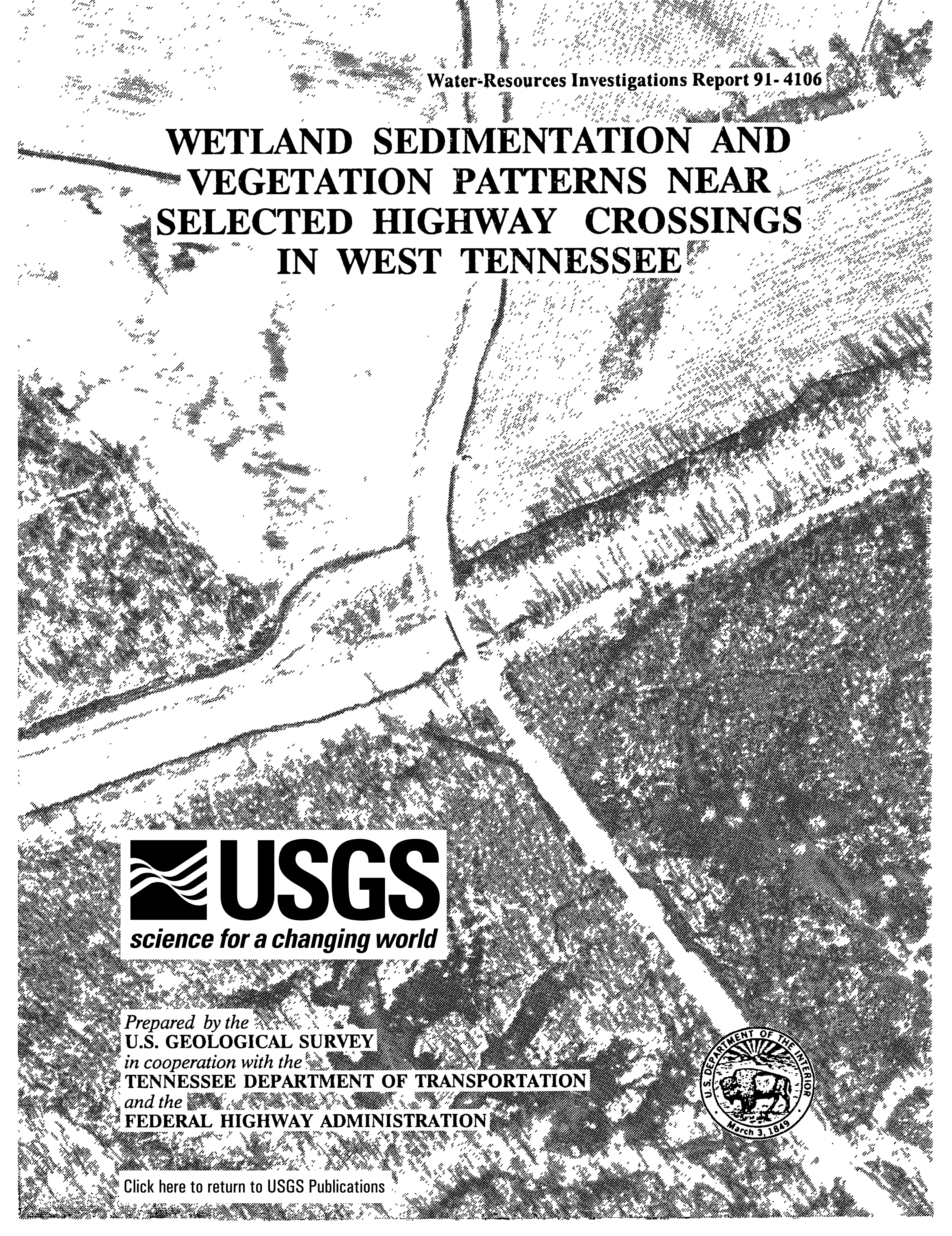

Water-Resources Investigations Report 91-4106

WETLAND SEDIMENTATION AND VEGETATION PATTERNS NEAR SELECTED HIGHWAY CROSSINGS IN WEST TENNESSEE

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Prepared by the
U.S. GEOLOGICAL SURVEY
in cooperation with the
TENNESSEE DEPARTMENT OF TRANSPORTATION
and the
FEDERAL HIGHWAY ADMINISTRATION

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

WETLAND SEDIMENTATION AND VEGETATION PATTERNS NEAR SELECTED HIGHWAY CROSSINGS IN WEST TENNESSEE

By David E. Bazemore, Cliff R. Hupp, and Timothy H. Diehl

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Nashville, Tennessee
1991

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
square mile (mi^2)	259.0	hectare
square mile (mi^2)	2.590	square kilometer
	Volume	
cubic foot (ft^3)	0.02832	cubic meter
cubic foot (ft^3)	28.32	liter
cubic foot (ft^3)	28,320	cubic centimeter
	Flow	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
	Mass	
ounce, avoirdupois (oz)	28.35	gram
ounce, avoirdupois (oz)	28,350	milligram
pound, avoirdupois (lb)	0.4536	kilogram
ton, short	0.9072	megagram
	Sediment Yield	
tons per square mile per year [($tons/mi^2$)/yr]	0.350	megagrams per square kilometer per year
	Sediment Deposition	
foot per year (ft/yr)	30.48	centimeter per year

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic 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.

WETLAND SEDIMENTATION AND VEGETATION PATTERNS NEAR SELECTED HIGHWAY CROSSINGS IN WEST TENNESSEE

by David E. Bazemore, Cliff R. Hupp, and Timothy H. Diehl

ABSTRACT

Wetland sedimentation and vegetation patterns at 11 highway crossings in West Tennessee were studied from 1987 to 1989. The purpose of the study was to investigate potential adverse effects of highway crossings on wetlands. Sedimentation rates, determined from root-burial depths, were highly variable. Average rates of fine-grained deposition ranged from 0.005 to 0.033 foot per year for stations in locally ponded areas and from -0.002 to 0.039 foot per year for stations in drained areas. Sedimentation rates upstream from highway crossings were not significantly different from downstream rates at 8 of the 11 study sites. Three study sites had significantly greater sedimentation rates downstream. Sand splays were observed downstream from bridges at most study sites. Vegetation patterns and tree growth appear most strongly related to hydroperiod, defined as the average length of time an area is covered by water each year. The influence of sedimentation on tree growth is difficult to separate from the influence of hydroperiod because areas with high sedimentation rates typically have long hydroperiods. Estimated hydroperiod increased no more than 1 percent because of backwater from the highway crossings at the 11 study sites, while the estimated average depth of flood-plain inundation increased by an average of 6 percent.

INTRODUCTION

Agencies responsible for wetland preservation are concerned that backwater upstream from highway crossings may accelerate sedimentation in wetland areas causing declines in biotic communities (Darnell, 1976). Relatively little is known about the effect of highway crossings on wetland sedimentation or vegetation. To determine these effects, precise measurements of sedimentation rates were combined with quantitative measures of vegetation patterns.

In 1987, the U.S. Geological Survey (USGS) in cooperation with the Tennessee Department of Transportation (TDOT) and the Federal Highway Administration initiated a study of 11 forested wetland sites (bottomlands) in West Tennessee. The goal of the investigation was to determine if highway crossings significantly increase sedimentation or adversely affect bottomland forests.

Background

Rivers in West Tennessee transport some of the highest concentrations of suspended sediment in the United States (Milliman and Meade, 1983; Trimble and Carey, 1984;

Simon, 1989a). Sediment yields for channelized streams range from 250 to 1,000 tons per square mile per year; sediment yield for the unchannelized Hatchie River is 150 tons per square mile per year (Trimble and Carey, 1984). Suspended-sediment concentrations and suspended-sediment discharges are highly variable for West Tennessee streams (Trimble and Carey, 1984; Simon, 1989a). Variability is greatest on adjusting channelized streams (Simon, 1989a). Simon and Hupp (1987) described channel adjustments to modifications using a six stage model of channel evolution (fig. 1). Most of the sites examined in this study were located along river reaches in various stages of channel adjustment after channelization; site 7 was the only site along an unmodified reach (table 1).

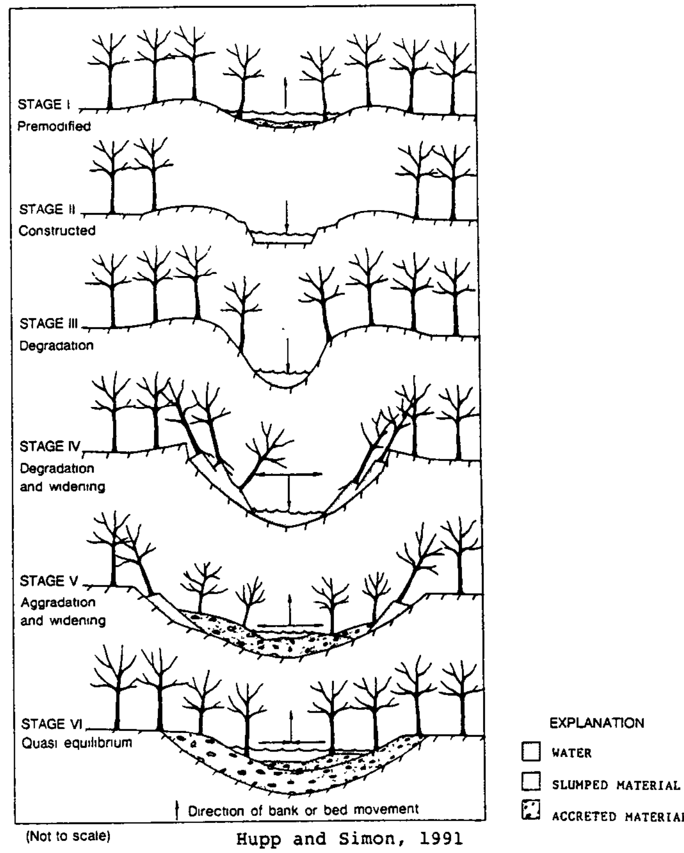


Figure 1.--Six stages of channel evolution.

The sediment-storage function of alluvial wetlands is well known, although not well understood (Trimble, 1977; Trimble, 1983; Richards, 1982; Walling, 1983; Phillips, 1989). Sediment-budget studies provide information on sediment storage, but typically do not differentiate among storage of sediment in channels, natural levees, flood plains, or terraces. Thus other means are needed to determine sedimentation rates in bottomlands.

Sigafoos (1964) and Everitt (1968) showed that sedimentation depths and rates on flood plains could be estimated by excavating buried tree roots and coring these trees for age. The technique was used extensively by Hupp (1987) in a previous study of the banks of channelized West Tennessee streams to estimate sedimentation rates. These bank-accretion rates closely agreed with rates determined from repeated channel-cross-section surveys (Simon and Hupp, 1987).

Several investigators have reported sedimentation rates for alluvial wetlands. Mitsch and others (1979), using sediment traps, estimated an average sedimentation rate of less than 0.003 foot per year in a cypress-tupelo swamp in southern Illinois. Johnston and others (1984) reported sedimentation rates of 0.08 foot per year for natural levees along a stream in Wisconsin, based on cesium-137 (^{137}Cs) dating, but did not estimate sedimentation rates over the broad extent of their wetland study area. Cooper and others (1987) used ^{137}Cs dating techniques to estimate sedimentation rates of less than 0.008 foot per year for a flood-plain swamp in North Carolina. Hupp and Morris (1990) reported mean sedimentation rates of 0.01 foot per year for sloughs and 0.002 foot year for "islands" (elevated portions of the flood plain) in a forested wetland on the Cache River in Arkansas.

Boto and Patrick (1979) discussed the role of wetlands in suspended-sediment removal, but indicated that most studies have been of tidal marshes or aquatic beds, rather than freshwater, forested wetlands. Sedimentation was studied in relation to rising water levels in coastal Louisiana forests by Conner and Day (1988). Delaune and others (1978) compared sedimentation and coastal subsidence.

Tree-ring analyses in wetlands are not common and are largely devoted to determining growth responses in relation to the frequency and magnitude of flooding (Mitsch and Rust, 1984), species distribution in relation to hydroperiod (Bedinger, 1971), nutrient cycling (Mitsch and others, 1979) in relation to volumes of runoff (Cleaveland and Stahle, 1989), or tree-growth models (Phipps, 1979). Several studies have related tree growth (basal area increment) to nutrient enrichment (Brown, 1981; Marois and Ewel, 1983; Brown and van Peer, 1989).

Table 1.--*Drainage area, stage of channel evolution, and presence or absence of levees or spoil banks at each study site*

Study site number	Study site location	Drainage area, in square miles	Stage of channel evolution[1]	Presence of levees or spoil banks
1	Beaver Creek at State Route 1 Bypass.	41.1	IV	Levees
2	Beaver Creek at State Route 22.	45.0	IV	Levees
3	Beech River at State Route 202.	191	V	Levees
4	Big Sandy River at State Route 69.	321	V	Spoil banks.
5	Hatchie River at State Route 3.	2,310	V	Spoil banks near bridge.
6	Hatchie River at State Route 54.	2,620	V	Spoil banks near bridge.
7	Hatchie River at State Route 57.	837	I	None
8	Middle Fork Forked Deer River at State Route 188.	473	V	Levees
9	Obion River at State Route 3.	1,870	V	Levees
10	South Fork Forked Deer River at State Route 54.	769	IV	Levees
11	Wolf River at Yager Drive.	208	V	None

[1]Simon and Hupp, 1987

Purpose and Scope

This report:

- presents sedimentation rates determined by geomorphic and tree-ring techniques,

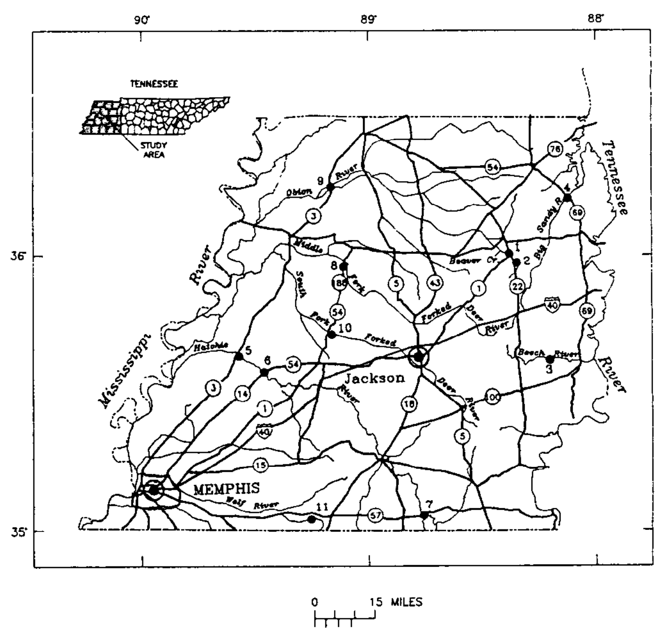
- describes variation of sedimentation rates with location upstream or downstream of highway crossings,
- describes variation of sedimentation rates with elevation,
- describes variation of sedimentation rates with drainage characteristics,
- describes temporal trends of sedimentation and tree growth,
- presents the results of modeling efforts to evaluate bottomland sedimentation, and
- characterizes vegetation patterns at 11 forested wetland study sites in West Tennessee.

The investigation included the establishment of 11 study sites in October 1987 and collection of field data from October 1987 to October 1989. Data used in this report include long-term sedimentation rates determined by geomorphic and tree-ring techniques, short-term sedimentation rates measured over clay-marker layers, results of field surveys, suspended-sediment data, growth-trend data from tree cores, and vegetation-plot data. Available stream-gage data were used to supplement the modeling efforts.

Description of Study Area

The 11 study sites are located in West Tennessee, which is in the Mississippi embayment and part of the Gulf Coastal Plain province (fig. 2). Nine of the 11 study sites are on the Obion, Forked Deer, Hatchie, and Wolf River systems, which drain into the Mississippi River. The remaining two study sites are on the Big Sandy and the Beech Rivers, which drain into the Tennessee River (fig. 2). Rivers in West Tennessee have sand-bed channels and predominantly silt-clay banks.

The Obion, Forked Deer, Hatchie, and Wolf River systems occupy valleys cut into unconsolidated Quaternary sediments (Miller and others, 1966; fig. 3). The study sites on these river systems are along reaches that flow through loess-derived alluvium, except for sites 1, 2 and 7, where the rivers flow through alluvium derived predominantly from the Tertiary Midway Group (Miller and others, 1966). The Big Sandy and the Beech Rivers generally are incised into sediments predominantly of Cretaceous age. The study sites on these rivers are along reaches that flow through alluvium derived mainly from the Cretaceous McNairy Sand and Coon Creek Formation (Miller and others, 1966; fig. 3).



EXPLANATION

•7 STUDY SITE AND NUMBER--Refer to table 1 for detailed site description

Figure 2.--Location of wetland study sites in West Tennessee

Unchannelized rivers in West Tennessee generally have low gradients, meandering alluvial channels, and broad, relatively flat flood

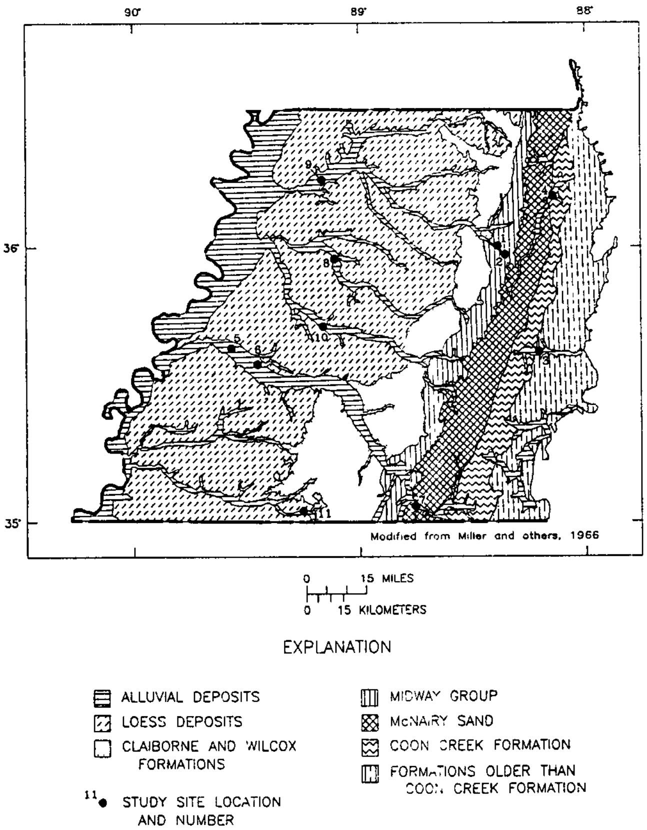


Figure 3 --Geology of West Tennessee and location of study sites

plains and terraces. Naturally vegetated flood plains and terraces are characterized by bottomland-hardwood forests, cypress-tupelo swamps, and marshes. Most perennial streams in West Tennessee were channelized in the early 1900's and have been dredged periodically since that time. Of the 11 study sites, 8 are on channelized rivers. The other 3 study sites are on the Hatchie River, which has not been channelized. However, segments of the Hatchie River have been straightened and enlarged near the bridges at sites 5 and 6. These segments are approximately 1,500 feet long and 3,000 feet long, respectively. Site 7, also on the Hatchie River, is the only study site at which the dimensions of the channel have not been altered (table 2).

The highway crossings at the 11 study sites consist of causeways (roadway embankments) that traverse the bottomlands and bridge structures that cross the river channels (figs. 4-14). Roadway embankments at nine of the study sites have been in place since the early 1900's (table 2). Sites 1, 5, and 9 are the only study sites with recently constructed roadway embankments, completed in 1988, 1974, and 1978, respectively.

Figures 4 through 14 also show the locations of vegetation sampling stations. The symbol used to mark the position of each station indicates the sedimentation rate and degree of drainage at that station. This information is discussed in detail in the following section.

METHODS FOR ESTIMATING SEDIMENTATION RATES

Rates of sedimentation on bottomland surfaces were measured using geomorphic and tree-ring techniques. Buried tree roots were excavated to determine the depth of sediment deposited since the tree germinated. Tree age was determined by taking an increment core from near the base of the tree; ring counts were then made from the biological center (first year of growth) to the outside ring. Depth of burial divided by tree age provides an estimate of average annual sedimentation (root-burial rate) near the tree (fig. 15). In the example shown in figure 15, excavation to the original roots shows 1 foot of deposition since germination, and tree ring analysis indicates that the tree is 20 years old. Therefore, the sedimentation rate near this tree is estimated to be 0.05 foot per year. This type of analysis has been termed dendrogeomorphic analysis. For more detailed descriptions of dendrogeomorphic analyses see Sigafoos (1964); Everitt (1968); Alestalo (1971); Shroder (1980); Shroder and Butler (1987); Hupp and others (1987); and Hupp (1988).

Table 2.--*History of highway-crossing construction and channel modification at the study sites*

[--, no data]

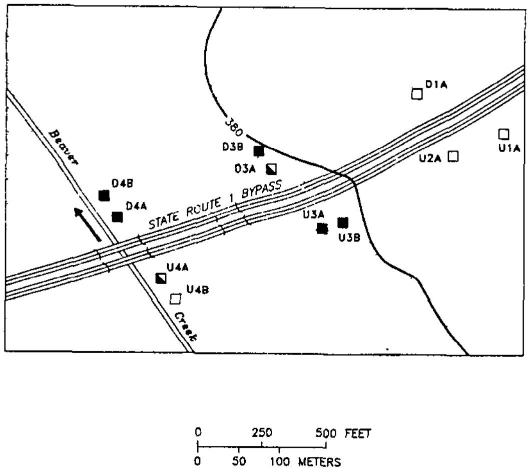
Study site number	Original highway crossing construction: Earliest records[1]	Original highway crossing construction: Visible on maps	Highway crossing modification	Channelization: Original	Channelization: Modified
1	1988	--	Not modified	1917-26	None
2	1923	1900	1928	1917-26	None
3	1940's	1937	1985	1920's	None
4	1922	--	1986	1918	
5	1930	--	1974	1930 (in reach)	
6	1945	1937	Not modified	1949 (in reach)	
7	1934	1923	Not modified	Not channelized	
8	--	1911	1960,1988,1989	1917-26	Several
9	1978	--	Not modified	1917-26	Several
10	1916	--	1959,1976,1985	1917-26	1940's, 1968-1969
11	--	1923	Not modified	Before 1923	None

[1]Tennessee Department of Transportation, unpublished data.

Many tree ages were determined in the field with the aid of a hand lens; however, most cores were returned to the laboratory for microscopic examination and cross dating (Phipps, 1985) as a check on field-dating accuracy and for later use in tree-growth analyses. Field dating generally fell within 4 percent of lab dating. Errors of less than 4 percent of the actual age for trees older than 25 years had little effect on the calculation of the average sedimentation rate. Tree species that do not have clearly defined ring boundaries were intentionally avoided. Most of the sampled trees were tupelo gum, bald cypress, or various hydric species of ash, hickory or oak. All of the tupelo gum and bald cypress cores were cross-dated because of the potential for false or missing rings.

Sampling stations were established upstream and downstream from highway crossings and generally 200 feet or more from the edge of the channel (figs. 4-14). This sampling design was used to determine the spatial distribution of fine-grained sedimentation (silt and clay, and small amounts of fine sand) over bottomlands, while minimizing sampling of relatively coarse levee sedimentation occurring near the channels. Root-burial rates were measured at between 4 and 19 trees at each sampling station (few samples were taken at sampling-stations with no sedimentation). A total of 1,551 trees were sampled for sedimentation rate.

Short-term rates of sedimentation were measured at each sampling station by placing an artificial marker layer on the ground surface. White powdered clay was poured onto a cleared area to a depth of 1 to 2 inches. This powdered clay becomes a fixed plastic marker after absorption of moisture from the ground (Baumann and others, 1984; Kleiss and others, 1989). All clay markers were in place for at least one hydroperiod or several inundation events. At the end of the field portion of the study, the clay pads were checked for depth of sedimentation above the marker layer. These data were compared to the long-term data obtained from root-burial rates.



EXPLANATION

FORESTED AREA

—380— LAND SURFACE ELEVATION CONTOUR, IN FEET ABOVE SEA LEVEL

STREAMFLOW DIRECTION

U4B SAMPLING STATION AND DESIGNATION

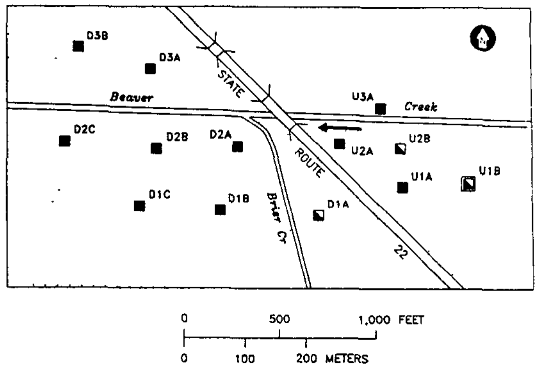
MEAN SEDIMENTATION RATE

LOW--Less than 0.005 foot per year

MEDIUM--0 005 to 0 013 foot per year

HIGH--Greater than 0.013 foot per year

Figure 4 --Study site 1, Beaver Creek at State Route 1 Bypass, Carroll County, Tennessee, and sampling sites



EXPLANATION

FORESTED AREA

STREAMFLOW DIRECTION

D1C SAMPLING STATION AND DESIGNATION

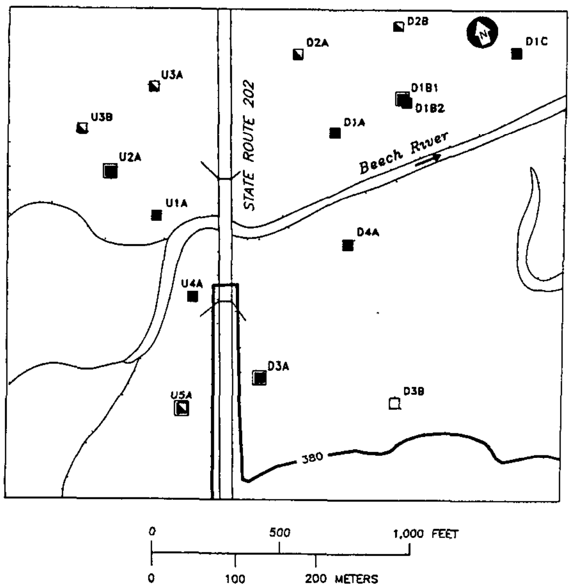
PONDED CONDITIONS

MEAN SEDIMENTATION RATE

MEDIUM--0 005 to 0.013 foot per year

HIGH--Greater than 0.013 foot per year

Figure 5.--Study site 2, Beaver Creek at State Route 22, Carroll County, Tennessee, and sampling sites.



EXPLANATION

FORESTED AREA

— 380 — LAND SURFACE ELEVATION CONTOUR, IN FEET ABOVE SEA LEVEL

STREAMFLOW DIRECTION

D3B SAMPLING STATION AND DESIGNATION

PONDED CONDITIONS

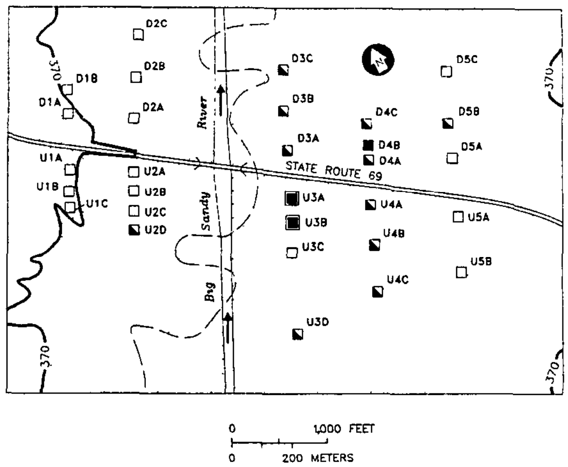
MEAN SEDIMENTATION RATE

LOW--Less than 0.005 foot per year

MEDIUM--0 005 to 0 013 foot per year

HIGH--Greater than 0.013 foot per year

Figure 6 --Study site 3, Beech River at State Route 202, Decatur County, Tennessee, and sampling sites



EXPLANATION

FORESTED AREA

—370— LAND SURFACE ELEVATION CONTOUR, IN FEET ABOVE SEA LEVEL

OLD CHANNEL

STREAMFLOW DIRECTION

U3D SAMPLING STATION AND DESIGNATION

PONDED CONDITIONS

MEAN SEDIMENTATION RATE

LOW--Less than 0 005 foot per year

MEDIUM--0.005 to 0.013 foot per year

HIGH--Greater than 0 013 foot per year

Figure 7 --Study site 4, Big Sandy River at State Route 69, Henry and Benton Counties, Tennessee, and sampling sites

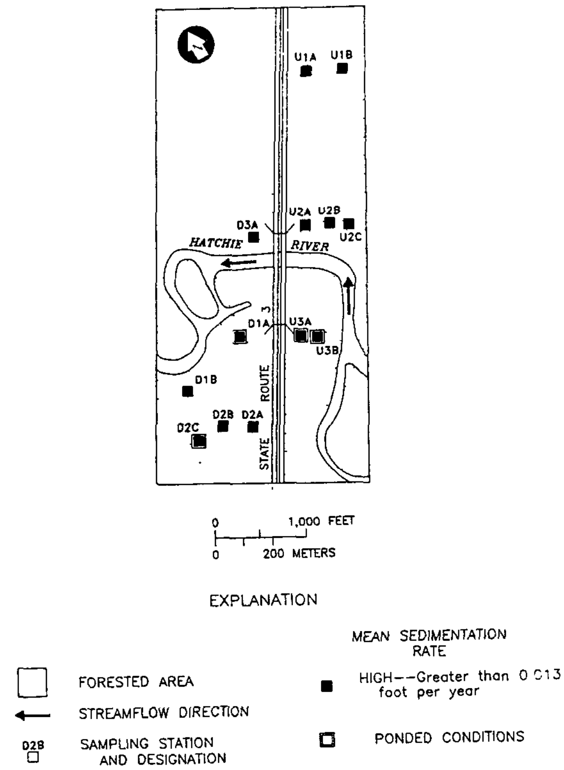


Figure 8.--Study site 5, Hatchie River at State Route 3, Lauderdale and Tipton Counties, Tennessee, and sampling sites.

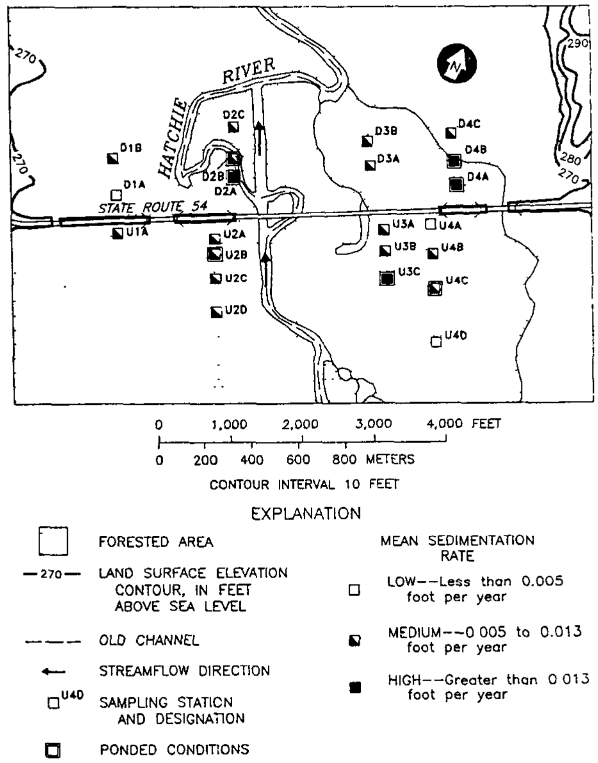


Figure 9.--Study site 6, Hatchie River at State Route 54, Tipton and Haywood Counties, Tennessee, and sampling sites.

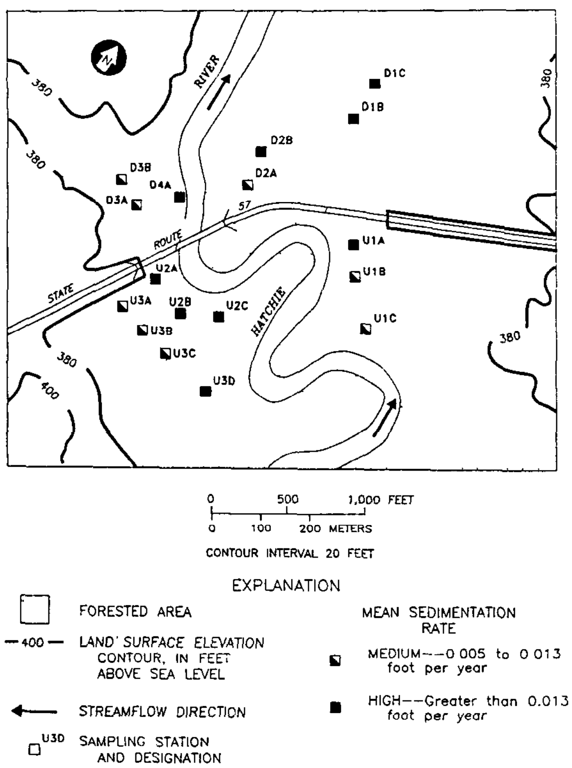


Figure 10.--Study site 7, Hatchie River at State Route 57, Hardeman County, Tennessee, and sampling sites

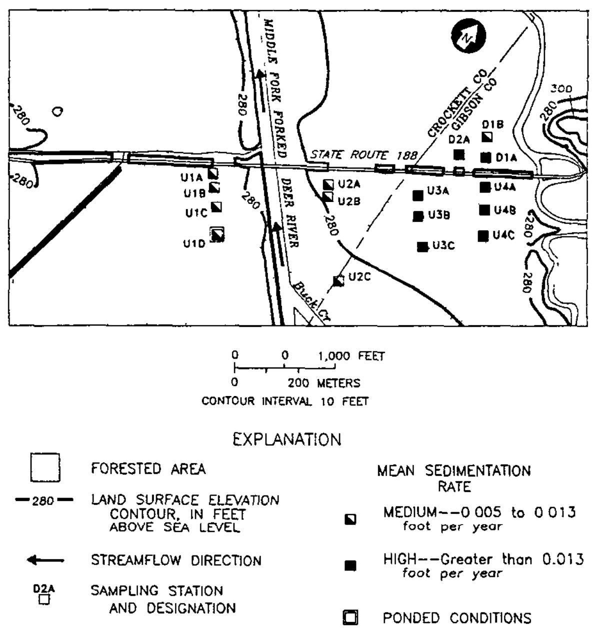
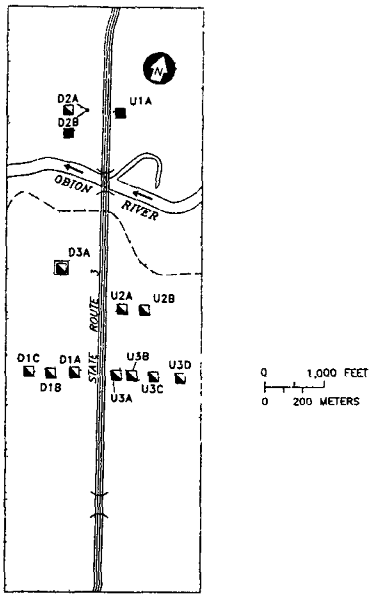


Figure 11.--Study site 8, Middle Fork Forked Deer River at State Route 188, Gibson and Crockett Counties, Tennessee, and sampling sites.



EXPLANATION

FORESTED AREA

OLD DRAINAGE CANAL

STREAMFLOW DIRECTION

D1C SAMPLING STATION AND DESIGNATION

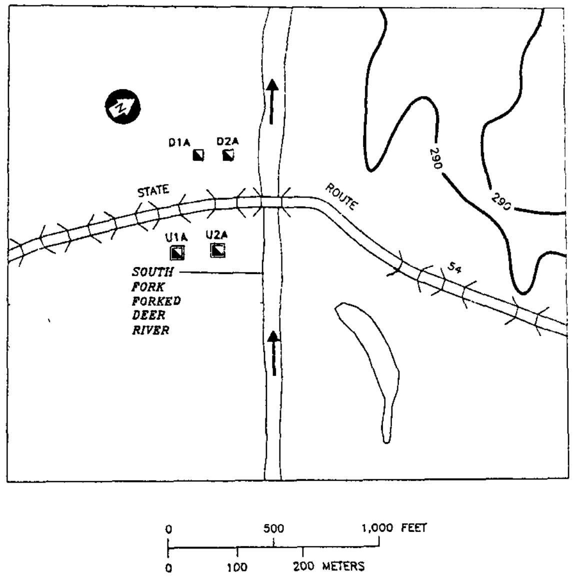
MEAN SEDIMENTATION RATE

MEDIUM--0 005 to 0 013 foot per year

HIGH--Greater than 0 013 foot per year

PONDED CONDITIONS

Figure 12.--Study site 9, Obion River at State Route 3, Obion County, Tennessee, and sampling sites.



EXPLANATION

FORESTED AREA

290 LAND SURFACE ELEVATION CONTOUR, IN FEET ABOVE SEA LEVEL

STREAMFLOW DIRECTION

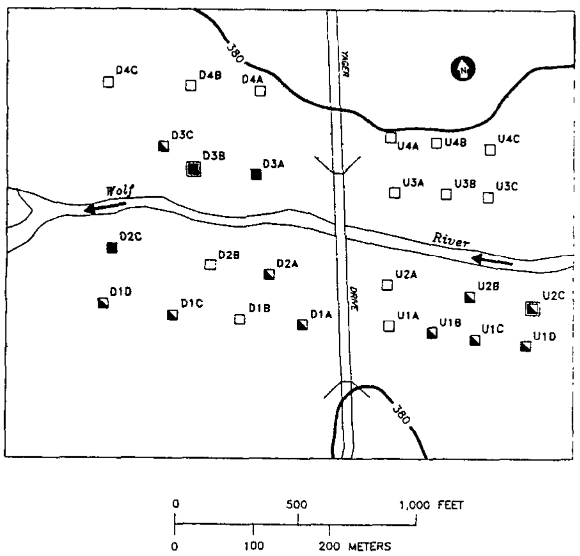
U1A SAMPLING STATION AND DESIGNATION

MEAN SEDIMENTATION RATE

MEDIUM--0 005 to 0 013 foot per year

PONDED CONDITIONS

Figure 13.--Study site 10, South Fork Forked Deer River at State Route 54, Haywood County, Tennessee, and sampling sites.



EXPLANATION

FORESTED AREA

380 LAND SURFACE ELEVATION CONTOUR, IN FEET ABOVE SEA LEVEL

STREAMFLOW DIRECTION

SAMPLING STATION AND DESIGNATION

PONDED CONDITIONS

MEAN SEDIMENTATION RATE

LOW--Less than 0 005 foot per year

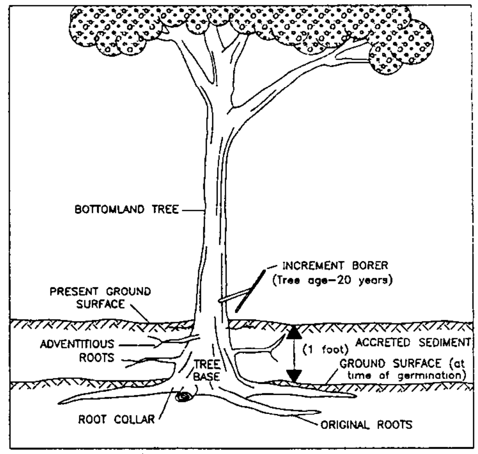
MEDIUM--0 005 to 0.013 foot per year

HIGH--Greater than 0 013 foot per year

Figure 14.--Study site 11, Wolf River at Yager Drive, Fayette County, Tennessee, and sampling sites

Sand splays were observed in localized areas on most flood plains downstream from bridges; several areas were sampled for rate of sand deposition. Sand deposition was not included in statistical comparisons of upstream and downstream sedimentation rates.

Several samples of deposited sediment were analyzed for percent clay, percent silt, and percent sand. Sediments deposited on the bottomlands (excluding near-channel sand splays) consisted of clay, silt, and small amounts of fine sand (table 3).



(Not to scale)

Figure 15.--Diagram of "buried" bottomland tree.

Several factors determine sediment concentrations available for deposition in bottomlands: drainage area, drainage density, geology of the source area, land use in the basin upstream from the site, and channelization. These factors were assumed to be constant among sampling stations at a given study site.

SPATIAL VARIATION OF SEDIMENTATION RATES

Sedimentation does not occur uniformly over the bottomlands studied in this investigation (figs. 4-14). Differences of more than 100 percent are common between lower and upper quartile values at individual sampling stations (table 4). Mean sedimentation rates range from -0.002 foot per year, reflecting erosion at station U1A, Site 4, to 0.136 foot per year in a sand splay at Station D4A, Site 3 (table 4). Typically, most sample means at a given site are within the range from 0.001 to 0.05 foot per year (table 4).

Burial depth of tree roots was weakly related to tree age at most of the study sites. Figure 16 shows burial depths and tree ages for site 7. This site is typical of sites at which a

Table 3.--*Particle-size analysis of deposited sediments at selected sampling stations*

Study site	Sampling station	Percent clay	Percent silt	Percent sand
Site 2	U2B	34.5	64.2	1.3
Site 2	U3A	20.8	78.4	.8
Site 2	D2B	9.9	67.6	22.5
Site 2	D3B	18.4	77.8	3.8
Site 3	U1A	21.2	68.5	10.3
Site 3	U5A	29.9	55.4	14.7
Site 3	D2B	46.6	48.4	5.0
Site 3	D3B	30.9	50.2	18.9
Site 4	U2C	36.1	61.3	2.6
Site 4	U3B	30.6	69.2	.2
Site 4	D2B	25.1	50.9	24.0
Site 5	U2B	14.6	85.1	.3
Site 5	D2A	23.0	71.9	5.1
Site 6	U2B	74.6	25.0	.4
Site 6	U4B	59.5	34.8	5.7
Site 6	D2B	28.5	66.4	5.1
Site 6	D4B	42.8	57.1	.1
Site 8	U1A	65.0	34.6	.4
Site 8	U2B	13.4	69.0	17.6
Site 9	U1A	41.6	57.4	1.0
Site 9	U3A	33.3	65.7	1.0
Site 9	D1B	43.3	56.5	.2
Site 9	D2A	31.7	68.0	.3
Site 11	U2B	47.9	47.7	4.4
Site 11	U4B	14.6	37.1	48.3
Site 11	D1C	51.6	44.9	3.5

Table 4.--*Sedimentation rates and elevations at sampling stations*

[SS, sampling station; N, number of trees sampled; MEAN, mean deposition rate in feet per year; Q1, lower quartile deposition rate in feet per year; MED, median deposition rate in feet per year; Q3, upper quartile deposition rate in feet per year; ME, median elevation in feet; AE, median elevation, adjusted for valley slope, in feet; CME, clay-marker elevation, adjusted for valley slope; --, no data]

Site 1

	Sedimentation rate							
SS	N	MEAN	Q1	MED	Q3	ME	AE	CME
D1A	10	0.000	0.000	0.000	0.000	--	--	377.5
D3A	11	.005	.000	.003	.008	--	--	376.9
D3B	6	.018	.003	.016	.029	--	--	376.8
D4A	6	.015	.012	.015	.020	--	--	376.5
D4B	10	.018	.010	.015	.021	--	--	376.5
U1A	11	.001	.000	.000	.002	--	--	377.5
U2A	10	.002	.000	.001	.004	--	--	377.0
U3A	11	.022	.014	.023	.032	--	--	376.8
U3B	11	.022	.016	.023	.029	--	--	376.8
U4A	9	.005	.001	.005	.007	--	--	376.5
U4B	8	.003	.001	.003	.004	--	--	376.5

Site 2

SS	N	MEAN	Q1	MED	Q3	ME	AE	CME
D1A	9	0.006	0.004	0.005	0.010	--	--	--
D1B	9	.021	.014	.018	.031	--	--	--
D1C	10	.026	.022	.023	.033	--	--	--
D2A	9	.020	.009	.019	.030	--	--	--
D2B	9	.021	.010	.017	.028	--	--	--
D2C	9	.024	.022	.025	.029	--	--	--
D3A[a]	10	.026	.018	.025	.036	369.5	369.7	369.3
D3B	10	.034	.016	.026	.045	369.5	369.8	369.7
U1A	10	.027	.020	.022	.034	--	--	--
U1B[b]	10	.008	.002	.006	.014	369.4	369.0	369.6
U2A	9	.022	.018	.020	.033	370.0	369.9	369.5
U2B	8	.009	.004	.009	.016	369.3	369.0	369.7
U3A	19	.022	.011	.018	.030	367.8	367.4	367.7

[a]Sand-splay area.
[b]Ponded.

Table 4.--*Sedimentation rates and elevations at sampling stations*--Continued

[SS, sampling station; N, number of trees sampled; MEAN, mean deposition rate in feet per year; Q1, lower quartile deposition rate in feet per year; MED, median deposition rate in feet per year; Q3, upper quartile deposition rate in feet per year; ME, median elevation in feet; AE, median elevation, adjusted for valley slope, in feet; CME, clay-marker elevation, adjusted for valley slope; --, no data]

Site 3

SS	N	MEAN	Q1	MED	Q3	ME	AE	CME
D1A[a]	4	0.071	0.058	0.072	0.083	--	--	368.5
D1B1[b]	6	.035	.014	.026	.060	365.1	365.4	--
D1B2	6	.016	.012	.013	.022	366.4	366.7	366.0
D1C	7	.018	.012	.015	.029	366.0	366.4	366.4
D2A	10	.010	.009	.010	.012	366.0	366.0	366.1
D2B	8	.011	.004	.011	.016	365.9	366.2	366.4
D3A[b]	5	.024	.008	.017	.042	369.8	369.8	368.7
D3B	5	.003	.001	.003	.005	368.6	368.8	369.2
D4A[a]	5	.136	.032	.051	.283	370.6	370.8	371.0
U1A	9	.028	.015	.026	.042	367.5	367.4	367.4
U2A[b]	6	.023	.017	.023	.028	366.3	366.1	366.1
U3A	9	.008	.006	.007	.011	367.2	367.1	366.6
U3B	10	.005	.002	.005	.008	367.9	367.6	367.2
U4A	5	.015	.005	.015	.024	369.2	369.1	369.4
U5A[b]	9	.009	.006	.008	.012	369.8	369.8	370.0

Site 4

SS	N	MEAN	Q1	MED	Q3	ME	AE	CME
D1A	10	0.000	-0.001	0.000	0.000	369.6	369.6	--
D1B	10	.002	.000	.000	.003	367.1	367.2	--
D2A	9	.002	.000	.000	.006	367.3	367.3	367.3
D2B	8	.002	.000	.001	.003	367.1	367.2	367.1
D2C	8	.004	.001	.003	.007	365.5	365.7	365.3
D3A	6	.010	.007	.008	.012	366.7	366.7	366.7
D3B	8	.008	.005	.007	.011	365.3	365.4	365.9
D3C	7	.006	.002	.005	.010	365.8	366.0	366.1
D4A	10	.009	.004	.008	.015	366.0	366.0	--
D4B	10	.016	.007	.014	.022	366.2	366.3	--
D4C	10	.012	.001	.010	.021	366.6	366.7	--
D5A	8	.004	.001	.004	.006	364.5	364.5	364.7
D5B	9	.005	.003	.005	.008	364.9	365.0	365.4
D5C	8	.003	.001	.003	.005	365.4	365.6	366.3
U1A	7	-.002	-.005	-.003	.000	371.2	371.2	371.5
U1B	8	-.001	-.007	.001	.004	371.0	370.9	370.9
U1C	7	-.001	-.004	.000	.001	371.3	371.1	371.5
U2A	8	.001	.000	.000	.001	365.7	365.6	365.4
U2B	9	.002	.000	.001	.003	366.1	366.0	366.0
U2C	9	.002	.000	.002	.004	366.5	366.3	366.3
U2D	8	.005	.000	.006	.010	367.8	367.6	367.2
U3A[b]	9	.024	.017	.021	.032	365.6	365.6	366.7
U3B[b]	9	.025	.019	.025	.030	365.2	365.1	365.2
U3C	6	.004	.000	.004	.009	365.3	365.1	365.2
U3D	10	.005	.000	.006	.008	365.4	365.0	365.4
U4A	9	.012	.008	.012	.014	365.6	365.5	365.1
U4B	8	.008	.000	.006	.010	365.5	365.4	365.6
U4C	13	.005	.002	.004	.008	365.6	365.4	365.2
U5A	9	.004	.001	.003	.006	365.0	365.0	364.8
U5B	7	.000	.001	.000	.001	366.5	366.3	366.6

[a]Sand-splay area.
[b]Ponded.

Table 4.--*Sedimentation rates and elevations at sampling stations*--Continued

[SS, sampling station; N, number of trees sampled; MEAN, mean deposition rate in feet per year; Q1, lower quartile deposition rate in feet per year; MED, median deposition rate in feet per year; Q3, upper quartile deposition rate in feet per year; ME, median elevation in feet; AE, median elevation, adjusted for valley slope, in feet; CME, clay-marker elevation, adjusted for valley slope; --, no data]

Site 5

SS	N	MEAN	Q1	MED	Q3	ME	AE	CME
D1A[b]	11	0.033	0.019	0.035	0.041	250.1	250.1	249.4
D1B[a]	10	.042	.028	.035	.060	250.1	250.2	250.6
D2A	8	.030	.026	.030	.035	250.4	250.4	250.8
D2B	10	.022	.018	.022	.025	250.1	250.2	250.2
D2C[b]	7	.024	.011	.016	.044	249.4	249.5	248.6
D3A[a]	7	.065	.046	.064	.071	252.4	252.4	252.4
U1A	8	.017	.013	.017	.019	252.1	252.1	252.1
U1B	8	.020	.011	.021	.028	252.3	252.1	252.0
U2A	8	.014	.006	.010	.022	251.2	251.2	251.1
U2B	8	.025	.012	.028	.035	253.1	253.0	253.6
U2C	8	.023	.016	.019	.022	253.4	253.2	253.8
U3A[b]	10	.032	.016	.027	.051	248.1	248.1	248.2
U3B[b]	11	.030	.014	.030	.036	249.5	249.4	249.6

Site 6

SS	N	MEAN	Q1	MED	Q3	ME	AE	CME
D1A	11	0.003	0.001	0.002	0.004	266.0	266.1	266.0
D1B	13	.005	.002	.004	.005	265.0	265.2	265.3
D2A[b]	13	.017	.011	.017	.026	263.0	262.7	262.9
D2B[b]	11	.012	.009	.010	.017	264.2	264.4	263.8
D2C	10	.007	.005	.007	.010	266.1	266.4	266.4
D3A	10	.006	.002	.007	.008	265.2	265.4	265.4
D3B	9	.005	.002	.004	.008	264.4	264.6	264.3
D4A[b]	11	.018	.008	.012	.025	262.0	262.1	261.7
D4B[b]	10	.028	.016	.024	.033	260.4	260.5	261.2
D4C	10	.006	.002	.006	.008	265.7	266.0	266.0
U1A	12	.009	.004	.007	.014	265.7	265.6	265.7
U2A	11	.005	.001	.004	.008	267.3	267.2	267.1
U2B[b]	9	.011	.006	.011	.015	261.2	261.0	260.9
U2C	13	.005	.003	.004	.006	265.2	265.0	264.9
U2D	11	.007	.000	.005	.011	264.4	264.0	263.7
U3A	10	.008	.003	.006	.012	263.6	263.5	263.2
U3B	10	.011	.008	.010	.014	263.8	263.6	263.5
U3C[b]	10	.017	.012	.020	.022	261.1	260.8	260.3
U4A	10	.002	.001	.002	.004	265.4	265.4	265.5
U4B	10	.007	.004	.006	.010	266.1	265.9	265.4
U4C[b]	13	.005	.002	.005	.010	264.6	264.2	263.5
U4D	10	.004	.002	.004	.005	265.3	264.7	266.0

[a]Sand-splay area.
[b]Ponded.

Table 4.--*Sedimentation rates and elevations at sampling stations*--Continued

[SS, sampling station; N, number of trees sampled; MEAN, mean deposition rate in feet per year; Q1, lower quartile deposition rate in feet per year; MED, median deposition rate in feet per year; Q3, upper quartile deposition rate in feet per year; ME, median elevation in feet; AE, median elevation, adjusted for valley slope, in feet; CME, clay-marker elevation, adjusted for valley slope; --, no data]

Site 7

SS	N	MEAN	Q1	MED	Q3	ME	AE	CME
D1B	11	0.016	0.011	0.012	0.021	367.6	367.8	367.7
D1C	11	.015	.009	.012	.021	366.3	366.5	366.5
D2A	10	.012	.009	.011	.015	367.8	367.9	369.0
D2B	11	.019	.014	.017	.024	367.7	367.8	367.8
D3A	10	.008	.005	.007	.011	367.7	367.8	367.6
D3B	10	.010	.003	.010	.014	368.5	368.6	368.7
D4A	7	.024	.013	.027	.031	--	--	--
U1A	10	.035	.016	.019	.052	364.8	364.7	364.6
U1B	10	.008	.004	.007	.012	370.6	370.5	370.8
U1C	10	.014	.009	.013	.019	368.8	368.6	368.5
U2A	10	.039	.019	.032	.055	364.6	364.6	363.9
U2B	10	.018	.010	.017	.025	367.3	367.1	366.8
U2C	10	.037	.025	.036	.044	366.6	366.3	366.0
U3A	9	.005	.002	.004	.008	367.4	367.3	367.4
U3B	10	.010	.004	.011	.014	366.7	366.5	367.0
U3C	10	.012	.008	.012	.016	368.5	368.2	368.7
U3D	10	.016	.011	.015	.021	368.2	367.8	367.4

Site 8

SS	N	MEAN	Q1	MED	Q3	ME	AE	CME
D1A	5	0.018	0.005	0.018	0.031	--	--	277.1
D1B	6	.010	.006	.010	.014	--	--	--
D2A	5	.016	.009	.015	.025	--	--	276.9
U1A	6	.011	.008	.009	.017	--	--	278.9
U1B	7	.010	.004	.007	.016	--	--	279.9
U1C	6	.006	.004	.006	.007	--	--	278.9
U1D[b]	6	.011	.006	.011	.015	--	--	277.6
U2A	5	.006	.004	.006	.007	--	--	278.9
U2B	4	.012	.008	.012	.016	--	--	279.5
U2C	5	.009	.000	.011	.017	--	--	279.4
U3A	7	.020	.008	.016	.022	--	--	277.3
U3B	6	.017	.012	.018	.022	--	--	277.8
U3C	5	.016	.008	.020	.023	--	--	278.0
U4A	5	.025	.019	.023	.031	--	--	277.0
U4B	5	.025	.018	.024	.032	--	--	277.4
U4C	5	.021	.017	.024	.024	--	--	277.7

[b]Ponded.

Table 4.--*Sedimentation rates and elevations at sampling stations*--Continued

[SS, sampling station; N, number of trees sampled; MEAN, mean deposition rate in feet per year; Q1, lower quartile deposition rate in feet per year; MED, median deposition rate in feet per year; Q3, upper quartile deposition rate in feet per year; ME, median elevation in feet; AE, median elevation, adjusted for valley slope, in feet; CME, clay-marker elevation, adjusted for valley slope; --, no data]

Site 9

SS	N	MEAN	Q1	MED	Q3	ME	AE	CME
D1A	10	0.008	0.005	0.006	0.011	375.1	375.2	375.2
D1B	10	.009	.006	.009	.011	375.1	375.4	375.4
D1C	11	.006	.004	.005	.010	375.1	375.5	375.5
D2A	3	.005	.004	.005	.006	374.3	374.4	--
D2B	2	.024	.018	.024	.028	369.7	369.8	--
D3A[b]	8	.012	.009	.012	.014	366.5	366.7	366.7
U1A	12	.025	.012	.016	.026	372.1	372.0	--
U2A	10	.006	.003	.007	.009	375.4	375.3	375.3
U2B	8	.010	.005	.010	.015	375.4	375.2	375.2
U3A	6	.005	.002	.006	.008	375.8	375.7	375.9
U3B	10	.006	.003	.005	.009	375.8	375.6	375.6
U3C	9	.012	.007	.009	.016	376.3	376.0	376.0
U3D	8	.006	.004	.005	.009	375.7	375.2	375.2

Site 10

SS	N	MEAN	Q1	MED	Q3	ME	AE	CME
D1A	7	0.009	0.003	0.007	0.016	--	--	--
D2A	8	.006	.001	.006	.010	--	--	--
U1A[b]	5	.012	.008	.011	.016	--	--	--
U2A[b]	9	.011	.005	.008	.016	--	--	--

Site 11

SS	N	MEAN	Q1	MED	Q3	ME	AE	CME
D1A	9	0.006	0.001	0.003	0.011	373.0	373.1	372.9
D1B	8	.004	.0001	.003	.008	372.8	373.6	373.4
D1C	9	.006	.001	.002	.011	372.1	372.5	372.3
D1D	10	.006	.000	.002	.008	371.8	372.5	372.4
D2A	9	.008	.003	.007	.010	372.6	372.8	373.5
D2B	8	.004	.000	.002	.007	373.0	373.3	372.9
D2C	6	.021	.019	.023	.025	372.7	373.3	372.5
D3A	10	.016	.010	.016	.022	372.6	373.0	372.8
D3B[b]	11	.016	.000	.012	.033	371.8	372.4	372.0
D3C	9	.009	.003	.008	.010	--	--	--
D4A	8	.002	.000	.0002	.001	375.6	375.8	375.8
D4B	8	-.001	-.002	.000	.000	373.3	373.7	374.0
D4C	10	.003	.000	.002	.006	372.5	373.1	372.8
U1A	9	.004	.001	.002	.006	374.1	374.2	373.6
U1B	8	.007	.002	.003	.015	374.7	374.4	374.0
U1C	9	.006	.002	.005	.011	374.5	374.1	374.2
U1D	9	.005	.000	.003	.008	373.8	373.3	373.8
U2A	8	.003	.000	.002	.004	373.7	373.6	373.5
U2B	8	.006	.001	.006	.011	374.8	374.3	373.8
U2C[b]	8	.006	.000	.003	.010	375.6	375.0	374.8
U3A	6	.000	.000	.000	.000	373.4	373.2	373.2
U3B	6	.000	.000	.000	.001	373.3	372.9	372.9
U3C	6	.000	.000	.000	.000	373.4	372.9	372.7
U4A	6	.000	.000	.000	.000	374.5	374.4	374.6
U4B	6	.001	.000	.001	.002	373.8	373.5	373.7
U4C	8	.001	.000	.001	.002	374.2	373.7	373.5

[b]Ponded.

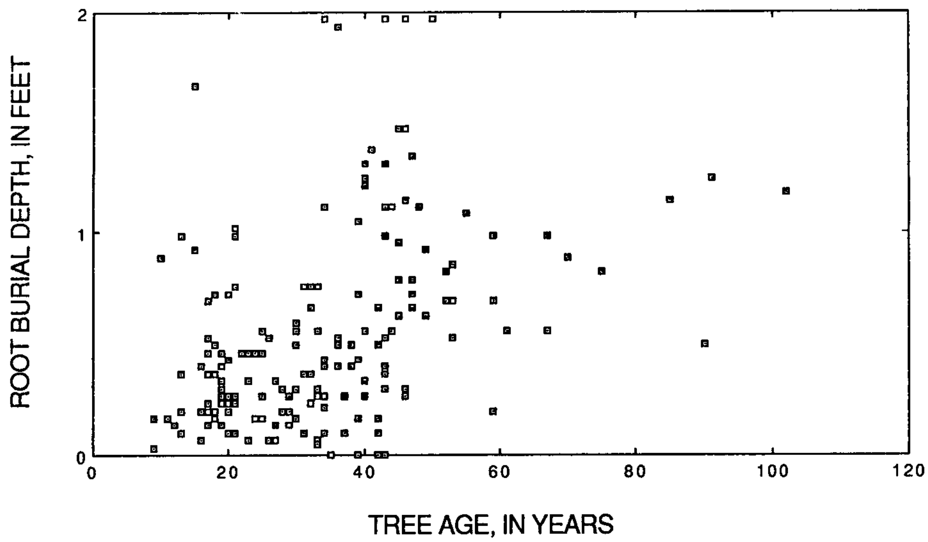


Figure 16 --Relation between root-burial depth and tree age at study site 7.

noticeable trend was observed. The weakness in the relation between tree age and depth of burial seems to be the result of the high degree of spatial variation of sedimentation. Variability of sedimentation rates was evaluated with respect to several spatial factors: location of sampling stations either upstream or downstream from highway crossings, elevation of sampling stations, and drainage characteristics of sampling stations.

Variation Between Upstream and Downstream Stations

Sedimentation rates upstream from highway crossings were tested to see if they were significantly different from downstream sedimentation rates; downstream sedimentation rates were assumed to represent sedimentation rates that would be observed if highway crossings were not present. Root-burial rates would be expected to be greater upstream of highway crossings, if backwater has accelerated sedimentation. Backwater caused by the highway crossing would be expected to increase sedimentation because of reduced velocities and increased depth of water.

Student's t-tests were performed on the ranks of sedimentation-rate data sorted by location either upstream or downstream from highway crossings. The null hypothesis (H_0) was that there was no difference between upstream and downstream sedimentation rates. The significance level (alpha) for all tests in this report was 0.05 indicating the maximum probability of rejecting a true null hypothesis. The p-values indicate the maximum probability that differences are simply because of chance. Thus, for p-values less than alpha (0.05), the H_0 was rejected. Root-burial rates from sand splays, observed downstream of bridges, were not included in the comparisons.

Upstream sedimentation rates were not significantly different from downstream rates at 7 of the 11 study sites (fig. 17; table 4). At the remaining four study sites, downstream rates were significantly greater than upstream rates (site 4, 5, 6, and 7; figs. 7, 8, 9, 10, 17). At no study site was the upstream sedimentation rate significantly greater than the downstream rate. This result suggests that, at the sites studied, highway crossings do not have a significant effect on sedimentation rates.

Variation with Topographic Elevation

Elevations of the bottomland surface were variable among sampling stations at each of the study sites. Potential for sedimentation in bottomlands is greater in areas of lower elevation because flooding occurs more frequently and for longer periods in these areas than in areas of higher elevation. Hupp and Morris (1990) observed an inverse correlation between sedimentation and topographic elevation in Black Swamp, Arkansas. In this study, sedimentation rates were checked for correlation with topographic elevation to determine whether elevation should be included in upstream-downstream comparisons.

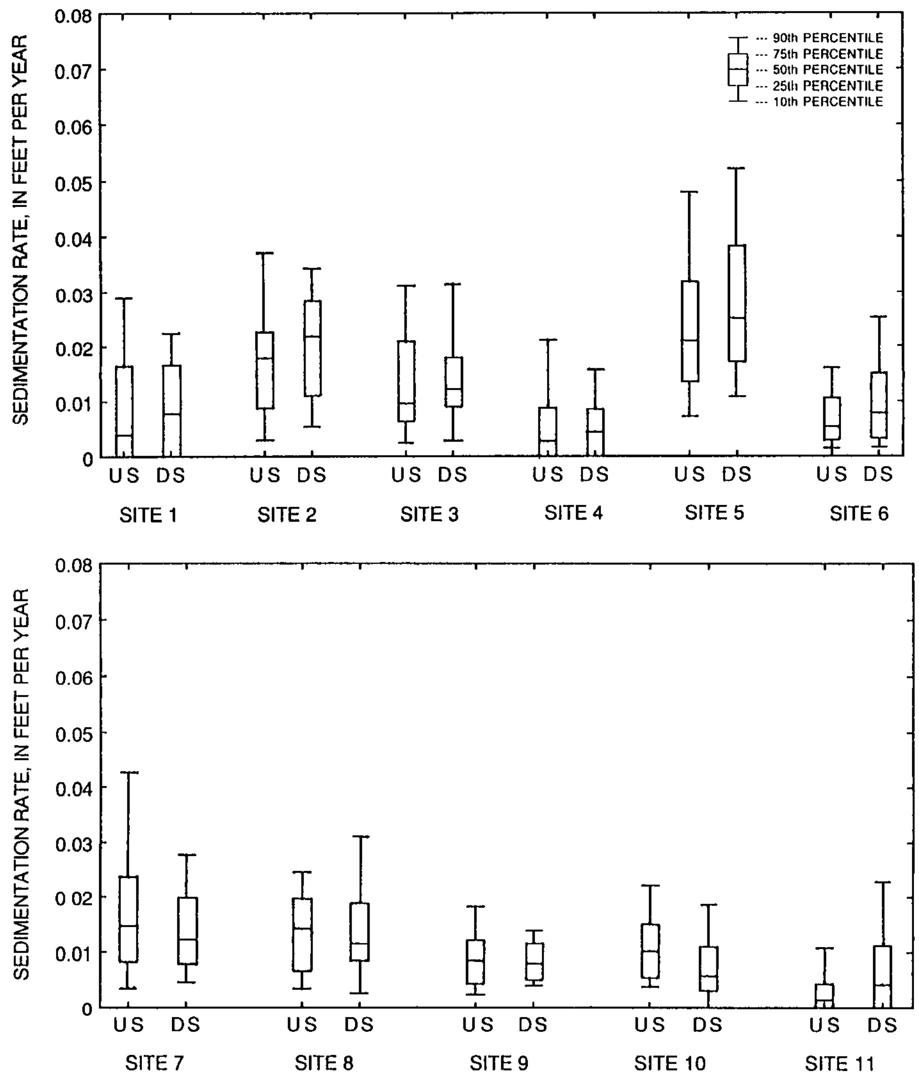


Figure 17.--Sedimentation rates upstream (US) and downstream (DS) from highway crossings at study sites

Correlation of sedimentation rate with topographic elevation generally is stronger at study sites on the unchannelized streams than at sites on the channelized streams, based on analysis of variance (ANOVA) tests of sedimentation rates by elevation groups (fig. 18). Flood-plain flow and ponding patterns are often altered as a result of channel relocation, spoil bank or levee construction (usually constructed parallel to channelized rivers), and ditch construction (often dammed by beavers). These alterations may explain why sedimentation rates are less strongly correlated with elevation at sites on channelized streams than at sites on unchannelized streams.

An inverse correlation between mean sedimentation rate and sampling-station elevation, adjusted to remove down-valley slope, was observed at study sites 4, 5, 6, 7, and 8 (figs. 7, 8, 9, 10, 11, 19). At study site 4 (fig. 7), the highest sedimentation rates occurred at the lowest elevations, and the lowest rates occurred at the highest elevations, but there was

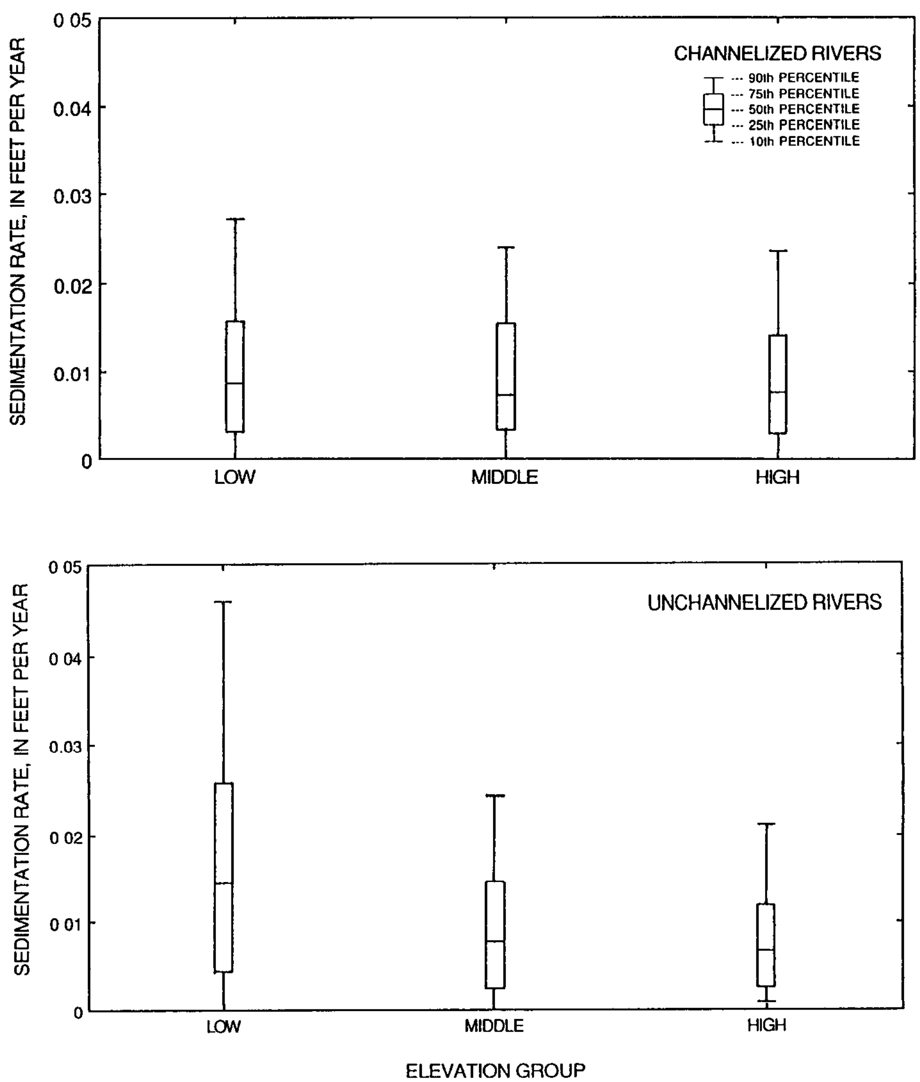


Figure 18.--Sedimentation rates by low, middle, and high sampling-station elevation groups for sites on channelized and unchannelized rivers.

substantial scatter about this weak overall trend (fig. 19). At the remaining study sites, mean sedimentation rate was not significantly correlated with elevation.

At the five study sites where sedimentation rates were correlated with elevation (fig. 19), sampling stations were categorized into high, middle, and low elevation groups before upstream-downstream comparison tests were performed: a two-way factorial ANOVA was performed on the ranks of sedimentation rates. Elevation groups (high, middle, and low) were assigned to divide the range of sampling-station elevations at each study site into three equal increments.

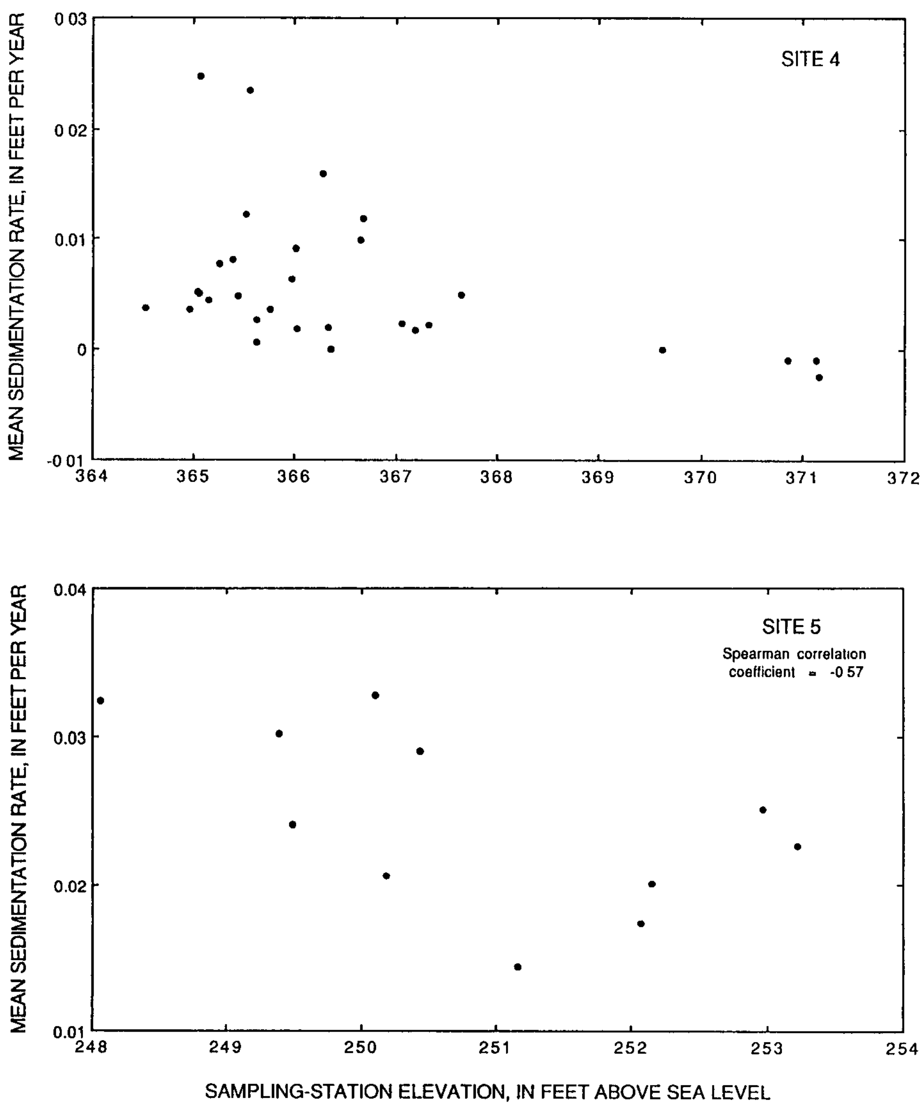


Figure 19.--Mean sedimentation rates and sampling-station elevations for study sites 4, 5, 6, 7, and 8.

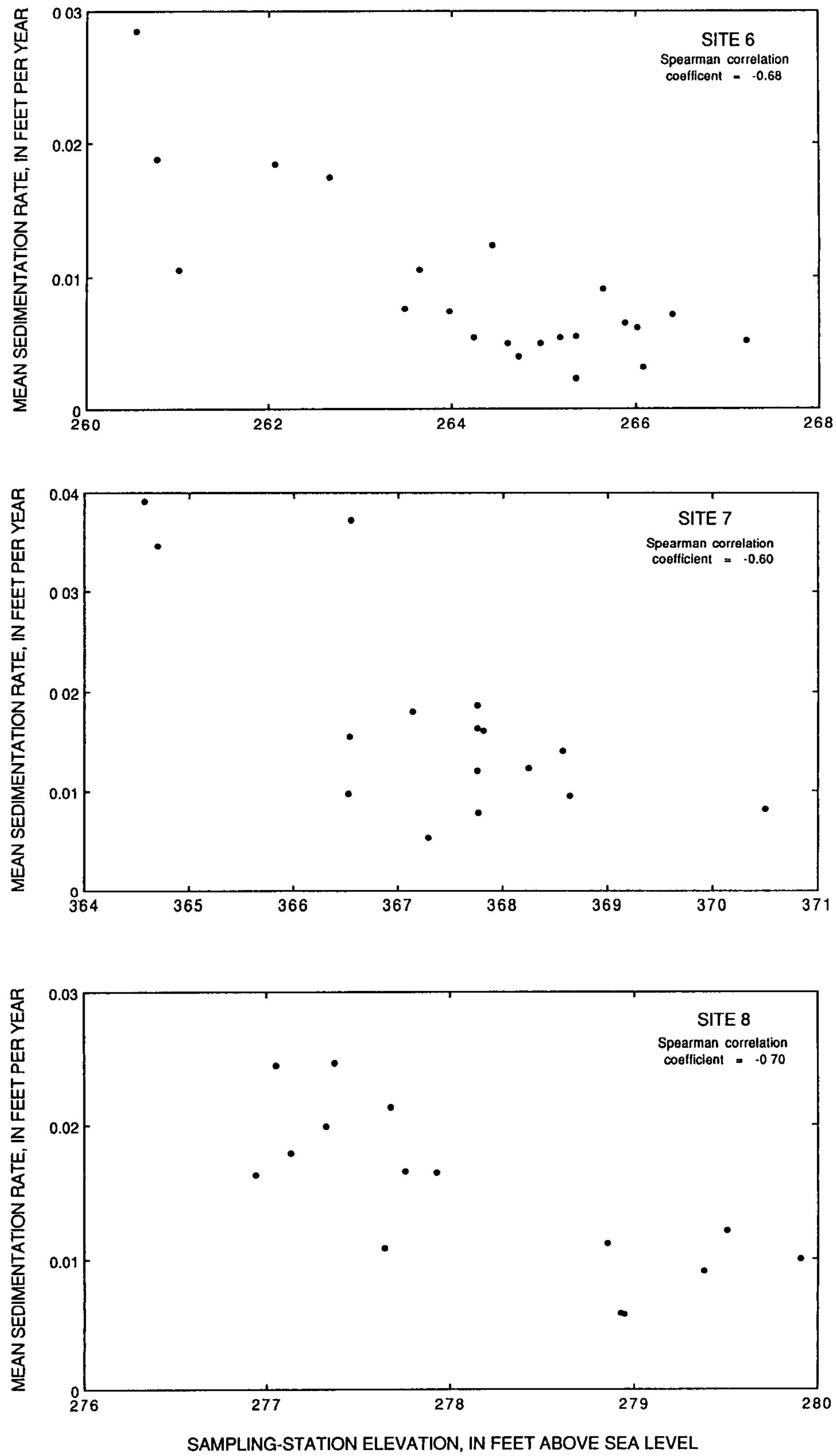


Figure 19.--Mean sedimentation rates and sampling-station elevations for study sites 4, 5, 6, 7, and 8--Continued

Significant differences in sedimentation rate were associated with elevation, but not with location (upstream-downstream), at site 4 and site 7 (figs. 7, 10, 20). Two study sites had significantly greater downstream rates within elevation groups: site 6 had greater downstream rates for middle and high elevations, and site 5 (fig. 5) had greater downstream rates for middle elevations (fig. 20). At no study site was the upstream sedimentation rate significantly greater than the downstream rate. These results agree with the simple upstream-downstream comparison (fig. 17), further suggesting that highway crossings do not significantly affect sedimentation rates. Site 8 was not tested because most of the downstream trees had been removed (fig. 11).

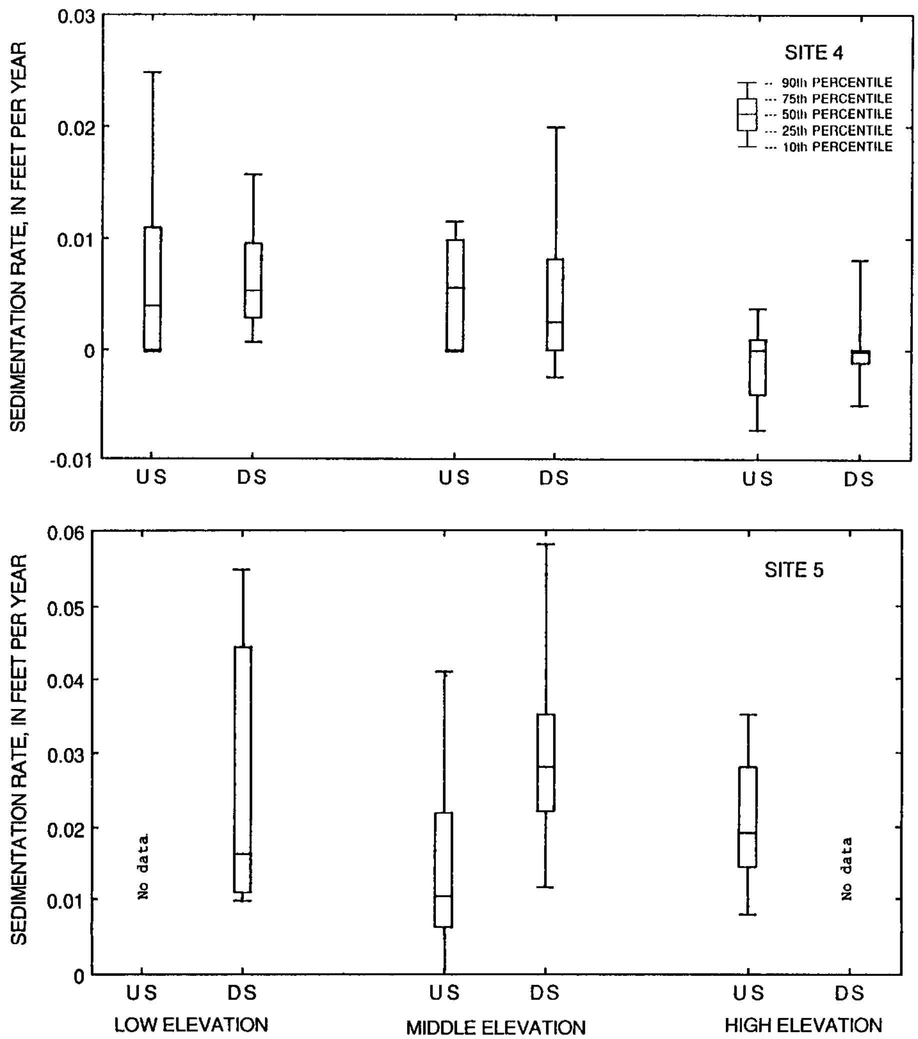


Figure 20.--Sedimentation rates upstream (US) and downstream (DS) from highway crossings by sampling-station elevation group for study sites 4, 5, 6, and 7.

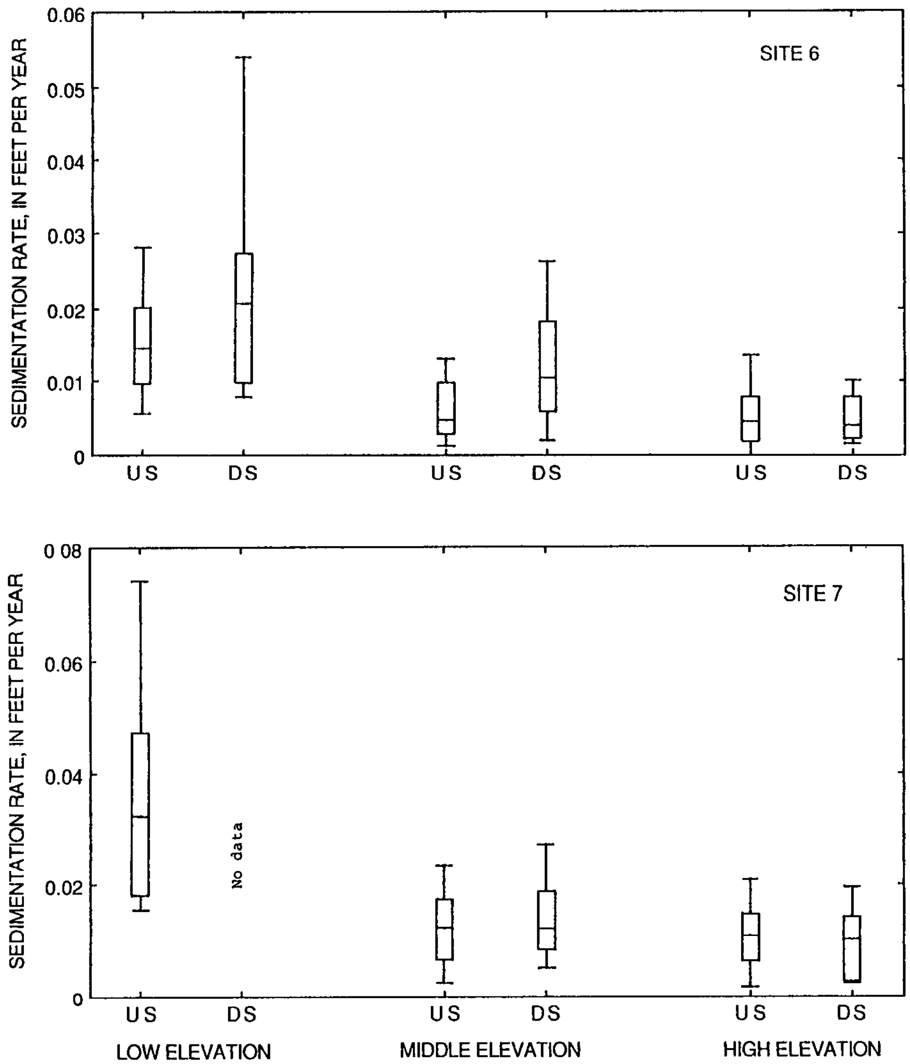


Figure 20.--Sedimentation rates upstream (US) and downstream (DS) from highway crossings by sampling-station elevation group for study sites 4, 5, 6, and 7--Continued.

Variation with Drainage Characteristics

Drainage characteristics were variable among the sampling stations at most of the study sites. Several factors determine drainage characteristics. These include topography, levees, ditches, beaver dams, and soil porosity. The potential for sedimentation is greater in poorly drained (ponded) parts of the bottomlands than in well-drained areas because sediments have more time to settle in ponded areas. Mean sedimentation rates at stations with ponded drainage conditions ranged from 0.005 to 0.033 foot per year. Mean values for drained stations fell within the range -0.002 to 0.136 foot per year.

Sedimentation rates were tested for correlation with drainage characteristics. Sampling stations were sorted into well-drained and ponded categories, and ANOVA tests were performed on the ranks of sedimentation-rate data. Well-drained areas were defined as areas inundated only during over-bank flow. These areas are usually higher in elevation than ponded areas, but not necessarily. Ponded areas were defined as areas in which flow from the area to the main channel is obstructed by topography (as in sloughs or backswamps), levees, beaver dams along ditches, or spoil banks.

Sedimentation rates were positively correlated with drainage categories at four study sites (fig. 21). Correlation was not significant at the remaining study sites. This analysis was not applied at study sites 1 and 2, where drainage characteristics were not distinctly variable among sampling stations.

At the four sites where sedimentation rates were correlated with drainage characteristics (fig. 21), upstream-downstream comparisons were made within the ponding categories. Upstream and downstream rates within ponding categories were not significantly different at sites 4, 5, and 9 (figs. 7, 12, 14). Site 6 (fig. 9) appeared to have greater sedimentation rates in ponded areas downstream than in ponded areas upstream, but the difference was not significant at the 0.05 significance level ($p = 0.055$, fig. 22). No tendency for greater sedimentation rates upstream from highway crossings was observed.

High sedimentation rates seemed to be associated with sloughs regardless of slough location. However, sloughs located close to main channels tended to have extremely high sedimentation rates (figs. 4-14). Areas that were ponded because of spoil banks, levees, or beaver dams also tended to have extremely high sedimentation rates if they were near channels (figs. 4-14).

The greater overall downstream sedimentation rates observed at sites 2, 5, 6, and 11 (fig. 17) may be related to flow constrictions, which locally increase flow velocity and turbulence, thereby increasing the ability of flow to transport sediment. These flow constrictions are caused by highway crossings, levees, and spoil banks. However, sedimentation rates were only slightly greater downstream than upstream, and only 4 of the 11 study sites had greater downstream rates.

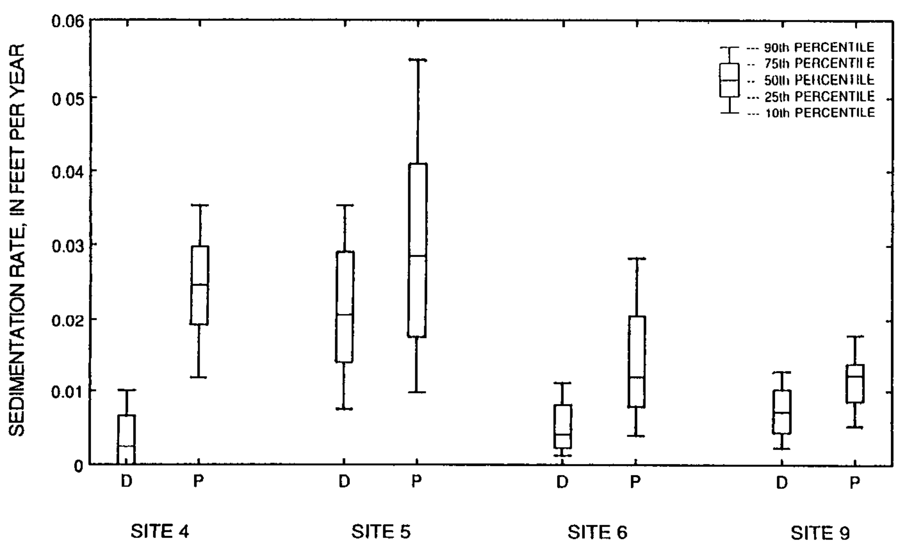


Figure 21.--Sedimentation rates in drained (D) and ponded (P) areas for study sites 4, 5, 6, and 9.

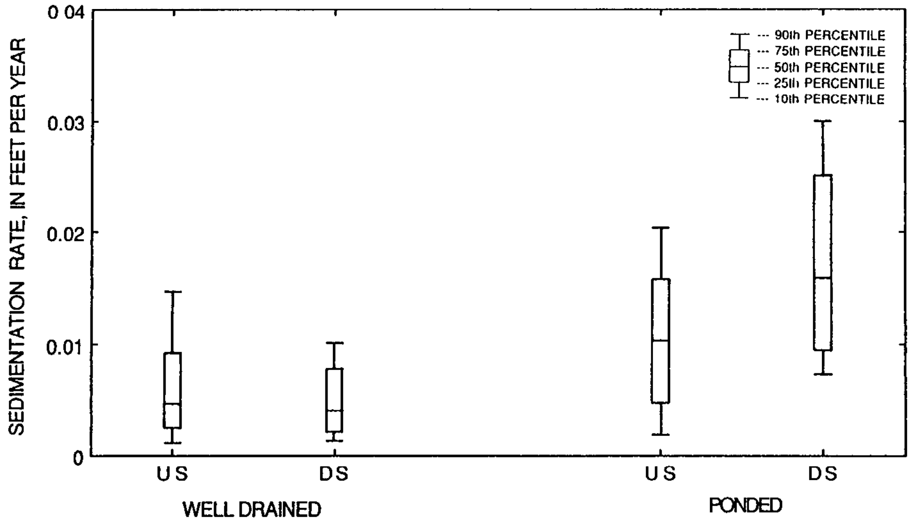


Figure 22.--Sedimentation rates upstream (US) and downstream (D) from highway crossing by sampling-station drainage category at site 6.

Deposition of Sand

Deposition of sand was typically observed on flood plains downstream from bridges. Sand deposition often appeared as splays, or lobes, of sand. Rates of sand deposition were measured at several stations at three of the study sites. Root-burial rates in sand-splay areas, however, reflect the movement and redistribution of splay deposits rather than a constant annual sedimentation rate. Average rates of sand deposition were 0.06 foot per year at a sand-splay station on the downstream flood plain at site 5 (fig. 8), 0.07 foot per year and 0.05 foot per year at sand-splay stations on the downstream flood plains at site 3 (fig. 6), and 0.02 foot per year at a sand-splay station downstream from a relief bridge at site 2 (fig. 5). These rates do not represent average sand deposition rates for entire study sites.

Sand deposition seemed to be related to flow constrictions. Flow constrictions locally increase flow velocity and turbulence, thereby increasing the ability of flow to transport sand. Highway crossings, levees, and spoil banks constrict flow. At site 4, for example, water on the upstream flood plain must pass through several constrictions to reach the downstream flood plain (fig. 7). Flow from the upstream flood plain is constricted by openings in spoil banks as it passes into the main channel; flow then passes through the bridge opening and is again constricted as it passes from the channel through spoil-bank openings to the downstream flood plain. Downstream from the bridge, sand in suspension is carried out onto the flood plain and deposited as splays. Sand splays 1 to 2 feet in height were observed at site 4 as far as 2,000 feet downstream from the highway crossing, extending as far as 150 feet from the channel. Observations made at site 4 indicated that splays, after being initially deposited on the flood plains near the main channel, were advanced further onto the flood plain by subsequent over-bank flows.

TEMPORAL TRENDS OF SEDIMENTATION AND TREE GROWTH

Long-term root-burial-depth data were sorted by tree ages to detect changes in sedimentation rates over time. The ages of the oldest sampled trees limited the length of time over which sedimentation rates could be estimated (table 5). Trees less than 10 years old were rare in the bottomland stands studied. The most recent 18 years (1970-88) were lumped into a single age category to ensure that a reliable number of trees were represented in the most recent sample category. Mean sedimentation rates ranged from less than 0.001 to 0.046 foot per year for the various age groups (table 5) and fell within the range of

Table 5.--*Summary of mean sedimentation rates by tree age group and site*

[Rates are in feet per year; s.e., standard error of mean; n, number of trees sampled; --, no data]

Study site number	All ages	Pre-1900	1900-09	1910-19	1920-29	1930-39	1940-49	1950-59	1960-69	1970-88
Site 1										
mean	0.010	0.000	0.000	0.010	0.003	0.013	0.012	0.006	0.009	0.014
s.e.	0.001	0.000	--	0.004	0.002	0.003	0.004	0.003	0.002	0.002
n	103	3	1	6	8	16	13	13	23	20
Site 2										
mean	0.021	--	--	0.013	0.020	0.009	0.014	0.019	0.020	0.029
s.e.	0.001	--	--	--	0.001	0.003	0.002	0.002	0.002	0.004
n	121	--	--	1	3	7	14	34	30	32
Site 3										
mean	0.015	0.001	0.015	--	0.019	0.012	0.011	0.016	0.021	0.008
s.e.	0.001	--	--	--	0.003	0.002	0.001	0.002	0.005	0.003
n	95	1	1	--	4	13	23	26	23	4
Site 4										
mean	0.006	0.009	--	0.007	0.007	0.006	0.005	0.004	0.006	0.010
s.e.	0.001	--	--	0.002	0.001	0.001	0.001	0.001	0.001	0.003
n	257	1	--	9	33	52	55	46	46	15
Site 5										
mean	0.026	0.013	0.016	--	0.014	0.019	0.019	0.022	0.032	0.046
s.e.	0.002	0.003	--	--	0.002	0.002	0.002	0.002	0.003	0.005
n	97	3	1	--	8	7	17	25	27	8
Site 6										
mean	0.009	0.009	0.008	0.008	0.009	0.009	0.008	0.007	0.014	0.019
s.e.	0.001	0.003	0.001	0.002	0.001	0.001	0.001	0.001	0.002	0.008
n	237	11	13	13	34	40	54	37	27	8
Site 7										
mean	0.018	0.010	0.014	0.012	0.011	0.018	0.017	0.014	0.016	0.028
s.e.	0.001	0.004	--	0.001	0.002	0.003	0.002	0.002	0.002	0.005
n	169	3	1	2	6	9	44	40	37	27
Site 8										
mean	0.014	0.006	--	0.005	0.016	0.016	0.013	0.014	0.015	0.017
s.e.	0.001	0.002	--	0.002	0.017	0.002	0.002	0.003	0.004	0.007
n	88	3	--	2	11	23	21	11	10	7
Site 9										
mean	0.010	0.009	0.005	0.006	0.008	0.008	0.010	0.010	0.015	0.017
s.e.	0.001	0.004	0.003	0.002	0.001	0.001	0.001	0.001	0.004	0.007
n	107	3	2	6	24	16	18	22	10	7
Site 10										
mean	0.009	0.006	--	0.005	--	0.003	0.012	0.013	0.008	0.010
s.e.	0.001	--	--	--	--	--	--	--	0.003	0.002
n	29	1	--	1	--	1	1	1	5	19
Site 11										
mean	0.006	0.007	0.006	0.003	0.004	0.004	0.007	0.006	0.008	0.006
s.e.	0.001	0.002	0.002	0.001	0.002	0.001	0.002	0.002	0.002	0.002
n	212	11	13	13	19	51	36	28	27	14

published sedimentation rates for bottomland-hardwood swamps (Boto and Patrick, 1979; Mitsch and others, 1979; Johnston and others, 1984; Cooper and others, 1987; Hupp and Morris, 1990). Sedimentation rates based on trees from age groups beginning 1 to 2 decades after channelization tended to be smaller than those based on other age groups. No trends were observed that seemed related to highway-crossing construction.

Sedimentation rates based on trees in the youngest age group generally are greater than rates based on older trees. Short-term sedimentation rates measured above clay-marker layers were greater than long-term averages (fig. 23), further indicating that sedimentation rates have increased since the early part of the century. However, greater short-term sedimentation rates may result in part from greater compaction of the older sediments and incorporation of leaf litter in short-term measurements. The compaction of sediment over time may decrease the rates determined for early time periods and exaggerate the most recent rates.

No trends were observed that seemed related to highway-crossing construction. Reduction of the bridge-opening length at study site 5 on the Hatchie River from 4,000 feet to 1,000 feet in 1975 coincided with the 1970-88 tree-age group, which showed the highest sedimentation rate, (fig. 24, site 5). However, this 1970-88 tree-age group was typically the group having the highest mean sedimentation rate at most study sites whether or not highway-crossing construction occurred.

Growth-trend analysis was conducted at seven of the sites for six species: American elm (*Ulmus americana*), bald cypress (*Taxodium distichum*), green ash (*Fraxinus pennsylvanica*), hickory (*Carya* species), overcup oak (*Quercus lyrata*), and tupelo gum (*Nyssa aquatica*). These species were selected to represent the typical bottomland species in the area. They are also common and have fairly easily determined ring boundaries. Sites 2, 3, 4, 6, 7, 8, and 11 had sufficient bottomland forest cover and species diversity to make this analysis meaningful.

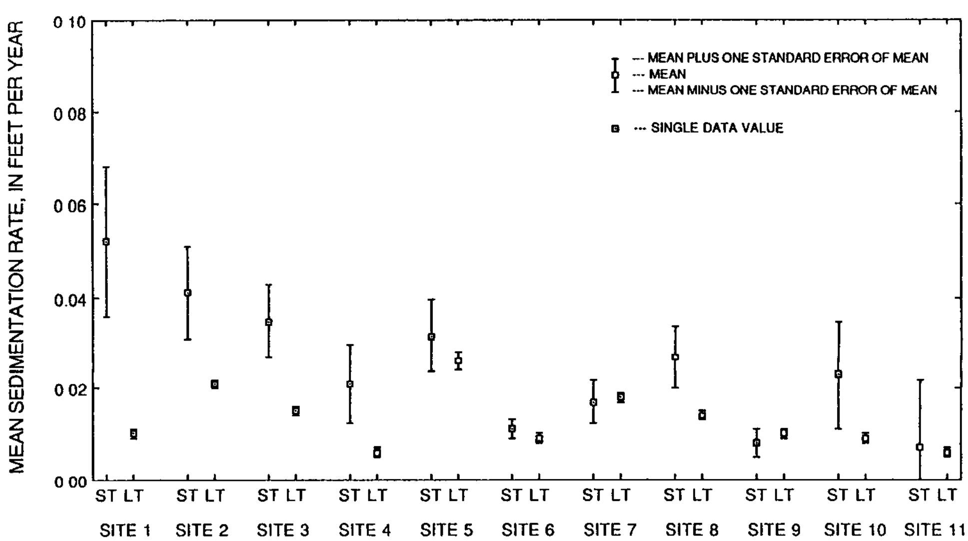


Figure 23.--Mean short-term (ST) and long-term (LT) sedimentation rates.

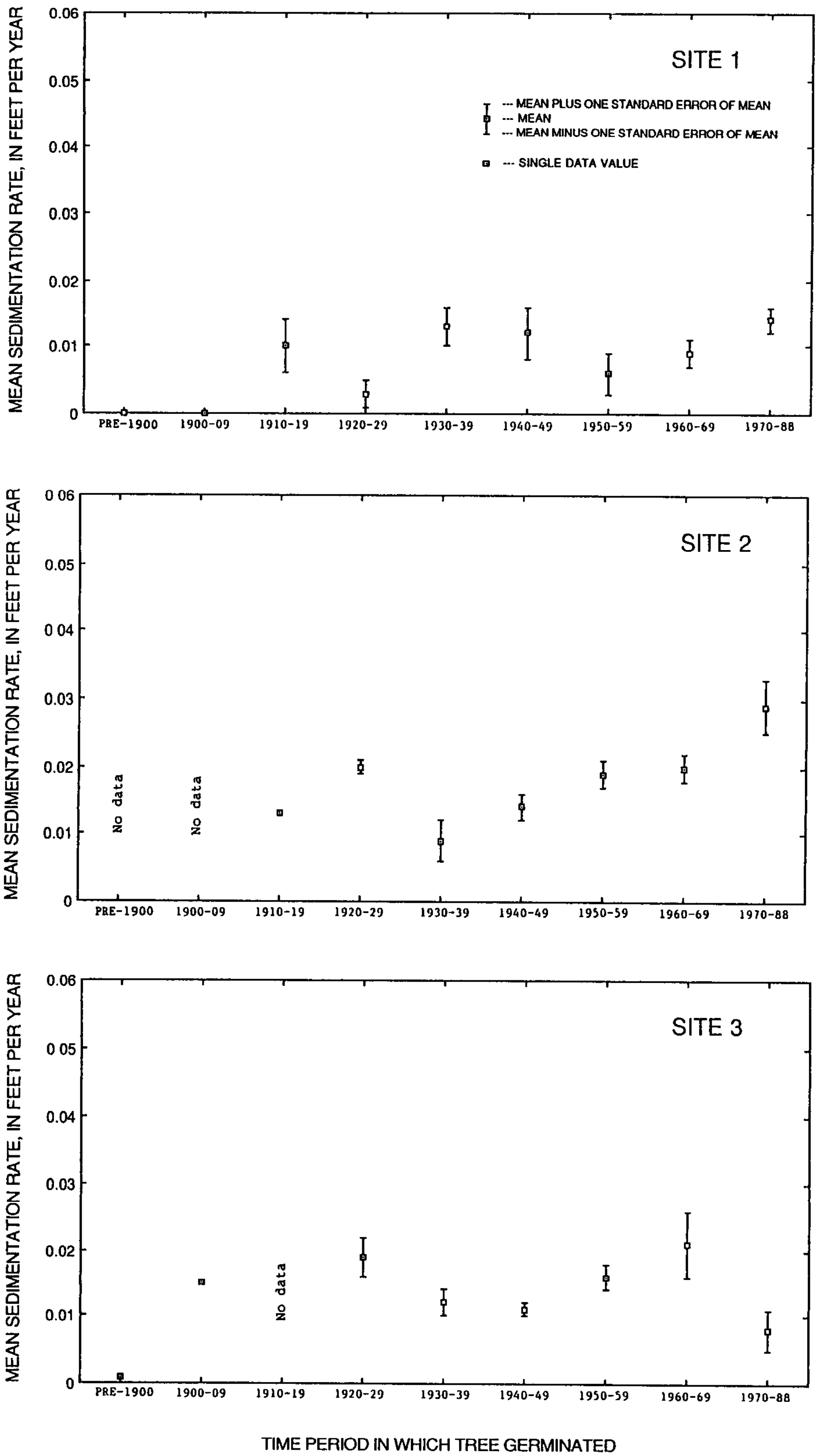


Figure 24.--Mean sedimentation rate from year of germination to 1988, based on trees that germinated within specified time periods.

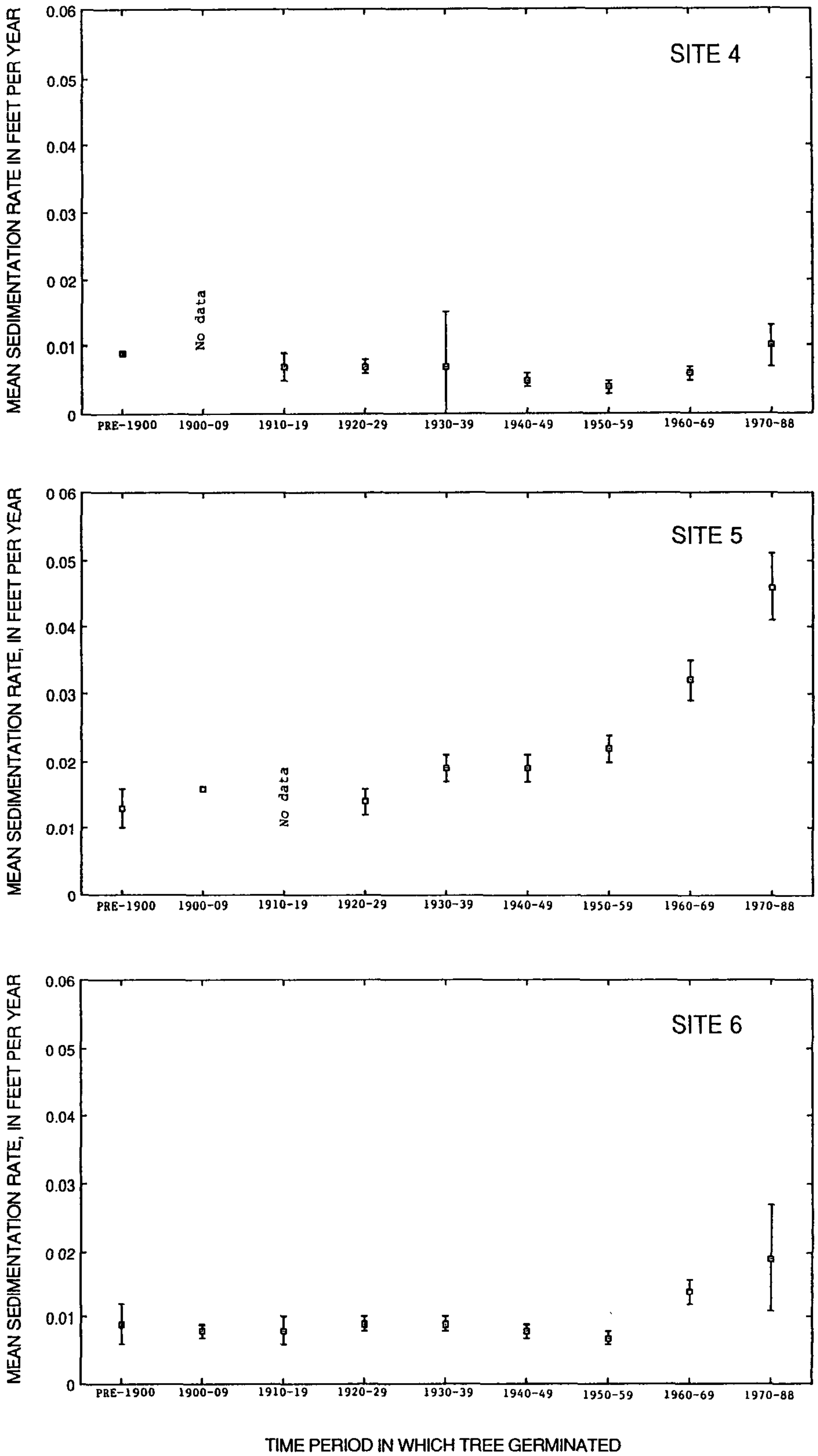


Figure 24.--Mean sedimentation rate from year of germination to 1988, based on trees that germinated within specified time periods--Continued.

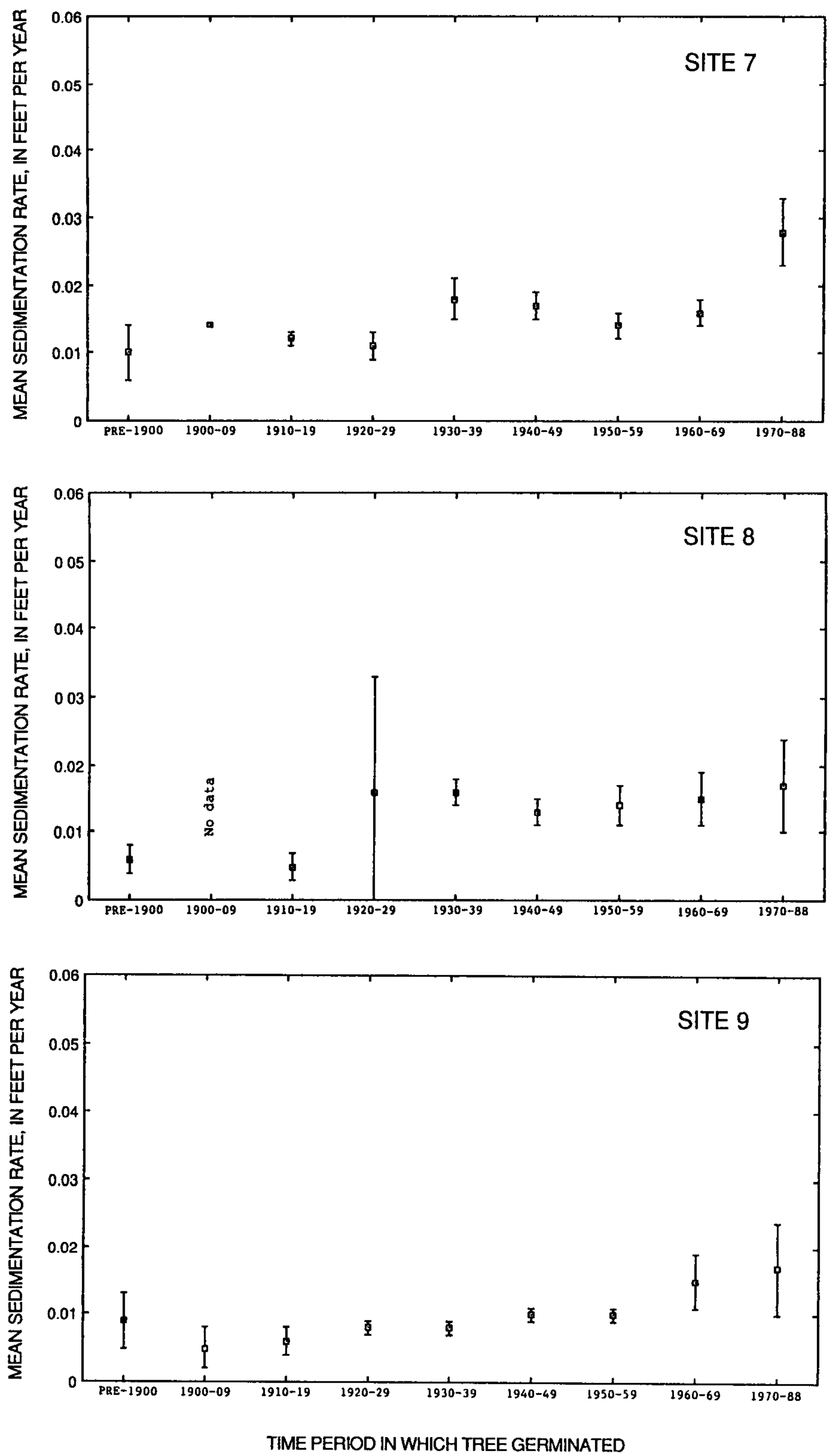


Figure 24.--Mean sedimentation rate from year of germination to 1988, based on trees that germinated within specified time periods--Continued

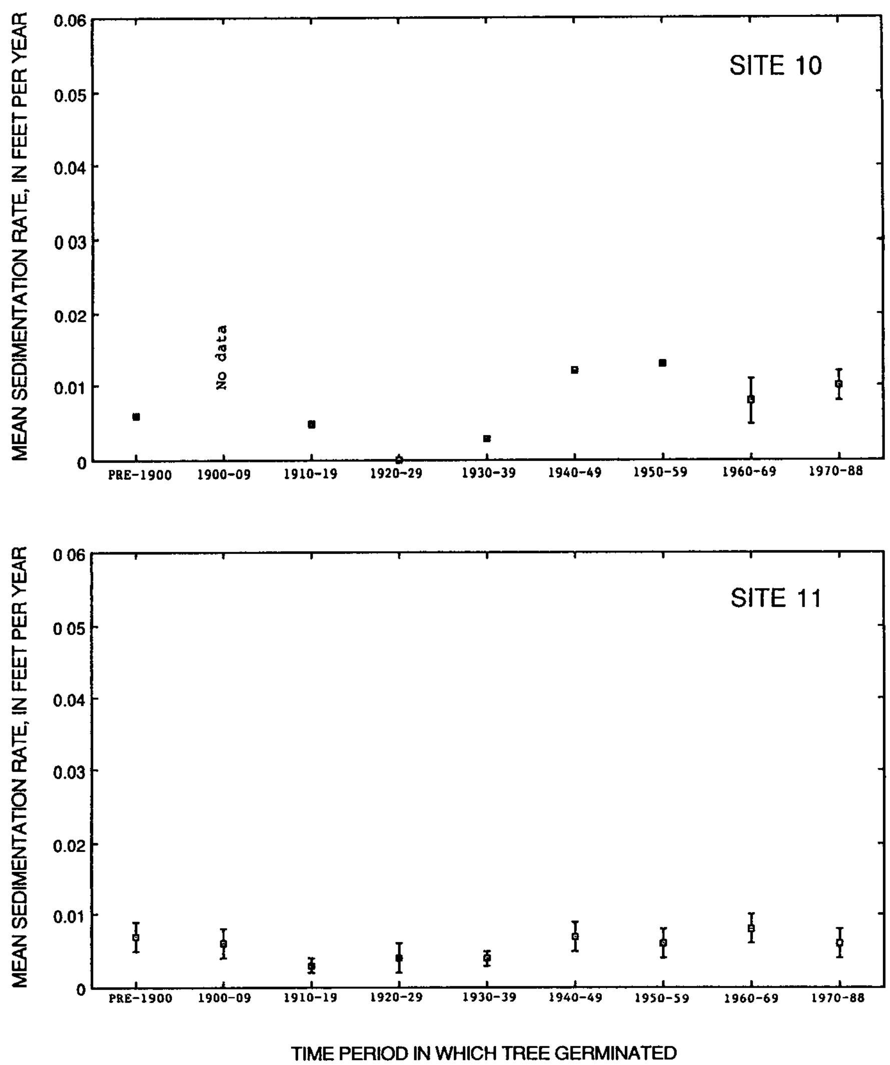


Figure 24.--Mean sedimentation rate from year of germination to 1988, based on trees that germinated within specified time periods--Continued.

Many of the tree increment cores used in the temporal analysis were measured for ring width variations and were cross dated. The scope of the present paper does not provide for a detailed assessment of growth-trend analyses. However, growth trends of a single bald cypress and a single tupelo gum, two common wetland species, are presented here as examples of tree growth in an area that has been subjected to channelization and bridge construction (fig. 25). These chronologies for trees located upstream from the bridge at site 8 (fig. 11) are representative of tree-growth trends at this site, which receives about 0.015 foot of fine-grained deposition per year. The influence of sedimentation on tree-growth is difficult to separate from the influence of hydroperiod because areas with high sedimentation rates typically have long hydroperiods. Tree-growth is related to ponding in that excessive ponding can cause tree death, especially of mesic tree species (Miller, 1990).

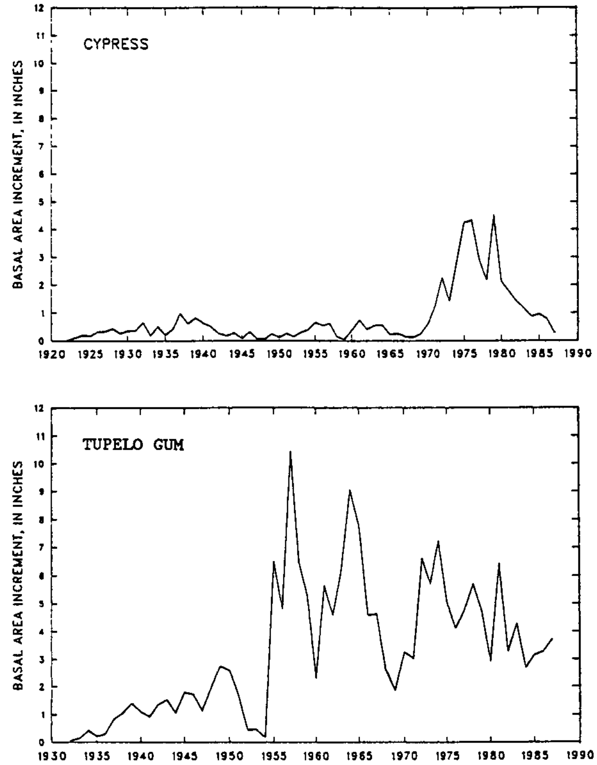


Figure 25.--Growth chronologies for a cypress tree and a tupelo gum tree at site 8, standardized by conversion to cross-sectional area increments.

FLOW AND SEDIMENTATION MODELING

The purpose of the modeling phase of the project was to develop an empirical formula to estimate sedimentation rates based on hydraulic and sediment-concentration data. Estimation of sedimentation rates based on root-burial rates is a labor-intensive process that requires measurement of the root-burial depth at a large number of mature trees. Where trees are not present, or where sediment-concentration data are available, use of an empirical formula may be preferable to estimating the sedimentation rate based on root-burial rates.

Hydraulic Modeling

Backwater caused by constrictions at highway crossings was modeled using WSPRO, a one-dimensional step-backwater model (Shearman and others, 1986). Because of the complex hydraulics at the highway crossings studied, the step-backwater model was calibrated to observations of water-surface elevation and discharge at sites where these data were available. Roughness values used in the step-backwater model were estimated from photographs and field observations using standard techniques (Arcement and Schneider, 1984; Chow, 1959; Barnes, 1967).

At sites with streamflow gages, the record of daily mean discharges was used to represent the variation of discharge over time. At other sites, the discharge record at the nearest gage on the same river was used, and the discharges were adjusted by the ratio of drainage area at the site to drainage area at the gage. The use of historic daily mean discharges is based on the assumption that the streamflow data collected at the gage are representative of the period used for root-burial-rate determinations. Discharge data from the Beech River basin at a drainage area comparable to that of site 3 were available only for the period before channelization, and therefore the empirical formula was not applied at this site.

Backwater effects for existing conditions, and for conditions estimated to exist if the highway crossings were not present, were assessed using the step-backwater model (table 6). Inundation depth was calculated by subtracting the mean elevation at upstream vegetation-sampling stations from the calculated water-surface elevation at the first cross-section upstream from the bridge. The adjusted daily mean discharges were used to develop estimates of the hydroperiod at the upstream sampling stations and the average depth of flood-plain inundation, with and without the highway crossing, at each site. The estimated effect

Table 6.--*Backwater, discharge, and ratio of drainage area at site to drainage area at gage for 10 selected study sites*

[A_S/A_G, drainage area at site divided by drainage area at gage, dimensionless; Q_{fp}, discharge with upstream water surface elevation equal to mean elevation of vegetation sampling stations on the flood plain, in cubic feet per second; Q_2, discharge with estimated recurrence interval of 2 years, in cubic feet per second; BW_{fp}, estimated backwater effect of highway crossing at Q_{fp}, in feet; BW_2, estimated backwater effect of highway crossing at Q_2, in feet; SR, state route]

Study site No.	Study site Location	A_S/A_G	Q_{fp}	Q_2	BW_{fp}	BW_2
1	Beaver Creek at SR 1 bypass.	0.74	495	2,660	0.00	0.12
2	Beaver Creek at SR 22.	.82	68	2,800	.00	.21
4	Big Sandy River at SR 69.	1.56	607	6,310	.02	1.67
5	Hatchie River at SR 3.	1.00	3,040	21,500	.00	.08
6	Hatchie River at SR 54.	.94	5,030	20,800	.00	.00
7	Hatchie River at SR 57.	1.00	2,460	14,800	.06	.45
8	Middle Fork Forked Deer River at SR 188.	.78	2,660	7,140	.00	.23
9	Obion River at SR 3.	.91	9,790	23,400	.00	.55
10	South Fork Forked Deer River at SR 54.	1.55	3,230	10,800	.00	.21
11	Wolf River at Yager Drive.	.41	2,780	6,060	.00	.05

of the highway crossings on the average hydroperiod and the average depth of flood-plain inundation was small (figs. 26, 27).

Field Data Collection Methods

The physical characteristics of the bridge opening and nearby flood plain were determined from field inspections by USGS personnel, from topographic maps, and from bridge plans provided by the TDOT. The assumption was made that hydraulic analysis based on current physical conditions was applicable throughout the lifetime of the trees used for root-burial-rate determination.

Upstream root-burial rates were determined at vegetation-sampling stations on the flood plain upstream from the highway crossing. Measurements were made at 2 to 16 stations across the flood plain within 1,800 feet of the highway at each site.

Suspended-sediment samples were collected at one to six single-stage suspended-sediment samplers at each site (Guy and Norman, 1970). The samplers were installed at upstream vegetation-sampling stations at each site to measure suspended-sediment concentration at a flood-plain inundation depth of 1 foot. Over the 2-year study period, suspended-sediment samples were collected during one to five flood plain inundations at each site. Sediment concentration in water inundating the flood plain over the period of the daily flow record was assumed to be equal to the average sediment concentration in these samples (table 7).

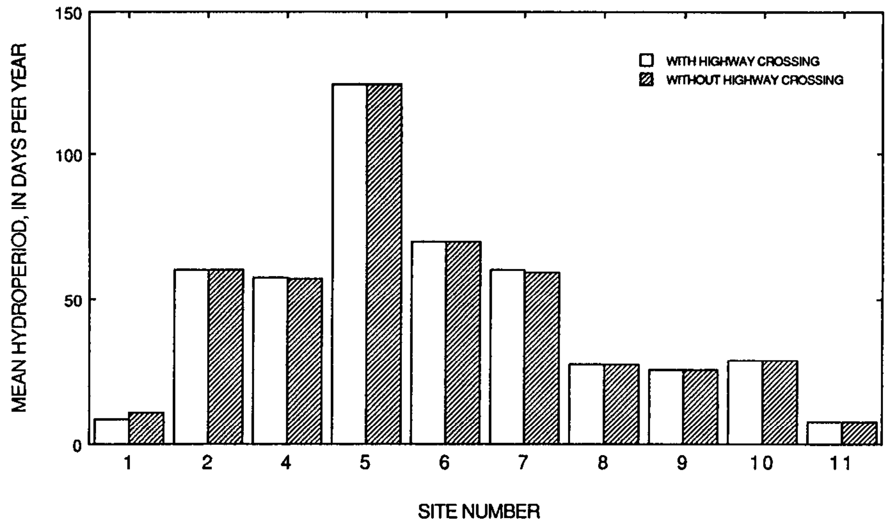


Figure 26.--Modeled hydroperiod at 10 selected study sites, with and without highway crossings.

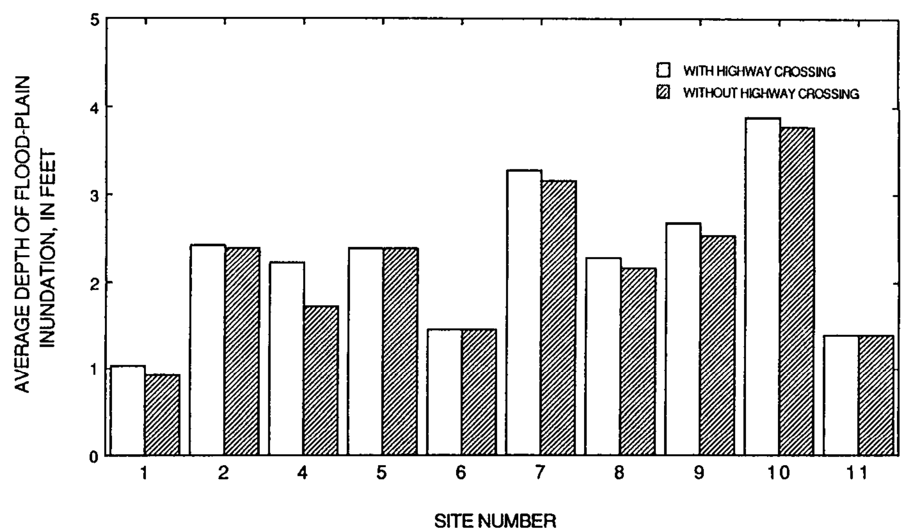


Figure 27.--Modeled average depth of inundation at 10 selected study sites, with and without higway crossings

Table 7.--*Mean sediment concentration for samples collected using single-stage sediment samplers*

[SR; state route]

Study site No.	Study site Location	Mean sediment concentration, in milligrams per liter	Standard error of mean sediment concentration	Number of sediment samples
1	Beaver Creek at SR 1 bypass.	353	72	9
2	Beaver Creek at SR 22.	181	33	10
3	Beech River at SR 202.	345	76	18
4	Big Sandy River at SR 69.	92	16	18
5	Hatchie River at SR 3.	184	54	3
6	Hatchie River at SR 54.	153	51	6
7	Hatchie River at SR 57.	127	13	13
8	Middle Fork Forked Deer River at SR 188.	440	48	25
9	Obion River at SR 3.	636	323	8
10	South Fork Forked Deer River at SR 54.	185	89	5
11	Wolf River at Yager Drive.	175	25	23

Sedimentation-Rate Equations

Empirical equations were developed on the basis of estimated suspended-sediment concentration and the estimated inundation depths upstream from the highway crossing. The equations were based on the assumption that the daily depth of sediment deposition increases with increasing depth of water over the flood plain up to some threshold depth ($D_{SETTLING}$), above which the daily depth of sediment deposition remains constant. The value of this threshold depth was adjusted to achieve the best fit of estimated sedimentation rates to mean root-burial rates upstream from the highway crossings. The daily depth of sediment deposition was calculated for each day in the period of the flow record. One of three equations was selected on the basis of daily mean inundation depth, and used to calculate the daily depth of sediment deposition. The mean density of flood-plain deposits was assumed to be 82 pounds per cubic foot (1.31 grams per cubic centimeter) (Vanoni, 1975).

$$S_{DAILY} = C(D_{SETTLING} / \gamma_{SED}) \text{ .if.} D_{DAILY} > D_{SETTLING} \quad (1)$$

$$S_{DAILY} = C(D_{DAILY} / \gamma_{SED}) \text{ ....if.} D_{DAILY} \leq D_{SETTLING} \quad (2)$$

$$S_{DAILY} = 0 \text{ ....if } D_{DAILY} = 0 \quad (3)$$

where

S_{DAILY} is the depth of sediment deposited on the flood plain in 1 day, in feet;
C is the sediment concentration in water inundating the flood plain, in milligrams per liter;
$D_{SETTLING}$ is the depth of water inundating the flood plain at which all suspended sediment is assumed to settle in 1 day, in feet;
γ_{SED} is the density of deposited sediment in milligrams per 1,000 cubic centimeters;
D_{DAILY} is the depth of water inundating the flood plain on a given day, in feet.

Calibration to upstream root-burial rates yielded an estimated $D_{SETTLING}$ of 2.6 feet.

The annual sedimentation rate was calculated by summing the estimated daily sedimentation depth over the period of the historic flow record and dividing by the number of years of record. The annual sediment yields calculated in this manner were between half the observed value and twice the observed value at 8 of the 10 sites (fig. 28).

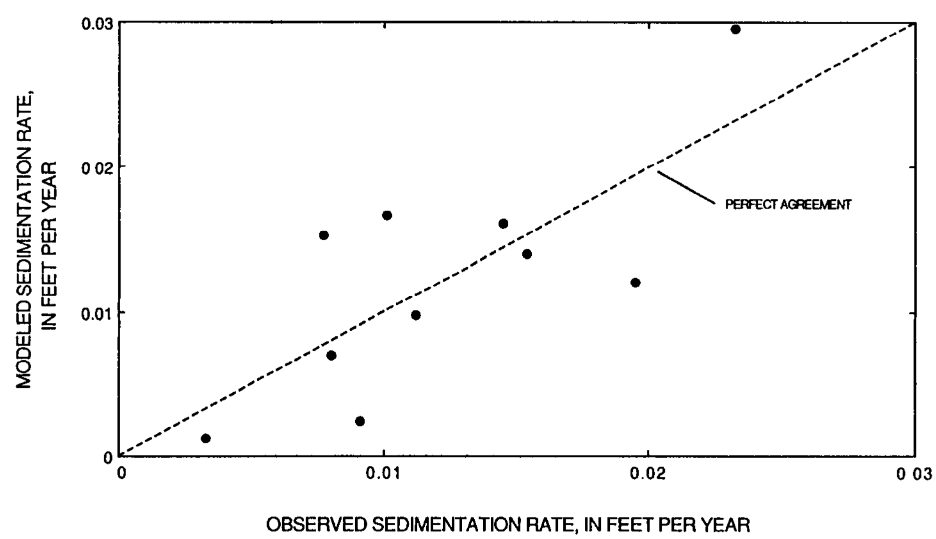


Figure 28.--Relation between modeled and observed sedimentation rates at 10 selected study sites.

The loose fit of the calculated sedimentation rates to the observed rates is partly due to the simplifying assumptions used in the analysis. The adjustment of discharge based on the difference in drainage area between the study site and the gage introduces some error. The use of current physical characteristics to represent physical characteristics over the lifetime of mature trees can introduce significant error at sites that have experienced channelization and subsequent channel evolution (Simon and Hupp, 1987; Brookes, 1988; Schumm and others, 1984). Nine of the 10 sites at which sedimentation rates were modeled have been subjected to some degree of channel modification. Spatial and temporal variation of sediment concentration is substantial (table 7), but available data are insufficient to allow these forms of variation to be taken into account in greater detail.

The equations presented above are based on step-backwater analyses, long-term flow records at or near the study site, and measurements of flood-water suspended-sediment concentrations over a period of 2 years. The equations could be suitable for estimating sedimentation rates at sites in West Tennessee with similar hydraulic characteristics where mature trees are absent. Because root-burial-rate determination gives a direct indication of the sedimentation rate, its use is preferable to modeling at sites where a mature flood-plain forest is present. Current bridge design practice in Tennessee limits backwater to 1 foot at the 100-year discharge, and actual backwater at the study sites is typically much less. The equations should not be applied at sites with backwater substantially greater than that observed at the study sites (table 6). The equations have been calibrated to long-term root-burial rates determined at sites in West Tennessee; their use in other regions would require calibration to local root-burial rates.

VEGETATION PATTERNS

Woody vegetation in these wetlands was characterized to determine if any of these forests were affected by altered sedimentation rates or hydrologic patterns because of bridge construction. The plant ecological analysis was conducted through the establishment of vegetation sampling plots measuring 66 feet by 66 feet at each station. The plot sampling included the tallying of each individual woody plant (greater than 1 inch in diameter at about 4.5 feet above the ground) by species, and recording the diameter. Relative stem density for a given species in a given plot was defined as the number of stems of that species, divided by the total number of woody stems in that plot. Relative dominance for a given species in a given plot was defined as the basal cross-sectional area of all stems of that species, divided by the total basal area of woody stems in that plot. The importance value (IV) of a given species in a given plot was defined as the sum of the relative stem density and relative dominance of that species in that plot. Analysis of IV's is used to classify species assemblages and to provide a basis for ecological inference. A list of plant species identified in the study area and their abbreviations is presented in table 8.

Ordination was used to reduce the plot data. Ordination uses multivariate analyses of matrices, with species as rows, and their abundance or presence value at particular sampling locations as columns (Gauch, 1982). The result is an arrangement of species (or samples) in two dimensions such that similar species (or samples) are close and dissimilar species (or

Table 8.--*Plant species and their abbreviations*

Scientific name	Common name	Abbreviation
Acer negundo	boxelder	ACNE
Acer rubrum	red maple	ACRU
Acer saccarhinum	silver maple	ACSC
Aesculus species	buckeye	AESP
Asimina triloba	pawpaw	ASTR
Betula nigra	river birch	BENI
Carpinus caroliniana	ironwood	CACA
Carya ovata	shagbark hickory	CAOV
Carya cordiformis	bitternut hickory	CACO
Celtis occidentalis	hackberry	CEOC
Cornus florida	dogwood	COFL
Crataegus species	hawthorn	CRSP
Fagus grandifolia	beech	FAGR
Forestiera acuminata	swamp forestiera	FOAC
Fraxinus pennsylvanica	green ash	FRPE
Gleditsia triacanthos	honey locust	GLTR
Ilex decidua	deciduous holly	ILDE
Ilex opaca	american holly	ILOP
Juglans nigra	black walnut	JUNI
Liquidambar styraciflua	sweet gum	LIST
Liriodendron tulipifera	tulip tree	LITU
Morus rubra	red mulberry	MORU
Nyssa aquatica	water tupelo	NYAQ
Nyssa sylvatica	black gum	NYSY
Planera aquatica	water elm	PLAQ
Platanus occidentalis	sycamore	PLOC
Populus deltoides	cottonwood	PODE
Quercus bicolor	swamp white oak	QUBI
Quercus falcata var. *pagodaefolia*	cherrybark oak	QUFP
Quercus lyrata	overcup oak	QULY
Quercus michauxii	swamp chestnut oak	QUMI
Quercus nigra	water oak	QUNI
Quercus palustris	pin oak	QUPA
Quercus phellos	willow oak	QUPH
Quercus species	oak species	QUSP
Salix nigra	black willow	SANI
Salix species	willow	SASP
Taxodium distichum	bald cypress	TADI
Tilia heterophylla	basswood	TIHE
Ulmus alata	winged elm	ULAL
Ulmus americana	american elm	ULAM
Ulmus rubra	slippery elm	ULRU

samples) are far apart (Gauch, 1982). The ordination procedure, Detrended Correspondence Analysis (DCA) (Hill and Gauch, 1980), was performed on the species IV's, using the DECORANA program (Hill, 1979).

The ecological patterns of species importance at most of the study sites were similar and reflect the establishment of bottomland species at sites conducive to their successful growth and reproduction. Most patterns have probably developed over long time spans, and largely reflect long-term environmental conditions. If conditions necessary for specific species assemblages, such as cypress-tupelo swamp, change enough, then this assemblage will eventually be replaced by species that tolerate and thrive in the altered state. Thus, if bridge construction, channelization, or agricultural practices cause enough change in the hydrologic-sedimentologic environment, then a change in the assemblage presumably can be expected.

A broad spectrum ordination of all species from all sites, divided into upstream and downstream parts, showed a general pattern (fig. 29). Species that plotted near the center tended to be typical bottomland species that were tolerant of relatively long periods of inundation; species that plotted away from the center tended to be more characteristic of mesic uplands, or of well-drained stream banks or levees. The tendency for species to ordinate along hydrologic gradients is typical in bottomlands (Hupp and Osterkamp, 1985; Hupp, 1987).

In the site ordination (fig. 30), ecologically similar sites plotted close together. Note that the upstream and downstream subsites at each site plotted relatively close together, indicating ecological similarity. The exception is study site 8, where most vegetation in the downstream part had been cleared. Thus, no upstream to downstream gradient was apparent in this ordination. If highway crossings increase upstream sedimentation enough to affect bottomland species patterns, it is not evident in these data when analyzed using this method.

Based on field observations, vegetation patterns were similar at all study sites. Sloughs were characterized by cypress and tupelo with overcup oak just outside the wettest parts. The middle elevations were characterized by ash, sweetgum, elm, and various hydric oaks. High, well-drained areas were characterized by beech, tulip tree, and various hydric oaks.

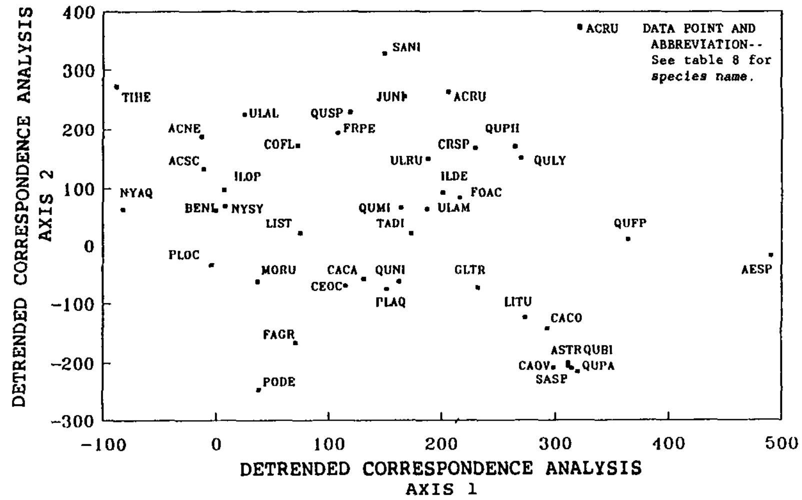


Figure 29.--Broad spectrum ordination of all species from all study sites

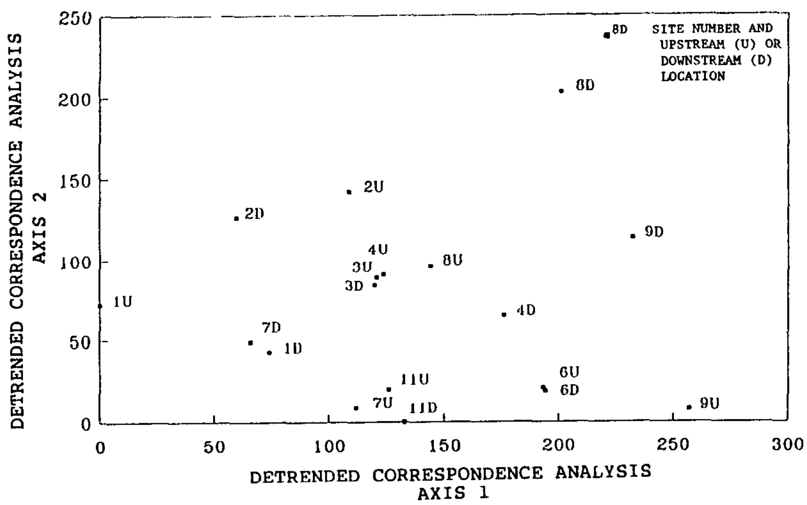


Figure 30.--Site ordination showing upstream and downstream subsites.

Disturbances, such as selective lumbering or clearing, also were reflected in the species patterns: young stands of low diversity typically included box elder, red maple, and ash. Highly ponded areas and areas of high deposition can be expected to support ash and tupelo in deference to other bottomland species. Vegetation patterns are related to ponding in that excessive ponding can cause tree death, especially of mesic tree species (Miller, 1990).

SUMMARY AND CONCLUSIONS

Wetland sedimentation and vegetation patterns at 11 highway crossings in West Tennessee were studied from 1987 to 1989. The goal of this investigation was to determine if highway crossings significantly increase sedimentation or adversely affect bottomland forests. In general, the results of this study suggest that highway crossings do not significantly increase sedimentation or adversely affect bottomland forests.

Sedimentation rates, determined from root-burial depths, were highly variable. Average rates of fine-grained deposition ranged from 0.005 to 0.033 foot per year for stations in locally ponded areas and from -0.002 to 0.039 foot per year for stations in drained areas. High sedimentation rates typically were associated with low, locally ponded areas of the flood plain. Sloughs and backswamps tended to have high sedimentation rates regardless of their location on the flood plain. Sloughs that were immediately adjacent to artificial channels, however, had higher sedimentation rates than the average for all sampled sloughs.

Long-term sedimentation rates of fine-grained materials were not significantly greater upstream from the highway crossings at the 11 study sites than downstream, suggesting that the highway crossings have not had a significant influence on upstream sedimentation rates. At four study sites, downstream rates were slightly greater than upstream rates. Greater downstream rates may have been related to flow constrictions at bridge openings and spoil-bank openings, which increase the sediment-transporting ability of flow returning to the downstream flood plain.

Sand splays were observed downstream from bridge openings at most study sites. Sand deposition seemed to be related to flow constrictions. Flow constrictions locally increase flow velocity and turbulence; this increases the ability of flow to transport sand. Highway crossings, levees and spoil banks constrict flow. Sand splays are deposited as flow returns to the flood plain downstream from the bridge. At sites where flows are constricted by levees or spoil banks that are parallel to the channel, sand splays can occur downstream for distances much greater than the width of the bridge opening.

Sedimentation rates based on trees in the youngest age group generally were greater than rates based on older trees. Sedimentation rates based on trees from age groups beginning 1 to 2 decades after channelization tended to be smaller than those based on other age groups. No trends were observed that seemed related to highway-crossing construction.

Tree-growth rates seemed to be more related to hydroperiod than to sedimentation. Although the influence of hydroperiod could not be separated from the effects of sedimentation, the effects of highway and bridge construction on growth rates were small.

Increases in the hydroperiod because of upstream backwater from the highway crossings were limited to 1 percent or less at the 11 study sites, based on modeling analysis.

Site-averaged sedimentation rates were calculated on the basis of a simplified flow model and sediment concentrations from 2 years of flood-plain inundations. This approach could not duplicate the precision and site specificity of root-burial-rate determinations; model generated rates were from one half to twice the observed rates. However, the model was sufficient to document the consistency in sedimentation rates among sites and was judged to be useful for estimating sedimentation rates at additional sites where root-burial rates could not be measured.

Vegetation patterns were similar at all study sites. Sloughs were characterized by cypress and tupelo with overcup oak just outside the wettest parts. The areas between sloughs and high, well-drained areas were characterized by ash, sweetgum, elm and various hydric oaks. High, well-drained areas were characterized by beech, tulip tree, and various hydric oaks. Disturbances, such as selective lumbering or clearing, were also reflected in the species patterns: young stands of low diversity typically included box elder, red maple, and ash. The vegetation patterns upstream and downstream from highway crossings did not differ substantially. Highly ponded areas and areas of high deposition rates supported ash and tupelo in deference to other bottomland species. Vegetation patterns were related to ponding in that excessive ponding eliminated less tolerant trees, especially mesic tree species.

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GLOSSARY

Accretion rate: the rate of increasing vertical depth on an aggrading surface, such as bank accretion.

Alluvial wetlands: wetlands associated with rivers.

Alluvium: stream-deposited sediment.

Basal area increment: an annual increment of wood tissue produced, measured in cross-sectional area, computed from tree-ring width.

Cesium-137: a radioactive isotope produced by atomic-weapons tests and used to determine the age of recent sedimentary deposits.

Conveyance: discharge capacity of a channel for a given water-surface slope.

Correlation: the degree of positive or negative association between two or more variables; a statistical measure of association.

Cretaceous Period: the latest period of the Mesozoic era, between about 136 and 65 million years ago.

Dendrogeomorphic: refers to techniques that use tree-ring information to infer quantitative information on geomorphic process.

Detrended correspondence analysis: a type of ecological ordination procedure that has been detrended, a specialized form of multivariate statistical analysis, such as principal components analysis.

Dominance: a term used in plant ecology referring to the amount of biomass a particular species contributes to a sampled space, such as basal area or areal cover in a plot measuring 66 feet by 66 feet.

Drainage density: the length of stream channels per unit area.

Hydroperiod: the average length of time an area is covered by water each year.

Importance value: a term used in plant ecology that quantitatively describes the presence and importance of a particular species, within a given area; derived from the frequency, density, and dominance of a species per unit area.

Inundated: covered by water.

Loess: deposits of silt-size, previously wind-borne material.

Matrices: plural of matrix, a regular array of numerical quantities.

Mississippi embayment: that portion of the Gulf Coastal Plain near the Mississippi River.

Multivariate: dealing with several variables simultaneously.

Ordination: an ecological statistical procedure that produces a two-dimensional array of species or sites; the location and proximity of entities is related to their degree of association.

Quaternary sediments: sediments deposited during the Quaternary Period, from about 1.6 million years ago to the present.

Sand splays: flood-plain deposits of sand associated with high water velocities and flooding.

Sedimentation: the deposition of sediment.

Sediment budget: the accounting of sediment scour, transport, and deposition in a defined area or drainage basin.

Sediment yield: the total amount of sediment transported past a point or out of a drainage basin, usually computed for yearly periods.

Slough: a low wet part of a river bottom, usually an abandoned channel, oxbow lake, or scroll depression.

Spatial: related to distance or location.

Spoil bank: a pile of excavated soil or sediment placed along a dredged channel in the form of a levee or berm.

Stage of channel evolution: one of the stages of a model of systematic channel change in response to channelization.

T-test: a statistical test for difference between two sets of data or their means.

Temporal trends: changes in forms or processes over time.

Tertiary Midway Group: part of a geologic formation named for Midway, Tennessee, deposited in the Tertiary Period (between about 65 and 1.6 million years ago).

Two-way factorial analysis of variance: a statistical test for difference among several categorical groups of data.