SEDIMENT TRANSPORT AND DEPOSITION IN LAKES MARION AND MOULTRIE, SOUTH CAROLINA, 1942-85

By Glenn G. Patterson, Ted W. Cooney, and Richard M. Harvey

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 95-4236

Prepared in cooperation with the

SOUTH CAROLINA DEPARTMENT OF HEALTH AND ENVIRONMENTAL CONTROL, *and the* SOUTH CAROLINA PUBLIC SERVICE AUTHORITY

Columbia, South Carolina
1996

U.S. DEPARTMENT OF THE INTERIOR

BRUCE BABBITT, ***Secretary***

U.S. GEOLOGICAL SURVEY

Gordon P. Eaton, ***Director***

For additional information write to:

District Chief
U.S. Geological Survey
Stephenson Center- Suite 129
720 Gracern Road
Columbia, SC 29210-7651

Copies of this report can be purchased from:
U.S. Geological Survey
Earth Science Information Center
Open-File Reports Section
Box 25286, Mail Stop 517
Denver Federal Center
Denver, CO 80225

CONTENTS

ILLUSTRATIONS

Page

TABLES

CONVERSION FACTORS AND ABBREVIATIONS OF UNITS

Multiply	By	To obtain
acre	4,047	square meter
acre-foot (acre-ft)	1,233	cubic meter
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year
cubic foot per second (ft^3/s)	0.0283	cubic meter per second
cubic yard (yd^3)	0.7636	cubic meter
foot (ft)	0.3048	meter
foot per second (ft/s)	0.3048	meter per second
gram (g)	0.035	ounce
inch (in.)	2.54	centimeter
inch per year (in/yr)	2.54	centimeter per year
mile (mi)	1.609	kilometer
mile per hour (mi/hr)	1.609	kilometer per hour
pint	0.4732	liter
pound (lb)	0.454	kilogram
pound per cubic foot (lb/ft^3)	10.03	kilogram per cubic meter
square mile (mi^2)	2.59	square kilometer
ton, short	0.9072	megagram
ton per day (ton/d)	0.0105	kilogram per second
ton per year (ton/yr)	0.9072	megagram per year
ton per square mile per year [(ton/mi^2)/yr]	0.3503	tonne per square kilometer per year

Additional abbreviations:
mg/L = milligram per liter
mg/kg = milligram per kilogra

Temperature in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) as follows:

$$°F = 1.8\ °C + 32$$

The use of trade names in this report is for identification only and does not necessarily imply endorsement by the U.S. Government.

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929–a geodetic datum derived from a general adjustment of the first-order level nets of the United State and Canada, formerly called Sea Level Datum of 1929.

SEDIMENT TRANSPORT AND DEPOSITION IN LAKES MARION AND MOULTRIE, SOUTH CAROLINA, 1942-85

By Glenn G. Patterson[1], Ted W. Cooney[1], and Richard M. Harvey[2]

ABSTRACT

Lakes Marion and Moultrie, two large reservoirs in the South Carolina Coastal Plain, receive large inflows of sediment from the Santee River. The average rate of sediment deposition for both lakes during the period 1942-85 was about 0.06 inch per year, or about 800 acre-feet per year. The rate during 1983-85 was about 0.037 inch per year, or about 490 acre-feet per year, reflecting the decreasing trend in sediment inflow. This is a reversal of a trend toward increasing suspended-sediment concentrations in streams that were caused by farming practices in the southern Piedmont from about 1800 to about 1920. Only a small part of the eroded sediment has been carried out of the Piedmont, but the remaining sediment is becoming less available for transport.

Sediment deposition is concentrated in several areas of upper Lake Marion where the velocity of the incoming water decreases significantly. Beds of aquatic macrophytes appear to encourage deposition which, in turn, creates favorable habitat for the plants. The rate of sediment accumulation in Lakes Marion and Moultrie averaged 650,000 tons per year during 1983-85, reflecting a trap efficiency of 79 percent of the total sediment inflow of 825,000 tons per year. Thickness of post-impoundment sediment varies from about 11 feet near the mouth of the Santee River in Lake Marion to 0 feet in Lake Moultrie near Bonneau. Sediments in Lake Marion tend to have finer texture and higher contents of organic matter, nutrients, and trace metals than those in Lake Moultrie.

INTRODUCTION

Large volumes of sediment have been eroded from the Piedmont part of the Santee River Basin since about 1800. Much of this sediment has created problematic deposits in downstream reservoirs such as Lakes Marion and Moultrie, and in Charleston Harbor (fig. 1).

In 1983, sediment transport and deposition in Lakes Marion and Moultrie were identified as major concerns by the Santee-Cooper River Basin Water-Quality Study team of the South Carolina Department of Health and Environmental Control (SCDHEC). To address these concerns, the U.S. Geological Survey (USGS) in cooperation with SCDHEC, studied several aspects of sediment transport and deposition in the basin.

[1] Hydrologist, U.S. Geological Survey

[2] Division Director, Water Facilities, Florida Department of Environmental Protection

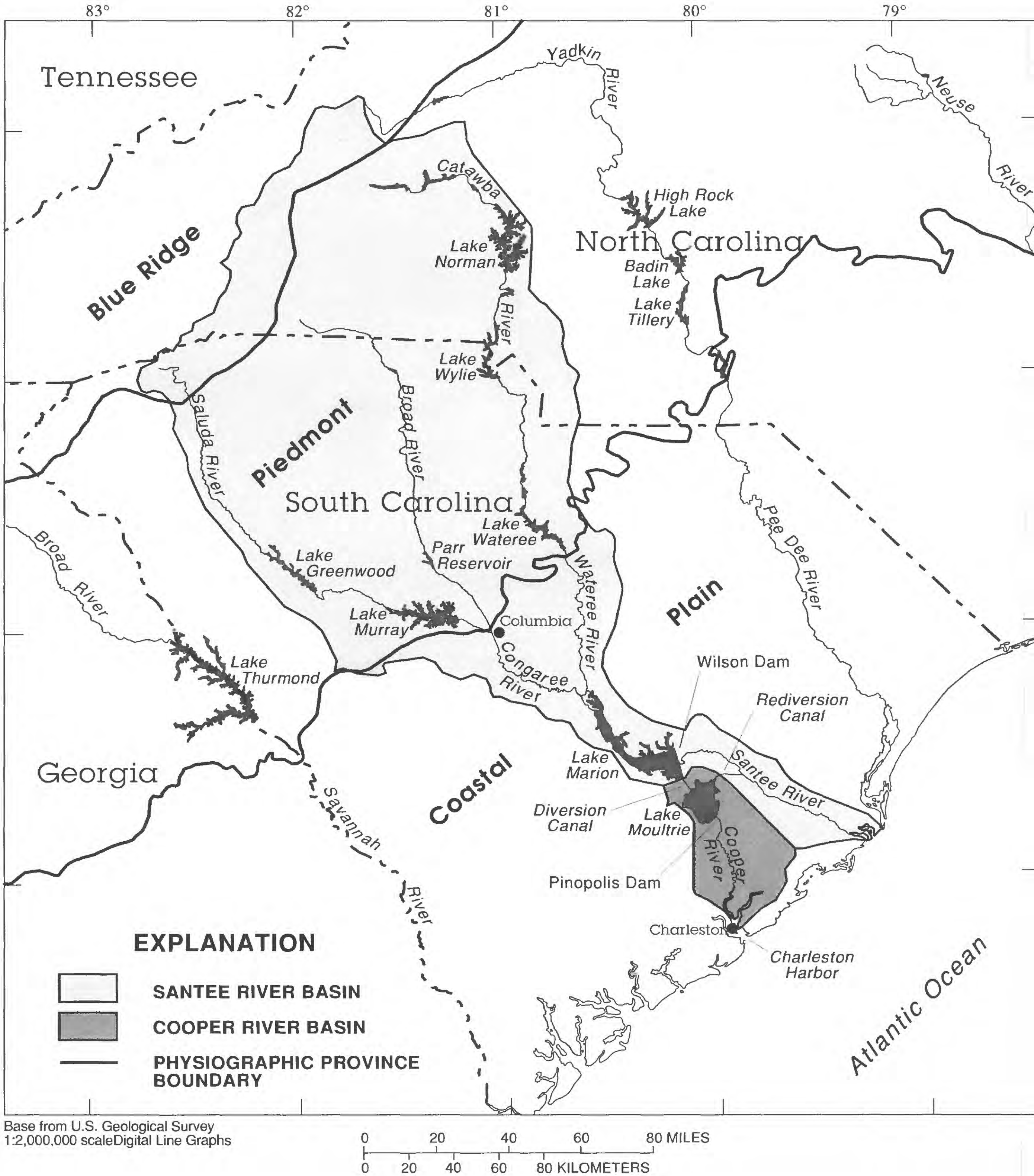


Figure 1. Santee and Cooper River Basins.

Purpose and Scope

This report documents the following aspects of sediment transport, and deposition in Lakes Marion and Moultrie:

1. Rates of sediment transport in the major inflows and outflows of the lakes.
2. Changes in storage capacity.
3. Chemical and physical characteristics and thickness of sediment deposits in the lakes.
4. Rates of deposition of sediment in the lakes.

The project work included the following activities:

1. Monitoring streamflow and concentrations of suspended sediment in the inflow and outflows of Lakes Marion and Moultrie during 1983-85.
2. Comparison of bathymetric maps.
3. Coring, sampling, and probing lakebed sediments.
4. Analyzing the sediment cores and samples for physical and chemical characteristics including ^{210}Pb activity, which is frequently used to determine sedimentation rates.

Acknowledgments

The authors are grateful to the South Carolina Public Service Authority for providing historical topographic data and for reviewing the report. They also are grateful to Jack Kindinger and John Benton of the U.S. Minerals Management Service (MMS) for invaluable assistance in obtaining sediment cores, to George Harrison of MMS for analyzing trace metals, and to Cyndi Rice of MMS for performing the analyses of ^{210}Pb for deposition rates for the cores.

DESCRIPTION OF STUDY AREA

Lakes Marion and Moultrie are heavily influenced by the hydrology of the Santee River Basin (fig. 1). Much of this influence involves transport and deposition of sediment.

Santee River Basin

The Santee River Basin has undergone significant hydrologic and geomorphic changes in the last two centuries. Most of the 16,800 mi^2 of the basin, the second largest on the east coast of the United States, is in the southern Piedmont physiographic province (fig. 1) where erodible soils, intense rainfall, and moderate slopes create a high potential for erosion (U.S. Department of Agriculture, 1973). The original forest cover stabilized the soil, but clearing of the forest and planting of crops by European settlers in the eighteenth and nineteenth centuries initiated a period of greatly accelerated erosion (Meade, 1976). From about 1800 to about 1920, the typical farming practice in the southern Piedmont was to clear a patch of forest, cultivate cotton or corn for several years, and then abandon the field because of erosion and exhaustion of the soil (Glenn, 1911). The average depth of man-induced soil loss ranges from less than 4.3 in. in the eastern Piedmont of North Carolina to more than 10 in. in the Santee and Savannah River Basins in South Carolina and Georgia, and the central Piedmont of Georgia (Trimble, 1975a). The eroded soil greatly increased sediment loads in Piedmont streams, resulting in new flood-plain deposits of sand and silt averaging 47 in. in depth in small valleys (Happ, 1945). These deposits account for about 50 percent of the man-induced soil loss from the uplands (Happ, 1945). An additional 4 percent, approximately, has been carried into the Coastal Plain by large rivers (Trimble, 1975b). The remaining sediment is in storage at the bottom of hill slopes, in stream channels, and in reservoirs.

The rate of erosion from upland fields in the southern Piedmont has decreased greatly since about 1920 because of the abandonment of many farms and the use of soil-conservation techniques on remaining farms. However, the rate of sediment transport in rivers and streams has generally decreased much more gradually (Meade and Trimble, 1974).

The sediment deposits derived from accelerated erosion contributed to several problems. For example, the aggraded channels and flood plains forced rivers to flow at higher levels to accommodate a given flow. Additionally, the farming practices also reduced the absorptive capacity of the remaining upland soils, causing higher rates of surface runoff during storms. As a result, floods reached abnormal heights and caused severe damage (Happ, 1945).

The utility of reservoirs in the Santee River Basin and of Charleston Harbor in the adjacent Cooper River Basin has been reduced during the last century by deposition of sediment. As of 1970, about 4 percent of the soil eroded from the Piedmont part of the basin during the period of accelerated erosion, or about 195,000 acre-ft, was stored in reservoirs, resulting in an overall loss of 3 percent of maximum storage capacity (U.S. Department of Agriculture, 1973). Parr Reservoir on the Broad River, a major tributary to the Santee (fig. 1), has lost 93 percent of its maximum storage capacity of 10,800 acre-ft (U.S. Department of Agriculture, 1973). In addition to reducing active storage capacity and impeding navigation, sediment deposits in reservoirs often create new shallow areas with sufficient light penetration to promote growth of aquatic macrophytes. Heavy growth of aquatic macrophytes impedes boat travel in many reservoirs in the basin, including Lakes Marion and Moultrie. Other problems caused by fluvial sediment in the Santee Basin include destruction of fish habitat, deterioration of water supplies, and transport and deposition of bacteria and toxic compounds that adhere to sediment (U.S. Department of Agriculture, 1973).

Diversion and Rediversion of the Santee River

In 1941, the Santee-Cooper Project created Lakes Marion and Moultrie and the Diversion Canal that connects them (fig. 1). The purpose of the project was to provide hydroelectric power. There was no suitable site for a hydroelectric generating station in the gently sloping course of the Santee River. However, impoundment of Lake Marion on the Santee River behind Wilson Dam and diversion of the flow through a canal into Lake Moultrie, a diked part of the Cooper River Basin, provided sufficient head at Pinopolis Dam to generate power (fig. 1). About 15,000 ft^3/s (80 percent of the long-term average flow of the Santee River) was diverted into the Cooper River Basin. Flow released through Wilson Dam was generally restricted to about 500 ft^3/s to maintain a minimal flow in the lower Santee River. When the total flow exceeded 30,000 ft^3/s, the excess was released into the Santee River.

Charleston Harbor is a major commercial and naval port at the mouth of the Cooper River. Sedimentation was not a serious problem in Charleston Harbor prior to the diversion. The rate of gross maintenance dredging averaged about 300,000 yd^3/yr prior to 1941; however, the dredging rate averaged 6,800,000 yd^3/yr during 1942-82, a twenty-fold increase over the pre-diversion rate (Patterson, 1983). The increased freshwater inflow to the harbor changed the estuarine circulation pattern from well mixed to partially mixed, thereby increasing the sediment-trapping efficiency of the harbor. Summing all known inputs of sediment does not account for all the sediment that has been dredged from the harbor since 1941. A significant part of the sediment, however, can be attributed to fine-grained sediment, primarily of Piedmont origin, carried by the diverted water of the Santee River (Neiheisel and Weaver, 1967; Patterson, 1983; U.S. Army Corps of Engineers, 1966).

The rate of maintenance dredging in Charleston Harbor peaked in the mid-1960's. By then, plans were underway for a new project to ameliorate the sedimentation problem in the harbor by rediverting all but 3,000 ft^3/s of the outflow from Lake Moultrie through a new Rediversion Canal, back across the drainage divide, and into the lower Santee River (fig. 2). A new power plant was built on the Rediversion Canal to generate most of the power lost by rediverting water away from Pinopolis Dam. The rediversion became operational in 1985, and it is expected to reduce the need for maintenance dredging in the harbor by 40 to 75 percent (Patterson, 1983).

Lakes Marion and Moultrie

Lakes Marion and Moultrie are large and shallow. Lake Marion, with a surface area of about 96,000 acres, is the largest reservoir in South Carolina. Lake Moultrie, with a surface area of about 64,000 acres, is the third largest. Due to the gentle topography of the Coastal Plain physiographic province in which they are situated, neither lake exceeds 65 ft in depth. Average depths are 15 ft in Lake Marion and 18 ft in Lake Moultrie. Residence times are about 2 to 6 weeks in Lake Marion and 1.5 to 3 weeks in Lake Moultrie.

Most of Lake Marion occupies the relatively flat, 2- to 5-mi wide flood plain of the Santee River (fig. 2). The upper end of the 40-mi long lake is a gradual transition from alluvial floodplain to impounded lake, with a gentle slope and a dense cover of bottomland hardwoods and cypress trees. Partially submerged natural levees, broken by occasional natural or artificial cuts, confine most of the flow of the Santee River to its old channel in the upper 10 mi of Lake Marion. The cuts and the gradually submerging main channel resemble a deltaic environment.

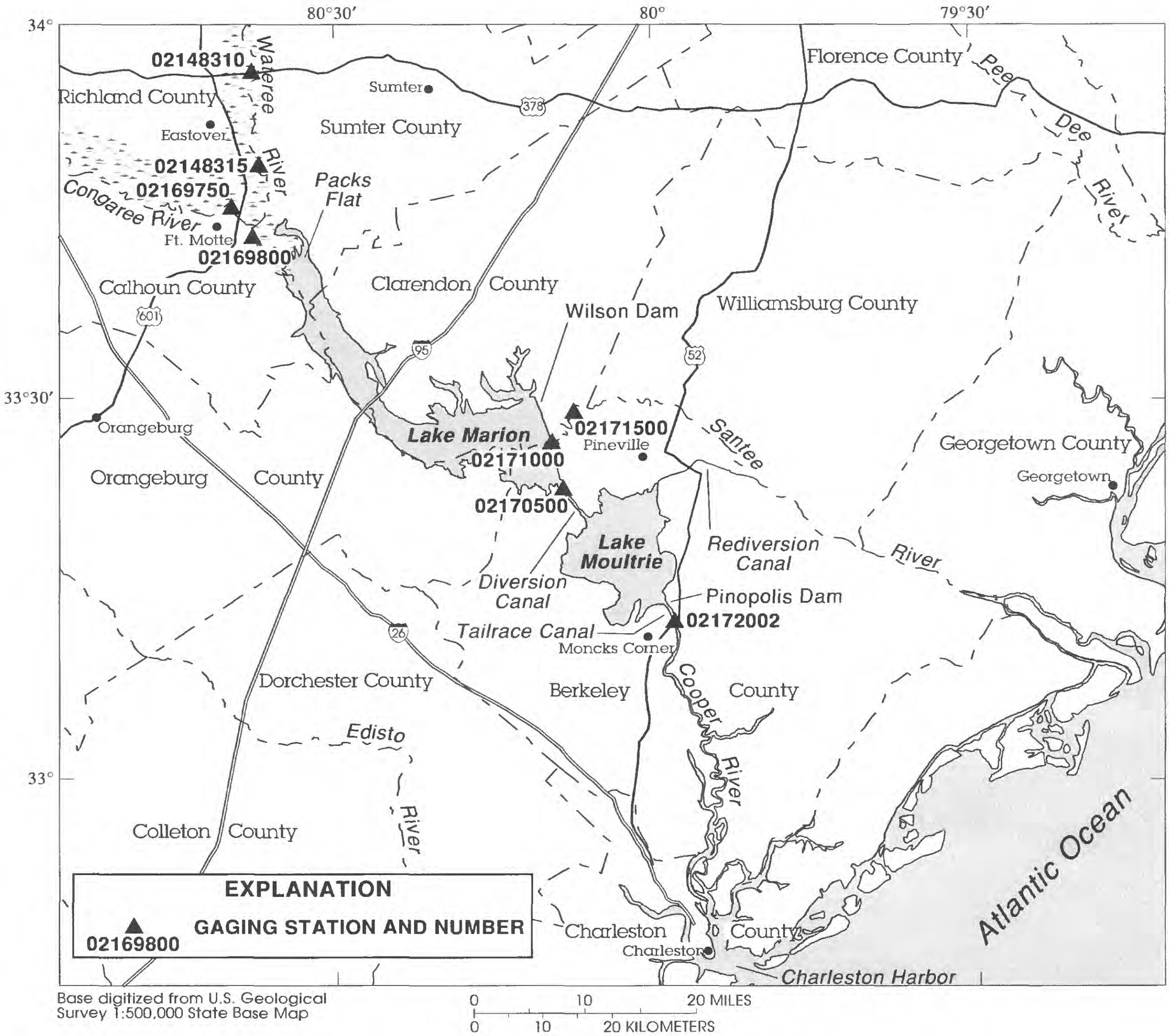


Figure 2. Lakes Marion and Moultrie, South Carolina.

The 4-mi long Diversion Canal connects the southeastern corner of Lake Marion with Lake Moultrie, with no significant change in water level. Lake Moultrie occupies a nearly circular basin that was formed by diking the swampy headwaters of the west branch of the Cooper River (fig. 2). The bottom topography of Lake Moultrie is also relatively flat, but shows a typical dendritic pattern of valleys that is intersected by prehistoric sandy beach ridges.

DATA COLLECTION AND ANALYSIS

Sediment transport and deposition can be analyzed by measuring the discharge of suspended sediment in flowing water, changes in water depths in lakes, or rates of accumulation on lakebeds. All of these aspects of sediment transport and deposition in Lakes Marion and Moultrie were studied during 1983-85.

Sediment Inflow and Outflow

The investigation of sediment inflow and outflow of Lakes Marion and Moultrie (Cooney, 1988) was basically a repetition of a similar investigation carried out by the USGS during 1966-68 (U.S. Geological Survey, 1966-68). In both studies, discharges of suspended sediment were monitored at the major inflows and outflows of Lakes Marion and Moultrie. In the 1966-68 study, samples of suspended sediment were taken at three gaging stations on outflows and at three stations on the inflow (table 1; fig. 2). In the 1983-85 study, samples were taken at three stations on outflows and at two stations on the inflow (table 2; fig. 2) (Cooney, 1988).

Nearly all the sediment that enters the lakes flows in through the Wateree and Congaree Rivers. A sampling frequency of weekly or greater is required to account for the variability in sediment concentrations in these rivers. The combined sediment discharges at the Wateree and Congaree River stations are comparable to the sediment discharge just downstream of the confluence of these two rivers at the Santee River near Fort Motte. During the 1966-68 study, 101 weekly samples were taken at the Fort Motte station. In addition, samples were taken at the Wateree and Congaree River stations on 5 days when access to the Fort Motte station was blocked by high water. Each of these 106 samples was a composite sample made by mixing three subsamples taken at quarter points across the river. At each quarter point, a USGS depth-integrating sampler was used to obtain the subsample, representing the total depth of the river, with a volume proportional to the flow in that vertical subsection.

Suspended sediment flows out of the lakes into the Santee River and the Lake Moultrie Tailrace Canal. Travel through the lakes reduces the variability in suspended-sediment concentrations in these outflows. Weekly, biweekly, or monthly sampling is generally sufficient to account for the variability in sediment concentration in the outflows. During the 1966-68 study, monthly samples were taken from the Santee River and weekly samples were taken from the Lake Moultrie Tailrace Canal. The compositing procedure used for the inflows was also used for the outflows.

Table 1.--*Sampling frequency for suspended sediment in inflow and outflow of Lakes Marion and Moultrie, July 1, 1966 to June 30, 1968*

Station number (fig. 2)	Station name	Inflow or outflow	Sampling frequency
02148310	Wateree River at U.S. Highway 378 near Eastover	Inflow	Daily during 7 days of high flow
02169750	Congaree River at U.S. Highway 601 near Fort Motte	Inflow	Daily during 14 days of high flow
02169800	Santee River near Fort Motte	Inflow	Weekly
02171000	Lake Marion Tailrace near Pineville	Outflow	Daily during 20 days of high flow
02171500	Santee River near Pineville	Outflow	Monthly
02172002	Lake Moultrie Tailrace near Moncks Corner	Outflow	Weekly

Table 2.--*Sampling frequency for suspended sediment in inflow and outflow of Lakes Marion and Moultrie, October 1, 1983 to March 31, 1985*

Station number (fig. 2)	Station name	Inflow or outflow	Sampling frequency
02148315	Wateree River below Eastover	Inflow	Every 6 hours
02169750	Congaree River at U.S. Highway 601 near Fort Motte	Inflow	Every 6 hours
02170500	Diversion Canal near Pineville	Outflow from Lake Marion, inflow to Lake Moultrie	Weekly
02171500	Santee River near Pineville	Outflow	Weekly
02172002	Lake Moultrie Tailrace near Moncks Corner	Outflow	Weekly

During the 1983-85 study, automatic suspended-sediment samplers were used to collect samples at 6-hour intervals at the Congaree and Wateree River inflow stations. These samplers provided a nearly continuous record of suspended-sediment concentration in the inflows. Mechanical problems caused some samples to be missed creating gaps in the continuous record, but samples were successfully taken at both inflow stations on 351 days. Short gaps in the concentration record were filled by estimating the temporal concentration graph. Longer gaps were filled by directly estimating discharge of suspended sediment using a suspended-sediment transport rating curve (Porterfield, 1972).

Automatic samplers obtained samples from intakes located at a single point in the river cross section. To adjust the point-sample concentration to the concentration representing the entire cross section, composite samples also were taken. The composite sampling, on 32 days, was done in a similar manner to the 1966-68 sampling, except the number of subsamples was increased from 8 to 12. An adjustment factor was computed and applied to the point-sample concentrations to more accurately reflect the entire cross section.

To detect trends in the suspended-sediment inflow to Lake Marion, streamflow and sediment concentrations and loads were compared for the 351 sampled days during 1983-85, and the 106 sampled days during 1966-68. To ensure that the daily means of point samples from 1983-85 were comparable to the instantaneous composite samples from 1966-68, a similar comparison was made between the 106 days with composite samples from 1966-68 and the 32 days with composite samples from 1983-85.

Annual mean values for streamflow, suspended-sediment concentration, and suspended-sediment discharge were computed for the inflows and outflows for both study periods. Based on the results, sediment-trap efficiencies were computed, and comparisons were made between the sediment budgets for the two periods.

The 1983-85 study included determinations of bedload transport of sediment in the inflows. No comparison could be made with the earlier period.

Bathymetric Mapping

Bathymetric maps of Lakes Marion and Moultrie were prepared using water depths measured during 1984-85 in cooperation with the South Carolina Public Service Authority (Patterson and Logan, 1988). A boat equipped with an automatic positioning systema and a depth sounder was driven along transects to collect the data for the maps. The depth sounder was equipped with a 200 kilohertz transducer. The positioning system used microwaves to measure the distances between the boat and two remote transponders at known locations. Coordinates for the transponders were determined from topographic maps. The boat had to be within sight of the transponders and within a nearly circular area of acceptable geometry where the bearings from the boat to the transponders formed an angle between 30 and 150 degrees. These requirements necessitated moving the transponders many times, especially in the upper part of Lake Marion. Coordinates for the boat position were automatically triangulated by the positioning system. The coordinates, along with time and mean water depth, were recorded every 7 seconds on magnetic tape. The boat speed and sampling frequency were such that depths were measured about every 100 ft along each transect. Depths were considered accurate within 0.2 ft, and horizontal position was considered accurate within 30 ft.

The upper end of Lake Marion contains large areas of dense cypress and tupelo forest submerged to a depth of several feet (fig. 3). Navigation in these areas is restricted to relatively narrow boat trails that generally follow pre-impoundment flood-plain channels. Depth observations were made along the boat trails and in the wooded areas immediately adjacent to the trails but outside the channels. Based on these observations, an average depth of 4 ft was assigned to the area (fig. 3). The straight boundary of this area at the Congaree-Wateree River confluence represents a somewhat arbitrary boundary for the upstream limit of Lake Marion. The actual upstream limit of impounded conditions fluctuates within a few miles of this line, depending on river flow and lake level.

Four staff gages and one recording gage on Lake Marion, and one recording gage on Lake Moultrie were used to monitor lake stage (fig. 4). All gages were surveyed relative to sea level. On each day of bathymetric-data collection, lake stage was determined at the closest gage to the area being mapped. The depth data were adjusted so that all depths were relative to elevations of 76.8 ft above sea level for Lake Marion and 75.0 ft above sea level for Lake Moultrie.

The adjusted depths were plotted on large-scale sectional maps of the lakes, and 4-ft depth contours were drawn by hand. The contours for each section were digitized into a computer file, and files were combined and edge-matched to form a complete contour map for each lake. Volume tables were prepared by digitizing the area enclosed by each contour, and computing the volume of each 4-ft layer of each lake.

Lakebed Sediment Sampling

Twenty sediment cores were withdrawn on October 18-20, 1983, from the beds of Lakes Marion and Moultrie to provide information on deposition rate, and physical and chemical characteristics of bed material. The sampling sites were chosen to represent the variety of depositional environments in the two lakes (table 3; figs. 3, 4, and 5). This physical and chemical analytical scheme for the sediment cores was based on the partitioning of each core for a specific analysis (table 4).

Cores were withdrawn under the supervision of personnel from the U.S. Minerals Management Service (MMS). The coring tubes were polyvinyl chloride (PVC) cylinders 40 in. long and 4 in. in diameter, split lengthwise and taped together. A tube was prepared for each core. A device was attached to the top of the tube to provide a handle and a sliding hammer. To obtain the core, two people wearing diving gear, if necessary, stood on the lakebed while they pushed and hammered the tube into the sediment to refusal or to a limit of 40 in. Following insertion, a top with a sealing ring was screwed on to a vent at the top of the tube to provide a partial vacuum to keep the core intact as the tube was gradually withdrawn from the sediment. When the bottom of the tube emerged from the sediment, an air-tight stopper was inserted into the bottom end of the tube and the core was transported in an upright position to the sampling boat. A detailed description of the coring device is given in Martin and Miller (1982). Extra samples of the top few inches of sediment were taken in a 1-pint freezer carton and in a small plastic bag.

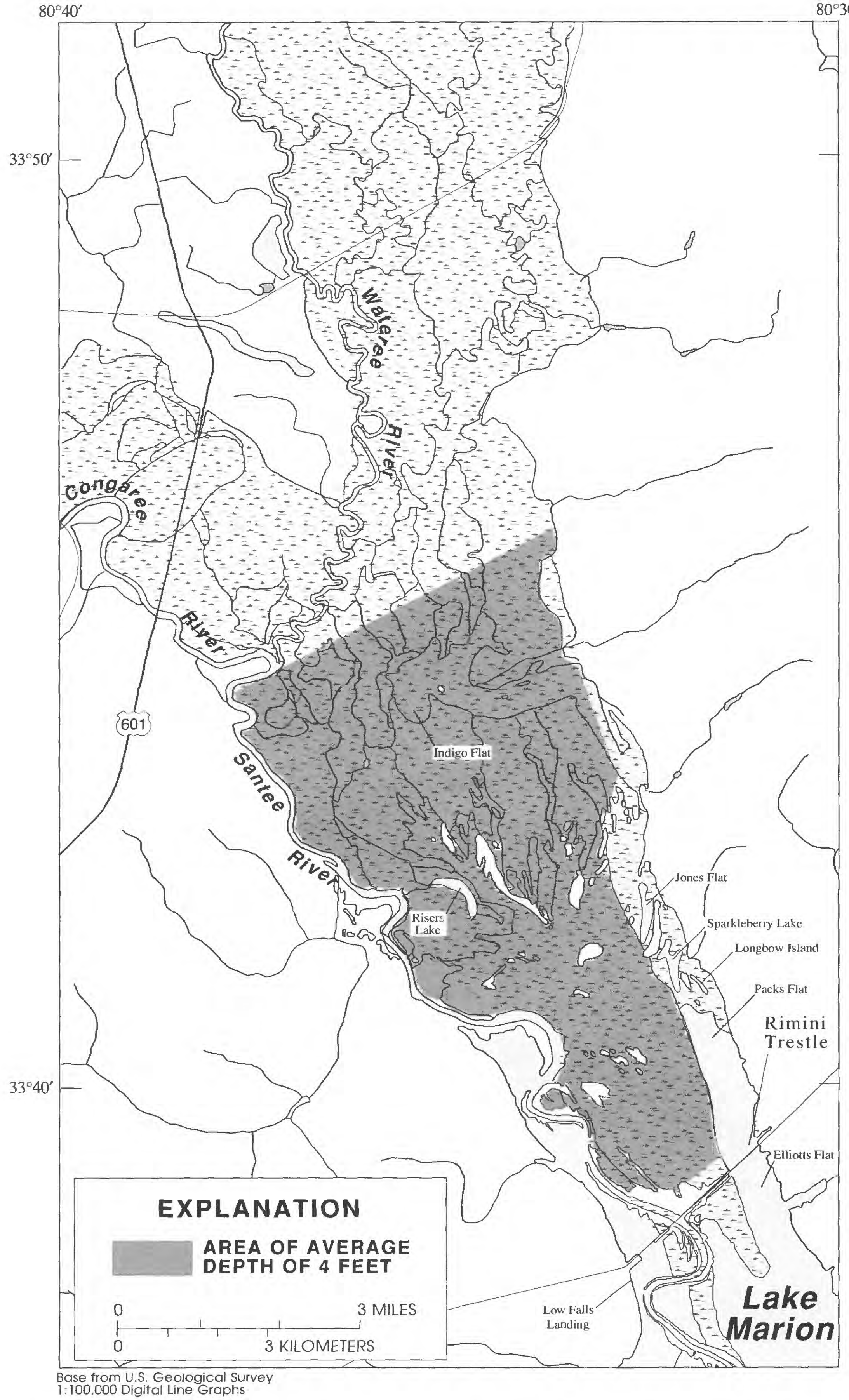


Figure 3. Upper Lake Marion, showing area with average depth of 4 feet.

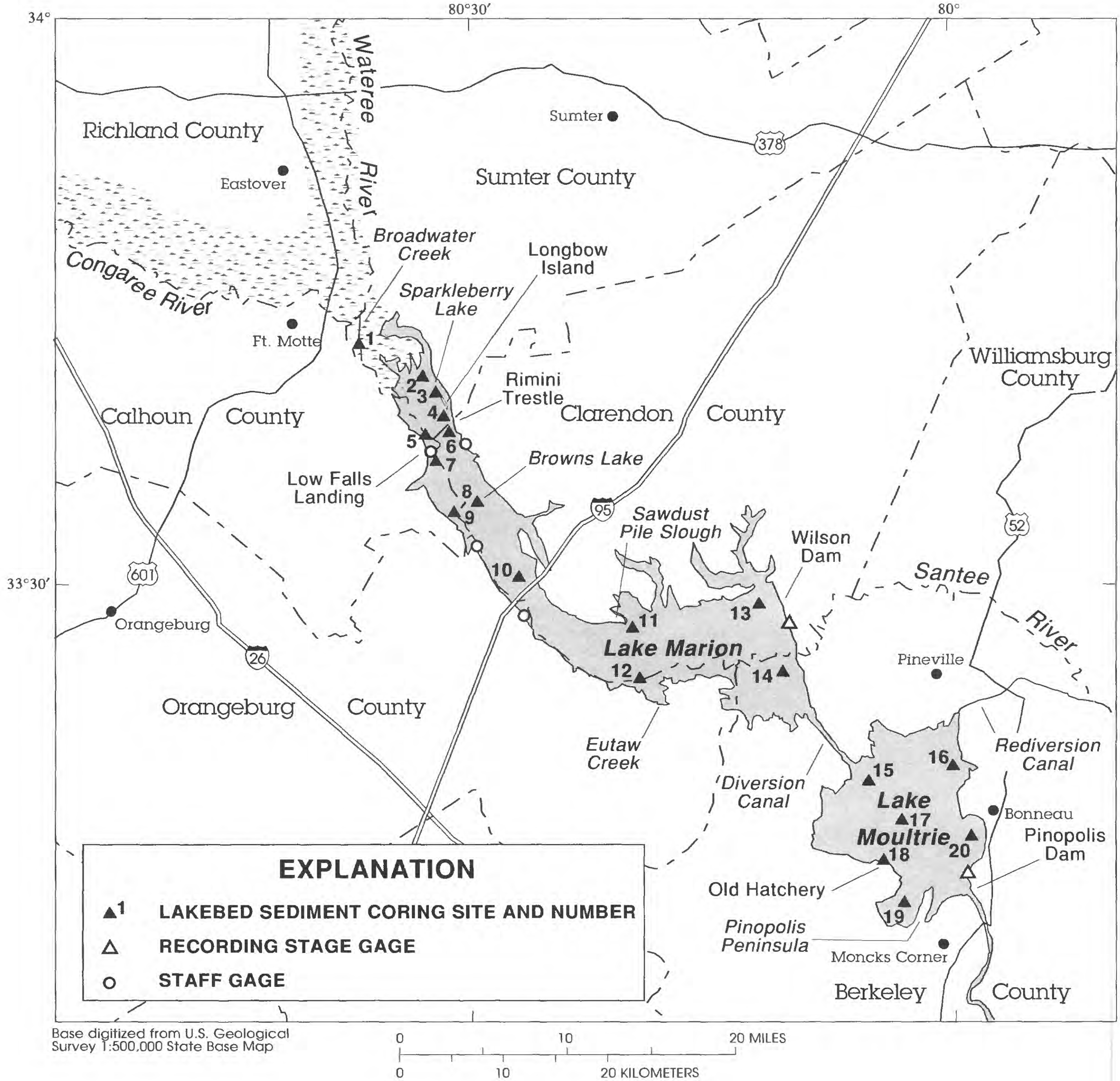


Figure 4. Lakebed sediment coring sites and lake-stage gages.

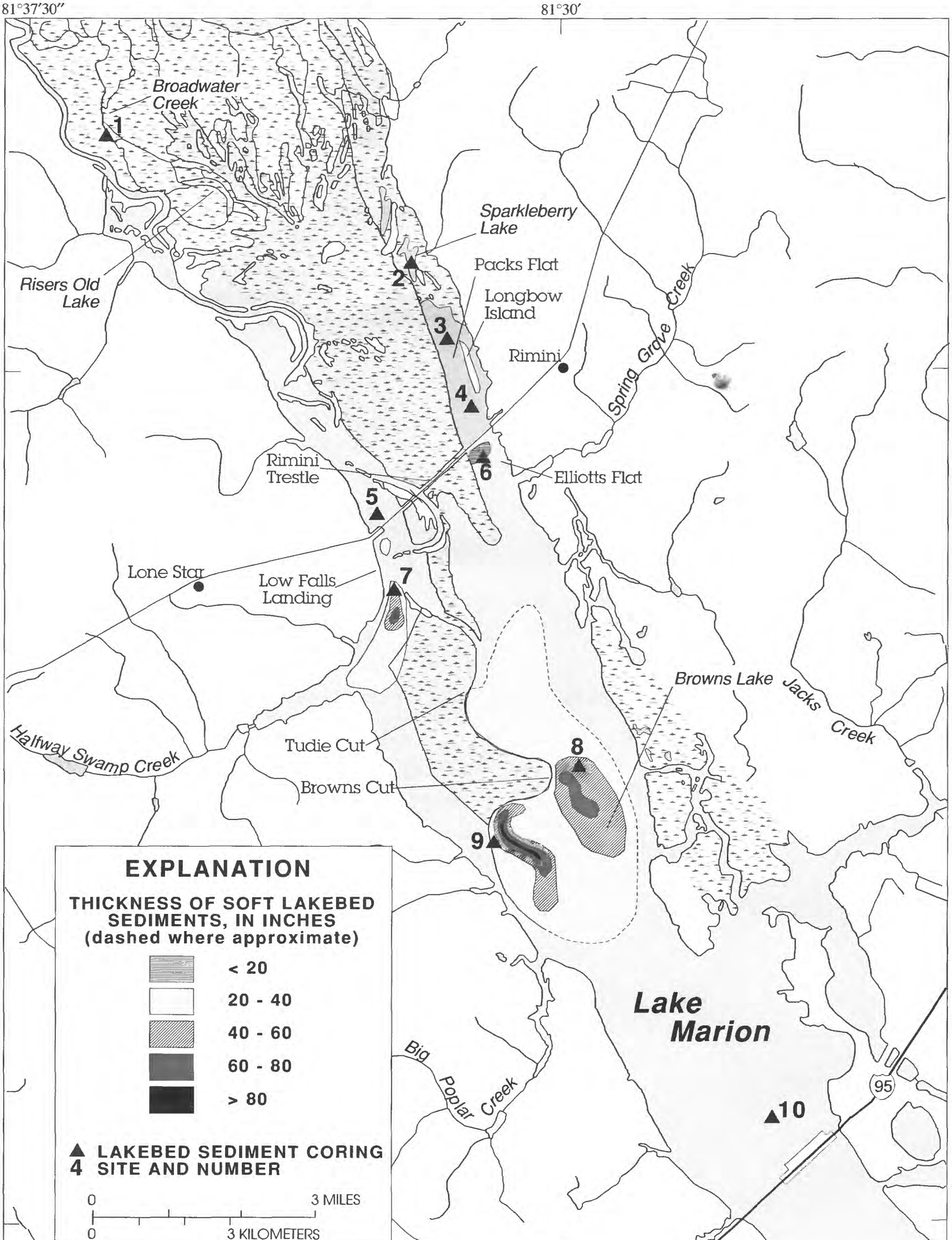


Figure 5. Thickness of soft lakebed sediments in upper Lake Marion.

Table 3.--*Locations and descriptions of lakebed coring sites, October 18-20, 1983*

[ft, feet; mi, mile]

Coring site number (figs. 4 and 5)	Latitude, longitude, and lake	Site description
1	33°42'50" 80°36'22" Lake Marion	First wide spot in Broadwater Creek, a Santee River distributary flowing into the flood plain at the upper limit of Lake Marion. Similar conditions prevailed prior to impoundment.
2	33°41'09" 80°32'06" Lake Marion	Middle of Sparkleberry Lake, a cutover part of the flood plain in upper Lake Marion, influenced more by relatively sediment-free Coastal Plain tributary inflow than by Santee River water. Periodically inundated prior to impoundment.
3	33°40'00" 80°31'24" Lake Marion	Near northern tip of Longbow Island in Packs Flat, similar to site 2. Periodically inundated prior to impoundment.
4	33°39'26" 80°31'17" Lake Marion	Middle of Packs Flat about 200 ft upstream of trestle; cut-over flood plain with some influence by river water during floods. Periodically inundated prior to impoundment.
5	33°38'18" 80°32'33" Lake Marion	Upper Low Falls Landing area, about 400 ft from western shore and 200 ft upstream of trestle, similar to site 2, but in a bed of the rooted macrophyte, Egeria densa. Periodically inundated prior to impoundment.
6	33°38'50" 80°31'19" Lake Marion	Elliotts Flat about 200 ft downstream from trestle. Similar to site 4, but channel along trestle carries about 10 percent of Santee River flow past the site. Periodically inundated prior to impoundment.
7	33°37'26" 80°32'25" Lake Marion	Lower Low Falls Landing area about 0.7 mi downstream from trestle. Deltaic environment in cut-over flood plain. Ten percent of Santee River flow enters area through cut adjacent to Low Falls Landing, then slows near site as confined width of flood plain increases. Periodically inundated prior to impoundment.
8	33°35'25" 80°29'35" Lake Marion	Flood-plain depression in Browns Lake area. Inundated prior to impoundment.
9	33°34'35" 80°30'58" Lake Marion	On submerged natural levee on right bank of Santee River channel. Periodically inundated prior to impoundment.

Table 3.--*Locations and descriptions of lakebed coring sites, October 18-20, 1983*--Continued

[ft, feet; mi, mile]

Coring site number (figs. 4 and 5)	Latitude, longitude, and lake	Site description
10	33°31'20" 80°27'05" Lake Marion	On submerged natural levee at channel marker 72. Periodically inundated prior to impoundment.
11	33°28'09" 80°20'57" Lake Marion	Flood-plain depression near Sawdust Pile Slough. Inundated prior to impoundment.
12	33°26'27" 80°20'56" Lake Marion	Submerged channel of Santee River near Eutaw Creek mouth. Inundated prior to impoundment.
13	33°30'12" 80°12'40" Lake Marion	Submerged flood plain. Periodically inundated prior to impoundment.
14	33°25'34" 80°10'36" Lake Marion	Submerged flood plain. Periodically inundated prior to impoundment.
15	33°20'30" 80°05'55" Lake Moultrie	Channel marker 12, near the mouth of the Diversion Canal in Lake Moultrie. Headwater swamp prior to impoundment.
16	33°21'45" 80°00'14" Lake Moultrie	In cove formed by crescent-shaped island in northeastern part of Lake Moultrie. Headwater swamp prior to impoundment.
17	33°18'31" 80°02'59" Lake Moultrie	Channel marker 4 near middle of Lake Moultrie. Small swampy Coastal Plain stream prior to impoundment.
18	33°15'35" 80°05'00" Lake Moultrie	Near middle of shallow, mostly diked part of Lake Moultrie, formerly used as fish hatchery. Dry land prior to impoundment.
19	33°14'20" 80°03'43" Lake Moultrie	Cove in Lake Moultrie between Pinopolis peninsula and the former hatchery. Headwater swamp prior to impoundment.
20	33°17'17" 79°59'05" Lake Moultrie	Large cove south of Bonneau. Dry land prior to impoundment.

Table 4.--*Analytical scheme for lakebed sediment cores*

Analysis	Depths	Analyzing laboratory
Deposition rate	all	U.S. Minerals Management Service
Trace metals	top	U.S. Minerals Management Service
Moisture content	top, middle	U.S. Army Corps of Engineers Waterways Experiment Station
Density	top, middle	U.S. Army Corps of Engineers Waterways Experiment Station
Organic content	top, middle	U.S. Army Corps of Engineers Waterways Experiment Station
Texture	top, middle	U.S. Army Corps of Engineers Waterways Experiment Station
Particle size	top, middle, bottom	U.S. Geological Survey Sediment Laboratory, Harrisburg, Pa.
Organic content	top, middle, bottom	U.S. Geological Survey Central Laboratory, Doraville, Ga.
Ammonia + organic N	top, middle, bottom	U.S. Geological Survey Central Laboratory, Doraville, Ga.
Nitrite +nitrate N	top, middle, bottom	U.S. Geological Survey Central Laboratory, Doraville, Ga.
Total phosphorus	top, middle, bottom	U.S. Geological Survey Central Laboratory, Doraville, Ga.
Bulk density	top, middle, bottom	U.S. Geological Survey Laboratory, Columbia, S.C.

The core was held in an upright position on the sampling boat while the tape holding the two halves of the tube together was punctured with a knife at the sediment-water interface, allowing the excess water to drain out. Then the tape was slit entirely while the tube was held together by hand, and a wire was pulled through the length of the core to divide it longitudinally. Next the tube was laid down and opened like a book, exposing the freshly cut, relatively intact halves of the core in each half of the tube. Absorbent paper was placed at the top of each half to stabilize the soft sediment at the top of the core so that accurate depth intervals could be assigned to subsamples.

One half of each core was wrapped in plastic film and left intact until a x-radiograph was taken to test for the presence of worm burrows that would indicate disturbance of the sediment. Then subsamples of that core half were taken from at least 2 depths for determination of bulk density and particle size. Bulk density was determined by measuring the length, and thus the volume of the subsample, drying the subsample at 105 °C for 2 hours or until a constant weight was obtained, and weighing the dried sample. Particle size was determined by the wet-seive and pipette method (Guy, 1969).

The other half core was subsampled on the sampling boat for several additional analyses. During subsampling, a description with notes on color and texture of the sediment layers represented in each core was recorded. The top 3.9 in. of the core was divided into 10 subsamples, and additional 0.4-in. subsamples were taken at 3.9-in. intervals to the bottom of the core. For each subsample, about 1 gram of sediment was taken from the center of the core slice to avoid possible contamination near the wall of the tube. The subsamples were analyzed for ^{210}Pb and trace-metal content. The ^{210}Pb analysis was made to determine deposition rate.

Trace metal concentrations were determined by the MMS. Atomic absorption spectrophotometry was used to determine concentrations of cadmium, copper, lead, and zinc.

Samples for nutrient and moisture-content analyses were taken from the 1-pint freezer carton sample of the top layer of sediment and from the middle and bottom of the core. Samples for moisture content, texture, and organic content were taken from the plastic bag of top-layer sediment and from the middle of the core. All samples were chilled and transported to the appropriate laboratory within 2 days.

Thickness of soft lakebed-sediment deposits was determined during the coring operation for those cores with less than 40 in. penetration. Additional determinations of sediment thickness were made by comparing new bathymetric data with information on pre-impoundment land-surface or river-bed altitudes. Finally, soft sediment thickness also was measured at about 50 sites in upper Lake Marion using an 18-ft probe made of 1-in. diameter PVC pipe. The probe was lowered through the water column until slight resistance was encountered to measure water depth. Then, the probe was pushed through the soft lakebed sediment until stiff resistance was encountered. The thickness of the soft lakebed sediments was determined by subtraction.

Sediment Dating

Radioactive ^{210}Pb is a natural by-product of the decay of radon gas, which is produced by the decay of uranium. Some of the radon gas remains underground where it is produced, and its decay to ^{210}Pb provides a low level of background ^{210}Pb activity throughout a typical sediment column. Most of the radon gas, however, escapes to the atmosphere, where its decay causes a constant fallout of ^{210}Pb. Surfaces such as lakebeds and the ground, which receive this ^{210}Pb fallout, are enriched with ^{210}Pb activity in excess of the background level. Once a sediment horizon in a lakebed is buried by newer sediment and is no longer exposed to atmospheric fallout, the excess ^{210}Pb activity contained in that horizon begins a gradual decline to background level as the ^{210}Pb-decays further to ^{208}Pb, a stable, nonradioactive isotope. The half-life for this decay is 22.3 years. The gradual decline in excess ^{210}Pb activity with increasing depth in a lakebed sediment column provides a convenient means of determining the sediment deposition rate, according to the following equation

$$A_d = A_0 e^{-\alpha t}, \qquad (1)$$

where

A_d is ^{210}Pb activity at depth d in disintegrations per minute per gram;

A_0 is ^{210}Pb activity at higher reference point in disintegrations per minute per gram;

α is ^{210}Pb decay constant (0.0311 yr^{-1}); and

t is age of sediment at depth d, in years.

Accurate dating of sediments can occur if the sediment column contains sufficient fine-grained sediment and has been undisturbed by currents or organisms since deposition. A more detailed description of the method, theory, and assumptions is given in Martin and Rice (1981).

Subsamples were taken as described above from the 20 cores from Lakes Marion and Moultrie for ^{210}Pb dating. The analyses were performed by the USMMS, Corpus Christi, Tex., using standard techniques (Martin and Rice, 1981).

SEDIMENT TRANSPORT AND DEPOSITION

Results of the four components of this study were analyzed to determine long-term and short-term rates of sediment inflow, outflow, and deposition in Lakes Marion and Moultrie. The results also illustrate the variation in sediment deposits within the lakes.

Sediment Inflow and Outflow

Streamflow and suspended-sediment data were obtained for 106 days during the 1966-68 sampling period and for 32 days during the1983-85 sampling period when composite samples were taken in the inflow to Lake Marion (table 5 at end of report). The daily mean suspended-sediment concentration values derived from the automatic point-sediment samplers during 1983-85 have been published separately (Cooney, 1988). Mean concentrations for the two sampling periods are listed in table 6.

Table 6.--*Comparison of suspended-sediment inflow data, Lake Marion, 1966-68 and 1983-85*
[ft^3/s, cubic feet per second; mg/L, milligrams per liter; --, indicate no data; +, increase; -, decrease]

					Change since 1966-68	
Sampling period	Type of sediment data	Number of values	Mean streamflow for sampled days (ft^3/s)	Mean suspended sediment concentration (mg/L)	Streamflow (percent)	Suspended sediment concentration (percent)
1966-68	Instantaneous composite	106	15,400	72	--	--
1983-85	Instantaneous composite	32	17,800	47	+16	-35
1983-85	Daily means of point samples	351	17,700	39	+15	-46

Comparison of the data from the two sampling periods shows a large decrease in mean concentration of suspended sediment from 1968 to 1985, despite an increase in mean streamflow (table 6). The decrease in suspended-sediment concentration is seen with the instantaneous composite samples from 1983-85 and with the daily mean values derived from point samples.

Part of the difference in mean suspended-sediment concentrations in the inflow to Lake Marion may be attributable to differences in stream regimen between the two sampling periods. During 1966-68, streamflow and suspended-sediment concentration showed more variability than during 1983-85 (table 6). Although 1966-68 had a lower rainfall and mean streamflow, it also had higher peak flows than 1983-84. Peak flows are important because most sediment transport occurs during floods.

As is often the case with sediment transport, the largest flood of 1966-68 (August 25-28, 1967; 116,500 ft^3/s; 243 mg/L) was not accompanied by the highest concentration of suspended sediment. This occurred on July 10-11, 1967 (24,100 ft^3/s; 524 mg/L). The higher concentration seems to be associated with a sharp rise to a moderately high peak flow, following 2 months of below-average flow. The larger flood following a shorter dry period of about 1 month, seems to have had a lesser supply of readily available sediment and more water with which to dilute it.

This effect tends to support the validity of the comparison of the two periods despite the difference in stream regimen. The 1983-85 period had streamflows as high as those that produced the highest sediment concentrations during 1966-68. The 1983-85 period also had sediment concentrations comparable to those produced by the highest streamflow of 1966-68. Both intervals had comparable periods of below-average flow followed by sharp peak flows. The comparison does not appear to be skewed by events in one period that were not comparable to the other period.

Streamflow values for the Congaree River at U.S. Highway 601 (02169750) for August 25 to September 8, 1967, published in this report, are lower than previously published (U.S. Geological Survey, 1966-68; Patterson and Cooney, 1986). In the course of this investigation, the authors noticed that the previously published streamflows were those that occurred at the Congaree River at Columbia (02169500) gaging station 2 days earlier. Without the benefit of a gaging station at the U.S. Highway 601 bridge (fig. 2), that was the most reasonable assumption that could be made during 1966-68. Operation of such a gaging station during the 1983-85 period showed that the 2-day lag time is essentially correct, but that the peaks are attenuated and extended as the river courses the 40 mi through the Coastal Plain from Columbia to U.S. Highway 601. Corrections to the 1966-68 data based on comparison of the Columbia and U.S. Highway 601 station records resulted in no significant changes in the streamflow record, except for the large flood of August 25 to September 8, 1967. Accordingly, these values were corrected for use in this report by using a relation of 1983-85 observed flows from the Columbia and the Highway 601 gages. This adjustment has little effect on the decrease in mean concentration of suspended sediment between 1966-68 and 1983-85.

Annual mean discharges of suspended sediment for the inflows and the outflows were computed during the 1966-68 and the 1983-85 studies (table 7). The outflow of suspended sediment was slightly greater during the recent study than during the earlier study, in part because of greater releases of floodwater from Lake Marion through the Wilson Dam spillway. The trap efficiency of the lakes for suspended sediment was 83 percent during 1966-68 and 76 percent during 1983-85 (table 7). These values are fairly close to the estimate of 86 percent derived by the capacity-inflow technique (Brune, 1953).

Table 7.--*Annual mean sediment discharge, inflow and outflow of Lakes Marion and Moultrie*
[--- indicate no data]

	July 1, 1966 to June 30, 1968	October 1, 1983 to March 31, 19^5
Annual mean suspended-sediment discharge, inflow, tons per year	978,000	722,000
Annual mean suspended-sediment yield, inflow, tons per square mile per year	65	48
Annual mean suspended-sediment discharge, outflow, tons per year	164,000	175,000
Trap efficiency for suspended-sediment, percent	83	76
Annual mean total sediment discharge, inflow, tons per year	---	825,000
Annual mean total sediment yield, inflow, tons per square mile per year	---	55
Annual mean total sediment discharge, outflow, tons per year	---	175,000
Trap efficiency for total sediment, percent	---	79

A small, but significant, bedload flows into Lake Marion in addition to the load of suspended sediment. Bedload was not addressed in the 1966-68 study, but it was estimated in the 1983-85 study using the modified Einstein procedure (Stevens, 1985). The 1983-85 annual mean rates of bed-material discharge are estimated to be 69,000 ton/yr for the Wateree River near Eastover (02148315) and 34,000 ton/yr for the Congaree River at U.S. Highway 601 bridge (02169750), for a total bed-material inflow of 103,000 ton/yr. This represents 12 percent of the annual mean total sediment discharge in the inflow to the lakes (table 7).

Bathymetric Mapping

The bathymetric maps of Lakes Marion and Moultrie produced during this study have been published separately due to their size (Patterson and Logan, 1988). The water volume of each reservoir was determined by digitizing and summing the areas enclosed by each depth contour. These volumes are compared with other previous volume determinations in table 8. The volume changes listed in table 8 have a large range of error for two reasons. The methods used to estimate the volume of the lakes in 1970 (U.S. Department of Agriculture, 1973) and in 1942 are not known in detail, and may not be precisely comparable to that used by the authors. Furthermore, the volume changes represent relatively small differences between two very large numbers.

Table 8.--*Changes in storage for Lakes Marion and Moultrie, S.C.*
[+, increase; -, decrease]

Dates	Parameter	Lake Marion	Lake Moultrie	Total
1942	Storage (acre-foot)	1,498,000	1,090,000	2,588,000
1970	Storage (acre-foot) (estimated)	1,453,000	1,083,000	2,536,000
1942-70	Volume change (acre-foot)	-45,000	-7,000	-52,000
	Volume change (percent)	-3.0	-.6	-2.0
	Annual mean change (acre-foot) (28 years)	-1,610	-250	-1,860
	Annual mean change (percent)	-.11	-.02	-.07
1985	Storage (acre-foot)	1,425,000	1,060,000	2,485,000
1970-85	Volume change (acre-foot)	-28,000	-23,000	-51,000
	Volume change (percent)	-1.9	-2.1	-2.0
	Annual mean change (acre-foot) (15 years)	-1,870	-1,530	-3,400
	Annual mean change (percent)	-.13	-.14	-.13
1942-85	Volume change (acre-foot)	-73,000	-30,000	-103,000
	Volume change (percent)	-4.9	-2.8	-4.0
	Annual mean change (acre-foot) (43 years)	-1,700	-700	-2,400
	Annual mean change (percent)	-.11	-.06	-.09

Lake Marion is experiencing more rapid sedimentation than Lake Moultrie, which is reasonable considering that the initial transition from river to lake occurs in Lake Marion. The most notable reductions in depth have occurred where the incoming flow of the Santee River leaves the confines of the river channel near Browns Cut and Low Falls Landing in upper Lake Marion (fig. 5). As much as 11 ft of sediment has accumulated in these areas during 1942-85, based on the assumption that the pre-impoundment river channel bottom had a constant slope near Browns Cut. Results from the sediment-core samples downstream from site 9 provided evidence that the depth of soft sediment downstream was less than in these three areas.

Sedimentation has also occurred in the deeper parts of both lakes. In the deepest part of Lake Moultrie, the bed material is fine-grained and loosely packed. Bathymetric surveys on different days show that this fine-grained sediment seems to move in response to wind-driven currents. The depth contours for this part of Lake Moultrie represent average conditions and may vary by several feet on occasion.

Lakebed Sediment Sampling

The character and thickness of lakebed sediments in Lakes Marion and Moultrie vary with location, and some trends are evident. The results of the sampling are summarized in table 9, and listed in appendix 1. In general, bulk density increased with depth in the sediment, and moisture content decreased with depth. Sediments from Lake Marion tended to have lower bulk density, higher moisture content, higher organic content, finer texture, and higher concentrations of nutrients and metals than sediments from Lake Moultrie.

Within Lake Marion, sediments tended to have finer texture and higher organic and nutrient content along the northeastern shore. In areas of upper Lake Marion where the waters of the Santee River flow into the backwater of the reservoir, lakebed sediments had abundant fine sand and silt, and relatively low organic content.

The lakebed sediment samples from Lake Moultrie were sandy, except for the shallow, protected, former hatchery area (site 18) and the broad cove near Bonneau (site 20) (fig. 4). At the latter site, the hard-packed consistency suggested that the sample was pre-impoundment soil. No sediment cores were obtained from the deepest part of Lake Moultrie, but qualitative samples from this area showed a fine-grained, loose, semi-fluid material on the lakebed. Successive bathymetric surveys showed that this semi-fluid mud appeared to migrate in response to currents in the lake.

Table 9.--*Summary of lakebed sediment characteristics*

[lb/ft^3, pounds per cubic foot; mg/kg, milligrams per kilogram; --, indicate no data; <, less than]

Characteristic or constituent	Lake Marion					Lake Moultrie					Combined mean
	Minimum	Station number(s) where minimum value was obtained (fig. 4)	Maximum	Station number(s) where maximum value was obtained (fig. 4)	Mean	Minimum	Station number(s) where minimum value was obtained (fig. 4)	Maximum	Station number(s) where maximum value was obtained (fig. 4)	Mean	
Bulk density, lb/ft^3	20	8	98	7	46	85	18	110	15	97	61
Moisture content, percent	18	2	80	5	47	13	16	30	19	23	40
Organic content, percent	4	10	17	2	12	.3	16, 17	7	20	2	9
Sand, percent	1	4	92	6	26	36	20	96	16	73	40
Nitrogen, nitrite +nitrate, dissolved (mg/kg as N)	<2	most	27	11	--	<2	all	2	18, 19	--	--
Nitrogen, ammonia, dissolved (mg/kg as N)	17	1	210	6	75	2.4	17	30	17	13	57

Table 9.--*Summary of lakebed sediment characteristics*--Continued

[lb/ft^3, pounds per cubic foot; mg/kg, milligrams per kilogram; --, indicate no data; <, less than]

Characteristic or constituent	Lake Marion					Lake Moultrie					Combined mean
	Minimum	Station number(s) where minimum value was obtained (fig. 4)	Maximum	Station number(s) where maximum value was obtained (fig. 4)	Mean	Minimum	Station number(s) where minimum value was obtained (fig. 4)	Maximum	Station number(s) where maximum value was obtained (fig. 4)	Mean	
Nitrogen, ammonia + organic, dissolved (mg/kg as N)	280	7	14,000	2	3,680	150	15	812	18	367	2,690
Phosphorus, total (mg/kg as P)	220	14	1,500	13	777	<2	20	1,100	15	101	574
Cadmium, mg/kg	.03	10	.58	1	.2	.007	17	.07	15	.02	.14
Copper, mg/kg	8	10	.78	8	36	.4	16	6.9	20	1.9	26
Lead, mg/kg	15	13	90	8	28	.8	16	21	15	6.2	22
Zinc, mg/kg	25	14	225	8	86	1	16	21	20	5.8	62

The thickness of soft sediments in Lake Moultrie varied from 0 in. near Bonneau to a mean of 16 in. at the other 5 coring sites, and to 5 to 10 ft in the fluid mud of the deepest part of the Lake. The thickness of soft sediment deposits in Lake Marion ranged from 9 in. in the northeastern end of the lake in the Sparkleberry Lake and Packs Flat (fig. 5) areas upstream of the Rimini Trestle, to a mean of 20 in. for the four coring sites downstream of the Interstate Highway 95 bridge (fig. 4), to more than 100 in. in the submerged river channel just downstream of the Browns Cut area where the natural levees become submerged (fig. 5). In the Browns Cut area, the depth of water in the river channel changes rather abruptly from an average of about 20 ft to about 7 ft as one moves downstream past the end of the exposed natural levees. In this area, therefore, the soft sediments almost certainly represent post-impoundment deposition. In some of the other areas, part of the soft sediments may represent pre-impoundment deposition. The deeper sampling sites were underwater in the river or in flood-plain channels, and presumably collecting some sediment prior to impoundment. At the sites that were not submerged prior to impoundment, pre-impoundment soil may have been penetrated with the corer. For example, at coring site 20, near Bonneau in Lake Moultrie (fig. 4), about 6 in. of pre-impoundment soil were penetrated, with some difficulty, by the corer. Perhaps the best indicator of the depth of post-impoundment sediments is the depth to which excess ^{210}Pb activity was measured at a site where sediment did not accumulate prior to impoundment. This is discussed in the following section.

Sediment Dating

The results of the ^{210}Pb dating of sediment cores were inconclusive and sedimentation rates could not be calculated for some of the sites because of sampling conditions that were less than ideal. An ideal sampling site is one where consistently fine-grained sediment accumulates at a constant rate and is not disturbed by currents or organisms following deposition. At coring sites 1, 3, 7, and 11 in Lake Marion, ^{210}Pb activity did not show a clear trend with depth. Some of these sites also had interbedded layers of sediment with different textures (fig. 4). Apparently, the sediment deposits at these sites were reworked by currents from Santee River floods. Similarly, coring sites 15, 16, and 17 in Lake Moultrie had sandy sediments that had been reworked by wind-driven currents.

Most of the coring sites did exhibit a decreasing trend of excess ^{210}Pb activity with depth, down to a more stable background level, and thus supported determination of deposition rates (table 10 and appendix 2). In most cases, ^{210}Pb activity decreased to a background rate at some distance above the bottom of the core, suggesting that the corer penetrated pre-impoundment sediments old enough (about 150 years) for all the excess ^{210}Pb to have decayed (table 10). An alternate method for estimating deposition rate is to divide the thickness of sediments exhibiting excess ^{210}Pb activity by the number of years sediment had been accumulating at the site. This divisor is 43 years for sites where sediment was not accumulating prior to impoundment, and about 150 years (the time required for ^{210}Pb to decay to background levels) for sites where sediment was accumulating prior to impoundment (table 10).

Table 10.--*Deposition rates for coring sites*

[in/yr, inch per year; in., inch; --, indicate no data; >, greater than]

Coring site (fig. 4)	Deposition rate using ^{210}Pb analysis (in/yr)	Thickness of sediment containing excess ^{210}Pb (in.)	Preimpoundment environment	Break in slope between ^{210}Pb excess and background	Number of years with excess ^{210}Pb accumulation	Deposition rate using sediment thickness (in/yr)
1	no rate	--	flood-plain channel	no	--	--
2	0.035	1.2	flood plain	yes	43	0.03
3	no rate	--	flood plain	no	--	--
4	.031, then 0.17	7.1	flood plain	no	150	.05
5	.071	10.6	flood plain	no	150	.07
6	.016, then 0.08	4.3	flood plain	no	150	.03
7	no rate	--	flood plain	no	--	--
8	.51	[1]>36	flood-plain depression	no	150	>.2
9	.012	1.2	natural levee	no	--	>.2
10	.031	2.4	natural levee	no	150	--
						.02
11	no rate	--	flood plain	--	--	--
12	.051	3.9	channel	yes	43	.09
13	.055	4.7	flood plain	no	150	.03
14	.071	[2]2.8	flood plain	no	43	.07
15	no rate	--	headwater swamp	no	--	--
16	no rate	--	headwater swamp	no	--	--
17	no rate	--	headwater swamp	no	--	--
18	.015	1.2	upland	yes	43	.03
19	.024	0.8	headwater swamp	yes	43	.02
20	no rate	0	upland	no[3]	--	--

[1]Not all soft sediment penetrated; consistent decline in ^{210}Pb activity with depth.
[2]All soft sediment penetrated, but perhaps no pre-impoundment (background) sediment penetrated.
[3]No soft sediment, inverse ^{210}Pb gradient; all pre-impoundment soil.

Deposition rates determined by these two methods are similar for most of the coring sites. Site 2, in the Sparkleberry Lake area of upper Lake Marion (fig. 4), was on the flood plain far from the river, and thus accumulated sediment very slowly, if at all, prior to impoundment. The upper 1.2 in. of sediment showed a clear decreasing trend in excess ^{210}Pb activity (appendix 2), indicating a deposition rate of 0.035 in/yr. Below this lay pre-impoundment sediment with a lower background level of ^{210}Pb activity. Dividing the thickness of the ^{210}Pb - enriched layer by the 43 years of deposition results in a rate of 0.03 in/yr, which agrees closely with the rate derived from ^{210}Pb activity.

Coring sites 4 and 6 were in areas that were accumulating sediment prior to impoundment. The ^{210}Pb analyses for these cores show slower pre-impoundment deposition rates that changed to more rapid rates around the time of impoundment. Coring sites 5, 10, and 13 were in areas that were accumulating sediment prior to impoundment, and continued to accumulate sediment at similar rates following impoundment. Coring site 7 was in an area with a rapid post-impoundment deposition rate, but the site was apparently subject to disturbance by floodwaters and a deposition rate could not be determined.

Coring site 8 was in a submerged flood-plain channel that was apparently subject to some disturbance, evidenced by the partial inversion of the ^{210}Pb profile. An averaged trend of the profile results in a rather high deposition rate of 0.51 in/yr, which seems plausible given the location in a depression near the mouth of the Santee River. The corer did not fully penetrate the soft post-impoundment sediments.

Coring site 9 was on a submerged natural levee near the mouth of the Santee River. The site seems to have been affected by both erosion and deposition, resulting in an abnormally low net-deposition rate.

Coring site 14, on the submerged flood plain near the Wilson Dam spillway in Lake Marion, shows a consistently decreasing trend of ^{210}Pb activity with depth. No stable background layer was encountered, probably because the pre-impoundment soil was too durable to penetrate with the corer.

Coring sites 15, 16, and 17 were in areas of Lake Moultrie where sandy sediments are constantly reworked by wind-driven currents. In Lake Moultrie, only coring sites 18 and 19 yielded reliable deposition rates. Coring site 20, because of its stiffness and its inverse ^{210}Pb profile, seemed to be wholly pre-impoundment soil.

Origin, Distribution, and Redistribution of Lake Sediments

Lakes Marion and Moultrie form an efficient trap for much of the load of sediment carried into Lake Marion by the Santee River. The primary source of sediments to Lakes Marion and Moultrie is clearly the Santee River. The great quantities of topsoil eroded from the Piedmont during 120 years of poor farming practices have put a large supply of sediment in storage in stream channels and flood plains. The Broad River, in particular, carries a large part of the sediment that enters Lake Marion because the Broad River has little regulation at high flows. The coarser alluvial sediment settles out in upper Lake Marion in several areas where the current diminishes on encountering backwater from the dam. Some of these areas, such as Broadwater Creek, Risers Old Lake, upper Elliotts Flat, the Low Falls Landing area, and Tudie Cut, are connected to the Santee River by cuts, some man-made, in natural levees (fig. 5). The largest sediment deposit is downstream of the Browns Cut area, where the natural levees become submerged.

The sediment cores from these delta-type deposits frequently displayed unconforming layers of coarse-grained material embedded within fine-grained material (for example, cores 6 and 7). These were probably deposited by floods that eroded and reworked earlier deposits.

Deposition of fresh inorganic sediment in the shallow upper end of Lake Marion has created new substrates within the photic zone conducive to growth of aquatic macrophytes (Barko and Smart, 1983). Extensive beds of aquatic macrophytes in upper Lake Marion have interfered with navigation to the extent that about $250,000 is spent annually on aquatic plant control in the lake. The plant beds also reduce flow velocities, resulting in additional sediment deposition. The trend toward a decreasing sediment load may further encourage plant growth by allowing deeper penetration of sunlight into the water.

Although sand and coarse silt tend to settle out in upper Lake Marion, deposition of fine silt and clay continues slowly as the water flows toward Wilson Dam and the Diversion Canal (fig. 4). About 20 percent of the incoming suspended sediment remains in suspension in the Diversion Canal and flows into Lake Moultrie, according to the inflow-outflow study of 1983-85. Another 6 percent of the incoming load leaves Lake Marion through the Wilson Dam spillway. Of the annual mean suspended load of 147,000 tons entering Lake Moultrie through the Diversion Canal, 128,000 tons, or 87 percent, remain in suspension through Lake Moultrie and leave by the outlet. Most of the bed of Lake Moultrie is covered with sand or with a durable, compacted pre-impoundment soil. Eroded shores, toppled trees, and sandy prehistoric dune ridges provide evidence that most of this sand originated in the Lake Moultrie Basin. In the deeper waters of Lake Moultrie, a loose, semi-fluid, fine-grained mud covers the bottom.

Wind-driven currents are the primary water movements in Lake Moultrie (Patterson and Harvey, 1986). These currents are capable of transporting sand-size particles in most of the shallow upper half of Lake Moultrie, and of transporting the fine-grained fluid mud in the deep part. On windy days, Lake Moultrie often becomes noticeably turbid. An aerial view of the lake on a windy day reveals turbulent vortices of sediment-laden water moving downwind near the surface. Plastic buckets, half filled with concrete, were used as anchors for buoys during a dye tracer test (Patterson and Harvey, 1986). When the anchors were retrieved after 3 months, many were full of sand on top of the concrete. These wind-driven currents seem to prevent deposition of sediment in at least one part of the lake (site 20), near Bonneau.

The wind also creates large waves in shallow, open Lake Moultrie. The waves actively erode exposed shorelines, as is evidenced by treefalls and freshly eroded surfaces along these shores. Relatively little sand from the Santee River remains in suspension long enough to pass into Lake Moultrie; therefore, this shoreline erosion is probably the main source of the sandy lakebed sediment prevalent in most of Lake Moultrie.

Lakebed Sediment Characteristics

Lakebed sediments reflect characteristics of the water column, the lake basin, and the tributary river basins. The concentrations of nutrients and metals in sediments from Lakes Marion and Moultrie range from values that are typical of natural lakes to values that are typical of lakes that receive moderate inflows of these substances due to human activities (table 9). Similar values were reported for lakes in the Great Lakes Chain (Kemp and others, 1976; Nriagu, 1979), in Sweden (Nriagu, 1979), and in Finland (Tolonen and Merilainen, 1983). The lower values for Lake Moultrie are probably related to the lack of fine-grained sediment and organic matter in the samples, and to settling of the constituents in Lake Marion. The thick, fine-grained sediments in the deeper parts of Lake Moultrie probably contain higher concentrations of organic matter, nutrients, and metals, perhaps comparable to those in Lake Marion.

Accumulation of Sediment

Direct measurements of suspended-sediment flow and outflow, and calculations of bedload in the inflow show that sediment was accumulating in Lakes Marion and Moultrie at the rate of 650,000 ton/yr during 1983-85. An average bulk density of 61 lb/ft^3 for the lakebed sediments, suggests that the average deposition rate for this period was

$$\frac{650,000 \ \text{ton/yr} \times 2,000 \ \text{lb/ton} \times 12 \ \text{in/ft}}{61 \ \text{lb/ft}^3 \times 43,560 \ \text{ft}^2\text{/acre} \times 160,000 \ \text{acres}} = 0.037 \ \text{in/yr} \qquad (2)$$

If we assume that bedload constituted the same proportion, 12 percent, of the total sediment load during 1966-68 as it did during 1983-85, then the deposition rate for that period becomes

$$\frac{\left(\frac{978,000}{0.88} - 164,000\right) \ \text{ton/yr} \times 2,000 \ \text{lb/ton} \times 12 \ \text{in/ft}}{61 \ \text{lb/ft}^3 \times 43,560 \ \text{ft}^2\text{/acre} \times 160,000 \ \text{acres}} = 0.053 \ \text{in/yr} \qquad (3)$$

The average of the deposition rates that were calculated from the ^{210}Pb data (table 10), omitting the questionable values for sites 8 and 9, is 0.06 in/yr. The average deposition rate determined from the thickness of the ^{210}Pb - enriched sediment (table 10) is 0.04 in/yr. All of these rates are fairly consistent. The fact that the current rate is less than the 1966-68 rate, and less than the average rate, shows that the deposition rate has been decreasing during the 43-year life of the reservoirs.

Deposition rates determined by probing the thickness of soft sediments and by comparing bathymetric surveys are greater than the above rates, but are probably in error. The soft sediments averaged about 16-in. thick in the reservoirs, for an average rate of 0.37 in/yr during the 43 years of impoundment. The patterns of ^{210}Pb activity, however, showed some of these soft sediments to date from prior to impoundment, implying that the rate of 0.37 in/yr is too high. Comparison of bathymetric surveys showed a loss of about 103,000 acre-ft of water volume between 1942 and 1985, which, over the 160,000 acres of the reservoirs, amounts to an average rate of 0.18 in/yr. This rate, however, is derived from a relatively small difference between two large numbers (the volumes of the reservoirs), and is therefore subject to significant error. Therefore, the rates determined by inflow and outflow monitoring and by ^{210}Pb analyses are considered the most accurate. The ^{210}Pb analyses and the inflow-outflow monitoring show that the load of sediment flowing into Lake Marion has been decreasing in recent years. This is consistent with the trend toward stabilization of topsoil in the Piedmont, brought about by reversion of cropland to pasture and forest, and by soil conservation practices on remaining cropland. It is also consistent with the theory that the colluvial and alluvial sediment deposits created during 120 years of heavy erosion have become more stable. One question that remains to be answered is: To what extent can those deposits be remobilized by a major flood? Barring such an event, and barring development of large new sources of sediment such as construction sites, the trend toward lower rates of sediment transport in the Santee River Basin should continue for the foreseeable future.

The trend toward decreasing suspended-sediment loads in recent years is not restricted to the Santee River Basin. The same trend is reported in several other basins in the Piedmont where long-term records of suspended sediment are available (table 11; fig. 6). The history of sediment transport in these basins is similar to that of the Santee River Basin.

Table 11.--*Trends in mean sediment concentrations in four streams draining the Piedmont*

[ND, not determined; +, increase; -, decrease]

	Santee River near Ft. Motte, S.C. 02169800	Broad River near Bell, Ga. 02192000	Neuse River near Falls, N.C. 02087183	Yadkin River at Yadkin College, N.C. 02116500
Early period	1966-68	1958-64	1969-73	1952-66
Number of years	2	6	5	15
Number of observations	106	150	ND	5,475
Mean streamflow for the period, cubic feet per second	16,500	3,530	813	2,860
Mean suspended-sediment concentration for the period, milligrams per liter	66	175	152	327
Numbers of intervening years	15	11	5	1
Recent period	1983-85	1975-79	1978-84	1967-84
Number of observations	351	26	89	6,570
Mean streamflow for the period, cubic feet per second	17,700	2,790	1,910	3,180
Mean suspended-sediment concentration for the period, milligrams per liter	39	80	85	293
Change in mean streamflow, percent	+7	-21	+135	+11
Change in suspended-sediment concentration, percent	-41	-54	-44	-10

Note: Data for this table were taken from Perlman, 1985; Simmons, 1976; U.S. Geological Survey, 1966-68; 1971-84.

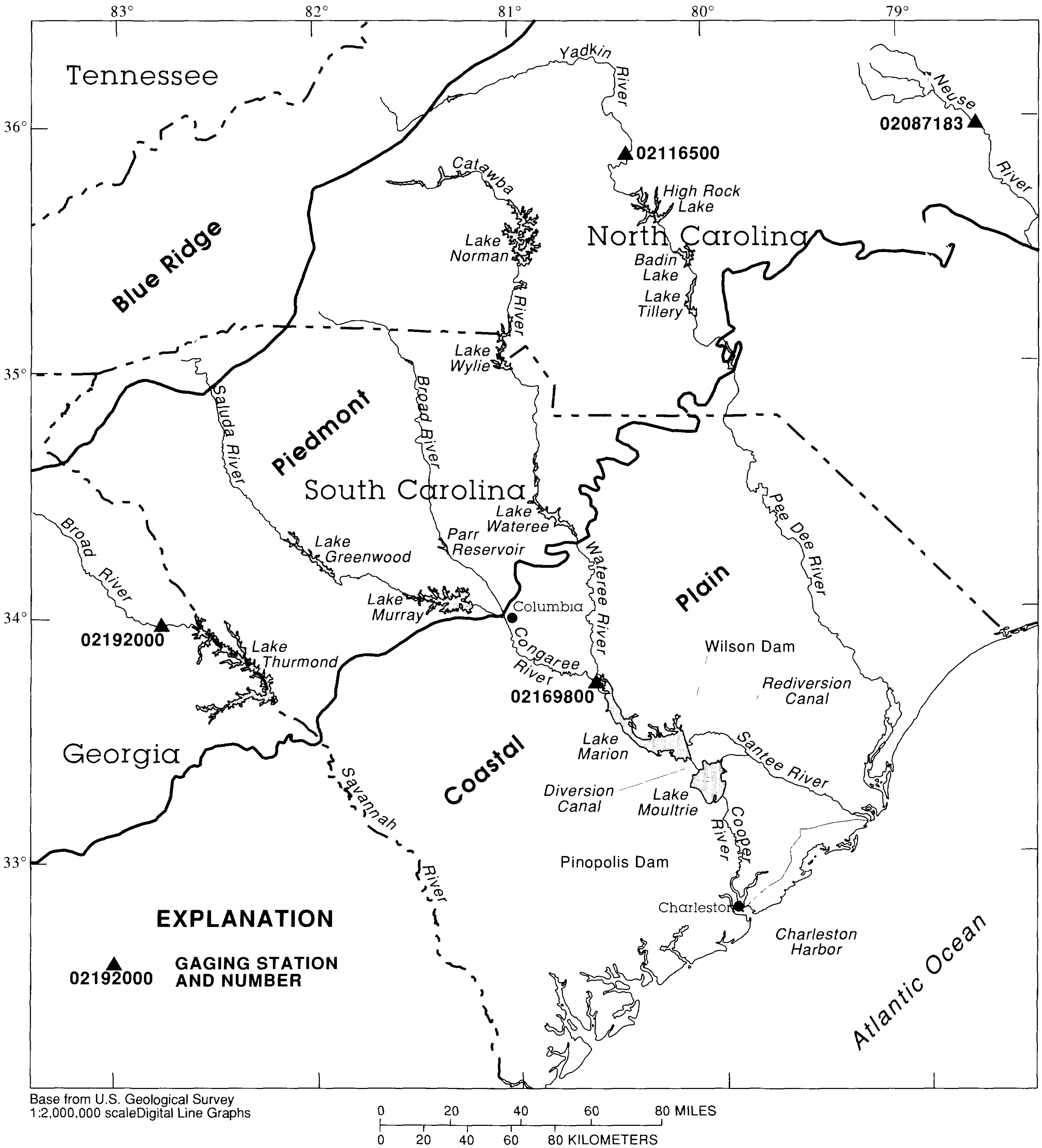


Figure 6. Locations of gaging stations used in the analysis.

SUMMARY

The 16,800 mi^2 Santee River Basin, second largest on the east coast of the United States, includes a large area of erodible soils in the southern Piedmont physiographic province. Lakes Marion and Moultrie, two large shallow reservoirs in the Coastal Plain, receive sediment eroded from the basin. Erosion during 120 years of row-crop farming augmented sediment loads in the Basin, resulting in deposition in channels, flood plains, reservoirs, and Charleston Harbor. In the Piedmont, where most of the eroded sediment is stored, channel and flood-plain deposits continue to supply sediment to streams.

Sediment transport and deposition in the lakes were studied during 1983-85 to determine rates of sediment inflow, outflow, and deposition. Comparisons were made with earlier data to determine trends in the rates.

The annual mean load of suspended sediment in the inflow to Lake Marion seems to have decreased about 26 percent, from 978,000 ton/yr to 722,000 ton/yr between 1968 and 1985, although the data from the two periods may not be directly comparable. The rate of sedimentation in Charleston Harbor seems to have been decreasing during the same period. The sediment deposits in the Piedmont are apparently becoming more stable through the loss of easily transportable sediment and the growth of plant cover.

Under normal conditions, this trend toward stabilization of sediment deposits and decreasing rates of sediment transport in the Santee River Basin is expected to continue. However, it is conceivable that a catastrophic flood could remobilize some of the sediment stored on flood plains, perhaps leading to a new episode of temporarily elevated sediment loads.

Bathymetric surveys of Lakes Marion and Moultrie, completed in 1985, show a loss of about 103,000 acre-ft of lake storage compared with pre-impoundment surveys. This value, however, is subject to error, being the difference between two large numbers. More reliable determinations of the rate at which the reservoirs are being filled are provided by the inflow-outflow data presented above, and by radioisotopic dating of sediments using ^{210}Pb. These show that the average rate of sediment deposition for both lakes during the period 1942-85 was about 0.06 in/yr, or about 1.1 million ton/yr, or 800 acre-ft/yr. Thedeposition rate during 1983-85 was about 0.037 in/yr, or about 490 acre-ft/yr.

The lakebed sediments vary in thickness and in physical and chemical characteristics at different locations in the reservoirs. Thick deposits of sand and coarse silt settle out in upper Lake Marion where the Santee River slows. These deposits provide habitat for growth of abundant aquatic macrophytes. Farther from the river, the deposits become thinner and finer in texture, with higher concentrations of organic matter, nutrients, and trace metals. The shallower parts of Lake Moultrie are covered with sand that moves about in response to wind-driven currents. Derived from the shorelines, the sand is impoverished of organic matter, nutrients, and trace metals. Near Bonneau, the wind-driven currents prevent sediment deposition. In the deeper waters of Lake Moultrie, the bottom is covered by a fine-grained semi-fluid mud that also moves about in response to the currents.

REFERENCES

Barko, J.M., and Smart, R.M., 1983, Effects of organic matter additions to sediments on the growth of aquatic plants: Journal of Ecology, v. 71, p. 1-15.

Brune, G.M., 1953, Trap efficiency of reservoirs: Transactions of the American Geophysical Union, v. 34, no. 3, p. 407-418.

Cooney, T.W., 1988, Sediment Inflow, outflow, and deposition for Lakes Marion and Moultrie, South Carolina, October 1983-March 1985: U.S. Geological Survey Water-Resources Investigations Report 88-4160, 49 p.

Glenn, L.C., 1911, Denudation and erosion in the Southern Appalachian region and the Monongahela Basin: U.S. Geological Survey Professional Paper 72, 137 p.

Guy, H.P., 1969, Laboratory theory and methods for sediment analysis: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. C1.

Happ, S.C., 1945, Sedimentation in South Carolina Piedmont valleys: American Journal of Science, v. 243, no. 3, p. 113-126.

Kemp, A.L., Thomas, R.L., Dell, C.I., and Jaquet, J.M., 1976, Cultural impact on the geochemistry of sediments in Lake Erie: Journal of Fisheries Research Board of Canada (now Canadian Journal of Fisheries and Aquatic Sciences) v. 23, p. 440-462.

Martin, E.A., and Miller, R.J., 1982, A simple, diver-operated coring device for collecting undisturbed shallow cores. Journal of Sedimentary Petrology, v. 52, no. 2, p. 641-642.

Martin, E.A., and Rice, C.A., 1981, Sampling and analyzing sediment cores for ^{210}Pb geochronology: U.S. Geological Survey Open-File Report 81-983, 34 p.

Meade, R.H., 1976, Sediment problems in the Savannah River Basin, *in* Dillman, B.L., and Stepp J.M., eds., The future of the Savannah River, Proceedings of a symposium held at Hickory Knob State Park, p. 109.

Meade, R.H., and Trimble, S.W., 1974, Changes in sediment loads in rivers of the Atlantic drainage of the United States since 1900, in Effects of man on the interface of the hydrologic cycle with the physical environment, Proceedings of the Paris Symposium, September, 1974, LAHS-AISH Publication No. 113, p. 99-104.

Neiheisel, J., and Weaver, C.E., 1967, Transport and deposition of clay minerals, southeastern United States: Journal of Sedimentary Petrology, v. 37, no. 4, p. 1084-1116.

Nriagu, J.O., 1979, Copper in the environment: Environmental Science and Technology, a Wiley-Interscience series of texts and monographs, 472 p.

Patterson, G.G., 1983, Effect of the proposed Cooper River rediversion on sedimentation in Charleston Harbor, S.C.: U.S. Geological Survey Water-Resources Investigations Report 83-4198, 65 p.

Patterson, G.G., and Cooney, T.W., 1986, Sediment transport and deposition in Lakes Marion and Moultrie, South Carolina: Proceedings of the Third International Symposium on River Sedimentation, Jackson, Miss., March-April 1986, p. 1336-1345.

Patterson, G.G., and Harvey, R.M., 1986, Retention times and flow patterns in Lake Moultrie, S.C.: U.S. Geological Survey Water-Resources Investigations Report 85-4121, 32 p.

Patterson, G.G., and Logan, S.W., 1988, Bathymetry of Lakes Marion and Moultrie, South Carolina, 1984-85: U.S. Geological Survey Water-Resources Investigations Report 88-4062, 2 sheets.

Perlman, H.A., 1985, Sediment data for Georgia streams, water years 1958-82: U.S. Geological Survey Open-File Report 84-722, 101 p.

Porterfield, George, 1972, Composition of fluvial-sediment discharge: Techniques of Water-Resources Investigations of the U.S. Geological Survey, book 3, chap. C3, 66 p.

Simmons, C.E., 1976, Sediment characteristics of streams in the eastern Piedmont and western Coastal Plain regions of North Carolina: U.S. Geological Survey Water-Supply Paper 1798-0, 32 p.

Stevens, H.H., 1985, Computer program for the computation of total sediment discharge by the modified Einstein procedure: U.S. Geological Survey Water-Resources Investigations Report 85-4047, 14 p.

Tolonen, K., and Merilainen, J., 1983, Sedimentary chemistry of a small polluted lake, Galltrask, S. Finland: Hydrobiologia, 38, v. 103, p. 309-318.

Trimble, S.W., 1975a, A volumetric estimate of man-induced soil erosion on the southern Piedmont Plateau, in Present and prospective technology for predicting sediment yields and sources: U.S. Department of Agriculture, Agricultural Research Service report ARS-S-40, p. 142-154.

-----, 1975b, Denudation studies, Can we assume stream steady state: Science, v. 188, n. 4194, p. 1207-1208.

U.S. Army Corps of Engineers, 1966, Survey report on Cooper River, S.C. (Shoaling in Charleston Harbor), Appendix A, Sources of shoaling material, Charleston District, S.C., 42 p.

U.S. Department of Agriculture, 1973, Santee River Basin water and land resources, Economic Research Service, Forest Service, Soil Conservation Service, Ft. Worth, Texas, 155 p.

U.S. Geological Survey, 1966-68, Quality of surface waters of the United States. Annual Reports as follows: 1966, Water-Supply Paper 1991; 1967, Water-Supply Paper 2011; 1968, Water-Supply Paper 2092.

U.S. Geological Survey, 1971-84, Water Resources Data, North Carolina.

Table 5.--*Results of suspended-sediment sampling, inflow to Lake Marion, 1966-68 and 1983-85*

[ft^3/s, cubic feet per second; mg/L, milligrams per liter; ton/d, tons per day; --, indicate no data]

Date	Wateree River near Eastover			Congaree River at U.S. Highway 601			Combined inflow		
	Streamflow (ft^3/s)	Suspended-sediment concentration (mg/L)	Suspended-sediment discharge (ton/d)	Streamflow (ft^3/s)	Suspended-sediment concentration (mg/L)	Suspended-sediment discharge (ton/d)	Streamflow (ft^3/s)	Suspended-sediment concentration (mg/L)	Suspended-sediment discharge (ton/d)
07-12-66	--	--	--	--	--	--	5,700	45	693
07-16-66	--	--	--	--	--	--	12,600	52	1,770
07-26-66	--	--	--	--	--	--	5,600	26	393
08-03-66	--	--	--	--	--	--	5,500	35	520
08-09-66	--	--	--	--	--	--	6,800	51	936
08-15-66	--	--	--	--	--	--	7,600	50	1,030
08-23-66	--	--	--	--	--	--	7,420	80	1,600
09-01-66	--	--	--	--	--	--	6,380	42	723
09-07-66	--	--	--	--	--	--	5,620	42	637
09-16-66	--	--	--	--	--	--	8,870	132	3,160
09-20-66	--	--	--	--	--	--	7,580	95	1,940
09-26-66	--	--	--	--	--	--	9,350	103	2,600
10-11-66	--	--	--	--	--	--	6,000	52	842
10-20-66	--	--	--	--	--	--	11,000	53	1,570
10-26-66	--	--	--	--	--	--	9,200	70	1,740
11-05-66	--	--	--	--	--	--	14,800	77	3,080

Table 5.--*Results of suspended-sediment sampling, inflow to Lake Marion, 1966-68 and 1983-85*--Continued

[ft^3/s, cubic feet per second; mg/L, milligrams per liter; ton/d, tons per day; --, indicate no data]

Date	Wateree River near Eastover			Congaree River at U.S. Highway 601			Combined inflow		
	Streamflow (ft^3/s)	Suspended-sediment concentration (mg/L)	Suspended-sediment discharge (ton/d)	Streamflow (ft^3/s)	Suspended-sediment concentration (mg/L)	Suspended-sediment discharge (ton/d)	Streamflow (ft^3/s)	Suspended-sediment concentration (mg/L)	Suspended-sediment discharge (ton/d)
11-18-66	--	--	--	--	--	--	11,000	42	1,250
11-22-66	--	--	--	--	--	--	4,800	24	311
11-30-66	--	--	--	--	--	--	10,700	55	1,590
12-05-66	--	--	--	--	--	--	6,500	18	316
12-17-66	--	--	--	--	--	--	8,300	38	852
12-21-66	--	--	--	--	--	--	7,250	49	959
12-29-66	--	--	--	--	--	--	7,500	40	810
01-06-67	--	--	--	--	--	--	16,400	40	1,770
01-09-67	--	--	--	--	--	--	8,600	28	650
01-21-67	--	--	--	--	--	--	15,600	33	1,390
01-23-67	--	--	--	--	--	--	7,500	21	425
02-02-67	--	--	--	--	--	--	10,700	72	2,080
02-11-67	--	--	--	--	--	--	21,600	60	3,500
02-16-67	--	--	--	--	--	--	16,000	72	3,110
02-24-67	--	--	--	--	--	--	26,600	86	6,180
03-02-67	--	--	--	--	--	--	18,100	30	1,470

Table 5.--*Results of suspended-sediment sampling, inflow to Lake Marion, 1966-68 and 1983-85*--Continued

[ft^3/s, cubic feet per second; mg/L, milligrams per liter; ton/d, tons per day; --, indicate no data]

Date	Wateree River near Eastover			Congaree River at U.S. Highway 601			Combined inflow		
	Streamflow (ft^3/s)	Suspended-sediment concentration (mg/L)	Suspended-sediment discharge (ton/d)	Streamflow (ft^3/s)	Suspended-sediment concentration (mg/L)	Suspended-sediment discharge (ton/d)	Streamflow (ft^3/s)	Suspended-sediment concentration (mg/L)	Suspended-sediment discharge (ton/d)
03-10-67	--	--	--	--	--	--	11,300	37	1,130
03-15-67	--	--	--	--	--	--	20,100	50	2,710
03-23-67	--	--	--	--	--	--	10,700	38	1,100
03-29-67	--	--	--	--	--	--	5,400	35	510
04-08-67	--	--	--	--	--	--	5,800	40	626
04-12-67	--	--	--	--	--	--	5,200	44	618
04-20-67	--	--	--	--	--	--	4,400	34	404
05-05-67	--	--	--	--	--	--	4,800	44	570
05-11-67	--	--	--	--	--	--	4,800	40	518
05-19-67	--	--	--	--	--	--	6,750	36	656
05-25-67	--	--	--	--	--	--	19,600	130	6,880
05-29-67	--	--	--	--	--	--	9,800	78	2,060
06-13-67	--	--	--	--	--	--	7,750	46	963
06-21-67	--	--	--	--	--	--	7,750	38	795
06-26-67	--	--	--	--	--	--	8,300	168	3,760
07-10-67	--	--	--	--	--	--	22,100	524	31,300
07-11-67	--	--	--	--	--	--	24,100	332	21,600

Table 5.--*Results of suspended-sediment sampling, inflow to Lake Marion, 1966-68 and 1983-85*--Continued

[ft^3/s, cubic feet per second; mg/L, milligrams per liter; ton/d, tons per day; --, indicate no data]

Date	Wateree River near Eastover			Congaree River at U.S. Highway 601			Combined inflow		
	Streamflow (ft^3/s)	Suspended-sediment concentration (mg/L)	Suspended-sediment discharge (ton/d)	Streamflow (ft^3/s)	Suspended-sediment concentration (mg/L)	Suspended-sediment discharge (ton/d)	Streamflow (ft^3/s)	Suspended-sediment concentration (mg/L)	Suspended-sediment discharge (ton/d)
07-12-67	--	--	--	--	--	--	22,600	211	12,900
07-13-67	--	--	--	--	--	--	27,100	144	10,500
07-20-67	--	--	--	--	--	--	12,500	60	2,020
07-27-67	--	--	--	--	--	--	13,200	96	3,420
08-02-67	--	--	--	--	--	--	15,200	56	2,300
08-09-67	--	--	--	--	--	--	12,500	76	2,560
08-18-67	--	--	--	--	--	--	9,500	48	1,230
08-25-67	13,600	134	4,920	10,000	393	10,600	23,600	243	15,500
08-26-67	64,600	65	11,300	31,700	276	23,600	96,300	134	34,900
08-27-67	77,000	53	11,000	39,500	141	15,000	116,500	83	26,000
08-30-67	19,400	89	4,660	17,800	71	3,410	37,200	80	8,070
09-01-67	16,000	92	3,970	17,500	63	2,980	33,500	77	6,950
09-08-67	--	--	--	--	--	--	19,100	85	4,330
09-15-67	--	--	--	--	--	--	23,600	52	3,310
09-21-67	--	--	--	--	--	--	13,200	53	1,890
09-29-67	--	--	--	--	--	--	10,100	62	1,690
10-04-67	--	--	--	--	--	--	11,000	59	1,750

Table 5.--*Results of suspended-sediment sampling, inflow to Lake Marion, 1966-68 and 1983-85*--Continued

[ft^3/s, cubic feet per second; mg/L, milligrams per liter; ton/d, tons per day; --, indicate no data]

Date	Wateree River near Eastover			Congaree River at U.S. Highway 601			Combined inflow		
	Streamflow (ft^3/s)	Suspended-sediment concentration (mg/L)	Suspended-sediment discharge (ton/d)	Streamflow (ft^3/s)	Suspended-sediment concentration (mg/L)	Suspended-sediment discharge (ton/d)	Streamflow (ft^3/s)	Suspended-sediment concentration (mg/L)	Suspended-sediment discharge (ton/d)
10-13-67	--	--	--	--	--	--	13,200	36	1,280
10-19-67	--	--	--	--	--	--	9,200	37	919
10-27-67	--	--	--	--	--	--	10,100	36	982
11-01-67	--	--	--	--	--	--	11,000	44	1,310
11-09-67	--	--	--	--	--	--	11,000	37	1,100
11-15-67	--	--	--	--	--	--	6,000	35	567
11-24-67	--	--	--	--	--	--	7,250	21	411
12-29-67	--	--	--	--	--	--	15,600	59	2,480
12-07-67	--	--	--	--	--	--	16,000	30	1,300
12-14-67	--	--	--	--	--	--	25,000	197	13,300
12-22-67	--	--	--	--	--	--	25,600	87	6,010
12-28-67	-	--	--	--	--	--	20,600	52	2,890
01-04-68	--	--	--	--	--	--	27,600	50	3,730
01-19-68	--	--	--	--	--	--	29,600	41	3,280
01-20-68	--	--	--	--	--	--	28,600	35	2,700
01-21-68	--	--	--	--	--	--	27,600	40	2,980

Table 5.--*Results of suspended-sediment sampling, inflow to Lake Marion, 1966-68 and 1983-85*--Continued

[ft^3/s, cubic feet per second; mg/L, milligrams per liter; ton/d, tons per day; --, indicate no data]

Date	Wateree River near Eastover			Congaree River at U.S. Highway 601			Combined inflow		
	Streamflow (ft^3/s)	Suspended-sediment concentration (mg/L)	Suspended-sediment discharge (ton/d)	Streamflow (ft^3/s)	Suspended-sediment concentration (mg/L)	Suspended-sediment discharge (ton/d)	Streamflow (ft^3/s)	Suspended-sediment concentration (mg/L)	Suspended-sediment discharge (ton/d)
01-22-68	--	--	--	--	--	--	25,600	38	2,630
01-23-68	--	--	--	--	--	--	25,100	30	2,030
01-25-68	--	--	--	--	--	--	25,600	49	3,390
01-31-68	--	--	--	--	--	--	23,100	43	2,680
02-07-68	--	--	--	--	--	--	16,800	32	1,450
02-13-68	--	--	--	--	--	--	16,000	32	1,380
02-20-68	--	--	--	--	--	--	8,600	23	534
02-28-68	--	--	--	--	--	--	9,500	25	641
03-07-68	--	--	--	--	--	--	8,000	19	410
03-13-68	--	--	--	--	--	--	13,600	54	1,980
03-20-68	--	--	--	--	--	--	26,600	83	5,960
04-04-68	--	--	--	--	--	--	11,600	38	1,190
04-09-68	--	--	--	--	--	--	12,500	43	1,450
04-11-68	--	--	--	--	--	--	12,500	45	1,520
04-18-68	--	--	--	--	--	--	8,900	46	1,100
04-25-68	--	--	--	--	--	--	11,000	49	1,460
04-29-68	--	--	--	--	--	--	8,600	30	697

Table 5.--*Results of suspended-sediment sampling, inflow to Lake Marion, 1966-68 and 1983-85*--Continued

[ft^3/s, cubic feet per second; mg/L, milligrams per liter; ton/d, tons per day; --, indicate no data]

Date	Wateree River near Eastover			Congaree River at U.S. Highway 601			Combined inflow		
	Streamflow (ft^3/s)	Suspended-sediment concentration (mg/L)	Suspended-sediment discharge (ton/d)	Streamflow (ft^3/s)	Suspended-sediment concentration (mg/L)	Suspended-sediment discharge (ton/d)	Streamflow (ft^3/s)	Suspended-sediment concentration (mg/L)	Suspended-sediment discharge (ton/d)
05-08-68	--	--	--	--	--	--	7,750	36	753
05-15-68	--	--	--	--	--	--	14,400	55	2,140
05-21-68	--	--	--	--	--	--	11,000	67	1,990
05-28-68	--	--	--	--	--	--	7,750	32	670
06-06-68	--	--	--	--	--	--	12,500	42	1,420
06-21-68	--	--	--	--	--	--	15,600	60	2,530
06-27-68	--	--	--	--	--	--	14,400	51	1,980
11-16-83	4,550	40	491	3,120	16	135	7,670	30	626
11-30-83	8,110	46	1,010	7,120	24	461	15,230	40	1,640
12-06-83	9,560	55	1,420	13,600	139	5,100	23,160	104	6,520
01-20-83	9,940	71	1,900	16,000	58	2,510	25,950	63	4,410
01-27-84	9,540	58	1,490	14,200	24	920	23,740	38	2,410
02-15-84	9,890	61	[1]1,630	14,100	186	7,080	23,990	134	8,710
02-16-84	9,950	52	1,400	16,600	285	10,040	26,550	160	11,400
03-07-84	9,920	48	1,290	[1]15,000	[1]54	[1]2,190	24,920	52	3,430

Table 5.--*Results of suspended-sediment sampling, inflow to Lake Marion, 1966-68 and 1983-85*--Continued

[ft^3/s, cubic feet per second; mg/L, milligrams per liter; ton/d, tons per day; --, indicate no data]

Date	Wateree River near Eastover			Congaree River at U.S. Highway 601			Combined inflow		
	Streamflow (ft^3/s)	Suspended-sediment concentration (mg/L)	Suspended-sediment discharge (ton/d)	Streamflow (ft^3/s)	Suspended-sediment concentration (mg/L)	Suspended-sediment discharge (ton/d)	Streamflow (ft^3/s)	Suspended-sediment concentration (mg/L)	Suspended-sediment discharge (ton/d)
03-23-84	9,740	50	1,320	13,000	34	1,190	22,740	41	2,510
04-18-84	9,880	38	1,010	[1]13,100	38	1,340	22,980	38	2,350
04-27-84	[1]9,870	25	[1]666	14,600	34	[1]1,340	24,470	30	2,010
05-02-84	9,180	32	793	[1]11,900	[1]35	[1]1,120	21,080	34	1,910
05-16-84	[1]9,390	[1]36	[1]913	15,000	36	1,460	24,390	36	2,370
05-24-84	7,460	44	886	[1]9,210	[1]48	[1]1,190	16,670	46	2,080
05-31-84	[1]9,700	[1]36	[1]943	17,200	62	2,880	26,900	53	3,820
06-07-84	8,020	54	1,170	[1]11,300	[1]34	[1]1,040	19,320	42	2,210
06-14-84	[1]6,530	[1]47	[1]829	9,090	41	1,010	15,620	44	1,840
06-27-84	5,290	52	743	[1]6,410	[1]42	[1]727	11,700	46	1,470
07-10-84	[1]7,770	[1]49	[1]1,020	8,030	41	889	15,800	45	1,910
07-13-84	5,230	52	734	[1]7,500	[1]41	[1]830	12,730	46	1,560
08-28-84	4,440	22	264	[1]8,060	[1]54	[1]1,180	12,500	43	1,450
08-30-84	[1]2,320	[1]24	[1]150	1,100	40	1,190	13,320	37	1,340
09-26-84	2,470	27	180	4,760	[1]15	180	7,230	18	360
11-01-84	[1]3,670	[2]25	[2]252	6,250	19	321	9,920	21	573
11-28-84	3,800	29	298	[1]3,480	[1]4	[1]38	7,280	17	336

Table 5.--*Results of suspended-sediment sampling, inflow to Lake Marion, 1966-68 and 1983-85*--Continued

[ft^3/s, cubic feet per second; mg/L, milligrams per liter; ton/d, tons per day; --, indicate no data]

Date	Wateree River near Eastover			Congaree River at U.S. Highway 601			Combined inflow		
	Streamflow (ft^3/s)	Suspended-sediment concentration (mg/L)	Suspended-sediment discharge (ton/d)	Streamflow (ft^3/s)	Suspended-sediment concentration (mg/L)	Suspended-sediment discharge (ton/d)	Streamflow (ft^3/s)	Suspended-sediment concentration (mg/L)	Suspended-sediment discharge (ton/d)
12-07-84	[1]8,020	[1]51	[1]1,100	10,200	44	1,210	18,220	47	2,310
12-11-84	5,180	24	336	[1]8,260	[1]27	[1]601	13,440	26	937
01-23-85	[1]4,080	[1]48	[1]563	12,300	41	1,360	16,380	43	1,920
01-24-85	3,080	16	133	[1]9,890	15	[1]404	12,970	15	537
02-19-85	[1]8,000	[1]56	[1]1,210	12,900	32	1,120	20,900	43	2,330
02-20-85	7,450	26	523	12,700	[1]22	[1]754	20,150	23	1,280
03-19-85	4,090	62	685	8,270	38	848	12,360	46	1,530

[1]denotes daily mean values.

[2]denotes daily mean value estimated using sediment-transport curve (Cooney, 1988).

Note: Data for combined inflow not accompanied by data for Congaree and Wateree Rivers were obtained from Santee River near Ft. Motte, S.C. (02169800) (fig. 2).
During 1966-68, the Wateree River sampling station was at the US-378 bridge (02148310) (fig. 2).
During 1983-85, the Wateree River sampling station was at the gaging station near Eastover (02148315) (fig. 2).

APPENDIX 1

Results of lakebed sediment sampling

APPENDIX 1

Results of lakebed sediment sampling

[in., inch; lb/ft^3, pound per cubic foot; mg/kg, milligram per kilogram; ft, feet; --, indicate no data; <, less than; L., Lake]

Lake Marion

Depth in.	Bulk Density, lb/ft^3	Moisture Content, percent	Organic Content, percent	Sand, percent	Silt, percent	Clay, percent	Nitrogen, as N, mg/kg NO_3+NO_2	Nitrogen, as N, mg/kg NH_4	Nitrogen, as N, mg/kg NH_4+ORG	Total Phosphorus, mg/kg	Cadmium, mg/kg	Copper, mg/kg	Lead, mg/kg	Zinc, mg/kg
Core 1	Broadwater Creek	Latitude 33°42'50"		Longitude 80°36'22"			Water Depth 8 ft			Penetration 36 in.		Compaction 8.3 in.		
0- 1.6	11	67	12	--	--	--	2	25	6,000	1,200	0.18	39	7	117
1.6- 3.1	--	--	--	--	--	--	--	--	--	--	.58	37	8	110
3.1- 3.9	--	--	--	--	--	--	--	--	--	--	.20	35	6	108
3.9- 7.9	38	--	--	--	--	--	--	--	--	--	--	--	--	--
7.9- 9.8	--	--	--	6	40	54	--	--	--	--	--	--	--	--
9.8-11.8	51	54	10	--	--	--	<2	130	380	920	--	--	--	--
11.8-17.7	48	--	--	--	--	--	--	--	--	--	--	--	--	--
17.7-25.6	53	--	--	--	--	--	--	--	--	--	--	--	--	--
25.6-27.6	--	49	--	--	--	--	<2	210	930	620	--	--	--	--
27.6	Bottom of core due to length of corer													
Core 2	Sparkleberry L.	Latitude 33°41'09"		Longitude 80°32'06"			Water Depth 6 ft			Penetration 9.8 in.		Compaction 2.4 in.		
0- 1.6	--	61	17	--	--	--	<2	38	14,000	740	.39	60	16	132
1.6- 3.1	38	--	--	--	--	--	--	--	--	--	.20	48	14	94
3.1- 3.9	--	41	16	6	5	89	<2	41	410	450	.12	46	11	88
5.9- 7.5	--	18	--	--	--	--	<2	34	5,500	860	--	--	--	--
7.5	Bottom of core due to extent of penetration													
Core 3	Upper Packs Flat	Latitude 33°40'00"		Longitude 80°31'24"			Water Depth 5 ft			Penetration 26.8 in.		Compaction 7.9 in.		
0- 2.0	8	74	16	--	--	--	5	54	450	580	.18	39	17	85
2.0- 3.9	--	--	--	9	12	79	--	--	--	--	.11	29	20	70
7.9- 9.8	--	45	13	--	--	--	<2	21	1,300	490	--	--	--	--
11.8-17.7	72	32	--	--	--	--	<2	28	790	240	--	--	--	--
18.9	Bottom of core due to extent of penetration													

APPENDIX 1--Continued

Results of lakebed sediment sampling

[in., inch; lb/ft^3, pound per cubic foot; mg/kg, milligram per kilogram; ft, feet; --, indicate no data; <, less than; L., Lake]

Lake Marion

Depth in.	Bulk Density, lb/ft^3	Moisture Content, percent	Organic Content, percent	Sand, percent	Silt, percent	Clay, percent	Nitrogen, as N, mg/kg NO_3+NO_2	NH_4	NH_4+ORG	Total Phosphorus, mg/kg	Cadmium, mg/kg	Copper, mg/kg	Lead, mg/kg	Zinc, mg/kg
Core 4	Lower Packs Flat	Latitude 33°39'26"		Longitude 80°31'17"			Water Depth 8 ft			Penetration 9.4 in.		Compaction 2.0 in.		
0- 2.0	--	57	14	--	--	--	<2	38	750	890	0.27	35	32	66
2.0- 3.9	--	--	--	--	--	--	--	--	--	--	.18	42	29	86
3.9- 5.1	--	43	12	1	11	88	<2	48	1,000	700	--	--	--	--
5.1- 7.1	47	40	--	--	--	--	<2	36	1,100	780	--	--	--	--
7.5	Bottom of core due to extent of penetration													
Core 5	Upper Low Falls	Latitude 33°38'18"		Longitude 80°32'33"			Water Depth 4 ft			Penetration 17.3 in.		Compaction 4.3 in.		
** In Egeria bed **														
0- 2.0	--	80	16	--	--	--	6	94	6,100	1,100	.44	52	25	112
2.0- 3.9	9	--	--	--	--	--	--	--	--	--	.16	53	25	102
3.9- 6.7	--	63	14	14	11	75	26	90	3,600	700	--	--	--	--
9.4-11.4	--	--	--	9	17	74	--	--	--	--	--	--	--	--
11.4-13.0	57	26	--	--	--	--	<2	39	1,700	550	--	--	--	--
13.0	Bottom of core due to extent of penetration													
Core 6	Elliotts Flat	Latitude 33°38'50"		Longitude 80°31'19"			Water Depth 6 ft			Penetration 16.9 in.		Compaction 2.8 in.		
0- 2.0	--	45	8	--	--	--	<2	79	310	1,100	.27	26	18	76
2.0- 3.9	--	--	--	40	35	25	--	--	--	--	.16	22	19	63
5.9- 7.9	--	30	6	92	4	4	<2	52	1,200	720	--	--	--	--
7.9- 9.8	53	--	--	--	--	--	--	--	--	--	--	--	--	--
12.2-14.2	--	22	--	--	--	--	<2	17	2,700	760	--	--	--	--
14.2	Bottom of core due to extent of penetration													

APPENDIX 1--Continued

Results of lakebed sediment sampling

[in., inch; lb/ft^3, pound per cubic foot; mg/kg, milligram per kilogram; ft, feet; --, indicate no data; <, less than; L., Lake]

Lake Marion

Depth in.	Bulk Density, lb/ft^3	Moisture Content, percent	Organic Content, percent	Sand, percent	Silt, percent	Clay, percent	Nitrogen, as N, mg/kg NO_3+NO_2	Nitrogen, as N, mg/kg NH_4	Nitrogen, as N, mg/kg NH_4+ORG	Total Phosphorus, mg/kg	Cadmium, mg/kg	Copper, mg/kg	Lead, mg/kg	Zinc, mg/kg
Core 7	Lower Low Falls	Latitude 33°37'26"		Longitude 80°32'25"			Water Depth 2 ft			Penetration 32.3 in.		Compaction 4.7 in.		
0- 2.0	--	59	9	--	--	--	2	140	1,200	740	0.19	29	28	80
2.0- 3.9	--	--	--	--	--	--	--	--	--	--	.24	28	31	80
9.0-11.8	--	--	--	77	15	8	--	--	--	--	--	--	--	--
11.8-13.8	93	32	9	--	--	--	<2	120	3,300	420	--	--	--	--
16.1-18.5	--	--	--	16	38	46	--	--	--	--	--	--	--	--
23.6-25.6	102	--	--	--	--	--	--	--	--	--	--	--	--	--
25.6-27.6	--	30	--	--	--	--	<2	98	280	680	--	--	--	--
27.6	Bottom of core due to length of corer													
Core 8	Browns Lake	Latitude 33°35'25"		Longitude 80°29'35"			Water Depth 20 ft			Penetration 36.2 in.		Compaction 16.9 in.		
0- 2.0	--	61	12	--	--	--	2	92	2,200	1,200	.22	41	46	103
2.0- 3.9	--	--	--	--	--	--	--	--	--	--	.34	78	90	225
6.3- 9.4	--	--	--	6	38	56	--	--	--	--	--	--	--	--
9.4-11.4	20	38	12	--	--	--	4	36	3,900	1,300	--	--	--	--
17.3-19.3	--	19	--	--	--	--	7	130	3,500	1,300	--	--	--	--
19.3	Bottom of core due to length of corer													
Core 9	Mouth of Santee R	Latitude 33°34'35"		Longitude 80°30'58"			Water Depth 6 ft			Penetration 11.8 in.		Compaction 0.8 in.		
0- 2.0	--	57	7	--	--	--	2	50	2,800	680	.13	18	18	57
2.0- 3.9	--	--	--	--	--	--	--	--	--	--	.11	17	24	52
3.9- 6.7	--	35	7	49	27	24	<2	88	3,300	310	--	--	--	--
6.7- 8.7	77	--	--	--	--	--	--	--	--	--	--	--	--	--
13.0-15.0	--	31	--	--	--	--	<2	51	2,100	340	--	--	--	--
15.0	Bottom of core due to extent of penetration													

APPENDIX 1--Continued

Results of lakebed sediment sampling

[in., inch; lb/ft^3, pound per cubic foot; mg/kg, milligram per kilogram; ft, feet; --, indicate no data; <, less than; L., Lake]

Lake Marion

Depth in.	Bulk Density, lb/ft^3	Moisture Content, percent	Organic Content, percent	Sand, percent	Silt, percent	Clay, percent	Nitrogen, as N, mg/kg NO_3+NO_2	NH_4	NH_4+ORG	Total Phosphorus, mg/kg	Cadmium, mg/kg	Copper, mg/kg	Lead, mg/kg	Zinc, mg/kg
Core 10	Channel Marker 72	Latitude 33°31'20"		Longitude 80°27'05"			Water Depth 20 ft			Penetration 15.7 in.		Compaction 7.9 in.		
0- 2.0	--	62	8	65	14	21	2	47	1,800	820	0.06	14	20	41
2.0- 3.9	46	--	--	--	--	--	--	--	--	--	.03	8	16	26
3.9- 5.9	--	38	4	71	14	15	2	35	2,300	440	--	--	--	--
5.9- 7.9	--	33	--	--	--	--	2	41	660	1,400	--	--	--	--
7.9	Bottom of core due to extent of penetration													
Core 11	Near Sawdust Pile Slough	Latitude 33°28'09"		Longitude 80°20'57"			Water Depth 25 ft			Penetration 28.7 in.		Compaction 3.5 in.		
0- 2.0	--	75	16	--	--	--	7	120	11,000	1,400	.19	46	51	96
2.0- 3.9	--	--	--	7	3	90	--	--	--	--	.18	50	65	106
9.8-11.8	27	68	15	--	--	--	27	83	9,200	980	--	--	--	--
19.7-21.6	--	--	--	17	9	74	--	--	--	--	--	--	--	--
21.6-23.6	60	--	--	--	--	--	--	--	--	--	--	--	--	--
23.6-25.2	--	44	--	--	--	--	3	190	4,100	660	--	--	--	--
25.2	Bottom of core due to extent of penetration													
Core 12	Near Eutaw Creek	Latitude 33°26'27"		Longitude 80°20'56"			Water Depth 30 ft			Penetration 19.7 in.		Compaction 11.4 in.		
0- 2.0	--	77	14	--	--	--	4	94	11,000	1,400	.18	44	42	107
2.0- 3.9	--	--	--	10	16	74	--	--	--	--	.19	44	43	95
4.7- 6.7	30	48	14	--	--	--	<2	120	6,600	500	--	--	--	--
6.7- 8.3	--	40	--	--	--	--	3	120	4,900	510	--	--	--	--
8.3	Bottom of core due to extent of penetration													

APPENDIX 1--Continued

Results of lakebed sediment sampling

[in., inch; lb/ft^3, pound per cubic foot; mg/kg, milligram per kilogram; ft, feet; --, indicate no data; <, less than; L., Lake]

Lake Marion

Depth in.	Bulk Density, lb/ft^3	Moisture Content, percent	Organic Content, percent	Sand, percent	Silt, percent	Clay, percent	Nitrogen, as N, mg/kg NO_3+NO_2	NH_4	NH_4+ORG	Total Phosphorus, mg/kg	Cadmium, mg/kg	Copper, mg/kg	Lead, mg/kg	Zinc, mg/kg
Core 13	Near Wyboo Creek		Latitude 33°30'12"		Longitude 80°12'40"			Water Depth 30 ft		Penetration 19.7 in.		Compaction 7.9 in.		
0- 2.0	--	64	16	--	--	--	6	76	6,300	1,500	0.18	46	39	89
2.0- 3.9	--	--	--	--	--	--	--	--	--	--	.16	46	15	89
3.9- 6.7	--	49	14	10	13	77	<2	100	4,100	1,200	--	--	--	--
6.7- 8.7	30	--	--	--	--	--	--	--	--	--	--	--	--	--
9.8-11.8	--	41	--	--	--	--	3	92	4,400	530	--	--	--	--
11.8	Bottom of core due to extent of penetration													
Core 14	Near Spillway		Latitude 33°25'34"		Longitude 80°10'36"			Water Depth 26 ft		Penetration 13.0 in.		Compaction 0.8 in.		
0- 2.0	--	54	7	--	--	--	3	32	6,700	300	.12	18	16	34
2.0- 3.9	--	--	--	68	16	16	--	--	--	--	.10	14	18	25
4.7- 6.7	63	44	7	--	--	--	<2	28	3,600	220	--	--	--	--
10.2-12.2	--	44	--	--	--	--	<2	110	7,400	470	--	--	--	--
12.2	Bottom of core due to extent of penetration													
Core 15	Channel Marker 12		Latitude 33°20'30"		Longitude 80°05'55"			Water Depth 15 ft		Penetration 14.2 in.		Compaction 0.4 in.		
0- 2.0	--	26	1.1	--	--	--	<2	16	270	40	0.07	2	21	10
2.0- 3.9	--	--	--	93	3	4	--	--	--	--	.04	1	10	6
3.9- 5.9	110	25	.7	--	--	--	<2	6	610	50	--	--	--	--
11.8-13.8	--	20	--	--	--	--	<2	12	150	1,100	--	--	--	--
13.8	Bottom of core due to extent of penetration													

APPENDIX 1--Continued

Results of lakebed sediment sampling

[in., inch; lb/ft^3, pound per cubic foot; mg/kg, milligram per kilogram; ft, feet; --, indicate no data; <, less than; L., Lake]

Lake Moultrie

Depth in.	Bulk Density, lb/ft^3	Moisture Content, percent	Organic Content, percent	Sand, percent	Silt, percent	Clay, percent	Nitrogen, as N, mg/kg NO_3+NO_2	NH_4	NH_4+ORG	Total Phosphorus, mg/kg	Cadmium, mg/kg	Copper, mg/kg	Lead, mg/kg	Zinc, mg/kg
Core 16	Crescent Island		Latitude 33°21′45′		Longitude 80°00′14"			Water Depth 8 ft		Penetration 15.4 in.		Compaction 0.4 in.		
0- 2.0	63	25	.3	96	1	3	<2	3.2	250	11	.01	.4	.8	1
2.0- 3.9	--	--	--	--	--	--	--	--	--	--	.01	.4	3	1
3.9- 5.9	113	--	--	--	--	--	--	--	--	--	--	--	--	--
5.9- 8.7	--	21	1.2	77	16	7	<2	6.1	390	39	--	--	--	--
13.0-15.0	--	13	--	75	14	11	<2	7.8	170	22	--	--	--	--
15.0	Bottom of core due to extent of penetration													
Core 17	Channel Marker 4		Latitude 33°18′31"		Longitude 80°02′59"			Water Depth 23 ft		Penetration 18.5 in.		Compaction 0.8 in.		
0- 2.0	--	23	.3	95	2	3	<2	2.4	390	18	.007	.9	1.5	2
2.0- 3.9	85	--	--	--	--	--	--	--	--	--	.005	.6	4	3
3.9- 5.9	--	--	--	71	14	15	--	--	--	--	--	--	--	--
5.9- 7.9	124	22	2.3	--	--	--	<2	23	310	26	--	--	--	--
15.7-17.7	--	19	--	--	--	--	<2	30	470	21	--	--	--	--
17.7	Bottom of core due to extent of penetration													
Core 18	Hatchery		Latitude 33°15′35"		Longitude 80°05′00"			Water Depth 3 ft		Penetration 17.7 in.		Compaction 2.4 in.		
0- 2.0	--	27	2.9	71	20	9	<2	8.4	440	34	0.01	0.9	3.6	2
2.0- 3.9	85	--	--	--	--	--	--	--	--	--	.01	.5	5	2
7.9- 9.8	--	26	2.5	56	21	23	<2	28	360	14	--	--	--	--
13.4-15.4	--	21	--	--	--	--	2	29	812	18	--	--	--	--
15.4	Bottom of core due to extent of penetration													

APPENDIX 1--Continued

Results of lakebed sediment sampling

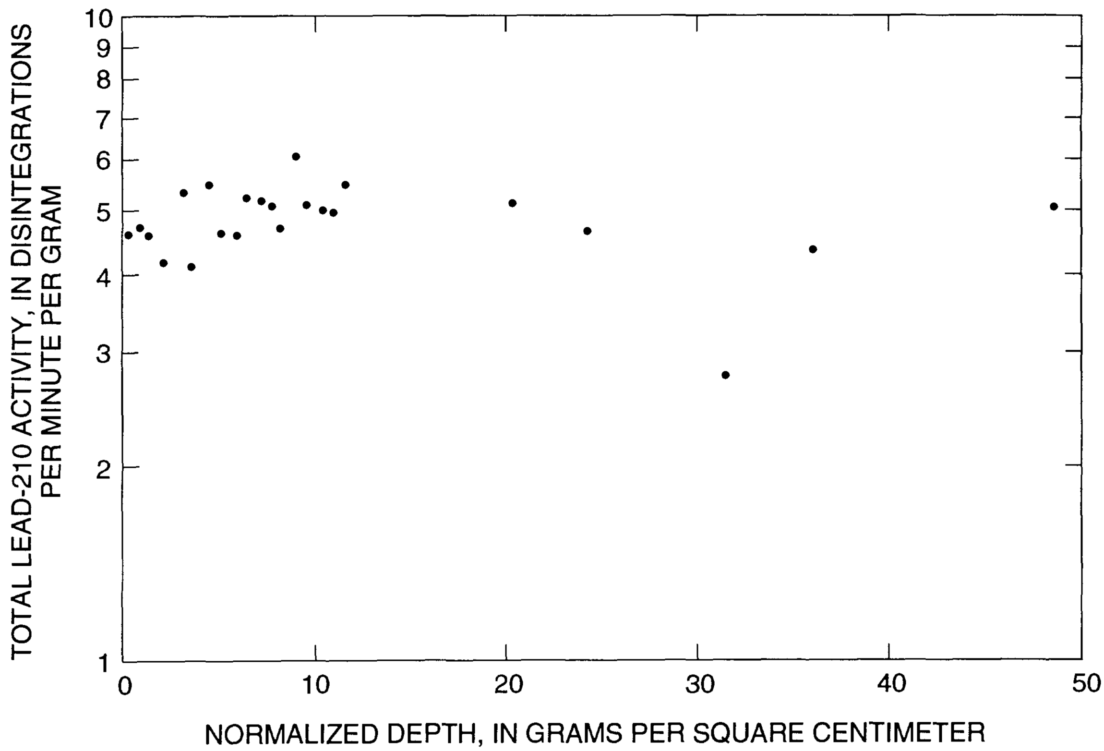
[in., inch; lb/ft^3, pound per cubic foot; mg/kg, milligram per kilogram; ft, feet; --, indicate no data; <, less than; L., Lake]

Lake Moultrie

Depth in.	Bulk Density, lb/ft^3	Moisture Content, percent	Organic Content, percent	Sand, percent	Silt, percent	Clay, percent	Nitrogen, as N, mg/kg NO_3+NO_2	NH_4	NH_4+ORG	Total Phosphorus, mg/kg	Cadmium, mg/kg	Copper, mg/kg	Lead, mg/kg	Zinc, mg/kg
Core 19	West of Wampee		Latitude 33°14'20"		Longitude 80°03'43"			Water Depth 12 ft		Penetration 16.5 in.		Compaction 3.1 in.		
0- 2.0	--	30	.8	--	--	--	2	3.7	332	68	.01	1.8	4.1	4
2.0- 3.9	--	--	--	--	--	--	--	--	--	--	.01	1.2	5.4	3
3.9- 5.1	--	--	--	79	14	7	--	--	--	--	--	--	--	--
5.1- 7.1	91	27	.8	--	--	--	<2	13	370	70	--	--	--	--
11.8-13.4	--	27	--	69	14	17	<2	19	490	68	--	--	--	--
13.4	Bottom of core due to extent of penetration													
Core 20	Near Bonneau		Latitude 33°17'17"		Longitude 79°59'05"			Water Depth 13 ft		Penetration 5.9 in.		Compaction 0.4 in.		
0- 2.0	--	20	7	--	--	--	<2	5	300	32	.02	6.3	7.4	15
2.0- 3.9	102	19	7	--	--	--	<2	17	270	<2	.02	6.9	8.1	21
3.9- 5.5	--	16	--	36	12	52	<2	6	230	56	--	--	--	--
5.5	Bottom of core due to extent of penetration													

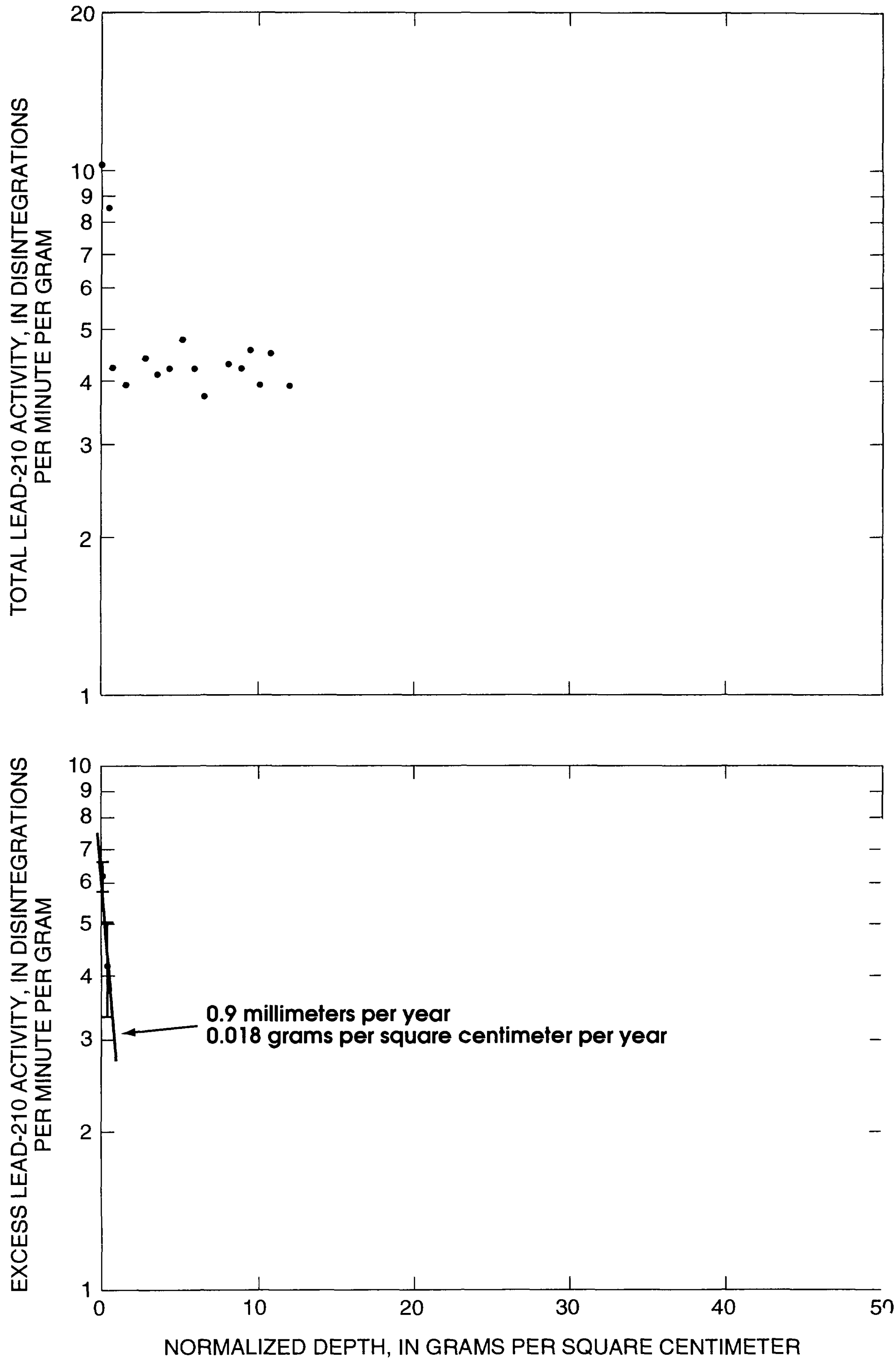
APPENDIX 2

Excess and total ^{210}Pb activity as a function of depth for 19 lakebed sediment cores from Lakes Marion and Moultrie

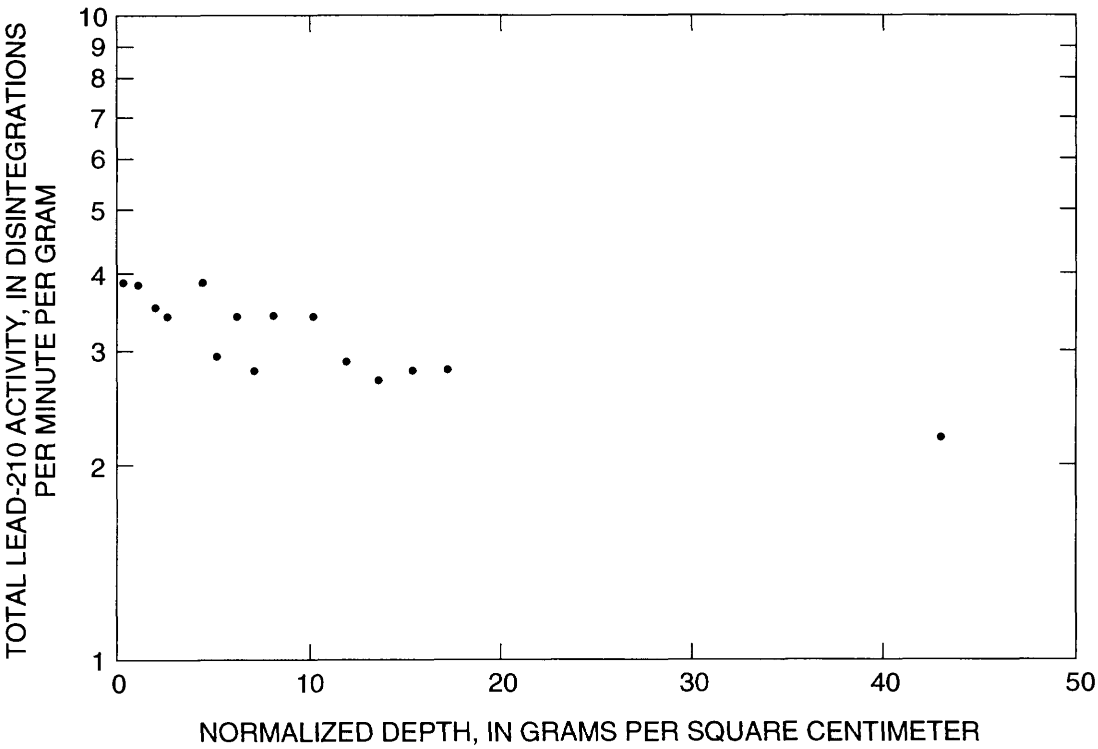


TOTAL LEAD-210 ACTIVITY, IN DISINTEGRATIONS PER MINUTE PER GRAM
10
9
8
7
6
5
4
3
2
1
0
10
20
30
40
50
NORMALIZED DEPTH, IN GRAMS PER SQUARE CENTIMETER

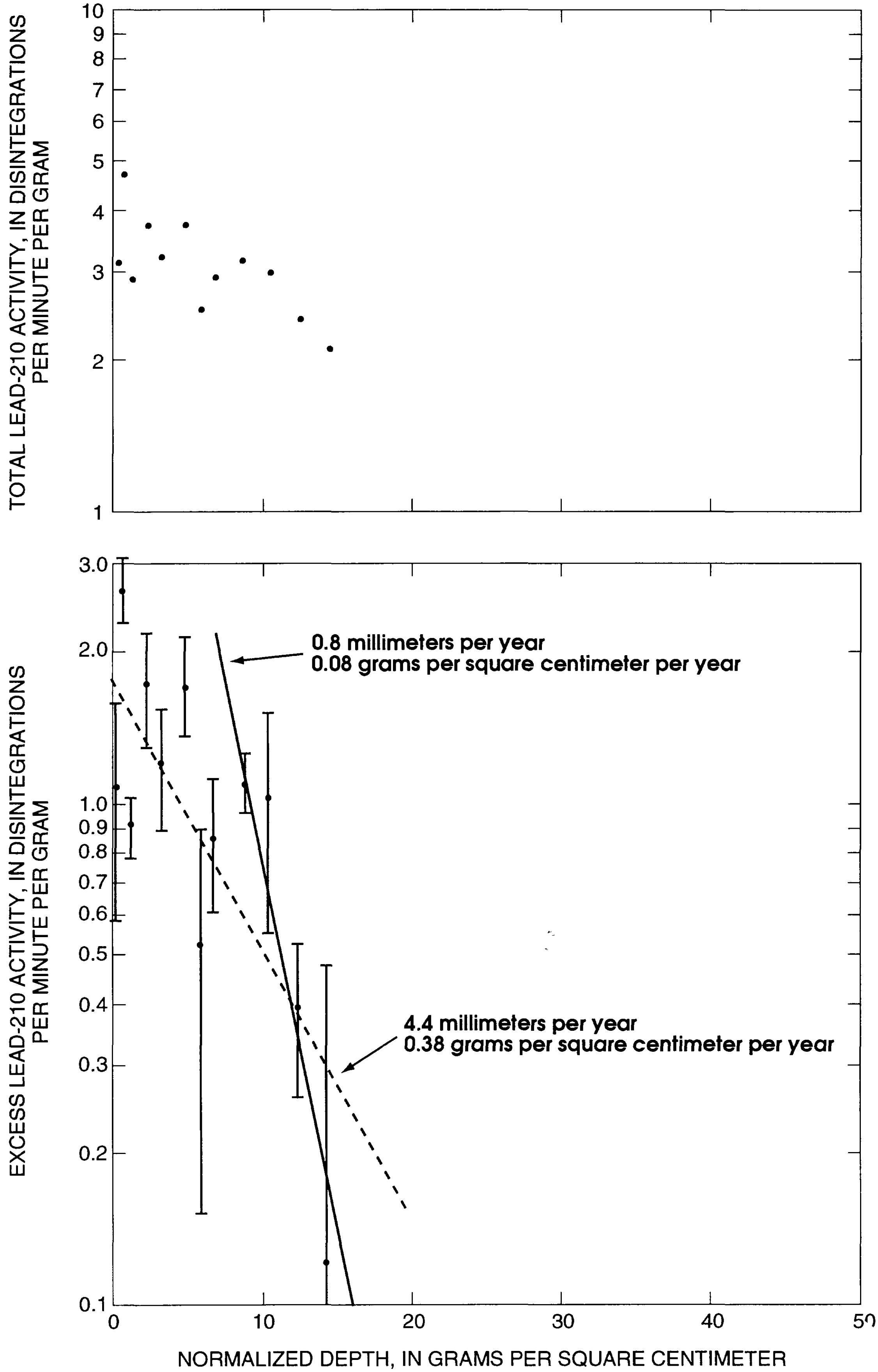
Core 1


20
10
9
8
7
6
5
4
3
2
1
TOTAL LEAD-210 ACTIVITY, IN DISINTEGRATIONS PER MINUTE PER GRAM
10
9
8
7
6
5
4
3
2
1
EXCESS LEAD-210 ACTIVITY, IN DISINTEGRATIONS PER MINUTE PER GRAM
0.9 millimeters per year
0.018 grams per square centimeter per year
0
10
20
30
40
50
NORMALIZED DEPTH, IN GRAMS PER SQUARE CENTIMETER

Core 2

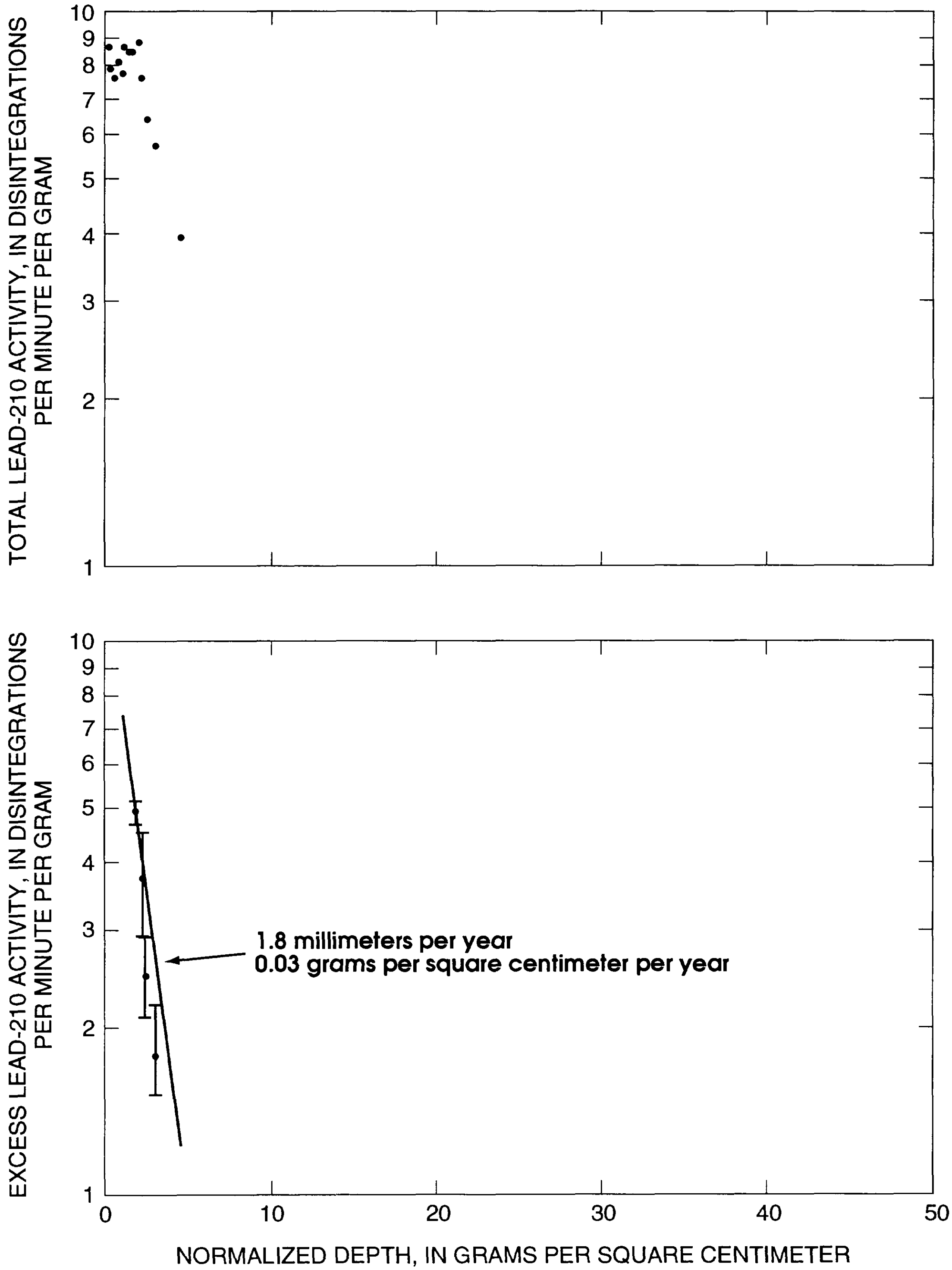

TOTAL LEAD-210 ACTIVITY, IN DISINTEGRATIONS PER MINUTE PER GRAM
10
9
8
7
6
5
4
3
2
1
0
10
20
30
40
50
NORMALIZED DEPTH, IN GRAMS PER SQUARE CENTIMETER

Core 3

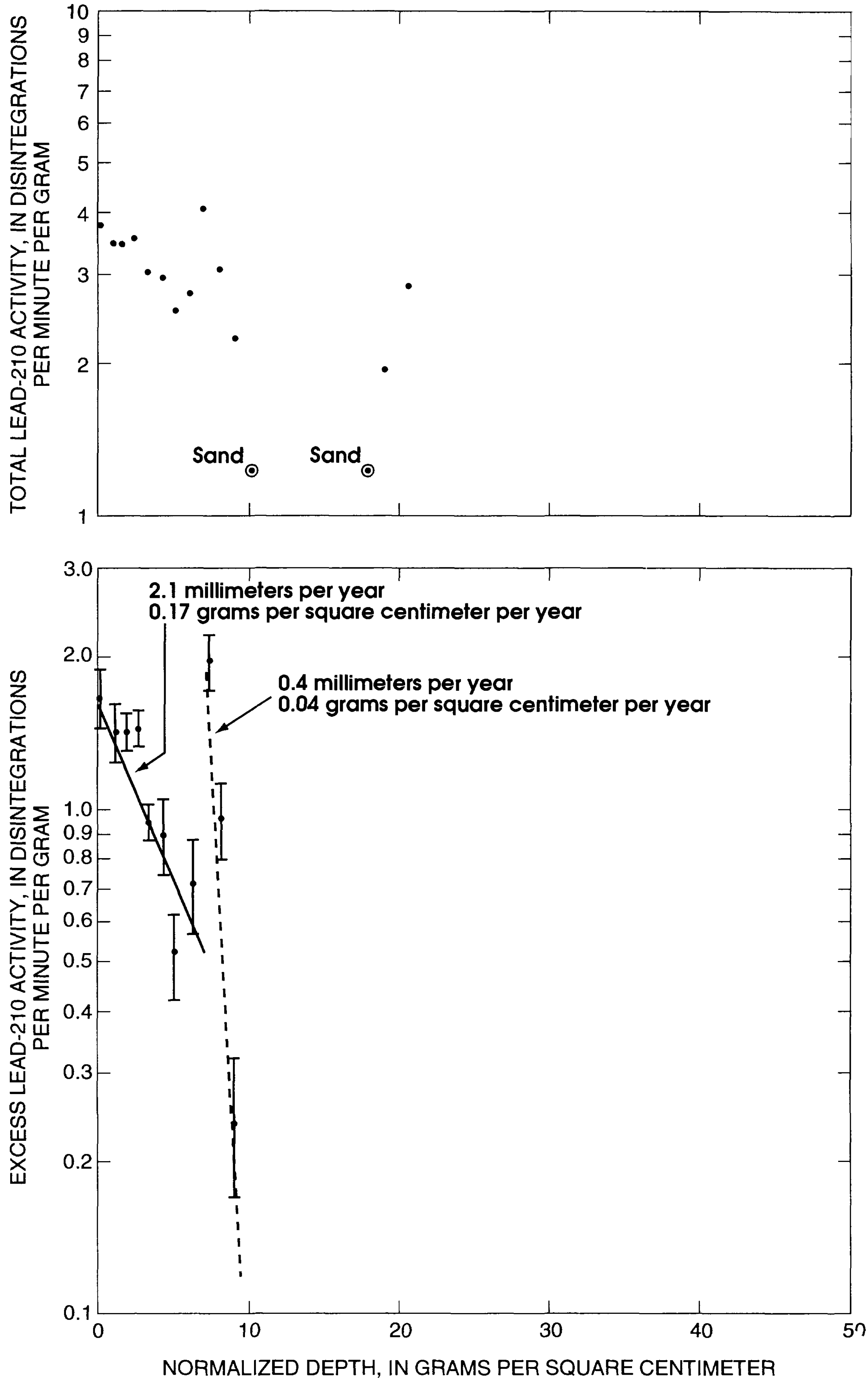


TOTAL LEAD-210 ACTIVITY, IN DISINTEGRATIONS PER MINUTE PER GRAM
10
9
8
7
6
5
4
3
2
1
EXCESS LEAD-210 ACTIVITY, IN DISINTEGRATIONS PER MINUTE PER GRAM
3.0
2.0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.8 millimeters per year
0.08 grams per square centimeter per year
4.4 millimeters per year
0.38 grams per square centimeter per year
0
10
20
30
40
NORMALIZED DEPTH, IN GRAMS PER SQUARE CENTIMETER

Core 4

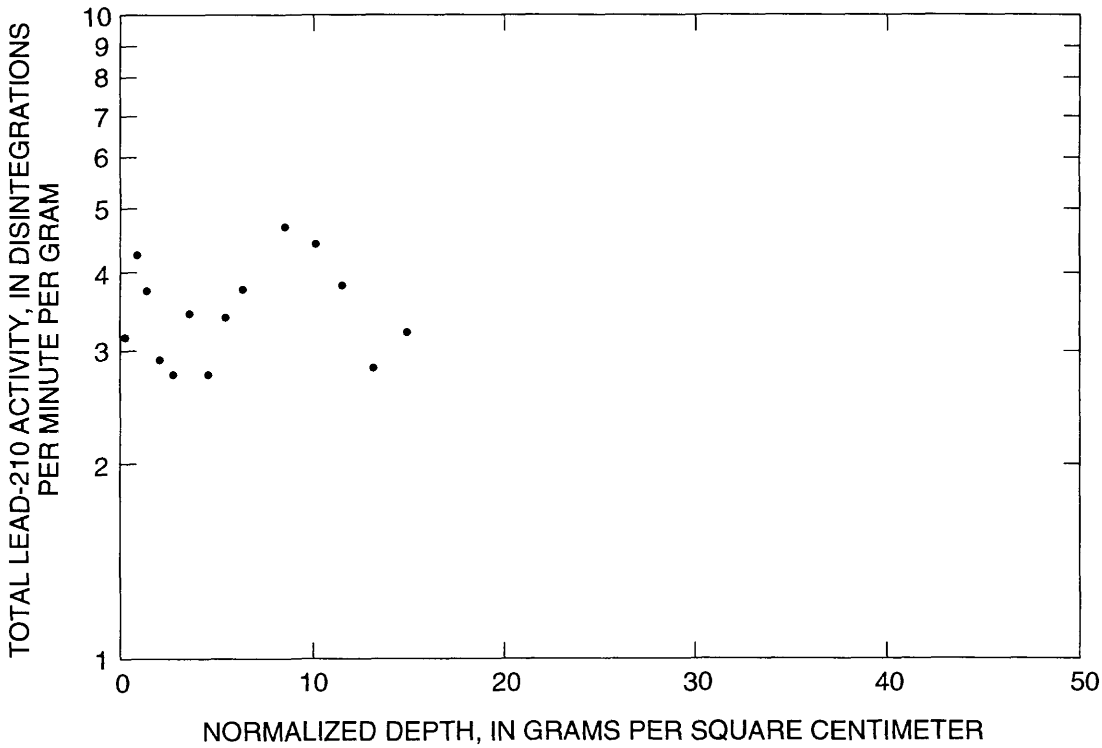

TOTAL LEAD-210 ACTIVITY, IN DISINTEGRATIONS PER MINUTE PER GRAM
10
9
8
7
6
5
4
3
2
1
EXCESS LEAD-210 ACTIVITY, IN DISINTEGRATIONS PER MINUTE PER GRAM
1.8 millimeters per year
0.03 grams per square centimeter per year
0
10
20
30
40
50
NORMALIZED DEPTH, IN GRAMS PER SQUARE CENTIMETER

Core 5

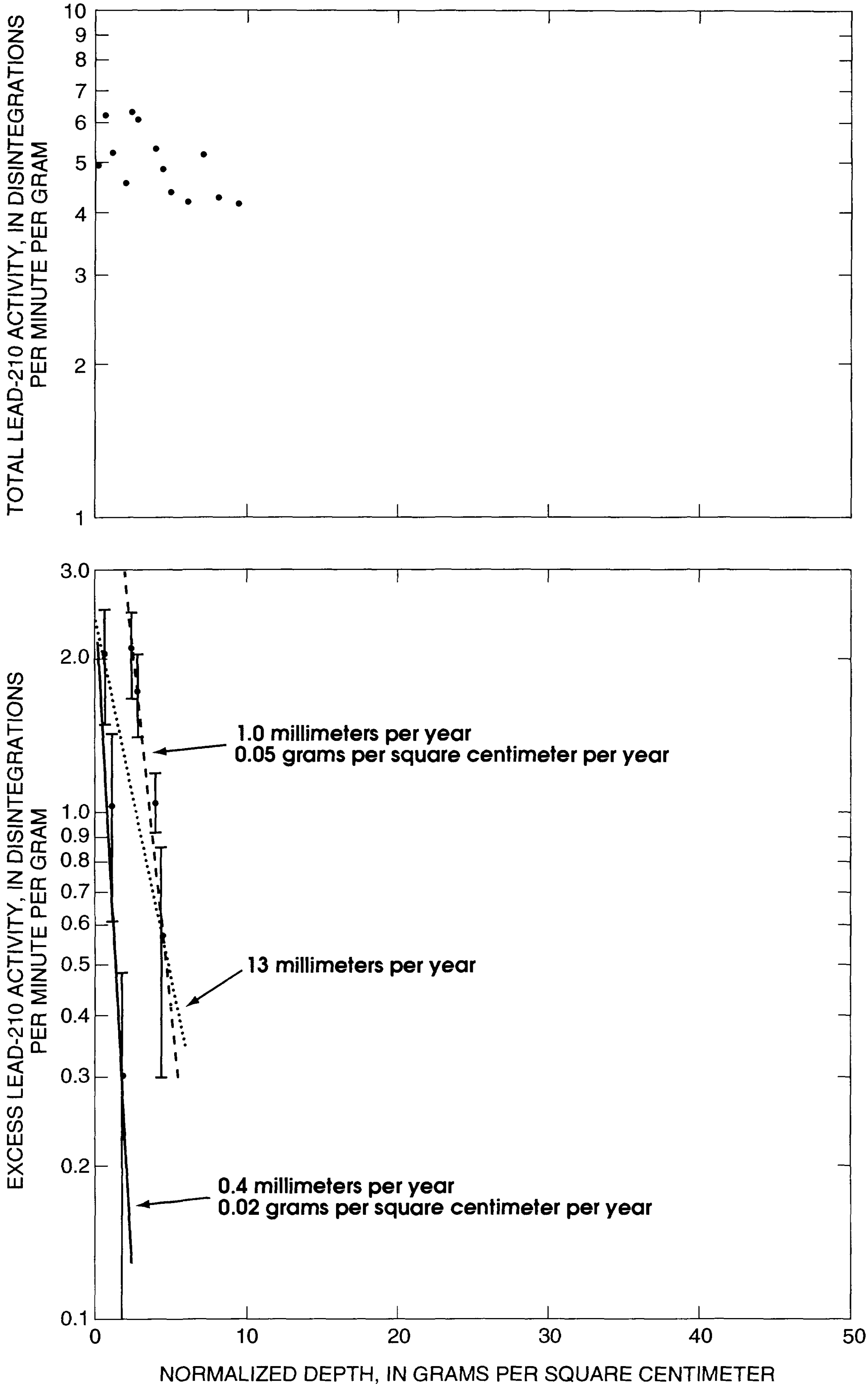


TOTAL LEAD-210 ACTIVITY, IN DISINTEGRATIONS PER MINUTE PER GRAM
10
9
8
7
6
5
4
3
2
1
Sand
Sand
EXCESS LEAD-210 ACTIVITY, IN DISINTEGRATIONS PER MINUTE PER GRAM
3.0
2.0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
2.1 millimeters per year
0.17 grams per square centimeter per year
0.4 millimeters per year
0.04 grams per square centimeter per year
0
10
20
30
40
50
NORMALIZED DEPTH, IN GRAMS PER SQUARE CENTIMETER

Core 6

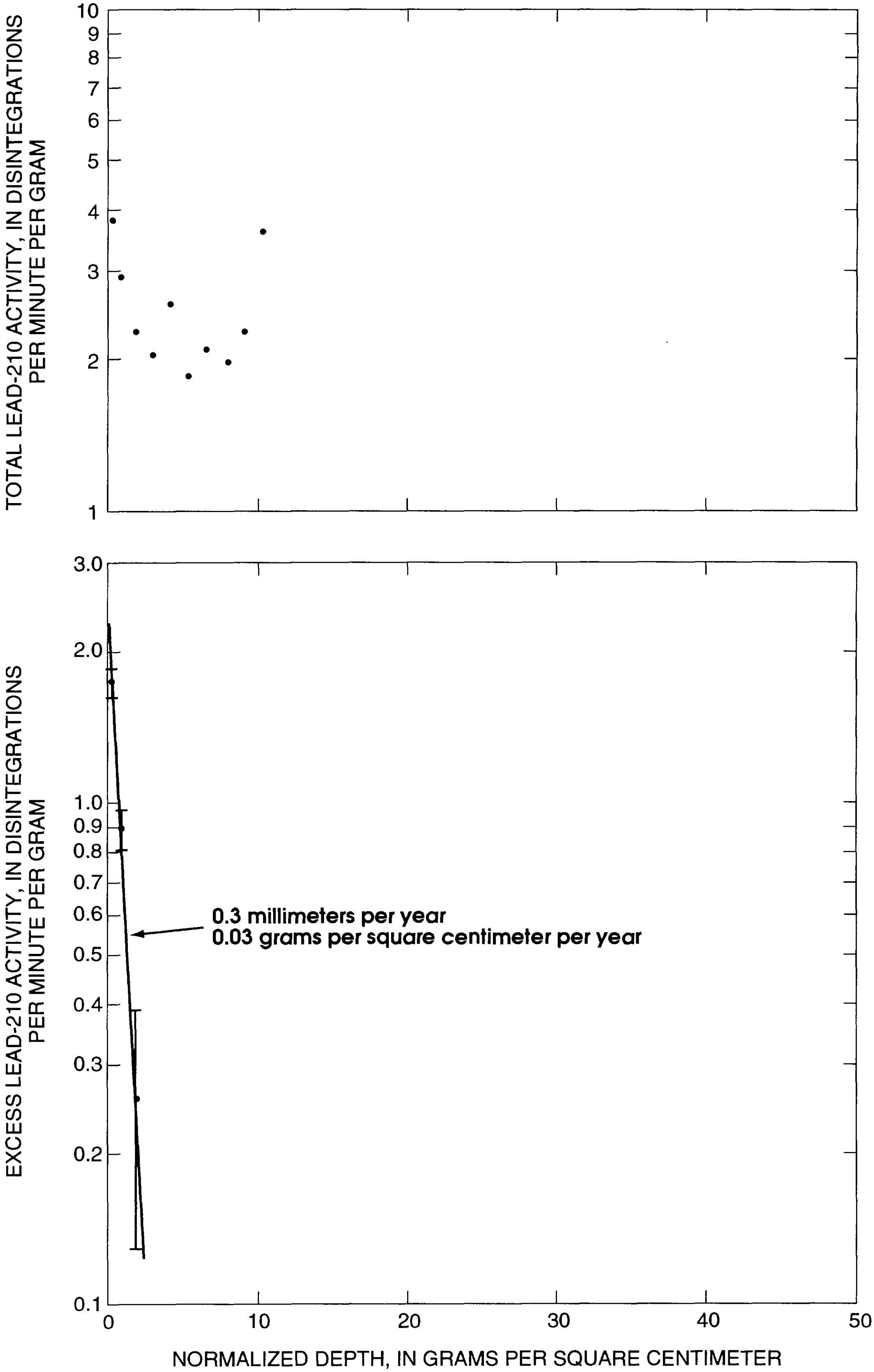

TOTAL LEAD-210 ACTIVITY, IN DISINTEGRATIONS PER MINUTE PER GRAM
10
9
8
7
6
5
4
3
2
1
0
10
20
30
40
50
NORMALIZED DEPTH, IN GRAMS PER SQUARE CENTIMETER

Core 7

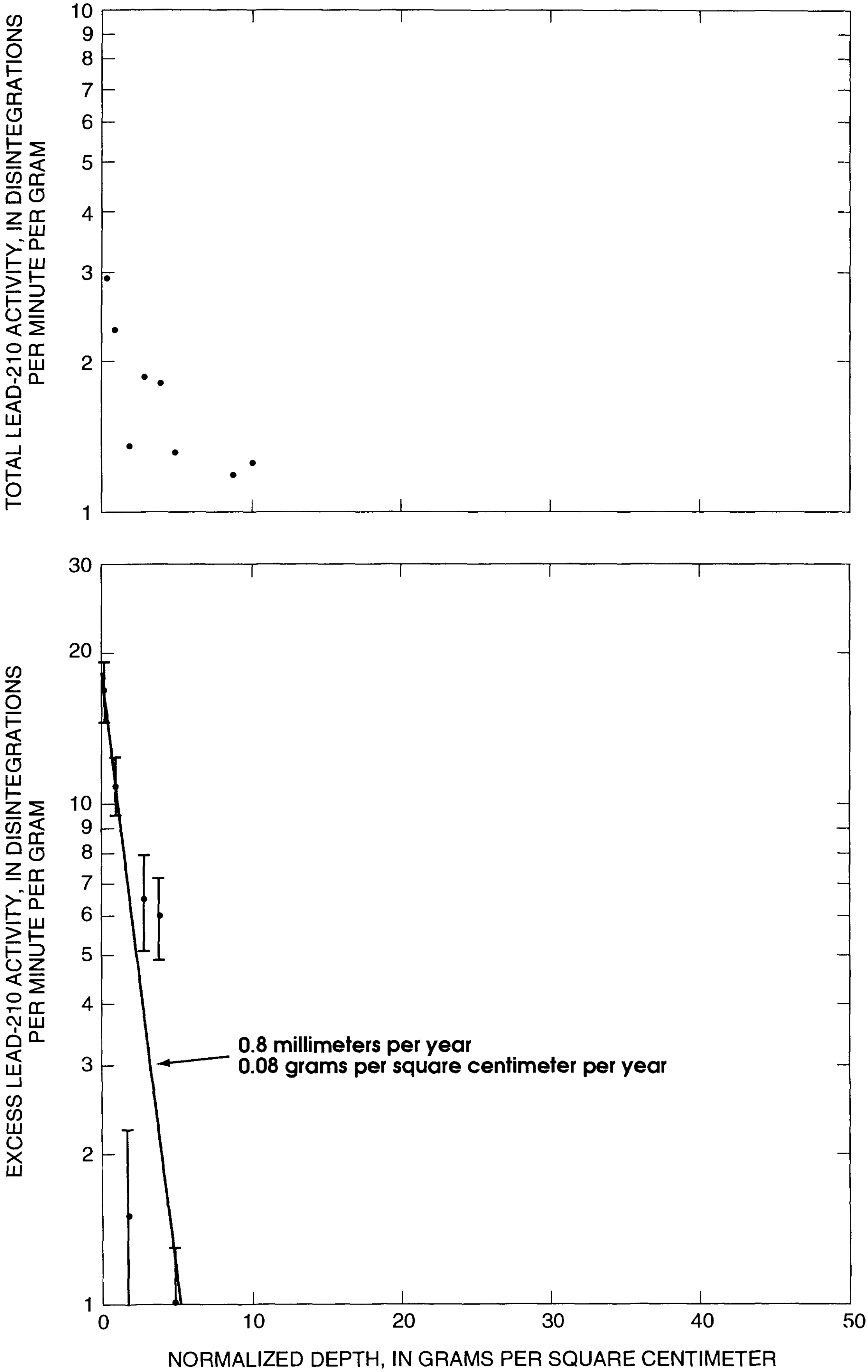


TOTAL LEAD-210 ACTIVITY, IN DISINTEGRATIONS PER MINUTE PER GRAM
EXCESS LEAD-210 ACTIVITY, IN DISINTEGRATIONS PER MINUTE PER GRAM
1.0 millimeters per year
0.05 grams per square centimeter per year
13 millimeters per year
0.4 millimeters per year
0.02 grams per square centimeter per year
NORMALIZED DEPTH, IN GRAMS PER SQUARE CENTIMETER

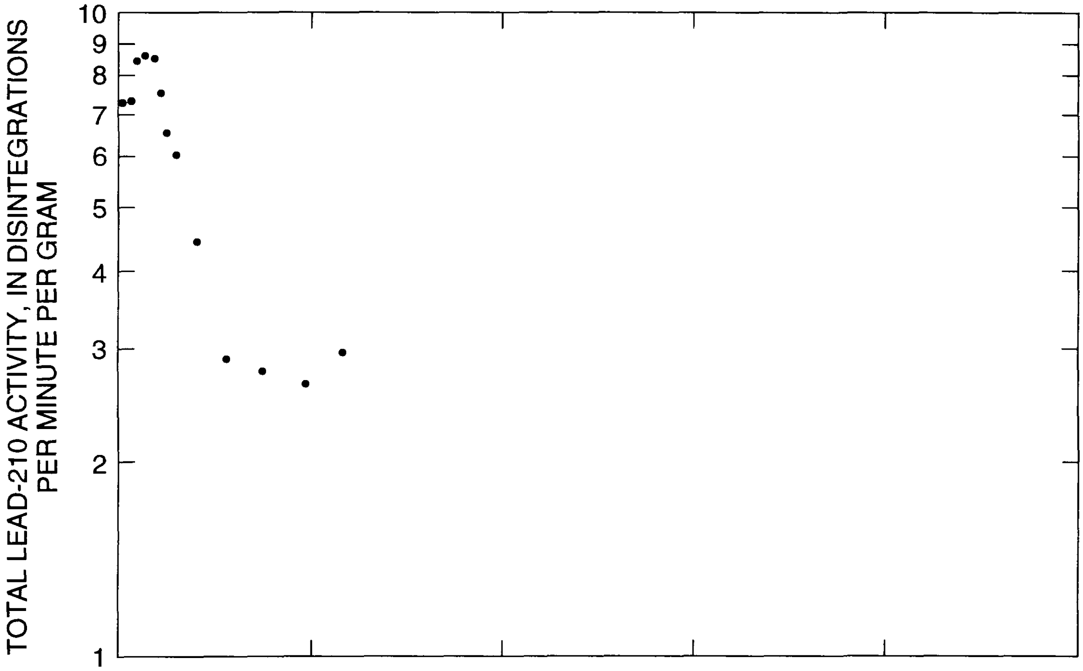
Core 8


TOTAL LEAD-210 ACTIVITY, IN DISINTEGRATIONS PER MINUTE PER GRAM
10
9
8
7
6
5
4
3
2
1
EXCESS LEAD-210 ACTIVITY, IN DISINTEGRATIONS PER MINUTE PER GRAM
3.0
2.0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.3 millimeters per year
0.03 grams per square centimeter per year
0
10
20
30
40
50
NORMALIZED DEPTH, IN GRAMS PER SQUARE CENTIMETER

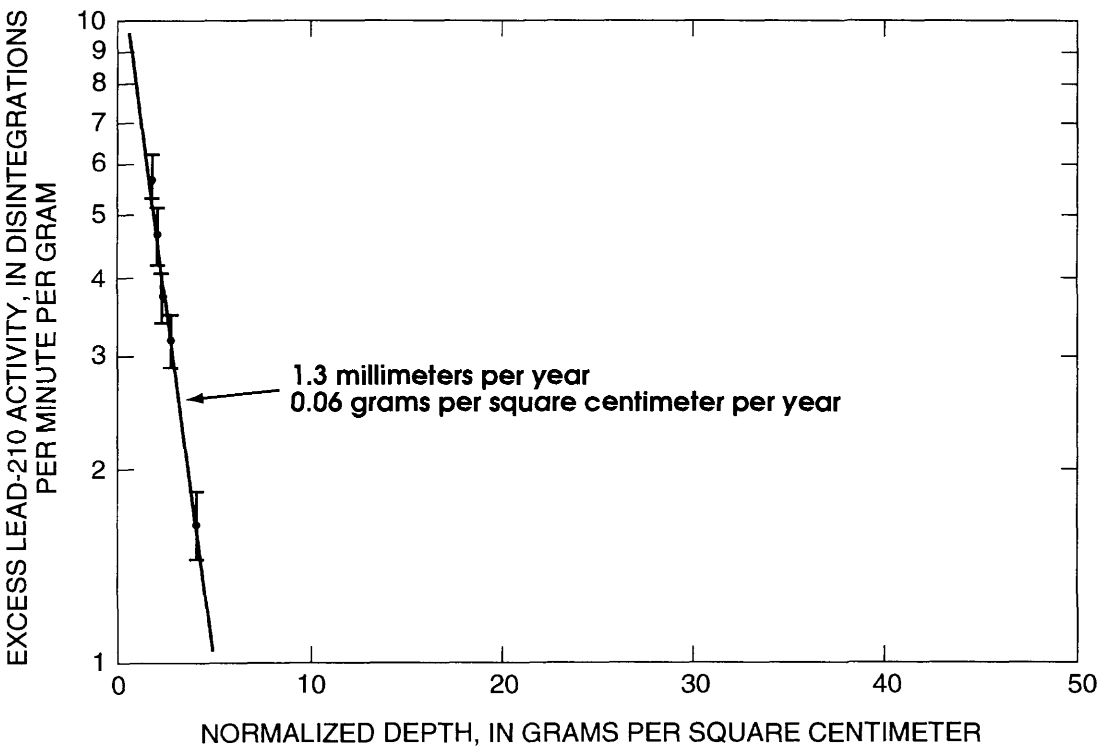
Core 9


TOTAL LEAD-210 ACTIVITY, IN DISINTEGRATIONS PER MINUTE PER GRAM
10
9
8
7
6
5
4
3
2
1
30
20
10
9
8
7
6
5
4
3
2
1
EXCESS LEAD-210 ACTIVITY, IN DISINTEGRATIONS PER MINUTE PER GRAM
0.8 millimeters per year
0.08 grams per square centimeter per year
0
10
20
30
40
50
NORMALIZED DEPTH, IN GRAMS PER SQUARE CENTIMETER

Core 10

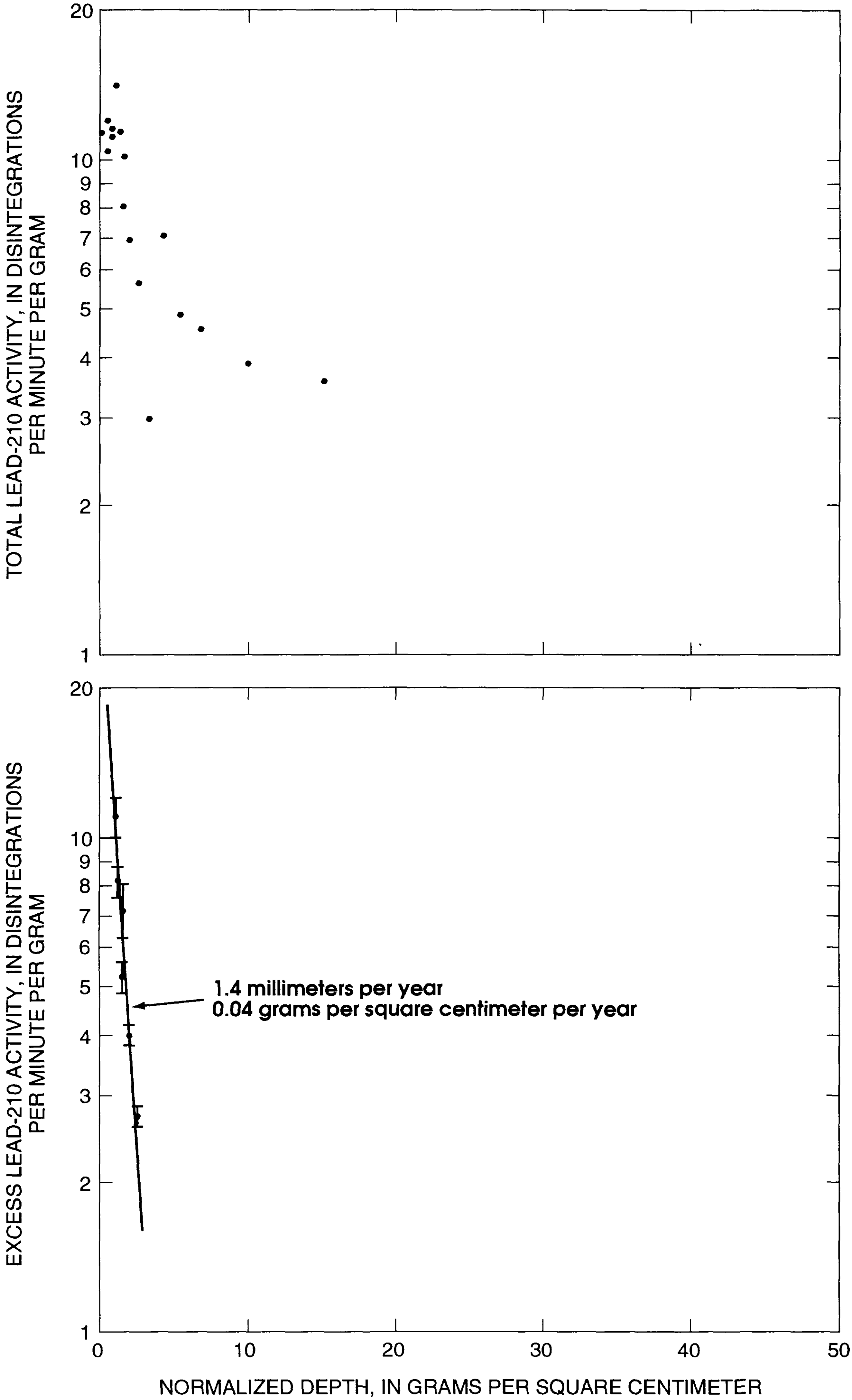


TOTAL LEAD-210 ACTIVITY, IN DISINTEGRATIONS PER MINUTE PER GRAM
10
9
8
7
6
5
4
3
2
1

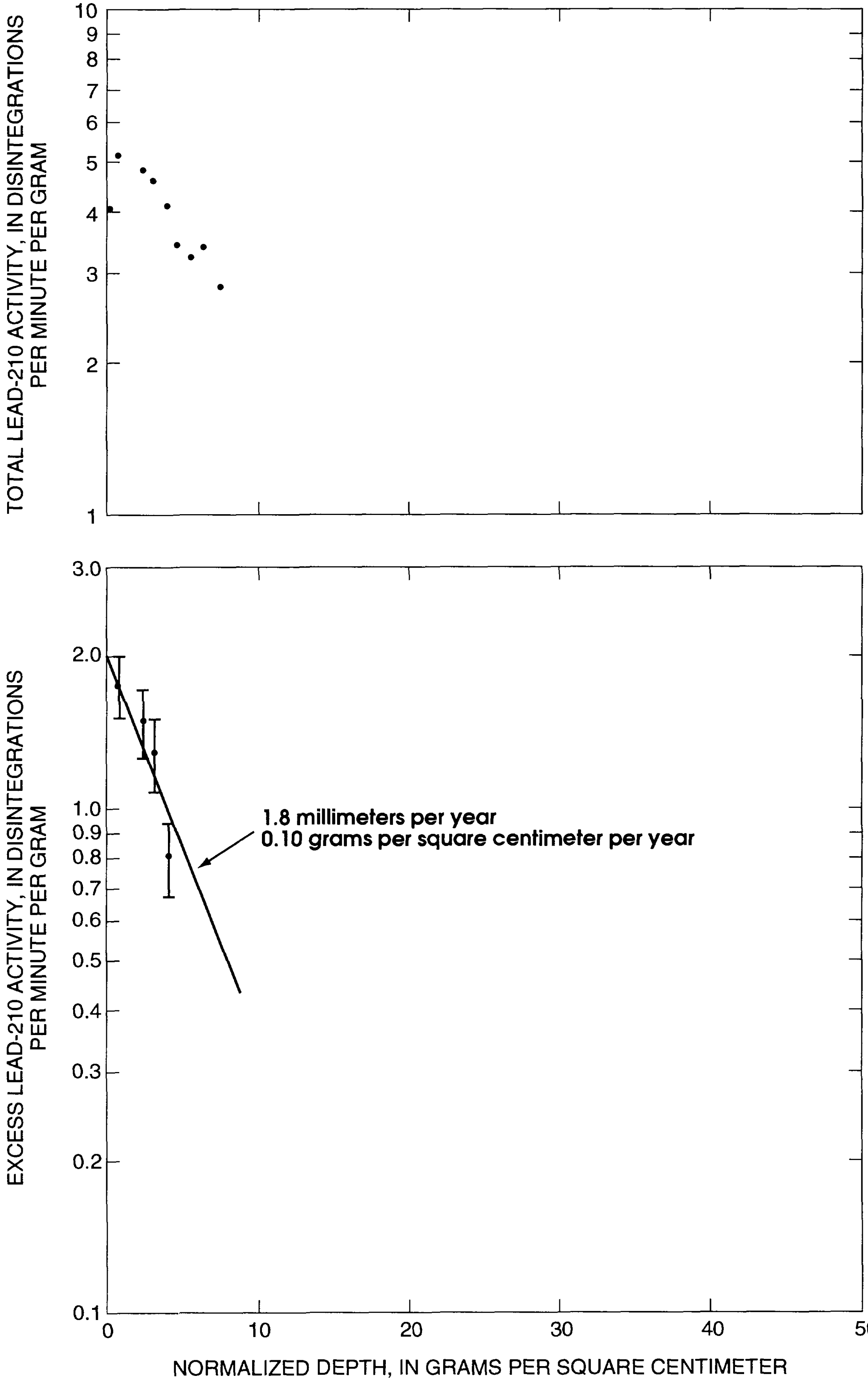


EXCESS LEAD-210 ACTIVITY, IN DISINTEGRATIONS PER MINUTE PER GRAM
10
9
8
7
6
5
4
3
2
1
1.3 millimeters per year
0.06 grams per square centimeter per year
0
10
20
30
40
50
NORMALIZED DEPTH, IN GRAMS PER SQUARE CENTIMETER

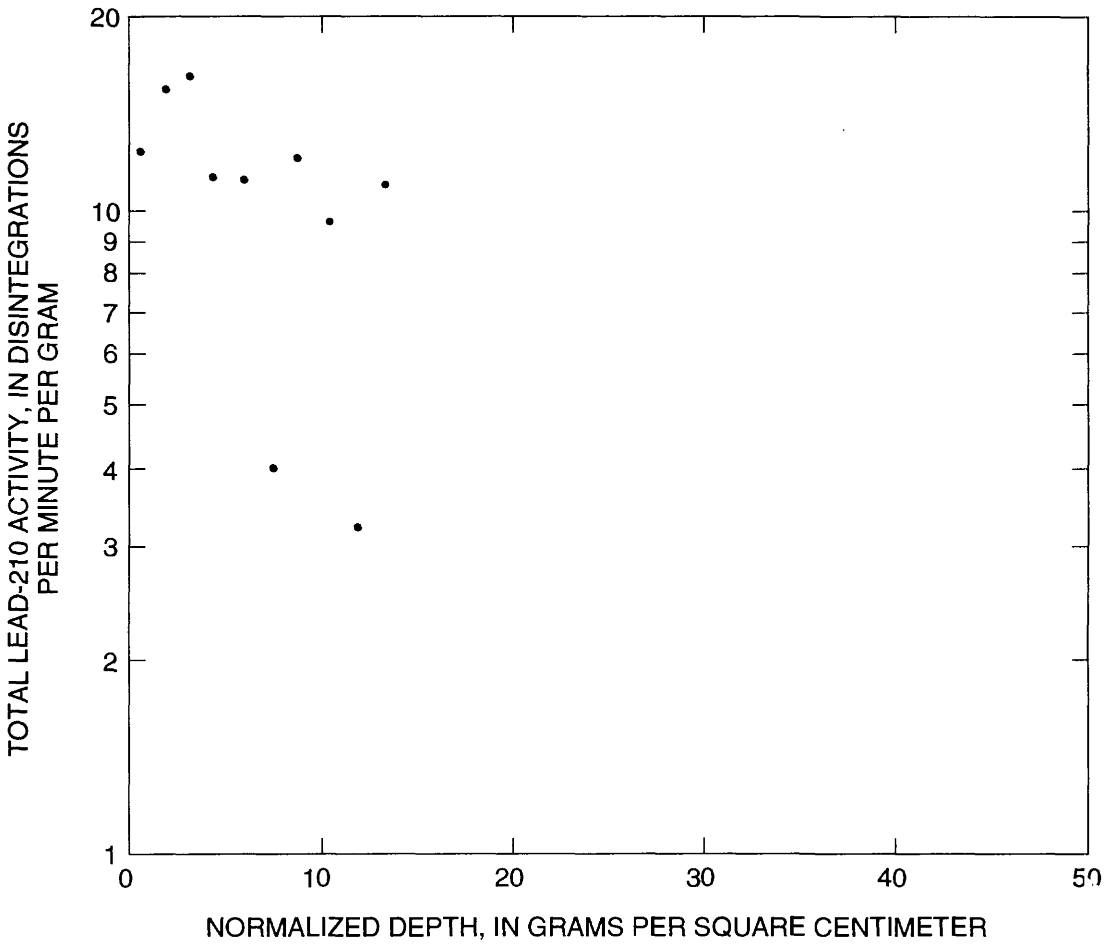
Core 12


TOTAL LEAD-210 ACTIVITY, IN DISINTEGRATIONS PER MINUTE PER GRAM
EXCESS LEAD-210 ACTIVITY, IN DISINTEGRATIONS PER MINUTE PER GRAM
1.4 millimeters per year
0.04 grams per square centimeter per year
NORMALIZED DEPTH, IN GRAMS PER SQUARE CENTIMETER
20
10
9
8
7
6
5
4
3
2
1
0
10
20
30
40
50

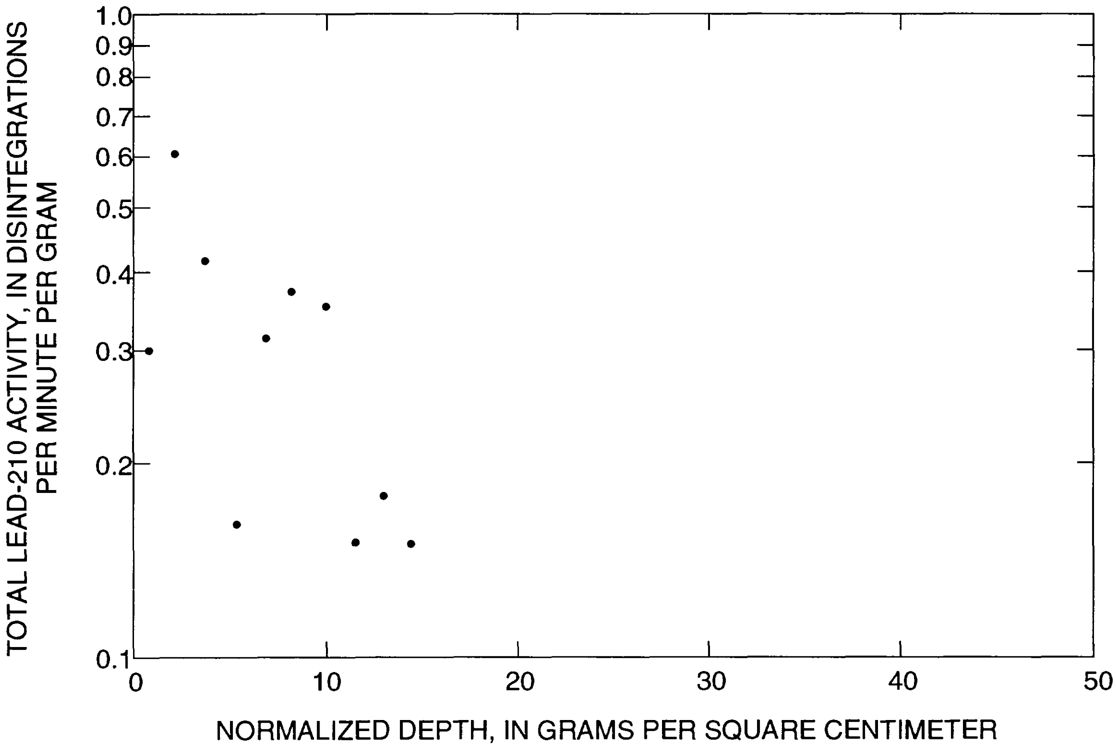
Core 13


TOTAL LEAD-210 ACTIVITY, IN DISINTEGRATIONS PER MINUTE PER GRAM
10
9
8
7
6
5
4
3
2
1
EXCESS LEAD-210 ACTIVITY, IN DISINTEGRATIONS PER MINUTE PER GRAM
3.0
2.0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
1.8 millimeters per year
0.10 grams per square centimeter per year
0
10
20
30
40
50
NORMALIZED DEPTH, IN GRAMS PER SQUARE CENTIMETER

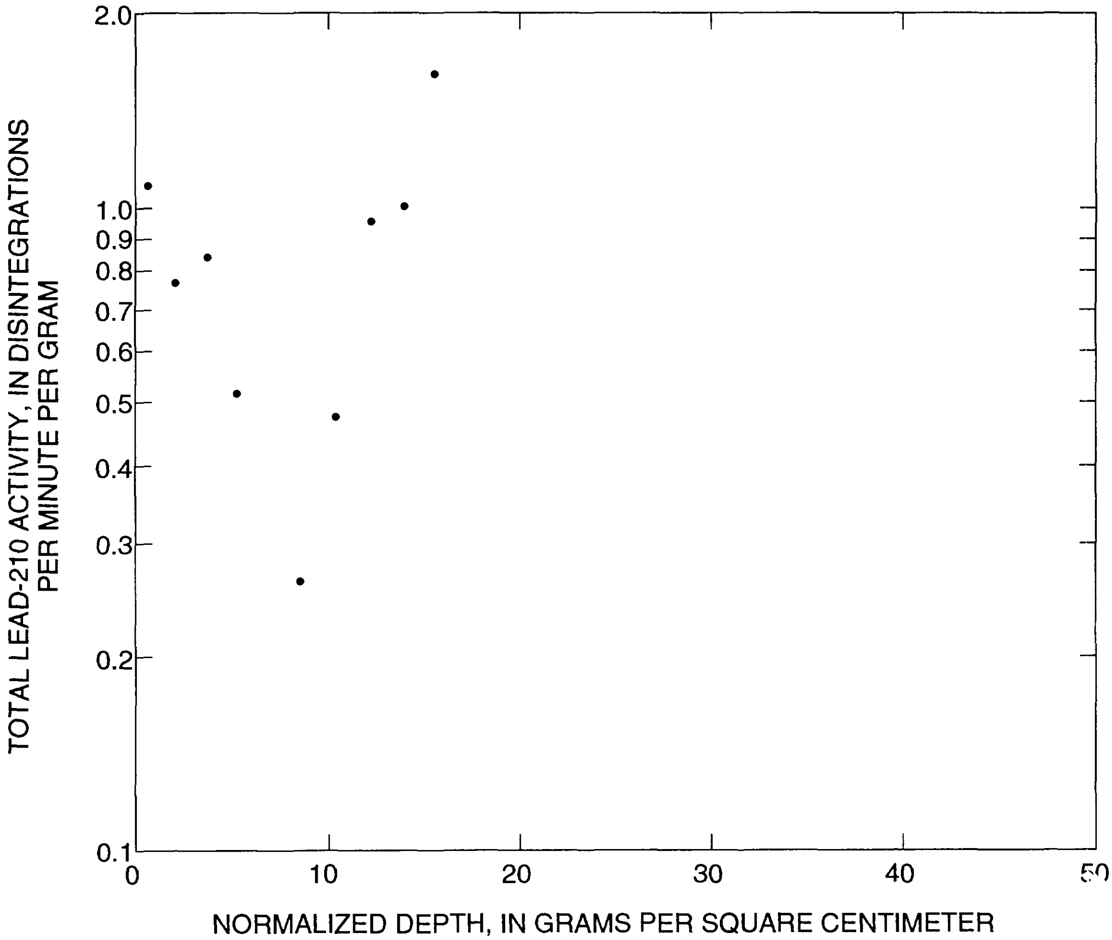
Core 14


TOTAL LEAD-210 ACTIVITY, IN DISINTEGRATIONS PER MINUTE PER GRAM
20
10
9
8
7
6
5
4
3
2
1
0
10
20
30
40
50
NORMALIZED DEPTH, IN GRAMS PER SQUARE CENTIMETER

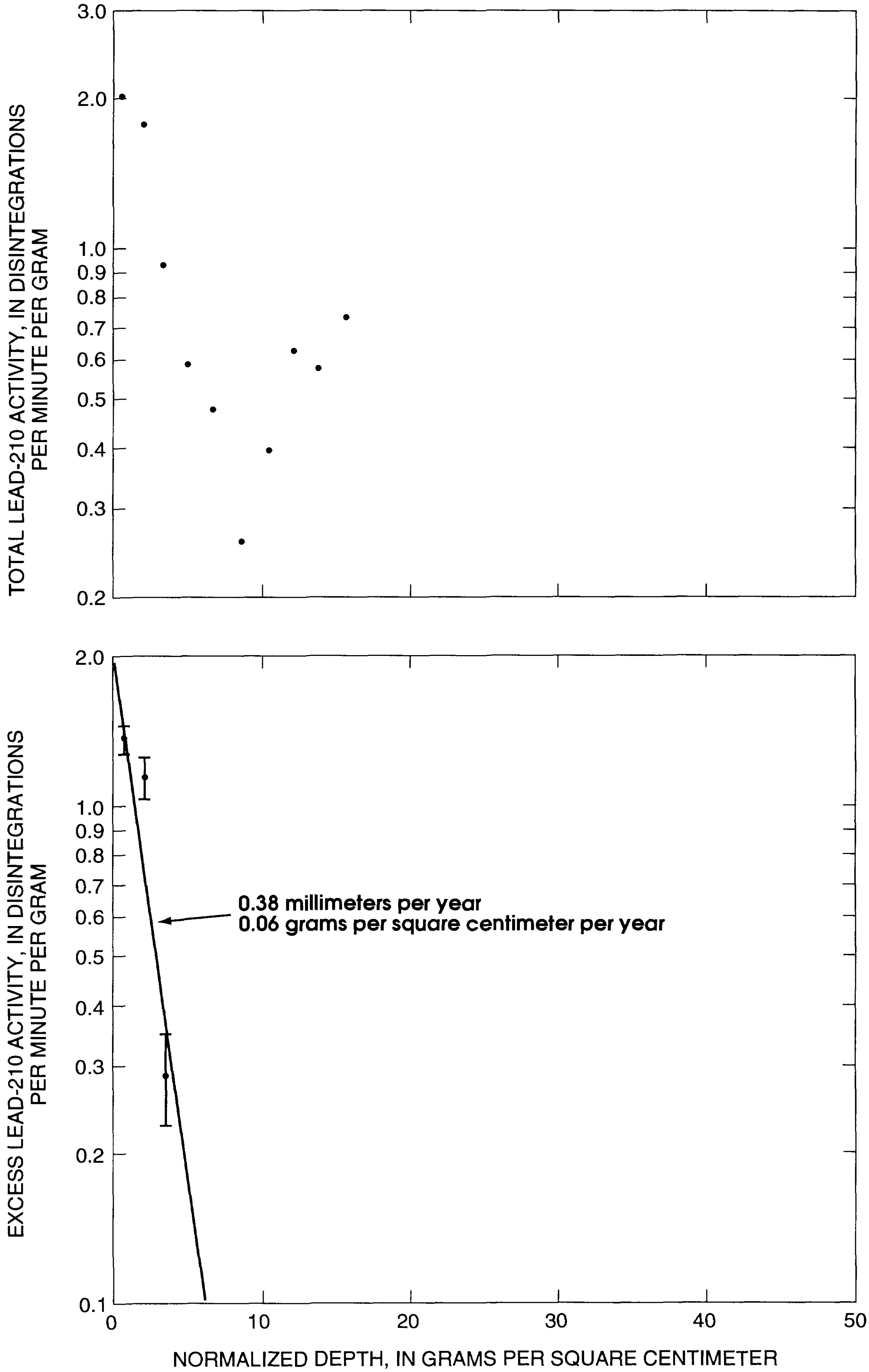
Core 15


TOTAL LEAD-210 ACTIVITY, IN DISINTEGRATIONS PER MINUTE PER GRAM
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10
20
30
40
50
NORMALIZED DEPTH, IN GRAMS PER SQUARE CENTIMETER

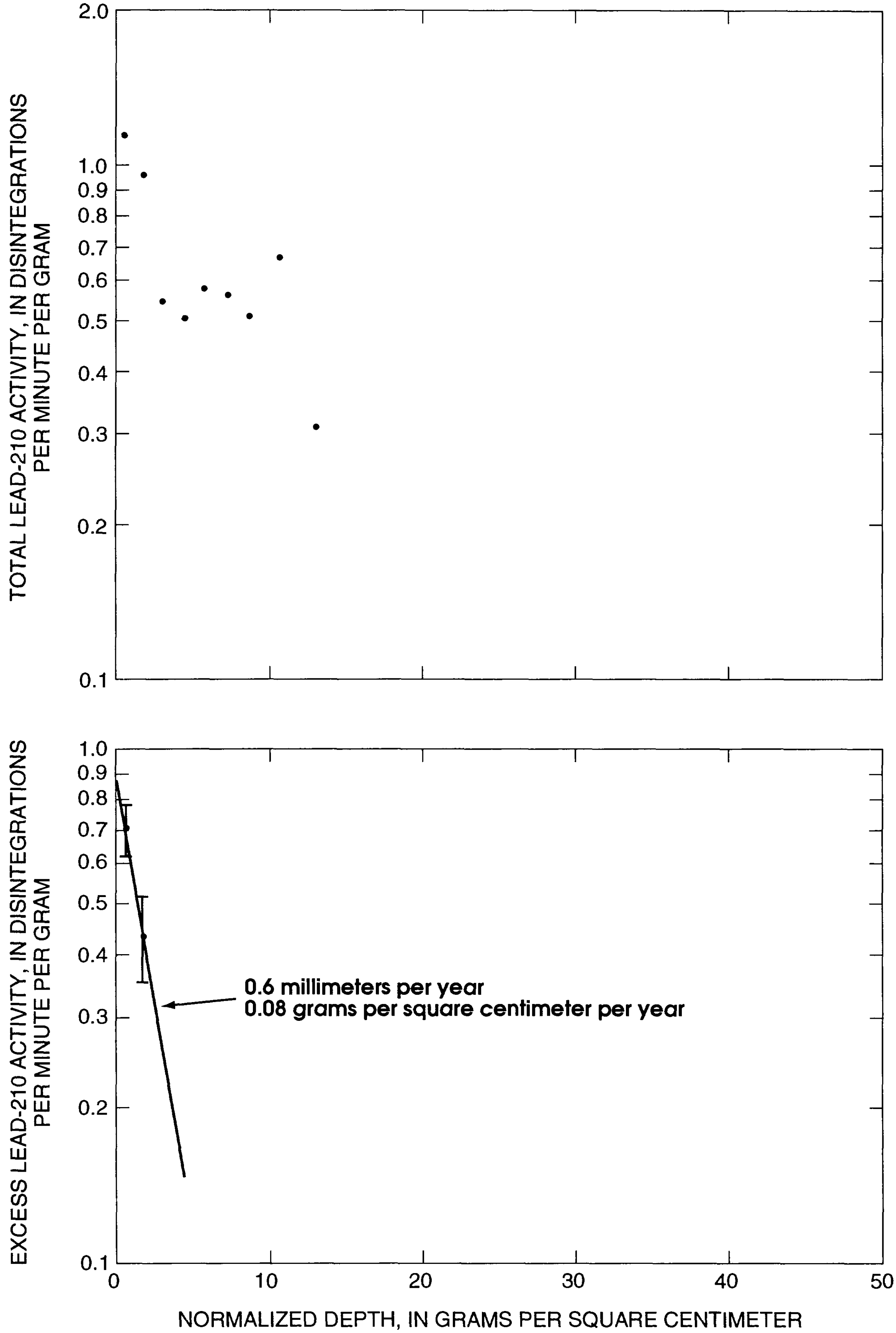
Core 16


TOTAL LEAD-210 ACTIVITY, IN DISINTEGRATIONS PER MINUTE PER GRAM
2.0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10
20
30
40
50
NORMALIZED DEPTH, IN GRAMS PER SQUARE CENTIMETER

Core 17

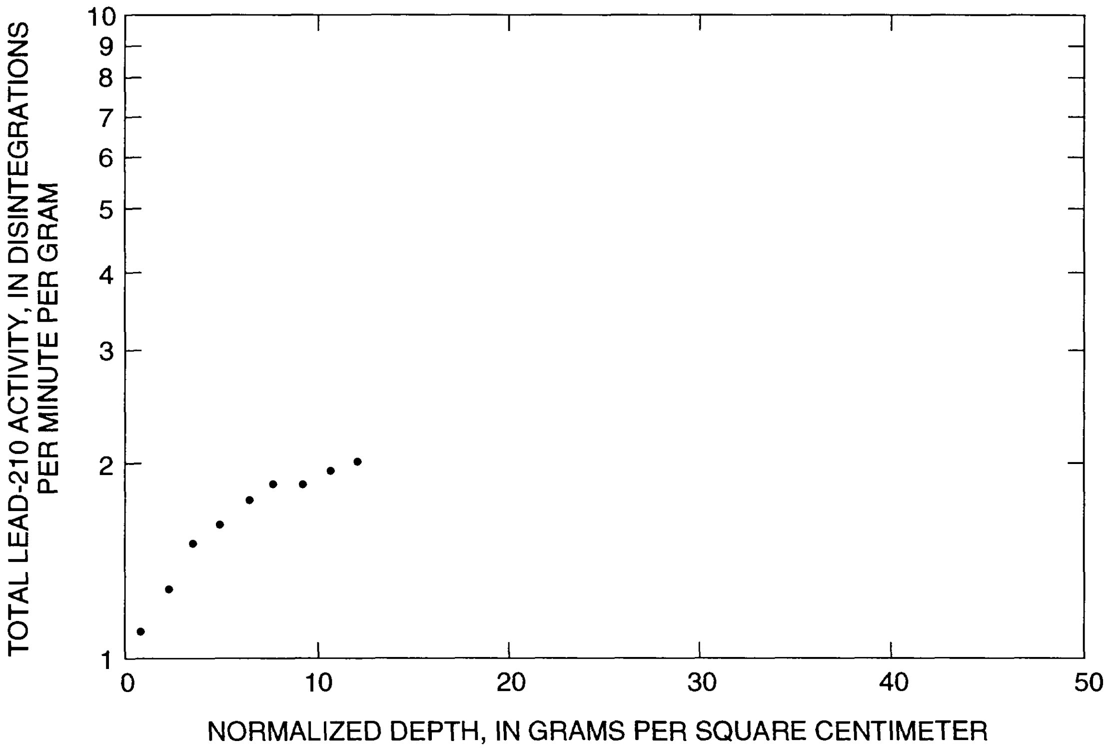

3.0
2.0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
TOTAL LEAD-210 ACTIVITY, IN DISINTEGRATIONS PER MINUTE PER GRAM
2.0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
EXCESS LEAD-210 ACTIVITY, IN DISINTEGRATIONS PER MINUTE PER GRAM
0.38 millimeters per year
0.06 grams per square centimeter per year
0
10
20
30
40
50
NORMALIZED DEPTH, IN GRAMS PER SQUARE CENTIMETER

Core 18



2.0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
TOTAL LEAD-210 ACTIVITY, IN DISINTEGRATIONS PER MINUTE PER GRAM
EXCESS LEAD-210 ACTIVITY, IN DISINTEGRATIONS PER MINUTE PER GRAM
0.6 millimeters per year
0.08 grams per square centimeter per year
0
10
20
30
40
50
NORMALIZED DEPTH, IN GRAMS PER SQUARE CENTIMETER

Core 19



Core 20

☆ U.S. GOVERNMENT PRINTING OFFICE — 1996 - 642-068/20014