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AN ANALYSIS OF RATES OF SEDIMENTATION LOADING AT SELECTED STATIONS IN THE BEAR CREEK SYSTEM, ALABAMA AND MISSISSIPPI, 2003-2004

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By

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On Figure 5, the date 12/11/04 should be 12/11/03.

On Figure 11, the date 1/15/03 should be 1/15/04.

On Figure 12, the date 12/11/04 should be 12/11/03

On Figure 17, the date 1/15/03 should be 1/15/04.

AN ANALYSIS OF RATES OF SEDIMENTATION LOADING AT SELECTED STATIONS IN THE BEAR CREEK SYSTEM, ALABAMA AND MISSISSIPPI, 2003-2004

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EXECUTIVE SUMMARY

Alteration of aquatic systems and habitats has had a profound influence on the native mussel fauna over much of North America. Results of these activities include physical stresses such as scour, deposition of sediments, altered suspended sediment loads, altered and often more variable flow regimes, permanent temperature changes and variable temperature fluctuations, long periods of oxygen depletion, changes in hydrostatic pressure, and filtering or blocking of light transmission. Some combinations of these changes have contributed to extreme changes in the Bear Creek mussel fauna based on comparisons of limited mussel sampling in the early and mid 20th century to more intensive surveys in the last decade of that century. However, the Bear Creek system retains one of the most diverse mussel faunas remaining in the lower Tennessee River basin, including the only population of one critically imperiled species, the Cumberlandian combshell, *Epioblasma brevidens,* remaining in the lower Tennessee basin.

Bear Creek is a 136-mile-long southern tributary of the Tennessee River. However, impoundments, channelization, and a flood diversion channel (floodway) have modified the stream into a series of relatively short, disjunct, free-flowing segments. The system drains 942 mi^2 in Colbert, Franklin, Lawrence, and Winston Counties, Alabama, and Itawamba and Tishomingo Counties, Mississippi, with about 85 percent of the watershed in Alabama. Monitoring sites for this study were selected on three tributaries to Bear Creek (Rock Creek at County Road 1, Colbert County, Alabama; Cedar Creek at Mingo, Tishomingo County, Mississippi; Little Bear Creek downstream from Alabama Highway 247, Franklin County, Alabama) and two sites on Bear Creek (at Alabama Highway 24 near Red Bay, Franklin County, Alabama; and at County Road 86, Tishomingo County, Mississippi, at the downstream end of the floodway).

Sedimentation is a process by which eroded particles of rock are primarily transported by moving water from areas of relatively high elevation to areas of relatively low elevation where the particles are deposited. Erosion rates are accelerated by human activity related to agriculture,

construction, timber harvesting, unimproved roadways, or any activity where soils or geologic units are exposed or disturbed. Sediment loads in streams are primarily composed of relatively small particles suspended in the water column (suspended load) and larger particles that move on or periodically near the streambed (bedload). The rate of transport of sediment is a complex process controlled by a number of factors primarily related to land use, precipitation runoff, erosion, stream discharge and flow velocity, stream base level, and physical properties of the sediment. Streamflow in the Bear Creek watershed is highly regulated. This is an additional factor that affects the movement of sediment.

Suspended sediment loads were estimated using the computer model Regr_Cntr.xls (*Regression with Centering*), an Excel adaptation of the USGS seven-parameter regression model. The largest suspended sediment load, both in total mass (41,458 tons per year (t/yr)) and in mass per unit area (498 tons per square mile per year (t/mi^2/yr)), is transported by the segment of Bear Creek between the Bear Creek monitoring sites (the segment including the floodway). The smallest loads were transported by Rock Creek (1,502 t/yr and 30 t/mi^2/yr) and Little Bear Creek (4,881 t/yr and 127 t/mi^2/yr).

Bedloads were estimated using a regression model applied with mean daily stream discharge. The largest bedload, both in total mass (12,491 t/yr and in mass per unit area (272 t/mi^2/yr, was transported by the segment of Bear Creek between the Bear Creek monitoring sites (the segment including the floodway). The smallest bedload was transported by Rock Creek (241 t/yr and 1.8 t/mi^2/yr).

In areas where land-use practices have caused the land surface to erode, sediment is transported by overland flow to relatively small tributary streams where it is transported to the major streams. The floodway appears to be a major sediment deposition center and conduit for sediment transport. A comprehensive evaluation of land use and areas of origin of sediment in the Bear Creek watershed will be performed during the 2005 water year.

INTRODUCTION

Freshwater mussels are considered one of the most imperiled faunal groups in North America based on the rapid extinction rate and preponderance of imperiled species when compared to other organismal groups (Master, 1993; Williams and others, 1993; Lydeard and Mayden, 1995). Historic records of 91 percent of the recognized North American fauna exist from the southeastern U.S. and 60 percent from Alabama (Neves and others, 1997). Of particular importance is the Tennessee River system, considered to be the most diverse system in the world (Ortmann, 1918, 1924, 1925; Remington and Clench, 1925; Dennis, 1984; Garner and McGregor, 2001). That diversity is due to the overlap of faunas from two important centers of mussel distribution, the Ohioan of the interior basin and the Cumberlandian of the interior highlands of the south, along with elements whose origins are unknown. The Cumberlandian species are restricted to the Cumberland River system upstream of Clarksville, Tennessee, and the Tennessee River system upstream of Muscle Shoals, Alabama, and occupy streams with generally high gradient and high quality and quantity water with clean gravel substrata (Ortmann, 1924; van der Schalie, 1939). The Ohioan species are more tolerant of streams known to be characterized by sluggish flow and less consolidated substrata (Ortmann, 1925; van der Schalie, 1939; Stansbery, 1964). Many Cumberlandian species have proven to be highly intolerant of modern habitat degradation and are now imperiled or extinct.

The Bear Creek system has experienced extreme changes to its mussel fauna based on a comparison of results of limited mussel sampling in the early and mid 20th century to more intensive surveys in the last decade of that century. One recognized change is the apparent altering of the faunal composition. This was indicated by a decrease in Cumberlandian species diversity and an increase in diversity of species of the Ohioan assemblage or of unknown origin (McGregor and Garner, 2004). These faunal changes were presumed to be the result of the effects of habitat alterations (such as those caused by impoundment, channelization, wastewater discharge and possibly other point-source pollution, and agricultural and silvicultural practices) that caused a shift in habitat quality or in the potential fish host composition.

The mussel fauna of the Bear Creek system has suffered greatly from modern perturbations to habitat. During recent intensive sampling, no evidence of 11 species historically known from the drainage, representing 24% of the cumulative species list, was found (McGregor and Garner, 2004). However, a diverse and viable fauna remains in a short reach of the main channel. The population of the Cumberlandian combshell, *Epioblasma brevidens* (Lea, 1831), in Bear Creek is the only known population of this species in the lower Tennessee River system (McGregor and Garner, 2004). Only two populations of the slabside pearlymussel, *Lexingtonia dolabelloides* (Lea, 1840), remain downstream of Paint Rock River, this one and one in Duck River of middle Tennessee (Ahlstedt, 1991). With concerted effort to identify and mitigate sources of impairment, it is possible the existing fauna in Bear Creek could eventually repopulate other areas of the system. With this healthy population in the lower free-flowing reach, mussel recovery in at least parts of the system is possible, should the roots of environmental problems be identified and mitigated. That the Bear Creek population includes remnants of its Cumberlandian element and is one of few or maybe the only viable population of some species in the lower Tennessee River system makes it even more valuable with respect to conservation of this group, which has suffered declines through most of its range.

Human altering of aquatic communities has had a profound influence on the native mussel fauna. Results of man's activities include physical stresses such as scour, deposition of sediments, altered suspended sediment loads, altered and often variable flow regimes, permanent temperature changes and variable temperature fluctuations, long periods of oxygen depletion, changes in hydrostatic pressure, and filtering or blocking of light transmission (Ellis, 1936; Bates, 1962; Bogan, 1993). Chemical effects from such sources as point and non-point source pollution (NPS) also affect the existence of mussels, which filter suspended particulate matter from the water column during normal feeding and store it in their tissues. The lethal effects of chemical uptake may be either acute or chronic (Naimo, 1995).

Impoundment is considered the primary negative anthropogenic influence on native mussel populations (Ortmann, 1924; Scruggs, 1960; Isom, 1969; Fuller, 1974; Benke, 1990; Williams and others, 1992; Yeager, 1993). Impoundment of free-flowing streams creates an environment unsuitable to native mussels that depend on that flow by altering the chemical and physical properties of the water body and therefore affecting feeding, respiration, reproduction, and other activities necessary for survival of the species. However, the downstream effects of impoundment are equally important. There may appear to be sufficient streamflow to support mussels on casual observation. However, changes in seasonality, intensity and duration of flow along with patterns of scour and deposition of sediment and altered components of suspended sediments, the source of mussel food, often renders such habitat unsuitable as well (Vaughn and Taylor, 1999). Furthermore, fragmenting of populations by impoundments may effectively diminish the functional survival of mussel populations by interrupting the gene flow and possibly reducing the availability of potential host fishes (Bogan, 1993).

Powell (1999) found that, although many water-quality and habitat variables were covariant with the density of cropland in streams in the Eastern Highland Rim Ecoregion of the lower Tennessee River basin, fish communities (and therefore mussel communities) primarily responded to the cumulative effects of sedimentation. Roy and others (2003) found that riffle habitats exhibited the strongest relations with environmental variables among riffle, pool, and bank habitats studied, and were negatively affected by both physical (*e.g*. bed mobility) and chemical (*e.g*. specific conductance, nutrient concentrations) variables.

In 2003, the Alabama Soil and Water Conservation Committee (SWCC) established a website with information on Watershed Assessment issues in hydrologic unit codes (HUCs) statewide (http://swcc.state.al.us/watershedmenu.htm). Such information as sources and rates of sedimentation, pesticides, animal and domestic waste production, wastewater discharge, and urban non-point source pollution were addressed. Subwatersheds within the Bear Creek system with the highest potential for pollution include Buzzard Roost, Cedar, Rock, and Upper Bear Creeks. About 2.7 million tons of sediment is introduced into the system annually, 58 percent in the main channel Bear Creek, 20 percent in Cedar Creek, and the remainder in Little Bear, Rock, and Buzzard Roost Creeks.

Bear Creek has seen a 32 percent reduction in available free-flowing stream channel after impoundment of its lower reach by Pickwick Reservoir and the permanent flooding of two reaches of the main channel by Bear Creek and Upper Bear Creek Dams. Only two significant reaches of free-flowing stream channel remain, one downstream of each dam, and mussels are essentially absent from one and are still relatively abundant in the other. The upper (Upper Bear Creek) has been the recipient of extensive biological sampling due to its history of poor water quality and reduced biological system function. The other, downstream of Bear Creek Dam, retains the only viable mussel population extant in the Bear Creek system, though its free-flowing integrity is compromised by the 9-mile-long floodway that cuts across the main channel of Bear Creek five times and also by sedimentation (TVA, 1994; McGregor, 2003). The floodway shunts water during high-water events, reducing flooding of agricultural land in the floodplain. In some reaches the floodway and main channel of Bear Creek are indistinguishable.

The objective of this study was to determine the major contributors of sediment to Bear Creek downstream of Bear Creek Dam, where the only viable mussel population persists in the system. The information gathered during this study will assist regulatory agencies and other responsible parties in determining specific problem areas where remediation efforts need to be implemented to best protect that fauna.

DESCRIPTION OF THE WATERSHED

Bear Creek (fig. 1) is a 136-mile-long southern tributary of the Tennessee River. The system drains 942 mi^2 in Colbert, Franklin, Lawrence, and Winston Counties, Alabama, and Itawamba and Tishomingo Counties, Mississippi, with about 85 percent of the watershed in Alabama (Mettee and others, 1996). Elevation ranges from 1,116 feet above mean sea level (msl) in the headwaters to 420 feet above msl at its confluence with the Tennessee River (Hollingsworth, 1991). Bear Creek contributes about 2.5 percent of the flow through Pickwick Reservoir annually (Dycus and Meinert, 1996). According to Taylor and Hall (1974), in the early 1970s approximately 70 percent of the watershed was in forest, 20 percent was in miscellaneous use such as commercial enterprise, roads, towns, etc., and 10 percent was in agricultural use. The Forest Riparian Habitat Survey conducted by the U.S. Environmental Protection Agency (USEPA) (1990) reported over 75 percent of the watershed to be forest. Conservation assessment worksheets compiled by local U.S.D.A. Soil and Water Conservation Districts (SWCDs) reported the following percentages of land use: forestland (72 percent), pastureland (12 percent), cropland (6 percent), urban land (3 percent), open water (3 percent), mining (2 percent), and other (2 percent) (Alabama Department of Environmental Management, 2000). Phillips (2001) reported that land use within the watershed showed little change between 1972 and 1992.

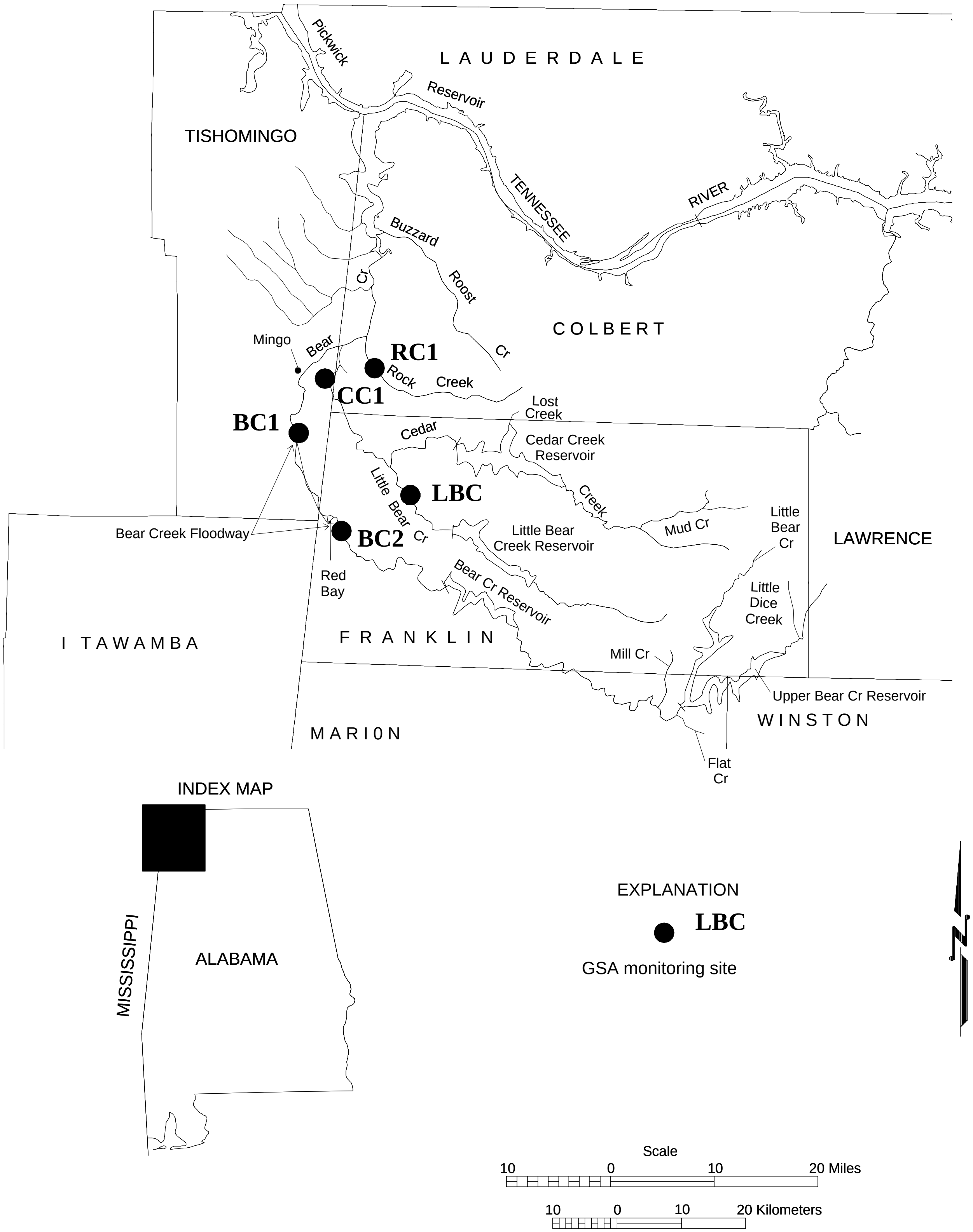


Figure 1.—Location of monitoring sites and evaluated streams in the Bear Creek watershed.

Isom and Yokley (1968) discussed the areal physiography in detail. Bear Creek proper originates in the Warrior Basin of the Cumberland Plateau (Pottsville Formation of Pennsylvanian age), with some of the eastern tributaries originating in the Moulton Valley of the Highland Rim (Parkwood Formation, Bangor Limestone, Hartselle Sandstone and Pride Mountain Formation of Mississippian age). The middle reaches and western tributaries of the system lie within the Fall Line Hills of the East Gulf Coastal Plain (Eutaw and Gordo Formations of Cretaceous age). The East Gulf Coastal Plain is characterized by gently rolling hills, sharp ridges, prairies, and broad alluvial flood plains over sediments composed of sand, gravel, porous limestone, chalk, marl, and clay. The Fall Line is a distinct topographic feature marking the boundary where the harder rocks of the Appalachian Plateau and Interior Low Plateau plunge under the unconsolidated sediments of the East Gulf Coastal Plain. The lower 16 miles of Bear Creek flow through the Tennessee Valley of the Highland Rim (Tuscumbia Limestone of Mississippian age). The Tennessee Valley district is the largest district in the Highland Rim section and is comprised of level red clay lands on both sides of the Tennessee River derived from the Tuscumbia limestone. There are numerous springs, small ponds, and lime sinks formed by solution of the underlying limestone. Most streams in the southern portion of the Highland Rim originate in the Pottsville escarpment of the Warrior Basin, flow northward through the Moulton Valley, and cut through Little Mountain in narrow valleys deeply cut in the sandstone beds (Isom and Yokley, 1968; Sapp and Emplaincourt, 1975; Harris and others, 1991; Osborne and others, 1992).

Pickwick Reservoir of the Tennessee River has inundated the lowermost 20 miles of Bear Creek since 1938. Four dams built within the Bear Creek system between 1969 and 1979 inundated several thousand acres and changed long reaches of free-flowing streams into large pools. Two of these dams were on the main channel, at Bear Creek mile (BCM) 75 (1969) and BCM 116 (1978), and one each on Little Bear Creek at mile 11.6 (1975), and Cedar Creek at mile 23.3 (1979). Other human alterations to habitat associated with flood control include channelization of selected reaches and a 9-mile-long floodway along an 18-mile-long stretch of the stream designed to limit flooding of about 15,000 acres of floodplain during high water events (TVA, 2001).

Bear Creek proper is about 136 miles long; however, impoundments, channelization, and the floodway have modified the stream into a series of relatively short, disjunct, free-flowing segments. These segments are separated by impoundments. Downstream of these impoundments the stream has been channelized and often cleared of riparian vegetation and attendant canopy cover, the banks covered in uniform quarried stone, and sections of the streambeds covered with concrete. The floodway interconnects some reaches of the creek and is separated from the main channel by weirs. This floodway was engineered to shunt water from the main channel of Bear Creek during high water events, therefore lessening the effects of occasional floods on surrounding agricultural land in the floodplain.

Pickwick Reservoir of the Tennessee River impounds the lowermost 20 miles of the main channel of Bear Creek, Bear Creek Reservoir impounds a further 16 miles, and Upper Bear Creek Reservoir another 7 miles. The cumulative reduction in free-flowing stream channel totals about 43 miles, or about 32 percent of the available stream channel. Substantial free-flowing stream reaches are now limited to the reaches immediately downstream of dams, and the effects of impoundments on downstream water quality exacerbate the severity of reduction in available physical habitat for freshwater mussels.

SEDIMENTATION

Sedimentation is a process by which eroded particles of rock are transported primarily by moving water from areas of relatively high elevation to areas of relatively low elevation, where the particles are deposited. Upland sediment transport is primarily accomplished by overland flow and rill and gully development. Lowland or floodplain transport occurs in streams of varying order, where upland sediment joins sediment eroded from floodplains, stream banks, and streambeds. Erosion rates are accelerated by human activity related to agriculture, construction, timber harvesting, unimproved roadways, or any activity where soils or geologic units are exposed or disturbed. Excessive sedimentation is detrimental to water quality, destroys biological habitat, reduces storage volume of water impoundments, impedes the usability of aquatic recreational areas, and causes damage to structures. Sediment loads in streams are primarily composed of relatively small particles suspended in the water column (suspended solids) and larger particles that move on or periodically near the streambed (bedload).

Five monitoring sites were established to measure sediment loads, flow conditions, and field water quality parameters. In addition, a limited number of bank pins were installed to measure stream bank erosion. The sites were on three tributaries to Bear Creek (Rock Creek at

Colbert County Road 1 near Maud; Cedar Creek at Mingo, Tishomingo County, Mississippi; and Little Bear Creek downstream from Alabama Highway 247, Franklin County, Alabama) and two sites on Bear Creek (at Alabama Highway 24 near Red Bay, Franklin County; and Tishomingo County Road 86 at the downstream end of the floodway) (fig. 1).

Sedimentation Loads Transported by Project Streams

The rate of sediment transport is a complex process controlled by a number of factors primarily related to land use, precipitation runoff, erosion, stream discharge and flow velocity, stream base level, and physical properties of the sediment. Streamflow in the Bear Creek watershed is highly regulated, and this is an additional factor affecting the movement of sediment. Streamflow is affected by releases of water from four impoundments in response to flooding or expected flooding. Flow rates may increase rapidly and may continue at high levels for extended periods several times each year.

One of the primary land uses in the Bear Creek watershed is row crop agriculture on rich soils at lower elevations. These soils were formed by deposition of sediment from upland areas and by weathering of the Bangor Limestone that underlies the floodplain. Timbering and construction occur at higher elevations on areas underlain by unconsolidated sands and gravels of the Eutaw Formation and Tuscaloosa Group. These and other land uses cause erosion that supplies sediment to Bear Creek and its tributaries. Excessive sedimentation causes changes in base level elevation of streams in the watershed and triggers downstream movement of the material as streams attempt to regain base level equilibrium. The movement of this material is accelerated by periodic extreme precipitation events and releases of impounded water that cause increased streamflow and streamflow velocity.

Due to the grain size composition of sediment in the Bear Creek watershed, movement of the material is controlled primarily by streamflow velocity. Large amounts of clay and silt may be suspended in the water column and transported at relatively low velocities during any discharge event greater than base flow. However, much of the bedload material in Bear Creek consists of coarse sand and gravel eroded from the Tuscaloosa Group (Cretaceous age fluvial sediments) that forms ridges in the mid and downstream portions of the watershed, and silt, sand, and cobbles eroded from the Pottsville Formation (Pennsylvanian age sandstone and shale) that underlies the headwaters of the watershed. In order for the bedload material to be transported, a critical flow velocity threshold must be exceeded. This occurs during large precipitation events or during releases of water from impoundments in the watershed. The duration of each pulse of bedload migration is dependent on the magnitude and duration of the discharge event. However, observations made during this project indicate that the downstream migration of bedload continues for three to seven days after the peak discharge and is not correlative to large discharge or the critical streamflow velocity threshold. Once the streambed material is mobilized, the level of energy required to keep the material moving on the falling limb of the hydrograph is much less. Therefore, large amounts of bedload will continue to be transported even as the stream approaches baseflow conditions. This is particularly true at the downstream end of the Bear Creek floodway, where base level is profoundly affected by large volumes of gravel bed material that forms longitudinal bars in the stream channel.

Streamflow Conditions

Sediment transport conditions in the Bear Creek watershed are segregated by particular stream segments based on instream conditions. Rock Creek (drainage area upstream from monitoring site RC1 to headwaters, 50 mi^2) is the only unregulated stream in the investigation and exhibits flashy flow conditions typical of most unregulated upland streams in the Upper Coastal Plain Paleozoic Complex Province (Cook and Kopaska-Merkel, 1997). The average observed streamflow conditions for all streams in the investigation are included in table 1.

Cedar Creek (drainage area upstream from monitoring site CC1 to headwaters, 331 mi^2) (drainage area upstream from monitoring site CC1 to Cedar Creek Dam, 56 mi^2) is highly regulated with periodic rapid changes in flow conditions.

Little Bear Creek (drainage area upstream from monitoring site LBC, 83 mi^2) (drainage area upstream from monitoring site LBC to Little Bear Creek Dam, 32 mi^2) exhibits flashy flow conditions and may experience periodic rapid changes in discharge in response to releases of water from Little Bear Creek Reservoir.

Bear Creek at Alabama Highway 24 (drainage area upstream from monitoring site BC2 to headwaters, 267 mi^2) (drainage area upstream from monitoring site BC2 to Bear Creek Dam, 21 mi^2) exhibits less flashy discharge due to the proximity of the monitoring site to Bear Creek Reservoir. However, this stream may experience periodic rapid changes in discharge in response to releases of water from Bear Creek Reservoir.

Table 1. Streamflow characteristics for selected sites in the Bear Creek watershed

Monitoring Site	Average Discharge (cfs[1])	Maximum Discharge (cfs)	Minimum Discharge (cfs)	Average Flow Velocity (ft/s)	Maximum Flow Velocity (ft/s)	Minimum Flow Velocity (ft/s)
Rock Creek	61	311	3	1.20	1.42	0.89
Cedar Creek	538	2,749	25	2.02	3.22	1.33
Little Bear Creek	144	741	7	2.00	2.8	1.12
Bear Creek at Tishomingo Co. Rd. 86	655	3,346	31	2.25	2.8	1.60
Bear Creek at Ala. Hwy. 24	467	2,390	22	1.45	2.02	1.02

[1]cfs- cubic feet per second
[2]ft/s- feet per second

Bear Creek at Tishomingo County Road 86 near the downstream end of the floodway (drainage area upstream from monitoring site BC1 to headwaters, 313 mi^2) (drainage area upstream from monitoring site BC1 to Bear Creek Dam, 67 mi^2) (drainage area upstream from monitoring site BC1 to monitoring site BC2, 46 mi^2) was observed to have the highest mean streamflow velocity and is subject to rapid increases in discharge in response to large precipitation events and releases of water from Bear Creek Reservoir.

Suspended Sediment

The basic concept of constituent loads in a river or stream is simple. However, the mathematics of determining a constituent load may be quite complex. The constituent load is the mass or weight of a constituent that passes a cross-section of a stream in a specific amount of time. Loads are expressed in mass units (*e.g.*, tons, kilograms) and are considered for time intervals that are relative to the type of pollutant and the watershed area for which the loads are calculated. Loads are calculated from concentrations of constituents obtained from analyses of water samples and stream discharge, which is the volume of water that passes a cross-section of the river in a specific amount of time.

The computer model Regr_Cntr.xls (*Regression with Centering*) was selected to calculate suspended sediment loads for this project. The program is an Excel adaptation of the USGS seven-parameter regression model for load estimation (Cohn and others, 1992). It estimates loads in a manner very similar to that used most often by the Estimatr.exe (*USGS Estimator*) program. The Regr_Cntr.xls program was adapted by R. Peter Richards at the Water Quality Laboratory at

Heidelberg College (Richards, 1999). The program establishes a regression model using a calibration set of data composed of concentrations of the constituent of interest and discharge values measured at the time of water sampling. Constituent loads can be estimated for any year for which mean daily discharge data are provided.

Suspended sediment is defined as that portion of a water sample that is separated from the water by filtering. This solid material may be composed of organic and inorganic material that includes algae, industrial and municipal wastes, urban and agricultural runoff, and eroded material from geologic formations. These materials are transported to stream channels by overland flow related to storm-water runoff.

The concentrations of suspended sediment in mg/L were determined by laboratory analysis of water grab samples collected periodically for one year at variable stream discharge rates. Measured stream discharge and flow velocity can be correlated with TSS volumes from grab samples to determine mean daily volumes of suspended sediment. Suspended sediment loads for each stream during the monitoring period were determined using measured total suspended solids (TSS) concentrations and estimated mean daily discharge values entered into the regression model.

The correlation between TSS concentrations and stream discharge for Bear Creek at site BC2 is portrayed in figure 2. This graph depicts an excellent correlation of discharge and TSS. Therefore, the accuracy of the regression model in predicting suspended sediment loads is assumed to also be excellent. Measured discharge and TSS for each monitored site are depicted in figures 3 through 7. Calculated suspended sediment loads for each monitored stream are shown in table 2. Graphic representations of suspended sediment loads are depicted in figures 8 and 9. The effects of impoundments on transport of suspended sediment through the Bear Creek, Little Bear Creek, and Cedar Creek watersheds was estimated from a limited amount of data collected from the impoundments. These data indicate that approximately 40 percent of the suspended sediment that enters the impoundments is retained. This finding will be substantiated

Figure 2.--Measured discharge and total suspended solids at site BC2, Bear Creek at Alabama Highway 24 near Red Bay, Alabama.

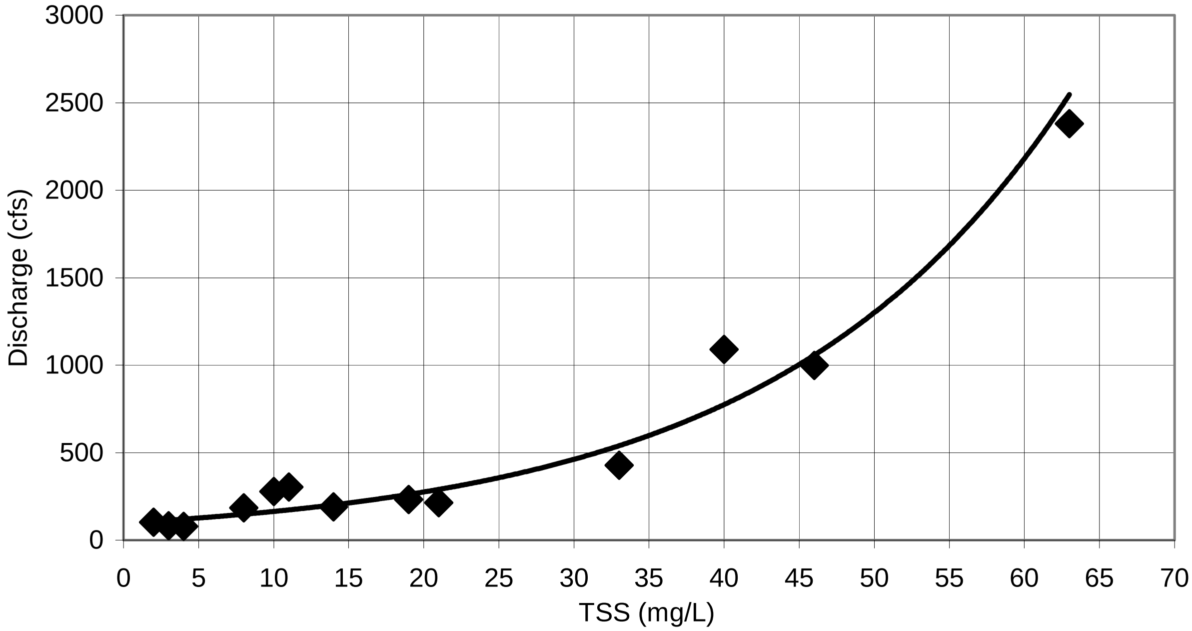


Table 2—TSS and suspended sediment loads measured in project streams

Monitoring Site	Maximum TSS (mg/L)	Minimum TSS (mg/L)	Average TSS (mg/L)	Suspended Sediment Load (t/year)	Suspended Sediment Load (t/mi^2/ year)
Rock Creek (RC1)	94	BDL[1]	20	1,502	30
Cedar Creek (CC1)	73	4	15	22,146	199 [2]
Little Bear Creek (LBC)	73	BDL	19	4,881	127 [2]
Bear Creek at Tishomingo Co. Rd. 86 (BC1)	172	BDL	44	41,458	498 [3]
Bear Creek at Ala. Hwy. 24 (BC2)	63	BDL	22	18,572	258 [2]

[1] BDL=below detection limit 4 mg/L.

[2] Effects of impoundments on suspended sediment transport were considered in calculating normalized loads.

[3] Drainage area utilized for calculation of normalized suspended sediment load from site BC1 to site BC2.

Figure 3.--Measured discharge and total suspended solids at site BC1, Bear Creek near downstream terminus of floodway, Tishomingo Co., Mississippi.

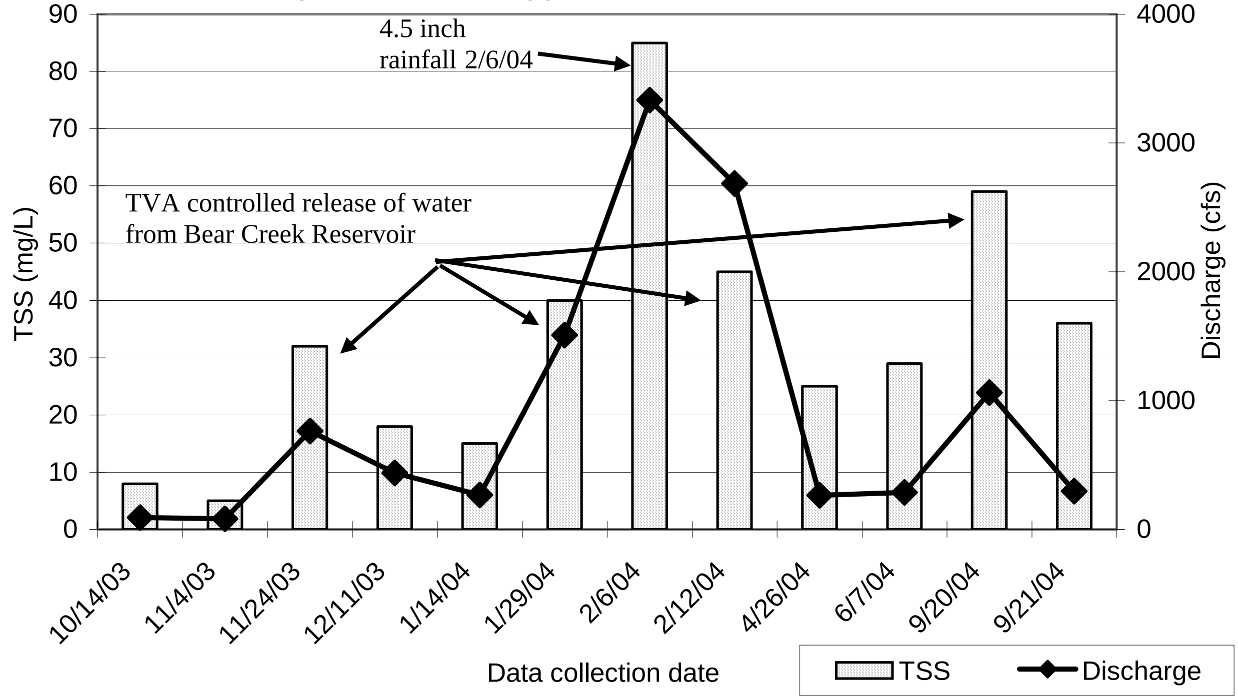


Figure 4.--Measured discharge and total suspended solids at site BC2, Bear Creek at Alabama Highway 24 near Red Bay, Alabama.

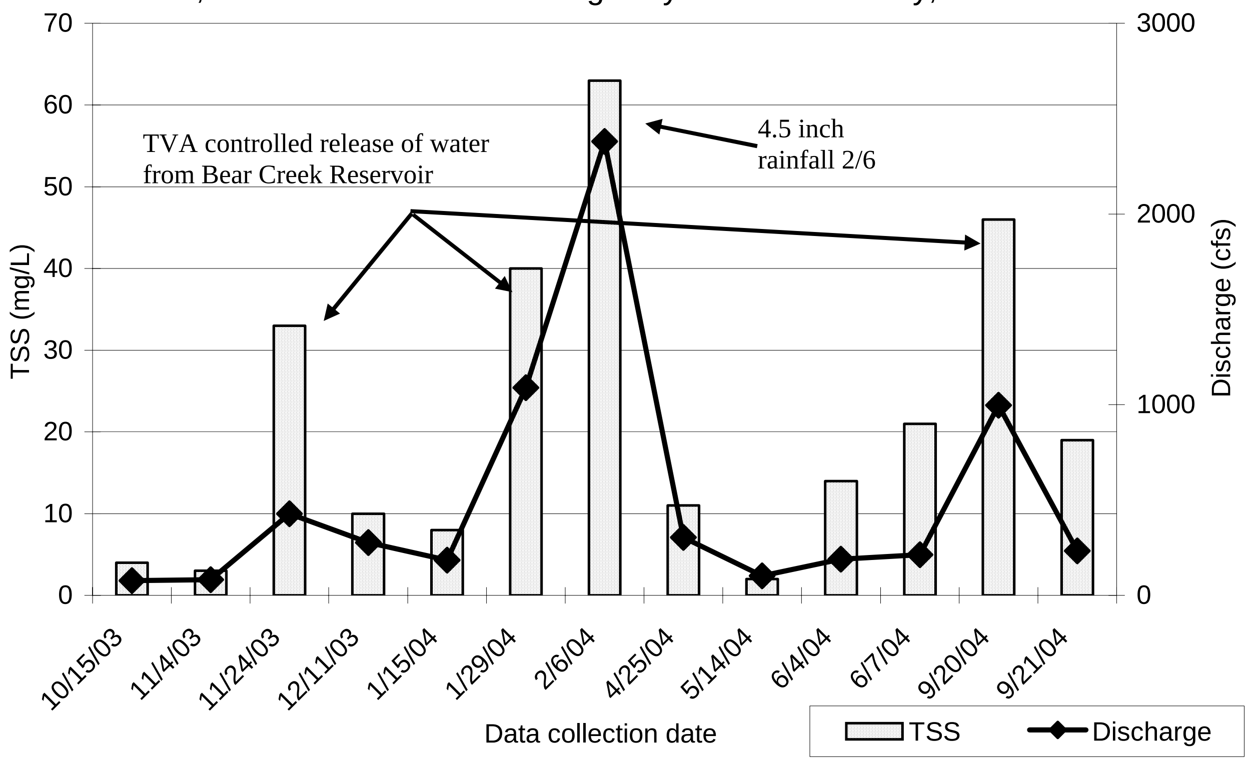


Figure 5.--Measured discharge and total suspended solids for site LBC on Little Bear Creek near Alabama Highway 247, Franklin County, Alabama.

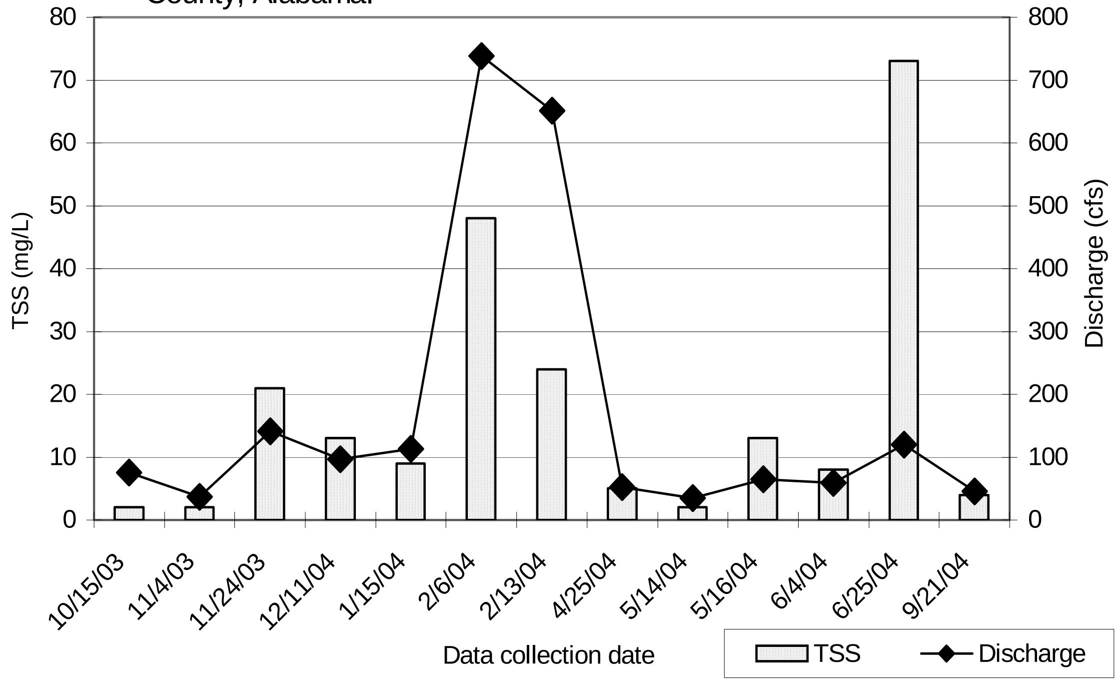


Figure 6.--Measured discharge and total suspended solids at site CC1, Cedar Creek at Mingo Road, Tishomingo County, Mississippi.

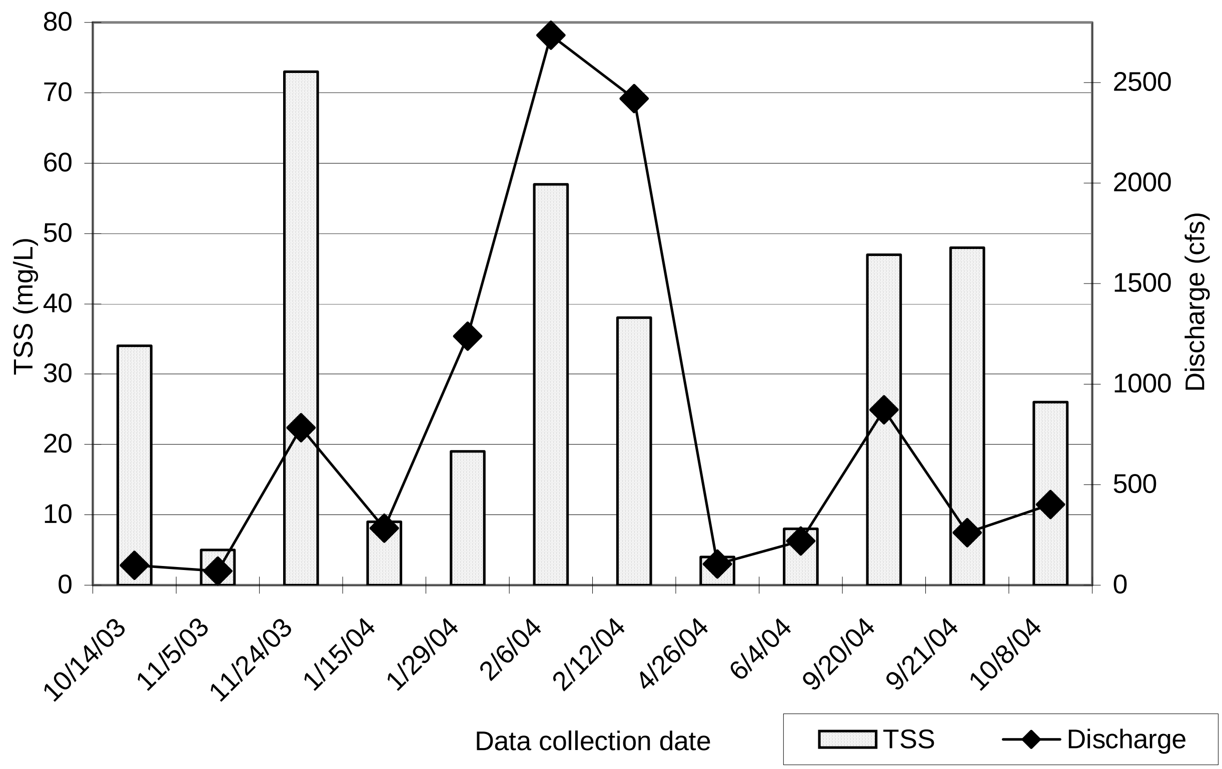


Figure 7.--Measured discharge and total suspended solids at site RC1, Rock Creek at Maud, Colbert County, Alabama.

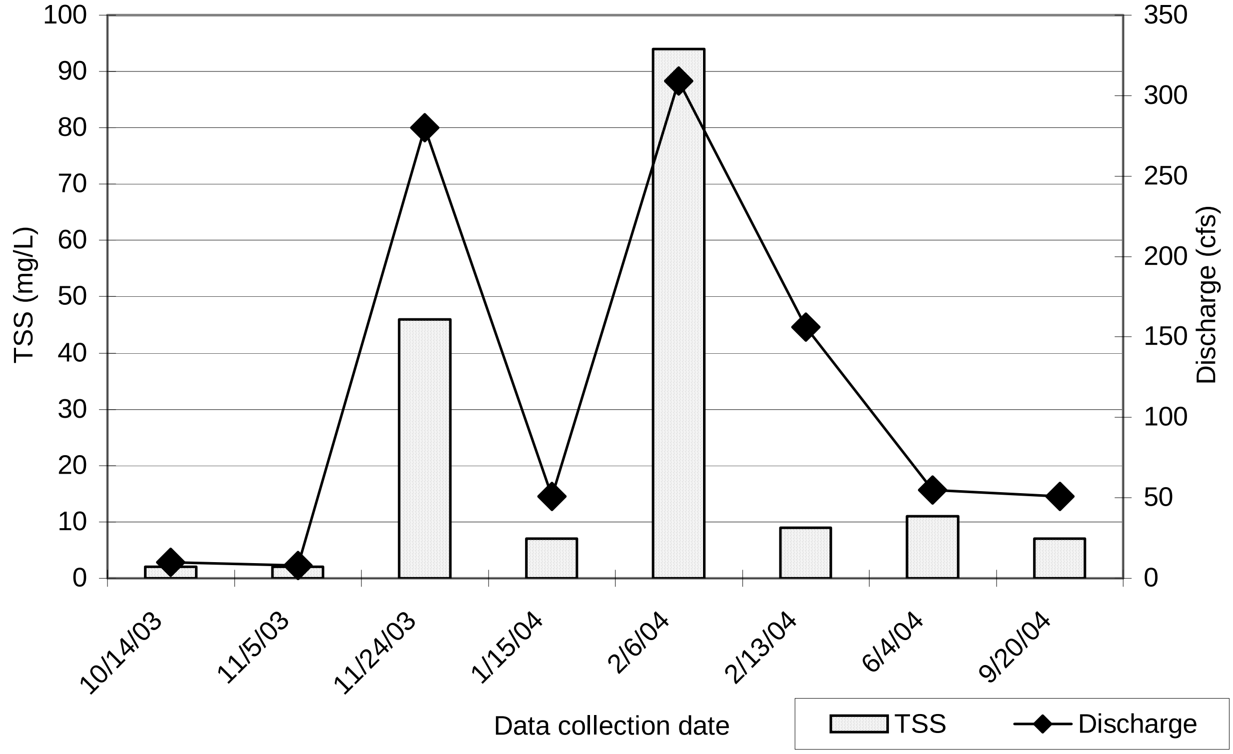


Figure 8.--Estimated suspended sediment loads for Bear Creek and selected tributaries (total watershed area).

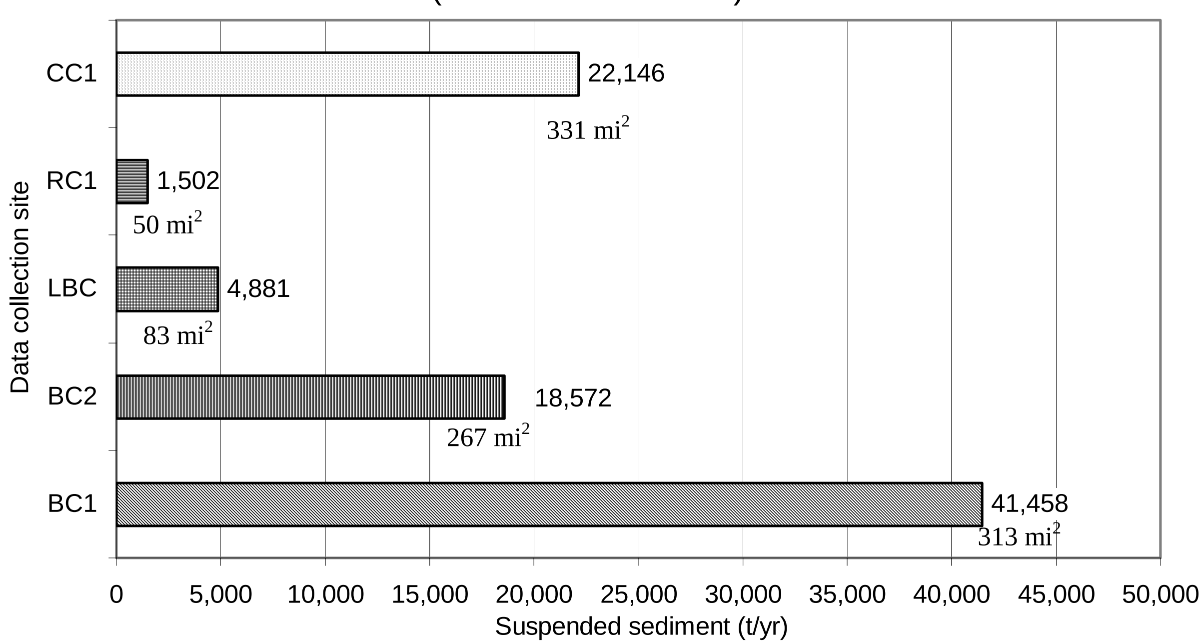
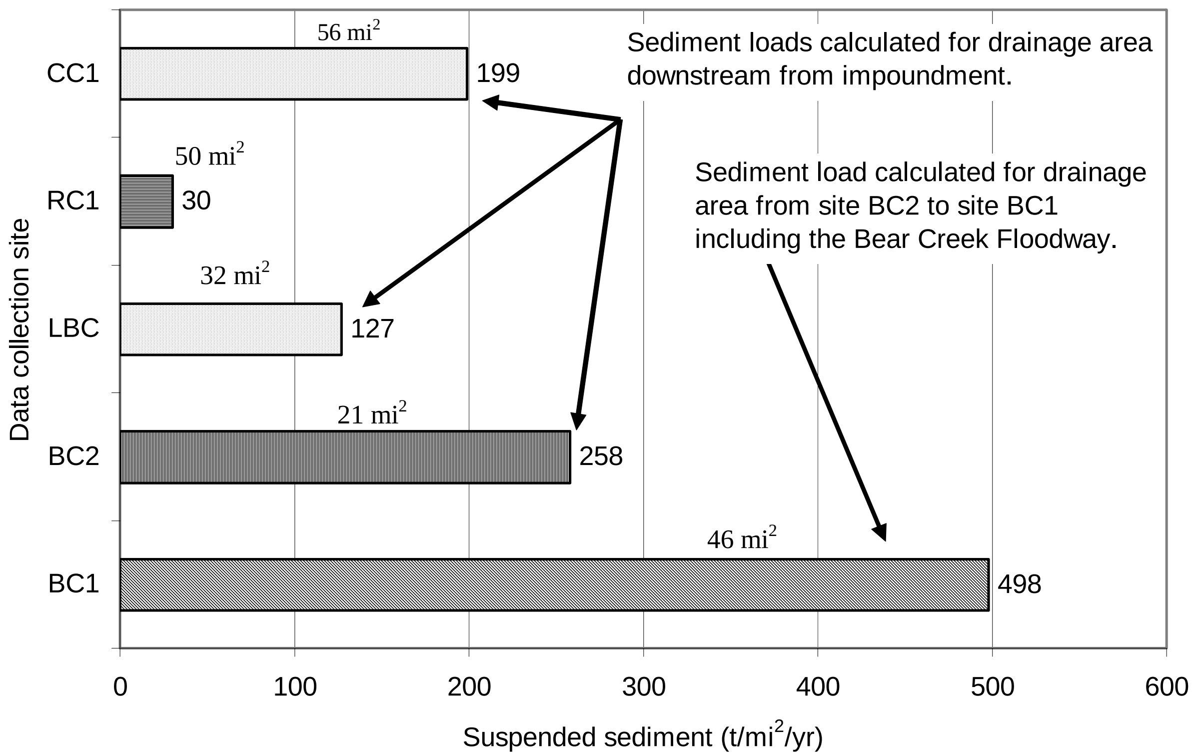


Figure 9.--Estimated suspended sediment loads for Bear Creek and selected tributaries (specified drainage areas).



with additional data collected during the 2005 water year. The retention of sediment in impoundments is considered in the calculation of normalized loads for sites BC1, BC2, LBC, and CC1 (table 2, fig. 9). Rock Creek (site RC1) is the only suspended sediment load calculated for an unregulated stream (table 2, fig. 7).

The largest suspended sediment load, both in total mass (41,458 t/yr) and in mass per unit area (498 tons t/mi^2/yr), is transported by the segment of Bear Creek between sites BC2 and BC1. The smallest loads were transported by Rock Creek (1,502 t/yr and 30 t/mi^2/yr) and Little Bear Creek (4,881 t/yr and 127 t/mi^2/yr).

Bedload Sediment

Transport of streambed material is controlled by a number of factors primarily related to stream discharge and flow velocity, erosion and sediment supply, stream base level, and physical properties of the streambed material. Most streambeds are in a state of constant flux in order to maintain a stable base level elevation. The energy of flowing water in a stream is constantly changing to supply the required power for erosion or deposition of bedload to maintain equilibrium with the local water table and regional or global sea level. Stream base level may be affected by regional or global events including fluctuations of sea level or tectonic movement. Local factors affecting base level include fluctuations in the water table elevation, changes in the supply of sediment to the stream caused by changing precipitation rates, and /or land use practices that promote excessive erosion in the floodplain or upland areas of the watershed.

Bedload sediment is composed of particles that are too large or too dense to be carried in suspension by streamflow. These particles roll, tumble, or are periodically suspended as they move downstream. Traditionally, bedload sediment has been difficult to quantify due to deficiencies in monitoring methodology or inaccuracies of estimating volumes of sediment being transported along the streambed. This is particularly true in streams that flow at high velocity or in streams with excessive sediment loads.

The Geological Survey of Alabama developed a portable bedload sedimentation rate-monitoring device that was designed to accurately measure bedload sediment in shallow sand or gravel bed streams. This device was utilized in the Bear Creek watershed, where bedload was measured periodically during the project period to obtain a well-distributed data set with respect to stream discharge and velocity. These data were used to create a regression model to determine mean daily bedload volumes. The bedload regression was applied to mean daily discharge for each monitored stream for the 2004 water year. Values of mean daily bedload mass were calculated from these data. Table 3 includes measured daily and estimated annual bedload sediment data for the Bear Creek project sites. Figures 10 through 13 graphically depict measured daily bedload sedimentation rates and stream discharge. Due to morphology of the stream channel at site CC1, insufficient bedload data were collected for a statistically valid assessment of bedload sedimentation in the Cedar Creek watershed. As discussed previously, streamflow velocity is a critical component of rates of bedload transport. Average flow velocity is depicted on figure 14. Correlations of measured mean flow velocity and bedload mass indicate that once a critical threshold of flow velocity is achieved, the bed material is mobilized and bedload transport rates increase significantly. This velocity threshold is dependent on sediment supply and bedload grain size and is stream or stream segment specific. The critical velocity for site BC1 is approximately 2.2 ft/s (fig. 15), 1.36 ft/s at site BC2 (fig. 16), and 1.25 ft/s at site RC1 (fig. 17). A critical velocity could not be determined from the data collected at site LBC.

Table 3—Measured daily bedload and estimated annual bedload for project streams

Monitoring Site	Maximum Bedload (t/d)	Minimum Bedload (t/d)	Average Bedload (t/d)	Bedload Sediment (t/yr)	Bedload Sediment (t/mi^2/ yr)
Rock Creek (RC1)	2.9	0.02	1.3	241	4.8
Cedar Creek (CC1)	0.22	0	ID[1]	ID[1]	ID[1]
Little Bear Creek (LBC)	73	BDL[2]	19	1,346	43
Bear Creek at Tishomingo Co. Rd. 86 (BC1)	76	0.16	21	12,491	272[3]
Bear Creek at Ala. Hwy 24 (BC2)	63	BDL	22	464	22[4]

[1] Insufficient data to calculate average measured bedload or annual sediment loads.

[2] Below detection limit.

[3] Drainage area utilized for calculation of normalized suspended sediment load extends from monitoring sites BC1 to BC2.

[4] Drainage area utilized for calculation of normalized suspended sediment load extends downstream from impoundment to monitoring site.

Figure 10.--Measured discharge and bedload, Bear Creek at site BC1, near downstream terminus of floodway, Tishomingo Co., Mississippi.

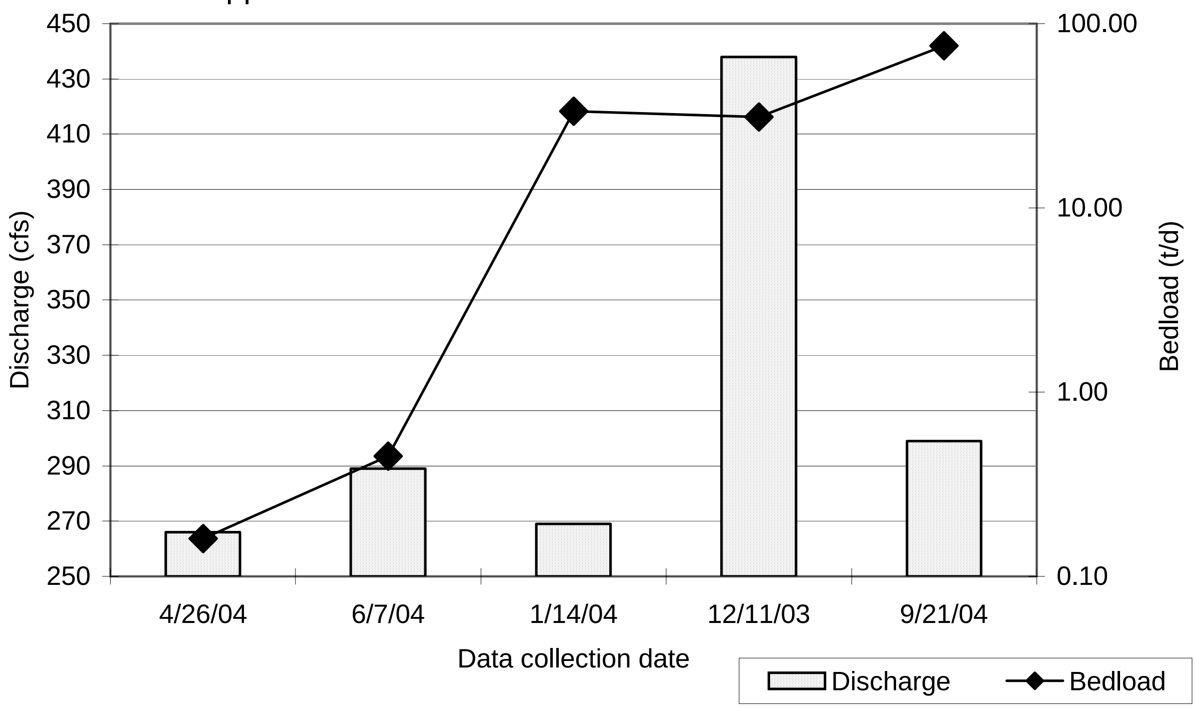


Figure 11.--Measured discharge and bedload at site BC2, Bear Creek at highway 24 near Red Bay, Alabama.

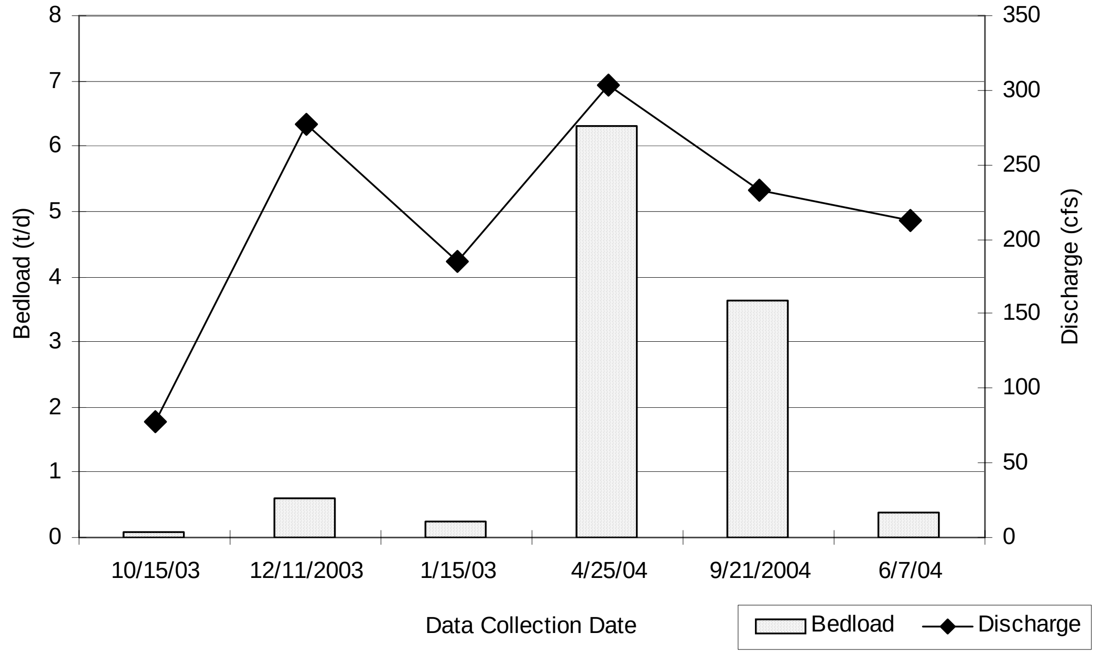


Figure 12.--Measured discharge and bedload for site LBC, Little Bear Creek near Alabama Highway 247, Franklin Co., Alabama.

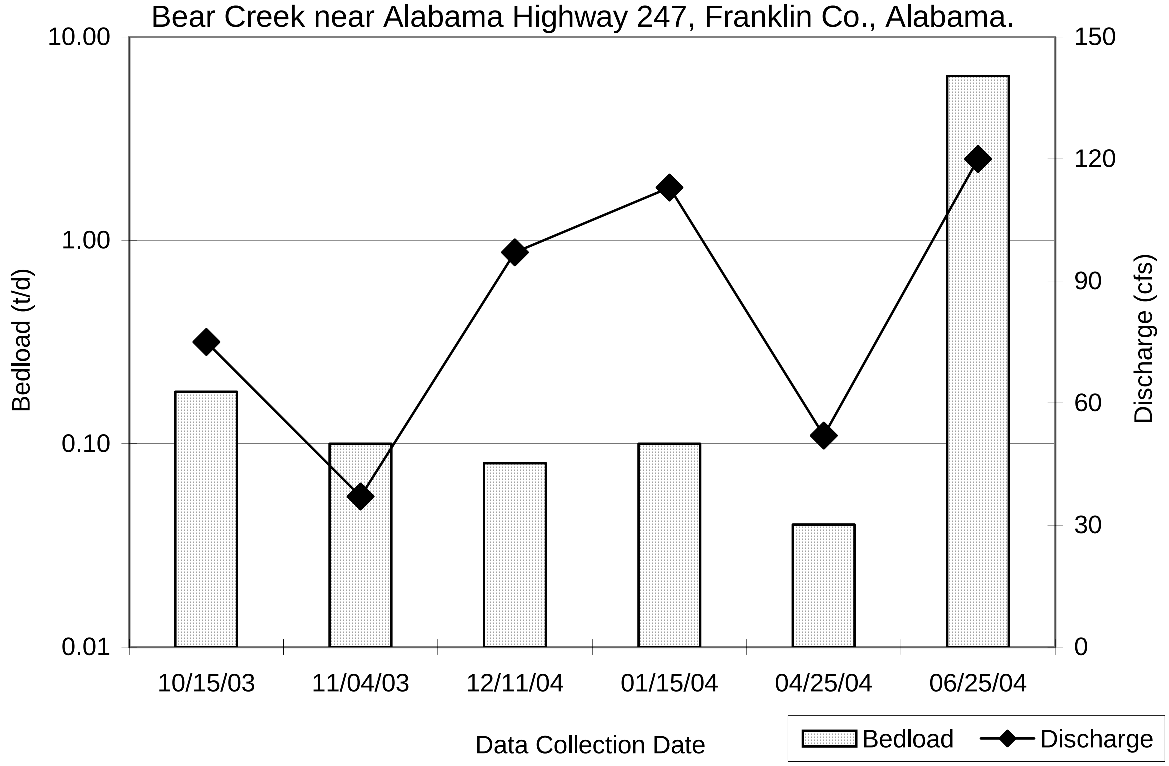


Figure 13.--Measured discharge and total suspended solids at site RC1, Rock Creek at Maud, Colbert Co., Alabama.

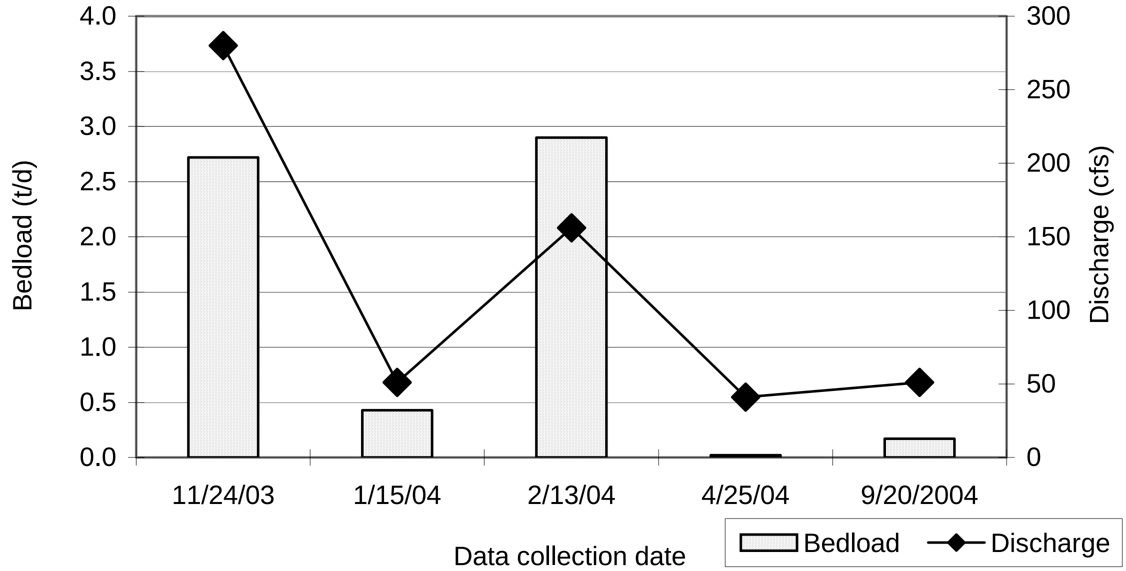


Figure 14.--Average stream flow velocity, Bear Creek and selected tributaries.

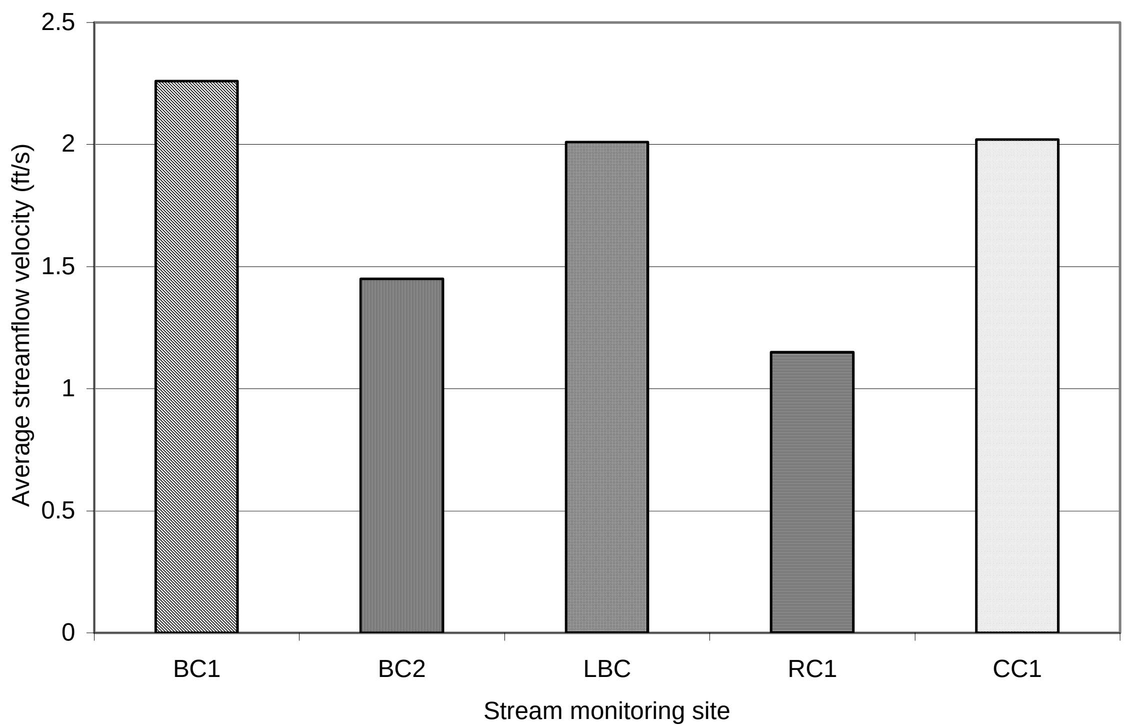


Figure 15.--Mean streamflow velocity and bedload at site BC1, Bear Creek near downstream terminus of floodway, Tishomingo Co., MS.

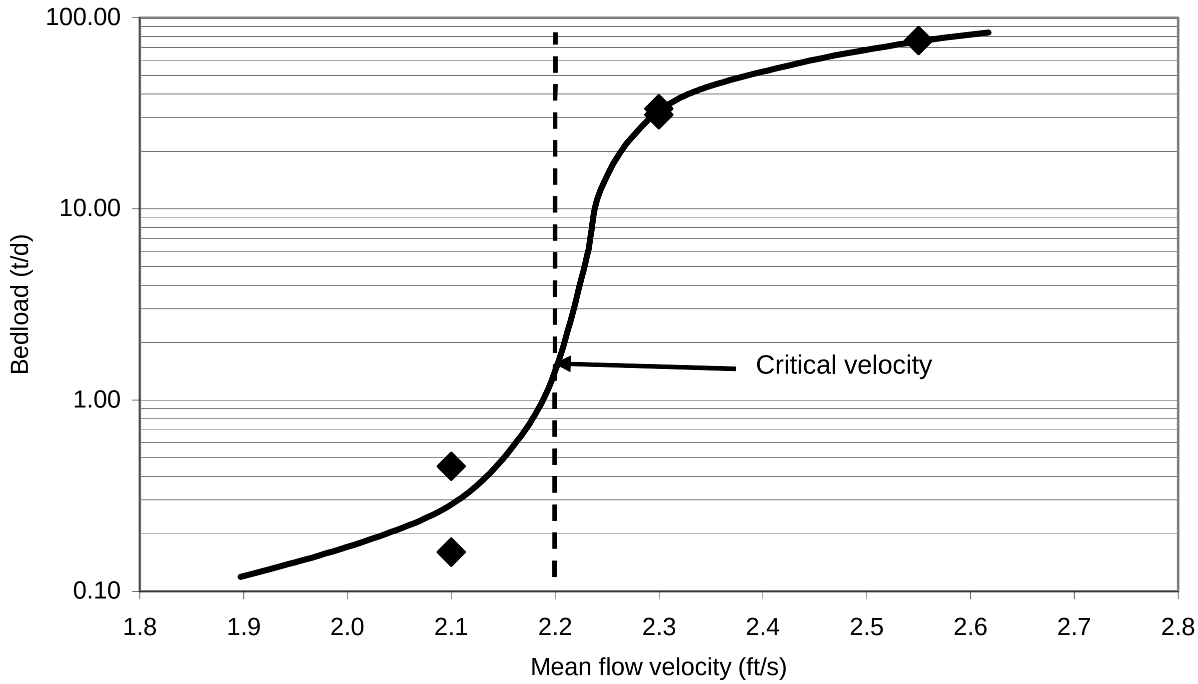


Figure 16.--Mean streamflow velocity and bedload at site BC2, Bear Creek at Alabama Highway 24 near Red Bay, Alabama.

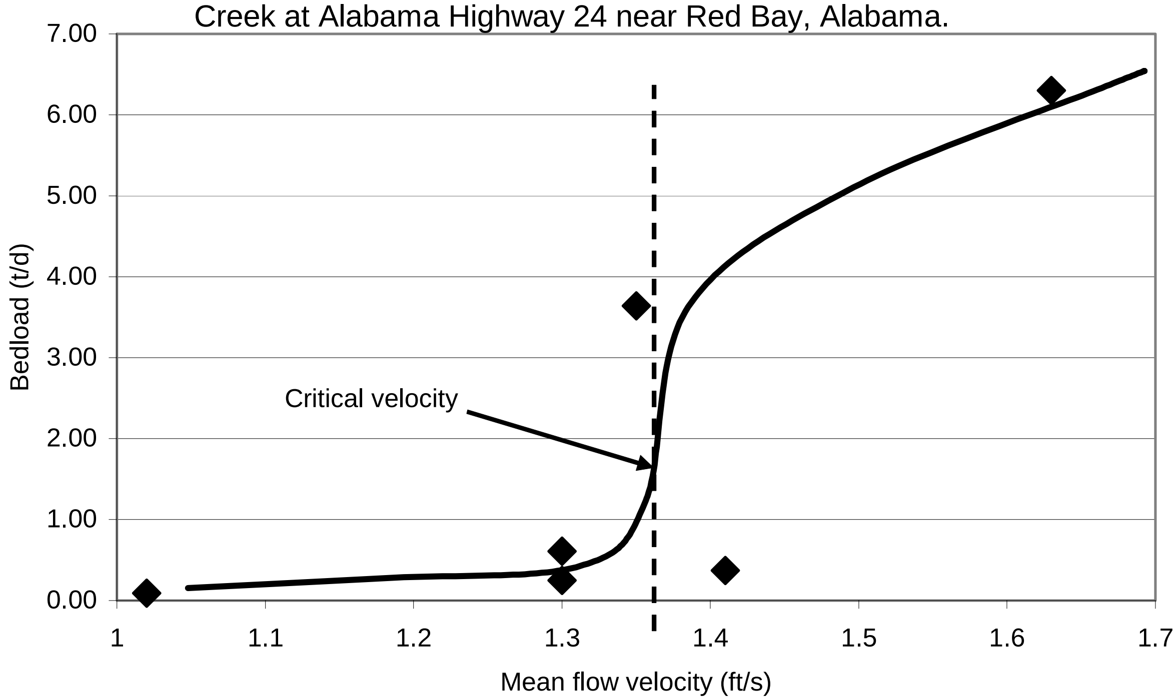
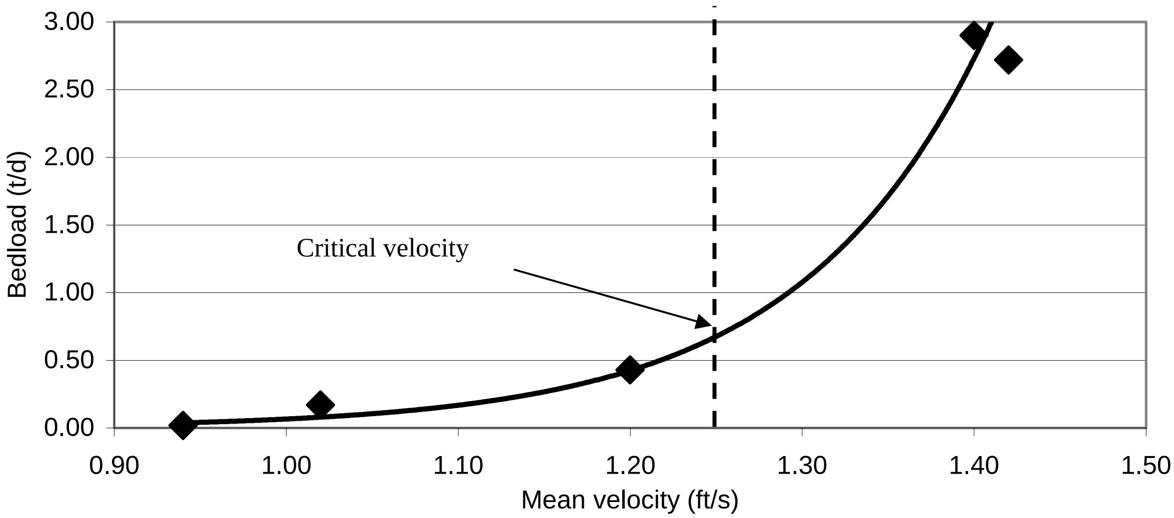


Figure 17.--Mean streamflow velocity and bedload at site RC1, Rock Creek at Maud, Colbert Co., Alabama.



After the bed material is mobilized during a high streamflow event, bedload will continue to move at increased rates until the stream approaches baseflow or until the stream bed achieves base level equilibrium. Stream bedload transport was measured at increased rates up to seven days after high intensity, short duration discharge events at site BC1 for January 14 and September 21, 2004, bedload measurements (fig. 18). Calculated bedloads, discharges, and streamflow velocities measured in the monitored streams are portrayed in figures 18 through 21.

Figure 18.--Measured discharge, mean streamflow velocity, and bedload, Bear Creek at site BC1 near downstream terminus of floodway, Tishomingo Co., Mississippi.

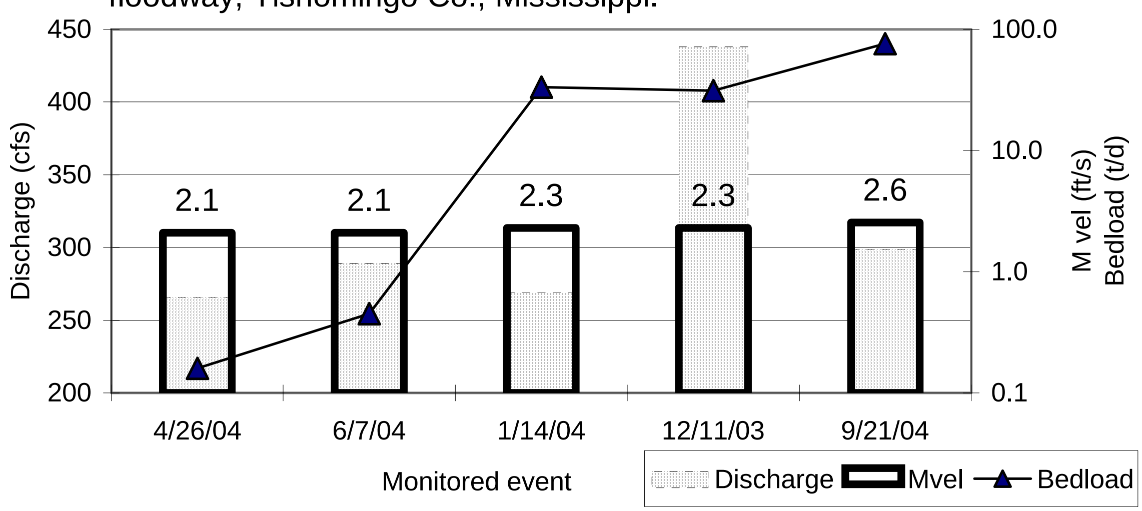


Figure 19.--Measured discharge, mean streamflow velocity, and bedload at site BC2, Bear Creek at Alabama Highway 24 near Red Bay, Alabama.

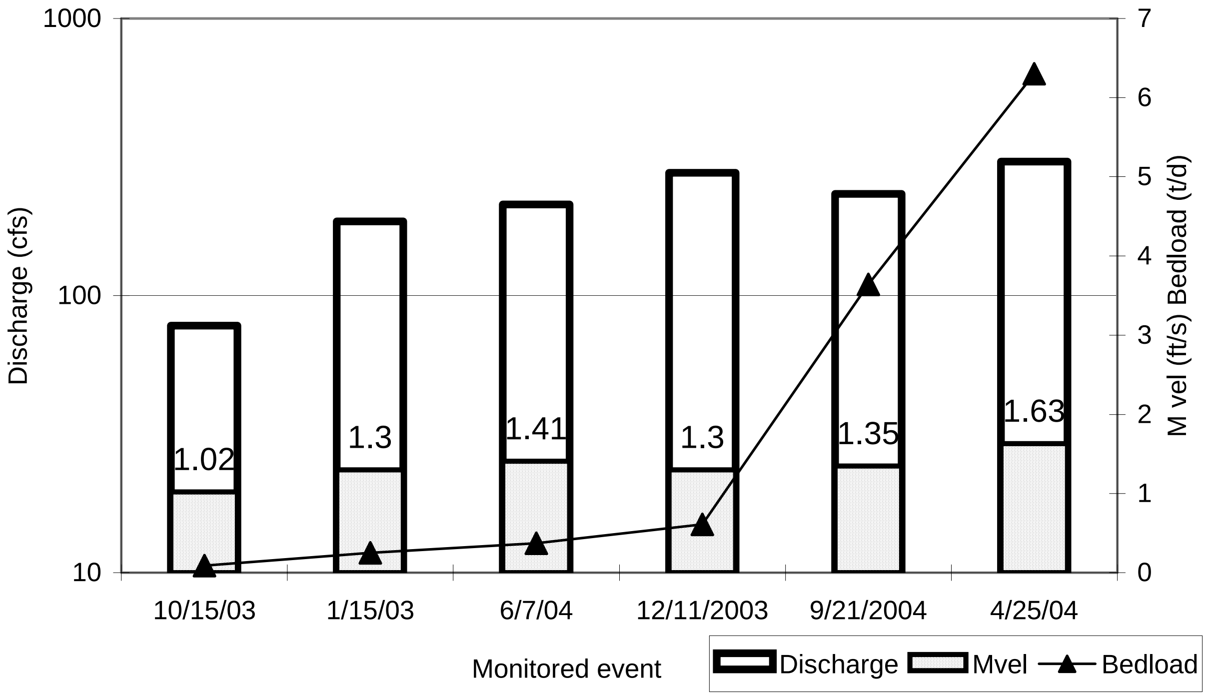
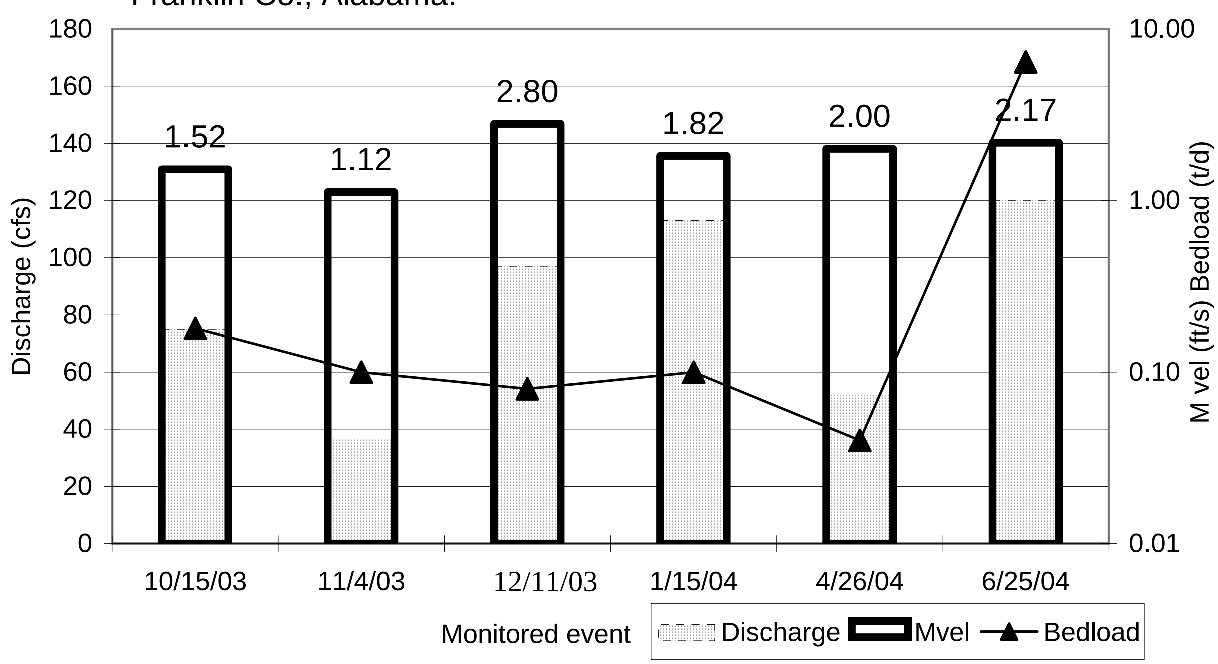


Figure 20.--Measured discharge, mean streamflow velocity, and bedload at site LBC, Little Bear Creek near Alabama Highway 247, Franklin Co., Alabama.



The largest bedload, both in total mass (12,491 t/yr) and in mass per unit area (272 t/mi^2/yr), was transported by the segment of Bear Creek between sites BC2 and BC1. The smallest bedload was transported by Rock Creek (241 t/yr and 4.8 t/mi^2/yr) (table 3, figs. 22, 23).

Total sediment loads (suspended load and bedload) are depicted in figures 24 and 25. Comparisons of bedload for the Bear Creek project streams and other previously evaluated streams in the Choctawhatchee, Pea, and Yellow Rivers Watershed of south Alabama are portrayed in figure 26.

Sources of Sediment and Land Use

Sources of sediment are related to land use practices employed in the watershed and erosion from high flow events that occur frequently each year. As previously discussed, the primary land uses in the Bear Creek watershed are row crop agriculture on rich soils at lower elevations and timbering and construction that occur at higher elevations. The largest concentration of row crop agriculture occurs in the Bear Creek floodplain along the floodway

Figure 21.--Measured discharge, mean stream flow velocity, and bedload at site RC1, Rock Creek at Maud, Colbert Co., Alabama.

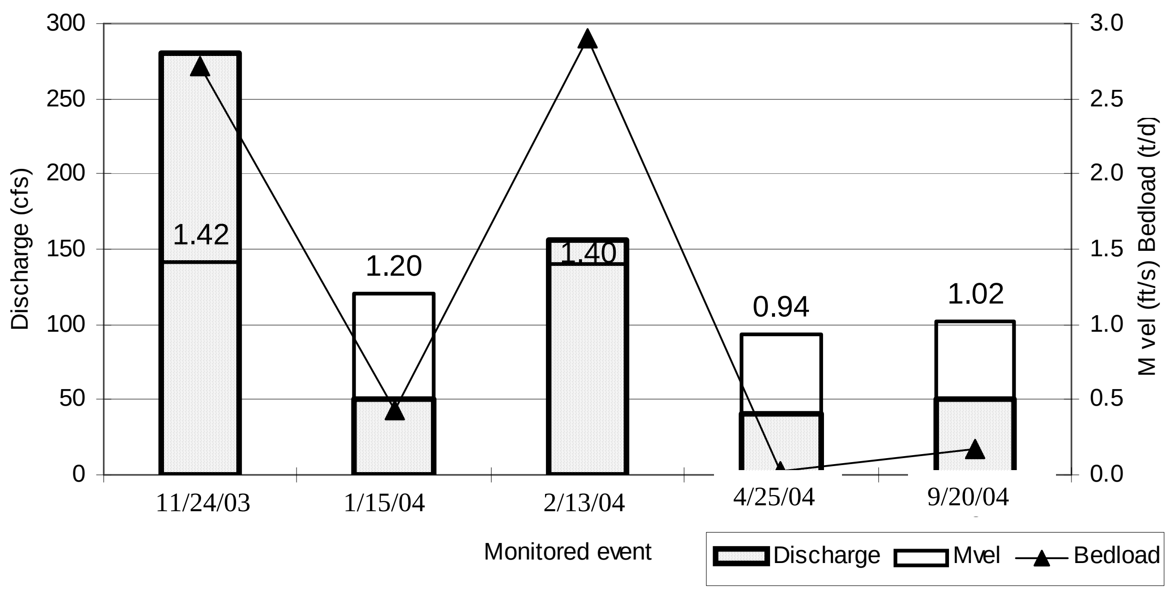


Figure 22.--Estimated total bedload sediment, Bear Creek and selected tributaries (t/yr) (total drainage areas).

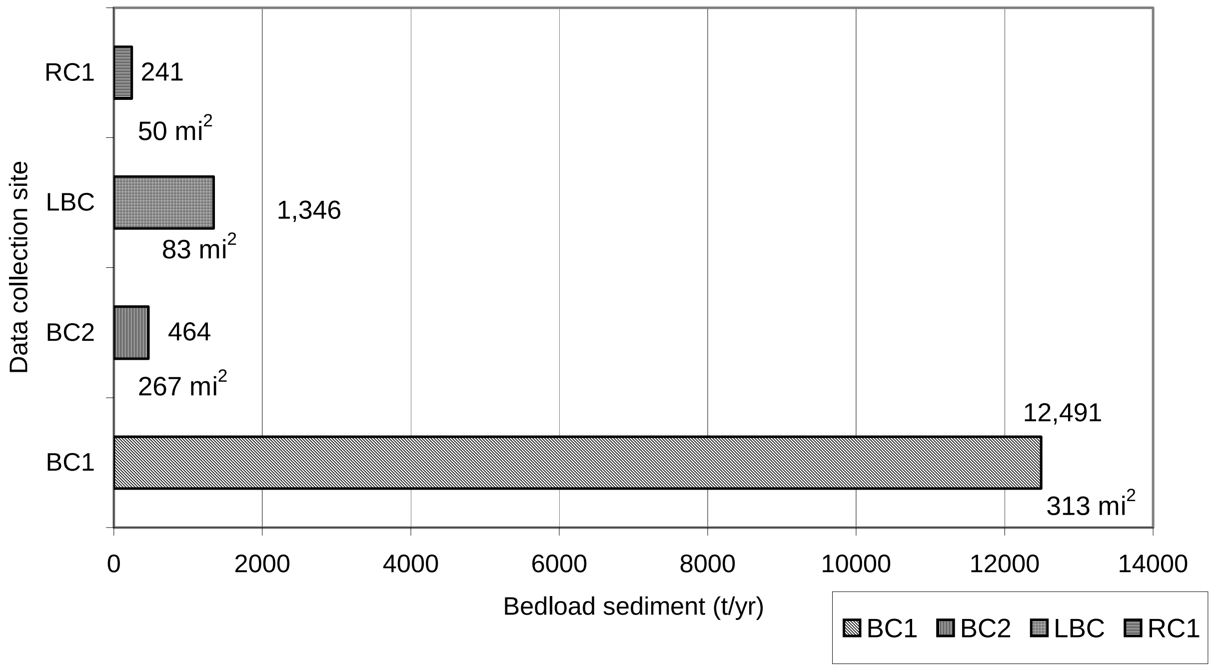


Figure 23.--Estimated total bedload sediment, Bear Creek and selected tributaries ($t/mi^2/yr$) (specified drainage areas).

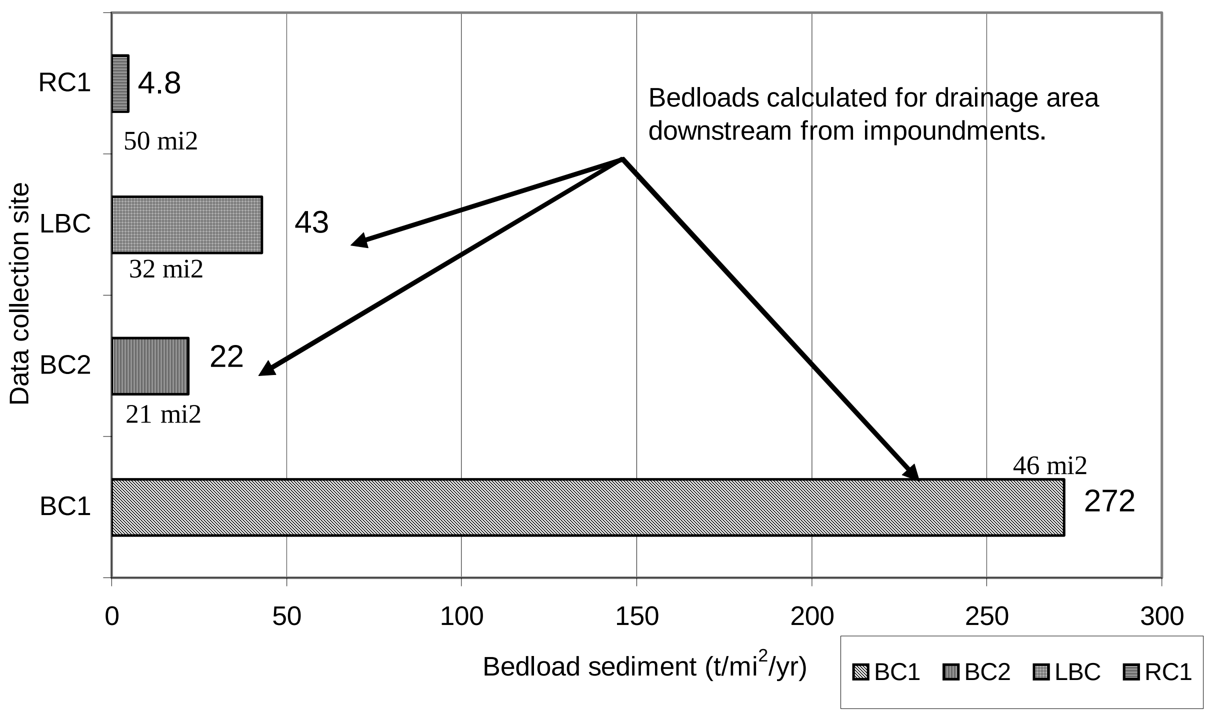


Figure 24.--Estimated total sediment loads, Bear Creek and selected tributaries (t/yr).

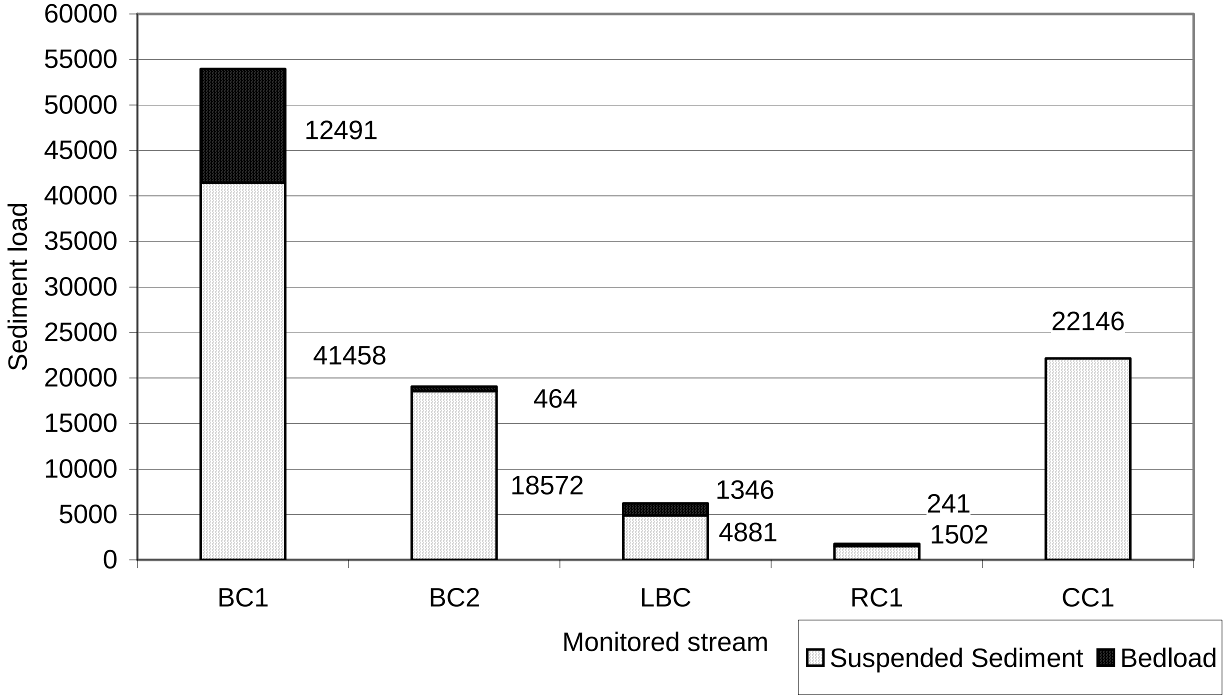
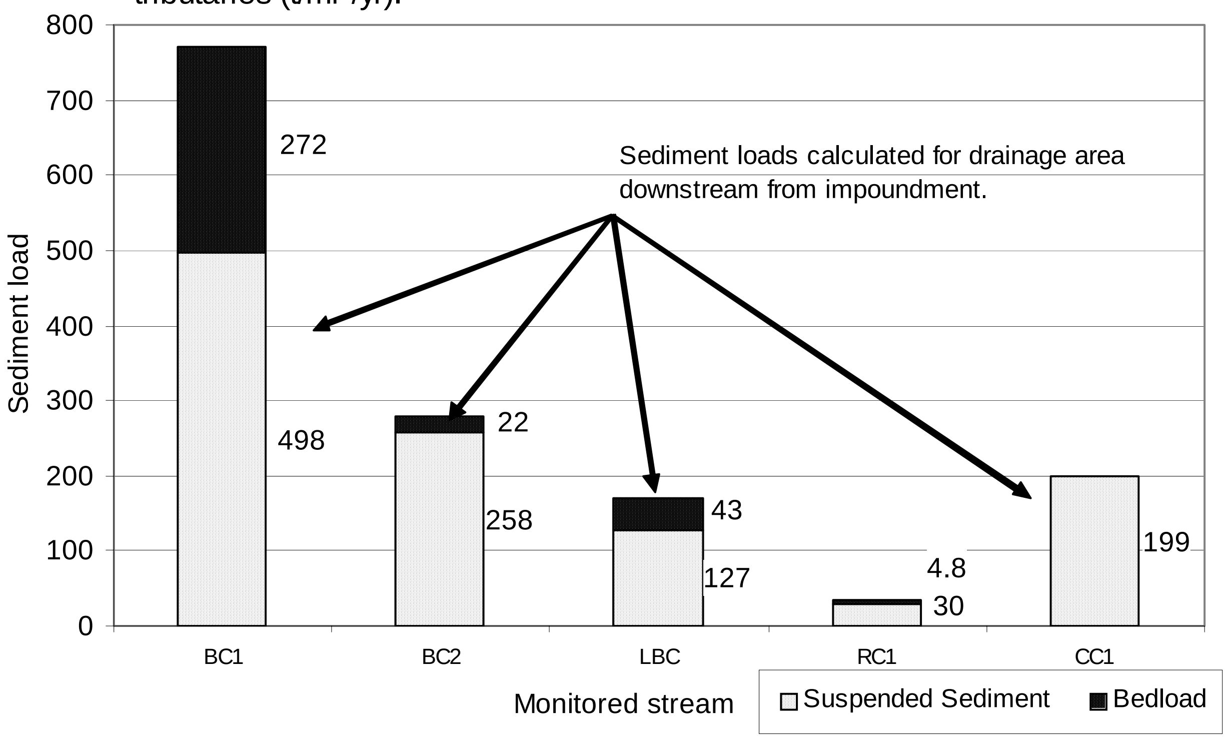


Figure 25.--Estimated total sediment loads, Bear Creek and selected tributaries (t/mi²/yr).



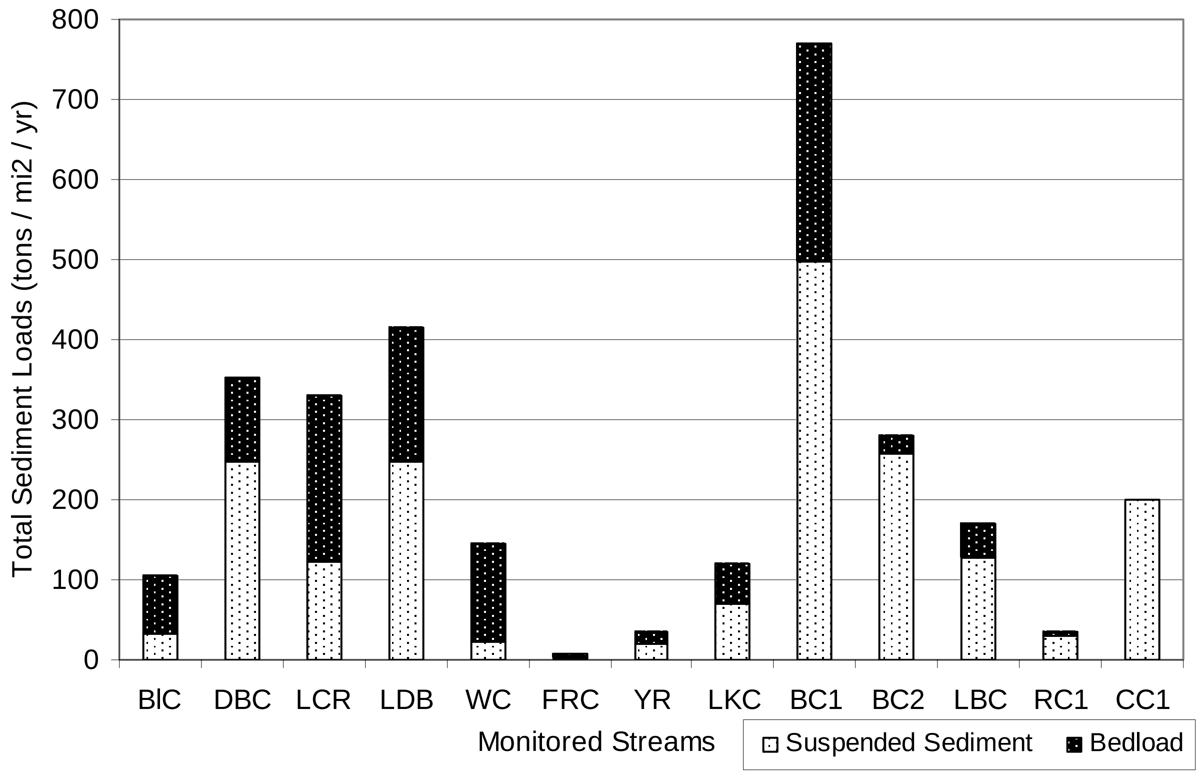


Figure 26.--Total annual sediment loads for major streams in southeast Alabama and the Bear Creek watershed in northwest Alabama and northeast Mississippi.

that extends 18 miles from near Red Bay, Alabama, downstream to County Road 86 in Tishomingo County, Mississippi. The largest area of silviculture is in the Cedar and Rock Creek watersheds in Tishomingo County, Mississippi, and Colbert County, Alabama. In areas where land-use practices have caused the land surface to erode, sediment is transported by overland flow to relatively small tributary streams where it is transported to the major streams. The floodway appears to be a major sediment deposition center and conduit for sediment transport. A comprehensive evaluation of land use and areas of sediment origin in the Bear Creek watershed will be performed during the 2005 water year.

Stream bank erosion is also a major source of sediment in the watershed. A limited number of bank pins were installed at sites BC1, LBC, and RC1 in October 2003. The length of the exposed portion of each pin was measured and a volume of eroded bank sediment was calculated. The monitored segment of stream bank (100 feet long) at site BC1 contributed approximately 54 cubic yards (yds^3) (65 tons) of sediment to Bear Creek during the 2004 water year. Erosion from the monitored segment of stream bank (100 feet long) upstream from site

LBC contributed approximately 175 yds^3 (95 tons) of sediment to Little Bear Creek during the 2004 water year. The monitored segment of stream bank (75 feet long) at site RC1 contributed approximately 33 yds^3 (18 tons) of sediment to Rock Creek during the 2004 water year.

Impoundments in the Bear Creek watershed serve as very efficient sediment retention structures. Streams or stream segments that are upstream from reservoirs transport their sediment loads into the impoundments where all bedload and approximately 40 percent of suspended sediment loads are retained. Suspended sediment that is not retained and the total sediment loads downstream from impoundments and from unimpounded streams are transported to Bear Creek and eventually to the Tennessee River.

SUMMARY AND RECOMMENDATIONS

A short reach of Bear Creek harbors a diverse population of freshwater mussels, rare in post-impoundment Tennessee River tributaries, and includes individuals of species critical to survival of their respective species. Results of this study indicate that significant and, in some cases, excessive sedimentation is occurring in the Bear Creek system, primarily in the Bear Creek floodway, threatening the continued existence of mussel populations. All sites evaluated during this study showed some level of potential for continued habitat degradation due to sedimentation. However, the reach of Bear Creek from Red Bay, Alabama, to Tishomingo County, Mississippi, County Road 86, including the floodway, consistently yielded sediment values of most concern. Those values include (a) the largest volume of gravel bed material mobilized, (b) the highest mean streamflow velocity, (c) the largest suspended sediment load in total mass and in mass per unit area, and (d) the largest bedload in total mass and in mass per unit area. The gravel bed material moving through the floodway is composed of materials eroded from ridges in the mid and downstream reaches of the watershed (Tuscaloosa Group) and from the headwaters (Pottsville Formation). This suggests that disturbances of the land surface in those areas introduce large volumes of sediment into tributaries that transport it to Bear Creek and the floodway, which act as conduits for transport of sediment to the Tennessee River. Based on these results and on some incomplete evaluations of tributary systems discussed in this paper, we make the following recommendations:

- Evaluations of current land use practices should be completed and areas of greatest potential sediment contribution determined. The results of these evaluations should be utilized to design best management practices (BMPs) for the watershed. These BMPs should be installed throughout the watershed, not just along major streams, and should include areas near small headwater tributaries and ephemeral streams.

- Areas of denuded streambanks or with minimal riparian buffer should be identified and corrected.
- After sediment supply sources in the tributary headwaters are reduced, streamflow velocities in regulated streams should be maintained below the critical thresholds required to mobilize bedload and erode stream banks and channels. Additional data should be collected to determine critical sediment transport threshold velocities for Cedar Creek and Little Bear Creek.
- Further evaluation of the contributions of impoundments in the Bear Creek system to sediment entrapment should be completed. This would aid in refining the calculation of normalized loads of suspended sediments in respective tributaries.
- Bedload sedimentation in Cedar Creek should be determined. If necessary, data should be gathered from an upstream station more conducive to sampling efficiency.

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