ANALYSIS OF SEDIMENT LOADING RATES FOR THE D'OLIVE CREEK WATERSHED UPSTREAM FROM THE INTERSTATE 10 CROSSING, BALDWIN COUNTY, ALABAMA

Mobile Bay National Estuary Program

Geological Survey of Alabama
Founded 1848

Alabama Department of Transportation
Enriching lives in Alabama through excellence in transportation

GEOLOGICAL SURVEY OF ALABAMA

Berry H. (Nick) Tew, Jr.
State Geologist

ANALYSIS OF SEDIMENT LOADING RATES FOR THE D'OLIVE CREEK WATERSHED UPSTREAM FROM THE INTERSTATE 10 CROSSING, BALDWIN COUNTY, ALABAMA

OPEN FILE REPORT 1206

By

Marlon R. Cook
and
Neil E. Moss

This project was supported wholly or in part by Mobile Bay National Estuary Program as part of a grant from Alabama Department of Transportation.

Tuscaloosa, Alabama
2012

Contents

Illustrations

INTRODUCTION

Land-use change can have tremendous deleterious impacts on water quality and biological habitat of streams. This is particularly true in parts of Baldwin County where topographic relief and highly erodible soils are subjected to disturbances related to residential and commercial development.

The D'Olive Creek watershed drains part of the eastern shore of Mobile Bay, including parts of the cities of Spanish Fort and Daphne. The watershed is in transition from forested, agricultural, and residential land uses to residential and commercial development. This land-use transition and its related urban contaminants and impervious surfaces have the potential to profoundly impact water quality and habitat in the watershed and Mobile Bay. Increasing runoff accelerates erosion and stream channel degradation, which leads to excessive sediment loads and destroys habitat and infrastructure.

Preceding investigations by the Geological Survey of Alabama (GSA) in October 2006 and October 2007 included evaluations of sedimentation in the watershed. In 2008, severe headward erosion of the D'Olive Creek channel was discovered between U.S. Highway 90 and Interstate 10. This erosion was accelerated by excessive rainfall from Tropical Storm Fay, which had landfall near Carrabelle in the Florida Panhandle on August 23, 2008, and Hurricane Gustav, which had landfall in southeastern Louisiana on September 1, 2008. The stream channel was eroded to more than 10 feet deep and more than four times its original width, destroying timber and draining wetlands. When the headward erosion reached Interstate 10, the concrete culverts under the highway were undermined, leading the Alabama Department of Transportation to take emergency remedial action to prevent damage to the highway. Subsequently, a stream restoration project was initiated to repair damage to the stream channel downstream from Interstate 10 (I-10).

In order to document runoff and sediment loads resulting from current impacts of land-use upstream from Interstate 10 and to collect data for future management strategies to protect water quality and habitat, this investigation was initiated by the GSA and the Mobile Bay National Estuary Program with the cooperation of the Dauphin Island Sea Lab.

ACKNOWLEDGMENTS

Several individuals contributed to the development and completion of this project, including Congressman Jo Bonner, Representative Randy Davis, Ms. Ashley Campbell (City of Daphne), and Ms. Roberta Swann (Director of the Mobile Bay National Estuary Program).

PROJECT AREA

The D'Olive Creek I-10 project watershed area covers 2.2 square miles (mi^2) of the headwaters of D'Olive Creek, upstream from Interstate 10 in east-central Baldwin County (fig. 1). Land use/land cover in the project area is dominated by pasture and pecan orchards along State Highway 181 in the Malbis area in the southeastern part of the watershed (fig. 2). The remaining upland parts of the watershed are dominated by residential and commercial development along the State Highway 181, U.S. Highway 31, Interstate 10, and U.S. Highway 90 corridors in Spanish Fort and Daphne. Areas of lower elevation include stream flood plains and wetlands and are dominated byforest and wetland vegetation.

STREAM DISCHARGE

The I-10 monitoring site was fitted with an instrument house containing an American Sigma 900 Max digital water sampler and data logger, which collected water level and water samples. When adequate water level and discharge data were collected, a rating table was entered into the digital data logger so that stream discharge at 15-minute intervals was collected during the entire project (fig. 3). The recorded discharge data were used to calculate average daily flow, which was used to estimate sediment loads. The largest discharge was 1,737 cubic feet per second (cfs) measured on July 16, 2011. The average daily flow for the monitored period (December 2010 to February 2012) was 6.2 cfs.

TURBIDITY

Turbidity values measured from water samples can be utilized to estimate long-term trends of total suspended solids (TSS). Figure 4 shows an excellent correlation between turbidity and TSS at the I-10 site. Turbidity data can also be used to evaluate suspended sediment content of surface waters and is commonly correlated with stream discharge (fig. 5). The highest turbidity (>1,000 NTU) and discharge (1,737 cfs) were measured on July 16, 2011. Turbidity values at the project monitoring site correlated well with discharge and varied from 21 to more than 1,000 NTU (fig. 5).

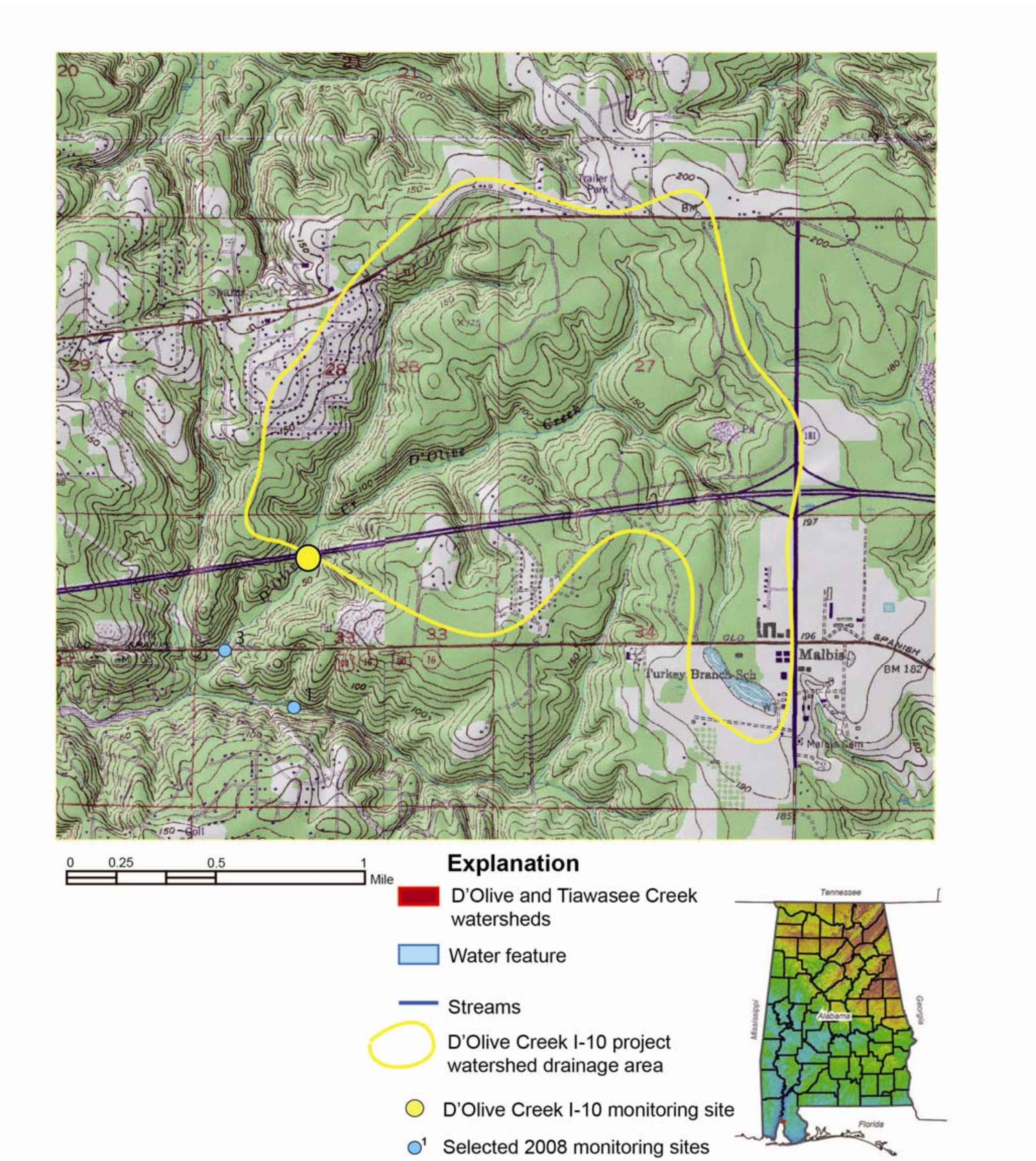

Figure 1.—Location map for the D'Olive Creek I-10 monitoring project area.

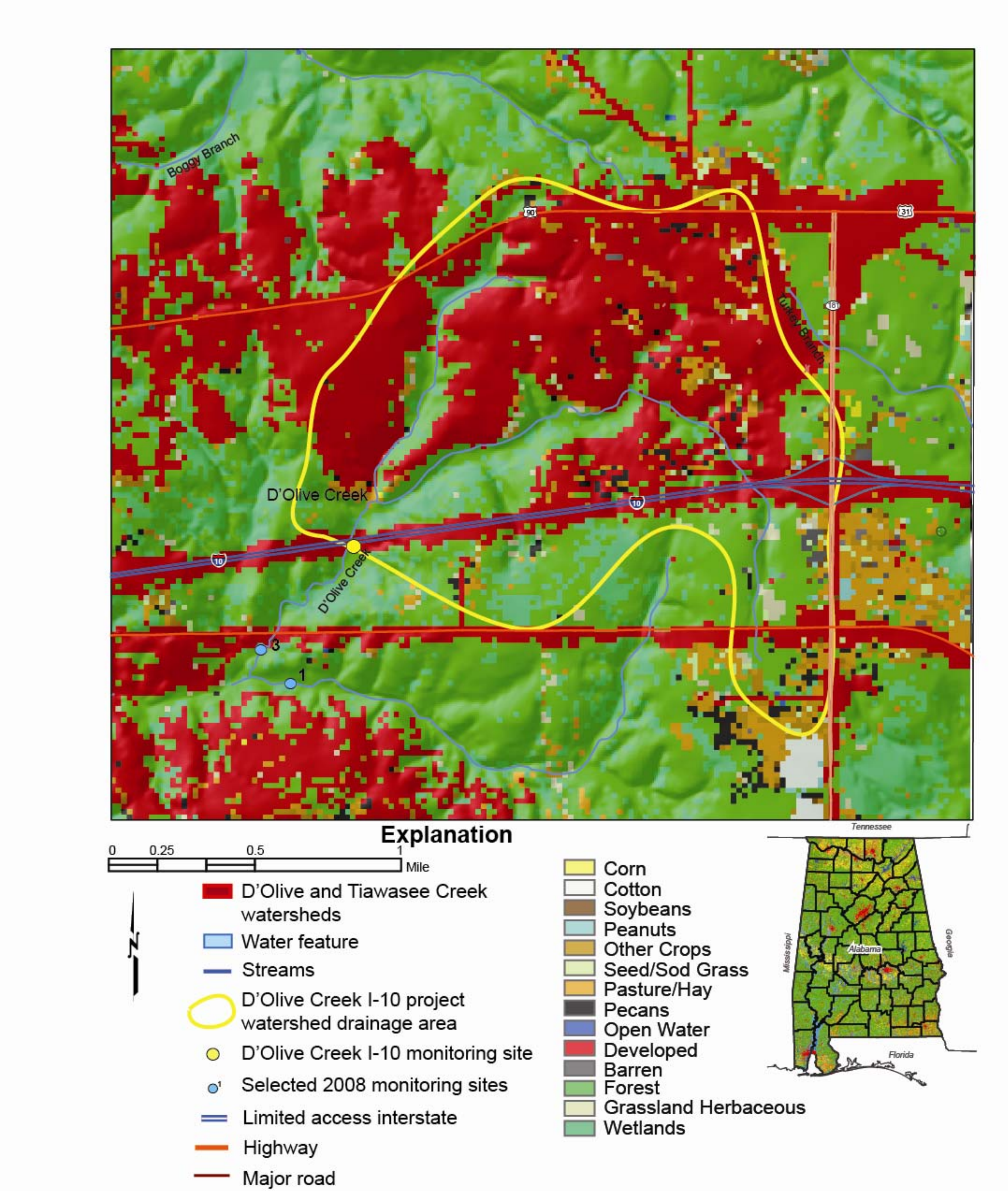

Figure 2.—Land-use/land-cover for the D'Olive Creek I-10 monitoring project area.

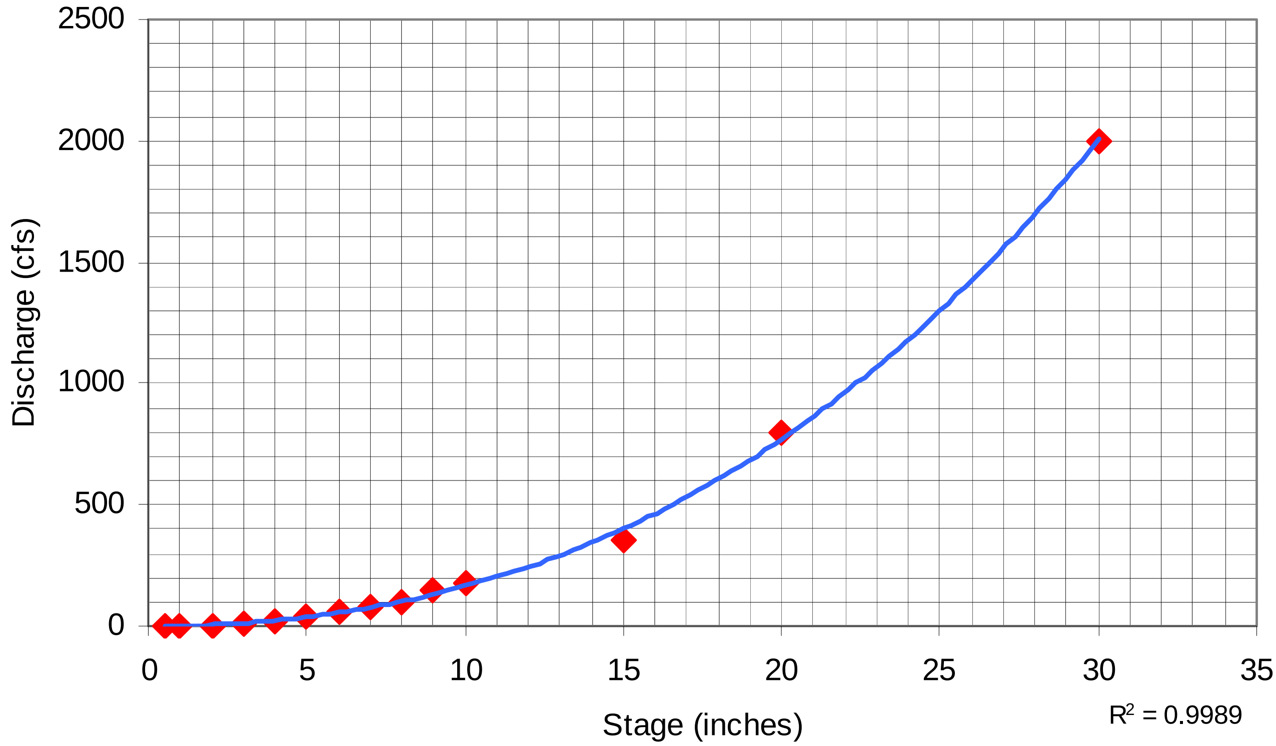

Figure 3.—Discharge rating curve for the D'Olive Creek I-10 monitoring site.

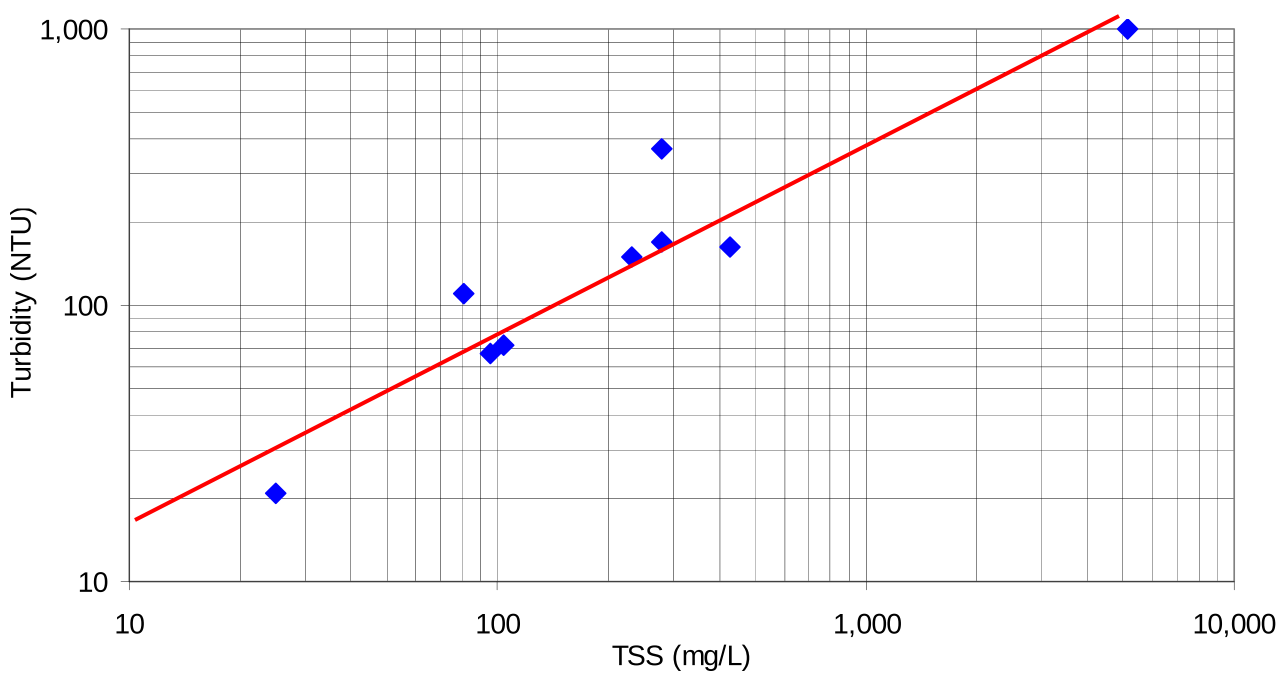

Figure 4.—Measured turbidity and total suspended solids at the D'Olive Creek I-10 monitoring site.

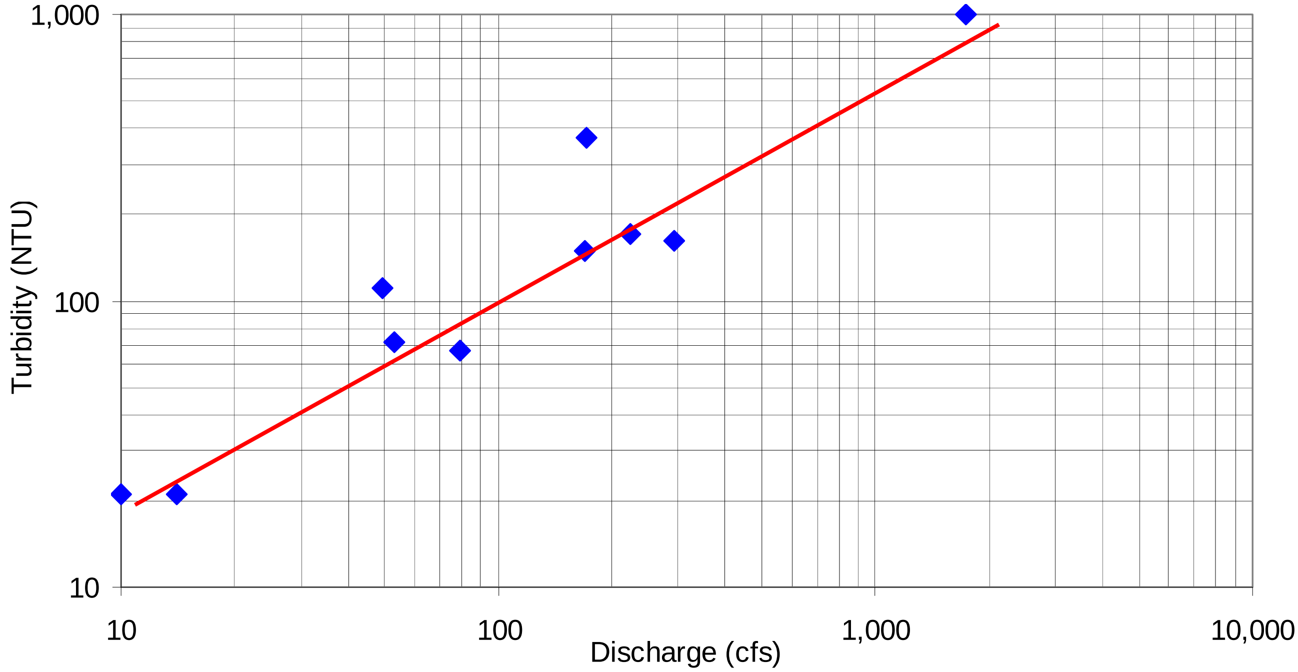

Figure 5.—Measured turbidity and discharge at the D'Olive Creek I-10 monitoring site.

CONSTITUENT LOADING IN PROJECT STREAMS

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 constituent loads for this project. The program is an Excel implementation 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, 1998).

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.

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 flood plain transport occurs in streams of varying order, where upland sediment joins sediment eroded from flood plains, stream banks, and stream beds. 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. Erosion rates are also influenced by amounts of rainfall and resulting runoff. 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 composed of relatively small particles suspended in the water column (suspended solids) and larger particles that move on or periodically near the stream bed (bed load). The D'Olive Creek I-10 monitoring site was located at the downstream end of the concrete culvert system that conveys D'Olive Creek flow under Interstate 10 (fig. 6). Since all samples were collected from stream flow moving across a concrete surface at relatively high velocity, it is assumed that the total sediment load is represented in the samples as suspended sediment as described below.

SUSPENDED SEDIMENT

Suspended solids are 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 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. For the purposes of this

Figure 6.—D'Olive Creek I-10 project monitoring site, highway culverts, and headward erosion restoration.

investigation, TSS is synonymous with suspended sediment transported by the project stream.

Concentrations of TSS in mg/L were determined by laboratory analysis of water samples. Samples were collected during a range of discharge events from low to high flow. Results of analyses indicate that TSS in high flow samples was from 10 to more than 100 times greater than samples collected during low flow (fig. 7). As discussed previously, amounts of rainfall and resulting runoff impact erosion and sediment volumes. This was documented during two previous investigations by GSA in the D'Olive Creek watershed (Cook, 2007, Cook and others, 2008), where suspended sediment loads estimated for several streams during the period October 2007 to October 2008 were two to seven times greater than those estimated for the period October 2006 to October 2007. Rainfall in the watershed for the period October 2006 to October 2007 (44.7 inches) was 60 percent of the October 2007 to October 2008 period (74.1 inches)

(Hutchinson, Moore & Rauch, LLC, 2008). Rainfall in the D'Olive Creek watershed for 2011 was well below

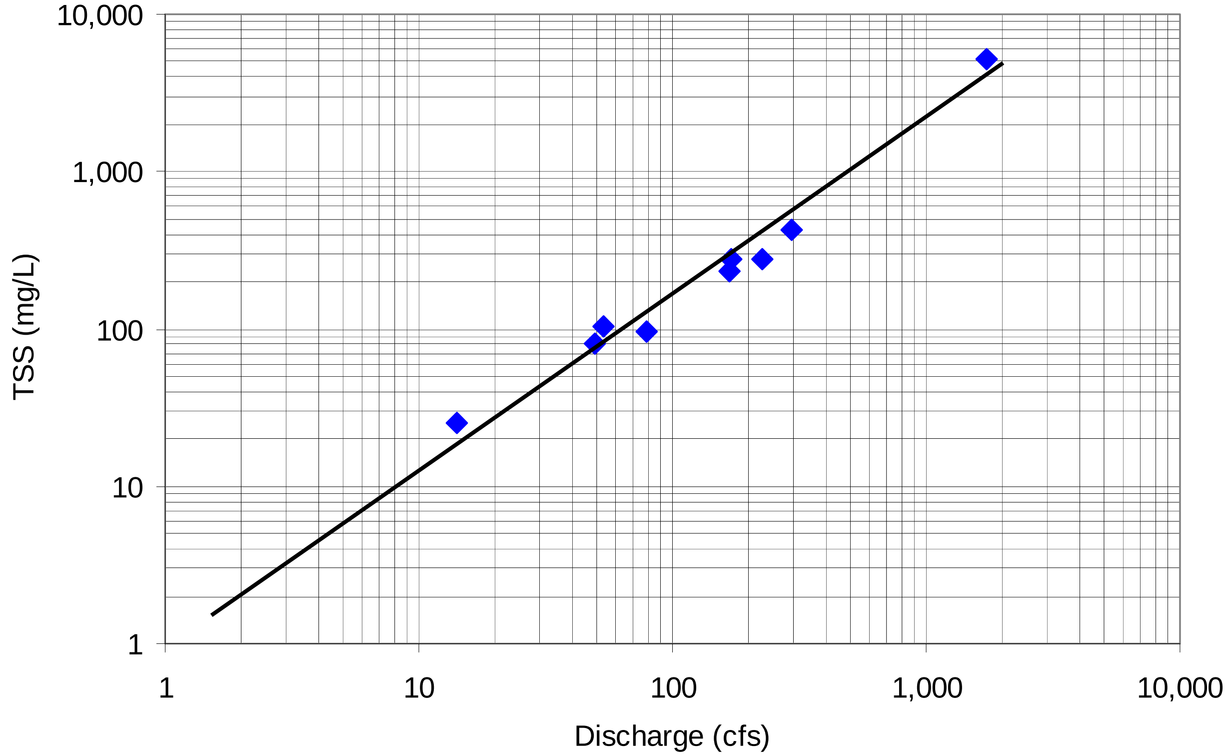

Figure 7.—Total suspended solids and stream discharge measured at the D'Olive Creek I-10 monitoring site.

average (41.4 inches) and probably resulted in lower sediment transport rates than would be observed during a year with average or greater than average precipitation.

Suspended sediment loads for the monitored segment of D'Olive Creek were estimated using measured TSS concentrations and mean daily discharge values with the regression with centering model, discussed previously in this report. Estimated annual suspended sediment load for the I-10 site during 2011 was 196 tons. When the load was normalized with respect to unit watershed area, the load was 90 tons per mi^2 per year ($tons/mi^2/yr$).

STREAM BED SEDIMENT

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 volumes of sediment being transported along the stream bed. This is particularly true in streams that flow at high velocity or in streams with excessive sediment loads.

The GSA developed a portable bed load sedimentation rate monitoring device to accurately measure bed sediment in shallow sand or gravel bed streams (Cook and Puckett, 1998). The device was utilized during this project to periodically measure bed load over a range of discharge events to calculate daily bed load sedimentation rates.

As a result, this and other erosion in the watershed upstream from U.S. Highway 90 resulted in an annual bed sedimentation rate of 3,097 tons as estimated by GSA in 2008. Figure 7 shows bed sediment loads and discharge measured at D'Olive Creek site 3 (D'Olive Creek at U.S. Highway 90 crossing). The largest individual bed sediment measurements occurred on May 16, 2008, during a large rainfall event (62 tons/day) and on August 25, 2008, during Tropical Storm Fay (52 tons/day) (fig. 8). The data are divided into values measured prior to the upstream channel restoration and values measured after the restoration. The regression shown by figure 8 indicates that the restoration has probably had little impact on sediment loads transported through site 3.

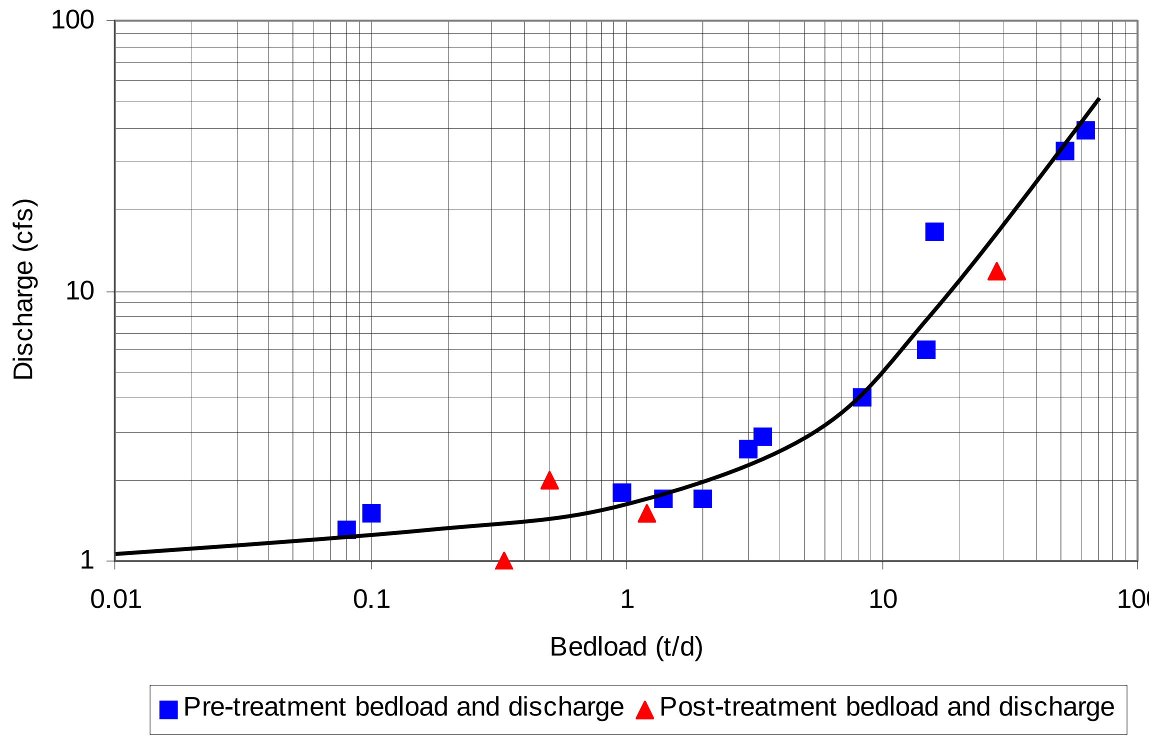

Figure 8.—Measured bed sediment loads and discharge for pre- and post-treatment periods for D'Olive Creek monitoring site 3.

TOTAL SEDIMENT LOADS

Total sediment loads are composed of suspended and bed sediment. Without human impact, the geologic erosion rate is about 64 tons/mi^2/yr (Maidment, 1993). Sediment loads were estimated by GSA for several streams in the D'Olive Creek watershed from 2006 through 2008. The largest total annual sediment loads in the D'Olive Creek watershed (551 tons/yr in 2007 and 3,716 tons/yr in 2008) were estimated at site 3 (D'Olive Creek at U.S. Highway 90) (Cook, 2007, Cook and others, 2008). This site is about 0.3 mile downstream from the I-10 site. When total sediment loads were normalized with respect to watershed area, the largest loads also occurred at D'Olive Creek site 3 (348 tons/mi^2/yr in 2007 and 1,987 tons/mi^2/yr in 2008) (Cook, 2007, Cook and others, 2008) (fig. 9). This is about 5.5 and 31 times the geologic erosion rate, respectively. Rainfall was 44.7 inches in 2007 and 74.1 inches in 2008 (fig. 9).

The total sediment load for the I-10 monitoring site was 196 tons/yr (90 tons/mi^2/yr) or about 1.4 times the geologic erosion rate (fig. 9). Rainfall in 2011, during the project period, was 41.4 inches, which is about 67 percent of average precipitation. Therefore, the sediment load estimated for the project period is most likely less than sediment loads for average or greater than average precipitation and can be compared to the 2007 load for D'Olive Creek site 3 due to similar precipitation. The normalized sediment load for the I-10 site was about 26 percent of the load at site 3. Therefore, it can be concluded that most sediment transported by D'Olive Creek originates on the south (downstream) side of I-10.

SUMMARY OF FINDINGS

In order to document runoff and sediment loads resulting from current impacts of land-use upstream from Interstate 10 and to collect data for future management strategies to protect water quality and habitat, the Geological Survey of Alabama performed this investigation of runoff and sediment transport. The D'Olive Creek I-10 project watershed area covers 2.2 square miles of the headwaters of D'Olive Creek, upstream from Interstate 10 in east-central Baldwin County.

Land use/land cover in the project area is dominated by pasture and pecan orchards in the southeastern part of the watershed. The remaining upland parts of the watershed are dominated by residential and commercial development along the State

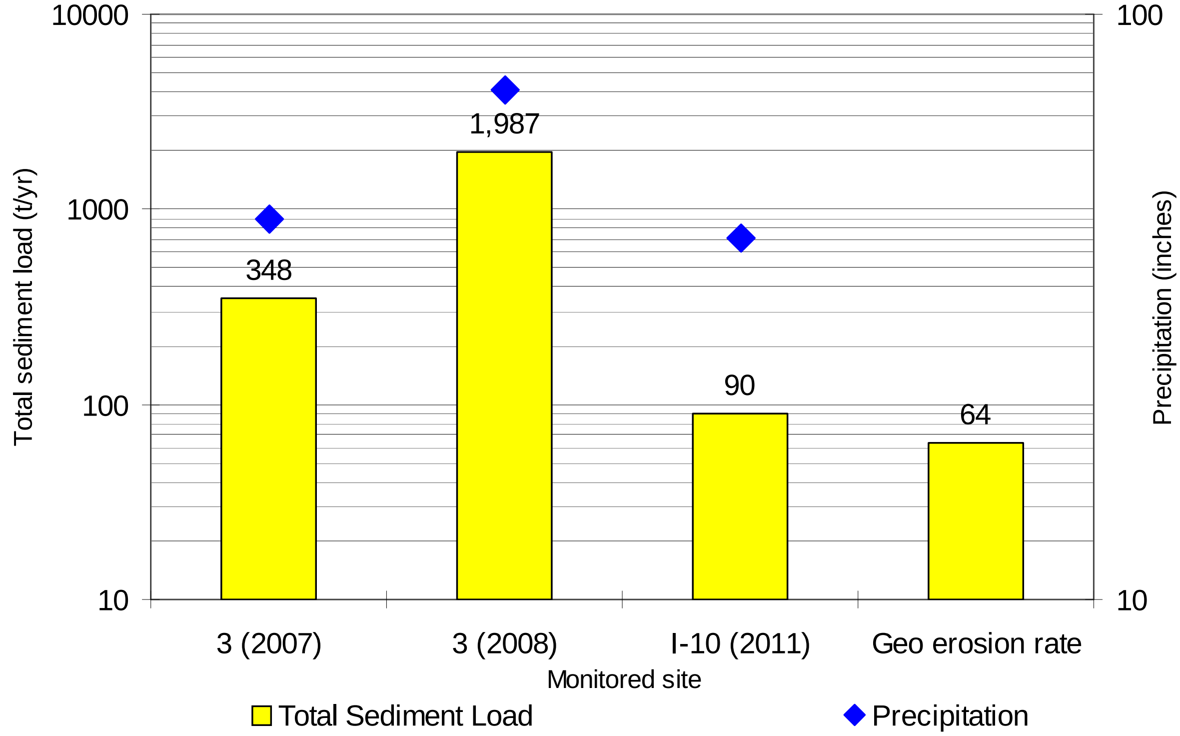

Figure 9.—Estimated normalized total sediment loads and annual precipitation for D'Olive Creek monitoring sites 3 and I-10 and the geologic erosion rate.

Highway 181, U.S. Highway 31, Interstate 10, and U.S. Highway 90 corridors. Areas of lower elevation include stream flood plains and wetlands and are dominated by forest and wetland vegetation.

Turbidity data can also be used to evaluate suspended sediment content of surface waters and is commonly correlated with stream discharge. Turbidity values at the project monitoring site correlated well with discharge and varied from 21 to more than 1,000 NTU.

The D'Olive Creek I-10 monitoring site was located at the downstream end of the concrete culvert system that conveys D'Olive Creek flow under Interstate 10. Since all samples were collected from stream flow moving across a concrete surface at relatively high velocity, it is assumed that the total sediment load is represented in the samples as suspended sediment. Suspended sediment loads for the monitored segment of D'Olive Creek were estimated using measured TSS concentrations and mean daily discharge values with the regression with centering model. The total sediment load for the I-10 monitoring site was 196 tons/yr (90 tons/mi^2/yr) or about 1.4 times the geologic erosion rate of 64 tons/mi^2/yr. Rainfall in 2011, during the project period, was 41.4 inches, which is about 67 percent of average precipitation. Therefore, the sediment load estimated for the project period is most likely less than sediment loads for average or greater than average precipitation. A comparison of D'Olive Creek site 3 and I-10 sediment loads estimated with similar precipitation indicates that sediment contributed to D'Olive Creek upstream from I-10 is relatively small when compared to loads originating south (downstream) from I-10.

REFERENCES CITED

Cohn, T. A., Caulder, D. L., Gilroy, E. J., Zynjuk, L. D., and Summers, R. M., 1992, The validity of a simple statistical model for estimating fluvial constituent loads: an empirical study involving nutrient loads entering Chesapeake Bay: Water Resources Research, v. 28, p. 2353-2363.

Cook, M. R., 2007, Analysis of sediment loading rates and impacts of land-use change on the D'Olive and Tiawasee Creek watersheds, Baldwin County, Alabama, 2007: Geological Survey of Alabama open-file report 0710, 18 p.

Cook, M. R., Moss, N. E., Jennings, S. P., 2008, Analysis of water quality, sediment loading rates, biological resources, and impacts of land-use change on the D'Olive and Tiawasee Creek watersheds, Baldwin County, Alabama, 2008: Geological Survey of Alabama open-file report 0811, 85 p.

Cook, M. R., and Puckett, T. M., 1998, Section 319 national monitoring program project for Lightwood Knot Creek Watershed in southeast Alabama: A report to the Alabama Department of Environmental Management, 1997 Annual Report and Paired Watershed Calibration: Geological Survey of Alabama open file report, 140 p.

Hutchinson, Moore & Rauch, LLC, 2008, Unpublished rainfall data collected as part of the National Pollution Discharge Elimination System reporting requirements for the Daphne Utilities wastewater treatment plant located in the D'Olive Creek watershed: 34 p.

Maidment, D. R., ed., 1993, Handbook of hydrology: New York, McGraw-Hill Inc., p. 11.37-11.54.

Richards, R. Peter., 1998, Estimation of pollutant loads in rivers and streams: A guidance document for NPS programs: Project report prepared under Grant X998397-01-0, U.S. Environmental Protection Agency, Region VIII, David Rathke, Project Officer, 108 p.

GEOLOGICAL SURVEY OF ALABAMA
P.O. Box 869999
420 Hackberry Lane
Tuscaloosa, Alabama 35486-6999
205/349-2852

Berry H. (Nick) Tew, Jr., State Geologist

A list of the printed publications by the Geological Survey of Alabama can be obtained from the Publications Sales Office (205/247-3636) or through our web site at http://www.gsa.state.al.us/.

E-mail: info@gsa.state.al.us