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Estimation of Sediment Inflows to Lake Tuscaloosa, Alabama, 2009–11

Scientific Investigations Report 2013–5152

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

Cover: Aerial photograph of Carroll Creek, a tributary to Lake Tuscaloosa. Photograph taken by Scott Sanderford, Lakes Manager, City of Tuscaloosa.

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SALLY JEWELL, Secretary

U.S. Geological Survey
Suzette M. Kimball, Director

U.S. Geological Survey, Reston, Virginia: 2013

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
acre	0.4047	square hectometer (hm^2)
acre	0.004047	square kilometer (km^2)
square foot (ft^2)	929.0	square centimeter (cm^2)
square foot (ft^2)	0.09290	square meter (m^2)
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
cubic foot (ft^3)	28.32	cubic decimeter (dm^3)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
cubic yard (yd^3)	0.7646	cubic meter (m^3)
acre-foot (acre-ft)	1,233	cubic meter (m^3)
acre-foot (acre-ft)	0.001233	cubic hectometer (hm^3)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [(ft^3/s)/mi^2]	0.01093	cubic meter per second per square kilometer [(m^3/s)/km^2]
	Mass	
ton, short (2,000 lb)	0.9072	megagram
ton per day (ton/d)	0.9072	metric ton per day
ton per year (ton/yr)	0.9072	metric ton per year

SI to Inch/Pound

Multiply	By	To obtain
	Length	
millimeter (mm)	0.03937	inch (in.)

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows: °C=(°F–32)/1.8

A water year is the 12-month period October 1 through September 30 designated by the calendar year in which it ends.

Datums

Elevation refers to distance above the vertical datum based on the National Geodetic Vertical Datum of 1929 (NGVD 29).

Concentrations of chemical constituents in water are given in milligrams per liter (mg/L).

Estimation of Sediment Inflows to Lake Tuscaloosa, Alabama, 2009–11

By K.G. Lee

Abstract

The U.S. Geological Survey, in cooperation with the City of Tuscaloosa, evaluated the concentrations, loads, and yields of suspended sediment in the tributaries to Lake Tuscaloosa in west-central Alabama, from October 1, 2008, to January 31, 2012. The collection and analysis of these data will facilitate the comparison with historical data, serve as a baseline for future sediment-collection efforts, and help to identify areas of concern.

Lake Tuscaloosa, at the reservoir dam, receives runoff from a drainage area of 423 square miles (mi^2). Basinwide in 2006, forested land was the primary land cover (68 percent). Comparison of historical imagery with the National Land Cover Database (2001 and 2006) indicated that the greatest temporal land-use change was timber harvest. The land cover in 2006 was indicative of this change, with shrub/scrub land (12 percent) being the secondary land use in the basin. Agricultural land use (10 percent) was represented predominantly by hay and pasture or grasslands. Urban land use was minimal, accounting for 4 percent of the entire basin. The remaining 6 percent of the basin has a land use of open water or wetlands.

Storm and monthly suspended-sediment samples were collected from seven tributaries to Lake Tuscaloosa: North River, Turkey Creek, Binion Creek, Pole Bridge Creek, Tierce Creek, Carroll Creek, and Brush Creek. Suspended-sediment concentrations and streamflow measurements were statistically analyzed to estimate annual suspended-sediment loads and yields from each of these contributing watersheds.

Estimated annual suspended-sediment yields in 2009 were 360, 540, and 840 tons per square mile ($tons/mi^2$) at the North River, Turkey Creek, and Carroll Creek streamflow-gaging stations, respectively. Estimated annual suspended-sediment yields in 2010 were 120 and 86 $tons/mi^2$ at the Binion Creek and Pole Bridge Creek streamflow-gaging stations, respectively. Estimated annual suspended-sediment yields in 2011 were 190 and 300 $tons/mi^2$ at the Tierce Creek and Brush Creek streamflow-gaging stations, respectively.

The North River watershed at the streamflow-gaging station contributes 53 percent of the drainage area for Lake Tuscaloosa. A previous study in the 1970s analyzed streamflow and historical suspended-sediment samples to estimate a long-term average suspended-sediment yield of 300 tons per year per square mile in the North River watershed. Analysis of data collected in the North River watershed during the 2009 water year (October 2008 to September 2009) estimated a sediment yield of 360 $tons/mi^2$. The North River watershed, a major portion of the Lake Tuscaloosa drainage basin, has not experienced a substantial increase in sedimentation rates.

During the 2009 water year, the Turkey Creek watershed (6.16 mi^2) and the Carroll Creek watershed (20.9 mi^2) produced greater suspended-sediment yields than the North River watershed but contribute a much smaller drainage area to Lake Tuscaloosa. Aerial photography and bathymetric surveys indicate that Carroll Creek has experienced increased sediment deposition in the upstream portions of the channel. Carroll Creek is also the only watershed in the current study that has a substantial percentage (11 percent) of urban land use.

Introduction

Lake Tuscaloosa, constructed in 1969 on the North River in Tuscaloosa County, Alabama, serves as the water supply for Tuscaloosa, Northport, and other communities in Tuscaloosa County (fig. 1). The lake is also used for recreational activities in western Alabama. Protection and monitoring of this water supply has been a concern for many years. Changes in land use, such as agriculture, timber clear-cutting, coal mining, and residential development in basins that drain into the lake have caused concern about possible changes in the rate of sedimentation in the reservoir. Sedimentation damages a reservoir if the decreased storage capacity prevents supplying the full service for which it was designed. Sufficient capacity must be maintained in domestic water supply reservoirs to assure continuity of supply during periods of prolonged drought and to meet expected increases in water demand.

The U.S. Geological Survey (USGS), in cooperation with the City of Tuscaloosa, performed intensive suspended-sediment studies for seven tributaries in the Upper Black Warrior subbasin (hydrologic unit code (HUC) 03160112). The collection and analysis of suspended-sediment data will allow a better understanding of sedimentation rates and their effects on reservoir capacity.

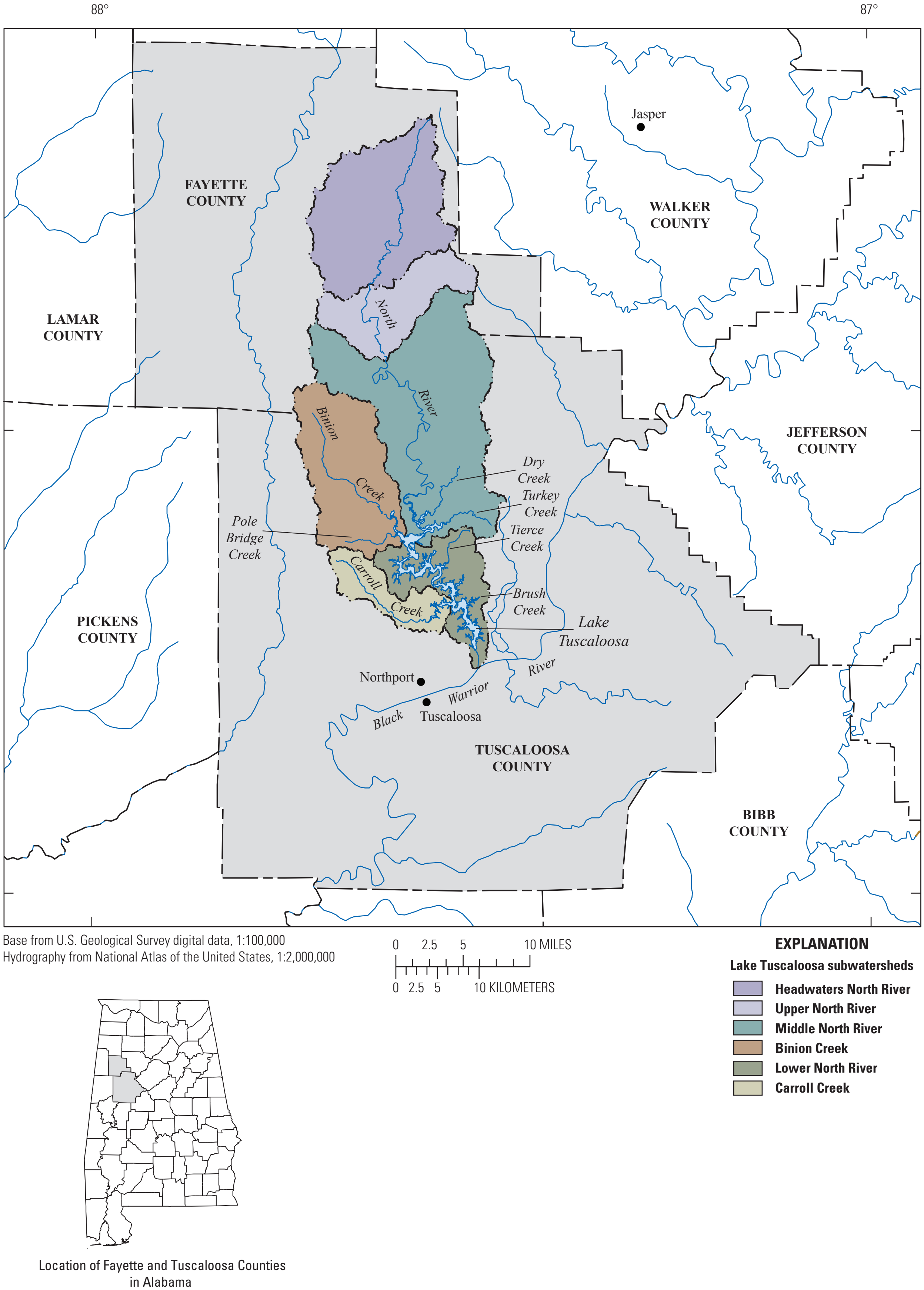

Figure 1. Location of Lake Tuscaloosa contributing subwatersheds and tributaries, Fayette and Tuscaloosa Counties, Alabama.

Purpose and Scope

The purpose of this report is to provide estimates of suspended-sediment concentrations and loads delivered to the Lake Tuscaloosa reservoir during 2009–11. To accomplish this, (1) previous suspended-sediment data and studies for the study area were reviewed; (2) land-use changes were investigated; (3) data were collected at seven tributaries to the Lake Tuscaloosa reservoir; and (4) using current and historic data, suspended-sediment loads to the Lake Tuscaloosa reservoir were estimated.

Acknowledgments

The assistance of Mr. Jimmy Junkin, Director, City of Tuscaloosa Water and Sewer Department, and Mr. Scott Sanderford, Lakes Manager, City of Tuscaloosa, is greatly appreciated. Appreciation is also extended to Mr. Vic Stricklin and others who performed fieldwork or otherwise assisted with this study. The field work and sample collection were performed by the USGS Alabama Water Science Center Tuscaloosa Field Office.

Description of Study Area

Lake Tuscaloosa is located in north-central Tuscaloosa County, Alabama. The reservoir was created by the impoundment of the North River approximately 1.5 miles (mi) upstream from its confluence with the Black Warrior River (fig. 1). The Lake Tuscaloosa watershed (Black Warrior-North River HUC 0316011204) drains surface area from Fayette and Tuscaloosa Counties. Lake Tuscaloosa, at the reservoir dam, receives runoff from a drainage area of 423 square miles (mi^2). The Black Warrior-North River watershed (confluence of Black Warrior River and North River) has a total drainage area of 425 mi^2. The Black Warrior-North River watershed contains six subwatersheds; headwaters of the North River, upper North River, middle North River, Binion Creek, lower North River, and Carroll Creek, (fig. 1; table 1).

Seven major streams flow into Lake Tuscaloosa: North River and Dry, Turkey, Binion, Tierce, Carroll, and Brush Cree*ks* (fig. 1). The normal pool elevation of Lake Tuscaloosa is 223.2 feet (ft)—National Geodetic Vertical Datum of 1929 (NGVD 29). The lake, approximately 25 mi long as measured along the old river channel, has a surface area and capacity, at normal pool, of 5,250 acres and 168,917 acre feet (acre-ft), respectively (Charley Foster and Associates, Inc., 2004).

The area of study has a subtropical climate characterized by warm, humid weather. According to long-term climatological records compiled by the National Oceanic and Atmospheric Administration (NOAA), the mean annual air temperature is 62.2 °F (degrees Fahrenheit). Generally, July is the hottest month with a mean temperature of 83.8 °F, and January is the coldest with a mean temperature of 52.5 °F (National Oceanic and Atmospheric Administration, 2002). Average annual precipitation, based on records for the 1971–2000 period at NOAA precipitation stations in Tuscaloosa and Fayette Counties, is about 56 inches (National Oceanic and Atmospheric Administration, 2002). Higher streamflow is generally observed during December through April and lower during May through November. Average annual runoff at long-term USGS gaging stations in the watershed is about 22 inches or 1.6 cubic feet per second per square mile [$(ft^3/s)/mi^2$].

Table 1. Hydrologic Unit Code (HUC) designations for the drainage area contributing to Lake Tuscaloosa in the Upper Black Warrior subbasin, Alabama.

[mi^2, square miles; —, no data]

HUC 8 subbasin	HUC 10 watershed	HUC 12 subwatershed	Name	Drainage area (mi^2)
03160112	—	—	Upper Black Warrior	—
—	0316011204	—	Black Warrior-North River (Lake Tuscaloosa)	425
—	—	031601120401	Headwaters North River	96
—	—	031601120402	Upper North River	44
—	—	031601120403	Binion Creek	72
—	—	031601120404	Middle North River	145
—	—	031601120405	Carroll Creek	26
—	—	031601120406	Lower North River	42

Approximately 68 percent of the land in the study area is forested (Fry and others, 2011; fig. 2). Inspection of land-use trends indicate that the primary change in the Lake Tuscaloosa watershed has been forested areas. Three datasets were used for comparison: National Land Cover Database (NLCD) 1992–2001 Retrofit Change Product (Fry and others, 2009), NLCD 2001 (Homer and others, 2004), and NLCD 2006 (Fry and others, 2011). The results indicated 3 percent of the basin changed from forest to grassland/shrub from 1991 to 2001. Similarly, the 2001 and 2006 NLCD showed a 3-percent decrease in forested land, changing from 71 to 68 percent, respectively. Direct comparison of the two datasets indicate a decrease in evergreen forest specifically and an increase in shrub/scrub and grasslands. This decrease could be attributed to timber harvesting without replanting, or to increased development.

Although the relatively impermeable Pottsville Formation of Pennsylvanian age underlies all of the study area, it is exposed mainly in the northeastern part. The Pottsville Formation consists primarily of sandstone, shale, and siltstone with shale being dominant (Metzger, 1965). Beds of coal and underclay are present in some parts of the formation. Groundwater usually occurs in openings along joints, fractures, and bedding planes (Culbertson, 1964).

The more permeable Coker Formation of Cretaceous age lies above the Pottsville Formation and has outcrops in the southern and western parts of the study area. Although the upper 300 ft of the Coker Formation consists chiefly of clay (Metzger, 1965), the permeable sand and gravel beds in the lower 100 ft provide substantial quantities of base flow to streams and are the principal source of water for wells in much of the Lake Tuscaloosa area (Cole, 1985b).

Previous Investigations

Since the impoundment of North River to form Lake Tuscaloosa, there have been numerous efforts to monitor the water quality, sedimentation rate, and bathymetric changes of the reservoir. Some investigations have been reconnaissance in nature and provide information to define the hydrologic conditions of the reservoir since impoundment. Keener and others (1975) presented geologic and hydrologic data for Lake Tuscaloosa, its tributaries, and drainage basin. They described the geology in the general area, soil associations and thickness, and provided basic data on groundwater and surface-water quality. They also presented baseline sedimentation data collected from a fathometer survey of 39 cross sections in the lake. Almon and Associates (1976) addressed requirements of the Federal Water Pollution Control Act Amendments of 1972, Public Law 92–500, as they relate to the Lake Tuscaloosa area. Included were descriptions of the reservoir and drainage area, housing development information, and water-quality data. Hubbard (1976a) estimated a long-term average sediment yield of 300 tons per year per square mile for North River. Hubbard also addressed the magnitude of potential sedimentation that could result from an increase in logging activities, coal mining, construction, or agriculture in the basin. Hubbard (1976b) presented results of a water-quality reconnaissance study of the lake for the period March–June 1975 that included: standard chemical analyses of surface waters with analyses for nutrients and trace elements, bacteria concentrations, chemical analyses of bottom deposits, and temperature and dissolved oxygen vertical profiles.

Several studies of the effects of coal mining on hydrology that are pertinent to this investigation have been made in the Warrior Coal Field. Puente and others (1980) provided baseline hydrologic information for selected basins. Harkins and others (1980) described the hydrology of part of the Warrior Coal Field that included the North River basin. The U.S. Bureau of Land Management (1980, 1983) assessed impacts of coal mining on Federal coal-lease tracts in North River and adjacent basins. Puente and Newton (1982) developed methods to estimate effects of surface mining on the hydrology of basins in the Warrior Coal Field. Puente and others (1982) described hydrologic conditions in four coal-lease tracts in the Warrior Coal Field. Cole (1985a, 1985b) sampled 14 sites in the North River basin to determine if surface coal mining had impacted the quality of water in the lake and selected tributaries. Slack (1987) described the flow, water quality, and changes in the water quality by compiling historical data and collecting data at 17 sites in Lake Tuscaloosa and selected tributaries.

Since impoundment, several data collection efforts have been undertaken to determine bathymetric changes in Lake Tuscaloosa. The bathymetric surveys were collected in 1973 (Hubbard, 1975), 1982 (Cole, 1985b), 1986 (Slack and Prichett, 1988), 2000 (Stricklin, 2001), 2004 (Charley Foster and Associates, Inc., 2004), and 2010 (Lee and Kimbrow, 2011). For the 1982 bathymetric survey (Cole, 1985b), 17 cross sections were established in 7 principal tributaries to Lake Tuscaloosa, including North River, Dry Creek, Turkey Creek, Binion Creek, Tierce Creek, Carroll Creek, and Brush Creek. Results revealed that sediment depositions ranged from 2 to 20 ft in 14 of 17 cross sections (Cole, 1985b). These cross sections were resurveyed in 1986 (Slack and Prichett, 1988) and in May 2000 (Stricklin, 2001) to determine whether any additional sedimentation or scour occurred. Results from the 2000 survey indicated that the maximum amount of sediment deposition occurred in the upper end of Carroll Creek (Stricklin, 2001). Charley Foster and Associates, Inc., conducted a survey of Lake Tuscaloosa and its tributaries in 2004 and computed a capacity of 190,495 acre-ft at a water-surface elevation of 223.2 ft NGVD 29. As a byproduct of this investigation, a 3.5-mile reach of Carroll Creek was surveyed in 2010 (Lee and Kimbrow, 2011) to prepare a current bathymetric map, determine storage capacities at specified water-surface elevations, and compare current conditions to historical cross sections. The capacity for the 3.5-mile reach of Carroll Creek was estimated to be 7,100 acre-ft at a water-surface elevation of 223 ft (NGVD 29).

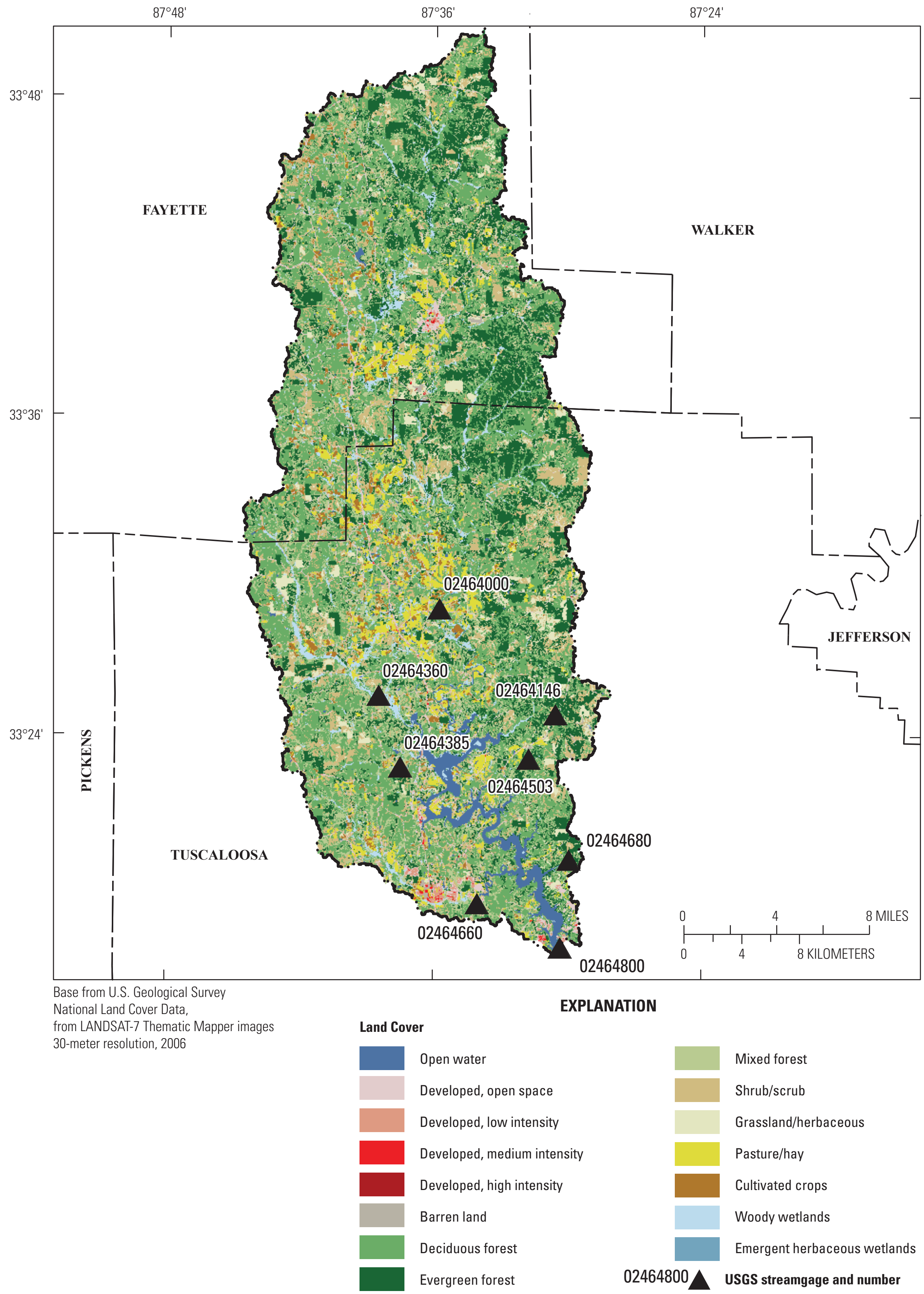

Figure 2. National Land Cover Database (NLCD) land use in the Lake Tuscaloosa watershed in 2006, Tuscaloosa and Fayette Counties, Alabama.

Approach and Methods

Streamflow and suspended-sediment data were collected for seven tributaries (fig. 3) to Lake Tuscaloosa (Black Warrior-North River watershed). These data were collected during water years (October to September) 2009 to 2012, and used to develop sediment transport curves, estimate annual loads, and evaluate the tributaries for areas of concern. The approach and methodology used to measure streamflow and collect suspended-sediment samples are described in the following sections.

Streamflow Data Collection

Streamflow data were collected for seven tributaries to Lake Tuscaloosa. Of the seven collection sites, three are long-term streamflow-gaging stations. At the remaining four sites, streamflow-gaging stations were installed. The streamflow-gaging stations are equipped with data collection platforms (DCPs) that allow for near real-time access (data transmitted every hour) to the hydrologic data from the USGS Alabama Water Science Center (ALWSC) Web site (*http://al.water.usgs.gov*, accessed May 8, 2012). Continuous streamflow data were computed at all streamflow-gaging stations by using standard USGS stage-discharge techniques (Carter and Davidian, 1968; Rantz and others, 1982; Kennedy, 1984). Streamflow data are reviewed, approved, and stored in the USGS Automated Data-Processing System (ADAPS) of the National Water Information System (NWIS) database. Quality-assured surface-water data are available for retrieval on the Internet at *http://waterdata.usgs.gov/al/nwis/sw,* accessed January 11, 2013.

Suspended-Sediment Data Collection

Two methods of data collection were used for the sediment samples, manual and automatic. The manually collected samples were taken by USGS personnel and represent a streamflow-weighted suspended-sediment concentration. The automatic samples were collected using an ISCO 6712 automatic pump sampler (manufactured by Teledyne Isco, Inc.). These samples are taken at a fixed point and do not represent a streamflow-weighted suspended-sediment concentration. Both methods are explained in detail in the following paragraphs.

Monthly low-flow and various flood events were sampled using the equal-width-increment method. Using standard USGS protocols and quality-control procedures (U.S. Geological Survey, 2006), an isokinetic sampler was used to collect suspended-sediment samples. An isokinetic sampler collects a water-sediment sample from the stream at a rate such that the velocity in the intake nozzle is equal to the incident stream velocity at the nozzle entrance. The water-sediment sample collected is proportional to the instantaneous stream velocity at the locus of the intake nozzle and, therefore, is representative of the sediment load at that point (Davis, 2005). Samples were collected at equally spaced intervals (fig. 4) across the stream channel and were depth-integrated by lowering and raising the sampler through the water at a constant rate. The samples from each equal-width segment were then combined into a single composite sample for analysis. A composite water-sediment sample is horizontally and vertically averaged throughout the stream cross section and is assumed to represent the average streamflow-weighted suspended-sediment concentration (Edwards and Glysson, 1999; U.S. Geological Survey, 2006). The monthly low-flow samples were used to evaluate conditions during normal flow conditions. Samples were also collected during four flood events. A total of five samples were taken during various flood events. Two were collected during the rising limb of the hydrograph, one around the peak of flood flow, and two on the falling limb of the hydrograph. These cross-section samples were collected and used to adjust the fixed-point automatic samples collected during flooding.

Isokinetic, depth-integrated (cross section) sediment samples provide samples representative of stream conditions necessary to make sediment load estimates for a stream. Manually collected isokinetic samples can be time consuming and expensive, and in some cases may not define the entire hydrograph. In order to collect more frequent sediment samples, ISCO 6712 automatic water samplers (Teledyne Isco, Inc., 2005) were deployed at selected sites. The ISCO sampler features an electrically driven peristaltic pump, which is activated on a predetermined schedule by an internal timer or in response to stage change. The intake tube is purged before and after each pumping period by automatic reversal of the pump. The automatic sampler can collect up to 24 discrete samples over the rise and fall of the hydrograph. The discrete sample frequency was set to collect samples at a uniform time. The sample frequency was determined based on the typical storm duration for each site. Samples for 10 storm events were collected for each site with an automatic sampler. Although the samples collected are efficient, they represent a point sample and are not necessarily indicative of average streamflow-weighted sediment concentrations. In order to adjust the point sample to represent streamflow-weighted suspended-sediment concentrations, automatic (fixed point) samples and manual (cross section) samples were taken simultaneously. These samples were collected for 4 of the 10 storm events. A regression was developed for each site, between concentrations of the fixed-point automatic samples (dependent variable) and the cross-section manual samples (independent variable). This relation was used to adjust the automatic (fixed point) sample concentrations to manual (cross section) sample concentrations. At all sampling locations the coefficient of determination (R^2) for the regression equation was greater than 0.7, with three sites having R^2 values of 0.9.

Suspended-sediment samples were analyzed by the USGS sediment laboratory in Louisville, Kentucky. Samples were analyzed for suspended-sediment concentration, and selected samples were analyzed for sand separation. Sand-separation analysis gives the percentage of sediment, by weight, that is finer and coarser than 0.0625 millimeter (mm). Particle sizes smaller than 0.0625 mm are defined as silt and clay; particle sizes 0.0625 millimeter or larger are defined as sand (Guy, 1969). Quality-assured water-quality data are available for retrieval on the Internet at *http://waterdata.usgs.gov/al/nwis/qw*, accessed January 11, 2013.

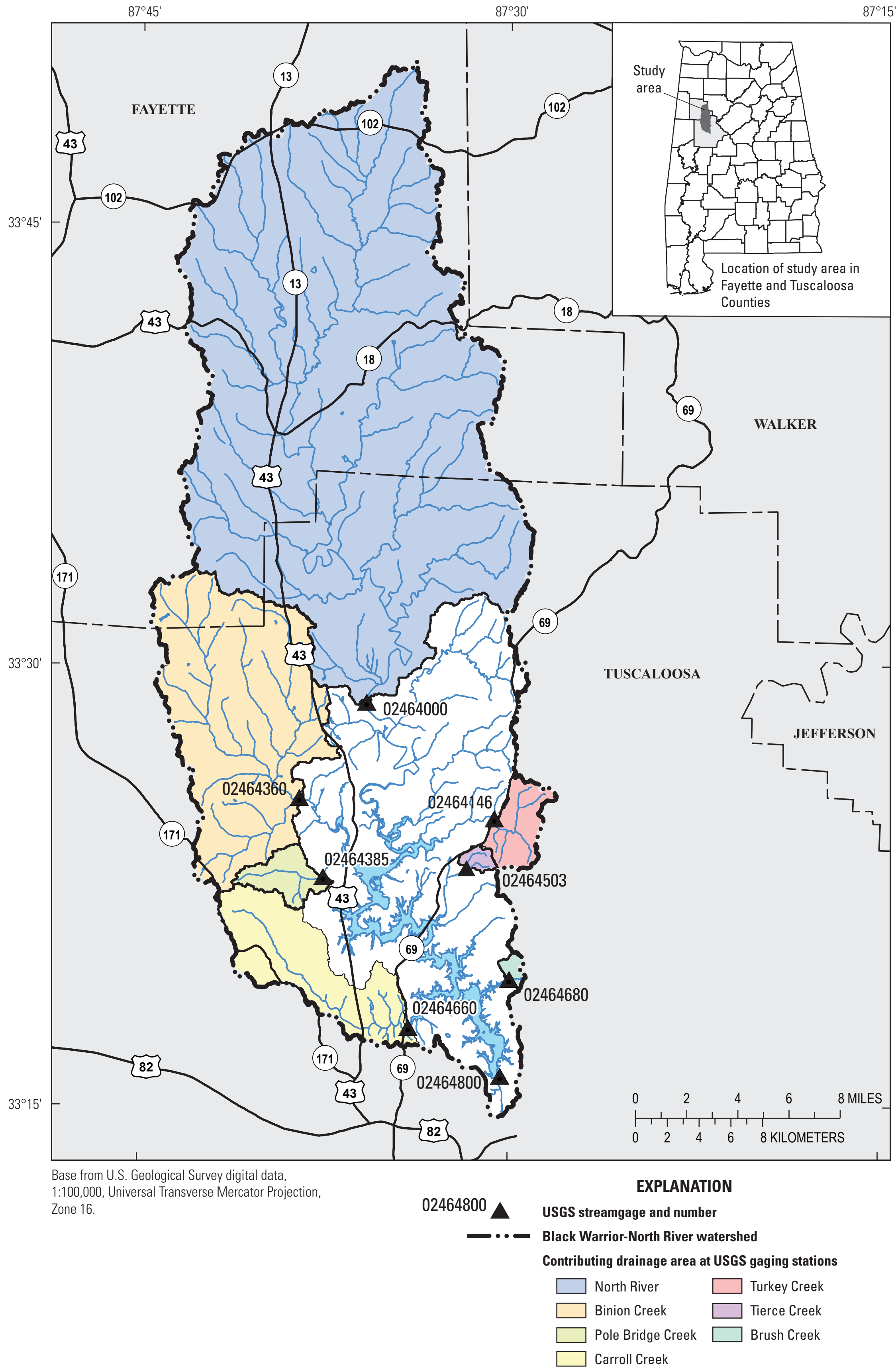

Figure 3. Location of sampling sites and contributing drainage area at U.S. Geological Survey streamflow-gaging stations in the Black Warrior-North River watershed, Alabama.

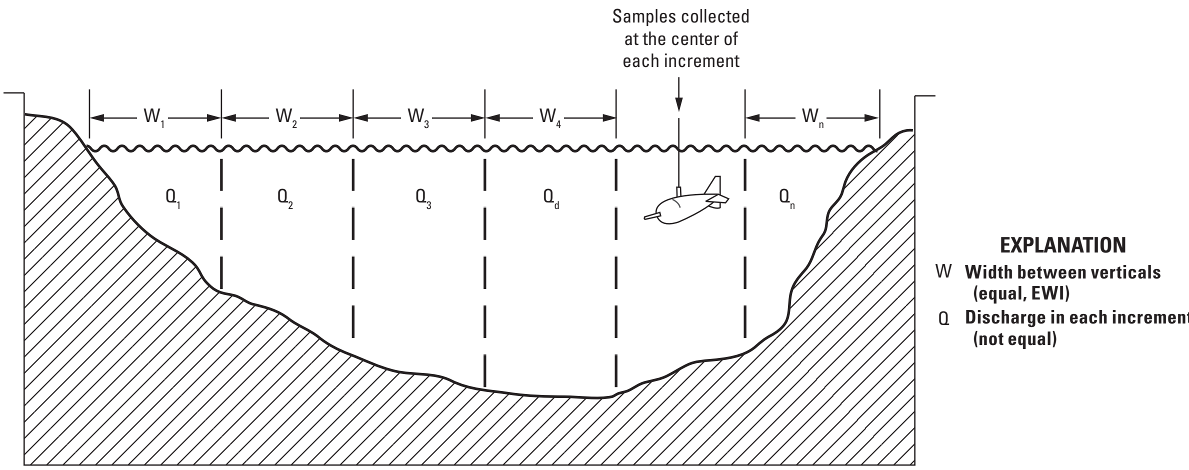

Figure 4. A diagram of the equal-width-increment sampling method (Edwards and Glysson, 1999) used to collect sediment samples in tributaries to Lake Tuscaloosa, Alabama. EWI, equal width increment.

Data Analysis

Suspended-sediment and streamflow data were collected at seven tributaries to Lake Tuscaloosa and analyzed using graphical and statistical techniques. The data-analysis effort focused on developing daily sediment-transport curves and estimating sediment loads and yields at each site. A sediment-transport curve is the curve that defines the average relation between suspended-sediment discharge and streamflow. Several factors can affect the shape, slope, and intercept of the sediment transport curve. Some of the major factors are (1) seasons, (2) timing between sediment concentration peak and streamflow peak, and (3) extreme high-water events (Glysson, 1987). Seasons can have a major effect on sediment yield, especially in the more humid areas. In the region of study, during the summer when high-intensity storms are prevalent, raindrop impact is high and thus sediment concentrations are higher, particularly in nonforested land-use areas. An additional complication may also occur when a large area of the drainage basin is used for agricultural purposes. Typically, the fields are bare during the winter and spring, but as the crops begin to grow the soil becomes protected from erosion by the plants (Glysson, 1987).

Suspended-sediment samples were collected at each streamflow-gaging station, as described in the Suspended-Sediment Data Collection section. Samples were collected for 10 storm events; during 4 of the events, samples were collected by both manual and automatic methods. The samples were collected in efforts to reflect seasonal variations and their variable antecedent conditions. However, streamflow is generally higher during December through April than during May through November, and therefore the storm event samples typically were collected during the December to April timeframe. In addition to the storm events, samples were collected on a monthly basis to represent normal daily streamflows.

The shape of the sediment transport curve is strongly affected by time offsets in the streamflow hydrograph and suspended-sediment time series for specific runoff events. Although suspended-sediment concentration generally increases with streamflow, the relation is more complex. Streamflow and instantaneous sediment concentration may not have a stationary relation during a single storm flow. The tendency for sediment concentration to have different values at identical stream discharges (a hysteresis effect) is the primary drawback to application of a single transport curve during storm flow (Walling, 1977; Williams, 1989; Dinehart, 1998). When substantial timing variations exist between the suspended-sediment concentration peak and the streamflow peak, separate regression curves may need to be developed for rising and falling data. The sediment hydrographs for each storm event were graphically analyzed to determine if they preceded, tracked, or lagged the streamflow hydrographs. The sites that have preceding peaks have hysteresis that are clockwise. This can be attributed to depletion of available sediment before the streamflow hydrograph peaks or formation of an armored layer prior to the occurrence of the streamflow peak (Williams, 1989). The sites that have lagging peaks have hysteresis that are counterclockwise. This can result from at least three possible causes: relative travel times of the flood wave and the sediment flux, high soil erodibility in conjunction with prolonged erosion during the flood, and seasonal variability of rainfall distribution and of sediment production within the drainage basin (Williams, 1989). In the event of the hysteresis effect, separate instantaneous sediment transport curves were developed for the rising and falling data.

Another variable affecting the shape and applicability of the sediment-transport curve is streamflow magnitude. Once the available sediment is exhausted, additional rainfall does not increase suspended sediment and the transport curve will flatten out. A comparison was made with streamflow to determine how climatic conditions during this investigation may have influenced the data collected and may limit the applicability of the regression equations developed by this investigation to periods of differing climatic conditions.

For existing streamflow-gaging stations (streamgages), annual mean streamflows for the period of record and the individual water years were examined. Flow duration curves were developed to evaluate the average streamflow conditions for the site compared to the period of investigation. For sites that were newly installed and lack a long-term record (10 or more years), the peak streamflow during data collection was evaluated based on regional flood-frequency relations. A flood-frequency relation was developed based on regression equations developed in “Magnitude and Frequency of Floods in Alabama, 2003” (Hedgecock and Feaster, 2007). A flood-frequency relation is the relation of peak streamflow to probability of exceedance. Probability of exceedance refers to the chance that a given peak streamflow will be exceeded in any one year. For example, a 50-percent chance exceedance flood corresponds to the flow magnitude that has a probability of 0.50 of being equaled or exceeded in any given year. Typically, the channel forming (bankfull) flow has a magnitude in the range of a 67- to 50-percent chance exceedance flood.

Sediment-transport curves were developed for each site after evaluating seasonality, flow magnitude, and hysteresis. The first step taken was to adjust the suspended-sediment samples to reflect average streamflow-weighted suspended-sediment concentrations. As described in the Suspended Sediment Data Collection section of this report, two types of samples were collected, point samples and horizontally and vertically averaged samples. To adjust the point sample to represent streamflow-weighted suspended-sediment concentrations, automatic (point) samples and manual samples (horizontally and vertically averaged) were taken simultaneously. These samples were collected for 4 of the 10 storm events. A cross-section coefficient, automatic sample concentration divided by manual sample concentration, was computed for each sample. Many factors can affect the cross-section coefficient; for example, size distribution of sediment, channel alignment, bank stability, source of sediment, streamflow, and location of sampling intake. According to Stokes Law, suspended sediment considered to be fine material will have a fairly even distribution throughout the water column, whereas coarse material will have a larger concentration closer to the bed. The smaller channel slopes in the study area provide a good indication that the suspended sediment will be considered fine. Chanel slopes were investigated on a site-by-site basis by analyzing a sand/fines split for some of the suspended-sediment samples. The cross-section coefficients were graphically compared with respect to time and streamflow to determine if any trends exist. The other factors affecting the cross-section coefficient were accounted for by developing a linear regression equation (ordinary least squares) for each site. The regression equation describes the relation between the automatic samples (dependent variable) and the manual samples (independent variable). The regression equation was used to calculate the mean suspended-sediment concentration from the concentrations of the point samples. A linear regression equation (ordinary least squares) provides a line about which the sum of the square deviations of observed values from the regression line was minimized. At all sampling locations the coefficient of determination (R^2) for the regression equation was greater than 0.7, with three sites having R^2 values of 0.9.

The resulting suspended-sediment concentrations (*SSC*) were converted to suspended-sediment discharge (*SSQ*). Suspended-sediment discharge is defined as the quantity of sediment per unit time carried past any cross section of a stream (Vanoni, 1977) and will be reported in tons per day. Each suspended-sediment sample was associated with a streamflow value. Streamflow data were obtained from the stage-discharge rating curve at the streamflow-gaging station where suspended-sediment samples were collected. The availability of streamflow data and suspended-sediment concentration data allowed computation of suspended-sediment discharge, according to equation 1:

$$SSQ = Q(SSC)(ks) \qquad (1)$$

where

- *SSQ* is the suspended-sediment discharge, in tons per day;
- *Q* is the streamflow, in cubic feet per second;
- *SSC* is the suspended-sediment concentration, in milligrams per liter; and
- *ks* is a conversion factor of 0.0027, which results in a suspended-sediment discharge in tons per day, given streamflow in cubic feet per second and suspended-sediment concentration in milligrams per liter.

The suspended-sediment concentration (*SSC*) was graphically and statistically compared with streamflow (*Q*) to evaluate the relation and determine if any seasonal bias exists. The suspended-sediment discharge (*SSQ*) was then graphically and statistically compared with streamflow (*Q*) to develop sediment-transport curves. A linear regression equation (ordinary least squares) was developed to provide a line about which the sum of the square deviations of observed values from the regression line was minimized. A composite regression equation was developed to include all of the data and separate regression equations were developed for the rising and falling limb of the hydrograph for sites that have documented hysteresis effects. The relation of log-transformed suspended-sediment discharge and streamflow was linear and was expressed in the form of equation 2:

$$SSQ = aQ^b \text{ or } \mathrm{Log}(SSQ) = \mathrm{Log}(a) + b\,\mathrm{Log}(Q) \qquad (2)$$

where

- *SSQ* is the suspended-sediment discharge, in tons per day;
- *Q* is the streamflow, in cubic feet per second;
- *a* is the intercept; and
- *b* is the slope.

Because the regression equations were developed in log space and the predictions are made in original engineering units, retransformation of the data is required. This retransformation results in a systematic distortion of the statistic, a bias. The regression equation will provide a value that is closer to the median response as opposed to the mean, and the resulting suspended-sediment load will be too low due to the skewed distribution. Several methods exist to remove this bias and have been tested (Cohn and others, 1989) to determine their applicability. For this study the smearing estimator, a nonparametric estimator, was used to remove the potential bias. A full description of the smearing estimator is described by Duan (1983).

The resulting sediment-transport regression equation with bias correction may be classified according to either the period of the basic data that defined a curve or the kind of sediment discharge that a curve represents. Sediment-transport curves based on the period of the basic data may be classified as instantaneous, daily, monthly, seasonal, annual, or flood- or storm-period curves (Colby, 1956). The suspended-sediment samples collected for the seven tributaries to Lake Tuscaloosa represent sediment concentrations at a given time and streamflow conditions, and produce a sediment-transport curve that is classified as instantaneous. These curves are useful in estimating an average annual sediment load expressed in tons and based on 15-minute streamflow values. This process can be laborious without the use of an automated program. For ease of use, these curves were used to develop daily sediment-transport curves. The instantaneous sediment-transport curves were used in conjunction with the 15-minute streamflow data to compute an average daily suspended-sediment discharge for every day during the period of data collection. These average daily suspended-sediment discharges were graphically and statistically compared to the average daily streamflow to produce a regression equation in the same manner that the instantaneous sediment-transport curves were developed. The resulting daily sediment-transport curve was used to compute an average annual sediment load and yield. The specific process and results are described for each site in later sections.

North River

North River was impounded in 1969 to form the Lake Tuscaloosa reservoir. The USGS streamflow-gaging station at North River near Samantha, Ala. (station number 02464000, also referred to as the North River streamgage) (fig. 5) is one of seven locations for sampling suspended-sediment inflow into Lake Tuscaloosa. The North River streamgage was established in December 1938, at County Road 38, about 11 mi upstream from the backwater of Lake Tuscaloosa. The drainage area for this streamgage is 223 mi^2, about 53 percent of the drainage area to Lake Tuscaloosa. The upstream area of the lake (near Bull Slough Road) has experienced sediment deposition. A comparison of historical (1974) and recent (2011) aerial photography illustrates the changes in the shoreline (fig. 6). A closer aerial photograph (fig. 7) shows newly formed sediment islands.

Land Use

In general, land use within the North River subwatershed in 2006 (Fry and others, 2011) can be classified as rural. Forested land (cumulative total of mixed, deciduous, and evergreen) was the predominant basinwide land use in 2006 at 72 percent. Shrub/scrub, represented predominantly by shrubs less than 16 ft tall with shrub canopy typically greater than 20 percent of total vegetation, accounted for approximately 11 percent of the subwatershed. Low-, medium-, and high-intensity residential and developed open-space land coverages were combined to compute total urban land use. Urban land use was approximately 3 percent in 2006 (fig. 8). Inspection of aerial photography indicates little to no urban development since completion of the 2006 NLCD.

General changes in land use were evaluated by inspecting the NLCD 1992–2001 Land Cover Change Retrofit product (Fry and others, 2009) and direct comparison of the NLCD 2001(Homer and others, 2004) and the NLCD 2006 (Fry and others, 2011). One of the largest reductions in land use from 1992 to 2001 was forested land that decreased by 4 percent. During this period, 2 percent of the basin was converted to forested land. Direct comparison of NLCD 2001 and 2006 (fig. 8), shows a small shift from forest categories to the shrub/scrub category, indicating that land use in the basin has been stable and the inclusion of historical data for analysis with recent data is acceptable.

Historical Data

Historical data can provide various benefits in assessing current datasets. If the basin is relatively stable, historical data can be used in conjunction with current data to develop sediment transport curves. If the basin is dynamic, the historical and current data can be used to monitor temporal changes. Periodic monthly sediment samples (table 2) were collected at the same location as the North River streamgage from 1979 to 1983. The smallest low-flow and largest storm event sampled had a streamflow of 4 and 2,390 cubic feet per second (ft^3/s), respectively. The historical data were included in the dataset to develop the suspended-sediment transport curve because the land-use changes described above indicate a relatively stable basin. Suspended-sediment data were also collected at this streamgage from March to September 1975 to estimate the long-term average sediment yield of 300 tons per year per square mile (Hubbard, 1976a). This estimation was based on daily and flood event samples. The suspended-sediment concentrations were available for inclusion in the dataset, but the corresponding streamflows were not published. For comparison, the corresponding average daily streamflows were taken from the published annual data report and correlated with the suspended-sediment concentrations. The resulting dataset was plotted and compared with other historical data and current data, but not included in the suspended-sediment transport curve. Even though the 1975 dataset is an approximation of what was collected, it followed the same trend as the data used to develop the current sediment transport curve.

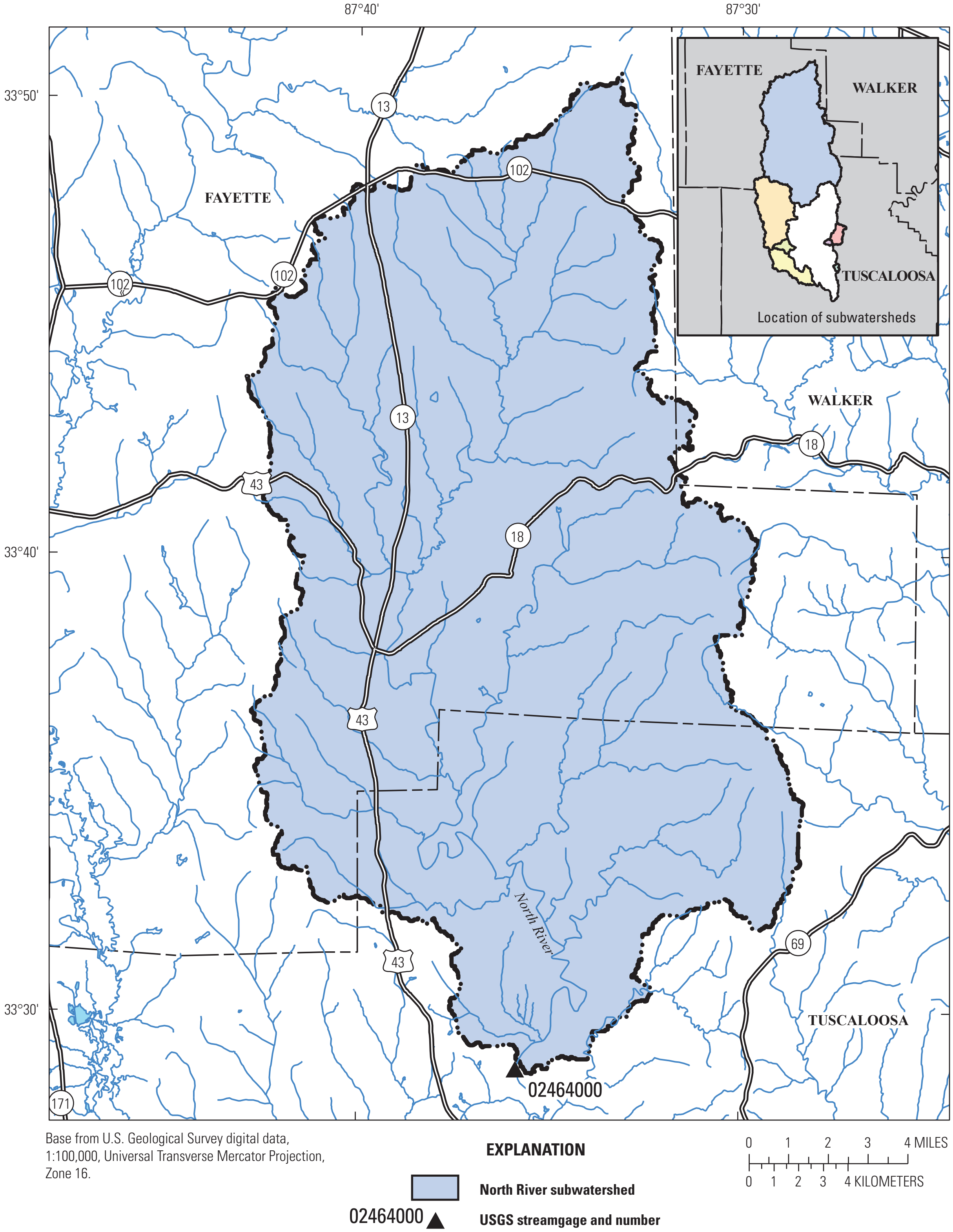

Figure 5. Location of U.S. Geological Survey streamflow-gaging station 02464000 North River near Samantha, Alabama, and the contributing drainage area.

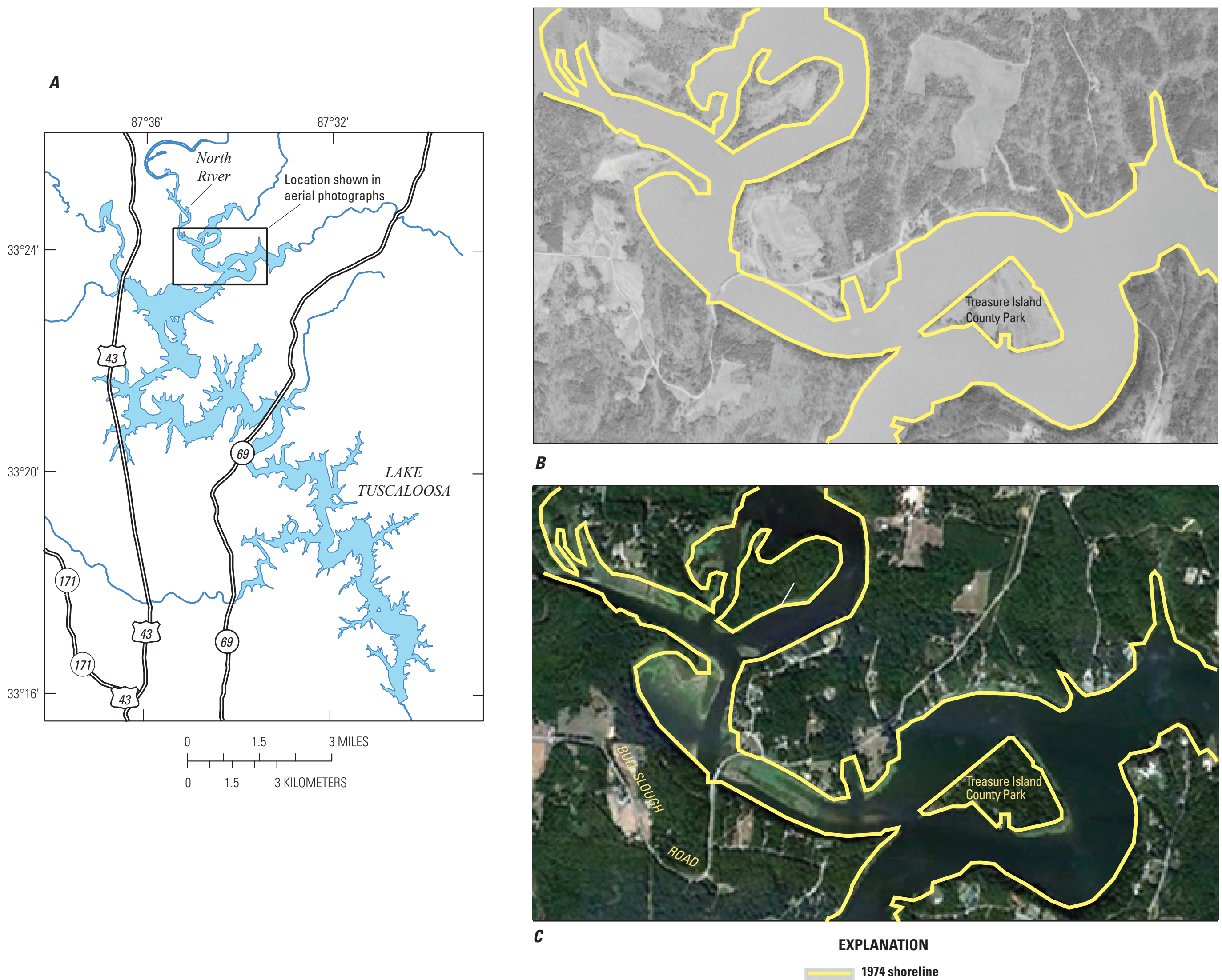

Figure 6. Location of the North River in Alabama at (*A*) Bull Slough Road as shown in aerial photography dated (*B*) February 12, 1974 and (*C*) September 29, 2011.

Figure 7. Locations of sediment deposition near the upstream extent of the backwater of Lake Tuscaloosa on the North River, Alabama. (*A*) Aerial photography dated 2009 shows sediment deposition to the (*B*) northwest and (*C*) southeast of Bull Slough Road.

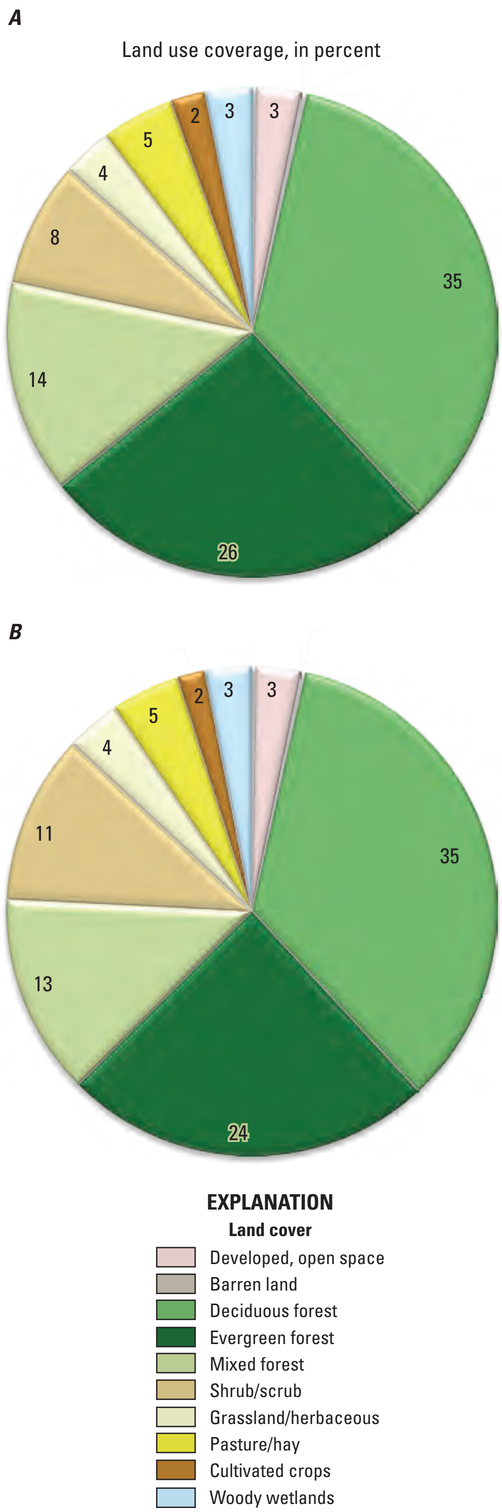

Figure 8. Percentage of land-use coverage at the U.S. Geological Survey streamflow-gaging station 02464000 North River near Samantha, Alabama. (*A*) National Land Cover Database 2001 and (*B*) National Land Cover Database 2006.

Table 2. Historical streamflow and suspended-sediment data for U.S. Geological Survey streamflow-gaging station 02464000 North River near Samantha, Alabama.

[Data are available at http://waterdata.usgs.gov/al/nwis/qw. Dates are by month/day/year. Abbreviations: ft^3/s, cubic foot per second; mg/L, milligram per liter]

Date	Mean streamflow (ft^3/s)	Suspended sediment (mg/L)	Suspended sediment discharge (tons/day)
6/5/1979	98	16	4.2
8/28/1979	59	41	6.5
11/28/1979	896	35	85
1/30/1980	410	7	7.7
2/28/1980	105	7	2.0
3/27/1980	874	14	33
4/29/1980	830	16	36
5/27/1980	360	22	21
6/23/1980	93	15	3.8
7/17/1980	15	20	0.79
10/9/1980	24	14	0.91
11/20/1980	234	18	11
1/20/1981	63	7	1.2
3/18/1981	170	12	5.5
4/14/1981	221	10	6
5/14/1981	30	4	0.33
5/28/1981	69	66	12
10/5/1982	4	13	0.13
11/2/1982	10	3	0.08
2/8/1983	1,290	41	143
3/11/1983	800	35	76
4/8/1983	2,390	265	1,710
5/4/1983	243	7	4.6
5/31/1983	247	9	6.0
7/8/1983	56	6	0.91
8/4/1983	23	58	3.6
9/9/1983	41	43	4.8

Data Collected

Streamflow and suspended-sediment data were collected at the North River streamgage. Streamflow is computed from stage values that are continuously measured and recorded every 15 minutes. Periodic and event suspended-sediment samples were collected during the 2009 water year using isokinetic and equal-width increment methods.

Streamflow

Climatic conditions have a direct effect on streamflow. Average annual mean streamflow for the period of record (1940–54; 1969–2011) and the individual water years were examined and are shown in figure 9. The suspended-sediment samples collected in 2009 were collected during a period when annual streamflow was above average. The North River streamgage has a long period of record (10 or more years), which was used to evaluate the average streamflow conditions for the site. A flow duration curve (fig. 10) was constructed and used to evaluate how well the sampled streamflows represented the range of possible flow conditions. Flow duration curves provide the percentage of the time a certain streamflow can be expected to be equaled or exceeded for a site based on the daily mean streamflows for the period of record at that site. The streamflows at the time of sampling were overlain on the curve to determine if a fairly representative range of streamflows were sampled. Approximately 60 percent of the samples were collected at median or higher flow conditions (exceedance percentiles equal to or less than 50). The peak streamflow of record was also evaluated based on regional regression relations. A flood-frequency relation was developed (Hedgecock and Feaster, 2007), and the 67- and 50-percent chance exceedance flood flows for the North River streamgage are 6,600 and 8,230 ft^3/s, respectively. The peak streamflow during the suspended-sediment data collection period (2009) was 15,600 ft^3/s. The largest peak streamflow that was sampled during the collection period was 15,400 ft^3/s, which is greater than the streamflow corresponding to 0.1 annual exceedance probability.

Suspended Sediment

Suspended-sediment samples were collected at the North River streamgage isokinetically and horizontally and vertically averaged throughout the stream cross section. Because of the extensive historical data, samples were collected for two storm events (table 3). The streamflows sampled were close in magnitude to the streamflows sampled in the1975 dataset. In addition to the storm events, samples were collected on a monthly basis to represent normal daily streamflows.

Estimation of North River Suspended-Sediment Loads

The suspended-sediment concentrations were converted to suspended-sediment discharges (*SSQ*) and graphically and statistically compared with streamflow (*Q*) to develop instantaneous sediment-transport curves. A linear regression equation (ordinary least squares) was developed, and a smearing estimator applied, using all data (composite). The composite instantaneous sediment transport curve was used to compute an average daily sediment discharge for every day in the 2009 water year. These values were regressed with the average daily flow to provide a daily transport curve (fig. 11; eq. 3) using the following equation:

$$SSQ = 0.0135\,(Q)^{1.4483} \text{ for } Q \leq 15{,}400 \text{ ft}^3/\text{s} \quad (3)$$

where

SSQ is the average daily suspended-sediment discharge, in tons per day; and

Q is the average daily streamflow, in cubic feet per second.

The application of the daily suspended-sediment transport curve is limited to the maximum measured flow, 15,400 ft^3/s, for which suspended-sediment samples were collected. Suspended-sediment transport curves have the tendency to flatten out once the available sediment is exhausted and additional rainfall no longer increases the suspended sediment. Because this exact point is not known, extrapolation of the suspended-sediment transport curve should be based on engineering judgment and analysis.

Annual load and yield values were estimated for suspended sediment at North River for the 2009 water year. The suspended-sediment discharge was estimated for each day of the water year using the daily transport curve (eq. 3). Load computations were performed by application of the mid-interval method (Porterfield, 1972). The estimated average annual load for the 2009 water year, based on average daily streamflow and the North River daily transport curve is 81,400 tons and the average yield is 360 tons per square mile (tons/mi^2).

It is worth noting that the daily mean sediment concentration is a time-weighted mean value. Thus, calendar days can be divided and analyzed in shorter periods of time when water or sediment discharge exceed certain limits. The term “subdivide” refers to the division of data for a calendar day into shorter periods of time to obtain correct daily mean values of streamflow or suspended-sediment discharge when one or both change beyond certain limits during the day. The values for these periods are then summed to obtain values of suspended-sediment discharge. Computation of a daily mean sediment discharge requires subdivision of the day when both water discharge and concentration are changing because the average of the products of two variable quantities is not the same as the product of the averages of the quantities (Porterfield, 1972). For comparison, the instantaneous suspended-sediment transport curve, streamflow, and the mid-interval method were used to compute an estimated average annual load for the 2009 water year, based on a 15-minute interval. This computation resulted in an average annual load that is 1 percent more than the load calculated using the average daily values. It was determined that the use of the average daily streamflow and the daily transport curve is more practical for estimating average annual loads.

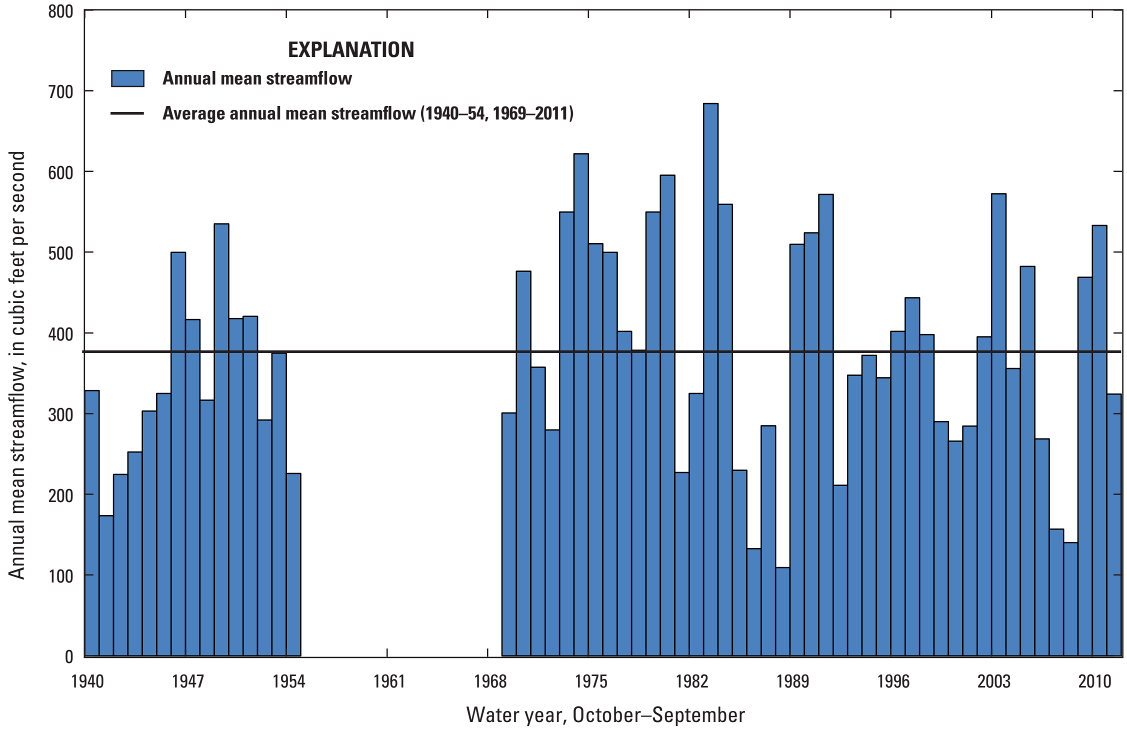

Figure 9. Annual mean streamflow for the U.S. Geological Survey streamflow-gaging station 02464000 North River near Samantha, Alabama.

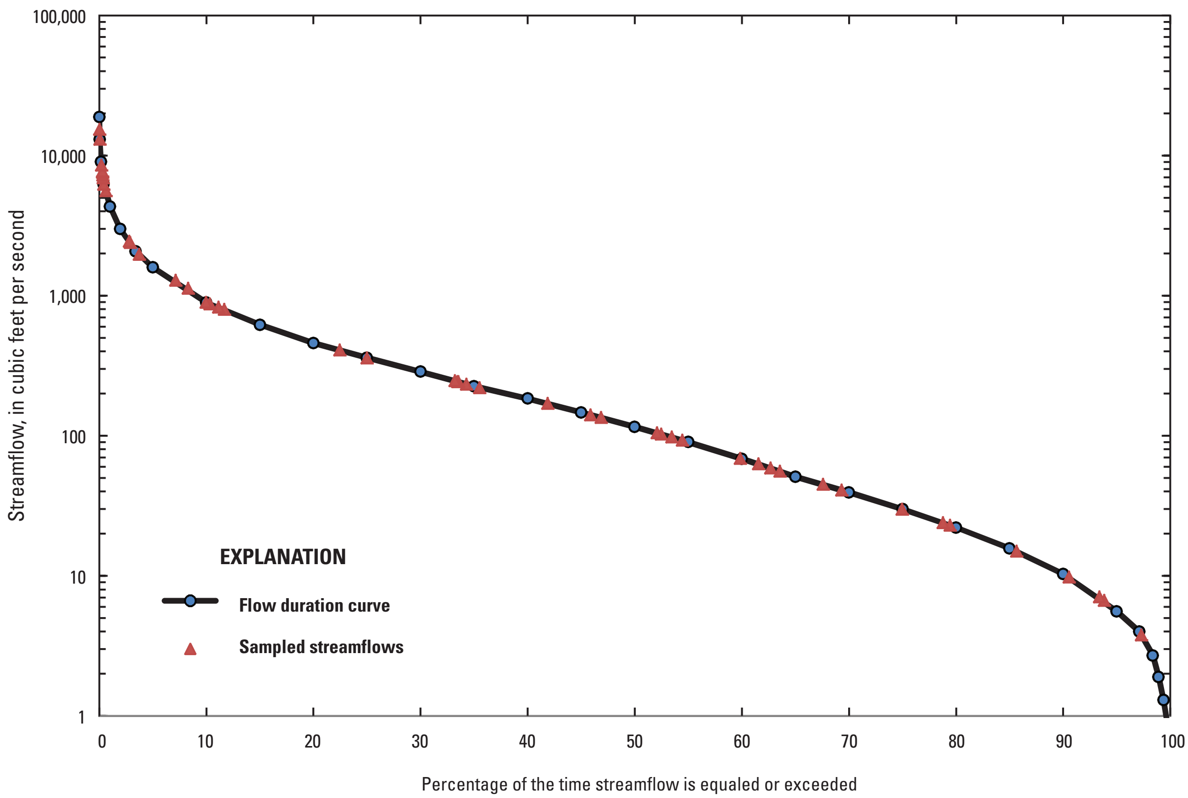

Figure 10. Flow duration curve and sampled streamflow for the U.S. Geological Survey streamflow-gaging station 02464000 North River near Samantha, Alabama, for 1940–54 and 1969–2011.

Table 3. Summary of suspended-sediment samples collected at U.S. Geological Survey streamflow-gaging station 02464000 North River near Samantha, Alabama.

[Data are available at *http://waterdata.usgs.gov/al/nwis/qw*. Dates are by month/day/year. Abbreviations: ft³/s, cubic foot per second; <, less than]

Date	Collection type*	Peak streamflow (ft³/s)	Annual exceedance probability
1/6/2009	Storm	15,400	10
3/26/2006	Storm	7,620	<50
10/24/2008	Monthly	7	<67
11/25/2008	Monthly	7	<67
12/29/2008	Monthly	1,130	<67
1/27/2009	Monthly	141	<67
2/26/2009	Monthly	103	<67
4/28/2009	Monthly	135	<67
5/27/2009	Monthly	244	<67
6/30/2009	Monthly	30	<67
7/30/2009	Monthly	45	<67

* Storm indicates that the suspended-sediment samples were collected during a significant rainfall event. Monthly indicates that the suspended-sediment sample was collected during average daily flow.

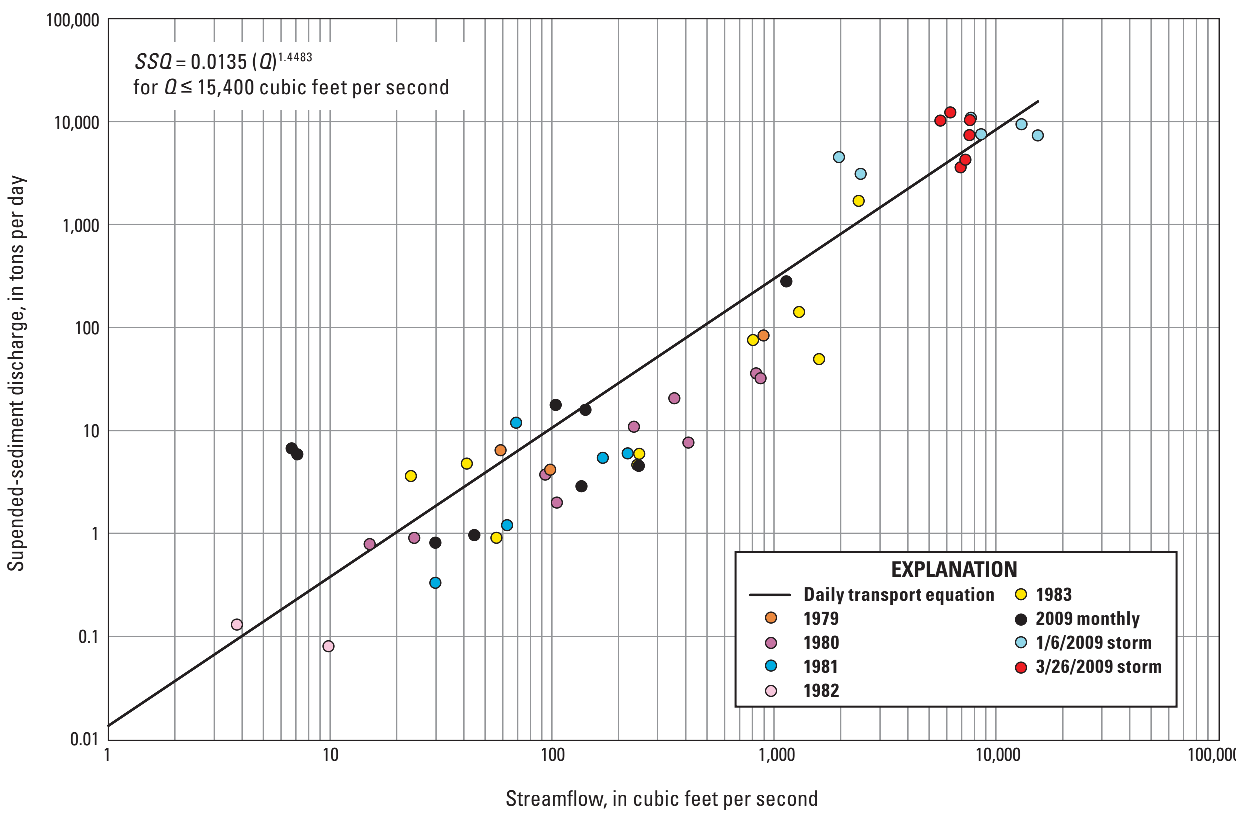

Figure 11. Daily suspended-sediment transport curve for U.S. Geological Survey streamflow-gaging station 02464000 North River near Samantha, Alabama. *SSQ*, suspended sediment concentration; *Q*, streamflow, in cubic feet per second.

Turkey Creek

The USGS streamflow-gaging station on Turkey Creek near Tuscaloosa, Ala. (station number 02464146, also referred to as the Turkey Creek streamgage) was established in February 1981 on Turkey Creek at Turkey Creek Road, near Tuscaloosa. The drainage area for this site (fig. 12) is 6.16 mi^2 and is located 3 mi upstream of the backwater of Lake Tuscaloosa. The upstream extent of the pooled portion of Turkey Creek (near Treasure Island County Park) has experienced increased sediment deposition. A comparison of historical and current aerial photography illustrates the changes in the shoreline (fig. 13). A close aerial photograph (fig. 14) shows a newly formed sediment island.

Land Use

In general, land use within the Turkey Creek subwatershed in 2006 (Fry and others, 2011) can be classified as rural. Forested land (cumulative total of mixed, deciduous, and evergreen) was the predominant basinwide land use in 2006 at 64 percent. Barren land and shrub/scrub land use accounted for approximately 21 percent of the subwatershed. Low-, medium-, and high-intensity residential, and developed open space land coverages were combined to compute total urban land use. Urban land use was approximately 2 percent in 2006 (fig. 15). Inspection of aerial photography indicates little to no urban development since completion of the 2006 NLCD.

General changes in land use were evaluated by inspecting the NLCD 1992–2001 Land Cover Change Retrofit product (Fry and others, 2009) and direct comparison of the NLCD 2001 (Homer and others, 2004) and the NLCD 2006 (Fry and others, 2011). One of the largest reductions in land use from 1992 to 2001 was a 12-percent change from forested land to barren or grasslands. During this period, 3 percent of the basin was converted to forested land. Direct comparison of NLCD 2001 and 2006 (fig. 15) shows a decrease in forested land of 7 percent and an increase in shrub/scrub and grassland of 3- and 5- percent, respectively. The temporal trend indicates that land use in the basin is not stable and the inclusion of historical data for analysis with recent data is not acceptable.

Historical Data

Monthly sediment samples (table 4) were collected at two discontinued streamflow-gaging stations. Data were collected for the 1977 to 1979 water years (October 1 to September 30) at Turkey Creek near Tuscaloosa (station number 02464145), located 1,000 ft downstream at State Highway 69. Additionally, various samples were collected from Turkey Creek near the Patterson Chapel streamflow-gaging station (station number 02464149). The drainage areas at these sites are comparable to the 2009 sampling location and therefore the data were used for comparison. The maximum and minimum streamflows sampled were 410 and 1.1 ft^3/s, respectively. Because samples taken during normal low-flow conditions are a variable function of the available sediment fines (wash load), the samples above a streamflow of 30 ft^3/s were graphically and statistically compared with the 2009 data. Comparison of the historical data and the 2009 data showed a slight upward trend of the measured suspended-sediment discharge. The historical data were not included in the development of the suspended-sediment transport equation.

Data Collected

Streamflow and suspended-sediment data were collected at the Turkey Creek streamgage at Turkey Creek Road, near Tuscaloosa (station number 02464145). A streamflow-gaging station was installed in February 1981 and has a well-established stage-discharge rating curve. Stage values are recorded every 15 minutes and suspended-sediment samples were collected isokenetically using equal-width-increment methods. Suspended-sediment samples were collected during the 2009 water year. Sediment samples were automatically collected using an automatic water sampler. Streamflow data have been collected at this site from installation to present.

Streamflow

Climatic conditions have a direct effect on streamflow. A comparison was made with streamflow (fig. 16) and the dates of data collection to determine how climatic conditions during this investigation may have influenced the data collected and may limit the applicability of the regression equations developed by this investigation to periods of differing climatic conditions. The Turkey Creek streamgage has a long period of record (10 or more years) that was used to evaluate the average streamflow conditions for the site. Average annual mean streamflow for the period of record (1982–2011) and the individual water years were examined and are shown in figure 17. The suspended-sediment samples collected in 2009 were collected during a period when annual streamflow magnitude was above average. A flow duration curve (fig. 18) was constructed and used to evaluate how well the sampled streamflows represented the range of possible flow conditions at each site. Flow duration curves provide the percentage of the time a certain streamflow can be expected to be equaled or exceeded for a site based on the daily mean streamflows for the period of record at that site. The streamflows at the time of sampling were overlain on the curve to determine if a fairly representative range of streamflows were sampled. Approximately 96 percent of the samples were collected at median or higher flow conditions (exceedance percentiles equal to or less than 50). The peak streamflow of record was also evaluated based on regional regression relations. A flood-frequency relation was developed (Hedgecock and Feaster, 2007) and the 67- and 50-percent chance exceedance flood flows for the Turkey Creek streamgage are 390 and 640 ft^3/s, respectively. The peak streamflow during the suspended-sediment data collection period (2009) was 1,060 ft^3/s. The largest streamflow that was sampled during the collection period was 1,020 ft^3/s, which is less than the streamflow corresponding to a 20-percent chance exceedance flood.

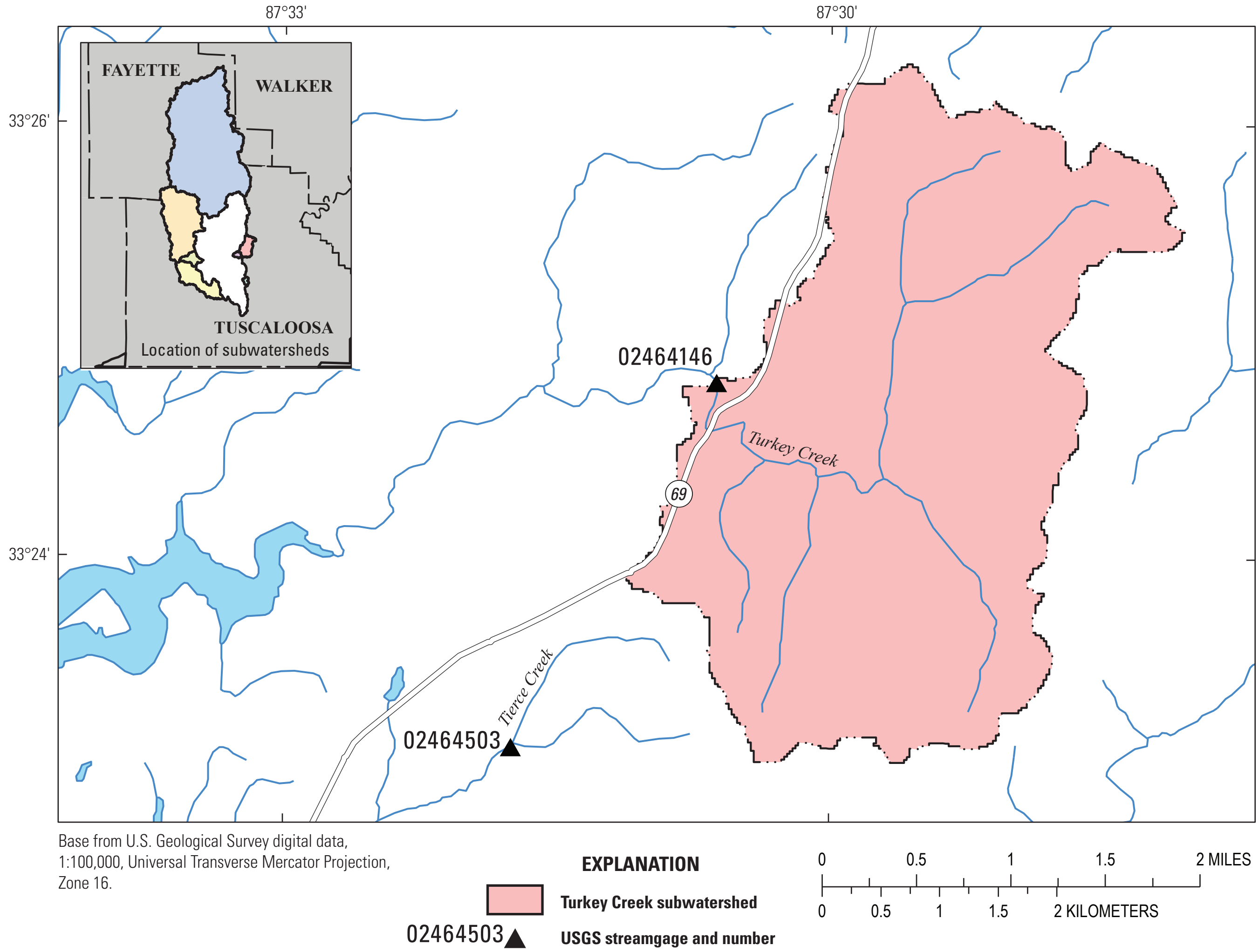

Figure 12. Location of U.S. Geological Survey streamflow-gaging station 02464146 Turkey Creek near Tuscaloosa, Alabama, and the contributing drainage area.

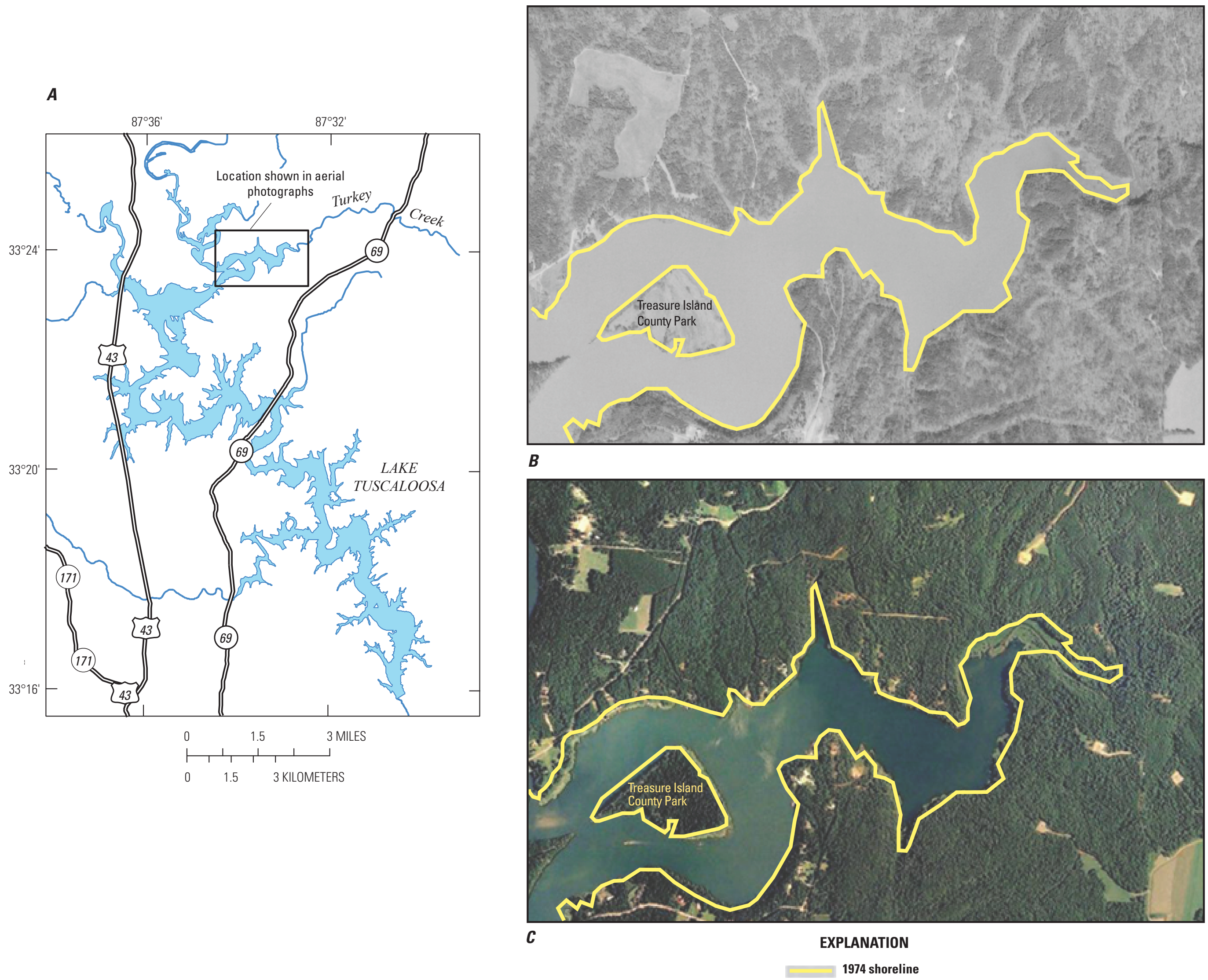

Figure 13. The upstream extent of the backwater of (*A*) Lake Tuscaloosa on Turkey Creek, Alabama, is shown in aerial photography dated (*B*) February 12, 1974, and (*C*) September 29, 2011.

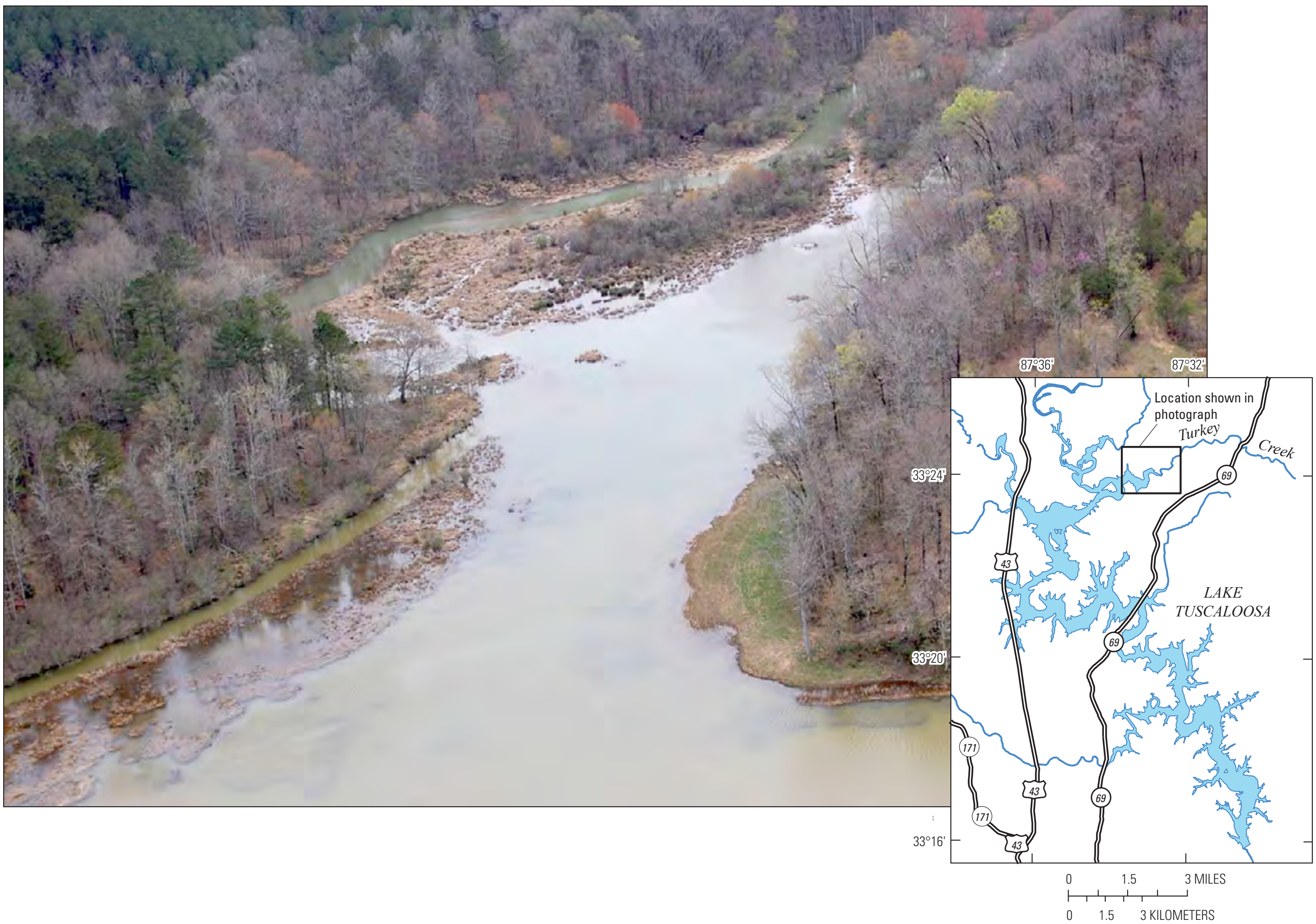

Figure 14. Aerial photograph taken in 2009 shows sediment deposition near the upstream extent of the backwater of Lake Tuscaloosa on Turkey Creek, Alabama.

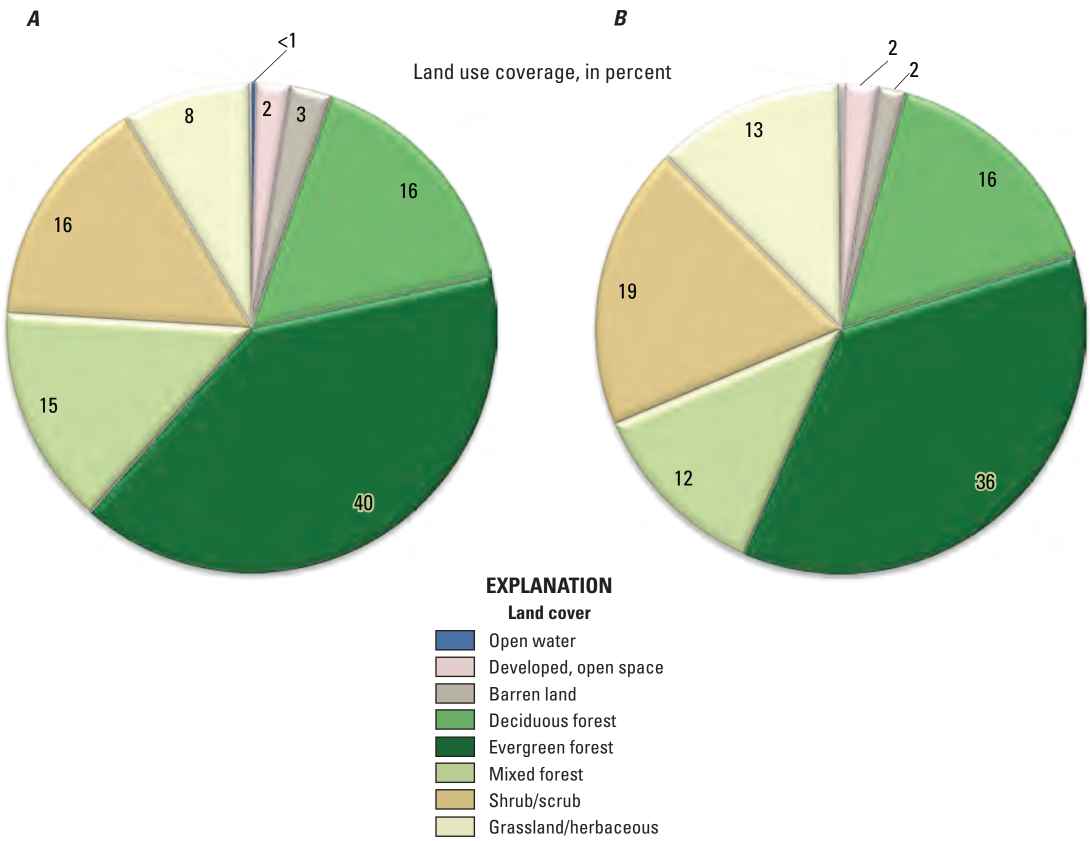

Figure 15. Percentage of land-use coverage at the U.S. Geological Survey streamflow-gaging station 02464146 Turkey Creek near Tuscaloosa, Alabama. (*A*) National Land Cover Database 2001 and (*B*) National Land Cover Database 2006.

Table 4. Historical streamflow and suspended-sediment data for U.S. Geological Survey streamflow-gaging stations 02464145 and 02464149 Turkey Creek near Tuscaloosa, Alabama.

[Data are available at *http://waterdata.usgs.gov/al/nwis/qw.* Dates are by month/day/year. Abbreviations: ft^3/s, cubic foot per second; mg/L, milligram per liter]

Station number	Date	Mean streamflow (ft^3/s)	Suspended sediment (mg/L)	Suspended sediment discharge (tons/day)
02464145	11/3/1976	3.5	1	0.01
02464145	12/7/1976	4.8	1	0.01
02464145	1/7/1977	12	5	0.16
02464145	1/7/1977	13	5	0.18
02464145	1/9/1977	106	141	40
02464145	1/9/1977	106	141	40
02464145	1/14/1977	60	28	4.5
02464145	3/12/1977	135	215	78
02464145	3/12/1977	135	215	78
02464145	3/12/1977	225	360	219
02464145	3/12/1977	390	476	501
02464145	4/4/1977	275	234	174
02464145	4/4/1977	275	234	174
02464145	4/4/1977	340	245	225
02464145	4/4/1977	340	245	225
02464145	4/4/1977	410	481	532
02464145	4/5/1977	220	236	140
02464145	4/11/1977	3.7	16	0.16
02464145	4/11/1977	11	5	0.15
02464145	5/16/1977	3.7	16	0.16
02464145	6/22/1977	2.4	7	0.05
02464145	8/18/1977	2.3	11	0.07
02464145	9/19/1977	4.0	4	0.04
02464145	10/17/1977	3.8	12	0.12
02464145	11/14/1977	5.5	0	0
02464145	1/5/1978	6.2	0	0
02464145	4/4/1978	5.0	3	0.04
02464145	5/1/1978	14	26	0.98
02464145	5/3/1978	30	69	5.6
02464145	5/8/1978	193	168	88
02464145	5/31/1978	4.5	11	0.13
02464145	7/10/1978	1.9	12	0.06
02464145	10/2/1978	1.1	4	0.01
02464145	11/6/1978	1.7	1	0
02464145	12/6/1978	2.5	17	0.11
02464145	1/3/1979	15	1	0.04
02464145	1/30/1979	15	2	0.08
02464145	2/27/1979	20	9	0.49
02464145	3/28/1979	8.7	6	0.14
02464145	4/27/1979	12	5	0.16
02464145	5/23/1979	5.8	7	0.11
02464145	6/4/1979	4.7	19	0.24
02464145	9/4/1979	2.9	10	0.08
02464145	1/20/1981	3.9	1	0.01
02464149	10/14/1982	5.6	13	0.20
02464149	4/20/1983	21	5	0.28

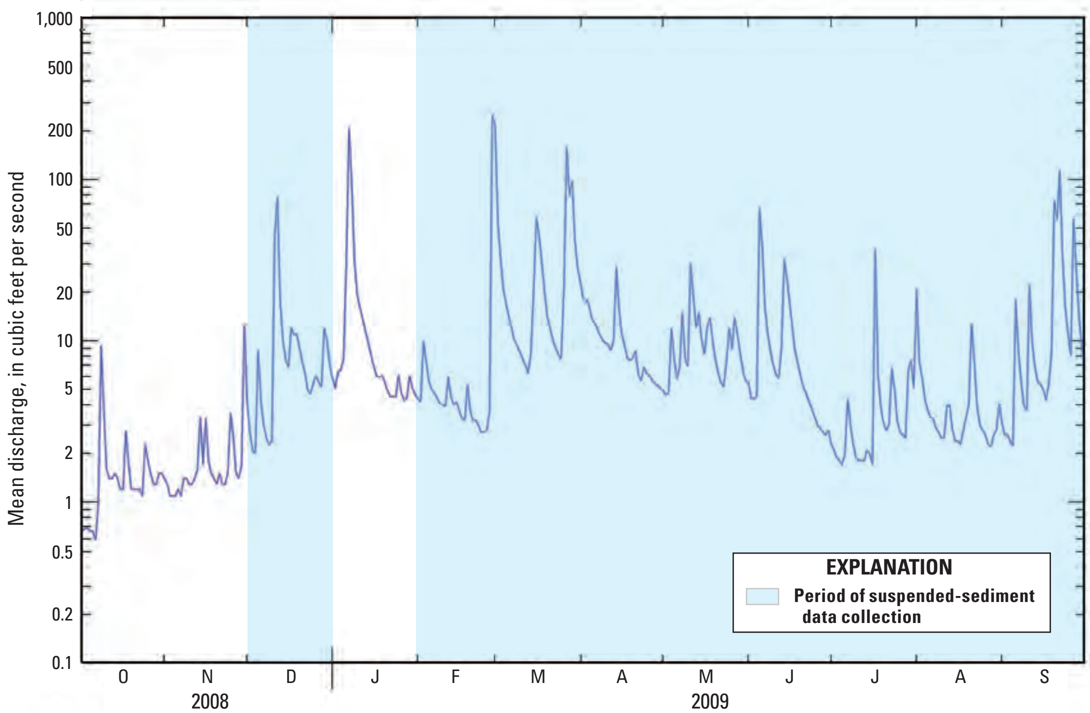

Figure 16. Streamflow hydrograph for the 2009 water year at U.S. Geological Survey streamflow-gaging station 02464146 Turkey Creek near Tuscaloosa, Alabama.

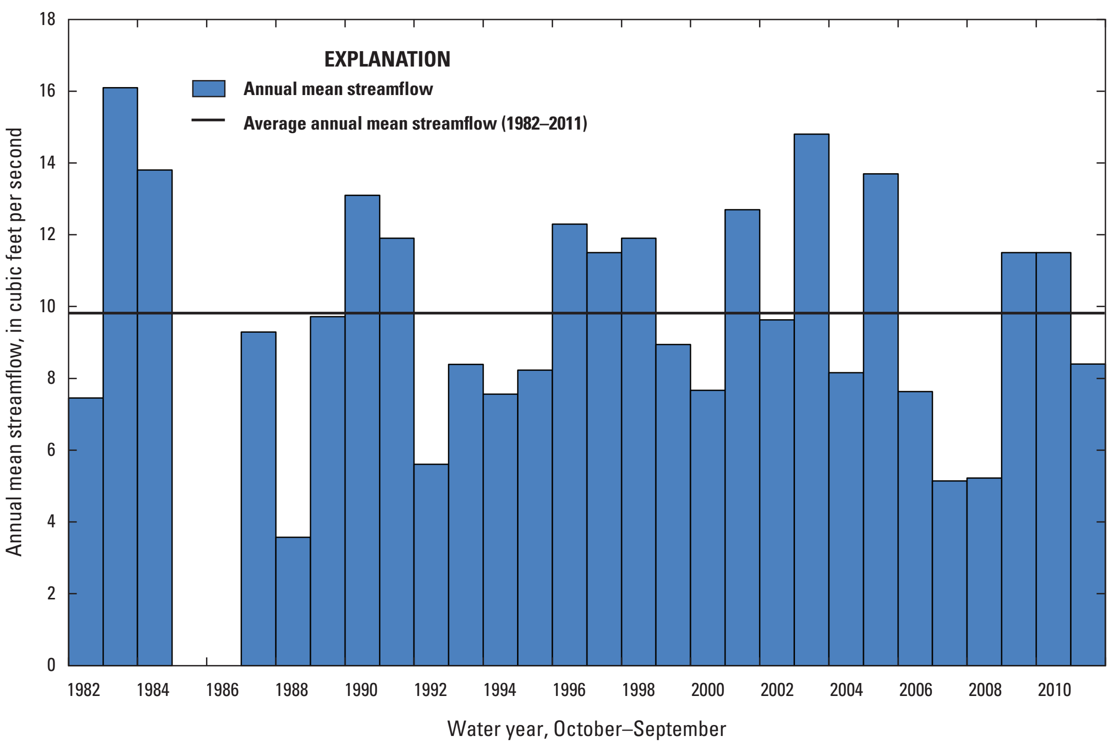

Figure 17. Annual mean streamflow for U.S. Geological Survey streamflow-gaging station 02464146 Turkey Creek near Tuscaloosa, Alabama.

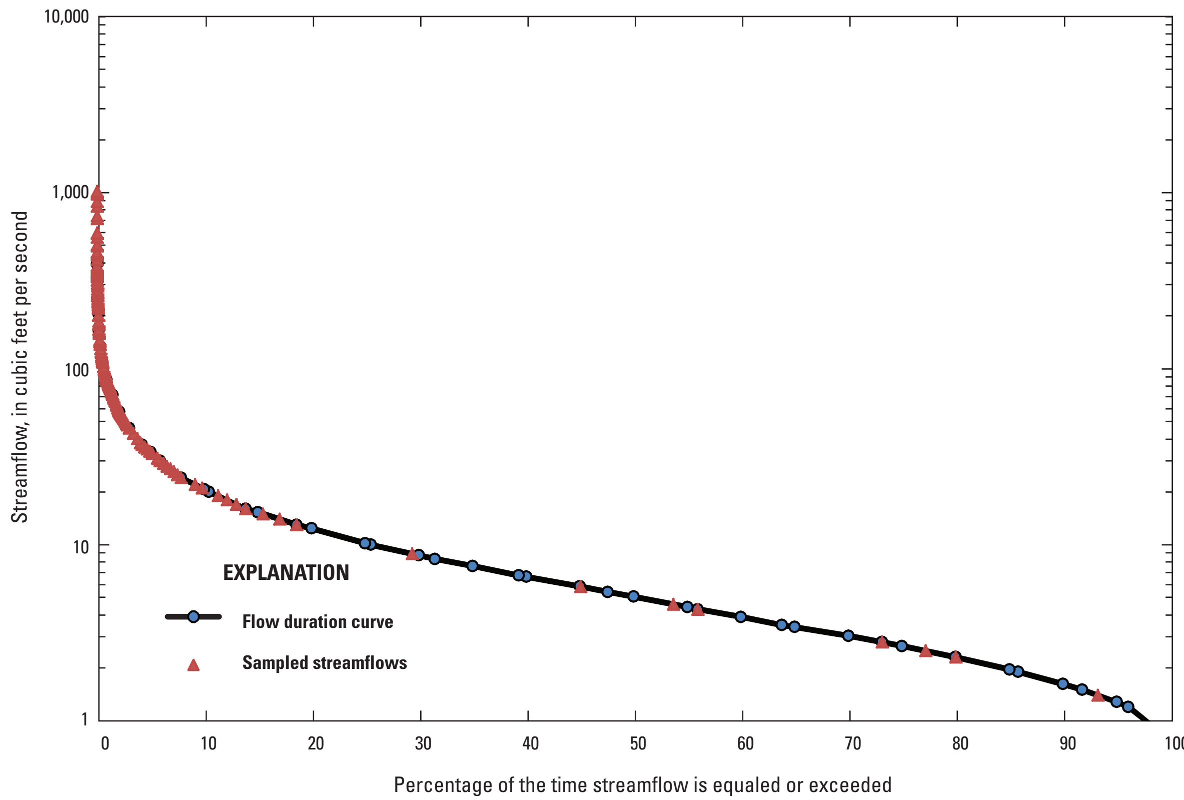

Figure 18. Flow duration curve and sampled streamflow for U.S. Geological Survey streamflow-gaging station 02464146 Turkey Creek near Tuscaloosa, Alabama, 1982–2011.

Suspended Sediment

Suspended sediment samples were collected at the Turkey Creek streamgage as described in the Suspended-Sediment Data Collection section (see Approach and Methods). Samples were collected for 11 storm events (table 5); during 4 of the events, samples were collected by both manual and automatic methods. In addition to the storm events, samples were collected on a monthly basis to represent normal daily streamflows. The samples were collected to reflect seasonal variations and their variable antecedent conditions. Figure 16 illustrates the periods of data collection and how they relate to the annual hydrograph. The ISCO 6712 automatic pump sampler was set to collect samples at a time interval ranging from 15 to 30 minutes to ensure that suspended-sediment concentrations were collected over the rise, peak, and fall of the hydrograph. The sediment hydrographs for Turkey Creek were graphically compared to the streamflow hydrographs. The majority of the runoff events sampled had a sediment hydrograph whose peak preceded the streamflow hydrograph (clockwise hysteresis), which is often ascribed to resuspension of sediment from the stream channel at the initiation of storm runoff, and to relatively limited sediment supply on the stormflow recession.

Table 5. Summary of suspended-sediment samples collected at U.S. Geological Survey streamflow-gaging station 02464146 Turkey Creek near Tuscaloosa, Alabama.

[Data are available at *http://waterdata.usgs.gov/al/nwis/qw*. Dates are by month/day/year. Abbreviations: ft^3/s, cubic foot per second; <, less than]

Date	Collection type*	Peak streamflow (ft^3/s)	Annual exceedance probability
12/10/2008	Manual/Automatic	240	<67
2/27/2009	Manual/Automatic	1,020	<20
3/14/2009	Automatic	99	<67
3/25/2009	Automatic	266	<67
4/2/2009	Automatic	22	<67
5/16/2009	Automatic	50	<67
5/26/2009	Automatic	34	<67
6/4/2009	Automatic	588	<67
7/16/2009	Automatic	295	<67
8/20/2009	Manual/Automatic	82	<67
9/20/2009	Manual/Automatic	359	<67

* Automatic—suspended-sediment samples collected by an automatic water sampler. Manual—manually collected isokenetic suspended-sediment samples.

Estimation of Suspended-Sediment Loads from Turkey Creek

The suspended-sediment concentrations of the automatic pump samples were adjusted to reflect average streamflow-weighted suspended-sediment concentrations as described in the Data Analysis section (see Approach and Methods). The suspended-sediment concentrations were converted to suspended-sediment discharges (*SSQ*) and graphically and statistically compared with streamflow (*Q*) to develop instantaneous sediment-transport curves. A linear regression equation (ordinary least squares) was developed, and a smearing estimator applied, for the rise and fall of the hydrograph and using all data (composite). The resulting instantaneous sediment-transport curves converged for lower values of streamflow and slightly varied on the upper end of the curve. The composite instantaneous sediment transport curve was used to compute an average daily sediment discharge for every day in the 2009 water year. These values were regressed with the average daily flow to provide a daily transport curve (eq. 4; fig. 19) using the following equation:

$$SSQ = 0.1858\,(Q)^{1.3919} \text{ for } Q \leq 1{,}020 \text{ ft}^3\text{/s} \qquad (4)$$

where

SSQ is the average daily suspended-sediment discharge, in tons per day; and

Q is the average daily streamflow, in cubic feet per second.

The application of the daily suspended-sediment transport curve is limited to the maximum measured flow, 1,020 ft^3/s, that suspended-sediment samples collected. Suspended-sediment transport curves have the tendency to flatten out once the available sediment is exhausted and additional rainfall no longer increases the suspended sediment. Because this exact point is not known, extrapolation of the suspended-sediment transport curve should be based on engineering judgment and analysis.

Annual load and yield values were estimated for suspended sediment at Turkey Creek for the 2009 water year. The suspended-sediment discharge was estimated for each day of the water year using the daily transport curve (eq. 4). Load computations were performed by application of the mid-interval method (Porterfield, 1972). The estimated average annual load for the 2009 water year, based on average daily streamflow and the Turkey Creek daily transport curve, is 3,350 tons and the average yield is 540 tons/mi^2.

It is worth noting that the daily mean sediment concentration is a time-weighted mean value. Thus, calendar days can be divided and analyzed in shorter periods of time when water or sediment discharge exceeds certain limits. The term “subdivide” refers to the division of data for a calendar day into shorter periods of time to obtain correct daily mean values of streamflow or suspended-sediment discharge when one or both change beyond certain limits during the day. The values for these periods are then summed to obtain values of suspended-sediment discharge. Computation of a daily mean sediment discharge requires subdivision of the day when both water discharge and concentration are changing because the average of the products of two variable quantities is not the same as the product of the averages of the quantities (Porterfield, 1972). For comparison, the instantaneous suspended-sediment transport curve, streamflow, and the mid-interval method were used to compute an estimated average annual load for the 2009 water year, based on a 15-minute interval. This computation resulted in an average annual load that is 4 percent more than the load calculated using the average daily values. It was determined that the use of the average daily streamflow and the daily transport curve is more practical for estimating average annual loads.

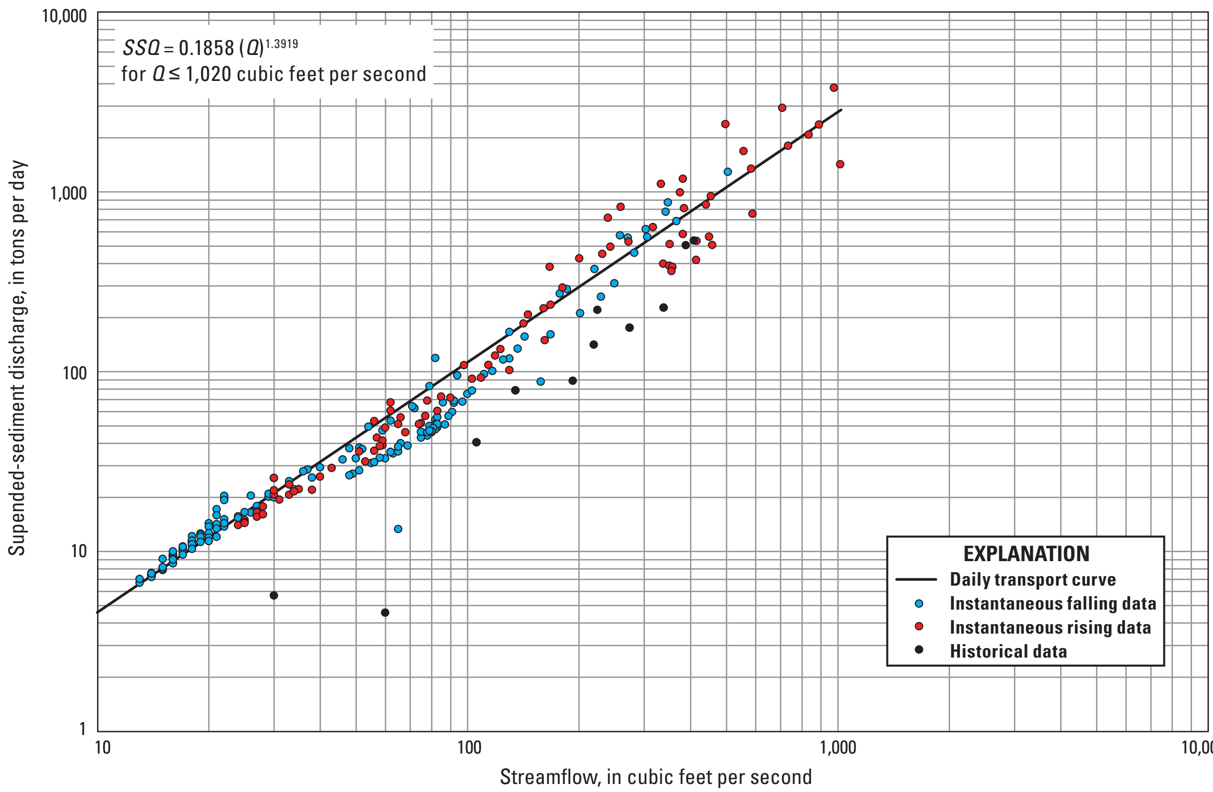

Figure 19. Daily suspended-sediment transport curve for U.S. Geological Survey streamflow-gaging station 02464146 Turkey Creek near Tuscaloosa, Alabama. *SSQ*, suspended sediment concentration; *Q*, streamflow in cubic feet per second.

Binion Creek

The USGS streamflow-gaging station on Binion Creek below Gin Creek, near Samantha, Ala. (station number 02464360, also referred to as the Binion Creek streamgage) was established in October 1986 on Binion Creek at Old Fayette Road, near Samantha. The drainage area for this site (fig. 20) is 57.2 mi^2, and it contributes 14 percent of the surface drainage area to Lake Tuscaloosa. The streamgage is located 2 mi upstream of the backwater region of Lake Tuscaloosa.

Land Use

In general, land use within the Binion Creek subwatershed in 2006 (Fry and others, 2011) can be classified as rural. Forested land (cumulative total of mixed, deciduous, and evergreen) was the predominant basinwide land use in 2006 at 65 percent. Barren land and shrub/scrub land use accounted for approximately 14 percent of the subwatershed. Low-, medium-, and high-intensity residential and developed open space land coverages were combined to compute total urban land use. Urban land use was approximately 3 percent in 2006 (fig. 21). Inspection of aerial photography indicates little to no urban development since completion of the 2006 NLCD.

General changes in land use were evaluated by inspecting the NLCD 1992–2001 Land Cover Change Retrofit product (Fry and others, 2009) and direct comparison of the NLCD 2001 (Homer and others, 2004) and the NLCD 2006 (Fry and others, 2011). Comparison of the 1992 and 2001 datasets showed little change. The only notable change was a 1-percent increase in grasslands. Direct comparison of NLCD 2001 and 2006 (fig. 21) indicates a decrease in forested land of 7 percent and an increase in shrub/scrub and grassland of 8 percent. Current conditions were examined using 2009 and 2010 aerial photography in conjunction with the NLCD 2006. Comparison of the two timeframes indicated between 2006 and 2009 and 2009 and 2010, approximately 2 and 1.4 mi^2 of timber were harvested, respectively. The clear-cut areas closest to the streamflow-gaging station were further inspected. Approximately 1 mi upstream of the Binion Creek streamgage, 33 acres of timber were harvested. The timber company confirmed that the timber was removed from September 7 to October 15, 2010, which was during the collection period.

Historical Data

Monthly sediment samples (table 6) were collected at the same location as the Binion Creek streamflow-gaging station (station number 02464360) for the 1983 water year (October 1, 1982, to September 30, 1983). The historical data were used to show temporal trends, because the land-use changes described above indicate a decrease in forested land. Comparison of the 1983 and 2010 datasets indicate a similar trend for the lower values of streamflow. The samples collected at high streamflow fall within the range of data collected in 2010 during the rising limb of the hydrograph. Because the 1983 samples were collected prior to the installation of the streamgage, the hydrographs are not available to determine when the samples were collected relative to the peak streamflow.

Data Collected

Streamflow and suspended-sediment data were collected at Binion Creek at Old Fayette Road near Samantha, Ala. (station number 02464360). This streamflow-gaging station was established in 1986 and has a well-established stage-discharge rating curve. Stage values are recorded every 15 minutes, and suspended-sediment samples were collected isokenetically using equal-width-increment methods. Suspended-sediment samples were collected during the 2010 water year.

Streamflow

Climatic conditions have a direct effect on streamflow. A comparison was made with streamflow (fig. 22), and the dates of data collection, to determine how climatic conditions during this investigation may have influenced the data collected and may limit the applicability of the regression equations developed by this investigation to periods of differing climatic conditions. The Binion Creek streamgage has a long period of record (10 or more years) that was used to evaluate the average streamflow conditions for the site. Average annual mean streamflow for the period of record (1987–2011) and the individual water years were examined and are shown in figure 23. The suspended-sediment samples collected in 2010 were collected during a period when annual streamflow magnitude was above average. A flow duration curve (fig. 24) was constructed and used to evaluate how well the sampled streamflows represented the range of possible flow conditions at each site. Flow duration curves provide the percentage of the time a certain streamflow can be expected to be equaled or exceeded for a site based on the daily mean streamflows for the period of record at that site. The streamflows at the time of sampling were overlain on the curve to determine if a fairly representative range of streamflows were sampled. Approximately 99 percent of the samples were collected at median or higher flow conditions (exceedance percentiles equal to or less than 50). The peak streamflow of record was also evaluated based on regional regression relations. A flood-frequency relation was developed (Hedgecock and Feaster, 2007), and the 67- and 50-percent chance exceedance flood flows for the Binion Creek streamgage are 1,130 and 2,000 ft^3/s, respectively. The peak streamflow during the suspended-sediment data-collection period (2010–11) was 3,210 ft^3/s. The largest streamflow that was sampled during the collection period was 2,900 ft^3/s, which is larger than the streamflow corresponding to a 50-percent chance exceedance flood.

Figure 20. Location of the U.S. Geological Survey streamflow-gaging station 02464360 Binion Creek near Samantha, Alabama, and the contributing drainage area.

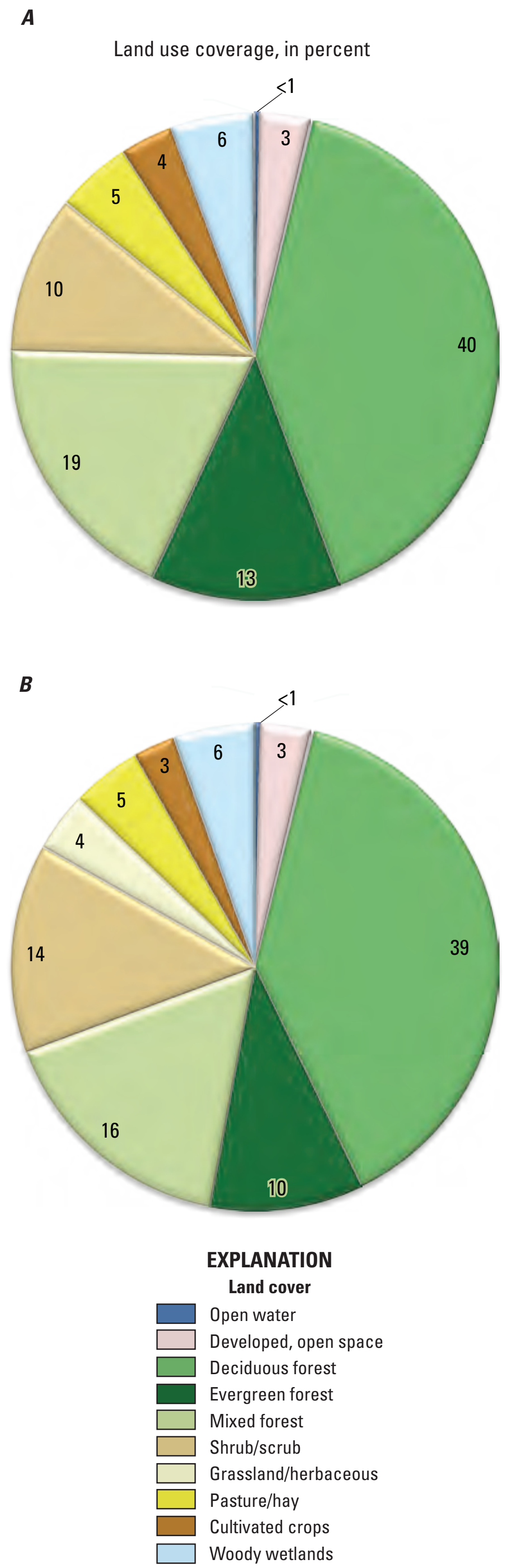

Figure 21. Percentage of land-use coverage at the U.S. Geological Survey streamflow-gaging station 02464360 Binion Creek near Samantha, Alabama. (*A*) National Land Cover Database 2001 and (*B*) National Land Cover Database 2006.

Table 6. Historical streamflow and suspended-sediment data for U.S. Geological Survey streamflow-gaging station 02464360 Binion Creek near Samantha, Alabama.

[Data are available at *http://waterdata.usgs.gov/al/nwis/qw*. Dates are by month/day/year. Abbreviations: ft^3/s, cubic foot per second; mg/L, milligram per liter]

Date	Mean streamflow (ft^3/s)	Suspended sediment (mg/L)	Suspended sediment discharge (tons/day)
10/5/1982	16	10	0.43
11/6/1982	30	7	0.57
12/3/1982	132	27	9.6
1/4/1983	106	18	5.2
2/7/1983	370	94	94
3/4/1983	152	491	202
4/5/1983	98	23	6.1
5/3/1983	84	111	25
6/6/1983	79	17	3.6
7/6/1983	52	20	2.8
8/3/1983	34	23	2.1
9/6/1983	34	12	1.1

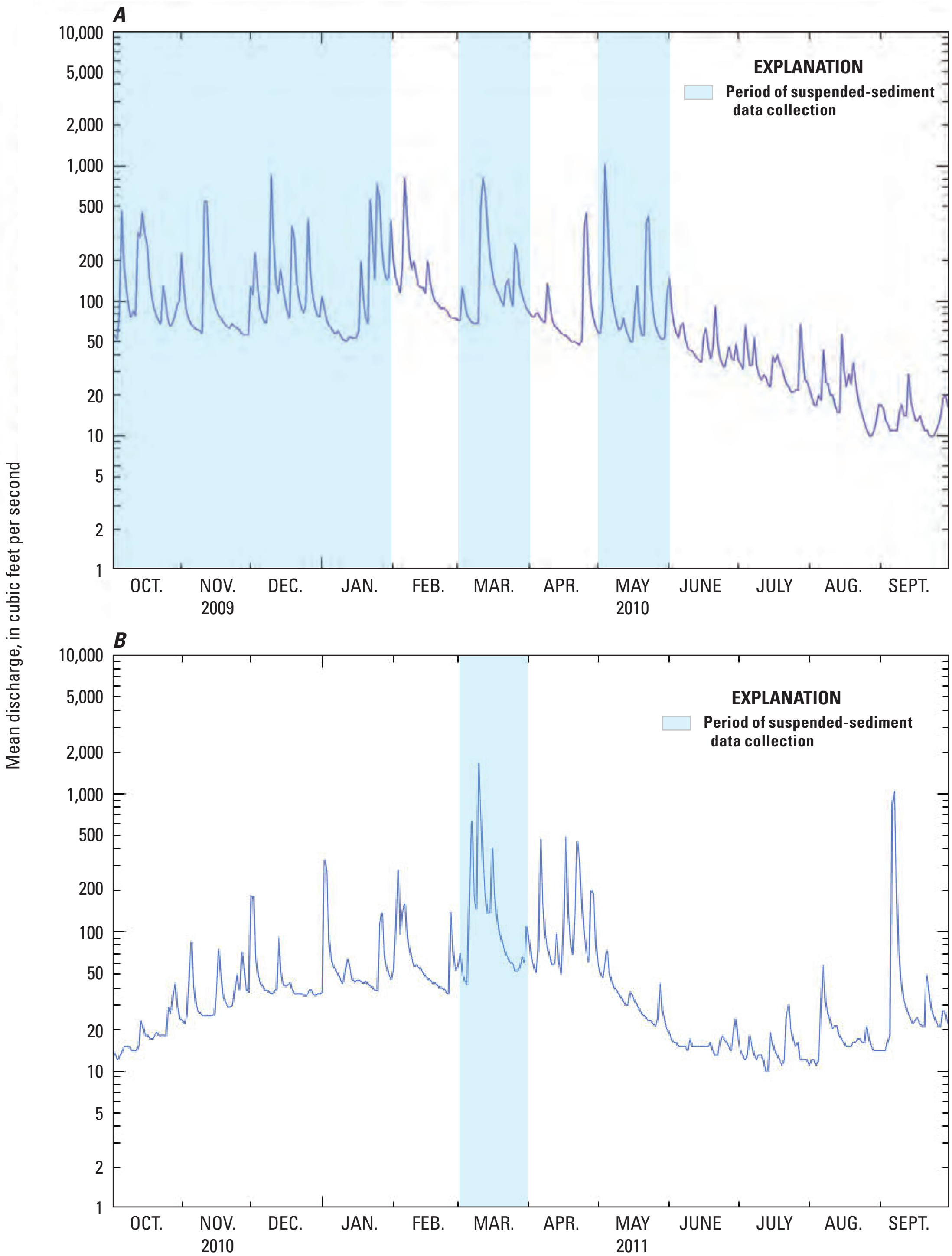

Figure 22. Streamflow hydrograph at U.S. Geological Survey streamflow-gaging station 02464360 Binion Creek near Samantha, Alabama. (*A*) 2010 water year. (*B*) 2011 water year.

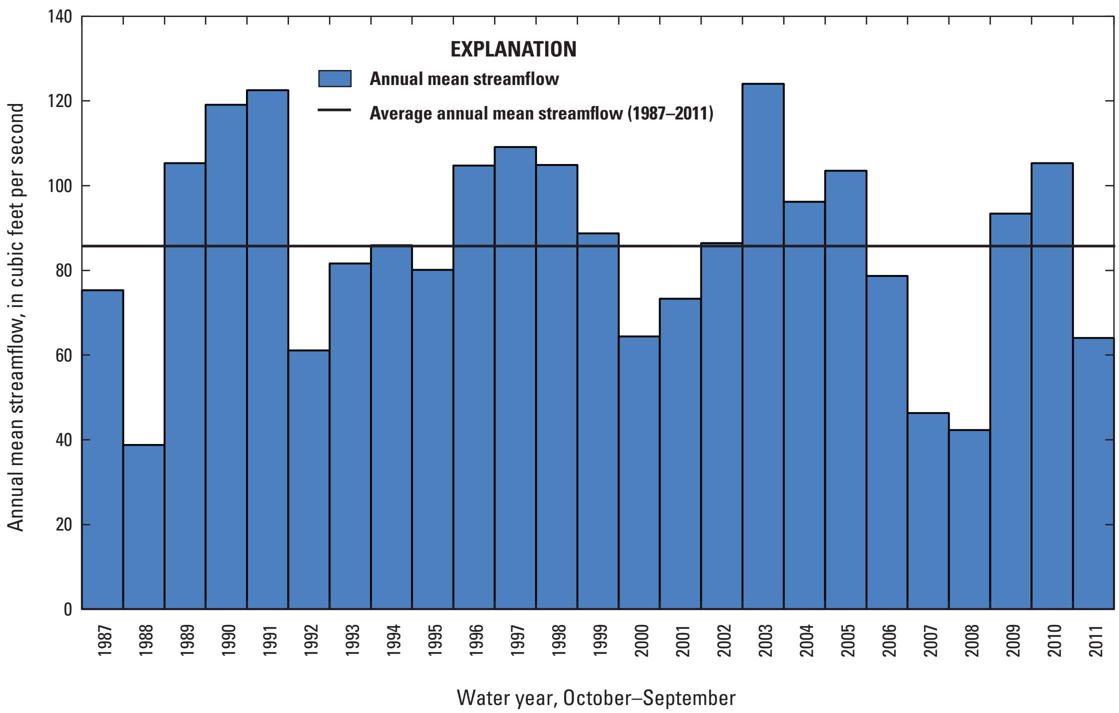

Figure 23. Annual mean streamflow for U.S. Geological Survey streamflow-gaging station 02464360 Binion Creek near Samantha, Alabama.

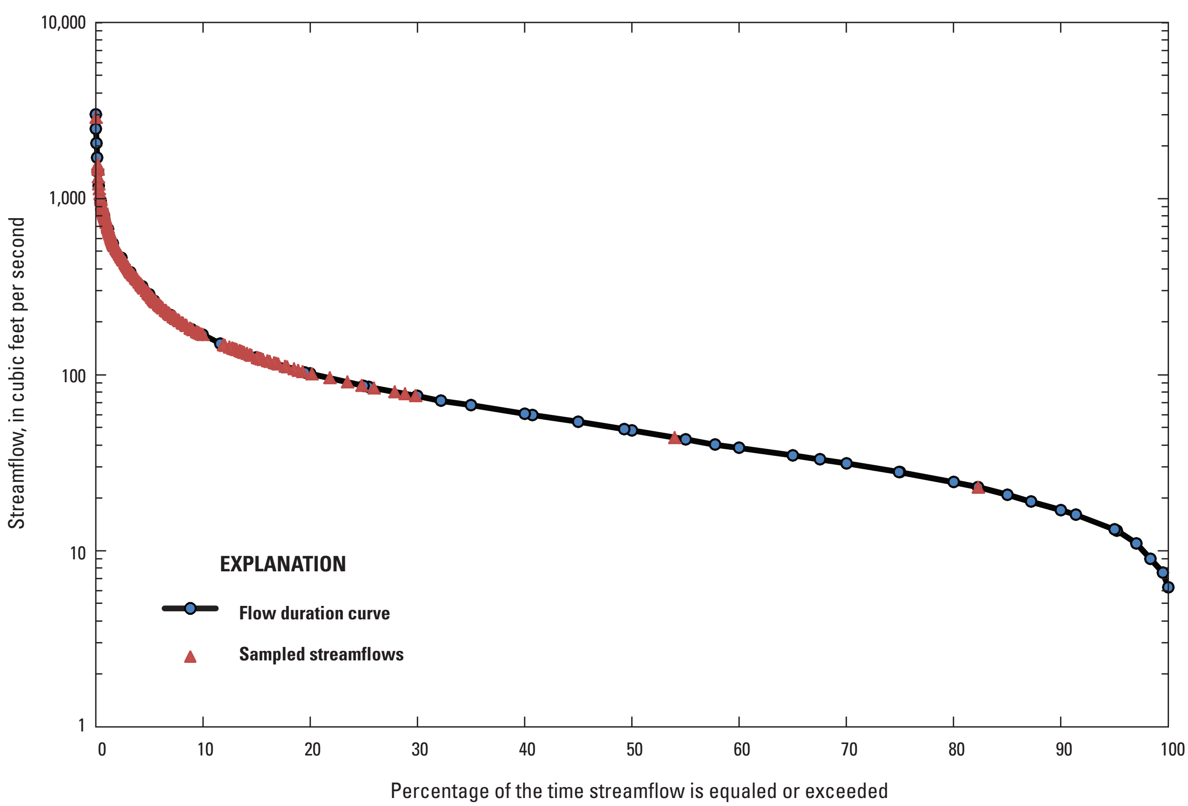

Figure 24. Flow duration curve and sampled streamflow for U.S. Geological Survey streamflow-gaging station 02464360 Binion Creek near Samantha, Alabama, 1987–2011.

Suspended Sediment

Suspended-sediment samples were collected at the Binion Creek streamgage as described in the Suspended-Sediment Data Collection section (see Approach and Methods). Samples were collected for 11 storm events (table 7); during 3 of the events, samples were collected by both manual and automatic methods. In addition to the storm events, samples were collected on a monthly basis to represent normal daily streamflows. The samples were collected to reflect seasonal variations and their variable antecedent conditions. Figure 22 illustrates the periods of data collection and how they relate to the annual hydrograph. The ISCO 6712 automatic pump sampler was set to collect samples at a time interval of 2 hours. This was done to ensure that suspended-sediment concentrations were collected over the rise, peak, and fall of the hydrograph. The sediment hydrographs for Binion Creek were graphically compared to the streamflow hydrographs. The majority of the runoff events sampled had a sediment hydrograph whose peak preceded the streamflow hydrograph (clockwise hysteresis), which is often ascribed to resuspension of sediment from the stream channel at the initiation of storm runoff, and to relatively limited sediment supply on the stormflow recession.

Table 7. Summary of suspended-sediment samples collected at U.S. Geological Survey streamflow-gaging station 02464360 Binion Creek near Samantha, Alabama.

[Data are available at *http://waterdata.usgs.gov/al/nwis/qw*. Dates are by month/day/year. Abbreviations: ft^3/s, cubic foot per second; <, less than; >, greater than; ≈, approximately equal to]

Date	Collection type*	Peak streamflow (ft^3/s)	Annual exceedance probability
10/30/09	Automatic	259	<67
11/10/09	Automatic	1,010	≈67
12/24/09	Automatic	558	<67
01/21/10	Manual/Automatic	835	<67
03/10/10	Manual/Automatic	921	<67
03/25/10	Automatic	468	<67
05/02/10	Automatic	1,510	>67
05/21/10	Automatic	818	<67
03/05/11	Manual/Automatic	935	<67
03/09/11	Manual	2,900	>50
03/30/11	Automatic	124	<67

* Automatic—suspended-sediment samples collected by an automatic water sampler. Manual—manually collected isokenetic suspended-sediment samples.

Estimation of Suspended-Sediment Loads from Binion Creek

The suspended-sediment concentrations of the automatic pump samples were adjusted to reflect average streamflow-weighted suspended-sediment concentrations as described in the Data Analysis section (see Approach and Methods). The suspended-sediment concentrations were converted to suspended-sediment discharges (*SSQ*) and graphically and statistically compared with streamflow (*Q*) to develop instantaneous sediment-transport curves. A linear regression equation (ordinary least squares) was developed, and a smearing estimator applied, for the rise and fall of the hydrograph and using all data (composite). Visual inspection of the data points showed significant scatter in the data collected on the rising limb of the hydrographs. This could be attributed to the anthropogenic changes in the basin or be a natural characteristic of the stream. Comparison of current and historical data indicates that poor correlation on the rising limb of the hydrograph is a natural characteristic of the stream. In order to improve the statistical correlation between suspended-sediment discharge and streamflow, the group averaging process as described by Glysson (1987) was used. The dataset was divided into 15 classes based on a logarithmic distribution of streamflow. The average, maximum, and minimum streamflow and suspended-sediment discharge were determined for each class. A suspended-sediment transport curve was developed using linear regression (ordinary least squares), with a smearing estimator applied, for the group averaged data. Comparison of the group average and non-group averaged data indicated that the group averaging did not provide any additional benefits.

Because the intercepts of the rising and falling instantaneous sediment-transport curves are substantially different, the unit value (15 minute) streamflows for the entire water year were visually and statistically inspected and the appropriate rising/falling instantaneous equation was used to compute a suspended-sediment discharge. These values were used to compute an average daily sediment discharge for every day in the 2010 water year. These values were regressed with the average daily flow to develop a daily transport curve (eq. 5; fig. 25). The resulting equation has a small intercept value similar to the falling equation:

$$SSQ = 0.043\,(Q)^{1.2689} \text{ for } Q \leq 2{,}900 \text{ ft}^3\text{/s} \qquad (5)$$

where

SSQ is the average daily suspended-sediment discharge, in tons per day; and

Q is the average daily streamflow, in cubic feet per second.

The application of the daily suspended-sediment transport curve is limited to the maximum measured flow, 2,900 ft^3/s, at which suspended-sediment samples were collected. Suspended-sediment transport curves have the tendency to flatten out once the available sediment is exhausted and additional rainfall no longer increases the suspended sediment. Because this exact point is not known, extrapolation of the suspended-sediment transport curve should be based on engineering judgment and analysis.

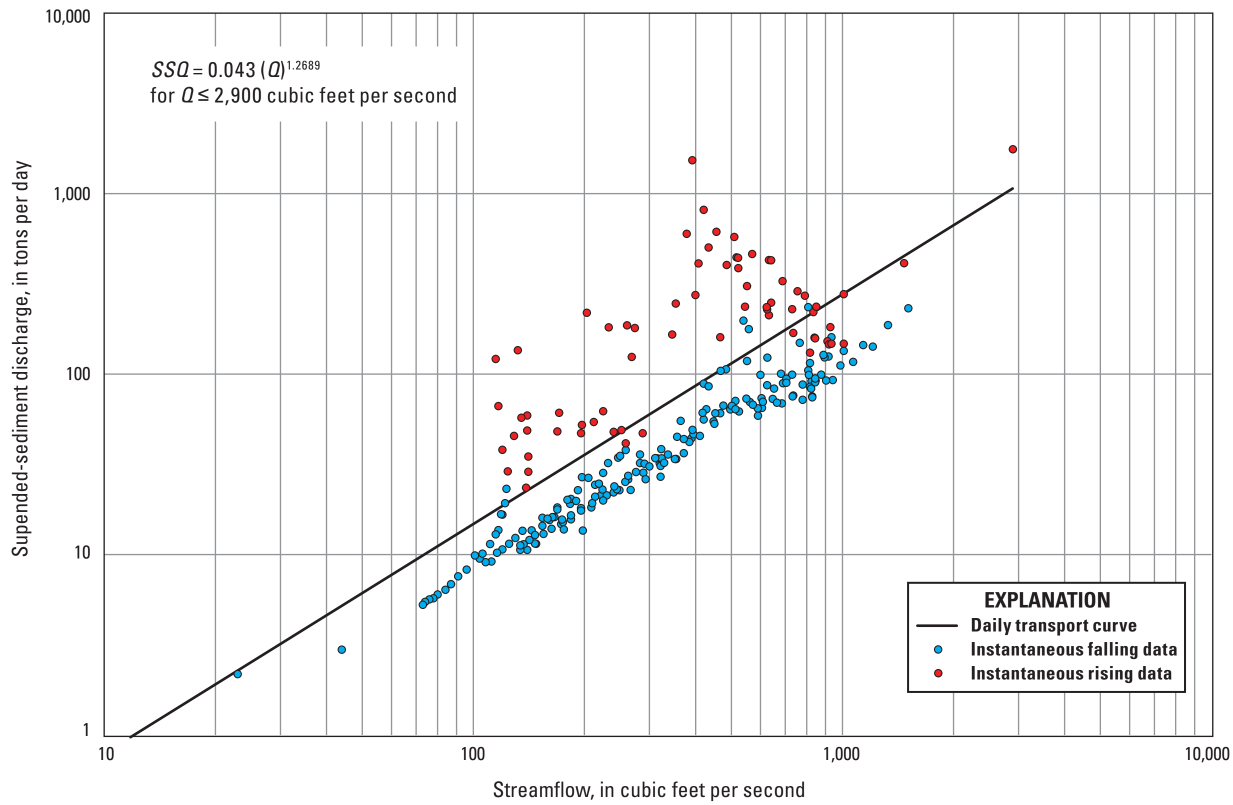

Figure 25. Daily suspended-sediment transport curve for U.S. Geological Survey streamflow-gaging station 02464360 Binion Creek near Samantha, Alabama. *SSQ*, suspended sediment concentration; *Q*, streamflow in cubic feet per second.

Annual load and yield values were estimated for suspended sediment at Binion Creek for the 2010 water year. The suspended-sediment discharge was estimated for each day of the water year using the daily transport curve (eq. 5). Load computations were performed by application of the mid-interval method (Porterfield, 1972). The estimated average annual load for the 2010 water year, based on average daily streamflow and the Binion Creek daily transport curve, is 6,860 tons, and the average yield is 120 tons/mi^2.

It is worth noting that the daily mean sediment concentration is a time-weighted mean value. Thus, calendar days can be divided and analyzed in shorter periods of time when water or sediment discharge exceed certain limits. The term “subdivide” refers to the division of data for a calendar day into shorter periods of time to obtain correct daily mean values of streamflow or suspended-sediment discharge when one or both change beyond certain limits during the day. The values for these periods are then summed to obtain values of suspended-sediment discharge. Computation of a daily mean sediment discharge requires subdivision of the day when both water discharge and concentration are changing because the average of the products of two variable quantities is not the same as the product of the averages of the quantities (Porterfield, 1972). For comparison, the instantaneous suspended-sediment transport curve, streamflow, and the mid-interval method were used to compute an estimated average annual load for the 2010 water year, based on a 15-minute interval. This computation resulted in an average annual load that is 4 percent more than the load calculated using the average daily values. It was determined that the use of the average daily streamflow and the daily transport curve is more practical for estimating average annual loads.

Pole Bridge Creek

The USGS streamflow-gaging station on Pole Bridge Creek near Samantha, Ala. (station number 02464385, also referred to as the Pole Bridge Creek streamgage) was established in January 2010 on Pole Bridge Creek at Old Fayette Road, near Samantha. The drainage area for this site (fig. 26) is 4.67 mi^2, and it is located 1.3 mi upstream of the backwater portion of Lake Tuscaloosa.

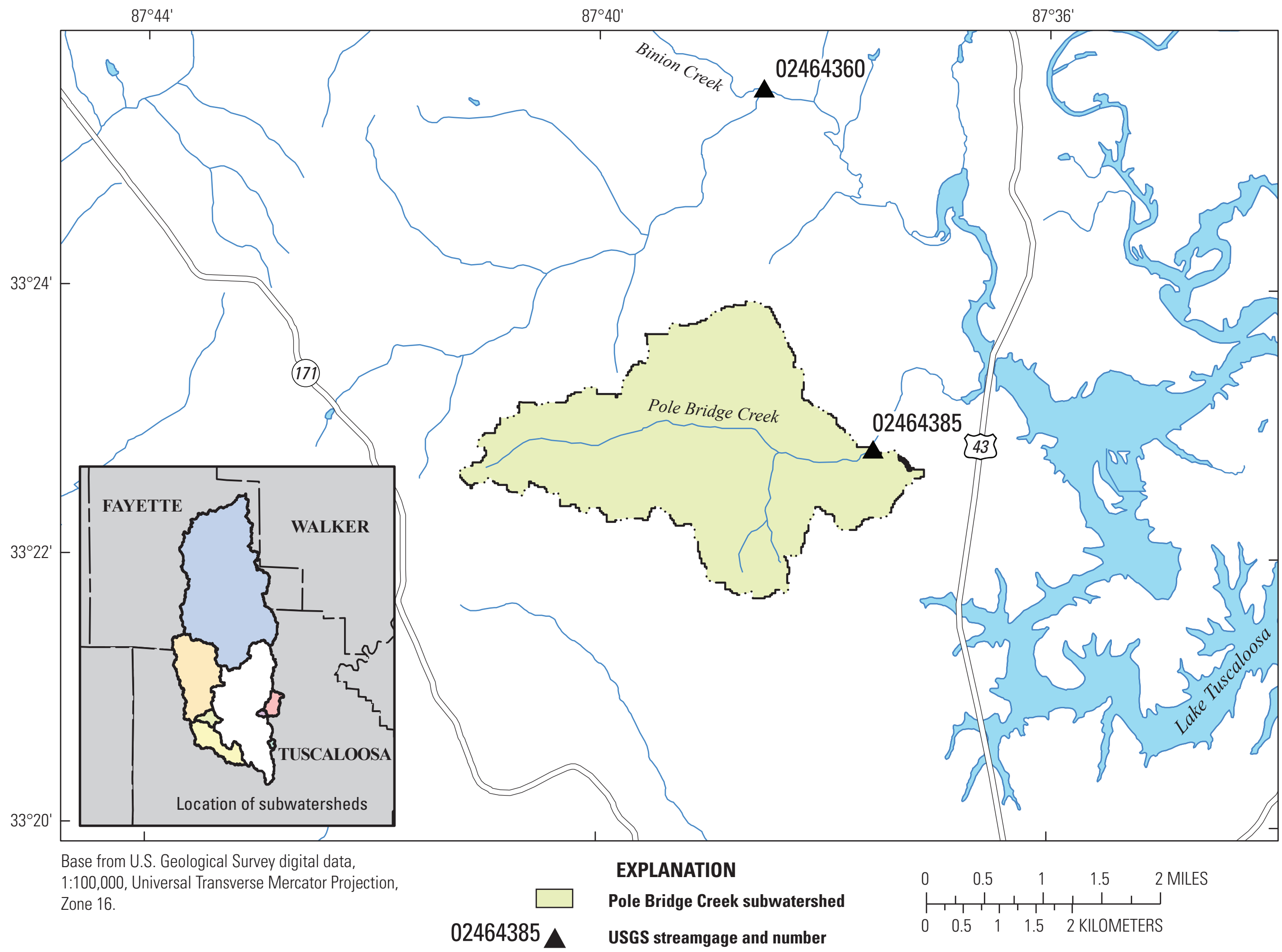

Figure 26. Location of U.S. Geological Survey streamflow-gaging station 02464385 Pole Bridge Creek near Samantha, Alabama, and the contributing drainage area.

Land Use

In general, land use within the Pole Bridge Creek subwatershed in 2006 (Fry and others, 2011) can be classified as rural. Forested land (cumulative total of mixed, deciduous, and evergreen) was the predominant basinwide land use in 2006 at 75 percent. Shrub/scrub land use accounted for approximately 18 percent of the subwatershed. Low-, medium-, and high-intensity residential, and developed open space land coverages were combined to compute total urban land use. Urban land use was approximately 1 percent in 2006 (fig. 27).

General changes in land use were evaluated by inspecting the NLCD 1992–2001 Land Cover Change Retrofit product (Fry and others, 2009) and direct comparison of the NLCD 2001 (Homer and others, 2004) and the NLCD 2006 (Fry and others, 2011). Comparison of the 1992 and 2001datasets indicates little change. The only notable change was a 4-percent change from forest to grassland and agriculture. Direct comparison of NLCD 2001 and 2006 (fig. 27) shows a decrease in forested land of 6 percent and an increase in shrub/scrub and grassland of 7 percent. Current conditions were examined using 2009 and 2010 aerial photography in conjunction with the NLCD 2006. Comparison of the two timeframes indicated that between 2009 and 2010, approximately 43 acres of timber were harvested.

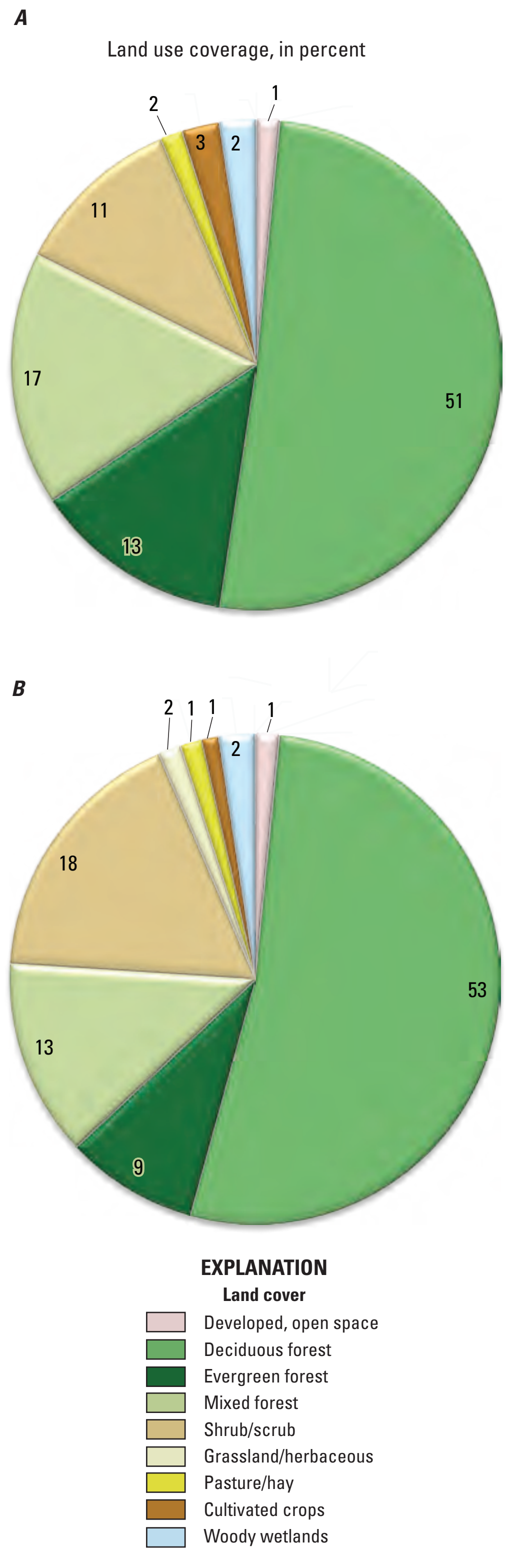

Figure 27. Percentage of land-use coverage at U.S. Geological Survey streamflow-gaging station 02464385 Pole Bridge Creek near Samantha, Alabama. (*A*) National Land Cover Database 2001. (*B*) National Land Cover Database 2006.

Data Collected

Streamflow and suspended-sediment data were collected at Pole Bridge Creek at Old Fayette Road near Samantha, Ala. (station number 02464385). A streamflow-gaging station was installed in January 2010. Stage values are recorded every 15 minutes and a stage-discharge rating curve was developed. Sediment samples were automatically collected using an automatic water sampler. Suspended-sediment samples were collected during the 2010–11 water year.

Streamflow

Climatic conditions have a direct effect on streamflow. A comparison was made with streamflow (fig. 28) and the dates of data collection (2010–11) to determine how climatic conditions during this investigation may have influenced the data collected and may limit the applicability of the regression equations developed by this investigation to periods of differing climatic conditions. The Pole Bridge Creek streamgage does not have a long period of record (10 or more years) and therefore assumptions cannot be made about the average streamflow conditions for the site. However, the peak streamflow of record was evaluated based on regional regression relations. A flood-frequency relation was developed (Hedgecock and Feaster, 2007) and the 67- and 50-percent chance exceedance flood flows for the Pole Bridge Creek streamgage are 510 and 690 ft^3/s, respectively. The peak streamflow experienced during the suspended-sediment data-collection period (2010–11) was 431 ft^3/s. The largest streamflow that was sampled during the collection period was 96 ft^3/s, which is significantly less than the streamflow that corresponds to a 67-percent chance exceedance flood.

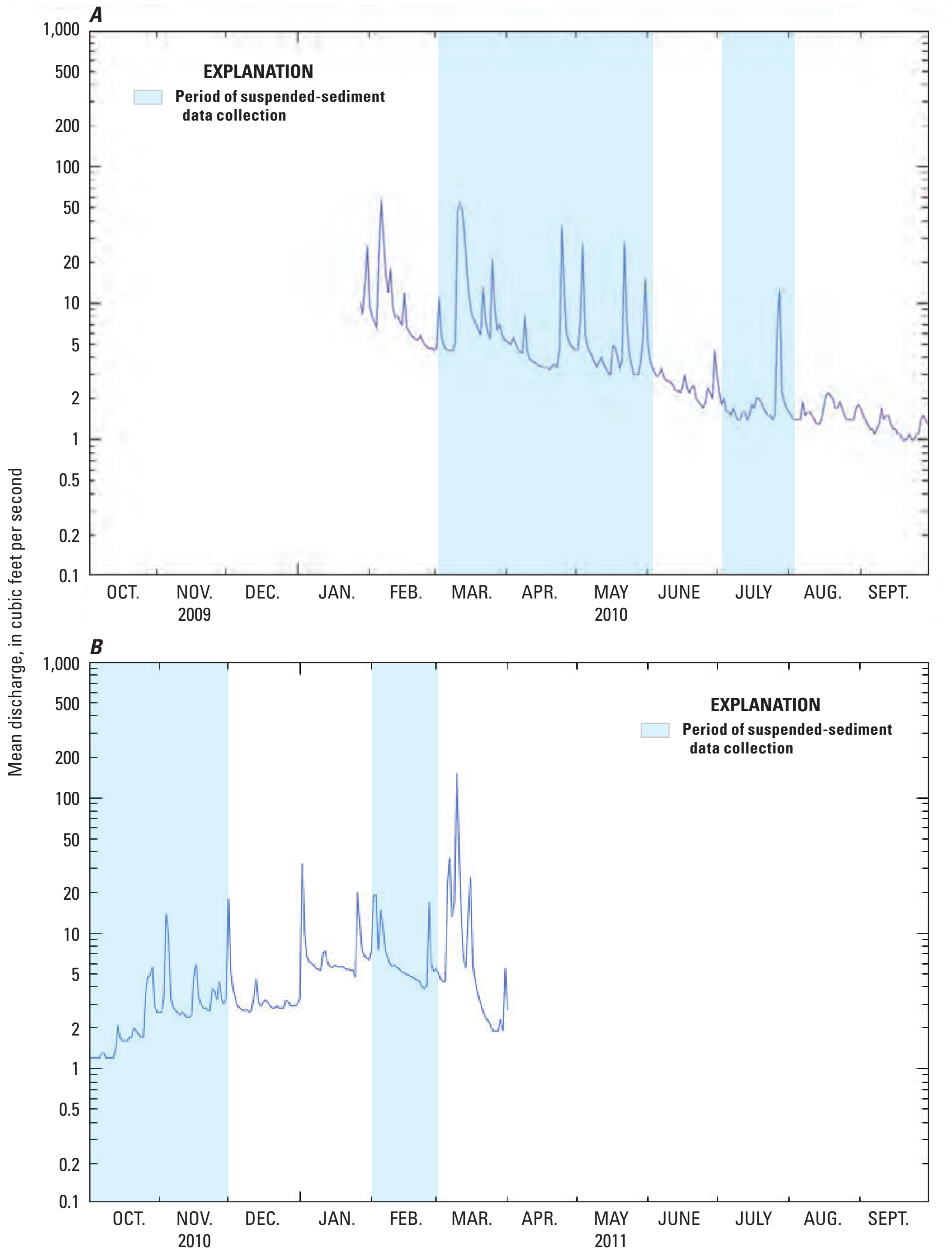

Figure 28. Streamflow hydrograph at U.S. Geological Survey streamflow-gaging station 02464385 Pole Bridge Creek near Samantha, Alabama. (*A*) 2010 water year. (*B*) 2011 water year.

Suspended Sediment

Suspended-sediment samples were collected at the Pole Bridge Creek streamgage as described in the Suspended-Sediment Data Collection section (see Approach and Methods). Samples were collected for 11 storm events (table 8); during 4 of the events, samples were collected by both manual and automatic methods. In addition to the storm events, samples were collected on a monthly basis to represent normal daily streamflows. The samples were collected to reflect seasonal variations and their variable antecedent conditions. Figure 28 illustrates the periods of data collection and how they relate to the annual hydrograph. The automatic pump sampler was set to collect samples at a time interval of 30 to 45 minutes to ensure that suspended-sediment concentrations were collected over the rise, peak, and fall of the hydrograph. The sediment hydrographs for Pole Bridge Creek were graphically compared to the streamflow hydrographs. The majority of the runoff events sampled had a sediment hydrograph whose peak preceded the streamflow hydrograph (clockwise hysteresis), which is often ascribed to resuspension of sediment from the stream channel at the initiation of storm runoff, and to a relatively limited sediment supply on the stormflow recession.

Table 8. Summary of suspended-sediment samples collected at U.S. Geological Survey streamflow-gaging station 02464385 Pole Bridge Creek near Samantha, Alabama.

[Data are available at *http://waterdata.usgs.gov/al/nwis/qw*. Dates are by month/day/year. Abbreviations: ft^3/s, cubic foot per second; <, less than]

Date	Collection type*	Peak streamflow (ft^3/s)	Annual exceedance probability
03/10/10	Manual	62	<67
03/25/10	Manual/Automatic	43	<67
04/08/10	Automatic	13	<67
04/23/10	Automatic	46	<67
05/02/10	Automatic	46	<67
05/21/10	Automatic	51	<67
05/30/10	Automatic	36	<67
07/26/10	Automatic	96	<67
10/26/10	Automatic	23	<67
11/30/10	Manual/Automatic	44	<67
02/01/11	Manual/Automatic	46	<67

* Automatic—suspended-sediment samples collected by an automatic water sampler. Manual—manually collected isokenetic suspended-sediment samples.

Estimation of Suspended-Sediment Loads from Pole Bridge Creek

The suspended-sediment concentrations of the automatic pump samples were adjusted to reflect average streamflow-weighted suspended-sediment concentrations as described in the Data Analysis section (see Approach and Methods). The suspended-sediment concentrations were converted to suspended-sediment discharges (*SSQ*) and graphically and statistically compared with streamflow (*Q*) to develop instantaneous sediment-transport curves. The graphical comparison of all the data indicated significant scatter among the dataset. The points were compared to the unit value (15 minute) streamflow hydrographs to determine if they were collected on the rising or falling limb of the hydrograph and they were plotted accordingly. The dataset was also plotted by date of storm event. The plot indicated grouping among individual rainfall events. In an effort to determine if any other biases exist, the rising and falling plots were color coded to indicate season and identify rainy months. The data collected on the rising limb of the hydrograph indicated no general trend. The data collected on the falling limb of the hydrograph showed a trend of higher concentrations for the summer months. During the summer when high-intensity storms are prevalent, raindrop impact is high and thus sediment concentrations are higher (Glysson, 1987). A portion of the trend may be attributed to the grouping among storm events. It was determined that not enough data exist to develop seasonal curves for the falling limb of the hydrograph, but bias may exist.

In order to improve the statistical correlation between suspended-sediment discharge and streamflow, the group averaging process as described by Glysson (1987) was used. The dataset was divided into 15 classes based on a logarithmic distribution of streamflow. The average, maximum, and minimum streamflow for suspended-sediment discharge were determined for each class. A suspended-sediment transport curve was developed using linear regression (ordinary least squares), and a smearing estimator applied, for the group-averaged data. The results of both curves (rising and falling) were higher for the group average as opposed to using all data points. Inspection of the rising curve showed no obvious benefit using the group averaging process. Inspection of the falling data indicated that the group averaging process improved the correlation between suspended-sediment discharge and streamflow. Because of the grouping among individual events for the falling data, the group averaging process provides a better representation of the data and is less influenced by how many falling data points were collected for each storm. In order to provide consistency, the group averaging process was used to determine an instantaneous suspended-sediment transport equation for rising, falling, and all data (composite). The unit value (15 minute) streamflows for the entire water year were visually and statistically inspected and the appropriate rising/falling (group averaged) equation was used to compute a suspended-sediment discharge. These values were used to compute an average daily sediment discharge for every day in the 2010 water year. These values were regressed with the average daily flow to provide a daily transport curve (eq. 6; fig. 29):

$$SSQ = 0.0169\,(Q)^{1.9611} \text{ for } Q \leq 96 \text{ ft}^3/\text{s} \qquad (6)$$

where

SSQ is the average daily suspended-sediment discharge, in tons per day; and

Q is the average daily streamflow, in cubic feet per second.

The application of the daily suspended-sediment transport curve is limited to the maximum measured flow, 96 ft^3/s, at which suspended-sediment samples were collected. Suspended-sediment transport curves have the tendency to flatten out once the available sediment is exhausted and additional rainfall no longer increases the suspended sediment. Because this exact point is not known, extrapolation of the suspended-sediment transport curve should be based on engineering judgment and analysis.

Annual load and yield values were estimated for suspended sediment at Pole Bridge Creek for the data collection period (2010–11). The suspended-sediment discharge was estimated for each day of the water year using the daily transport curve (eq. 6). Load computations were performed by application of the mid-interval method (Porterfield, 1972). The estimated average annual load for the data collection period, based on average daily streamflow and the Pole Bridge Creek daily transport curve, is 400 tons, and the average yield is 86 $tons/mi^2$.

It is worth noting that the daily mean sediment concentration is a time-weighted mean value. Thus, calendar days can be divided and analyzed in shorter periods of time when water or sediment discharge exceed certain limits. The term "subdivide" refers to the division of data for a calendar day into shorter periods of time to obtain correct daily mean values of streamflow or suspended-sediment discharge when one or both change beyond certain limits during the day. The values for these periods are then summed to obtain values of suspended-sediment discharge. Computation of a daily mean sediment discharge requires subdivision of the day when both water discharge and concentration are changing because the average of the products of two variable quantities is not the same as the product of the averages of the quantities (Porterfield, 1972). For comparison, the instantaneous suspended-sediment transport curve, streamflow, and the mid-interval method were used to compute an estimated average annual load for the data collection period, based on a 15-minute interval. This computation resulted in an average annual load that is 6 percent less than the load calculated using the average daily values. It was determined that the use of the average daily streamflow and the daily transport curve is more practical for estimating average annual loads.

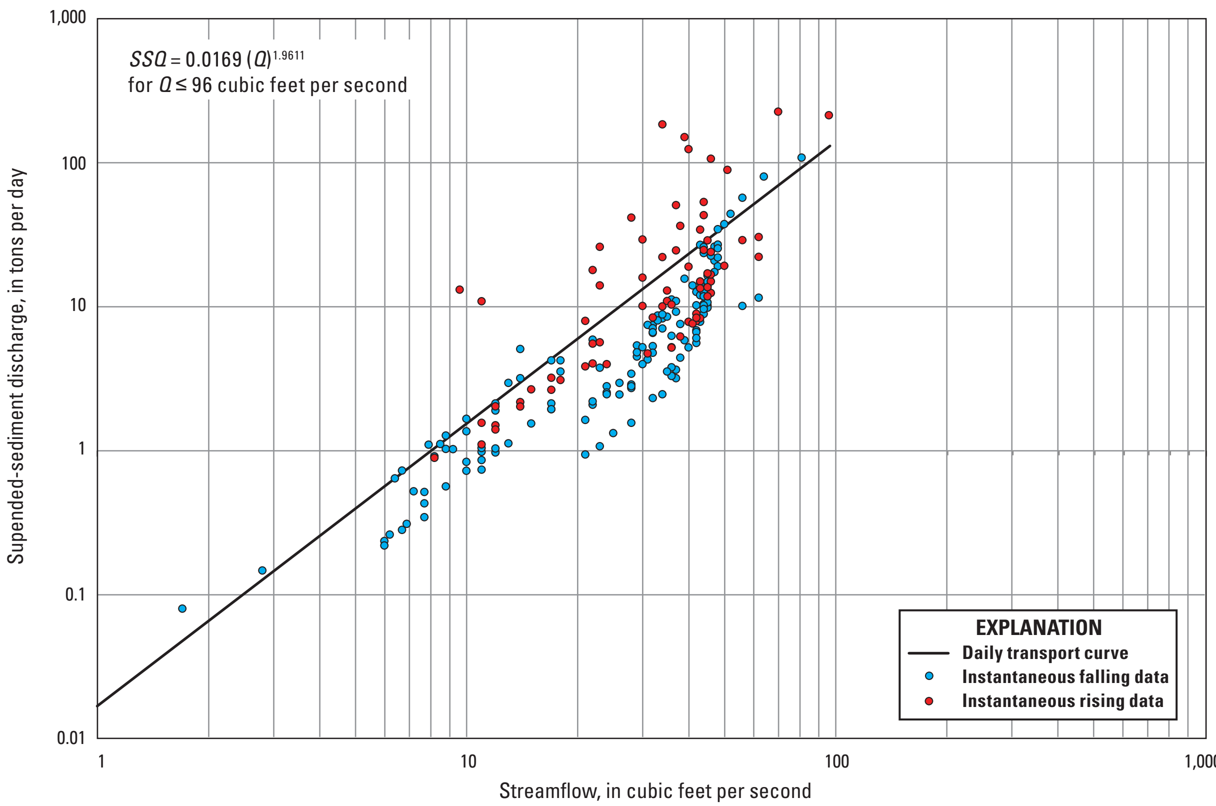

Figure 29. Daily suspended-sediment transport curve for U.S. Geological Survey streamflow-gaging station 02464385 Pole Bridge Creek near Samantha, Alabama. *SSQ*, suspended sediment concentration; *Q*, streamflow in cubic feet per second.

Tierce Creek

The USGS streamflow-gaging station on Tierce Creek above Northport, Ala. (station number 02464503, also referred to as the Tierce Creek streamgage) was established in November 2010 on Tierce Creek at Tierce Creek Road, near Northport. The drainage area for this site (fig. 30) is 1.03 mi^2. The Tierce Creek streamgage is located 2 mi upstream of the backwater of Lake Tuscaloosa. Although the Tierce Creek streamgage was not established until 2010, various historical water-quality and discharge measurements have been collected 1.2 mi downstream from the gage.

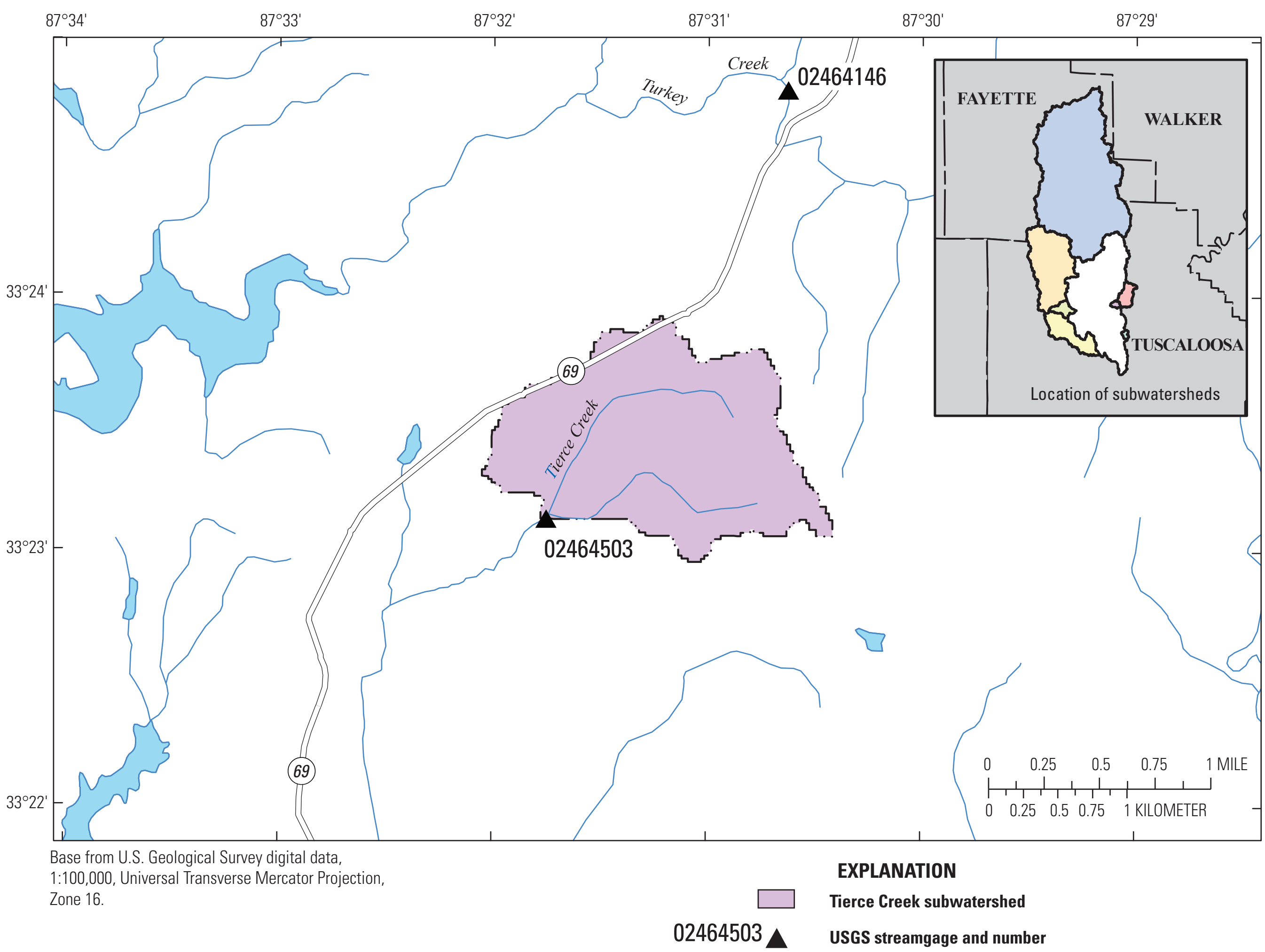

Figure 30. Location of U.S. Geological Survey streamflow-gaging station 02464503 Tierce Creek near Northport, Alabama, and the contributing drainage area.

Land Use

In general, land use within the Tierce Creek subwatershed in 2006 (Fry and others, 2011) can be classified as rural. Forested land (cumulative total of mixed, deciduous, and evergreen) was the predominant basinwide land use in 2006 at 66 percent. Agricultural land use, represented predominantly by hay and pasture or grasslands, accounted for about 18 percent of the subwatershed. Low-, medium-, and high-intensity residential, and developed open space land coverages were combined to compute total urban land use. Urban land use was approximately 4 percent in 2006 (fig. 31).

General changes in land use were evaluated by inspecting the NLCD 1992–2001 Land Cover Change Retrofit product (Fry and others, 2009) and direct comparison of the NLCD 2001 (Homer and others, 2004) and the NLCD 2006 (Fry and others, 2011). One of the largest reductions in land use from 1992 to 2001 was forested land that decreased by 6 percent. Direct comparison of NLCD 2001 and 2006 (fig. 31) shows a decrease in forested land of 6 percent and an increase in agricultural lands of 5 percent. Inspection of aerial photography indicates minimal land-use changes since completion of the 2006 NLCD. Comparison of the NLCD 2006 and aerial photography (2010–11) shows an increase in forested land of 22 acres.

Historical Data

Monthly sediment samples (table 9) were collected 1.2 mi downstream of the current sampling location on Tierce Creek near the Northport streamgage (station number 02464505) for the 1983 water year (October 1, 1982–September 30, 1983). Comparison of the 1983 and 2011 datasets indicates similar suspended-sediment concentration values for lower streamflow. Because samples taken during normal low-flow conditions are a variable function of the available sediment fines, no quantitative conclusions were drawn from the comparison.

Data Collected

Streamflow and suspended-sediment data were collected at Tierce Creek at Tierce Creek Road, near Northport, Ala. (station number 02464503). A streamflow-gaging station was installed in November 2010. Stage values are recorded every 15 minutes and a stage-discharge rating curve was developed. Sediment samples were automatically collected using an automatic water sampler. Streamflow data was collected at this site from installation to May 2012. Suspended-sediment samples were collected during the 2011–12 water year.

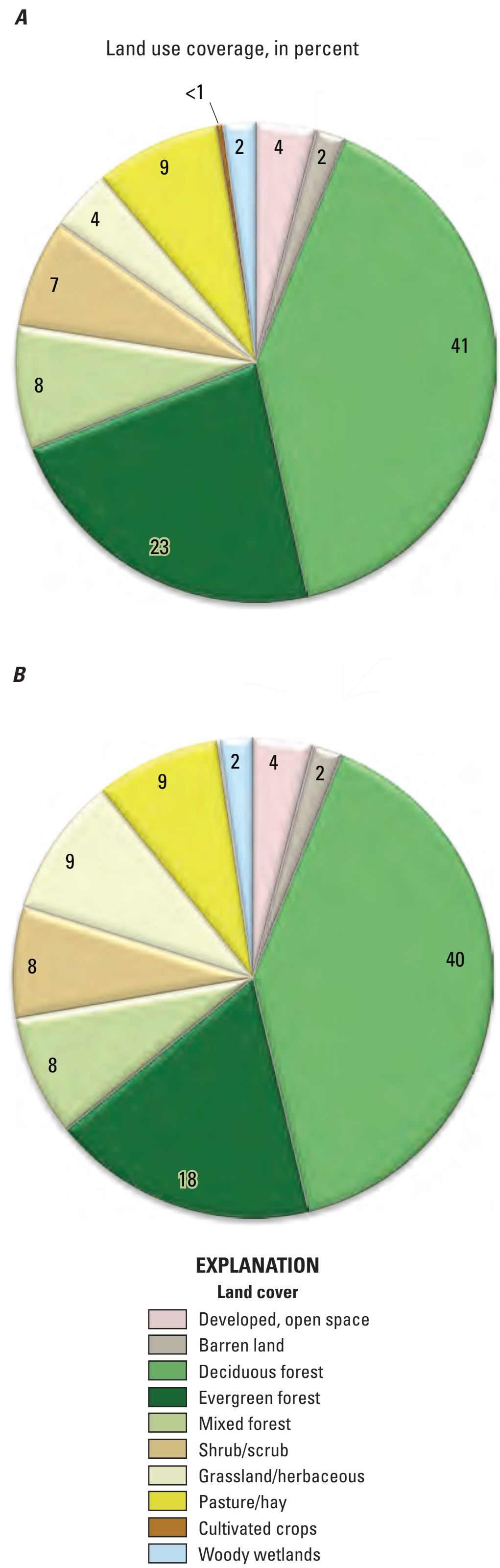

Figure 31. Percentage of land-use coverage at U.S. Geological Survey streamflow-gaging station 02464503 Tierce Creek near Northport, Alabama. (*A*) National Land Cover Database 2001. (*B*) National Land Cover Database 2006.

Table 9. Historical streamflow and suspended-sediment data for U.S. Geological Survey streamflow-gaging station 02464505 Tierce Creek near Northport, Alabama.

[Data are available at *http://waterdata.usgs.gov/al/nwis/qw*. Dates are by month/day/year. Abbreviations: ft^3/s, cubic foot per second; mg/L, milligram per liter]

Date	Mean streamflow (ft^3/s)	Suspended sediment (mg/L)	Suspended sediment discharge (tons/day)
10/4/1982	0.98	3	0.01
11/4/1982	1.6	5	0.02
12/2/1982	9.2	16	0.40
1/3/1983	4.8	7	0.09
2/3/1983	11	5	0.15
3/2/1983	7.9	4	0.08
4/5/1983	4.6	3	0.04
5/4/1983	4.9	9	0.12
6/3/1983	4.2	3	0.03
7/6/1983	3.2	8	0.07
8/2/1983	2.6	10	0.07
9/2/1983	2.1	5	0.03

Streamflow

Climatic conditions have a direct effect on streamflow. A comparison was made with streamflow (fig. 32) and the dates of data collection (2011–12) to determine how climatic conditions during this investigation may have influenced the data collected and may limit the applicability of the regression equations developed by this investigation to periods of differing climatic conditions. The Tierce Creek streamgage does not have a long period of record (10 or more years) and therefore assumptions cannot be made on the average streamflow conditions for the site. However, the peak streamflow of record was evaluated based on regional regression relations. A flood-frequency relation was developed (Hedgecock and Feaster, 2007) and the 67- and 50-percent chance exceedance flood flows for the Tierce Creek streamgage are 190 and 260 ft^3/s, respectively. The peak streamflow experienced during the suspended-sediment data-collection period (2011–12) was 110 ft^3/s. The largest peak streamflow that was sampled during the collection period was 110 ft^3/s, which is less than the streamflow that corresponds to a 67-percent chance exceedance flood.

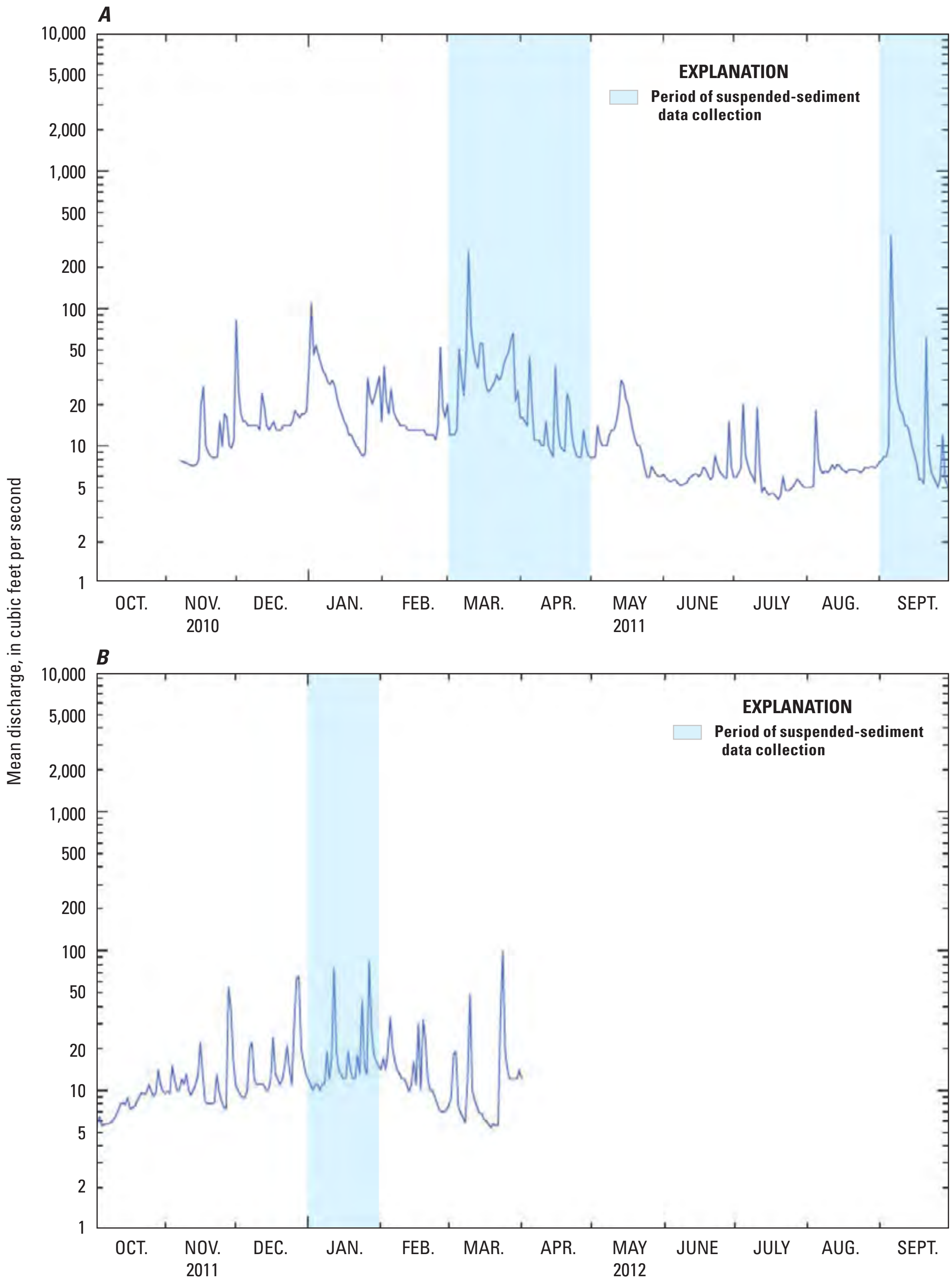

Figure 32. Streamflow hydrograph at U.S. Geological Survey streamflow-gaging station 0246503 Tierce Creek near Northport, Alabama. (*A*) 2011 water year and (*B*) 2012 water year.

Suspended Sediment

Suspended-sediment samples were collected at the Tierce Creek streamgage as described in the Suspended-Sediment Data Collection section (see Approach and Methods). Samples were collected for 10 storm events (table 10) during 4 of the events, samples were collected by both manual and automatic methods. In addition to the storm events, samples were collected on a monthly basis to represent normal daily streamflows. The samples were collected to reflect seasonal variations and their variable antecedent conditions. Figure 32 illustrates the periods of data collection and how they relate to the annual hydrograph. The automatic pump sampler was set to collect samples at a time interval ranging from 15 to 25 minutes to ensure that suspended-sediment concentrations were collected over the rise, peak, and fall of the hydrograph. The sediment hydrographs for Tierce Creek were graphically compared to the streamflow hydrographs. The majority of the runoff events sampled had a sediment hydrograph whose peak tracked the streamflow hydrograph, which could be an indication of a uniform source of sediment and (or) a lack of sediment stored in the channel.

Table 10. Summary of suspended-sediment samples collected at U.S. Geological Survey streamflow-gaging station 02464503 Tierce Creek near Northport, Alabama.

[Data are available at *http://waterdata.usgs.gov/al/nwis/qw*. Dates are by month/day/year. Abbreviations: ft^3/s, cubic foot per second; <, less than]

Date	Collection type*	Peak streamflow (ft^3/s)	Annual exceedance probability
3/5/11	Manual/Automatic	21	<67
3/8/11	Manual/Automatic	57	<67
4/11/11	Automatic	7	<67
4/15/11	Automatic	19	<67
9/5/11	Manual/Automatic	110	<67
9/19/11	Automatic	26	<67
11/27/11	Automatic	17	<67
1/11/12	Automatic	32	<67
1/23/12	Automatic	18	<67
1/26/12	Manual/Automatic	25	<67

* Automatic—suspended-sediment samples collected by an automatic water sampler. Manual—manually collected isokenetic suspended-sediment samples.

Estimation of Suspended-Sediment Loads from Tierce Creek

The suspended-sediment concentrations of the automatic pump samples were adjusted to reflect average streamflow-weighted suspended-sediment concentrations as described in the Data Analysis section (see Approach and Methods). The suspended-sediment concentrations were converted to suspended-sediment discharges (*SSQ*) and graphically and statistically compared with streamflow (*Q*) to develop instantaneous sediment-transport curves. A linear regression equation (ordinary least squares) was developed, with a smearing estimator applied, for the rise and fall of the hydrograph and using all data (composite). The resulting instantaneous sediment-transport curves had almost the same slope. The composite instantaneous sediment transport curve was used to compute an average daily sediment discharge for every day (November 2010–October 2011). These values were regressed with the average daily flow to provide a daily transport curve (eq. 7; fig. 33):

$$SSQ = 0.2249\,(Q)^{1.3927} \text{ for } Q \leq 110 \text{ ft}^3\text{/s} \qquad (7)$$

where

SSQ is the average daily suspended-sediment discharge, in tons per day; and

Q is the average daily streamflow, in cubic feet per second.

The application of the daily suspended-sediment transport curve is limited to the maximum measured flow, 110 ft^3/s, at which suspended-sediment samples were collected. Suspended-sediment transport curves have the tendency to flatten out once the available sediment is exhausted and additional rainfall no longer increases the suspended sediment. Because this exact point is not known, extrapolation of the suspended- sediment transport curve should be based on engineering judgment and analysis.

Annual load and yield values were estimated for suspended sediment at Tierce Creek for the collection period (November 2010–October 2011). The suspended-sediment discharge was estimated for each day of the water year using the daily transport curve (eq. 7). Load computations were performed by application of the mid-interval method (Porterfield, 1972). The estimated average annual load for the collection period, based on average daily streamflow and the Tierce Creek daily transport curve is 200 tons, and the average yield is 190 tons/mi^2.

It is worth noting that the daily mean sediment concentration is a time-weighted mean value. Thus, calendar days can be divided and analyzed in shorter periods of time when water or sediment discharge exceed certain limits. The term “subdivide” refers to the division of data for a calendar day into shorter periods of time to obtain correct daily mean values of streamflow or suspended-sediment discharge when one or both change beyond certain limits during the day. The values for these periods are then summed to obtain values of suspended-sediment discharge. Computation of a daily mean sediment discharge requires subdivision of the day

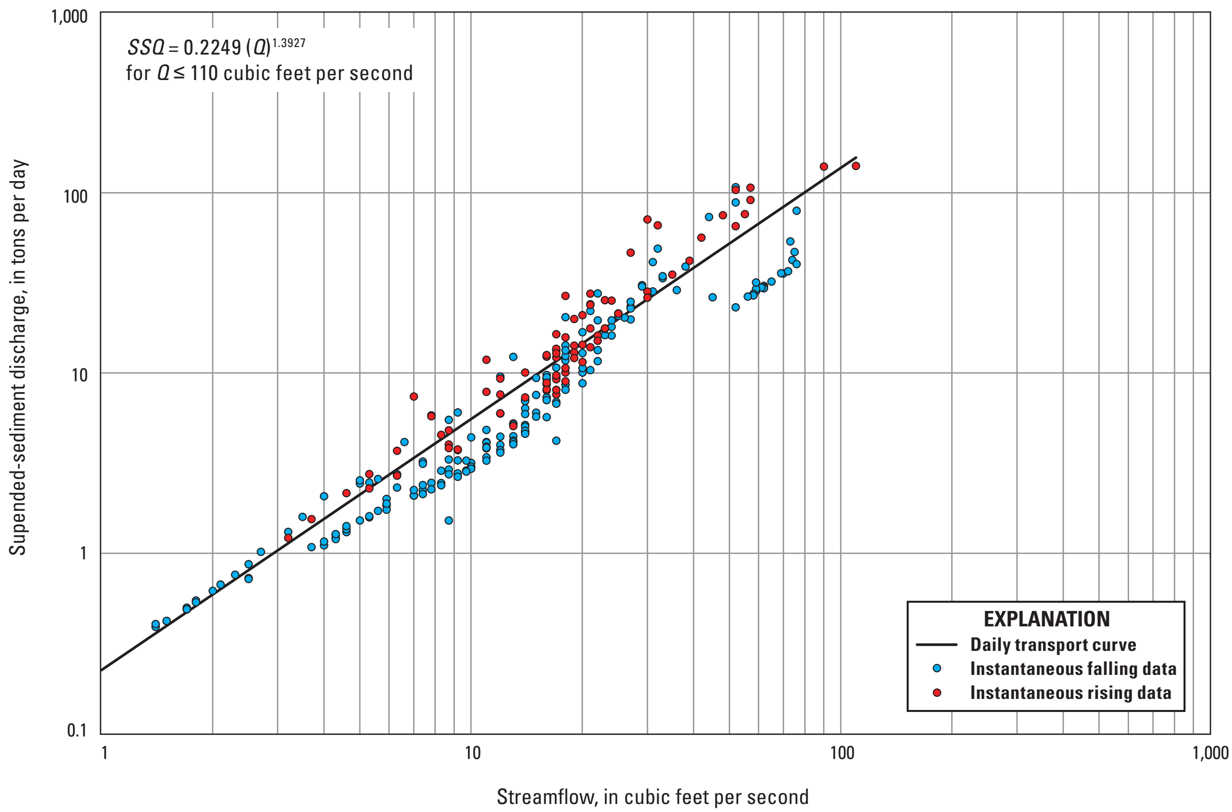

Figure 33. Daily suspended-sediment transport curve for U.S. Geological Survey streamflow-gaging station 02464503 Tierce Creek near Northport, Alabama. *SSQ*, suspended sediment concentration; *Q*, streamflow in cubic feet per second.

when both water discharge and concentration are changing because the average of the products of two variable quantities is not the same as the product of the averages of the quantities (Porterfield, 1972). For comparison, the instantaneous suspended-sediment transport curve, streamflow, and the mid-interval method were used to compute an estimated average annual load for the collection period, based on a 15-minute interval. This computation resulted in an average annual load that is 15 percent more than the load calculated using the average daily values. It was determined that the use of the average daily streamflow and the daily transport curve is more practical for estimating average annual loads.

Carroll Creek

Carroll Creek is one of six subwatersheds (Carroll Creek, Binion Creek, headwaters of the North River, upper North River, middle North River, and lower North River) that drain into Lake Tuscaloosa (fig. 1, table 1). Carroll Creek at the mouth of the main body of the reservoir has a drainage area of 25.6 mi^2 and contributes approximately 5 percent of the surface drainage area to Lake Tuscaloosa (fig 34). Carroll Creek is in backwater of the reservoir for approximately 3.5 mi. The upstream extent of the backwater portion of Carroll Creek has experienced increased sediment deposition (figs. 35 and 36). The City of Tuscaloosa dredged portions of Carroll Creek in 2009. As a byproduct of this scientific investigation, a 3.5-mi reach of Carroll Creek was surveyed to prepare a current bathymetric map, determine storage capacities at specified water-surface elevations, and compare current conditions to historical cross sections.

The USGS streamflow-gaging station on Carroll Creek near Northport, Ala. (station number 02464660, also referred to as the Carroll Creek streamgage) was established in November 2008 on Carroll Creek at State Highway 69, near Northport. Although the streamgage was established in 2008, various historical water quality and discharge measurements have been made at this location. The drainage area for this site (fig. 36) is 20.9 mi^2 and is 3.75 mi upstream from the mouth of Carroll Creek and the reservoir.

Land Use

In general, land use within the Carroll Creek subwatershed in 2006 (Fry and others, 2011) can be classified as rural. Forested land (cumulative total of mixed, deciduous, and evergreen) was the predominant basinwide land use in 2006 at 59 percent. Agricultural land use, represented predominantly by hay and pasture or grasslands, accounted for about 11 percent of the subwatershed. Low-, medium-, and high-intensity residential, and developed open space land coverages were combined to compute total urban land use. Urban land use was approximately 11 percent in 2006 (fig. 37). Inspection of aerial photography indicates urban development since completion of the 2006 NLCD.

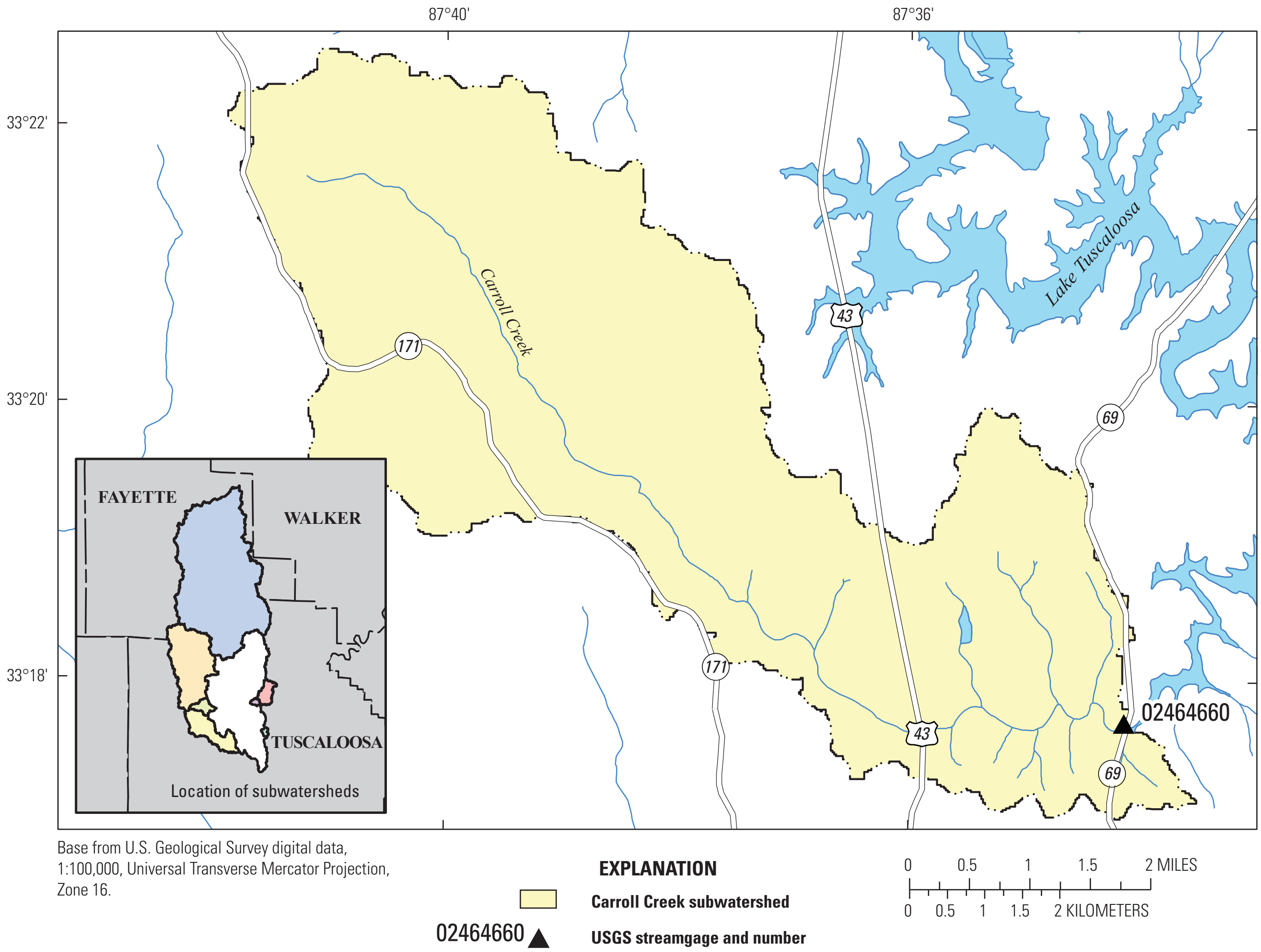

Figure 34. Location of U.S. Geological Survey streamflow-gaging station 02464660 Carroll Creek near Northport, Alabama, and the contributing drainage area.

Figure 35. Aerial photograph showing the upstream extent of the backwater portion of Carroll Creek near Northport, Alabama, November 29, 2007. Lake Tuscaloosa water-surface elevation is 221.04 feet (National Geodetic Vertical Datum of 1929).

Figure 36. Aerial photograph showing the upstream extent of the backwater portion of Carroll Creek near Northport, Alabama, March 24, 2009. Lake Tuscaloosa water-surface elevation is 223.74 feet (National Geodetic Vertical Datum of 1929).

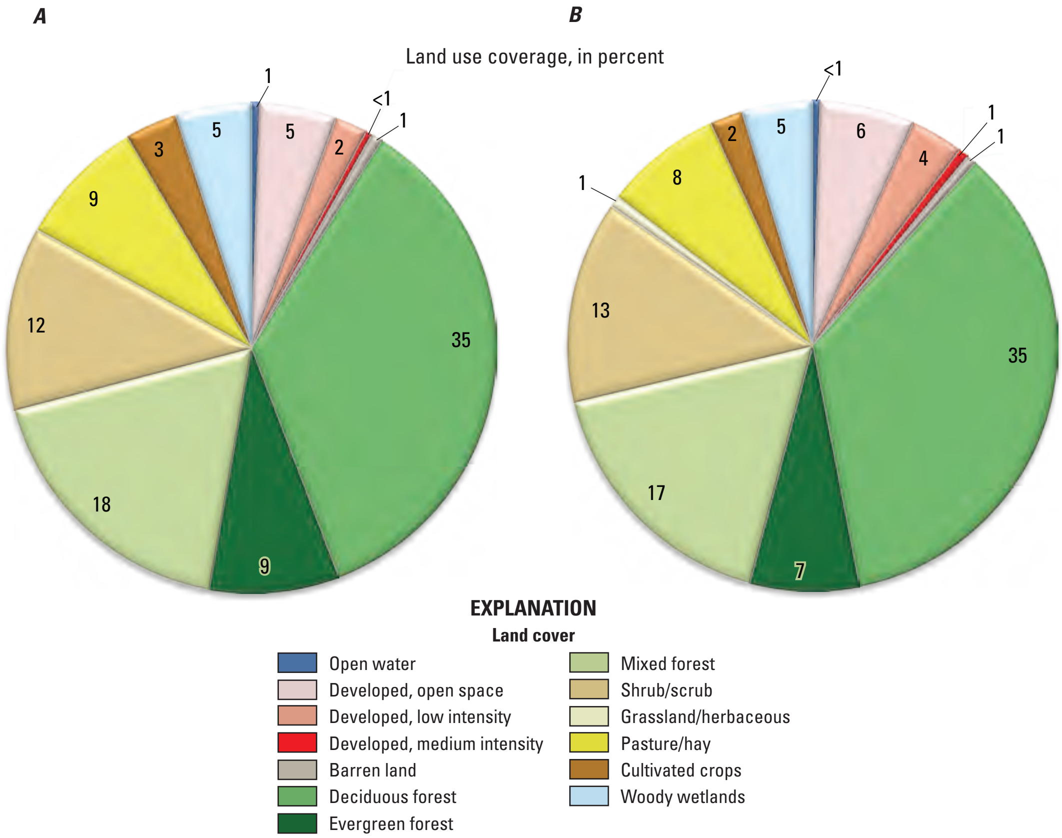

Figure 37. Percentage of land-use coverage at U.S. Geological Survey streamflow-gaging station 02464660 Carroll Creek near Northport, Alabama. (*A*) National Land Cover Database 2001 and (*B*) National Land Cover Database 2006.

General changes in land use were evaluated by inspecting the NLCD 1992–2001 Land Cover Change Retrofit product (Fry and others, 2009) and direct comparison of the NLCD 2001(Homer and others, 2004) and the NLCD 2006 (Fry and others, 2011). One of the largest reductions in land use from 1992 to 2001 was forested land that decreased by 3 percent. During this period, urbanization increased by 0.5 percent. Direct comparison of NLCD 2001 and 2006 (fig. 38), show a decrease in forested land of 3 percent and an increase in urbanization of 3 percent. Comparison of the NLCD Impervious Cover (2006) and aerial photography (2009) (fig. 38) shows new development in the southeastern portion of the basin, as indicated by impervious cover.

Historical Data

Monthly sediment samples (table 11) were collected at the same location as the Carroll Creek streamgage (station number 02464660) for the 1983 water year (October 1982–September 1983). The historical data were used to show temporal trends because the land-use changes described above indicate an increase in urbanization. Comparison of the 1983 and 2009 datasets show a slight increase in suspended-sediment concentrations. Because samples taken during normal low-flow conditions are a variable function of the available sediment fines, no quantitative conclusions were drawn from the comparison.

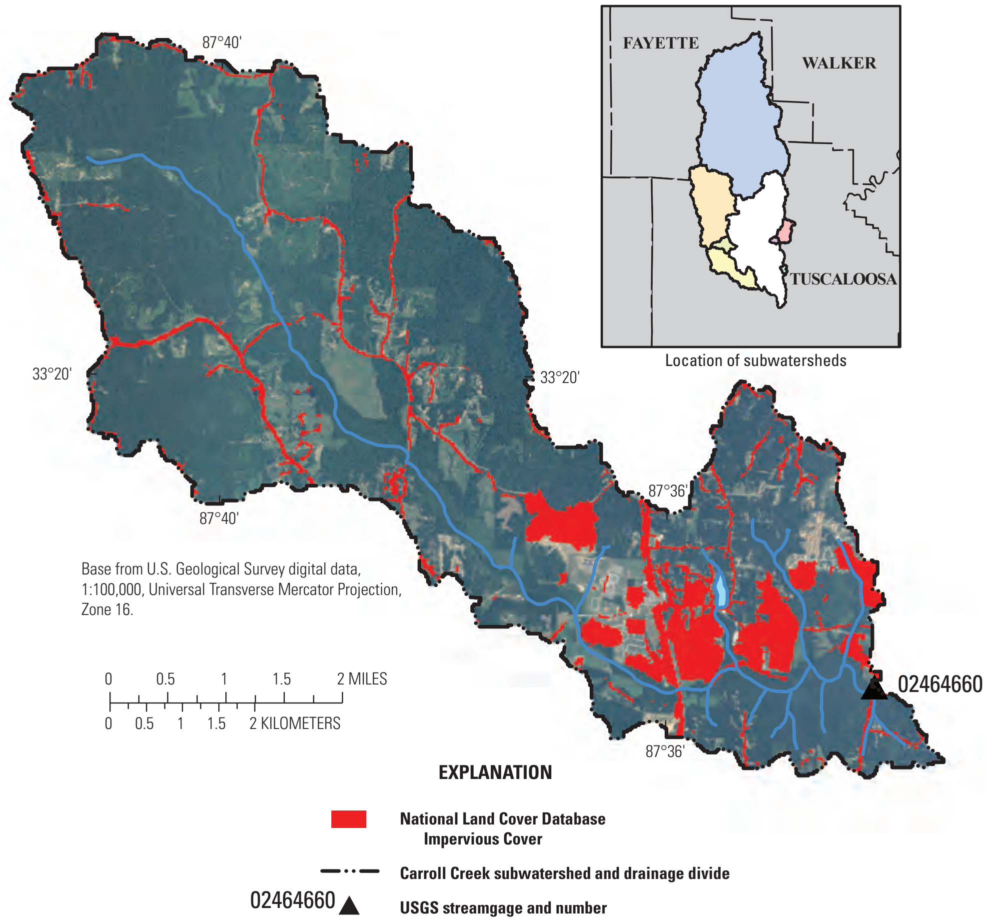

Figure 38. Comparison of aerial photography (2009) and National Land Cover Database Impervious Cover (2006) for the Carroll Creek subwatershed draining into Lake Tuscaloosa, Alabama.

Table 11. Historical streamflow and suspended-sediment data for U.S. Geological Survey streamflow-gaging station 02464660 Carroll Creek near Northport, Alabama.

[Data are available at *http://waterdata.usgs.gov/al/nwis/qw*. Dates are by month/day/year. Abbreviations: ft³/s, cubic foot per second; mg/L, milligram per liter]

Date	Mean streamflow (ft^3/s)	Suspended sediment (mg/L)	Suspended sediment discharge (tons/day)
10/4/1982	1.80	34	0.16
11/4/1982	14	12	0.45
12/3/1982	74	39	7.8
1/3/1983	57	35	5.4
2/4/1983	94	19	4.8
3/2/1983	111	31	9.3
4/4/1983	38	9	0.92
6/2/1983	22	13	0.77
7/5/1983	13	14	0.49
8/1/1983	9.80	17	0.45
9/1/1983	4.90	9	0.12

Data Collected

Streamflow and suspended-sediment data were collected at Carroll Creek at State Highway 69 near Northport, Ala. (station number 02464660). A streamflow-gaging station was installed in November 2008. Stage values are recorded every 15 minutes and a stage-discharge rating curve was developed. Sediment samples were automatically collected using an automatic water sampler. Streamflow data have been collected at this site from installation to present. Suspended-sediment samples were collected during the 2009 water year.

Streamflow

Climatic conditions have a direct effect on streamflow. A comparison was made with streamflow (fig. 39) and the dates of data collection to determine how climatic conditions during this investigation may have influenced the data collected and may limit the applicability of the regression equations developed by this investigation to periods of differing climatic conditions. Average annual mean streamflow (2009–11) was examined for the period of record and for the individual water years (fig. 40). The suspended-sediment samples collected in 2009 were collected during a period when annual streamflow magnitude was above average. The Carroll Creek streamgage does not have a long period of record (10 or more years) and therefore assumptions cannot be made about the average streamflow conditions for the site. However, the peak streamflow of record was evaluated based on regional regression relations. A flood-frequency relation was developed (Hedgecock and Feaster, 2007) and the 67- and 50-percent chance exceedance flood flows for the Carroll Creek streamgage are 1,390 and 1,840 ft^3/s, respectively. The peak streamflow experienced during the suspended-sediment data-collection period (2009) was 1,630 ft^3/s. The largest peak streamflow that was sampled during the collection period was 670 ft^3/s, which is less than the streamflow that corresponds to a 67-percent chance exceedance flood.

Suspended Sediment

Suspended-sediment samples were collected at the Carroll Creek streamgage as described in the Suspended-Sediment Data Collection section (see Approach and Methods). Samples were collected for nine storm events (table 12); during four of the events, samples were collected by both manual and automatic methods. In addition to the storm events, samples were collected on a monthly basis to represent normal daily streamflows. The samples were collected to reflect seasonal variations and their variable antecedent conditions. Figure 39 illustrates the periods of data collection and how they relate to the annual hydrograph. The automatic pump sampler was set to collect samples at a time interval ranging from 15 to 45 minutes to ensure that suspended-sediment concentrations were collected over the rise, peak, and fall of the hydrograph. The sediment hydrographs for Carroll Creek were graphically compared to the streamflow hydrographs. The majority of the runoff events sampled had a sediment hydrograph whose peak preceded the streamflow hydrograph (clockwise hysteresis), which is often ascribed to resuspension of sediment from the stream channel at the initiation of storm runoff and to a relatively limited sediment supply on the stormflow recession.

Estimation of Suspended-Sediment Loads from Carroll Creek

The suspended-sediment concentrations of the automatic pump samples were adjusted to reflect average streamflow-weighted suspended-sediment concentrations as described in the Data Analysis section (see Approach and Methods). The suspended-sediment concentrations were converted to suspended-sediment discharges (*SSQ*) and graphically and statistically compared with streamflow (*Q*) to develop instantaneous sediment-transport curves. A linear regression equation (ordinary least squares) was developed, and a smearing estimator applied, for the rise and fall of the hydrograph and using all data (composite). The resulting instantaneous sediment-transport curves had almost the same slope, with the rising equation having a higher intercept. The composite instantaneous sediment-transport curve was used to compute an average daily sediment discharge for every day in the 2009 water year. These values were regressed with the average daily flow to provide a daily transport curve (eq. 8; fig. 41):

$$SSQ = 0.0627\,(Q)^{1.6113} \text{ for } Q \leq 670 \text{ ft}^3/\text{s} \qquad (8)$$

where

SSQ is the average daily suspended-sediment discharge, in tons per day; and

Q is the average daily streamflow, in cubic feet per second.

The application of the daily suspended-sediment transport curve is limited to the maximum measured flow, 670 ft^3/s, at which suspended-sediment samples were collected. Suspended-sediment transport curves have the tendency to flatten out once the available sediment is exhausted and additional rainfall no longer increases the suspended sediment. Because this exact point is not known, extrapolation of the suspended-sediment transport curve should be based on engineering judgment and analysis.

Annual load and yield values were estimated for suspended sediment at Carroll Creek for the 2009 water year. The suspended-sediment discharge was estimated for each day of the water year using the daily transport curve (eq. 8). The maximum average daily streamflow for the period of estimation is 1,070 ft^3/s (February 28, 2009). This exceeds the maximum streamflow at which sediment was sampled. The daily transport curve was extended linearly to estimate suspended-sediment discharge for this period of high flow. Load computations were performed by application of the mid-interval method (Porterfield, 1972).

The estimated average annual load for the 2009 water year, based on average daily streamflow and the Carroll Creek daily transport curve, is 17,600 tons, and the average yield is 840 tons/mi^2.

It is worth noting that the daily mean sediment concentration is a time-weighted mean value. Thus, calendar days can be divided and analyzed in shorter periods of time when water or sediment discharge exceed certain limits. The term "subdivide" refers to the division of data for a calendar day into shorter periods of time to obtain correct daily mean values of streamflow or suspended-sediment discharge when one or both change beyond certain limits during the day. The values for these periods are then summed to obtain values of suspended-sediment discharge. Computation of a daily mean sediment discharge requires subdivision of the day when both water discharge and concentration are changing because the average of the products of two variable quantities is not the same as the product of the averages of the quantities (Porterfield, 1972). For comparison, the instantaneous suspended-sediment transport curve, streamflow, and the mid-interval method were used to compute an estimated average annual load for the 2009 water year, based on a 15-minute interval. This computation resulted in an average annual load that is 12 percent less than the load calculated using the average daily values. It was determined that the use of the average daily streamflow and the daily transport curve is more practical for estimating average annual loads.

Brush Creek

The USGS streamflow-gaging station on Brush Creek near Northport, Ala. (station number 02464680, also referred to as the Brush Creek streamgage) was established in November 2010 on Brush Creek at Turner Road, near Northport. The drainage area (fig. 42) for this site is 0.92 mi^2, and it is located 0.3 mi upstream of the backwater of Lake Tuscaloosa. Although the streamgage was established in 2010, various historical water-quality and discharge measurements have been collected at this site.

Land Use

In general, land use within the Brush Creek subwatershed in 2006 (Fry and others, 2011) can be classified as rural. Forested land (cumulative total of mixed, deciduous, and evergreen) was the predominant basinwide land use in 2006 at 84 percent. Shrub/scrub, represented predominantly by shrubs less than 16 ft tall with shrub canopy typically greater than 20 percent of total vegetation, accounted for about 10 percent of the subwatershed (fig. 43).

General changes in land use were evaluated by inspecting the NLCD 1992–2001 Land Cover Change Retrofit product (Fry and others, 2009) and direct comparison of the NLCD 2001 (Homer and others, 2004) and the NLCD 2006 (Fry and others, 2011). The NLCD 1992–2001 Land Cover Change Retrofit product indicated no substantial change in land use from 1992 to 2001. Direct comparison of NLCD 2001 and 2006 (fig. 43) indicates a decrease in forested land of 10 percent and an increase in shrub/scrub land use of 10 percent. Inspection of aerial photography indicates a decrease in forested land since completion of the 2006 NLCD. Comparison of the NLCD and aerial photography indicates that in the time period of 2006 to 2010, approximately 74 acres of the drainage basin were clear cut.

Historical Data

Monthly sediment samples (table 13) were collected at the Brush Creek near Northport streamgage (station number 02464680) for the 1983 water year (October 1, 1982–September 30, 1983). Comparison of the 1983 and 2011 datasets indicates a similar trend for the lower values of streamflow. Because samples taken during normal low-flow conditions are a variable function of the available sediment fines, no quantitative conclusions were drawn from the comparison.

Data Collected

Streamflow and suspended-sediment data were collected at Brush Creek at Turner Road, near Northport, Ala. (station number 02464680). A streamflow-gaging station was installed in November 2010. Stage values are recorded every 15 minutes and a stage-discharge rating curve was developed. Sediment samples were automatically collected using an automatic water sampler. Streamflow data were collected at this site from installation to present. Suspended-sediment samples were collected during the 2011–12 water years.

Streamflow

Climatic conditions have a direct effect on streamflow. A comparison was made with streamflow (fig. 44) and the dates of data collection (2011–12) to determine how climatic conditions during this investigation may have influenced the data collected and may limit the applicability of the regression equations developed by this investigation to periods of differing climatic conditions. The Brush Creek streamgage does not have a long period of record (10 or more years) and therefore assumptions cannot be made on the average streamflow conditions for the site. However, the peak streamflow of record was evaluated based on regional regression relations. A flood-frequency relation was developed (Hedgecock and Feaster, 2007) and the 67- and 50-percent chance exceedance flood flows for the Brush Creek streamgage are 170 and 240 ft^3/s, respectively. The peak streamflow experienced during the suspended-sediment data-collection period (2011–12) was 140 ft^3/s. The largest peak streamflow that was sampled during the collection period was 130 ft^3/s, which is less than the streamflow that corresponds to a 67-percent chance exceedance flood.

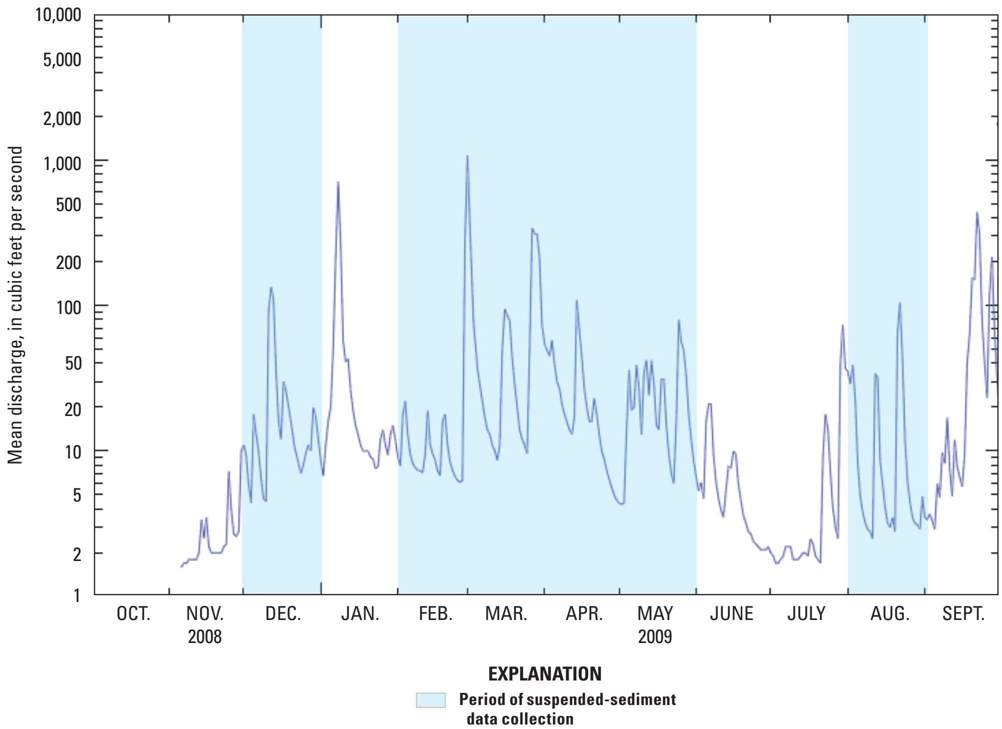

Figure 39. Streamflow hydrograph for the 2009 water year at U.S. Geological Survey streamflow-gaging station 02464660 Carroll Creek near Northport, Alabama.

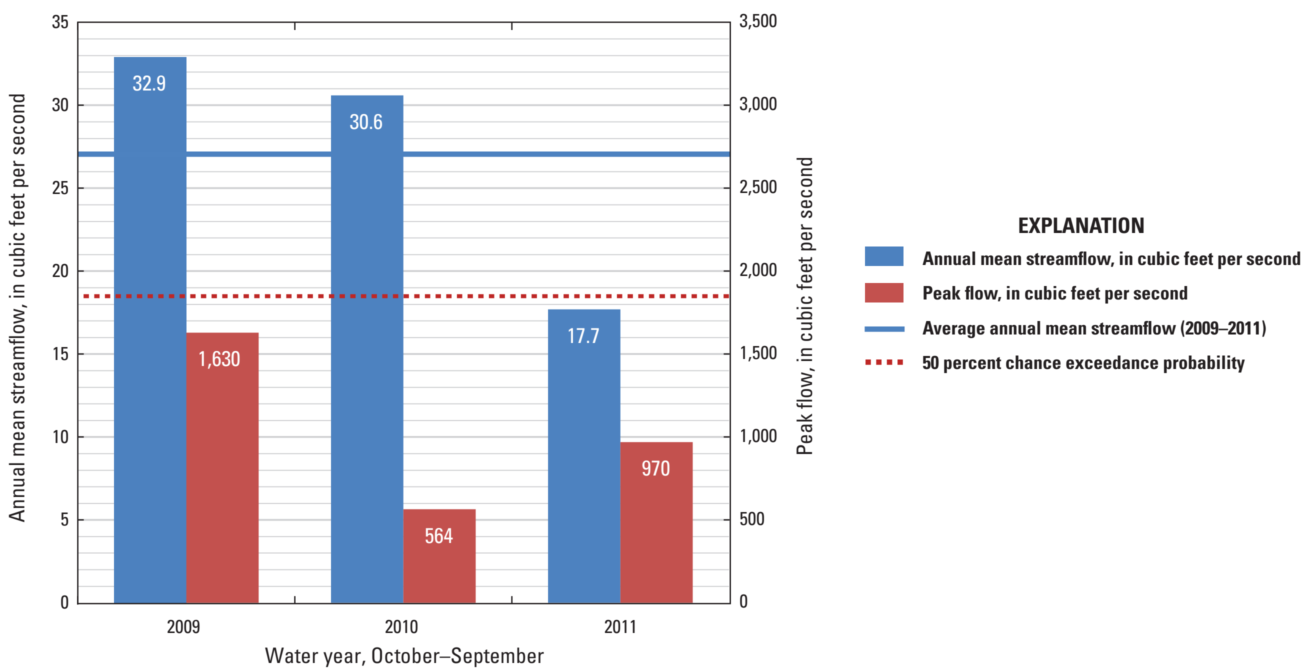

Figure 40. Annual mean streamflow for U.S. Geological Survey streamflow-gaging station 02464660 Carroll Creek near Northport, Alabama.

Table 12. Summary of suspended-sediment samples collected at U.S. Geological Survey streamflow-gaging station 02464660 Carroll Creek near Northport, Alabama.

[Data are available at *http://waterdata.usgs.gov/al/nwis/qw*. Dates are by month/day/year. Abbreviations: ft³/s, cubic foot per second; <, less than]

Date	Collection type*	Peak streamflow (ft³/s)	Annual exceedance probability
12/10/2008	Manual/Automatic	250	<67
2/27/2009	Manual/Automatic	670	<67
3/14/2009	Automatic	83	<67
3/25/2009	Automatic	436	<67
4/2/2009	Automatic	65	<67
5/14/2009	Automatic	44	<67
5/24/2009	Automatic	221	<67
8/11/2009	Manual/Automatic	134	<67
8/20/2009	Manual/Automatic	285	<67

* Automatic—suspended-sediment samples collected by an automatic water sampler. Manual—manually collected isokenetic suspended-sediment samples.

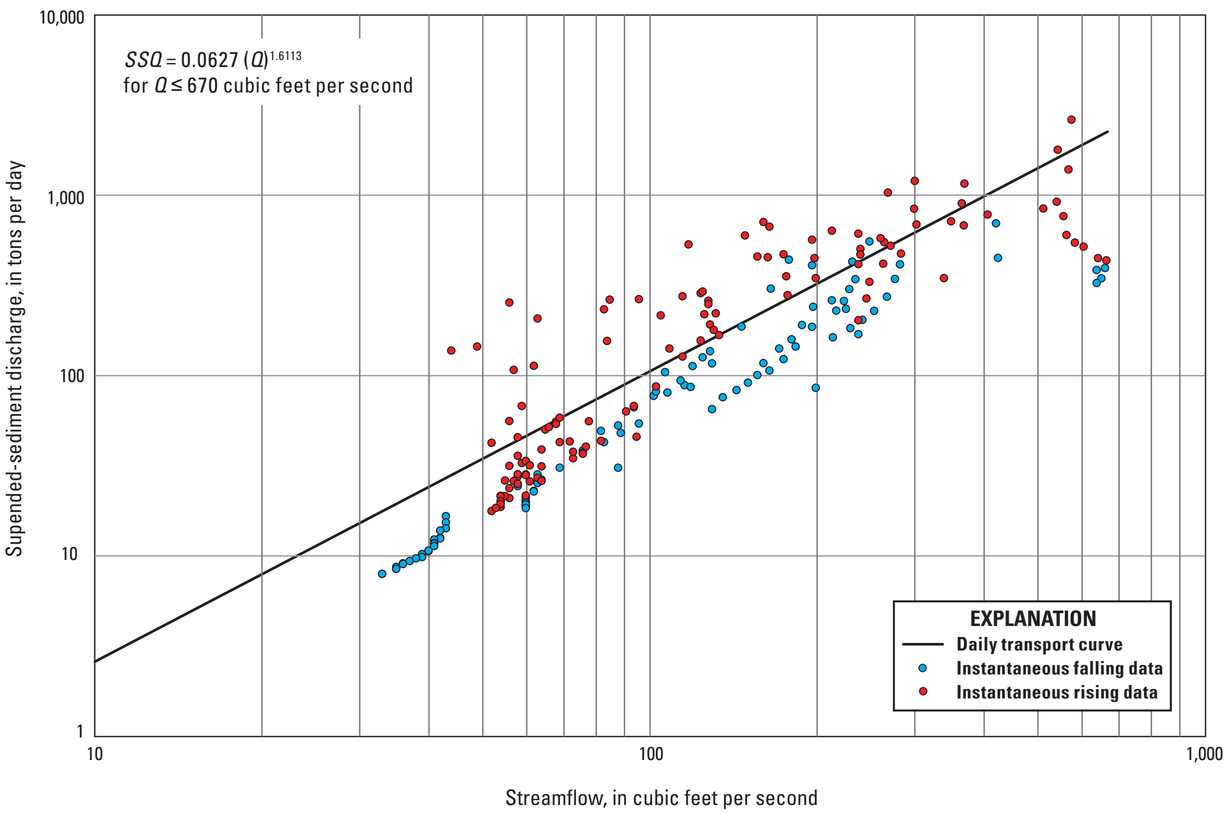

Figure 41. Daily suspended-sediment transport curve for U.S. Geological Survey streamflow-gaging station 02464660 Carroll Creek near Northport, Alabama. *SSQ*, suspended sediment concentration; *Q*, streamflow in cubic feet per second.

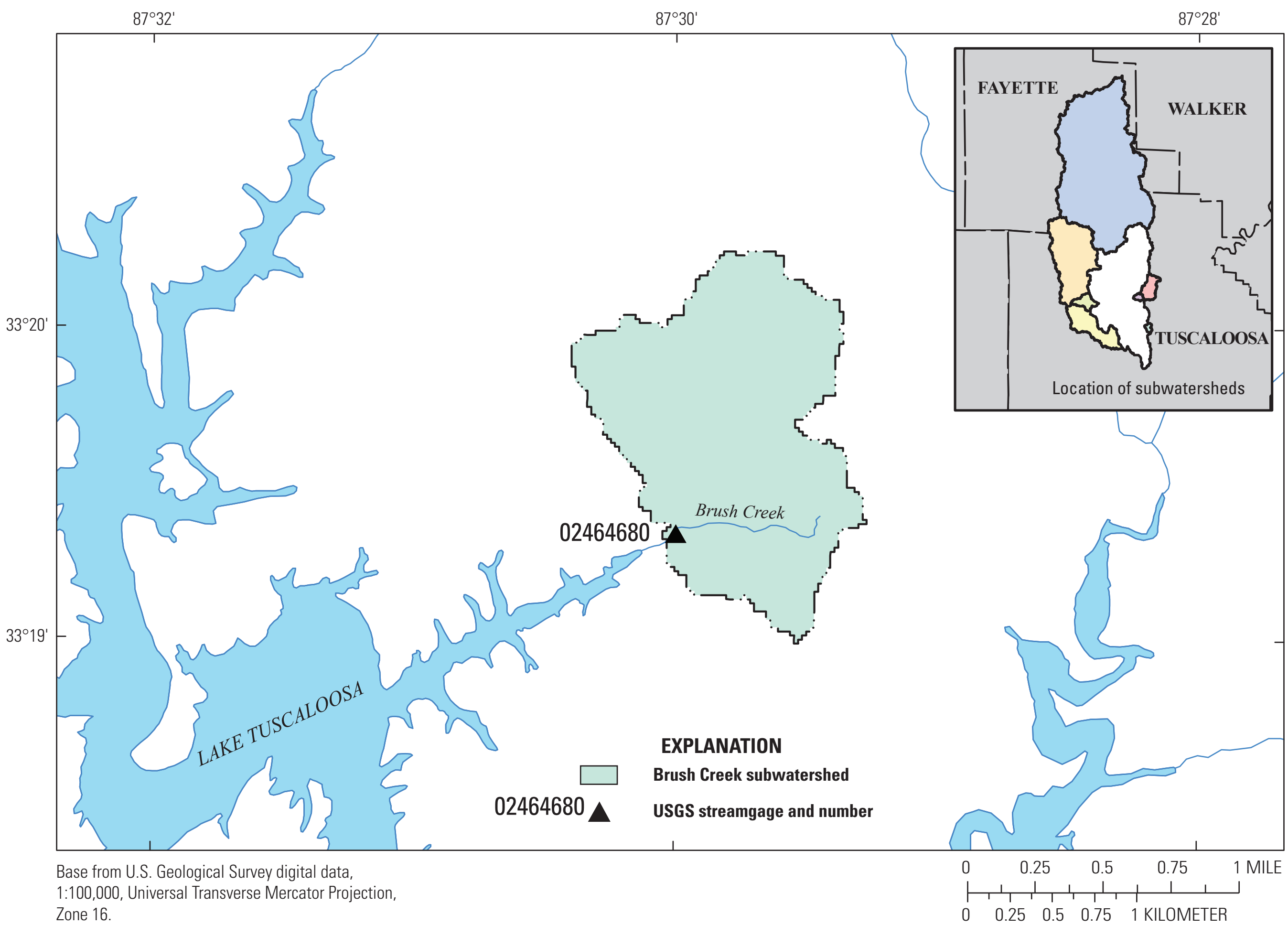

Figure 42. Location of U.S. Geological Survey streamflow-gaging station 02464680 Brush Creek near Northport, Alabama, and the contributing drainage area.

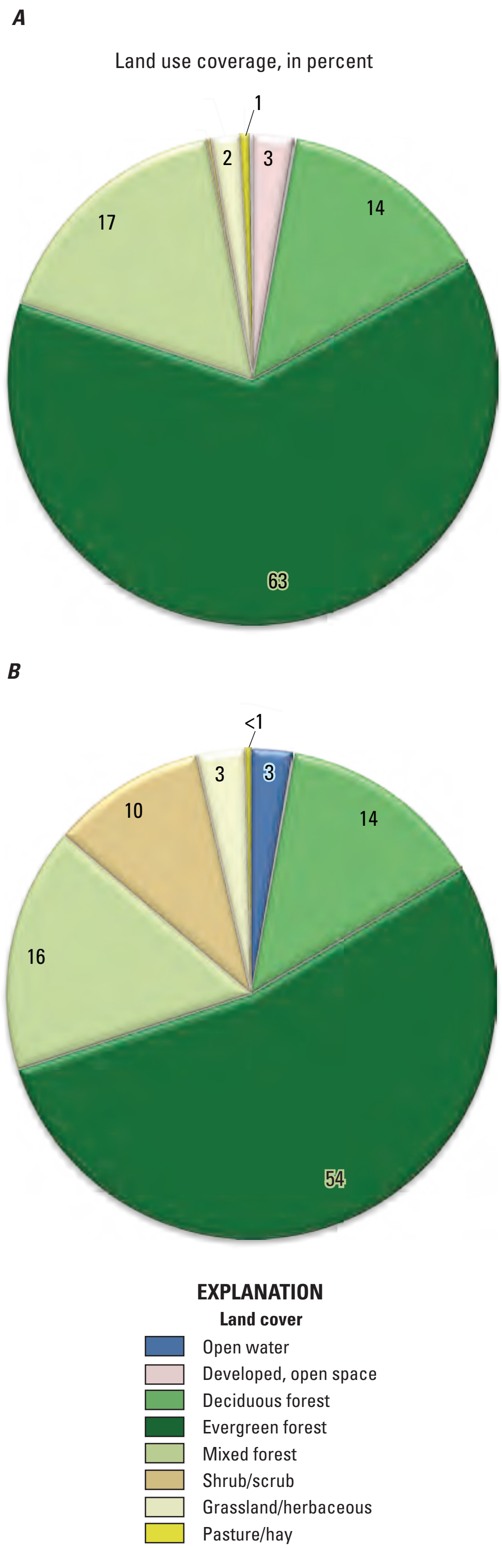

Figure 43. Percentage of land-use coverage at U.S. Geological Survey streamflow-gaging station 02464680 Brush Creek near Northport, Alabama. (*A*) National Land Cover Database 2001. (*B*) National Land Cover Database 2006.

Table 13. Historical streamflow and suspended-sediment data for U.S. Geological Survey streamflow-gaging station 02464680 Brush Creek near Northport, Alabama.

[Data are available at *http://waterdata.usgs.gov/al/nwis/qw*. Dates are by month/day/year. Abbreviations: ft^3/s, cubic foot per second; mg/L, milligram per liter]

Date	Mean streamflow (ft^3/s)	Suspended sediment (mg/L)	Suspended sediment discharge (tons/day)
10/4/1982	0.88	11	0.03
11/4/1982	1.2	0	0
12/6/1982	2.8	5	0.04
1/4/1983	2	10	0.05
2/3/1983	3.7	4	0.04
3/2/1983	3.4	3	0.03
4/4/1983	2.6	1	0.01
5/2/1983	2.6	7	0.05
6/2/1983	2.7	11	0.08
7/5/1983	2.5	20	0.14
8/2/1983	1.9	10	0.05
9/2/1983	1.6	8	0.03

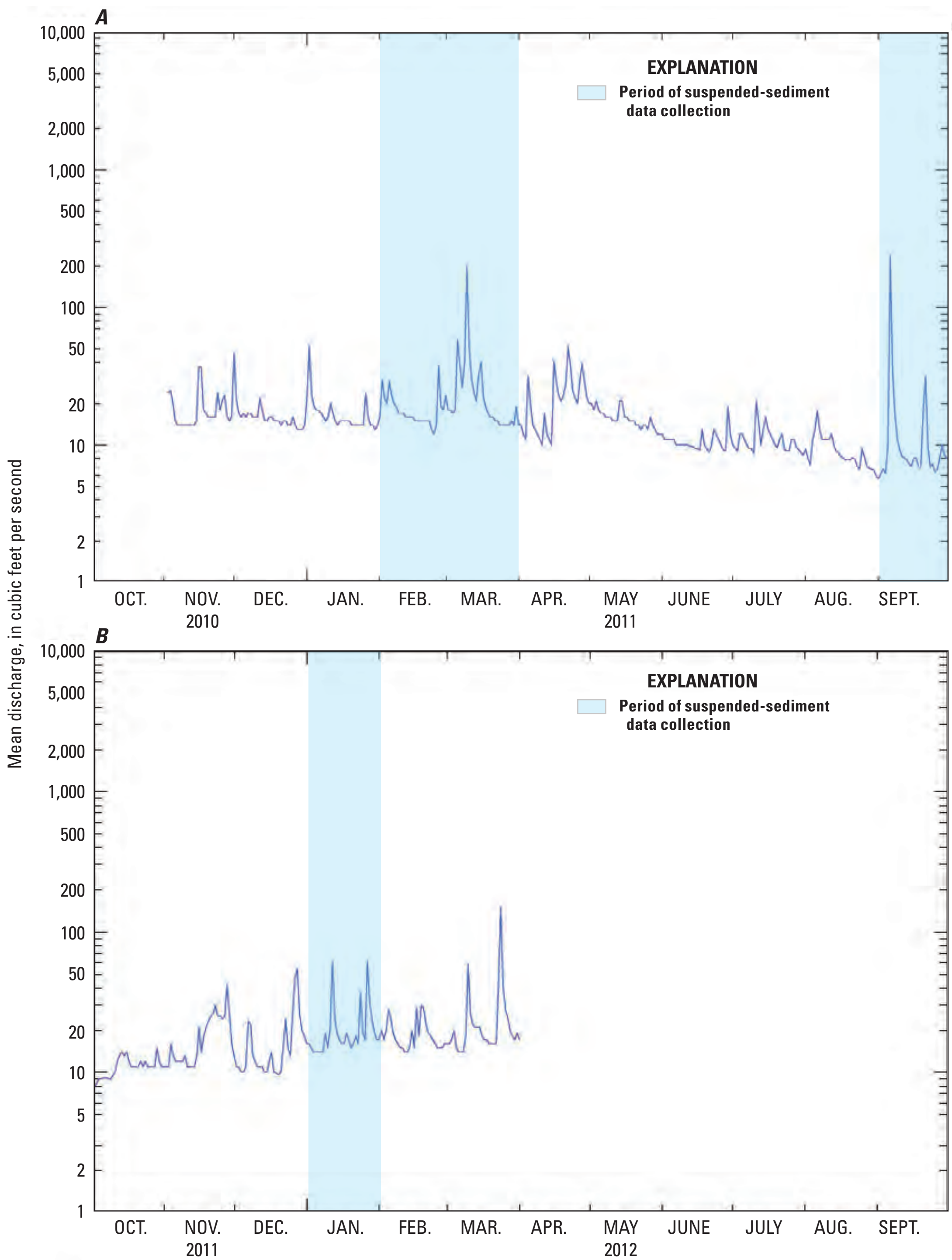

Figure 44. Streamflow hydrograph at U.S. Geological Survey streamflow-gaging station 02464680 Brush Creek near Northport, Alabama. (*A*) 2011 water year. (*B*) 2012 water year.

Suspended Sediment

Suspended-sediment samples were collected at the Brush Creek streamgage as described in the Suspended-Sediment Data Collection section (see Approach and Methods). Samples were collected for six storm events (table 14) during four of the events, samples were collected by both manual and automatic methods. In addition to the storm events, samples were collected on a monthly basis to represent normal daily streamflows. The samples were collected to reflect seasonal variations and their variable antecedent conditions. Figure 44 illustrates the periods of data collection and how they relate to the annual hydrograph. The automatic pump sampler was set to collect samples at a time interval of 15 minutes to ensure that suspended-sediment concentrations were collected over the rise, peak, and fall of the hydrograph. The sediment hydrographs for Brush Creek were graphically compared to the streamflow hydrographs. The majority of the rain events sampled had a sediment hydrograph whose peak tracked the streamflow hydrograph, which could be an indication of a uniform source of sediment and (or) a lack of sediment stored in the channel.

Table 14. Summary of suspended-sediment samples collected at U.S. Geological Survey streamflow-gaging station 02464680 Brush Creek near Northport, Alabama.

[Data are available at *http://waterdata.usgs.gov/al/nwis/qw*. Dates are by month/day/year. Abbreviations: ft^3/s, cubic foot per second; <, less than]

Date	Collection type*	Peak streamflow (ft^3/s)	Annual exceedance probability
2/25/11	Automatic	18	<67
2/28/11	Manual/Automatic	7.3	<67
3/5/11	Manual/Automatic	35	<67
3/9/11	Manual/Automatic	70	<67
9/5/11	Manual/Automatic	130	<67
1/26/12	Automatic	18	<67

* Automatic—suspended-sediment samples collected by an automatic water sampler. Manual—manually collected isokenetic suspended-sediment samples.

Estimation of Suspended-Sediment Loads from Brush Creek

The suspended-sediment concentrations of the automatic pump samples were adjusted to reflect average streamflow-weighted suspended-sediment concentrations as described in the Data Analysis section (see Approach and Methods). The suspended-sediment concentrations were converted to suspended-sediment discharges and graphically and statistically compared with streamflow (Q) to develop instantaneous sediment-transport curves. A linear regression equation (ordinary least squares) was developed, and a smearing estimator applied, for the rise and fall of the hydrograph and using all data (composite). The composite instantaneous sediment transport curve was used to compute an average daily sediment discharge for every day (November 2010–October 2011). These values were regressed with the average daily flow to provide a daily transport curve (eq. 9; fig. 45):

$$SSQ = 0.2798\,(Q)^{1.5774} \text{ for } Q \leq 130 \text{ ft}^3\text{/s} \qquad (9)$$

where

SSQ is the average daily suspended-sediment discharge, in tons per day; and

Q is the average daily streamflow, in cubic feet per second.

The application of the daily suspended-sediment transport curve is limited to the maximum measured flow, 130 ft^3/s, at which suspended-sediment samples were collected. Suspended-sediment transport curves have the tendency to flatten out once the available sediment is exhausted and additional rainfall no longer increases the suspended sediment. Because this exact point is not known, extrapolation of the suspended-sediment transport curve should be based on engineering judgment and analysis.

Annual load and yield values were estimated for suspended sediment at Brush Creek for the collection period (November 2010–October 2011). The suspended-sediment discharge was estimated for each day of the water year using the daily transport curve (eq. 9). Load computations were performed by application of the mid-interval method (Porterfield, 1972). The estimated average annual load for the collection period, based on average daily streamflow and the Brush Creek daily transport curve, is 280 tons, and the average yield is 300 tons/mi^2.

It is worth noting that the daily mean sediment concentration is a time-weighted mean value. Thus, calendar days can be divided and analyzed in shorter periods of time when water or sediment discharge exceed certain limits. The term “subdivide” refers to the division of data for a calendar day into shorter periods of time to obtain correct daily mean values of streamflow or suspended-sediment discharge when one or both change beyond certain limits during the day. The values for these periods are then summed to obtain values of suspended-sediment discharge. Computation of a daily mean sediment discharge requires subdivision of the day when both water discharge and concentration are changing because the average of the products of two variable quantities is not the same as the product of the averages of the quantities (Porterfield, 1972). For comparison, the instantaneous suspended-sediment transport curve, streamflow, and the mid-interval method were used to compute an estimated average annual load for the collection period, based on a 15-minute interval. This computation resulted in an average annual load that is 6 percent more than the load calculated using the average daily values. It was determined that the use of the average daily streamflow and the daily transport curve is more practical for estimating average annual loads.

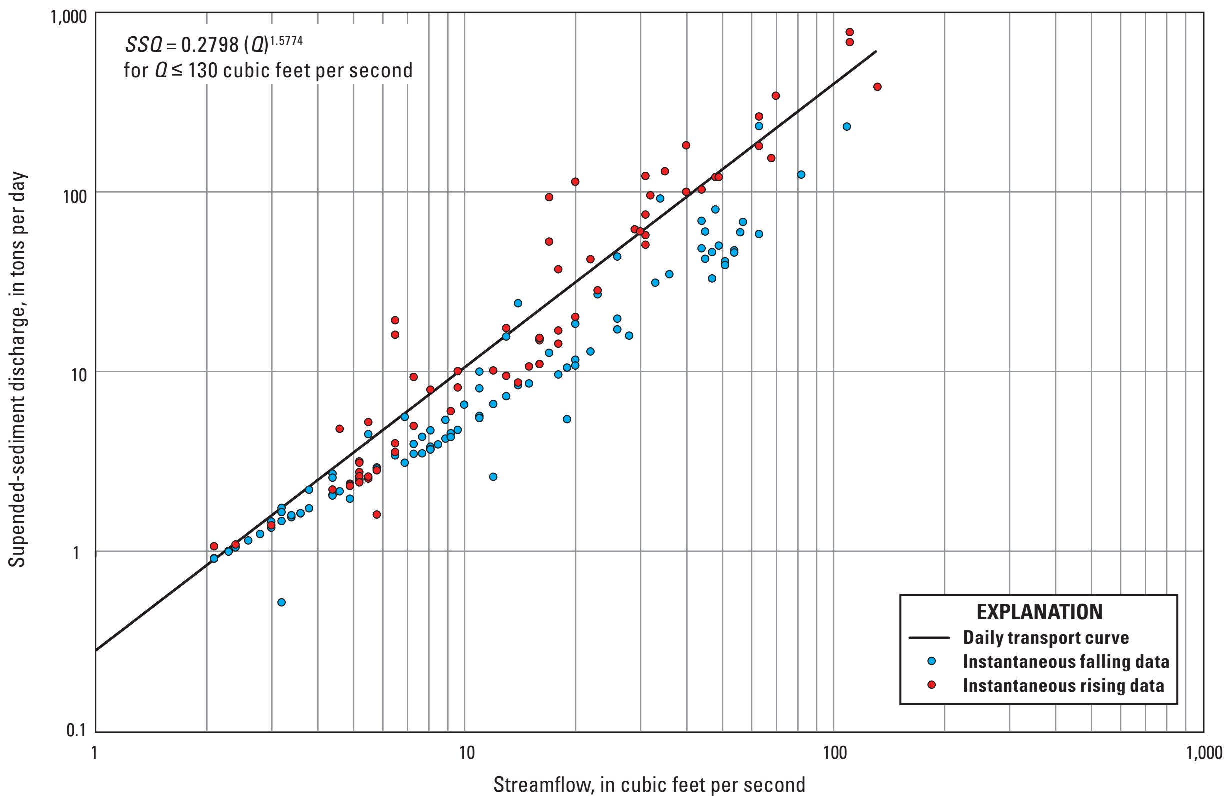

Figure 45. Daily suspended-sediment transport curve for U.S. Geological Survey streamflow-gaging station 02464680 Brush Creek near Northport, Alabama. *SSQ*, suspended sediment concentration; *Q*, streamflow in cubic feet per second,.

Estimation of Suspended-Sediment Loads to Lake Tuscaloosa

*Q*uantification of sediment inflows from the contributing watersheds is useful to help focus management efforts in targeting areas around the reservoir. The comparison of the seven tributaries monitored in this study can be made by examining the loads and resulting yields for each site. Loads were computed for each site for the period of sediment data collection (table 15). The estimated load is computed from the daily average flow and daily sediment transport curve for each site. Because the installation of some streamgages was not finished by the beginning of the water year, the estimated load corresponds to a 1-year period beginning at the time of installation (table 15). The estimated load is dependent on the hydrologic conditions during the period for which it is estimated. The study area was under drought conditions during portions of the data collection period. Therefore, the loads/yields estimated are compared based on the year for which they were estimated. This assumes that the hydrologic conditions were roughly the same at the selected sites during the year of data collection. Comparison of the annual runoff for the period of data collection and the average runoff for the entire period of streamflow data record for the long-term stations (North River, Turkey Creek, Binion Creek, and Carroll Creek) shows that annual runoff for the period during data collection was well above the average values for 2009 and 2010 and below the average values for 2011. This difference is illustrated by the North River streamgage. The average annual runoff for the period of record (1939–2011) is 22.9 in. The average runoff for the 2009–11 water years is 28.6, 32.4, and 19.7 in., respectively. Because of the close proximity of the sites, it can be assumed that the North River streamgage is a good representative for all seven sites.

Because the sampling sites vary in drainage area from 0.92 to 223 mi^2, the best comparison is the load per unit area, or yield. The 2009 estimated yields for North River, Turkey Creek, and Carroll Creek are 360, 540, and 840 tons/mi^2, respectively. Based on this comparison, Carroll Creek contributes more sediment per square mile to the Lake Tuscaloosa reservoir than North River or Turkey Creek. Inspection of table 15 shows that the Carroll Creek streamgage had a smaller peak flow (higher probability of exceedance) during data collection than North River or Turkey Creek, and yet it still had a higher yield than the other sites.

Table 15. Summary of suspended-sediment data collection, transport curves, and loads for seven tributaries to the Lake Tuscaloosa reservoir, Alabama.

[mi^2, square mile; ft^3/s, cubic foot per second; $tons/mi^2$, tons per square mile; *SSQ*, suspended-sediment concentration; *Q*, streamflow in cubic feet per second; %, percent; <, less than; >, greater than; ≤, less than or equal to; ≥, greater than or equal to]

Station number	Station name	Drainage area (mi^2)	Streamflow gage installation date	Streamflow gage discontinued date	Water year ISCO sampler was installed	Sediment collection period	Daily transport curve equation	Daily transport curve streamfllow limits (ft^3/s)	Probability of exceedance of maximum streamflow sampled	Estimated suspended-sediment load (tons)	Time period of estimated load	Estimated suspended-sediment yield ($tons/mi^2$)
02464000	North River near Samantha AL	223	December 1938	—	—	Jaunary 2009–July 2009	$SSQ = 0.0135\,(Q)^{1.4483}$	$Q \leq 15{,}400$	>10 %	81,400	Oct 2008–Sept 2009	360
02464146	Turkey Creek near Tuscaloosa, AL	6.16	February 1981	—	2009	December 2008–September 2009	$SSQ = 0.1858\,(Q)^{1.3919}$	$Q \leq 1{,}020$	<20%	3,350	Oct 2008–Sept 2009	540
02464360	Binion Creek below Gin Creek near Samantha, AL	57.2	October 1986	—	2010	October 2009–March 2011	$SSQ = 0.043\,(Q)^{1.2689}$	$Q \leq 2{,}900$	>50%	6,860	Oct 2009–Sept 2010	120
02464385	Pole Bridge Creek near Samantha, AL	4.67	January 2010	March 2011	2010	March 2010–February 2011	$SSQ = 0.0169\,(Q)^{1.9611}$	$Q \leq 96$	<67 %	400	Jan 2010–Dec 2010	86
02464503	Tierce Creek above Northport, AL	1.03	November 2010	March 2012	2011	March 2011–January 2012	$SSQ = 0.2249\,(Q)^{1.3927}$	$Q \leq 110$	<67 %	200	Nov 2010–Oct 2011	190
02464660	Carroll Creek at St Hwy 69 nr Northport, AL	20.9	November 2008	—	2009	December 2008–August 2009	$SSQ = 0.0627\,(Q)^{1.6113}$	$Q \leq 670$	<67 %	17,600	Nov 2008–Oct 2009	840
02464680	Brush Creek near Northport, AL	0.92	November 2010	March 2012	2011	February 2011–January 2012	$SSQ = 0.2798\,(Q)^{1.5774}$	$Q \leq 130$	<67 %	280	Nov 2010–Oct 2011	300

The 2010 estimated yields for Binion Creek and Pole Bridge Creek are 120 and 86 tons/mi^2, respectively. The Binion Creek streamgage was established 1986; flow statistics indicate that the annual mean streamflow was above average in 2010 and was higher than 2009 and 2011. The largest peak flow recorded at the streamgage during data collection was greater than the 50-percent chance exceedance. It should be noted that both basins had timber harvested during the data collection period.

The 2011 estimated yields for Tierce Creek and Brush Creek are 190 and 300 tons/mi^2, respectively. These streamgages were newly installed and do not have flow statistics to qualify the hydrologic conditions based on historical data. However, based on flood-frequency relations, both sites had peak streamflows less than the 67-percent probability of exceedance, indicating drier hydrologic conditions for the 2011 estimation period.

Another quantitative approach for comparing the seven suspended-sediment sampling sites is to estimate the sediment load/yield for each year where streamflow data are available (table 16). Streamflow data are available for North River, Turkey Creek, Binion Creek, and Carroll Creek for the entire study period (2009–11). The daily transport curves were used to estimate sediment loads and yields for each site where data were available; however, it should be noted that the Turkey Creek and Binion Creek drainage basins had ongoing timber harvest operations, and so these numbers are for comparison purposes only. Comparison of the sampling sites over the 3 years shows that Carroll Creek consistently had the highest estimated sediment yield during the study period. The sampling site with the second highest sediment yield was Turkey Creek.

Comparison of the sites monitored indicates that Carroll Creek is the largest producer of suspended-sediment under similar hydrologic conditions and the largest producer per square mile for the timeframes estimated. Aerial photography and bathymetric surveys also support that Carroll Creek has experienced increased sediment deposition in the upstream extent of the backwater. Carroll Creek is also the only basin that has a substantial percentage (11 percent) of urban land use. It is also the only basin that experienced an increase in urban land use from 2001 to present.

Table 16. Estimated suspended-sediment load for seven tributaries to the Lake Tuscaloosa reservoir, Alabama.

[mi^2, square mile; tons/mi^2, tons per square mile; —, no data]

Station number	Station name	Drainage area (mi^2)	Estimated suspended-sediment load in tons (Estimated suspended-sediment yield in tons/mi^2)		
			2009	2010	2011
02464000	North River near Samantha, AL	223	81,400 (360)	78,100 (350)	51,100 (230)
02464146	Turkey Creek near Tuscaloosa, AL	6.16	3,370 (550)	2,670 (430)	2,160 (350)
02464360	Binion Creek below Gin Creek near Samantha, AL	57.2	6,820 (120)	6,860 (120)	4,060 (71)
02464385	Pole Bridge Creek near Samantha, AL	4.67	— —	400 (86)	— —
02464503	Tierce Creek above Northport, AL	1.03	— —	— —	200 (190)
02464660	Carroll Creek at St Hwy 69 nr Northport, AL	20.9	17,600 (840)	10,800 (520)	7,270 (350)
02464680	Brush Creek near Northport, AL	0.92	— —	— —	280 (300)

Summary

The U.S. Geological Survey (USGS), in cooperation with the City of Tuscaloosa, conducted an investigation of suspended-sediment loads to the Lake Tuscaloosa reservoir, which is formed by the impoundment of the North River in Fayette and Tuscaloosa Counties, Alabama. One of the objectives of the investigation was to develop sediment transport curves and estimate annual loads for seven tributaries to the reservoir. *Q*uantification of sediment inflows from the contributing watersheds is needed by the City of Tuscaloosa because this information will augment ongoing collaboration with local and State groups and help focus their management efforts to target areas around the reservoir. Sedimentation damages a reservoir if the decreased storage capacity prevents the reservoir from supplying the full service for which it was designed. Sufficient capacity must be maintained in domestic water-supply reservoirs to assure continuity of supply during periods of prolonged drought and to meet expected increases in water demand.

Storm and monthly suspended-sediment samples were collected at seven tributaries to Lake Tuscaloosa from October 2008 to January 2012. Suspended-sediment concentrations and streamflow measurements were statistically analyzed and correlated to develop daily suspended-sediment transport curves. The individual basins were investigated for temporal changes in land use. Based on the stability of the basin and anthropogenic changes, historical measurements were compared to, or included in, the resulting sediment transport curves.

Basinwide in 2006 (Fry and others, 2011), forested land (68 percent) was the primary land cover. Comparison of historical imagery and the National Land Cover Database (2001 and 2006) indicated that the greatest temporal land-use change was attributed to timber harvest. The land cover in 2006 was indicative of this change with shrub/scrub land (12 percent) being the secondary land use in the basin. Agricultural land use (10 percent) was represented predominantly by hay and pasture or grasslands. Urban land use was minimal, accounting for 4 percent of the entire basin.

Data collection at the seven tributaries (North River, Turkey Creek, Binion Creek, Pole Bridge Creek, Tierce Creek, Carroll Creek, and Brush Creek) was spread out over the 2009, 2010, and 2011 water years. Of the seven sites, three (North River, Turkey Creek, and Binion Creek) had existing USGS streamflow-gaging stations (streamgages). At the remaining four sites (Pole Bridge Creek, Tierce Creek, Carroll Creek, and Brush Creek), streamgages were installed.

The North River streamgage (station number 02464000) was established in December 1938 on North River at County Road 38, near Samantha. The drainage area upstream of the North River streamgage is 223 square miles (mi^2), and it contributes 53 percent of the total drainage area to Lake Tuscaloosa. Review of land-use data (1992, 2001, and 2006) indicates that the only major changes in the basin occurred in forested land. Comparison of the two timeframes indicated that between 1992 and 2001 and between 2001 and 2006, the basin had an approximately 4- and 3-percent reductions in forested land, respectively. The minor changes indicate that overall the basin is stable; therefore, the inclusion of historical data would be acceptable. Historical data include streamflow and periodic monthly sediment samples collected from 1979 to 1983. Suspended-sediment data were also collected at this streamgage from March to September 1975 to estimate the long-term average sediment yield of 300 tons per year per square mile. Streamflow and isokinetic equal-width-increment suspended-sediment data were collected during the 2009 water year. The combination of the historical and current data was used to develop a daily sediment transport curve. The transport curve is rated to a streamflow value of 15,400 cubic feet per second (ft^3/s), the maximum streamflow sampled. This value corresponds to a greater than 10-percent probability of exceedance. The daily transport curve was used in conjunction with the daily average streamflow to estimate a load for the 2009 water year. The load estimated for the 2009 water year is 81,400 tons, which corresponds to a yield of 360 tons per square mile (tons/mi^2). The average yield estimated compares closely with the long-term average sediment yield of 300 tons per square mile per year estimated in 1975.

The Turkey Creek streamgage (station number 02464146) was established in February 1981 on Turkey Creek at Turkey Creek Road, near Tuscaloosa. The drainage area upstream of the Turkey Creek streamgage is 6.16 mi^2. Inspection of land use (1992, 2001, and 2006) indicates that the only major changes in the basin occurred in forested land. Comparison of the two timeframes indicated that between 1992 and 2001 and between 2001 and 2006, the basin had an approximately 12- and 7-percent reductions in forested land, respectively. Monthly sediment samples were collected 1,000 feet (ft) downstream at the State Highway 69 streamgage (station number 02464145) for the 1977 to 1979 water years. Additionally, various samples were collected at Turkey Creek near Patterson Chapel (station number 02464149). Because of the changes in forested land, the historical data were not included in the development of current transport curves. Streamflow, automatically collected suspended-sediment samples, and isokinetic equal-width-increment suspended-sediment samples were collected during the 2009 water year. Comparison of the historical data and the 2009 data showed an upward trend of the measured suspended-sediment discharge. The 2008–09 data were used to develop a daily sediment transport curve. The transport curve is rated to a streamflow value of 1,020 ft^3/s, the maximum streamflow sampled. This value corresponds to a less than 20-percent probability of exceedance. The daily transport curve was used in conjunction with the daily average streamflow to estimate a load for the 2009 water year. The load estimated for the 2009 water year is 3,350 tons, which corresponds to a yield of 540 tons/mi^2.

The Binion Creek streamgage (station number 02464360) was established in October 1986 on Binion Creek at Old Fayette Road, near Tuscaloosa. The drainage area for this site is 57.2 mi^2, and it contributes 14 percent of the surface drainage area to Lake Tuscaloosa. Inspection of land use (1992, 2001, and 2006) indicates no major change in land use from 1992 to 2001 and a decrease in forested land (7 percent) from 2001 to 2006. Current conditions were examined using 2009 and 2010 aerial photography in conjunction with the National Land Cover Database 2006 (NLCD 2006). Comparison of the two timeframes indicated that between 2006 and 2009 and between 2009 and 2010, approximately 2 and 1.4 mi^2, respectively, of timber were harvested. The deforested areas closest to the streamgage were further inspected. Approximately 1 mi upstream of the Binion Creek streamgage, 33 acres of timber were harvested.

Monthly sediment samples were collected at the Binion Creek streamgage for the 1983 water year. The historical data were used to show temporal trends because the land-use changes described above indicate a decrease in forested land. Streamflow, automatic suspended-sediment samples, and isokinetic equal-width-increment suspended-sediment samples were collected during the 2010 water year. Comparison of the 1983 and 2010 datasets indicates a similar trend for the lower values of streamflow. The 2009–10 data were used to develop a daily sediment transport curve. The transport curve is rated to a streamflow value of 2,900 ft^3/s, the maximum streamflow sampled. This value corresponds to a greater than 50-percent probability of exceedance. The daily transport curve was used in conjunction with the daily average streamflow to estimate a load for the 2010 water year. The load estimated for the 2010 water year is 6,860 tons, which corresponds to a yield of 120 tons/mi^2.

The Pole Bridge Creek streamgage (station number 02464385) was established in January 2010 on Pole Bridge Creek at Old Fayette Road, near Samantha. The drainage area for this site is 4.67 mi^2. Inspection of land use (1992, 2001, and 2006) indicates no major change in land use from 1992 to 2001 and a decrease in forested land (6 percent) from 2001 to 2006. Current conditions were examined using 2009 and 2010 aerial photography in conjunction with the NLCD 2006. Comparison of the two timeframes indicated that between 2009 and 2010, approximately 43 acres of timber were harvested. Streamflow, automatic suspended-sediment samples, and isokinetic equal-width-increment suspended-sediment samples were collected during the 2010 water year. The 2009–10 data were used to develop a daily sediment transport curve. The transport curve is rated to a streamflow value of 96 ft^3/s, the maximum streamflow sampled. This value corresponds to a less than 67-percent probability of exceedance. The daily transport curve was used in conjunction with the daily average streamflow to estimate a load for the 2010 calendar year. The load estimated for 2010 is 400 tons, which corresponds to a yield of 86 tons/mi^2.

The Tierce Creek streamgage (station number 02464503) was established in November 2010 on Tierce Creek at Tierce Creek Road, near Northport. The drainage area for this site is 1.03 mi^2. Inspection of land use (1992, 2001, and 2006) indicates that the only major changes in the basin were a decrease in forested land. Comparison of the two timeframes indicated that between 1992 and 2001 and between 2001 and 2006, the basin had approximately a 6-percent reduction in forested land during both timeframes. Streamflow, automatic suspended-sediment samples, and isokinetic equal-width-increment suspended-sediment samples were collected during the 2011–12 water years. The data were used to develop a daily sediment transport curve. The transport curve is rated to a streamflow value of 110 ft^3/s, the maximum streamflow sampled. This value corresponds to a less than 67-percent probability of exceedance. The daily transport curve was used in conjunction with the daily average streamflow to estimate a load for November 2010 to October 2011. The load estimated for the timeframe is 200 tons, which corresponds to a yield of 190 tons/mi^2.

The Carroll Creek streamgage (station number 02464660) was established in November 2008 on Carroll Creek at State Highway 69, near Northport. The drainage area for this site is 20.9 mi^2. Inspection of land use (1992, 2001, and 2006) indicates that the only major changes in the basin were decreases in forested land and urbanization. Comparison of the two timeframes indicated that between 1992 and 2001 and between 2001 and 2006, the basin had approximately a 3-percent reduction in forested land during both timeframes. During these same timeframes, urbanization increased 0.5 and 3 percent, respectively. Streamflow, automatic suspended-sediment samples, and isokinetic equal-width-increment suspended-sediment samples were collected during the 2009 water year. The 2008–09 data were used to develop a daily sediment transport curve. The transport curve is rated to a streamflow value of 670 ft^3/s, the maximum streamflow sampled. This value corresponds to a less than 67-percent probability of exceedance. The daily transport curve was used in conjunction with the daily average streamflow to estimate a load for November 2008 to October 2009. The load estimated for the timeframe is 17,600 tons, which corresponds to a yield of 840 tons/mi^2.

The Brush Creek streamgage (station number 02464680) was established in November 2010 on Brush Creek at Turner Road, near Northport. Inspection of land use (1992, 2001, and 2006) indicates no major change in land use from 1992 to 2001 and a decrease in forested land (10 percent) from 2001 to 2006. Streamflow, suspended-sediment samples collected using an automatic pump sampler, and isokinetic equal-width-increment suspended-sediment samples were collected during the 2011and 2012 water years. The data were used to develop a daily sediment transport curve. The transport curve is rated to a streamflow value of 130 ft^3/s, the maximum streamflow sampled. This value corresponds to a less than 67-percent probability of exceedance. The daily transport curve was used in conjunction with the daily average streamflow to estimate a load for November 2010 to October 2011. The load estimated for the timeframe is 280 tons, which corresponds to a yield of 300 tons/mi^2.

*Q*uantification of sediment inflows from the contributing watersheds is useful to help focus management efforts in targeting areas around the reservoir. Loads were computed for each site for the period of sediment data collection. The estimated load is dependent on the hydrologic conditions during the period for which it is estimated. The study area was under drought conditions during portions of the data collection period. Therefore, the loads/yields estimated are compared based on the year for which they were estimated. This assumes that the hydrologic conditions were roughly the same at the selected sites during the year of data collection. Because the sampling sites vary in drainage area from 0.92 to 223 mi^2, the best comparison is the load per unit area, or yield.

The 2009 estimated yields for North River, Turkey Creek, and Carroll Creek are 360, 540, and 840 tons/mi^2, respectively. Based on this comparison, Carroll Creek contributes more sediment per square mile to the Lake Tuscaloosa reservoir than either North River or Turkey Creek. The Carroll Creek streamgage had a smaller peak flow (higher probability of exceedance) during data collection than North River or Turkey Creek, yet it still had a higher yield than the other sites.

The 2010 estimated yields for Binion Creek and Pole Bridge Creek were 120 and 86 tons/mi^2, respectively. The Binion Creek streamgage was established in 1986, and flow statistics indicate that the annual mean streamflow was above average in 2010 and was higher than 2009 and 2011. The largest peak flow recorded on the streamgage during data collection was greater than a 50-percent chance exceedance. It should be noted that both basins had timber harvested during the data collection period.

The 2011 estimated yields for Tierce Creek and Brush Creek were 190 and 300 tons/mi^2, respectively. These streamgages were both newly installed and do not have flow statistics to qualify the hydrologic conditions based on historical data. However, based on flood-frequency relations, both sites had peak streamflows with less than a 67-percent probability of exceedance, indicating drier hydrologic conditions for the 2011 estimation period.

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