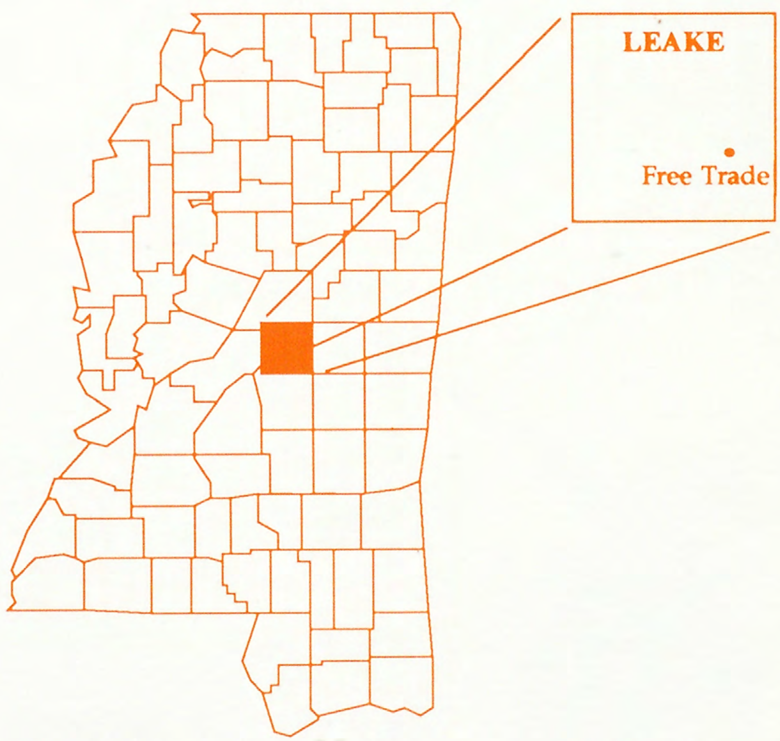
CHANNEL-BED AND CHANNEL-BANK STABILITY OF STANDING PINE CREEK TRIBUTARY AT STATE HIGHWAY 488 AT FREE TRADE, LEAKE COUNTY, MISSISSIPPI



U.S. GEOLOGICAL SURVEY
Open-File Report 93-37

Prepared in cooperation with the

MISSISSIPPI DEPARTMENT OF TRANSPORTATION

CHANNEL-BED AND CHANNEL-BANK STABILITY OF STANDING PINE CREEK TRIBUTARY AT STATE HIGHWAY 488 AT FREE TRADE, LEAKE COUNTY, MISSISSIPPI

By K. Van Wilson, Jr. and D. Phil Turnipseed

U.S. GEOLOGICAL SURVEY
Open-File Report 93-37

Prepared in cooperation with the
MISSISSIPPI DEPARTMENT OF TRANSPORTATION

Jackson, Mississippi
1993

DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

For additional information write to:

District Chief
U.S. Geological Survey
100 W. Capitol Street
Suite 710, Federal Building
Jackson, Mississippi 39269

Copies of this report can be purchased from:

U.S. Geological Survey
Books and Open-File Reports Section
Box 25425, Federal Center
Denver, Colorado 80225

CONTENTS

	Page
Abstract	1
Introduction	2
Purpose and scope	2
Approach	2
General description of Standing Pine Creek tributary	2
Channel modifications to Standing Pine Creek tributary	2
Acknowledgments	4
Channel-bed stability	4
Channel-bed profiles	4
Botanical evidence	4
Gradation analyses	6
Channel-bank stability	10
Channel cross sections	11
Botanical evidence	12
Stability analyses	13
Widening analyses	13
Summary and conclusions	17
References	20

ILLUSTRATIONS

Figure 1. Map showing the location of Standing Pine Creek tributary at State Highway 488 at Free Trade ... 3

2. Graph showing channel-bed profiles in 1973, 1978, and 1987-88 for Standing Pine Creek tributary at Free Trade ... 5

3. Graph showing estimated pattern of channel-bed degradation for Standing Pine Creek tributary at State Highway 488 at Free Trade, 1973-2010 ... 8

4. Graph showing estimated patterns of channel-bed degradation for four selected channel reaches of Standing Pine Creek tributary, 1973-2010 ... 9

Page

5. Cross section showing critical-failure surfaces for channel banks of Standing Pine Creek tributary about 350 feet downstream from State Highway 488 at Free Trade, 1988....... 14

6. Cross section showing critical-failure surfaces for channel banks of Standing Pine Creek tributary about 100 feet downstream from State Highway 488 at Free Trade, 1987....... 15

7. Cross section showing critical-failure surfaces for channel banks of Standing Pine Creek tributary about 100 feet upstream from State Highway 488 at Free Trade, 1987............ 16

8. Graph showing estimated patterns of channel widening for four selected channel reaches of Standing Pine Creek tributary, 1973-2010.. 18

9. Cross sections showing estimated near-future channel widening for Standing Pine Creek tributary in the vicinity of State Highway 488 at Free Trade, 1987-88............... 19

TABLES

Table 1. Measured channel-bed elevation and total degradation since 1973 for Standing Pine Creek tributary at State Highway 488 at Free Trade 6

2. Total channel-bed degradation since 1973 and estimated additional degradation by the year 2010 for four selected channel reaches of Standing Pine Creek tributary 10

3. Average bankfull channel width and estimated additional widening by the year 2010 for four selected channel reaches of Standing Pine Creek tributary.. 11

4. Dry bulk-unit weight and shear-strength properties of soils as determined from borehole tests on the left (south) bank of Standing Pine Creek tributary about 100 feet downstream from State Highway 488 at Free Trade 12

CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
foot (ft)	0.3048	meter
foot per mile (ft/mi)	0.1894	meter per kilometer
mile (mi)	1.609	kilometer
pounds per cubic foot (lb/ft^3)	157.1	newtons per cubic meter
pounds per square foot (lb/ft^2)	47.88	newtons per square meter
square mile (mi^2)	2.590	square kilometer

Mississippi Department of Transportation Datum: In this report, elevations are referenced to Mississippi Department of Transportation Datum (MDOTD)--a site-specific datum. At this site, add 94.8 feet to elevations referenced to MDOTD to convert to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929 and referred to in this report as sea level.

DEFINITION OF TERMS

Selected terms used in this report are defined below.

Angle of internal friction -angle of the plane of contact of soil particles with the horizontal at the point of sliding (shearing); angle whose tangent is the coefficient of friction between the soil particles (Cernica, 1982).

Channel-bed aggradation - filling in of the channel because streamflows are not sufficient to transport the material delivered from upstream channel-bed degradation (Simon and Hupp, 1986a).

Channel-bed degradation -headward erosion of the channel bed usually caused by increases in downstream channel gradient and cross-sectional area by man (Simon and Hupp, 1986a).

Cohesion -attraction of adsorbed water and soil particles that produce a body, which holds together but deforms plastically at varying water contents (Sowers, 1979).

Dry bulk-unit weight -ratio of the weight of the soil solids to the volume of the soil sample (Das, 1984).

Factor of safety -ratio of the resisting force (shear strength of the soil) to the driving force (weight of the soil). If the resisting force is less than the driving force, the factor of safety is less than 1.0, and therefore, failure occurs (Huang, 1983).

Failure-block width -the measured width of the failure block or the distance between affected stems of woody plants growing in bank material that has failed and fallen down slope and the existing top-bank edge (Hupp, 1987).

Iowa Borehole Shear Test -direct measure of shear strength of fine- to medium-grained soils in situ (from inside a borehole) (Handy, 1981).

Moisture content -ratio of the weight of the water present to the weight of the soil solids (Das, 1984).

Planar failure -slides along a surface of rupture whereby the mass progresses down and out along a more or less planar or gently-undulatory surface and has little rotational movement or backward tilting characteristics (Huang, 1983).

Rotational failure -landslide along a surface of rupture that is concave upward. The exposed cracks are concentric in plan and concave toward the direction of movement (Huang, 1983).

Shear strength -capacity of a soil to resist shear; in terms of effective stress, it can be given by the equation:

$$s' = c' + \sigma' \tan \phi'$$

where:

σ' is effective normal stress on plane of shear;

c' is effective cohesion or apparent cohesion of the soil; and

ϕ' is effective angle of internal friction (Das, 1984).

Slough-line angle -angle attained by projecting the slope of failed blocks of soil mass (which represents a temporary angle of stability) to its intersection with the top of channel bank (flood-plain level). It is used to determine short-term (10-20 years) bank widening (Simon and Hupp, 1986b).

CHANNEL-BED AND CHANNEL-BANK STABILITY OF STANDING PINE CREEK TRIBUTARY AT STATE HIGHWAY 488 AT FREE TRADE, LEAKE COUNTY, MISSISSIPPI

by K. Van Wilson, Jr. and D. Phil Turnipseed

ABSTRACT

The channel of Standing Pine Creek tributary in the vicinity of State Highway 488 at Free Trade in Leake County, Mississippi, has typically degraded about 6 feet and widened about 10 feet between 1973 (when channelized) and 1991. In a scour hole located about 100 feet downstream from State Highway 488, as much as 15 feet of localized scour and degradation and 105 feet of widening occurred for that period. From field observations made in 1991, no significant degradation or widening seemed to have occurred since 1987. As much as 3 feet of additional degradation and 15 feet of additional widening are projected through the year 2010 on Standing Pine Creek tributary in the vicinity of State Highway 488. These projections are based on the assumption that no additional channel modifications and no unusually large and destructive flooding will occur by the year 2010.

INTRODUCTION

The Mississippi Department of Transportation (MDOT) proposes to reconstruct the State Highway 488 bridge crossing of Standing Pine Creek tributary at Free Trade, Leake County, Miss. (fig. 1), where channel-bed degradation and channel-bank widening have occurred recently. The U.S. Geological Survey (USGS), in cooperation with the MDOT, visited this site during 1988 and 1991 to study channel-bed and channel-bank stability.

Purpose and Scope

This report describes existing channel-bed and channel-bank conditions and presents the results of a study to determine the potential for future (through the year 2010) degradation and widening for Standing Pine Creek tributary at State Highway 488 at Free Trade, in Leake County, Miss. Past and present channel-bed and channel-bank conditions were determined based on field observations of channel-bed elevations, bank failures, ages and types of trees on the channel banks, and dry bulk-unit weight and shear-strength properties of bank material. This report is the eighth in a series of similar reports for selected stream crossings in Mississippi.

Approach

The potential for future degradation and widening for Standing Pine Creek tributary at State Highway 488 at Free Trade, Miss., was estimated using past and present stream data. The potential for future degradation was estimated by using channel-bed elevations at the State Highway 488 bridge as a power function with time and by using a semi-logarithmic function of total degradation with time for four selected channel reaches of Standing Pine Creek tributary in the vicinity of State Highway 488. The potential for future channel widening was estimated by using both the potential for near-future bank failures, based on 1987 and 1988 channel geometry and dry bulk-unit weights and shear-strength properties of the bank material, and application of a power function of past channel widths with time for four selected channel reaches of the tributary.

General Description of Standing Pine Creek Tributary

Standing Pine Creek tributary is located in the North-Central Plateau, East Gulf Coastal Plain physiographic region (Thornbury, 1965). The drainage area of Standing Pine Creek tributary at State Highway 488 is 12.2 mi^2, of which flood discharges from 5.34 mi^2 are controlled by a flood-retarding dam (fig. 1). The length of the channel upstream of the site is about 3.0 mi. The average valley slope in the vicinity of the crossing is about 11 ft/mi. The average channel slopes in the vicinity of the crossing are about 15 ft/mi just upstream of the crossing, about 5 ft/mi from 0.1 mi to 0.7 mi downstream of the crossing, and about 10 ft/mi from 0.7 mi downstream of the crossing to the mouth of the tributary. The tributary flows into Standing Pine Creek about 1.1 mi downstream from the State Highway 488 crossing (fig. 1).

The channel bed of the tributary in the vicinity of State Highway 488 is composed of uniform fine sand. At State Highway 488, the channel bed and banks are covered with riprap from about 50 ft upstream to about 50 ft downstream. Due to channel-bed degradation and bank widening, the riprap has slipped and is currently acting as a channel grade-control structure. At small discharges, a water-surface differential of about 4 ft exists across the channel reach.

Channel Modifications to Standing Pine Creek Tributary

Standing Pine Creek and Standing Pine Creek tributary were both channelized by the U.S. Soil Conservation Service (SCS) in 1973. Additional modifications have been

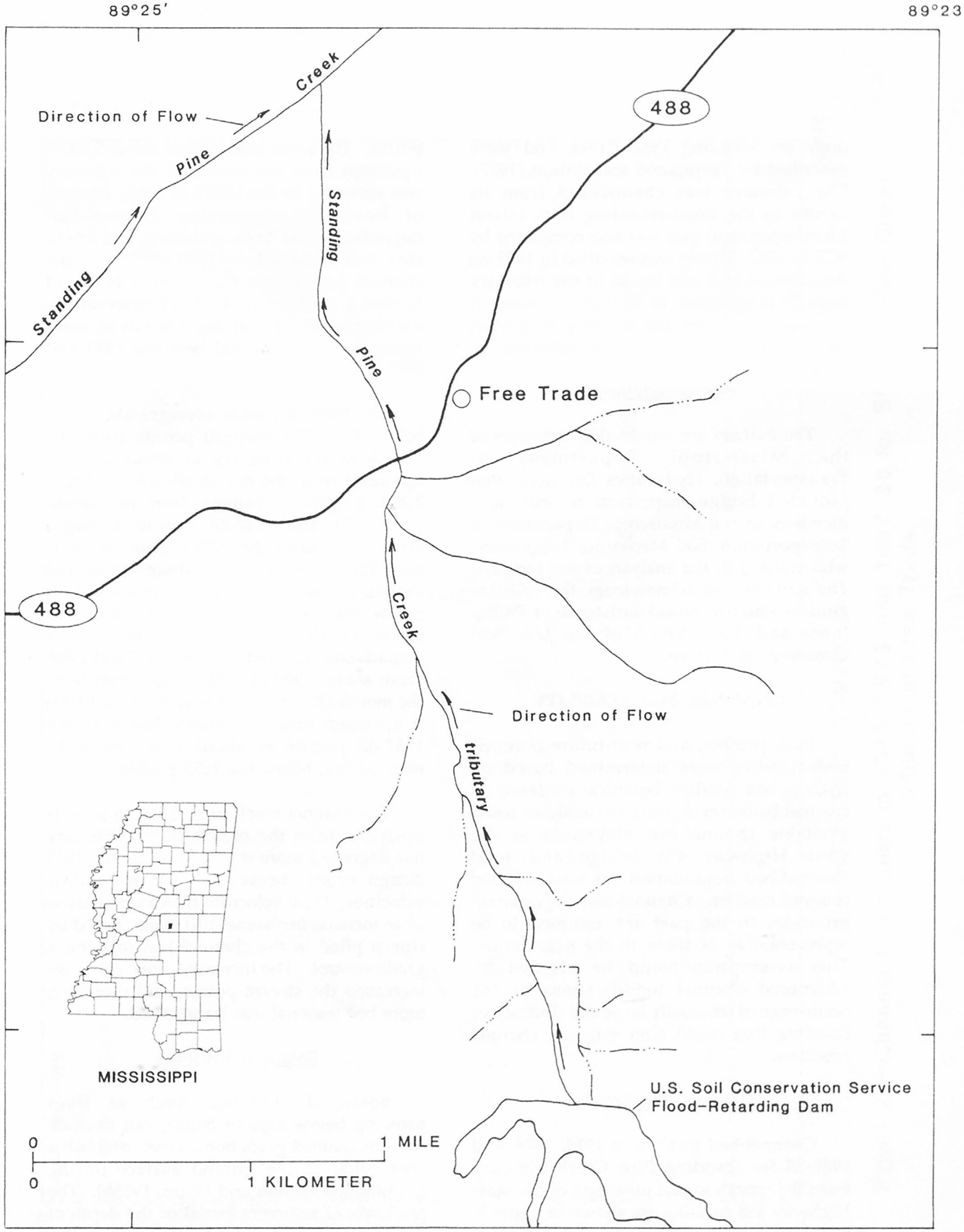


Figure 1.--Location of Standing Pine Creek tributary of State Highway 488 at Free Trade.

done on Standing Pine Creek and were described by Turnipseed and Wilson (1992). The tributary was channelized from its mouth to the flood-retarding dam (about 2.8 mi upstream) that was also completed by SCS in 1973. Riprap was installed in 1973 on the channel bed and banks of the tributary from 50 ft upstream to 50 ft downstream of the State Highway 488 crossing to protect the bridge from increased flow velocities.

Acknowledgments

The authors are indebted to members of the Mississippi Department of Transportation, Hydraulics Division, who provided bridge inspection records, and members of the Mississippi Department of Transportation, Soil Mechanics Laboratory, who assisted in the analysis of soil samples. The authors also acknowledge the valuable guidance and technical assistance of Phillip Jones and Tyler Smith of the U.S. Soil Conservation Service.

CHANNEL-BED STABILITY

Past, present, and near-future channel-bed stability were determined based on channel-bed profiles, botanical evidence on channel banks, and gradation analyses using available channel-bed elevations at the State Highway 488 bridge and total channel-bed degradation for four selected channel reaches. Channel-bed degradation processes in the past are assumed to be representative of those in the near future. This assumption could be negated by additional channel modifications or the occurrence of unusually large and destructive flooding that could alter ongoing channel processes.

Channel-Bed Profiles

Channel-bed profiles in 1973, 1978, and 1987-88 for Standing Pine Creek tributary from the mouth to just upstream of the State Highway 488 crossing are shown in figure 2. Data for these profiles were obtained from the SCS, except for parts of the 1987-88 profile. The scour hole located about 5,800 ft upstream from the mouth of the tributary was surveyed by the USGS in 1988. Because of headward-progressing channel-bed degradation and bank widening, the riprap that was installed in 1973 fell from the channel banks into the channel bed and formed a grade control. Field observations indicate no significant degradation or scour seems to have occurred between 1988 and 1991.

The 1987-88 profile averages about 6 ft below the 1973 (design) profile from the mouth of the tributary to about 2,200 ft upstream from the mouth (Reach 1). From 2,200 to 5,600 ft upstream from the mouth (Reach 2), the 1987-88 profile averages about 10 ft below the 1973 profile. A scour hole (about 5,800 ft upstream from the mouth) extends to a maximum of about 15 ft below the 1973 profile; consequently, as much as 15 ft of localized scour and degradation occurred between 1973 and 1988. From about 5,900 to 8,200 ft upstream from the mouth (Reach 3) and from 8,200 to 10,000 ft upstream from the mouth (Reach 4), the 1987-88 profile is about 6 ft and 4 ft, respectively, below the 1973 profile.

The channel reach from 2,200 to 5,900 ft upstream from the mouth of the tributary has degraded more than 6 ft below the 1973 design profile because of increased flow velocities. Flow velocities increased because of an increase in channel-bed slope caused by riprap piled in the channel bed forming a grade control. The increased flow velocities increased the stream power, and therefore, more bed material was transported.

Botanical Evidence

Botanical evidence, such as trees growing below tops of banks, can indicate rates of channel gradation. Trees establish a root collar at the ground surface during germination (Simon and Hupp, 1986b). The thickness of sediment burial or the depth of exhumation relative to the root collar defines the degree of aggradation or

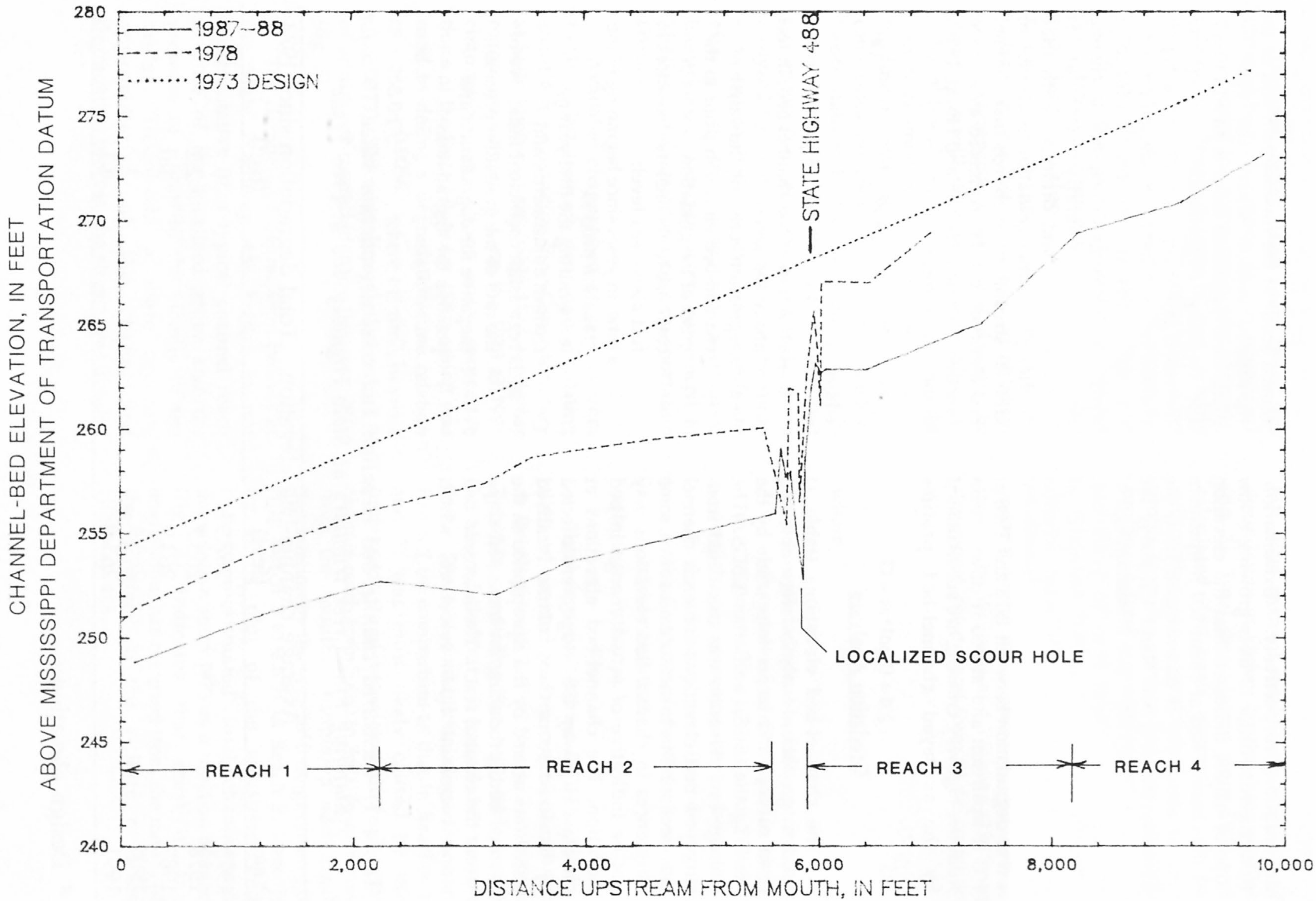


Figure 2.--Channel-bed profiles in 1973, 1978, and 1987-88 for Standing Pine Creek tributary at Free Trade.

degradation, respectively. Exhumation, from the root collar of trees growing below tops of banks, indicated that the elevation of the channel bed at about 100 ft upstream and at about 400 ft downstream from the highway crossing was about 4 ft above the channel bed in 1988. The maximum age of the trees was about 7 to 10 years old. Therefore, the botanical estimate of degradation only represents what occurred since about 1978. The botanical estimates of 4 ft of degradation between 1978 and 1988 at 100 ft upstream and at 400 ft downstream from the highway crossing are substantiated by the surveyed channel-bed profiles (fig. 2).

Gradation Analyses

The channel-bed elevations (table 1) used in gradation analyses were obtained from surveys and inspections made by the MDOT, the SCS, and the USGS. The average bed elevation was calculated from surveyed bed elevations for each channel cross section. Due to measurement error, some differences in channel-bed elevations may not be indicative of actual change in bed elevation. The channel-bed elevations at the State Highway 488 bridge were affected by localized scour. Most of the localized scour was caused by the riprap piled in the channel bed, producing an increased slope across the channel reach. The increased bed slope increased flow velocities, which caused scour at the downstream end of the rip-rapped section where the velocities dissipated. Localized scour is an addition to the ongoing degradation process and, therefore, is not representative of a typical channel reach. Channel-gradation processes on an alluvial stream undergoing morphologic change in response to channel modifications generally start at an accelerated rate and diminish with time. Studies of channel-gradation processes on alluvial streams have shown that channel-bed elevation can be expressed as a power function with time (Simon and Hupp, 1986a) in the general form:

$$E = a \cdot t^b , \tag{1}$$

where

- **E** is elevation of the channel bed, in feet above sea level;
- **a** is regression constant, indicative of channel-bed elevation prior to the onset of the gradation process in response to channel modification, in feet above sea level;
- **t** is time, in years since beginning of the gradation process ($t = 1$ during the first year of channel adjustment); and
- **b** is regression coefficient indicative of the rate of the gradation process (negative for degradation and positive for aggradation).

Table 1.--*Measured channel-bed elevation and total degradation since 1973 for Standing Pine Creek tributary at State Highway 488 at Free Trade*

Year	Average channel-bed elevation (feet)	Total degradation since 1973 (feet)
1973	267.9[a]	0
1978	265.7	2.2
1987	263.9	4.0
1988	263.4	4.5
1991	263.8	4.1

[a] Design elevation.

Datums other than sea level for channel-bed elevations (E) in equation 1 may be used for convenience (for example, when sea level datum is not readily available at a site), but this will affect values of **a** and **b**. If elevations above the assumed datum are greater than the elevations obtained when referenced to sea level datum, the value of **a** will increase, but the absolute value of **b** will decrease. Conversely, if elevations above the assumed datum are less than the elevations obtained when referenced to sea level datum, the value of **a** will decrease, but the absolute value of **b** will increase. Also, by varying the datum, an imposed logarithmic offset for the log-linear relation will change; thus, in some cases, improving or worsening the log-linear statistical fit of the data points. In previous studies, the effects of channel-bed elevations on gradational trends were analyzed by varying the datum of the study sites; the analysis indicated no significant effects on the gradation estimates. Elevations in this report are referenced to Mississippi Department of Transportation Datum.

Available channel-bed elevations from 1973 to 1991 indicate degradation totaling about 4 ft on Standing Pine Creek tributary at State Highway 488 (table 1). A log-linear regression computed from the 1973 to 1991 channel-bed elevations with respective times at the State Highway 488 crossing was used to define a degradation-time relation ($E = 268.0 \cdot t^{-0.00567}$, where t is time, in years since 1973). The relation projects about 1.3 ft of additional degradation by the year 2010 (fig. 3).

The channel-bed degradation process at the State Highway 488 bridge is not representative of a typical channel reach because of the localized scour and the presence of riprap in the vicinity of the bridge. To obtain a more accurate approximation of the channel-bed degradation process, the stream was divided into four channel reaches on the basis of degradation as shown by the three profiles (fig. 2). Total degradation since 1973 was calculated for each channel reach by subtracting the average bed along each profile from the average bed along the 1973 profile. A total degradation curve for each channel reach was estimated by use of a semi-logarithmic equation of total degradation (arithmetic scale) as a function of time (logarithmic scale). This function seemed to fit most cases of the streams studied by Williams and Wolman (1984). In this report, the general form of the equation is:

$$D = m \cdot \log(t) + b \ , \qquad (2)$$

where

- **D** is total channel-bed degradation since channel modification, in feet;
- **m** is slope of the best-fit straight line;
- **t** is time, in years since beginning of the degradation process, (**t** = 1 during the first year of channel adjustment); and
- **b** is the intercept.

Total degradation from 1973 to 1987 for the four channel reaches ranged from 4.4 ft in Reach 4 to 10.2 ft in Reach 2 (table 2). Typically (excluding Reach 2), the channel has degraded about 6 ft (rounded to nearest foot). The 4 ft of additional degradation in Reach 2 (in comparison to that in Reaches 1 and 3) was most likely caused by the increased flow velocities through the channel reach from 5,600 to 5,900 ft upstream from the mouth. Estimated additional degradation by the year 2010 ranges from 1.0 ft in Reach 3 to 2.6 ft in Reach 2 (table 2; fig. 4). A plot of the measured and regression-estimated total channel-bed degradation since 1973 as a function of time (fig. 4) indicates that most of the degradation has occurred from the mouth of the tributary to the vicinity of State Highway 488.

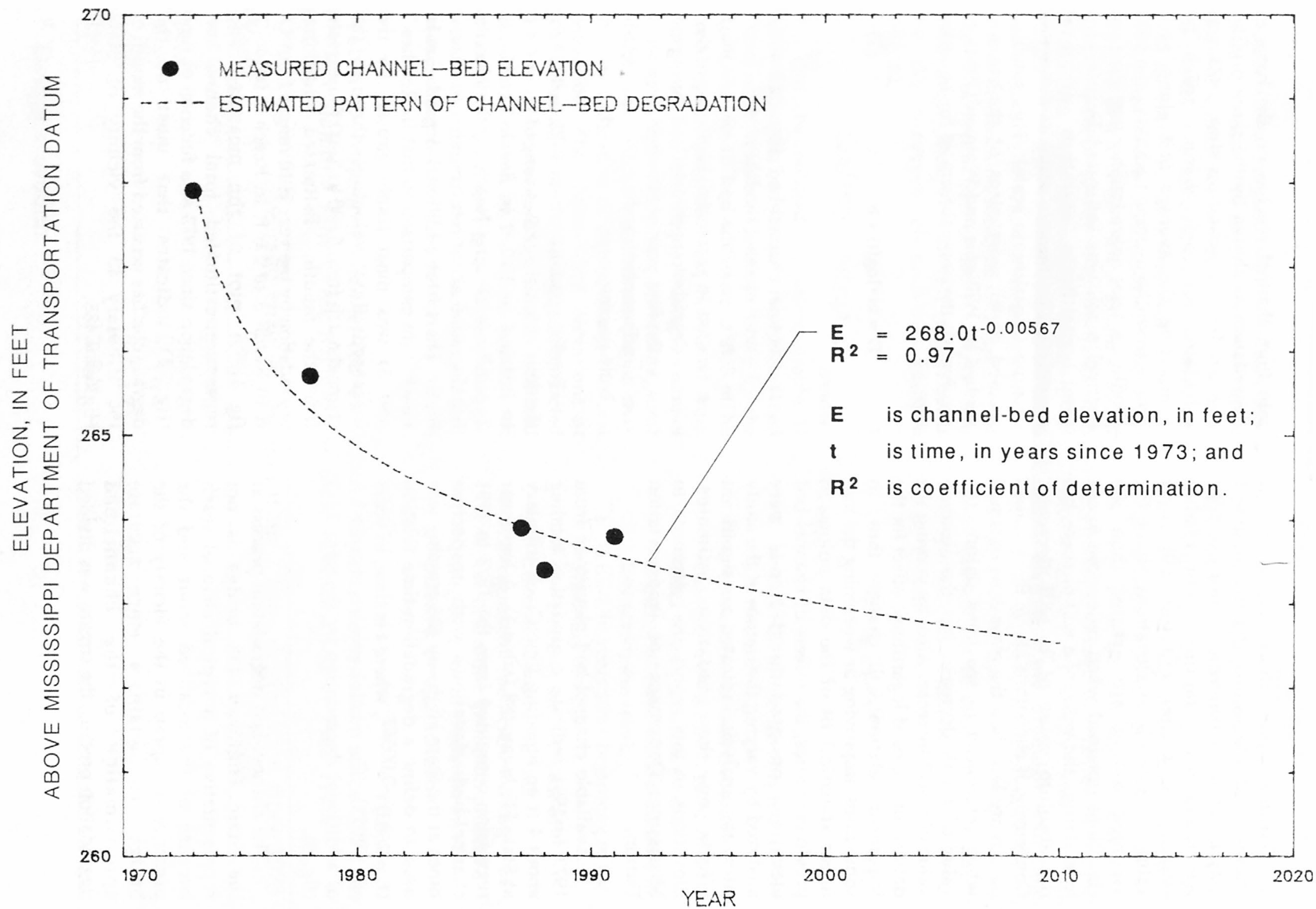
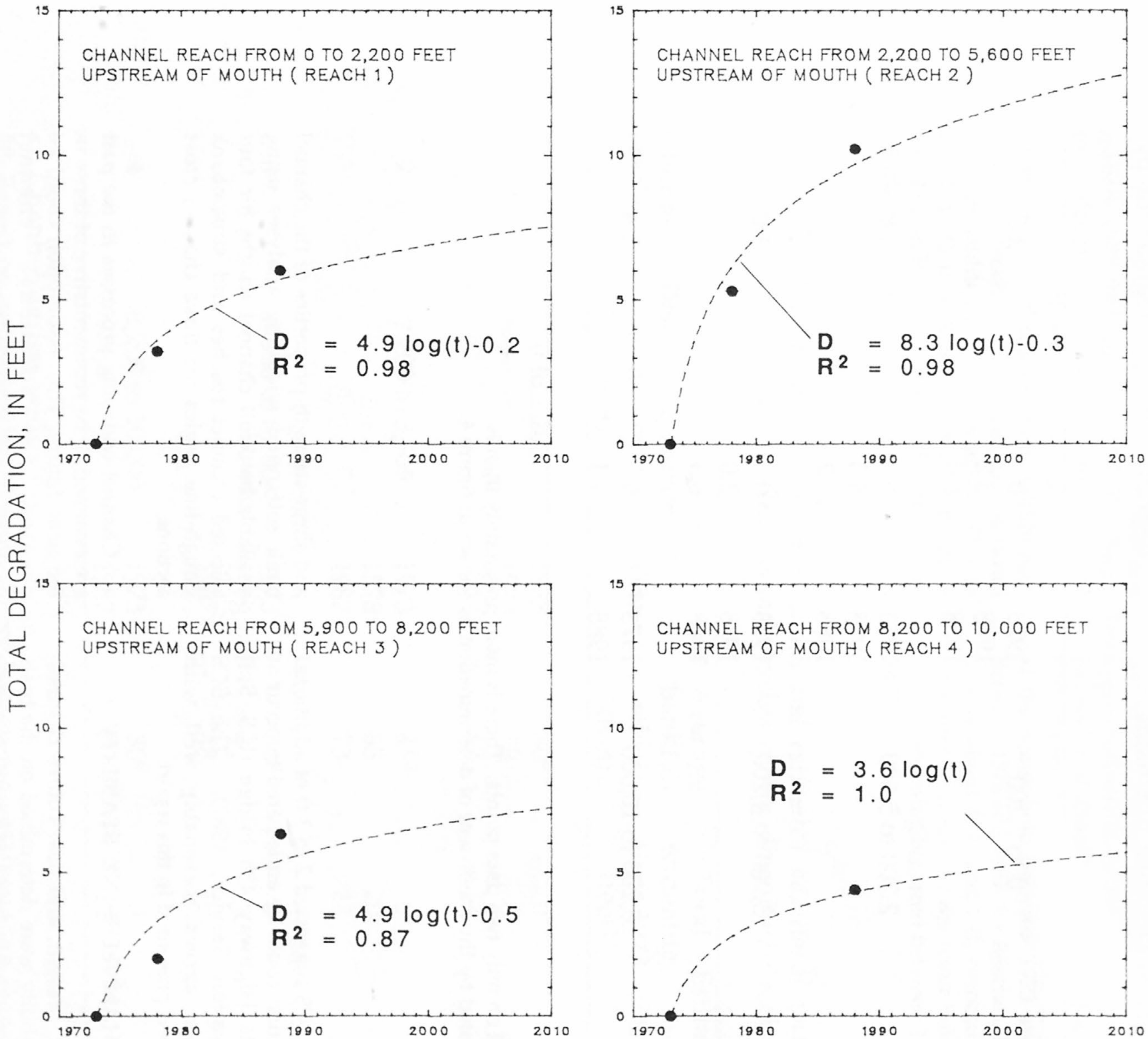


Figure 3.--Estimated pattern of channel-bed degradation for Standing Pine Creek tributary at State Highway 488 at Free Trade, 1973-2010.



D is total channel-bed degradation since 1973, in feet;

t is time, in years since 1973; and

R^2 is coefficient of determination.

Figure 4.--Estimated patterns of channel-bed degradation for four selected channel reaches of Standing Pine Creek tributary, 1973-2010.

Table 2.--*Total channel-bed degradation since 1973 and estimated additional degradation by the year 2010 for four selected channel reaches of Standing Pine Creek tributary*

Channel reach	Distance upstream from mouth (feet)	Year	Total degradation since 1973 (feet)	Estimated additional degradation by the year 2010 (feet)
1	0 to 2,200	1973	0	1.5
		1978	3.2	
		1988	6.0	
2	2,200 to 5,600	1973	0	2.6
		1978	5.3	
		1988	10.2	
3	5,900 to 8,200	1973	0	1.0
		1978	2.0	
		1988	6.3	
4	8,200 to 10,000	1973	0	1.4[a]
		1988	4.4	

[a] Based on only two data points. There is more uncertainty than is indicated by the coefficient of determination as shown in figure 4.

The SCS suggested 2 to 3 ft of additional degradation could be anticipated to occur at the State Highway 488 bridge (U.S. Soil Conservation Service, 1987). The SCS projection agrees reasonably well with projections presented in this report.

CHANNEL-BANK STABILITY

Past, present, and near-future channel-bank stability were determined on the basis of channel cross sections, botanical evidence on channel banks, stability analyses of the channel banks using dry bulk-unit weight and shear-strength properties of the channel bank soils, and widening analyses using available bankfull channel widths for four selected channel reaches and streambank slough-line angles for three channel cross sections.

Channel-widening processes in the past are assumed to be representative of those in the near future. This assumption could be negated by additional channel modifications or the occurrence of unusually large and destructive flooding that could alter ongoing widening processes.

Channel Cross Sections

Channel cross sections for Standing Pine Creek tributary were surveyed in 1973, 1978, and 1987 by the SCS and in 1987-88 in the vicinity of State Highway 488 by the MDOT and the USGS. From field observations made in 1991, no significant widening seemed to have occurred since 1988. Average bankfull channel width was calculated from surveyed channel cross sections within each channel reach. The average bankfull channel width in 1987 was about 62 ft in Reach 1; 73 ft in Reach 2; 48 ft in Reach 3; and 41 ft in Reach 4 (table 3). The maximum width of the scour hole at about 100 ft downstream of State Highway 488 was about 148 ft in 1987. The 1973 channel-design width was about 50 ft for Reach 1; 45 ft for Reach 2; 38 ft for Reach 3; and 30 ft for Reach 4. Therefore, for Reaches 1, 2, 3, and 4, about 12, 28, 10, and 11 ft, respectively, of widening occurred between 1973 and 1987. Typically (excluding Reach 2), the channel has widened about 10 ft (rounded to nearest 5 ft). As much as 105 ft of widening occurred at the scour hole between 1973 and 1987. Between 1978 and 1987, for Reaches, 1, 2, and 3, only about 4, 8, and 7 ft, respectively, of widening occurred. At the scour hole, about 11 ft of widening occurred between 1978 and 1987.

Table 3.--*Average bankfull channel width and estimated additional widening by the year 2010 for four selected channel reaches of Standing Pine Creek tributary*

Channel reach	Distance upstream from mouth (feet)	Year	Average bankfull width (feet)	Total widening since 1973 (feet)	Estimated additional widening by the year 2010 (feet)
1	0 to 2,200	1973	50[a]	0	5
		1978	58	8	
		1987	62	12	
2	2,200 to 5,600	1973	45[a]	0	15
		1978	65	20	
		1987	73	28	
3	5,900 to 8,200	1973	38[a]	0	2
		1978	41	3	
		1987	48	10	
4	8,200 to 10,000	1973	30[a]	0	5[b]
		1987	41	11	

a Channel-design width.
b Based on only two data points. There is more uncertainty than is indicated by the coefficient of determination as shown in figure 8.

Botanical Evidence

Botanical evidence, such as trees growing below tops of banks, can indicate rates of bank failures. Bank failures along unstable channel reaches may kill, tilt, or scar existing trees, and create fresh surfaces upon which trees may become established. Scars and sprouts from parental stems of tilted trees yield reliable dates (accurate within 1 year, often within one season) of bank failure (Hupp, 1987, 1988; Sigafoos, 1964).

Eccentric growth, resulting in anomalous tree-ring series, occurs when the stem is inclined. This type of growth is easily determined from tree cross sections in which concentric-ring formation abruptly shifts to the eccentric--ring width is greater in the upslope direction than in the downslope direction. Eccentric-ring patterns yield reliable dates, usually accurate within one season, of tilting. Dating of stems that have become established on disturbed surfaces yields minimum ages for those surfaces (Simon and Hupp, 1986b).

Stem morphology, anatomy, and ages of trees growing on bank surfaces along Standing Pine Creek tributary near the State Highway 488 crossing indicate the development of a fairly stable lower-bank slough line and some active upper-bank sloughing. Botanical data were collected by taking cross sections or increment borings of sprouts from tilted trees and of saplings (such as catalpa, sycamore, river birch, willow, alder and sweet gum) to determine their ages and by measuring bank failure-block widths. These data indicate the maximum age of trees on lower-bank slough lines was about 10 years. On the left (south) bank, a 2-ft-wide bank failure about 400 ft downstream from the bridge occurred in 1985-86, a 4-ft-wide failure about 300 ft downstream from the bridge occurred in 1985-86, a 2-ft-wide failure about 320 ft downstream from the bridge occurred in 1987-88, and a 3-ft-wide failure about 250 ft downstream from the bridge occurred in 1984-85. Botanical evidence of previous bank failures may have been obscured with time and by succeeding large floods (Simon and Hupp, 1986b).

Table 4.--*Dry bulk-unit weight and shear-strength properties of soils as determined from borehole tests on the left (south) bank of Standing Pine Creek tributary about 100 feet downstream from State Highway 488 at Free Trade*

[ft, feet; lb/ft^3, pounds per cubic foot; lb/ft^2, pounds per square foot]

General soil description	Borehole depth (ft)	Dry bulk-unit weight (lb/ft^3)	Cohesion (lb/ft^2)	Angle of internal friction (degrees)
Light-brown, silty sand	0-3.2	97	0	39
Orange-gray, clayey sand	3.2-6.0	109	100	38
Orange-gray, chalky-sandy clay	6.0-7.6	109	370	35
White sand	7.6-11.0	101	0	34
Gray, sandy clay	11.0-12.8	109	370	24
Gray sand	12.8-15.0	109	0	34
White sand	15.0-18.0	101	0	34

Stability Analyses

Dry bulk-unit weight and shear-strength properties of the channel banks soils (table 4) used in the stability analyses were determined from borehole tests done in 1988 on the left (south) bank of Standing Pine Creek tributary about 100 ft downstream from State Highway 488. An Iowa Borehole Shear Tester[1] (BST), (Handy and Fox, 1967) was used to determine the shear-strength properties of the soils. The average moisture content of the soils during testing was about 13 percent. Shear-strength data obtained using the BST have compared reasonably well with the results of triaxial shear-strength tests that have been made by the MDOT. BST results for individual soil strata were used in the stability analyses.

The factor of safety used to describe channel-bank stability is the ratio of the resisting force (shear-strength of the bank material) to the driving force (weight of the bank material). Therefore, if the resisting force is equal to the driving force, then the factor of safety is 1.0. Theoretically, when the factor of safety is less than 1.0, failure occurs, and when it is greater than 1.0, failure does not occur. This is based on the assumption that all the forces are considered. A factor of safety of at least 1.5 generally is used in design. Factors of safety for bank failures at selected percentages of bank saturation were determined by using the dry bulk-unit weights and shear-strength properties of the bank material at cross sections surveyed in 1987 and 1988. Computer programs REAME (Rotational Equilibrium Analysis of Multilayered Embankments) and SWASE (Sliding Wedge Analysis of Sidehill Embankments) developed by Huang (1983) and UTEXAS2 (University of Texas Analysis of Slopes Version 2) developed by Wright (1986) were used in the bank-stability analyses. An iterative search was made by these programs to determine the minimum factor of safety for each percentage of bank saturation.

Analyses of both planar and rotational bank failures indicated rotational bank failures were more likely to occur. The critical-rotational failure surfaces for the channel cross sections at 0- and 100-percent bank saturation are shown in figures 5, 6, and 7. Failure-block widths ranged from 2 to 6 ft. The computed failure-block widths agreed reasonably well with failure-block widths observed in the field. Factors of safety for 0-percent bank saturation ranged from 1.4 on the right (north) bank of the cross section located 350 ft downstream from the bridge (fig. 5) to 2.6 on the left (south) bank of the cross section located 100 ft downstream from the State Highway 488 bridge (fig. 6). Factors of safety for 100-percent bank saturation ranged from 0.6 on the right bank of the cross section located 350 ft downstream from the bridge (fig. 5) to 1.4 for the left and right banks of the cross section located 100 ft downstream from the bridge (fig. 6). The analyses indicate that the cross section 100 ft downstream from the bridge, which is just upstream of the deepest part of the scour hole, is the most stable.

Widening Analyses

Channel-widening processes on an alluvial stream undergoing morphologic change in response to channel modifications generally start at a high rate and diminish with time. Channel-bed degradation increases bank heights and angles and causes channel widening by mass wasting. Depending on the soil properties of the bank material, some time generally elapses between the beginning of degradation and the beginning of widening. In this report, the time interval is assumed to be negligible because of insufficient data to support any other assumption. Channel-width information for Standing Pine Creek tributary was used to develop a power function of bankfull channel width with

---

[1] The use of trade or product names in this report is for identification purposes only, and does not constitute endorsement by the U.S. Geological Survey.

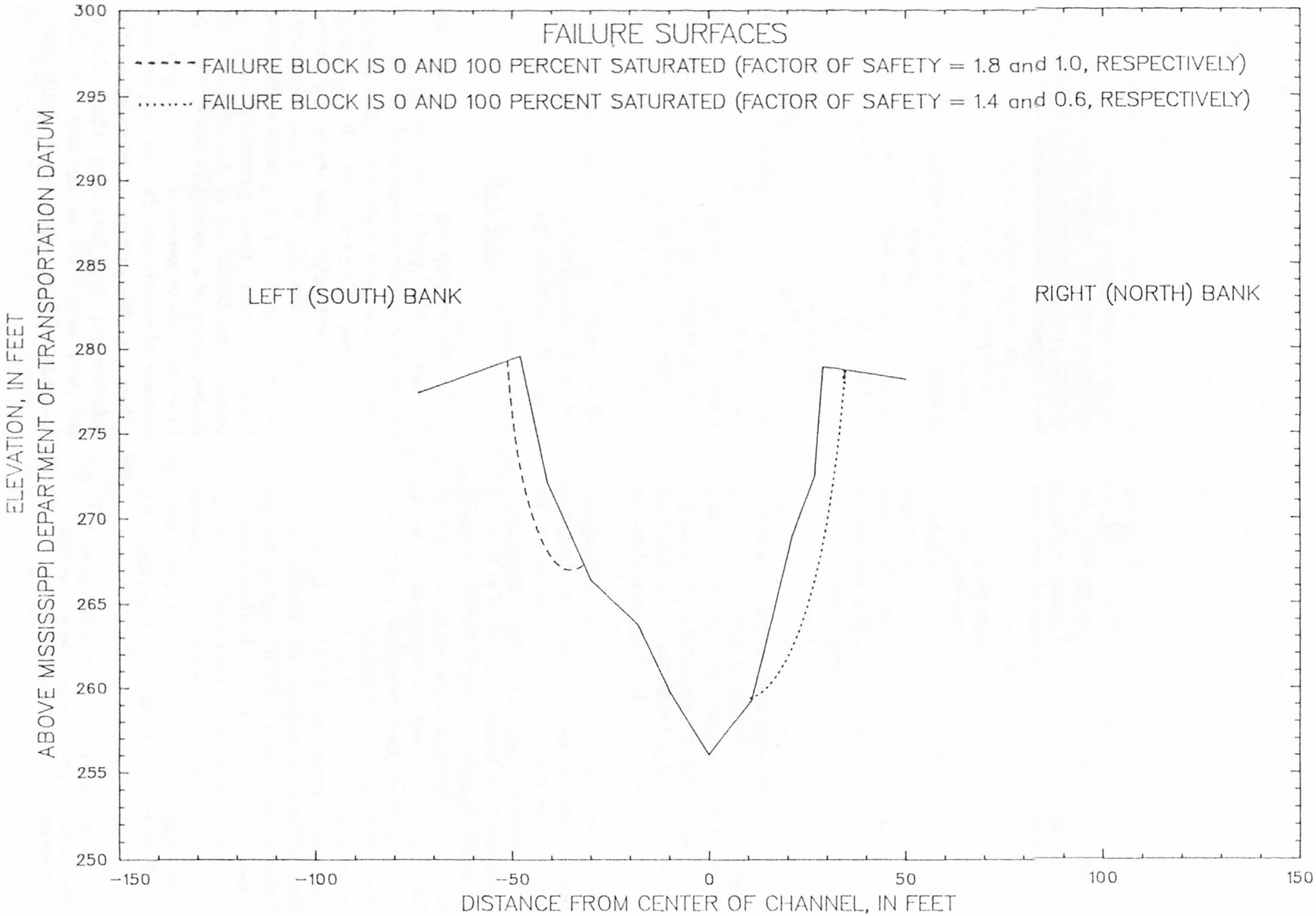


Figure 5.--Cross section showing critical-failure surfaces for channel banks of Standing Pine Creek tributary about 350 feet downstream from State Highway 488 at Free Trade, 1988.

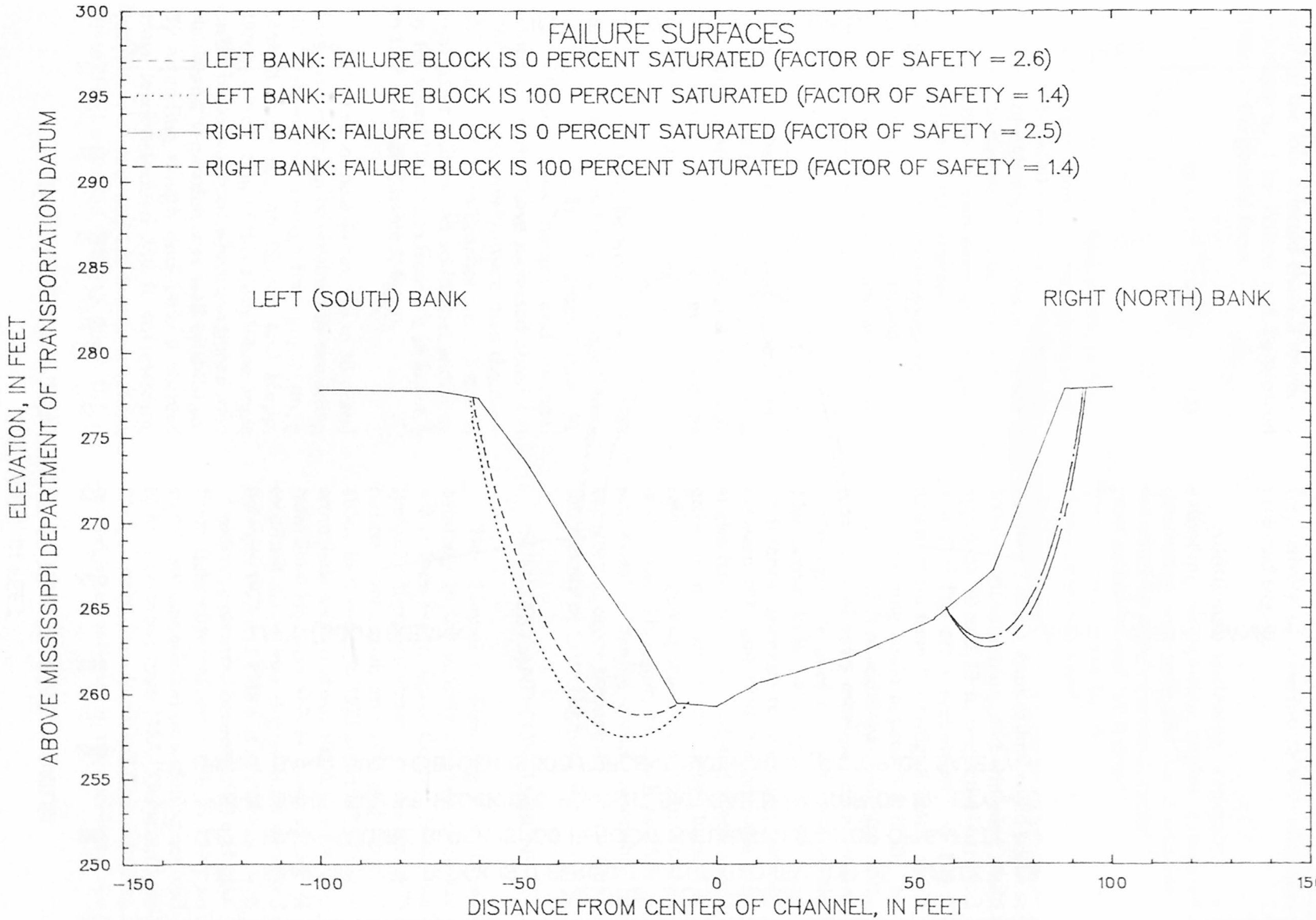


Figure 6.--Cross section showing critical-failure surfaces for channel banks of Standing Pine Creek tributary about 100 feet downstream from State Highway 488 at Free Trade, 1987.

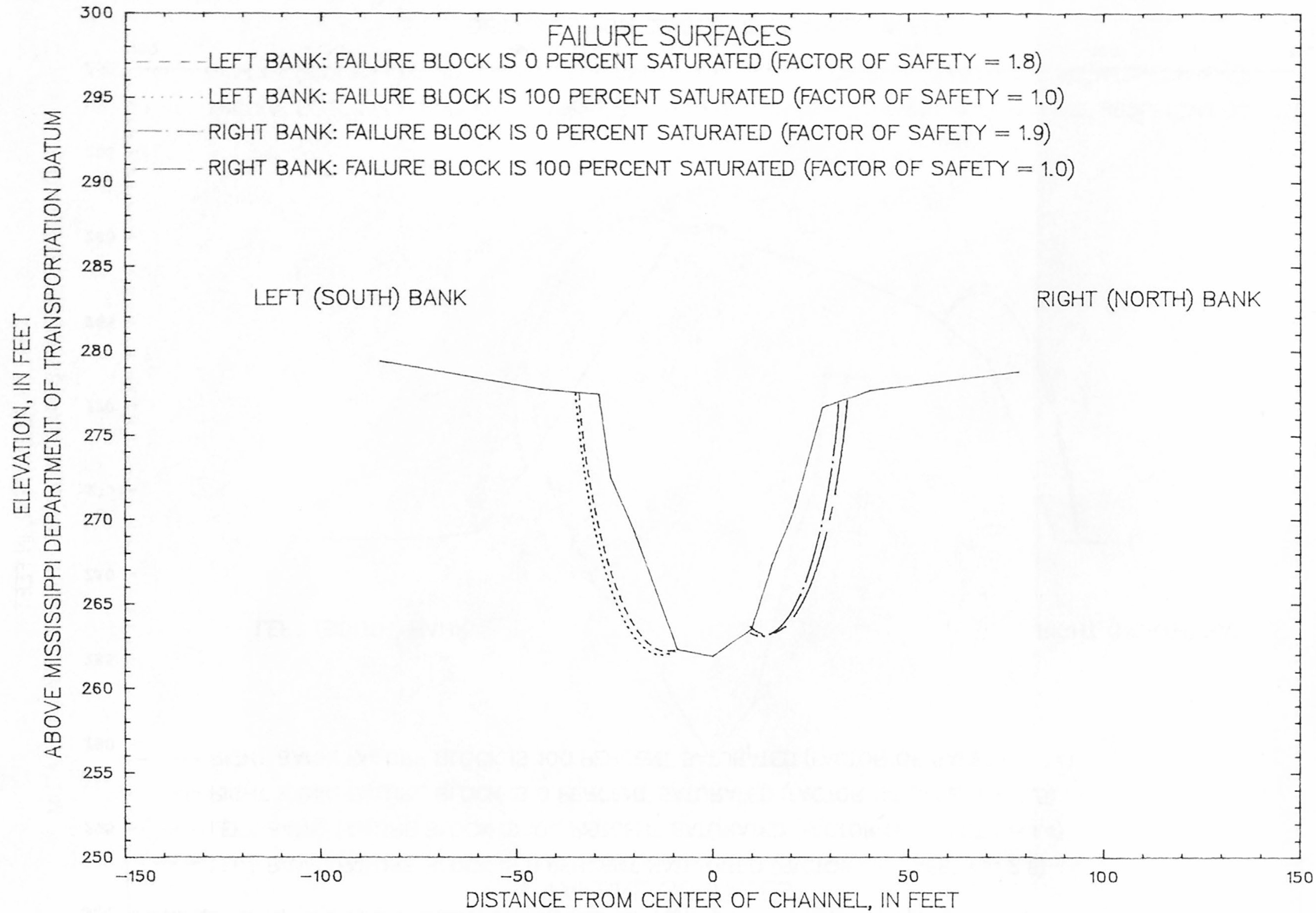


Figure 7.--Cross section showing critical-failure surfaces for channel banks of Standing Pine Creek tributary about 100 feet upstream from State Highway 488 at Free Trade, 1987.

time for the four selected channel reaches, a technique used by Wilson and Turnipseed (1989), in the general form:

$$W = c \cdot t^{d} \quad (3)$$

where

- **W** is bankfull channel width, in feet;
- c is regression constant indicative of bankfull width prior to the onset of widening processes in response to channel modification, in feet;
- t is time, in years since beginning of the widening process ($t = 1$ during the first year of channel adjustment); and
- d is regression coefficient indicative of the rate of widening.

As with channel-bed elevations, the channel widths (table 3) used in equation 3 were obtained from surveys and inspections made by the MDOT, the SCS, and the USGS. Some changes in width may not be indicative of actual change.

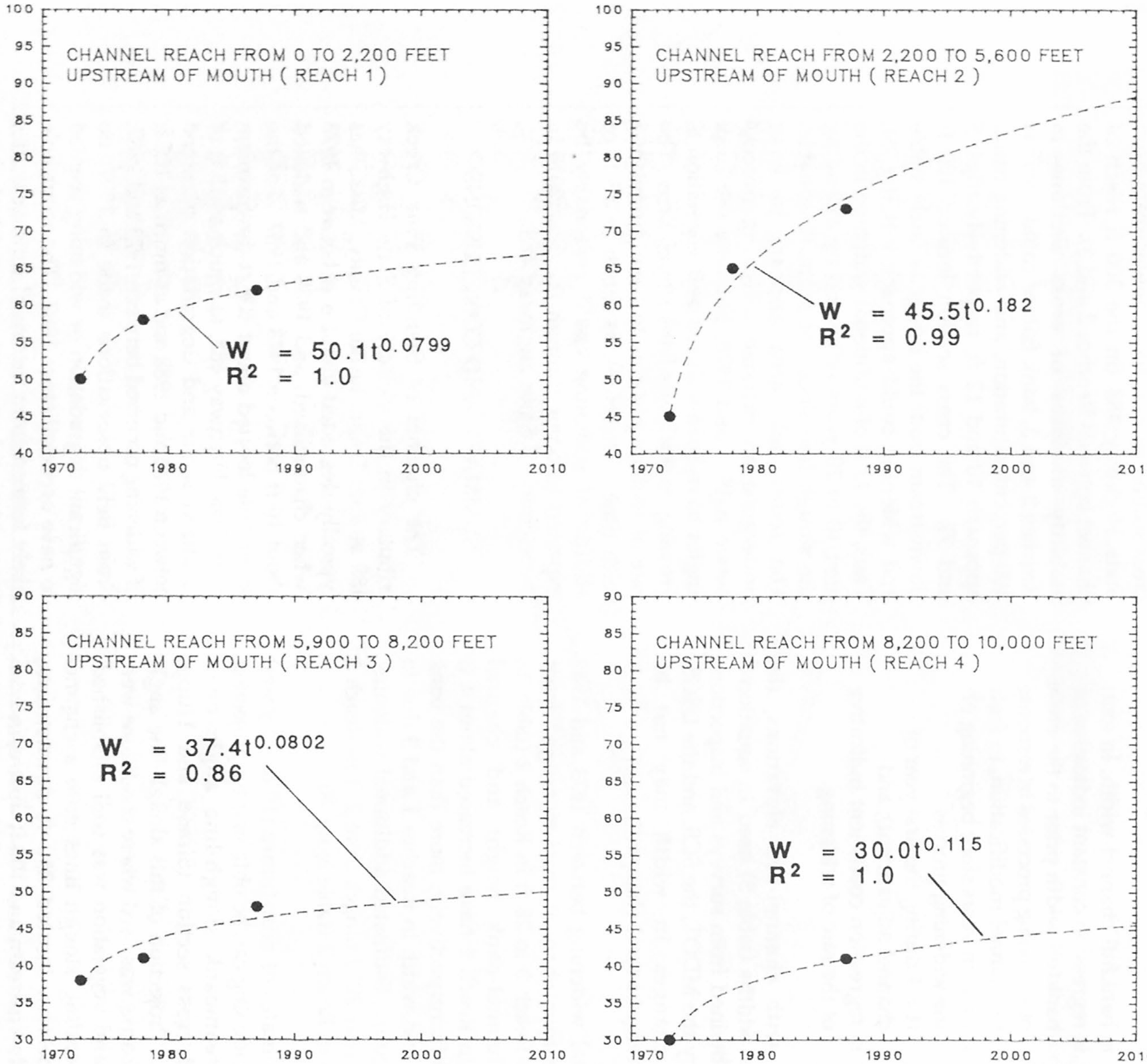
Total widening between 1973 and 1987 for the four channel reaches ranged from 10 ft in Reach 3 to 28 ft in Reach 2 (table 3). The channel-bank height and channel width in Reach 2 have increased about 4 ft and 18 ft, respectively, more than the bank height and width in Reaches 1 and 3 due to local scour. Estimated additional widening by the year 2010 ranges from 2 ft in Reach 3 to 15 ft in Reach 2 (table 3; fig. 8).

Estimates of near-future (10 to 20 years) bank widening can be obtained by projecting the streambank slough-line angle on a plotted cross section (Simon and Hupp, 1986b). Projection of this slough-line angle on the banks was used where conditions were stable and vegetation was well established. By extending slough lines onto a channel cross section located 350 ft downstream, 100 ft downstream and 100 ft upstream from State Highway 488, 15, 43, and 10 ft, respectively of near-future widening was projected (fig. 9).

Additional widening estimated by extending slough-line angles compared reasonably well with additional widening estimated by using equation 3, except for the cross section located 100 ft downstream from State Highway 488 (in the 300 ft reach of channel between Reaches 2 and 3). From the stability analyses of cross sections in Reaches 2 and 3, bank failure could occur at 100-percent saturation, and widening could approach 10 and 12 ft, respectively (figs. 5 and 7). The cross section located 100 ft downstream from the bridge is fairly stable and widening could approach 9 ft (fig. 6). Thus, the 43 ft of additional widening in the next 10 to 20 years estimated by extending the slough line does not seem reasonable. The scour hole area appears to have undergone an extreme widening process between 1973 and 1978, but now the bank angles have been reduced and vegetation is growing on the lower-bank slough lines. The rate of widening seems to have diminished with time. Therefore, as much as 15 ft of additional widening could reasonably be expected to occur through the year 2010 in the vicinity of State Highway 488.

SUMMARY AND CONCLUSIONS

The channel of Standing Pine Creek tributary in the vicinity of State Highway 488 at Free Trade, Leake County, Miss., has typically degraded about 6 ft between 1973 (when channelized) and 1988 and widened about 10 ft between 1973 and 1987. For the scour hole located about 100 ft downstream from State Highway 488, as much as 15 ft of localized scour and degradation occurred between 1973 and 1988 and as much as 105 ft of widening occurred between 1973 and 1987. From field observations made in 1991, no significant degradation or widening seemed to have occurred since 1987. The scour hole likely formed from increased flow velocities caused by an increase in channel-bed slope



W is bankfull channel width, in feet;

t is time, in years since 1973; and

R^2 is coefficient of determination.

Figure 8.--Estimated patterns of channel widening for four selected channel reaches of Standing Pine Creek tributary, 1973-2010.

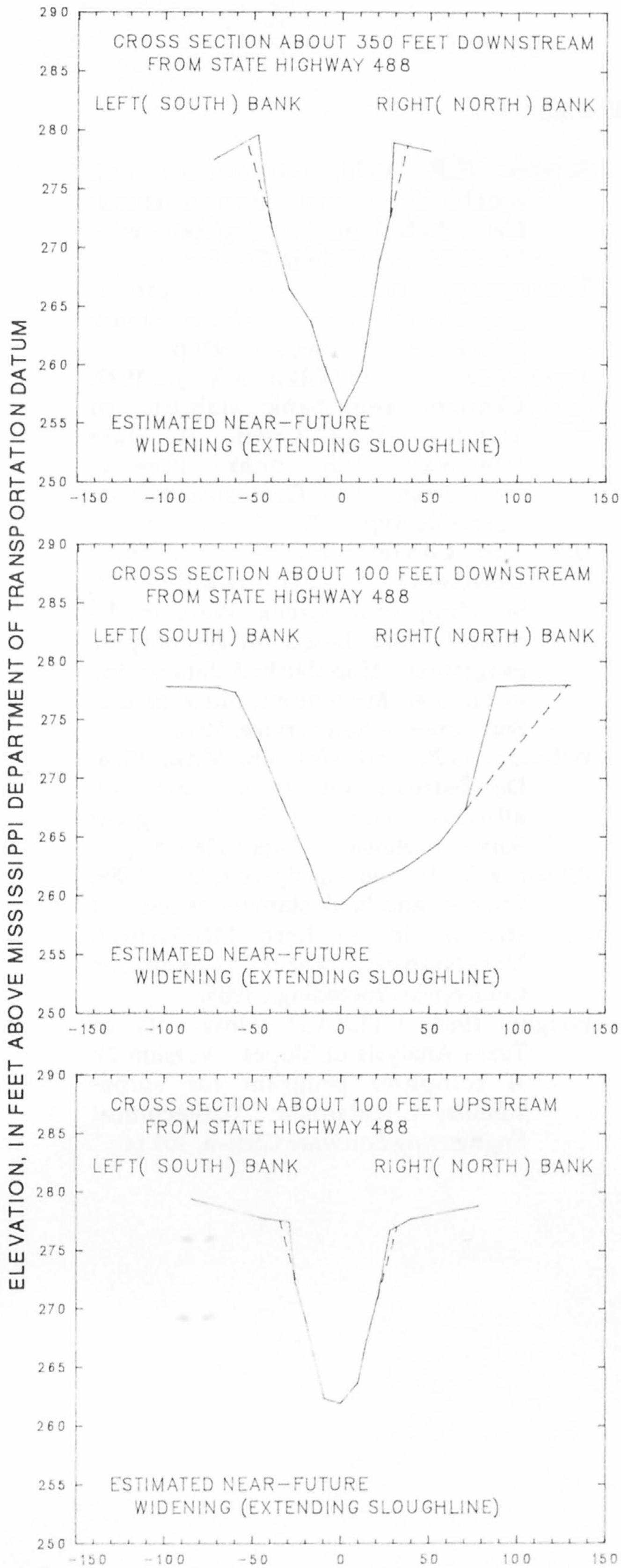


Figure 9.--Cross sections showing estimated near-future channel widening for Standing Pine Creek tributary in the vicinity of State Highway 488 at Free Trade, 1987-88.

where riprap is piled in the channel bed. The riprap fell from the channel banks into the channel bed due to channel-bed degradation and bank widening and formed a grade control at the State Highway 488 bridge. Rates of channel degradation and widening were used in conjunction with soil properties to estimate probable future channel-bed degradation and channel-bank widening through the year 2010. Additional channel-bed degradation and channel-bank widening through the year 2010 are projected to be as much as 3 ft and 15 ft, respectively, in the vicinity of State Highway 488. These projections are based on the assumption that no additional channel modifications and no unusually large and destructive flooding will occur by the year 2010.

REFERENCES

Cernica, J.N., 1982, Geotechnical engineering: CBS College Publishing, 488 p.

Das, B.M., 1984, Principles of foundation engineering: Wadsworth, Inc., 595 p.

Handy, R.L., 1981, Borehole shear test, instructions version 9-81: Ames, Iowa, Handy Geotechnical Instruments, Inc., 26 p.

Handy, R.L., and Fox, N.W., 1967, A soil bore-hole direct-shear device: Highway Research News No. 27, p. 42-51.

Huang, Y.H., 1983, Stability analysis of earth slopes: Van Nostrand and Co., 305 p.

Hupp, C.R., 1987, Determination of bank widening and accretion rates and vegetation recovery along modified West Tennessee streams, *in* International Symposium Proceedings of Ecological Aspects of Tree-Ring Analysis: Department of Energy Conference 8608144, p. 224-233.

-----1988, Plant ecological aspects of flood geomorphology and paleoflood history: Flood Geomorphology, John Wiley and Sons, Inc., p. 335-356.

Sigafoos, R.S., 1964, Botanical evidence of floods and floodplain deposition: U.S. Geological Survey Professional Paper 485-A, p. A1-A33.

Simon, Andrew, and Hupp, C.R., 1986a, Channel evolution in modified Tennessee channels: Federal Interagency Sedimentation Conference, 4th, Las Vegas, Nevada, 1986, Proceedings, v. 2, p. 5-71 to 5-82.

-----1986b, Channel widening characteristics and bank slope development along a reach of Cane Creek, West Tennessee, *in* Subitzky, Seymour, ed., Selected papers in the hydrologic sciences: U.S. Geological Survey Water-Supply Paper 2290, p. 113-126.

Sowers, G.F., 1979, Introductory soil mechanics and foundations: Geotechnical engineering (4th ed.): MacMillan Publishing Co., Inc., 621 p.

Thornbury, W.E., 1965, Regional geomorphology of the United States: John Wiley and Sons, Inc., 609 p.

Turnipseed, D.P., and Wilson, K.V., Jr., 1992, Channel and bank stability of Standing Pine Creek at State Highway 488 near Freeny, Mississippi: U.S. Geological Survey Open-File Report 92-112, 18 p.

U.S. Soil Conservation Service, 1987, Deficiency report supplement, Standing Pine Creek Watershed--Stability plan based on geomorphic evaluation: Unpublished data on file in Jackson, Mississippi, office of U.S. Soil Conservation Service, 50 p.

Williams, G.P., and Wolman, M.G., 1984, Downstream effects of dams on alluvial rivers: U.S. Geological Survey Professional Paper 1286, 83 p.

Wilson, K.V., Jr., and Turnipseed, D.P., 1989, Channel and bank stability of selected streams in northern Mississippi: Mississippi Water Resources Conference Proceedings, 1989.

Wright, 1986, UTEXAS2 (University of Texas Analysis of Slopes - Version 2): A computer program for slope-stability calculations: Geotechnical Engineering Software GS86-a, 109 p.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1993—755-177