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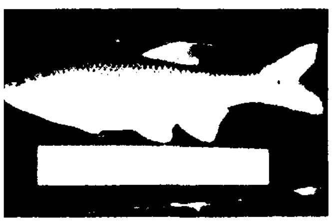

TECHNICAL REPORT EL-90-14

HYDRAULIC AND ENVIRONMENTAL EFFECTS OF CHANNEL STABILIZATION TWENTYMILE CREEK, MISSISSIPPI

by

F. Douglas Shields, Jr., Jan Jeffrey Hoover, Nelson R. Nunnally, K. Jack Killgore, Thomas E. Schaefer

Environmental Laboratory

and

Terry N. Waller

Hydraulics Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
3909 Halls Ferry Road, Vicksburg, Mississippi 39180-6199

US ARMY ENGINEER WATERWAYS EXPERIMENT STATION

December 1990

Final Report

Approved for Public Release, Distribution Unlimited

Prepared for US Army Engineer District, Mobile
Mobile, Alabama 36628-2288

ENVIRONMENTAL LABORATORY

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) Technical Report EL-90-14	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION USAEWES, Environmental and Hydraulics Laboratories 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) 3909 Halls Ferry Road Vicksburg, MS 39180-6199	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION USAED, Mobile 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER Intra-Army Order for Reimbursable Services No. FC-88-0069
8c. ADDRESS (City, State, and ZIP Code) Mobile, AL 36628-2288	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
Hydraulic and Environmental Effects of Channel Stabilization, Twentymile Creek, Mississippi

12. PERSONAL AUTHOR(S) Shields, F. Douglas, Jr.; Waller, Terry N.; Nunnally, Nelson R.; Hoover, Jan Jeffrey; Killgore, K. Jack; Schaefer, Thomas E.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final report	FROM ____ TO ____	December 1990	117

16. SUPPLEMENTARY NOTATION
Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	See reverse.

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Twentymile Creek, located in northeast Mississippi, was straightened and enlarged about 1910, 1936-37, and in 1966. Extreme channel instability followed the 1966 modifications, and corrective measures (placement of bank protection and construction of three grade control structures (GCS)) were taken between 1982 and 1988. Hydraulic and environmental studies described herein were performed to determine effects of the corrective measures.

Channel surveys and hydrologic data from Twentymile Creek were used to compare hydraulic conditions just before, just after, and 7 years after construction of grade control structures at RM 11.7 and RM 19.9 in late 1982. Grade control structures did not halt general bed degradation, but did promote local aggradation for about 1 mile upstream of each structure. The channel degraded and widened downstream of the GCS. Riprap revetments were inspected in 1989 and were functioning properly.

(Continued)

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE (Include Area Code) / 22c. OFFICE SYMBOL

18. SUBJECT TERMS (Continued).

Aquatic habitat
Biotechnical
Channel stability
Channelization
Erosion
Fish
Flood control
Grade control
Habitat diversity
Incision
Riparian vegetation
Sediment transport
Sedimentation
Species diversity
Streambank protection
Streams

19. ABSTRACT (Continued).

Environmental studies were structured to investigate recovery mechanisms suggested by previous workers. Other investigators have noted that other incised Mississippi streams have recovered stability by forming low-flow channels and vegetated longitudinal berms within the enlarged section. Low-flow channels have been suggested as features to ameliorate channel modification impacts on aquatic habitats. Habitat value of pools created by local scour below GCS placed in channelized streams has also been previously noted.

A poorly defined low-flow channel was observed in Twentymile Creek upstream of RM 9.1, but was not evident on 1980 survey cross sections. Low-flow channel capacity was about 100 cfs, which is equaled or exceeded about 30 percent of the time.

Woody vegetation cover on bank lines of selected reaches of Twentymile Creek and two reference streams (Big Brown and Mubby-Chiwapa Creeks) was mapped from aerial photos taken before (1981) and 3 years after (1985) GCS construction. The reference streams have had similar histories of modification and similar watershed land-use patterns. One GCS has been constructed on Big Brown; none have been constructed along Mubby-Chiwapa. Woody vegetation cover increased from 64.1 to 71.7 percent along Twentymile, but was relatively static along the other two streams, decreasing from 98.4 to 95.5 percent along Big Brown and increasing from 86.0 to 87.5 percent along Mubby-Chiwapa.

Aquatic habitat diversity was quantified for selected reaches along Twentymile and Mubby-Chiwapa Creeks by measuring depth, velocity, cover, and bottom type at regularly spaced points during summer low flow and using results to compute a Shannon function index. Fish were sampled concurrently from the same reaches using seines. Higher levels of aquatic habitat diversity were observed below GCS relative to other reaches. Fish species diversity and richness were also higher below GCS. Thirty-nine fish species were found in Twentymile, but only 22 species were found in Mubby-Chiwapa. Fish species diversity and habitat diversity were only weakly correlated.

PREFACE

This report was prepared by the Hydraulics and Environmental Laboratories (HL and EL), US Army Engineer Waterways Experiment Station (WES), in fulfillment of Intra-Army Order for Reimbursable Services No. FC-88-0069. Messrs. Gary Melton and Mike Eubanks of the US Army Engineer District (USAED), Mobile, were District points-of-contact. Sections of the report dealing with hydraulic engineering were written and prepared by Mr. Terry N. Waller of the Hydraulic Analysis Branch (HAB), Hydraulic Structures Division (HSD), HL, and Dr. F. Douglas Shields, Jr. of the Water Resources Engineering Group (WREG), Environmental Engineering Division (EED), EL. Sections of the report dealing with environmental engineering were written and prepared by Dr. N. R. Nunnally, Dr. Shields, and Mr. T. E. Schaefer, all of the WREG. Sections of the report dealing with fishes were written and prepared by Dr. Jan Jeffrey Hoover and Mr. K. Jack Killgore of the Aquatic Habitat Group (AHG), Environmental Resources Division (ERD), EL.

Dr. Shields coordinated and managed the project. Mr. W. A. Thomas of the Waterways Division, HL, made many helpful suggestions regarding the hydraulic engineering analyses. Messrs. Larry Sanders, Ken Conley, Mike Potter, and John Baker and Dr. Neil Douglas of the AHG, Cadet Kevin Hoppens of the US Military Academy, and Mrs. Glenda Nunnally of the University of North Carolina-Charlotte provided assistance with field data collection. Technical reviews of the draft report were provided by Dr. A. C. Miller of the AHG, Dr. John J. Ingram of the WREG, and Mr. W. A. Thomas of the HL. The report was edited for publication by Ms. Janean Shirley of the WES Information Technology Laboratory.

The work was accomplished under the direct supervision of Dr. John J. Ingram, Chief, WREG, Dr. Bobby J. Brown, Chief, HAB, and Mr. Edwin A. Theriot, Chief, AHG, and under the general supervision of Dr. Raymond L. Montgomery, Chief, EED; Dr. Conrad J. Kirby, Chief, ERD; Dr. John Keeley, Assistant Chief, EL; Dr. John Harrison, Chief, EL; Mr. Glen Pickering, Chief, HSD, and Mr. Frank Herrmann, Chief, HL.

COL Larry B. Fulton, EN, was Commander and Director of WES. Dr. Robert W. Whalin was Technical Director.

This report should be cited as follows:

Shields, F. Douglas, Jr., Waller, Terry N., Nunnally, Nelson R., Hoover, Jan Jeffrey, Killgore, K. Jack, and Schaefer, Thomas E. 1990. "Hydraulic and Environmental Effects of Channel Stabilization, Twentymile Creek, Mississippi," Technical Report EL-90-14, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

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CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
acres	4,046.873	square metres
acre-feet	1,233.489	cubic metres
cubic feet per second	0.02831685	cubic metres per second
Fahrenheit degrees	5/9	Celsius degrees or kelvins*
feet	0.3048	metres
feet per mile	0.1893935	metres per kilometre
inches	2.54	centimetres
miles (US statute)	1.609347	kilometres
pounds (mass)	0.4535924	kilograms
pounds (force) per square foot	47.88026	pascals
square feet	0.09290304	square metres
square miles	2.589998	square kilometres
tons (2,000 pounds, mass)	907.1847	kilograms

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: C = (5/9)(F - 32). To obtain kelvin (K) readings use: K = (5/9)(F - 32) + 273.15.

HYDRAULIC AND ENVIRONMENTAL EFFECTS OF CHANNEL STABILIZATION TWENTYMILE CREEK, MISSISSIPPI

PART I: INTRODUCTION

Background

1. Twentymile Creek is a 30-mile*-long, southeasterly flowing tributary that joins the East Fork Tombigbee River at river mile (RM) 481.2 It drains an area of approximately 174 square miles in Prentiss, Lee, and Itawamba Counties in northeastern Mississippi (Figure 1). Twentymile Creek was straightened by local interests to improve drainage about 1910 (Ramser 1930) and the lower reaches were further modified by the US Army Corps of Engineers (CE) in 1938 in response to the Flood Control Acts of 1936 and 1937 (Northwest Hydraulic Consultants, Inc. (NHC) 1987). Little information exists about the hydrology or channel geometry of the original (premodification) stream, but NHC (1987) suggested that it had a slope of 1 ft/mile, a bank-full discharge of 1,500 cfs (based on meander wavelength), an average width of 70 ft, and a depth of 8 ft.

2. Section 203 of the Flood Control Act, approved July 3, 1958 (Public Law (PL) 85-500), authorized projects for flood control and related purposes on the Tombigbee River and tributaries. Six tributaries of the East Fork of the Tombigbee River, including Twentymile Creek, were modified for flood control under this authorization. Modification of Twentymile Creek, which was completed in December 1966, involved channel enlargement for the lower 9.1 miles and clearing for the next 2.6 miles. The channel was enlarged to accommodate a design flow of 3,200 to 3,700 cfs, roughly estimated to be a .33-year return interval discharge.** Bottom widths in the lower reaches were enlarged to 40 ft from RM 0 to 3, 25 ft from RM 3 to 7, and 10 ft from RM 7 to 9. The design bed slope for the excavated reach was 2.3 ft/mile.

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 6.

** The .33-year return interval discharge is a flow that occurs on an average of three times a year over a long period.

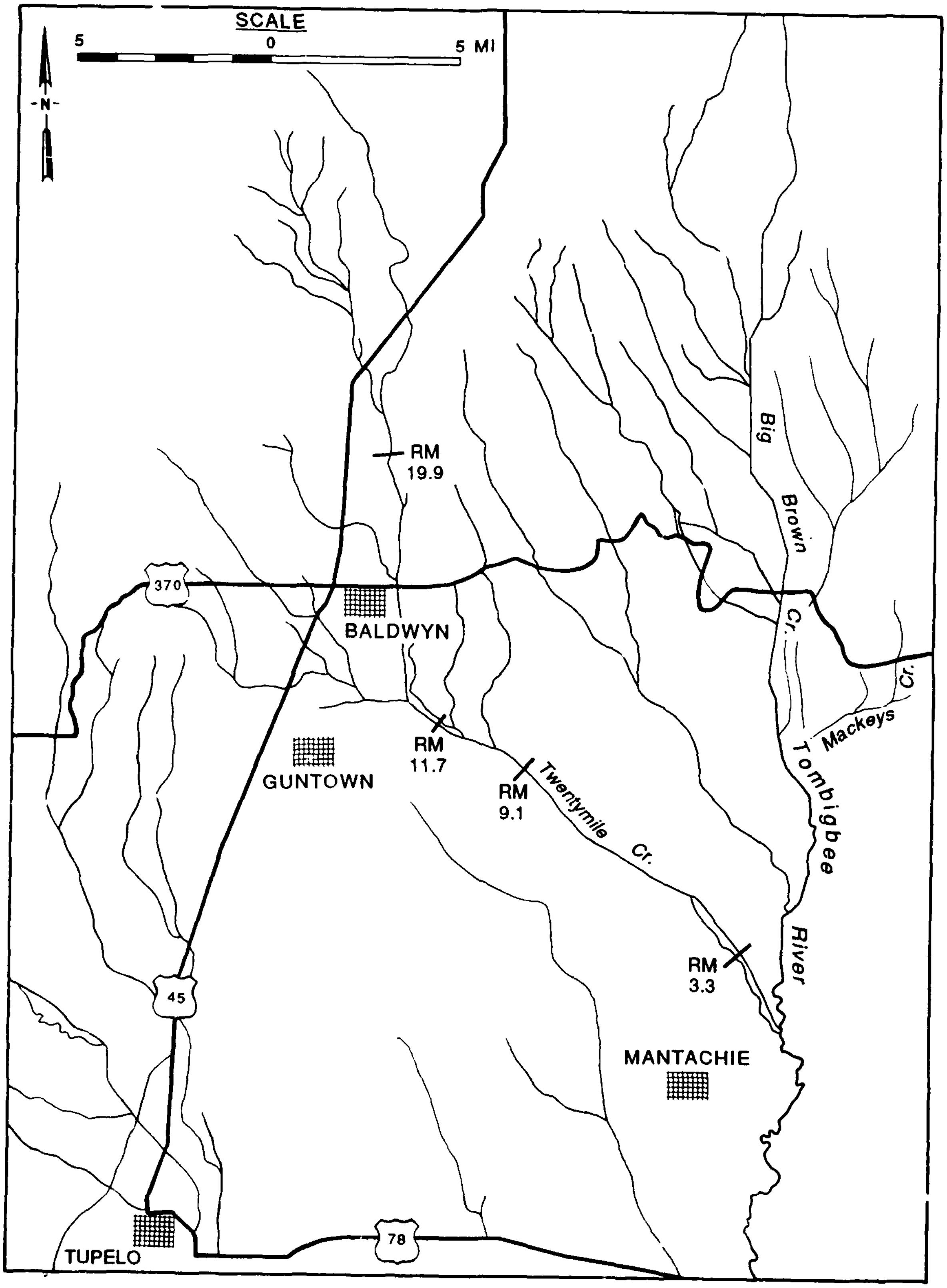


Figure 1. Twentymile Creek, Mississippi, and vicinity

Channel response

3. In April 1967, only 4 months after the project had been completed, complaints were received by the US Army Engineer District (USAED), Mobile (Mobile District) about streambank failures at RM 11.7, located just upstream from the project terminus. Over the next 10 to 12 years, channel degradation developed and worked upstream to RM 22. As the bed of Twentymile Creek degraded, waves of degradation propagated up the tributaries also. By 1979 conditions had deteriorated to the point where remedial channel stabilization work was proposed. Figures 2 and 3 show some of the effects of the channel instability. Degradation and subsequent bank failures doubled the channel cross-sectional area in the reach between RM 12.0 and RM 20.0. The reach between RM 5.5 and RM 12.0 also experienced bank failures, although not as severe as those associated with the degradation further upstream. Sediments derived from upstream bed and bank erosion and tributary erosion caused the channel below RM 5.5 to aggrade (USAED, Mobile 1981), reducing channel capacity and perhaps aggravating flood problems.

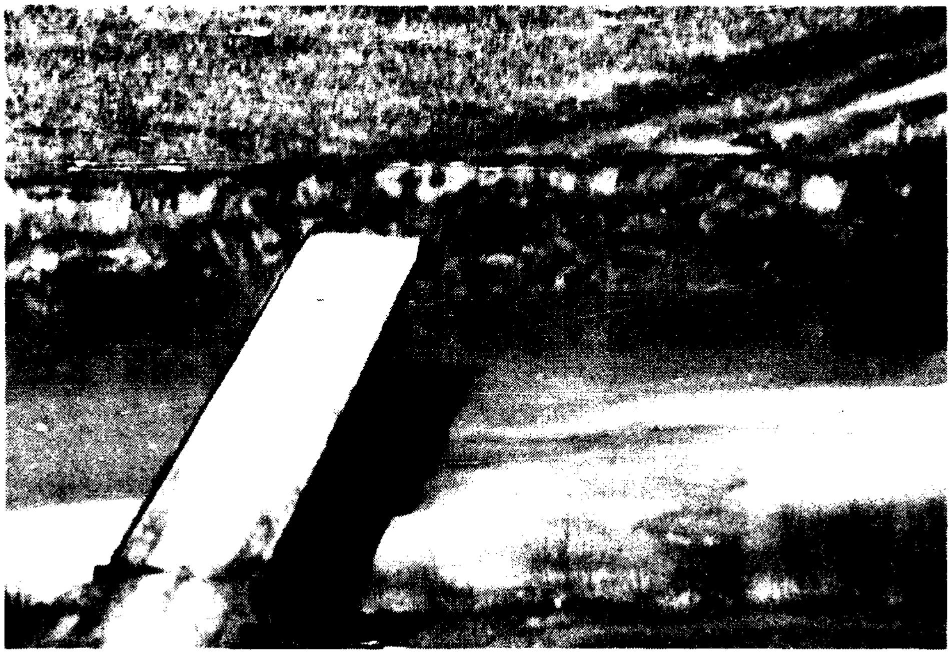
4. Although it is impossible to precisely identify the causes of the Twentymile Creek channel instability, the following conditions were contributing factors:

a. Soils throughout the drainage basin of Twentymile Creek are highly erodible. The basin lies in the Black Belt Prairie, which is underlain by chalky formations of the Selma Group. The eastern and central portions of the project area are underlain by the sands of the older Eutaw formation, while the western portion rests on the Coffee Sand, a member of the Selma Group (Vestal 1947; Parks 1960).

b. The natural channel appears to have been a highly sinuous, low-gradient stream before it was originally straightened. Ramser (1930) reported that the 1910 channel modifications caused significant channel enlargement (~2X) at Highway 370 (RM 16.3) between 1910 and 1918. The channel that existed in 1965 had a slope of about 1.5 ft/mile and a channel capacity of about 1,500 cfs (NHC 1987).

c. The modifications in 1965-1967 increased bed slope by 50 percent, and the channel capacity in the enlarged reach was more than doubled to 3,500 cfs. NHC (1987) estimated the capacity may have been quadrupled. Hydraulic gradient was increased even more in the upper reaches by the bed lowering at RM 9.1, and this caused a dramatic increase in flow velocity during flooding which led to upstream degradation.

d. Improved drainage facilitated additional land clearing for croplands, and the loss of streamside vegetation exacerbated streambank erosion problems, even in the lower reaches not affected by degradation (Mobile District 1981).



a. Bridge crossing destroyed by channel degradation

b. Degradation at bridge pier, August 1981

Figure 2. Effects of channel instability, Twentymile Creek

Figure 3. Bank failure and channel enlargement, Twentymile Creek, August 1981

e. Once instability is initiated, the processes of degradation and streambank erosion continue until the decrease in channel slope and the increase in channel width reduce unit stream power* to the point where forces resisting and driving sediment transport achieve equilibrium.

Remedial stabilization**

5. Two grade control structures*** (GCS) proposed as remedial work were authorized by PL 96-304 in 1980 and construction was completed by November 1982. One structure was installed just below a bridge at RM 11.7, and the other was located at RM 19.9 (Figure 4). The GCS at RM 11.7 was a sheet pile weir with a crest elevation about 5 ft higher than the channel bottom and a riprap stilling basin. Figure 5 depicts the RM 11.7 GCS in March 1989. The GCS at RM 19.9 was a grouted stone weir constructed about 5 ft above the channel bottom. This GCS was built upstream of a large headcut and scour hole, shown in Figure 6, to prevent upstream degradation. Willow and maiden cane were planted for bank protection upstream of the bridge at the lower GCS and downstream of the scour hole at the upper GCS. Concrete jacks and a slotted board fence were installed for bank protection in a 1/2-mile reach below the upper GCS. Severe floods in November and December 1982 and April 1983 caused some damage to the willows, jacks, and fence installed for bank protection, and emergency repair work was done during the spring and early summer of 1983.

6. A channel stability study on Twentymile Creek was performed for the Mobile District in 1982 (Simons, Li, and Associates (SLA) 1982). The objectives of this study were to develop a monitoring program for the two GCS, analyze erosion problems on Twentymile Creek, identify particularly troublesome reaches, recommend actions to alleviate erosion problems in these reaches, and estimate the potential for future erosion. The report recommended a preliminary protection plan consisting of the following components:

a. Use of rock riprap, fences, cribs, and vegetation to protect streambanks and train the stream.

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* Unit stream power is defined as the time rate of work done by the stream on the bed per unit stream width. Unit stream power is directly related to sediment transport potential.

** The structures described below this heading are also referred to as remedial measures or corrective measures elsewhere in this report.

*** Grade control structures (GCS) are used in preventing erosion of channels by controlling channel slope and preventing upstream degradation. There are many types, but almost all include some type of flume and a stilling basin for energy dissipation below the flume.

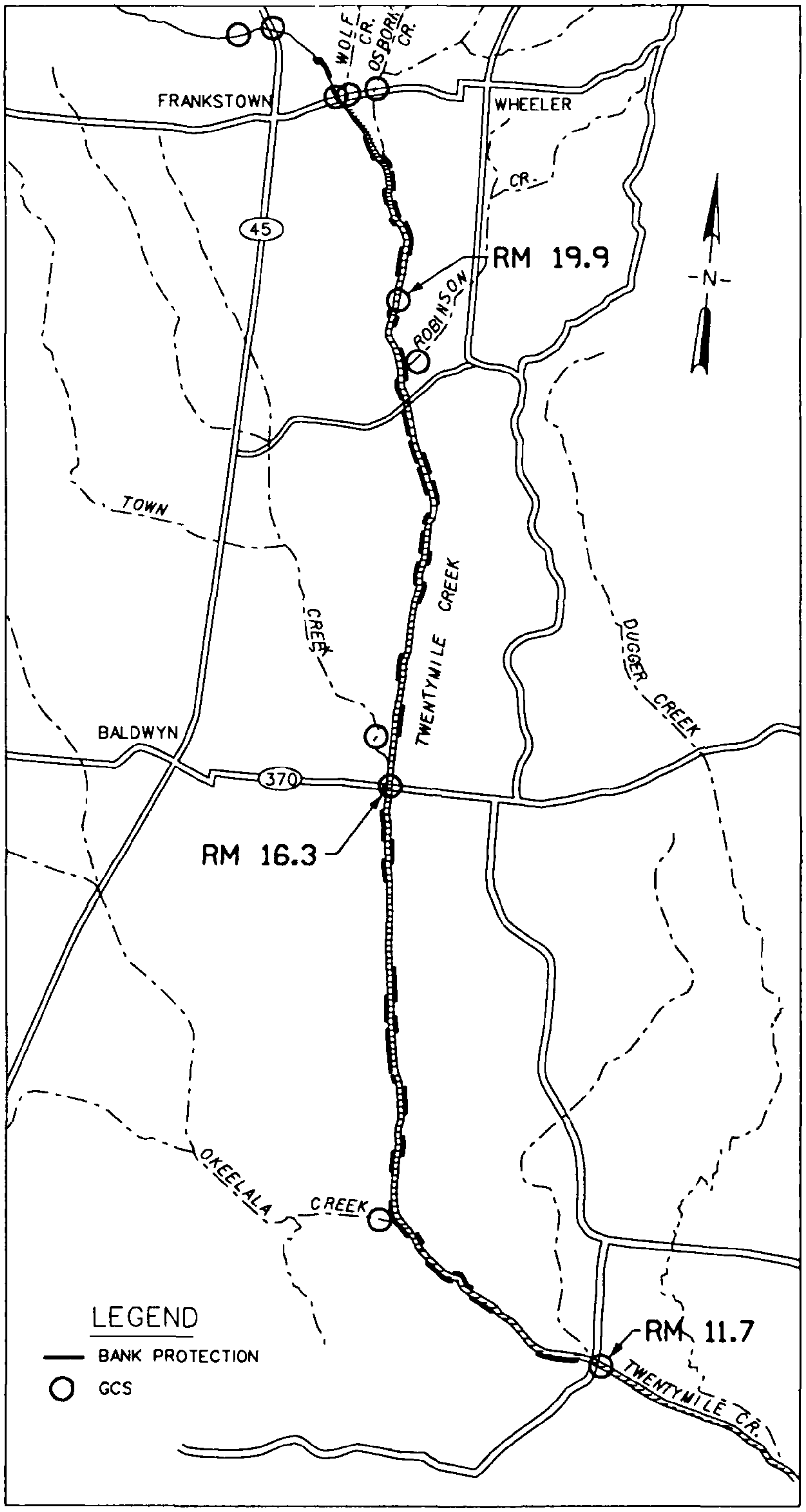

Figure 4. Locations of grade control structures (GCS) and bank protection work, Twentymile Creek

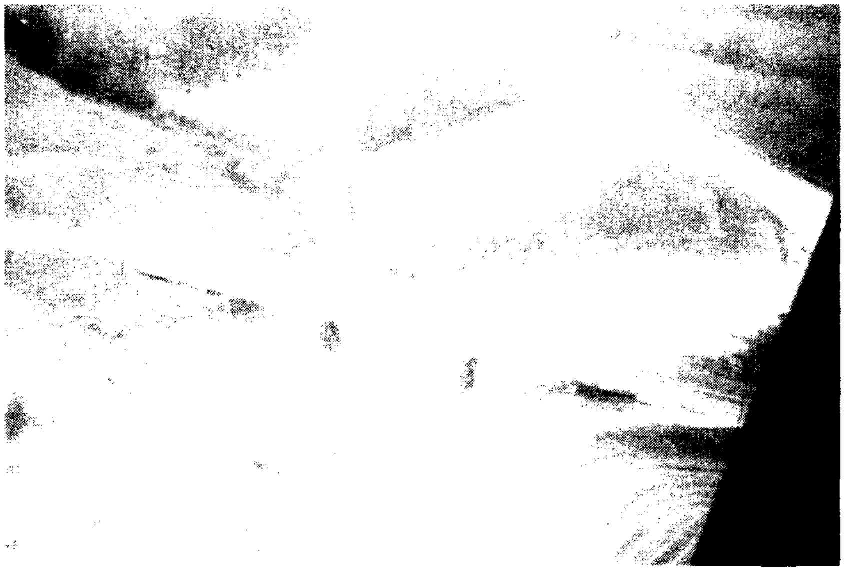

Figure 5. Grade control structure, RM 11.7, March 1989

Figure 6. Grade control structure, RM 19.9, March 1989

b. Installation of a GCS on Twentymile Creek immediately downstream of the US Highway 45 bridge.

c. Installation of a GCS at RM 20.9 to stabilize Wolf Creek, Osborne Creek, and the State Highway 362 bridge.

d. Installation of GCS at the mouths of Okeelala, Town, and Robinson Creeks.

7. Work began in 1983 on the three GCS proposed as interim stability measures on Okeelala, Town, and Robinson Creeks near their confluences with Twentymile Creek (Phase II-interim measures). These structures were needed to stop headcuts that had developed on these streams.

8. Instead of constructing a GCS at RM 20.9 on Twentymile Creek, GCS were installed under State Highway 362 bridges on Twentymile, Wolf, and Osborne Creeks to address erosion which had threatened these bridges since 1981. Construction of these GCS began in 1983. At the same time emergency streambank protection measures were initiated at the following sites (Figure 4):

a. County road crossing on Twentymile Creek at RM 13.0;

b. County road crossing on Twentymile Creek at RM 19.0;

c. US Highway 45 crossings on Twentymile and Wolf Creeks;

d. Airport Road crossing on Twentymile Creek.

The work on Wolf and Osborne Creeks and the streambank protection at Airport Road were conducted under authority of Section 14 of the Flood Control Act of 1946, as amended. The remaining work was constructed under PL 96-304 authority.

9. In September 1984, 13 additional reaches within the authorized project limits (RM 11.7 to RM 22.0) were identified for treatment under the Phase III bank protection measures. These reaches were essentially the ones identified by SLA (1982). The treatments recommended included bioengineering (use of structures with components of living vegetation) at nine sites; a combination of bioengineering and conventional treatment (such as riprap and concrete jacks) at one site; and conventional riprap, concrete jacks, and grouted riprap grade control at the remainder. A grouted riprap flume GCS was also installed at the Highway 370 bridge (RM 16.3) in 1986.

Environmental response

10. Although the biological resources of Twentymile Creek have not been extensively surveyed (with the exception of Boschung (1989)), relationships between fish communities and channelized habitat can be surmised based on precedent (e.g., Swales (1982); Gregory et al. (1985); Brookes (1988)).

Typically, stream channel enlargement and straightening decrease complexity of aquatic habitats by reducing instream cover (e.g., woody debris), substrate size and stability, and variability in depth (e.g., pools). Since these factors are all positively associated with invertebrate diversity and productivity (Hynes 1970; Wallace and Benke 1984; Smock, Gilinsky, and Stoneburner 1985), fish abundance (Hickman 1975; Angermeier and Karr 1984; Power 1984), and fish diversity (Sheldon 1968; Evans and Noble 1979), channelization and attendant channel instability are typically detrimental to aquatic communities.

11. Fish diversity may not always be associated with comparable measures of habitat diversity (Tramer and Rogers 1973), but pronounced positive correlations have been documented (Gorman and Karr 1978; Foltz 1982). Sections of channelized streams that afford substantial cover, coarse or cohesive substrates, and increased depth could therefore harbor more complex fish faunas due to broader food bases and increased habitat availability (i.e., greater number of potential niches). In the case of Twentymile Creek, installation of the corrective measures may have increased the complexity of aquatic habitat and fauna by causing formation or enlargement of scour holes, increasing the amount of cover* and stable substrate, and encouraging formation of a low-flow channel.

12. Schumm, Harvey, and Watson (1984) proposed a five-phase model for the evolution of channels enlarged by bed degradation in the Yazoo River basin in northwestern Mississippi. The five phases are illustrated in Figure 7. The initial degradation of the channel bed leads to bank failure and widening, followed by formation of vegetated berms that define a low-flow channel within the enlarged channel. Harvey and Watson (1987) documented formation of this kind of two-stage channel in Muddy Creek, a northeast Mississippi stream with a history of modification for drainage and flood control similar to Twentymile Creek. The evolution of Muddy Creek was consistent with the five-phase model. Harvey and Watson (1986) and Peterson, Watson, and Harvey (1988) documented similar behavior in Yazoo basin channels in northern Mississippi; Brookes (1988) described similar channel response to enlargement in the United Kingdom.

* Riprap and other bank protection structures provide cover. In addition, woody vegetation on stabilized banks and the longitudinal berms that form in the enlarged channel provide overhanging cover.

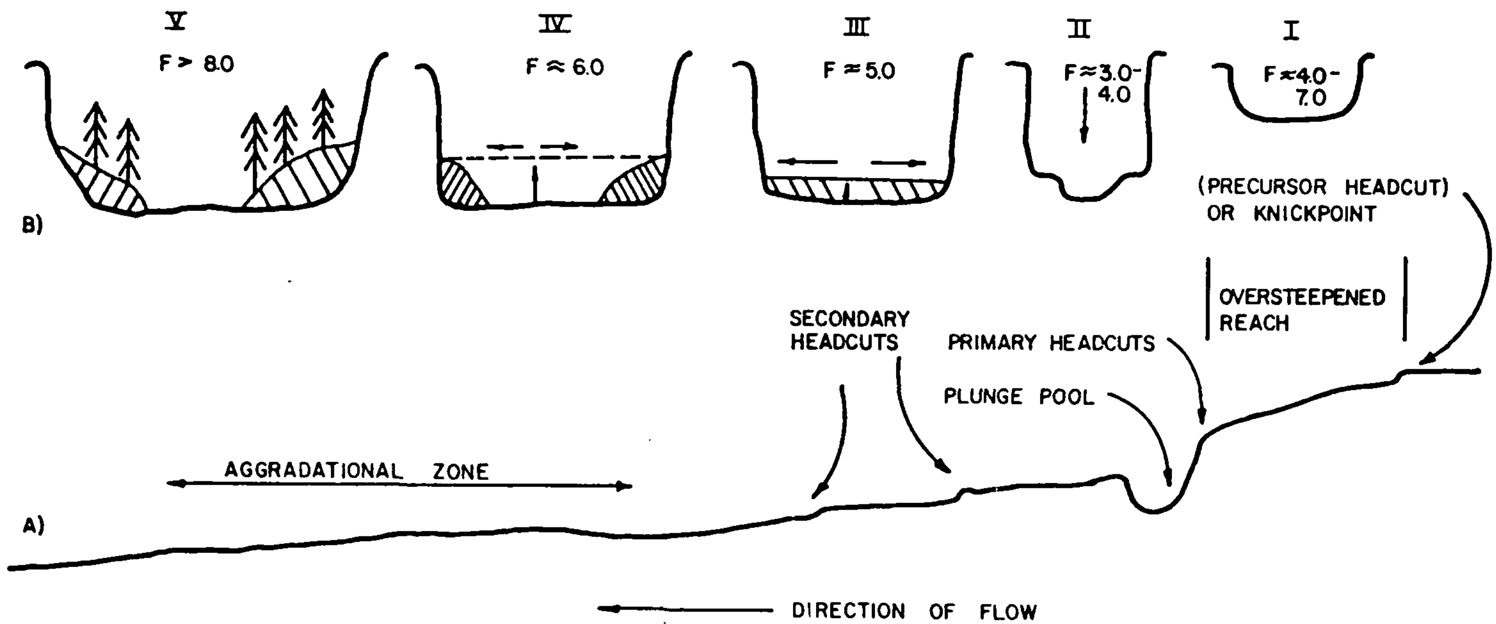

Figure 7. Five-phase channel evolution model (Schumm, Harvey, and Watson 1984)
F = ratio of channel width to channel depth

13. The final phase of the five-phase model is a two-stage channel similar to that proposed by Keller and Brookes (1984), US Army Corps of Engineers (1988 and 1989), Brookes (1985), Richards (1982), Nunnally and Shields (1985) and others for counteracting adverse environmental and channel stability effects of channel enlargement. Since the final phase of the five-phase model cannot occur in a given reach until channel degradation in that reach is arrested, installation of GCS and bank protection may facilitate development of a final phase channel and thus environmental recovery (Peterson, Watson, and Harvey 1988).

Purpose

14. The purpose of this study is to assess hydraulic and environmental effects of Twentymile Creek remedial stabilization measures. In particular, the effects of the measures on channel stability, bank line vegetation, and aquatic habitat were studied. Specific objectives for each major study component included:

a. Compare and contrast the hydraulics and channel stability of Twentymile Creek before and after construction of the corrective measures using hydrographic surveys, hydrologic records, and numerical simulation models.

b. Compare the fraction of the bank line covered by woody vegetation before and after construction of the corrective measures using aerial photography. Evaluate any changes with reference to similar data measured from photos of two similar stream channels without extensive corrective measures or a low-flow channel.

c. Evaluate effects of the GCS on physical aquatic habitat diversity by collecting depth, velocity, substrate, and cover measurements in the vicinity of the structures, in reaches of Twentymile Creek away from the GCS, and from a reference stream without a GCS.

d. Assess the impact of the GCS on fish community diversity by surveying fishes at the GCS, at other sites on Twentymile Creek, and at sites on a stream without a GCS, Chiwapa Creek.

Scope

Hydraulic engineering

15. Grade control. Channel surveys* and field reconnaissance were used to determine if channel stability improved after remedial measure construction. The discharge range for which the GCS served as hydraulic controls was determined using calculated backwater profiles.** This range of flows was compared with the channel-forming discharge.

16. General channel stability. The combined impact of GCS and bank protection was evaluated using hydrologic records and channel surveys made before and after the corrective measures were installed. Annual sediment yield was calculated at locations near each GCS to determine if the stabilization measures reduced the sediment load in the vicinity of the structures.

17. Bank protection. Several kinds of streambank protection have been employed on Twentymile Creek, including riprap, jacks, board fences, and vegetation used singly or in combination with structural measures like fences or riprap. Field inspections and information from aerial photographs were used to assess the effectiveness of these measures in controlling erosion. Channel response in the vicinity of bank protection and the effects of various bank protection measures on flow and on sediment deposition were also investigated.

Environmental engineering

18. Three types of data were collected to assess the effects of the corrective measures on biological resources: aerial photography, physical habitat measurements, and fish surveys.

a. Aerial photographs of Twentymile Creek and two comparison streams (Big Brown and Mubby-Chiwapa Creeks), taken shortly before installation of the corrective measures and several years afterward, were examined to assess changes in bank line and channel margin vegetation.

b. Physical aquatic habitat diversity was sampled in selected reaches of Twentymile and Mubby-Chiwapa Creeks using methods described by Gorman and Karr (1978). The comparison stream was an unstable, channelized stream similar to Twentymile Creek prior to installation of corrective measures. Habitat components measured included depth, velocity, substrate, and cover.

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* District files, 1980 and 1989, US Army Engineer District, Mobile, AL.

** A backwater profile is a plot of water surface elevation versus longitudinal distance for a given discharge. These profiles were calculated using a numerical simulation model, HEC-2.

c. Fishes were sampled from the same reaches where physical habitat data were collected.

d. In addition to analysis of these three types of data, the 1989 survey of the channel of Twentymile Creek was analyzed using the approach of Harvey and Watson (1987) to determine the existence and geometry of a naturally formed low-flow channel.

PART II: METHODS

Study Design

Hydraulic engineering

19. The hydraulic engineering portions of this study focused exclusively on Twentymile Creek reaches described in Part I. The effects of the stabilization measures on the channel were studied by examining data (channel surveys, aerial photos, and hydrologic records) collected before and after the measures were constructed. Field reconnaissance to determine the current status of stabilization structures was also conducted.

Environmental engineering

20. Environmental aspects of this study included consideration of data from three streams as shown in Table 1 and Figure 8. Chiwapa and Big Brown Creeks were chosen as reference streams for the vegetation study after visual inspections of the northwestern portion of the Tombigbee River Basin from a helicopter and on the ground. Selection of these channels also included consideration of the basic hydrologic and morphologic variables tabulated in Table 2.

21. Both Big Brown and Chiwapa Creeks were straightened for drainage about 1910 and further modified for flood control in the mid-1960s, about the same time that the Twentymile project was constructed (Ramser 1930; Water and Engineering Technology 1988). Big Brown was a Corps project, but Chiwapa Creek was part of a PL 566 US Soil Conservation Service watershed project. Big Brown Creek has remained relatively stable in recent years; only one minor GCS has been constructed along it. Chiwapa Creek is underlain by Selma chalk, and because of this, it has experienced less bed degradation than Twentymile Creek. No GCS have been installed; concrete jack fields are the only form of channel stabilization used. The chalk bed of the channel is veneered with sand throughout most of the study area, although locally bare chalk reaches can be found that often contain numerous potholes or troughs. No low-flow channel or longitudinal berms were observed along Chiwapa, and low-flow width/depth ratios were generally higher than for Twentymile due to the absence of a low-flow channel.

22. Fish and aquatic habitat data were collected from selected reaches of Chiwapa Creek including a major tributary, Mubby Creek, for comparison with similar data from selected reaches of Twentymile Creek (Figure 8 and Table 3).

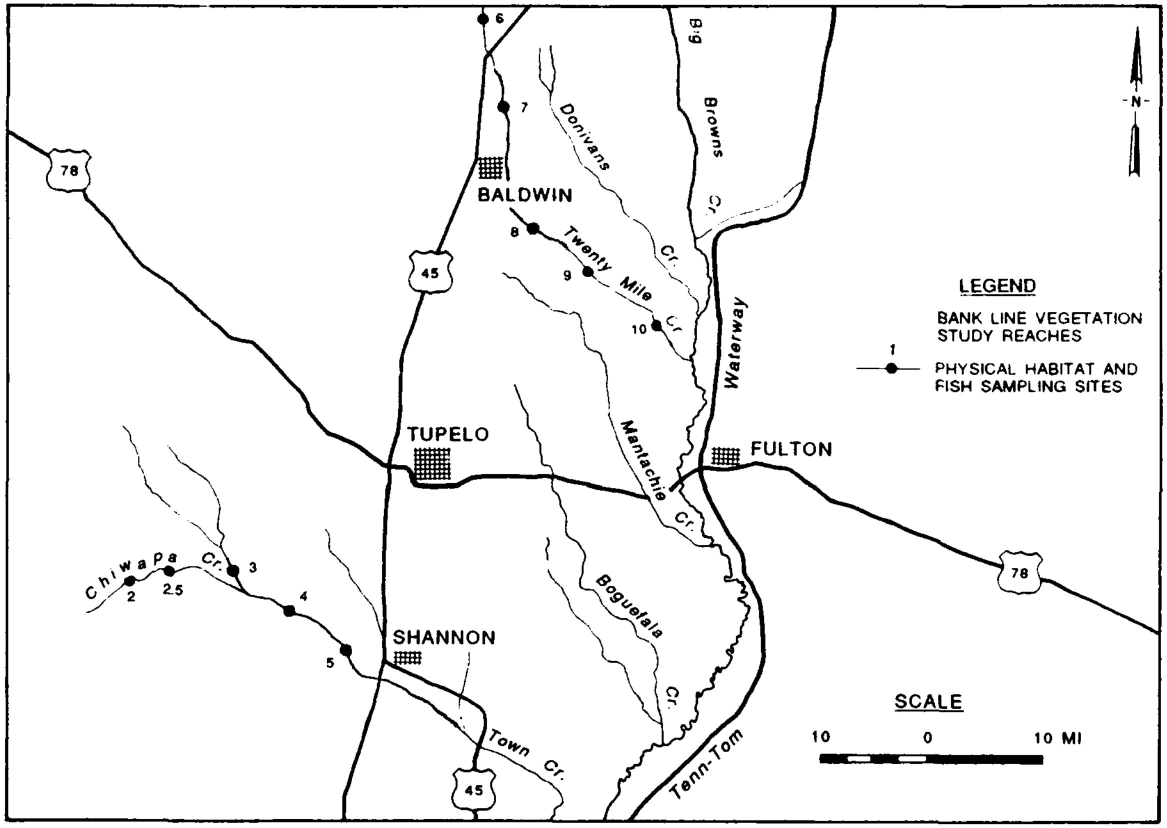


Figure 8. Environmental study areas, Mubby-Chiwapa Creek, Twentymile Creek, and Big Brown Creek

Sampling locations on Mubby-Chiwapa were similar (distance above mouth, upstream drainage area, etc.) to the sampling sites on Twentymile.

Hydraulic Engineering Studies

Grade control

23. Profiles and aerial photos. Initial assessment of GCS impact on channel stability was based on direct comparisons of channel profiles obtained from the 1980 and 1989 channel surveys. The surveys consisted of channel cross sections at intervals of several thousand feet between RM 3.0 and RM 20.7 (1989) and between RM 0.0 and RM 22.15 (1980). Channel thalweg elevations were surveyed (1989) at smaller intervals near the two major GCS (RM 11.7 and RM 19.9) to ascertain aggradation-degradation of the channel bed in the vicinity of the structures. Stability trends for river reaches away from the structures were based on thalweg elevations obtained from the cross-section surveys. Channel profiles were evaluated with respect to location and construction date of the GCS in order to determine their influence on the stability of the channel bed. Aerial photography was used to identify head-cuts and their movement and to identify areas of channel widening.

24. GCS as hydraulic controls. Flow profile computations were calculated using three HEC-2 (US Army Corps of Engineers 1982) model setups to determine the range of discharges at which the GCS functioned as hydraulic controls. The three HEC-2 model setups consisted of (a) a 1980 survey without GCS, (b) a 1980 survey with GCS, and (c) a 1989 survey which included GCS.

25. Since survey data were not obtained immediately after construction of the GCS in 1982, the 1980 model with GCS was used to represent conditions immediately after construction. Although the assumption may not be completely correct, changes during the 2-year interval were not assumed to be that drastic. The 1989 model was used to simulate the current conditions of the river. The cross sections in the 1989 model were not spaced as close together as in the 1980 model; however, extra cross sections were included in the vicinity of the structures at RM 11.7 and 19.9; and sections representing the GCS at RM 16.3 (Highway 370 bridge) were included. Moreover, the 1989 model did not extend upstream to any of the other road crossing GCS (Highway 362 and Highway 45).

26. Model calibration. The downstream boundary cross section of the 1989 HEC-2 model was just downstream of the Mantachie gaging station (RM 3.3)

where gaging and bed material data were available. Using the Brownlie (1981) method with the existing channel geometry and bed material gradation, an average Manning roughness coefficient (n value) of 0.018 was determined for discharges greater than 3,000 cfs. Calculated water surface elevations using the n values from Brownlie's method compared favorably with data from a 1978 Mobile District rating curve for the Mantachie gage. It was assumed that the Mantachie rating curve was still valid since this reach of the river is maintained. Upstream of the maintained river reach (RM 9.1), the Manning n value was increased to 0.027 to account for sinuosity and for bank vegetation as described by Chow (1959, pp 106-109).

27. The HEC-2 water surface elevations just upstream of RM 11.7 compared favorably with US Geological Survey (USGS) peak discharge data for 1984-1988 (Figure 9). Discharge data for 1983 events were not consistent with the data for the 1984-1988 period, probably indicating a change in the rating curve. The same Manning n values were used in both of the 1980 HEC-2 models.

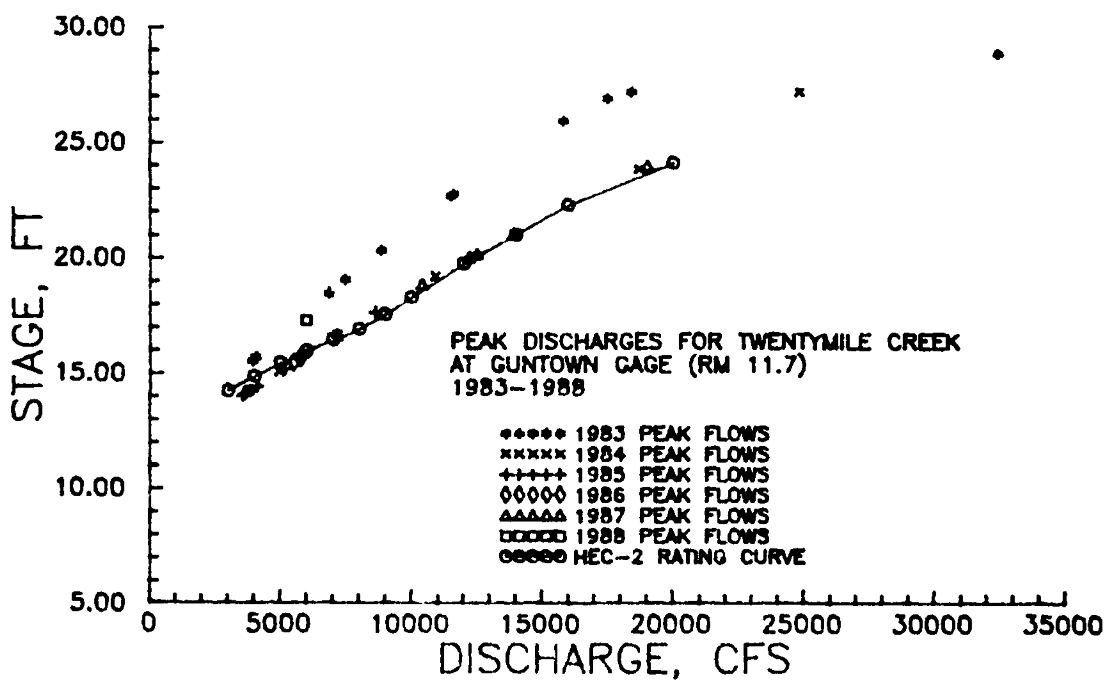


Figure 9. Peak discharges at Guntown gage (RM 11.7) for 1983-1988 and HEC-2 calibration curve

28. Sensitivity analysis. The sensitivity of the calculated water surface elevations using the HEC-2 model with the 1989 survey data was determined by varying the Manning roughness coefficient ±10 percent. Rating curves

(Figure 10) were developed at cross sections 250 ft downstream of the RM 11.7 GCS and 500 ft downstream of the RM 19.9 GCS to determine the variation in the water surface elevations with a 10-percent variation in the Manning roughness coefficient. At both structures, a 10-percent variation in the Manning roughness coefficient resulted in less than a 1.0-ft change in the calculated water surface elevations.

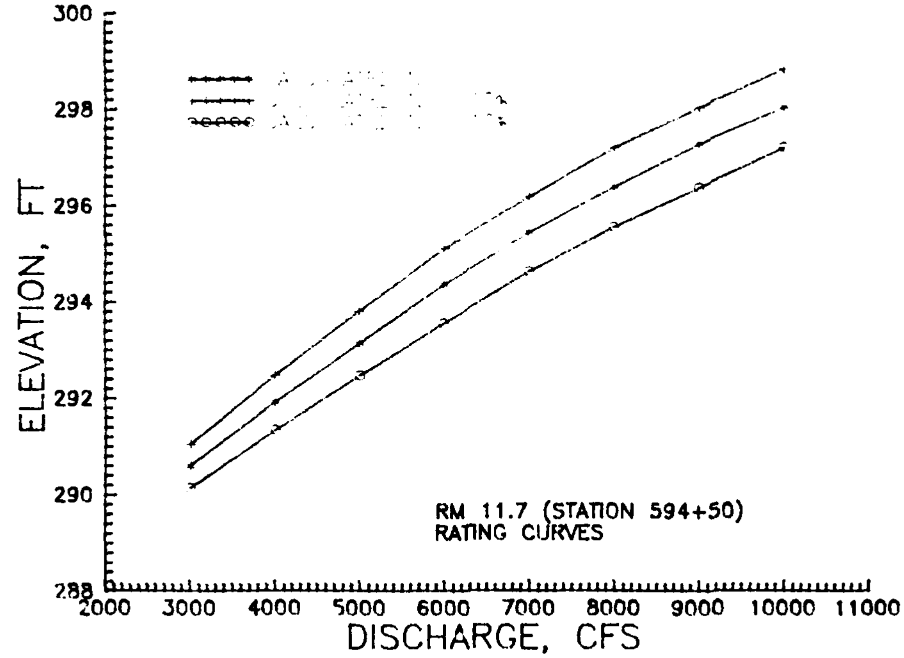
29. Effective discharge. The 1989 model results were used to determine the range of discharges for which each GCS functioned as a hydraulic control and therefore affected the river's sediment transport capacity. Plots showing the relation between discharge and stage and discharge and energy grade lines were developed for sections upstream and downstream of each structure. These plots illustrated the discharge range at which the GCS functioned as hydraulic controls. Results from the 1980 model without GCS were compared to results for the 1980 model with GCS to determine how far upstream the structures influenced water surface profiles and, subsequently, the sediment transport capacity of the reach.

Sediment transport

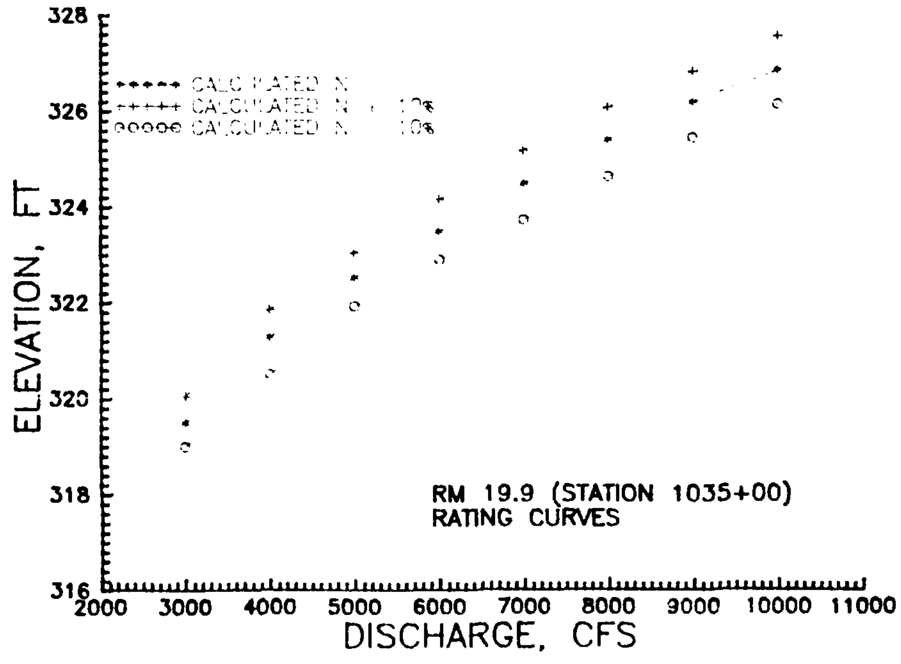
30. Suspended sediment data were used to select a sediment transport function. The selected transport function, 1989 model results, and bed sediment size gradation were used to calculate sediment rating curves in the vicinity of each GCS. Sediment rating curves were developed for the reaches immediately upstream and downstream of both GCS. The rating curves were combined with the discharge duration curve for the RM 11.7 gage to calculate the annual sediment yield at each rating curve location. These curves were then used to determine the GCS effect on sediment transport.

Changes in channel parameters

31. Changes in the Twentymile Creek channel over time were evaluated. The US Army Corps of Engineers (1988) defines six degrees of channel freedom: width, depth, slope, hydraulic roughness, planform, and lateral movement of the channel bank and states that these parameters will change according to the forces placed on the stream. Five parameters relating to these variables (slope, area, top width, depth, and average bed shear) were evaluated near each GCS before construction, after construction, and at present. Evaluation of these parameters showed changes in channel stability upstream and downstream of the GCS. Additionally, changes in channel bank lines were observed in the vicinity of each structure.



a. RM 11.7 (n = 0.027)



b. RM 19.9 (n = 0.027)

Figure 10. Effects of Manning n value on discharge rating curves downstream of GCS

Evaluation of bank protection

32. Several types of bank protection have been used on Twentymile Creek. Some of the initial bank protection work on the channel used living plant materials such as bundled willows in various configurations to form bank protection. Riprap is used in most of the recent bank protection work. Specific designs include full-bank stone revetment and half-bank revetments with willows or sod on the upper half of the bank. Both designs involve sloping the bank to a stable grade and making provisions for overbank drainage. Rock groins and toe dikes have been used on some sections of the channel where complete bank protection was not necessary.

33. Field investigations were conducted to evaluate the effectiveness of the various types of bank protection found along Twentymile Creek. Riprap gradation was evaluated using the latest design criteria from physical model studies.

Environmental Engineering Studies

Vegetation

34. The effects of stabilization of Twentymile Creek on vegetative growth in and along the channel was investigated by comparing aerial photographs taken before and after stabilization. To help differentiate the effects of stabilization from the effects of climatic and cultural effects, photos of Chiwapa and Big Brown Creeks were also examined. Enlarged high altitude program (HAP) (US Geological Survey 1984) photographs taken in 1980-1981 and in 1985 were used to map the extent of woody vegetation on or within channel bank lines. Photo dates bracketed Twentymile Creek GCS construction. Mapping was accomplished by placing clear overlays on top of the enlarged photos and indicating in-channel woody vegetation on the overlays with permanent markers. The length of bank line bordered by woody vegetation was measured from the overlays with a digitizer.

35. Similar reaches on each stream were mapped, as shown in Figure 8. Streambank vegetation is mowed on the lower reaches of Twentymile and Big Brown, and these reaches were excluded from the analysis along with the comparable lower reach of Chiwapa. The 12.5-mile-long study reach on Twentymile Creek extended from the upper end of the maintained reach to Highway 362. A total of 15.7 miles were mapped along Mubby-Chiwapa between the mouth of Chiwapa and the county road crossing on Mubby 1 mile due east of Zion.

Although this reach is a total of 19.1 miles long, 3.4 miles were not adequately covered on the photos. The 10.75-mile reach of Big Brown began at the upstream end of the maintained reach and terminated at State Highway 30.

Physical aquatic habitat

36. No pre-stabilization baseline data were available for Twentymile Creek that would allow comparison to existing post-stabilization conditions. In order to study effects of channel stabilization on physical habitat, existing conditions in Twentymile Creek were compared to existing conditions on Chiwapa Creek (space for time substitution). Physical habitat diversity was determined using methods similar to those described by Gorman and Karr (1978). Physical habitat measurements were made along cross-channel transects during the period 24-26 July 1989 at the time and at the reaches where fish were sampled. The number of cross-channel transects sampled at each reach varied depending on channel width. At each transect, velocity, depth, substrate, and cover were measured at 3-ft intervals (except for the large pool below GCS 19.9 where 5-ft intervals were used). A tagline was used to locate sampling points. Depths were measured with a wading rod to the nearest tenth of a foot, and velocities were measured at the 0.6 depth in centimetres per second with a Marsh-McBirney current meter. Depth and velocity measurements were later converted into integer values and bed material and cover were visually categorized in the field (Table 4). Periodic samples of bed material were collected for laboratory sieve analyses using standard sieve sizes 4, 10, 40, 100, and 200 (4.75-, 1.0-, 0.425-, 0.15-, and 0.075-mm openings, respectively).

37. Information-theoretical measures quantify the uncertainty in predicting randomly encountered entities within a system. Originally developed for communication systems (Shannon 1948), these measures are frequently used to characterize aquatic habitats (Tramer and Rogers 1973; Gorman and Karr 1978; Foltz 1982) and biotic communities (Magurran 1988; Ludwig and Reynolds 1988). Two frequently used information-theoretical measures are the Shannon diversity function and Pielou evenness index.

38. The Shannon diversity index (Magurran 1988) was calculated for all combinations of physical habitat measurements for each sample reach. The Shannon diversity index, H' is:

$$H' = -\sum p_i \ln[p_i] \quad (1)$$

where p_i is the proportion of observations in the ith group or category. The Shannon diversity or heterogeneity index incorporates both richness (i.e., the number of categories present) and equitability (numerical distribution of observations among categories) into a single value. However, it is more responsive to richness than to the abundance of individual categories and consequently is "sensitive" to the presence of rare categories.

39. Each unique combination of the integer scores for the four variables in Table 4 constitutes a category. Some 1,200 possible combinations of the values in Table 4 exist, and thus 1,200 categories were possible. However, many of these categories are physically unreasonable. If a reach is perfectly uniform (i.e., all four habitat variables are the same at all points), then $H' = 0$ because $i = 1$ and $p_i = 1$. Diverse streams yield H' values between 3 and 4 (Gorman and Karr 1978; Shields*).

40. The Pielou evenness index, E, (Magurran 1988) was also calculated for selected groups of sites to eliminate the effects of unequal numbers of sampling points. Evenness is quantified as the ratio of the calculated Shannon function to its maximum possible value and is calculated as

$$E = \frac{H'}{\ln(S)} \quad (2)$$

where S = number of categories. Evenness ranges from approximately zero (when all points have identical physical habitat characteristics) to approximately one (when no category is numerically dominant). Unlike the Shannon index, though, evenness is primarily responsive to abundances (rather than richness), and consequently is "insensitive" to the presence of rare categories.

Low-flow channels

41. Low-flow channels were identified on 1989 cross sections (Figure 11) and cross-sectional area, mean depth, mean width, and slope were measured. Slope was determined at each cross-section location by dividing the

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* Unpublished data, 1989, F. Douglas Shields, Jr., Research Civil Engineer, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

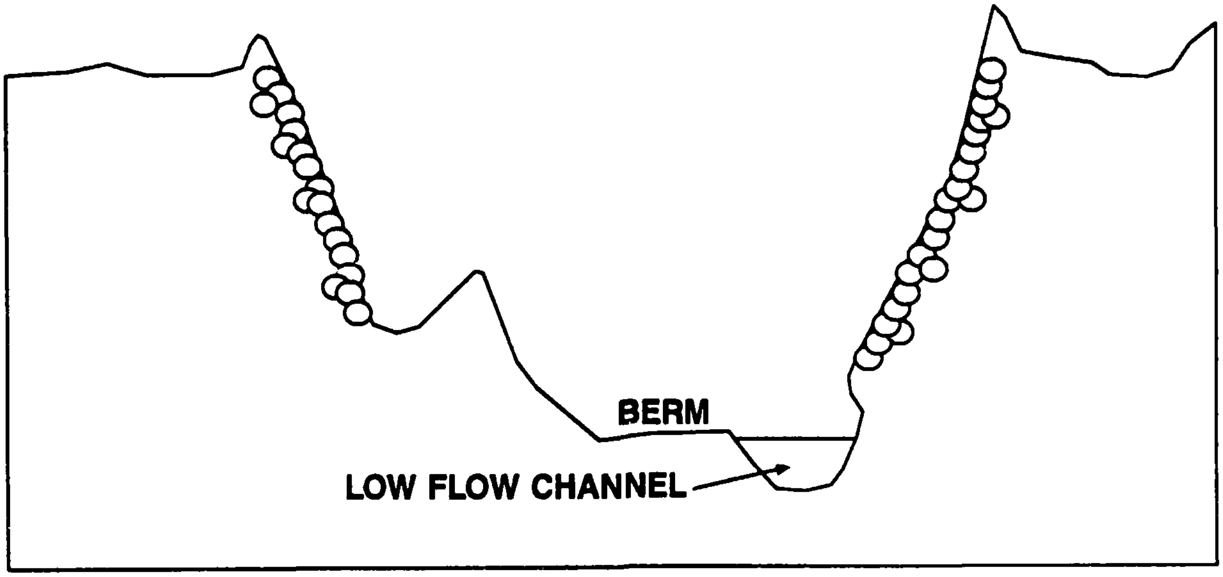

Figure 11. Identification of low-flow channel on cross-section surveys

vertical drop in bar or berm elevation from the nearest upstream cross section to the nearest downstream cross section and dividing by the horizontal distance between the two stations.

42. Low-flow channel capacities were calculated in two ways. The first approach involved using the Manning formula to compute discharge for each surveyed cross section. Mean depth was used for hydraulic radius. The second approach, similar to that described by Harvey and Watson (1987), involved using the HEC-2 computer program to compute water surface elevations for several discharges between 25 and 200 cfs. The water surface elevations were then compared to the elevations of the top of the longitudinal berm, and the discharge corresponding to the best-fit profile was selected as the channel capacity. Values of Manning's n for both approaches were computed using the hydraulic design package (HDP).* Low-flow channel capacities were then evaluated in terms of the flow duration curve from the gage at RM 11.7.

Fish collections

43. Fishes were collected in Mubby-Chiwapa and Twentymile Creeks 22-24 May and 24-26 July 1989. Data from May collections were used to evaluate longitudinal distribution of fishes, describe fish assemblages associated

* The HDP for flood control channels is a group of computer programs being developed at WES for use in the design of stable flood control channels.

with grade control structures (weirs), and identify stations for the subsequent habitat study; unit collecting effort consisted of 20 hauls with a 10-ft, 0.25-in. mesh straight seine.

44. July collections provided data on the association between fish diversity and habitat diversity. Collecting effort varied with size and physical complexity of each station, continued until all areas were sampled and no new species were encountered, and averaged 20 hauls with 5-, 10-, and/or 30-ft, 0.25-in.-mesh straight seines. The entire cross-sectional area of all sites was completely sampled by seining as shown in Figure 12, except for the large scour hole in Twentymile Creek below the GCS at RM 19.9 (site 7.2). Seines could only be used along the shoreline at this site because scour hole depths exceeded 6 ft. Therefore two experimental monofilament gill nets, each 150 ft long, with 0.5- to 4-in. mesh, were set overnight, and the fishes were incorporated with the collection made by shoreline seining. Large fishes were identified, measured, and released in the field; small fishes were preserved in 10-percent Formalin, and later washed and transferred to 55-percent isopropanol. Identifications were made according to Douglas (1974) and Suttkus and Boschung (1990).

Figure 12. Fish collection by seining

Analysis of fish community data

45. Numbers of individuals for each species were considered representative of abundance and were used to quantify interspecific associations, identify faunistically similar sites, and calculate measures of fish diversity.

To identify species associations, Pearson product moment correlation coefficients (r)* were calculated among all species comprising more than 1 percent of all individuals collected; species pairs were considered associates if they were positively correlated ($p < .05$)** in May and July samples. To evaluate ichthyofaunal similarity among streams and among stations, samples were ordinated using principal component analysis (PCA)*** to plot individual stations in multivariate (species) space (Ludwig and Reynolds 1988). Species used for PCA were abundant (more than 1 percent of all individuals collected) or common (occurring in eight or more samples). Samples included those from May and July collections. Because all sampling efforts were not equal, numbers of fishes were converted to relative abundance (percentages).

46. Ichthyofaunal diversity was described using the Shannon diversity index and the Pielou evenness index. Shannon diversity and Pielou evenness were calculated using the formulas given above, except p_i was the proportion of individuals belonging to the ith species instead of the ith habitat category. Values for the Shannon index describing fish communities can range from 0 (when only one species is present) to ln S, the natural logarithm of the number of species (when all species occur in equal numbers), although H' rarely exceeds 4.50 in natural situations.

47. Correlations between fish diversity (H') and habitat measurements for July were determined using product moment correlation coefficients and regression analysis (SAS Institute 1987). Correlations were calculated between fish species diversity (dependent variable) and the means of water depth, water velocity, substrate, and between fish species diversity and the variability (coefficient of variation) in depth, velocity, and substrate (six independent variables). Correlations were also calculated between fish diversity and habitat diversity (depth, velocity, bottom type, and all possible

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* The coefficient of determination, r^2, is a statistic that indicates the degree of association between two variables based on a set of paired observations. The correlation coefficient, r, is simply the square root of r^2.

** $p < 0.05$ indicates that there is less than a 5-percent probability that observed relationships were due to chance.

*** Algebraically, PCA is a technique that "factors" a matrix of correlation coefficients. Geometrically, it reduces a hyperspace of n dimensions (in this study, 17 fish species) to fewer dimensions (in this study, two components) while preserving spatial relationships among points (in this study, 18 samples). A general description of PCA is provided by Gould (1981), and a more detailed explanation of PCA use with biotic data is provided by Gauch (1982).

combinations of those parameters). Regression analysis identified combinations of environmental variables most closely associated with fish diversity and developed predictive models; the maximum r^2 improvement technique was used to find the best one-variable equation, two-variable equation, and three-variable equation. Correlation coefficients and regression analyses were considered significant if $p \leq .10$.

PART III: RESULTS

Hydraulic Engineering - Grade Control Structure (GCS)

Overall channel profile

48. The 1989 survey included surveying most of the cross sections recommended for resurvey by SLA (1982); plus, additional sections were surveyed above and below the GCS at RM 11.7 and RM 19.9 to provide more detail of the channel profile near the structures. No additional cross sections were surveyed at the RM 16.3 GCS. The 1980 survey is shown in Figure 13 with the corresponding sections from the 1989 survey plotted for comparison. Generally the two profiles parallel each other with the 1989 survey indicating the channel bed had degraded throughout the entire channel system with the exception being just upstream of each GCS. Comparison between the two profiles indicates that in the lower 10 miles of the river, channel degradation-aggradation was insignificant except at Station 501+00 (RM 9.5) where approximately 8 ft of degradation had occurred. However, this cross section was in a bend and that may account for the difference. Between the GCS at RM 11.7 and RM 16.3 the channel had degraded approximately 2 to 3 ft except just upstream from the RM 11.7 structure. The most severe degradation, an average of 5 ft, occurred in the 6,000-ft reach downstream from the RM 19.9 GCS.

Detailed thalweg profile

49. Detailed 1989 thalweg profiles of the reaches extending 4,000 ft downstream and 6,000 ft upstream of the GCS at RM 11.7 and RM 19.9 are plotted with the 1980 survey in Figures 14a and 14b, respectively. The channel bed slope downstream of the RM 11.7 GCS (Figure 14a) increased from 0.00050 in 1980 to 0.00072 in 1989. The bed profile in 1989 was not as irregular as it was in 1980, and it was 2 to 3 ft lower in elevation indicating general scour throughout the downstream reach. Upstream of the structure, for a distance of approximately 2,000 ft, aggradation of the crossing bars was evident while there was degradation in the bends (see Figure 14a). However, degradation was indicated at all cross sections further upstream and the irregular profile probably reflects the bends and crossings in the channel.

50. The detailed 1989 thalweg survey upstream and downstream of the GCS at RM 19.9 and corresponding portions of the 1980 survey are shown in Figure 14b. The headcut that existed at the time of the 1980 survey (prior to construction of the structure in 1982) is clearly visible. The headcut

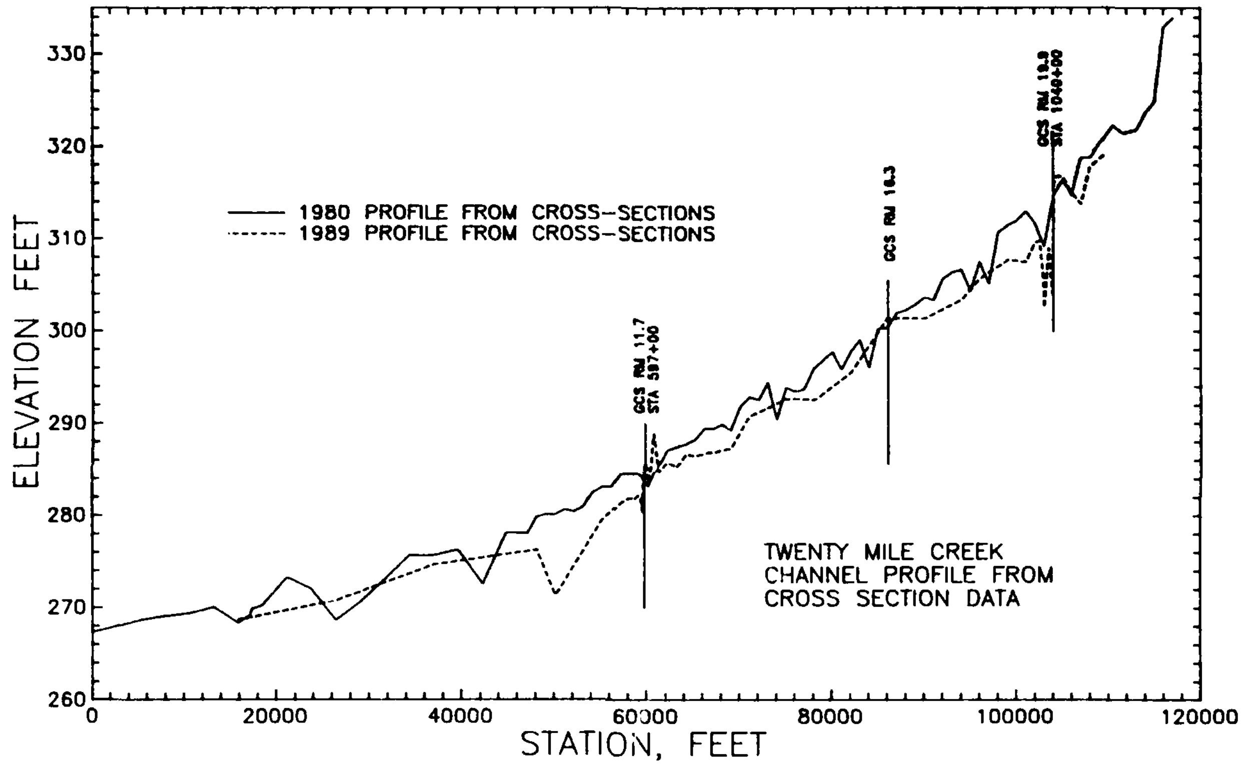
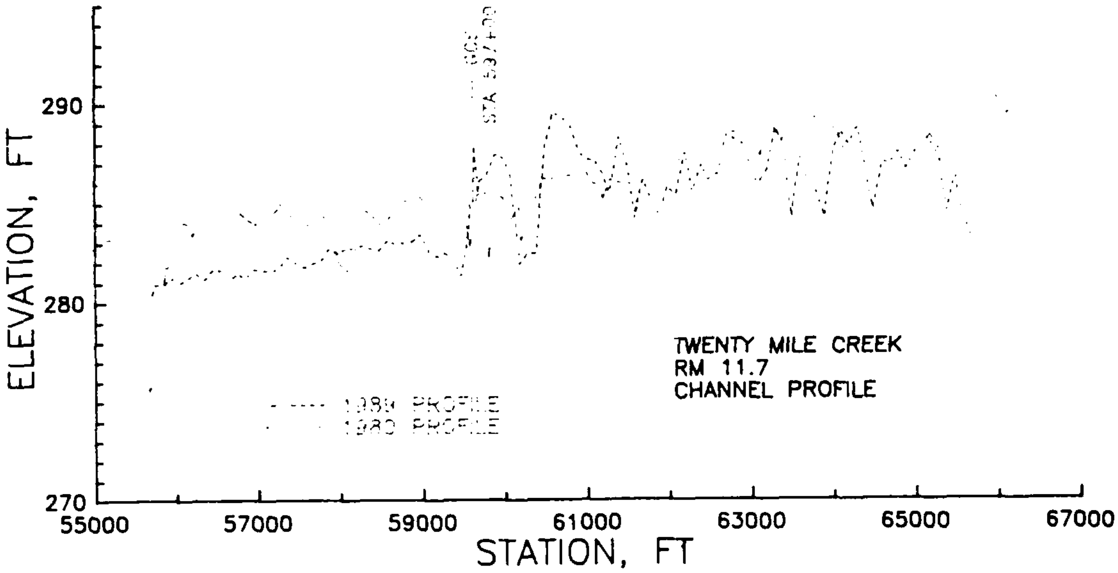
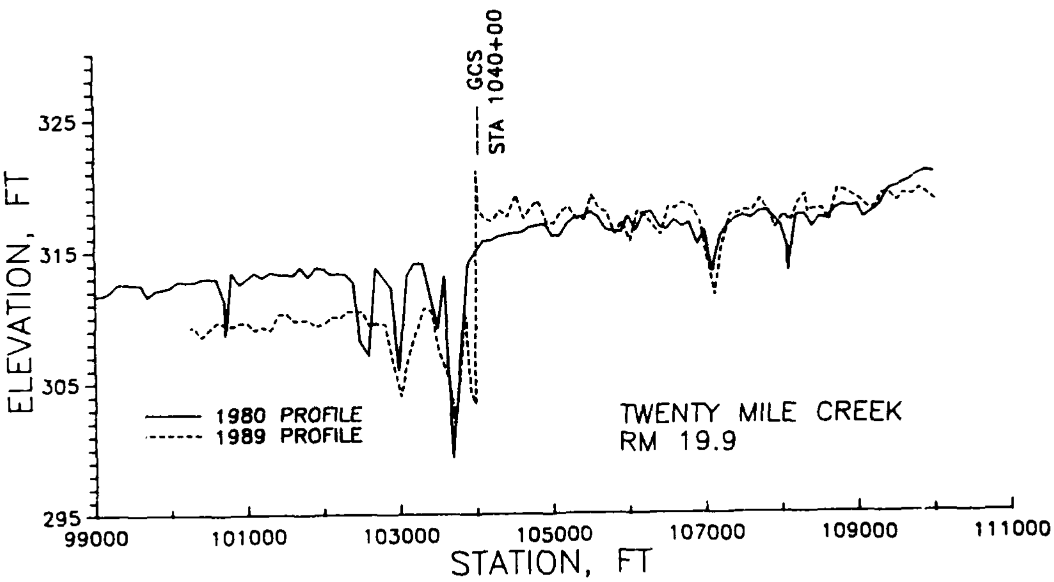


Figure 13. Twentymile Creek thalweg profiles, 1980 and 1989



a. RM 11.7 (GCS weir is located at station 597+00)



b. RM 19.9 (GCS weir is located at station 1040+00)

Figure 14. Detailed thalweg profiles near RM 11.7 GCS and RM 19.9 GCS

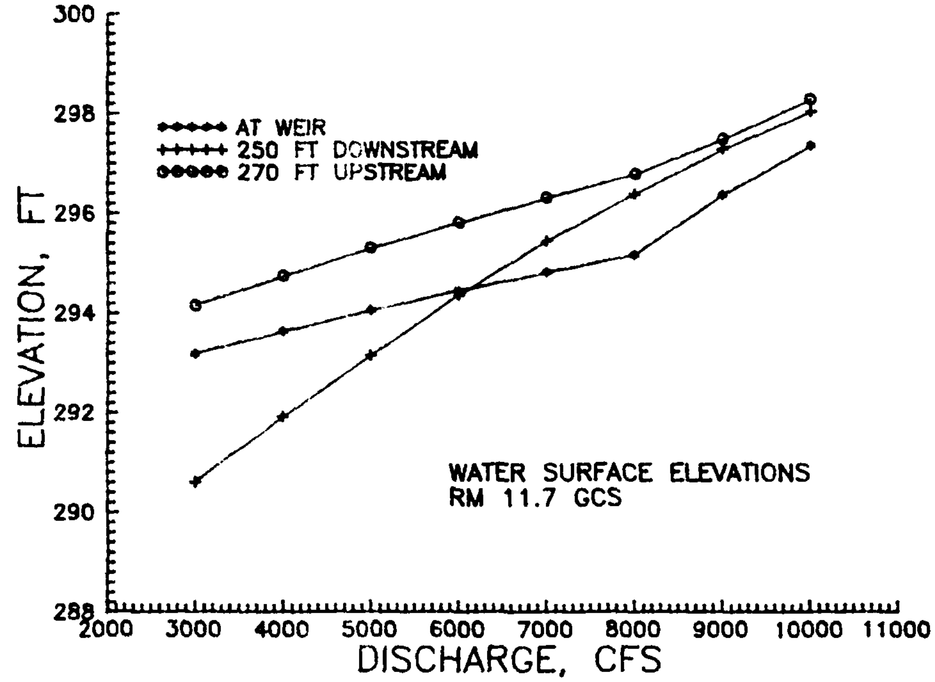
remained stationary but significant degradation (approximately 5 ft) occurred in the downstream reach. A study of 1981 and 1985 aerial photography confirmed that the headcut had remained stationary. However, since the GCS was constructed on an outcrop of erosion-resistant material which functioned as a geologic control it would be incorrect to assume that the GCS was solely responsible for stopping the headcut. The slope of the bed in the downstream reach was 0.004, and the difference in thalweg elevation across the GCS was 8 ft. Aerial photography also indicated another headcut site about 7,000 ft downstream from RM 19.9, near the downstream end of the degraded reach, and it appeared to function as a hydraulic control that influenced the flow conditions upstream to the GCS. Moreover, there was no visible movement of the headcut during the period between the aerial photos. The lack of headcuts and subsequent movement thereof as observed on aerial photos indicates that most of the channel degradation occurred as general bed scour. Upstream of the structure, aggradation was apparently induced by the GCS for a distance of approximately 5,000 ft.

GCS as hydraulic controls

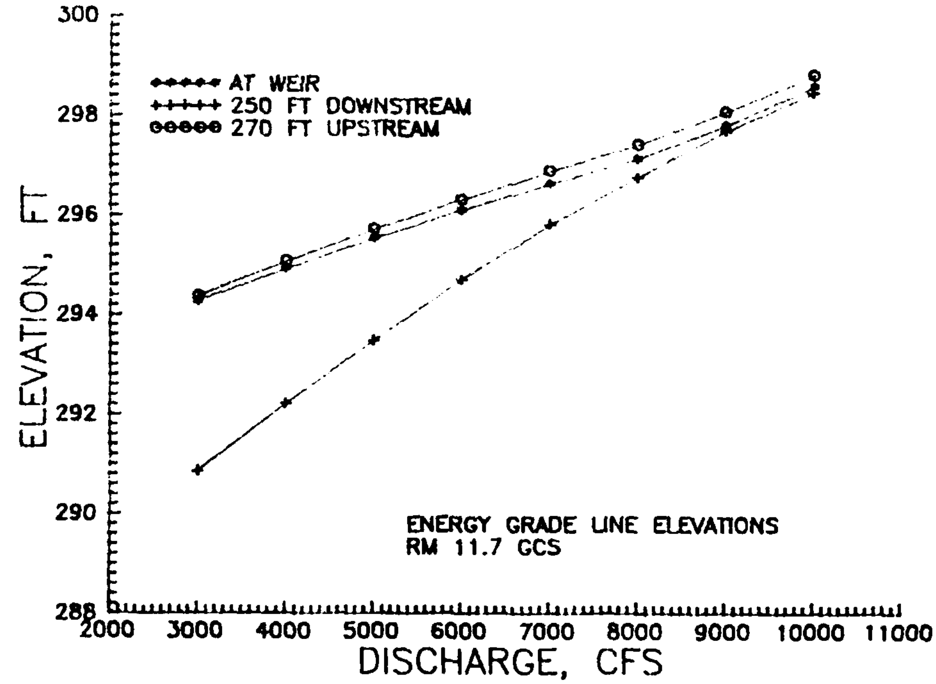
51. Results from the 1989 HEC-2 model were used to develop curves for evaluating the effectiveness of the GCS to function as hydraulic controls. Water surface elevations and energy grade line* elevations for a range of discharges were plotted at three cross sections in the vicinity of the two GCS to determine the discharge at which the structure ceased to function as a hydraulic control.

52. Figures 15a and 15b show the results for the GCS at RM 11.7 where the three sections were 250 ft downstream of the weir, at the weir, and 270 ft upstream of the weir. Figure 15a shows that the water surface elevation at the upstream section is only slightly higher (0.4 ft) than the downstream section elevation at a discharge of approximately 8,000 cfs. Above a discharge of about 6,000 cfs, the water surface elevation at the weir is lower than at either the upstream or downstream section due to the flow accelerating over the raised bottom of the weir. Figure 15b is a plot of the energy grade line elevations and shows that at discharges above 8,000 cfs, the energy loss

* The energy grade line is an imaginary line running along the channel. The elevation of the energy grade line at a given location is equal to the water surface elevation plus the square of the mean velocity divided by two times the acceleration of gravity.



a. Water surface elevations



b. Energy grade line elevations

Figure 15. Water surface elevations and energy grade line elevations at the RM 11.7 GCS (1989 data)

across the structure had become minimal and constant with increasing discharge, indicating that the energy loss from section to section is due to channel boundary roughness. Therefore, it appears that the GCS at RM 11.7 ceased to function as a hydraulic control for discharges above approximately 8,000 cfs.

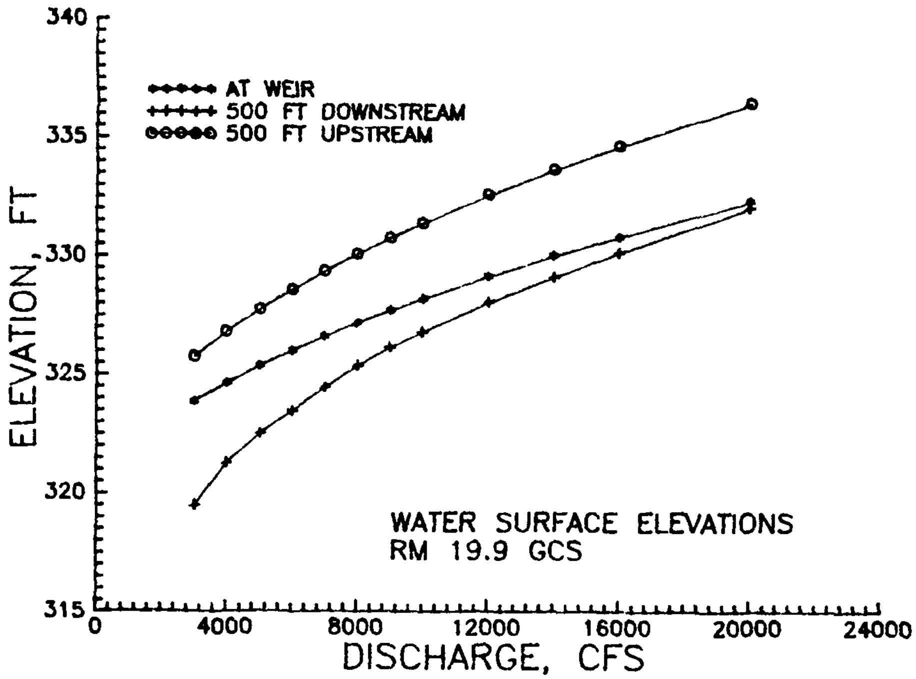
53. Figures 16a and 16b are similar plots for the GCS at RM 19.9 where the upstream and downstream cross sections were 500 ft from the weir. Figure 16a shows that the downstream water surface elevation was over 4 ft below the upstream surface elevation for discharges up to 20,000 cfs. Also, Figure 16b shows that the energy loss across the structure was over 5 ft at discharges up to 20,000 cfs, indicating that the structure functions as a hydraulic control for even the very high discharges. However, this is not surprising because of the significant degradation in the downstream channel and the large difference in thalweg elevation upstream and downstream of the structure (8 ft).

54. Results from the HEC-2 models were also used to estimate the upstream region of influence of each structure. Output data from the 1980 HEC-2 models, with and without GCS, were compared to determine the discharges and distances upstream of the structures that were influenced by the structure. The RM 11.7 GCS had little effect on flow conditions for a discharge of 5,000 cfs at a section 2,500 ft upstream. However, at a discharge of 3,000 cfs, the RM 11.7 GCS caused a 3.9-percent reduction in average flow velocity, a 9.0-percent reduction in average shear stress, and a 0.2-ft increase in water surface elevation at the cross section 6,450 ft upstream of the weir.

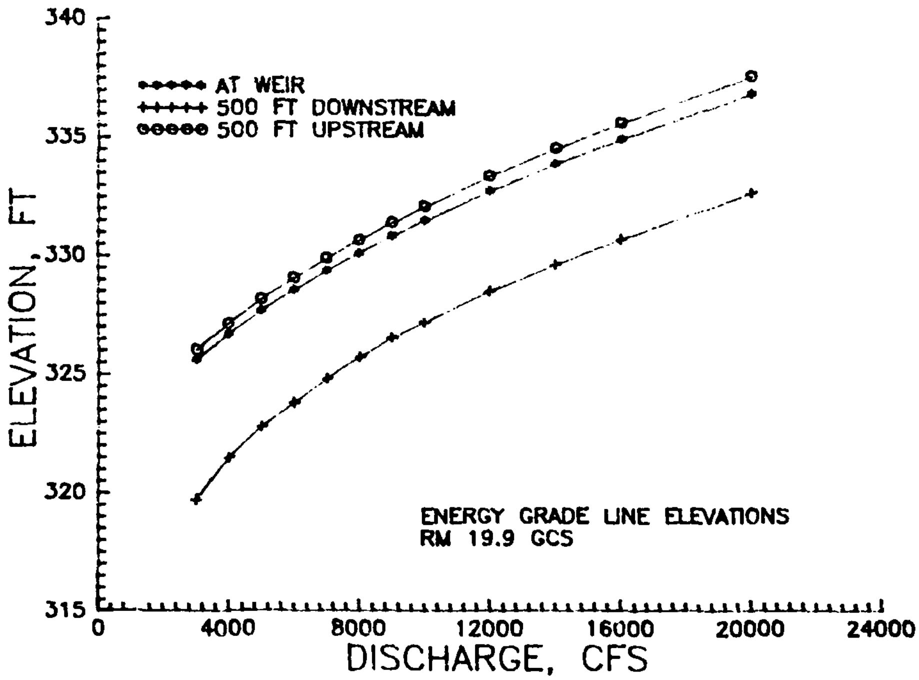
55. As previously discussed, the RM 19.9 GCS functioned as a hydraulic control for much higher discharges than the RM 11.7 structure. At a discharge of 10,000 cfs, the RM 19.9 GCS caused a 4-percent reduction in flow velocity and a 10-percent reduction in shear stress at a distance of 5,500 ft upstream; and a 2.6-percent reduction in flow velocity, a 5-percent reduction in shear stress, and a 0.3-ft increase in water surface elevation at a distance of 6,500 ft upstream of the weir. Although the influence does not appear to be that significant, it probably explains why the aggradation extends farther upstream of the RM 19.9 GCS than at the RM 11.7 structure (Figure 14).

<u>Sediment transport</u>

56. <u>Sediment data.</u> Suspended sediment and bed material data from two gaging stations, RM 3.3 (Mantachie) and RM 11.7 (Guntown), were available from



a. Water surface elevations



b. Energy grade line elevations

Figure 16. Water surface elevations and energy grade line elevations at the RM 19.9 GCS (1989 data)

Mobile District files. Since Mantachie gaging data were used to calibrate the HEC-2 models, sediment data from this gaging station were also used to select a sediment transport function. Particle size distribution of the suspended sediment samples consisted only of sand breaks (percent finer than 0.0625 mm). The measured suspended sand concentration in ppm was calculated by multiplying the total suspended sediment concentration by the sand fraction (percent greater than 0.0625 mm). The unmeasured sediment discharge, which was also assumed to consist of sand-size particles, was estimated at 10 percent of the total measured sediment discharge. The total bed material discharge was estimated as the sum of the unmeasured sediment discharge and the measured sand discharge (Table 5).

57. Sediment transport function. Two sediment transport functions were tested to determine if they compared favorably with the estimated total bed material discharge using the hydraulic parameters from the Brownlie (1981) method and the bed material gradation at the RM 3.3 gaging station. The bed material gradation (shown in the table below) had a median grain size (D_{50}) of 0.2 mm.

Bed Material Grain Size (mm)	Percent Finer
1.00	100
0.50	99
0.25	64
0.20	50
0.125	12
0.062	2

58. Total bed material discharges calculated from the new Laursen (Madden 1985) and the Colby (1964) methods were converted to sediment concentrations to determine which function best fit the data from Twentymile Creek. The results are tabulated in Table 6 and plotted in Figure 17 and indicate that the Colby method adequately predicts the bed material discharge and thus it was chosen to develop sediment rating curves for the study. In using the Colby method, water temperature was assumed to be 60° F and concentration of fine material was assumed to be zero; i.e., no corrections for temperature or concentration of fine material were made in the computations.

59. Sediment rating curves. At each GCS the Colby method was used with the hydraulic parameters from the 1989 HEC-2 model at cross sections upstream and downstream of the GCS to determine the effect of the structures on the sediment transport capacity. Colby's empirical unadjusted bed material

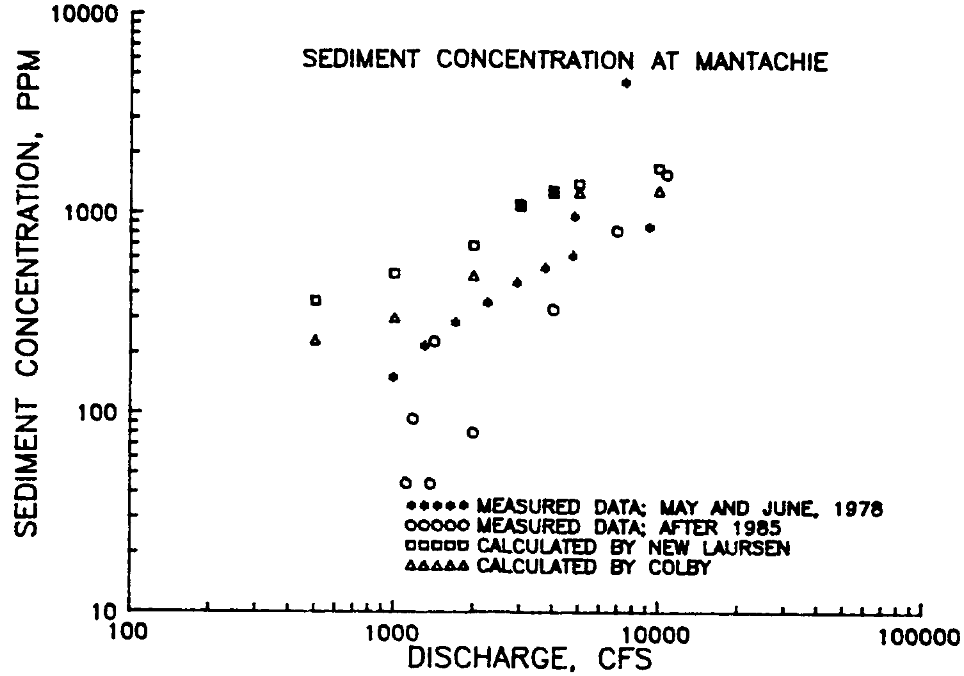
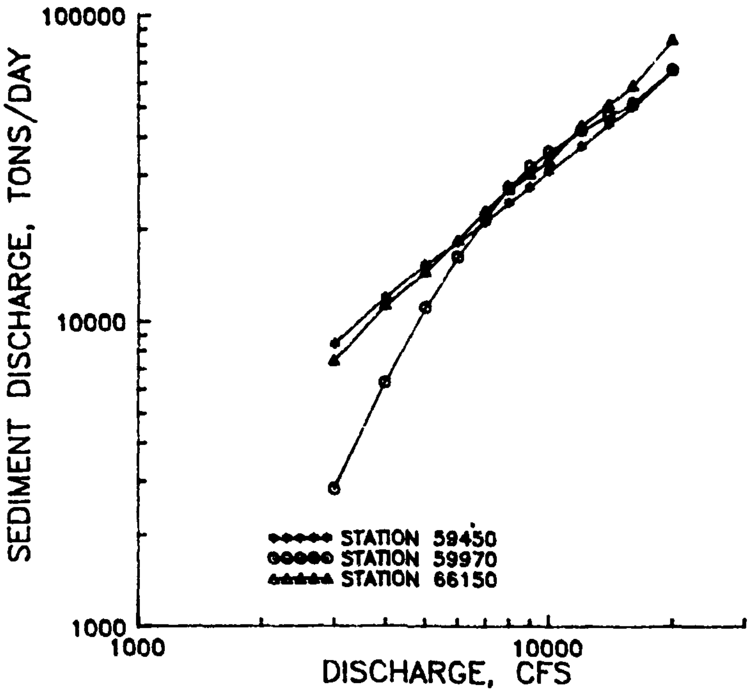


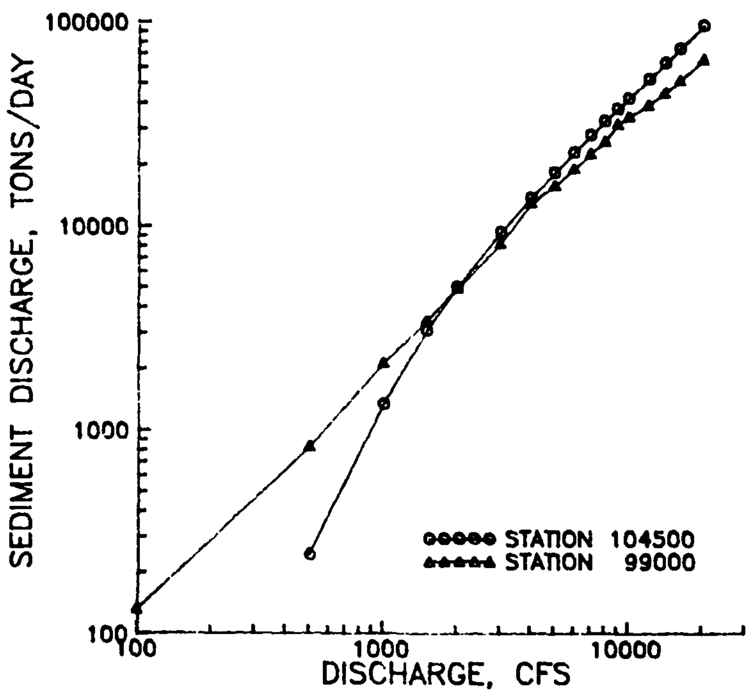
Figure 17. Measured and calculated sediment concentrations at RM 3.3 (Mantachie)

discharge is a function of flow velocity and flow depth. Therefore, prior to selecting typical cross sections, flow velocity and flow depth were plotted at several sections in the vicinity of the GCS, and representative sections were selected for application of the Colby procedure. Figures 18a and 18b show the sediment rating curves for the cross sections in the vicinity of the structures at RM 11.7 and RM 19.9.

60. RM 11.7 rating curves. The channel cross sections, near the RM 11.7 GCS, were located 250 ft downstream, 270 ft upstream, and 6,450 ft upstream of the structure. Figure 18a shows the sediment rating curve for the three sections. The farthest upstream section represents the sediment inflow into the reach containing the GCS. Figure 18a shows that for discharges greater than 7,000 cfs, which is approximately the discharge at which the structure loses hydraulic control, the GCS has little effect on the sediment transport capacity. However, in the discharge range where the structure functions as a hydraulic control (< 7,000 cfs), the transport capacity at the section just upstream of the structure is less than at the downstream or farthest upstream section, indicating that the GCS would affect upstream aggradation and downstream degradation at the lower discharges.



a. RM 11.7 GCS (the weir is located at station 597+00)



b. RM 19.9 GCS (the weir is located at station 1040+00)

Figure 18. Calculated sediment rating curves near the GCS

61. RM 19.9 rating curves. Figure 18b indicates that the sediment rating curves in the vicinity of the RM 19.9 GCS are not significantly affected by the GCS. The channel cross sections, near the RM 19.9 GCS, were located 500 ft upstream and 5,000 ft downstream of the GCS. It was not feasible to select an upstream inflow sediment section similar to the RM 11.7 GCS because the upstream boundary section in the 1989 HEC-2 model was within the region of influence of the structure and flow velocities and flow depths fluctuated due to wide variations in channel width. At discharges less than 2,000 cfs, the sediment transport capacity at the section 500 ft upstream (Sta 1045+00) of the GCS was less than the capacity at the downstream section (Sta 990+00). At higher discharges the rating curves cross, and the transport capacity at the upstream section is more than at the downstream section.

62. Discharge duration. Discharge duration data based on mean daily discharges at the RM 11.7 gaging station were obtained from the USGS for water years 1983 to 1987. The discharge duration curve (Figure 19) shows the percent time that a given mean daily discharge has been equalled or exceeded in Twentymile Creek since the GCS were constructed in 1982.

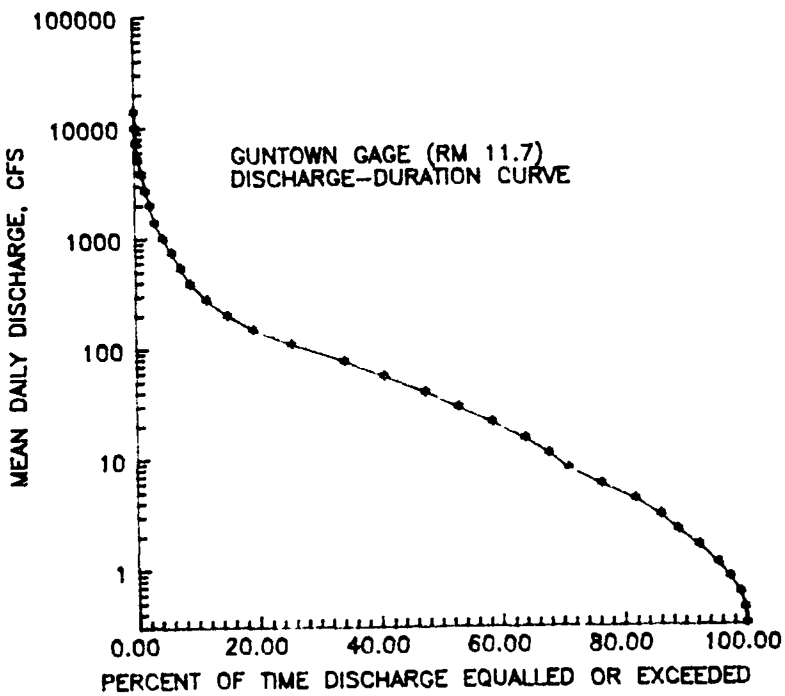


Figure 19. Discharge duration curve at RM 11.7 (Guntown gage data), 1983-1987

63. <u>Sediment yield.</u> The annual sediment yield was calculated at each GCS using a method described in Engineer Manual (EM) 1110-2-4000 (US Army Corps of Engineers 1988). The method integrates the sediment rating curve and the discharge duration curve at a channel cross section to calculate the annual sediment yield.

64. <u>RM 11.7 yield.</u> Integration of the sediment rating curves and the discharge duration curve at the RM 11.7 GCS yielded an average annual water volume of 160,000 acre-ft. The annual sediment yields were as follows:

Distance from GCS	Annual Sediment Yield (thousands of tons)
250 ft downstream	143
270 ft upstream	87
6,450 ft upstream (inflow section)	134

These results show that the downstream section is capable of transporting all the sediment that is delivered at the upstream boundary but the section just upstream of the GCS is not, and therefore aggradation should occur in the reach upstream and degradation in the reach downstream of the structure.

65. <u>RM 19.9 yield.</u> Since there was not a gaging station at RM 19.9, the discharge duration curve from RM 11.7 was used with the sediment rating curves at the RM 19.9 GCS sections to calculate the sediment yields. The annual sediment yields were as follows:

Distance from GCS	Annual Sediment Yield (thousands of tons)
5,000 ft downstream	192
500 ft upstream	179

The annual sediment yields at RM 19.9 are inflated because less water passes this location than at RM 11.7, but if the discharge duration curve at RM 19.9 has the same shape as RM 11.7, then the downstream section has the greater sediment transport capacity.

66. <u>Channel-forming discharge.</u> Biedenharn et al. (1987) described a method which allows determination of the channel discharge below which most of the sediment load was transported. Annual water and sediment yield were calculated for 500-cfs discharge increments. The total annual sediment yield below each incremental discharge was determined for the sediment and gaging data at RM 11.7, and the results were plotted in Figure 20 as cumulative sediment yield versus channel discharge. The slopes of the cumulative sediment

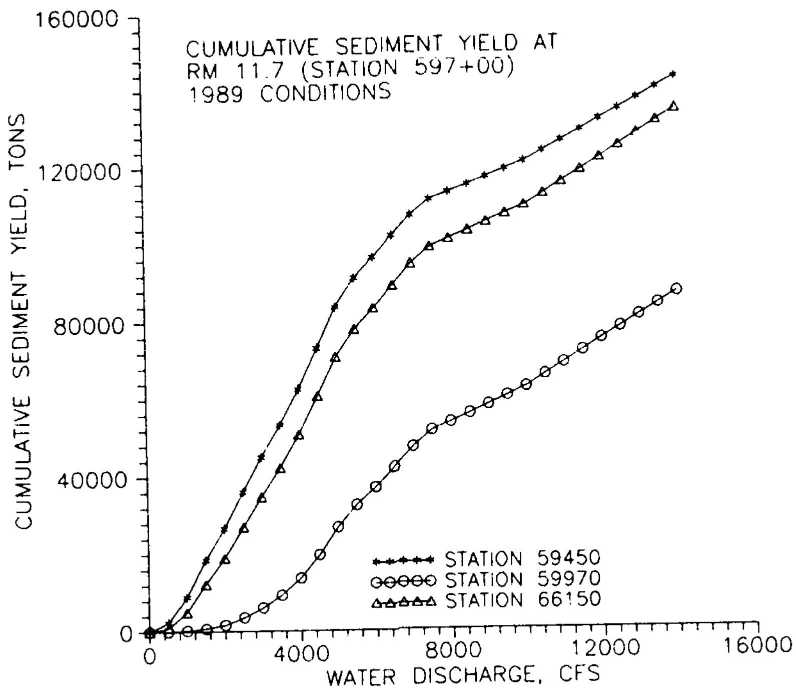


Figure 20. Cumulative annual sediment yield near RM 11.7 GCS (GCS weir is located at station 597+00)

yield curves (at all three cross sections) break and decrease between mean daily discharges of 7,000 to 8,000 cfs. Furthermore, the cumulative sediment yield below 8,000 cfs is between 70 and 80 percent of the total annual sediment yield in the downstream and upstream sections. Therefore, it appears that the mean daily discharges that have a long-term channel-forming effect on the channel are below 8,000 cfs.

67. Channel characteristics. In the vicinity of each GCS, the variation in channel hydraulic characteristics such as top width, flow depth, cross-section area, average shear stress, and energy slope were analyzed using the three HEC-2 models to ascertain the stability of the channel. A discharge corresponding to a 2-year recurrence interval was used in the analysis. The 2-year discharge was used because, in natural rivers, bank-full flow generally has a recurrence interval between 1 and 2 years (Wolman and Leopold 1957). However, the 2-year event is no longer a bank-full discharge on Twentymile Creek because the channel has become incised.

68. The Mobile District provided discharge frequency curves at each of the GCS that were developed from a method recommended by the USGS (Colson and Hudson 1976). The method uses drainage basin characteristics such as channel

length, channel slope, and drainage area to calculate the discharge frequencies. As shown in Figure 21, the 2-year discharge is 7,500 cfs at RM 11.7 based on the USGS method. Numerous peak discharges over 7,500 cfs have occurred even though lower discharges have generally prevailed during the last few years. The peak discharge frequency curve, developed from gaging data for the period subsequent to construction of the GCS (1983-1988), shows a 2-year peak discharge to be approximately 14,000 cfs (Figure 21). This estimate is a rough approximation because of the short (6-yr) period of record.

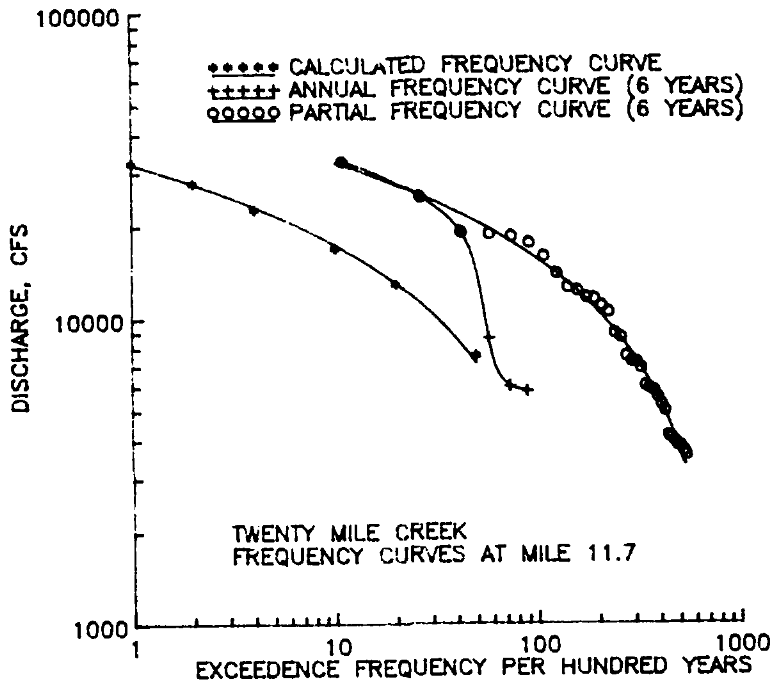


Figure 21. Discharge frequency curves at RM 11.7 (Guntown gage) (the annual and partial curves area based on actual data)

69. Since gaging data were not available at RM 19.9, the 2-year discharge at RM 19.9 was interpolated from the USGS curve based on the relationship between the peak discharge curve and the USGS curve at RM 11.7 (Figure 21). The 2-year discharge from the peak discharge curve (14,000 cfs) corresponded to a 6.2-year discharge on the USGS curve for RM 11.7. The 6.2-year discharge on the USGS curve for RM 19.9 was 10,000 cfs and this value was used in the HEC-2 models for the 2-year discharge at RM 19.9.

70. Although the RM 11.7 GCS did not function as a hydraulic control at 14,000 cfs, comparison between the channel characteristics at this discharge indicated some change had occurred between 1982 and 1989. However, since the

RM 11.7 functioned as a hydraulic control for discharges less than approximately 8,000 cfs, the channel's hydraulic parameters were also calculated for a discharge of 8,000 cfs. The 10,000-cfs discharge at the RM 19.9 GCS was controlled by the structure and comparison between models indicated change had occurred between surveys.

71. Variation of channel characteristics. The results of the analysis on the variation of channel hydraulic characteristics are presented in Figures 22, 23, and 24. Figures 22 and 23 are plots of the hydraulic parameters to include flow depth, top width, cross-sectional area, average shear stress, and energy slope for discharges of 14,000 cfs and 8,000 cfs, respectively, from the 1982 and 1989 HEC-2 models. The results from the 1980 model (without GCS) were not included because the 1980 model and the 1982 model produced essentially the same results, since the GCS had little effect on water surface profiles for discharges greater than 8,000 cfs. Figure 24 shows the same five hydraulic parameters in the vicinity of the RM 19.9 GCS for all three surveys and a discharge of 10,000 cfs.

72. RM 11.7 trends. Figure 22 shows the trends in the hydraulic parameters for RM 11.7 at a discharge of 14,000 cfs. The energy slope decreased downstream of the structure but increased significantly for a distance of approximately 5,000 ft upstream. The flow cross-section area increased downstream but decreased for a distance of 4,000 ft upstream. The top width varied erratically and trends were not detectable. Flow depth generally increased both upstream and downstream of the structure. The average shear stress decreased slightly downstream but increased slightly for 4,000 ft upstream. The changes in the hydraulic parameters were generally consistent with one another. For example, upstream of the structure, the energy slope increased, the cross-sectional area decreased, and the shear stress increased; while downstream, the energy slope decreased, the cross-sectional area increased, and the shear stress decreased. Figure 23 shows that the above trends were also consistent with the results from the model for a discharge of 8,000 cfs. The hydraulic effects did extend a little farther upstream for the 8,000-cfs discharge and the top width decreased upstream. The trends shown by the channel hydraulic parameters in the vicinity of RM 11.7 are consistent with the channel degradation and channel widening which occurred downstream of the GCS.

73. RM 19.9 trends. Figure 24 shows the trends in the hydraulic parameters for RM 19.9. Downstream of the structure, the 1980 and 1982 models

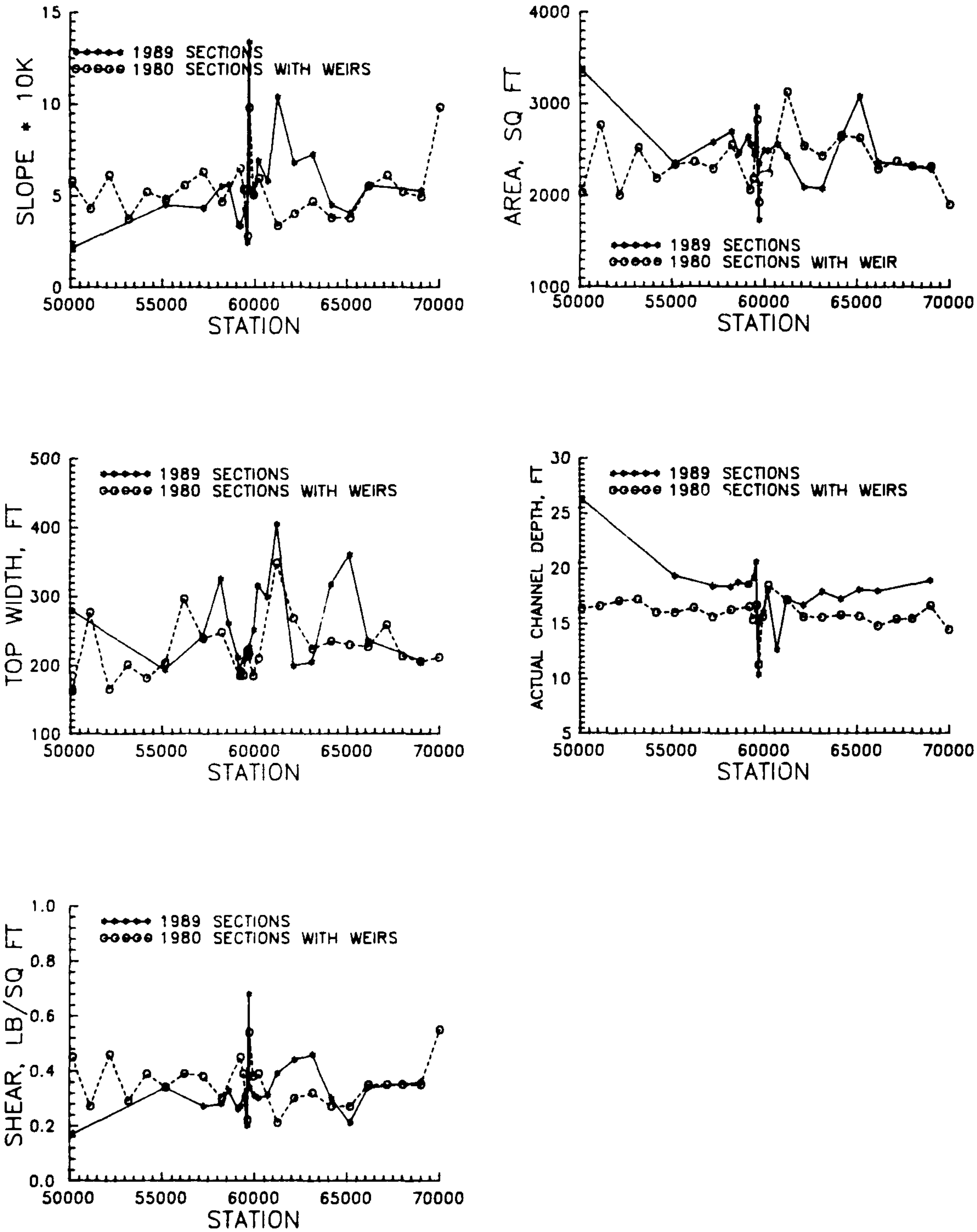


Figure 22. Channel parameters at RM 11.7 (station 597+00) for 14,000 cfs discharge

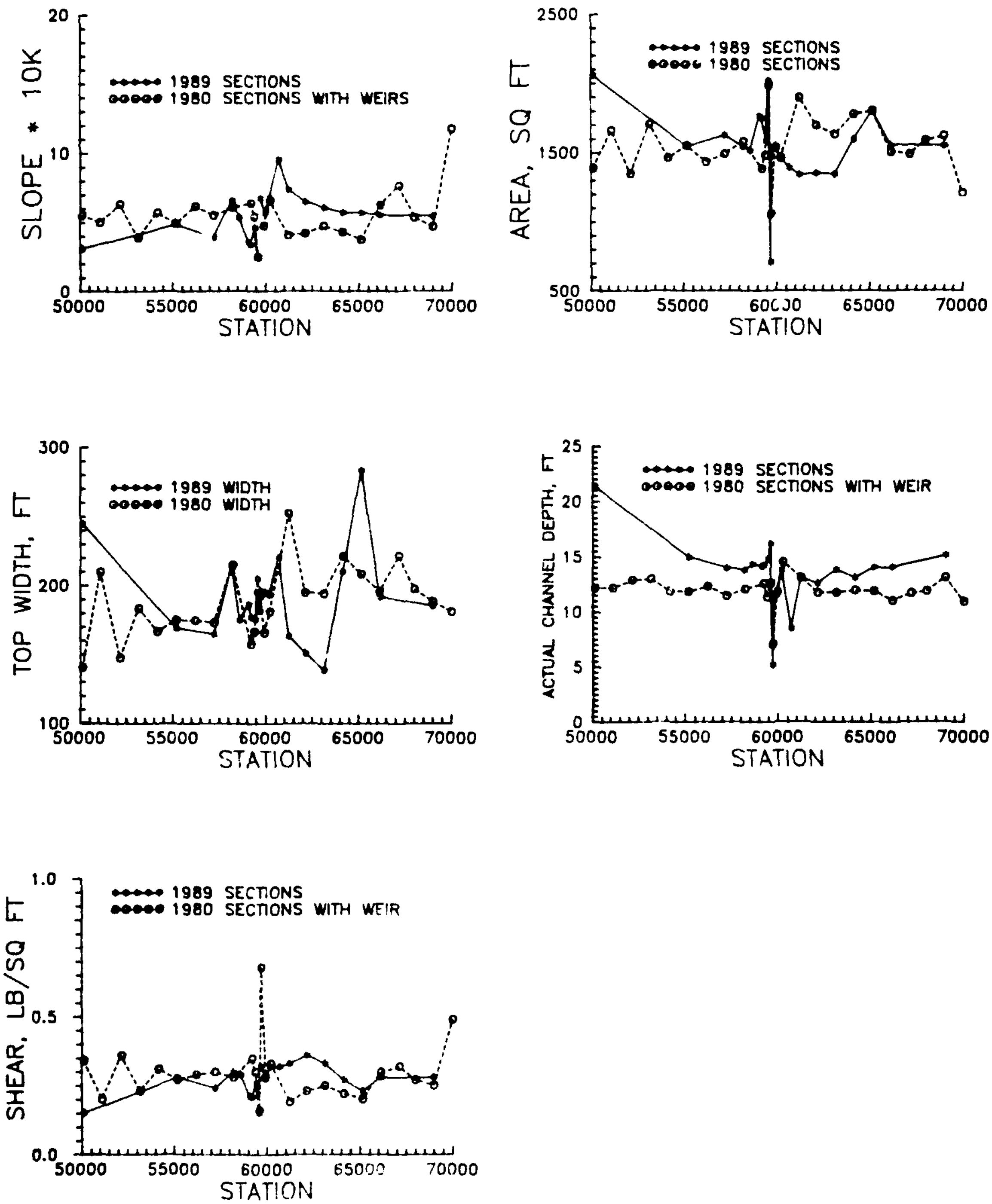


Figure 23. Channel parameters at RM 11.7 (station 597+00) for 8,000 cfs discharge

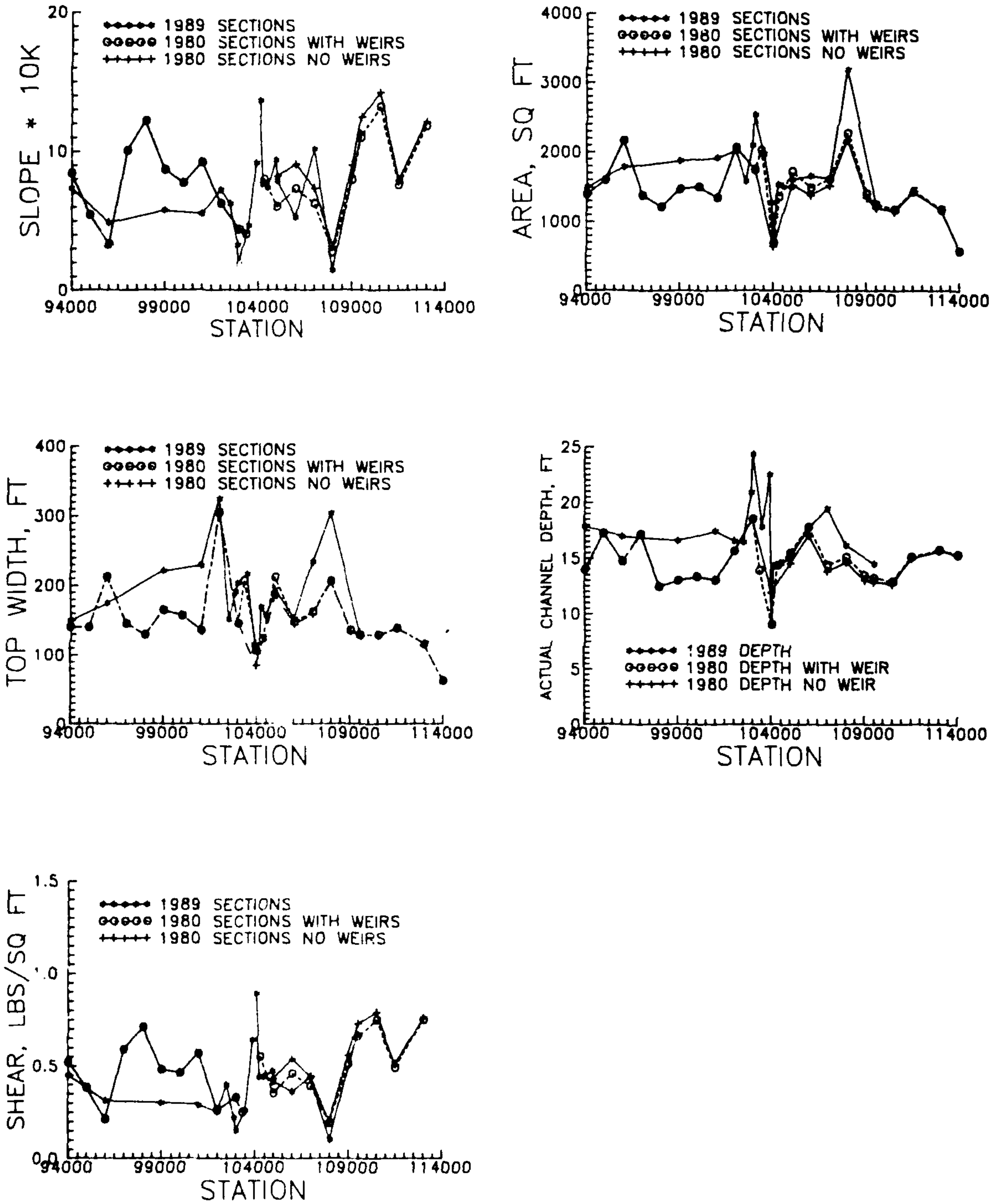


Figure 24. Channel parameters at RM 19.9 (station 1040+00) for 10,000 cfs discharge

showed identical results. Furthermore, upstream of the structure, the changes in the hydraulic parameters were consistent with one another in that after construction of the GCS the energy slope decreased, the flow cross-sectional area increased, top width increased, flow depth increased, and shear stress decreased. Moreover, these trends were evident for over 7,000 ft upstream and appear to be the result of backwater from the GCS. There was no other apparent difference between the two models.

74. Comparison of hydraulic parameters in the reach downstream of the structure from the 1982 and 1989 models showed that the energy slope decreased, cross-sectional area increased, top width generally increased, flow depth increased, and shear stress remained nearly constant. The downstream changes are the result of channel degradation and channel widening. Comparison of parameters in the upstream reach showed that the energy slope, cross-sectional area, top width, flow depth, and shear stress remained nearly constant for the same period except at one cross section where the cross-sectional area and top width increased significantly. These results indicate that the upstream channel has not changed significantly since the RM 19.9 GCS was built in 1982.

Channel planform

75. Aerial photography was used to study the migration of the meandering bends of the stream, i.e., channel planform. The sources and dates of the digitized aerial photos are listed below:

Photography Sources

Source	Date	Location, RM
Mobile District	12-14-68	11.7
	03-30-69	19.9
	02-01-79	11.7 and 19.9
US Department of Agriculture-Agricultural Stabilization and Conservation Service Aerial Photography Field Office	03-02-81	11.7 and 19.9
	04-01-85	11.7 and 19.9

76. Approximately 3 miles of bank line in the vicinity of each GCS was digitized from the photos and superimposed to ascertain planform changes. Figure 25 shows the superimposed bank line for short reaches in the vicinity of each structure and illustrates the tendency of the bends to migrate downstream and outward.

77. The 1968 photos showed the lower 10 miles of channel shortly after the project was completed. Downstream of the bridge at RM 11.7, the tress had

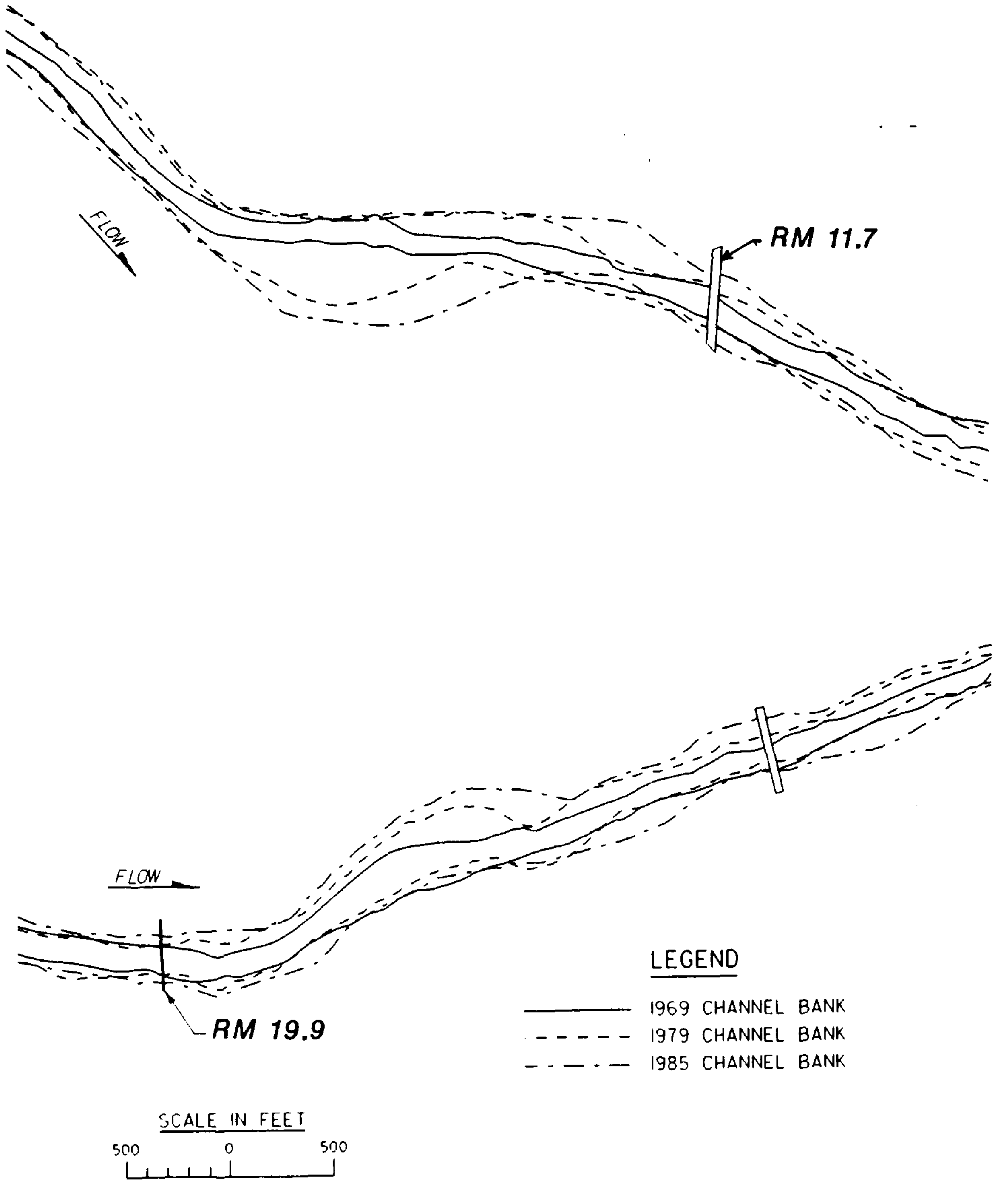


Figure 25. Bank lines in vicinity of RM 11.7 and 19.9 for 1969, 1979, and 1985

been removed from the banks, and bank erosion was evident. Upstream of the bridge, vegetation was still intact and the banks appeared stable. In the vicinity of RM 19.9 the 1969 photos showed that the channel was small with little vegetation on the banks but there was no apparent instability such as scour holes. The 1979 photos indicated that the channel was beginning to meander in the vicinity of RM 11.7 and a low-flow channel was beginning to form on the outside of the bends. A similar increase in channel meandering was indicated at RM 19.9 and the large scour hole indicated the hydraulic control at RM 19.9. A similar control point was noted several thousand feet downstream.

78. Channel meandering was more pronounced at both sites by 1981. The meander belt was increasing in width and moving downstream. The scour holes in the vicinity of RM 19.9 also appeared to be larger. The 1985 photos showed that the meanders continued to erode the outer banks and move downstream and the point bars appeared larger.

79. Aerial photography dated later than 1985 was not available, but substantial bank stabilization measures were constructed between 1985 and 1989. Therefore, field inspections were made in 1989 to evaluate the effectiveness of these measures. Most of the riprap bank protection appears to be functioning as designed and the lateral movement of the channel banks has been significantly reduced. Moreover, large sand bars were observed to be developing on the inside of the bends.

Hydraulic Engineering--Bank Protection

80. Twentymile Creek bank protection was evaluated by visual inspection in January and August 1989. The January inspection followed a flood, and high flow prevented full observation of some of the revetment toes. However, the August inspection took place during low water, and many of the revetment toes were entirely visible.

81. Most of the bank protection was riprap blanket, and no major damage was observed to riprap on either trip. In the vicinity of the two major GCS, methods such as board fences, concrete Kellner jacks, and sod have been used. More recent work has included bioengineering techniques involving willows. Some rock revetments provided protection to the top bank. Other banks were protected with rock from the toe to mid-bank with the remainder of the bank

protected with willows or sod. Groins and stone toes were used at some locations. Willows were used in various ways to protect the channel bank.

82. Reaches just below the GCS at RM 11.7 and 19.9 were protected with riprap, concrete jacks, slotted board fencing, sod, and seeding (USAED, Mobile 1984). The Mobile District noted that some of the concrete jacks were displaced, but they generally induced sedimentation in the scour hole downstream of the structure. (The 1989 inspections revealed that the jacks had caused sediment deposition on the outside of the scour hole but many of the jacks have been displaced and are nearly submerged at low flows.) The USAED Mobile (1984) recommended that the use of board fencing be discontinued because of failures associated with flow behind the structures. The sod bank protection near RM 11.7 had been eroded by high flows before it was fully established and subsequently repaired with rock. Most of the biotechnical bank protection works that did not incorporate either rock or cobble had been replaced with stone revetment by 1989. No intact biotechnical sites that were without some stone protection were noted. However, the original number of these sites was small.

<u>January 1989 inspection</u>

83. The condition of riprap bank protection works was observed during the two inspections. The January inspection was made soon after two flood events. A debris line showing near bank-full discharges was evident at most sites. None of the riprap revetment sites showed signs of stress. Sites with lower bank paving and brush layering on the upper bank appear to be well established with excellent willow growth (Figure 26). The sites with lower bank paving and sodded upper banks appeared to be in excellent condition even though significant flows had occurred on the sodded portion of the slope (Figure 27). The system of letting the overbank flow enter the channel only at selected drain points appeared to be functioning well. One of the bioengineering sites using only brush layering (site I-7) failed just prior to the January 1989 inspection even though it was in a fairly straight reach. This site had been repaired with a rock toe and groins by August 1989. One biotechnical site (site H to I) using live cobble fill toe protection and brush layering (willows) appeared to be functioning quite well.

<u>August 1989 inspection</u>

84. In August 1989 the stone toes of most of the revetments constructed in 1988 were still in place at the bottom of the slope. Not enough scour had

Figure 26. Bank protection site K-1 with brush layering on the upper bank, 18 January 1989

Figure 27. Bank protection site L-1 with sodded upper bank, 18 January 1989

occurred during the 1989 floods to cause the rock to launch. The sod placed on the top section of channel bank that was constructed in 1988 had grown into large grasses and weeds 4 to 6 ft high (Figure 28). These sites should be observed to determine if the next generation of vegetation will maintain a root system that protects the bank.

85. Sediment had been deposited on some of the riprap, and vegetation was growing in the revetment (Figure 29). This process will probably continue since an increase in sand deposits allows more vegetation to grow and an increase in vegetation causes more sand to deposit.

Riprap gradation

86. Stone protection failures were limited to grouted riprap downstream of the RM 19.9 GCS; however, no revetment failures were observed. Riprap revetments and stone protection below GCS were designed differently. All of the Twentymile Creek revetments were constructed using the same riprap gradation and stone layer thickness. Revetment riprap gradation was examined to determine if existing standard design criteria should be modified for future construction away from GCS. If the stone layer thickness could be safely reduced, significant savings would result. For example, reduction of rock blanket thickness from 24 to 18 in. would generate a 25-percent savings in material costs.

87. Channel velocities between 4 and 7 fps were expected when the revetments were designed (USAED, Mobile 1984). The stone was sized for a design velocity of 7 fps and a safety factor of 1.5. A layer thickness of 24 in. was used with the following gradation:

Cumulative Percent Lighter by Weight	Stone Weight-Pounds
Maximum weight	710
64-100	295
41-65	175
10-38	96
0-15	45

88. The velocity used for sizing the stone (7 fps) was similar to the maximum velocity (about 8 fps) that resulted from the HEC-2 runs described above. Calculations using the newest design method (Maynord 1988) show that the gradation used should withstand a velocity of 13.4 fps in water 15 ft deep when placed on a channel bank side slope flatter than 1 vertical on 2 horizontal. Existing Corps design guidance (US Army Corps of Engineers 1970) also indicates that the rock is possibly oversized. If smaller stone is available,

Figure 28. Bank protection site L-3 with sodded upper bank. Tall grasses are growing in both the revetment and the upper bank, 30 August 1989

Figure 29. Bank protection site RS showing willow growth in the revetment, 30 August 1989

consideration should be given to reducing the size of stone and the layer thickness when designing future bank protection sites.

Environmental Engineering

Vegetation

89. Bank lines and woody vegetation were clearly visible on the 1:15,840-scale (HAP) photographs. Scale differences between the two coverages were slight (less than 1 percent), and results were adjusted to eliminate this difference. As shown in Table 7 and Figure 30, the percentage of Twentymile Creek channel length bordered by woody vegetation increased from 64.1 percent in 1981 to 71.7 percent in 1985, while bank line vegetation cover declined slightly along Big Brown Creek (from 98.4 to 95.5 percent) and was essentially unchanged along Mubby-Chiwapa (from 86.4 to 88.1 percent) during the same interval.

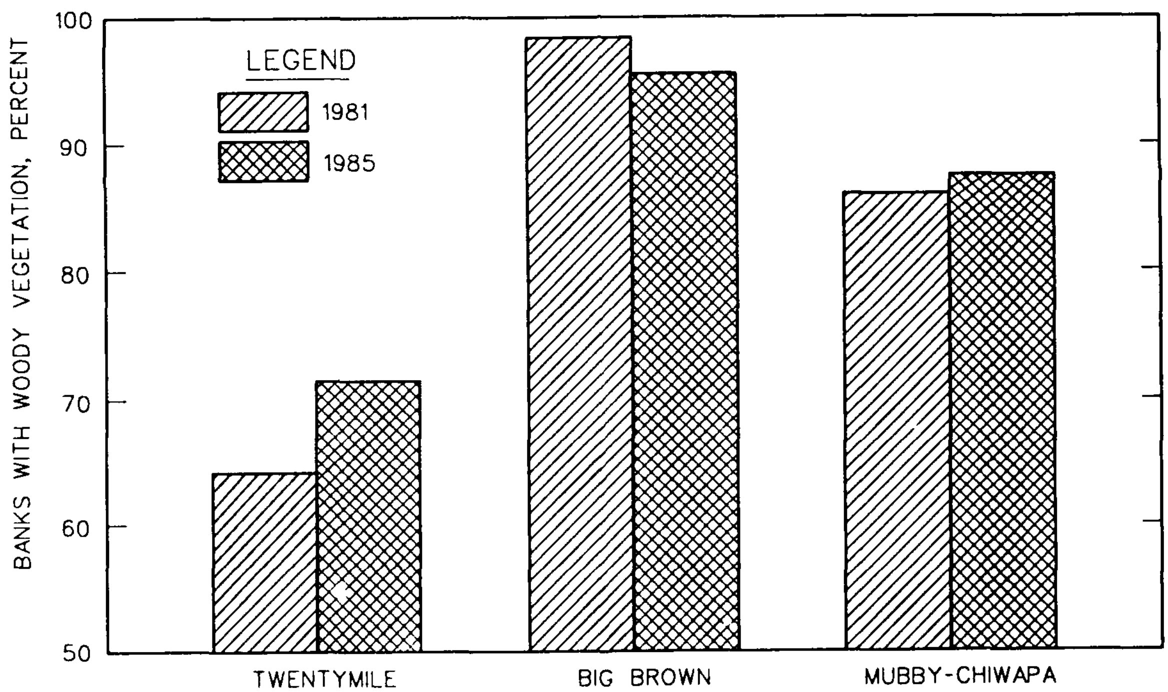


Figure 30. Bank line vegetation for Twentymile, Big Brown, and Chiwapa Creeks, 1981 and 1985

90. To examine association between GCS construction and bank line vegetation recovery, mapping results for reaches below each of the two major GCS were examined (Table 7). In the 3.30-mile-long reach below RM 19.9, the increase in vegetated banks and berms was only 5.5 percent, but in the

2.60-mile-long reach below RM 11.7, there was an increase of 12.0 percent. Comparison of the 1981 and 1985 photos revealed that vegetation growth was associated with point bars and protected banks within enlarged cross sections.

Physical habitat

91. Depth, velocity, substrate, and cover were evaluated under low-flow conditions on Chiwapa and Twentymile Creeks during the period July 24-27. Discharges on both streams were between 30 and 50 cfs. Plots of depth and velocity at selected transects are presented in Figure 31. Figure 32 contains frequency histograms for velocities measured in selected reaches.

92. Habitat diversity indices were calculated using the Shannon function and all possible combinations of the physical variables. Maximum diversity values occurred at sites either above or below GCS for all variable combinations. Cover was the most uniform variable for all sites; velocity was the most diverse variable for all Mubby-Chiwapa sites (Table 8). Habitat diversity indices based on all four physical variables ranged from a low of 1.22 (site 10.0, the lower, highly maintained reach of Twentymile Creek) to a

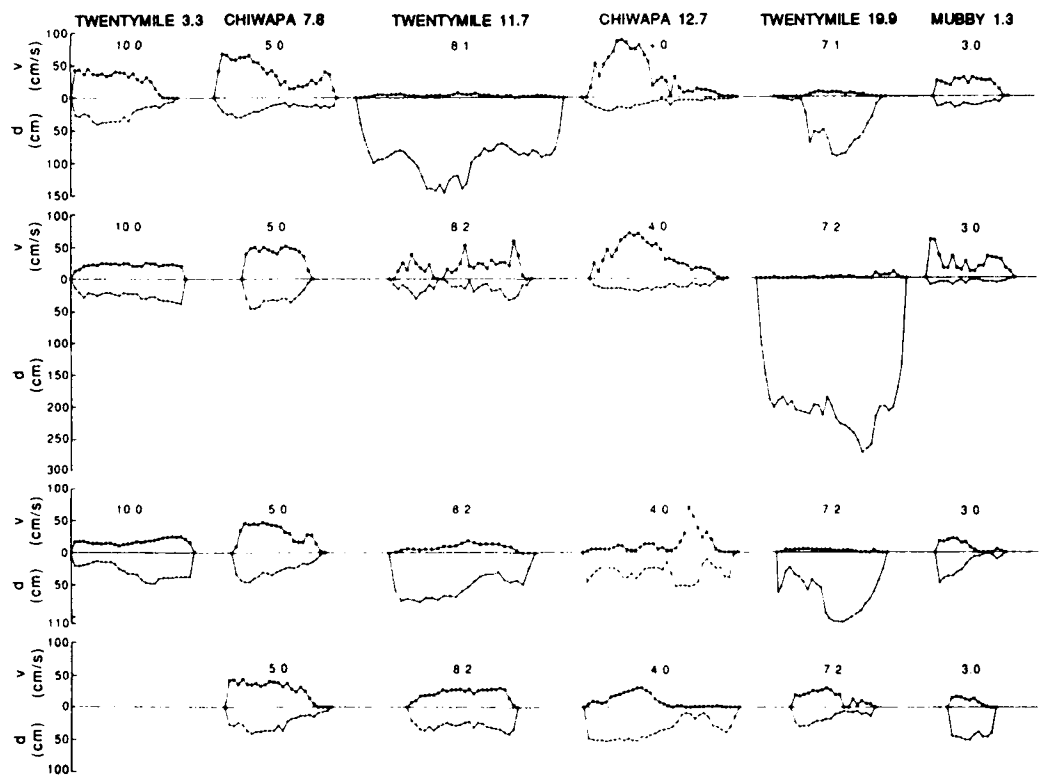


Figure 31. Depth and velocity plots for selected sampling transects

high of 3.33 (for the reach immediately below RM 19.9 GCS). Diversity indices for Chiwapa based on all four variables ranged from 2.18 to 2.61. Diversity indices were greater below GCS than elsewhere.

93. The effect of the GCS on habitat diversity is highlighted by Table 9, which shows composite diversity indices for sites above and below each GCS. Diversity indices tend to be slightly higher for sites with a greater number of sampled points. To eliminate this effect, the maximum possible diversity index (which is equal to the natural log of the number of points) was calculated for each site, and diversity indices were expressed as percentages of the maximum possible index (Table 9). Diversity was higher in reaches containing GCS. Reach 10.0 was located at RM 3.3 on Twentymile Creek where sedimentation and regular channel maintenance had produced a uniform channel with little habitat diversity, as indicated in Figures 32 and 33. The remaining Twentymile reaches were located near the two GCS, and all exhibited significantly greater physical habitat diversity.

94. Physical habitat diversity on Chiwapa Creek depended primarily on the nature of the bed material. Throughout most of its length Chiwapa ran on a bed of Selma chalk. At some places the chalk was badly eroded and had deep pockets alternating with shallower depths. In other places the chalk was partially or entirely covered with a sandy substrate that varied from a few inches to several feet in depth. Physical habitat diversity was noticeably higher in the former reaches than in the latter.

95. Of 425 surficial bed sediment samples from Mubby-Chiwapa that were classified in the field, 61 percent were chalk, 37 percent were sand, and 2 percent were silt/clay. Sampled reaches of Twentymile Creek had less chalk and more riprap. Of 497 samples, 10 percent were chalk, 21 percent were boulders (riprap), 56 percent were sand, and 11 percent were silt/clay. Sixty-eight samples of surficial bed sediment were collected and sieved to verify field visual classifications. Results of the sieve analysis are compared with field classifications in Table 10. Visual classifications were usually accurate. Fifty-eight of the samples were visually classified as sand in the field; 32 of these were 100-percent sand size based on sieve analysis. Twenty-three of the remaining 26 samples classified as sand in the field were at least 62-percent sand. Two of the six samples visually classified as clay/silt were 100-percent sand, but the other four contained between 8 and 66 percent fine material.

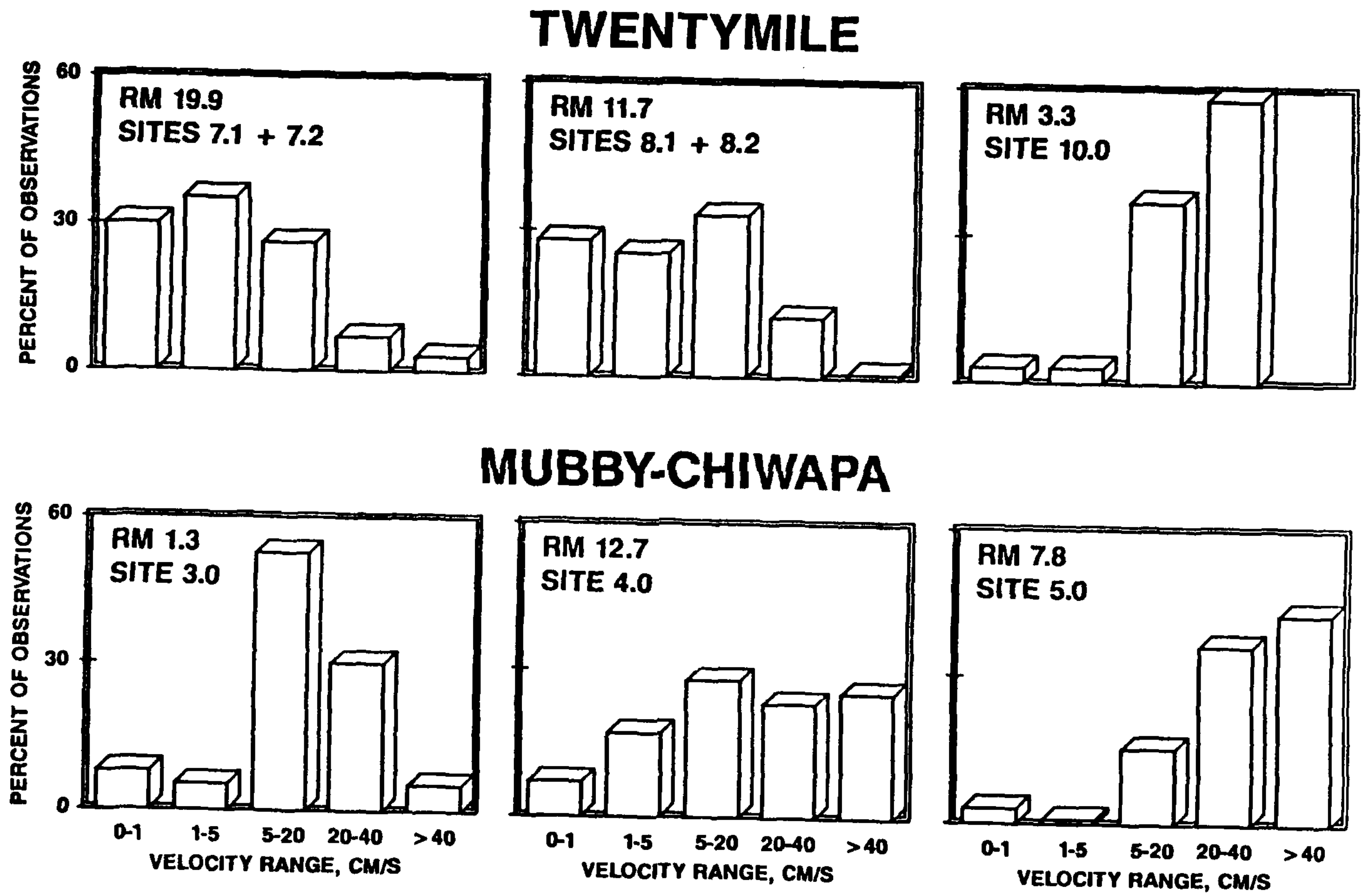


Figure 32. Frequency histograms for velocity measurements (Twentymile sites 7 and 8 are influenced by GCS)

a. August 1981

b. October 1988

Figure 33. Low-flow channel, Twentymile Creek, near RM 19.5

Low-flow channel

96. No low-flow channel was evident on the 1980 cross sections, but with a few exceptions, the 1989 cross sections revealed a low-flow channel clearly delineated by bar deposits (berms) along one or both sides. Furthermore, a distinct low-flow channel was evident in the field (except in pooled areas just upstream from the GCS) as shown in Figure 33.

97. As described in Part II above, capacity for each low-flow channel cross section was computed using the Manning formula and an n value of 0.022 computed by the HDP. Results are shown in Table 11. The mean of the discharge values was 88 cfs, with a standard deviation of 37.9 cfs. This discharge is equalled or exceeded 31 percent of the time based on the daily discharge-duration curve for RM 11.7 (Figure 34).

98. Low-flow channel capacities were also determined using the method of Harvey and Watson (1987). HEC-2 simulations were run using the 1989 model and discharges of 25, 50, 75, 100, 125, 150, and 200 cfs. The resulting water surface profiles were superimposed on a plot of low-flow channel berm elevation versus longitudinal distance. Although there was little difference among the profiles for discharges in the 75-150 cfs range, a discharge of about 100 cfs best fit (by eye) the berm elevation profile, as shown in Figure 35. A discharge of 100 cfs is equalled or exceeded 27 percent of the time based on the duration curve for RM 11.7 (Figure 34).

Fish studies

99. Species richness and diversity of fish collections were higher in Twentymile Creek than in Mubby-Chiwapa. Within Twentymile Creek, species richness and diversity were higher at sites with GCS than at the downstream site (10.0) which had no GCS.

100. Fish species. Forty-three species of fish were collected from Mubby-Chiwapa and Twentymile Creeks (Table 12). Assemblages were dominated taxonomically by minnows (14 species), sunfishes (9 species) and darters (7 species). Collections from Twentymile Creek contained nearly twice the number of species than those from Mubby-Chiwapa but the majority of these were rare, constituting less than 1 percent of all individuals collected. In general, species that were abundant in one stream were also abundant in the other. These species included the blacktail shiner (averaging 41 percent of all fishes), bluntnose minnow (13 percent), orangefin (9 percent) and pretty shiners (8 percent), mosquitofish (6 percent), bluegill (5 percent), and longear sunfish (4 percent) (Tables A1 and A2, Appendix A). Several species of

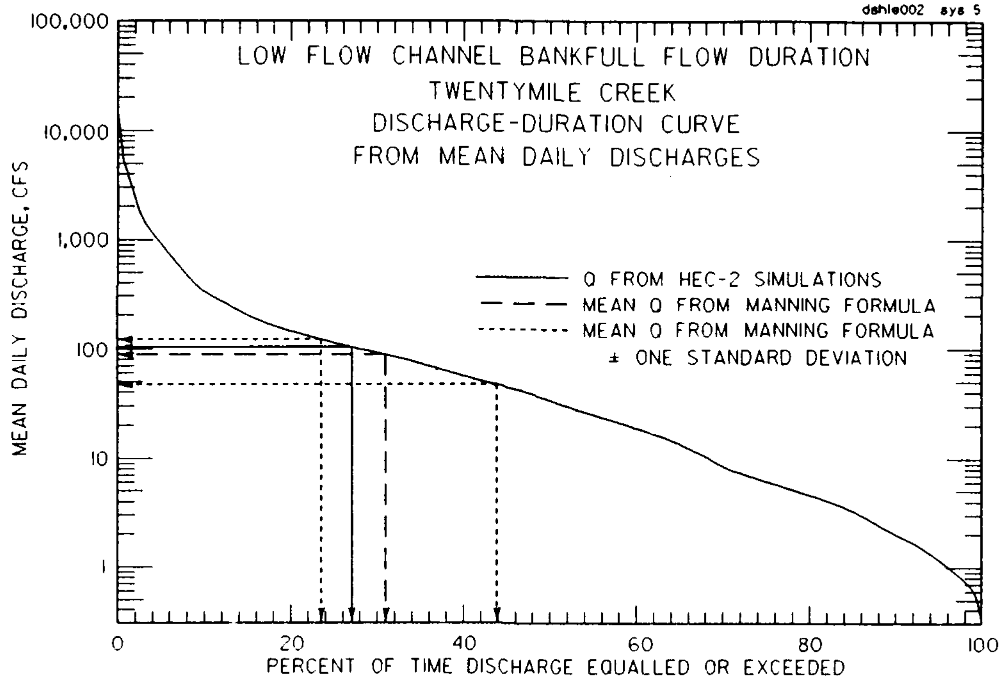


Figure 34. Low-flow channel capacity discharge duration

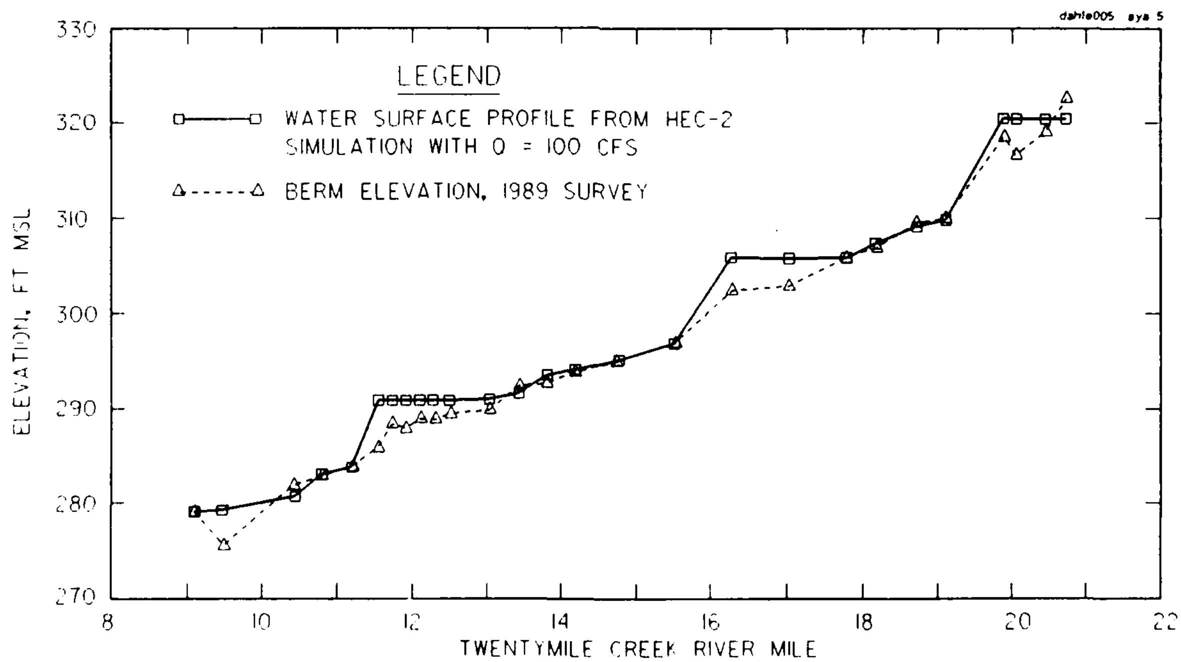


Figure 35. Best fit of HEC-2 simulated water surface profile (Q = 100 cfs) to the low-flow channel berm elevation profile

economic and recreational importance were collected in both streams but highfin carpsucker, largemouth bass, and white crappie appeared more abundant in Twentymile Creek (Appendix A).

101. Longitudinal zonation. Longitudinal patterns in distribution were marginal. No species exhibited consistent and progressive shifts in relative abundance and only a few species (mosquitofish, bullhead minnow, and silverstripe shiner) abundant at downstream stations were absent from upstream stations (Appendix A).

102. Interspecific associations. Principal component analysis of fish collections suggested that velocity was the primary habitat variable influencing species composition (Figure 36). The first principal component (PCI) accounted for the greatest amount of data set variance (19.9 percent). PCI was correlated positively with the abundance of a swiftwater species, the blacktail shiner ($r = .771$, $p < .01$), and negatively with the abundance of three slackwater species, the bluntnose minnow, bluegill, and longear sunfish ($r < -.687$, $p < .01$). This velocity gradient, suggested by species composition, was confirmed by flow data. Sites 8.1 and 7.1 were numerically dominated by all three slackwater species (Table A2) and mean velocities were low (≤3.0 cm/s). Site 5.0 was dominated by the swiftwater species and mean velocity was high (34.7 cm/s). Other stations, with moderate numbers of at least two slackwater species, were characterized by intermediate velocities (7.5-24.4 cm/s).

103. The second and third principal components (PCII and PCIII) were both orthogonal to PCI and accounted for comparable variance (13.7 and 13.6 percent, respectively), but PCII was not readily interpretable. Four species associated with this component were absent from 7 to 13 collections, did not exhibit significant interspecific correlations, and did not represent conspicuously different habitat types. PCIII, however, was negatively correlated with the abundance of a shallow water species, the orangefin shiner ($r = -.600$, $p < .01$) and positively correlated with the abundance of a habitat generalist, the channel catfish, ($r = .726$, $p < .01$), a species frequently found in pools. PCIII, therefore, represented the influence of depth on species composition.

104. Diversity and evenness indices. Ichthyofaunal diversity, as measured by the Shannon function, ranged from $H' = 0.61$ to $H' = 2.26$ (Table 13). High values ($H' > 1.95$) were recorded at stations immediately downstream from GCS in July (sites 7.2 (RM 19.9) and 8.2 (RM 11.7)). Overall mean values

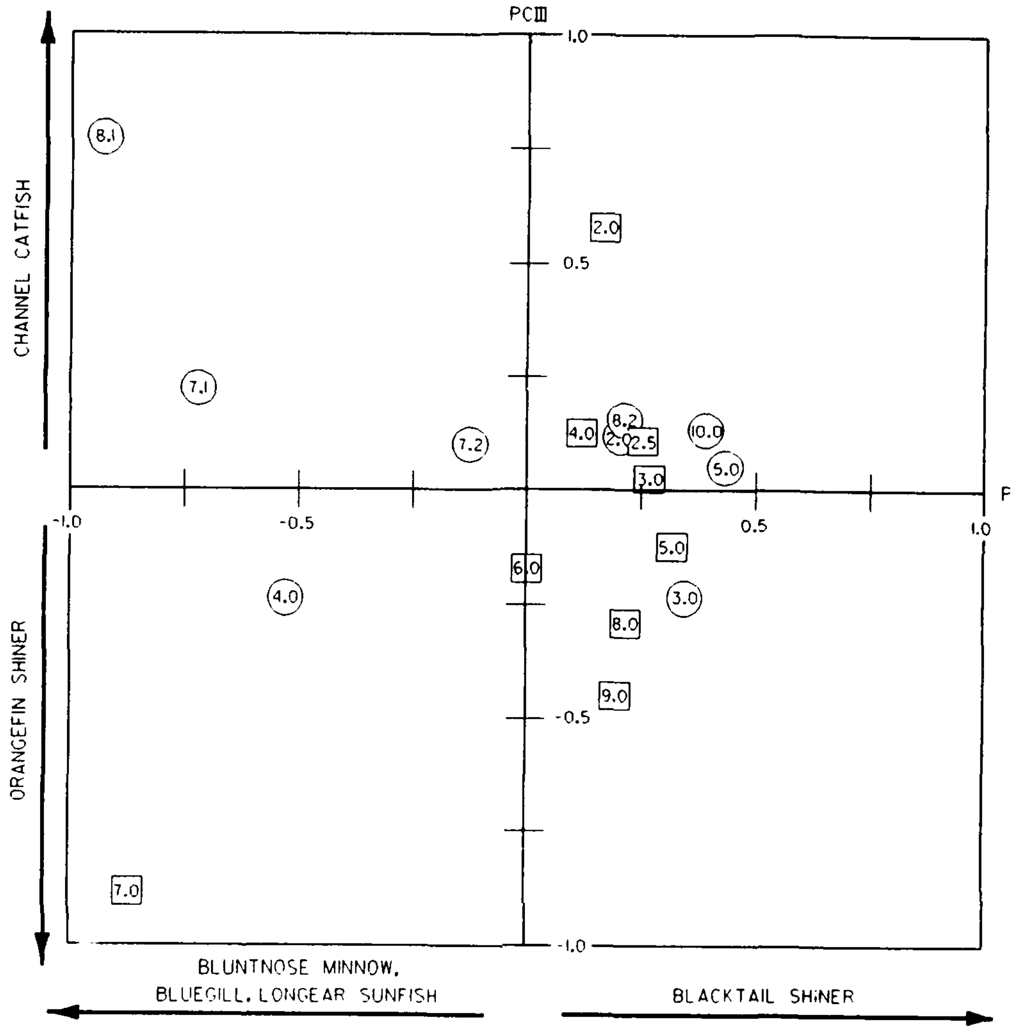


Figure 36. Principal component analysis of fish data from Mubby-Chiwapa and Twentymile Creeks (numerals correspond to sites listed in Table 3. Collections represented by squares were made in May 1989, circles in July 1989)

across stations were significantly higher in Twentymile Creek (H' = 1.84) than in Mubby-Chiwapa Creek (H' = 1.43; d.f. = 1/16, p = .01), although mean values for May and for July were not significantly different in either stream (d.f. = 1/7, p > .50). Mean evenness values were also significantly higher in Twentymile Creek (E = 0.69) than in Mubby-Chiwapa Creek (E = 0.57; d.f. = 1/16; p = .04). Diversity and evenness measures were significantly correlated for Mubby-Chiwapa (r = .995, N = 9, p < .01), but not so for Twentymile Creek (r = .544, N = 9, p > .10), indicating higher spatial variation in species richness at Twentymile Creek.

105. Correlations. Significant correlations existed between ichthyofaunal diversity and several habitat measurements (Table 14) and habitat diversity (Figure 37). Ichthyofaunal diversity was positively correlated with mean water depth and variation in bottom type; it was negatively correlated with mean bottom type. Two Shannon measures for habitat were also positively correlated with those for fishes: diversity of bottom type and diversity of bottom type with water velocity.

106. Regressions. Regression analysis indicated that bottom type, and to a lesser extent, water velocity and depth, could be used to predict ichthyofaunal diversity. Selected regression results are presented in Figure 38 and Table 15.

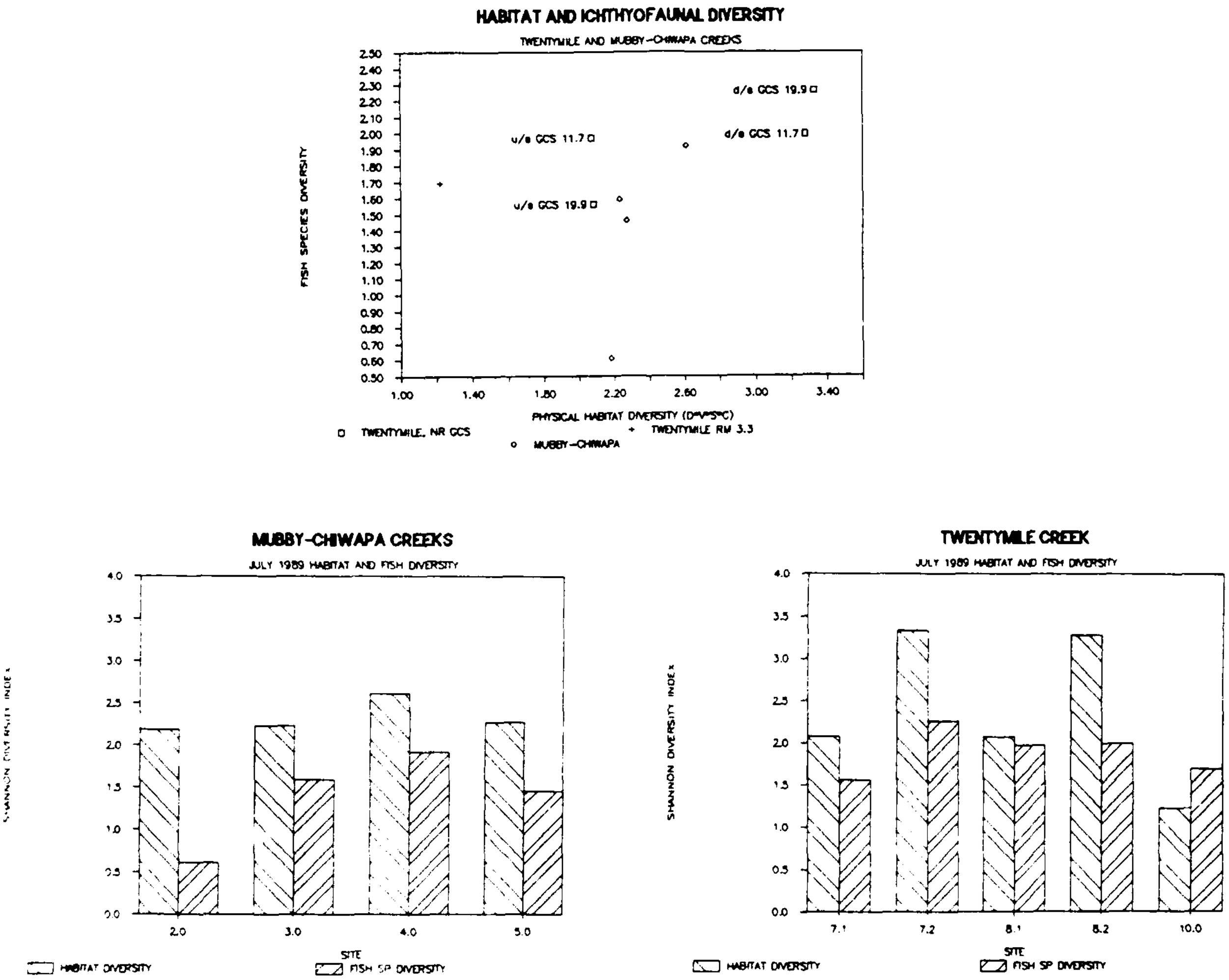


Figure 37. Habitat and ichthyofaunal diversity associations

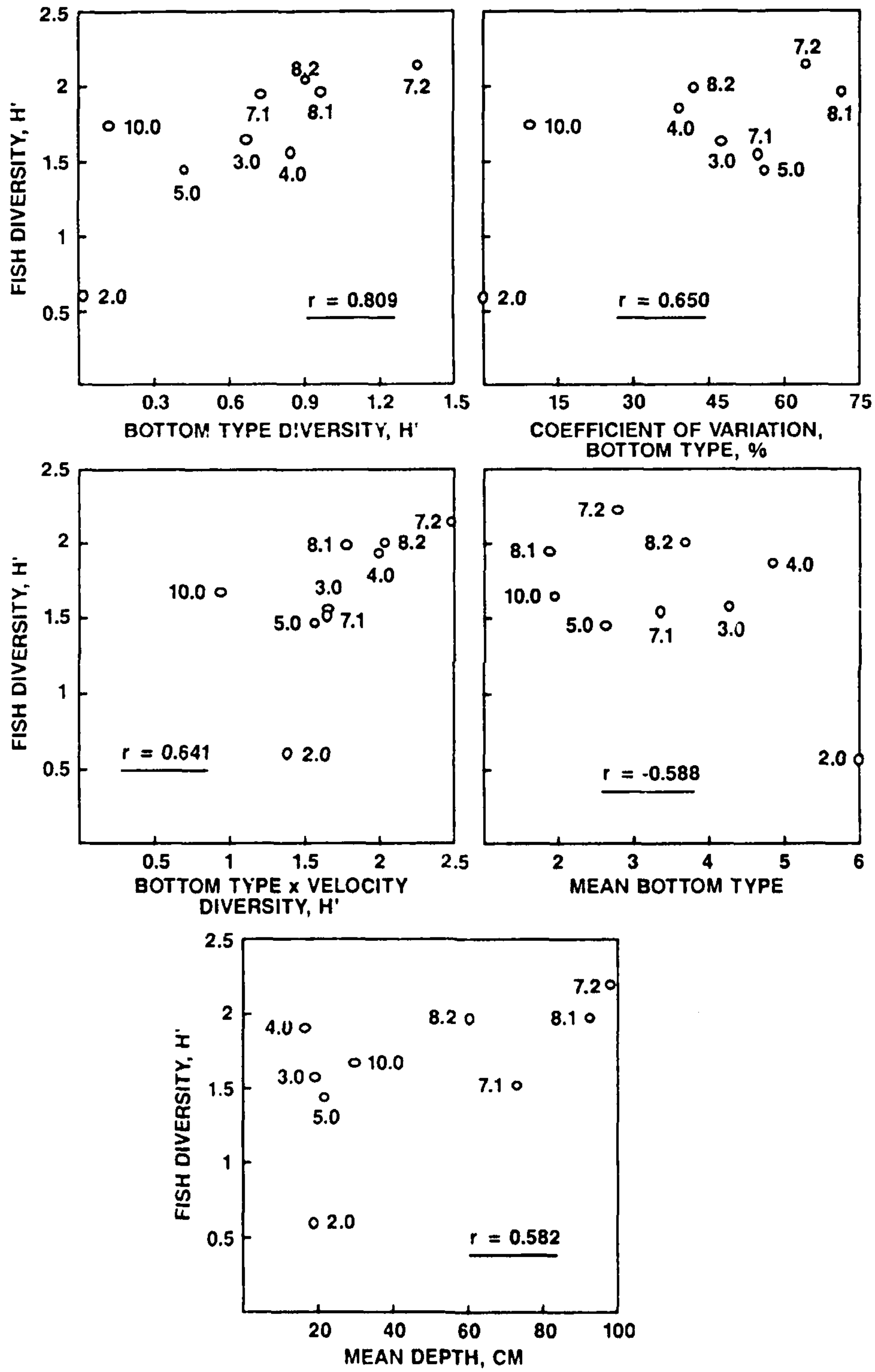


Figure 38. Results of selected regression analyses

PART IV: DISCUSSION

Introduction

107. Although the dramatic response of Twentymile Creek to channel modification is unusual, it is not unique. Rapid channel enlargement to several hundred percent of the original cross-sectional area upstream of channel work has been described by Emerson (1971), Jahn and Trefethan (1973), Parker and Andres (1976), Barnard (1977), Wilson (1979), and Barclay (1980). Aggradation of lower reaches of channelized streams has been documented by Cederholm (1972), Parker and Andres (1976), and Griggs and Paris (1982). Effects of channel instability on highways and bridges are reviewed by Brown, McQuivey, and Keefer (1981) and Brice (1981).

108. Although biological effects of channel straightening and enlargement have been widely studied, specific effects of channel instability caused by channel modification are less well documented. However, many of the physical effects of channel modification are amplified in unstable channels--loss of pool habitat, overall physical diversity, and bank vegetation; and elevated sediment loads. In addition to biological effects, the caving, denuded bank lines, wide, empty channels, and sediment deposits typical of unstable channels often create adverse aesthetic (visual) impact.

109. Adverse effects of Twentymile Creek modification on channel stability were addressed by a program of constructing corrective measures--GCS and bank protection. The efficiency of these measures in ameliorating the conditions described above was assessed in two ways, depending upon data availability. Hydraulic effects of GCS were assessed using channel surveys and hydrologic records to compare conditions just before, just after, and 7 years after GCS construction. Similarly, effects of corrective measures on bank line vegetation were assessed using a before-and-after approach. On the other hand, physical habitat and fish were sampled from Twentymile Creek and a reference stream that was an unstable channel without corrective measures. Neither of these two approaches was entirely adequate to gage the effects of the corrective measures. A better test of corrective measure efficiency would involve comparison of present conditions on Twentymile Creek to conditions that would presently exist if corrective measures had not been installed. Evaluation of the results of this study should be done with this in mind. An overview of study results is presented in Table 16.

Physical Effects of Corrective Measures

Channel changes

110. Significant bed degradation occurred along much of the channel between 1980 and 1989, continuing earlier trends (NHC 1987, Wilson and Turnipseed 1989). Since survey data were unavailable for as-built conditions, it is unknown how much of the observed 1980-89 degradation occurred before corrective measures were installed. The stability of the bank protection works, the development of woody vegetation along the channel boundary, and the formation of a low-flow channel all indicate that degradation rates decreased following GCS construction. Experts evaluated plans and designs for construction of the two major GCS in 1981 and predicted that they would not materially affect flow lines except at very low flows and thus would not halt general degradation (Tuttle 1982). Their predictions regarding effects of the GCS on flow lines were verified by the simulations done in the course of this study. However, since aggradation occurred for about 1 mile upstream of each GCS, and since the GCS remained intact and thus limited degradation at least locally, it is likely that degradation between 1980 and 1989 would have been more severe had the corrective measures not been installed. The RM 19.9 GCS was built on a geologic control which retarded upstream channel degradation prior to GCS construction. The amount of aggradation actually caused by the RM 11.7 GCS between 1980 and 1989 is impossible to determine exactly because degradation may have occurred there between 1980 and GCS construction in 1982. Because of site characteristics, the RM 19.9 GCS served as a hydraulic control over a wider range of flows and caused more upstream deposition than the RM 1-1.7 GCS. Effective discharges for both GCS have increased as a result of downstream degradation.

111. Computed channel parameters (flow area, top width, depth, energy slope, and shear stress) for specific discharges indicated that construction of the GCS has promoted aggradation upstream. Downstream channel parameters show a trend of channel degradation and widening. Two-year discharge flow depths increased below the GCS after construction, while boundary shear stress and energy slope decreased.

Sediment yield

112. Annual sediment yields were calculated for channel sections upstream and downstream of each GCS. The Colby (1964) method for calculating sediment transport was selected for use on Twentymile Creek based on discharge

and suspended sediment data at RM 3.3. The annual sediment yield at each station was calculated by integrating the sediment rating curve at each station with the duration curve from the RM 11.7 gage. This duration curve was based on mean daily discharges. A duration curve based on mean hourly discharges would have more accurately represented the peak discharges in this watershed.

113. Downstream of the RM 11.7 GCS the calculated annual bed material load was 143,000 tons, only 19 percent of the annual suspended load of 757,750 tons computed by James (1989). This difference is not unreasonable since the bed material load is a fraction (generally less than 35 percent) of the suspended load. Also the annual water volume calculated by James was 36 percent larger than the water volume at RM 11.7 calculated herein.

114. The sediment loads were reduced upstream of each of the GCS, indicating the potential for aggradation. The cumulative sediment yield analysis at the RM 11.7 GCS indicated that about 70 to 80 percent of the bed material load in the sediment inflow reach and downstream of the GCS was transported at discharges below 8,000 cfs. Since the RM 11.7 GCS had no impact on discharges over 8,000 cfs, large quantities of sediment were transported at discharges over which the GCS had no effect.

115. One of the initial study objectives was to evaluate the effects of the corrective measures on Twentymile Creek sediment discharge into the Tombigbee River. The available suspended sediment data were evaluated. However, since very few suspended sediment samples were collected after the construction of the GCS,* changes in suspended sediment transport could not be determined. The techniques used for calculating sediment yield were applied to cross sections downstream of the RM 11.7 GCS for both pre- and post-project conditions, but results were inconclusive.

116. Some conclusions can be made about the impact of the GCS on sediment transport. The GCS may have prevented additional increases in sediment load by preventing some channel degradation in the main channel and its tributaries. The reach length over which degradation is controlled depends on upstream channel slope. The sediment yield analysis showed that less sediment was transported in reaches just upstream of a GCS than for either downstream reaches or for the inflow reach further upstream. However, only a limited

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* Continuing collection of suspended sediment data was recommended before the GCS were constructed (Tuttle 1982).

amount of sediment can be stored upstream of a GCS. Channel reaches upstream of a GCS adjusted to the hydraulic conditions imposed by the GCS. At RM 11.7 this influence extended upstream for about 5,000 ft, and at RM 19.9 the region of influence was slightly larger.

117. Since the GCS at RM 11.7, 16.3, and 19.9 each influence only about 1 mile or less of the channel, there are not enough GCS to adequately control sediment transport. The GCS probably have not significantly reduced Twentymile Creek sediment load relative to preproject conditions. Consideration of additional smaller low-water weirs placed closer together than the two original GCS was recommended in 1981 (Tuttle 1982).

Streambank protection

118. Riprap revetments were the most effective form of bank protection on Twentymile Creek. The rock revetments appeared to be functioning well. Most bioengineering sites that did not include rock toe protection have been replaced. The use of board fences has also been discontinued. Consideration should be given to reducing the layer thickness of the riprap blanket for bank protection.

119. Potential problems associated with vegetation growing on the revetments should be considered. In some cases vegetation can reduce the conveyance, but this should not be a problem on Twentymile Creek. Other concerns relate to vegetation effects on rock stability, but at this time the vegetation is small and the banks are stable. Shields et al. (1990) present a review of existing information regarding effects of vegetation on riprap stability. In some cases woody vegetation may reinforce stone-protected streambanks.

120. Another potential problem that was noted is that many of the revetments tend to be almost straight. This is probably because many of the revetted reaches were fairly straight when the revetments were constructed. Meanders are now developing inside the enlarged straight channel. Channel meanders tend to move laterally and downstream. Even if bank protection stops the lateral movement, the channel could still migrate downstream and require additional bank protection. If possible, bank protection should be designed as a system so that the downstream migration will also be stopped before an unprotected bank is attacked. A comprehensive program of bank protection was recommended earlier (Tuttle 1982).

Low-flow channel

121. In 1989 a poorly developed low-flow channel was observed in the reach of Twentymile Creek upstream of RM 9.1. The channel below this point is subjected to regular maintenance (removal of bank vegetation and sediment). Low-flow channel dimensions were developed to provide a bank-full capacity of about 100 cfs, which is equaled or exceeded about 30 percent of the time. This flow capacity compares favorably with the findings of others. Osterkamp and Hupp (1984) studied geometries of three unmodified perennial northern Virginia streams draining forested watersheds with mean discharges of 6.9, 69, and 11,000 cfs. They found the elevation of depositional bars to correspond to the water surface elevation for flows equaled or exceeded about 40 percent of the time. Depositional bars were defined as the lowest prominent in-channel features above the channel bed. Harvey and Watson (1987) were unable to provide a return interval for the low-flow channel they studied, because the basin was not gaged. They simply noted that the low-flow channel formative discharge was 12 percent of the flood channel design discharge and was related to low-water reservoir releases and uncontrolled tributary base flows.

122. The role of the corrective measures in allowing and encouraging low-flow channel formation is not clear. Low-flow channel formation commenced prior to installation of corrective measures. A low-flow channel was observed on the outside of large meanders in 1979 aerial photos. However, longitudinal berms defining the low-flow channel were not sufficiently developed in 1980 to be discerned on the cross sections from the 1980 channel survey. Without the GCS, additional degradation upstream of the GCS locations would have mobilized large volumes of sediment. Movement of this sediment through the system might have led to a braided condition at low flow and delayed low-flow channel development.

Physical habitat diversity

123. Habitat diversity indices for the nine sampled sites varied from 1.22 to 3.33. Reaches below GCS had indices of 3.28 and 3.33, which are substantially higher than a mean of 2.09 for the remaining seven sites. When data from reaches above and below GCS were combined (as in Table 9), the resulting indices for GCS reaches were 65 percent of the possible maximum,*

* Pielou evenness (E) may be thought of as the ratio of observed Shannon diversity (H') to the maximum possible value of H', given the number of points sampled.

while other reaches produced indices that were only 30 to 50 percent of the maximum. Nevertheless, even the relatively diverse reaches below the GCS were less diverse than a smaller, undisturbed stream in Indiana, which produced indices between 3.5 and 4 (Gorman and Karr 1978). The GCS reaches were also less diverse than reaches of a relatively undisturbed sand and gravel bed stream in central Mississippi (Clear Creek near Bovina, drainage area = 15.3 and 31.6 square miles), which produced indices that were 70 to 80 percent of the possible maximum (Shields*). One of these reaches is shown in Figure 39, which offers a stark comparison with Figures 5 and 6. Swales (1987) found channelized reaches of a lowland English river physically less diverse than a partially channelized reach and an unmodified reach downstream. Scarnecchia (1988) found channelized sections of a prairie stream in Iowa to have less width, velocity, and substrate diversity than unchannelized sections.

Figure 39. Clear Creek near Bovina, MS, July 1989

124. Habitat diversity was primarily dependent upon depth and velocity, and those reaches having the greatest variation in depth and velocity had the highest indices (Figure 31 and Table 9). On Mubby-Chiwapa Creek, these were reaches containing deeply eroded potholes in the chalk bed. On Twentymile Creek they were associated with the scour holes below the GCS. Thus the highest physical habitat diversity on Twentymile Creek was clearly associated with

* Unpublished data, 1989, F. Douglas Shields, Jr., Research Civil Engineer, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

the GCS. However, this higher level of diversity was not entirely due to the GCS because there was a large scour hole at RM 19.9 prior to GCS construction. Habitat diversity decreased in a downstream direction on both creeks due to the uniform conditions in lower reaches. The lowest habitat diversity index for the entire study was for the lower, maintained reach of Twentymile Creek (Site 10.0, RM 3.3).

Biological Effects of Corrective Measures

Bank vegetation

125. Increased cover along Twentymile Creek may be related to improved channel stability due to the corrective measures. The greatest increase occurred above the RM 11.7 GCS in the reaches that SLA (1982) recommended for bank protection.

126. Riparian vegetation beneficially affects both aquatic and terrestrial habitat, and in some cases, improves bank stability. Routine maintenance (mowing) of the banks of Twentymile Creek below RM 9.1 is detrimental to habitat resources. Consideration should be given to revision of current maintenance standards to allow unrestricted woody growth, isolated clumps of vegetation, or isolated trees. New maintenance criteria should meet engineering, cost, and environmental constraints.

Fish communities

127. Species counts and diversity indices are not statistics and their interpretation is often subject to sampling error. The higher number of species (Appendix A) and higher diversity values (Table 13) for fish assemblages at GCS could be attributable to sample size bias; lower numbers of individuals were collected at some sites with low species richness and diversity (e.g., site 2) and large numbers of individuals were collected at sites characterized by high species richness and diversity (e.g., site 8). A mathematical technique called rarefaction and appropriate selection of a diversity formula can compensate for such bias, however (Magurran 1988). Rarefaction analysis was performed on May and July fish collections. For a uniform sample size, mean species richness at the GCS (11.5 species/60 individuals) was still higher than for other sites (8.4 species/60 individuals). The selected diversity index (Shannon function) exhibits only moderate sensitivity to sample size, and even this bias was minimized by relatively large collections (number of individuals $>$ 125 for 16/18 collections). Consequently, it was concluded that

the fish assemblages at a GCS are more diverse than at other sites on Twentymile Creek and on Mubby-Chiwapa.

128. Longitudinal zonation. Other studies of stream fish assemblages have documented pronounced downstream increases in species richness and species diversity (Sheldon 1968; Whiteside and McNatt 1972) or strong positive correlations between species diversity and habitat diversity (Gorman and Karr 1978; Foltz 1982). Fish assemblages in Mubby-Chiwapa and Twentymile Creeks exhibited no major trends in longitudinal zonation (Appendix A, Table A2) and correlations between habitat diversity and species diversity were generally nonsignificant (Table 14). Smaller sample size (N < 15) relative to those other studies (N - 21-202) contributed to the difficulty of documenting such patterns, but another factor may have been more important. The sampled channels were flanked by farmland and were subject to agricultural runoff. Furthermore, despite the favorable response of Twentymile Creek to the corrective measures, both stream systems had high sediment concentrations relative to less severely modified streams. Pollutants (sediment, organics, and heavy metals) can obscure patterns in longitudinal zonation (e.g., Reash and Berra 1987) and species diversity and habitat diversity (Tramer and Rogers 1973) by selectively impacting "intolerant" species.

129. Habitat diversity. Habitat diversity and fish diversity are positively associated (Wesche 1985). Individual habitat components correlated with fish diversity may include water velocity (Burton and Odum 1945), depth (Sheldon 1968; Evans and Noble 1979), bottom type (Foltz 1982; Matthews 1985; Matthews, Hoover, and Milstead 1985), or all of the above (Gorman and Karr 1978). For Mubby-Chiwapa and Twentymile Creeks, substrate characteristics were most strongly correlated with diversity of fish assemblages. However, variation in velocity and mean depth were also important habitat features to fish.

130. Substrate. Fish diversity was higher at locations with sand, gravel, or larger substrates than at those characterized by chalk. Diversity was also higher at locations where there were more bottom types (i.e., greater C.V.* or greater diversity). Similar patterns have been documented for fishes living in springs and in midwestern streams (Foltz 1982; Matthews 1985; and

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* The coefficient of variation (C.V.) is the ratio of the standard deviation to the mean.

Matthews, Hoover, and Milstead 1985). Such patterns may be a result of substrate affinities by the fishes, but since the majority of the species (and the individuals) are cyprinids that live in the water column, other variables such as depth and water velocity may be important. The correlation between fish diversity and substrate characteristics could reflect historical responses to other hydrological conditions; water velocity or depth may change on a daily basis, but substrate is a consistent structural feature that changes only gradually. This correlation may also simply reflect less favorable habitat conditions in Mubby-Chiwapa, which was dominated by chalk.

131. Depth and velocity. The importance of depth and water velocity to fish community composition was supported primarily by interspecific associations among species: swiftwater, slackwater, and generalist habitat guilds were represented. Species characteristic of moderate-to-large streams with moderate-to-fast flowing water (e.g., blacktail, silverstripe, and orangefin shiners) were significantly correlated in numbers (Appendix A), and multivariate analysis of fish assemblages suggested gradients of velocity (PCI) and depth (PCII) influenced relative abundance of several slackwater species (e.g., bullhead minnow, bluegill, and longear sunfish) and a generalist (channel catfish) (Figure 37). The absence of some habitats (e.g., large riffles, natural scour pools) in channelized streams such as these may explain why overall species richness (43 species) is so much lower than the number of species known from the drainage (119) or from spatially complex streams in the eastern part of the drainage (Boschung 1987, 1989; Boschung, Personal Communication*).

132. Comparison of streams. The higher species richness (Table 12) and Shannon measures (Table 13) observed for Twentymile Creek are interesting, given the physical similarity and geographic proximity of the two streams. The possibility exists that the two streams represent two zoogeographically distinct regions with correspondingly different ichthyofaunas. There are no major physical barriers to dispersal between streams, however, and the majority of species collected occur in both districts. Differences in observed diversity between the two streams are probably attributable to the fact that four of the five sites sampled on Twentymile Creek were influenced by GCS while none of the Chiwapa sites were so influenced. This conclusion is

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* Personal Communication, 1989, H. T. Boschung, Professor Emeritus, Department of Biology, University of Alabama, Tuscaloosa, AL.

supported by the low Shannon measures of habitat diversity for Mubby-Chiwapa compared to those for Twentymile Creek (Tables 8 and 9). Relatively high habitat diversity was only observed at sites immediately downstream from the Twentymile Creek GCS.

133. GCS effects. It is doubtful that the Twentymile Creek GCS influenced ichthyofaunal diversity throughout the stream*, but the highest number of species and the highest Shannon values in July were observed for collections made downstream from the GCS. This suggests that a GCS impacts fish community structure, at least on a small geographic scale. Areas below a GCS, like artificial gravel bars in other systems, may increase species diversity and act as important enhancement features for channelized streams (Cooper and Knight 1987; Miller et al. 1988; Edwards et al. 1984.) Three different mechanisms are suggested for the high fish diversity observed at a GCS:

a. Physical obstructions to fishes migrating upstream can result in high below-GCS densities of some otherwise less-abundant species. Since construction of the Tennessee-Tombigbee Waterway, there has been a trend for some riffle-breeding fishes (e.g., a darter, *Percina vigil*, and the frecklebelly madtom, *Norturus munitus*) to move into tributary streams (Boschung 1987; Boschung, Personal Communication**). In May, a relatively large number of spawning highfin carpsuckers were collected below the RM 11.7 GCS. These observations, though, suggest that GCS could act as upstream limits on distribution for migratory, swiftwater species.

b. GCS act as a disturbance, reducing some forms of habitat (e.g., raceways) and creating others (e.g., overflows, scour pools, and rocky riffles). Therefore, habitat for very abundant species is reduced while new habitats for rare species are created. Both phenomena were observed at the Twentymile Creek GCS. At RM 19.9, the blacktail shiner, the most abundant species in the system, comprised less than 17 percent of all fishes collected, but at other stations it comprised 21-85 percent of all fishes; evenness at RM 19.9 was higher ($E > 0.70$) than at any other station in Mubby-Chiwapa and was higher than 5/7 of the other values observed in Twentymile Creek (Table 13). At RM 11.7, evenness was lower ($E < 0.60$) but taxonomic richness (30 species) was higher than at any other location (7 to 23 species). Several species were collected here that were not found at any other station. Some of those species were pool dwellers, like the cypress and pugnose minnows, and others were rocky-bottom riffle dwellers, like

* However, the GCS have indirectly influenced conditions throughout the system by preventing further upstream degradation.

** Personal Communication, 1989, H. T. Boschung, Professor Emeritus, Department of Biology, University of Alabama, Tuscaloosa, AL.

declining in abundance (Pfleiger 1975; Boschung 1987; Robison and Buchanan 1988).

c. Velocities are generally lower and depths greater immediately downstream from a GCS. Species with specialized habitat requirements (like those mentioned above) or those poorly adapted to swift flow conditions are able to establish and maintain reproducing populations below GCS. Reduced temporal variability in discharge is positively associated with species richness (Horwitz 1978). Except at very high discharge, velocity downstream from a GCS is reduced, reproductive habitat is preserved, and several food bases (periphyton, detritus, macroinvertebrates) are not destroyed (Cooper and Knight 1987).

PART V: SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

134. GCS constructed at RM 11.7 and 19.9 on Twentymile Creek in late 1982 have improved channel stability. The RM 11.7 structure has promoted aggradation for several thousand feet upstream, while the RM 19.9 GCS has prevented several feet of bed degradation from occurring upstream. Hydraulic effects of the two GCS differ markedly because of site conditions: the RM 19.9 GCS was built atop a natural geologic control just upstream from a large scour hole. Accordingly, the RM 19.9 GCS exerts control over a wider range of discharges than the RM 11.7 GCS. Both GCS have reduced annual sediment loads for about 9,000 ft upstream but have had little impact on sediment transport elsewhere.

135. Riprap has been the most effective type of bank protection used on Twentymile Creek. All of the riprap revetments appeared to be functioning well when inspected in 1989. Revetments composed of riprap on the lower bank and vegetation on the upper bank were also in excellent condition. Use of the latest criteria (Maynard 1988) for the design of riprap could result in smaller stone sizes on future revetments. Future bank protection sites should be planned and designed to address channel meander tendencies.

136. Woody vegetation cover along the banks of Twentymile Creek increased between 1981 and 1985; similar changes were not observed along two reference channels without GCS or low-flow channels. Physical aquatic habitat diversity was also higher in selected Twentymile Creek reaches than for a comparison stream without GCS. Higher diversity values for Twentymile Creek were due to scour holes and low-flow channels below GCS. Lowest aquatic habitat diversity was observed in the highly maintained, enlarged reach of Twentymile Creek below RM 9.1. Modification of maintenance guidelines for this reach to allow more woody riparian vegetation might enhance bank stability and slightly improve existing habitat resources. Modified guidelines could allow unrestricted growth, cutting unrestricted growth at long (3-4 year) intervals, clumps of vegetation at staggered intervals, or isolated trees with lower limbs trimmed.

137. A clearly identifiable low-flow channel had developed in Twentymile Creek by 1989. Low-flow channel capacity roughly corresponded to a 30-percent duration flow, which is comparable to low-flow channel capacities observed in three unmodified streams. Further investigation of low-flow

channel development and capacities on modified and naturally enlarged channels might provide a basis for low-flow channel design criteria.

138. Ichthyofaunal diversity differed substantially between two channelized streams and among stations within each stream. Species richness, evenness, and Shannon measures of diversity were higher in Twentymile Creek than in Mubby-Chiwapa; species richness and diversity were highest at stations downstream from GCS. Additional GCS that provide deep, permanent scour holes and stable, stony substrate (riprap) would improve Twentymile Creek aquatic habitat.

139. Shannon measures of fish diversity were significantly correlated with substrate characteristics, although these may have been indicative of other hydrological variables.

140. Fish assemblages associated with GCS were more diverse than assemblages at other stations; abundant species were less abundant and rare species with specialized habitat requirements were present.

REFERENCES

Angermeier, P. L., and Karr, J. R. 1984. "Relationships Between Woody Debris and Fish Habitat in a Small Warmwater Stream," Transactions of the American Fishery Society, Vol 113, pp 716-726.

Barclay, J. S. 1980. "Impact of Stream Alterations on Riparian Communities in Southcentral Oklahoma," Report No. FWS/OBS-80/17, Office of Biological Services, Fish and Wildlife Service, US Department of the Interior, Washington, DC.

Barnard, R. S. 1977. "Morphology and Morphometry of a Channelized Stream: The Case History of Big Pine Creek Ditch, Benton County, Indiana," Technical Report No. 92, Purdue University, Water Resources Research Center, West Lafayette, IN.

Biedenharn, David S., Little, Charles D., and Thorne, Colin R. "Magnitude and Frequency Analysis in Large Rivers," Hydraulic Engineering, Proceedings of the 1987 National Conference on Hydraulic Engineering, ASCE, New York, pp 782-787.

Boschung, H. T. 1987. "Physical Factors and the Distribution and Abundance of Fish in the Upper Tombigbee River System of Alabama and Mississippi, with Emphasis on the Tennessee-Tombigbee Waterway," Community and Evolutionary Ecology of North American Stream Fishes, W. J. Matthews and D. C. Heins, eds., University of Oklahoma Press, Norman, OK, pp 184-192.

Boschung, H. 1989. "Atlas of Fishes of the Upper Tombigbee River Drainage, Alabama-Mississippi," Proceedings of the Southeastern Fishes Council, No. 19, pp 1-104.

Brice, J. C. 1981. "Stability of Relocated Stream Channels," Technical Report FHWA/RD-80/158, Federal Highway Administration, US Department of Transportation, Washington, DC.

Brookes, A. 1985. "River Channelization: Traditional Engineering Methods, Physical Consequences and Alternative Practices," Progress in Physical Geography, Vol 9, No. 1, pp 44-73.

Brookes, A. 1988. Channelized Rivers: Perspectives for Environmental Management, John Wiley and Sons, New York.

Brown, S. A., McQuivey, R. S., and Keefer, T. N. 1981. "Stream Channel Degradation and Aggradation: Analysis of Impacts to Highway Crossings," Technical Report FHWA/RD-80/159, Federal Highway Administration, US Department of Transportation, Washington, DC.

Brownlie, William R. 1981 (Nov). "Prediction of Flow Depth and Sediment Discharge in Open Channels," Report No. KH-R-43A, California Institute of Technology, Pasadena, CA.

Burton, G. W., and Odum, E. P. 1945. "The Distribution of Stream Fish in the Vicinity of Mountain Lake, Virginia," Ecology, Vol 26, pp 182-194.

Cederholm, C. J. 1972. "The Short-Term Physical and Biological Effects of Stream Channelization at Big Beef Creek, Kitsap County, Washington," M.S. thesis, University of Washington, Seattle, WA.

Chow, Ven Te. 1959. Open-Channel Hydraulics, McGraw-Hill, New York.

Colby, B. R. 1964. "Discharge of Sands and Mean Velocity Relationships in Sand Bed Streams," Professional Paper 462-A, US Geological Survey, Washington, DC.

Colson, B. E., and Hudson, J. W. 1976. "Flood Frequency of Mississippi Streams," US Geological Survey, Washington, DC.

Cooper, C. M., and Knight, S. S. 1987. "Fisheries in Man-Made Pools Below Grade-Control Structures and in Naturally Occurring Scour Holes of Unstable Streams," Journal of Soil and Water Conservation, Vol 42, pp 370-373.

Douglas, N. H. 1974. Freshwater Fishes of Louisiana, Claitor Publishing, Baton Rouge, LA.

Edwards, C. J., Griswold, B. L., Tubb, R. A., Weber, E. C., and Woods, L. C. 1984. "Mitigating Effects of Artificial Riffles and Pools on the Fauna of a Channelized Warmwater Stream," North American Journal of Fishery Management, Vol 4, pp 194-203.

Emerson, J. W. 1971. "Channelization: A Case Study," Science, Vol 173, pp 325-326.

Evans, J. W., and Noble, R. L. 1979. "The Longitudinal Distribution of Fishes in an East Texas Stream," American Midland Naturalist, Vol 101, pp 333-343.

Foltz, J. W. 1982. "Fish Species Diversity and Abundance in Relation to Stream Habitat Characteristics," Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies, Vol 36, pp 305-311.

Gauch, H. G., Jr. 1982. Multivariate Analyses in Community Ecology, Cambridge University Press, New York.

Gorman, O. T., and Karr, J. R. 1978. "Habitat Structure and Stream Fish Communities," Ecology, Vol 59, pp 507-515.

Gould, S. J. 1981. The Mismeasure of Man, W. W. Norton and Co., New York.

Gregory, K. J., et al. 1985. "The Impact of River Channelization," The Geographical Journal, Vol 151, No. 1, pp 53-74.

Griggs, G. B., and Paris, L. 1982. "The Failure of Flood Control on the San Lorenzo River, California," Environmental Management, Vol 6, pp 407-419.

Harvey, M. D., and Watson, C. C. 1986. "Fluvial Responses and Morphological Thresholds in Incised Channel Restoration," Water Resources Bulletin, Vol 22, pp 359-368.

Harvey, M. D., and Watson, C. C. 1987. "Channel Responses to Grade-Control Structures on Muddy Creek, Mississippi," Regulated Rivers: Research and Management, John Wiley & Sons, Ltd., Vol 2, pp 79-92.

Hickman, G. D. 1975. "Value of Instream Cover to the Fish Populations of the Middle Fabius River, Missouri," Missouri Department of Conservation Aquatic Series, No. 14, pp 1-7, Jefferson City, MO.

Horwitz, R. J. 1978. "Temporal Variability Patterns and the Distributional Patterns of Stream Fishes," Ecology Monograph, Vol 48, pp 307-321.

Hynes, H. B. N. 1970. The Ecology of Running Water, University of Toronto Press, Toronto, Ontario, Canada.

Jahn, L. R., and Trefethan, J. B. 1973. "Placing Channel Modifications in Perspective," Proceedings of the National Symposium on Watersheds in Transition, American Water Resources Association, pp 15-21.

James, M. 1989. "Investigation of Hydrologic, Hydraulic and Sediment Characteristics of the East Fork Tombigbee River," Final Draft Report, US Army Engineer District, Mobile, AL.

Keller, E. A., and Brookes, A. 1984. Consideration of Meandering in Channelization Projects: Selected Observations and Judgements," River Meandering, Proceedings of Conference Rivers '83, C. Elliott, ed., American Society of Civil Engineers, pp 384-398.

Ludwig, J. A., and Reynolds, J. F. 1988. Statistical Ecology, John Wiley and Sons, New York.

Madden, Edward B. 1985. "Modified Laursen Method for Estimating Bed-Material Sediment Load," Draft Miscellaneous Paper, Hydraulics Laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Magurran, A. E. 1988. Ecological Diversity and Its Measurement, Princeton University Press, Princeton, NJ.

Matthews, W. J. 1985. "Distribution of Midwestern Fishes on Multivariate Environmental Gradients, with Emphasis on *Notropis lutrensis*," American Midland Naturalist, Vol 113, pp 225-237.

Matthews, W. J., Hoover, J. J., and Milstead, W. B. 1985. "Fishes of Oklahoma Springs," Southwestern Naturalist, Vol 30, pp 23-32.

Maynord, Stephen T. 1988. "Stable Riprap Size for Open Channel Flows," Technical Report HL-88-4, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Miller, A. C., Killgore, K. J., King, R. H., and Naimo, T. J. 1988. "Biological and Physical Conditions at a Newly Placed Gravel Bar Habitat in the Tombigbee River," MP EL-88-4, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Northwest Hydraulic Consultants, Inc. 1987. "Hydraulic Design of Stable Flood Control Channels; III. Case Studies of Morphologic Response," Kent, WA.

Nunnally, N. R., and Shields, F. D. 1985. "Incorporation of Environmental Features in Flood Control Channel Projects," Technical Report E-85-3, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Osterkamp, W. R., and Hupp, C. R. 1984. "Geomorphic and Vegetative Characteristics Along Three Virginia Streams," US Geological Survey Professional Paper 1242, Washington, DC.

Parker, G., and Andres, D. 1976. "Detrimental Effects of River Channelization," Proceedings of the Symposium on Inland Waters for Navigation, Flood Control, and Water Diversions, American Society of Civil Engineers, pp 1248-1266.

Parks, W. S. 1960. "Prentiss County Geology," Bulletin 87, Mississippi State Geological Survey, University, MS.

Peterson, M. R., Watson, C. C., and Harvey, M. D. 1988. "Performance Evaluation of Channels Stabilized with ARS-Type Low-Drop Structures," Contract Report DACW39-87-C0021, Submitted to US Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS.

Pflieger, W. L. 1975. The Fishes of Missouri. Missouri Department of Conservation, Jefferson City, MO.

Power, M. E. 1984. "Depth Distributions of Armored Catfish: Predator-induced Resource Avoidance?" Ecology, Vol 65, pp 523-528.

Ramser, C. E. 1930. "Erosion and Silting of Dredged Drainage Ditches," Technical Bulletin 184, US Department of Agriculture, Washington, DC.

Reash, R. J., and Berra, T. M. 1987. "Comparison of Fish Communities in a Clean-Water and an Adjacent Polluted Stream," American Midland Naturalist, Vol 118, pp 301-322.

Richards, K. 1982. Rivers, Form and Process in Alluvial Channels, Methuen and Co. Ltd., New York.

Robison, H. W., and Buchanan, T. M. 1988. Fishes of Arkansas, University of Arkansas Press, Fayetteville, AR.

SAS Institute, Inc. 1987. "SAS/STAT Guide for Personal Computers, Version 6 Edition," SAS Institute, Inc., Cary, NC.

Scarnecchia, D. L. 1988. "The Importance of Streamlining in Influencing Fish Community Structure in Channelized and Unchannelized Reaches of a Prairie Stream," Regulated Rivers: Research and Management, John Wiley & Sons, Ltd., Vol 2, pp 155-166.

Schumm, S. A., Harvey, M. D., and Watson, C. C. 1984. Incised Channels: Initiation, Evolution, Dynamics, and Control, Water Resources Publications, Littleton, CO.

Shannon, C. E. 1948. "A Mathematical Theory of Communication," Bell System Technical Journal, Vol 27, pp 379-423.

Sheldon, A. L. 1968. "Species Diversity and Longitudinal Succession in Stream Fishes," Ecology, Vol 49, pp 193-198.

Simons, Li, and Associates. 1982. "Appendix "A"--Channel Stability Study of Twenty Mile Creek Near Guntown, Mississippi," in "Design Report, Bank Stabilization Project, Twenty-Mile Creek Interim Measures," US Army Engineer District, Mobile, AL.

Shields, F. D., Waller, T. N., and Ethridge, L. T. 1990. "A Study of Vegetation on Revetments, Sacramento River Bank Protection Project, Phase I: Literature Review and Pilot Study," Draft Technical Report, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Smock, L. A., Gilinsky, E., and Stoneburner, D. L. 1985. "Macroinvertebrate Production in a Southeastern United States Blackwater Stream," Ecology, Vol 66, pp 1491-1503.

Suttkus, R. D., and Boschung, H. T. 1990. "*Notropis ammophilus*, A New Cyprinid Fish From Southeastern United States," Tulane Studies in Zoology and Botany, Vol 27, pp 49-63.

Swales, S. 1982. "Environmental Effects of River Channel Works Used in Land Drainage Improvements," Journal of Environmental Management, Vol 14, pp 103-126.

Swales, S. 1987. "Fish Populations of a Small Lowland Channelized River in England Subject to Long-term River Maintenance and Management Works," Regulated Rivers: Research and Management, John Wiley & Sons, Ltd., New York, Vol 2, pp 493-506.

Tramer, E. J., and Rogers, P. M. 1973. "Diversity and Longitudinal Zonation in Fish Populations of Two Streams Entering a Metropolitan Area," American Midland Naturalist, Vol 90, pp 366-374.

Tuttle, J. R. 1982. "Minutes of the Thirty-Fifth Meeting, Committee on Channel Stabilization, 18-19 August 1981," Inclosure to LMVED-RP letter dated 11 Jan 82, US Army Engineer Division, Lower Mississippi Valley, Vicksburg, MS.

US Army Engineer District, Mobile. 1981. "Pilot Bank Stabilization Project, Twentymile Creek, Lee, Prentiss, and Itawamba Counties, Mississippi," Design Report, US Army Engineer District, Mobile, AL.

US Army Engineer District, Mobile. 1964. "Tombigbee River and Tributaries, Mississippi and Alabama, Design Memorandum No. 1, General Design for Big Brown, Mantachie, Twentymile, and Donivan Creeks, Itawamba, Lee, and Prentiss Counties, Mississippi," US Army Engineer District, Mobile, AL.

US Army Engineer District, Mobile. 1984. "Bank Stabilization Project, Twentymile Creek, Phase III Interim Measures, Lee and Itawamba Counties, Mississippi," Design Report, US Army Engineer District, Mobile, AL.

US Army Corps of Engineers. 1970. "Hydraulic Design of Flood Control Channels," Engineer Manual 1110-2-1601, Washington, DC.

US Army Corps of Engineers. 1982. "HEC-2, Water Surface Profiles, Users Manual," Computer Program 723-X6-L202A, The Hydrologic Engineering Center, Davis, CA.

US Geological Survey. 1984. "NHAP, National High Altitude Photography Program," Fact Sheet: Black and White Photographs, Department of the Interior, EROS Data Center, Sioux Falls, SD.

US Army Corps of Engineers. 1988. "Sedimentation Investigations of Rivers and Reservoirs," Draft Engineer Manual No. 1110-2-4000, Washington, DC.

__________. 1989. "Environmental Engineering for Flood Control Channels," Engineer Manual No. 1110-2-1205, Washington, DC.

Vestal, F. E. 1947. "Itawamba County Mineral Resources," Bulletin 64, Mississippi State Geological Survey, University, MS.

Wallace, J. B., and Benke, A. C. 1984. "Quantification of Wood Habitat in Subtropical Coastal Plain Streams," Canadian Journal of Fisheries and Aquatic Science, Vol 41, pp 1643-1652.

Water and Engineering Technology. 1988. "Geologic and Geomorphic Analysis of the Tombigbee and Black Warrior River Basins, Mississippi and Alabama," Contract Report DACW001-87-D-00233, US Army Corps of Engineers, Mobile, AL.

Wesche, T. A. 1985. "Stream Channel Modifications and Reclamation Structures to Enhance Fish Habitat," The Restoration of Rivers and Streams, James A. Gore, ed., Butterworth Publishers, Boston, MA, pp 103-16?.

Whiteside, B. G., and McNatt, R. M. 1972. "Fish Species Diversity in Relation to Stream Order and Physicochemical Conditions in the Plum Creek Drainage Basin," American Midland Naturalist, Vol 88, pp 90-101.

Wilson, K. V. 1979. "Changes in Channel Characteristics 1938-74, of the Homochitto River and Tributaries, Mississippi," US Geological Survey Open-File Report 79 554, Jackson, MS.

Wilson, K. V., and Turnipseed, D. P. 1989. "Channel Stability of Selected Streams in Northern Mississippi in the Vicinity of Highway Crossings," paper presented to the 1989 Joint Spring Meeting of the Louisiana and Mississippi Sections of ASCE, Unpublished prcceedings of April 24, 1989, US Geological Survey, Jackson, MS.

Wolman, M. Gordon, and Leopold, Luna B. 1957. "River Flood Plains: Some Observations on Their Formation," Professional Paper 282-C, US Geological Survey, Washington, DC.

Table 1

Study Areas

Study Component	Base Condition	Comparison
Hydraulics Studies	Twentymile Creek, 1989	Twentymile Creek, 1982
Environmental Studies		
-Vegetation	Change in Twentymile Creek, 1981-1985	Change in Mubby-Chiwapa and Big Brown Creeks, 1981-85
-Physical Aquatic Habitat	Twentymile Creek, 1989	Mubby-Chiwapa Creek, 1989
-Fish	Twentymile Creek, 1989	Mubby-Chiwapa Creek, 1989

Table 2

Comparison of Basic Hydrologic and Morphologic Variables for Streams in the Upper Tombigbee River Basin*

Stream	Drainage Area (sq mi)	Stream Length (mi)	Modified Length (ft)	Channel Width (ft)	Channel Depth (ft)	Design Flow (cfs)	Pre-project Slope (ft/mi)	Design Event (yrs)	Watershed Length (mi)	Watershed Max Width (mi)	Flood-plain Area (acres)	Amt of Flood-plain Cleared for Crops or Pasture (acres)	Date of CE Project Construction
Twentymile	174	29.7	11.4	30	2-20	3,200-3,700	2.3	0.33	31	11.0	4,500	3,500	1966
Big Brown	162	21.0	3.5	20	8-15	4,500	2.4	0.50	21	9.0	4,500	3,000	1965
Donivan	44	18.0	4.1	18	8-13	2,200	4.2	0.4	15	4.0	1,280	640	
Mantachie	65	21.0	5.0	45	15	2,500	3.3	1.3	21	6.0	1,300	600	
Chiwapa	158	25.0	25.0						27	14.0			Mid 1960's

* All information is from Mobile District (1964), except for *Chiwapa Creek entries, which are from a USDA Soil Conservation Service Watershed Map.*

Table 3

Chiwapa Creek and Twentymile Creek Sampling Site Descriptions

Site	Stream	River Mile	Location	Description	Depth* (cm) Mean	Depth* (cm) Std	Velocity* (cm/s) Mean	Velocity* (cm/s) Std	Substrate
2.0	Chiwapa	21.8	Hwy 41	Riffles, runs, knickpoints	21	23	24	20	Sand
2.5	Chiwapa	20.1	Near Bethel Church	Riffles and runs	NS**	NS	NS	NS	Sand
3.0	Mubby	1.3	Upstream from Chiwapa confluence	Riffles, runs, small pools	20	22	18	13	Sand
4.0	Chiwapa	12.7	Natchez Trace	Riffles and runs	18	14	24	23	Sand
5.0	Chiwapa	7.8	North Rd E of Shannon	Riffles, runs, pools	24	11	35	16	Sand
6.0	Twentymile	25.2	Mt. Olive Church	Riffles, backwaters	NS	NS	NS	NS	Cut through chalk
7.1	Twentymile	19.9	Upstream from GCS		72	39	3	3	Sand
7.2	Twentymile	19.9	Downstream from GCS	Large scour hole w/eddies	96	86	8	12	Riprap, chalk
8.1	Twentymile	11.7	Upstream from GCS		93	28	3	2	Sand
8.2	Twentymile	11.7	Downstream from GCS	Smaller scour hole than at 19.9	61	33	10	12	
9.0	Twentymile	9.1	Natchez Trace	Riffle, deep run, small backwater	NS	NS	NS	NS	
10.0	Twentymile	3.3	Hwy 371		30	9	18	6	Sand

* Means and standard deviations of July 1989 measurements.
** NS = not sampled.

Table 4

Values of Variables Describing Physical Habitat

Variable	Value Assigned to Variable for Calculation of Diversity					
	1	2	3	4	5	6
Depth, cm	0-5	5-20	20-50	50-80	>80	
Velocity, m/s	<0.01	0.01-0.05	0.05-0.20	0.20-0.40	>0.40	
Substrate diameter in mm*	(Silt) <0.05	(Sand) .05-2	(Gravel) 2-10	(Cobble) 10-30	(Boulder) >30	(Chalk)
Cover	None	Small logs	Log jams	Undercut banks and rootwads	Canopy	Other

* Substrates also include Vegetation (7) and Litter (8)

Table 5

Calculation of Bed Material Load

Twentymile Creek at RM 3.3 (Mantachie)

			Suspended Sediment Measurements				
			Measured Load				
			Total				
Date	Time	Dis-charge (cfs)	(ppm)	(tons/day)	Finer than 0.062 (percent)	Sand Concentration (ppm)	Bed Material Concentration (ppm)
May 04 1978	0700	4,800	4,977	64,500	91	465	963
May 04 1978	1000	2,250	2,067	12,560	87	147	354
May 04 1978	1100	1,700	1,895	8,700	95	92	281
May 04 1978	1300	1,300	1,570	5,510	96	59	216
May 04 1978	1525	990	1,137	3,040	97	36	150
May 07 1978	1920	9,200	2,770	68,800	79	581	858
May 07 1978	1250	7,400	10,146	202,700	65	3,548	4,560
Jun 08 1978	0900	4,700	2,876	36,500	89	325	613
Jun 08 1978	1000	3,700	2,485	24,800	89	281	530
Jun 08 1978	1100	2,900	2,180	17,070	90	226	444
Feb 27 1987	1030	3,994.	969.	10,449.	76.	232	329
Feb 27 1987	1650	1,994.	464.	2,498.	93.	32	78.8
Feb 27 1987	2030	1,374.	338.	1,253.	97.	10	43.9
Feb 28 1987	1045	10,675.	2,713.	78,195.	52.	1,300	1,573
Feb 28 1987	1900	6,926.	1,697.	31,734.	62.	645	815
Mar 01 1987	1120	1,114.	339.	1,019.	97.	10	44.1
Mar 13 1986		1,180.	357.	1,137.	84.	57	92.8
May 08 1985		1,420.	688.	2,638.	77.	158	227.

Table 6

Calculated Sediment Transport, Twentymile Creek

at RM 3.3 (Mantachie)

Water Discharge (cfs)	Bed Material Load (Colby Method) (tons/day)	(ppm)	Bed Material Load (New Laursen Method) (tons/day)	(ppm)
500.	307.	228.	489.	361.
1,002.	803.	297.	1,342.	496.
1,997.	2,591.	480.	3,678.	682.
3,000.	8,754.	1,080.	8,928.	1,102.
3,999.	13,654.	1,264.	14,004.	1,297.
4,995.	17,102.	1,268.	18,915.	1,402.
9,995.	35,086.	1,300.	45,625.	1,691.

Table 7

Bank Line Woody Vegetation Cover, Percent

Channel	1981	1985	Change
Twentymile	64.1	71.7	-7.6
RM 19.9 - RM 16.3	70.5	76.0	+5.5
RM 11.7 - RM 9.1	51.6	63.6	+12.0
Big Brown	98.4	95.5	-2.9
Chiwapa	86.0	87.5	+1.5

Source: Measured from 1:15,840 scale HAP aerial photos.

Table 8

Shannon Diversity Indices for Twentymile Creek and Mubby-Chiwapa Creek for Various Combinations of Physical Variables

Stream	RM	Site No.	No. of Sample Transects	No. of Sample Points	River Mile	Diversity Indices for Physical Variable Combinations*								
						DVSC	DVS	DV	DS	VS	D	V	S	C
Twentymile	19.9	7.1	4	85	19.9	2.08	2.64	2.07	2.03	1.71	1.33	1.08	0.84	0.39
	19.9	7.2	6	142		3.33	3.21	2.41	2.26	2.61	1.32	1.42	1.36	0.30
	11.7	8.1	1	47	11.7	2.07	2.08	1.32	1.54	1.83	0.65	0.85	0.98	0.00
	11.7	8.2	5	146		3.28	3.12	2.66	2.07	2.09	1.42	1.36	0.88	0.32
	3.3	10.0	3	78	3.3	1.22	1.18	1.10	0.47	0.95	0.36	0.87	0.12	0.00
Mubby-Chiwapa	21.8	2.0	10	44	21.8	2.18	2.18	2.18	1.22	1.38	1.22	1.38	0.00	0.00
	1.3	3.0	6	90	1.3	2.23	2.19	2.02	1.37	1.69	1.05	1.17	0.68	0.21
	12.7	4.0	6	206	12.7	2.61	2.67	2.42	1.57	2.07	1.12	1.53	0.71	0.11
	7.3	5.0	4	85	7.8	2.27	2.05	1.67	1.15	1.58	0.73	1.19	0.43	0.31

* D = Depth, V = Velocity, S = Substrate (bed type), and C = Cover.

Table 9

Effect of GCS on Physical Habitat Diversity and Evenness

Twentymile					Mubby-Chiwapa				
Site	RM	n*	H'	E	Site	RM	n*	H'	E
7.1 + 7.2	19.9	227	3.51	0.65	3.0	1.3	90	2.23	0.50
8.1 + 8.2	11.7	193	2.42	0.65	4.0	12.7	206	2.61	0.49
10.0	3.3	78	1.22	0.28	5.0	7.8	85	2.27	0.51

* n is number of sample points.

Table 10

Surfical Bed Sediment Sampled from Twentymile and Chiwapa Creeks

Stream	Site No.	Sample No.	Substrate Field Classification No.	Substrate Field Classification Description	Sieve Analysis*, Percent Fines	Sand	Gravel
Chiwapa (Mubby)	3.0	2-5	2	Sand	0	100	0
Chiwapa	4.0	2-3	2	Sand	0	100	0
	4.0	2-30	1	Clay/silt	8	91	1
	4.0	2-33	1	Clay/silt	66	33	1
Chiwapa	5.0	2-15	2	Sand	0	100	0
	5.0	4-10	2	Sand	0	98	2
				Means	12.3	87.0	0.7
Twentymile	7.1	2-8	2	Sand	0	100	0
	7.1	2-20	2	Sand	0	100	0
	7.1	2-22	2	Sand	0	100	0
	7.1	2-23	2	Sand	0	99	1
	7.1	4-4	2	Sand	0	100	0
	7.1	4-8	2	Sand	0	100	0
	7.1	4-12	2	Sand	0	100	0
Twentymile	7.2	2-4	1	Clay/silt	0	100	0
Twentymile	7.2	1-22	2	Sand	24	72	4
	7.2	2-1	2	Sand	0	100	0
	7.2	2-2	2	Sand	0	100	0
	7.2	2-3	2	Sand	0	100	0
	7.2	2-4	2	Sand	0	100	0
	7.2	2-5	2	Sand	0	73	27
	7.2	2-6	2	Sand	0	100	0
	7.2	2-7	2	Sand	3	93	4
	7.2	2-8	2	Sand	2	96	2
	7.2	2-9	2	Sand	0	43	57
	7.2	2-10	2	Sand	0	99	1
	7.2	2-11	2	Sand	0	98	2
	7.2	2-12	2/6	Sand/chalk	13	39	48
	7.2	2-13	2/6	Sand/chalk	0	22	78
	7.2	2-14	3	Gravel	0	25	75
	7.2	4-1	2	Sand	0	100	0
	7.2	4-2	2	Sand	0	100	0
	7.2	4-3	2	Sand	0	100	0
	7.2	4-4	2	Sand	0	100	0
	7.2	4-5	2	Sand	0	100	0
	7.2	4-6	2	Sand	0	100	0
	7.2	4-7	2	Sand	0	100	0

(Continued)

Table 10 (Concluded)

Stream	Site No.	Sample No.	Substrate Field Classification No.	Substrate Field Classification Description	Sieve Analysis*, Percent Fines	Sand	Gravel
	7.2	4-8	2	Sand	0	100	0
	7.2	4-9	2	Sand	4	62	30
	7.2	4-10	2	Sand	0	99	1
	7.2	4-11	2	Sand	2	74	24
	7.2	4-12	2	Sand	2	79	19
	7.2	4-13	2	Sand	0	69	31
	7.2	4-14	2	Sand	0	100	0
	7.2	4-15	2	Sand	0	99	1
	7.2	4-16	2	Sand	4	88	8
	7.2	4-17	2	Sand	2	89	9
	7.2	4-18	2	Sand	7	88	5
	7.2	4-19	2	Sand	7	83	10
	7.2	4-20	2	Sand	5	87	12
Twentymile	8.1	1-9	1	Clay/silt	40	60	0
	8.1	1-32	2	Sand	3	94	3
	8.1	1-37	2	Sand	3	95	2
	8.1	1-40	1	Clay/silt	37	62	1
	8.1	1-46	1	Clay/silt	52	46	2
Twentymile	8.2	2-4	2	Sand	0	100	0
	8.2	2-10	2	Sand	0	100	0
	8.2	2-20	2	Sand	0	100	0
Twentymile	8.2	2-1	2	Sand	0	100	0
	8.2	2-3	2	Sand	0	75	25
	8.2	2-4	2	Sand	4	83	13
	8.2	2-7	2	Sand	0	100	0
	8.2	2-15	2	Sand	1	97	2
	8.2	4-1	1	Clay/silt	0	100	0
	8.2	4-2	2	Sand	0	100	0
	8.2	4-8	2	Sand	0	100	0
	8.2	4-13	2	Sand	6	85	9
	8.2	4-19	2	Sand	0	100	0
Twentymile	10.0	2-1	2	Sand	0	100	0
				Means	3.6	88.3	8.2

* Fines is the percent of sediment finer than 0.075 mm. Sand is the percent of sediment larger than 0.075 mm and finer than 2.0 mm. Gravel is the percent coarser than 2.0 mm.

Table 11

Low-Flow Channel Dimensions and Capacities from

Manning's Formula with n = 0.022

Section	Station 100 ft	River Mile	Width ft	Mean Depth ft	Area sq ft	Slope	Discharge cfs
TV23	50.14	0.95	32.50	2.48	80.60	0.000426	205.9
TV28	55.18	1.05	38.00	1.10	41.80	0.001059	97.9
TV30	57.22	1.08	69.98	0.83	58.08	0.000496	77.2
TV32	59.21	1.12	45.00	1.14	51.30	0.000748	103.4
TV34	61.23	1.16	61.30	0.75	45.98	0.001370	94.9
TV35	62.13	1.18	44.90	0.80	35.92	0.001053	67.8
TV36	63.13	1.20	32.50	1.60	52.00	0.000495	106.9
TV37	64.15	1.21	43.85	1.60	70.16	0.000495	144.2
TV38	65.15	1.23	37.50	1.70	63.75	0.000253	97.6
TV39	66.13	1.25	32.50	1.70	55.25	0.000519	121.1
TV42	69.00	1.31	40.00	1.50	60.00	0.000513	120.3
TV44	71.00	1.34	62.50	1.00	62.50	0.000700	111.7
TV48	75.00	1.42	44.00	0.90	39.60	0.000440	52.3
TV51	78.00	1.48	24.00	1.56	37.44	0.000500	76.1
TV55	82.00	1.55	47.50	1.00	47.50	0.000938	98.3
TV58	86.00	1.63	67.31	0.52	35.00	0.000688	40.1
TV62	90.00	1.70	23.50	1.10	25.85	0.000438	38.9
TV66	94.00	1.78	22.50	1.60	36.00	0.000667	85.9
TV68	96.00	1.82	32.00	0.70	22.40	0.000700	31.6
TV70	99.00	1.88	32.50	1.10	35.75	0.000600	63.0
TV71	101.00	1.91	29.00	0.98	28.42	0.001500	73.4
TV73	103.00	1.99	37.00	1.10	40.70	0.001286	105.1
TV76	106.00	2.01	22.00	1.50	33.00	0.000250	46.2
TV78	108.00	2.05	64.00	0.60	38.40	0.000889	55.0
					Mean		88.1
					Standard deviation		37.9

Table 12

Fish Species Collected from the Twentymile and Mubby-Chiwapa Stream Systems in Northern Mississippi: 23 March, 22-24 May, 24-26 July 1989

	Mubby and Chiwapa Creeks	Twentymile Creek
Lepisosteidae		
Lepisosteus oculatus, spotted gar		X
L. osseus, longnose gar		X
Clupeidae		
Dorosoma cepedianum, gizzard shad	X	X
Cyprinidae		
Cyprinus carpio, carp		X
Hybopsis aestivalis, speckled chub	X	
Hybognathus hayi, cypress minnow		X
Notemigonus crysoleucas, golden shiner		X
Notropis ammophilus, orangefin shiner	X	X
N. bellus, pretty shiner	X	X
N. emiliae, pugnose minnow		X
N. stilbius, silverstripe shiner		X
N. texanus, weed shiner		X
N. volucellus, mimic shiner		X
N. venustus, blacktail shiner	X	X
Pimephales notatus, bluntnose minnow	X	X
P. vigilax, bullhead minnow	X	X
Semotilus atromaculatus, creek chub		X
Catostomidae		
Carpiodes velifer, highfin carpsucker	X	X
Ictiobus niger, black buffalo		X
Minytrema melanops, spotted sucker		X
Moxostoma poecilurum, blacktail redhorse		X
Ictaluridae		
Ictalurus natalis, yellow bullhead		X
I. punctatus, channel catfish	X	X
Cyprinodontidae		
Fundulus notatus, blackstripe topminnow	X	
F. olivaceus, blackspotted topminnow	X	X
Poeciliidae		
Gambusia affinis, mosquitofish	X	X

(Continued)

Table 12 (Concluded)

	Mubby and Chiwapa Creeks	Twentymile Creek
Atherinidae		
Menidia beryllina, inland silverside		X
Centrarchidae		
Lepomis cyanellus, green sunfish	X	X
L. humilus, orangespotted sunfish	X	
L. macrochirus, bluegill	X	X
L. megalotis, longear sunfish	X	X
L. microlophus, redear sunfish	X	X
Micropterus salmoides, largemouth bass	X	X
M. punctulatus, spotted bass		X
Pomoxis annularis, white crappie	X	X
P. nigromaculatus, black crappie		X
Percidae		
Ammocrypta meridiana, southern sand darter	X	X
Etheostoma chlorosomum, bluntnose darter		X
E. nigrum, johnny darter		X
E. rupestre, rock darter		X
E. stigmaeum, specked darter	X	X
E. whipplei, redfin darter	X	X
Percina sciera, dusky darter		X
Total number of species	22	40

Table 13

Shannon (H') and Pielou (E) Diversity and Evenness Measures for Fish Collections from the Twentymile and Mubby-Chiwapa Stream Systems in Northeastern Mississippi

Date	Stream	Site*	H'	E
May 1989	Chiwapa	2.0	1.22	0.49
		2.5	1.32	0.53
	Mubby	3.0	1.65	0.62
		4.0	1.61	0.61
		5.0	1.51	0.57
	Twentymile	6.0	1.82	0.87
		7.2	2.09	0.84
		8.2	1.75	0.58
		9.0	1.44	0.56
July 1989	Chiwapa	2.0	0.61	0.31
	Mubby	3.0	1.59	0.62
		4.0	1.92	0.69
		5.0	1.46	0.59
	Twentymile	7.1	1.56	0.59
		7.2	2.26	0.72
		8.1	1.97	0.89
		8.2	1.99	0.59
		10.0	1.69	0.58

* Site numbers ending in zero indicate collections of fishes pooled across habitats; site numbers ending in one or two indicate respective collections made upstream and downstream from grade control structures.

Table 14

Correlation Coefficients (and Probability Levels) for Fish Diversity and Habitat Variable Combinations for the Twentymile and Mubby-Chiwapa Stream Systems in Northeastern Mississippi, July 1989 (N = 9)

Habitat Variables	Correlation (Probability)
Mean depth	.582 (.100)
Coefficient of variation in depth	-.374 (.321)
Mean velocity	-.489 (.181)
Coefficient of variation in velocity	.418 (.262)
Mean bottom type	-.588 (.096)
Coefficient of variation in bottom type	.650 (.058)
Habitat diversity (Shannon indices)	
Depth X velocity X bottom type	.405 (.280)
Depth X velocity	.105 (.788)
Depth X bottom type	.457 (.216)
Velocity X bottom type	.641 (.063)
Depth	.013 (.973)
Velocity	-.021 (.956)
Substrate	.809 (.008)

Table 15

Selected* Regression Analysis Results for Fish Diversity (H') and Habitat Parameters

Equation	d.f.	r^2	F	P
H' = 1.138 + 0.013 (CV bottom type)	1/7	0.42	5.13	0.06
H' = 1.942 + 0.007 (CV velocity) - 0.247 (mean bottom type)	2/6	0.67	6.07	0.04
H' = 2.62 - 0.005 (mean depth) + 0.010 (CV velocity) - 0.336 (mean bottom type)	3/5	0.71	4.06	0.08

* The best 1-, 2-, and 3-variable equations are listed.

Table 16

Overview of Results

Characteristic	Time Frame	Twentymile Near GCS	Twentymile Lower Reach	Mubby-Chiwapa
Bed elevation	1980-89	Aggradation above GCS	Not surveyed in 1989	NS*
Two-year discharge	1980-89	Below GCS:	NS	NS
Flow depth		Increased		
Flow area		Increased		
Mean velocity		Decreased		
Shear stress		Decreased		
Energy slope		Decreased		
Low-flow channel development	1980-89	Yes	No	No
Bank line vegetation	1981-85	Increased	None present either time	No change
Relative physical habitat diversity	July 1989	High	Low	Moderate
Relative fish species diversity	July 1989	High	Moderate	Low

* NS = Not sampled.

APPENDIX A
FISH COLLECTIONS

Table A1

Fishes from Three Streams in Northeastern Mississippi

Catch Per Hour of Seining (Number), 22-24 May 1989

	Mubby-Chiwapa					Twentymile			
	2.0	2.5	3.0	4.0	5.0	6.0	7.0	8.0	9.0
Lepisosteidae									
Lepisosteus, osseus, longnose gar								1	
Clupeidae									
Dorosoma cepedianum, gizzard shad	2	2	9	3			4	6	
Cyprinidae									
Hybognathus hayi, cypress minnow								2	
Notemigonus crysoleucas, golden shiner								2	
Notropis ammophilus, orangefin shiner	4	49	92	12	92	19	16	172	66
N. bellus, pretty shiner	67	14	92	47		20		27	14
N. stilbius, silverstripe shiner							77	5	
N. venustus, blacktail shiner	247	204	224	158	272	41	17	447	171
Pimephales notatus, bluntnose minnow	4	3	2	52	38	36	16	11	22
P. vigilax, bullhead minnow		3	2	8	2		2	27	10
Semotilus atromaculatus, creek chub						9			
Catostomidae									
Carpiodes velifer, highfin carpsucker	3	5	5	4	1			21	
Ictaluridae									
Ictalurus punctatus, channel catfish	34	13	13	3	6				
Cyprinodontidae									
Fundulus notatus, blackstripe topminnow			4	1	10				
F. olivaceus, blackspotted topminnow		1					2	4	

(Continued)

Table A1 (Concluded)

	Mubby-Chiwapa					Twentymile			
	2.0	2.5	3.0	4.0	5.0	6.0	7.0	8.0	9.0
Poeciliidae									
Gambusia affinis, mosquitofish					5	96	1	12	453
Centrarchidae									
Lepomis cyanellus, green sunfish	1		2	3	6	8			7
L. macrochirus, bluegill	25	21	7	10	11		10	33	7
L. megalotis, longear sunfish	4	9	20		2	6	26	7	3
L. microlophus, redear sunfish				2	4	2	2	6	1
Micropterus salmoides, largemouth bass	+	+	1	1	3		5	32	45
M. punctulatus, spotted bass								2	
Pomoxis annularis, white crappie					1			5	
Percidae									
Ammocrypta meridiana, southern sand darter								1	11
Etheostoma whipplei, redfin darter			1			4	3	2	
Number of fishes per hour	392	324	502	311	542	143	104	897	815
Number of species	11	11	14	14	14	8	12	21	13

Table A2

Fishes From Three Streams in Northeastern Mississippi, 24-26 July 1989; Table Entries are Total Number Collected

	Mubby-Chiwapa				Twentymile				
Stations	2.0	3.0	4.0	5.0	7.1	7.2	8.1	8.2	10.0
Lepisosteidae									
Lepisosteus oculatus, spotted gar								2	
Clupeidae									
Dorosoma cepedianum, gizzard shad	1	33	1			2		3	
Cyprinidae									
Cyprinus carpio, carp						1		2	
Hybopsis aestivalis, speckledchub				2					
Hybognathus hayi, cypress minnow								5	
Notemigonus crysoleucas, golden shiner								25	7
Notropis ammophilus, orangefin shiner		71	13	30		13		77	10
N. bellus, pretty shiner		51	18	1	27	123	4	94	21
N. emiliae, pugnose minnow								9	
N. stilbius, silverstripe shiner					37	32	2	311	4
N. texanus, weed shiner								7	1
N. venustus, blacktail shiner	109	196	112	233	41	88	1	577	76
N. volucellus, mimic shiner								2	
Pimephales notatus, bluntnose minnow	1	36	137	36	322	77	9	74	1
P. vigilax, bullhead minnow			7		13	8		48	
Catostomidae									
Carpiodes velifer, highfin carpsucker		3	2	5		10		4	
Ictiobus niger, black buffalo						2			
Moxostoma poecilurum, blacktail redhorse						4			

(Continued)

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Table A2 (Continued)

Stations	Mubby-Chiwapa 2.0	3.0	4.0	5.0	Twentymile 7.1	7.2	8.1	8.2	10.0
Ictaluridae									
Ictalurus natalis, yellow bullhead						1			
I. punctatus, channel catfish	2	2	3	9	10	12	10	18	1
Cyprinodontidae									
Fundulus notatus, blackstripe topminnow									
F. olivaceus, blackspotted topminnow						12		3	
Poeciliidae									
Gambusia affinis, mosquitofish			19	45		8		103	3
Atherinidae									
Menidia beryllina, inland silverside									1
Centrarchidae									
Lepomis cyanellus, green sunfish		2	6	29	3	2		2	1
L. humilus, orangespotted sunfish		1							
L. macrochirus, bluegill	6	2	31	7	69	7	9	15	3
L. megalotis, longear sunfish	3	10	1		22	18	5	10	2
L. microlophus, redear sunfish		1	21		2				
Micropterus salmoides, largemouth bass	4	2	8	3	7	9	1	1	1
M. punctulatus, spotted bass								1	1
Pomoxis annularis, white crappie						2		4	
P. nigromaculatus, black crappie							2		

(Continued)

Table A2 (Concluded)

Stations	Mubby-Chiwapa 2.0	3.0	4.0	5.0	Twentymile 7.1	7.2	8.1	8.2	10.0
Percidae									
Ammocrypta meridiana, souther sand darter				1				17	3
Etheostoma chlorosomum, bluntnose darter					1	2	5	1	1
E. nigrum, johnny darter					6	1			
E. rupestre, rock darter								2	
E. stigmaeum, specked darter			7					1	
E. whipplei, redfin darter			5		2	9			1
Percina sciera, dusky darter								7	
Total number of fish	126	410	391	401	562	443	46	1,427	139
Total number of species	7	13	16	12	14	23	9	30	18

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