CKL)	07250697	35° 17’18"	94° 09’40"	FF, FL, S, W
Darby Lake	Darby Lake (DL)	07253520	35° 15’51"	94° 01’45"	FF, FL, S, W
Engineer Lake	Engineer Lake (EL)	07250690	35° 16’45"	94° 06’59"	FF, FL, S, W
Gin Creek near Washburn	Gin Creek (GinC)	07258320	35° 10’26"	94° 04’23"	S, W
Grayson Creek south of Highway 22	Grayson Creek (GRC)	07250573	35° 18’56"	94° 16’36"	S, W
Mendenhall Swamp Lake	Mendenhall Swamp Lake (MSL)	07250597	35° 17’43"	94° 15’10"	FF, FL, S, W
Vache Grasse Creek near Greenwood	Vache Grasse Creek Site 0 (VG0)	07250593	35° 14’11"	94° 14’03"	FF, FL, W
Vache Grasse Creek near Howard Hill	Vache Grasse Creek Site 1 (VG1)	07250595	35° 15’75"	94° 17’54"	FF, FL, S, W
Vache Grasse Creek near Lavaca	Vache Grasse Creek Site 2 (VG2)	07250600	35° 19’03"	94° 12’56"	FF, FL, S, W

[1]Latitude and longitude were obtained using North American Datum of 1927 (NAD 27).

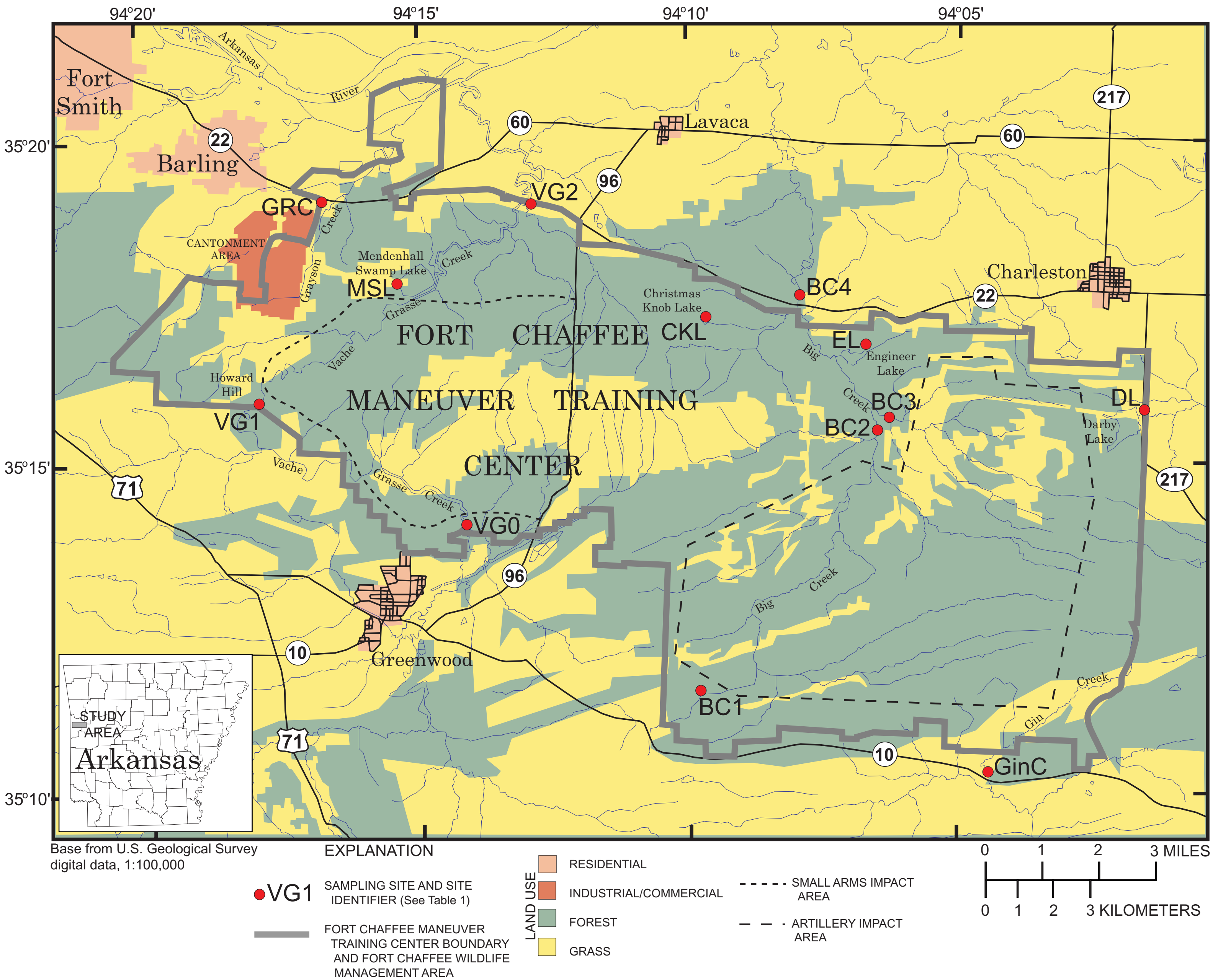

Figure 1. Fort Chaffee boundaries and training ordnance-impact area and sampling sites.

Quality Assurance/Quality Control

Several steps were completed to ensure quality assurance of samples and the analyses. All sampling equipment was constructed of Teflon or Teflon-coated materials and was cleaned prior to sampling. The cleaning procedure for sampling equipment was as follows. All equipment first was rinsed with tap water. Sampling equipment used to collect samples for analysis of trace elements then was rinsed with a weak acid followed with a rinse of deionized water. Following the tap water rinse, sampling equipment used to collect samples for analysis of organic compounds was rinsed with methanol, followed by a rinse of deionized water.

Once samples were collected, chain of custody and pertinent sample information forms were completed and copies were sent with all samples to the analytical laboratory. Three quality assurance/quality control (QA/QC) samples were collected. Duplicate samples were sent to the laboratory for one lake water-quality sample, one stream water-quality sample, and one bed-sediment sample for trace elements. Data for QA/QC samples are included with results for all other sample analyses.

Water Quality

Water-quality sampling methods varied depending on the type of waterbody being sampled and the flow condition during the sampling event. Stream sites that had a mean water velocity less than 1.5 feet per second (ft/s) were sampled using the grab method (Wilde and others, 1999). Grab samples were collected in the appropriate sample container just beneath the water surface; or if the sample required filtering, water was pumped directly from the stream through a filter and into a sample container. At streams where mean water velocity exceeded 1.5 ft/s, water samples were collected throughout the water column using the equal-width increment (EWI) method and composited (combined from several points in a stream cross section or from different lake sampling points) (Wilde and others, 1999). Composite samples from wadeable streams were collected using a depth-integrated sampler attached to a wading rod by the EWI method. When not wadeable, streams were sampled using the EWI method by lowering depth-integrating samplers into the stream from road bridges with a truck boom.

Lakes were sampled using protocols described by Wilde and others (1999). Water samples were collected from a boat by lowering a cylindrical bailer (a Teflon coated plastic tube (5.2 cm $\times$ 0.9 m) with check valves at each end and having a capacity of about 1 liter, into the water column. Two liters of water collected at seven sampling points were composited for each lake sample. Where lake depth exceeded 1.8 m, 1 liter was collected at two depths (near 0.2 and 0.8 of total depth). Where the lake depth was less than 1.8 m, 2 liters were collected near mid depth.

Composite samples were processed in a different manner than grab samples. For the composite samples each subsample collected was composited into a 14-liter Teflon churn splitter. After all subsamples were collected, the sample was mixed thoroughly by churning to keep sediment suspended during processing of raw (unfiltered) samples. Sample containers for the unfiltered samples then were filled from a spigot, and sample containers for organic and dissolved constituents were filled with water pumped from the churn and through a filter. All composite samples were processed (split and filtered) in a mobile laboratory in the field.

Standard shipping procedures were followed once samples were processed. Water samples were placed on ice and shipped to the analytical laboratory within 12 hours of sampling. Standard quality assurance and quality control procedures were completed for each shipment.

Water-quality samples were collected during three flow conditions—base flow, stormflow, and event flow—to determine the relation between surface-water discharge and constituent concentrations. For this study, stormflow samples are distinguished from event-flow samples by the time lapse between the rain event and when sampling occurred. Event-flow samples were collected throughout the rise, peak, and fall of the hydrograph, while stormflow samples generally were collected several hours after the storm and subsequent to peak stormflow. All water samples were analyzed for the same constituents using the same analytical methods (table 2). One base-flow and stormflow sample were collected at all nine stream sites and all four lake sites.

Sampling procedures for event-flow sampling differed from sampling procedures for base-flow and stormflow sampling in other aspects. For the event-flow sampling effort, two sites each were sampled on Vache Grasse and Big Creeks (fig. 1). For both streams, event-flow sampling sites were established where the streams flowed on and off of Fort Chaffee. All event-flow samples were collected during the same storm event. EWI water-quality samples were collected during the rise, peak, and fall of the storm-event hydrograph (for a total of three samples), at a frequency based on changes in stage (volume). Stream discharge was measured concurrent to water-quality sampling to compute total storm-discharge volume. Flow-weighted aliquots of water-quality samples collected during the rise, peak, and fall were divided volumetrically and were composited to make one analytical sample.

Composite sample results were used as an event-mean concentration (EMC) to compute the loads for the storm event. The estimated storm load for each constituent detected above the MDL was computed using the equation:

$$LOAD = EMC \times AFV \times CF$$

Where *LOAD* is constituent load (in pounds) for the sampled storm,
EMC is event-mean concentration (in milligrams per liter) for the sampled storm,
AFV is accumulated flow volume (in cubic feet per second) for the sampled storm, and
CF is conversion factor (6.2382×10^{-5} if constituent concentration is reported in milligrams per liter or 6.2382×10^{-8} if constituent concentration is reported in micrograms per liter).

Table 2. Constituents analyzed in water samples collected at Fort Chaffee, Arkansas, 2002 through 2004.

[DDD, dichlorodiphenyldichloroethane; DDE, dichlorodiphenyldichloroethylene; DDT, dichlorodiphenyltrichloroethane; BHC; Benzene hexachloride; PETN, Pentaerythritoltetranitrate; HMX, Cyclotetramethylene tetranitramine; RDX, Cyclotrimethylene trinitramine; 2,4-D, 2,4 Dichlorophenoxy acetic acid; 2,4-DB, 2,4-Dichlorophenoxybutyric acid; MCPA, 4-chloro-2-methylphenoxy acetic acid; MCPP, 2-methyl-4-chlorophenoxy propionic acid; 2,4,5-T , 2,4,5-Trichlorophenoxyacetic acid; 2,4,5-TP, 2,4,5-Trichlorophenoxypropionic acid; PCBs, polychlorinated biphenyls; HEM, hexane extractable material]

Biologic	**Explosives**	**Other organic analytes**
Fecal coliform indicator bacteria	4-Nitrotoluene	Total Organic Carbon
	PETN	HEM (Oil and Grease)
Field parameters	4-Amino-2,6-dinitrotoluene	
Dissolved oxygen	3-Nitrotoluene	**Nutrients**
pH	2-Nitrotoluene	Ammonia as nitrogen
Specific conductance	2-Amino-4,6-dinitrotoluene	Ammonia plus organic nitrogen as nitrogen
Water temperature	2,6-Dinitrotoluene	Nitrate plus nitrite as nitrogen
Turbidity	2,4-Dinitrotoluene	Nitrite as nitrogen
	HMX	Orthophosphate as phosphorus
Organochlorine insecticides	Nitrobenzene	Total phosphorus as phosphorus
4,4’-DDD	1,3,5-Trinitrobenzene	
4,4’-DDE	Nitroglycerin	**Physical**
4,4’-DDT	RDX	Total dissolved solids
Aldrin	2,4,6-Trinitrotoluene	Total suspended solids
alpha-BHC	1,3-Dinitrobenzene	
alpha-Chlordane	Tetryl	**Trace elements**
beta-BHC		Antimony
Chlordane (technical)	**Herbicides**	Arsenic
delta-BHC	Dinoseb	Barium
Dieldrin	2,4-DB	Beryllium
Endosulfan I	2,4-D	Cadmium
Endosulfan II	Dalapon	Chromium
Endosulfan sulfate	Dicamba	Cobalt
Endrin	Dichlorprop	Copper
Endrin aldehyde	MCPA	Lead
Endrin ketone	MCPP	Manganese
gamma-BHC (Lindane)	2,4,5-T	Mercury
gamma-Chlordane	2,4,5-TP (Silvex)	Molybdenum
Heptachlor		Nickel
Heptachlor epoxide	**PCBs**	Selenium
Methoxychlor	Aroclor 1242	Silver
Toxaphene	Aroclor 1016	Thallium
	Aroclor 1232	Zinc
	Aroclor 1248	
	Aroclor 1254	
	Aroclor 1260	
	Aroclor 1221	

As a further comparison of constituent loads in Big and Vache Grasse Creeks, event loads at a site on Big Creek were normalized by flow to the most upstream site on Vache Grasse Creek. This was done by dividing the flow during the sampled event at the site on Vache Grasse by the flow during the sampled event on Big Creek and then multiplying the quotient by the event load at the same Big Creek site. Streamflow was calculated during the sampling event by direct measurement or using a stage-discharge relation curve (Rantz and others, 1982).

Fish Tissue

Fish tissue was collected and processed in the field according to protocols established by the USGS National Water-Quality Assessment Program (NAWQA) (Crawford and Luoma, 1993). Fish sampling was conducted on four lakes in September 2002 and at five stream sites in October 2002. Fish tissue was not sampled from Big Creek at sites 1 (BC1) and 3 (BC3) and from Gin and Grayson Creeks (fig. 1) because the streams were too small at the sampling sites to collect fish samples that were comparable (for size and species) to fish samples collected at other sites.

To reduce variability in the constituent dataset, individual fish targeted for tissue samples were of comparable size and of the same species. Composite samples of six largemouth or spotted bass or a combination of these two black bass species were targeted. Black bass were collected at seven of the nine sites, and at the two sites where black bass were not collected, golden redhorse were sampled at Big Creek Site 2 (BC2) and black crappie were sampled at Mendehall Swamp Lake (MSL).

Processing of fish samples involved euthanizing each fish, collecting information pertaining to fish size, removing the appropriate fish tissue (sample), and preparing the sample for shipment to the analytical laboratory. The length and weight of each fish composited in a sample were recorded (table 3). Two types of tissue—fillet and liver—were removed and composited for separate analyses. Many contaminants are more concentrated in internal organs than fillets (Stober, 1991), and fillet samples were processed before liver samples to avoid contaminating the fillet. Fillets were collected by removing the left side of each fish on a plastic cutting board. Once the left side fillet had been removed from all fish collected for the composite sample, an incision was made through the stomach lining of each fish and the liver was removed. Both fillet and liver samples were stored in labeled glass jars and were immediately placed on dry ice. Fish tissue samples were shipped overnight to the laboratory.

Fish tissue samples were analyzed for numerous constituents (pesticides) that were historically associated with Fort Chaffee or other military bases (table 4). Liver samples were analyzed for trace elements to facilitate comparison to a large number of samples collected across the Nation by NAWQA. Fillet samples were analyzed for organic compounds and trace elements to indicate the risk associated with human consumption.

Table 3. Characteristics of fish collected for tissue (fillet and liver) analysis at Fort Chaffee, Arkansas, 2002.

[--, weight not taken because of scale malfunction]

Site	Fish species	Number of individuals	Mean total length (millimeters)	Mean weight (grams)
Big Creek Site 2	Golden redhorse (*Moxostoma erythrurum*)	4	258	223
Big Creek Site 4	Largemouth/Spotted bass (*Micropterus* spp.)	5	274	249
Christmas Knob Lake	Largemouth bass (*Micropterus salmoides*)	6	258	272
Darby Lake	Largemouth bass (*Micropterus salmoides*)	6	283	266
Engineer Lake	Largemouth bass (*Micropterus salmoides*)	6	295	300
Mendenhall Swamp Lake	Black crappie (*Pomoxis nigromaculatus*)	6	243	260
Vache Grasse Creek Site 0	Largemouth/Spotted bass (*Micropterus* spp.)	5	258	--
Vache Grasse Creek Site 1	Largemouth/Spotted bass (*Micropterus* spp.)	6	260	247
Vache Grasse Creek Site 2	Largemouth/Spotted bass (*Micropterus* spp.)	5	304	384

Table 4. Constituents analyzed in bed sediment and fish tissue samples collected from lakes and streams at Fort Chaffee, Arkansas, 2002.

[PCBs, polychlorinated biphenyls; DDD, dichlorodiphenyldichloroethane; DDE, dichlorodiphenyldichloroethylene; DDT, dichlorodiphenyltrichloroethane; alpha-BHC, alpha-Hexachlorocyclohexane; delta-BHC; Benzene hexachloride; HMX, Cyclotetramethylene tetranitramine; PETN, Pentaerythritoltetranitrate; RDX, Cyclotrimethylene trinitramine]

Organic Compounds				
Explosives	Insecticides and metabolites	PCBs	Trace elements[1]	Other[2]
1,3,5-Trinitrobenzene	4,4'-DDD	Aroclor 1016	Antimony	Total organic carbon
1,3-Dinitrobenzene	4,4'-DDE	Aroclor 1221	Arsenic	
2,4,6-Trinitrotoluene	4,4'-DDT	Aroclor 1232	Beryllium	
2,4-Dinitrotoluene	Aldrin	Aroclor 1248	Cadmium	
2,6-Dinitrotoluene	alpha-BHC	Aroclor 1254	Chromium	
2-Amino-4,6-dinitrotoluene	alpha-Chlordane	Aroclor 1260	Copper	
2-Nitrotoluene	beta-BHC		Lead	
3-Nitrotoluene	Chlordane (technical)		Mercury	
4-Amino-2,6-dinitrotoluene	delta-BHC		Nickel	
4-Nitrotoluene	Dieldrin		Selenium	
HMX	Endosulfan I		Silver	
PETN	Endosulfan II		Thallium	
Nitrobenzene	Endosulfan sulfate		Zinc	
Nitroglycerin	Endrin			
RDX	Endrin aldehyde			
Tetryl	Endrin ketone			
	gamma-BHC (Lindane)			
	gamma-Chlordane			
	Heptachlor			
	Heptachlor epoxide			
	Methoxychlor			
	Toxaphene			

[1]Fish liver samples were analyzed only for trace elements.
[2]Analyzed only in sediment samples.

Bed Sediment

Fine-grain sediments in depositional areas naturally accumulate trace element and hydrophobic organic compounds (Shelton and Capel, 1994). To determine concentrations of these chemicals on Fort Chaffee, bed sediment was sampled at eight stream sites and four lake sites in late September 2002. Bed sediments were collected from multiple depositional areas in the sampling reaches using methods described in Shelton and Capel (1994). Wadeable streams were sampled using a teflon spoon or spatula to collect bed sediment, and bed sediments from nonwadeable streams and lakes were sampled using a grab sampler (petite Ponar) lowered from a boat. Regardless of the sampling method, bed sediment was collected from no more than 2 inches below the water/sediment interface. Composite sediment samples were mixed and then split into three sample components for analysis—trace elements, organic compounds, and total organic carbon (table 4).

Continuous Monitoring

USGS established a monitoring station in late 2003 at Vache Grasse Creek at Highway 22 (Site 2) where the stream flows off of Fort Chaffee. USGS continuously monitored stream stage, water quality, and precipitation at this site (data are available in USGS National Water Information System at http://water.usgs.gov/nwis.station number 07250600). The streamflow gage records stream stage, which can then be related to measured discharge to establish a rating curve that can be used to estimate discharge at various stream stages (Rantz and others, 1982). Knowing discharge, or the volume of water that flows past a gaging station in a given time, can be beneficial because these data facilitate the computation of constituent loads for a given time.

The primary purpose for continuously monitoring water quality at this site was to investigate long-term relations between turbidity and stream stage (stream stage is a surrogate for discharge; increasing stage generally indicates increasing discharge). However, because specific conductance can be indicative of the presence of contaminants, monitoring this parameter also could be beneficial to ANG. Continuous water-quality monitoring equipment was calibrated according to USGS protocols (Wagner and others, 2000).

Constituents Detected in Water, Fish Tissue, and Bed Sediment

Water Quality

Of the 55 organic compounds analyzed in 36 water samples, only 10 compounds had concentrations above the MDL and none were above the RL on any occasion (table 5). Four explosive constituents were detected, resulting in explosives being the most frequently detected of the four types of organic compounds (explosives, herbicides, oil and grease, and organochlorine insecticides and metabolites). Although there was only one oil and grease constituent (hexane extractable material or HEM), it was detected the most frequently of all organic constituents (in 32 of 36 samples), but never above the RL.

Water samples were analyzed for 17 trace elements, but only 7 trace elements—arsenic, barium, copper, lead, manganese, nickel, and zinc—were detected at concentrations higher than the RL (table 6). Five of those seven trace elements—arsenic, copper, lead, nickel, and zinc—are considered to be priority pollutants and aquatic life criteria have been established (U.S. Environmental Protection Agency, 2002; table 6). None of the five priority pollutants were detected above the aquatic life criteria. All detections above the RL for arsenic and lead occurred in stormflow and event flow samples at Vache Grasse Creek Site 0, the upstream site on Vache Grasse Creek, which is located immediately downstream from an off-post wastewater-treatment facility. Five of the seven detections for both nickel and zinc above the RL also were from sites located on Vache Grasse Creek. Detections above the RL for copper were more common in the Big Creek drainage than in the Vache Grasse Creek drainage (six of seven detections). The estimated concentration of cadmium (above MDL but below RL) in a stormflow sample from Big Creek Site 2 was above the aquatic life criterion (table 6).

Manganese and barium are not considered to be priority pollutants by the USEPA but were detected above the RL for every water sample collected. USEPA is in the process of developing new aquatic life criteria for manganese (U.S. Environmental Protection Agency, 2004) but earlier USEPA publications suggest that manganese can be toxic to some freshwater aquatic life at 1,500 μg/L (U.S. Environmental Protection Agency, 1979). The manganese concentration in one sample at Mendenhall Swamp Lake had a concentration of 2,000 μg/L, and manganese concentrations were higher in lake samples than in stream samples. Drinking water regulations proposed by the USEPA recommend a concentration of 200 μg/L be used as a drinking water standard for manganese (U.S. Environmental Protection Agency, 1993), and the United Nations Food and Agricultural Organization also uses 200 μg/L as a recommended maximum concentration in irrigation water (Pais and Jones, 1997). Nine of 36 water samples exceeded 200 μg/L. A previous USGS study (Lamb, 1978), conducted in the headwaters of Vache Grasse Creek, also noted that concentrations of manganese were relatively high (greater than 1,000 μg/L). One possible explanation for elevated manganese concentrations is that background concentrations seem to be higher in western Arkansas than for most other regions (Gustavsson and others, 2001). Another possible explanation for elevated manganese concentrations, particularly for stream samples, is related to the redox potential of the aquatic environments sampled. Accumulated bed sediments and organic material in the bottom substrate may result in a high biochemical oxygen demand and a reducing environment for several of the waterbodies sampled,

Table 5. Concentrations of organic compounds detected in water samples collected at Fort Chaffee, Arkansas, 2002 through 2004.

[Concentrations in micrograms per liter; E, explosive; H, herbicide; OI, organochlorine insecticide; OG, oil and grease; --, not detected; e, value is between the minimum detection limit and the reporting limit and is an estimated value; delta-BHC; Benzene hexachloride; HEM, Hexane extractable material; MCPA, 4-chloro-2-methylphenoxy acetic acid; RDX, Cyclotrimethylene trinitramine; EMC, Event mean concentration; 2,4-D, 2,4-Dinitrotoluene]

Sampling site	Sample type	Date sampled	1,3-Dinitrobenzene	Nitroglycerin	RDX	Tetryl	2,4-D	Dicamba	MCPA	HEM	delta-BHC	Lindane
			E	E	E	E	H	H	H	OG	OI	OI
Big Creek Site 1	Base flow	9/18/2002	--	--	--	--	--	--	--	1.1e	--	--
Big Creek Site 1	Stormflow	3/19/2003	--	--	--	--	--	--	--	3.2e	--	--
Big Creek Site 1	Event (EMC)	5/16/2003	--	--	--	--	--	--	--	4.4e	--	--
Big Creek Site 2	Base flow	9/17/2002	--	--	--	--	--	--	--	2.2e	--	--
Big Creek Site 2	Stormflow	3/19/2003	--	--	--	--	--	--	--	3.2e	--	--
Big Creek Site 3	Base flow	9/17/2002	--	--	0.50e	--	--	--	--	3.1e	--	--
Big Creek Site 3	Stormflow	3/19/2003	--	--	--	--	--	--	--	2.2e	--	--
Big Creek Site 4	Base flow	9/17/2002	--	--	--	--	--	--	--	2.6e	--	--
Big Creek Site 4	Stormflow	3/19/2003	--	--	--	--	--	--	--	2.6e	--	--
Big Creek Site 4	Event (EMC)	5/17/2003	--	--	--	--	--	--	--	4.1e	--	--
Big Creek Site 4	Base flow	9/04/2003	--	--	--	--	--	--	--	2.7e	--	--
Big Creek Site 4	Stormflow	1/18/2004	--	--	0.06e	--	--	--	--	1.5e	--	--
Christmas Knob Lake	Base flow	9/24/2002	--	--	--	--	0.71e	--	--	1.1e	--	--
Christmas Knob Lake	Base flow[1]	9/24/2002	--	--	--	--	0.46e	--	--	2.2e	--	--
Christmas Knob Lake	Stormflow	12/30/2003	--	--	--	--	--	--	--	--	--	--
Darby Lake	Base flow	9/23/2002	--	--	--	--	1.2e	--	--	0.9e	0.034e	--
Darby Lake	Stormflow	12/29/2003	0.015e	--	--	--	--	--	--	--	--	--
Engineer Lake	Base flow	9/24/2002	--	--	--	--	0.48e	--	--	2.0e	--	--
Engineer Lake	Stormflow	12/29/2003	--	--	--	--	--	--	--	--	--	--
Gin Creek	Base flow	9/18/2002	--	--	--	--	--	--	--	1.7e	--	--
Gin Creek	Stormflow	3/20/2003	--	--	--	--	--	--	42e	1.8e	--	--
Grayson Creek	Base flow	9/17/2002	--	--	--	--	--	--	--	2.2e	--	--
Grayson Creek	Stormflow	3/20/2003	--	--	--	--	--	--	--	2.5e	--	--
Mendenhall Swamp Lake	Base flow	9/24/2002	--	0.087e	--	--	1.7e	--	--	1.1e	--	--
Mendenhall Swamp Lake	Stormflow	12/30/2003	--	--	--	--	--	--	--	1.2e	--	--
Vache Grasse Creek Site 0	Base flow	11/5/2002	--	0.048e	--	--	--	--	--	0.84e	--	--
Vache Grasse Creek Site 0	Stormflow	5/16/2003	--	--	--	--	0.50e	0.099e	--	4.1e	--	--
Vache Grasse Creek Site 0	Event (EMC)	5/17/2003	--	--	--	0.013e	0.91e	--	--	4.8e	--	--
Vache Grasse Creek Site 0	Base flow	9/04/2003	--	--	--	--	--	--	--	3.6e	--	0.009e
Vache Grasse Creek Site 0	Stormflow	1/18/2004	--	--	--	--	--	--	--	2.2e	--	--
Vache Grasse Creek Site 1	Base flow	9/18/2002	--	--	--	--	--	--	--	1.7e	--	--
Vache Grasse Creek Site 2	Base flow	9/16/2002	--	0.087e	--	--	--	--	--	--	--	--
Vache Grasse Creek Site 2	Stormflow	5/17/2003	--	--	--	--	--	--	--	4.1e	--	--
Vache Grasse Creek Site 2	Event (EMC)	5/18/2003	--	--	--	--	--	--	--	3.9e	--	--
Vache Grasse Creek Site 2	Base flow	9/04/2003	--	--	--	--	--	--	--	2.4e	--	--
Vache Grasse Creek Site 2	Stormflow	1/18/2004	--	--	--	--	--	--	--	1.2e	--	--
Minimum detection limit[2]			0.013/0.023	0.03/0.039	0.012/0.1	0.012/ 0.024	0.16/0.24	0.081/0.23	12/37	0.83/1	0.005/0.01	0.008/0.0085
Reporting limit			0.12	0.12	0.12/0.6	0.12	4.00	2.00	400	5.0	0.05	0.05

[1]Duplicate sample.

[2]Analytical laboratory reported two minimum detection limits and reporting limits for some constituents.

Table 6. Trace element concentrations for water samples collected at Fort Chaffee, Arkansas, 2002 through 2004.

[Concentrations are in micrograms per liter; e, value is between the minimum detection limit and the laboratory reporting limit and is an estimated value; **bold**, values are above the reporting limit; --, not detected; median values were calculated using estimated values as absolute numbers; n/a, constituent not detected for specified event; EMC, Event mean concentration]

Sampling site	Sample type	Date sampled	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Copper	Lead
Big Creek Site 1	Base flow	9/18/2002	--	0.52e	**34**	--	--	0.34e	0.18e	**1.4**	--
Big Creek Site 1	Stormflow	3/19/2003	0.53e	0.57e	**20**	0.042e	0.034e	1.5e	0.37e	**3.3**	--
Big Creek Site 1	Event (EMC)	5/16/2003	0.20e	0.37e	**25**	--	0.14e	0.74e	0.24e	**2.6**	0.31e
Big Creek Site 2	Base flow	9/17/2002	0.22e	0.48e	**16**	--	--	0.40e	0.10e	0.71e	--
Big Creek Site 2	Stormflow	3/19/2003	--	0.20e	**11**	0.028e	0.35e	1.1e	0.13e	1.2e	0.17e
Big Creek Site 3	Base flow	9/17/2002	0.09e	0.39e	**15**	--	--	0.39e	0.077e	**3.8**	--
Big Creek Site 3	Stormflow	3/19/2003	0.042e	0.24e	**12**	0.036e	0.19e	1.2e	0.18e	**2.3**	0.19e
Big Creek Site 4	Base flow	9/17/2002	0.055e	1.1e	**23**	--	--	0.39e	0.45e	1.1e	--
Big Creek Site 4	Stormflow	3/19/2003	0.071e	0.18e	**9.8**	--	0.077e	1.1e	0.25e	1.7e	0.15e
Big Creek Site 4	Event (EMC)	5/17/2003	0.27e	0.48e	**15**	--	--	0.54e	0.16e	1.2e	0.20e
Big Creek Site 4	Base flow	9/04/2003	0.064e	1.3e	**27**	--	--	0.57e	0.63e	0.33e	--
Big Creek Site 4	Stormflow	1/18/2004	0.18e	0.22e	**11**	--	--	0.59e	0.15e	1.2e	0.25e
Christmas Knob Lake	Base flow	9/24/2002	0.042e	0.97e	**2.5**	--	--	0.59e	0.26e	--	--
Christmas Knob Lake	Base flow[1]	9/24/2002	--	0.94e	**3.6**	--	--	0.45e	0.23e	--	0.53e
Christmas Knob Lake	Stormflow	12/30/2003	0.067e	0.48e	**19**	--	--	0.59e	0.13e	0.62e	--
Darby Lake	Base flow	9/23/2002	--	0.44e	**7.6**	--	--	0.41e	0.093e	0.74e	--
Darby Lake	Stormflow	12/29/2003	--	0.39e	**17**	--	--	0.68e	0.072e	0.71e	--
Engineer Lake	Base flow	9/24/2002	--	0.06e	**1.8**	--	--	0.47e	0.048e	0.71e	--
Engineer Lake	Stormflow	12/29/2003	0.33e	0.45e	**8.4**	--	--	0.67e	0.06e	0.72e	--
Gin Creek	Base flow	9/18/2002	--	2.4e	**46**	--	--	0.46e	0.51e	0.92e	--
Gin Creek	Stormflow	3/20/2003	0.076e	0.22e	**14**	--	0.055e	1.2e	0.12e	0.84e	--
Grayson Creek	Base flow	9/17/2002	0.085e	0.5e	**25**	--	--	--	0.14e	1.6e	--
Grayson Creek	Stormflow	3/20/2003	0.27e	0.33e	**17**	--	0.091e	1.1e	0.20e	**4.7**	0.23e
Mendenhall Swamp Lake	Base flow	9/24/2002	1.3e	0.64e	**12**	--	--	0.26e	0.71e	--	--
Mendenhall Swamp Lake	Stormflow	12/30/2003	0.082e	0.3e	**3.8**	--	--	0.65e	0.098e	0.77e	--

Table 6. Trace element concentrations for water samples collected at Fort Chaffee, Arkansas, 2002 through 2004.—Continued

[Concentrations are in micrograms per liter; e, value is between the minimum detection limit and the laboratory reporting limit and is an estimated value; **bold**, values are above the reporting limit; --, not detected; median values were calculated using estimated values as absolute numbers; n/a, constituent not detected for specified event; EMC, Event mean concentration]

Sampling site	Sample type	Date sampled	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Copper	Lead
Vache Grasse Creek Site 0	Base flow	11/05/2002	0.099e	1.9e	**28**	--	0.03e	0.61e	0.36e	1.3e	--
Vache Grasse Creek Site 0	Stormflow	5/16/2003	0.73e	**15**	**31**	--	--	0.61e	0.62e	1.6e	--
Vache Grasse Creek Site 0	Event (EMC)	5/17/2003	0.28e	**6**	**29**	--	--	0.67e	0.58e	1.7e	--
Vache Grasse Creek Site 0	Base flow	9/04/2003	0.60e	1.9e	**27**	--	0.074e	0.54e	0.69e	**2.4**	--
Vache Grasse Creek Site 0	Stormflow	1/18/2004	--	0.43e	**22**	--	--	0.68e	0.31e	**2.0**	**1.2**
Vache Grasse Creek Site 1	Base flow	9/18/2002	--	0.63e	**39**	--	--	0.39e	0.21e	0.89e	--
Vache Grasse Creek Site 2	Base flow	9/16/2002	1.4e	1e	**33**	--	--	0.55e	0.17e	0.81e	--
Vache Grasse Creek Site 2	Stormflow	5/17/2003	0.18e	0.72e	**31**	--	--	0.49e	0.5e	0.83e	--
Vache Grasse Creek Site 2	Event (EMC)	5/18/2003	0.16e	0.63e	**28**	--	0.061e	0.43e	0.35e	0.95e	--
Vache Grasse Creek Site 2	Base flow	9/04/2003	--	1.4e	**43**	--	--	0.69e	0.54e	0.55e	--
Vache Grasse Creek Site 2	Stormflow	1/18/2004	0.072e	0.49e	**19**	--	--	0.61e	0.24e	1.2e	0.22e
Base flow median			0.09	0.97	25	n/a	0.05	0.46	0.23	0.91	0.53
Event and stormflow median			0.18	0.43	17	0.04	0.08	0.67	0.20	1.2	0.22
Median for all flows			0.17	0.51	19	0.04	0.08	0.59	0.22	1.2	0.23
Aquatic life criteria			--	150	--	--	0.25	11		9.0	2.5
Reference fresh water[2]			0.20	0.50	10.00	0.10	0.20	1.0	0.50	3.0	3.0
Minimum detection limit[3]			0.024, 0.04	0.061, 0.12	0.057, 0.081	0.028, 0.032	0.022, 0.051	0.13, 0.24	0.015, 0.017	0.17, 0.63	0.15, 0.19
Reporting limit			2.0	5.0	1.0	1.0	1.0	2.0	1.0	2.0	1.0

Table 6. Trace element concentrations for water samples collected at Fort Chaffee, Arkansas, 2002 through 2004.--Continued

[Concentrations are in micrograms per liter; e, value is between the minimum detection limit and the laboratory reporting limit and is an estimated value; **bold**, values are above the reporting limit; --, not detected; median values were calculated using estimated values as absolute numbers; n/a, constituent not detected for specified event; EMC, Event mean concentration]

Sampling site	Sample type	Date sampled	Manganese	Mercury	Molybdenum	Nickel	Selenium	Silver	Thallium	Zinc
Big Creek Site 1	Base flow	9/18/2002	**17**	--	0.15e	1.5e	0.53e	--	--	8.4e
Big Creek Site 1	Stormflow	3/19/2003	**43**	--	0.26e	**2.4**	--	0.035e	--	6.2e
Big Creek Site 1	Event (EMC)	5/16/2003	**10**	0.029e	0.096e	**2.5**	--	--	--	**13**
Big Creek Site 2	Base flow	9/17/2002	**52**	--	0.21e	0.94e	0.35e	--	--	2.7e
Big Creek Site 2	Stormflow	3/19/2003	**14**	--	0.032e	1.1e	--	0.014e	--	2.7e
Big Creek Site 3	Base flow	9/17/2002	**13**	--	0.11e	0.79e	0.50e	--	--	2.5e
Big Creek Site 3	Stormflow	3/19/2003	**22**	--	--	1.1e	--	0.022e	--	4.6e
Big Creek Site 4	Base flow	9/17/2002	**430**	--	0.14e	1.2e	0.31e	--	--	3.6e
Big Creek Site 4	Stormflow	3/19/2003	**45**	--	0.062e	1.2e	--	0.013e	--	2.7e
Big Creek Site 4	Event (EMC)	5/017/2003	**54**	0.017e	0.15e	1.1e	--	--	--	6.4e
Big Creek Site 4	Base flow	9/04/2003	**950**	--	0.19e	1.3e	--	--	--	2.1e
Big Creek Site 4	Stormflow	1/18/2004	**24**	--	0.16e	0.88e	--	--	--	7.5e
Christmas Knob Lake	Base flow	9/24/2002	**1,000**	--	0.20e	0.83e	0.63e	--	--	5.9e
Christmas Knob Lake	Base flow[1]	9/24/2002	**950**	--	0.054e	1.0e	0.46e	--	--	4.1e
Christmas Knob Lake	Stormflow	12/30/2003	**70**	--	0.046e	1.2e	--	--	--	2.3e
Darby Lake	Base flow	9/23/2002	**6.7**	--	--	0.35e	--	--	--	5.4e
Darby Lake	Stormflow	12/29/2003	**34**	--	0.083e	0.37e	--	--	--	1.7e
Engineer Lake	Base flow	9/24/2002	**140**	--	0.085e	0.47e	0.31e	--	--	5.0e
Engineer Lake	Stormflow	12/29/2003	**33**	--	0.17e	0.36e	--	--	--	1.5e
Gin Creek	Base flow	9/18/2002	**270**	--	0.13e	1.7e	0.51e	--	--	5.5e
Gin Creek	Stormflow	3/20/2003	**16**	--	0.037e	0.93e	--	0.016e	--	--
Grayson Creek	Base flow	9/17/2002	**59**	--	0.14e	1.2e	0.36e	--	--	**16**
Grayson Creek	Stormflow	3/20/2003	**34**	--	0.12e	1.6e	--	0.038e	--	4.5e
Mendenhall Swamp Lake	Base flow	9/24/2002	**2,000**	--	1.3e	0.32e	0.23e	0.13e	0.054e	7.7e
Mendenhall Swamp Lake	Stormflow	12/30/2003	**72**	--	0.056e	0.38e	--	--	--	2.2e

Table 6. Trace element concentrations for water samples collected at Fort Chaffee, Arkansas, 2002 through 2004.--Continued

[Concentrations are in micrograms per liter; e, value is between the minimum detection limit and the laboratory reporting limit and is an estimated value; **bold**, values are above the reporting limit; --, not detected; median values were calculated using estimated values as absolute numbers; n/a, constituent not detected for specified event; EMC, Event mean concentration]

Sampling site	Sample type	Date sampled	Manganese	Mercury	Molybdenum	Nickel	Selenium	Silver	Thallium	Zinc
Vache Grasse Creek Site 0	Base flow	11/05/2002	**120**	--	0.24e	1.5e	0.32e	0.071e	--	**12**
Vache Grasse Creek Site 0	Stormflow	5/16/2003	**260**	0.026e	0.58e	**2.3**	--	--	--	**10**
Vache Grasse Creek Site 0	Event (EMC)	5/17/2003	**150**	0.032e	0.49e	**2.6**	0.24e	--	--	**19**
Vache Grasse Creek Site 0	Base flow	9/04/2003	**50**	--	0.76e	**3.4**	--	--	--	8.2e
Vache Grasse Creek Site 0	Stormflow	1/18/2004	**140**	--	0.18e	1.5e	--	--	--	6.3e
Vache Grasse Creek Site 1	Base flow	9/18/2002	**99**	--	0.32e	**2.1**	0.47e	--	--	8.2e
Vache Grasse Creek Site 2	Base flow	9/16/2002	**150**	--	1.4e	1.9e	0.71e	--	0.029e	**2.83**
Vache Grasse Creek Site 2	Stormflow	5/17/2003	**380**	0.042e	0.31e	1.8e	--	--	--	**39**
Vache Grasse Creek Site 2	Event (EMC)	5/18/2003	**180**	0.038e	0.27e	1.8e	--	--	--	6.5e
Vache Grasse Creek Site 2	Base flow	9/04/2003	**630**	--	0.53e	**2.3**	--	--	--	1.9e
Vache Grasse Creek Site 2	Stormflow	1/18/2004	**64**	--	0.20e	1.4e	--	--	--	3.8e
Base flow median			140	n/a	0.20	1.2	0.46	0.13	0.04	5.4
Event- and stormflow median			45	0.03	0.16	1.2	0.24	0.02	n/a	5.4
Median for all flows			67	0.03	0.17	1.2	0.41	0.04	0.04	5.4
Aquatic life criteria[2]				0.77		52	5.0			120
Reference fresh water [3]			5.0	0.10	1.0	0.30	0.20	0.30	0.04	5.0
Minimum detection limit[4]			0.061, 0.10	0.015, 0.028	0.023, 0.04	0.15, 0.25	0.19, 0.24	0.012, 0.058	0.012, 0.015	1.2, 2.3
Reporting limit			1.0	2.0	2.0	2.0	5.0	5.0	1.0	10

[1]Duplicate sample.
[2]U.S. Environmental Protection Agency, 2002.
[3]Pais and Jones, 1997.
[4]Analytical laboratory reported two minimum detection limits for some constituents.

particularly where large amounts of sediments have been deposited. Trace elements such as manganese can occur in water in high concentrations in this situation because under reduced conditions, manganese solubility (the ability to mix with water) can increase (Mitsch and Gosselink, 1993).

A reducing environment also could partially explain consistent detections of barium in waterbodies at Fort Chaffee. Low concentrations of barium were detected in all 36 water samples. Barium will sometimes dissolve from barium sulfate ($BaSO4$) under low sulfate, anaerobic conditions common to stagnant waterbodies that are cutoff from other surface and ground waters (U.S. Environmental Protection Agency, 1997). Observations indicate that this situation persists for some small streams on Fort Chaffee during base-flow periods and this could explain why barium concentrations consistently were higher for base-flow samples than for stormflow or event samples. Phosphate fertilizers, which can contain as much as 200 mg/L of barium (Pais and Jones, 1997), and explosives also are potential sources of barium.

Nutrient concentrations in water samples generally were below the RL at most sites; however, nutrient concentrations generally were higher at sites located on Vache Grasse Creek than at other sampling sites (table 7). Of the three sites on Vache Grasse Creek, nutrient concentrations were highest at Vache Grasse Creek Site 0. Higher nutrient concentrations at this site could indicate released or overflowing effluent from an off-post wastewater-treatment facility, which would provide some explanation for why total phosphorus concentrations were higher in base-flow samples than in stormflow samples (table 7).

Nutrient concentrations in waterbodies sampled at Fort Chaffee were compared to data collected at 14 sites sampled by NAWQA in the Ozark Plateaus from 1993 to 1995 (Davis and Bell, 1998). Median maximum values for the NAWQA data were compared to median values for base-flow, event-flow, and stormflow sampling events (table 7). Median values for the sites sampled at Fort Chaffee exceeded the median maximum value for the 14 sites sampled in the Ozark Plateaus for three of six nutrient constituents: dissolved ammonia, total ammonia plus organic nitrogen, and total phosphorus.

Total dissolved solids concentrations varied more by waterbody than by sampling date or the amount of flow associated with the sampling event (table 7). Highest concentrations consistently occurred at Vache Grasse Creek Site 0, followed by Vache Grasse Creek Site 2, and sites on Big Creek. The median value for all dissolved solids concentrations measured in this study (87 milligrams per liter (mg/L)) was slightly higher than typical values for the Arkansas River Valley physiographic region (50-75 mg/L; Petersen, 1988). In contrast to total dissolved solids concentrations, the highest total suspended solids concentrations occurred at sites located on Big Creek and for samples collected during event-flow or stormflow events.

Fecal coliform bacteria concentrations were higher in samples from streams than from lakes, and were higher for stormflow and event-flow compared to base-flow samples (table 7). Concentrations ranged from less than 1 colony/100 milliliter (col/100 mL) to 18,400 col/100 mL. Arkansas standards for primary contact state that the 30-day geometric mean values should not exceed 200 col/100 mL, from April through September (Arkansas Department of Environmental Quality, 2004). Eleven of 15 stormflow samples exceeded this criterion (although the sample results for this report do not represent a 30-day geometric mean); however, the median value for all fecal coliform concentrations measured in this study (78 col/100 mL) was typical for the Arkansas River Valley physiographic region (20-100 col/100 mL; Petersen, 1988). Dense wildlife populations in the Fort Chaffee Wildlife Management Area may account for elevated bacteria concentrations.

Event-mean storm concentrations calculated from samples collected at two sites each on Big and Vache Grasse Creeks indicate that most constituents occurred at higher concentrations in Vache Grasse Creek than in Big Creek for the storm sampled in May 2003 (table 8). Of the 25 detected constituents, 20 were highest at one of the two sites on Vache Grasse Creek and of those, 18 were highest at Vache Grasse Creek Site 0, the site immediately downstream from an off-post wastewater-treatment facility.

Event loads calculated from event-mean concentrations also indicate that water-quality contamination is greater at Vache Grasse Creek than at Big Creek. Event loads were highest at the two Vache Grasse Creek sites for 24 of the 25 constituents detected (table 9). Higher event loads at Vache Grasse Creek could be partially explained by higher streamflows at the Vache Creek sites compared to the Big Creek sites during the sampled event (table 8). However, further evaluation by normalizing event loads at Big Creek Site 4 (the most downstream site on Big Creek) to event loads at Vache Grasse Creek Site 0 (the most upstream site on Vache Grasse Creek) by streamflow indicates that event loads at Vache Grasse Creek Site 0 were about two or more times higher than the loads at Big Creek Site 4 for 15 of the 25 constituents measured (table 10). Constituent loads that were five or more times higher at Vache Grasse 0 than at the two sites on Big Creek included nitrite plus nitrate as N, nitrite as N, total ammonia plus organic nitrogen as N, total phosphorus, arsenic, and total suspended solids.

Daily mean values measured for stage, temperature, specific conductance, and turbidity at Vache Grasse Creek Site 2 (appendixes 3-6) reveal the relations between the water-quality constituents measured and stream stage. Stream stage, specific conductance, and turbidity are compared for the month of April 2004 to illustrate these relations (fig. 2). In general, there is a pronounced parallel relation between stage and turbidity. Conversely, there is a less pronounced inverse relation between stage and specific conductance. Continuous data collected thus far indicate that turbidity and specific conductance have potential as surrogates that can be used to monitor the possible presence of contaminants in surface-water runoff.

Table 7. Nutrient and other selected constituents detected in water samples collected at Fort Chaffee, Arkansas, 2002 through 2004.

[e, value is between the minimum detection limit and the reporting limit and is an estimated value; --, constituent not detected for specified event; n/a, not applicable; **bold**, indicates where median values exceeded the median maximum of 14 sites sampled in the Ozark Plateaus, mg/L, milligrams per liter; col./100 mL, colonies per 100 milliliters; NAWQA, National Water-Quality Assessment Program; EMC, Event mean concentration]

Sampling site	Sampling type	Data sampled	Ammonia as N (mg/L)	Nitrite plus nitrate as N (mg/L)	Nitrite as N (mg/L)	Total ammonia plus organic nitrogen as N (mg/L)	Ortho-phosphorus as P (mg/L)	Total phosphorus (mg/L)	Total dissolved solids (mg/L)	Total suspended solids (mg/L)	Fecal coliform bacteria (col./100 mL)
Big Creek Site 1	Base flow	9/18/2002	0.022e	0.019e	0.0039e	0.36e	--	0.071	85	16	300
Big Creek Site 1	Stormflow	3/19/2003	0.098e	0.24	0.011	0.37e	0.063	0.21	110	160	7,900
Big Creek Site 1	Event (EMC)	5/16/2003	--	0.41	0.014	0.33e	--	0.053	110	270	--
Big Creek Site 2	Base flow	9/17/2002	0.039e	0.025e	--	--	--	0.036e	57	7.2	16
Big Creek Site 2	Stormflow	3/19/2003	0.076e	0.014e	0.0075e	0.60	0.036e	0.019e	81	21	1,630
Big Creek Site 3	Base flow	9/17/2002	0.042e	--	--	--	--	0.10	110	24	96
Big Creek Site 3	Stormflow	3/19/2003	0.048e	0.031e	0.013	0.62	0.042e	0.14	130	53	8,000
Big Creek Site 4	Base flow	9/17/2002	0.04e	--	--	--	--	0.10	62	3.6e	196
Big Creek Site 4	Stormflow	3/19/2003	0.066e	0.029e	0.01	0.49e	0.05	0.078	97	380	18,400
Big Creek Site 4	Event (EMC)	5/17/2003	0.073e	0.087e	0.0075e	0.34e	--	0.038e	77	21	--
Big Creek Site 4	Base flow	9/04/2003	0.068e	--	0.0048e	0.4e	--	0.027e	69	3.2e	38
Big Creek Site 4	Stormflow	1/18/2004	--	0.15	--	0.57	--	0.033e	88	18	1,060
Christmas Knob Lake	Base flow	9/24/2002	0.16	--	0.0028e	0.63	--	0.51	36	8.4	<1
Christmas Knob Lake	Base flow[1]	9/24/2002	0.16	--	0.0028e	0.69	--	0.12	46	10	--
Christmas Knob Lake	Stormflow	12/30/2003	0.19	0.24	0.0053e	1.1	--	0.019e	39	6.4	7
Darby Lake	Base flow	9/23/2002	--	0.041e	0.0035e	0.22e	--	0.02e	24	--	58
Darby Lake	Stormflow	12/29/2003	--	0.11	0.0048e	0.61	--	--	48	4.4	188
Engineer Lake	Base flow	9/24/2002	0.06e	0.029e	0.003e	0.16e	--	0.12	21	5.6	140
Engineer Lake	Stormflow	12/29/2003	0.038e	0.046e	0.0031e	0.47e	--	--	40	2.0e	35
Gin Creek	Base flow	9/18/2002	0.067e	0.23	0.011	0.14e	--	0.26	110	25	1,060
Gin Creek	Stormflow	3/20/2003	0.082e	--	0.0044e	0.29e	0.032e	--	71	6.8	480
Grayson Creek	Base flow	9/17/2002	0.043e	0.014e	--	--	--	0.038e	89	4.8	192
Grayson Creek	Stormflow	3/20/2003	0.069e	0.047e	0.0088e	0.56	0.034e	0.021e	100	11	580
Mendenhall Swamp Lake	Base flow	9/24/2002	0.072e	--	0.0028e	0.44e	--	0.11	54	15	270
Mendenhall Swamp Lake	Stormflow	12/30/2003	--	--	0.0036e	1.1	--	0.044e	48	8.4	2
Vache Grasse Creek Site 0	Base flow	11/5/2002	0.087e	2.0	0.11	0.62	0.31	--	160	41	700
Vache Grasse Creek Site 0	Stormflow	5/16/2003	0.29	1.3	0.073	0.62	0.15	0.30	160	82	600
Vache Grasse Creek Site 0	Event (EMC)	5/17/2003	0.36	1.7	0.08	0.73	0.27	0.25	170	130	--
Vache Grasse Creek Site 0	Base flow	9/04/2003	--	4.3	0.031	0.59	0.74	0.83	240	3.2e	48

Table 7. Nutrient and other selected constituents detected in water samples collected at Fort Chaffee, Arkansas, 2002 through 2004.—Continued

[e, value is between the minimum detection limit and the reporting limit and is an estimated value; --, constituent not detected for specified event; n/a, not applicable; **bold**, indicates where median values exceeded the median maximum of 14 sites sampled in the Ozark Plateaus, mg/L, milligrams per liter; col./100 mL, colonies per 100 milliliters; NAWQA, National Water-Quality Assessment Program; EMC, Event mean concentration]

Sampling site	Sampling type	Data sampled	Ammonia as N (mg/L)	Nitrite plus nitrate as N (mg/L)	Nitrite as N (mg/L)	Total ammonia plus organic nitrogen as N (mg/L)	Ortho-phosphorus as P (mg/L)	Total phosphorus (mg/L)	Total dissolved solids (mg/L)	Total suspended solids (mg/L)	Fecal coliform bacteria (col./100 mL)
Vache Grasse Creek Site 0	Stormflow	1/18/2004	0.051e	0.66	0.004e	0.58	0.029e	0.12	140	17	640
Vache Grasse Creek Site 1	Base flow	9/18/2002	--	--	0.0029e	--	--	0.061	160	5.6	68
Vache Grasse Creek Site 2	Base flow	9/16/2002	0.10	0.023e	0.003e	--	--	0.56	84	4.4	52
Vache Grasse Creek Site 2	Stormflow	5/17/2003	0.22	0.23	0.026	0.40e	0.018e	0.056	150	28	260
Vache Grasse Creek Site 2	Event (EMC)	5/18/2003	0.17	0.37	0.024	0.32e	0.02e	0.068	160	26	--
Vache Grasse Creek Site 2	Base flow	9/04/2003	0.066e	0.022e	0.0052e	0.44e	--	0.041e	150	13	78
Vache Grasse Creek Site 2	Stormflow	1/18/2004	0.042e	0.52	0.0025e	0.85	--	0.10	130	33	1,700
Base-flow median[2]			**0.060**	0.019	0.004	**0.220**	0.000	**0.100**	69	8.0	87
Event and stormflow median[2]			**0.069**	0.150	0.008	**0.570**	0.020	0.053	100	21	35
Median[2] for all flows			**0.066**	0.036	0.005	**0.440**	0.000	0.065	87	15	78
Ozark NAWQA median (maximum at 14 sites)			0.020	3.1	n/a	< 0.20	0.070	0.080	n/a	n/a	570
Ozark NAWQA 90th percentile (maximum at 14 sites)			0.060	4.7	n/a	0.500	0.590	0.600	n/a	n/a	9,000
Minimum detection limit[3]			0.013/0.029	0.012/0.21	0.0013/0.002	0.013	0.83/0.14	0.013/0.019	3/5	1.8	0
Reporting limit			0.10	0.10	0.01	0.05/0.1	5.0	0.05	10	4/10	n/a

[1]Duplicate sample.

[2]Median values were calculated using estimated values as absolute numbers.

[3]Analytical laboratory reported two minimum detection levels for some constituents.

Table 8. Flow volumes and event mean concentrations for constituents detected above the laboratory minimum detection limit at four sites for the same storm event at Fort Chaffee, Arkansas, May 2003.

[Concentrations above the laboratory minimum detection limit and less than the reporting limit are shown as actual values (rather than estimated values, see tables 6 and 7 for estimated values); µg/L, micrograms per liter; --, constituent was not detected; **bold** text denotes highest value of the four sites; N, nitrogen; mg/L, milligrams per liter; P, phosphorus; ft^3, cubic feet]

Constituent	Big Creek Site 1	Big Creek Site 4	Vache Grasse Site 0	Vache Grasse Site 2
Ammonia as N (mg/L)	--	0.07	**0.36**	0.17
Nitrite as N (mg/L)	0.01	0.01	**0.08**	0.02
Nitrite plus nitrate as N (mg/L)	0.41	0.09	**1.7**	0.37
Total ammonia plus organic nitrogen as N (mg/L)	0.33	0.03	**0.73**	0.32
Orthophosphorus as P (mg/L)	--	--	**0.27**	0.02
Total phosphorus (mg/L)	0.053	0.038	**0.250**	0.068
Antimony (µg/L)	0.20	0.27	**0.28**	0.16
Arsenic (µg/L)	0.37	0.48	**6.0**	0.63
Barium (µg/L)	25	15	**29**	28
Cadmium (µg/L)	**0.14**	--	--	0.06
Chromium (µg/L)	**0.74**	0.54	0.67	0.43
Cobalt (µg/L)	0.24	0.16	**0.58**	0.35
Copper (µg/L)	**2.6**	1.2	1.7	0.95
Lead (µg/L)	**0.31**	0.20	--	--
Manganese (µg/L)	10	54	150	**180**
Mercury (µg/L)	0.029	0.017	0.03	**0.038**
Molybdenum (µg/L)	0.096	0.150	**0.49**	0.27
Nickel (µg/L)	2.5	1.1	**2.6**	1.8
Selenium (µg/L)	--	--	**0.24**	--
Zinc (µg/L)	13	6.4	**19**	6.5
2,4-D (µg/L)	--	--	**0.91**	--
Tetryl (µg/L)	--	--	**0.01**	--
Hexane extractable material (HEM) (mg/L)	4.4	4.1	**4.8**	3.9
Total dissolved solids (mg/L)	110	77	**170**	160
Total suspended solids (mg/L)	**270**	21.0	130	26
Accumulated flow volume (ft^3)	148,000	1,336,000	2,911,000	52,100,000

Table 9. Computed storm loads for stream sites sampled at Fort Chaffee, Arkansas, May 2003.

[Loads are in pounds; --, constituent was not detected; **bold** text denotes highest value calculated at the four sites]

Constituent	Big Creek Site 1	Big Creek Site 4	Vache Grasse Site 0	Vache Grasse Site 2
Ammonia as N	--	6.08	65.4	**553**
Nitrite plus nitrate as N	3.80	7.25	308.7	**1,203**
Nitrite as N	0.13	0.62	14.5	**78.0**
Orthophosphorus as P	--	--	49	**65**
Total ammonia plus organic nitrogen as N	3.05	2.83	132.6	**1,040**
Total phosphorus	0.49	3.17	45.4	**221**
Antimony	<0.01	0.02	0.05	**0.52**
Arsenic	<0.01	0.04	1.09	**2.05**
Barium	0.23	1.25	5.27	**91.0**
Cadmium	<0.01	--	--	**0.20**
Chromium	0.01	0.04	0.12	**1.4**
Cobalt	<0.01	0.01	0.11	**1.14**
Copper	0.02	0.10	0.31	**3.09**
Lead	<0.01	**0.02**	--	--
Manganese	0.09	4.50	27.2	**585**
Mercury	<0.01	<0.01	0.01	**0.12**
Molybdenum	<0.01	0.01	0.09	**0.88**
Nickel	0.02	0.09	0.47	**5.85**
Selenium	--	--	**0.04**	--
Zinc	0.12	0.53	3.45	**21.1**
2,4-D	--	--	**0.17**	--
Tetryl	--	--	**0.002**	--
Hexane extractable material (HEM)	40.7	342	872	**12,700**
Total dissolved solids	1,000	6,400	31,000	**520,000**
Total suspended solids	2,500	1,800	24,000	**85,000**

Table 10. A comparison of actual storm loads measured at Vache Grasse Creek Site 0 to flow-normalized storm loads at Big Creek Site 4, May 2003.

[Loads are in pounds; normalized event loads at Big Creek Site 4 were obtained by dividing the event flow volume at Vache Grasse Creek Site 0 by the event flow volume at Big Creek Site 4 and then multiplying that quotient by the event load measured at Big Creek Site 4; ft^3, cubic feet; **bold**, denotes highest event load; n/a, constituent not detected at one or more sites; N, nitrogen; P, phosphorus; --, not detected]

Constituent	Vache Grasse Site 0 (actual)	Big Creek Site 4 (actual)	Big Creek Site 4 (normalized)	Load ratios[1]
Ammonia as N	**65.4**	6.08	13.26	4.9
Nitrite plus nitrate as N	**309**	7.25	15.80	19.5
Nitrite as N	**14.5**	0.62	1.36	10.7
Orthophosphorus as P	**49.0**	--	--	n/a
Total ammonia plus organic nitrogen as N	**133**	2.83	6.17	21.5
Total phosphorus	**45.4**	3.17	6.90	6.6
Antimony	**0.05**	0.02	0.05	1.0
Arsenic	**1.09**	0.04	0.09	12.5
Barium	**5.27**	1.25	2.72	1.9
Cadmium	--	--	--	n/a
Chromium	**0.12**	0.04	0.10	1.2
Cobalt	**0.11**	0.01	0.03	3.6
Copper	**0.31**	0.10	0.22	1.4
Lead	--	0.02	**0.04**	n/a
Manganese	**27.2**	4.50	9.81	2.8
Mercury	**0.01**	0.00	0.00	1.9
Molybdenum	**0.09**	0.01	0.03	3.3
Nickel	**0.47**	0.09	0.20	2.4
Selenium	**0.04**	--	--	n/a
Zinc	**3.45**	0.53	1.16	3.0
2,4-D	**0.17**	--	--	n/a
Tetryl	**< 0.01**	--	--	n/a
Hexane extractable material (HEM)	**872**	342	745	1.2
Total dissolved solids	**30,871**	6,416	13,983	2.2
Total suspended solids	**23,607**	1,750	3,813	6.2
Stormflow volume (ft^3)	**2,911,000**	1,336,000	2,911,000	

[1]Load ratios were calculated by dividing loads for Vache Grasse Creek Site 0 by the normalized load for Big Creek Site 4.

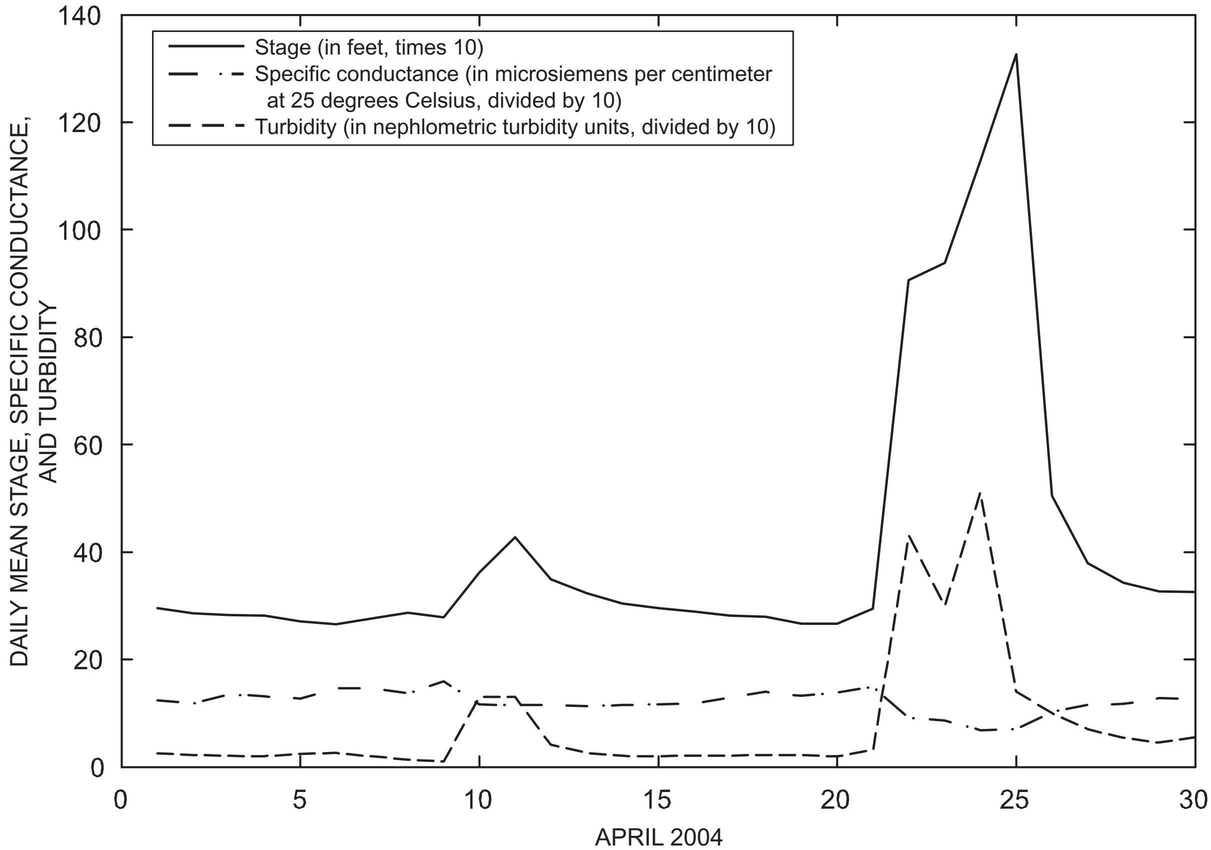

Figure 2. Continuous stage, specific conductance, and turbidity data collected at Vache Grasse Creek Site 2, April 2004.

Fish Tissue

DDT and metabolites of DDT, heptachlor, and endrin ketone were the only insecticides detected in fish fillet samples (table 11). Some of these results are questionable, however, because detections of heptachlor and endrin ketone, and four of nine detections for DDT or DDT metabolites were in samples that had an associated laboratory blank sample that also contained these compounds. Although one detection for DDT in fish tissue exceeded the RL, all DDT concentrations in fish tissue were lower than in bed sediment samples (table 4).

Trace element detections were common in fish liver samples (table 12) and less common in fillet samples (table 13). Concentrations in fish liver samples were compared to median concentrations from 31 to 281 sites (depending on the constituent) analyzed nationally by the NAWQA program (Zappia, 2002). Concentrations in fish livers exceeded the NAWQA median at one site for mercury (Darby Lake) and at one site for nickel (Vache Grasse Creek Site 0). The concentration of mercury in fish livers from Darby Lake was 66 percent higher than the NAWQA median at 285 sites and the concentration of nickel in fish livers collected from Vache Grasse Creek Site 0 was 45 percent higher than the median of 140 NAWQA sites (Zappia, 2002). Detections for all trace element constituents in fillet samples were less than the RL except for chromium, copper and mercury (table 13); however, chromium data are suspect because this constituent also was detected in associated blank samples. Mercury concentrations in edible fish tissue, which are a widespread concern in the United States (U.S. Environmental Protection Agency, 2001), exceeded an USEPA criterion for methylmercury of 300 µg/kg in four of nine samples; however, concentrations are typical of mercury concentrations in fish tissues for the State of Arkansas (U.S. Environmental Protection Agency, 2001b).

Table 11. Concentrations of organic compounds detected in fish fillets collected at Fort Chaffee, Arkansas, 2002.

[Values are in micrograms per kilogram; DDD, dichlorodiphenyldichloroethane; DDE, dichlorodiphenyldichloroethylene; DDT, dichlorodiphenyltrichloroethane; c, constituent detected in associated laboratory blank sample; e, value is less than the reporting limit and was estimated by the analytical laboratory]

Site	4,4′-DDD	4,4′-DDE	4,4′-DDT	Heptachlor	Endrin ketone
Big Creek at Site 2	<0.6	<0.6	<1.4	0.63c	<0.6
Big Creek at Site 4	<0.6	<0.6	<1.4	<0.6	<0.6
Christmas Knob Lake	2.6e	2.2e	<1.4	<0.6	<0.6
Darby Lake	<0.6	1.7c	<1.4	<0.6	0.92c
Engineer Lake	2.5c	7.6	1.7c	<0.6	<0.6
Mendenhall Swamp Lake	<0.6	1.4c	<1.4	<0.6	<0.6
Vache Grasse Creek Site 0	<0.6	<0.6	<1.4	<0.6	<0.6
Vache Grasse Creek Site 1	<0.6	1.4e	<1.4	<0.6	<0.6
Vache Grasse Creek Site 2	0.73c	<0.6	<1.4	<0.6	<0.6
Minimum detection limit	0.6	0.6	1.4	0.6	0.6
Laboratory reporting limit	6	6	6	6	6

Table 12. Trace element concentrations in fish livers collected at Fort Chaffee, Arkansas, 2002.

[Concentrations are in micrograms per kilogram; ND, not detected; e, estimated value; c, constituent detected in associated laboratory blank sample; (31), number of National Water Quality Assessment Program (NAWQA) sites where fish livers were analyzed; **bold** text represents samples that exceeded NAWQA median values; n/a, not analyzed]

	Antimony	Arsenic	Beryllium	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Silver	Thallium	Zinc
Big Creek at Site 2	<200	160e	ND	230	270c	5,000	45e	39e	190c	2,000	31e,c	ND	20,000c
Big Creek at Site 4	<200	130e	ND	290	240c	7,600	22e	160	130c	1,500	71e,c	4.4e	24,000c
Christmas Knob Lake	<200	43e	2.7e	30e	390c	4,200	ND	11e	96e,c	330e	24e,c	ND	18,000c
Darby Lake	<200	110e	ND	250	460c	10,000	73e	**400**	72e,c	1,800	19e,c	ND	34,000c
Engineer Lake	<200	190e	ND	640	380c	3,400	ND	230	160c	1,800	25e,c	2.1e	24,000c
Mendenhall Swamp Lake	<200	110e	3.1e	630	370c	4,400	32e	98e	79e,c	1,700	29e,c	3.0e	25,000c
Vache Grasse Creek Site 0	<200	100e	ND	180	260c	3,000	ND	100	**580c**	1,300	16e,c	6.2e	22,000c
Vache Grasse Creek Site 1	<200	68e	ND	150	390c	1,700	ND	96e	74e,c	1,100	6.4e,c	2.4e	21,000c
Vache Grasse Creek Site 2	<200	95e	ND	250	240c	3,500	ND	100	95e,c	1,100	43e,c	3.0e	21,000c
Minimum detection limit	20	7.6	2.3	2.7	34	61	20	5.9	11	18	2.0	2.0	130
Reporting limit	200	500	100	100	200	200	100	100	100	500	100	100	1,000
Median	<20	110	<2.3	250	370	4,200	<20	100	96	1,500	25	3.0	22,000
NAWQA median[1]	200 (31)	400 (189)	(280)[2]	1,500 (238)	700 (280)	55,900 (281)	320(97)	240(285)	400(140)	5,300(273)	600(172)	n/a	123,000 (281)

[1]Zappia (2002).

[2]Reporting limit for beryllium in fish tissue sampled for NAWQA Program was 100 µg/kg.

Table 13. Trace element concentrations in fish fillets collected at Fort Chaffee, Arkansas, 2002.

[Concentrations are in micrograms per kilogram; ND, not detected; e, estimated value; c, constituent detected in associated blank sample]

	Antimony	Arsenic	Beryllium	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Silver	Thallium	Zinc
Big Creek at Site 2	ND	60e	ND	ND	310c	250	ND	180	15e,c	490e	ND	ND	5,400c
Big Creek at Site 4	ND	23e	ND	ND	320c	240	ND	550	19e,c	330e	ND	ND	4,800c
Christmas Knob Lake	ND	15e	ND	ND	440c	250	ND	280	40e,c	400e	25e,c	ND	3,800c
Darby Lake	ND	21e	ND	ND	460c	170e	ND	580	30e,c	460e	15e,c	ND	5,300c
Engineer Lake	ND	59e	ND	ND	490c	200	ND	350	31e,c	470e	19e,c	ND	4,500c
Mendenhall Swamp Lake	96e	16e	2.6e	3.6e	420c	190e	ND	18e	33e,c	69e	27e,c	2.4e	6,000c
Vache Grasse Creek Site 0	ND	30e	ND	ND	300c	230	ND	280	34e,c	280e	ND	ND	4,700c
Vache Grasse Creek Site 1	ND	31e	ND	ND	480c	250	ND	220	33e,c	330e	8.9e,c	ND	4,900c
Vache Grasse Creek Site 2	ND	63e	ND	ND	470c	260	ND	420	200c	420e	ND	ND	4,800c
Minimum detection limit	20	7.6	2.3	2.7	34	61	20	5.9	11	18	2.0	2.0	130
Reporting limit	200	500	100	100	200	200	100	100	100	500	100	100	1,000
Median	<20	30	<2.3	<2.7	440	240	<20	280	33	400	8.9	<2.0	4,800

Bed Sediment

Detection of DDT in bed-sediment samples indicates that previous activities on post have influenced environmental conditions. Of the 44 organic compounds that were analyzed in bed sediment, only two were detected above the MDL. The two compounds detected were dichlorodiphenyltrichloroethane (4,4',DDT) and a DDT metabolite dichlorodiphenyldichloroethylene (4,4',DDE) and both detections occurred at Grayson Creek (fig. 1, table 14), the site closest to the administrative and residential area of Fort Chaffee (known as the cantonment area). Although both detections were lower than the RL (and are estimated values), concentrations for total DDT at Grayson Creek exceeded median concentrations at 45 of 46 NAWQA study units (including about 700 sites) (Chalmers, 2002). DDT is a chemical compound that was used primarily as an insecticide until it was banned in 1972. Low levels of DDT and its metabolites are common in bed-sediment samples collected throughout the United States and result both from widespread use and the persistent nature of this compound (Nowell and others, 1999).

Table 14. Organic compounds detected in bed-sediment samples at Fort Chaffee, Arkansas, 2002.

[Concentrations are in micrograms per kilogram; DDE, dichlorodiphenyldichloroethylene; DDT, dichlorodiphenyltrichloroethane;e, value is less than the reporting limit and was estimated by the analytical laboratory]

Site	4,4′-DDE	4,4′-DDT
Grayson Creek	19e	22e
Minimum detection limit	13	15
Reporting limit	51	51

Concentrations of some trace elements in bed sediments (as well as other media) sampled for this study also could have a relation to on-post activities or conditions. Detections at low to moderate concentrations are to be expected, however, because these constituents occur naturally in soils and, in appropriate amounts, are considered essential or beneficial to both plants and humans (Pais and Jones, 1997). Trace element concentrations were compared to bed sediment and geochemical background concentrations established by two trace element studies conducted previously in the United States (table 15; MacDonald and others, 2000; Gustavsson and others, 2001). Trace element concentrations in bed-sediment samples at one or more sites slightly exceeded estimated geochemical background concentrations for western Arkansas for arsenic, copper, lead, manganese, nickel, and zinc (table 15; Gustavsson and others, 2001), and slightly exceeded lowest effect level criteria at one site each for arsenic and at two sites for nickel. The site located on Grayson Creek had concentrations that were above background concentrations for all six of the aforementioned constituents, and arsenic and nickel concentrations exceeded lowest effect level (toxicity) criteria to aquatic life; 9,790 and 22,700 µg/kg, respectively (table 15; MacDonald and others, 2000).

Aside from potential contamination at Grayson Creek, two possible explanations for elevated trace element concentrations in Fort Chaffee streams are relatively high background concentrations in soils of western Arkansas (Gustavsson and others, 2001), and field observations of excessive bed sediment deposition at Fort Chaffee. Excessive bed sediment deposition rates can lead to high biochemical oxygen demand which ultimately results in anoxic conditions. In this situation, trace elements favored by a reducing environment (such as manganese) can occur in bed sediments in high concentrations (Mitsch and Gosselink, 1993).

Possible Relations of Sediment Deposition to Erosion and Turbidity

Excessive bed sediment deposition observed at Fort Chaffee also could have a relation to on-post activities or conditions. Sedimentation in Fort Chaffee waterbodies may be a possible consequence of soil erosion resulting from training activities (tank exercises and disruption of the landscape by exploding ordnances) and an extensive road system. Turbidity in streams may be a surrogate for erosion and bed sedimentation. Mean turbidity for 4 of 9 months for which data were collected, at the most downstream site on Vache Grasse Creek, exceeded 40 nephlometric turbidity units (NTUs); a state stream-stormflow standard for the Arkansas River Valley (Arkansas Department of Environmental Quality, 2004). Turbidity and excessive bed sediment deposition are chronic physical impairments that may be influencing the ecological integrity of Fort Chaffee streams to some degree.

Effects of Land Use Both On and Off Post

The constituents detected in water, fish tissue, and bed-sediment samples collected in this study indicate that land use activities both on and off post are influencing environmental conditions in waterbodies of Fort Chaffee. Contaminants such as explosives that were sometimes detected in water samples have an obvious relation to military training; however, the occurrence and locations of some nutrient, insecticide, and trace-element detections indicate that land use both on and off post also could be influencing environmental conditions to some degree.

Constituent concentrations at sites on Vache Grasse Creek, and particularly at Site 0, indicate that environmental conditions were being influenced by an off-post source. Sites on Vache Grasse Creek had the highest number of constituent detections and the highest concentrations detected of all other sites for most media sampled, and also had much higher event-mean storm concentrations and normalized storm loads than sites on Big Creek.

Table 15. Concentrations and associated toxicity values for trace elements analyzed in bed-sediment samples collected at Fort Chaffee, Arkansas, 2002.

[Concentrations are reported as micrograms per kilogram except for TOC (total organic carbon), which is grams per kilogram; **bold** text represents samples that exceeded "lowest effect level" criteria and background concentrations; green text indicates values that met or exceeded only background concentrations; c, constituent detected in associated blank sample; e values were estimated; n/a, criteria not available; NS, not sampled]

	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Copper	Lead
Big Creek Site 1	13e,c	5,100	100,000c	660	89e,c	22,000c	14,000	8,300	12,000
Big Creek Site 2	79e,c	3,200	68,000c	520	42e,c	15,000c	8,400	5,200	8,300
Big Creek Site 3	36e,c	6,900	160,000c	910	200e,c	29,000c	14,000	12,000	16,000
Big Creek Site 4	18e,c	3,900	88,000c	600	63e,c	17,000c	9,300	5,700	10,000
Christmas Knob Lake	67e,c	84e	2,100c	16e	<4	500e,c	190e	6,000c	220ec
Darby Lake	18e,c	4,600	93,000c	650	96e,c	17,000c	11,000	14,000	12,000
Engineer Lake	36e,c	350e	4,400c	32e	<4	940c	330	380ec	370c
Gin Creek	12e,c	4,800	61,000c	560	46e,c	21,000c	8,400	5,600	9,600
Grayson Creek	26e,c	**10,000**	160,000c	950	330c	29,000c	19,000	17,000	28,000
Mendenhall Swamp Lake	130e,c	270e	5,800c	52e	14e	1,300c	470	1,500c	1,000c
Vache Grasse Creek Site 1	14e,c	2,900	61,000c	420	70e,c	10,000c	7,000	8,400	7,500
Vache Grasse Creek Site 2[1]	24e,c	5,700	110,000c	900	140e	22,000c	13,000	9,200	16,000
Vache Grasse Creek Site 2[1]	19e,c	5,000	100,000c	740	100e	20,000c	12,000	8,100	14,000
Minimum detection limit[2]	7	44	62	11	4	47	3	39	11
Reporting limit	517	1,283	258	258	258	517	258	517	258
Median (for Fort Chaffee samples)	23.75	4,250	78,000	580	79.5	17,000	8,850	7,150	9,800
Lowest effect level (MacDonald and others, 2000)	n/a	9,790	n/a	n/a	990	43,400	n/a	31,600	35,800
Highest effect level (MacDonald and others, 2000)	n/a	33,000	n/a	n/a	4,980	111,000	n/a	149,000	128,000
Background[3]	n/a	10,000	260,000	n/a	n/a	50,000	n/a	16,900	16,600

Table 15. Concentrations and associated toxicity values for trace elements analyzed in bed-sediment samples collected at Fort Chaffee, Arkansas, 2002.--Continued

[Concentrations are reported as micrograms per kilogram except for TOC (total organic carbon), which is grams per kilogram; **bold** text represents samples that exceeded "lowest effect level" criteria and background concentrations; green text indicates values that met or exceeded only background concentrations; c, constituent detected in associated blank sample; e values were estimated; n/a, criteria not available; NS, not sampled]

	Manganese	Mercury	Molybdenum	Nickel	Selenium	Silver	Thallium	Zinc	TOC
Big Creek Site 1	9,100c	20e	290e,c	20,000	480e	74e,c	120e	48,000	13
Big Creek Site 2	620,000c	13e	360c	12,000	370e	84e,c	100e	28,000	7.1
Big Creek Site 3	710,000c	5.5e	440c	**23,000**	650e	140e,c	190e	57,000	16
Big Creek Site 4	500,000c	16e	280e,c	13,000	430e	67e,c	100e	31,000	8
Christmas Knob Lake	16,000c	<7	99e,c	340	85e	19e,c	29e	1,400e	27
Darby Lake	890,000c	43e	390e,c	16,000	550e	87e,c	120e	59,000	17
Engineer Lake	36,000c	<9	58e,c	700c	<127	13e,c	6.6e	2,300e	20
Gin Creek	300,000c	10e	330c	14,000	430e	60e,c	74e	31,000	5.9
Grayson Creek	13,000c	21e	670c	**24,000**	680e	130e,c	140e	79,000	13
Mendenhall Swamp Lake	29,000c	ND	290e,c	970c	70e	39e,c	57e	5,000	24
Vache Grasse Creek Site 1	6,000c	19e	250e,c	10,000	360e	62e,c	80e	37,000	5.8
Vache Grasse Creek Site 2[1]	790,000c	30e	300e	18,000	510e	130e,c	140e	52,000	7.4
Vache Grasse Creek Site 2[1]	710,000c	26e	260e	16,000	450e	88e,c	120e	45,000	NS
Minimum detection limit[2]	107	4-11	6	34	127	6	3	500-1,600	0.59
Reporting limit[2]	465	48-150	517	258	1,283	258	258	1,400-4,600	2
Median (for Fort Chaffee samples)	168,000	19	290	13,500	430	70.5	100	34,000	13
Lowest effect level (MacDonald and others, 2000)	n/a	180	n/a	22,700	n/a	n/a	n/a	121,000	n/a
Highest effect level (MacDonald and others, 2000)	n/a	1,060	n/a	48,600	n/a	n/a	n/a	459,000	n/a
Background[3]	800,000	65	n/a	16,700	740	n/a	n/a	49,000	n/a

[1]Duplicate samples were analyzed at Vache Grasse Site 2.
[2]Analytical laboratory reported two minimum detection limits for some constituents and reporting limits.
[3]Estimated geochemical background for western Arkansas (Gustavsson and others, 2001).

Constituent concentrations at other sites provide evidence that environmental conditions are being influenced by on-post activities. Explosives and oil and grease were the most common organic constituents detected above the MDL in water samples. Bed-sediment samples from one site located on Grayson Creek, and nearest the administrative and residential (cantonment) area, had detections for several trace elements that were above background concentrations and concentrations for arsenic and nickel at this site exceeded lowest effect level criteria established by the U.S. Environmental Protection Agency. The site on Grayson Creek also had the only detections of DDT metabolites in bed sediment. Turbidity and excessive bed sediment deposition are chronic physical impairments that probably are influenced by on-post activities and that could be influencing the ecological integrity of Fort Chaffee streams to some degree.

Summary

The Fort Chaffee Maneuver Training Center is a facility used to train as many as 50,000 Arkansas National Guardsmen each year. Due to the nature of ongoing training and also to a poor understanding of environmental procedures that were practiced in the WWII era, areas within Fort Chaffee have the potential to be sources of a large number of contaminants. Because some streams flow on to Fort Chaffee, there is also the potential for sources that are off post to affect environmental conditions on post. To address these concerns the USGS in cooperation with the ANG, conducted a study to document constituent concentrations in water, fish tissue, and bed sediment collected from waterbodies on Fort Chaffee from September 2002 through July 2004. Constituent concentrations detected in the three media and measured at 13 sites were compared to national and regional criteria when available.

Concerning constituents that were analyzed in water samples, sites on Vache Grasse Creek, and particularly Site 0, a site immediately downstream from an off-post wastewater-treatment facility, had both the highest number of detections and the highest concentrations detected of all the other sites sampled. Of the 55 organic constituents analyzed in water samples, only 10 were detected above the minimum detection limit (MDL) but four of those were explosives. No priority pollutants detected in water—arsenic, copper, lead, nickel, or zinc—were above aquatic life criteria established by the U.S. Environmental Protection Agency. All detections for arsenic and lead above the laboratory reporting limit (RL) occurred in high-flow event samples at Vache Grasse Creek Site 0. Five of the seven detections each for nickel and zinc also were from sites located on Vache Grasse Creek. Detections for copper were more common in the Big Creek drainage than in the Vache Grasse Creek drainage (six of seven detections). The estimated concentration of cadmium (above MDL but below RL) in a stormflow sample from Big Creek was above the aquatic life criterion.

Nutrient concentrations tended to be higher at sites located on Vache Grasse Creek than at other sampling sites. Of the three sites on Vache Grasse, and similar to other constituents, nutrient concentrations were highest at Vache Grasse Creek Site 0. High nutrient concentrations at this site could indicate released or overflowing effluent, which would provide some explanation for why total phosphorus concentrations were higher in baseflow samples than in stormflow samples.

Event-mean storm concentrations and storm loads calculated from stormflow samples at two sites each for Big and Vache Grasse Creeks indicate that storm loads were highest at the two Vache Grasse Creek sites for 24 of the 25 constituents detected. Further evaluation by normalizing storm loads at Big Creek to storm loads at Vache Grasse Creek by streamflow indicate that normalized event loads at Vache Grasse Creek were about two or more times higher than those at Big Creek for 15 of the 25 constituents measured.

Manganese and barium are not considered to be priority pollutants by USEPA but were detected above the RL for every water sample collected. Manganese concentrations tended to be higher in lake samples than in stream samples.

Mercury concentrations in edible fish tissue, which are a widespread concern in the United States (U.S. Environmental Protection Agency, 2001), exceeded an USEPA criterion for methylmercury of 300 µg/kg in four of nine samples; however, concentrations are typical of mercury concentrations in fish tissues for the State of Arkansas (U.S. Environmental Protection Agency, 2001b). The concentration of mercury in fish livers from Darby Lake was 66 percent higher than the NAWQA median at 285 sites and the concentration of nickel in fish livers from Vache Grasse Creek Site 0 was 45 percent higher than the NAWQA median at 140 sites. DDT and metabolites of DDT were the only organic compounds detected in bed sediment and were the most common compound detected in fish tissue samples. One site located on Grayson Creek, and nearest the administrative and residential (cantonment) area, had the only detections of DDT metabolites in bed sediment and values reported exceeded median concentrations at 45 of 46 NAWQA study units (including about 700 sites).

Trace element concentrations in bed-sediment samples slightly exceeded estimated geochemical background concentrations for soils in western Arkansas for arsenic, copper, lead, manganese, nickel, and zinc at one or more sites and slightly exceeded lowest effect level (toxicity) criteria at one site for arsenic and at two sites for nickel. The site located on Grayson Creek had detections that were above background concentrations for all six of the aforementioned constituents and, for arsenic and nickel, detections exceeded lowest effect level (toxicity) criteria established by the U.S. Environmental Protection Agency.

Concentrations of some trace elements in all media sampled for this study could be a consequence of on-post activities or conditions. One possible explanation for elevated trace element concentrations is that background concentrations seem to be higher in western Arkansas than for most other regions. However, another possible reason may be the redox potential of the aquatic environments sampled. Accumulated bed sediments and organic material in the bottom substrate may result in a high biochemical oxygen demand and a reducing environment for several of the waterbodies sampled, particularly where large amounts of sediments have been deposited. In this situation, trace elements such as manganese can occur in sediments in high concentrations, and under these reduced conditions their solubility (ability to mix with water) can increase. Turbidity may be a good surrogate for bed sedimentation and soil erosion. Mean turbidity for four of nine months for which data were collected exceeded 40 nephlometric turbidity units (NTUs); a state stream-stormflow standard for the Arkansas River Valley.

The constituents detected in water, fish tissue, and bed-sediment samples collected in this study indicate that land use activities both on and off post are influencing environmental conditions in waterbodies of Fort Chaffee. Contaminants such as explosives that were sometimes detected in water samples have an obvious relation to military training, and various chemical compounds used in the cantonment area since the WWII era may be the source of contamination in Grayson Creek. Elevated contaminant concentrations and storm loads in Vache Grasse Creek, particularly at Site 0, suggest that an off-post source could be impairing water quality. Some trace elements detected may result from the combined effects of sedimentation (a possible consequence of soil erosion resulting from training activities and an extensive road system) and trace element concentrations in soils that are higher than for most other regions. Turbidity data collected at the most downstream site on Vache Grasse Creek, and observations of substantial sediment deposition in both Vache Grasse and Big Creeks suggest that turbidity and excessive bed sediment deposition are chronic physical impairments that may be influencing the ecological integrity of Fort Chaffee streams.

References

Arkansas Department of Environmental Quality, 2004, Regulation 2, Regulation establishing water quality standards for the state of Arkansas, accessed 10/27/04 at URL http://www.adeq.state.ar.us/regs/default.htm

Chalmers, Ann, 2002, Trace elements and organic compounds in streambed sediment and fish tissue of coastal New England streams, 1998-99: U.S. Geological Survey Water-Resources Investigations Report 02-4179, 30 p.

Crawford, J.K., and Luoma, S.N., 1993, Guidelines for studies of contaminants in biological tissues for the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 92-494, 69 p.

Davis, J.V., and Bell, R.W., 1998, Water-quality assessment of the Ozark Plateaus study unit, Arkansas, Kansas, Missouri, and Oklahoma--Analysis of information on nutrients, suspended sediment, and suspended solids, 1970-92: U.S. Geological Survey Water-Resources Investigations Report 95-4042, 112 p.

Fenneman, N.M., 1938, Physiography of the eastern United States: New York, McGraw-Hill, 714 p.

Gustavsson, N., Bølviken, B., Smith, D.B., and Severson, R.C., 2001, Geochemical landscapes of the conterminous United States- New map presentations for 22 elements: U.S. Geological Survey Professional Paper 1648, 38 p.

Haley, B.R., Glick, E.E., Bush, W.V., Clardy, B.F., Stone, C.G., Woodward, M.B., and Zachry, D.L., 1993, Geologic map of Arkansas: Arkansas Geological Commission, scale 1:500,000.

Lamb, T.E., 1978, Water-quality investigation of the Vache Grasse Creek Drainage, Sebastian County, Arkansas: U.S. Geological Survey Open-File Report 78-903, 24 p.

MacDonald, D.D., Ingersoll, C.G., Berger, T.A., 2000, Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems: Archives of Environmental Contamination and Toxicology, v. 39, p. 20-31.

Mitsch W.J., and Gosselink, J.G., 1993, Wetlands, (2nd ed): Van Nostrand Reinhold, 722 p.

Nowell, L.H., Capel, P.D., and Dileanis, P.D., 1999, Pesticides in stream sediment and aquatic biota-Distribution, trends, and governing factors, in Gilliom, R.J., ed., Pesticides in the hydrologic system: U.S. Geological Survey National Water-Quality Assessment Program, v. 4, 1001 p.

Pais, I., and Jones, J. B., Jr., 1997, Handbook of trace elements in the environment: CRC Press, 223 p.

Petersen, J.C., 1988, Statistical summary of selected water-quality data (water years 1975 through 1985) for Arkansas rivers and streams: U.S. Geological Survey Water-Resources Investigations Report 88-4112, 189 p.

Rantz, S.E. and others, 1982, Measurement and computation of streamflow: U.S. Geological Survey Water Supply Paper 2175, 631p.

Shelton, L.R., and Capel, P.D., 1994, Guidelines for collecting and processing samples of stream bed sediment for analysis of trace elements and organic compounds for the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 94-458, 20 p.

Stober, Q.J., 1991, Guidelines for fish sampling and tissue preparation for bioaccumulative contaminants: U.S. Environmental Protection Agency, Environmental Services Division, Region 4, Athens, Georgia.

U.S. Department of Defense, 2000, Fort Chaffee History, accessed 9/07/2004 at URL http://www.5tharmy.army.mil/2_393/fort1.htm

U.S. Environmental Protection Agency, 1979, Quality criteria for water: U.S. Environmental Protection Agency, Washington, DC,. 259 p.

U.S. Environmental Protection Agency, 1983, Methods for chemical analysis of water and wastes: U.S. Environmental Protection Agency 600/4-79-020.

U.S. Environmental Protection Agency, 1986a, Methods for organic chemical analysis of municipal and industrial wastewater: Federal Register, 40 CFR 136, App. A, July 1, 1986.

U.S. Environmental Protection Agency, 1986b, Test methods for evaluating solid waste, physical/chemical methods, SW846 (3rd ed): U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency, 1993, Drinking water criteria document for manganese, accessed 11/02/2004 at URL http://www.epa.gov/waterscience/library/wqcriteria/manganese.pdf.

U.S. Environmental Protection Agency, 2001, Mercury update: Impact on fish advisories: U.S. Environmental Protection Agency, Office of Water, Washington, D.C,. EPA-823-F-01-011, 10 p.

U.S. Environmental Protection Agency, 1997, Barium compounds; toxic chemical release reporting; Community Right-to-Know, U. S. Environmental Protection Agency Federal Register, accessed 05/04/2004 at URL http://www.epa.gov/docs/fedrgstr/EPA-TRI/1997/January/Day-03/pr-64DIR/pr-64.html

U.S. Environmental Protection Agency, 2002, Aquatic life criteria: U.S. Environmental Protection Agency, Office of Water, Washington, D.C., accessed 05/04/2004 at URL http://www.epa.gov/waterscience/criteria/aqlife.html

U.S. Environmental Protection Agency, 2004, National recommended water quality criteria: U.S. Environmental Protection Agency, Office of Water, Washington, D.C., 822-R-02-047, 36 p. also can be accessed at URL http://www.epa.gov/waterscience/pc/revcom.pdf

Wagner, R.J., Mattraw, H.C., Ritz, G.F., and Smith, B.A., 2000, Guidelines and standard procedures for continuous water-quality monitors: Site selection, field operation, calibration, record computation, and reporting: U.S.Geological Survey Water-Resources Investigations Report 00-4252, 53 p.

Wilde, F.D. and Radke, D.B., 1998, Field measurements: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6, variously paginated.

Wilde, F.D., Radtke, D.B., Gibs, J., and Iwatsubo, R.T., 1999, National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water Resources Investigations, Book 9, Chapter A4, A5, A6.

Zappia, H., 2002, Organochlorine compounds and trace elements in fish tissue and streambed sediment in the Mobile River Basin, Alabama, Mississippi, and Georgia, 1998: U.S. Geological Survey Water-Resources Investigations Report 02-4160, 85 p.

APPENDIXES

Appendix 1. Sampling details and field parameters for lake sampling sites at Fort Chaffee, Arkansas, 2002 through 2003.

[° C, degrees Celsius; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; --, field meter malfunction, no data collected]

Sampling site	Sample type	Date sampled	Average sample depth (feet)	Average total depth (feet)	Water temperature (° C)	Dissolved oxygen (mg/L)	Specific conductance (µS/cm)	pH
Christmas Knob Lake	Baseflow	9/24/2002	2.7	6.5	23.3	5.4	46	6.4
Christmas Knob Lake	Baseflow	9/24/2002	9.0	6.5	22.4	3.2	68	6.2
Christmas Knob Lake	Stormflow	12/30/2003	1.3	6.0	7.3	5.0	56	6.9
Christmas Knob Lake	Stormflow	12/30/2003	4.8	6.0	7.1	4.5	56	6.8
Darby Lake	Baseflow	9/23/2002	2.5	12.4	24.4	6.5	46	6.7
Darby Lake	Baseflow	9/23/2002	9.7	12.4	23.5	5.7	46	6.6
Darby Lake	Stormflow	12/29/2003	1.3	5.8	8.9	--	72	7.5
Darby Lake	Stormflow	12/29/2003	4.6	5.8	8.8	--	72	7.5
Engineer Lake	Baseflow	9/24/2002	2.3	9.7	24.9	6.8	42	6.6
Engineer Lake	Baseflow	9/24/2002	9.3	9.7	24.4	6.4	42	6.5
Engineer Lake	Stormflow	12/29/2003	2.0	6.8	8.4	8.3	57	7.1
Engineer Lake	Stormflow	12/29/2003	8.1	6.8	8.4	8.1	57	7.1
Mendenhall Swamp Lake	Baseflow	9/24/2002	2.7	6.2	21.3	0.6	60	5.8
Mendenhall Swamp Lake	Baseflow	9/24/2002	7.0	6.2	21.4	1.0	113	6.0
Mendenhall Swamp Lake	Stormflow	12/30/2003	1.3	4.9	7.5	--	63	6.8
Mendenhall Swamp Lake	Stormflow	12/30/2003	4.5	4.9	6.7	--	63	6.7

Appendix 2. Sampling details and results for field and laboratory constituents measured at stream sampling sites on Fort Chaffee, Arkansas, 2002 through 2004.

[° C, degrees Celsius, mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; cols./100 mL, colonies per 100 milliliters; ft^3/s cubic foot per second; --, not sampled]

Sampling site	Sample type	Date sampled	Water temperature (° C)	Dissolved oxygen (mg/L)	Specific conductance (µS/cm)	pH	Fecal coliform bacteria (cols./ 100 mL)	Discharge (ft^3/s)	Alkalinity[1] (mg/L)	Hardness[1] (mg/L)
Big Creek Site 1	Baseflow	9/18/2002	23.2	4.0	190	7.9	300	0	--	--
Big Creek Site 1	Stormflow	3/19/2003	13.0	9.1	77	7.6	7,900	21.1	--	--
Big Creek Site 1	Eventflow	5/16/2003	--	--	124	7.4	--	--	--	--
Big Creek Site 2	Baseflow	9/17/2002	23.2	4.0	89	6.6	16	0	--	--
Big Creek Site 2	Stormflow	3/19/2003	15.6	9.2	45	8.6	1,630	91.3	--	--
Big Creek Site 3	Baseflow	9/17/2002	25.2	3.4	84	7.1	96	0	--	--
Big Creek Site 3	Stormflow	3/19/2003	13.9	9.5	55	7.6	8,000	37.6	--	--
Big Creek Site 4	Baseflow	9/17/2002	23.1	4.4	113	7.1	196	0	--	--
Big Creek Site 4	Stormflow	3/19/2003	13.6	8.8	49	7.7	18,400	37.6	--	--
Big Creek Site 4	Eventflow	5/17/2003	--	--	77	7.5	--	--	--	--
Big Creek Site 4	Baseflow	9/04/2003	25.2	9.1	106	7.1	38	0	98.2	34
Big Creek Site 4	Stormflow	1/18/2004	8.9	10.4	60	8.4	640	--	12.2	--
Gin Creek	Baseflow	9/18/2002	25.1	2.3	151	7.8	1,060	0	--	--
Gin Creek	Stormflow	3/20/2003	12.1	9.9	96	8.7	480	48	--	--
Grayson Creek	Baseflow	9/17/2002	27.5	4.8	153	7.1	192	0	--	--
Grayson Creek	Stormflow	3/20/2003	12.6	8.6	110	7.5	580	3.8	--	--
Vache Grasse Creek Site 0	Baseflow	11/5/2002	11.1	7.0	257	7.7	700	17.8	--	--
Vache Grasse Creek Site 0	Eventflow	5/17/2003	21.2	4.2	232	7.7	600	22.3	--	--
Vache Grasse Creek Site 0	Baseflow	9/04/2003	26.4	8.2	375	7.7	48	--	113.0	86
Vache Grasse Creek Site 0	Stormflow	1/18/2004	9.7	8.9	179	8.2	1,060	--	34.0	--
Vache Grasse Creek Site 1	Baseflow	9/18/2002	23.0	4.5	270	7.8	68	0.62	--	--
Vache Grasse Creek Site 2	Baseflow	9/16/2002	27.1	4.8	199	6.8	52	0.06	--	--
Vache Grasse Creek Site 2	Stormflow	5/16/2003	--	--	246	7.3	260	--	--	--
Vache Grasse Creek Site 2	Eventflow	5/18/2003	--	--	240	7.3	--	--	--	--
Vache Grasse Creek Site 2	Baseflow	9/04/2003	25.2	8.7	249	7.4	78	1.82	141.6	56
Vache Grasse Creek Site 2	Stormflow	1/18/2004	9.0	9.3	125	8.4	1,700	--	20.4	--

[1]Alkalinity and hardness analyses were analyzed only for selected samples.

Appendix 3. Daily mean values for stream stage data at Vache Grasse Creek Site 2 from November 2003 to July 2004.

[Values are in feet; ---, missing data]

Day	November	December	January	February	March	April	May	June	July
1	1.89	2.46	2.49	2.62	2.47	2.96	3.54	2.65	4.59
2	1.88	2.43	2.47	2.62	2.48	2.86	3.69	2.45	9.02
3	1.88	2.41	2.45	2.60	2.54	2.83	3.40	4.47	15.83
4	1.90	2.40	2.44	2.60	2.63	2.81	3.18	3.13	---
5	1.93	2.36	2.42	4.44	3.95	2.71	3.07	2.71	---
6	2.06	2.42	2.39	3.93	3.53	2.66	2.95	2.56	3.90
7	2.69	2.19	2.38	3.40	2.94	2.76	2.92	2.49	3.72
8	2.43	2.15	2.36	3.29	3.96	2.87	2.80	2.44	---
9	2.37	2.25	2.34	3.09	4.68	2.78	2.72	2.40	---
10	2.25	2.33	2.33	2.91	4.74	3.62	2.67	2.42	---
11	2.11	2.58	2.32	2.85	4.70	4.28	2.69	2.87	---
12	2.01	2.45	2.31	2.82	4.68	3.49	2.57	2.97	---
13	1.97	2.40	2.34	2.79	4.72	3.23	2.54	---	3.20
14	1.95	2.39	2.35	2.76	4.53	3.04	2.58	---	2.88
15	1.95	---	2.36	2.72	3.82	2.96	2.59	2.38	---
16	1.93	---	2.49	2.70	3.25	2.89	2.52	7.35	---
17	1.98	2.44	3.60	2.67	4.20	2.81	2.48	12.29	---
18	2.41	2.44	3.31	2.64	8.24	2.80	2.47	4.15	2.63
19	2.77	2.43	2.99	2.63	4.81	2.67	2.43	3.83	2.71
20	2.65	2.40	2.84	2.62	3.51	2.67	2.38	---	2.65
21	2.50	2.39	2.75	2.60	3.29	2.94	2.36	---	2.58
22	2.41	2.37	2.70	2.56	3.10	9.06	2.34	7.79	2.50
23	2.37	2.34	2.65	2.58	2.99	9.38	2.31	7.48	2.47
24	2.32	2.33	2.61	2.59	3.02	11.29	2.30	---	2.51
25	2.55	2.38	3.07	2.54	3.31	13.26	2.30	3.72	2.52
26	2.45	2.40	3.16	2.50	3.16	5.05	2.30	3.50	2.51
27	2.43	2.37	2.89	2.47	3.01	3.79	2.29	3.32	2.70
28	2.44	2.39	2.78	2.47	3.13	3.43	2.32	3.13	2.55
29	2.54	2.56	2.73	2.46	3.42	3.27	2.32	3.23	---
30	2.49	2.62	2.69	---	3.20	3.26	2.35	4.59	2.53
31	---	2.54	2.65	---	3.02	---	2.89	---	2.53
Minimum	1.88	2.15	2.31	2.46	2.47	2.66	2.29	2.38	2.47
Maximum	2.77	2.62	3.60	4.44	8.24	13.26	3.69	12.29	15.83
Mean	2.25	2.40	2.63	2.81	3.71	4.15	2.65	4.01	3.83

Appendix 4. Daily mean values for water temperature data at Vache Grasse Creek Site 2 from November 2003 to July 2004.

[Temperature in degrees Celsius; ---, missing data]

Day	November	December	January	February	March	April	May	June	July
1	17.5	6.4	6.3	3.3	9.7	14.1	19.1	24.2	23.3
2	17.3	6.2	7.6	3.9	10.7	14.6	17.1	24.3	22.4
3	17.4	6.5	9.2	3.5	11.4	15.1	16.6	21.5	22.5
4	18.3	6.8	10.1	3.5	12.2	15.3	17.0	22.2	---
5	17.1	6.4	8.1	3.6	13.4	15.1	18.4	21.5	---
6	15.1	5.9	5.6	4.9	13.2	15.5	19.6	22.2	25.4
7	13.8	5.7	4.1	4.3	12.5	16.1	20.8	23.6	24.8
8	12.6	6.4	3.7	3.2	11.9	16.8	21.5	24.5	---
9	12.4	7.9	3.8	3.8	12.5	16.9	21.9	24.2	---
10	12.3	6.5	3.6	4.6	12.1	15.9	22.4	24.1	---
11	13.2	5.4	3.5	5.2	12.4	15.7	22.7	24.2	---
12	14.8	4.9	4.0	5.3	12.0	14.9	22.8	25.2	---
13	13.1	4.9	5.0	4.6	11.7	14.3	22.6	---	---
14	11.8	4.7	6.1	4.6	11.3	14.0	21.6	---	27.8
15	11.4	---	6.3	4.8	11.5	15.2	20.4	---	---
16	12.2	---	6.6	5.1	11.6	16.9	20.2	24.6	---
17	12.9	4.5	7.6	6.0	11.9	18.6	20.9	24.0	---
18	13.7	4.4	8.7	6.5	13.6	19.7	21.9	24.2	27.4
19	13.0	4.3	6.7	7.8	14.6	19.7	23.2	24.4	26.6
20	12.0	4.0	4.7	9.3	15.3	19.4	24.4	---	26.8
21	11.9	4.2	4.5	9.0	15.1	19.1	25.1	---	27.6
22	12.9	5.5	4.4	9.0	13.9	17.4	25.1	22.0	28.0
23	12.9	6.4	4.4	9.3	14.5	18.8	25.1	22.5	28.1
24	9.9	5.6	5.5	9.8	14.9	18.2	25.1	---	27.8
25	8.2	5.0	7.1	9.3	14.9	18.4	24.6	23.6	26.5
26	8.1	5.0	7.9	8.6	16.2	18.0	24.4	23.8	---
27	8.4	5.5	5.4	8.3	17.6	17.7	24.7	23.9	---
28	7.3	6.8	3.4	8.5	17.9	18.2	25.2	24.3	24.0
29	6.3	6.9	3.4	9.0	16.4	18.7	25.7	24.6	---
30	6.2	5.9	3.5	---	16.0	19.0	26.0	23.2	23.3
31	---	5.5	3.0	---	14.8	---	24.6	---	---
Minimum	6.2	4.0	3.0	3.2	9.7	14.0	16.6	21.5	22.4
Maximum	18.3	7.9	10.1	9.8	17.9	19.7	26.0	25.2	28.1
Mean	12.5	5.7	5.6	6.2	13.5	16.9	22.3	23.6	25.8

Appendix 5. Daily mean values for specific conductance at Vache Grasse Creek Site 2 from November 2003 to July 2004.

[Values are in microsiemens per centimeter at 25 degrees Celsius; ---, missing data]

Day	November	December	January	February	March	April	May	June	July
1	---	---	182	113	188	124	134	323	97
2	---	310	186	115	197	118	127	299	72
3	---	281	193	122	198	135	118	150	50
4	---	259	196	122	175	131	129	133	---
5	---	250	204	95	140	127	134	165	---
6	---	251	206	118	130	147	143	183	125
7	223	259	210	114	109	146	160	196	145
8	217	259	212	111	129	137	161	207	---
9	247	263	217	107	127	159	167	215	---
10	281	238	229	101	125	116	195	220	---
11	302	271	232	121	124	115	214	226	---
12	313	276	235	120	126	115	212	245	---
13	314	268	231	118	143	113	190	---	---
14	312	267	223	121	133	115	187	---	175
15	311	---	217	123	134	116	212	---	---
16	312	---	188	125	139	118	226	139	---
17	312	241	132	127	144	129	254	76	---
18	309	239	120	132	95	140	294	130	235
19	---	239	114	136	110	132	252	139	260
20	---	241	113	138	111	138	236	---	299
21	---	237	111	140	114	149	232	---	287
22	---	236	109	142	116	91	236	91	263
23	---	236	107	143	114	86	233	88	280
24	---	241	104	145	120	68	245	---	278
25	---	253	101	153	116	70	252	126	273
26	---	268	124	152	121	102	255	141	---
27	288	275	121	153	114	116	264	143	---
28	284	265	126	160	116	117	268	155	320
29	299	256	121	173	122	129	271	171	---
30	---	221	116	---	119	132	272	125	259
31	---	190	114	---	119	---	284	---	---
Minimum	217	190	101	95	95	68	118	76	50
Maximum	314	310	235	173	198	159	294	323	320
Mean	288	253	164	129	131	121	212	170	214

Appendix 6. Daily mean values for turbidity data at Vache Grasse Creek Site 2 from November 2003 to July 2004.

[Data are in nephlometric turbidity units; ---, missing data]

Day	November	December	January	February	March	April	May	June	July
1	---	80	13	20	12	25	---	55	85
2	---	40	14	20	9.9	22	---	60	170
3	---	13	14	18	9.7	20	50	220	130
4	---	10	16	18	44	20	37	77	---
5	---	8.6	16	200	280	24	34	71	---
6	---	5.2	16	120	140	26	33	66	40
7	22	3.5	---	44	52	---	33	64	34
8	39	1.7	---	43	41	13	33	57	---
9	19	---	---	37	34	9.8	33	51	---
10	21	---	6.6	32	31	130	32	51	---
11	23	14	6.6	27	28	130	28	67	---
12	42	13	14	24	26	41	29	52	---
13	16	19	16	21	22	26	30	---	---
14	11	12	18	20	22	20	34	---	20
15	9.1	---	9.7	19	25	19	51	---	---
16	7.6	---	14	18	21	21	29	340	---
17	9.1	17	120	18	20	21	32	130	---
18	19	16	88	16	430	22	29	89	15
19	29	12	61	17	110	22	31	86	17
20	16	22	37	17	67	19	31	---	16
21	18	17	28	15	50	32	30	---	13
22	19	13	24	13	35	430	27	260	21
23	18	13	22	13	31	300	26	170	40
24	31	12	21	12	33	510	26	---	33
25	33	11	41	12	40	140	25	---	25
26	39	8.9	52	11	42	100	24	25	---
27	58	8.2	47	11	38	70	26	24	---
28	53	9.3	37	10	40	54	30	23	17
29	14	12	29	11	53	45	32	23	---
30	20	12	25	---	60	55	36	140	24
31	---	14	22	---	35	---	81	---	---
Minimum	7.6	1.7	6.6	10	9.7	9.8	24	23	13
Maximum	58	80	120	200	430	510	81	340	170
Mean	24	15	30	30	61	82	34	96	44

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