USGS
science for a changing world

# Stream-Water Quality, Fort Cobb Reservoir Watershed, November 2004 to May 2007

Chapter 7 of
**Assessment of Conservation Practices in the Fort Cobb Reservoir Watershed, Southwestern Oklahoma**

Compiled by the U.S. Geological Survey and the Agricultural Research Service

Scientific Investigations Report 2010–5257

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

# Stream-Water Quality, Fort Cobb Reservoir Watershed, November 2004 to May 2007

By Carol J. Becker, Jean L. Steiner, and John A. Daniel

Chapter 7 of
**Assessment of Conservation Practices in the Fort Cobb Reservoir Watershed, Southwestern Oklahoma**

Compiled by the U.S. Geological Survey and the Agricultural Research Service

Scientific Investigations Report 2010–5257

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

**U.S. Department of the Interior**
KEN SALAZAR, Secretary

**U.S. Geological Survey**
Marcia K. McNutt, Director

U.S. Geological Survey, Reston, Virginia: 2011

This and other USGS information products are available at http://store.usgs.gov/
U.S. Geological Survey
Box 25286, Denver Federal Center
Denver, CO 80225

To learn about the USGS and its information products visit http://www.usgs.gov/
1-888-ASK-USGS



Suggested citation:
Becker, C.J., Steiner, J.L., and Daniel, J.A., 2011, Stream-water quality, Fort Cobb Reservoir watershed, November 2004 to May 2007, chap. 7 *of* Becker, C.J., ed., Assessment of conservation practices in the Fort Cobb Reservoir watershed, southwestern Oklahoma: U.S. Geological Survey Scientific Investigations Report 2010–5257, 50 p.

# Contents

# Figures

# Tables

# Conversion Factors

SI to Inch/Pound

| Multiply | By | To obtain |
|---|---|---|
| | Length | |
| millimeter | 0.039 | inch |
| | Area | |
| hectare | 2.47 | acre |
| square kilometer ($km^2$) | 0.3861 | square mile |
| | Volume | |
| liter | 0.264 | gallon |
| | Flow Rate | |
| cubic meter per second ($m^3/s$) | 35.311 | cubic foot per second ($ft^3/s$) |
| | Mass | |
| metric ton per year | 1.102 | ton per year |
| metric ton per year | 0.001 | kilogram per year |
| milligram per second (mg/s) | 31.6888 | metric ton per year |
| kilogram per year (kg/yr) | 2.205 | pound per year |

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

$°F = (1.8 \times °C) + 32$

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

$°C = (°F - 32) / 1.8$

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Altitude, as used in this report, refers to distance above the vertical datum.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in water are given in milligrams per liter (mg/L). Laboratory reporting level (LRL) — The LRL is generally equal to twice the yearly determined long-term method detection (LT–MDL). The LRL controls false negative error. The probability of falsely reporting a nondetection for a sample that contained an analyte at a concentration equal to or greater than the LRL is predicted to be less than or equal to 1 percent. The value of the LRL will be reported with a "less than" remark code for samples in which the analyte was not detected. The National Water Quality Laboratory collects quality-control data from selected analytical methods on a continuing basis to determine LT–MDLs and to establish LRLs. These values are reevaluated annually based on the most current quality-control data, and therefore, may change (Childress and others, 1999).

# Stream-Water Quality, Fort Cobb Reservoir Watershed, November 2004 to May 2007

By Carol J. Becker,[1] Jean L. Steiner,[2] and John A. Daniel[2]

## Abstract

The Fort Cobb Reservoir watershed encompasses about 813 square kilometers of rural farm land in Caddo, Custer, and Washita Counties in southwestern Oklahoma. From November 2004 to May 2007 the U.S. Geological Survey (USGS) Oklahoma Water Science Center and Agricultural Research Service, Grazinglands Research Laboratory, collaborated on a project to measure streamflow, water properties, and nutrient-compound and suspended-sediment concentrations in water-quality samples collected at three USGS streamflow-gaging stations. Additionally, from January 2005 to May 2007 the Agricultural Research Service, Grazinglands Research Laboratory measured nutrient-compound and suspended-sediment concentrations at 15 sites distributed throughout the streamflow network upstream from the Fort Cobb reservoir.

Streamflows tend to be highest in the spring months of March, April, and May, decrease through the summer months, and increase during October and November. Cobb Creek carries the greatest portion of streamflow in the watershed, about 73 percent. Measurements of specific conductance, dissolved oxygen, and alkalinity were significantly higher during base flow than runoff at Cobb Creek, Lake Creek, and Willow Creek. These water properties also were substantially higher during the dormant season (October-April) than the growing season (May-September) in Cobb and Willow Creeks.

Water-quality samples collected by the USGS indicate that Cobb Creek generally had higher concentrations of all nitrogen compounds than Lake Creek and Willow Creek. Higher concentrations were evident during both seasons and streamflow conditions. Water-quality samples collected by the Agricultural Research Service, Grazinglands Research Laboratory indicated that three sites on Cobb Creek had the highest mean concentrations of nitrate nitrogen (of 15 sites) in the watershed.

Organic nitrogen was the largest component of total nitrogen in samples collected from the three streams; 70 to 80 percent of nitrogen measured in water-quality samples was in the form of organic nitrogen transported in streams during runoff conditions. At all three streams, ammonia nitrogen, ammonia plus organic nitrogen, organic nitrogen, and total nitrogen concentrations were highest during the growing season during runoff, similar to trends shown in concentrations of phosphorus (dissolved), total phosphorus, orthophosphate, and suspended sediment.

Water-quality samples collected by the USGS indicate during runoff and the growing season, water in Willow Creek had the highest mean concentrations of dissolved phosphorus and orthophosphate, with Lake Creek having the lowest concentrations during these conditions. Water-quality samples collected by the Agricultural Research Service, Grazinglands Research Laboratory showed similar results; the highest mean concentrations of orthophosphate and dissolved phosphorus were in samples collected at a site on Cherry Dale Creek, about 2 to 3 miles upstream from where the USGS collected samples from Willow Creek. Cobb Creek had the highest mean concentrations of total phosphorus during both seasons and streamflow conditions, with the highest concentration occurring during runoff.

Suspended sediment measured by the USGS indicates that Cobb Creek transported the highest concentrations of suspended sediments in the watershed, with Willow Creek transporting the highest percentage of fine-suspended sediment. Sixty-five percent of the suspended sediment transported by Willow Creek on sampled days during the study period was clay to silt sized, compared to 55 percent by Cobb Creek and 53 percent by Lake Creek. The volume of suspended sediment in all three creeks was directly related to streamflow, and as expected, was significantly higher in samples collected during runoff than during base

[1] U.S. Geological Survey, Oklahoma Water Science Center, Oklahoma City, Oklahoma.

[2] Agricultural Research Service, Grazinglands Research Laboratory, El Reno, Oklahoma.

flow. Although streamflow was not significantly higher during the growing season, the concentration of suspended sediment was somewhat greater in samples collected during that part of the year, and was significantly higher in Cobb Creek samples indicating that agricultural activities may increase the volume of suspended sediment in the streams. The Agricultural Research Service, Grazinglands Research Laboratory measured the highest concentrations of suspended sediment at Fivemile Creek, a tributary of Cobb Creek, and the next highest concentrations at four sites on Lake Creek. At sustained streamflows of 100 cubic feet per second the quantity of sediment transported in Cobb Creek, Lake Creek, and Willow Creek ranged from 200 to 1,000 metric tons per day, with about 200 to 400 metric tons composed of silt and clay.

# Introduction

The Fort Cobb Reservoir watershed encompasses about 813 square kilometers of rural farm land in Caddo, Custer, and Washita Counties in southwestern Oklahoma (fig. 1). The largest water body in the watershed is the Fort Cobb Reservoir with a surface area of 1,659 hectares at normal-pool elevation. The combination of agricultural activities and the vulnerability of soils to erosion have caused water-quality issues for the three major tributaries that drain the watershed, Cobb Creek, Lake Creek, and Willow Creek, and the Fort Cobb Reservoir.

The reservoir and six stream segments were identified on the Oklahoma 1998 Clean Water Act Section 303(d) list as not supporting the designated beneficial uses because of impairment from nutrients, suspended solids, siltation, pesticides, and unknown toxicity (Storm and others, 2003a). The Fort Cobb Reservoir was listed on the Oklahoma 303(d) list in 2002 for water-quality impairment from excessive phosphorus, Willow Creek was listed for pathogens, and Lake Creek was listed for unknown contaminants, low dissolved oxygen, and turbidity (Oklahoma Department of Environmental Quality, 2002). Water-quality data collected from 1998 through 2001 for preliminary Total Maximum Daily Load computations estimated the tributaries were carrying a sediment load to the Fort Cobb Reservoir (excluding roads) of 276,000 metric tons per year and a phosphorus load of 65.43 metric tons per year during those four years (Yue and Derichsweiler, 2005). Conservation practices have decreased erosion and the transport of phosphorus to the reservoir; from 1998 to 2005 phosphorus loading was reduced by 20 percent (Yue, 2006). Water quality in the tributaries also has improved. The Index of Biological Integrity score for Lake Creek improved from 1990 to 1998, resulting in removal of Lake Creek from the 303(d) list in 2002 (U.S. Environmental Protection Agency, 2007).

The Natural Resources Conservation Service and Agricultural Research Service selected the Fort Cobb Reservoir watershed in 2003 as one of 14 Benchmark Watersheds under the Conservation Effectiveness Assessment Project (CEAP). CEAP is a multiagency effort established to quantify the environmental benefits resulting from agricultural conservation programs at a national level and in selected case-study projects where benefits of specific conservation practices can be evaluated at a watershed scale (Mausbach and Dedrick, 2004).

From November 2004 to May 2007 the U.S. Geological Survey (USGS) Oklahoma Water Science Center and Agricultural Research Service, Grazinglands Research Laboratory (ARS GRL), collaborated on a project to measure water properties, streamflow, and suspended-sediment and nutrient-compound concentrations in water-quality samples collected at three USGS streamflow-gaging stations and suspended-sediment and nutrient-compound concentrations in water-quality samples collected at 15 sites in the Fort Cobb Reservoir watershed. The purpose of the data collection was to support CEAP by measuring nutrient and sediment concentrations in streams over a range of streamflow conditions and seasons to provide information for assessing the success of conservation programs implemented in the watershed.

## Purpose and Scope

The purpose of this chapter is to describe (1) stream-water quality, including water properties and nutrient-compound and suspended-sediment concentrations in water-quality samples collected at three USGS streamflow-gaging stations upstream from the Fort Cobb reservoir in Caddo county, Oklahoma, from November 2004 through May 2007 and (2) nutrient-compound and suspended-sediment concentrations of water-quality samples collected bi-weekly at 15 stream sites distributed throughout the Fort Cobb Reservoir watershed from January 2005 through May 2007.

The scope of work for the USGS entailed sampling streams at three USGS streamflow-gaging stations (fig. 1); collecting 35 water-quality samples at Cobb Creek near Eakly, Oklahoma, (07325800), 34 water-quality samples at Lake Creek near Eakly, Oklahoma, (07325850), and 34 water-quality samples at Willow Creek near Albert, Oklahoma, (07325860). Water-quality samples were collected during base-flow and runoff conditions and analyzed for nitrite nitrogen, nitrite plus nitrate nitrogen, ammonia nitrogen, phosphorus, and orthophosphate in filtered water and ammonia plus organic nitrogen and total phosphorus in unfiltered water (table 1). All nitrogen compounds in this report are reported in milligrams per liter (mg/L) as nitrogen. Orthophosphate is reported in milligrams per liter as phosphorus. Streamflow, the water properties—specific conductance, pH, water temperature, and dissolved oxygen—alkalinity, suspended sediment, and fine-suspended sediment (less than 0.063 millimeter (mm), were measured. Turbidity was measured during 17 sampling events. Four precipitation samples were collected in March 2006, October 2006, April 2007, and

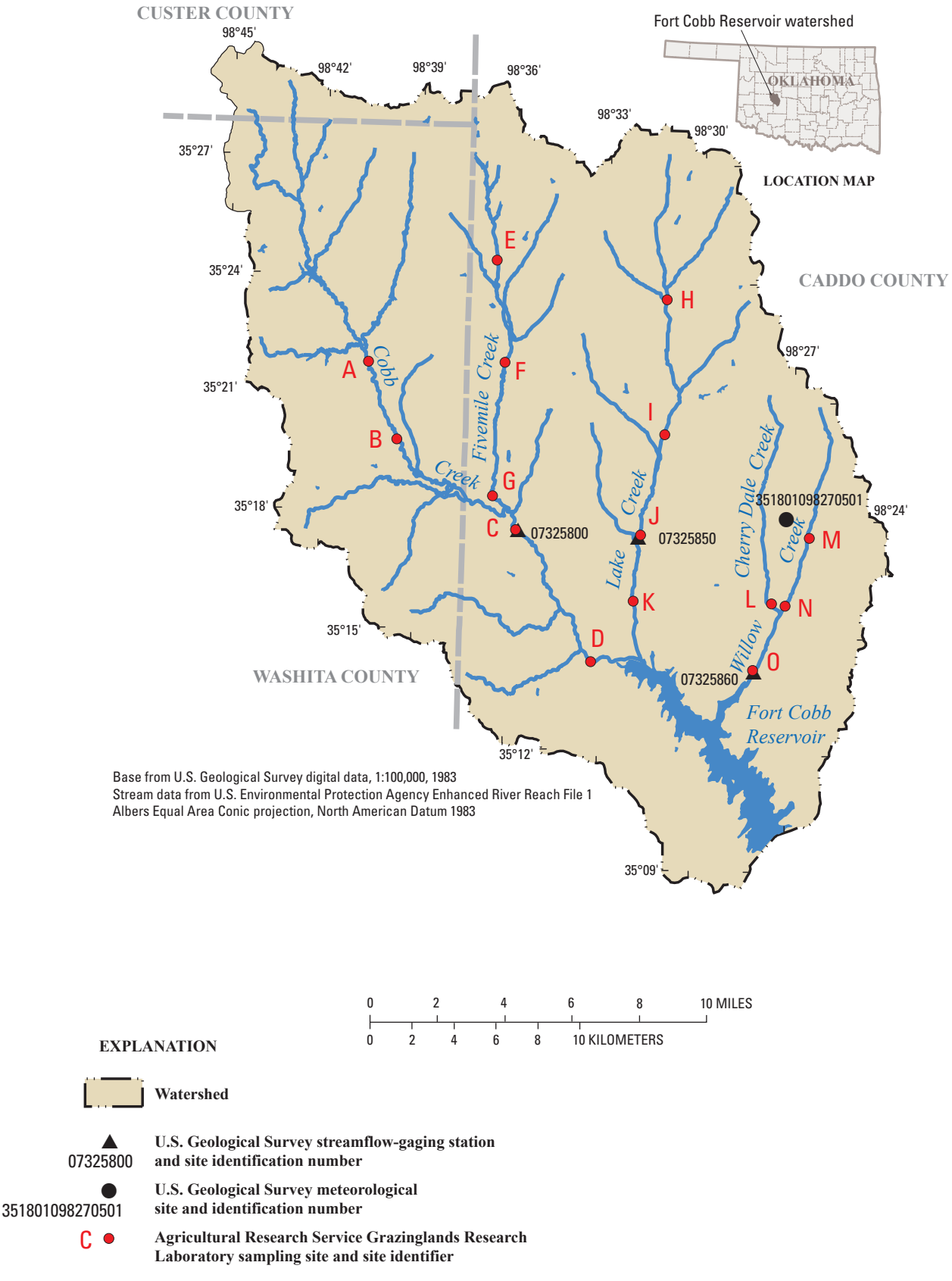


**Figure 1.** Location of the Fort Cobb Reservoir watershed, U.S. Geological Survey streamflow-gaging stations, meteorological site, and Agricultural Research Service, Grazinglands Research Laboratory sample sites, southwestern Oklahoma.

**Table 1.** Constituents measured in water samples collected at U.S. Geological Survey streamflow-gaging stations and meteorological site and at sites sampled by the Agricultural Research Service, Grazinglands Research Laboratory, Fort Cobb Reservoir watershed, southwestern Oklahoma, November 2004 to May 2007.

[USGS, U.S. Geological Survey; ARS GRL, Agricultural Research Service, Grazinglands Research Laboratory; $ft^3/s$, cubic feet per second; mg/L, milligrams per liter; NTU, nepheletic turbidity units; N, nitrogen; µS/cm, microsiemens per centimeter at 25 degrees Celsius; $CaCO_3$, calcium carbonate; P, phosphorus; °C, degrees Celsius]

| Constituents measured | Stream samples | Precipitation | Method |
|---|---|---|---|
| USGS water properties | | | |
| Instantaneous streamflow ($ft^3/s$) | X | | Wilde and Radtke (1998) |
| Specific conductance, field (µS/cm) | X | | Wilde and Radtke (1998) |
| pH, field (standard units) | X | | Wilde and Radtke (1998) |
| Water temperature, field (°C) | X | | Wilde and Radtke (1998) |
| Turbidity (NTU) | X | | Wilde and Gibs (1998) |
| Dissolved oxygen, field (mg/L) | X | | Wilde and Radtke (1998) |
| Alkalinity, field (mg/L as $CaCO_3$) | X | | Wilde and Radtke (1998) |
| USGS nutrients and suspended sediment | | | |
| Nitrite nitrogen (mg/L as N), dissolved | X | X | Fishman (1993) Method ID: I-2540-90, I-2542-89 |
| Nitrite plus nitrate nitrogen (mg/L as N), dissolved | X | X | Fishman (1993) Method ID: I-2546-91 |
| Ammonia nitrogen (mg/L as N), dissolved | X | X | Fishman (1993) Method ID: I-2522-90, I-2525-89 |
| Ammonia plus organic nitrogen (mg/L as N), total | X | | Patton and Truitt (2000) Method ID: I-4515-91 |
| Total nitrogen (mg/L), dissolved | | X | Patton and Kryskalla (2003) Method ID: I-2650-03 |
| Phosphorus (mg/L), dissolved | X | X | U.S. Environmental Protection Agency (1983) |
| Total phosphorus (mg/L), total | X | | Patton and Kryskalla (2003) Method ID: I-4650-03 |
| Orthophosphate (mg/L as P), dissolved | X | | Fishman (1993) Method ID: I-2601-90, I-2606-89 |
| Suspended sediment (mg/L) | X | | Edwards and Glysson (1999) |
| ARS GRL nutrients and suspended sediment | | | |
| Nitrate nitrogen (mg/L as N), dissolved | X | | U.S. Environmental Protection Agency (1983) |
| Orthophosphate (mg/L as P), dissolved | X | | U.S. Environmental Protection Agency (1983) |
| Phosphorus (mg/L), dissolved | X | | U.S. Environmental Protection Agency (1983) |
| Suspended sediment (mg/L) | X | | U.S. Environmental Protection Agency (1983) |

May 2007 with an automatic bucket sampler. Filtered water samples were analyzed for nitrite nitrogen, nitrite plus nitrate nitrogen, ammonia nitrogen, total nitrogen, and phosphorus.

The ARS GRL collected water-quality samples biweekly at 15 stream sites for a total of 60 samples (fig. 1). Samples were collected at four sites on Cobb Creek (A-D), three sites on Fivemile Creek (a tributary of Cobb Creek) (E, F, and G), four sites on Lake Creek (H-K), one site on Cherry Dale Creek (a tributary of Willow Creek) (L), and three sites on Willow Creek (M, N, and O). Three sites, C, J, and O were near the USGS streamflow-gaging stations on Cobb Creek, Lake Creek, and Willow Creek. Water-quality samples were analyzed for nitrate nitrogen, orthophosphate, and phosphorus in filtered water and suspended-sediment concentrations (table 1).

## Previous Studies

In 2000, the USGS Columbia Environmental Research Center, Columbia, Missouri, studied the Fort Cobb Reservoir watershed to evaluate the influence of streamflow on nutrient loading to Fort Cobb Reservoir (Fairchild and others, 2004). The study found that nutrient loading to the reservoir (total phosphorus and total nitrogen) responded differently by season and tributary. Loading of phosphorus and nitrogen was highest mostly in early spring in association with peak streamflow and was strongly streamflow dependant. Total-phosphorus loading from Cobb Creek (total mean 139 milligrams per second (mg/s) (4,405 metric tons per year) was substantially greater than that of Lake Creek (15 mg/s) (475 metric tons per year) or Willow Creek (7 mg/s) (222 metric tons per year). Cobb Creek, which comprises 62 percent of the watershed, was reported to deliver 86 percent of the total phosphorus load to the reservoir.

Fairchild and others (2004) reported that total-nitrogen loading from Cobb Creek (1,199 mg/s) (37,995 metric tons per year) was substantially greater than loading by Lake Creek (194 mg/s) (6,147 metric tons per year) or Willow Creek (63 mg/s) (1,996 metric tons per year). The study found that Cobb Creek delivered 82 percent of the total-nitrogen load, which was similar in proportion to total phosphorus and greater than the actual watershed percentage (62 percent). Total-nitrogen loading was substantially greater (about a two-fold increase) during the growing season (May to September), which was attributed to the greater streamflow during this period because of the influence of spring rainfall. Fairchild and others (2004) also reported that seasonal trends of total-nitrogen loading for the three tributaries had the same relative trends as streamflow and total-phosphorus loading.

# Methods

## Stream Water-Quality Data Collection and Analysis

The USGS collected streamflow and water-quality data at three continuous streamflow-gaging stations in the Fort Cobb watershed from November 2004 to May 2007 for this study. Streamflow gages were operated and streamflows were measured according to methods described in Rantz and others (1982). Representative water-quality samples were collected during base-flow and runoff conditions by using equal-width increment methods (Edwards and Glysson, 1999). Instantaneous streamflow and the water properties specific conductance, pH, water temperature, and dissolved oxygen were measured in addition to alkalinity and suspended-sediment concentration. Water samples were analyzed for nitrite nitrogen, nitrite plus nitrate nitrogen, ammonia nitrogen, orthophosphate, and phosphorus in filtered water, and ammonia plus organic nitrogen and total phosphorus in unfiltered water (table 1). Concentrations of nitrate nitrogen, organic nitrogen, and total nitrogen were estimated for water-quality samples from summation of concentrations of other nitrogen compounds measured in the laboratory. Water samples were analyzed for nitrogen and phosphorus compounds at the USGS National Water Quality Laboratory in Lakewood, Colorado. Samples of suspended sediment were analyzed for the concentration of suspended materials and the percent of fine-grained material less than 0.063 millimeters in diameter (clay and silt sized) in the samples. Suspended-sediment concentrations were analyzed at the USGS Sediment Laboratory in Rolla, Missouri (Guy, 1969). All streamflow and water-quality data are available through the World Wide Web at http://waterdata.usgs.gov/ok/nwis.

Water-quality data collected by the USGS were separated into groups based on streamflow and season to determine if these factors influenced stream-water quality. Streamflow was separated into base-flow and runoff groups determined by the daily-mean streamflow on the day of water-quality sampling (fig. 2). The daily-mean streamflow (not instantaneous streamflow) for each site was retrieved from the USGS National Water Information System and separated into base-flow and runoff components by using the hydrograph separation program, Base Flow Index (Institute of Hydrology, 1980a, 1980b; Wahl and Wahl, 1995), to determine whether streamflow conditions represented base flow or runoff on the days of water-quality sampling. Base flow is the component of

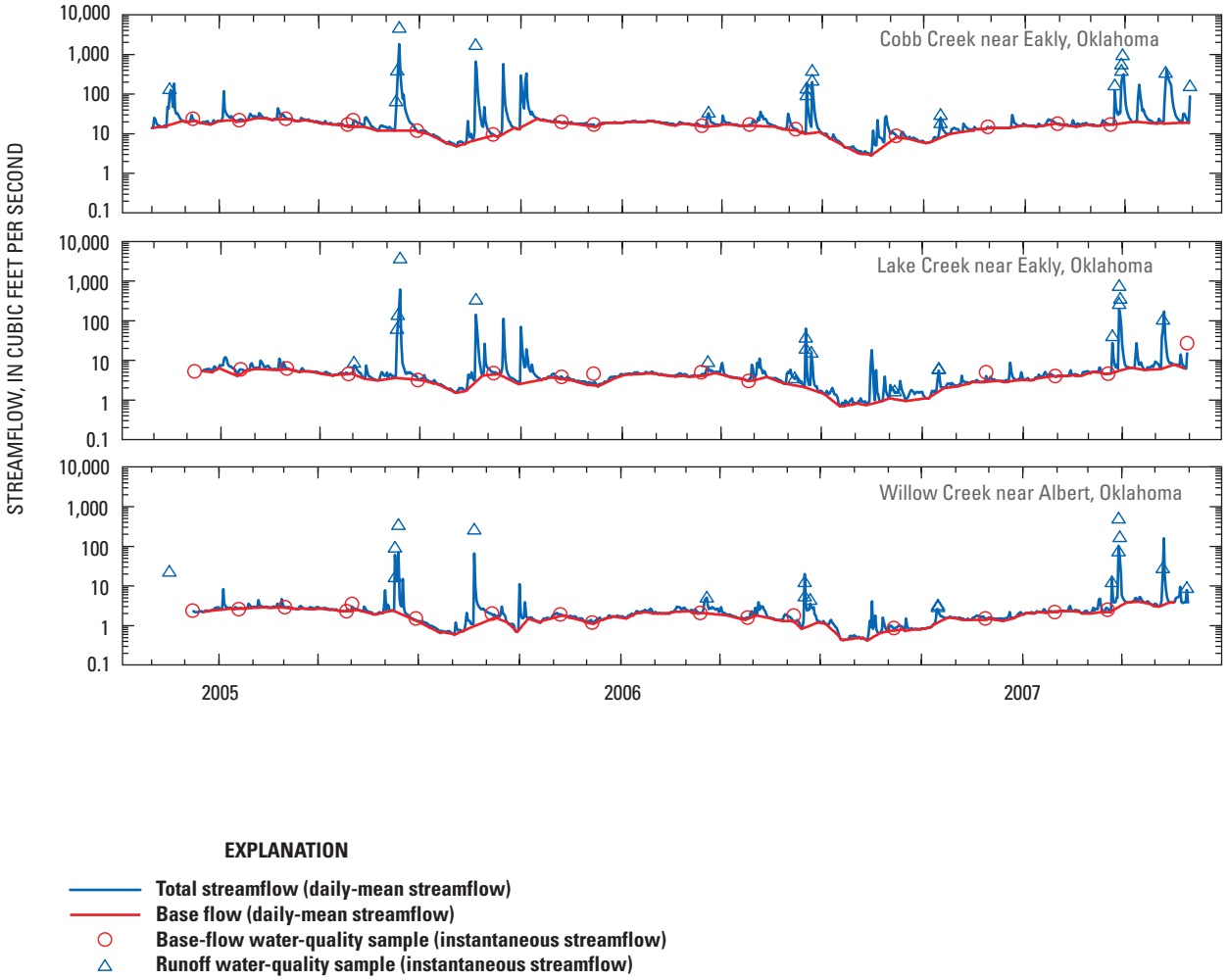


**Figure 2.** Total streamflow and base flow with base-flow and runoff water-quality samples collected at streamflow-gaging stations Cobb Creek near Eakly (07325800), Lake Creek near Eakly (07325850), and Willow Creek near Albert (07325860), Fort Cobb Reservoir watershed, southwestern Oklahoma, November 2004 to May 2007.

total streamflow that is derived from groundwater discharge, and runoff is the component of total streamflow derived from precipitation. Base-flow days were defined as days when total streamflow was composed of 70 percent or greater of base flow; runoff days were defined as days when runoff contributed more than 30 percent of total streamflow. Water-quality samples also were separated into seasonal groups: May through September were designated as the growing season and October through April as being the dormant season.

The quantity of suspended sediment that passes a stream cross section in a day is referred to as suspended-sediment discharge (Blumer, 1983). The suspended-sediment discharge was calculated by multiplying the instantaneous streamflow, in cubic feet per second, by suspended-sediment concentration in milligrams per liter and a factor 0.00245 to convert to metric tons per day. Fine-sediment discharge was calculated by multiplying the suspended-sediment discharge, in metric tons per day, by the mean clay-to-silt fraction determined from the samples analyzed by the USGS Sediment Laboratory in Rolla, Missouri. All constituent concentrations are reported as the mean concentration in this report unless otherwise noted.

The Mann-Whitney rank-sum test (Helsel and Hirsch, 1992) was used to determine the statistical significance of differences of water-quality data in the streamflow and seasonal groups. The Mann-Whitney rank-sum test is a nonparametric test and requires no assumptions about population distribution and is less affected by outlying data. The null hypothesis of the rank-sum test is that the base-flow and runoff datasets have similar medians and distributions. The null hypothesis was rejected if the p-value (probability) was less than or equal to 0.05, which is equal to 95 percent confidence of the relation. The alternate hypothesis was that the populations of constituent concentrations are significantly different.

The ARS GRL collected bi-weekly one-liter grab samples at 15 sites, A through O, distributed throughout the Cobb Creek, Lake Creek, and Willow Creek drainages from January 2005 through May 2007 (fig. 1). Water samples were collected, primarily during base flow, from just below the stream surface and away from the bank. A total of 60 samples were analyzed at the ARS GRL laboratory in El Reno, Oklahoma for concentrations of nitrate nitrogen, orthophosphate, and phosphorus in filtered water and suspended sediment by using methods described in U.S. Environmental Protection Agency (1983) (table 1).

## Precipitation

Precipitation samples were collected in the Fort Cobb Reservoir watershed (fig. 1) at the USGS meteorological site (351801098270501) by using an Aerochem Metrics 301 precipitation collector (National Atmospheric Deposition Program, 1999). The collector was electrically powered and used a clean 13.25-liter polyethylene bucket that was uncovered for each rain event by use of a modem. Precipitation samples were collected on March 20 and October 16, 2006, and April 4 and May 8, 2007. Those samples were filtered and analyzed for nitrite plus nitrate nitrogen, nitrite nitrogen, total nitrogen, and total phosphorus at the USGS National Water Quality Laboratory in Lakewood, Colorado.

## Quality Control

Ten percent of the USGS water-quality samples were quality-control samples consisting of six equipment blanks and seven replicate samples (appendix 1). Equipment-blank samples were collected during the study to check if samples were contaminated by the sampling equipment and procedures. Blank samples indicated that no substantial contamination affected the samples from the sampling equipment and procedures. Replicate samples are an extra set of samples collected at the same time of the regular samples to determine the precision of laboratory analytical procedures. A comparison of consituent concentrations between the regular and replicate sample sets collected at the stream sites and at the precipitation site showed no substantial problems with the laboratory analytical procedures.

# Stream Water Quality

Water-quality data collected by the USGS were statistically tested to determine if streamflow and season affected values of water properties and nutrient concentrations during the study. Statistical summaries in addition to scatter plots are used to compare water-quality data.

## Streamflow

Mean monthly streamflows for about 37 years indicate that streamflows tend to be highest in the spring months of March, April, and May, decrease through the summer months, and increase during October and November (fig. 3) (U.S. Geological Survey, 2007). Cobb Creek carries the greatest portion of streamflow in the watershed, about 73 percent, whereas Lake Creek carries about 18 percent and Willow Creek carries 9 percent. During this study, instantaneous streamflow at Cobb Creek ranged from 8.9 to 4,540 cubic feet per second ($ft^3/s$) with a median of 27 $ft^3/s$; streamflow at Lake Creek ranged from 1.6 to 3,620 $ft^3/s$, with a median of 5.9 $ft^3/s$ and at Willow Creek ranged from 0.8 to 486 $ft^3/s$, with a median of 3 $ft^3/s$ (appendixes 2, 3, and 4).

## Water Properties

Specific conductance, dissolved oxygen concentration, and alkalinity were significantly higher during base flow than runoff (p-value less than 0.01) and substantially higher during the dormant season than the growing season at each stream site (table 2). Streamflow had the greatest effect on specific conductance and alkalinity; because base flow/groundwater discharge from the Rush Springs aquifer is more mineralized (Becker and Runkle, 1998), base flow/groundwater discharge has a higher specific conductance and greater acid buffering capacity than runoff, which is diluted by precipitation.

Cobb Creek had a substantially greater mean specific conductance, 590 microsiemens per centimeter at 25 degrees Celsius (µS/cm), than Lake Creek (447 µS/cm ) and Willow Creek (426 µS/cm) (appendixes 2, 3, and 4) indicating that streamflow at Cobb Creek may have a greater proportion of groundwater discharge than the other two creeks. Median values of specific conductance for base-flow samples were 786, 584, and 581 µS/cm and runoff samples were 318, 244, and 219 µS/cm for Cobb Creek, Lake Creek and Willow Creek, respectively (appendixes 2, 3, and 4).

pH was significantly higher in base-flow samples than runoff samples from Cobb Creek and Lake Creek (p-value less than 0.01 and p-value equal to 0.04); at Willow Creek there was a small, but statistically insignificant, difference in pH between flow conditions (table 2). Median pH was slightly higher in dormant-season samples than in growing-season samples at Cobb Creek, similar during both seasons in Lake Creek samples, and slightly higher in the growing season in Willow Creek samples. At Cobb Creek, pH ranged from 7.6 to 8.5, Lake Creek 7.5 to 8.6, and Willow Creek 7.3 to 8.5 (appendixes 2, 3, and 4).

Dissolved oxygen was lowest during runoff, similar to results observed in other studies (Mallin and others, 1999; and Wilcock and others, 1995), and can be attributed to the high biochemical oxygen demand of organic material washed into streams with runoff. Lesser dissolved oxygen concentrations measured during the growing season may result from higher

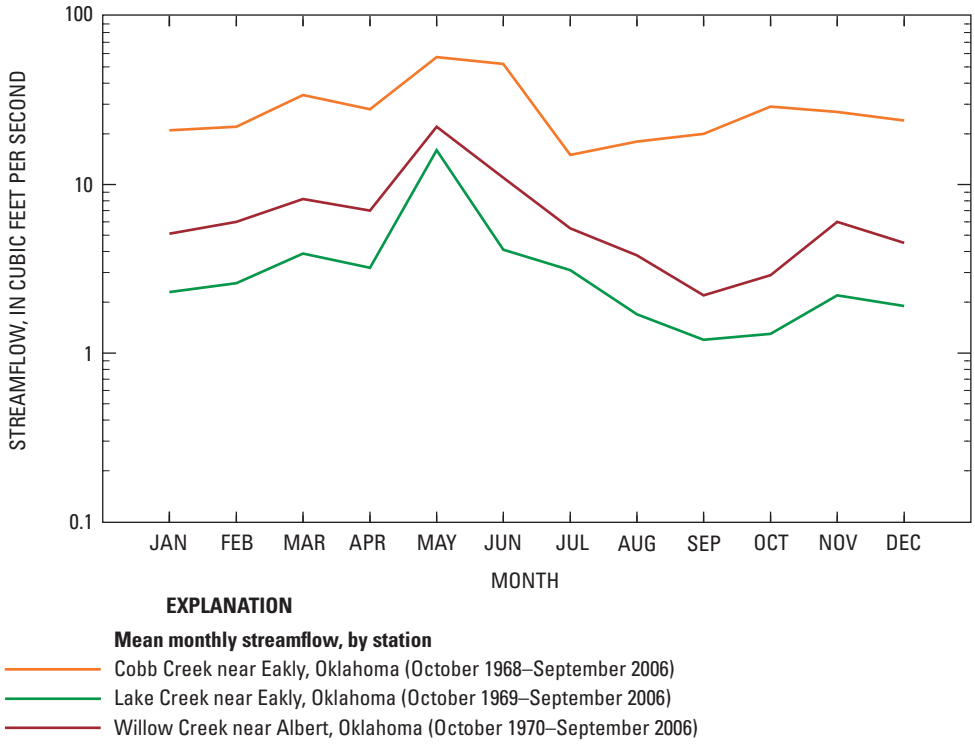


**Figure 3.** Mean monthly streamflow measured at U.S. Geological Survey streamflow-gaging stations Cobb Creek near Eakly (07325800), Lake Creek near Eakly (07325850), and Willow Creek near Albert (07325860), Fort Cobb Reservoir watershed, southwestern Oklahoma, November 2004 to May 2007.

streamflows and more frequent surface-water runoff than during the dormant season. Lesser oxygen concentrations during the growing season also may be related to higher water temperatures and greater rates of oxidation of organic matter by microbes in soils and water (Hem, 1992). Mean values of dissolved oxygen measured during base flow ranged from 10 to 12 mg/L; during runoff, 6.9 to 8.2 mg/L; during the growing season, 7.2 to 8.4 mg/L; and during the dormant season, 9.7 to 11.1 mg/L (appendixes 2, 3, and 4).

Alkalinity was significantly higher in base-flow samples than runoff samples (p-value less than 0.01) at each stream site. Alkalinity also was significantly higher in samples collected during the dormant season at Cobb Creek and Willow Creek (p-value equal to 0.03, table 2). The source of alkalinity in base flow (groundwater discharge) is attributed to an enrichment of carbon dioxide in the soil and unsaturated zone from plant respiration and oxidation of organic material (Hem, 1992). A decrease in alkalinity during runoff and the growing season may be the result of dilution of base flow from precipitation. Median values of alkalinity ranged from 201 to 236 mg/L in base-flow samples from the three creeks; 62 to 100 mg/L in runoff samples; 82 to 172 mg/L in samples collected during the growing season, and 197 to 225 mg/L in samples collected during the dormant season. Alkalinity values were similar in samples collected from Cobb and Willow Creeks and were lowest in samples from Lake Creek.

## Nitrogen Compounds

Water-quality samples collected by the USGS indicate that Cobb Creek generally had higher concentrations of all nitrogen compounds than Lake Creek and Willow Creek, similar to results reported in Fairchild and others (2004). Higher nitrogen-compound concentrations were evident during both seasons and streamflow conditions (appendixes 2, 3, and 4). The mean nitrate nitrogen concentration of 0.902 mg/L in samples from Cobb Creek was almost two times higher than in samples collected from Lake Creek (0.487 mg/L) and about 2.5 times higher than in samples collected from Willow Creek (0.374 mg/L) during the study period. Nitrate nitrogen composed 25 percent of the total nitrogen in samples from Cobb Creek, compared to 17 percent in samples from Lake Creek and 15 percent in samples from Willow Creek. Organic nitrogen was the largest component of total nitrogen in samples collected from the three streams; 70 to 80 percent of nitrogen measured in samples was in the form of organic nitrogen transported into streams during runoff.

Water-quality data collected by ARS GRL indicate that the three highest mean concentrations of nitrate nitrogen measured in the watershed were in samples collected at Cobb Creek sites B (1.17 mg/L), C (1.18 mg/L), and D (1.16 mg/L) (fig. 4*A* and table 3). The highest mean concentrations of nitrate nitrogen at Lake Creek (0.81 mg/L, site H) and Willow

**Table 2.** Mann-Whitney rank-sum test (Helsel and Hirsch, 1992) results comparing physical properties and concentrations of nutrient compounds in stream sample groups (streamflow and season) collected at U.S. Geological Survey streamflow-gaging stations in the Fort Cobb watershed, southwestern Oklahoma, 2004 to 2007.

[The months May through September are considered the growing season and October through April dormant; p-values are decimal percentages; <, less than; =, equal to. The null hypothesis is that the base-flow and runoff datasets have similar medians and distributions. The null hypothesis was rejected if the p-value (probability) was less than or equal to 0.05 which is equal to 95 percent confidence of the relation. Underlined p-values (≤ 0.05) indicate constituent concentrations are significantly different between the comparison groups]

| | Cobb Creek near Eakly, Oklahoma (07325800) | | | | Lake Creek near Eakly, Oklahoma (07325850) | | | | Willow Creek near Albert, Oklahoma (07325860) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Physical properties and nutrient compounds | p-value | Streamflow group with highest median | p-value | Seasonal group with highest median | p-value | Streamflow group with highest median | p-value | Seasonal group with highest median | p-value | Streamflow group with highest median | p-value | Seasonal group with highest median |
| Streamflow | p <0.01 | runoff | p = 0.53 | growing | p <0.01 | runoff | p = 0.53 | growing | p <0.01 | runoff | p = 0.53 | growing |
| Specific conductance | p <0.01 | base flow | p = 0.01 | dormant | p <0.01 | base flow | p = 0.29 | dormant | p <0.01 | base flow | p = 0.01 | dormant |
| pH | p <0.01 | base flow | p = 0.30 | dormant | p = 0.04 | base flow | p = 0.94 | dormant | p = 0.64 | base flow | p = 0.17 | growing |
| Dissolved oxygen | p <0.01 | base flow | p = 0.01 | dormant | p <0.01 | base flow | p = 0.01 | dormant | p <0.01 | base flow | p = 0.01 | dormant |
| Turbidity | p <0.01 | runoff | p = 0.47 | growing | p = 0.09 | runoff | p = 0.72 | growing | p = 0.01 | runoff | p = 0.47 | growing |
| Suspended sediment | p <0.01 | runoff | p = 0.01 | growing | p <0.01 | runoff | p = 0.14 | growing | p <0.01 | runoff | p = 0.29 | growing |
| Fine-suspended sediment | p = 0.11 | runoff | p = 0.02 | growing | p = 0.82 | base flow | P = 0.37 | dormant | p = 0.12 | runoff | P = 0.37 | growing |
| Alkalinity | p <0.01 | base flow | p = 0.03 | dormant | p <0.01 | base flow | p = 0.27 | dormant | p <0.01 | base flow | p = 0.03 | dormant |
| Nitrite nitrogen | p = 0.78 | runoff | p = 0.28 | growing | p = 0.38 | runoff | p = 0.37 | growing | p = 0.01 | runoff | p = 0.05 | growing |
| Nitrate nitrogen, calculated | p <0.01 | base flow | p = 0.37 | dormant | p = 0.08 | base flow | p = 0.06 | dormant | p = 0.03 | runoff | p = 1 | growing |
| Nitrite plus nitrate nitrogen | p <0.01 | base flow | p = 0.39 | dormant | p = 0.09 | base flow | p = 0.07 | dormant | p = 0.02 | runoff | p = 0.96 | growing |
| Ammonia nitrogen | p <0.01 | runoff | p = 0.19 | growing | p <0.01 | runoff | p = 0.61 | growing | p <0.01 | runoff | p = 0.24 | growing |
| Ammonia plus organic nitrogen | p <0.01 | runoff | p = 0.07 | growing | p <0.01 | runoff | p = 0.17 | growing | p <0.01 | runoff | p = 0.06 | growing |
| Organic nitrogen, calculated | p <0.01 | runoff | p = 0.04 | growing | p <0.01 | runoff | p = 0.16 | growing | p <0.01 | runoff | p = 0.05 | growing |
| Total nitrogen, calculated | p <0.01 | runoff | p = 0.03 | growing | p <0.01 | runoff | p = 0.71 | growing | p <0.01 | runoff | p = 0.23 | growing |
| Phosphorus, dissolved | p <0.01 | runoff | p = 0.12 | growing | p <0.01 | runoff | p <0.01 | growing | p <0.01 | runoff | p <0.01 | growing |
| Total phosphorus | p <0.01 | runoff | p = 0.01 | growing | p <0.01 | runoff | p = 0.07 | growing | p <0.01 | runoff | p = 0.01 | growing |
| Orthophosphate | p <0.01 | runoff | p = 0.02 | growing | p <0.01 | runoff | p <0.01 | growing | p <0.01 | runoff | p <0.01 | growing |

Creek (0.96 mg/L, site M) were in samples collected at the headwaters of the drainage basins.

Statistical tests describing the USGS data indicate that nitrate nitrogen in Cobb Creek and Lake Creek was affected differently by streamflow and season than nitrite nitrogen, ammonia nitrogen, organic nitrogen, and total nitrogen (table 2); nitrate nitrogen concentrations were highest in base-flow samples and in samples collected during the dormant season. In Willow Creek, however, nitrate nitrogen concentrations were significantly higher during runoff than base flow (p-value less than 0.01, table 2) and were similar during the growing and dormant seasons. In all three streams, ammonia nitrogen, ammonia plus organic nitrogen, organic nitrogen, and total nitrogen concentrations were highest during the growing season and during runoff (table 2), similar to trends shown in concentrations of phosphorus (dissolved), total phosphorus, orthophosphorus, and suspended sediment.

Total nitrogen concentrations increased with increasing streamflow (fig. 5); at streamflows greater than 50 $ft^3/s$ organic nitrogen concentrations continued to increase, whereas nitrite nitrogen, nitrate nitrogen, and ammonia nitrogen concentrations stayed relatively constant or decreased slightly (fig. 6).

## Phosphorus Compounds

Water-quality samples collected by the USGS indicate that Willow Creek during runoff and the growing season had the highest mean concentrations of dissolved phosphorus (0.181 mg/L, 0.177 mg/L) and orthophosphate (0.148 mg/L, 0.153 mg/L), with Lake Creek having the lowest concentrations during those conditions. Water-quality samples collected by the ARS GRL showed similar results; the highest mean concentrations of orthophosphate (0.23 mg/L) and dissolved phosphorus (0.27 mg/L) were in samples collected at site L on Cherry Dale Creek (figs. 3*B*, 3*C*, and table 4), just above the confluence with Willow Creek, about 2 to 3 miles upstream from the gage where the USGS collected water-quality samples from Willow Creek (station 07325860). Cobb Creek had the highest mean concentrations of total phosphorus during both seasons and streamflow conditions, with the highest concentration occurring during runoff (1.2 mg/L) similar to results reported in Fairchild and others (2004).

Water-quality samples collected by the USGS indicate that dissolved phosphorus, total phosphorus, and orthophosphate concentrations were affected by streamflow and season in all three creeks. Dissolved phosphorus and orthophosphate concentrations were significantly higher in runoff samples than base-flow samples (p-value less than 0.01) and higher in samples collected during the growing season than in the dormant season (table 2). Overall, total phosphorus concentrations, similar to organic nitrogen, generally increased with increasing streamflow, whereas concentrations of dissolved phosphorus and orthophosphate stayed relatively constant or slightly decreased at higher streamflows (fig. 7).

## Nutrient Concentrations in Precipitation

The drought from 2002 to the autumn of 2006 ranked as the 6th driest period in Oklahoma since 1925 (Oklahoma Water Resources Board, 2007), whereas the first 6 months of 2007 ranked as the wettest spring in recorded Oklahoma history. The average annual precipitation for the study area ranges from 30 to 33 inches based on measurements made from 1971 to 2000 (Oklahoma Climatological Survey, 2007). Precipitation in 2005 and 2006 in the Fort Cobb watershed, was 20.1 and 21.6 inches, respectively (Oklahoma MESONET, 2007). Precipitation in southwestern Oklahoma for the first 180 days of 2007 was about 26 inches (Oklahoma MESONET, 2007).

Precipitation samples were collected four times during the study, March 20 and October 16, 2006, and April 4 and May 8, 2007, and analyzed for dissolved nitrogen compounds and phosphorus (table 4). The four precipitation samples had concentrations of total nitrogen ranging from 0.13 to 2.42 mg/L. The two highest concentrations, 0.73 and 2.42 mg/L, were measured in precipitation samples collected during April and May at the beginning of the growing season. Ammonia composed the largest percentage of total nitrogen measured and may be related to the concurrent application of ammonia nitrogen fertilizer to crops in the spring. However, the total nitrogen concentration of 2.42 mg/L seems unusually high and may reflect contamination by wind-blown material. The concentration of phosphorus in the precipitation samples ranged from less than 0.006 mg/L measured in October 2006 to 0.190 mg/L measured in May 2007.

## Suspended-Sediment Discharge and Concentration

Suspended sediment measured by the USGS indicates that Cobb Creek transported the highest concentrations of suspended sediments in the watershed with Willow Creek transporting the highest percentage of fine-suspended sediment. Based on the mean percentage, 65 percent of the suspended sediment transported by Willow Creek on sampled days (complete record) during the study period was clay-to-silt-sized compared to 55 percent by Cobb Creek and 53 percent by Lake Creek (appendixes 2, 3, and 4). The mass of suspended sediment in all three creeks was directly related to streamflow (figs. 8*A* and 8*B*), and as expected, was significantly higher in samples collected during runoff than during base flow (p-value less than 0.01). Although, streamflow was not significantly higher during the growing season (table 2), the volume of suspended sediment was somewhat greater in samples collected during this period of the year, and significantly higher in Cobb Creek samples (p-value equal to 0.01), indicating that agricultural activities may increase the volume of suspended sediment in these streams. Cobb Creek had the highest one-time concentration

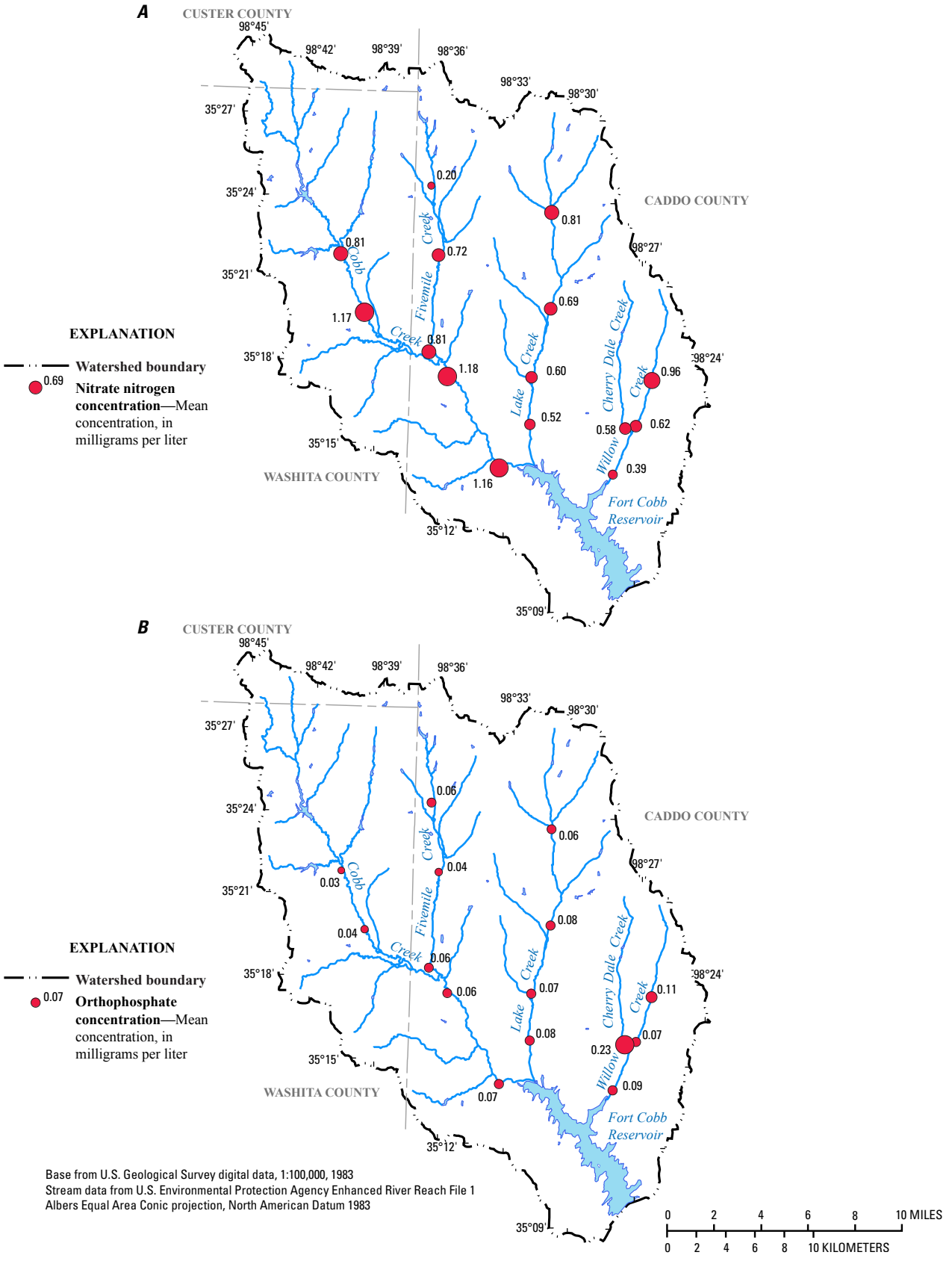


**Figure 4.** Mean concentrations of (*A*) nitrate nitrogen, (*B*) orthophosphate, (*C*) dissolved phosphorus, and (*D*) suspended sediment measured in stream samples by the Agricultural Research Service, Grazinglands Research Laboratory, Fort Cobb Reservoir watershed, southwestern Oklahoma, January 2005 through May 2007.

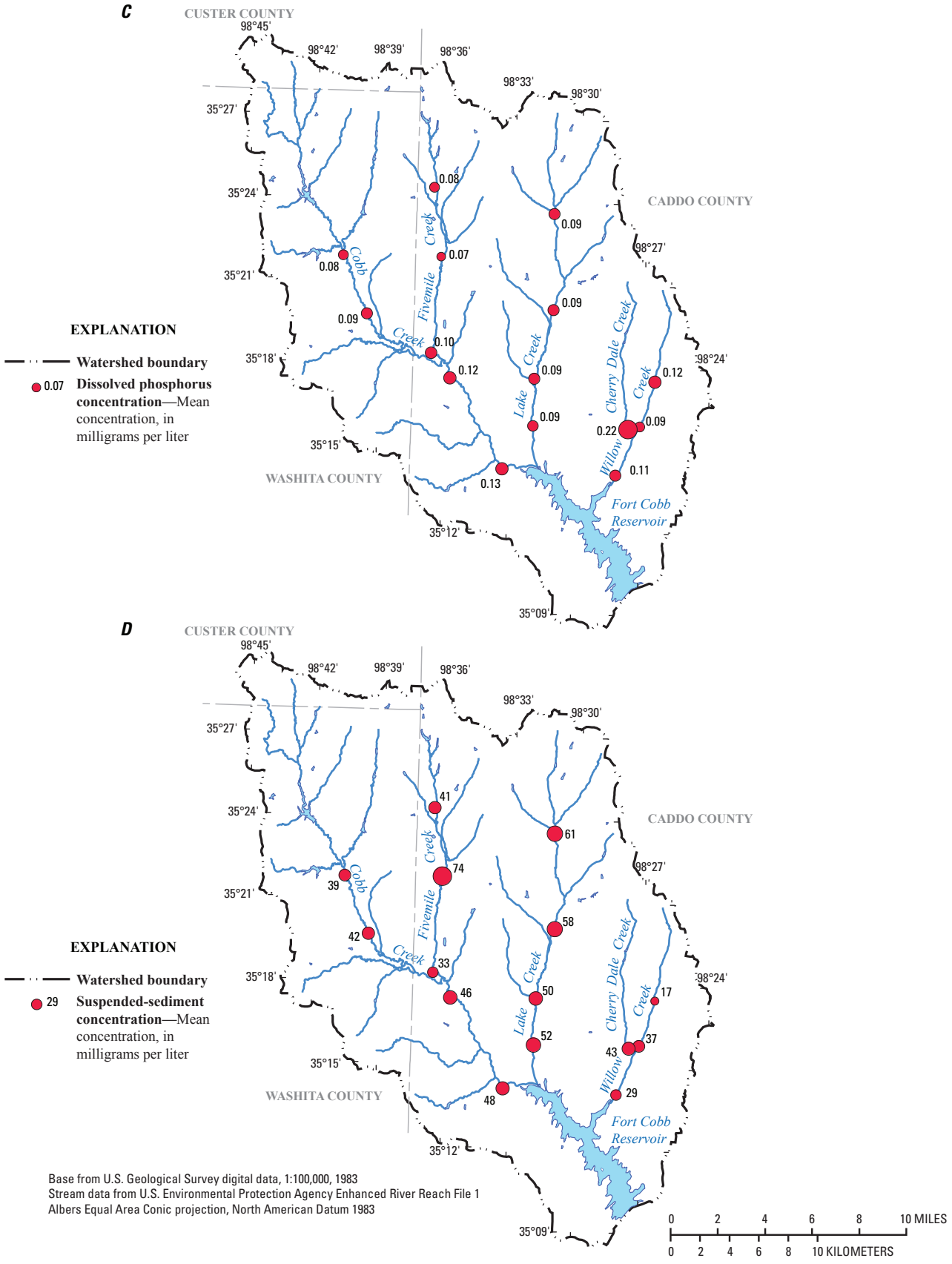


**Figure 4.** Mean concentrations of (*A*) nitrate nitrogen, (*B*) orthophosphate, (*C*) dissolved phosphorus, and (*D*) suspended sediment measured in stream samples by the Agricultural Research Service, Grazinglands Research Laboratory, Fort Cobb Reservoir watershed, southwestern Oklahoma, January 2005 through May 2007.

**Table 3.** Stream-site locations and mean concentrations of nutrient compounds and suspended sediment measured in stream samples by the Agricultural Research Service, Grazinglands Research Laboratory, Fort Cobb Reservoir watershed, southwestern Oklahoma, January 2005 through May 2007.

[DD, decimal degree; mg/L, milligrams per liter; N, nitrogen; P, phosphorus]

| Site identifier | Latitude (DD) | Longitude (DD) | Nitrate nitrogen (mg/L as N) | Dissolved phosphorus (mg/L as P) | Orthophosphate phosphorus (mg/L as P) | Suspended sediment (mg/L) |
|---|---|---|---|---|---|---|
| Cobb Creek | | | | | | |
| A | 35.3620 | -98.6758 | 0.81 | 0.03 | 0.08 | 39 |
| B | 35.3290 | -98.6595 | 1.17 | 0.04 | 0.09 | 42 |
| C[1] | 35.2916 | -98.5947 | 1.18 | 0.06 | 0.12 | 46 |
| D | 35.2358 | -98.5533 | 1.16 | 0.07 | 0.13 | 48 |
| Fivemile Creek (tributary of Cobb Creek) | | | | | | |
| E | 35.4069 | -98.6087 | 0.20 | 0.06 | 0.08 | 41 |
| F | 35.3633 | -98.6032 | 0.72 | 0.04 | 0.07 | 74 |
| G | 35.3057 | -98.6076 | 0.81 | 0.06 | 0.10 | 33 |
| Lake Creek | | | | | | |
| H | 35.3918 | -98.5176 | 0.81 | 0.06 | 0.09 | 61 |
| I | 35.3340 | -98.5170 | 0.69 | 0.08 | 0.09 | 58 |
| J[2] | 35.2908 | -98.5285 | 0.60 | 0.07 | 0.09 | 50 |
| K | 35.2623 | -98.5317 | 0.52 | 0.08 | 0.09 | 52 |
| Cherry Dale Creek (tributary of Willow Creek) | | | | | | |
| L | 35.2626 | -98.4582 | 0.58 | 0.23 | 0.27 | 43 |
| Willow Creek | | | | | | |
| M | 35.2912 | -98.4388 | 0.96 | 0.11 | 0.12 | 17 |
| N | 35.2619 | -98.4507 | 0.62 | 0.07 | 0.06 | 37 |
| O[3] | 35.2336 | -98.4669 | 0.39 | 0.09 | 0.11 | 29 |

[1] Near U.S. Geological Survey stream-gaging station Cobb Creek near Eakly, Oklahoma (07325800).

[2] Near U.S. Geological Survey stream-gaging station Lake Creek near Eakly, Oklahoma (07325850).

[3] Near U.S. Geological Survey stream-gaging station Willow Creek near Albert, Oklahoma (07325860).

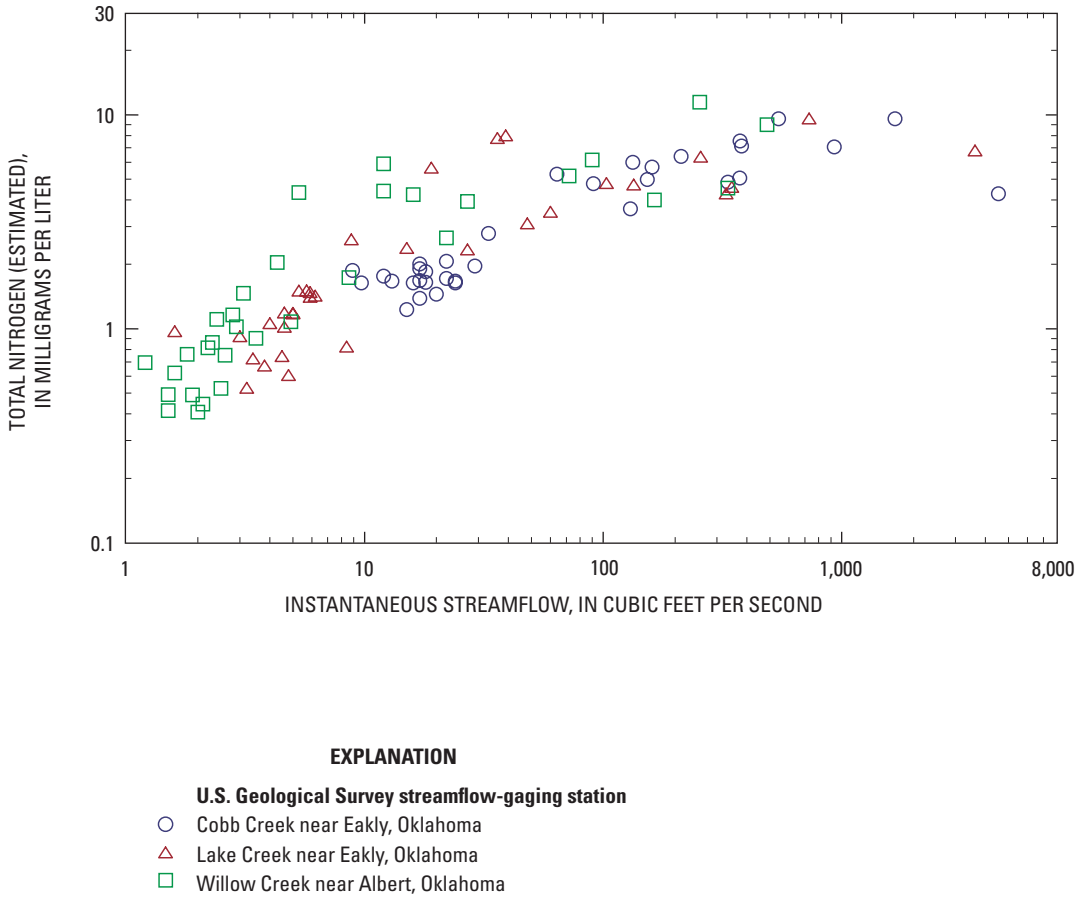


**Figure 5.** Estimated total nitrogen concentrations in stream samples compared to instantaneous streamflow measured at U.S. Geological Survey streamflow-gaging stations Cobb Creek near Eakly (07325800), Lake Creek near Eakly (07325850), and Willow Creek near Albert (07325860), Fort Cobb Reservoir watershed, southwestern Oklahoma, November 2004 to May 2007. Total nitrogen concentrations are the sum of ammonia plus organic nitrogen and nitrite plus nitrate nitrogen.

**Table 4.** Concentrations of nitrogen compounds and phosphorus measured in precipitation samples collected at the U.S. Geological Survey meteorological site (351801098270501), Fort Cobb watershed, southwestern Oklahoma, March 2006 to May 2007.

[All concentrations are dissolved. Total nitrogen is analytically determined; mg/L, milligrams per liter; N, nitrogen; E, estimated; <, less than]

| Date | Sample type | Nitrate (calculated) (mg/L as N) | Nitrite (mg/L as N) | Nitrite plus nitrate (mg/L as N) | Ammonia (mg/L as N) | Total nitrogen (mg/L) | Dissolved phosphorus (mg/L) |
|---|---|---|---|---|---|---|---|
| March 20, 2006 | regular | 0.139 | 0.003 | 0.142 | 0.212 | 0.40 | 0.007 |
| March 20, 2006 | replicate | 0.142 | 0.002 | 0.144 | 0.213 | 0.39 | 0.006 |
| October 16, 2006 | regular | 0.039 | E 0.001 | 0.04 | 0.034 | 0.13 | < 0.006 |
| October 16, 2006 | replicate | 0.048 | < 0.002 | 0.050 | 0.037 | 0.1 | < 0.006 |
| April 4, 2007 | regular | 0.223 | 0.005 | 0.228 | 0.436 | 0.73 | 0.042 |
| May 8, 2007 | regular | 0.191 | 0.008 | 0.199 | 0.576 | 2.42 | 0.190 |

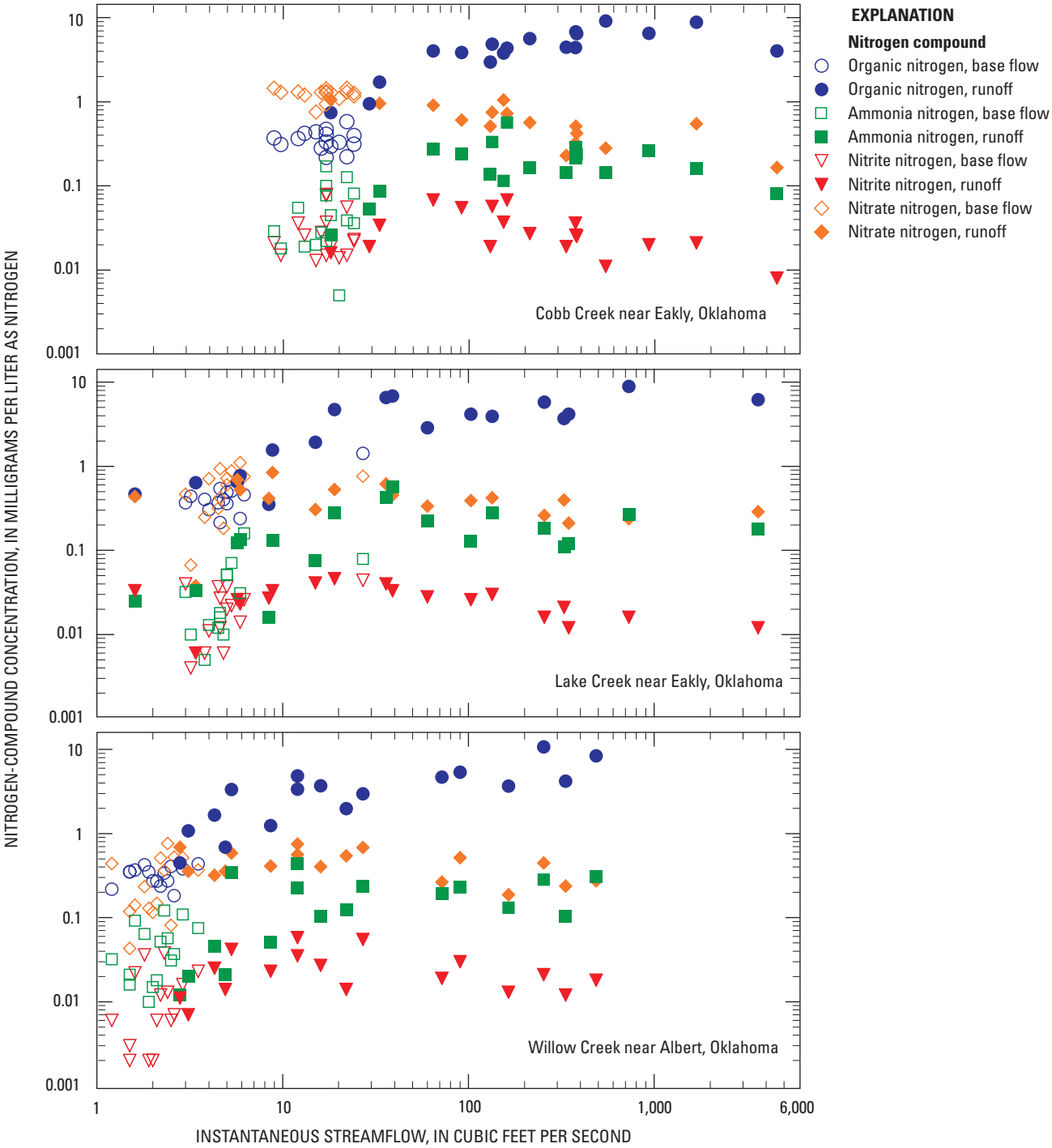


**Figure 6.** Nitrogen-compound concentrations compared to instantaneous streamflow measured at U.S. Geological Survey streamflow-gaging stations Cobb Creek near Eakly (07325800), Lake Creek near Eakly (07325850), and Willow Creek near Albert (07325860), Fort Cobb Reservoir watershed, southwestern Oklahoma, November 2004 to May 2007.

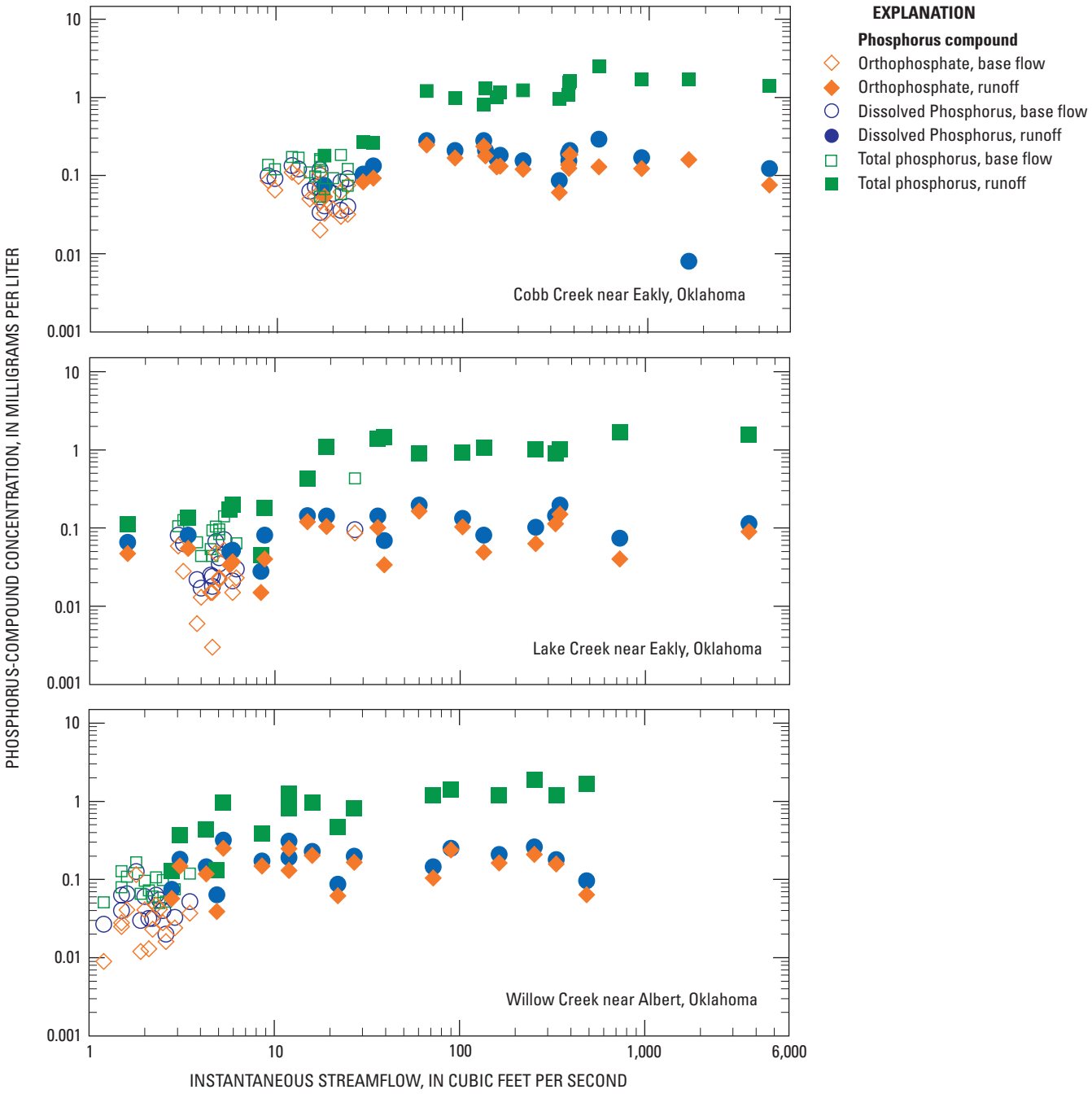


**Figure 7.** Phosphorus-compound concentrations compared to instantaneous streamflow measured at U.S. Geological Survey streamflow-gaging stations Cobb Creek near Eakly (07325800), Lake Creek near Eakly (07325850), and Willow Creek near Albert (07325860), Fort Cobb Reservoir watershed, southwestern Oklahoma, November 2004 to May 2007.

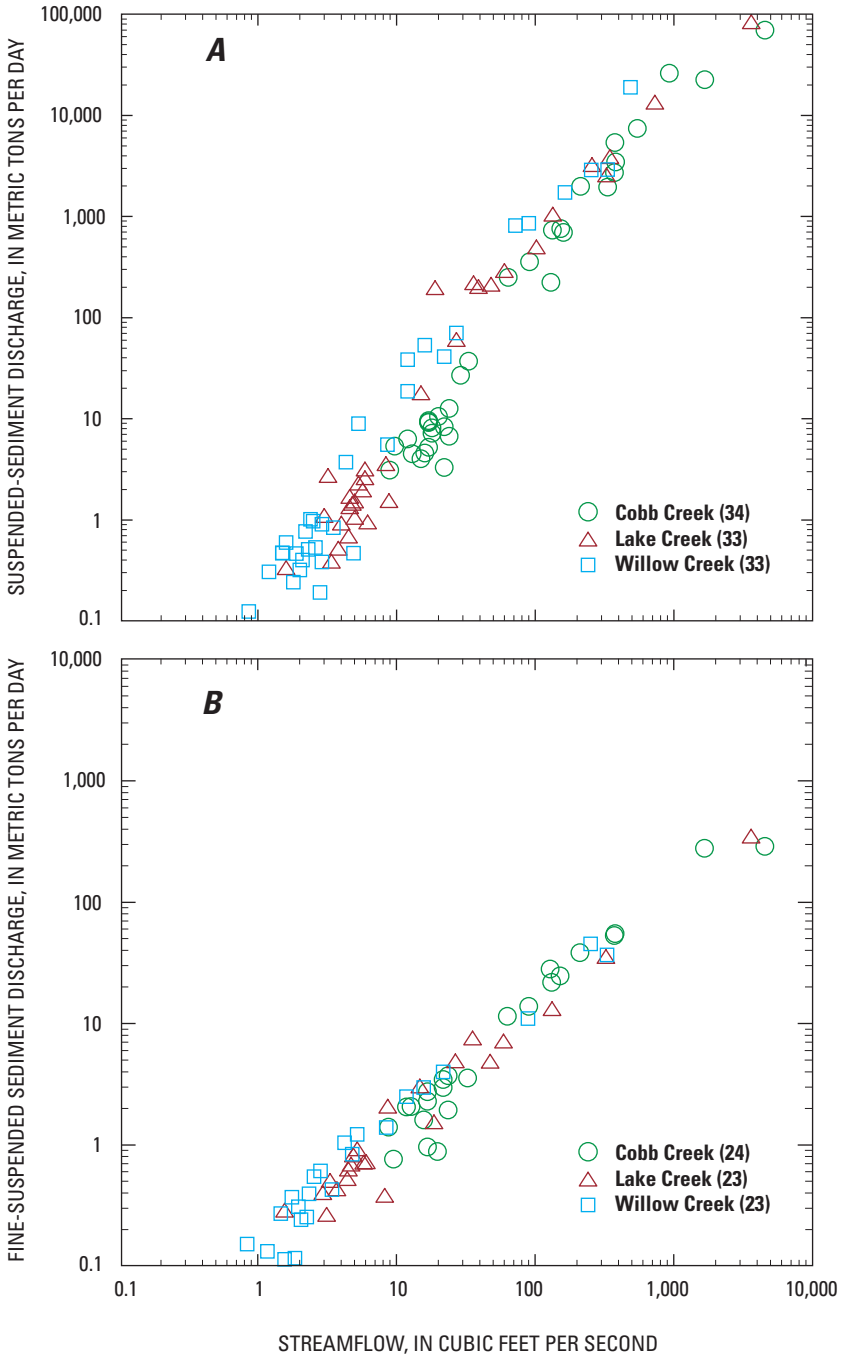


**Figure 8.** (*A*) calculated suspended-sediment discharge and (*B*) fine-suspended sediment (silt and clay, less than 0.063 millimeters) discharge at U.S. Geological Survey streamflow-gaging stations Cobb Creek near Eakly (07325800), Lake Creek near Eakly (07325850), and Willow Creek near Albert (07325860), Fort Cobb Reservoir watershed, southwestern Oklahoma, November 2004 to May 2007.

of suspended sediment (11,500 mg/L) and the highest mean suspended-sediment concentration measured in samples collected during the study period (1,804 mg/L). Lake Creek and Willow Creek had mean concentrations of suspended sediment of 1,566 mg/L and 1,430 mg/L, respectively.

Figures 8*A* and 8*B* show that at sustained streamflows of 100 $ft^3/s$ the mass of sediment transported ranged from 200 to 1,000 metric tons per day, with about 10 to 20 metric tons composed of silt and clay. To put those masses in perspective, for 31 days during the study period, daily mean streamflow at Cobb Creek was greater than 100 $ft^3/s$.

Suspended sediment measured by the ARS GRL indicated that in general, Lake Creek had the highest mean suspended-sediment concentrations ranging from 61 to 50 mg/L at sites H through K (fig. 4*D* and table 3). The highest suspended-sediment concentration in the Lake Creek drainage basin was measured at the uppermost stream site H. The highest suspended-sediment concentration in the watershed was measured at site F at Fivemile Creek (74 mg/L), a tributary of Cobb Creek (fig. 4*D* and table 3).

Mean concentrations of suspended sediment measured by the USGS at the three streamflow-gaging stations were two orders of magnitude greater than concentrations measured by the ARS GRL at nearby sites C, J, and O. Nineteen of the 34 to 35 USGS samples were collected during runoff, whereas the ARS GRL samples were collected primarily during base flow which transports lesser concentrations of suspended sediment. Median concentrations of suspended sediment measured by the USGS were more similar to the mean suspended-sediment concentrations in samples collected by the ARS GRL (appendixes 2, 3, and 4 and table 3).

# Summary

The Fort Cobb Reservoir watershed encompasses about 813 square kilometers of rural farm land in Caddo, Custer, and Washita Counties in southwestern Oklahoma. The largest water body in the watershed is the Fort Cobb Reservoir with a surface area of 1,659 hectares at normal pool. The combination of agricultural activities and the vulnerability of soils to erosion has resulted in water-quality issues for the three major tributaries that drain the watershed, Cobb Creek, Lake Creek, and Willow Creek, and the Fort Cobb Reservoir.

Streamflow and nutrient-compound and suspended-sediment concentrations were measured in water-quality samples collected by the USGS from November 2004 to May 2007 at three USGS streamflow-gaging stations. In addition, water-quality samples were collected by the ARS GRL bi-weekly at 15 stream sites distributed throughout the watershed from January 2005 through May 2007. The purpose of the data collection was to assist assessment of conservation practices implemented in the watershed by measuring nutrient and sediment concentrations in streams during base-flow and runoff conditions and during the growing season (May-September) and dormant season (October- April) to provide information for assessing the success of conservation programs implemented in the watershed.

Streamflows in the watershed tend to be highest in the spring months of March, April, and May, decrease through the summer months, and increase during October and November. Cobb Creek carries the greatest proportion of streamflow in the watershed, about 73 percent.

Specific conductance, dissolved oxygen concentration, and alkalinity were significantly higher during base flow than runoff in Cobb Creek, Lake Creek, and Willow Creek. These water properties also were substantially higher during the dormant season than the growing season in Cobb and Willow Creeks.

USGS and ARS GRL samples indicated that Cobb Creek had higher concentrations of nitrate nitrogen than Lake and Willow Creeks. The mean nitrate nitrogen concentration of 0.902 mg/L in samples from Cobb Creek was almost two times higher than in samples collected from Lake Creek (0.487 mg/L) and about 2.5 times higher than in samples collected from Willow Creek (0.374 mg/L) during the study period. Organic nitrogen was the largest component of total nitrogen in samples collected from the three streams; 70 to 80 percent of nitrogen measured in water-quality samples was in the form of organic nitrogen transported into streams during runoff conditions.

Statistical tests comparing the USGS data indicate that nitrate nitrogen in Cobb Creek and Lake Creek was affected differently by streamflow and season than nitrite nitrogen, ammonia nitrogen, organic nitrogen, and total nitrogen; nitrate nitrogen concentrations were highest in base-flow samples and in samples collected during the dormant season. In Willow Creek, however, nitrate nitrogen concentrations were significantly higher during runoff than base flow and were similar during the growing and dormant seasons. In all three streams, ammonia nitrogen, ammonia plus organic nitrogen, organic nitrogen, and total nitrogen concentrations were higher during the growing season than the dormant season and were significantly higher in runoff than base-flow samples, similar to trends in concentrations of phosphorus (dissolved), total phosphorus, orthophosphorus, and suspended sediment.

Water-quality samples collected by the USGS indicate that Willow Creek during runoff and the growing season had the highest mean concentrations of dissolved phosphorus (0.181 mg/L, 0.177 mg/L) and orthophosphate

(0.148 mg/L, 0.153 mg/L), with Lake Creek having the lowest concentrations during those conditions. Water-quality samples collected by the ARS GRL showed similar results; the highest mean concentrations of orthophosphate (0.23 mg/L) and dissolved phosphorus (0.27 mg/L) were in samples collected at site L on Cherry Dale Creek, just above the confluence with Willow Creek, about 2 to 3 miles upstream from the gage where the USGS collected water-quality samples from Willow Creek (station 07325860). Cobb Creek had the highest mean concentrations of total phosphorus during both seasons and streamflow conditions, with the highest concentration occurring during runoff (1.2 mg/L), similar to results reported in Fairchild and others (2004). Total phosphorus concentrations, similar to organic nitrogen, increased with increasing streamflow, whereas concentrations of dissolved phosphorus and orthophosphate stayed mostly constant or slightly decreased at higher streamflows.

Four precipitation samples collected in March 2006, October 2006, April 2007, and May 2007 had concentrations of total nitrogen ranging from 0.13 to 2.42 mg/L. The two highest concentrations, 0.73 and 2.42 mg/L, were detected in samples collected during April and May 2007 at the beginning of the growing season. Ammonia composed the largest percentage of total nitrogen measured and may be related to the concurrent application of ammonia nitrogen fertilizer to crops in the spring.

Suspended sediment measured by the USGS indicates that Cobb Creek transported the highest concentrations of suspended sediments in the watershed with Willow Creek transporting the highest percentage of fine-suspended sediment. Sixty-five percent of the suspended sediment transported by Willow Creek on sampled days was clay to silt sized compared to 55 percent by Cobb Creek and 53 percent by Lake Creek. The volume of suspended sediment in all three creeks was directly related to streamflow, and as expected, was significantly higher in samples collected during runoff than during base flow. Although, streamflow was not significantly higher during the growing season, the volume of suspended sediment was somewhat greater in samples collected during this period of the year, and significantly higher in Cobb Creek samples indicating that agricultural activities may increase the volume of suspended sediment in the streams.

Suspended sediment measured by the ARS GRL indicated that in general, Lake Creek had the highest mean suspended-sediment concentrations ranging from 61 to 50 mg/L at sites H through K. The highest concentration in the Lake Creek drainage basin was measured at the uppermost stream site H. The highest mean suspended-sediment concentration in the watershed was measured at site F at Fivemile Creek (74 mg/L), a tributary of Cobb Creek.

## Acknowledgments

The authors thank ARS GRL personnel and the USGS personnel Marty Phillips and Martin Schneider for their efforts and dedication during the monitoring and sampling of surface water.

## References Cited

Becker, C.J., 1994, Distribution and variability of nitrogen and phosphorus in the alluvial, High Plains, Rush Springs, and Blaine aquifers in western Oklahoma: U.S. Geological Survey Open-File Report 94-41, 30 p.

Becker, C.J., 2001, Ground-water quality, levels, and flow direction near Fort Cobb Reservoir, Caddo County, Oklahoma, 1998-2000: U.S. Geological Survey Water-Resources Investigations Report 01-4076, 20 p.

Becker, M.F. and Runkle, D.L., 1998, Hydrogeology, water quality, and geochemistry of the Rush Springs aquifer, western Oklahoma: U.S. Geological Survey Water-Resources Investigations Report 98-4081, 37 p.

Blumer, S.P., 1983, Sediment data for Mid-Arkansas and Upper Red River basins through 1980: U.S. Geological Survey Open-File Report 83-692, 799 p.

Childress, C.J.O., Foreman, W.T., Connor, B.F., and Maloney, T.J., 1999, New reporting procedures based on long-term method detection levels and some considerations for interpretations of water-quality data provided by the U.S. Geological Survey National Water Quality Laboratory: U.S. Geological Survey Open-File Report 99-193, 19 p.

Clark, G.M., Mueller, D.K., and Mast, M.A., 2000, Nutrient concentrations and yields in undeveloped stream basins of the United States: Journal of the American Water Resources Association, v. 36, no. 4, p. 849-860.

Curtis, N.M, and Ham, W.E., 1979, Geomorphic provinces of Oklahoma, *in* Johnson, K.S., and others, Geology and earth resources of Oklahoma: Oklahoma Geological Survey, Education Publication 1, 1972, 8 p.

Edwards, T.K., and Glysson, G.D., 1999, Field methods for measurement of fluvial sediment: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. C2, 89 p.

Fairchild, J. F., Lakish, B., Echols, K., Chapman, D., Johnson, B., and Jones, S., 2003, An integrated assessment of the trophic status of Fort Cobb Reservoir, Oklahoma: Final report to U.S. Bureau of Reclamation, Great Plains Region, Billings, Mont., 89 p., available online at http://pubs.usgs.gov/ds/270/data/DVD-1/REPORTS/USGSBRD.FortCobb.2001_Study.pdf.

Fishman, M.J., ed., 1993, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of inorganic and organic constituents in water and fluvial sediments: U.S. Geological Survey Open-File Report 93-125, 217 p.

Gronberg, J.M., 2005, Grid of inorganic nitrogen atmospheric (wet) deposition for 2004: U.S. Geological Survey NAWQA Nutrients National Synthesis, available online at http://water.usgs.gov/nawqa-only/nuts/data/inputs/#CurrentGrids (accessed June 5, 2007).

Guy, H.P., 1969, Laboratory theory and methods for sediment analysis: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. C1.

Hart, D.L., Jr., 1963, Ground water in the alluvial deposits of the Washita River between Clinton and Anadarko, Oklahoma: U.S. Geological Survey Open-File Report 63-41, 23 p., 2 pls. in pocket.

Hart, D.L., Jr., 1965, Ground water in the alluvial deposits—Washita River between Clinton to Anadarko, Oklahoma: Oklahoma Water Resources Board Bulletin 26, 23 p., 2 pls., in pocket.

Helsel, D.R., and Hirsch, R.M., 1992, Statistical methods in water resources: Amsterdam, Netherlands, Elsevier, 522 p.

Hem, J.D., 1992, Study and interpretation of the chemical characteristics of natural water (4th ed.): U.S. Geological Survey Water-Supply Paper 2254, 263 p.

Institute of Hydrology, 1980a, Low flow studies: Wallingford, United Kingdom, Research Report No. 1, 21 p.

Institute of Hydrology, 1980b, Low flow studies: Wallingford, United Kingdom, Research Report No. 3, p. 12-19.

Laine, L.L., 1957, Surface waters of the Washita River Basin in Oklahoma, magnitude, distribution, and quality of streamflow: U.S. Geological Survey Open-File Report 58-058, 34 p.

Leonard, A.R., Davis, L.V., Stacy, B.L., 1958, Ground water in the alluvial deposits of the Washita River and its tributaries in Oklahoma: U.S. Geological Survey Open-File Report 58-63, 10 p., 3 pls.

Mallin, M.A., Posey, M.H., Shank, Christopher, McIver, M.R., Ensign, S.H., and Alphin, T.D., 1999, Hurricane effects on water quality and benthos in the Cape Fear Watershed—Natural and anthropogenic impacts: Ecological Applications, v. 9, no. 1, p. 350-362, available online at http://links.jstor.org/sici?sici=1051-0761%28199902%299%3A1%3C350%3AHEOWQA%3E2.0.CO%3B2-2.

Martin, D. B., 2002, Fort Cobb Reservoir water quality investigations: U.S. Fish and Wildlife Service, Ecological Services, Agreement NO: 97-AA-60-09790, 112 p.

Mausbach, M. J., and Dedrick. A. R. 2004, The length we go—Measuring environmental benefits of conservation practices: Journal of Soil and Water Conservation, v. 59, no. 5, p. 96A-103A.

Miller, G.W., Stanley, T.M., Standridge, G.R., 2005, Geologic map of the Anadarko 30' x 60' quadrangle, Caddo, Canadian, Custer, Grady, Kiowa, and Washita Counties, Oklahoma: Oklahoma Geological Survey, Oklahoma Geologic Quadrangle Map 4-2005.

National Atmospheric Deposition Program, 1999, National trends network site operation manual: Illinois State Water Survey, NAPD Manual 1999-01c (revised), 99 p., available online at http://nadp.sws.uiuc.edu/lib/manuals/opman.pdf.

Natural Resources Conservation Service, 2006, ARS Benchmark Watershed Studies, available online at http://www.nrcs.usda.gov/technical/NRI/ceap/ars.html (accessed November 19, 2006).

Oklahoma Climatological Survey, 2007, Normal annual precipitation from 1971-2000, available online at http://climate.ocs.ou.edu/normals_extremes.html (accessed June 5, 2007).

Oklahoma Conservation Commission, 2005, Policies and approved conservation practices for Cobb Creek/Fort Cobb Reservoir Watershed—319 nonpoint pollution cost-share FY 2001 319 (h), Project 4, C9-996100-09-0, 25 p.

Oklahoma Conservation Commission, 2007, Fort Cobb Watershed TMDL Implementation project; FY 2005-2006 319(h) Project 5, 18 p.

Oklahoma Department of Environmental Quality, 2002, Water quality assessment integrated report, 2002: Oklahoma Department of Environmental Quality, available online at http://www.deq.state.ok.us/WQDnew/305b_303d/2002_integrated_report_final.pdf (accessed June 5, 2007).

Oklahoma MESONET, 2007, Summary products: Oklahoma Climatological Survey, available online at http://www.mesonet.org/index.php/weather/station_monthly_summaries (accessed May 8, 2007).

Oklahoma Water Resources Board, 2007, Hydrologic drought of water year 2006 a historical context: available online at http://www.owrb.ok.gov/studies/reports/reports_pdf/Drought_of_WY2006.pdf (accessed June 5, 2007).

Oklahoma Water Resources Board, 2003, Beneficial Use Monitoring Program (BUMP) Report, available online at www.http://www.owrb.ok.gov/studies/reports/bump/2003/bump2003.php.

Patton, C.J., and Kryskalla. J.R., 2003, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Evaluation of alkaline persulfate digestion as an alternative to Kjeldahl digestion for determination of total and dissolved nitrogen and phosphorus in water: U.S. Geological Survey Water-Resources Investigations Report 03-4174, 33 p.

Patton, C.J., and Truitt, E.P., 2000, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of ammonium plus organic nitrogen by a Kjeldahl digestion method and an automated photometric finish that includes digest cleanup by gas diffusion: U.S. Geological Survey Open-File Report 00-170, 31 p.

Rantz, S.E. and others, 1982, Measurement and computation of streamflow—Computation of discharge: U.S. Geological Survey Water-Supply Paper 2175, v. 2, p. 285-631

Steiner, J.L., Starks, P.J., Daniel, J.A., Garbrecht, J.D., Moriasi, Daniel, McIntyre, Sherwood and Chen, J.S., 2009, Environmental effects of agricultural conservation—A framework for research in two watersheds in Oklahoma's Upper Washita River Basin: Journal of Soil and Water Conservation , v. 63, no. 6, p. 443-452.

Stoner, J.D., 1982, Water type and suitability of Oklahoma surface waters for public supply and irrigation, part 5—Washita River Basin through 1979: U.S. Geological Survey Water-Resources Investigations 82-29, 150 p.

Storm, D.E., White, M. J. and Stoodley, Scott, 2003, Fort Cobb Basin—Modeling and land cover classification, final report to the Oklahoma Conservation Commission, available online at www.http://storm.okstate.edu/reports/Fort%20Cobb%20report%20Final%20Report%202_26_2003.pdf.

Storm, D.E., White, M.J., and Stoodley, Scott, 2003a, Modeling non-point source component for the Fort Cobb TMDL, final report to Oklahoma Department of Environmental Quality: Biosystems and Agricultural Engineering Dept., Oklahoma State University; Applied Analysis Incorporated, 171 p.

Tanaka, H.H., and Davis, L.V., 1963, Ground-water resources of the Rush Springs Sandstone in the Caddo County area, Oklahoma: Oklahoma Geological Survey Circular 61, 63 p.

U.S. Environmental Protection Agency, 2007, Oklahoma: Lake Creek—Improvement of surface and ground water quality: U.S. Environmental Protection Agency, Section 319 nonpoint source success stories, available online at http://www.epa.gov/nps/success/state/ok_lake.htm (accessed June 6, 2007).

U.S. Environmental Protection Agency, 1983, Determination of phosphorus by semi-automated colorimetry Revision 2.0, Methods for the determination of inorganic substances in environmental samples, EPA Method 365.1, *in* Methods for the determination of inorganic substances in environmental samples: U.S. Environmental Protection Agency, Office of Research and Development (EPA/600/R-93/100).

U.S. Geological Survey, 2007, National Water Information System, available online at http://waterdata.usgs.gov/ok/nwis (accessed June 6, 2007).

Wahl, K.L., and Wahl, T.L., 1995, Determining the flow of Comal Springs at New Braunfels, Texas, *in* Proceedings of Texas Water, 1995, A Component Conference of the First International Conference on Water Resources Engineering, American Society of Civil Engineers Symposium, August 16-17, 1995, San Antonio, Texas: American Society of Civil Engineers, p. 77-86.

Walling, I.W., 1949, Chemical character of surface waters in the Washita River Basin of Oklahoma 1946-47: Oklahoma Planning and Resources Board, Division of Water Resources, Bulletin 4, 31 p.

Wilcock, R.J., McBride, G.B., Nagels, J.W., Northcott, G.L, 1995, Water quality in a polluted lowland stream with chronically depressed dissolved oxygen—causes and effects: New Zealand Journal of Marine and Freshwater Research, v. 29, p. 277-288.

Wilde, F.C., and Gibs, Jacob, 1998, Turbidity—National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. 6.7, 30 p., available online at http://water.usgs.gov/owq/FieldManual/Chapter6/6.7_contents.html.

Wilde, F.D., and Radtke, D.B., eds., 1998, National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6, [variously paged], available online at http://water.usgs.gov/owq/FieldManual/Chapter6/Ch6_contents.html.

Yue, Paul, 2006, TMDL development for Fort Cobb Creek watershed and Fort Cobb Lake—Final Report: Oklahoma Department of Environmental Quality, 133 p.

Yue, Paul, and Derichsweiler, Mark, 2005, TMDL development for Fort Cobb Creek watershed and Fort Cobb Lake, *in* Proceedings of Oklahoma Water 2005, Tulsa, Okla., September 27 and 28, Paper no. 13: Stillwater, Okla., Oklahoma Water Resources Research Institute, 8 p.

# Appendix 1. Instantaneous streamflow, water properties, nutrient-compound concentrations, and statistical groups for stream samples collected at U.S. Geological Survey streamflow-gaging stations, Fort Cobb Reservoir watershed, southwestern Oklahoma, November 2004 to May 2007.

**Appendix 1.** Instantaneous streamflow, water properties, nutrient-compound concentrations, and statistical groups for stream samples collected at U.S. Geological Survey streamflow-gaging stations, Fort Cobb Reservoir watershed, southwestern Oklahoma, November 2004 to May 2007.

[$ft^3/s$, cubic feet per second; the months May through September are considered the growing season and October through April the dormant season; mg/L, milligrams per liter; NTU, nepheletic turbidity units; N, nitrogen; µS/cm, microsiemens per centimeter at 25 degrees Celsius; $CaCO_3$, calcium carbonate; P, phosphorus; blank, equipment blank; mm, millimeters; <, less than; >, greater than; °C, Celsius; --, not available; E, estimated; nitrate nitrogen, nitrite plus nitrate nitrogen, and ammonia nitrogen concentrations are dissolved; ammonia plus organic nitrogen concentrations are total; nitrate nitrogen was calculated by subtracting nitrite nitrogen from nitrite plus nitrate nitrogen concentrations; organic nitrogen was calculated by subtracting ammonia nitrogen from ammonia plus organic nitrogen concentrations, and total nitrogen was estimated by summing ammonia plus organic nitrogen and nitrite plus nitrate concentrations; phosphorus concentrations are dissolved; total phosphorus concentrations are total; orthophosphate concentrations are dissolved; all nutrient concentration measured in precipitation samples are dissolved; total nitrogen measured in precipitation samples at meteorological site was analytically determined]

| Date | Time | Sample type | Flow condition group | Season group | Instantaneous streamflow ($ft^3/s$) | Specific conductance (µS/cm) | pH (standard units) | Water temperature (degrees °C) | Turbidity (NTU) | Dissolved oxygen (mg/L) | Alkalinity (mg/L as $CaCO_3$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cobb Creek near Eakly, Oklahoma (U.S. Geological Survey site identification number 07325800) | | | | | | | | | | | |
| Nov 17, 2004 | 1405 | regular | runoff | dormant | 130 | 507 | 7.6 | 14.8 | -- | 8.8 | 138 |
| Dec 8, 2004 | 1130 | regular | base flow | dormant | 24 | 738 | 7.8 | 8.5 | -- | 11.1 | 194 |
| Jan 19, 2005 | 1130 | regular | base flow | dormant | 22 | 786 | 8.3 | 4.3 | -- | 12.6 | 203 |
| Mar 2, 2005 | 1630 | regular | base flow | dormant | 24 | 834 | 8.1 | 12.0 | -- | 12.3 | 235 |
| Apr 27, 2005 | 1030 | regular | base flow | dormant | 17 | 866 | -- | 14.0 | -- | 9.9 | 234 |
| May 2, 2005 | 1830 | regular | base flow | growing | 22 | 810 | 7.9 | 13.5 | -- | 11.5 | 233 |
| Jun 10, 2005 | 1152 | regular | runoff | growing | 64 | 544 | 7.9 | 21.5 | -- | 5.9 | 69 |
| Jun 11, 2005 | 1249 | regular | runoff | growing | 380 | 260 | 7.7 | 19.2 | -- | 6.4 | 65 |
| Jun 13, 2005 | 0345 | regular | runoff | growing | 4,540 | 135 | 8.2 | 18.8 | -- | 6.7 | 37 |
| Jun 29, 2005 | 1050 | regular | base flow | growing | 12 | 866 | 8.1 | 23.6 | -- | 8.3 | 240 |
| Jun 29, 2005 | 1051 | replicate | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Aug 8, 2005 | 0940 | regular | base flow | growing | -- | 795 | 8.1 | 22.8 | -- | 8.2 | 223 |
| Aug 21, 2005 | 0710 | regular | runoff | growing | 1,670 | 157 | 8.1 | 22.2 | -- | 6.3 | 44 |
| Sep 6, 2005 | 1220 | regular | base flow | growing | 9.7 | 768 | 8.2 | 22.4 | -- | 8.7 | 203 |
| Nov 7, 2005 | 1130 | regular | base flow | dormant | 20 | 750 | 8.3 | 13.5 | -- | 10.6 | 231 |
| Dec 6, 2005 | 1245 | regular | base flow | dormant | 17 | 780 | 8.5 | 3.1 | -- | 13.4 | 251 |
| Dec 21, 2005 | 1002 | blank | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Mar 14, 2006 | 1115 | regular | base flow | dormant | 16 | 746 | 8.2 | 10.5 | -- | 10.7 | 228 |
| Mar 14, 2006 | 1116 | blank | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Mar 20, 2006 | 1230 | regular | runoff | dormant | 33 | 838 | 8 | 9.9 | -- | 9.8 | 237 |

| Nitrite nitrogen (mg/L as N) | Nitrate nitrogen, calculated (mg/L as N) | Nitrite plus nitrate nitrogen (mg/L as N) | Ammonia nitrogen (mg/L as N) | Ammonia plus organic nitrogen (mg/L as N) | Organic nitrogen, calculated (mg/L as N) | Total nitrogen, calculated (mg/L) | Dissolved phosphorus (mg/L) | Total phosphorus (mg/L) | Ortho-phosphate (mg/L as P) | Fine-suspended sediment (percent < 0.063 mm ) | Suspended sediment (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cobb Creek near Eakly, Oklahoma (U.S. Geological Survey site identification number 07325800) | | | | | | | | | | | |
| 0.019 | 0.512 | 0.531 | 0.137 | 3.1 | 3.0 | 3.6 | 0.280 | 0.810 | 0.235 | 88 | 704 |
| 0.022 | 1.17 | 1.19 | 0.081 | 0.5 | 0.40 | 1.7 | 0.092 | 0.122 | 0.075 | 63 | 215 |
| 0.015 | 1.45 | 1.46 | 0.039 | 0.3 | 0.22 | 1.7 | 0.036 | 0.058 | 0.03 | 55 | 61 |
| 0.023 | 1.27 | 1.29 | 0.036 | 0.3 | 0.31 | 1.6 | 0.040 | 0.074 | 0.032 | 33 | 114 |
| 0.079 | 1.29 | 1.37 | 0.170 | 0.6 | 0.47 | 2.0 | 0.100 | 0.155 | 0.079 | 66 | 125 |
| 0.056 | 1.30 | 1.36 | 0.127 | 0.7 | 0.58 | 2.1 | 0.083 | 0.183 | 0.062 | 64 | 155 |
| 0.068 | 0.911 | 0.979 | 0.271 | 4.3 | 4.0 | 5.3 | 0.280 | 1.21 | 0.246 | 73 | 1,600 |
| 0.025 | 0.421 | 0.446 | 0.238 | 6.7 | 6.5 | 7.1 | 0.210 | 1.62 | 0.186 | 59 | 3,720 |
| 0.008 | 0.165 | 0.173 | 0.081 | 4.1 | 4.0 | 4.3 | 0.123 | 1.39 | 0.076 | 26 | 6,270 |
| 0.036 | 1.30 | 1.34 | 0.055 | 0.4 | 0.37 | 1.8 | 0.135 | 0.173 | 0.110 | 70 | 216 |
| <0.002 | -- | E 0.010 | <0.01 | <0.1 | -- | -- | <0.004 | <0.004 | <0.006 | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 0.021 | 0.547 | 0.568 | 0.160 | 9.0 | 8.8 | 9.6 | 0.008 | 1.69 | 0.160 | 68 | 5,540 |
| 0.015 | 1.30 | 1.31 | 0.018 | 0.3 | 0.31 | 1.6 | 0.092 | 0.120 | 0.065 | 32 | 226 |
| 0.014 | 1.10 | 1.11 | < 0.01 | 0.3 | E 0.34 | 1.5 | 0.060 | 0.093 | 0.037 | 18 | 215 |
| 0.015 | 1.43 | 1.44 | 0.022 | 0.2 | 0.22 | 1.7 | 0.034 | 0.054 | 0.020 | 23 | 230 |
| <0.002 | -- | E0.008 | E0.008 | <0.1 | -- | -- | <0.004 | E0.002 | <0.006 | -- | -- |
| 0.028 | 1.30 | 1.33 | 0.028 | 0.3 | 0.28 | 1.6 | 0.072 | 0.097 | 0.054 | 41 | 117 |
| <0.002 | -- | <0.016 | <0.01 | <0.1 | -- | -- | <0.004 | <0.004 | <0.006 | -- | -- |
| 0.034 | 1.0 | 0.994 | 0.086 | 1.8 | 1.7 | 2.8 | 0.133 | 0.260 | 0.093 | 44 | 460 |

**Appendix 1.** Instantaneous streamflow, water properties, nutrient-compound concentrations, and statistical groups for stream samples collected at U.S. Geological Survey streamflow-gaging stations, Fort Cobb Reservoir watershed, southwestern Oklahoma, November 2004 to May 2007.—Continued

[$ft^3/s$, cubic feet per second; the months May through September are considered the growing season and October through April the dormant season; mg/L, milligrams per liter; NTU, nepheletic turbidity units; N, nitrogen; µS/cm, microsiemens per centimeter at 25 degrees Celsius; $CaCO_3$, calcium carbonate; P, phosphorus; blank, equipment blank; mm, millimeters; <, less than; >, greater than; °C, Celsius; --, not available; E, estimated; nitrate nitrogen, nitrite plus nitrate nitrogen, and ammonia nitrogen concentrations are dissolved; ammonia plus organic nitrogen concentrations are total; nitrate nitrogen was calculated by subtracting nitrite nitrogen from nitrite plus nitrate nitrogen concentrations; organic nitrogen was calculated by subtracting ammonia nitrogen from ammonia plus organic nitrogen concentrations, and total nitrogen was estimated by summing ammonia plus organic nitrogen and nitrite plus nitrate concentrations; phosphorus concentrations are dissolved; total phosphorus concentrations are total; orthophosphate concentrations are dissolved; all nutrient concentration measured in precipitation samples are dissolved; total nitrogen measured in precipitation samples at meteorological site was analytically determined]

| Date | Time | Sample type | Flow condition group | Season group | Instantaneous streamflow ($ft^3/s$) | Specific conductance (µS/cm) | pH (standard units) | Water temperature (degrees °C) | Turbidity (NTU) | Dissolved oxygen (mg/L) | Alkalinity (mg/L as $CaCO_3$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cobb Creek near Eakly, Oklahoma (U.S. Geological Survey site identification number 07325800)—Continued | | | | | | | | | | | |
| Apr 26, 2006 | 1030 | regular | base flow | dormant | 17 | 786 | 8 | 14.4 | 17 | 8.8 | 228 |
| Jun 7, 2006 | 1100 | regular | base flow | growing | 13 | 810 | 8.2 | 25.3 | 18 | 8.2 | 228 |
| Jun 17, 2006 | 1330 | regular | runoff | growing | 133 | 328 | 7.8 | 20.9 | >1,000 | 5 | 68 |
| Jun 17, 2006 | 1331 | replicate | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Jun 17, 2006 | 1700 | regular | runoff | growing | 91 | 308 | 7.6 | 22.0 | >1,000 | 5.2 | 71 |
| Jun 22, 2006 | 1530 | regular | runoff | growing | 375 | 184 | 7.6 | 20.7 | >1,000 | 6.4 | 45 |
| Jun 22, 2006 | 1730 | regular | runoff | growing | 212 | 229 | 7.8 | 21.4 | >1,000 | 7 | 56 |
| Sep 6, 2006 | 1030 | regular | base flow | growing | 8.9 | 796 | 8.5 | 19.0 | 18 | 8.6 | 215 |
| Oct 16, 2006 | 0030 | regular | runoff | dormant | 18 | 657 | 8.2 | 15.7 | 66 | 8.4 | 198 |
| Oct 16, 2006 | 1430 | regular | runoff | dormant | 29 | 826 | 8.3 | 16.3 | 95 | 7.8 | 188 |
| Nov 28, 2006 | 1330 | regular | base flow | dormant | 15 | 775 | 8.4 | 15.7 | 14 | 9.3 | 229 |
| Jan 30, 2007 | 1300 | regular | base flow | dormant | 18 | 783 | 8.1 | 4.8 | 7.6 | 13.7 | 228 |
| Mar 19, 2007 | 1100 | regular | base flow | dormant | 17 | 780 | 8 | 16.2 | -- | 9.4 | 224 |
| Mar 23, 2007 | 1215 | regular | runoff | dormant | 160 | 521 | 7.6 | 17.5 | >1,000 | 7.4 | 111 |
| Mar 29, 2007 | 2015 | regular | runoff | dormant | 544 | 243 | 7.7 | 18 | >1,000 | 5.7 | 76 |
| Mar 29, 2007 | 2345 | regular | runoff | dormant | 372 | 267 | 7.7 | 18.2 | >1,000 | 6.1 | 81 |
| Mar 30, 2007 | 2345 | regular | runoff | dormant | 928 | 235 | 8 | 13.4 | >1,000 | 7.9 | 61 |
| May 8, 2007 | 1630 | regular | runoff | growing | 333 | 532 | 7.6 | 20.2 | >1,000 | 6.2 | 92 |
| May 30, 2007 | 1600 | regular | runoff | growing | 153 | 415 | 7.9 | 19.4 | >1,000 | 7 | 109 |

| Nitrite nitrogen (mg/L as N) | Nitrate nitrogen, calculated (mg/L as N) | Nitrite plus nitrate nitrogen (mg/L as N) | Ammonia nitrogen (mg/L as N) | Ammonia plus organic nitrogen (mg/L as N) | Organic nitrogen, calculated (mg/L as N) | Total nitrogen, calculated (mg/L) | Dissolved phosphorus (mg/L) | Total phosphorus (mg/L) | Ortho-phosphate (mg/L as P) | Fine-suspended sediment (percent < 0.063 mm ) | Suspended sediment (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cobb Creek near Eakly, Oklahoma (U.S. Geological Survey site identification number 07325800)—Continued | | | | | | | | | | | |
| 0.077 | 1.32 | 1.40 | 0.100 | 0.5 | 0.41 | 1.9 | 0.119 | 0.162 | 0.109 | 55 | 220 |
| 0.026 | 1.20 | 1.23 | 0.019 | 0.4 | 0.42 | 1.7 | 0.122 | 0.170 | 0.097 | 65 | 141 |
| 0.057 | 0.747 | 0.804 | 0.332 | 5.2 | 4.9 | 6.0 | 0.210 | 1.30 | 0.178 | 67 | 2,260 |
| 0.056 | 0.737 | 0.793 | 0.321 | 5.2 | 4.9 | 6.0 | 0.210 | 1.16 | 0.168 | -- | -- |
| 0.055 | 0.604 | 0.659 | 0.241 | 4.1 | 3.9 | 4.8 | 0.210 | 0.980 | 0.168 | 62 | 1,600 |
| 0.026 | 0.511 | 0.537 | 0.213 | 7.0 | 6.8 | 7.5 | 0.154 | 1.54 | 0.124 | 58 | 5,860 |
| 0.027 | 0.565 | 0.592 | 0.165 | 5.8 | 5.6 | 6.4 | 0.154 | 1.23 | 0.120 | 74 | 3,840 |
| 0.021 | 1.45 | 1.47 | 0.029 | 0.4 | 0.37 | 1.9 | 0.099 | 0.137 | 0.086 | 64 | 143 |
| 0.016 | 1.06 | 1.08 | 0.026 | 0.8 | 0.74 | 1.9 | 0.075 | 0.180 | 0.054 | -- | 163 |
| 0.019 | 0.944 | 0.963 | 0.053 | 1.0 | 0.9 | 2.0 | 0.105 | 0.268 | 0.083 | -- | 379 |
| 0.013 | 0.757 | 0.770 | < 0.02 | 0.5 | E 0.44 | 1.2 | 0.063 | 0.110 | 0.050 | -- | 110 |
| 0.019 | 1.29 | 1.31 | 0.045 | 0.3 | 0.30 | 1.7 | 0.041 | 0.067 | 0.033 | -- | 184 |
| 0.037 | 0.942 | 0.979 | 0.077 | 0.4 | 0.33 | 1.4 | 0.067 | 0.129 | 0.047 | -- | 224 |
| 0.068 | 0.722 | 0.79 | 0.568 | 4.9 | 4.3 | 5.7 | 0.182 | 1.16 | 0.132 | -- | 1780 |
| 0.011 | 0.280 | 0.291 | 0.143 | 9.3 | 9.2 | 9.6 | 0.292 | 2.52 | 0.129 | -- | 5,580 |
| 0.036 | 0.324 | 0.360 | 0.287 | 4.7 | 4.4 | 5.1 | 0.191 | 1.08 | 0.137 | -- | 2,990 |
| 0.02 | 0.261 | 0.281 | 0.261 | 6.8 | 6.5 | 7.1 | 0.169 | 1.68 | 0.123 | -- | 11,500 |
| 0.019 | 0.230 | 0.249 | 0.144 | 4.6 | 4.5 | 4.8 | 0.086 | 0.960 | 0.061 | -- | 2,390 |
| 0.037 | 1.05 | 1.09 | 0.115 | 3.9 | 3.8 | 5.0 | 0.164 | 1.00 | 0.129 | 66 | 2,030 |

**Appendix 1.** Instantaneous streamflow, water properties, nutrient-compound concentrations, and statistical groups for stream samples collected at U.S. Geological Survey streamflow-gaging stations, Fort Cobb Reservoir watershed, southwestern Oklahoma, November 2004 to May 2007.—Continued

[$ft^3/s$, cubic feet per second; the months May through September are considered the growing season and October through April the dormant season; mg/L, milligrams per liter; NTU, nepheletic turbidity units; N, nitrogen; µS/cm, microsiemens per centimeter at 25 degrees Celsius; $CaCO_3$, calcium carbonate; P, phosphorus; blank, equipment blank; mm, millimeters; <, less than; >, greater than; °C, Celsius; --, not available; E, estimated; nitrate nitrogen, nitrite plus nitrate nitrogen, and ammonia nitrogen concentrations are dissolved; ammonia plus organic nitrogen concentrations are total; nitrate nitrogen was calculated by subtracting nitrite nitrogen from nitrite plus nitrate nitrogen concentrations; organic nitrogen was calculated by subtracting ammonia nitrogen from ammonia plus organic nitrogen concentrations, and total nitrogen was estimated by summing ammonia plus organic nitrogen and nitrite plus nitrate concentrations; phosphorus concentrations are dissolved; total phosphorus concentrations are total; orthophosphate concentrations are dissolved; all nutrient concentration measured in precipitation samples are dissolved; total nitrogen measured in precipitation samples at meteorological site was analytically determined]

| Date | Time | Sample type | Flow condition group | Season group | Instantaneous streamflow ($ft^3/s$) | Specific conductance (µS/cm) | pH (standard units) | Water temperature (degrees °C) | Turbidity (NTU) | Dissolved oxygen (mg/L) | Alkalinity (mg/L as $CaCO_3$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lake Creek near Eakly, Oklahoma (U.S. Geological Survey site identification number 07325850) | | | | | | | | | | | |
| Nov 17, 2004 | 1230 | regular | runoff | dormant | 48 | 405 | 7.6 | 14.8 | -- | 8.2 | 149 |
| Dec 8, 2004 | 1330 | regular | base flow | dormant | 5.3 | 603 | 7.8 | 10.5 | -- | 11 | 217 |
| Jan 19, 2005 | 1330 | regular | base flow | dormant | 5.9 | 585 | 8.1 | 6.4 | -- | 13.1 | 215 |
| Mar 2, 2005 | 1430 | regular | base flow | dormant | 6.2 | 628 | 8.2 | 13.8 | -- | 13.2 | 258 |
| Mar 2, 2005 | 1431 | replicate | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Apr 27, 2005 | 1300 | regular | base flow | dormant | 4.5 | 582 | 8 | 20.1 | -- | 15.8 | 236 |
| May 2, 2005 | 1627 | regular | runoff | growing | 8.4 | 578 | 8.4 | 14.9 | -- | 16.8 | 232 |
| Jun 10, 2005 | 1055 | regular | runoff | growing | 60 | 209 | 8 | 21.6 | -- | 6.4 | 100 |
| Jun 11, 2005 | 1535 | regular | runoff | growing | 134 | 244 | 7.7 | 22.1 | -- | 5.9 | 81 |
| Jun 13, 2005 | 0045 | regular | runoff | growing | 3,620 | 96 | 8.4 | 18.7 | -- | 6.9 | 33 |
| Jun 29, 2005 | 1150 | regular | base flow | growing | 3.2 | 649 | 8.2 | 29 | -- | 8.2 | 273 |
| Jun 29, 2005 | 1152 | replicate | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Aug 8, 2005 | 1030 | regular | base flow | growing | -- | 584 | 8.2 | 26.7 | -- | 8.7 | 222 |
| Aug 21, 2005 | 0615 | regular | runoff | growing | 327 | 146 | 8.1 | 22.6 | -- | 6.7 | 48 |
| Sep 6, 2005 | 1300 | regular | base flow | growing | 4.8 | 605 | 8.4 | 28.2 | -- | 9.4 | 238 |
| Nov 7, 2005 | 1305 | regular | base flow | dormant | 3.8 | 571 | 8.3 | 18.1 | -- | 13.4 | 243 |
| Dec 6, 2005 | 1415 | regular | base flow | dormant | 4.6 | 590 | 8.6 | 4.6 | -- | 13.8 | 249 |
| Dec 21, 2005 | 1001 | blank | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Mar 14, 2006 | 1230 | regular | base flow | dormant | 5 | 555 | 8.3 | 14 | -- | 13.4 | 225 |
| Mar 20, 2006 | 1400 | regular | runoff | dormant | 8.8 | 724 | 8 | 11.6 | -- | 10.5 | 227 |

| Nitrite nitrogen (mg/L as N) | Nitrate nitrogen, calculated (mg/L as N) | Nitrite plus nitrate nitrogen (mg/L as N) | Ammonia nitrogen (mg/L as N) | Ammonia plus organic nitrogen (mg/L as N) | Organic nitrogen, calculated (mg/L as N) | Total nitrogen, calculated (mg/L) | Dissolved phosphorus (mg/L) | Total phosphorus (mg/L) | Ortho-phosphate (mg/L as P) | Fine-suspended sediment (percent < 0.063 mm ) | Suspended sediment (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lake Creek near Eakly, Oklahoma (U.S. Geological Survey site identification number 07325850) | | | | | | | | | | | |
| 0.011 | 0.352 | 0.363 | 0.116 | 2.7 | 2.6 | 3.1 | 0.106 | 0.570 | 0.085 | 40 | 1,750 |
| 0.022 | 0.882 | 0.904 | 0.071 | 0.6 | 0.51 | 1.5 | 0.072 | 0.141 | 0.052 | 69 | 170 |
| 0.014 | 1.11 | 1.12 | 0.031 | 0.3 | 0.24 | 1.4 | 0.021 | 0.051 | 0.015 | 48 | 211 |
| 0.026 | 0.758 | 0.784 | 0.160 | 0.6 | 0.46 | 1.4 | 0.030 | 0.064 | 0.023 | 46 | 60 |
| 0.026 | 0.757 | 0.783 | 0.161 | 0.6 | 0.46 | 1.4 | 0.030 | 0.062 | 0.023 | -- | -- |
| 0.037 | 0.316 | 0.353 | 0.012 | 0.4 | 0.37 | 0.73 | 0.025 | 0.054 | 0.015 | 46 | 60 |
| 0.027 | 0.414 | 0.441 | 0.016 | 0.4 | 0.35 | 0.81 | 0.028 | 0.045 | 0.015 | 18 | 168 |
| 0.028 | 0.337 | 0.365 | 0.221 | 3.1 | 2.9 | 3.5 | 0.197 | 0.910 | 0.164 | 47 | 1,910 |
| 0.030 | 0.420 | 0.450 | 0.279 | 4.2 | 3.9 | 4.7 | 0.081 | 1.07 | 0.049 | 39 | 3,090 |
| 0.012 | 0.289 | 0.301 | 0.180 | 6.4 | 6.2 | 6.7 | 0.115 | 1.55 | 0.090 | 38 | 9,120 |
| 0.004 | 0.067 | 0.071 | 0.010 | 0.4 | 0.44 | 0.52 | 0.063 | 0.127 | 0.028 | 33 | 336 |
| 0.004 | 0.065 | 0.069 | 0.011 | 0.4 | 0.42 | 0.50 | 0.065 | 0.122 | 0.041 | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 0.021 | 0.397 | 0.418 | 0.111 | 3.8 | 3.7 | 4.2 | 0.144 | 0.910 | 0.113 | 43 | 3,090 |
| 0.006 | 0.183 | 0.189 | < 0.010 | 0.4 | 0.41 | 0.60 | 0.067 | 0.105 | 0.048 | 57 | 119 |
| 0.006 | 0.247 | 0.253 | E 0.005 | 0.4 | E 0.41 | 0.66 | 0.022 | 0.066 | 0.006 | 45 | 54 |
| 0.012 | 0.931 | 0.943 | 0.016 | 0.2 | 0.21 | 1.2 | 0.018 | 0.044 | E 0.003 | 54 | 115 |
| E.001 | -- | <0.016 | E0.006 | < 0.1 | -- | -- | <0.004 | <0.004 | <0.006 | -- | -- |
| 0.037 | 0.721 | 0.758 | 0.052 | 0.4 | 0.36 | 1.2 | 0.042 | 0.084 | 0.022 | 65 | 83 |
| 0.033 | 0.843 | 0.876 | 0.131 | 1.7 | 1.6 | 2.6 | 0.081 | 0.180 | 0.040 | 93 | 69 |

**Appendix 1.** Instantaneous streamflow, water properties, nutrient-compound concentrations, and statistical groups for stream samples collected at U.S. Geological Survey streamflow-gaging stations, Fort Cobb Reservoir watershed, southwestern Oklahoma, November 2004 to May 2007.—Continued

[$ft^3/s$, cubic feet per second; the months May through September are considered the growing season and October through April the dormant season; mg/L, milligrams per liter; NTU, nepheletic turbidity units; N, nitrogen; µS/cm, microsiemens per centimeter at 25 degrees Celsius; $CaCO_3$, calcium carbonate; P, phosphorus; blank, equipment blank; mm, millimeters; <, less than; >, greater than; °C, Celsius; --, not available; E, estimated; nitrate nitrogen, nitrite plus nitrate nitrogen, and ammonia nitrogen concentrations are dissolved; ammonia plus organic nitrogen concentrations are total; nitrate nitrogen was calculated by subtracting nitrite nitrogen from nitrite plus nitrate nitrogen concentrations; organic nitrogen was calculated by subtracting ammonia nitrogen from ammonia plus organic nitrogen concentrations, and total nitrogen was estimated by summing ammonia plus organic nitrogen and nitrite plus nitrate concentrations; phosphorus concentrations are dissolved; total phosphorus concentrations are total; orthophosphate concentrations are dissolved; all nutrient concentration measured in precipitation samples are dissolved; total nitrogen measured in precipitation samples at meteorological site was analytically determined]

| Date | Time | Sample type | Flow condition group | Season group | Instantaneous streamflow ($ft^3/s$) | Specific conductance (µS/cm) | pH (standard units) | Water temperature (degrees °C) | Turbidity (NTU) | Dissolved oxygen (mg/L) | Alkalinity (mg/L as $CaCO_3$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lake Creek near Eakly, Oklahoma (U.S. Geological Survey site identification number 07325850)—Continued | | | | | | | | | | | |
| Apr 26, 2006 | 1145 | regular | base flow | dormant | 3 | 594 | 8.3 | 17.3 | 15 | 12.4 | 234 |
| Jun 7, 2006 | 1300 | regular | runoff | growing | 3.4 | 560 | 8.3 | 32.6 | 11 | 11.4 | 223 |
| Jun 17, 2006 | 1200 | regular | runoff | growing | 36 | 204 | 7.9 | 20.3 | >1,000 | 6.1 | 69 |
| Jun 17, 2006 | 1615 | regular | runoff | growing | 19 | 215 | 7.8 | 23.3 | >1,000 | 5.6 | 73 |
| Jun 22, 2006 | 1630 | regular | runoff | growing | 15 | 436 | 7.8 | 25.8 | 300 | 7.5 | 172 |
| Sep 6, 2006 | 1200 | regular | runoff | growing | 1.6 | 570 | 8.5 | 21.8 | 23 | 11.3 | 223 |
| Oct 16, 2006 | 0200 | regular | runoff | dormant | 5.9 | 529 | 8.3 | 16 | 92 | 8.2 | 210 |
| Oct 16, 2006 | 1300 | regular | runoff | dormant | 5.7 | 540 | 8.3 | 16.4 | 84 | 7.8 | 214 |
| Nov 28, 2006 | 1230 | regular | base flow | dormant | 5 | 550 | 8.6 | 16.3 | 39 | 11.2 | 230 |
| Nov 28, 2006 | 1231 | replicate | -- | -- | -- | -- | -- | -- | -- | -- | 230 |
| Jan 30, 2007 | 1200 | regular | base flow | dormant | 4 | 559 | 8.2 | 4.4 | 12 | 16.1 | 233 |
| Mar 19, 2007 | 1215 | regular | base flow | dormant | 4.6 | 578 | 8.1 | 17.5 | -- | 13.2 | 239 |
| Mar 23, 2007 | 1115 | regular | runoff | dormant | 39 | 262 | 7.5 | 17.5 | >1,000 | 7.8 | 102 |
| Mar 29, 2007 | 1930 | regular | runoff | dormant | 729 | 158 | 7.9 | 17.9 | >1,000 | 5.9 | 67 |
| Mar 29, 2007 | 1931 | replicate | -- | -- | -- | -- | -- | -- | -- | -- | 67 |
| Mar 29, 2007 | 2315 | regular | runoff | dormant | 256 | 128 | 8 | 17.7 | >1,000 | 7.1 | 53 |
| Mar 30, 2007 | 2300 | regular | runoff | dormant | 346 | 154 | 8.1 | 13.4 | >1,000 | 9.1 | 65 |
| May 8, 2007 | 1530 | regular | runoff | growing | 102 | 176 | 7.8 | 20.4 | >1,000 | 7.4 | 76 |
| May 30, 2007 | 1500 | regular | base flow | growing | 27 | 574 | 8.1 | 22 | 340 | 7.7 | 247 |

| Nitrite nitrogen (mg/L as N) | Nitrate nitrogen, calculated (mg/L as N) | Nitrite plus nitrate nitrogen (mg/L as N) | Ammonia nitrogen (mg/L as N) | Ammonia plus organic nitrogen (mg/L as N) | Organic nitrogen, calculated (mg/L as N) | Total nitrogen, calculated (mg/L) | Dissolved phosphorus (mg/L) | Total phosphorus (mg/L) | Ortho-phosphate (mg/L as P) | Fine-suspended sediment (percent < 0.063 mm ) | Suspended sediment (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lake Creek near Eakly, Oklahoma (U.S. Geological Survey site identification number 07325850)—Continued | | | | | | | | | | | |
| 0.040 | 0.467 | 0.507 | 0.032 | 0.4 | 0.37 | 0.91 | 0.081 | 0.106 | 0.059 | 53 | 144 |
| 0.006 | 0.038 | 0.044 | 0.033 | 0.7 | 0.64 | 0.71 | 0.081 | 0.136 | 0.055 | 59 | 45 |
| 0.040 | 0.618 | 0.658 | 0.421 | 7.0 | 6.6 | 7.7 | 0.143 | 1.38 | 0.101 | 83 | 2,410 |
| 0.046 | 0.530 | 0.576 | 0.282 | 5.0 | 4.7 | 5.6 | 0.144 | 1.10 | 0.105 | 32 | 4,080 |
| 0.041 | 0.305 | 0.346 | 0.075 | 2.0 | 1.9 | 2.3 | 0.144 | 0.430 | 0.120 | 80 | 469 |
| 0.033 | 0.435 | 0.468 | 0.025 | 0.5 | 0.47 | 0.96 | 0.066 | 0.111 | 0.047 | 71 | 82 |
| 0.023 | 0.526 | 0.549 | 0.134 | 0.9 | 0.78 | 1.5 | 0.052 | 0.197 | 0.037 | -- | 173 |
| 0.026 | 0.695 | 0.721 | 0.123 | 0.8 | 0.65 | 1.5 | 0.050 | 0.172 | 0.034 | -- | 136 |
| 0.020 | 0.600 | 0.620 | 0.051 | 0.5 | 0.49 | 1.1 | 0.035 | 0.096 | 0.023 | -- | 120 |
| 0.020 | 0.605 | 0.625 | 0.052 | 0.5 | 0.45 | 1.1 | 0.036 | 0.095 | 0.024 | -- | -- |
| 0.011 | 0.715 | 0.726 | E0.013 | 0.3 | E 0.31 | 1.0 | 0.017 | 0.044 | 0.013 | -- | 91 |
| 0.027 | 0.420 | 0.447 | E0.018 | 0.6 | E 0.54 | 1.0 | 0.024 | 0.094 | 0.015 | -- | 145 |
| 0.033 | 0.456 | 0.489 | 0.566 | 7.4 | 6.8 | 7.9 | 0.069 | 1.46 | 0.034 | -- | 2,030 |
| 0.016 | 0.238 | 0.254 | 0.269 | 9.2 | 8.9 | 9.5 | 0.074 | 1.66 | 0.040 | -- | 7,290 |
| 0.017 | 0.225 | 0.242 | 0.279 | 9.3 | 9.0 | 9.5 | 0.078 | 1.47 | 0.040 | -- | -- |
| 0.016 | 0.260 | 0.276 | 0.184 | 6.0 | 5.8 | 6.3 | 0.102 | 1.03 | 0.063 | -- | 5,000 |
| 0.012 | 0.211 | 0.223 | 0.121 | 4.3 | 4.2 | 4.5 | 0.197 | 1.02 | 0.150 | -- | 4,410 |
| 0.026 | 0.391 | 0.417 | 0.129 | 4.3 | 4.2 | 4.7 | 0.133 | 0.930 | 0.103 | -- | 1,920 |
| 0.044 | 0.765 | 0.809 | 0.079 | 1.5 | 1.4 | 2.3 | 0.095 | 0.430 | 0.086 | 72 | 878 |

**Appendix 1.** Instantaneous streamflow, water properties, nutrient-compound concentrations, and statistical groups for stream samples collected at U.S. Geological Survey streamflow-gaging stations, Fort Cobb Reservoir watershed, southwestern Oklahoma, November 2004 to May 2007.—Continued

[$ft^3/s$, cubic feet per second; the months May through September are considered the growing season and October through April the dormant season; mg/L, milligrams per liter; NTU, nepheletic turbidity units; N, nitrogen; µS/cm, microsiemens per centimeter at 25 degrees Celsius; $CaCO_3$, calcium carbonate; P, phosphorus; blank, equipment blank; mm, millimeters; <, less than; >, greater than; °C, Celsius; --, not available; E, estimated; nitrate nitrogen, nitrite plus nitrate nitrogen, and ammonia nitrogen concentrations are dissolved; ammonia plus organic nitrogen concentrations are total; nitrate nitrogen was calculated by subtracting nitrite nitrogen from nitrite plus nitrate nitrogen concentrations; organic nitrogen was calculated by subtracting ammonia nitrogen from ammonia plus organic nitrogen concentrations, and total nitrogen was estimated by summing ammonia plus organic nitrogen and nitrite plus nitrate concentrations; phosphorus concentrations are dissolved; total phosphorus concentrations are total; orthophosphate concentrations are dissolved; all nutrient concentration measured in precipitation samples are dissolved; total nitrogen measured in precipitation samples at meteorological site was analytically determined]

| Date | Time | Sample type | Flow condition group | Season group | Instantaneous streamflow ($ft^3/s$) | Specific conductance (µS/cm) | pH (standard units) | Water temperature (degrees °C) | Turbidity (NTU) | Dissolved oxygen (mg/L) | Alkalinity (mg/L as $CaCO_3$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Willow Creek near Albert, Oklahoma (U.S. Geological Survey site identification number 07325860) | | | | | | | | | | | |
| Nov 17, 2004 | 1125 | regular | runoff | dormant | 22 | 416 | 7.3 | 14.9 | -- | 9.8 | 151 |
| Dec 8, 2004 | 1430 | regular | base flow | dormant | 2.4 | 604 | 7.8 | 11 | -- | 11.4 | 196 |
| Jan 19, 2005 | 1500 | regular | base flow | dormant | 2.6 | 590 | 8 | 7.5 | -- | 14.1 | 193 |
| Mar 2, 2005 | 1230 | regular | base flow | dormant | 2.9 | 625 | 7.9 | 9.8 | -- | 14 | 226 |
| Apr 27, 2005 | 1500 | regular | base flow | dormant | 2.3 | 635 | 7.7 | 21.3 | -- | 10.7 | 227 |
| May 2, 2005 | 1725 | regular | base flow | growing | 3.5 | 613 | 7.8 | 14.1 | -- | 12.5 | 224 |
| Jun 10, 2005 | 0937 | regular | runoff | growing | 90 | 133 | 8.3 | 19.6 | -- | 7 | 42 |
| Jun 10, 2005 | 1518 | regular | runoff | growing | 16 | 204 | 8 | 21.3 | -- | 6.9 | 62 |
| Jun 13, 2005 | 0215 | regular | runoff | growing | 333 | 124 | 8.2 | 19.8 | -- | 6.9 | 37 |
| Jun 29, 2005 | 1315 | regular | base flow | growing | 1.5 | 565 | 8.2 | 26.9 | -- | 9.1 | 204 |
| Aug 8, 2005 | 1115 | regular | base flow | growing | -- | 483 | 8 | 25.2 | -- | 8 | 164 |
| Aug 21, 2005 | 0515 | regular | runoff | growing | 254 | 117 | 8.3 | 22 | -- | 6.7 | 37 |
| Sep 6, 2005 | 1350 | regular | base flow | growing | 2 | 501 | 8.2 | 24.2 | -- | 9.5 | 183 |
| Nov 7, 2005 | 1445 | regular | base flow | dormant | 1.9 | 549 | 8.3 | 16.2 | -- | 13 | 201 |
| Dec 6, 2005 | 1530 | regular | base flow | dormant | 1.2 | 599 | 8.5 | 3.9 | -- | 14.2 | 217 |
| Dec 21, 2005 | 1003 | blank | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Mar 14, 2006 | 1400 | regular | base flow | dormant | 2.1 | 560 | 7.9 | 12.2 | -- | 13.4 | 197 |
| Mar 20, 2006 | 1530 | regular | runoff | dormant | 4.9 | 620 | 8.1 | 12.3 | -- | 11.9 | 227 |
| Apr 26, 2006 | 1230 | regular | base flow | dormant | 1.6 | 573 | 7.9 | 16.7 | 9.7 | 10 | 201 |
| Jun 7, 2006 | 1430 | regular | base flow | growing | 1.8 | 513 | 8.1 | 30.6 | 30 | 8.3 | 194 |

| Nitrite nitrogen (mg/L as N) | Nitrate nitrogen, calculated (mg/L as N) | Nitrite plus nitrate nitrogen (mg/L as N) | Ammonia nitrogen (mg/L as N) | Ammonia plus organic nitrogen (mg/L as N) | Organic nitrogen, calculated (mg/L as N) | Total nitrogen, calculated (mg/L) | Dissolved phosphorus (mg/L) | Total phosphorus (mg/L) | Ortho-phosphate (mg/L as P) | Fine-suspended sediment (percent < 0.063 mm ) | Suspended sediment (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Willow Creek near Albert, Oklahoma (U.S. Geological Survey site identification number 07325860) | | | | | | | | | | | |
| 0.014 | 0.545 | 0.559 | 0.125 | 2.1 | 2.0 | 2.7 | 0.087 | 0.470 | 0.062 | 74 | 764 |
| 0.013 | 0.764 | 0.777 | 0.057 | 0.3 | 0.27 | 1.1 | 0.055 | 0.050 | 0.042 | 67 | 173 |
| 0.007 | 0.525 | 0.532 | 0.037 | 0.2 | 0.18 | 0.75 | 0.020 | 0.052 | 0.016 | 86 | 84 |
| 0.016 | 0.517 | 0.533 | 0.109 | 0.5 | 0.38 | 1.0 | 0.033 | 0.075 | 0.024 | 86 | 54 |
| 0.038 | 0.364 | 0.402 | 0.122 | 0.5 | 0.34 | 0.86 | 0.063 | 0.107 | 0.047 | 45 | 91 |
| 0.023 | 0.368 | 0.391 | 0.075 | 0.5 | 0.44 | 0.90 | 0.052 | 0.119 | 0.037 | 50 | 98 |
| 0.03 | 0.516 | 0.546 | 0.229 | 5.6 | 5.4 | 6.1 | 0.250 | 1.40 | 0.238 | 50 | 3,900 |
| 0.027 | 0.405 | 0.432 | 0.103 | 3.8 | 3.7 | 4.2 | 0.230 | 0.960 | 0.204 | 76 | 1,360 |
| 0.012 | 0.238 | 0.250 | 0.103 | 4.3 | 4.2 | 4.6 | 0.180 | 1.20 | 0.158 | 45 | 3,560 |
| 0.002 | 0.043 | 0.045 | 0.016 | 0.3 | 0.35 | 0.42 | 0.063 | 0.128 | 0.025 | 74 | 129 |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 0.021 | 0.449 | 0.470 | 0.284 | 11 | 11 | 11.5 | 0.260 | 1.89 | 0.209 | 73 | 4,650 |
| 0.002 | 0.116 | 0.118 | 0.015 | 0.3 | 0.28 | 0.41 | 0.061 | 0.096 | 0.041 | 63 | 65 |
| 0.002 | 0.129 | 0.131 | <0.010 | 0.4 | E0.35 | 0.49 | 0.030 | 0.066 | 0.012 | 25 | 100 |
| 0.006 | 0.439 | 0.445 | 0.032 | 0.2 | 0.22 | 0.70 | 0.027 | 0.051 | 0.009 | 45 | 104 |
| <0.002 | -- | <0.016 | E0.006 | <0.1 | -- | -- | <0.004 | <0.004 | <0.006 | -- | -- |
| 0.006 | 0.148 | 0.154 | 0.018 | 0.3 | 0.27 | 0.44 | 0.032 | 0.073 | 0.013 | 47 | 78 |
| 0.014 | 0.355 | 0.369 | 0.021 | 0.7 | 0.69 | 1.08 | 0.064 | 0.133 | 0.039 | 70 | 39 |
| 0.022 | 0.140 | 0.162 | 0.092 | 0.5 | 0.37 | 0.62 | 0.066 | 0.109 | 0.041 | 29 | 153 |
| 0.036 | 0.234 | 0.270 | 0.064 | 0.5 | 0.43 | 0.76 | 0.127 | 0.166 | 0.116 | 84 | 55 |

**Appendix 1.** Instantaneous streamflow, water properties, nutrient-compound concentrations, and statistical groups for stream samples collected at U.S. Geological Survey streamflow-gaging stations, Fort Cobb Reservoir watershed, southwestern Oklahoma, November 2004 to May 2007.—Continued

[$ft^3/s$, cubic feet per second; the months May through September are considered the growing season and October through April the dormant season; mg/L, milligrams per liter; NTU, nepheletic turbidity units; N, nitrogen; µS/cm, microsiemens per centimeter at 25 degrees Celsius; $CaCO_3$, calcium carbonate; P, phosphorus; blank, equipment blank; mm, millimeters; <, less than; >, greater than; °C, Celsius; --, not available; E, estimated; nitrate nitrogen, nitrite plus nitrate nitrogen, and ammonia nitrogen concentrations are dissolved; ammonia plus organic nitrogen concentrations are total; nitrate nitrogen was calculated by subtracting nitrite nitrogen from nitrite plus nitrate nitrogen concentrations; organic nitrogen was calculated by subtracting ammonia nitrogen from ammonia plus organic nitrogen concentrations, and total nitrogen was estimated by summing ammonia plus organic nitrogen and nitrite plus nitrate concentrations; phosphorus concentrations are dissolved; total phosphorus concentrations are total; orthophosphate concentrations are dissolved; all nutrient concentration measured in precipitation samples are dissolved; total nitrogen measured in precipitation samples at meteorological site was analytically determined]

| Date | Time | Sample type | Flow condition group | Season group | Instantaneous streamflow ($ft^3/s$) | Specific conductance (µS/cm) | pH (standard units) | Water temperature (degrees °C) | Turbidity (NTU) | Dissolved oxygen (mg/L) | Alkalinity (mg/L as $CaCO_3$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Willow Creek near Albert, Oklahoma (U.S. Geological Survey site identification number 07325860)—Continued | | | | | | | | | | | |
| Jun 17, 2006 | 1030 | regular | runoff | growing | 12 | 162 | 7.8 | 19.6 | >1,000 | 6.8 | 49 |
| Jun 17, 2006 | 1500 | regular | runoff | growing | 5.3 | 221 | 7.7 | 22.6 | >1,000 | 5.7 | 62 |
| Jun 22, 2006 | 1445 | regular | runoff | growing | 4.3 | 219 | 7.7 | 22.8 | 530 | 6.9 | 79 |
| Sep 6, 2006 | 1330 | regular | base flow | growing | 0.86 | 515 | 8.2 | 22.3 | 48 | 9 | 197 |
| Oct 16, 2006 | 0300 | regular | runoff | dormant | 2.9 | 340 | 8.1 | 15.7 | 169 | 7.7 | 109 |
| Oct 16, 2006 | 1100 | regular | runoff | dormant | 2.8 | 537 | 8 | 15.8 | 25 | 7.6 | 176 |
| Nov 28, 2006 | 1100 | regular | base flow | dormant | 1.5 | 581 | 8 | 14.3 | 13 | 7.2 | 204 |
| Jan 30, 2007 | 1100 | regular | base flow | dormant | 2.2 | 623 | 7.6 | 3.9 | 7.4 | 12.1 | 228 |
| Mar 19, 2007 | 1315 | regular | base flow | dormant | 2.5 | 650 | 7.7 | 16.7 | -- | 10.2 | 239 |
| Mar 23, 2007 | 1000 | regular | runoff | dormant | 12 | 392 | 7.4 | 17.2 | 739 | 7.9 | 142 |
| Mar 29, 2007 | 1815 | regular | runoff | dormant | 486 | 138 | 7.9 | 18 | >1,000 | 6.4 | 51 |
| Mar 29, 2007 | 2200 | regular | runoff | dormant | 72 | 144 | 7.9 | 17.8 | >1,000 | 6.7 | 56 |
| Mar 30, 2007 | 2200 | regular | runoff | dormant | 164 | 126 | 8 | 13.5 | >1,000 | 8.6 | 52 |
| May 8, 2007 | 1430 | regular | runoff | growing | 27 | 305 | 7.8 | 20.3 | >1,000 | 7.2 | 130 |
| May 30, 2007 | 1330 | regular | runoff | growing | 8.6 | 497 | 8 | 21.1 | 120 | 7.6 | 200 |
| May 30, 2007 | 1331 | blank | -- | -- | -- | -- | -- | -- | -- | -- | -- |

| Nitrite nitrogen (mg/L as N) | Nitrate nitrogen, calculated (mg/L as N) | Nitrite plus nitrate nitrogen (mg/L as N) | Ammonia nitrogen (mg/L as N) | Ammonia plus organic nitrogen (mg/L as N) | Organic nitrogen, calculated (mg/L as N) | Total nitrogen, calculated (mg/L) | Dissolved phosphorus (mg/L) | Total phosphorus (mg/L) | Ortho-phosphate (mg/L as P) | Fine-suspended sediment (percent < 0.063 mm ) | Suspended sediment (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Willow Creek near Albert, Oklahoma (U.S. Geological Survey site identification number 07325860)—Continued | | | | | | | | | | | |
| 0.035 | 0.564 | 0.599 | 0.442 | 5.3 | 4.9 | 5.9 | 0.310 | 1.24 | 0.249 | 85 | 1,310 |
| 0.042 | 0.588 | 0.630 | 0.342 | 3.7 | 3.4 | 4.3 | 0.320 | 0.970 | 0.250 | 94 | 692 |
| 0.025 | 0.319 | 0.344 | 0.046 | 1.7 | <1.7 | 2.04 | 0.145 | 0.430 | 0.118 | 99 | 354 |
| 0.007 | 0.248 | 0.255 | 0.029 | 0.3 | 0.31 | 0.60 | 0.065 | 0.111 | 0.056 | 72 | 59 |
| 0.007 | 0.357 | 0.364 | <0.020 | 1.1 | <1.1 | 1.5 | 0.181 | 0.367 | 0.148 | -- | 127 |
| 0.011 | 0.690 | 0.701 | E0.012 | 0.5 | <0.45 | 1.2 | 0.075 | 0.128 | 0.057 | -- | 28 |
| 0.003 | 0.119 | 0.122 | 0.021 | 0.4 | 0.35 | 0.49 | 0.040 | 0.080 | 0.028 | -- | 128 |
| 0.012 | 0.513 | 0.525 | 0.052 | 0.3 | 0.24 | 0.82 | 0.032 | 0.061 | 0.023 | -- | 142 |
| 0.006 | 0.081 | 0.087 | 0.031 | 0.4 | 0.41 | 0.53 | 0.040 | 0.098 | 0.028 | -- | 159 |
| 0.058 | 0.747 | 0.805 | 0.226 | 3.6 | 3.4 | 4.4 | 0.192 | 0.820 | 0.131 | -- | 636 |
| 0.018 | 0.275 | 0.293 | 0.309 | 8.7 | 8.4 | 9.0 | 0.096 | 1.68 | 0.064 | -- | 15,900 |
| 0.019 | 0.265 | 0.284 | 0.192 | 4.9 | 4.7 | 5.2 | 0.145 | 1.21 | 0.104 | -- | 4,630 |
| 0.013 | 0.188 | 0.201 | 0.131 | 3.8 | 3.7 | 4.0 | 0.210 | 1.21 | 0.163 | -- | 4,320 |
| 0.055 | 0.680 | 0.735 | 0.238 | 3.2 | 3.0 | 3.9 | 0.200 | 0.820 | 0.166 | -- | 1,070 |
| 0.023 | 0.411 | 0.434 | 0.051 | 1.3 | 1.2 | 1.7 | 0.173 | 0.389 | 0.148 | -- | 263 |
| <0.002 | -- | <0.016 | <0.020 | <0.1 | -- | -- | <0.006 | <0.008 | <0.006 | 66 | -- |

**Appendix 1.** Instantaneous streamflow, water properties, nutrient-compound concentrations, and statistical groups for stream samples collected at U.S. Geological Survey streamflow-gaging stations, Fort Cobb Reservoir watershed, southwestern Oklahoma, November 2004 to May 2007.—Continued

[$ft^3/s$, cubic feet per second; the months May through September are considered the growing season and October through April the dormant season; mg/L, milligrams per liter; NTU, nepheletic turbidity units; N, nitrogen; µS/cm, microsiemens per centimeter at 25 degrees Celsius; $CaCO_3$, calcium carbonate; P, phosphorus; blank, equipment blank; mm, millimeters; <, less than; >, greater than; °C, Celsius; --, not available; E, estimated; nitrate nitrogen, nitrite plus nitrate nitrogen, and ammonia nitrogen concentrations are dissolved; ammonia plus organic nitrogen concentrations are total; nitrate nitrogen was calculated by subtracting nitrite nitrogen from nitrite plus nitrate nitrogen concentrations; organic nitrogen was calculated by subtracting ammonia nitrogen from ammonia plus organic nitrogen concentrations, and total nitrogen was estimated by summing ammonia plus organic nitrogen and nitrite plus nitrate concentrations; phosphorus concentrations are dissolved; total phosphorus concentrations are total; orthophosphate concentrations are dissolved; all nutrient concentration measured in precipitation samples are dissolved; total nitrogen measured in precipitation samples at meteorological site was analytically determined]

| Date | Time | Sample type | Flow condition group | Season group | Instantaneous streamflow ($ft^3/s$) | Specific conductance (µS/cm) | pH (standard units) | Water temperature (degrees °C) | Turbidity (NTU) | Dissolved oxygen (mg/L) | Alkalinity (mg/L as $CaCO_3$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Meteorological site (351801098270501) | | | | | | | | | | | |
| Mar 20, 2006 | 1500 | regular | -- | -- | -- | | | | -- | -- | -- |
| Mar 20, 2006 | 1501 | replicate | -- | -- | -- | | | | -- | -- | -- |
| Oct 16, 2006 | 1200 | regular | -- | -- | -- | | | | -- | -- | -- |
| Oct 16, 2006 | 1201 | replicate | -- | -- | -- | | | | -- | -- | -- |
| Apr 4, 2007 | 1655 | regular | -- | -- | -- | | | | -- | -- | -- |
| May 8, 2007 | 1700 | regular | -- | -- | -- | | | | -- | -- | -- |

[1] Total nitrogen in precipitation samples was filtered and analytically determined.

| Nitrite nitrogen (mg/L as N) | Nitrate nitrogen, calculated (mg/L as N) | Nitrite plus nitrate nitrogen (mg/L as N) | Ammonia nitrogen (mg/L as N) | Ammonia plus organic nitrogen (mg/L as N) | Organic nitrogen, calculated (mg/L as N) | Total nitrogen, calculated (mg/L) | Dissolved phosphorus (mg/L) | Total phosphorus (mg/L) | Ortho-phosphate (mg/L as P) | Fine-suspended sediment (percent < 0.063 mm ) | Suspended sediment (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Meteorological site (351801098270501) | | | | | | | | | | | |
| 0.003 | 0.139 | 0.142 | 0.212 | -- | -- | 0.40 | 0.007 | -- | -- | -- | -- |
| 0.002 | 0.142 | 0.144 | 0.213 | -- | -- | 0.39 | 0.006 | -- | -- | -- | -- |
| E 0.001 | 0.039 | 0.040 | 0.034 | -- | -- | 0.13 | <0.006 | -- | -- | -- | -- |
| <0.002 | 0.048 | 0.050 | 0.037 | -- | -- | 0.10 | <0.006 | -- | -- | -- | -- |
| 0.005 | 0.223 | 0.228 | 0.436 | -- | -- | 0.73 | 0.042 | -- | -- | -- | -- |
| 0.008 | 0.191 | 0.199 | 0.576 | -- | -- | 2.42 | 0.190 | -- | -- | -- | -- |

# Appendix 2. Summary statistics of water properties and nutrient compounds measured in stream samples collected at U.S. Geological Survey streamflow-gaging station Cobb Creek near Eakly, Oklahoma (07325800), Fort Cobb Reservoir watershed, southwestern Oklahoma, November 2004 to May 2007.

**Appendix 2.** Summary statistics of water properties and nutrient compounds measured in stream samples collected at U.S. Geological Survey streamflow-gaging station Cobb Creek near Eakly, Oklahoma (07325800), Fort Cobb Reservoir watershed, southwestern Oklahoma, November 2004 to May 2007.

[Samples were grouped for statistical summary based on streamflow condition and season; the months May through September are considered the growing season and October through April the dormant season; $ft^3/s$, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; MRL, largest minimum reporting level; --, not applicable; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus; total nitrogen is equal to the sum of ammonia plus organic nitrogen and nitrite plus nitrate nitrogen; <, less than; >, greater than; mm, millimeters; NTU, nephelometric turbidity units]

| Water properties and nutrients | Group | Sample size | MRL | Minimum | Percentiles | | | Maximum | Mean |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 25 | 50 Median | 75 | | |
| Instantaneous discharge ($ft^3/s$) | base flow | 17 | -- | 8.9 | 14.5 | 17 | 20 | 24 | 17 |
| Instantaneous discharge ($ft^3/s$) | runoff | 18 | -- | 18 | 101 | 186 | 379 | 4,540 | 565 |
| Instantaneous discharge ($ft^3/s$) | growing | 15 | -- | 8.9 | 12.8 | 112 | 344 | 4,540 | 501 |
| Instantaneous discharge ($ft^3/s$) | dormant | 19 | -- | 15 | 17 | 22 | 81.5 | 929 | 128 |
| Instantaneous discharge ($ft^3/s$) | complete record | 35 | -- | 8.9 | 17 | 27 | 199 | 4,540 | 307 |
| Specific conductance (µS/cm) | base flow | 17 | -- | 738 | 775 | 786 | 810 | 866 | 792 |
| Specific conductance (µS/cm) | runoff | 18 | -- | 135 | 237 | 318 | 529 | 838 | 399 |
| Specific conductance (µS/cm) | growing | 16 | -- | 135 | 252 | 474 | 795 | 866 | 496 |
| Specific conductance (µS/cm) | dormant | 19 | -- | 235 | 589 | 775 | 786 | 866 | 669 |
| Specific conductance (µS/cm) | complete record | 35 | -- | 135 | 318 | 746 | 791 | 866 | 590 |
| pH (standard units) | base flow | 16 | -- | 7.8 | 8.1 | 8.2 | 8.3 | 8.5 | 8.2 |
| pH (standard units) | runoff | 18 | -- | 7.6 | 7.6 | 7.8 | 8.0 | 8.3 | 7.9 |
| pH (standard units) | growing | 16 | -- | 7.6 | 7.8 | 7.9 | 8.1 | 8.5 | 8.0 |
| pH (standard units) | dormant | 19 | -- | 7.6 | 7.9 | 8.1 | 8.3 | 8.5 | 8.0 |
| Dissolved oxygen (mg/L) | base flow | 17 | -- | 8.2 | 8.7 | 9.9 | 11.5 | 13.7 | 10 |
| Dissolved oxygen (mg/L) | runoff | 18 | -- | 5.0 | 6.1 | 6.6 | 7.7 | 9.8 | 6.9 |
| Dissolved oxygen (mg/L) | growing | 16 | -- | 5.0 | 6.3 | 6.9 | 8.2 | 11.5 | 7.2 |
| Dissolved oxygen (mg/L) | dormant | 19 | -- | 5.7 | 8.2 | 9.4 | 10.9 | 13.7 | 9.7 |
| Alkalinity (mg/L as $CaCO_3$) | base flow | 17 | -- | 194 | 223 | 228 | 233 | 251 | 225 |
| Alkalinity (mg/L as $CaCO_3$) | runoff | 18 | -- | 37 | 62 | 74 | 111 | 237 | 97 |
| Alkalinity (mg/L as $CaCO_3$) | growing | 16 | -- | 37 | 63 | 82 | 217 | 240 | 125 |
| Alkalinity (mg/L as $CaCO_3$) | dormant | 19 | -- | 61 | 163 | 224 | 230 | 251 | 188 |
| Alkalinity (mg/L as $CaCO_3$) | complete record | 35 | -- | 37 | 74 | 198 | 228 | 251 | 159 |
| Nitrite nitrogen (mg/L as N) | base flow | 16 | 0.002 mg/L | 0.013 | 0.015 | 0.023 | 0.036 | 0.079 | 0.031 |
| Nitrite nitrogen (mg/L as N) | runoff | 18 | 0.002 mg/L | 0.008 | 0.019 | 0.026 | 0.037 | 0.068 | 0.031 |
| Nitrite nitrogen (mg/L as N) | growing | 15 | 0.002 mg/L | 0.008 | 0.021 | 0.026 | 0.046 | 0.068 | 0.033 |
| Nitrite nitrogen (mg/L as N) | dormant | 19 | 0.002 mg/L | 0.011 | 0.016 | 0.020 | 0.035 | 0.079 | 0.030 |
| Nitrite nitrogen (mg/L as N) | complete record | 35 | 0.002 mg/L | 0.008 | 0.019 | 0.024 | 0.037 | 0.079 | 0.031 |
| Nitrate nitrogen, calculated (mg/L as N) | base flow | 16 | -- | 0.757 | 1.20 | 1.29 | 1.31 | 1.45 | 1.24 |
| Nitrate nitrogen, calculated (mg/L as N) | runoff | 18 | -- | 0.165 | 0.348 | 0.556 | 0.870 | 1.06 | 0.601 |
| Nitrate nitrogen, calculated (mg/L as N) | growing | 15 | -- | 0.165 | 0.529 | 0.750 | 1.25 | 1.45 | 0.820 |
| Nitrate nitrogen, calculated (mg/L as N) | dormant | 19 | -- | 0.261 | 0.740 | 1.06 | 1.29 | 1.45 | 0.967 |
| Nitrate nitrogen, calculated (mg/L as N) | complete record | 35 | -- | 0.165 | 0.551 | 0.952 | 1.29 | 1.45 | 0.902 |

**Appendix 2.** Summary statistics of water properties and nutrient compounds measured in stream samples collected at U.S. Geological Survey streamflow-gaging station Cobb Creek near Eakly, Oklahoma (07325800), Fort Cobb Reservoir watershed, southwestern Oklahoma, November 2004 to May 2007. —Conituned

[Samples were grouped for statistical summary based on streamflow condition and season; the months May through September are considered the growing season and October through April the dormant season; $ft^3/s$, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; MRL, largest minimum reporting level; --, not applicable; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus; total nitrogen is equal to the sum of ammonia plus organic nitrogen and nitrite plus nitrate nitrogen; <, less than; >, greater than; mm, millimeters; NTU, nephelometric turbidity units]

| Water properties and nutrients | Group | Sample size | MRL | Minimum | Percentiles | | | Maximum | Mean |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 25 | 50 Median | 75 | | |
| Nitrite plus nitrate nitrogen (mg/L as N) | base flow | 16 | 0.016 mg/L | 0.770 | 1.22 | 1.32 | 1.38 | 1.47 | 1.27 |
| Nitrite plus nitrate nitrogen (mg/L as N) | runoff | 18 | 0.016 mg/L | 0.173 | 0.382 | 0.580 | 0.923 | 1.09 | 0.632 |
| Nitrite plus nitrate nitrogen (mg/L as N) | growing | 15 | 0.016 mg/L | 0.173 | 0.553 | 0.804 | 1.27 | 1.47 | 0.854 |
| Nitrite plus nitrate nitrogen (mg/L as N) | dormant | 19 | 0.016 mg/L | 0.281 | 0.780 | 1.08 | 1.32 | 1.46 | 0.997 |
| Nitrite plus nitrate nitrogen (mg/L as N) | complete record | 35 | 0.016 mg/L | 0.173 | 0.574 | 0.987 | 1.31 | 1.47 | 0.934 |
| Ammonia nitrogen (mg/L as N) | base flow | 16 | 0.02 mg/L | <0.01 | 0.02 | 0.04 | 0.08 | 0.17 | 0.05 |
| Ammonia nitrogen (mg/L as N) | runoff | 18 | 0.02 mg/L | 0.03 | 0.12 | 0.16 | 0.26 | 0.57 | 0.20 |
| Ammonia nitrogen (mg/L as N) | growing | 15 | 0.02 mg/L | 0.02 | 0.07 | 0.14 | 0.23 | 0.33 | 0.15 |
| Ammonia nitrogen (mg/L as N) | dormant | 19 | 0.02 mg/L | <0.01 | 0.03 | 0.08 | 0.14 | 0.57 | 0.115 |
| Ammonia nitrogen (mg/L as N) | complete record | 35 | 0.02 mg/L | <0.01 | 0.04 | 0.09 | 0.17 | 0.57 | 0.13 |
| Ammonia plus organic nitrogen (mg/L as N) | base flow | 16 | 0.10 mg/L | 0.2 | 0.3 | 0.4 | 0.5 | 0.7 | 0.4 |
| Ammonia plus organic nitrogen (mg/L as N) | runoff | 18 | 0.10 mg/L | 0.8 | 3.9 | 4.6 | 6.5 | 9.3 | 4.8 |
| Ammonia plus organic nitrogen (mg/L as N) | growing | 15 | 0.10 mg/L | 0.3 | 0.6 | 4.1 | 5.5 | 9.0 | 3.8 |
| Ammonia plus organic nitrogen (mg/L as N) | dormant | 19 | 0.10 mg/L | 0.2 | 0.3 | 0.5 | 2.4 | 9.3 | 1.9 |
| Ammonia plus organic nitrogen (mg/L as N) | complete record | 34 | 0.10 mg/L | 0.2 | 0.4 | 0.9 | 4.7 | 9.3 | 2.8 |
| Organic nitrogen, calculated (mg/L as N) | base flow | 16 | -- | 0.2 | 0.3 | 0.4 | 0.4 | 0.6 | 0.4 |
| Organic nitrogen, calculated (mg/L as N) | runoff | 18 | -- | 0.7 | 3.8 | 4.4 | 6.3 | 9.2 | 4.6 |
| Organic nitrogen, calculated (mg/L as N) | growing | 15 | -- | 0.3 | 0.5 | 4.0 | 5.2 | 8.8 | 3.6 |
| Organic nitrogen, calculated (mg/L as N) | dormant | 19 | -- | 0.2 | 0.3 | 0.4 | 2.3 | 9.2 | 1.8 |
| Organic nitrogen, calculated (mg/L as N) | complete record | 34 | -- | 0.2 | 0.4 | 0.8 | 4.4 | 9.2 | 2.6 |
| Total nitrogen, calculated (mg/L as N) | base flow | 16 | -- | 1.2 | 1.6 | 1.7 | 1.8 | 2.1 | 1.7 |
| Total nitrogen, calculated (mg/L as N) | runoff | 18 | -- | 1.8 | 4.4 | 5.2 | 6.9 | 9.6 | 5.5 |
| Total nitrogen, calculated (mg/L as N) | growing | 15 | -- | 1.6 | 2.0 | 4.8 | 6.2 | 9.6 | 4.6 |
| Total nitrogen, calculated (mg/L as N) | dormant | 19 | -- | 1.2 | 1.6 | 1.8 | 3.2 | 9.6 | 2.9 |
| Total nitrogen, calculated (mg/L as N) | complete record | 35 | -- | 1.2 | 1.7 | 2.0 | 5.2 | 9.6 | 3.7 |
| Phosphorus, dissolved (mg/L as P) | base flow | 16 | 0.006 mg/L | 0.034 | 0.055 | 0.078 | 0.099 | 0.135 | 0.078 |
| Phosphorus, dissolved (mg/L as P) | runoff | 18 | 0.006 mg/L | 0.008 | 0.126 | 0.167 | 0.210 | 0.292 | 0.168 |
| Phosphorus, dissolved (mg/L as P) | growing | 15 | 0.006 mg/L | 0.008 | 0.096 | 0.135 | 0.187 | 0.280 | 0.142 |
| Phosphorus, dissolved (mg/L as P) | dormant | 19 | 0.006 mg/L | 0.034 | 0.061 | 0.092 | 0.151 | 0.292 | 0.113 |
| Phosphorus, dissolved (mg/L as P) | complete record | 35 | 0.006 mg/L | 0.008 | 0.073 | 0.112 | 0.168 | 0.292 | 0.126 |

**Appendix 2.** Summary statistics of water properties and nutrient compounds measured in stream samples collected at U.S. Geological Survey streamflow-gaging station Cobb Creek near Eakly, Oklahoma (07325800), Fort Cobb Reservoir watershed, southwestern Oklahoma, November 2004 to May 2007. —Conituned

[Samples were grouped for statistical summary based on streamflow condition and season; the months May through September are considered the growing season and October through April the dormant season; $ft^3/s$, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; MRL, largest minimum reporting level; --, not applicable; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus; total nitrogen is equal to the sum of ammonia plus organic nitrogen and nitrite plus nitrate nitrogen; <, less than; >, greater than; mm, millimeters; NTU, nephelometric turbidity units]

| Water properties and nutrients | Group | Sample size | MRL | Minimum | Percentiles | | | Maximum | Mean |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 25 | 50 Median | 75 | | |
| Total phosphorus (mg/L as P) | base flow | 16 | 0.02 mg/L | 0.05 | 0.09 | 0.12 | 0.16 | 0.18 | 0.12 |
| Total phosphorus (mg/L as P) | runoff | 18 | 0.02 mg/L | 0.18 | 0.97 | 1.2 | 1.5 | 2.5 | 1.2 |
| Total phosphorus (mg/L as P) | growing | 15 | 0.02 mg/L | 0.12 | 0.18 | 1.0 | 1.4 | 1.7 | 0.91 |
| Total phosphorus (mg/L as P) | dormant | 19 | 0.02 mg/L | 0.05 | 0.1 | 0.16 | 0.54 | 2.5 | 0.48 |
| Total phosphorus (mg/L as P) | complete record | 35 | 0.02 mg/L | 0.05 | 0.12 | 0.22 | 1.2 | 2.5 | 0.67 |
| Orthophosphate (mg/L as P) | base flow | 16 | 0.006 mg/L | 0.020 | 0.036 | 0.058 | 0.081 | 0.110 | 0.062 |
| Orthophosphate (mg/L as P) | runoff | 18 | 0.006 mg/L | 0.054 | 0.100 | 0.129 | 0.166 | 0.246 | 0.135 |
| Orthophosphate (mg/L as P) | growing | 15 | 0.006 mg/L | 0.061 | 0.081 | 0.120 | 0.164 | 0.246 | 0.125 |
| Orthophosphate (mg/L as P) | dormant | 19 | 0.006 mg/L | 0.020 | 0.042 | 0.075 | 0.116 | 0.235 | 0.082 |
| Orthophosphate (mg/L as P) | complete record | 35 | 0.006 mg/L | 0.020 | 0.056 | 0.090 | 0.129 | 0.246 | 0.101 |
| Suspended sediment (mg/L) | base flow | 16 | -- | 61 | 123 | 170 | 217 | 230 | 168 |
| Suspended sediment (mg/L) | runoff | 18 | -- | 163 | 1,600 | 2,330 | 5,120 | 11,500 | 3,260 |
| Suspended sediment (mg/L) | growing | 15 | -- | 141 | 221 | 2,030 | 3,780 | 6,270 | 2,400 |
| Suspended sediment (mg/L) | dormant | 19 | -- | 61 | 119 | 215 | 227 | 704 | 246 |
| Suspended sediment (mg/L) | complete record | 35 | -- | 61 | 168 | 304 | 2,360 | 11,500 | 1,810 |
| Fine-suspended sediment (percent) | base flow | 13 | -- | 18 | 33 | 55 | 64 | 70 | 50 |
| Fine-suspended sediment (percent) | runoff | 10 | -- | 26 | 58 | 65 | 72 | 88 | 62 |
| Fine-suspended sediment (percent) | growing | 13 | -- | 26 | 59 | 64 | 68 | 74 | 60 |
| Fine-suspended sediment (percent) | dormant | 10 | -- | 18 | 35 | 50 | 61 | 88 | 49 |
| Fine-suspended sediment (percent) | complete record | 23 | -- | 18 | 43 | 62 | 67 | 88 | 55 |

# Appendix 3. Summary statistics of water properties and nutrient compounds measured in stream samples collected at U.S. Geological Survey streamflow-gaging station Lake Creek near Eakly, Oklahoma (07325850), Fort Cobb Reservoir watershed, southwestern Oklahoma, November 2004 to May 2007.

**Appendix 3.** Summary statistics of water properties and nutrient compounds measured in stream samples collected at U.S. Geological Survey streamflow-gaging station Lake Creek near Eakly, Oklahoma (07325850), Fort Cobb Reservoir watershed, southwestern Oklahoma, November 2004 to May 2007.

[Samples were grouped for statistical summary based on streamflow condition and season; the months May through September are considered the growing season and October through April the dormant season; $ft^3/s$, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; MRL, largest minimum reporting level; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus; total nitrogen is equal to the sum of ammonia plus organic nitrogen and nitrite plus nitrate nitrogen; --, not applicable; <, less than; >, greater than; mm, millimeters; NTU, nephelometric turbidity units]

| Water properties and nutrients | Group | Sample size | MRL | Minimum | Percentiles | | | Maximum | Mean |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 25 | 50 Median | 75 | | |
| Instantaneous streamflow ($ft^3/s$) | base flow | 15 | -- | 1.8 | 3.9 | 4.6 | 5.2 | 27 | 5.9 |
| Instantaneous streamflow ($ft^3/s$) | runoff | 19 | -- | 1.6 | 8.6 | 39 | 195 | 3,620 | 303 |
| Instantaneous streamflow ($ft^3/s$) | growing | 15 | -- | 1.6 | 4.1 | 19 | 82 | 3,620 | 291 |
| Instantaneous streamflow ($ft^3/s$) | dormant | 19 | -- | 3 | 4.6 | 5.7 | 24 | 729 | 78 |
| Instantaneous streamflow ($ft^3/s$) | complete record | 34 | -- | 1.6 | 4.6 | 5.9 | 39 | 3,620 | 176 |
| Specific conductance (µS/cm) | base flow | 15 | -- | 550 | 573 | 584 | 599 | 649 | 587 |
| Specific conductance (µS/cm) | runoff | 19 | -- | 96 | 167 | 244 | 535 | 724 | 333 |
| Specific conductance (µS/cm) | growing | 15 | -- | 96 | 207 | 436 | 576 | 649 | 390 |
| Specific conductance (µS/cm) | dormant | 19 | -- | 128 | 467 | 559 | 588 | 724 | 489 |
| Specific conductance (µS/cm) | complete record | 34 | -- | 96 | 215 | 559 | 584 | 724 | 447 |
| pH (standard units) | base flow | 15 | -- | 7.8 | 8.1 | 8.2 | 8.3 | 8.6 | 8.2 |
| pH (standard units) | runoff | 19 | -- | 7.5 | 7.8 | 8.0 | 8.3 | 8.5 | 8.0 |
| pH (standard units) | growing | 15 | -- | 7.7 | 7.9 | 8.1 | 8.4 | 8.5 | 8.1 |
| pH (standard units) | dormant | 19 | -- | 7.5 | 8.0 | 8.1 | 8.3 | 8.6 | 8.1 |
| Dissolved oxygen (mg/L) | base flow | 15 | -- | 7.7 | 10.2 | 13.1 | 13.4 | 16.1 | 12 |
| Dissolved oxygen (mg/L) | runoff | 19 | -- | 5.6 | 6.6 | 7.5 | 8.7 | 16.8 | 8.2 |
| Dissolved oxygen (mg/L) | growing | 15 | | 5.6 | 6.6 | 7.5 | 9.1 | 16.8 | 8.4 |
| Dissolved oxygen (mg/L) | dormant | 19 | -- | 5.9 | 8.2 | 11.2 | 13.3 | 16.1 | 11.1 |
| Alkalinity (mg/L as $CaCO_3$) | base flow | 15 | -- | 215 | 228 | 236 | 245 | 273 | 237 |
| Alkalinity (mg/L as $CaCO_3$) | runoff | 19 | -- | 33 | 68 | 100 | 212 | 232 | 127 |
| Alkalinity (mg/L as $CaCO_3$) | growing | 15 | -- | 33 | 75 | 172 | 228 | 273 | 154 |
| Alkalinity (mg/L as $CaCO_3$) | dormant | 19 | -- | 53 | 180 | 225 | 235 | 258 | 193 |
| Alkalinity (mg/L as $CaCO_3$) | complete record | 34 | -- | 33 | 81 | 222 | 234 | 273 | 177 |
| Nitrite nitrogen (mg/L as N) | base flow | 15 | 0.002 mg/L | 0.004 | 0.011 | 0.021 | 0.035 | 0.044 | 0.022 |
| Nitrite nitrogen (mg/L as N) | runoff | 19 | 0.002 mg/L | 0.006 | 0.016 | 0.026 | 0.033 | 0.046 | 0.025 |
| Nitrite nitrogen (mg/L as N) | growing | 15 | 0.002 mg/L | 0.004 | 0.014 | 0.028 | 0.038 | 0.046 | 0.026 |
| Nitrite nitrogen (mg/L as N) | dormant | 19 | 0.002 mg/L | 0.006 | 0.013 | 0.022 | 0.030 | 0.040 | 0.022 |
| Nitrite nitrogen (mg/L as N) | complete record | 34 | 0.002 mg/L | 0.004 | 0.014 | 0.026 | 0.033 | 0.046 | 0.024 |
| Nitrate nitrogen, calculated (mg/L as N) | base flow | 15 | -- | 0.067 | 0.342 | 0.658 | 0.763 | 1.11 | 0.584 |
| Nitrate nitrogen, calculated (mg/L as N) | runoff | 19 | -- | 0.038 | 0.297 | 0.397 | 0.491 | 0.843 | 0.408 |
| Nitrate nitrogen, calculated (mg/L as N) | growing | 15 | -- | 0.038 | 0.293 | 0.394 | 0.431 | 0.765 | 0.371 |
| Nitrate nitrogen, calculated (mg/L as N) | dormant | 19 | -- | 0.211 | 0.334 | 0.526 | 0.740 | 1.11 | 0.565 |
| Nitrate nitrogen, calculated (mg/L as N) | complete record | 34 | -- | 0.038 | 0.301 | 0.428 | 0.700 | 1.11 | 0.487 |

**Appendix 3.** Summary statistics of water properties and nutrient compounds measured in stream samples collected at U.S. Geological Survey streamflow-gaging station Lake Creek near Eakly, Oklahoma (07325850), Fort Cobb Reservoir watershed, southwestern Oklahoma, November 2004 to May 2007.—Continued

[Samples were grouped for statistical summary based on streamflow condition and season; the months May through September are considered the growing season and October through April the dormant season; $ft^3/s$, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; MRL, largest minimum reporting level; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus; total nitrogen is equal to the sum of ammonia plus organic nitrogen and nitrite plus nitrate nitrogen; --, not applicable; <, less than; >, greater than; mm, millimeters; NTU, nephelometric turbidity units]

| Water properties and nutrients | Group | Sample size | MRL | Minimum | Percentiles | | | Maximum | Mean |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 25 | 50 Median | 75 | | |
| Nitrite plus nitrate nitrogen (mg/L as N) | base flow | 15 | 0.016 mg/L | 0.071 | 0.377 | 0.673 | 0.803 | 1.12 | 0.606 |
| Nitrite plus nitrate nitrogen (mg/L as N) | runoff | 19 | 0.016 mg/L | 0.044 | 0.324 | 0.418 | 0.519 | 0.876 | 0.433 |
| Nitrite plus nitrate nitrogen (mg/L as N) | growing | 15 | 0.016 mg/L | 0.044 | 0.312 | 0.418 | 0.464 | 0.809 | 0.397 |
| Nitrite plus nitrate nitrogen (mg/L as N) | dormant | 19 | 0.016 mg/L | 0.223 | 0.358 | 0.549 | 0.771 | 1.12 | 0.588 |
| Nitrite plus nitrate nitrogen (mg/L as N) | complete record | 34 | 0.016 mg/L | 0.044 | 0.335 | 0.459 | 0.722 | 1.12 | 0.511 |
| Ammonia nitrogen (mg/L as N) | base flow | 15 | 0.02 mg/L | 0.005 | 0.012 | 0.025 | 0.052 | 0.160 | 0.040 |
| Ammonia nitrogen (mg/L as N) | runoff | 19 | 0.02 mg/L | 0.016 | 0.114 | 0.131 | 0.245 | 0.566 | 0.180 |
| Ammonia nitrogen (mg/L as N) | growing | 15 | 0.02 mg/L | 0.010 | 0.027 | 0.095 | 0.211 | 0.421 | 0.134 |
| Ammonia nitrogen (mg/L as N) | dormant | 19 | 0.02 mg/L | 0.005 | 0.025 | 0.071 | 0.133 | 0.566 | 0.111 |
| Ammonia nitrogen (mg/L as N) | complete record | 34 | 0.02 mg/L | 0.005 | 0.023 | 0.077 | 0.165 | 0.566 | 0.121 |
| Ammonia plus organic nitrogen (mg/L as N) | base flow | 15 | 0.10 mg/L | 0.23 | 0.39 | 0.41 | 0.56 | 1.5 | 0.51 |
| Ammonia plus organic nitrogen (mg/L as N) | runoff | 19 | 0.10 mg/L | 0.37 | 1.3 | 3.8 | 5.5 | 9.2 | 3.7 |
| Ammonia plus organic nitrogen (mg/L as N) | growing | 15 | 0.10 mg/L | 0.37 | 0.54 | 2.5 | 4.3 | 7.0 | 2.8 |
| Ammonia plus organic nitrogen (mg/L as N) | dormant | 19 | 0.10 mg/L | 0.23 | 0.41 | 0.58 | 2.2 | 9.2 | 2.0 |
| Ammonia plus organic nitrogen (mg/L as N) | complete record | 34 | 0.10 mg/L | 0.23 | 0.41 | 0.72 | 4.2 | 9.2 | 2.3 |
| Organic nitrogen, calculated (mg/L as N) | base flow | 15 | -- | 0.21 | 0.36 | 0.4 | 0.48 | 1.4 | 0.47 |
| Organic nitrogen, calculated (mg/L as N) | runoff | 19 | -- | 0.35 | 1.2 | 3.7 | 5.3 | 8.9 | 3.5 |
| Organic nitrogen, calculated (mg/L as N) | growing | 15 | -- | 0.34 | 0.51 | 2.4 | 4.1 | 6.6 | 2.7 |
| Organic nitrogen, calculated (mg/L as N) | dormant | 19 | -- | 0.21 | 0.37 | 0.51 | 2.1 | 8.9 | 1.9 |
| Organic nitrogen, calculated (mg/L as N) | complete record | 34 | -- | 0.21 | 0.40 | 0.64 | 4.0 | 8.9 | 2.2 |
| Total nitrogen, calculated (mg/L as N) | base flow | 15 | -- | 0.52 | 0.78 | 1.1 | 1.3 | 2.3 | 1.1 |
| Total nitrogen, calculated (mg/L as N) | runoff | 19 | -- | 0.71 | 1.9 | 4.2 | 5.9 | 9.4 | 4.1 |
| Total nitrogen, calculated (mg/L as N) | growing | 15 | -- | 0.52 | 0.85 | 2.9 | 4.7 | 7.7 | 3.2 |
| Total nitrogen, calculated (mg/L as N) | dormant | 19 | -- | 0.66 | 1.1 | 1.4 | 2.8 | 9.4 | 2.6 |
| Total nitrogen, calculated (mg/L as N) | complete record | 34 | -- | 0.52 | 0.99 | 1.5 | 4.6 | 9.4 | 2.8 |
| Phosphorus, dissolved (mg/L as P) | base flow | 15 | 0.006 mg/L | 0.017 | 0.023 | 0.033 | 0.066 | 0.095 | 0.044 |
| Phosphorus, dissolved (mg/L as P) | runoff | 19 | 0.006 mg/L | 0.028 | 0.072 | 0.102 | 0.143 | 0.197 | 0.106 |

**Appendix 3.** Summary statistics of water properties and nutrient compounds measured in stream samples collected at U.S. Geological Survey streamflow-gaging station Lake Creek near Eakly, Oklahoma (07325850), Fort Cobb Reservoir watershed, southwestern Oklahoma, November 2004 to May 2007.—Continued

[Samples were grouped for statistical summary based on streamflow condition and season; the months May through September are considered the growing season and October through April the dormant season; $ft^3/s$, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; MRL, largest minimum reporting level; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus; total nitrogen is equal to the sum of ammonia plus organic nitrogen and nitrite plus nitrate nitrogen; --, not applicable; <, less than; >, greater than; mm, millimeters; NTU, nephelometric turbidity units]

| Water properties and nutrients | Group | Sample size | MRL | Minimum | Percentiles | | | Maximum | Mean |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 25 | 50 Median | 75 | | |
| Phosphorus, dissolved (mg/L as P) | growing | 15 | 0.006 mg/L | 0.028 | 0.071 | 0.105 | 0.143 | 0.197 | 0.107 |
| Phosphorus, dissolved (mg/L as P) | dormant | 19 | 0.006 mg/L | 0.017 | 0.025 | 0.050 | 0.078 | 0.197 | 0.059 |
| Phosphorus, dissolved (mg/L as P) | complete record | 34 | 0.006 mg/L | 0.017 | 0.034 | 0.070 | 0.105 | 0.197 | 0.078 |
| Total phosphorus (mg/L as P) | base flow | 15 | 0.02 mg/L | 0.044 | 0.057 | 0.089 | 0.106 | 0.430 | 0.108 |
| Total phosphorus (mg/L as P) | runoff | 19 | 0.02 mg/L | 0.045 | 0.189 | 0.910 | 1.09 | 1.66 | 0.782 |
| Total phosphorus (mg/L as P) | growing | 15 | 0.02 mg/L | 0.045 | 0.129 | 0.670 | 1.04 | 1.55 | 0.660 |
| Total phosphorus (mg/L as P) | dormant | 19 | 0.02 mg/L | 0.044 | 0.065 | 0.106 | 0.384 | 1.66 | 0.375 |
| Total phosphorus (mg/L as P) | complete record | 34 | 0.02 mg/L | 0.044 | 0.915 | 0.157 | 0.953 | 1.66 | 0.494 |
| Orthophosphate (mg/L as P) | base flow | 15 | 0.006 mg/L | 0.003 | 0.015 | 0.023 | 0.043 | 0.086 | 0.029 |
| Orthophosphate (mg/L as P) | runoff | 19 | 0.006 mg/L | 0.015 | 0.040 | 0.063 | 0.104 | 0.164 | 0.076 |
| Orthophosphate (mg/L as P) | growing | 15 | 0.006 mg/L | 0.015 | 0.048 | 0.088 | 0.105 | 0.164 | 0.080 |
| Orthophosphate (mg/L as P) | dormant | 19 | 0.006 mg/L | 0.003 | 0.015 | 0.034 | 0.046 | 0.150 | 0.038 |
| Orthophosphate (mg/L as P) | complete record | 34 | 0.006 mg/L | 0.003 | 0.023 | 0.044 | 0.087 | 0.164 | 0.055 |
| Suspended sediment (mg/L) | base flow | 14 | -- | 54 | 77 | 119 | 151 | 336 | 133 |
| Suspended sediment (mg/L) | runoff | 19 | -- | 45 | 166 | 1,968 | 3,585 | 9,120 | 2,481 |
| Suspended sediment (mg/L) | growing | 14 | -- | 45 | 168 | 1,910 | 3,090 | 9,120 | 2,068 |
| Suspended sediment (mg/L) | dormant | 19 | -- | 54 | 91 | 151 | 1,365 | 7,217 | 1,213 |
| Suspended sediment (mg/L) | complete record | 33 | -- | 45 | 115 | 169 | 2,313 | 9,120 | 1,566 |
| Fine-suspended sediment (percent) | base flow | 10 | -- | 33 | 46 | 51 | 56 | 69 | 52 |
| Fine-suspended sediment (percent) | runoff | 12 | -- | 18 | 39 | 45 | 73 | 93 | 54 |
| Fine-suspended sediment (percent) | growing | 12 | -- | 18 | 37 | 45 | 62 | 83 | 50 |
| Fine-suspended sediment (percent) | dormant | 10 | -- | 40 | 46 | 51 | 62 | 93 | 56 |
| Fine-suspended sediment (percent) | complete record | 22 | -- | 18 | 41 | 48 | 64 | 93 | 53 |

# Appendix 4. Summary statistics of water properties and nutrient compounds measured in stream samples collected at U.S. Geological Survey streamflow-gaging station Willow Creek near Albert, Oklahoma (07325860), Fort Cobb Reservoir watershed, southwestern Oklahoma, November 2004 to May 2007.

**Appendix 4.** Summary statistics of water properties and nutrient compounds measured in stream samples collected at U.S. Geological Survey streamflow-gaging station **Willow Creek near Albert, Oklahoma (07325860)**, Fort Cobb Reservoir watershed, southwestern Oklahoma, November 2004 to May 2007.

[Samples were grouped for statistical summary based on streamflow condition and season; the months May through September are considered the growing season and October through April the dormant season; $ft^3/s$, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; MRL, largest minimum reporting level; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus; total nitrogen is equal to the sum of ammonia plus organic nitrogen and nitrite plus nitrate nitrogen; --, not applicable; <, less than; >, greater than; mm, millimeters; NTU, nephelometric turbidity units]

| Water properties and nutrients | Group | Sample size | MRL | Minimum | Percentiles | | | Maximum | Mean |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 25 | 50 Median | 75 | | |
| Instantaneous streamflow ($ft^3/s$) | base flow | 17 | -- | 0.8 | 1.5 | 2.0 | 2.4 | 3.5 | 2.0 |
| Instantaneous streamflow ($ft^3/s$) | runoff | 17 | -- | 2.8 | 5.3 | 16 | 90 | 486 | 89 |
| Instantaneous streamflow ($ft^3/s$) | growing | 15 | | 0.8 | 1.9 | 5.3 | 22 | 333 | 51 |
| Instantaneous streamflow ($ft^3/s$) | dormant | 19 | -- | 1.2 | 2.2 | 2.6 | 8.5 | 486 | 41.6 |
| Instantaneous streamflow ($ft^3/s$) | complete record | 34 | -- | 0.8 | 2 | 3 | 15 | 486 | 45.6 |
| Specific conductance (µS/cm) | base flow | 17 | -- | 483 | 549 | 581 | 613 | 650 | 575 |
| Specific conductance (µS/cm) | runoff | 17 | -- | 117 | 138 | 219 | 392 | 620 | 276 |
| Specific conductance (µS/cm) | growing | 15 | -- | 117 | 183 | 305 | 507 | 613 | 345 |
| Specific conductance (µS/cm) | dormant | 19 | -- | 126 | 404 | 573 | 612 | 650 | 490 |
| Specific conductance (µS/cm) | complete record | 34 | -- | 117 | 220 | 507 | 588 | 650 | 426 |
| pH (standard units) | base flow | 17 | -- | 7.6 | 7.8 | 8.0 | 8.2 | 8.5 | 8.0 |
| pH (standard units) | runoff | 17 | -- | 7.3 | 7.8 | 8.0 | 8.1 | 8.3 | 7.9 |
| pH (standard units) | growing | 15 | -- | 7.7 | 7.8 | 8.0 | 8.2 | 8.3 | 8.0 |
| pH (standard units) | dormant | 19 | -- | 7.3 | 7.8 | 7.9 | 8.0 | 8.5 | 7.9 |
| Dissolved oxygen (mg/L) | base flow | 17 | -- | 7.2 | 9.1 | 10.7 | 13 | 14.2 | 11 |
| Dissolved oxygen (mg/L) | runoff | 17 | -- | 5.7 | 6.8 | 7.0 | 7.7 | 11.9 | 7.5 |
| Dissolved oxygen (mg/L) | growing | 15 | -- | 5.7 | 6.9 | 7.2 | 8.7 | 12.5 | 7.9 |
| Dissolved oxygen (mg/L) | dormant | 19 | -- | 6.4 | 7.8 | 10.2 | 12.6 | 14.2 | 10.4 |
| Alkalinity (mg/L as $CaCO_3$) | base flow | 17 | -- | 164 | 196 | 201 | 224 | 239 | 206 |
| Alkalinity (mg/L as $CaCO_3$) | runoff | 17 | -- | 37 | 51 | 62 | 142 | 227 | 98 |
| Alkalinity (mg/L as $CaCO_3$) | growing | 15 | -- | 37 | 56 | 130 | 196 | 224 | 124 |
| Alkalinity (mg/L as $CaCO_3$) | dormant | 19 | -- | 51 | 147 | 197 | 222 | 239 | 173 |
| Alkalinity (mg/L as $CaCO_3$) | complete record | 34 | -- | 37 | 66 | 188 | 203 | 239 | 152 |
| Nitrite nitrogen (mg/L as N) | base flow | 17 | 0.002 mg/L | 0.002 | 0.005 | 0.007 | 0.017 | 0.038 | 0.013 |
| Nitrite nitrogen (mg/L as N) | runoff | 17 | 0.002 mg/L | 0.007 | 0.014 | 0.021 | 0.030 | 0.058 | 0.025 |
| Nitrite nitrogen (mg/L as N) | growing | 15 | 0.002 mg/L | 0.002 | 0.014 | 0.024 | 0.034 | 0.055 | 0.024 |
| Nitrite nitrogen (mg/L as N) | dormant | 19 | 0.002 mg/L | 0.002 | 0.007 | 0.013 | 0.017 | 0.058 | 0.015 |
| Nitrite nitrogen (mg/L as N) | complete record | 34 | 0.002 mg/L | 0.002 | 0.007 | 0.014 | 0.025 | 0.058 | 0.019 |
| Nitrate nitrogen, calculated (mg/L as N) | base flow | 17 | -- | 0.043 | 0.127 | 0.241 | 0.458 | 0.764 | 0.297 |
| Nitrate nitrogen, calculated (mg/L as N) | runoff | 17 | -- | 0.188 | 0.319 | 0.411 | 0.564 | 0.747 | 0.447 |
| Nitrate nitrogen, calculated (mg/L as N) | growing | 15 | -- | 0.043 | 0.241 | 0.387 | 0.499 | 0.680 | 0.370 |
| Nitrate nitrogen, calculated (mg/L as N) | dormant | 19 | -- | 0.081 | 0.168 | 0.357 | 0.521 | 0.764 | 0.377 |
| Nitrate nitrogen, calculated (mg/L as N) | complete record | 34 | -- | 0.043 | 0.234 | 0.364 | 0.517 | 0.764 | 0.374 |

**Appendix 4.** Summary statistics of water properties and nutrient compounds measured in stream samples collected at U.S. Geological Survey streamflow-gaging station **Willow Creek near Albert, Oklahoma (07325860)**, Fort Cobb Reservoir watershed, southwestern Oklahoma, November 2004 to May 2007. —Continued

[Samples were grouped for statistical summary based on streamflow condition and season; the months May through September are considered the growing season and October through April the dormant season; $ft^3/s$, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; MRL, largest minimum reporting level; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus; total nitrogen is equal to the sum of ammonia plus organic nitrogen and nitrite plus nitrate nitrogen; --, not applicable; <, less than; >, greater than; mm, millimeters; NTU, nephelometric turbidity units]

| Water properties and nutrients | Group | Sample size | MRL | Minimum | Percentiles | | | Maximum | Mean |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 25 | 50 Median | 75 | | |
| Nitrite plus nitrate nitrogen (mg/L as N) | base flow | 17 | 0.016 mg/L | 0.045 | 0.129 | 0.263 | 0.465 | 0.777 | 0.309 |
| Nitrite plus nitrate nitrogen (mg/L as N) | runoff | 17 | 0.016 mg/L | 0.201 | 0.344 | 0.434 | 0.599 | 0.805 | 0.472 |
| Nitrite plus nitrate nitrogen (mg/L as N) | growing | 15 | 0.016 mg/L | 0.045 | 0.259 | 0.412 | 0.527 | 0.735 | 0.394 |
| Nitrite plus nitrate nitrogen (mg/L as N) | dormant | 19 | 0.016 mg/L | 0.087 | 0.182 | 0.369 | 0.533 | 0.805 | 0.392 |
| Nitrite plus nitrate nitrogen (mg/L as N) | complete record | 34 | 0.016 mg/L | 0.045 | 0.25 | 0.391 | 0.533 | 0.805 | 0.393 |
| Ammonia nitrogen (mg/L as N) | base flow | 17 | 0.02 mg/L | 0.01 | 0.02 | 0.04 | 0.07 | 0.12 | 0.05 |
| Ammonia nitrogen (mg/L as N) | runoff | 17 | 0.02 mg/L | 0.01 | 0.05 | 0.13 | 0.24 | 0.44 | 0.17 |
| Ammonia nitrogen (mg/L as N) | growing | 15 | 0.02 mg/L | 0.02 | 0.05 | 0.09 | 0.24 | 0.44 | 0.15 |
| Ammonia nitrogen (mg/L as N) | dormant | 19 | 0.02 mg/L | 0.01 | 0.02 | 0.05 | 0.12 | 0.31 | 0.09 |
| Ammonia nitrogen (mg/L as N) | complete record | 34 | 0.02 mg/L | 0.01 | 0.03 | 0.06 | 0.13 | 0.44 | 0.11 |
| Ammonia plus organic nitrogen (mg/L as N) | base flow | 17 | 0.10 mg/L | 0.22 | 0.3 | 0.4 | 0.5 | 0.5 | 0.4 |
| Ammonia plus organic nitrogen (mg/L as N) | runoff | 17 | 0.10 mg/L | 0.5 | 1.7 | 3.7 | 4.9 | 11 | 3.8 |
| Ammonia plus organic nitrogen (mg/L as N) | growing | 15 | 0.10 mg/L | 0.3 | 0.5 | 2.4 | 4.2 | 11 | 3.0 |
| Ammonia plus organic nitrogen (mg/L as N) | dormant | 19 | 0.10 mg/L | 0.22 | 0.3 | 0.5 | 1.6 | 8.7 | 1.5 |
| Ammonia plus organic nitrogen (mg/L as N) | complete record | 34 | 0.10 mg/L | 0.22 | 0.37 | 0.51 | 3.7 | 11 | 2.2 |
| Organic nitrogen, calculated (mg/L as N) | base flow | 17 | -- | 0.18 | 0.27 | 0.34 | 0.37 | 0.43 | 0.32 |
| Organic nitrogen, calculated (mg/L as N) | runoff | 17 | -- | 0.45 | 1.6 | 3.4 | 4.7 | 11 | 3.7 |
| Organic nitrogen, calculated (mg/L as N) | growing | 15 | -- | 0.27 | 0.43 | 2.3 | 4.1 | 11 | 2.8 |
| Organic nitrogen, calculated (mg/L as N) | dormant | 19 | -- | 0.18 | 0.30 | 0.38 | 1.5 | 8.4 | 1.5 |
| Organic nitrogen, calculated (mg/L as N) | complete record | 34 | -- | 0.18 | 0.35 | 0.45 | 3.4 | 11 | 2.0 |
| Total nitrogen, calculated (mg/L as N) | base flow | 17 | -- | 0.41 | 0.49 | 0.66 | 0.83 | 1.1 | 0.68 |
| Total nitrogen, calculated (mg/L as N) | runoff | 17 | -- | 1.1 | 2.0 | 4.2 | 5.2 | 11 | 4.3 |
| Total nitrogen, calculated (mg/L as N) | growing | 15 | -- | 0.41 | 0.80 | 3.0 | 4.5 | 11 | 3.4 |
| Total nitrogen, calculated (mg/L as N) | dormant | 19 | -- | 0.44 | 0.66 | 1.0 | 2.1 | 9.0 | 1.9 |
| Total nitrogen, calculated (mg/L as N) | complete record | 34 | -- | 0.41 | 0.70 | 1.1 | 4.2 | 11 | 2.5 |
| Phosphorus, dissolved (mg/L as P) | base flow | 17 | 0.006 mg/L | 0.020 | 0.032 | 0.046 | 0.063 | 0.127 | 0.050 |
| Phosphorus, dissolved (mg/L as P) | runoff | 17 | 0.006 mg/L | 0.064 | 0.145 | 0.181 | 0.230 | 0.320 | 0.183 |

**Appendix 4.** Summary statistics of water properties and nutrient compounds measured in stream samples collected at U.S. Geological Survey streamflow-gaging station **Willow Creek near Albert, Oklahoma (07325860)**, Fort Cobb Reservoir watershed, southwestern Oklahoma, November 2004 to May 2007. —Continued

[Samples were grouped for statistical summary based on streamflow condition and season; the months May through September are considered the growing season and October through April the dormant season; $ft^3/s$, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; MRL, largest minimum reporting level; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus; total nitrogen is equal to the sum of ammonia plus organic nitrogen and nitrite plus nitrate nitrogen; --, not applicable; <, less than; >, greater than; mm, millimeters; NTU, nephelometric turbidity units]

| Water properties and nutrients | Group | Sample size | MRL | Minimum | Percentiles | | | Maximum | Mean |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 25 | 50 Median | 75 | | |
| Phosphorus, dissolved (mg/L as P) | growing | 15 | 0.006 mg/L | 0.052 | 0.081 | 0.177 | 0.245 | 0.320 | 0.174 |
| Phosphorus, dissolved (mg/L as P) | dormant | 19 | 0.006 mg/L | 0.020 | 0.033 | 0.063 | 0.092 | 0.210 | 0.078 |
| Phosphorus, dissolved (mg/L as P) | complete record | 34 | 0.006 mg/L | 0.020 | 0.052 | 0.075 | 0.181 | 0.320 | 0.119 |
| Total phosphorus (mg/L as P) | base flow | 17 | 0.02 mg/L | 0.05 | 0.07 | 0.09 | 0.11 | 0.17 | 0.09 |
| Total phosphorus (mg/L as P) | runoff | 17 | 0.02 mg/L | 0.13 | 0.43 | 0.96 | 1.2 | 1.9 | 0.90 |
| Total phosphorus (mg/L as P) | growing | 15 | 0.02 mg/L | 0.10 | 0.14 | 0.63 | 1.1 | 1.9 | 0.71 |
| Total phosphorus (mg/L as P) | dormant | 19 | 0.02 mg/L | 0.05 | 0.07 | 0.11 | 0.42 | 1.7 | 0.36 |
| Total phosphorus (mg/L as P) | complete record | 34 | 0.02 mg/L | 0.05 | 0.10 | 0.13 | 0.96 | 1.9 | 0.51 |
| Orthophosphate (mg/L as P) | base flow | 17 | 0.006 mg/L | 0.009 | 0.021 | 0.028 | 0.041 | 0.116 | 0.035 |
| Orthophosphate (mg/L as P) | runoff | 17 | 0.006 mg/L | 0.039 | 0.104 | 0.148 | 0.204 | 0.250 | 0.148 |
| Orthophosphate (mg/L as P) | growing | 15 | 0.006 mg/L | 0.025 | 0.071 | 0.153 | 0.208 | 0.250 | 0.144 |
| Orthophosphate (mg/L as P) | dormant | 19 | 0.006 mg/L | 0.009 | 0.024 | 0.041 | 0.063 | 0.163 | 0.055 |
| Orthophosphate (mg/L as P) | complete record | 34 | 0.006 mg/L | 0.009 | 0.028 | 0.057 | 0.148 | 0.250 | 0.093 |
| Suspended sediment (mg/L) | base flow | 17 | -- | 54 | 75 | 99 | 132 | 173 | 104 |
| Suspended sediment (mg/L) | runoff | 17 | -- | 28 | 558 | 1,240 | 4,060 | 16,330 | 2,750 |
| Suspended sediment (mg/L) | growing | 15 | -- | 55 | 98 | 692 | 1,360 | 4,650 | 1,340 |
| Suspended sediment (mg/L) | dormant | 19 | -- | 28 | 88 | 127 | 400 | 16,330 | 1,490 |
| Suspended sediment (mg/L) | complete record | 34 | -- | 28 | 89 | 148 | 1,200 | 16,330 | 1,430 |
| Fine-suspended sediment (percent) | base flow | 13 | -- | 25 | 45 | 63 | 74 | 86 | 59 |
| Fine-suspended sediment (percent) | runoff | 9 | -- | 45 | 70 | 74 | 85 | 99 | 74 |
| Fine-suspended sediment (percent) | growing | 12 | -- | 45 | 60 | 74 | 84 | 99 | 72 |
| Fine-suspended sediment (percent) | dormant | 10 | -- | 25 | 45 | 57 | 73 | 86 | 57 |
| Fine-suspended sediment (percent) | complete record | 22 | -- | 25 | 48 | 71 | 82 | 99 | 65 |