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AN ANALYSIS OF RATES OF SEDIMENTATION LOADING FOR SELECTED TRIBUTARIES TO THE BEAR CREEK FLOODWAY, ALABAMA AND MISSISSIPPI, 2005-2006

OPEN FILE REPORT 0612

By

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For
National Fish and Wildlife Foundation
Contract Number 1997-0282-023

Tuscaloosa, Alabama
2006

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INTRODUCTION

Previous investigations of sedimentation by the Geological Survey of Alabama documented a dramatic increase in sediment loading in Bear Creek between the Alabama Highway 24 bridge and the termination of the Bear Creek floodway at Tishomingo County, Mississippi, Road 86 (McGregor and Cook, 2004). In an attempt to determine the sources of this sediment, an investigation of sediment contributions from tributary streams was performed during 2005 and 2006. Two streams were selected and monitored for suspended and bed sediment loads to determine the impact of tributary streams to the total sediment loading in the Bear Creek floodway (fig.1).

SEDIMENTATION

Sedimentation is a process by which eroded particles of rock are transported by moving water from areas of relatively high elevation to areas of relatively low elevation, where the particles are deposited. Upland sediment transport is 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 (bed load).

Two monitoring sites were established to measure sediment loads, flow conditions, and selected water-quality parameters. The sites were on two tributaries to the Bear Creek floodway (Mud Creek at Franklin County, Alabama Road 28

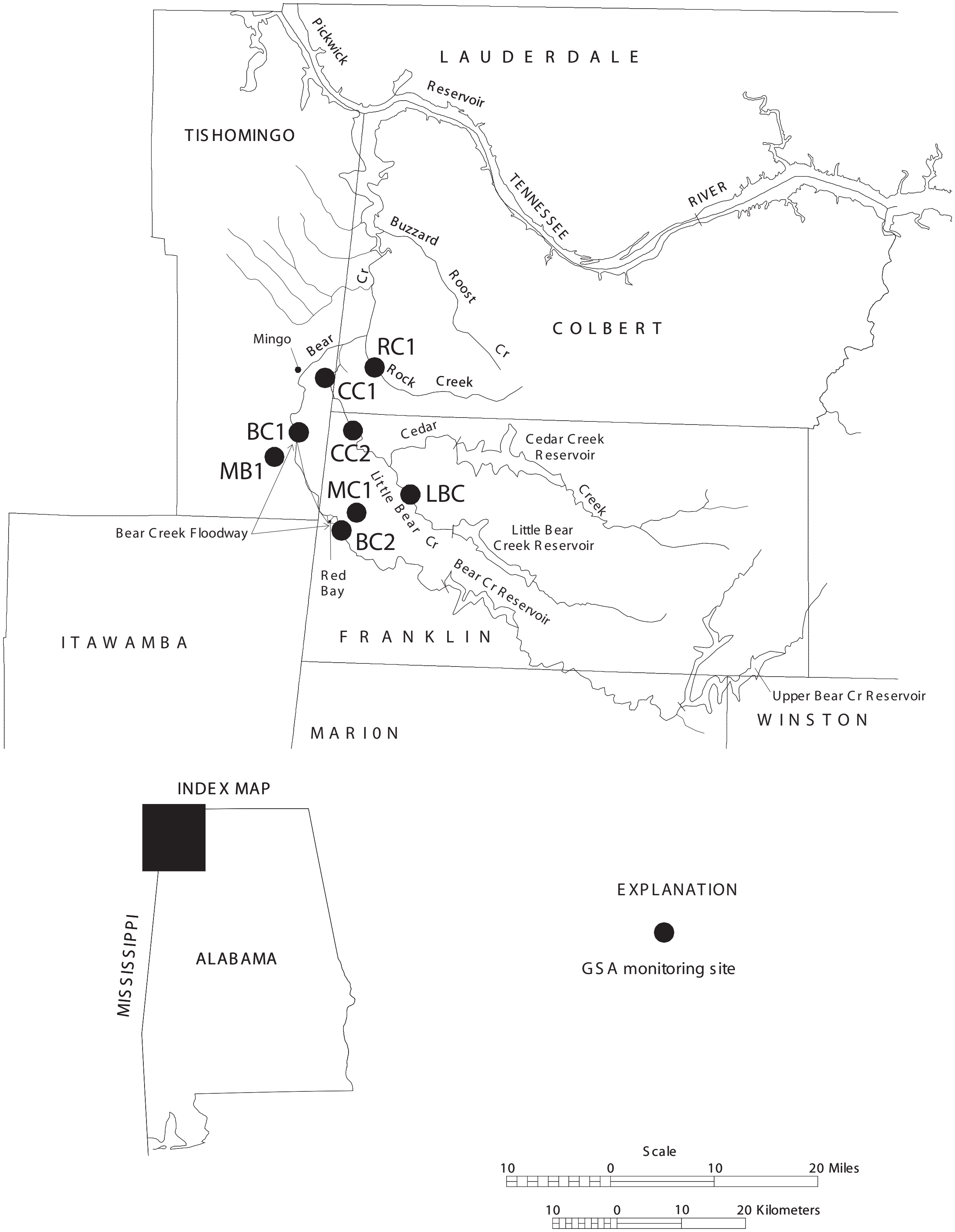


Figure 1.—Locations of monitoring sites and evaluated streams in the Bear Creek watershed.

near Red Bay, MC1; and McNutt Branch at Tishomingo County, Mississippi, Road 57 near Dennis, MB1) (fig. 1).

SEDIMENT LOADS TRANSPORTED BY PROJECT STREAMS

The rate of sediment transport is a complex process controlled by a number of factors related to land use, precipitation runoff, erosion, stream discharge and flow velocity, stream base level, and physical properties of the sediment.

Tributaries to Bear Creek drain upland areas and are characterized by relatively high gradients and flashy discharge. Land uses in tributary watersheds include limited row crop agriculture, timbering, pasture and hay, construction, and runoff from small urban areas. Soils are formed from the underlying Bangor Limestone and Tuscaloosa Group sediments. These and other land uses cause erosion, which supplies sediment to Bear Creek and its tributaries. Excessive sedimentation causes changes in base level elevation of streams and triggers downstream movement of sediment as streams attempt to regain base level equilibrium. The movement of this material is accelerated by periodic extreme precipitation events that cause increased stream flow and stream flow velocity.

STREAM FLOW CONDITIONS

Sediment transport conditions in the Bear Creek watershed are segregated by particular stream segments based on a variety of conditions, such as precipitation, stream gradient, geology, land use, and influence of regulated flows. Average observed stream flow conditions for the monitored streams in the investigation are included in table 1.

Table 1. Stream flow characteristics for two sites in the Bear Creek watershed.

Monitoring Site	Discharge (ft^3/s)[1]			Flow Velocity (ft/s)[2]		
	Maximum	Minimum	Average	Maximum	Minimum	Average
Mud Creek	20	37	6	1.2	2.2	0.7
McNutt Branch	4.1	8.3	0.9	1.3	1.4	0.7

[1]ft^3/s- cubic feet per second
[2]ft/s- feet per second

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 a stream in a specified time.

Suspended sediment is defined as that portion of a water sample that is separated from the water by filtering. This solid material is composed of organic and inorganic material including 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.

These materials are transported by overland flow related to storm-water runoff to stream channels. Suspended sediment is quantified by the formula:

$$Q_s = Q_w \; C_s \; k,$$

where

Q_s is the sediment discharge, in tons per day (tons/day)

Q_w is the water discharge, in cubic feet per second (cfs)

C_s is the concentration of suspended sediment, in milligrams per liter (mg/L)

and

k is a coefficient based on the unit of measurement of water discharge and assumes a specific weight of 2.65 for sediment (Porterfield, 1972).

Concentrations of total suspended solids (TSS) in mg/L were determined by laboratory analysis of periodic water grab samples. These results were used to calculate the mass of TSS in tons/day, for specific individual samples, by applying the Porterfield formula to the laboratory analytical results. Annual suspended sediment loads may be estimated using the computer regression model Regr_Cntr.xls (*Regression with Centering*). The program is an Excel implementation of the USGS seven-parameter regression model for load estimation (Cohn et al., 1992). This method was used in the previous Bear Creek assessment (McGregor and Cook, 2004). However, insufficient discharge and TSS data were collected during this project to utilize this method.

An excellent correlation between TSS concentrations and stream discharge for Mud Creek and McNutt Branch was observed during the monitoring period. Although sufficient data were not collected to employ the Regr_Cntr.xls (*Regression with*

Centering) model, it is recommended for future investigations to accurately predict annual suspended sediment loads in these streams. Calculated suspended sediment loads for each monitored stream are shown in table 2. Graphic representations of suspended sediment loads are depicted in figures 2 and 3. The largest monitored suspended sediment load, both in total mass and in mass per unit area, was transported by Mud Creek on May 10, 2006 (fig. 2).

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

Monitoring site	Total suspended solids (mg/L)			Average suspended sediment load	
	Maximum	Minimum	Average	Tons/day	Tons/mi^2/day
Mud Creek	128	11	60	4.9	30
McNutt Branch	189	5	67	1.3	199

BED LOAD SEDIMENT

Transport of streambed material is controlled by a number of factors, including stream discharge and flow velocity, erosion and sediment supply, stream base level elevation, 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 bed load 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.

Bed load sediment is composed of particles that are too large or too dense to be carried in suspension by stream flow. These particles roll, tumble, or are periodically suspended as they move downstream. Traditionally, bed load sediment has been difficult to quantify due to deficiencies in monitoring methodology or inaccuracies of estimating

Figure 2.--Calculated instantaneous suspended sediment loads and measured discharge in Mud Creek at County Road 28, Franklin County, Alabama.

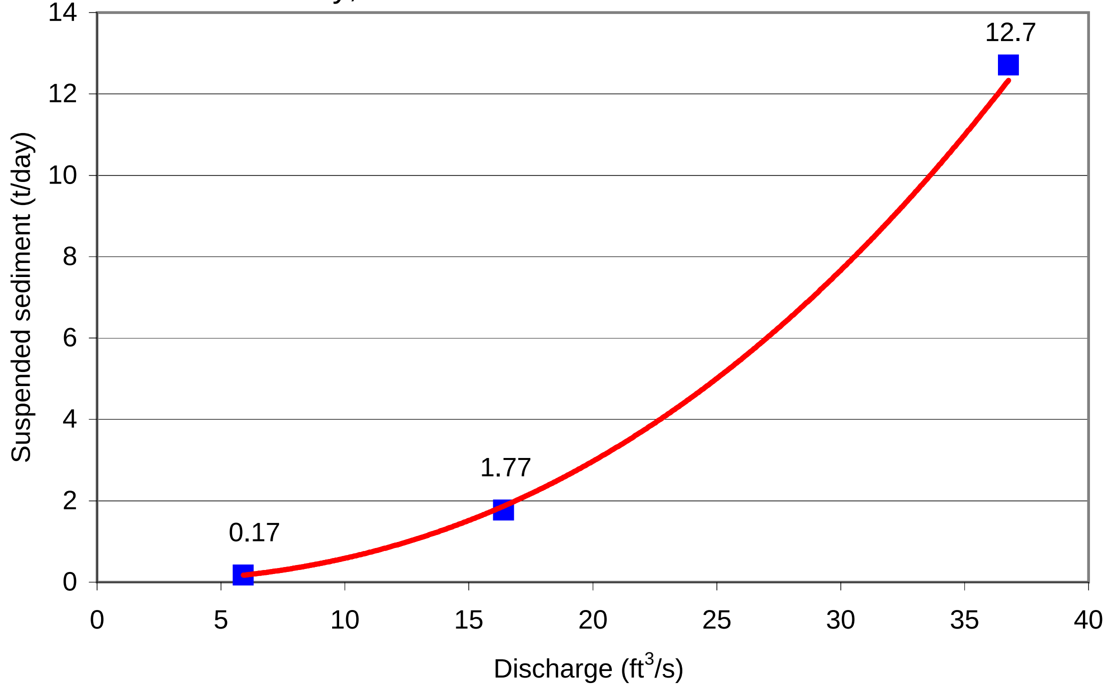
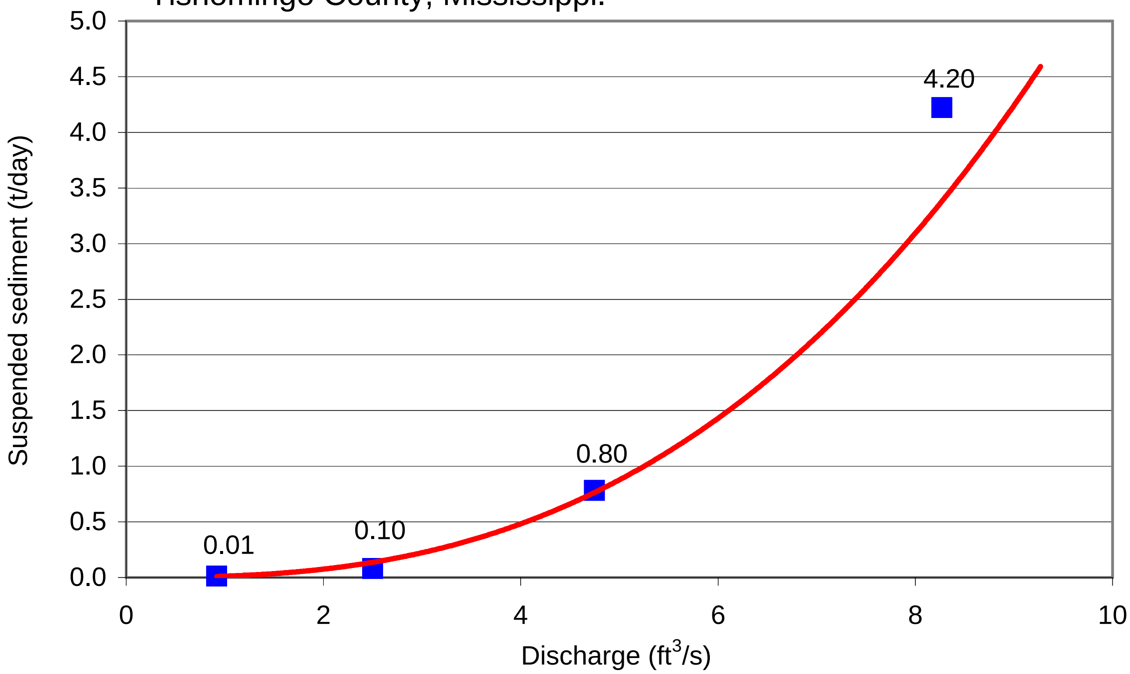


Figure 3.--Calculated instantaneous suspended sediment loads and measured discharge in McNutt Branch at County Road 57, Tishomingo County, Mississippi.



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 bed load sedimentation rate-monitoring device that was designed to accurately measure bed load sediment in shallow sand or gravel bed streams. This device was utilized during this project, where bed load was measured periodically. Stream discharge and mean stream flow velocities were determined to allow comparison of sediment and stream flow conditions with other streams. As with suspended sediment, it is possible to construct a regression model to determine mean daily bed load volumes and annual bed sediment loads. This method is recommended for future investigations where sufficient sediment data are collected. Table 3 includes measured bed load and estimated daily loads for the project streams. Figures 4 and 5 graphically depict estimated daily bed load sedimentation rates and stream discharge. As discussed previously, stream flow velocity is a critical component of rates of bed load transport. Average stream flow velocity and bed load are depicted on figures 6 and 7. The largest estimated bed load was transported by Mud Creek (1.6 t/day or 0.22 $t/mi^2/day$) on May 10, 2006.

Table 3—Estimated daily bed load for project streams.

Monitoring site	Bed load (t/day)			Average bed load ($t/mi^2/day$)
	Maximum	Minimum	Average	
Mud Creek	1.6	0.4	0.9	0.12
McNutt Branch	1.4	0.02	0.5	0.48

Total sediment loads are composed of suspended and bed sediment. The largest total sediment load estimated for Mud Creek was 14.2 tons/day (approximately 237 cubic feet). The largest load estimated for McNutt Branch was 5.6 tons/day (approximately 93 cubic feet).

CONCLUSIONS

The previous investigation of sedimentation in the Bear Creek watershed (McGregor and Cook, 2004) indicated a large increase in sediment volume between sites BC2 (Bear Creek at Alabama Highway 25, near Red Bay) and BC1 (downstream

Figure 4.--Measured bed load sediment and discharge in Mud Creek at County Road 28, Franklin County, Alabama.

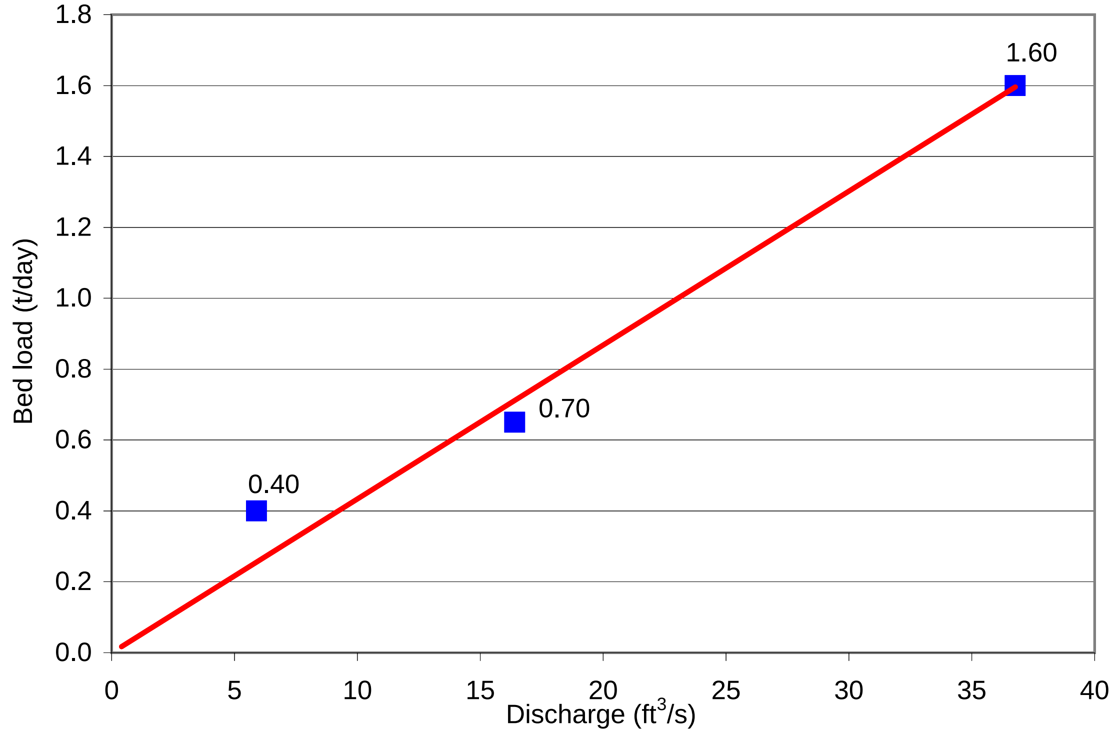


Figure 5.--Measured bed load sediment and discharge in McNutt Branch at County Road 57, Tishomingo County, Mississippi.

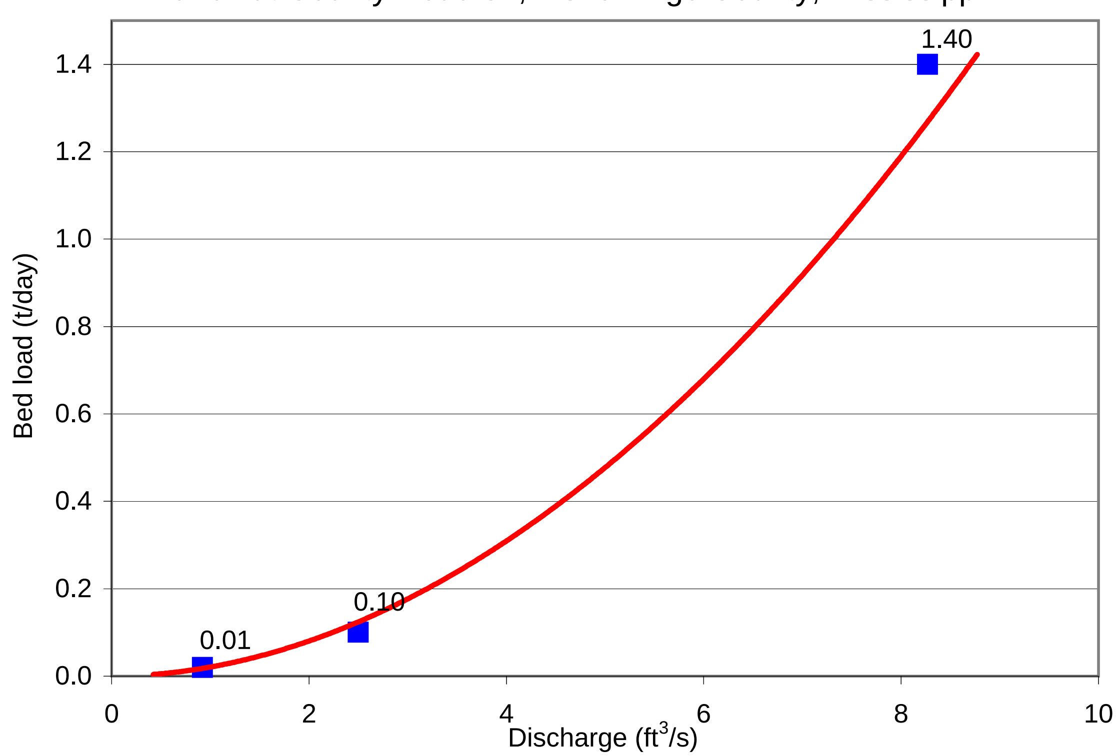


Figure 6.--Measured bed load sediment and mean streamflow velocity in Mud Creek at County Road 28, Franklin County, Alabama.

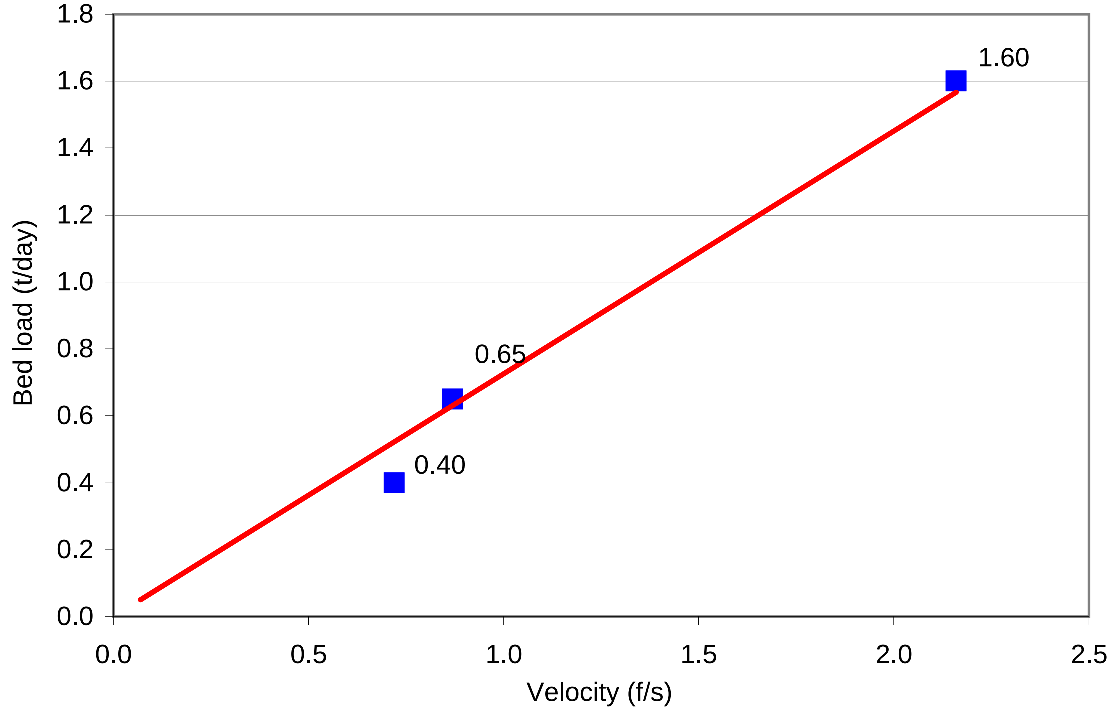
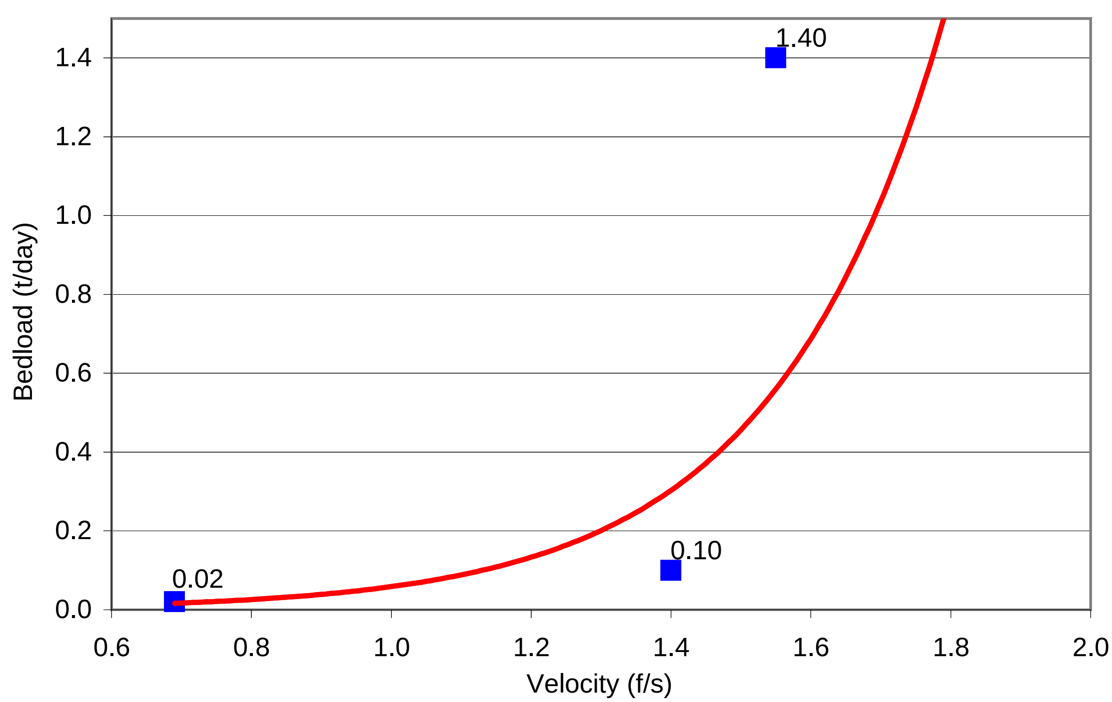


Figure 7.--Measured bed load sediment and mean streamflow velocity in McNutt Branch at County Road 57, Tishomingo County, Mississippi.



terminus of the Bear Creek Floodway at Tishomingo County, Mississippi, Road 86) (fig. 1). Sources of this sediment to the floodway may include bank erosion and scour, channel incision, and contributions of sediment from tributaries to the floodway. A field inspection of the floodway indicates that the banks are relatively stable and appear to be only a minor source of sediment. Due to the water table level in much of the floodway, base level appears to be stable. Therefore channel incision, even during flood of reservoir release events, is probably minor and is not a significant source of sediment (Cook and others, 2005). During the 2004 investigation, observations of bed load grain sizes indicated that much of the sediment originated from erosion and transport of gravel and cobbles from the Tuscaloosa Group (McGregor and Cook, 2004). The Tuscaloosa Group forms ridges in the project area and is eroded by headwaters of Bear Creek tributaries.

Comparisons of sediment loads for sites throughout the Bear Creek watershed also provide insight into the sources and transport of sediment. Table 4 contains monitoring site locations and descriptions for monitoring sites included in the 2004 and 2006 assessments of the Bear Creek watershed. Figures 8 and 9 depict the cumulative impact of erosion and sediment transport.. Site BC1 (downstream terminus of the Bear Creek floodway) is characterized by large bed and suspended sediment loads while upstream sites exhibit much lower rates. However, when the sediment data are normalized relative to discharge and watershed drainage areas, it is apparent that tributaries supply a large portion of the sediment transported through the Bear Creek floodway. Figures 10 through 13 indicate that Mud Creek and McNutt Branch (floodway tributaries) are major contributors of sediment to the floodway. If sediment loads calculated for these streams are typical of most floodway tributaries, much of the increased load observed at site BC1 is a result of headwaters erosion and transport of sediment by tributary streams. Assessment of sediment loads from additional floodway tributaries will support the conclusions of this investigation and more accurately document total sediment loads contributed to the Bear Creek system from this portion of the watershed.

Table 4.—Sampling station descriptions and map coordinates.

Station name	Station name	Map coordinates
BC1	Bear Creek at Tishomingo County Road 86 at lower end of Bear Creek Floodway near Dennis, Mississippi	34° 33.92'N, 88° 11.42'W
BC2	Bear Creek at Alabama Highway 24 near Red Bay, Franklin County, Alabama	34° 26.65'N, 88° 6.92'W
CC1	Cedar Creek at Mingo Road near Mingo, Tishomingo County, Mississippi	34° 37.64'N, 88° 8.53'W
CC2	Cedar Creek at Franklin County Road 90 near Pogo, Alabama	34° 33.76'N, 88° 6.52'W
LBC	Little Bear Creek downstream of Alabama Highway 247, Franklin County, Alabama	34° 31.19'N, 88° 3.16'W
MB1	McNutt Branch at Tishomingo County Road 57, near Dennis, Mississippi	34° 33.17'N, 88° 12.22'W
MC1	Mud Creek at Franklin County Road 28 near Red Bay, Alabama	34° 27.46'N, 88° 6.24'W
RC1	Rock Creek at Colbert County Road 1 near Maude, Alabama	34° 37.92'N, 88° 5.45'W

Figure 8.--Calculated average bed load sediment and measured discharge for Bear Creek and selected tributaries.

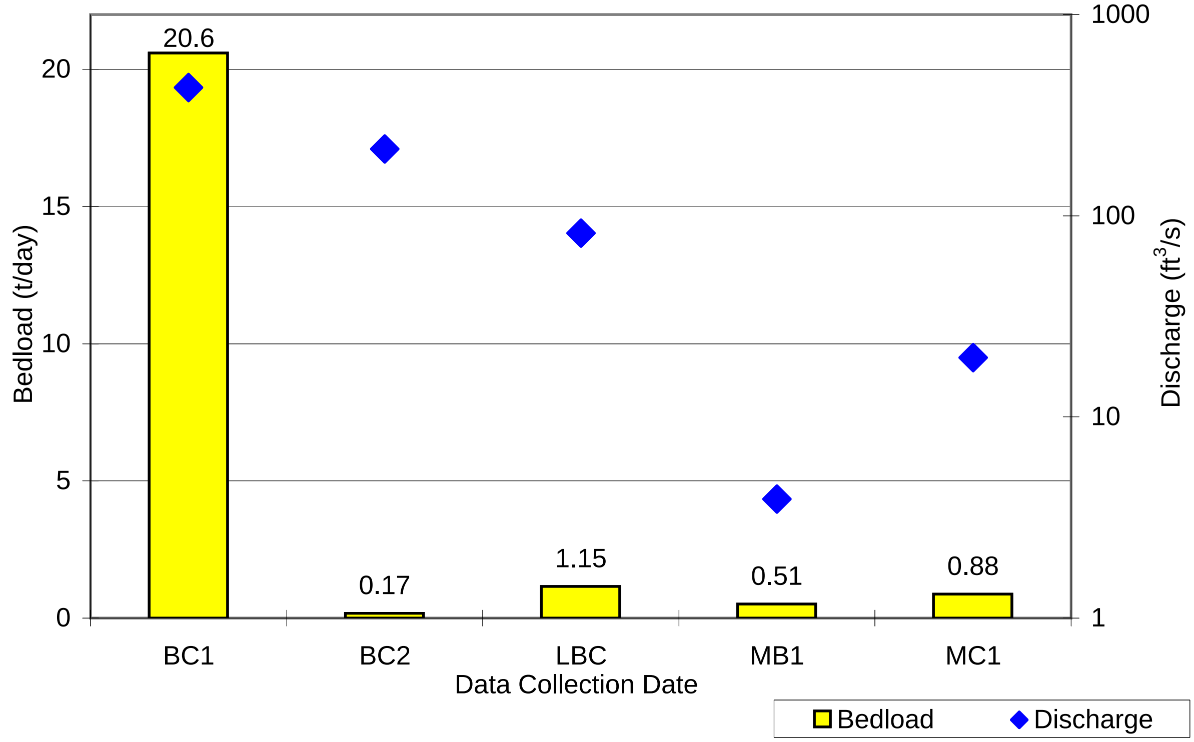


Figure 9.--Calculated average suspended sediment load and measured discharge for Bear Creek and selected tributaries.

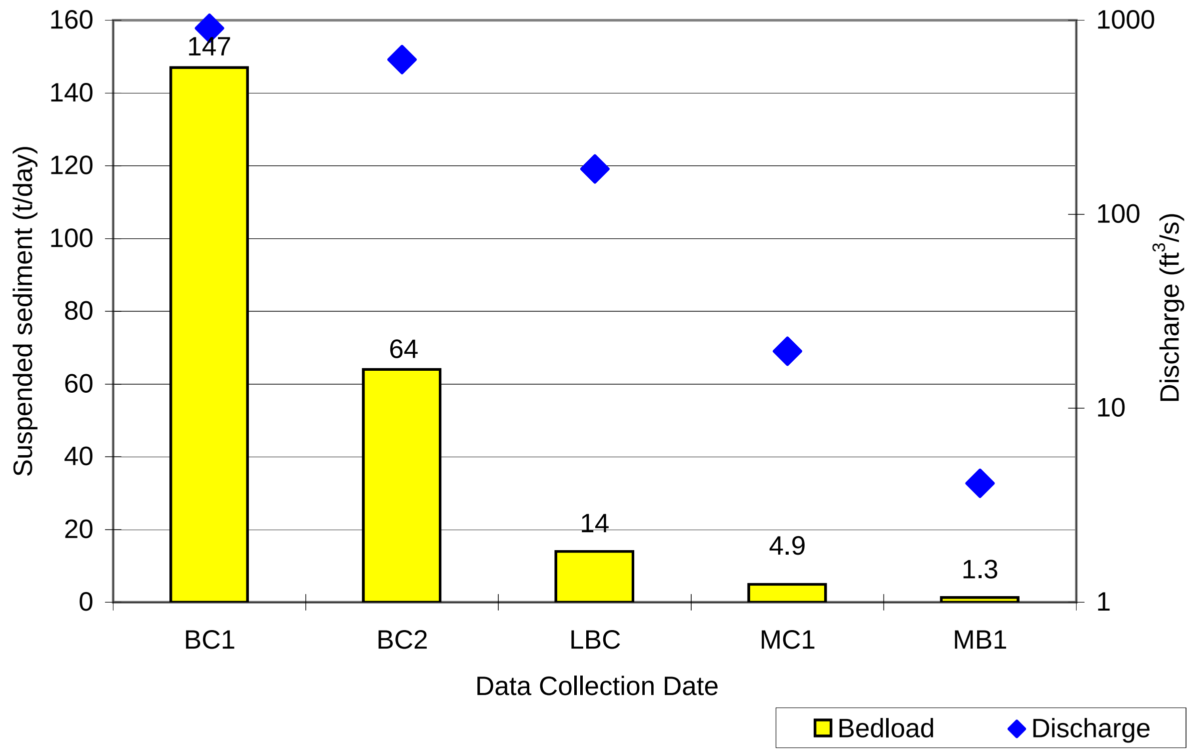


Figure 10.--Calculated average suspended sediment load per unit discharge for Bear Creek and selected tributaries.

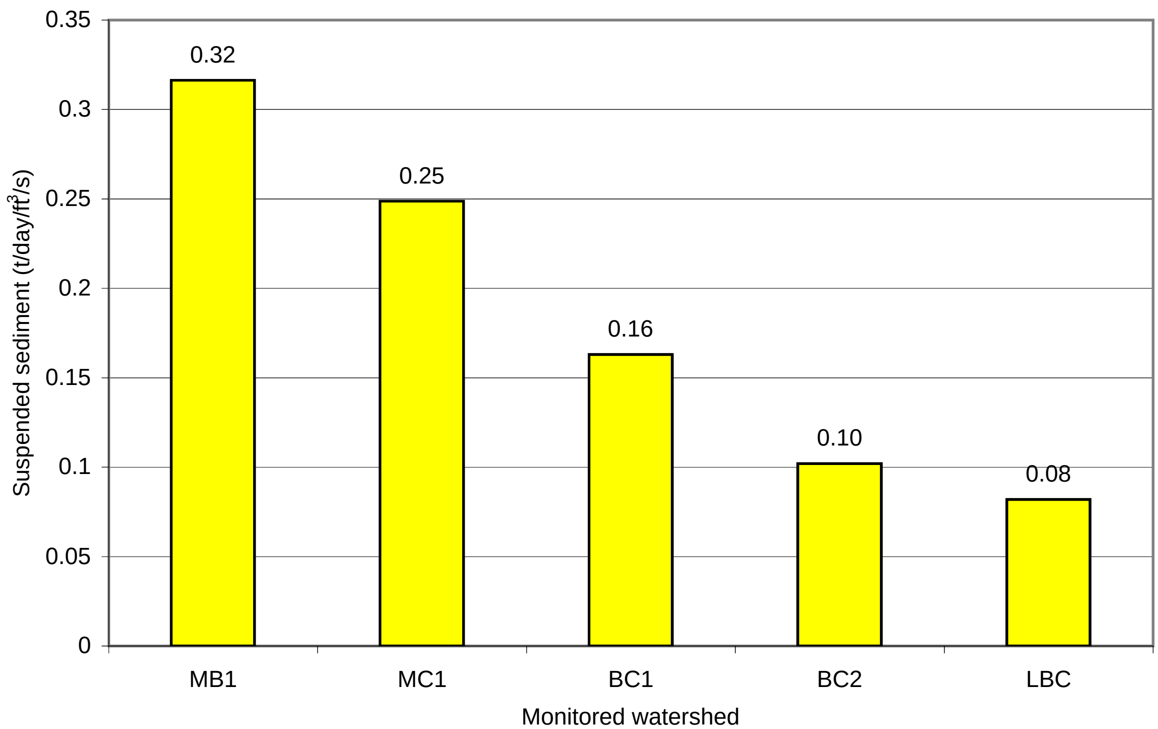


Figure 11.--Calculated average bed load sediment per unit discharge for Bear Creek and selected tributaries.

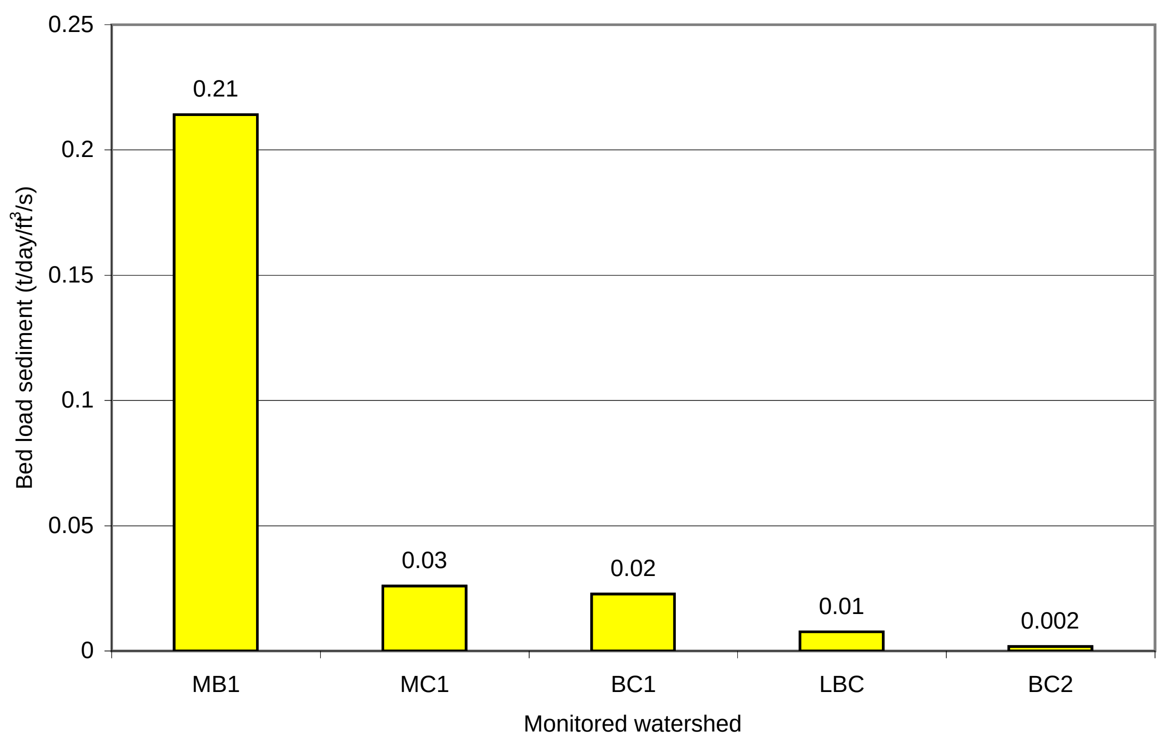


Figure 12.--Calculated average suspended sediment load per unit area for Bear Creek and selected tributaries.

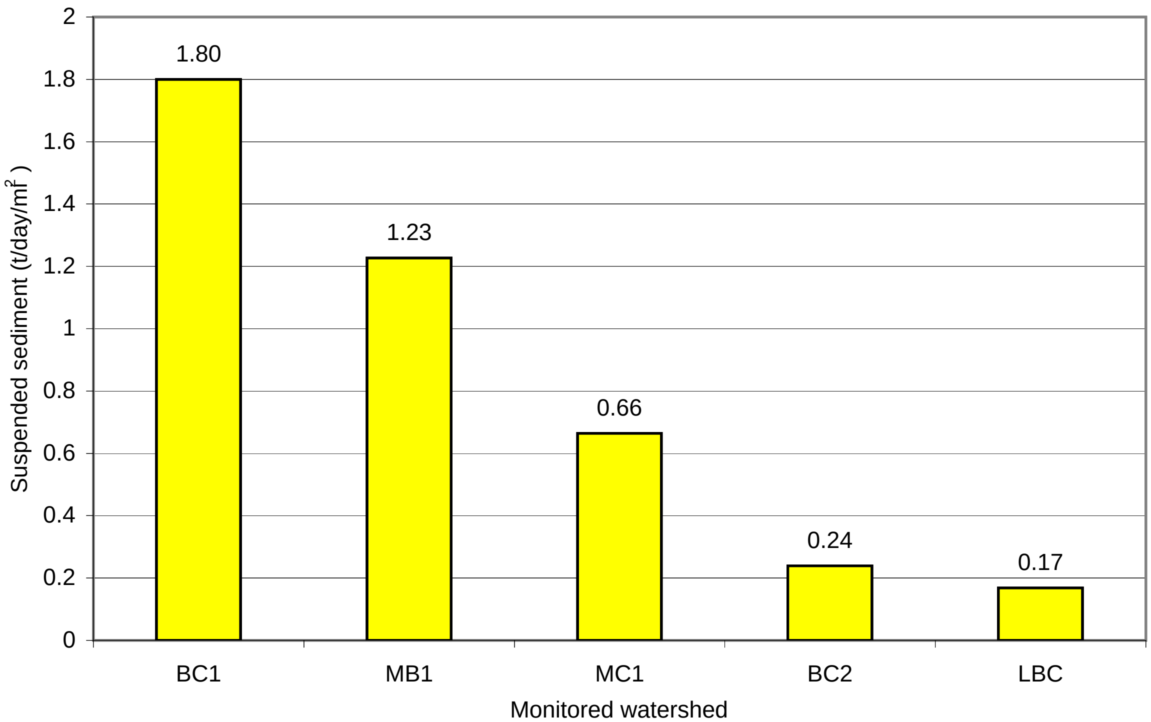
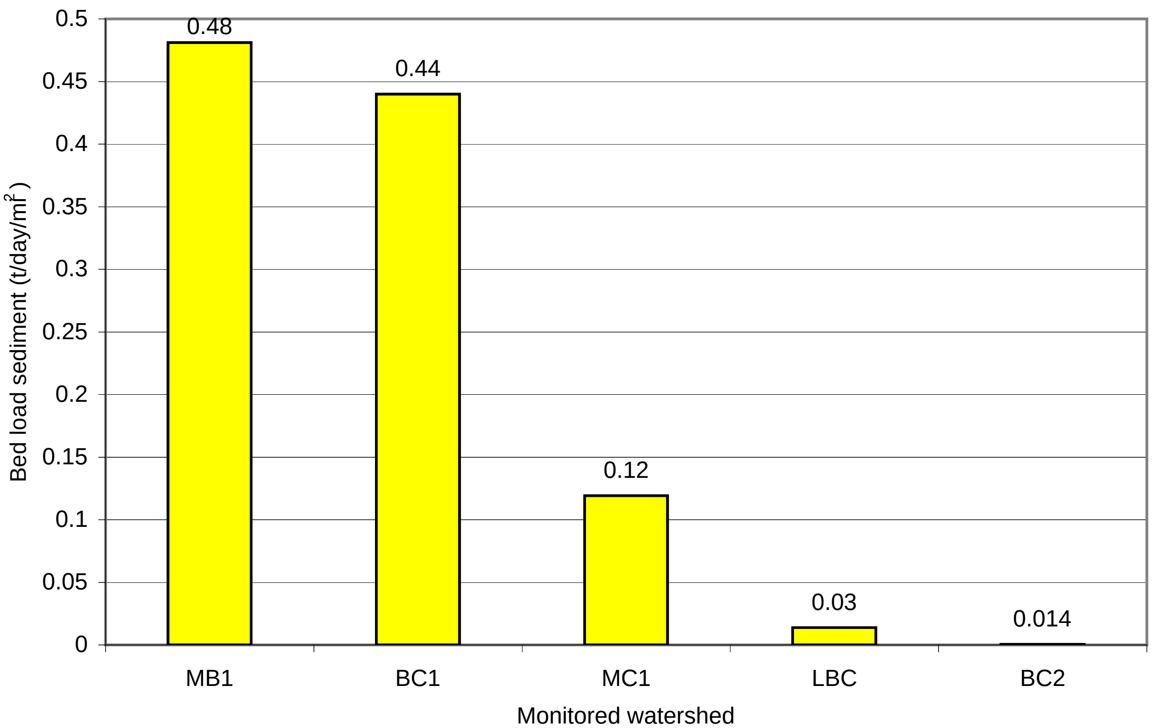


Figure 13.--Calculated average bed load sedimentd per unit area for Bear Creek and selected tributaries.



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