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Sedimentation in the Cache River Wetlands: Comparison of Two Methods

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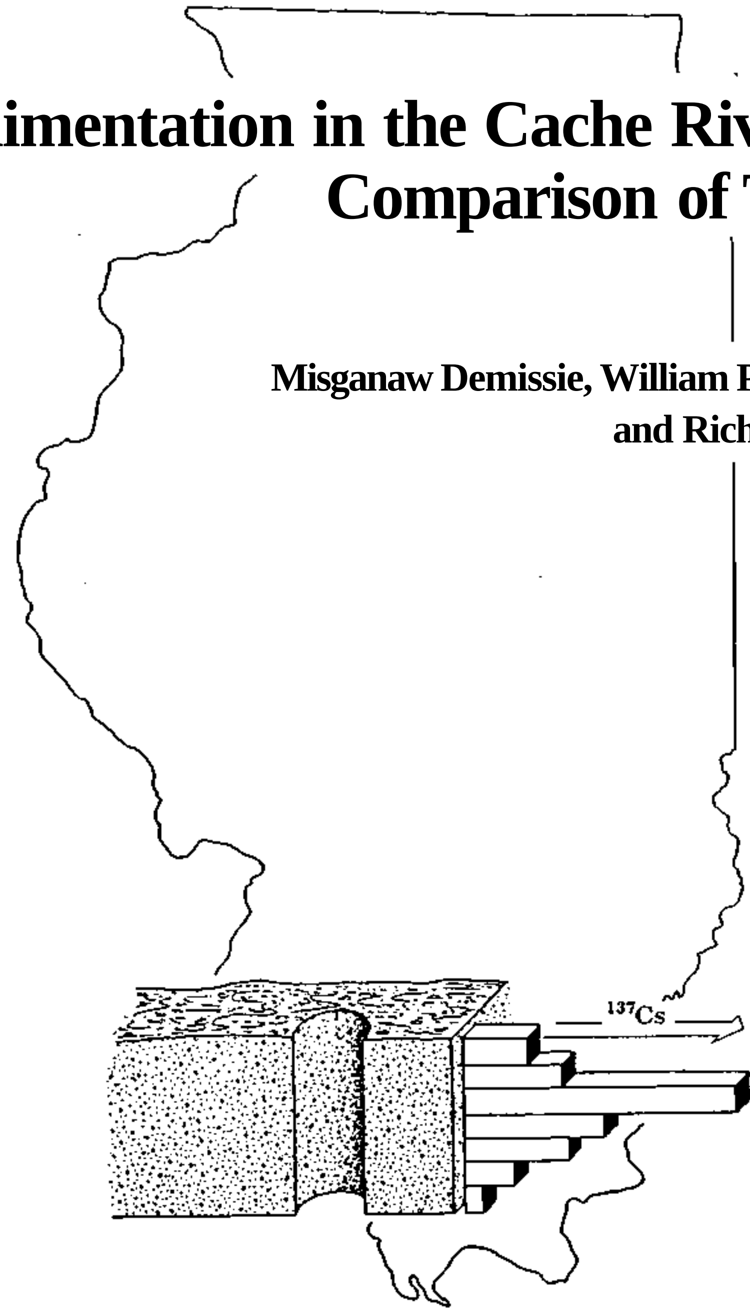
and Richard A. Cahill



ILLINOIS STATE WATER SURVEY
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DEPARTMENT OF ENERGY AND NATURAL RESOURCES

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SEDIMENTATION IN THE CACHE RIVER WETLANDS: COMPARISON OF TWO METHODS

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ABSTRACT

The Cache River wetlands, located in the Cache River basin in southern Illinois, are small remnants of a vast wetland system that used to occupy the Cache River valley before commercial logging and agricultural developments significantly altered the area. In the Lower Cache River basin, a wetland system called "Buttonland Swamp" is under great stress because of increased sediment inflow from tributary streams. The Cache River wetlands act as sedimentation basins that trap significant amounts of sediment inflow from tributary streams. Continual accumulation of sediment is altering the hydrology and hydraulics of the wetlands and causing flooding in tributary streams.

The rates of sedimentation in the wetlands were investigated by using two different methods to provide a better understanding of the amount and areal distribution of the sediment. The first method is based on monitoring sediment flowing into and out of the wetlands. The second method is based on radiometric dating techniques of sediment cores collected at selected points within the study area. This study demonstrates that the two methods can provide consistent sedimentation information if properly applied and if the limitations of each method are properly recognized.

INTRODUCTION

The Lower Cache River wetlands are small remnants of an extensive wetland system in the Cache River valley. The wetlands are bottomland forests that are frequently flooded by tributary streams that drain upland watersheds. The Cache River basin is located in the extreme southern part of Illinois, just north of the confluence of the Ohio and Mississippi Rivers (figure 1). The basin covers parts of six southern Illinois counties: Union, Johnson, Alexander, Pulaski, Massac, and Pope. The total drainage area of the watershed is 1909 square kilometers (km^2) or 737 square miles (mi^2). Since the construction of the Post Creek

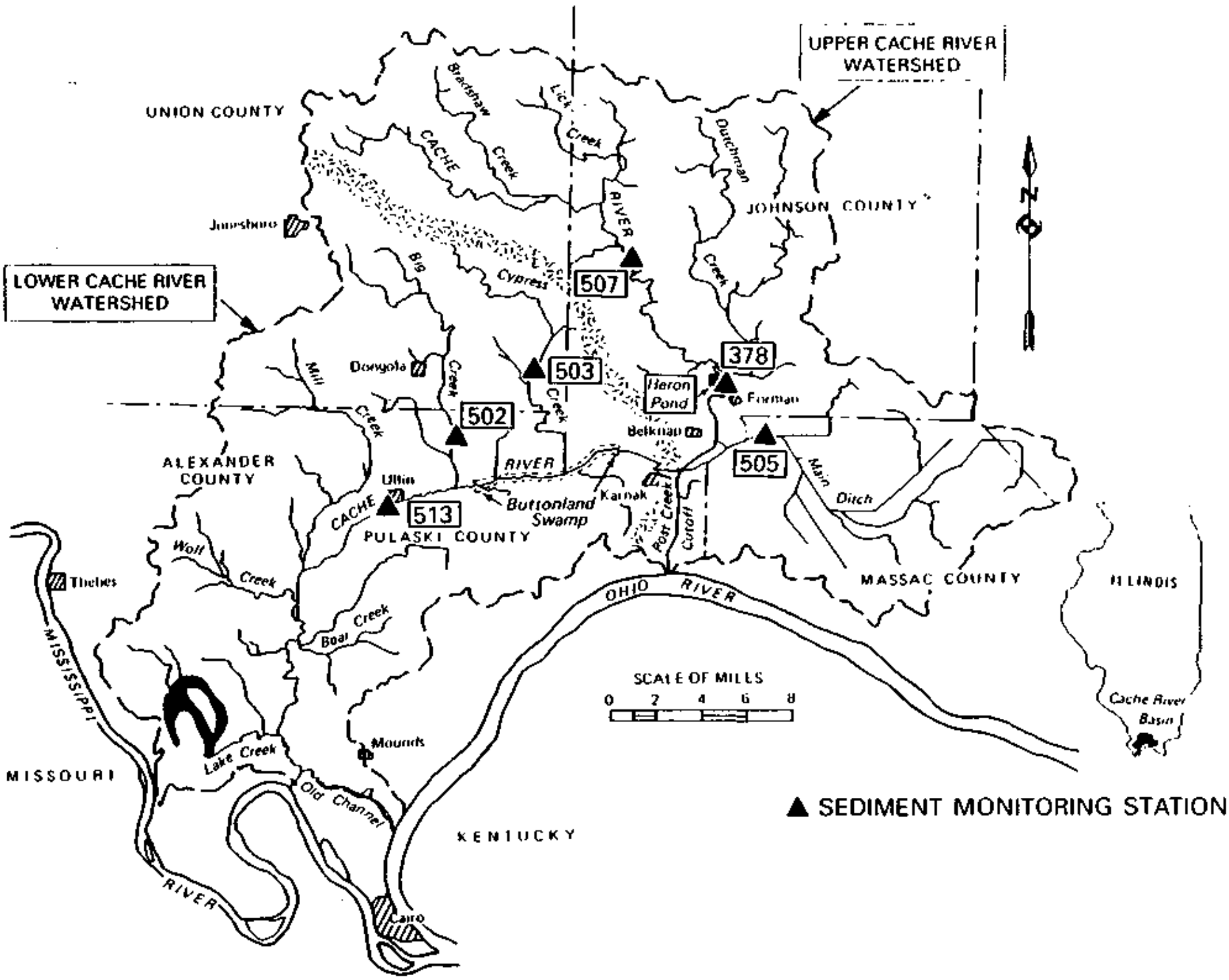

Figure 1. Sediment monitoring stations in the Lower and Upper Cache Rivers

Cutoff in 1915, the Cache River basin has been divided into the Upper Cache and Lower Cache River subwatersheds, as shown in figure 1. The Upper Cache River watershed consists of the eastern part of the Cache River basin with a drainage area of 953 km^2 (368 mi^2); it drains directly to the Ohio River at River Mile 957.8 through the Post Creek Cutoff. The Lower Cache River watershed consists of the western part of the Cache River basin with a drainage area of 927 km^2 (358 mi^2); it drains to the Mississippi River at River Mile 13.2 through the diversion channel at the downstream end of the river.

The Upper and Lower Cache River basins are separated by the Cache River levee along the western bank of the Post Creek Cutoff near Karnak. This levee was built across the old Cache River channel and forces drainage from the Upper Cache River to flow directly to the Ohio River through the Post Creek Cutoff; drainage from the Lower Cache basin is forced to flow to the west to empty into the Mississippi River. Two 4-foot culverts in this levee allow some water from the Lower Cache River basin to discharge into the Post Creek Cutoff.

Upland erosion and subsequent sedimentation in stream channels and wetlands are sources of major problems in the Cache River basin. In the Lower Cache River, the problems are related to excessive accumulation of sediment eroded from upland watersheds and streambanks, and deposited in wetlands and stream channels. The accumulation of sediment in stream channels retards the flow in the stream, decreases the efficiency of the channels, and increases flooding potential. The accumulation of sediment in wetlands changes the hydrologic balance in the wetland, significantly alters the available habitats, and induces environmental stresses that could result in a change in the types of plants and animals that could survive in the area. The Cache River project was initiated as part of the state's attempt to prevent further degradation of important natural habitats and to develop environmentally sound management alternatives that will protect and restore these areas.

Two different approaches were integrated to gain a detailed understanding of *the* sedimentation problem in the Lower Cache River. The two approaches are the hydrologic budget and geochemical analysis. Neither approach by itself was capable of providing all the information needed to quantify the sedimentation pattern in the complex ecosystem found in the Lower Cache River. Very often, the geochemical approach relies on a limited number of sediment cores (usually only one core) to determine the sedimentation rate; *the* results are then extrapolated over unreasonably large areas, often incorrectly assuming a uniform sedimentation rate. On the other hand, the hydrologic approach is designed to determine average sedimentation rates based on sediment budgets for large areas; those values are then applied uniformly to all the different units within the ecosystem. Application of the two approaches independently could result in contradicting concepts and conclusions as discussed by Christophersen and Neal (1990). This study demonstrates how the two approaches should be used to complement each other and provide a more complete picture of the sedimentation process in a complex environment. The two methods can also be used to test and validate the accuracy of the results from each individual approach.

SEDIMENTATION RATE BASED ON SEDIMENT BUDGET

Because erosion and sedimentation were the main causes of many of the problems in the Cache River basin, a sediment data collection program was initiated in 1985 as part of the Cache River basin project. The data collection program was designed to quantify the amount of sediment transported by different streams so that the best alternative solutions could be developed for reducing the inflow of sediment into the area (Demissie and Bhowmik, 1985). Sediment monitoring stations were located at strategic sites to provide the best data on which to construct the sediment budget for the study area. The sediment monitoring stations in the entire Cache River basin, in both the upper and lower subwatersheds, are shown in figure 1 and listed in table 1. Even though sediment concentrations were monitored at other stations, including a station in the middle of the swamp, these six stations — three in the Upper Cache and three in the Lower Cache — were the principal locations at which sediment loads could be calculated with reasonable accuracy. The results of monitoring the sediment transport rates in the Upper Cache River were used in developing a sediment transport model to simulate channel scour in the Upper Cache River and the Post Creek Cutoff. They were reported by Demissie et al. (1990b).

Table 1. Sediment Monitoring Stations in the Cache River Basin

Station number	*Location*	*Drainage area*	
		(mi^2)	*(km^2)*
Upper Cache River			
378	Cache River at Forman	241	624
505	Main Ditch at Route 45	97	251
507	Cache River at Route 146	122	316
Lower Cache River			
502	Big Creek at Perks Road	31	80
503	Cypress Creek at Dongola Road	24	62
513	Cache River at Route 51	164	425

In the Lower Cache River, two stations were located on the two major tributaries draining into the Buttonland Swamp area to monitor the inflow of sediment, and the third was located on the main stem of the Lower Cache River at Ullin to monitor sediment outflow from the Buttonland Swamp area. This arrangement made it possible to estimate the amount of sediment entering and leaving this wetland complex, and thus develop a sediment budget. The sediment budget for the area was determined after calculating the sediment yields at the monitoring stations and extrapolating the results to the ungaged area. The procedure and results are presented in the following sections.

Sediment Loads at Gaging Stations

The sediment loads at gaging stations were determined from sediment concentration samples collected on a regular basis at the stations. Two of the gaging stations have ISCO samplers to collect daily data, and more frequently during storm events. Each station is serviced weekly by a technician to collect the samples, take cross-sectional sediment concentration samples, and measure the water discharge. The data collected is then analyzed following the procedures outlined by Porterfield (1977) for the U.S. Geological Survey. The daily sediment load is computed by the following equation.

$$Qs = Qw \times C_s \times k \tag{1}$$

where

Q_s = the sediment load in metric tons per day

Q_w = water discharge in cubic meters per second (m /s)

C_s = concentration of suspended sediment in milligrams per liter (mg/1)

k = 0.0864, the coefficient of conversion based on units of measurement and the specific weight of the sediment

The computed sediment load data, along with water discharges for the three monitoring stations, during the three-year monitoring period, are presented in figures 2-4. Big Creek (figure 2) and Cypress Creek (figure 3) are the tributary streams, while Cache River (figure 4) is the main river.

Sediment Yield

The total annual sediment yields from the three monitoring stations in the Lower Cache River for the three water years from 1986 to 1988 were determined by summing the daily loads shown in figures 2-4. The results are summarized in table 2, and plotted in figure 5 to show the variation of sediment yield from year to year and from station to station (Demissie, 1989;

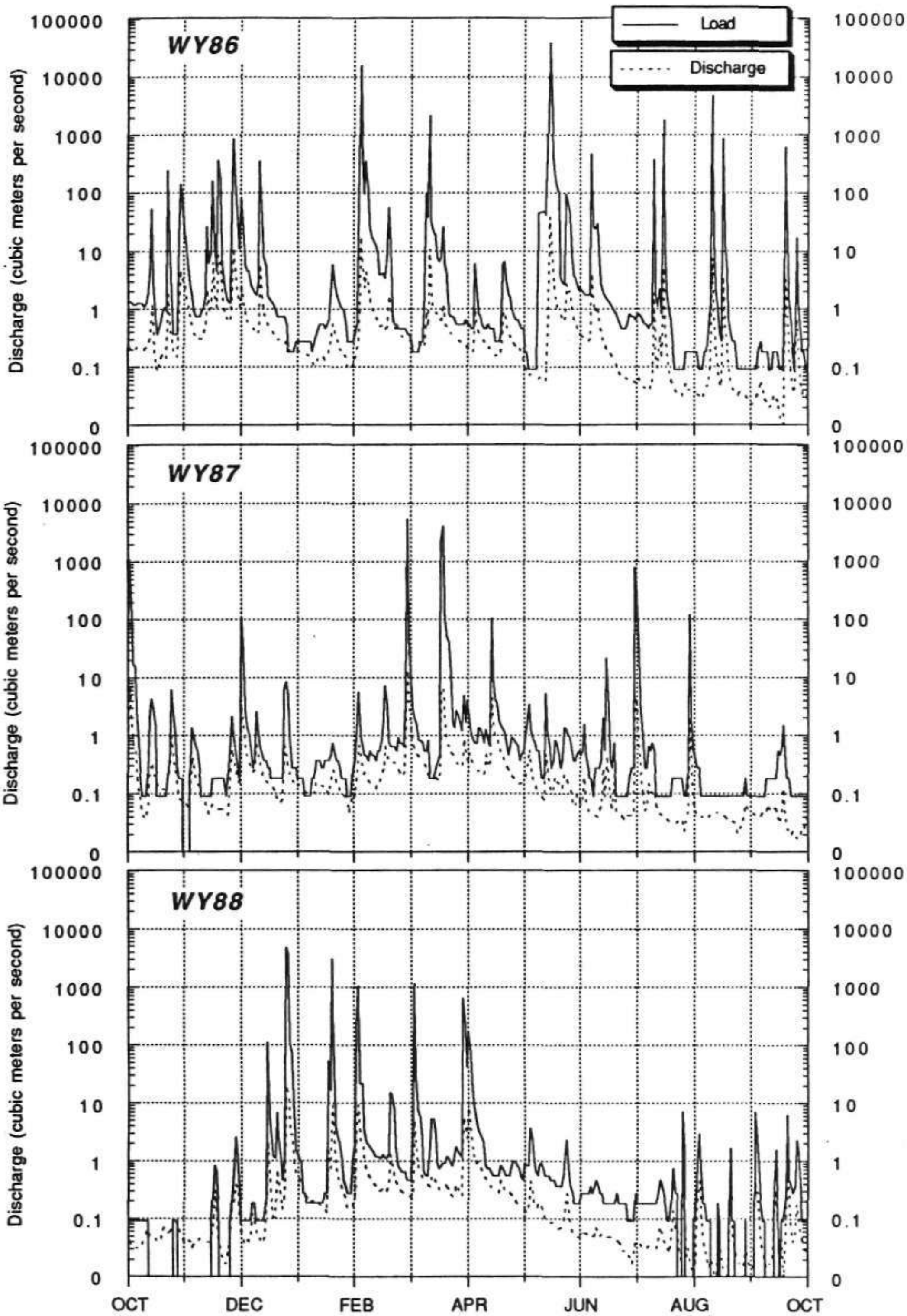

Figure 2. Sediment load and water discharge for Big Creek

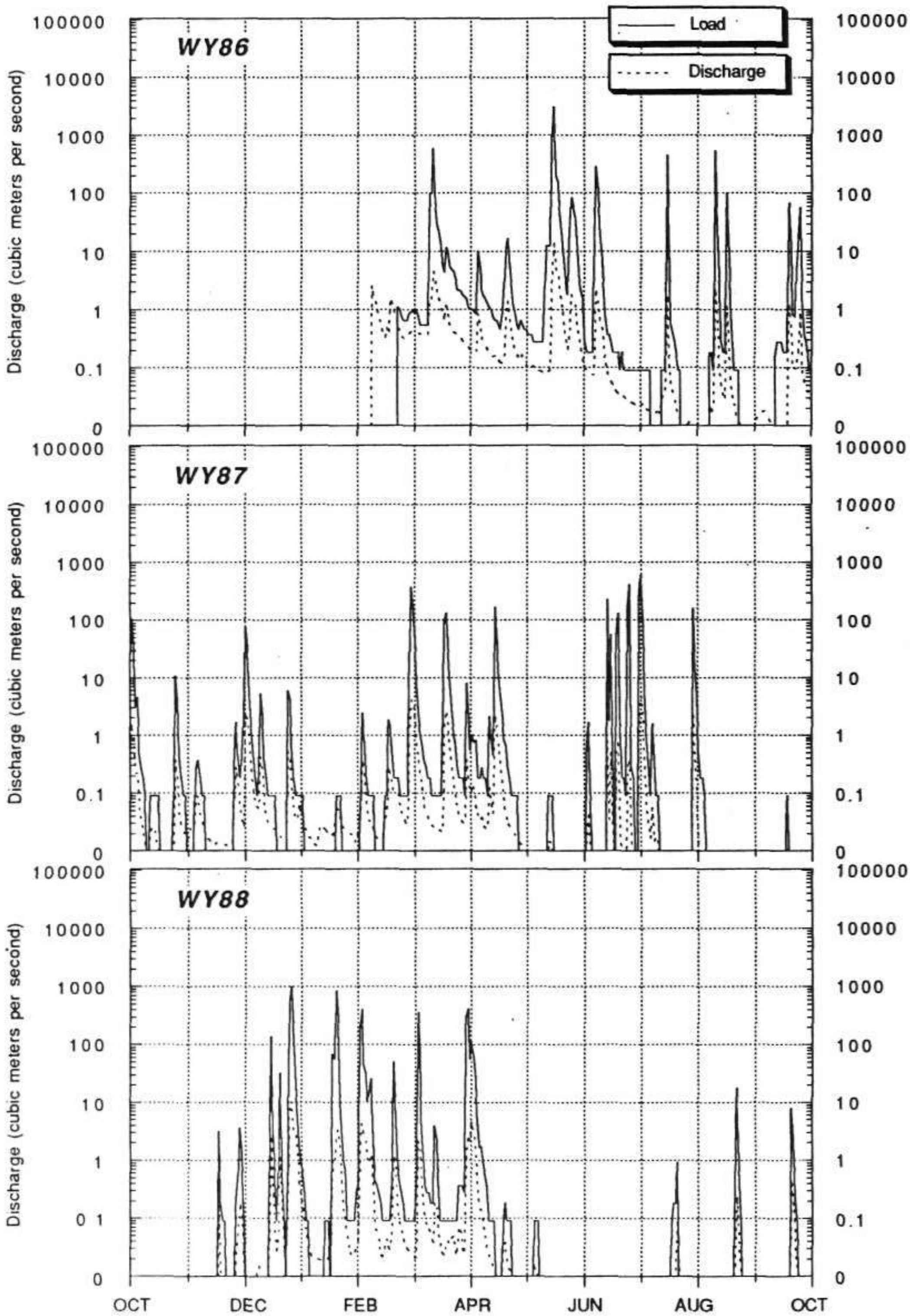

Figure 3. Sediment load and water discharge for Cypress Creek

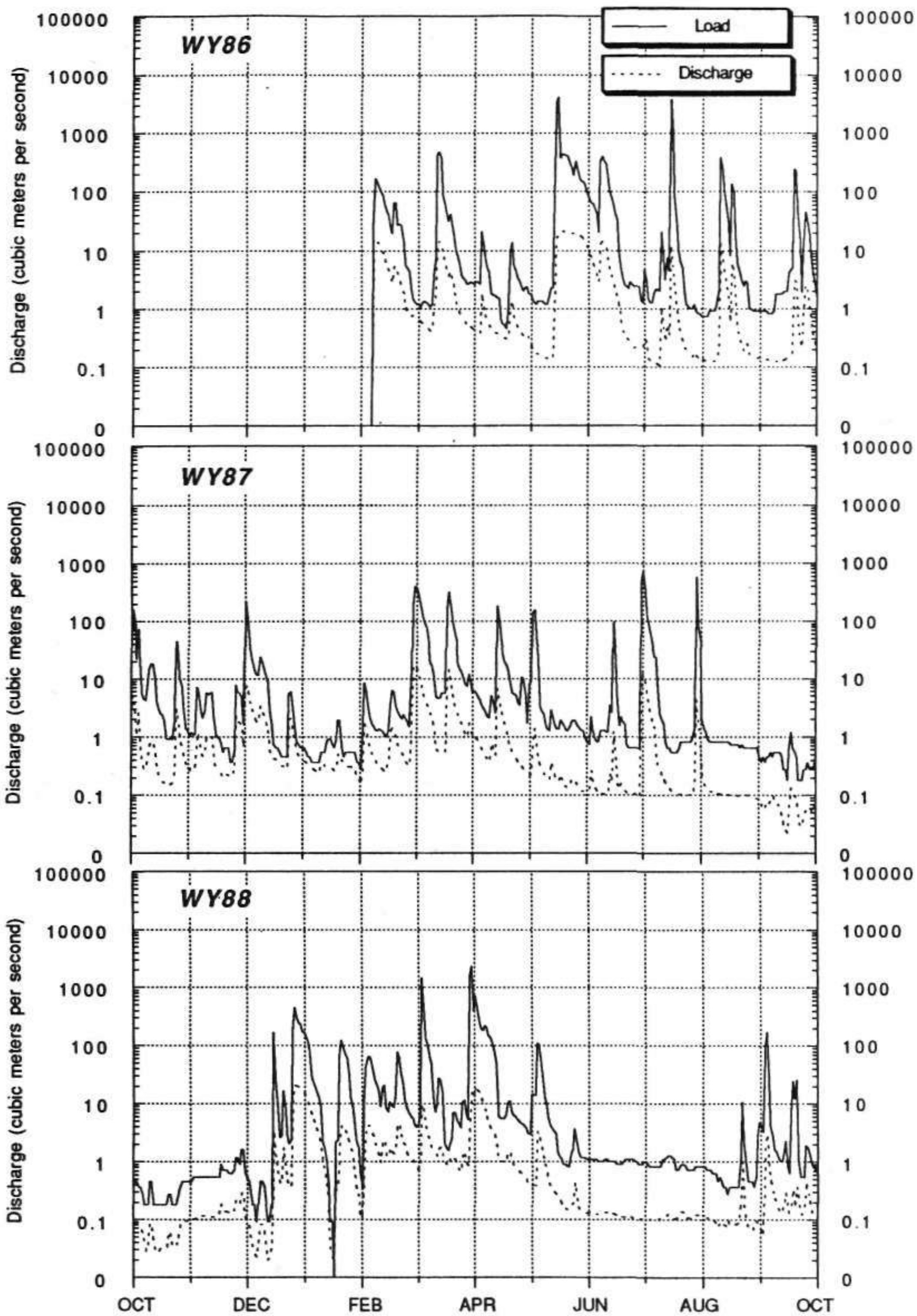

Figure 4. Sediment load and water discharge for the Cache River at Route 51

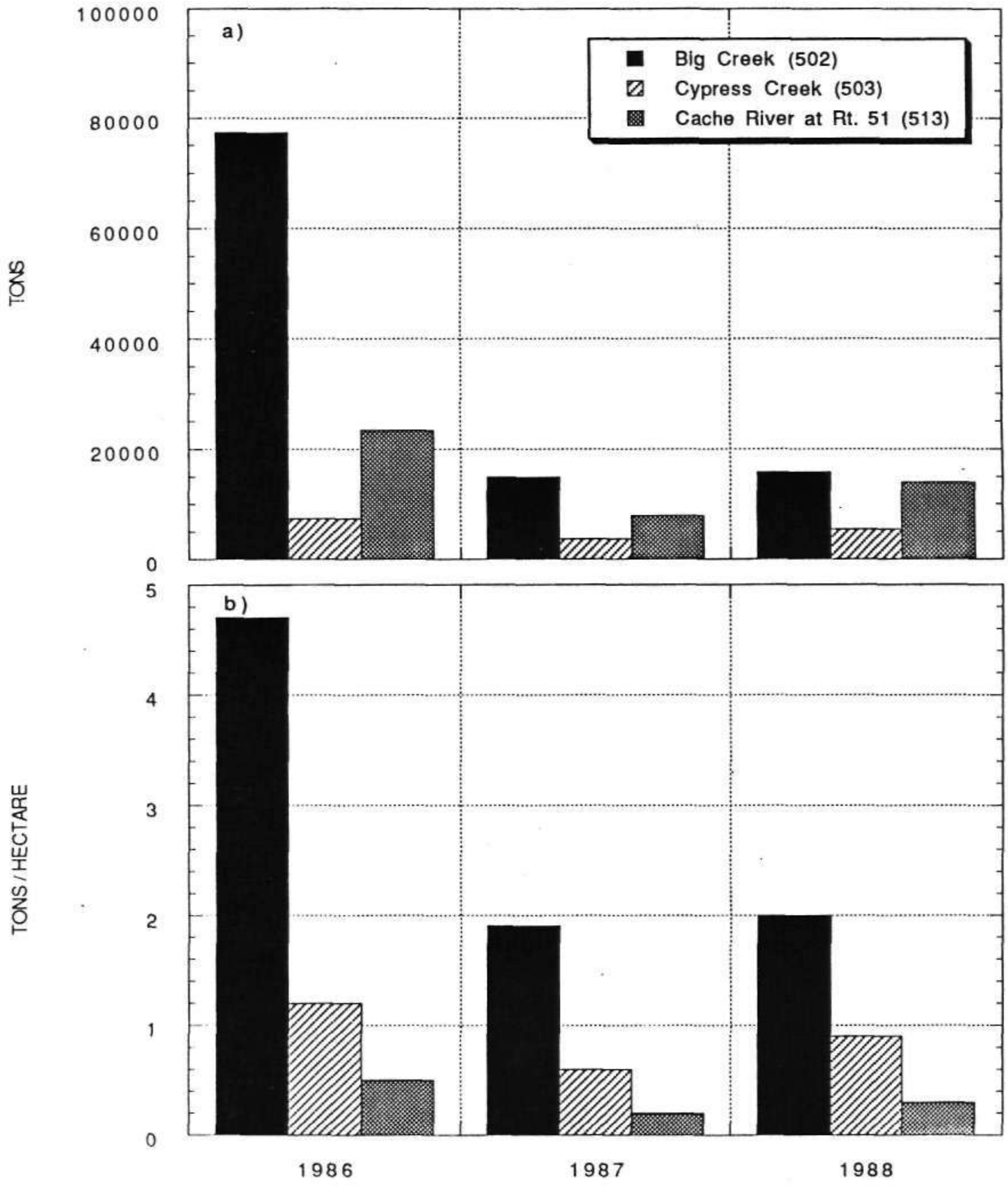

Figure 5. Annual sediment yield at three stations in the Lower Cache River

Demissie et al., 1990a). Figure 5a shows the total sediment yields in tons (T), while figure 5b shows the sediment yield rates per unit area in tons per hectare (T/ha). In terms of total sediment yield, the Big Creek watershed generates more sediment than the Cypress Creek watershed and even more than the entire Lower Cache River watershed upstream of Ullin, which includes the Big Creek watershed. The amount of sediment yield depends on the annual runoff. Generally a wet year will yield much more sediment than a low-flow year. The annual flows for the three years are shown in figure 6. Based on long-term flow records, 1986 was a near-normal water year, while 1987 and 1988 were both low-flow water years. In 1986 the total annual sediment yield from the Big Creek watershed was 77,370 tons as compared to 7,408 and 23,336 tons for Cypress Creek and the Lower Cache River at Ullin, respectively. Therefore the total amount of sediment from Big Creek was more than ten times that of Cypress Creek and more than three times that of the Lower Cache River. In 1987 the total annual sediment yield from Big Creek was 14,904 tons as compared to 3,656 and 7,892 tons for Cypress Creek and the Lower Cache River, respectively. In 1988 the sediment yield from Big Creek was 15,814 tons as compared to 5,460 and 14,013 tons for Cypress Creek and the Lower Cache River, respectively. Therefore the sediment yield from Big Creek is generally several times (up to ten times) that of Cypress Creek and up to three times more than that of the Lower Cache River. The sediment yield from the Lower Cache River at Ullin is less than that of Big Creek because a significant amount of the sediment entering the area is trapped within Buttonland Swamp and the adjoining wetlands and floodplains before it reaches the gaging station at Ullin.

On the basis of sediment yield per unit area as shown in figure 5b, for 1986 the sediment yields per hectare for Big Creek, Cypress Creek, and the Lower Cache River were 9.7, 1.2, and 0.5 tons, respectively. For 1987 for Big Creek, Cypress Creek, and the Lower Cache River, they were 1.9, 0.6, and 0.2 tons, respectively. For 1988 for Big Creek, Cypress Creek, and the Lower Cache River, they were 2.0, 0.9, and 0.3 tons, respectively. Therefore,

Table 2. Measured Annual Sediment Yields in the Lower Cache River Basin

	Big Creek at Perks Road		*Cypress Creek*		*Cache River at Route 51*	
Water Year	*Tons*	*Tons/ha*	*Tons*	*Tons/ha*	*Tons*	*Tons/ha*
1986	77,370	9.7	7,408	1.2	23,336	0.5
1987	14,904	1.9	3,656	0.6	7,892	0.2
1988	15,814	2.0	5,460	0.9	14,013	0.3

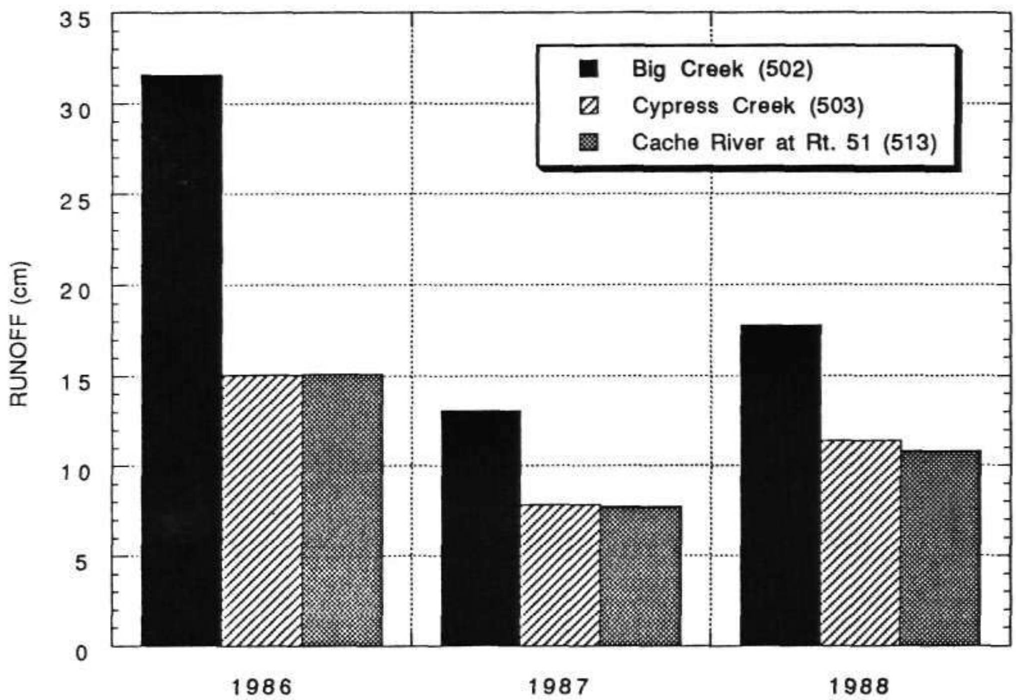

Figure 6. Annual flows in the Lower Cache River for 1986, 1987, 1988

the sediment yield per unit area from Big Creek is from 2 to 8 times that of Cypress Creek and from 6 to 17 times that of the Lower Cache River.

The Big Creek watershed yields more sediment per unit area than the Cypress Creek watershed because of differences in watershed characteristics, land use, stream channel characteristics, and floodplain wetlands. Since the watersheds are adjacent, any differences in climatic or soil characteristics should not be significant. However, the stream channels and floodplains of the two creeks are very different. While the floodplains of Big Creek are relatively devoid of trees, many places along Cypress Creek are forested. These forested floodplains tend to trap sediment and reduce sediment yield downstream.

Sediment Budget

As stated in the introduction, a principal problem of the Lower Cache River is excessive accumulation of sediment in wetlands and stream channels. Because of its location and hydraulic characteristics, the Buttonland Swamp area is a sedimentation basin. Sediment yield data collected at the three Lower Cache sediment monitoring stations were used in developing a sediment budget for the Buttonland Swamp area to determine the amount of sediment accumulated. Sediment yield values calculated for Big Creek and Cypress Creek were used for those watersheds not monitored to generate the total sediment inflow into the Buttonland Swamp area. The sediment outflow from the area was calculated from outflow measured in the Cache River at Ullin and was adjusted for outflow through the culverts at the Cache River levee on the east end of the Buttonland Swamp area. The total sediment discharge from the Buttonland Swamp area was calculated by increasing the measured sediment load of the Cache River at Ullin by 10 percent to account for the outflow of water and sediment through the culverts.

For the purpose of sediment budget calculations, the entire area draining into the Buttonland Swamp area was divided into nine sub-watersheds as shown schematically in figure 7. Sub-watersheds 1 and 8 are the Big Creek and Cypress Creek watersheds, which have been monitored at the gaging stations shown in figure 1. The other sub-watersheds either join Big Creek and Cypress Creek or drain directly into the Cache River. Cypress Creek's sediment yield rate was used for sub-watersheds 3-7 and 9. Big Creek's sediment yield rate was used to calculate the sediment budget for sub-watershed 2, the Little Creek watershed adjacent to the Big Creek watershed and sharing similar characteristics with it. Because the sediment yield rates assigned to the sub-watersheds are conservative, they would tend to underestimate the sediment yield from the entire area. However, the results from the calculations provide a reasonable estimate for the Lower Cache River.

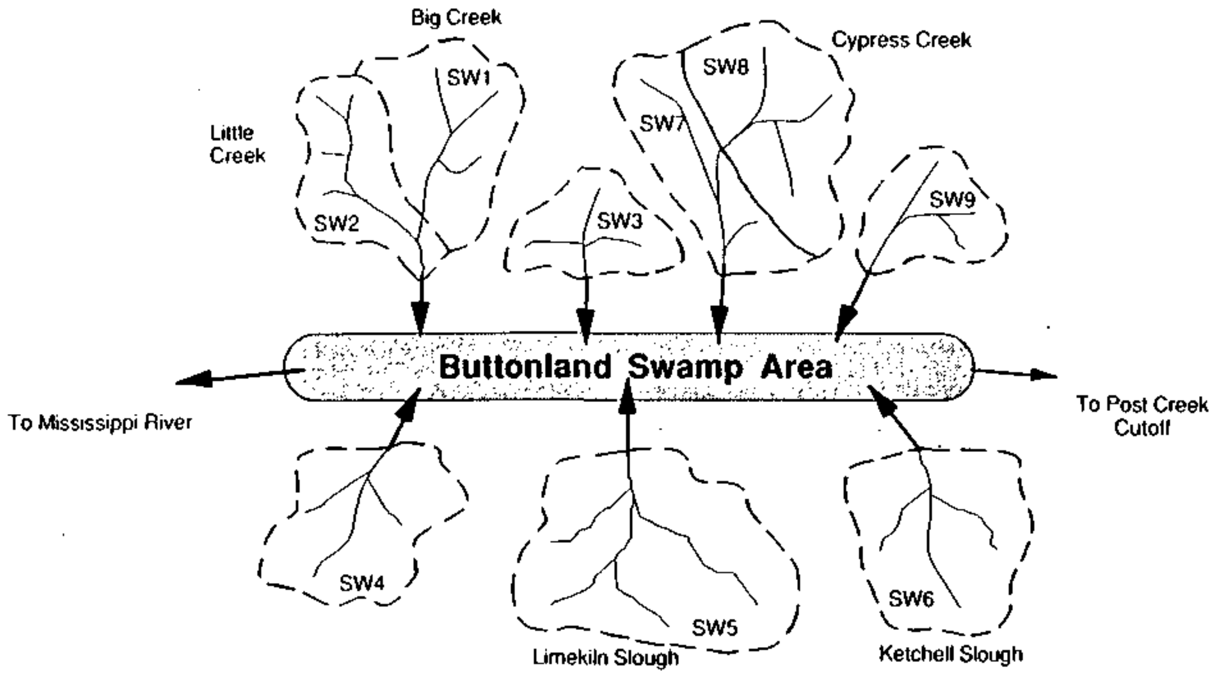

Figure 7. Sub-watersheds draining into the Buttonland Swamp area

The sediment budget for the Lower Cache River wetland area can be calculated by an equation similar to one used by Parker (1988) to calculate sediment budget for the Missouri River:

$$\Delta Q_S = \sum_{i=1}^{N} QS_{Ti} - QS_0 \qquad (2)$$

where

ΔQ_S = amount of sediment trapped/scoured from the study area
QS_O = amount of sediment outflow from the study area
QS_{Ti} = sediment inflow from tributary stream
N = number of tributary streams

The results of the sediment budget calculations are given in table 3. Calculations were performed for three water years where data were collected at all stations. Water Year 1985 was excluded because data were not available for two of the three stations. For Water Year 1986, sediment inflow into the Buttonland Swamp area was calculated to be 157,300 tons, but only 25,700 tons left the area. Therefore, 131,600 tons of sediment were trapped in the area,

Table 3. Sediment Budget of the Buttonland Swamp Area

	Drainage areas		*Sediment yield rates (tons/ha)*			*Sediment yields (tons x 1000)*		
Sub-watersheds	*(km²)*	*(ha x 1000)*	*1986*	*1987*	*1988*	*1986*	*1987*	*1988*
SW1	81.3	8.1	9.7	1.9	2.0	78.4	15.2	16.1
SW2	48.4	4.8	"	"	"	46.4	9.0	9.5
SW3	32.6	3.2	1.2	0.6	0.9	3.8	1.9	2.8
SW4	15.8	1.6	"	"	"	1.9	0.9	2.8
SW5	57.2	5.7	"	"	"	6.8	3.4	5.0
SW6	30.0	3.0	"	"	"	3.5	1.7	2.6
SW7	57.8	5.8	"	"	"	6.9	3.4	5.1
SW8	62.2	6.2	"	"	"	7.4	3.6	5.4
SW9	17.4	1.7	"	"	"	2.1	1.0	1.5
Total	402.7	40.2				157.3	40.0	49.4
Sediment yield at Cache River at Ullin			0.5	0.2	0.3	23.3	7.9	14.0
Adjusted sediment yield for the Lower Cache River*						25.7	8.7	15.3
Sediment trapped in the Buttonland Swamp area						131.6	31.3	34.1
Trap efficiency						84%	78%	69%

Note: *Sediment yield at Cache River at Ullin x 1.10

indicating an 84 percent trap efficiency. In Water Year 1987, a dry year, sediment inflow into the area was only 40,000 tons and the outflow was 8,700 tons, indicating 78 percent trap efficiency. In Water Year 1988, another dry year, sediment inflow was 49,400 tons and outflow was 15,300 tons, indicating 69 percent trap efficiency. Therefore, the results from the three years of data collection indicate that 69 to 84 percent of the total amount of sediment that enters the Buttonland Swamp area is trapped in the area. These very high sediment trapping efficiencies, similar to those for man-made reservoirs, account for the high sedimentation rate within the Buttonland Swamp area.

SedimentationRate Based on Sediment Budget

The total annual sediment deposition in the wetlands based on sediment budget calculations are presented in table 3. Although these values provide the magnitude of sediment deposition in the entire area, they do not provide areal sediment distribution and vertical accretion rates at different locations. For aquatic habitat preservation and restoration purposes, the vertical rate of sediment deposition is important since it affects water depth and substrate characteristics. Therefore there was a need to determine the vertical rate of sediment deposition in addition to the determination of the total amount of sediment deposited in the area.

In order to determine the vertical rate of sediment deposition, two additional parameters must be determined: area of sediment deposition and sediment density. Once these are determined, then it is possible to calculate the average sedimentation rates based on sediment budget. The volume of sediment deposited in an area is determined from the sediment budget by dividing the sediment weight by the sediment density. The sediment thickness or the rate of vertical deposition is then calculated by dividing the sediment volume by the area of sediment deposition. The equation for calculating vertical sediment deposition rate is given by:

$$\Delta Z = \frac{S_{wt}}{S_d \times A_s} \tag{3}$$

where

ΔZ = sedimentation rate in inches (in.) or centimeters (cm)

S_{wt} = weight of sediment deposited

S_d = density of the deposited sediment

A_s = area of sediment deposition

The average sediment density for the entire area is estimated from the densities of several submerged and exposed samples analyzed in the lab. The average value used for the entire area was 800 kilograms per cubic meter (kg/m^3). This is slightly higher than the average submerged sediment density (641 kg/m^3) but less than the dry density (1,442-1,602 kg/m^3). After selecting the value for the density, the only parameter that remains to be determined is the area of sediment deposition.

Based on general analysis of the regional hydrology and field observations after flood periods, it is reasonable to assume that the Lower Cache River floodplain as a whole is an area of sediment deposition. However, it is also known that all flooded areas in the floodplain are not areas of sediment deposition. There are even areas of localized scour within an area of net sediment deposition. In general, the total area of sediment deposition will vary from year to year and depend on the water level in the valley. If the water level in the valley is high and large areas of the floodplain are flooded, then the area of sediment deposition will be large. But if the water level in the valley is low and did not overtop the river banks for the entire year, then the area of sediment deposition will be confined within the stream channels, side channels, and backwater areas that had been inundated with floodwater. Therefore, the area of sediment deposition was estimated based on the analysis of water levels in the valley. The water level was monitored continuously at a gaging station in the center of Buttonland Swamp. The fluctuation of water levels for the three years of data collection is shown in figure 8. The bankfull elevation is about 328 feet mean sea level (ft msl). Stages above this level represent flood events that overtopped the streambanks and inundated adjacent wetlands and floodplain. Most of the remaining wetlands in the Lower Cache River valley are located below the 330 ft msl elevation.

The water level records for the Lower Cache River in the Bottomland Swamp area (figure 8), were analyzed to generate the stage exceedence curves for each year shown in figure 9. The curves show the percent of time mat water levels have been above a certain elevation for each of the three years. The maximum water surface elevations for each year were the elevations exceeding 0 percent time. Therefore it can be assumed that the maximum possible area of sediment deposition will be the area inundated at least once a year during the annual flood. Even though it is unrealistic to assume the entire area flooded once a year is the actual area of sediment deposition, the areas were determined and used to calculate the minimum possible rates of sediment deposition. The maximum potential areas of sediment deposition were determined from the area-stage curve shown in figure 10 for the maximum water levels for each year. The maximum potential areas of sediment deposition for 1986, 1987, and 1988 were 5,100, 1,600, and 2,800 hectares, respectively.

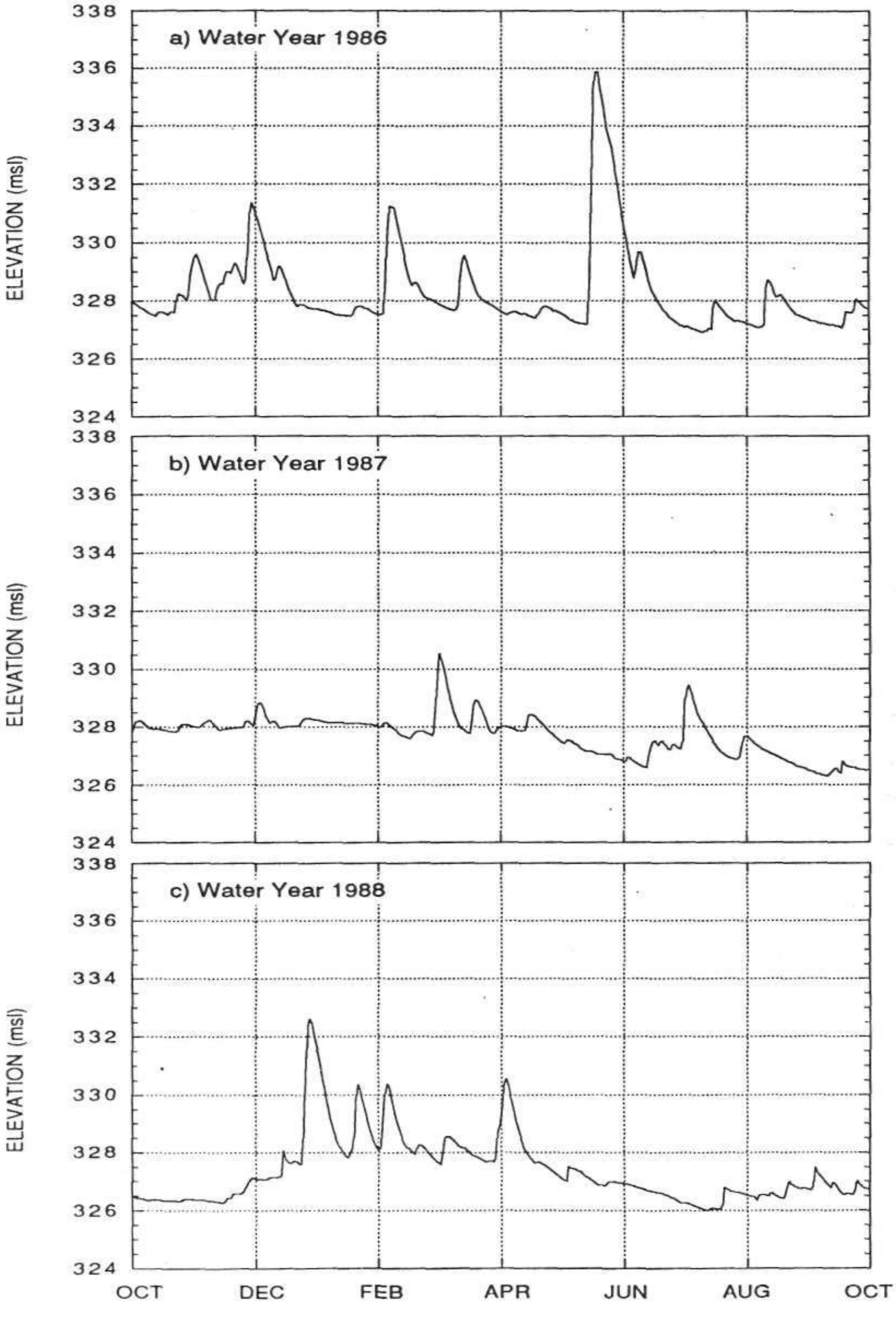

Figure 8. Water levels in the Buttonland Swamp area of the Lower Cache River

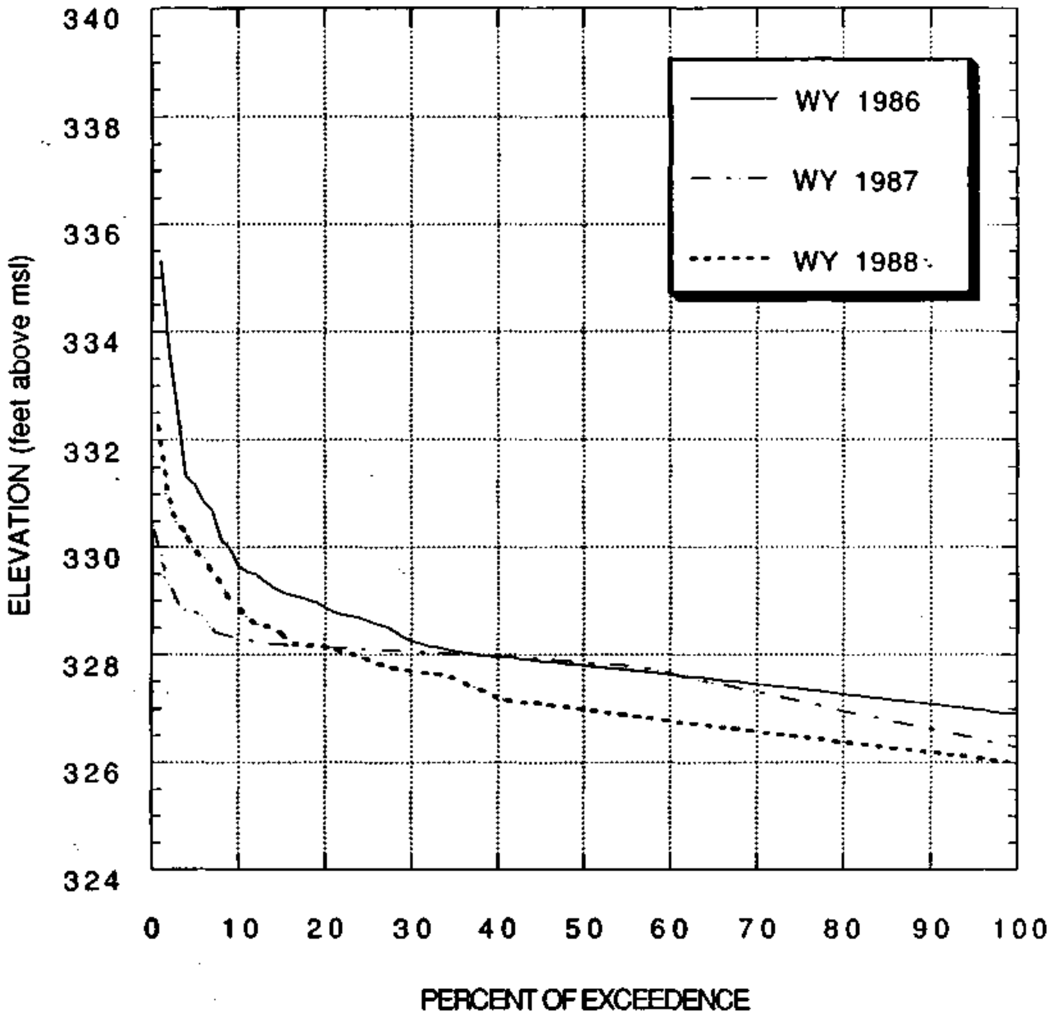

Figure 9. Stage-frequency curves for the Lower Cache River in the Buttonland Swamp area

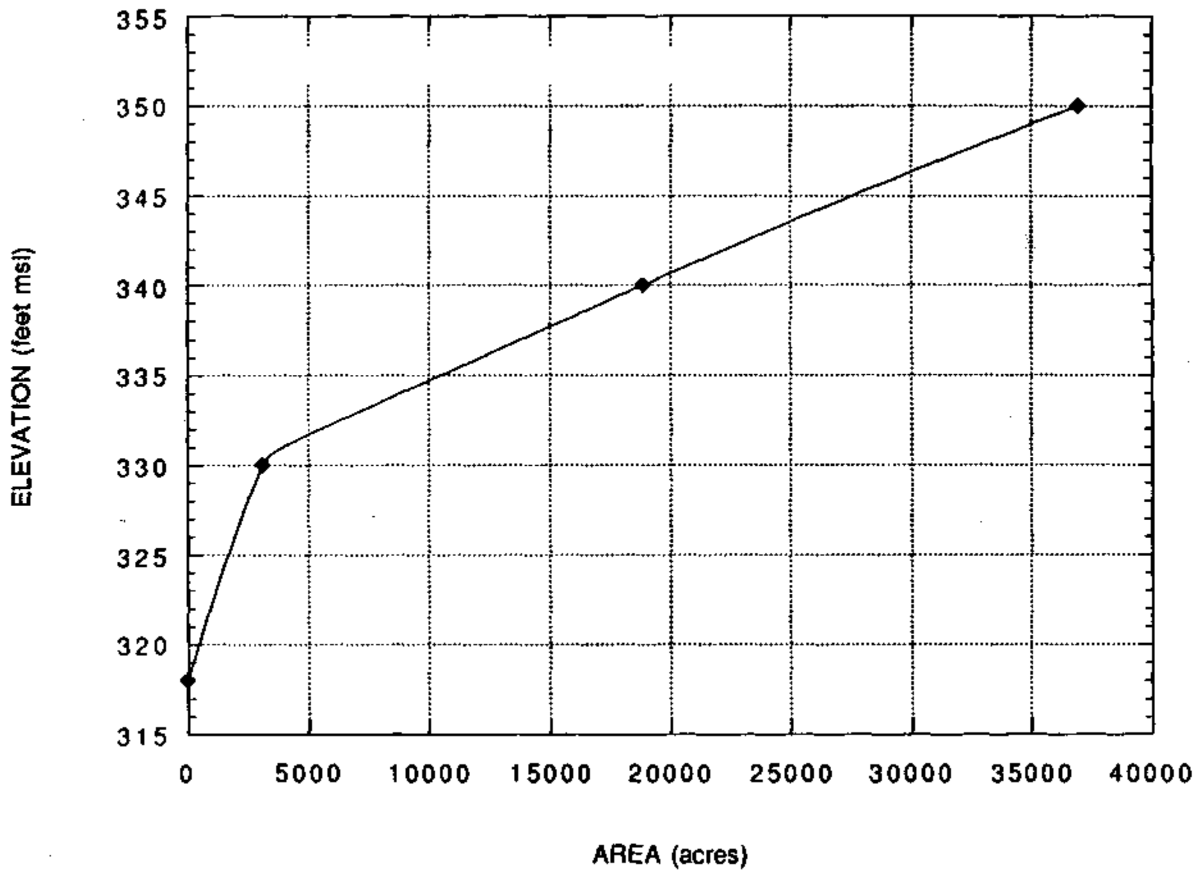

Figure 10. Elevation-surface area curve for the Lower Cache River floodplain in the Buttonland Swamp area

A more realistic estimate of the area of sediment deposition, based on the knowledge of. the area, would be to include all stream channels, backwaters, sloughs, and the wetlands along the streambanks. These areas are generally flooded every year, and most of them support some form of wetland vegetation. The best estimate of this area is made by including all areas below the 330 ft msl elevation. From the elevation-surface area curve shown in figure 10, the area within 330 ft msl is 1,200 hectares. Therefore for comparison purposes, two different areas of sediment deposition were determined for each year: the maximum potential area of sediment deposition based on maximum flood elevation, and the most probable area of sediment deposition based on the area's physical characteristics.

The results of the sedimentation rate calculations based on the sediment budget are summarized in table 4. The sedimentation rates calculated based on the maximum possible area of sediment deposition are the minimum sedimentation rates that can be expected. The sedimentation rates calculated based on the most probable depositional area, which includes stream channels, backwaters, sloughs, and wetlands, most likely approximate the actual sedimentation rates.

The average minimum sedimentation rate for the three years is 0.25 cm (0.10 in.) with a low of 0.15 cm (0.06 in.) in 1988 and a high of 0.33 cm (0.13 in.) in 1986. The sedimentation rate based on the most probable depositional area ranges from a low of 0.33 cm (0.13 in.) in 1987 and 1988 to a high of 1.32 cm (0.52 in.) in 1986. The rates are equivalent to an average of 0.66 cm (0.26 in.) over the three-year period. One major factor that should be noted is that 1987 and 1988 were dry years and only 1986 was a near-normal year.

Table 4. Sedimentation Rates Based on Sediment Budget

Water year	*Sediment accumulation (tons x 10^3)*	*Volume of sediment[1] (m^3 x 10^3)*	*Area of sedimentation (ha x 10^3)*		*Sedimentation rates*			
			Maximum[2]	*Estimate[3]*	*Minimum (cm)*	*Minimum (in.)*	*Estimate (cm)*	*Estimate (in.)*
1986	131.6	164.3	5.1	1.2	0.33	0.13	1.32	0.52
1987	31.3	39.6	1.6	1.2	0.25	0.10	0.33	0.13
1988	34.1	42.5	2.8	1.2	0.15	0.06	0.33	0.13
Average	65.7	82.1	3.2	1.2	0.25	0.10	0.66	0.26

Notes:
[1] based on sediment density of 800 kg/m^3
[2] based on high water elevation
[3] based on estimated wetland area at 330 ft msl

Therefore the amount of sediment transported during the three-year period is expected to be below normal, and thus the calculated sedimentation rates are expected to be less than the long-term average.

The vertical sediment deposition rates calculated based on sediment budget will be compared with those determined by radiometric analysis later in this report.

SEDIMENTATION RATE BASED ON RADIOMETRIC ANALYSIS

The sedimentation rate calculations based on sediment load monitoring at tributary streams inflowing into an area and at the outlets provide the overall average sedimentation rate for the entire area for the period of data collection. However, it is well known that the sedimentation rate will vary both in time and space. Certain areas such as backwaters and side channels experience more sedimentation than areas such as floodplain fringes and constricted stream channels. Therefore, to obtain a more detailed resolution of the temporal and spatial variation of the sedimentation rate, sediment core samples were collected at selected areas for analysis using a radiometric dating technique.

Cesium-137 (^{137}Cs) is among the radioisotopes distributed globally as a result of atmospheric testing of nuclear weapons in the atmosphere. The initial input of ^{137}Cs in measurable quantities represents the period from 1952-1954. The peak period of fallout was 1963. By measuring the activity of Cs in discrete intervals of sediment, the pattern observed from atmospheric testing is often replicated in a sediment column. The onset of measurable activity in the core (1954) and the peak activity (1963) are assumed.

The validity of ^{137}Cs in the study of sedimentation processes in aquatic environments has been critically reviewed by Crickmore et al. (1990), Ritchie and McHenry (1990), and Santschi and Honeyman (1989). Brown et al. (1981), Lance et al. (1986), and McHenry et al. (1973) demonstrated the application of ^{137}Cs to measure accumulation patterns in small watersheds and Kadlec and Robbins (1984), in a wetland area. The technique has been successfully used in Illinois to study sedimentation processes in lakes associated with Illinois and Mississippi Rivers (Cahill and Steele, 1986a; and Cahill and Autrey, 1987) and to study depositional processes in Lake Michigan (Cahill and Steele, 1986b).

The key assumptions made when using ^{137}Cs to measure depositional processes is that following deposition, there is no significant downward movement of ^{137}Cs as a result of chemical, physical, or biological processes. The critical evaluations of Ritchie and McHenry (1990) and Santschi and Honeyman (1989) indicate that ^{137}Cs is strongly adsorbed on clay materials and would not migrate under normal conditions. A number of studies have measured ^{137}Cs contamination from nuclear facilities to trace contamination in streams (Cerling et al., 1990; Sobocinski et al., 1990). These studies found that ^{137}Cs adsorption on sediments was essentially irreversible and immobile. However, under anaerobic conditions when high organic and low clay content are present, the ^{137}Cs ion-exchange process may lead to the mobilization of ^{137}Cs (Evans et al, 1983; Crickmore et al., 1990). The physical conditions in the study area and the Cs profiles observed in the cores indicate no significant downward movement of Cs in the cores.

Field Sampling Methods

Sediment cores were collected from the channel and floodplain deposits of the Cache River in the vicinity of Buttonland Swamp. Nine core samples were collected in July 1988 and one core sample in September 1986. The locations of the sampling sites with respect to the Cache River channel and tributary streams are shown in figure 11. The samples were identified by the letters A through J.

Locations of the core sampling sites were determined by field measurements to local landmarks (e.g., roads, river bends) by visual positioning of the sampling boat to shorelines (e.g., midpoint of channel), and by compass bearings to known landmarks. Sketches of the sampling locations and relevant measurements and observations were recorded in a fieldbook.

The core samples were collected using two techniques: a 3-ft-long 2-in. diameter stainless steel thin-wall piston lake sediment core sampler and a 2-cm soil corer for submerged sediments in the river channel and backwater areas and for aerated floodplain sediments, respectively. The samples were collected in areas not disturbed by dredging or tillage operations and should be fairly representative of the sedimentation rates of the areas sampled.

The coring techniques were selected to minimize compaction and disturbance of the sediment materials. Gravity- and momentum-driven core samplers were judged to be inappropriate due to the shallow water depths and potential core distortion. Vibratory coring techniques were dismissed due to the bulk and complexity of these samplers and the difficulty of access to most of the sampling sites in the wetlands. The piston sampler was constructed without a cutting bit on the barrel opening to minimize both internal and external friction between the sediments and the sampler barrel, which in turn minimizes core compaction and distortion. The piston sampler was operated to reduce surface disturbances on the sediment water interface by slowly lowering the sampler to the bed. Sediment compaction during sampling was minimized by fixing the piston elevation at the water sediment interface during the driving process. The core sampler was withdrawn from the bed by pulling on the core barrel. The piston was prevented from sliding within the barrel during extraction to maintain suction within the barrel and reduce losses from the bottom of the core.

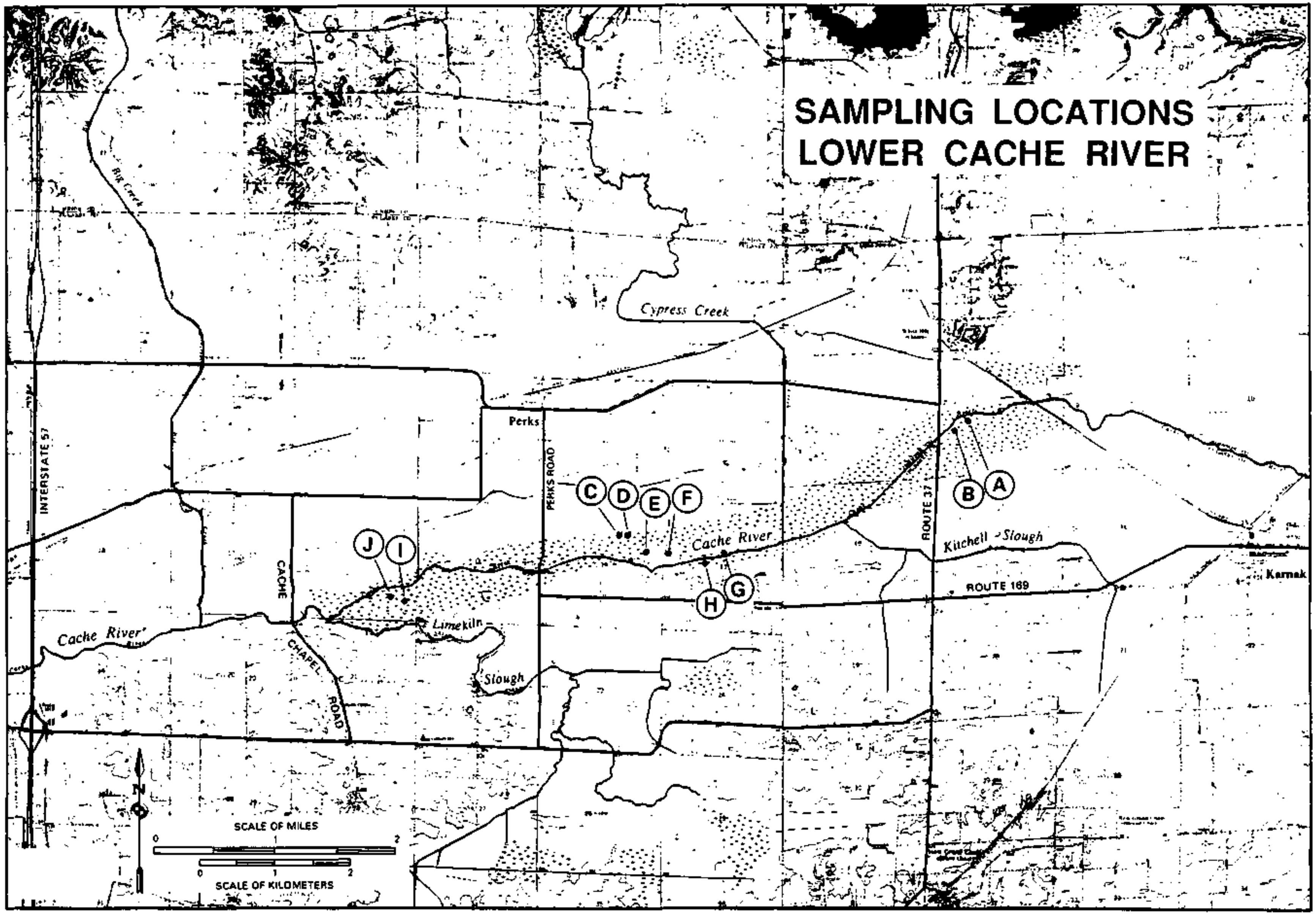

Figure 11. Location of sediment core sampling sites in the Buttonland Swamp area

At sampling sites with submerged sediments, water depth was measured with a sounding pole. The relative compaction of the sediments was also measured by pushing the pole through the bottom materials to refusal. This technique has been extensively used in hydrographic surveying and lake sedimentation surveys to determine original valley bottom elevation of reservoirs (Fitzpatrick et al., 1985; 1987). In general, non-aerated sediments will exhibit much lower densities and compaction than typical valley soils or aerated sediments, and the depth of refusal of a sounding pole will correlate with the depth below the water surface of the aerated sediments or soils. These measurements determine the depth of aerated materials and provide a marker layer in the sediments to determine of the compaction of sediments by the coring process and possible losses of the top very loose, uncompacted fluff layer of sediments by the core sampler or sampling technique.

Aerated sediments could be sampled to greater depths than submerged sediments. Aerated sediment samples on the floodplain were more competent and compacted than the submerged sediments, which allowed the soil corer to extract several succeeding cores from each sampling hole. Successively deeper cores were extracted from each sampling hole until the boring hole closed from the weight and pressure of the surrounding sediments. The average maximum depth of the aerated floodplain sediments sampled with the soil corer was 88 cm.

Submerged and/or saturated sediments from the area's swamp and sloughs were sampled with the sediment corer. These sediments were less compacted than the aerated materials, and each sampling hole tended to close upon withdrawal of the sampler, precluding successive samples from the same boring hole. Sediment core samples from the submerged sediments averaged 62 cm in length.

To reduce potential mixing between cores and core subsamples, all sediment cores were inspected and subsampled in the field immediately after collection and placed into heavy plastic bags. The bags were sealed to reduce drying, and each sample bag was identified by site location, subsample depth interval, and sampling date. The cores collected for radiometric dating were generally subsampled at 3 cm intervals. The cores collected for sediment particle size distribution analyses were subsampled at two or three depths, and individual subsamples were 3 cm in length. Particle size subsamples were obtained from five sites.

All sediment samples were inventoried prior to delivery to the analytical laboratory. All sample bags were inspected for damage and proper identification. Pertinent information was recorded on sample transmittal sheets.

Description of Sampling Sites

Sampling sites A and B (figure 11) were in the floodplain forest east of Route 37 and south of the Cache River channel. The sediments at these sites were primarily silt with leaves and stems. Sampling sites I and J (figure 11) were wetland meadows south of the Cache River channel and north of Limekiln Slough. The sediments at these sites were also primarily silt. Sampling sites C-H (figure 11) were located in the Cache River backwaters and ponds in the Buttonland Swamp area. The sediments from the swamp were primarily clays with some silt and little sand. Sites C and D were in Eagle Pond, an open water pond, averaging 0.7 m in depth, surrounded by dense swamp forests of cypress and gum trees. One cypress on the southern end of the pond was marked with a sign identifying the tree as being 800 years old. Sites E and F were located in a flooded oxbow side channel of the Cache River, an area of widely spaced cypress trees. Water depths at these sampling sites averaged 0.7 m. Sites G and H were located near the middle portions of the swamp about 1/2 mile west of the mouth of Cypress Creek in backwater sloughs with water depths of 0.3 m.

Laboratory Methods

Porosity and Water Content. Sediment samples were weighed and dried at 110°C overnight after delivery to the laboratory. Water content was calculated as percent water based on the percentage of total weight lost from the wet sample during drying. Porosity ϕ was calculated based on the volume of water lost by drying divided by the total volume of the sample (equation 4).

$$\phi = (Mw/pw) / (Mw/pw + Ms/ps) \qquad (4)$$

where Mw is the mass of water, Ms is the mass of the dry sediment, pw is the density of water (1.0 grams per cubic centimeter *(g/cc)),* and ps is the density of sediment (2.45 g/cc). The values of water content and porosity are only estimates of the in-situ values due to the likelihood of loss of moisture during sampling, transport, and storage prior to laboratory analysis.

Radiometric Dating. Analysis of the concentration of the atmospheric fallout radioactive isotope ^{137}Cs was the technique used for radiometric dating of the sediment subsamples. The relative concentration of Cs was determined by counting the gamma activity of a 10 g subsample of sediment on a 15 percent efficient Ge(Li) detector for a minimum of 24 hours. The area of the 661 kiloelectron volts (keV) photon activity of the sediment sample was compared to the activity of the National Bureau of Standards Environmental Radioactivity Standards (NBS 4350B, NBS 4353, NBS 4354, and NBS 4355).

The precision of the measurement based on counting statistics is generally ±30 percent. The detection limit is dependent on the length of counting time and the background count rate. Samples with peak to background ratios of less man two were assigned less than the detection limit values.

The gamma activities are related to the pattern of nuclear weapon testing in the atmosphere. The interval with the maximum activity is assumed to represent sediments deposited in 1963. Sediments with no detectable activity (below the analytical limit of quantification) were assumed to have been deposited prior to 1954. The ages of individual core subsamples were determined by prorating the time periods between the date of sampling, the subsample with maximum activity assigned to the year 1963, and the shallowest subsample with activity less than the analytical limit of quantification assigned to the year 1954. Core subsamples from below the depth assigned to 1954 were dated based on extrapolation of the slope of the time-depth distribution of the 1963-1954 period subsamples. Table 5 is a summary of the ^{137}Cs gamma activity measurements, and figure 12 presents the ^{137}Cs gamma activity profiles for the ten core samples.

Sediment Particle Size. Sediment samples were air-dried and weighed after delivery to the laboratory. Visible organic matter was removed from the samples prior to analysis. The samples were first dry-sieved through a 0.0625 millimeter (mm) sieve. Sediment retained on the sieve was weighed to determine the sample fraction larger than sand size. On samples with

Table 5. Summary of ^{137}Cs Analysis

Core	*Depth to peak activity (cm)*	*Maximum activity (Bq/g)*	*1963 sedimentation rate (cm/yr)*	*Depth to no activity (cm)*	*1954 sedimentation rate (cm/yr)*	*Number of samples counted*
A	9	0.049	0.3	12	0.3	14
B	8	0.83	0.3	17	0.5	6
C	35	0.099	1.4	47	1.4	14
D	36	0.099	1.4	51	1.5	17
E	27	0.107	1.1	40	1.2	8
F	71	0.099	2.8	*	*	26
G	14	0.053	0.5	29	0.8	11
H	41	0.128	1.6	56	1.6	19
I	41	0.050	1.6	72	1.7	24
J	14	0.062	0.5	27	0.8	16

Note: *Depth to no activity not reached in this core

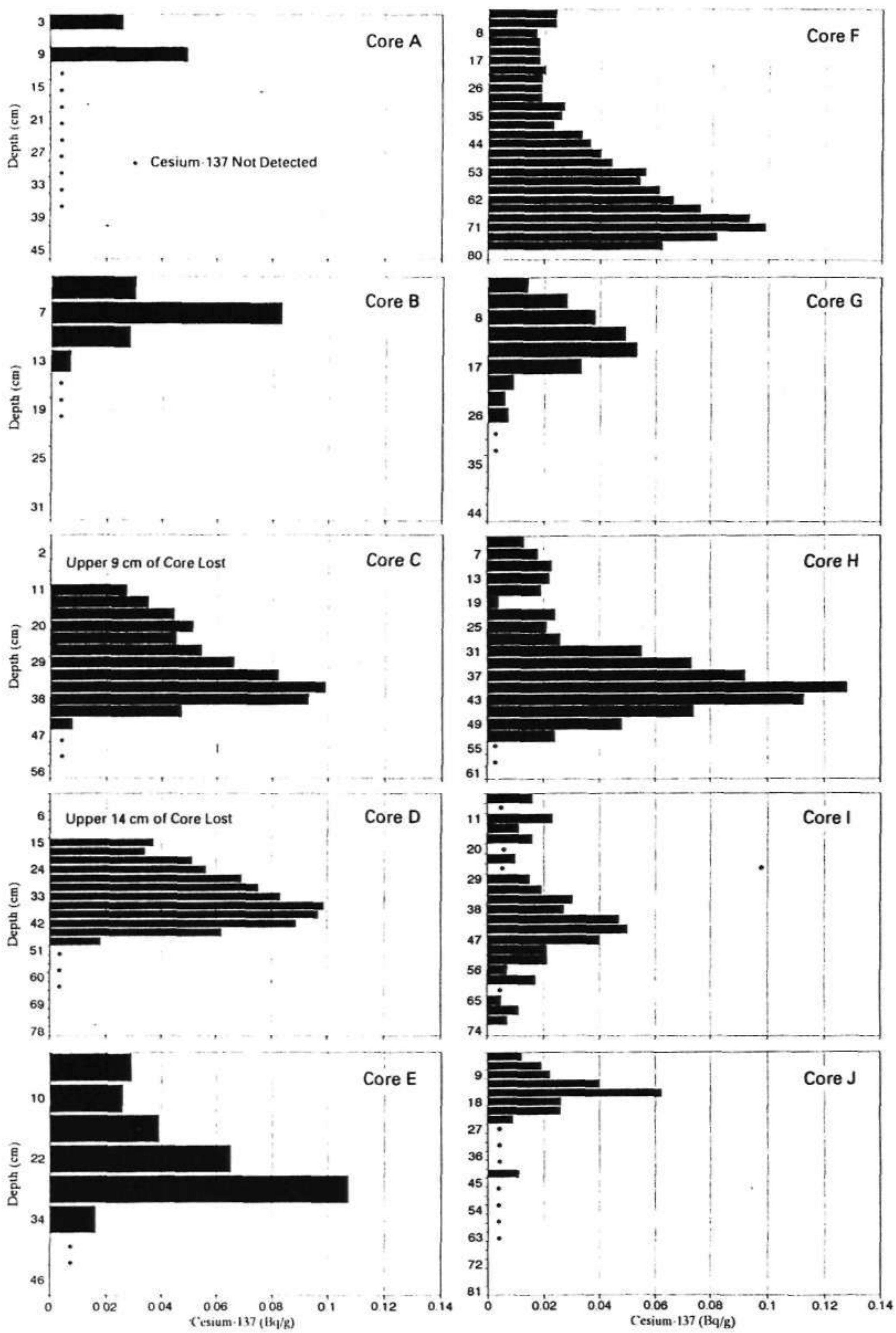

Figure 12. ^{137}Cs profiles for the ten core samples

a significant amount of sand-sized and larger particles, additional sieves were used to measure the size intervals above 0.0625 mm. The fraction of the sediment sample below sand size was treated with a dispersion agent and deionized water, and then mechanically mixed. The pipette technique was used to measure the relative concentration of particle sizes below 0.0625 mm (down to 0.002 mm).

The results of particle size analysis are summarized in table 6. The sediments were predominately clay (68%) and silt (30%) with a trace of sand (2%). The exception was the upper 3 cm interval of core I, that contained 19 percent sand-sized sediments.

Sedimentation Rate Based on ^{137}Cs

The detailed results of the laboratory analyses for the ten core samples are presented in Appendix A. The sedimentation rates determined based on Cs analysis at the ten locations where core samples were collected are summarized in table 7. The annual sedimentation rate varies from a low of 0.3 cm (0.1 in.) at site A to a high of 2.8 cm (1 in.) at site F. In general, the side channels to the Cache River had the highest rate of sedimentation followed by backwater sloughs, ponds, and wetland meadows. The samples collected from the floodplain showed the lowest rate of sedimentation, and the sites directly connected to the Cache River channel have the highest sedimentation rates.

Table 6. Summary of Particle Size Data

Site	*Midpoint depth*		*Sand (%)*	Silt *(%)*	*Clay (%)*
	(ft)	*(cm)*			
D	1.15	35	0	7	93
D	1.65	50	1	71	92
D	2.55	78	4	19	77
F	0.45	14	0	28	72
F	1.55	47	0	17	83
F	2.55	78	0	10	90
H	0.30	9	0	26	73
H	1.40	43	2	11	88
I	3.00	5	19	58	22
I	0.92	28	0	83	17
J	0.07	2	1	52	48
J	0.38	12	1	42	57
Average			2	30	68

Table 7. Sedimentation Rates Based on ^{137}Cs Results

Core	*Location type*	*1963 sedimentation rate (cm/yr)*	*(in/yr)*
A	Floodplain	0.3	0.1
B	Floodplain	0.3	0.1
C	Pond	1.4	0.5
D	Pond	1.4	0.6
E	Side channel	1.1	0.4
F	Side channel	2.8	1.1
G	Backwater slough	0.5	0.2
H	Backwater slough	1.6	0.6
I	Wetland meadow	1.6	0.6
J	Wetland meadow	0.5	0.2

COMPARISON OF THE TWO METHODS

The two techniques were used in this project because each method has some limitations. The sediment budget technique provides reliable information on how much sediment is being transported into and out of the area. The sediment that is trapped within the area provides the average sedimentation rate over the entire area and useful information on sediment yield that will help identify high sediment yield areas. The major shortcoming of this method, however, is its inability to provide the spatial resolution of the sedimentation rate: only the average rate can be calculated.

There is, however, a need to know the spatial variation of sedimentation rate so that areas impacted more significantly can be identified. The radiometric technique provides site-specific data that can be used to reconstruct the spatial distribution of the sedimentation rate. However, unless sufficient samples are collected, analyzed, and then the results properly interpreted, the radiometric technique could provide misleading information, because of the wide variation of sedimentation rates from site to site.

The results obtained for this project illustrate the utility and potential problems discussed above. The average sedimentation rate in the Buttonland Swamp area based on the sediment budget varies from 0.3 cm (0.1 in.) to 1.32 cm (0.5 in.) per year. The values are based on the assumption that most of the sediment is deposited in channels and wetlands below 330 ft msl. The sedimentation rates determined from radiometric dating varied from a low of 0.3 cm (0.1 in.) to a high of 2.8 cm (1 in.) per year. The average rate determined from the sediment budget is within the range of sedimentation rates determined by the radiometric dating technique as should be expected. If the average sedimentation rates derived from the sediment budget were the only data we had, we could not have determined that some areas have sedimentation rates exceeding 2 cm per year. It will also be very difficult to determine the average sedimentation rate over the entire area based on the local sedimentation rates determined at the ten sampling sites for radiometric dating. A combination of the two techniques, however, provides a more complete picture of the sedimentation pattern in the area.

SUMMARY AND CONCLUSIONS

Sediment data collected at three streamgaging stations over a three-year period was used to develop a sediment budget for a wetland complex in the Lower Cache River. The sediment budget calculations based on measuring the inflow and outflow of sediment from the study area showed that from 69 to 84 percent of the sediment flowing into the wetlands is trapped within the wetlands. Sedimentation rates expressed as vertical deposition of sediment were men calculated based on the sediment budget. The results show that the average sedimentation rates could vary from a low of 0.15 cm (0.06 in.) to a high of 0.33 cm (0.13 in.) assuming areas inundated by the highest flood of the year are zones of sediment deposition. However, based on the best estimate of the most likely area for sediment deposition, the sedimentation rates varied from a low of 0.33 cm (0.13 in.) per year to a high of 1.32 cm (0.52 in.) per year.

Sedimentation rates were also determined at selected sites by using a radiometric dating technique. Sediment cores were collected at ten locations and the sedimentation rates analyzed by determining the concentrations of ^{137}Cs for different segments of the sediment core. The results of the analysis showed that the sedimentation rates varied from a low of 0.34 cm (0.13 in.) to a high of 2.75 cm (1.08 in.) per year. The lowest sedimentation rates were found in the floodplains, while the highest were in the side channels of the Cache River. Sedimentation rates in ponds, wetland meadows, and backwater sloughs fall between the two ranges.

Sedimentation rates determined by using the two techniques (sediment budget and radiometric dating) were found to be consistent with each other. The radiometric technique provides site-specific information and the spatial variation of the sedimentation rate, while the sediment budget technique provides the total amount of sediment being trapped in the area and the average rate of sediment accumulation over an assumed area of sediment deposition. Even though sedimentation rates vary widely from one location to another, the radiometric technique provides quick, reliable sedimentation rate values if an adequate number of samples is collected and analyzed with the proper interpretation of the results as they relate to the physical settings of the areas of sediment deposition.

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APPENDIX

RESULTS OF LABORATORY ANALYSIS AND FIELD OBSERVATIONS FOR TEN SEDIMENT CORE SAMPLES

Table A1. Sediment Core A, Cache River Floodplain (1/4 mile east of Route 37, 180 feet south of the river)

Segment midpoint (cm)	*137 Cs activity (Bq/g)*	*Year**	*Water (%)*	*Porosity*	*Wet wt (g)*	*Dry wt (g)*
0.0		1988				
2.0	0.026	1983	38.6	0.61	5.70	3.50
5.5		1972	64.5	0.57	7.50	4.90
8.5	0.049	1963	26.2	0.47	10.30	7.60
11.5	<0.004	1954	24.3	0.44	14.40	10.90
14.5	<0.004	1945	23.2	0.43	13.80	10.60
17.5	<0.004	1936	19.1	0.37	19.40	15.70
20.5	<0.004	1927	25.0	0.45	10.40	7.80
23.5	<0.004	1918	22.5	0.42	12.00	9.30
26.5	0.007	1909	23.0	0.42	16.10	12.40
29.5	0.007	1900	22.8	0.42	17.10	13.20
32.5	<0.004	1891	21.3	0.40	17.80	14.00
35.5	<0.004	1882	20.6	0.39	17.50	13.90
38.5	<0.004	1873	21.5	0.40	10.70	8.40
41.2	<0.004	1865	20.0	0.38	19.00	15.20
44.5	<0.004	1855	20.3	0.38	17.20	13.70
100.0	bottom of core					

SEDIMENTATION RATE SUMMARY

Period	*cm/yr*	*ft/yr*	*Density (lb/cu ft)*
1963-1988	.34	.011	69.50
1954-1988	.34	.011	73.52

Note:
* Year based on a proration of time between the date of sampling, the assumed 1963 137 Cs peak activity, and the assumed 1954 137 Cs zero activity (assigned to the first value below the analytical limit of quantification). Years prior to 1954 were determined by the slope of the time-depth distribution of the 1954-1963 period.

Table A2. Sediment Core B, Cache River Floodplain (700 feet east of Route 37, 200 feet south of the river)

Segment midpoint (cm)	*^{137}Cs activity (Bq/g)*	*Year**	*Water (%)*	*Porositv*	*Wet wt (g)*	*Dry wt (g)*
0.0		1988				
3.0	0.030	1978	39.5	0.62	16.8	10.2
7.5	0.083	1963	36.3	0.58	10.2	6.5
10.5	0.028	1960	38.2	0.60	14.4	8.9
13.5	0.007	1957	37.5	0.60	14.4	9
16.5	<0.003	1954	30.4	0.52	13.8	9.6
19.5	<0.002	1951	33.1	0.55	16.9	11.3
22.0		1949	35.8	0.58	9.5	6.1
24.5		1946	31.4	0.53	15.9	10.9
27.5		1943	31.4	0.53	15.9	10.9
30.5		1940	29.2	0.50	15.4	10.9
95.5	bottom of core					

SEDIMENTATION RATE SUMMARY

Period	*cm/yr*	*ft/yr*	*Density (lb/cu ft)*
1963-1988	.29	.010	61.52
1954-1988	.48	,016	63.92

Note:
* Year based on a proration of time between the date of sampling, the assumed 1963 ^{137}Cs peak activity, and the assumed 1954 ^{137}Cs zero activity (assigned to the first value below the analytical limit of quantification). Years prior to 1954 were determined by the slope of the time-depth distribution of the 1954-1963 period.

Table A3. Sediment Core C, Eagle Pond (west 1/3 point)

*Segment midpoint (cm)**	*137 Cs activity (Bq/g)*	*Year***	*Water (%)*	*Porosity*	*(g)*	*Wet wt (g)*	*Field observations*
0		1988					Water depth =76 cm.
10.5	0.027	1981	76.39	.89	37.70	8.90	Loose uncompacted silty clay, greenish-grey with leaf bits and root hairs.
13.5	0.035	1979	68.83	.84	38.50	12.00	
16.5	0.044	1977	65.50	.82	51.60	17.80	Similar material as above but more compact and denser. Abundant gas pockets.
19.5	0.051	1974	63.33	.81	64.90	23.80	
22.5	0.045	1972	63.99	.81	57.20	20.60	
25.5	0.054	1970	62.98	.81	57.80	21.40	
28.5	0.066	1968	48.78	.70	57.20	29.30	
31.5	0.082	1966	67.88	.84	55.10	17.70	
34.5	0.099	1963	70.16	.85	57.30	17.10	
37.5	0.093	1961	69.13	.85	58.30	18.00	
40.5	0.047	1959	66.45	.83	62.00	20.80	
43.5	0.008	1956	61.06	.79	67.80	26.40	
46.5	<0.003	1954	55.72	.76	61.20	27.10	Transition layer, possible dried horizon. Blocky structure.
49.5	<0.004	1952	48.97	.70	63.30	32.30	
52.5	<0.005	1950	49.19	.70	67.90	34.50	
55.5		1948	54.28	.74	54.90	25.10	Very dense silty clay, blocky structure.
57.8	bottom of core						

SEDIMENTATION RATE SUMMARY

Period	*Cm/yr*	*Ft/yr*	*Density (lb/cu ft)*
1963-1988	1.38	.045	27.64
1954-1988	1.37	.045	28.27

Note:
* Core segment midpoint depths were adjusted based on field observation of loss of 9 cm (0.3 ft) of top fluff layer.
** Year based on a proration of time between the date of sampling, the assumed 1963 137 Cs peak activity, and the assumed 1954 137 Cs zero activity (assigned to the first value below the analytical limit of quantification).
Years prior to 1954 were determined by the slope of the time-depth distribution of the 1954-1963 period.

Table A4. Sediment Core D, Eagle Pond (east 1/3 point)

*Segment midpoint (cm)**	*137 Cs activity (Bq/g)*	*Year**	*Water (%)*	*Porosity*	*Sand (%)*	*Silt (%)*	*Clay (%)*	*Wet wt (g)*	*Dry wt (g)*	*Field observations*
0		1988								Water depth = 7 cm.
15.3	0.037	1978	69.22	.85				34.40	10.59	Very loose uncompacted silty clay with greenish arev color, leaf bits.
18.3	0.034	1976	65.59	.82				56.90	19.58	
21.3	0.051	1974	65.34	.82				57.09	19.79	
24.3	0.056	1971	65.40	.82				57.89	20.03	
27.3	0.069	1969	66.38	.83				59.78	20.10	
30.3	0.075	1967	66.09	.83				59.06	20.03	
33.3	0.083	1965	65.12	.83				57.26	19.97	
36.3	0.099	1963	68.60	.84	0	7	93	54.39	17.08	Similar materal as above but denser. Abundant gas pockets.
39.3	0.097	1961	69.25	.85				62.08	19.09	
42.3	0.089	1959	70.00	.85				63.27	18.98	
45.3	0.062	1958	69.08	.85				50.78	15.70	
48.3	0.018	1956	62.62	.80				61.64	23.04	
51.3	<0.005	1954	60.05	.79	1	7	92	56.24	22.47	
54.3	<0.004	1952	59.85	.79				36.99	14.85	
57.3	<0.003	1950	54.49	.75				74.49	33.90	Blockv structure. Break in core.
60.3	<0.005	1949	55.02	.75				76.66	34.48	Very dense silty clay, abundant organics, and root layer. Possible old soil layer.
63.3	<0.001	1947	63.34	.81				68.71	25.19	
66.3		1945	62.48	.80				67.77	25.43	
69.3		1943	67.11	.83				64.34	21.16	
72.3		1941	68.35	.84				57.00	18.04	Less dense layer. Greenish-grey silty clay with sand.
75.3		1940								
78.3		1938			4	19	77			
79.2	bottom of core									

SEDIMENTATION RATE SUMMARY

Period	*Cm/yr*	*Ft/yr*	*Density (lb/cu ft)*
1963-1988	1.42	.047	26.13
1954-1988	1.48	.049	26,27

Notes:

* Core segment midpoint depths were adjusted based on field observation of loss of 14 cm (0.45 ft) of top fluff layer.

** Year based on a proration of time between the date of sampling, the assumed 1963 137 Cs peak activity, and the assumed 1954 137 Cs zero activity (assigned to the first value below the analytical limit of quantification). Years prior to 1954 were determined by the slope of the time-depth distribution of the 1954-1963 period.

Table A5. Sediment Core E (formerly AE), Cache River Floodplain (1/4 mile east of Route 37, 180 feet south of the river)

Segment midpoint (cm)	*137 Cs activity (Bq/g)*	*Year**	*Water (%)*	*Porosity*	*Wet wt (g)*	*Dry wt (g)*	*Field Observations*
0.0		1986					Water depth ± 60 cm. Very loose uncompacted silty clay with abundant leaves and stems.
3.0	.029	1984	61.9	0.80	94.8	36.1	
9.0	.026	1979	59.5	0.78	153.3	62.1	Greenish-grey silty clay, more compact than above. Air pockets.
15.0	.039	1974	59.5	0.78	151	61.2	
21.0	.065	1968	61.5	0.80	141.2	54.3	
27.0	.107	1963	68.4	0.84	131.2	41.4	
33.5	.016	1959	61.7	0.80	110.9	42.5	Abundant leaves, stems, wood chips, root hairs Possible Dre-disturbance bottom @ 37 cm.
40.0	<0.005	1954	51.3	0.72	138.3	67.3	
46.0	<0.002	1950	43.8	0.66	168.1	94.4	Dense siltv clav with few air Dockets.
48.8	bottom of core						

SEDIMENTATION RATE SUMMARY

Period	*Cm/yr*	*Ft/yr*	*Density (lb/cu ft)*
1963-1986	1.14	.037	30.51
1954-1986	1.22	.040	32,31

Note:

* Year based on a proration of time between the date of sampling, the assumed 1963 137 Cs peak activity, and the assumed 1954 137 Cs zero activity (assigned to the first value below the analytical limit of quantification). Years prior to 1954 were determined by the slope of the time-depth distribution of the 1954-1963 period.

Table A6. Sediment Core F, Cache River, Buttonland Swamp (Short Reach area)

Segment midpoint (cm)	137 Cs activity (Bq/g)	Year*	Water (%)	Porosity	Sand (%)	Silt (%)	Clay (%)	Wet wt (g)	Dry wt (g)	Field observations
0		1988								Water depth = 76 cm. Very loose uncom-
1.5	.024	1988	65.48	.82				42.93	14.82	Dacted silty clay, greenish arev color.
4.5	.024	1987	63.51	.81				42.86	15.64	
7.5	.017	1986	64.62	.82				54.75	19.37	Loose uncompacted silty clay,
10.5	.018	1985	59.49	.78				56.75	22.99	greenish grey color, pudding texture.
13.5	.018	1984	57.82	.77	0	28	72	60.08	25.34	
16.5	.018	1983	57.73	.77				67.81	28.66	
19.5	.020	1982	57.49	.77				55.30	23.51	
22.5	.019	1980	56.27	.76				65.75	28.75	
25.5	.019	1979	55.30	.75				68.61	30.67	
28.5	.019	1978	57.12	.77				67.66	29.01	
31.5	.027	1977	59.84	.79				62.98	25.29	
34.5	.026	1976	56.61	.76				68.33	29.65	Silty clay gradually increasing in
37.5	.023	1975	55.70	.75				70.68	31.31	density and compaction with depth.
40.5	.033	1974	56.35	.76				54.30	23.70	Abundant gas pockets, leaf bits and
43.5	.036	1973	58.37	.77				72.90	30.35	other organics.
46.5	.040	1972	59.79	.78	0	17	83	63.49	25.53	
49.5	.044	1971	57.95	.77				68.45	28.78	
52.5	.056	1970	60.65	.79				59.55	23.43	
55.5	.054	1968	60.68	.79				68.49	26.93	
58.5	.061	1967	61.00	.79				66.18	25.81	
61.5	.066	1966	63.72	.81				62.51	22.68	
64.5	.076	1965	64.57	.82				63.93	22.65	
67.5	.093	1964	66.06	.83				60.04	20.38	Dark grey brown color, denser than
70.5	.099	1963	66.40	.83				66.36	22.30	above. Increasing density with depth.
73.5	.082	1962	65.74	.82				58.37	20.00	Very abundant leaf bits, stems, and
76.5	.062	1961	64.28	.82	0	10	90	54.96	19.63	whole leaves - more than above.
79.5		1960	62.08	.80				22.23	8.43	Very abundant stems at bottom of core
80.8	bottom of core									Dossible old soil layer.

SEDIMENTATION RATE SUMMARY

Period	Cm/yr	Ft/yr	Density (lb/cu ft)
1963-1988	2.75	.090	32.70
1954-1988	-	-	-

Note:
* Year based on a proration of time between the date of sampling and the assumed 1963 137 Cs peak activity. Years prior to 1963 were determined by the slope of the time-depth distribution of the 1963-1988 period.

Table A7. Sediment Core G, Buttonland Swamp (center of Section 13, 150 feet north of river)

Segment midpoint (cm)	*137 Cs activity (Bq/g)*	*Year**	*Water (%)*	*Porosity*	*Wet wt (g)*	*Dry wt (g)*	*Field observations*
0		1988					Water depth = 30 cm. Silty clay with very high organics. Abundant leaves and stems.
1.5	0.014	1986	72.5	0.87	32.7	9	
4.5	0.028	1980	50.7	0.72	44.8	22.1	
7.5	0.038	1974	48.6	0.70	67.3	34.6	Silty clay partially oxidized with high organics. Blocky structure 1/16-1/8 in. blocks. Break in core at 15 cm.
10.5	0.049	1969	50.1	0.71	74.9	37.4	
13.5	0.053	1963	54.4	0.75	70.9	32.3	
16.5	0.033	1961	52.8	0.73	73.3	34.6	
19.5	0.009	1959	49.9	0.71	73.8	37	Greenish gray silty clay more compact than above. Increase in density with depth. Blocky.
22.5	0.006	1958	40.3	0.62	77.4	46.2	
25.5	0.007	1956	33.8	0.56	95.2	63	Silty clay. Increase in density with depth. Very dense at base.
28.5	<0.003	1954	29.8	0.51	91.3	64.1	
31.5	<0.003	1952	28.8	0.50	95.4	67.9	
34.5		1950	31.0	0.52	78.3	54	
37.5		1949	39.5	0.61	81.1	49.1	
40.5		1947	37.6	0.60	86.7	54.1	
43.5		1945	38.3	0.60	75	46.3	
44.2	bottom of core						

SEDIMENTATION RATE SUMMARY

Period	*Cm/yr*	*Ft/yr*	*Density (lb/cu ft)*
1963-1988	.53	.017	38.67
1954-1988	.82	.027	47.93

Note:
* Year based on a proration of time between the date of sampling, the assumed 1963 137 Cs peak activity, and assumed 1954 137 Cs zero activity (assigned to the first value below the analytical limit of quantification). Years prior to 1954 were determined by the slope of the time-depth distribution of the 1954-1963 period.

Table A8. Core H, Buttonland Swamp (2/3 mile east of Cypress Creek, 225 feet south of the river)

Segment midpoint (cm)	*137 Cs activity (Bq/g)*	*Year**	*Water (%)*	*Porositv*	*Sand (%)*	*Silt (%)*	*Clay (%)*	*Wet wt (g)*	*Dry wt (g)*	*Field observations*
0.0		1988								Water depth = 0 cm.
3.0	0.013	1987	61.0	0.79				73.40	28.60	Very loose uncompacted greenish
7.5	0.018	1984	58.4	0.78	0	26	73	64.00	26.60	arav silty clay.
10.5	0.023	1982	56.5	0.76				67.30	29.30	
13.5	0.022	1980	58.4	0.77				69.00	28.70	
16.5	0.019	1978	54.6	0.75				67.40	30.60	
19.5	0.004	1976	52.9	0.73				75.00	35.30	
22.5	0.024	1974	52.7	0.73				73.60	34.80	
25.5	0.021	1972	49.4	0.71				82.20	41.60	Silty clay, gradual increase
28.5	0.026	1971	48.9	0.70				70.60	36.10	in density with depth.
31.5	0.055	1969	53.0	0.73				72.50	34.10	Abundant gas pockets.
34.5	0.073	1967	56.1	0.76				75.00	32.90	
37.5	0.092	1965	59.1	0.78				66.70	27.30	
40.5	0.128	1963	63.3	0.81				69.30	25.40	
43.5	0.113	1961	65.4	0.82	2	11	88	65.30	22.60	
46.5	0.074	1959	68.2	0.84				47.50	15.10	
49.5	0.048	1958	67.5	0.84				61.30	19.90	
52.5	0.024	1956	65.5	0.82				59.40	20.50	
55.5	<0.007	1954	61.7	0.80				59.30	22.70	Very abundant roots and leaves.
58.5	<0.008	1952	60.9	0.79				50.40	19.70	Darker color than above.
60.7		1950	60.6	0.79				27.40	10.80	Gas Dockets.
62.5	bottom of core									

SEDIMENTATION RATE SUMMARY

Period	cm/yr	ft/yr	lsitv lbs/cu. ft.
1963-1988	1.58	.052	37.62
1954-1988	1.60	.053	34.65

Note:

* Year based on a proration of time between the date of sampling, the assumed 1963 137 Cs peak activity, and the assumed 1954 137 Cs zero activity (assigned to the first value below the analytical limite of quantification). Yeras prior to 1954 were determined by the slope of the time-depth distribution of the 1954-1963 period.

Table A9. Sediment Core I, East wetlands near Limekiln Slough (400 ft. south of Cache River, 9/10 mile east of Cache Chapel Rd.)

Segment midpoint (cm)	*137 Cs activity (Bq/g)*	*Year**	*Water (%)*	*Porosity*	*Sand (%)*	*Silt (%)*	*Clay (%)*	*Wet wt (g)*	*Dry wt (g)*	*Field observations*
0.0		1988								Water depth = 0 cm.
1.5	0.016	1988	38.2	0.60				13.10	8.10	Silt with sand and clay. Oxidized
4.5	<0.012	1986	41.0	0.63	19	58	22	6.10	3.60	in top portion reduced in lower
7.5	0.023	1984	39.0	0.61				10.00	6.10	portion. Hydrogen sulfide smell.
10.5	0.011	1982	34.0	0.56				14.40	9.50	Abundant organics: stems, leaves,
14.0	0.016	1980	25.4	0.45				20.90	15.60	wood chips. Water table at 6 cm.
17.5	<0.004	1978	25.5	0.46				18.40	13.70	Very dense gray silty clay.
20.5	0.010	1976	21.1	0.40				20.40	16.10	
23.5	<0.004	1974	21.5	0.40				20.00	15.70	
26.5	0.015	1972	20.4	0.39				19.60	15.60	
29.5	0.019	1970	24.9	0.45	0	83	17	18.90	14.20	
32.5	0.030	1968	24.6	0.44				19.10	14.40	
35.5	0.027	1967	23.2	0.43				18.10	13.90	
38.3	0.047	1965	26.6	0.47				12.40	9.10	
41.3	0.050	1963	30.2	0.52				20.50	14.30	
44.5	0.040	1961	27.0	0.48				16.30	11.90	
47.5	0.021	1960	27.4	0.48				17.50	12.70	
50.5	0.021	1958	27.8	0.48				17.30	12.50	Dense reduced gray silty clay.
53.5	0.007	1957	29.7	0.51				17.20	12.10	
56.5	0.017	1955	28.0	0.49				16.10	11.60	
59.5	<0.005	1954	26.0	0.46				15.40	11.40	
62.5	0.005	1953	26.7	0.47				15.00	11.00	
65.5	0.011	1951	25.8	0.46				16.30	12.10	
68.5	0.007	1950	27.3	0.48				16.50	12.00	
71.5	<.005	1948	26.5	0.47				13.60	10.00	
74.0		1947	31.9	0.53				9.40	6.40	
75.0	bottom of core									

SEDIMENTATION RATE SUMMARY

Period	*Cm/yr*	*Ft/yr*	*Density (lb/cu ft)*
1963-1988	1.61	.053	78.69
1954-1988	1.72	.056	78.80

Note:
* Year based on a proration of time between the date of sampling, the assumed 1963 137 Cs peak activity, and the assumed 1954 137 Cs zero activ (assigned to the first value below the analytical limit of quantification). Years prior to 1954 were determined by the slope of the time-depth distribution of the 1954-1963 period.

Table A10. Sediment Core J, west wetlands near Limekiln Slough (300 ft. southeast of Cache River, 8/10 mile east of Cache Chapel Rd.)

Segment midpoint (cm)	*137 Cs activity (Bq/g)*	*Year**	*Water (%)*	*Porositv*	*Sand (%)*	*Silt (%)*	*Clay (%)*	*Wet wt (g)*	*Dry wt (g)*	*Field observations*
0.0		1988								Water depth = 0 cm.
1.5	0.012	1983	49.1	0.70	1	52	48	10.75	5.47	Oxidized silty clay. Gray brown color. Root zone with root hairs and iron staining.
4.5	0.019	1978	41.2	0.63				12.14	7.14	
7.5	0.022	1973	34.6	0.56				15.56	10.17	
10.5	0.040	1968	31.2	0.53	1	42	57	16.29	11.21	
13.5	0.062	1963	30.3	0.52				16.05	11.19	Water table at 12 cm.
16.5	0.026	1961	28.0	0.49				17.01	12.24	
19.7	0.026	1959	28.3	0.49				19.54	14.01	
23.2	0.009	1956	30.4	0.52				17.54	12.20	
26.5	<.004	1954	29.1	0.50				16.43	11.64	
29.5	<0.001	1952	30.2	0.51				17.33	12.10	
32.5	<0.001	1950	28.9	0.50				14.63	10.40	Dense dark gray reduced silt with some iron staining.
35.5	<0.003	1947	28.1	0.49				15.02	10.80	
37.5	<0.003	1945	27.0	0.48				17.27	12.60	
41.2	0.011	1943	28.1	0.49				14.60	10.50	
44.2		1941	28.3	0.49				14.92	10.70	
47.5		1938	30.0	0.51				17.13	12.00	
50.5	<0.002	1936	32.4	0.54				18.06	12.20	
53.5	<0.004	1934	35.3	0.57				14.69	9.50	
56.0		1932	33.9	0.56				12.11	8.00	
58.5		1929	32.6	0.54				12.16	8.20	
61.5		J927	27.6	0.48				17.69	12.80	
64.5		1925	30.3	0.52				17.80	12.40	Gray brown silty clay with organics.
67.5		1923	25.8	0.46				21.70	16.10	
71.5		1920	34.4	0.56				12.20	8.00	
74.5		1918	30.2	0.52				16.20	11.30	
78.0		1916	28.1	0.49				16.40	11.80	
81.2		1914	25.7	0.46				18.70	13.90	
82.5	bottom of core									

SEDIMENTATION RATE SUMMARY

Period	*Cm/yr*	*Ft/yr*	*Density (Ib/cu ft)*
1963-1988	.53	.017	62.98
1954-1988	.77	.025	68.99

Note:
* Year based on a proration of time between the date of sampling, the assumed 1963 137 Cs peak activity, and the assumed 1954 137 Cs zero activity (assigned to the first value below the analytical limit of quantification). Years prior to 1954 were determined by the slope of the time-depth distribution of the 1963-1954 period.