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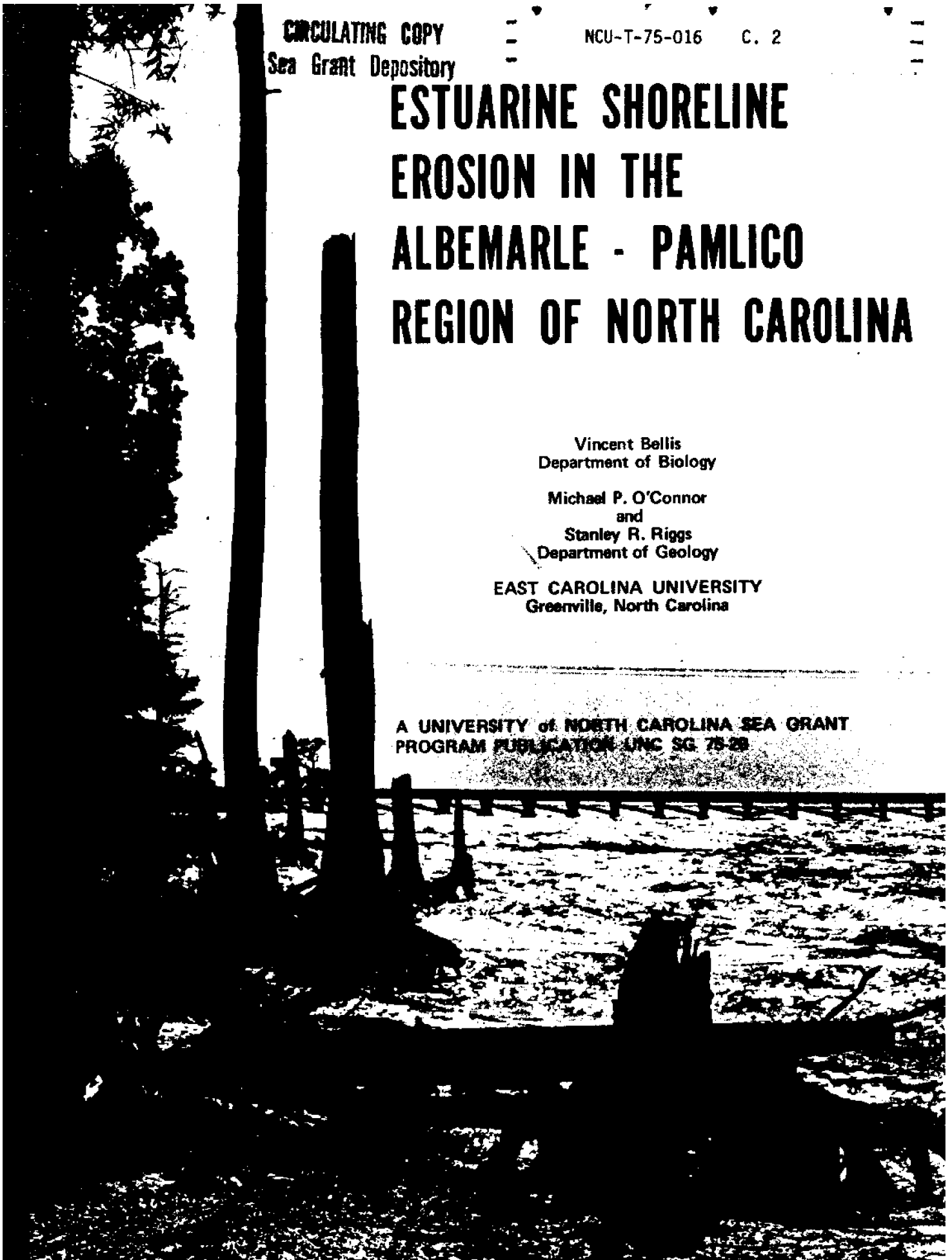
ESTUARINE SHORELINE EROSION IN THE ALBEMARLE - PAMLICO REGION OF NORTH CAROLINA

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Greenville, North Carolina

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ALBEMARLE-PAMLICO REGION OF NORTH CAROLINA**

by

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Estuarine Shoreline Erosion in the Albemarle-Pamlico Region of
 North Carolina
 UNC-SG-75-29

Errata

<u>page</u>	<u>paragraph</u>	<u>line</u>	<u>correction</u>
iv	1	8	Claude Jones
13	1	3	Table 2 is on p. 20, not p. 17
16	1	5	Figure 8, not Figure 9
18	2	2	Table 3 is on p. 20, not p. 17
25	1	1	east, not west
	2	5	Table 3 is on p. 20
32	3	8	omit last two words - "the end"
51	3	2	...costing \$100 and up <u>per</u> linear foot...
53	3	heading	omit "the"
64	reference 3		Comberford, not Cumberland
	reference 10		Philos., not Philoso.
65	glossary		underline bathymetry
66	glossary		under entry 'grass marsh' last word should be fowl not foul

CONTENTS

ABSTRACT.	ii
ACKNOWLEDGMENTS	iv
INTRODUCTION.	1
SHORELINE TYPES AND THE CAUSES OF EROSION	4
Early History of the Region.	4
Region in Modern Times	6
Shoreline Types and Processes.	13
Sand and Clay Banks	13
Low Bank	18
High Bank.	23
Bluff.	29
Swamp Forest.	32
Cypress Fringe	34
River Swamp.	39
Grass Marsh	41
COPING WITH ESTUARINE EROSION	47
Shoreline Protection Structures.	47
Seawalls and Bulkheads.	51
Revetment or Riprap	51
Groins.	53
Enhancement of Natural Erosion Barriers.	53
Cypress Fringe Inducement	53
Multiple Bulkheads.	57
Discussion.	57
Setback Regulations.	57
Recommendations.	58
SIGNIFICANCE OF OBSERVATIONS REPORTED HERE TO COASTAL PLANNING AND SHORELINE DEVELOPMENT	60
REFERENCES.	64
GLOSSARY.	65

ABSTRACT

Shoreline erosion within the estuaries of North Carolina is a continuing process which has been in operation for several thousand years. Actual rates of erosion range up to twenty feet per year but average 2-3 feet per year. Variables affecting rate of shoreline erosion are: bank height and composition, vegetative cover, exposure to prevailing winds and fetch, offshore topography, and various human activities. Three major shoreline types are identified on the basis of these parameters. These are: 1) Sand and Clay Banks, 2) Swamp Forest, and 3) Grass Marsh. Of these shoreline types only the sand and clay banks can be easily developed. All types, however, can be protected by shoreline modification structures, utilization of natural protective features, or appropriate setback regulations.

Field observations and laboratory studies of Albemarle and Pamlico Sounds indicate the following general conclusions and recommendations.

- 1) Development of estuarine shorelines will increase as ocean frontage becomes scarce and developmental restrictions become more stringent.
- 2) Cypress headlands, resistant clay bluffs, cypress fringe, swamp forest, and peat marshlands function as natural barriers to shoreline erosion and should be designated Areas of Environmental Concern (AEC).
- 3) Coves or other natural segments of shoreline lying between resistant headlands respond to erosive forces as a unit and should be treated as such when developing local shoreline protection strategy.
- 4) While all beaches can be protected by artificial structures, excessive bulkheading may lead to loss of sandy beaches. Alternative measures such as setback regulations or enhancement of natural erosion barriers should thus be considered.

- 5) Protection of cropland bordering estuarine shorelines by structural methods is economically unfeasible. Strip development will be encouraged as cropland owners learn that they can protect their farmland by transferring shoreline protection responsibility to cottage owners who will then have a major investment to protect.
- 6) Shoreline developers should utilize existing erosion data available from county SCS offices.

ACKNOWLEDGEMENTS

Our initial efforts in this work were greatly facilitated by a comprehensive analysis of estuarine shoreline erosion just completed by the USDA Soil and Water Conservation Service. Mr. Harry Gibson of the Soil Conservation Service office in Edenton, North Carolina provided draft copies of SCS data for the northeastern counties and established contacts for us with county SCS officers where we were cordially received and ably assisted by Junius Russell, Ed Karnowski, James Griffin, Ed Kraft, Claud Jones, and Frank Veach.

Graduate and student assistants who served in all capacities including stump watcher, ships carpenter, helmsman, draftsman, proof reader, idea contributor, etc. included Cindy Blanck, Scott Hardaway, Scott Hartness, Paul Albertson, and Kelly Scarborough. Lucy Mauger prepared the line drawings and provided editorial comments. Tom Willis of the E. C. U. Regional Development Institute arranged dock space for 'Sweet Agona' throughout the Albemarle-Pamlico Region. We would also thank the many other individuals who allowed us to tie up at their docks or who permitted us to examine their shoreline property.

INTRODUCTION

A recent shoreline inventory completed by the Soil and Water Conservation Service (USDA) has confirmed that erosion is pervasive throughout North Carolina estuaries (Table 1). Erosion rates of up to 20 feet per year over the last 30 years have been reported, and losses of 2-3 feet per year are typical. Areas of shoreline buildup are rare and appear to be strictly temporary features.

Observations and recommendations reported in this publication are the results of work initiated in June 1975 and funded by the North Carolina Sea Grant Program. The objective of this study is to inventory the estuarine shoreline of North Carolina and to produce maps delineating shoreline types, erosion potential, and environmental factors affecting shoreline erosion. Upon completion of field work for each county, a detailed erosion potential map will be published including a mile-by-mile description and discussion of that shoreline. These publications will be useful to local government officials, county and regional planners, shoreline developers, farmers, current and potential cottage owners, environmentalists, and others interested in developing, managing, or protecting estuarine shoreline.

The present publication is the first in this series and is intended to rapidly convey our initial results to county planners currently under mandate to designate interim areas of environmental concern as required under the Coastal Area Management Act of 1974 and to establish minimum setback lines to be incorporated in subdivision ordinances currently being drawn up in many coastal counties. Information presented here is based on field observations made along the Chowan River, western Albemarle Sound, and the Pamlico River

Table 1 Mean rate of shoreline erosion for selected counties in the Albemarle-Pamlico region (data supplied by the Soil Conservation Service, U.S. Department of Agriculture and based on comparison of air photos).

COUNTY	MEAN EROSION RATE (feet per year)	INTERVAL BETWEEN PHOTOS (years)
Beaufort	1.7	32 (1938-1970)
Bertie	0.9	32 (1938-1970)
Chowan	0.9	31 (1938-1969)
Tyrrell	2.0	22 (1947-1969)
Washington	4.5	32 (1938-1970)

and is thus most applicable to the northeastern region of North Carolina. To the extent that similar shoreline types and erosion producing factors occur in all of our estuaries, conclusions and recommendations reported here can be applied elsewhere.

SHORELINE TYPES AND THE CAUSES OF EROSION Early History of the Region

Eastern North Carolina is covered by a wedge of light colored sand and clay soils. These soils originated from river and estuarine sediment deposits during several periods when the sea extended much further west of the present coastline. Some 30,000 years ago, the sea stood at very nearly its current level. Approximately 18,000 years ago, sea level reached its lowest point, perhaps 400 feet lower than present. During this last 'ice age' much of the continental shelf lay exposed and presumably was covered by cold lowland marshes and swamps. Our earliest record of human occupation in the Albemarle-Pamlico Region consists of projectile points, judged by archeologists to have been fashioned by a paleoindian culture over 15,000 years ago. Indian occupation of the region coincided closely with a general warming climate which resulted in the thawing of the glacial ice and a rising sea level. Quite possibly much of the remaining archeological record of these early Carolinians now lies beneath the ocean. Studies of plant pollen trapped in successive layers of peat within the Great Dismal Swamp support the hypothesis that northern forests of fir and spruce occupied the cold uplands of Beaufort and Bertie while freshwater marsh and rivers occupied deeper valleys of the Albemarle and Pamlico Rivers. Gradual warming forced the spruce-fir forest to retreat northward to higher elevations. Relicts of this forest survive to this day on scattered mountain tops at mile high elevations in the Smokies and Blue Ridge. With the warming trend, beech and maple replaced the conifers and then in their turn were replaced by oak and hickory. Pines occupied well drained sandy beach ridges and vast areas within the hardwood forest cleared by frequent fires. Freshwater marsh, then brackish marsh, and finally salt marsh invaded

river valleys and swales between relict beach ridges. From its early development to the present, human culture in eastern North Carolina has had to adjust to changing climate and rising sea level. Very recent evidence gathered by the U. S. Coast and Geodetic Survey suggests that the rate of apparent sea flooding at any given locality may be modified by very slow uplift or subsidence of the land surface by mechanisms as yet incompletely understood.

The first Europeans visited coastal Carolina only about 400 years ago. They found a landscape similar to what we see today: shallow brackish sounds and lagoons, extensive grass marsh, great swamp forests of bald cypress and tupelo reaching inland along the river floodplains, and a scattered mosaic of pine and upland hardwoods. Modern man has superimposed farms, towns, and roads upon the face of coastal Carolina; however, the fundamental geological and biological patterns still show through and are readily observable to the discerning eye in aerial photos.

Imagine for a moment that you had a timelapse film of a single area along the shoreline. If one frame had been taken each decade during the past 18,000 years the entire period would flash by in about a minute if projected at normal speed and the river bluff would appear to melt like a sugar cube in hot coffee. Geological studies indicate that shoreline erosion has been taking place in our estuaries for most if not all of the past 18,000 years. Similarly observations of the shoreline flora reveal that successful plant species have been grasses and trees that can withstand periods of flooding by brackish water. Considered on a real time scale, erosion occurs relatively slowly when measured against a single human life-span. Shoreline erosion was either not recognized, not

considered particularly important, or simply accepted as 'nature's way' until recently. Extensive cottage and shoreline development during the last two decades has greatly increased the relative value of waterfront property and has heightened concern when such property becomes threatened by erosion.

Region In Modern Times

In eastern Chowan County boats entering the Yeopim River from Albemarle Sound must cross an unexpected shoal. Unwary fishermen are often startled to see their prop suddenly churn up a yellow plume where seconds before there was only a froth of white bubbles rising through a wake resembling diluted tea. This location is a popular fishing area because of the fine bass habitat afforded by an abundance of submerged stumps and logs. More observant boaters and fishermen might wonder at the presence of a single cypress ghost still standing here almost 3/4 mile from the nearest landfall (Figure 1). Examination of early maps and navigation charts reveals that these snags are all that remain of Batts Island. In 1749 Batts Island was occupied by houses and orchards and was 40 acres in area.

The Comberford map of 1657 (Figure 2) identifies this island as Hariots Island, presumably in honor of the naturalist-surveyor Thomas Hariot, who accompanied the Grenville Expedition to Roanoke Island in 1585. On this same map the representation of a house located near the mouth of the Roanoke River is identified as 'Batts House'. Captain Nathaniel Batts, 'Governor of Roan-oak', was the first Virginian known to have established a permanent residence in the Albemarle region. Captain Batts later purchased land east of Yeopim River, and it seems likely that he lived out his life in that vicinity. In any event, Hariot's Island is labeled Batts Grave on the Moseley map of 1733.

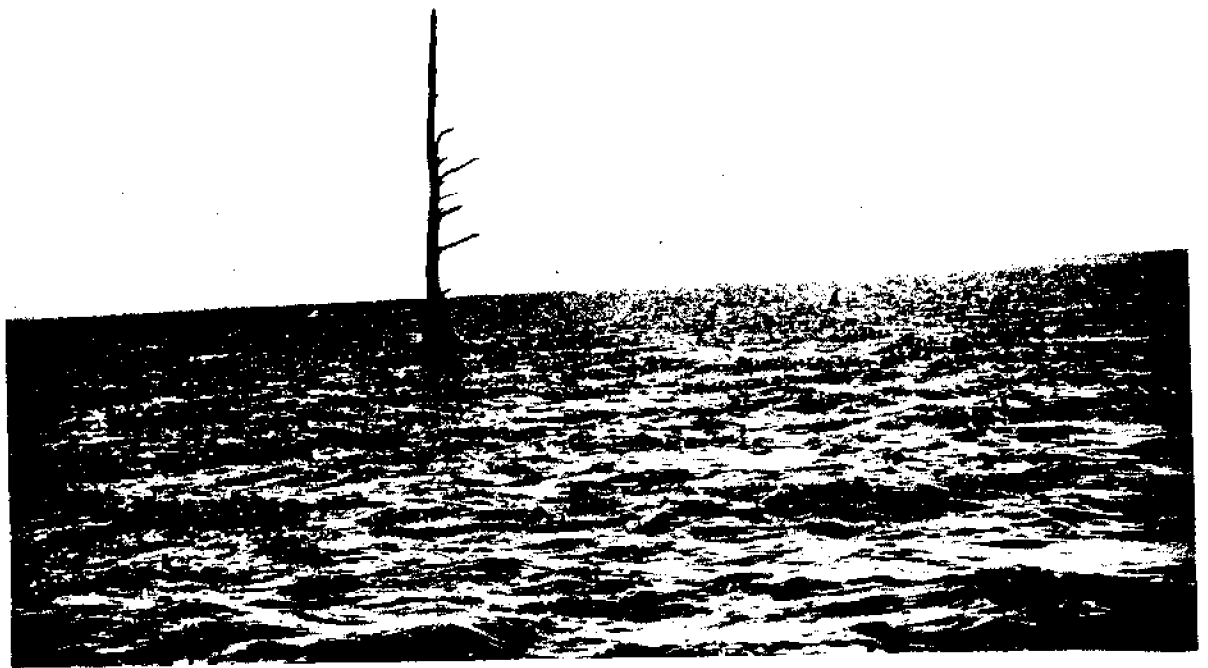


Figure 1. A lone cypress snag, now located three-quarters of a mile off the Perquimans County mainland in Albemarle Sound marks the site of Batt's Grave Island. Noted on early maps of the Albemarle Region, this island disappeared sometime in the 1950's.

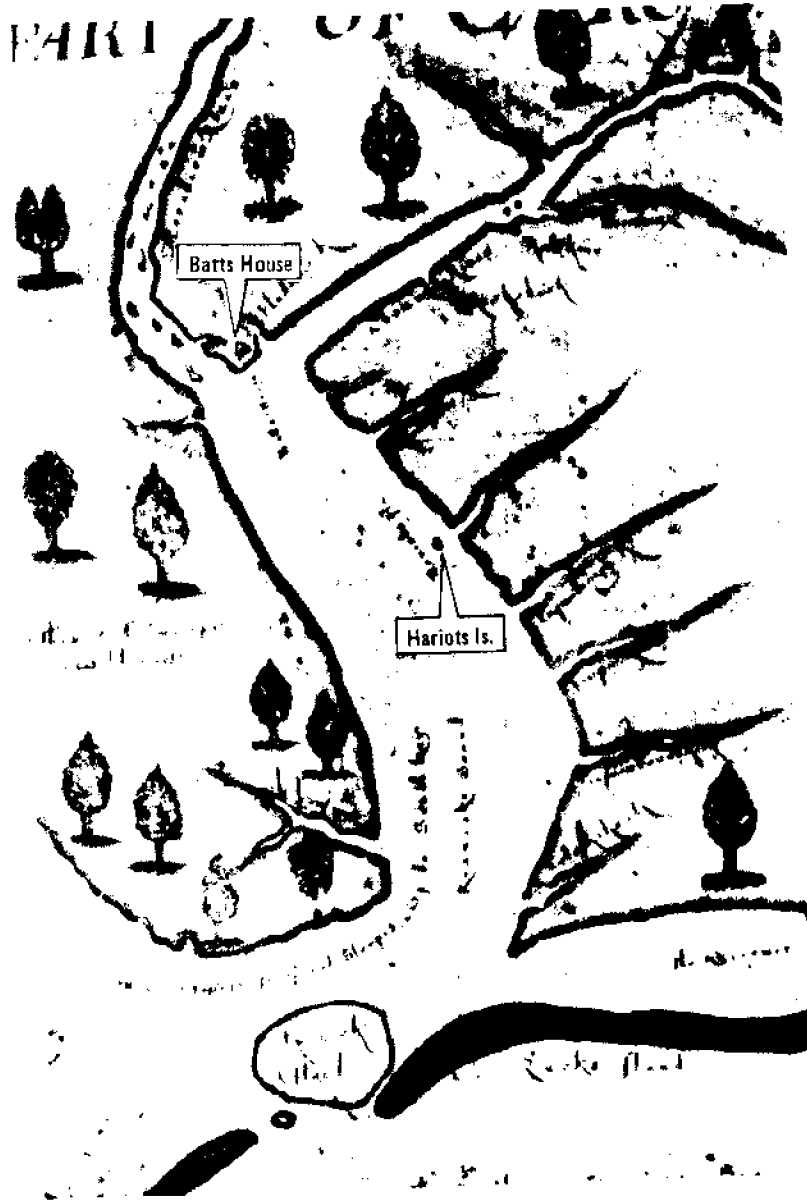


Figure 2. The Comberford Map of 1657 shows 'Batts House' at the confluence of the Roanoke and Chowan Rivers. 'Hariots Is' appears as a triangular dot off the mouth of Yeopim River.

According to the N. C. Gazeteer published in 1968 Batts Island (or Batts Grave) was 40 acres in area in 1749 and had houses and orchards on it; by 1756 it had been reduced to 27 acres. Early in the twentieth century it was a campsite for fishermen, but in recent years had been reduced to a mud flat with a few dead trees. A hurricane in the 1950's completely destroyed the island. Based on the 1849 U. S. Coast and Geodetic Survey Smooth Sheet of the area (Figure 3) we have estimated the area of Batts Island at that time to have been approximately 10 acres. The 1915 USC & GS Smooth Sheet (Figure 4) indicates that only a small portion of the original island remains. The 1974 USC & GS Navigation chart indicates only shallow shoals at the site (Figure 5). Shoreline erosion in the Albemarle Sound region can thus be documented from the early colonial period right up to the present.

Today a comparable island, Indian Island, lies about a mile offshore in the Pamlico River near South Creek (Figure 6). Soil and Water Conservation Service data shows an average shoreline loss for Indian Island of 102 feet between 1938 and 1970. At the present rate of erosion (3.2 feet per year) Indian Island can be expected to disappear in about 150 years.

The disappearance of Batts Grave and other islands shown on early maps indicates that estuarine shoreline erosion was occurring even before man began modifying drainage and shoreline through agriculture, forestry, and development.

Recently several attempts have been made to measure estuarine shoreline erosion rate at selected points. Unfortunately adequate documentation, in the form of air photos, is available for only the last 30-35 years. Estimates of erosion rates based only on comparison of old and new photos cannot be assumed to represent long term trends for planning purposes. Some evidence suggests that

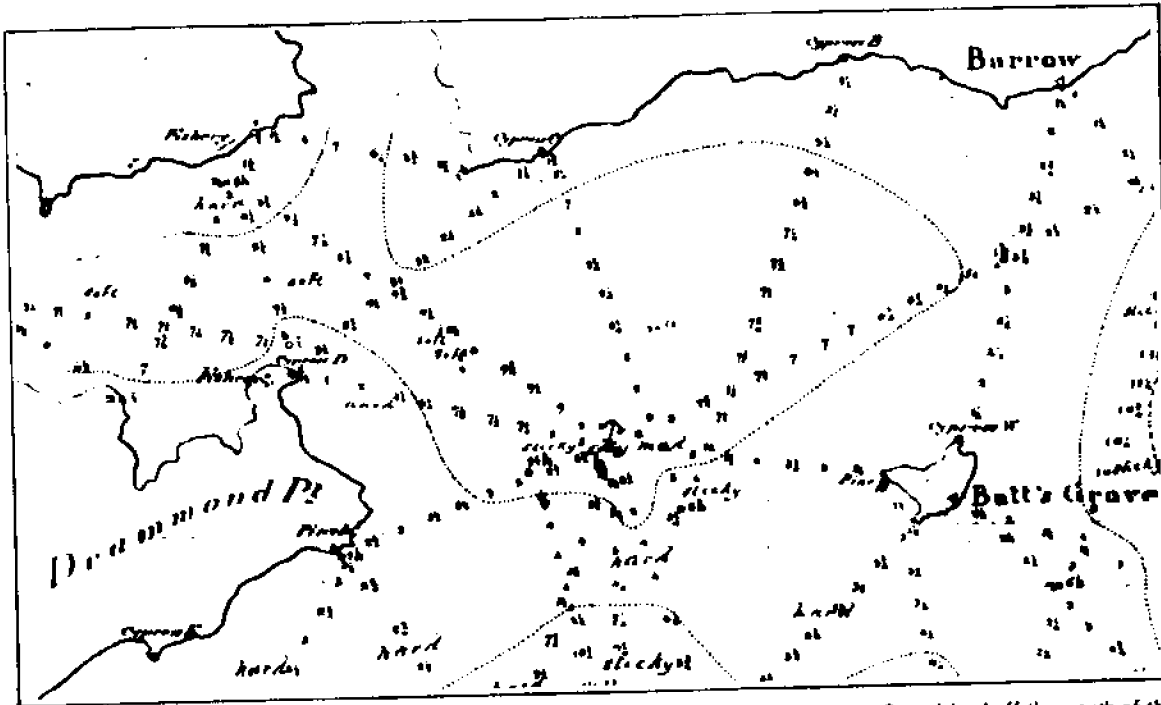


Figure 3. This U. S. Coast and Geodetic Survey smooth sheet, prepared in 1849, shows Batts Grave Island off the mouth of the Yeopim River in Albemarle Sound.

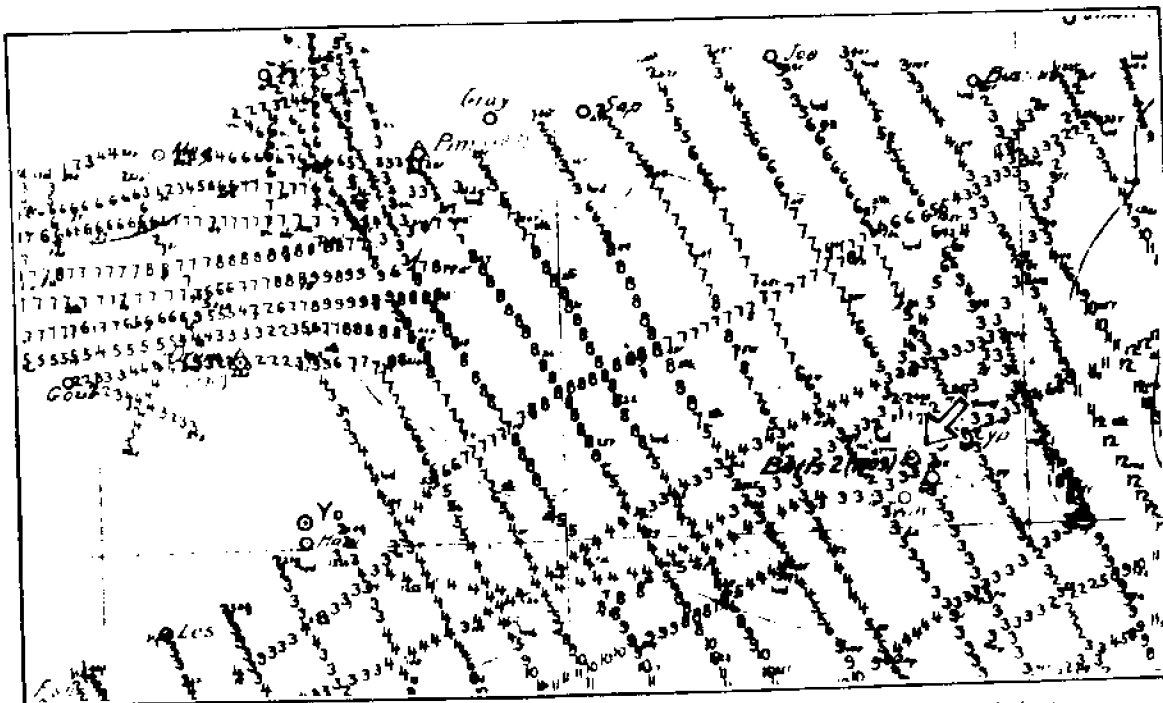


Figure 4. Batts Grave Island has all but disappeared on this 1915 U. S. Coast and Geodetic Survey smooth sheet.

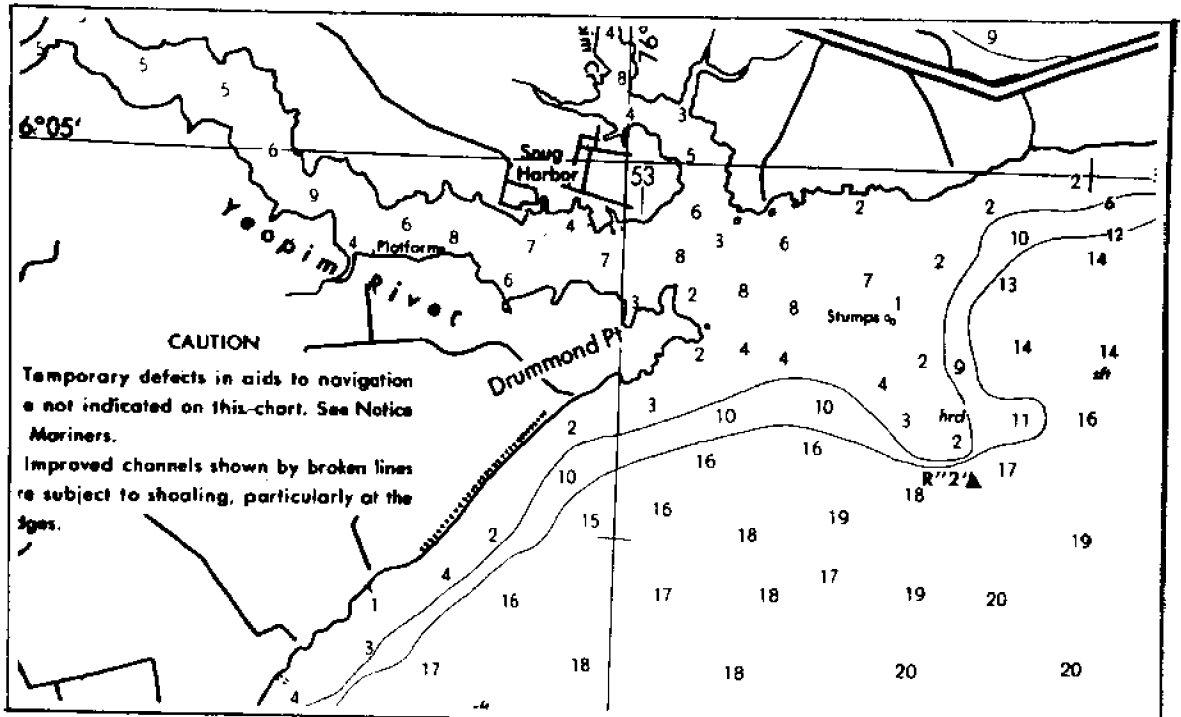


Figure 5. The 1974 navigation chart published by the U. S. Coast and Geodetic Survey indicates only shallow water and stumps at the site of the former Batts Grave Island.

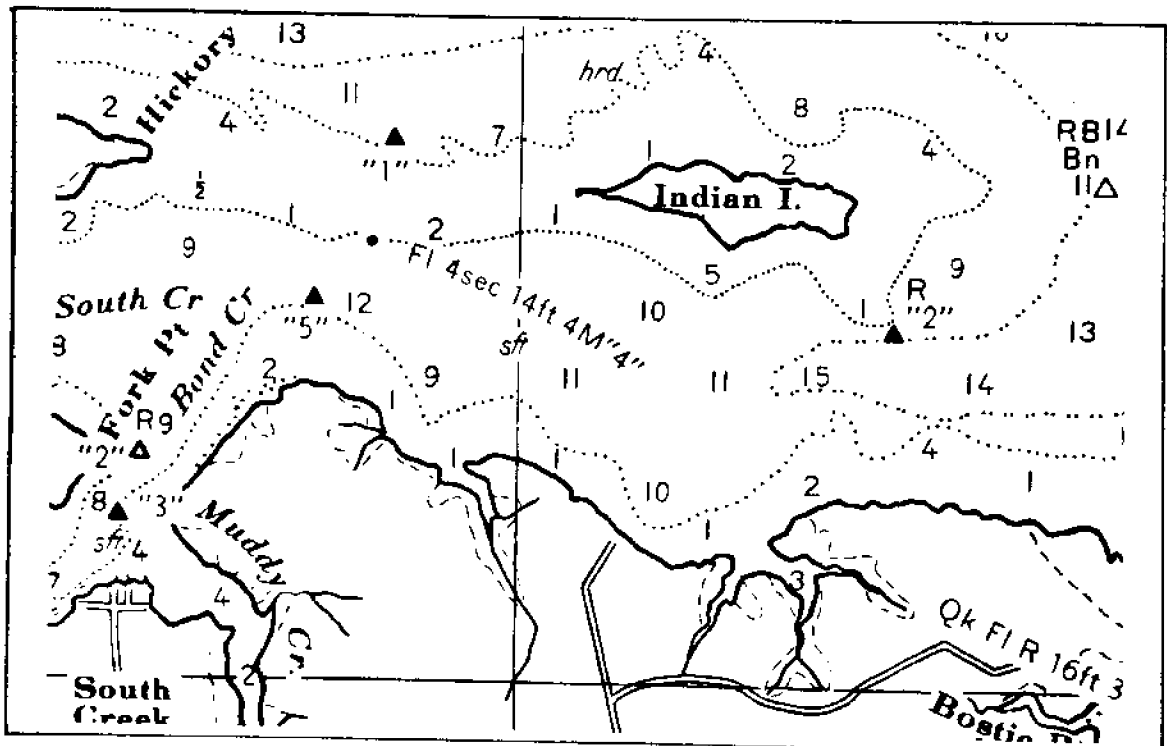


Figure 6. Indian Island, located in the Pamlico River is currently eroding at a mean rate of 3.2 feet per year around its entire perimeter. At this rate of erosion, Indian Island should disappear in about 150 years.

erosion severity may vary with geological and climatological periodicities such as rate of sea level rise, sinking or rising of the earth's crust, and storm frequency. Local variables may control erosion rate at a particular site. Erosion is slowed by the presence of iron-cemented sandstone or clay at the waterline. Logging of the shoreline cypress fringe during the early 1900's exposed formerly protected sand-clay bluffs to increased wave cutting. In some instances ditches draining cropland have been cut perpendicular to the shoreline and result in gully erosion along the riverbank.

All available data indicates a pattern of general erosion. The actual rate of erosion may vary widely along adjacent segments of the shore. There are even isolated instances of temporary beach build-up. Man and nature have scarred the earth and in so doing, both have left an historical record. Interpretation of this record as history can give modern man the advantage of foresight in his future interactions with a slowly flooding landscape.

Shoreline Types and Processes

Three general shoreline types and five subtypes have been established for the Albemarle-Pamlico region (Table 2, p. 17). Classification criteria include slope characteristics and conspicuous vegetative cover.

Sand and Clay Banks

Shorelines consisting of various layers and mixtures of sand, silt, and clay comprise only about one-third of the Albemarle-Pamlico estuarine shoreline, yet they must accommodate virtually all shoreline development. Erosion rates and general developmental suitability are extremely variable within each major shoreline category. Such variability can be considered as a function of

- (1) primary or internal factors such as bank height and composition, and
- (2) secondary or external characteristics such as offshore bathymetry (water depth), fetch (expanse of open water in front of beach), exposure (to prevailing winds), tidal variation, and currents. With few exceptions, almost all of the primary shoreline characteristics were produced by the great Ice Ages which shaped most of the world's shorelines during that period of earth history known as the Pleistocene Epoch. The formation and southward advance of continent-sized, mile-thick plates of ice in the Northern Hemisphere during the Pleistocene was accompanied by world-wide lowering of sea level, perhaps as much as 400 feet. Conversely, the retreat and melting of these ice sheets brought about a world-wide rise in sea level, sometimes exceeding that of the present level. Such advance and retreat of the glacial ice has occurred four times during the last 400,000 years (Figure 7). Presently sea level continues to rise at a rate of 0.5 to 1.5 feet per century.

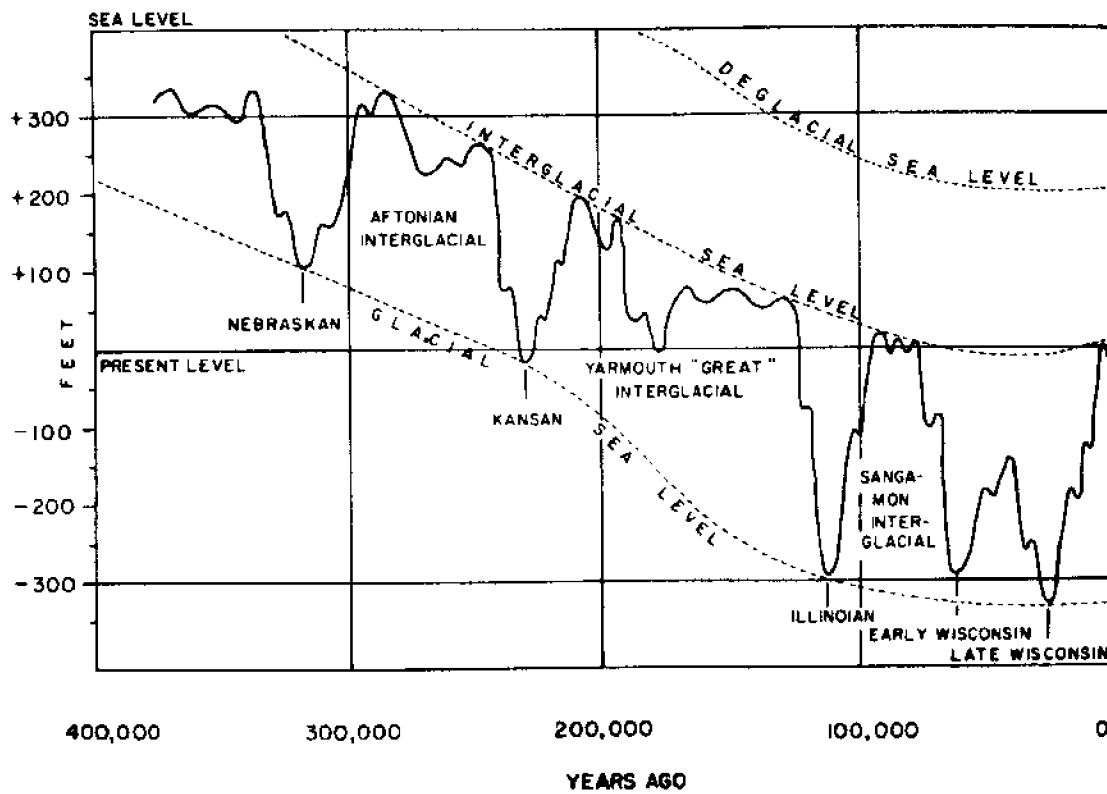


Figure 7. The figure reproduced here (after Fairbridge 1960) indicates that the sea has advanced and retreated on at least four separate occasions during the last 400,000 years. (Recent data suggests that these events actually occurred over a period of 1.5 to 2.0 million years ago.) Sea level is currently rising at a rate of 0.5 to 1.5 feet per century, thus continuing a trend established about 18,000 years ago.

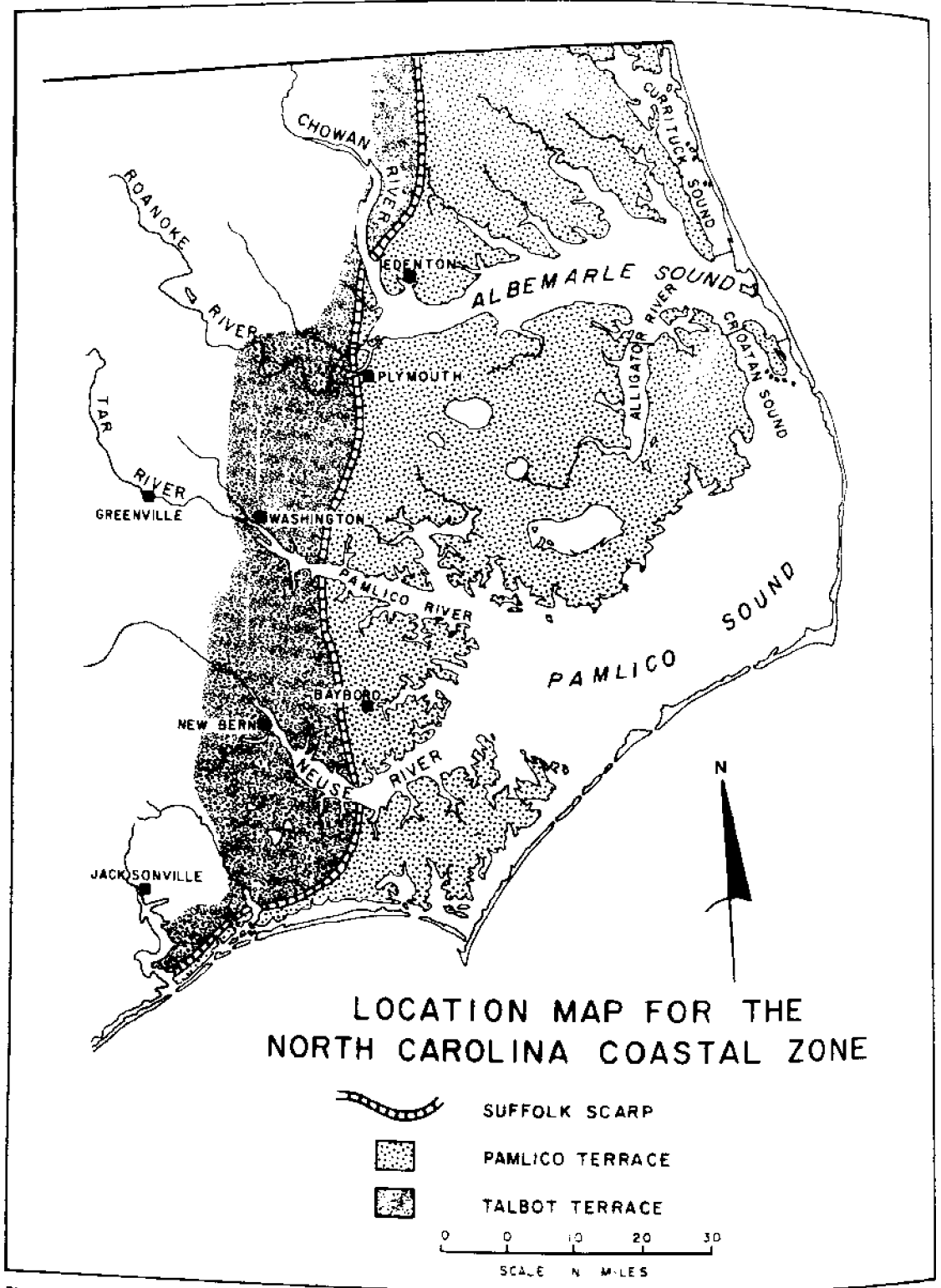


Figure 8. The Suffolk Scarp separates the upland Talbot Terrace from the lower Pamlico Terrace. High banks and bluffs are predominant west of the escarpment while low banks and marshes predominant to the east.

In the North Carolina estuarine region the advance and retreat of the ice sheets is recorded in the form of ancient shorelines and marine sediment deposits which are found far inland from today's Outer Banks. Most conspicuous among those ancient features is a prominent ridge or scarp traced throughout northeastern North Carolina known as the Suffolk Scarp or Pamlico Shoreline (Figure 9). The Suffolk Scarp is considered to be a remnant shoreline of the sea which formed during the Sangamon Interglacial (Figure 7) about 100,000 years ago. The foot of this scarp lies at elevations of 15 to 20 feet while its crest ranges up to 40 or 50 feet above present sea level. The term 'scarp' is in most places misleading, for the break in elevation is far from steep and, at best, is perceived as a gentle slope. East of the scarp, elevations are very low averaging less than 10 feet. This gently sloping surface is known to geologists as the Pamlico Terrace and consists of fossiliferous marine sands and clays deposited during the Sangamon when the sea was washing the Suffolk Scarp shoreline. Today the Suffolk Scarp is 20-25 feet higher than present sea level. An irregular, stream dissected surface averaging 40-50 feet in elevation extends west of the scarp. This surface is known as the Talbot Terrace and, like the Pamlico, consists of fossiliferous marine sands and clays. The age of the Talbot deposits is uncertain but they probably represent sea floor deposition from an interglacial prior to the Sangamon when sea level was higher, and the shoreline was even farther to the west. These three units: the Talbot Terrace, the Suffolk Scarp, and the Pamlico Terrace dictate the primary or internal controls over shoreline erosion in North Carolina estuaries. On the basis of these controlling factors three subtypes are recognized for the sand and clay banks; they are: 1) low bank, 2) high bank and 3) high bluff. Each subtype possesses different erosional characteristics or potential and must be considered separately.



Figure 9. Low bank about 1-2 feet above water level along Chowan County side of the Chowan River. Although this area is subject to flooding by storm tides, erosion is minimal.



Figure 10. Severely eroding sandy-clay low bank. Eighteenth Century farm home on the north shore of Albemarle Sound in Chowan County faces imminent destruction near Drummond Point.

Low Bank

Low bank shorelines are defined as those sand and clay shorelines which have 1 to 5 feet of relief above sea level (Figures 9 and 10). They are the most abundant of the sand and clay bank shorelines and with the exception of restricted intervals around creek mouths occur only east of the Suffolk Scarp. Low Bank shorelines generally consist of a moderately cohesive mixture of medium sand, silt, and clay, and quite commonly have a clay-rich layer which occurs at or just below the water level (Figure 11).

The low bank shoreline is moderately to highly susceptible to erosion (Table 3, p. 17). Generally speaking, the narrower the beach and the steeper the bank the more active the erosion. Vertical to somewhat undercut banks (2-5 foot) with exposed root masses and seaward falling shrubs and trees are signs of rapid erosion (Figures 12 and 13). Vegetated gentle slopes with small seedlings growing in loose sand accumulations, on the other hand, reflect negligible erosion or even shoreline build-up (Figure 14). Those low banks which have only 1-2 feet of relief may differ in their erosional characteristics in that the trees will fall landward as the seaward side of the root base is eroded and onshore winds topple them over.

Low bank shorelines offer easy access to the estuary and thus are most important to both the commercial and private sectors. In areas where low bank shorelines are not extensive, conflict of usage can arise. Simple bulkheading is generally sufficient to protect the low bank shoreline from erosion with only minimal grading or backfilling required. An alternative to bulkheading, however, is sometimes possible. Undeveloped low bank shorelines commonly exhibit natural phenomena or processes which serve to check or at least retard shoreline erosion. Fringing stands of cypress or grass have a damping effect on incoming



Figure 11. A moderately erosion resistant layer of clay or clayey sand is frequently encountered at the waterline along the **low** bank. Photo taken near Drummond Point in Chowan County, North Carolina.

Table 2

Estuarine Shoreline Classification for the Albemarle-Pamlico Region of North Carolina

I. SAND and CLAY BANK	II. SWAMP FOREST	III. GRASS MARSH
A. Low (1-5 feet)	A. Cypress fringe (Taxodium distichum)	A. Smooth cordgrass (Spartina alterniflora)
B. High (5-20 feet)	B. Cypress-gum river swamp (Taxodium distichum, Nyssa aquatica)	B. Black needle rush (Juncus roemerianus)
C. Bluff (greater than 20 feet)		

Table 3

Susceptibility of various shoreline types in the Albemarle-Pamlico region to erosion (estimates based on data supplied by Soil Conservation Service, U.S. Department of Agriculture and field observations by the authors made during 1975).

SHORELINE TYPE	EROSION RATE (ft./yr.)	
	(protected)	(exposed)
I. Sand and Clay Banks		
A. Low Bank	1	3-8*
B. High bank	1	2-5*
C. Bluff	1/2	1-2
II. Swamp Forest	(negligible)	(negligible)
III. Grass Marsh	2	6-20

* Cropland generally more susceptible to erosion than forested land.

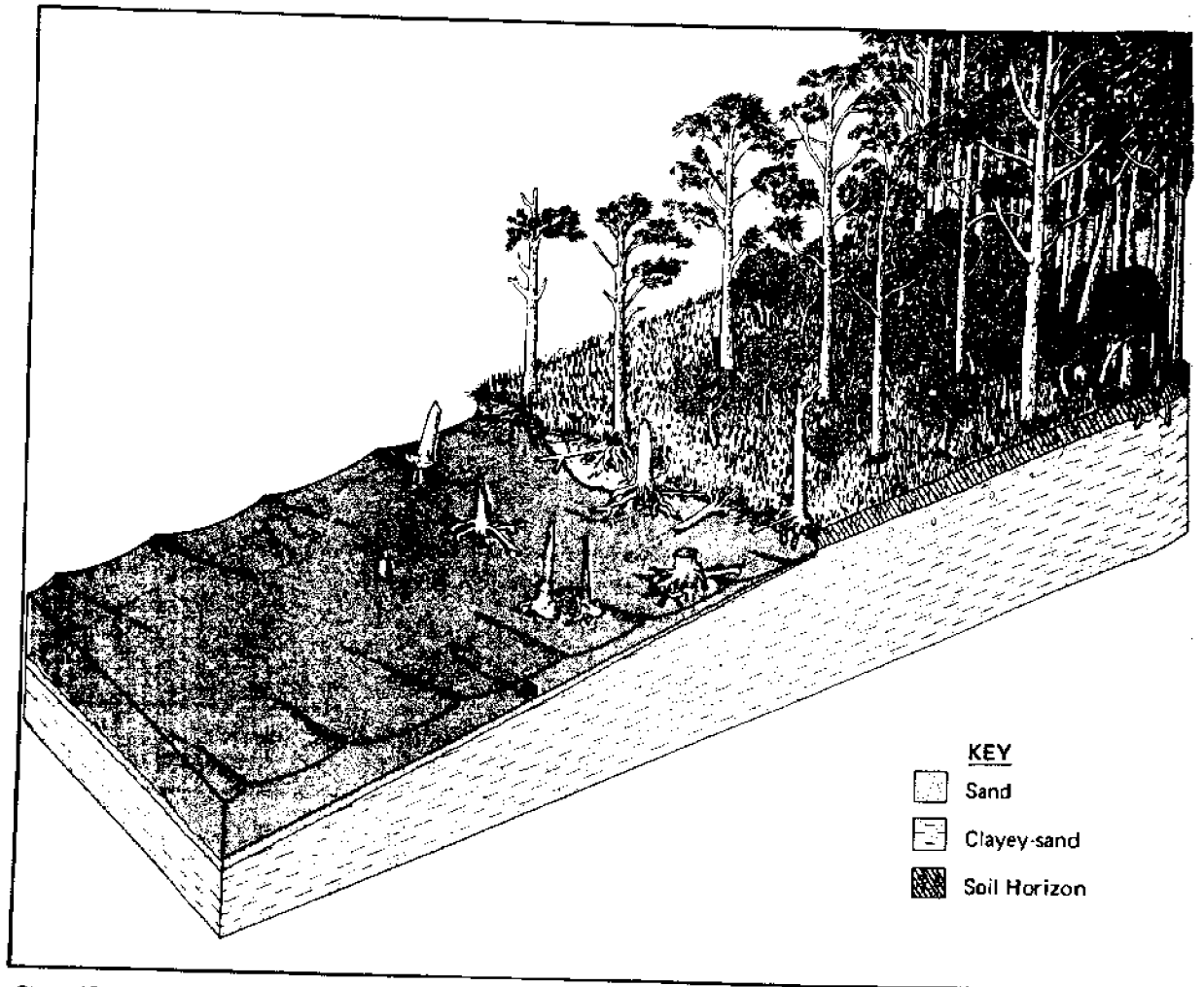


Figure 12. Erosion of the low bank often involves drowning of pine forest and subsequent invasion by marsh grasses. Decaying pine stumps, still in growth position several yards out into the river, indicate that this forest is slowly yielding to rising water level.



Figure 13. Rapid erosion occurs wherever the low bank contains a high sand content. Concave banks undercut the trees and they are blown over into the water by strong offshore winds. Such wind-thrown timber may act as a natural groin with the sediments captured tending to retard further erosion. Photo taken near Greenfield Plantation, Chowan County, N. C.

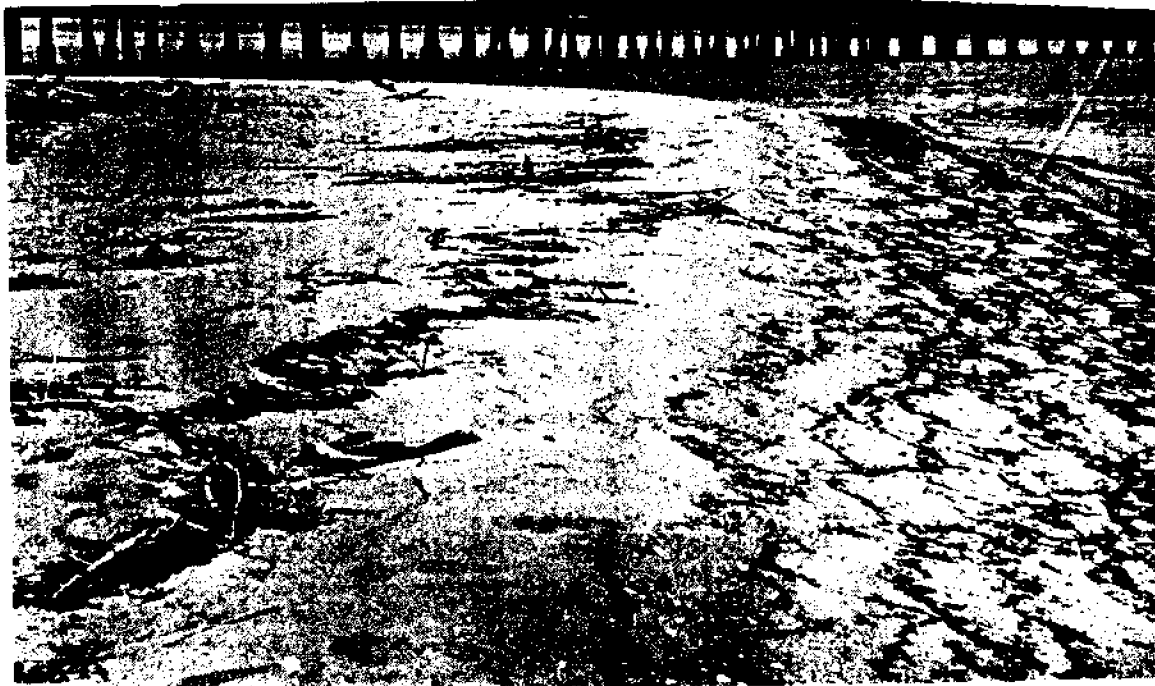


Figure 14. Accretion or beach build-up is only rarely observed along North Carolina estuaries. When accretion does occur, it appears to result from some major structure which behaves as a groin. In this case the 'groin' is the western portion of the U. S. Highway 17 Bridge across the Chowan River. Photo taken near Eden House, Bertie County, N. C.

waves and retard bottom sediment transport offshore. This phenomena is obvious, extremely important, and is discussed more fully elsewhere in the text. Less obvious is the role of fallen trees, stumps and debris which accumulate in front of the retreating shoreline. Most new shoreline property owners fear such accumulations as "snakey places", harbingers of erosion, and, as obstacles hazardous to boating and swimming they strive to remove all of them as quickly as possible. This practice should be reconsidered because, in its fallen state, the tree is even more effective than the living tree at slowing erosion. The mechanism is simply that of acting as a natural groin or underwater sediment trap which collects eroded bank sediment and slows or prevents its transportation out of the area. Similarly, the shoals that often occur in front of eroding shorelines should also be considered as an erosion limiting factor. If soils from recently eroded banks are not carried away by currents they tend to accumulate as nearshore sand bars. More of the wave energy thus becomes dissipated offshore thereby reducing the rate of shoreline erosion. Projects, such as harbor construction, channel dredging, and beach nourishment which take sand from the immediate offshore area will permit higher energy waves to reach the shoreline, thus accelerating erosion. In view of the above a strong case can be made for leaving some shorelines in as natural a condition as possible, thereby postponing or possibly eliminating the need for costly bulkheading.

High Bank

High bank shorelines are those sand and clay shorelines which have 5-20 feet of relief above sea level (Figure 15). High banks occur throughout the estuaries but are most commonly associated with the Suffolk Scarp and the Talbot Terrace (Figure 8). They consist of moderately to occasionally well-hardened mixtures of

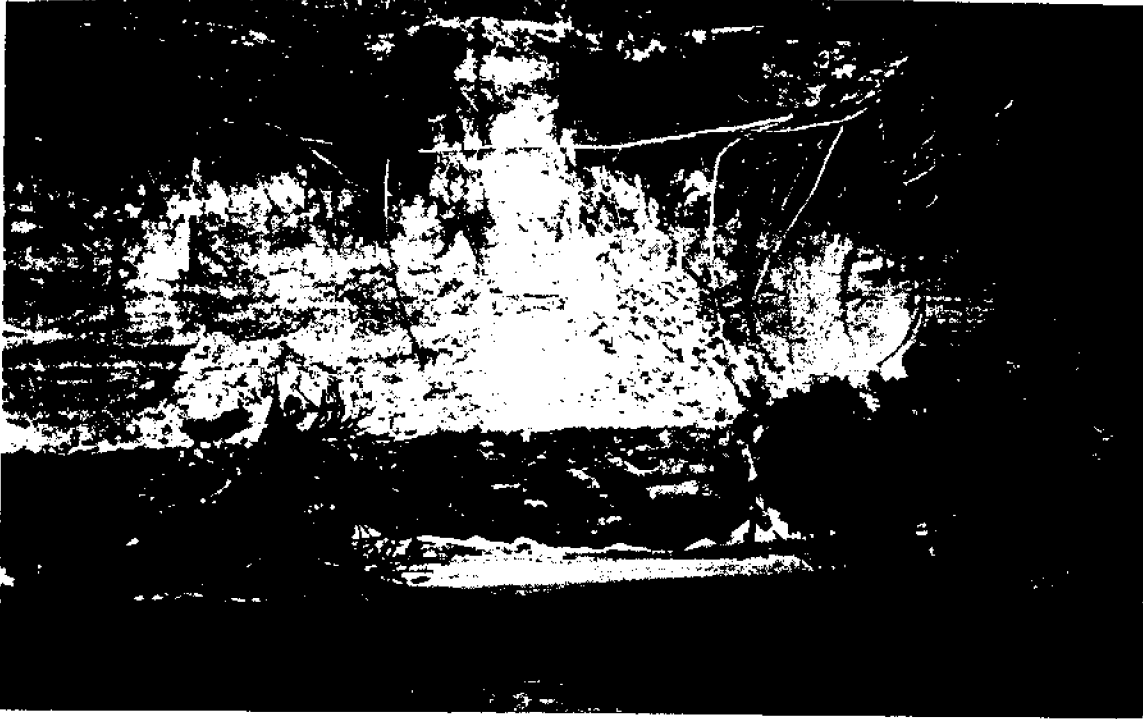


Figure 15. High bank shoreline along the east side of the Chowan River, Chowan County, N.C. Note darker iron-stained clay layer at bottom and bedded layers of sand above. Surface soils are held together by the root mass and form a curled lip at the bank face. On the right two trees have recently fallen onto the beach and another appears about ready to fall.



Figure 16. This zone of bedded clays in the high bank along the base of the riverbank offers some resistance to erosion. It is also the source of the light colored suspended sediments which cause the near shore waters to appear chalky during storms.

sand, silt and clay. In isolated areas west of the foot of the Suffolk Scarp, extremely resistant cliffs of clay, clayey sand, and iron-cemented sand make up the base of the high bank (Figure 16). The top of these resistant deposits is generally less than 8 feet above water level, and commonly, the deposits contain abundant fossil marine shell material. Most of these exposures are the uppermost units of what is known as the Miocene Yorktown Formation, while some are probably younger Pleistocene deposits. The Yorktown Formation is a highly fossiliferous marine clay and sand deposit which was deposited over much of Eastern North Carolina during the Miocene Epoch several millions of years ago.

The presence or absence of hardened Miocene or older Pleistocene deposits is an important factor when considering the erosion potential of the high bank shoreline. If they are absent, the shoreline is subject to moderate or severe erosion at rates comparable to those for the low bank, and protective measures are often necessary (Table 3). If they are present, then erosion is extremely slow due to the resistant nature of this well-packed, semi-cemented, clayey material and protective measures are generally unnecessary (Figure 17). Whenever sands overlying the Miocene clays are water bearing, this often leads to slumping or caving of the overlying units.

Evidence for erosion in the high banks is similar to that for the low banks except that it is much more dramatic. Huge slump blocks of sand, clay and topsoil, often carrying clumps of trees and shrubs, cascade slowly down the slopes to melt in the encroaching sound and leave behind sun bleached skeletons of trunks, limbs, and stumps to litter the waters edge (Figures 18 and 19).

High bank shorelines offer some problems in terms of access to the beach and are generally less suitable than low bank shorelines for water-based commercial use. They are, however, highly desirable for permanent and second homes because



Figure 17. Bedded and iron-cemented clays at the base of this high bank on the eastern shore of the Chowan River provide moderate resistance to erosion.

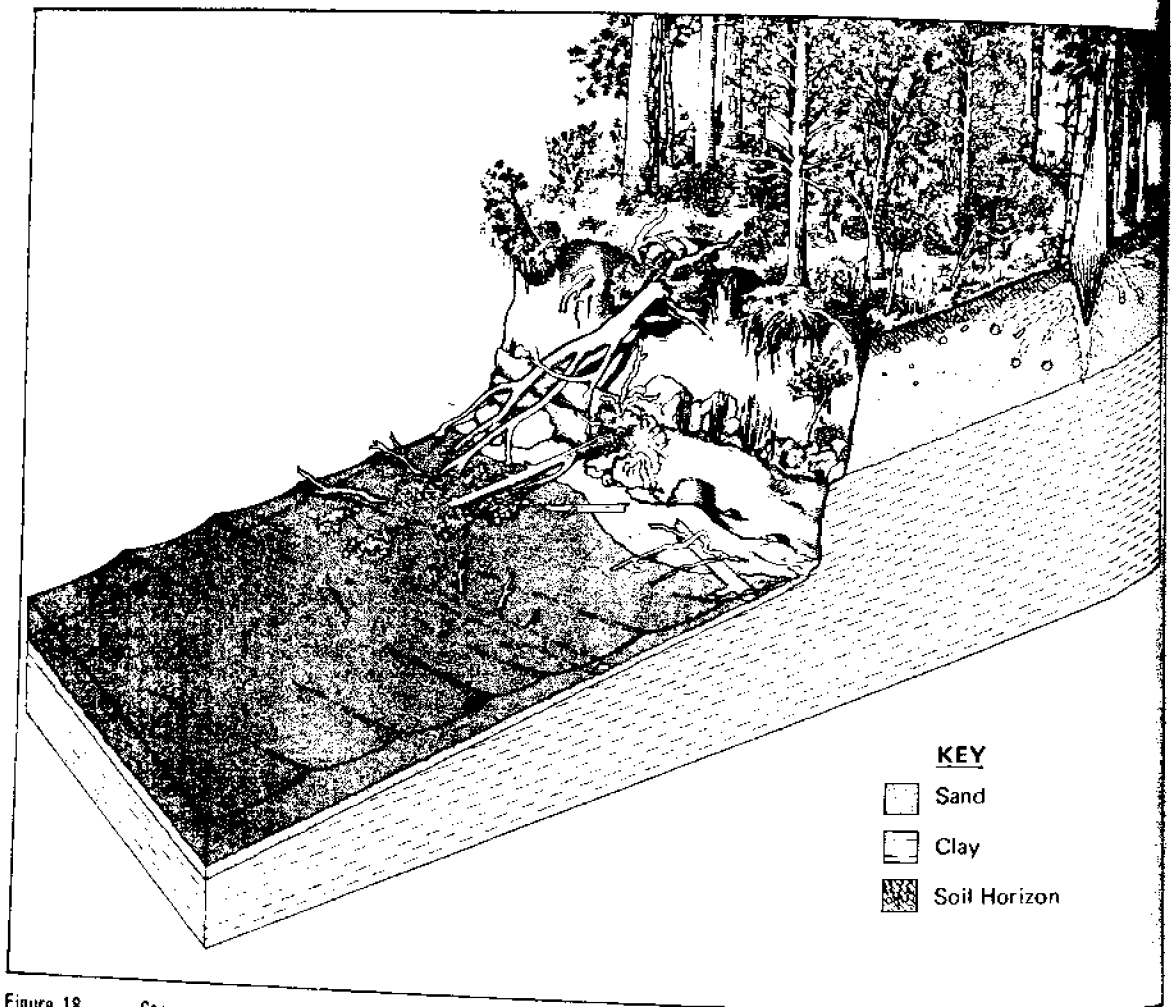


Figure 18. Storm waves undercut the high bank causing slump blocks, along with their vegetative cover, to slide onto the beach. Here the slump blocks are reduced by further wave action, leaving behind accumulations of fallen timber.



Figure 19. Eroding high bank. Compare with diagram (Figure 18) and note trees, shrubs, and root masses littering the sandy beach. Undermined trees usually slip onto the beach along the high bank. Photo taken at Drummond Point, Chowan County, N. C.

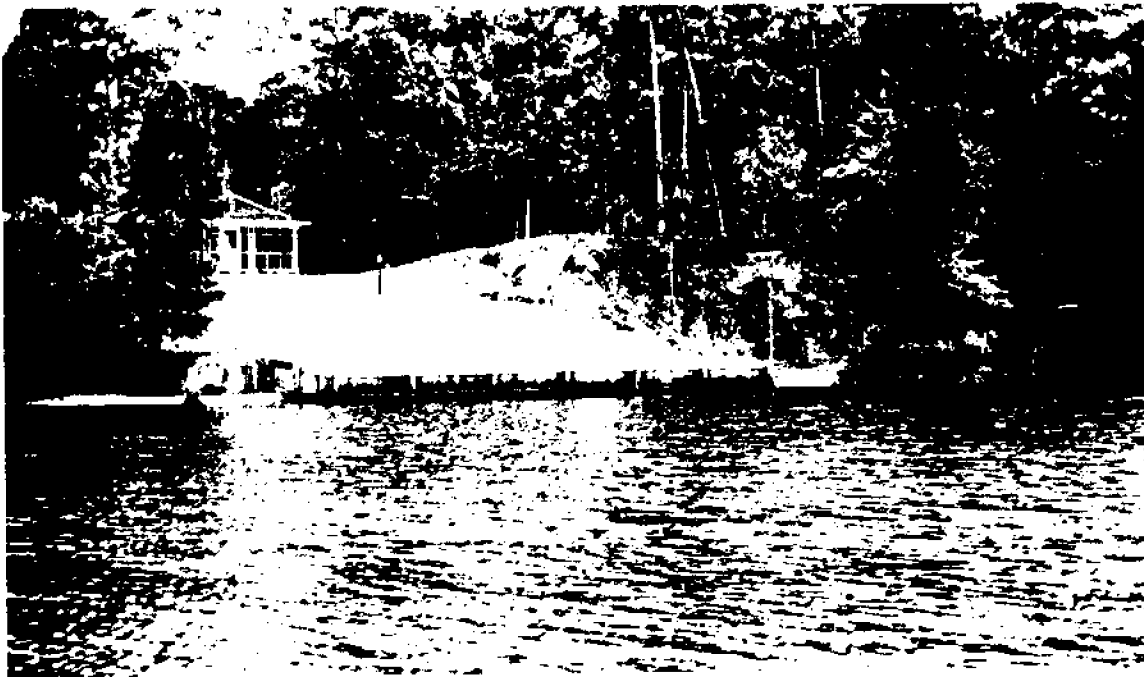


Figure 20. Protection for the high bank is most often achieved through installation of a treated wood bulkhead placed several feet out beyond the shoreline. The bank is then pushed down into the void created and leveled to a desired grade. The cumulative effects of extensive bulkheading may include permanent loss of sandy beaches and shallow water habitat.

of the extended view and apparent sense of security afforded by 'high land'. Unfortunately, this sense of security often turns out to be false, a fact discovered only after the lot is purchased and construction completed.

Protective measures for high bank are more difficult to install and more costly than for the low bank. Creosoted wooden bulkheading is the favored method, coupled with extensive bulldozing and grading of the high bank down to the top of the (3 to 5 foot) low bulkhead (Figures 19 and 20). The problem that exists with this practice is that, in the past, property owners have been allowed to put the bulkhead well out into the water beyond the natural shoreline and then use the bank to fill in behind. The advantage of such procedures is obvious; an increased lot size for 'free'. However, such installations are disruptive to the natural shoreline energy system and can lead to accelerated erosion of adjacent, unprotected shorelines. Although such practice has been largely stopped by existing dredge and fill requirements, it should be prohibited permanently. The discussion of natural shoreline erosion limiting processes considered under low bank shorelines applies to the high bank shorelines as well. In fact, since manmade protective measures are more expensive and difficult for the high bank shorelines, the natural processes should be considered carefully as a reasonable alternative.

Bluff

Bluff shorelines are those sand and clay shorelines which rise higher than 20 feet above the water (Figure 21). They are the least abundant yet at the same time the most spectacular of the shorelines to be found along the North Carolina estuaries. Most occurrences are within the Suffolk Scarp, however some may be related to the Talbot Terrace. The highest banks occur on the Bertie County side

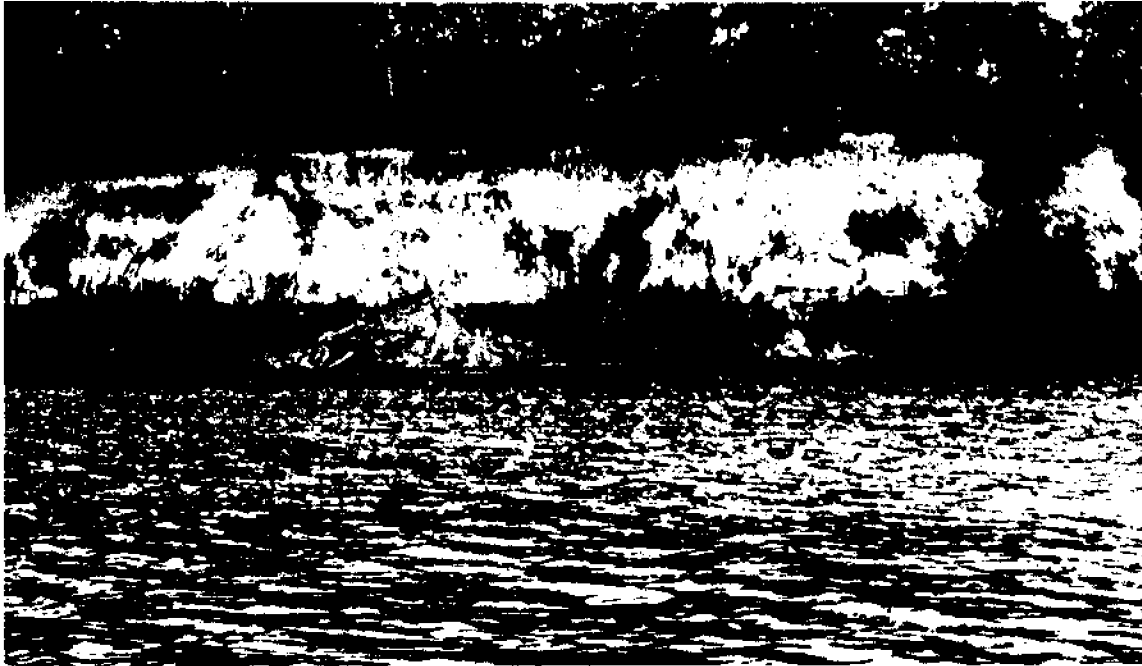


Figure 21. Spectacular bluff shorelines, rising abruptly to twenty feet or more, occur only west of the Suffolk Scarp. Bluff erosion is an important source of fresh sediments for sandy beaches; and, although considerable vertical bank may be lost each year, the actual shoreline loss in linear feet is often quite low. Photo taken along western shore of the Chowan River, Bertie County, N. C.



Figure 22. Bluffs can be protected from wave erosion by bulkheads, however this practice does not stop slumping and erosion by wind and rain. Access to the beach may be difficult but this is compensated for by the spectacular view. Removal of protective vegetation may accelerate wind and rain erosion.

of the Chowan River. Here long stretches of shoreline persist with bank heights rising 30 to 40 feet or even higher. Compositionally, the bluffs are the same as the high banks except that the base of the bluff shoreline is much more likely to consist of the hardened Miocene clays and sands. This is fortunate for landowners choosing to build on these shorelines because of the additional expense and effort necessary to bulkhead at the base of a 40 foot cliff.

Bluff shorelines are unsuitable for most commercial ventures with perhaps the exception of restaurant or resort facilities capitalizing on the view. They are, however, highly desirable for homes and cottages even if access to the water is very difficult, or, as in some cases, impossible (Figure 22). Bulkheading and bulldozing, as described under high bank, to obtain waterside access is unfeasible and destroys the overall aesthetics of this very unique shoreline; it should be prohibited. There really is little that can be done to check erosion on these shorelines without the investment of considerable effort and money; thus, the requirement of setbacks should be considered carefully. To an even greater extent than the high bank, the bluff shoreline offers a sense of false security to the prospective cottage or home builder. It is true that on the bluff one is removed from the water; however, this is only a vertical separation and undercutting and slumping continue to cut back the cliff. Fortunately, the rate is somewhat slower since a much greater volume of eroded sediment is produced with each foot of eroded bank face (Table 3).

Bulkheading and other protective measures can be installed from barges on the water, but maintenance is difficult and costly. Perhaps an even more important reason for establishing setback regulations rather than implementing protective measures lies in the aesthetic qualities of the natural cliffs

themselves. They are geologically unique and should definitely be considered for protection as Areas of Environmental Concern.

Swamp Forest

The bald cypress bearing its gray mantle of spanish moss is symbolic of southern river swamps (Figure 23). In northeastern North Carolina swamp forest occurs abundantly along river floodplains and their tributaries. Where these forests broaden into estuaries, as at the mouth of the Roanoke, Chowan, or Pamlico rivers, a fringe of nearly pure cypress continues along the tidal wash zone between low tide and the higher land behind (Figures 23 and 24). Extensive river swamp forests constitute a refuge for mature cypress. Such refuges are a source of floating seeds which may be distributed by river currents to estuarine beaches downstream. Cypress continues along the estuary margin wherever sandy beaches provide adequate light for seed germination together with solid substrate for root anchorage. Cypress cannot establish itself naturally on high energy beaches where the sediments are shifted about so rapidly that seedlings are washed away before they develop firm anchorage. Cypress seeds do not develop in marsh peats and appear to be inhibited by extremely brackish or full strength seawater.

We believe that prior to European influence, large portions of the North Carolina estuarine shorelines with low topography were bordered by cypress fringe or grass marsh. Development of the area since that time has greatly altered this simple vegetative cover pattern. Agricultural development began in the 1660's and continues to be the predominant economic endeavor. Forests were cut right to the riverbank and edge vegetation was removed to provide landings for steamer access. Cypress has long been a choice timber tree because of its resistance to rot and ease of milling. Failure of the Southern Cause in 1865 signaled the end

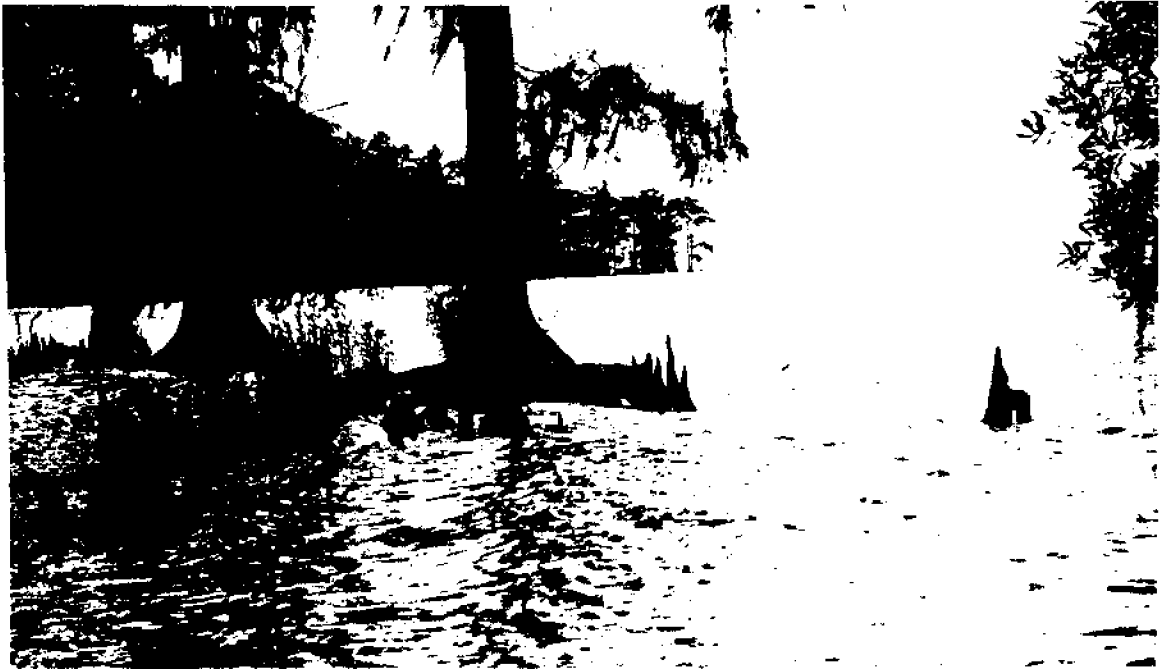


Figure 23. Cypress headlands (background) and cypress fringe (foreground) still occupy significant portions of the shoreline in northeastern North Carolina. Buttressed trunks, knees, and lateral root systems of the cypress form effective natural bulkheads which dissipate the erosive force of waves. Photo taken near Greenfield Plantation, Chowan County, N.C.



Figure 24. Cypress headlands occur at intervals along the estuary. Low shoreline profile together with the ability of bald cypress to withstand permanent flooding combine to produce an area having great natural capacity to absorb wave energy. The Cypress fringe captures sediments carried along the shore by currents. Because permanent flooding stresses the cypress trees, those trees along the outer margin of the fringe typically have bleached leaves and are of smaller stature than trees growing closer to shore. Such stressed trees often exhibit dead or broken tops. Photo taken near Greenfield Plantation, Chowan County, N.C.

the end of 'King Cotton', but a positive effect of that war was expansion and increasing capacity of the railroads. Urban and industrial expansion in the North brought an increased demand for lumber. Railroads provided an economical means of supplying that demand. Between 1870 and 1914-18 great lumber barons dealing in timber, shingles, barrel staves, and veneer brought renewed prosperity to Edenton, Belhaven, and Washington. In 1913 a record of one billion board feet of bald cypress was produced in the southeastern states with comparable annual figures for other years during the early 20th century. Even today files and remnants of huge rotted pilings scattered along our rivers indicate the extent of this once great industry. Clearly, bald cypress and swamp gum were natural resources exploited in return for cultural survival during reconstruction and collapse of the plantation economy in northeastern North Carolina.

Cypress Fringe

If you walk shoreward from a boat anchored just off the cypress fringe, you will first encounter cypress trees with their trunk bases continually submerged in 3-5 feet of water (Figure 25). The trunk base itself is often swollen and fluted to a point several feet above the waterline. Such trees are often noticeably shorter than cypress closer to shore. Frequently their leaves are lighter green, and they bear leafed branches almost to the waterline. Occasionally a sunbleached dead tree or a tree which is green only near its base, and dead above can be seen. Since cypress seeds cannot germinate and develop when fully submerged, such trees must have begun growing when the water level was several feet lower than its present level. When you come in line with the first few trees, glance first to your right and then to your left. Many times this first stand of cypress will line up along a remarkably uniform curved to straight line. Note also the total absence of very young trees. Most trees within the line



Figure 25. This line of cypress trees forms a 'cypress fringe'. These trees remain with their roots submerged throughout the year. Today there is insufficient soil within the fringe area for establishment of cypress seedlings. These trees must have grown from seeds deposited along a periodically submerged beach some time in the past when the mean water level was lower and the shoreline was further out than at present. The average age of these trees divided by the average distance to shore should give an estimate of the actual rate of shoreline erosion at this point. Note the broken top of the tree at center.

seem to be of a similar stage in growth. It seems probable that such a line of cypress indicates the drift line of a former sandy beach which occupied that site when the cypress seeds washed in and germinated. If this is correct, then:

$$\Delta E = \frac{S}{t}$$

where ' ΔE ' represents local beach erosion rate; 't' represents mean age of the cypress trees; and 's' represents distance from the cypress line to the present drift line.

Closer to shore the cypress increase in density as water depth decreases. Broad fluted trunk bases extend laterally and become contiguous with elongated cypress 'knees'. Some knees are firmly anchored by roots while others bob gently with the swell. If you stand at such a point during a storm, you will be impressed by the effectiveness of this natural bulkhead in disrupting wave patterns and damping wave height. This and other functional aspects of the cypress fringe are illustrated in Figure 26.

Storm waves transport suspended sediments from the river bottom and from eroding banks into the cypress fringe. Larger objects including Indian potsherds, stone chips, old bricks, broken bottles, rounded waterlogged wood fragments, and gravel may also be deposited among the cypress roots. Thus, the Cypress fringe functions as a natural bulkhead and groin system capable of dissipating erosive wave energy (Figure 27) and actually accomplishing shoreline accretion. An incoming wave is slowed along one segment as it collides with the cypress trunk. Drag bends the wave such that it tends to wrap itself around the tree. The two 'halves' of this broken wave have now lost some of their energy and are directed on a collision course. Disruption of wave frequency together with loss of energy causes the waves to drop their suspended load along a line between tree and beach. Thus a natural groin is established and maintained (Figure 26).

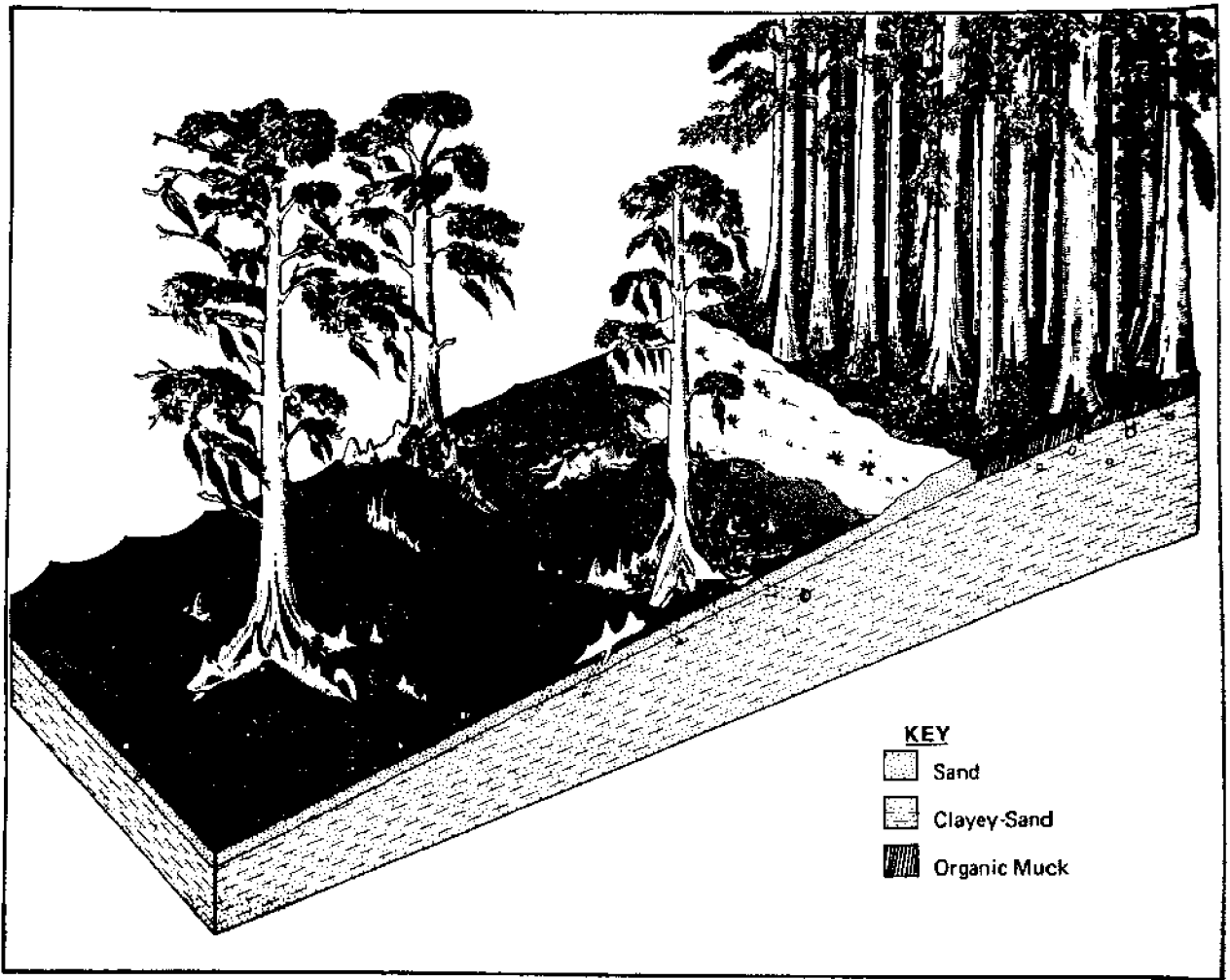


Figure 26. The function of the cypress fringe in damping erosive wave forces and trapping sediments is illustrated in this figure. Basically, the cypress trees form a natural bulkhead which dissipates wave energy and traps sand upon which new cypress trees can become established. Thus, under natural conditions, the cypress fringe perpetuates itself in the face of slow flooding. A detailed explanation of this process is given beginning on p. 34.



Figure 27. Here at Sandy Point on the north shore of Albemarle Sound, the cypress fringe disrupts choppy waves generated across a five mile fetch of the estuary. Note breaking waves at the base of the tree and calmer water on the inside of the cypress fringe. Suspended sediments will drop out in the calmer water. In addition, the cypress fringe collects shoal sands carried along the beach by currents. Logs, leaves, and floating debris are also filtered out and accumulated by the cypress fringe.

Severe storms periodically overrun this natural defense system and deposit excess accumulations of sand above the mean water level along the beach. This creates a low sand berm upon which aquatic weeds and dead branches are deposited by storm driven winds. This drift line of debris retains moisture required for seed germination and initial development of cypress seedlings. Where the cypress fringe is dense the berm is kept in deep shade by the tree canopy, and seedlings seldom survive beyond the first year. Seedling survival is greatly enhanced at sites where the cypress canopy is sparse but where there is still an accreting beach. The cypress fringe thus functions directly in its own rejuvenation in the face of gradual flooding from the sound. It does not stop erosion but simply slows the erosion rate. If the cypress fringe is completely breached the resulting undercut bank and high energy beach cannot support cypress. Storm waves now pound unchecked against the base of devegetated banks and bluffs. The clay fraction washed from the eroded soils is deposited as fine silt in deeper portions of the estuary, while the sands drift with long shore currents to form long bars parallel to shore or shoals off headlands.

River Swamp

In many places relict river channels are being drowned by rising sea level. Low gradient together with generally low elevation cause such areas to flood easily and retain standing water during wet seasons of the year (Figure 28). Probably the most extensive swamp forest in North Carolina occurs at the mouth of the Roanoke River near Batchelor's Bay. Swamp forest also occupies the broad flood plains of the Tar, and Chowan Rivers and their tributaries. Fingers of swamp forest gradually ascend the natural drainage system as sea level rises. Such swamps can be expected to be most extensive east of the Suffolk scarp. West of this boundary drainage gradients tend to be steeper with streams having at



Figure 28. At some points where streams intersect the estuarine shoreline there is a sudden transition from exposed sandy beach to dense swamp forest. Storm waves from the estuary deposit a low sand berm along this interface between swamp and estuary. Cypress seeds germinate and establish new growth along this berm, probably creating a future 'cypress fringe', but they seldom develop to maturity in the dark swamp behind.

least one 'high' bank not suitable for river swamp development. North Carolina rivers tend to undercut their south bank and deposit sands along the north bank. Consequently the largest river swamps occupy former river channels in the broad floodplain north of the present channel. River swamps along the north side of rivers having a base level above sea level have expanded in size as the river channel migrates southward. Thus, the river swamps adjacent to the rivers are being drowned along their entire contact with the estuarine shoreline and migrate upward by lapping over the forested uplands.

Grass Marsh

Marshes are characterized by oxygen deficient, water-saturated peat soils subject to periodic flooding by fresh to brackish water (Figure 29). Marshes are especially abundant on organic soils filling old stream channels.

The rise in elevation of grass marshes is keyed to the rate of sea level rise. Marsh grasses respond rapidly to slight changes in water level. Low water level promotes evaporation and oxidation while high water retards these processes. Salt and brackish grass marshes are very productive of plant material. Under conditions of rising sea level some of this annual production remains in the marsh to form a new layer of peat.

The marsh gradually laps up on forested sandy ridges and eventually buries them beneath peat. This fact is amply demonstrated by the abundance of partially decayed stumps and logs which are continually eroded out of their preserving blanket of peat as the shoreline recedes (Figure 30). As the local watertable rises, forest trees come under increasing stress caused by flooding of their shallow root systems. Wherever the slope is gradual and the elevation low, these trees eventually die and, after a period as a ghost forest of dead timber, fall



Figure 29. Much of the estuarine shoreline in the lowlands east of the Suffolk Scarp is lined with brackish grass marsh. Accumulations of marsh peat to a depth of four feet or more are not uncommon. Living grass roots bind the upper layer of peat into a tough erosion resistant mat which only reluctantly yields to wave cutting. During periods of high wind tide water overflows the marsh, and the grasses absorb wave energy. Marsh peats are eroded when the lower, more decayed, and thus softer peat is washed out during periods of low wind tide. Then the resistant upper layer is undermined and falls away in blocks leaving U-shaped notches along the edge. Deep peats tend to have very soft underpinnings and erode much more rapidly than other types of estuarine shoreline. Photo taken near Kilby Island, Beaufort County, N. C.

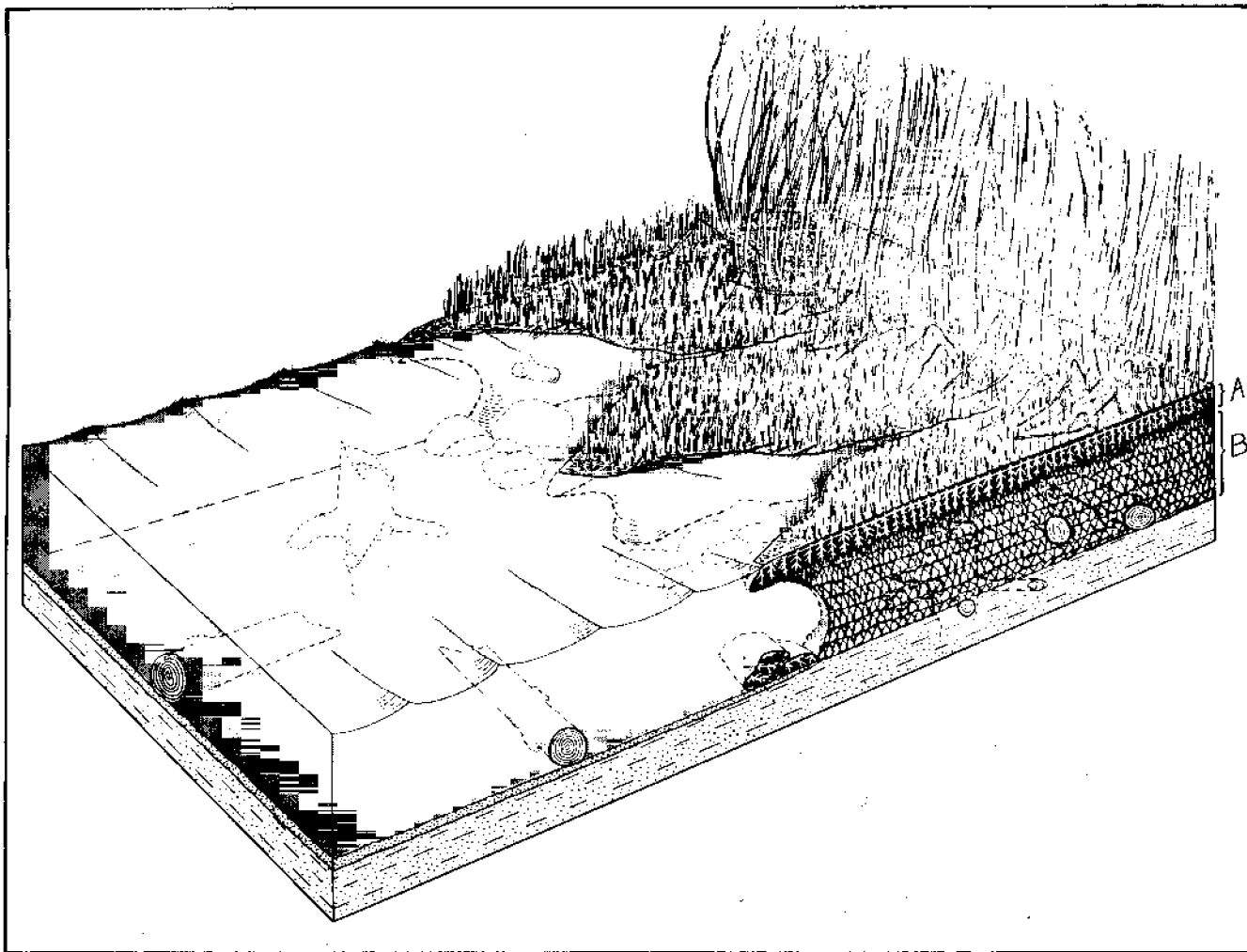


Figure 30. This figure illustrates the factors involved in erosion of the brackish marsh shoreline. During low tide, wave action erodes the softer underlying peat (B), undercutting the firm surface layer (A). The resulting peat shelf breaks into blocks that fall into the water, leaving U-shaped notches along the bank. A detailed discussion of this process begins on p. 41.

into the marsh. Broad fingers of marsh can be seen extending into a forest fringed by bleached and leaning trunks. Vines such as poison ivy, catbrier; and evergreen shrubs such as wax myrtle, and salt myrtle exploit the open, but not yet fully flooded, transition between marsh and forest.

Even as the marsh rises and expands landward, it is being eroded on its flank exposed to wave action. It is not uncommon to step directly from the marsh edge into several (3-5) feet of water (Figure 30). Immediately offshore from the eroding marsh, the bottom is littered with logs, stumps, and blocks of peat dislodged from the marsh flank. The water adjacent to the marsh is often very turbid due to the presence of colloidal or suspended peat. Such areas are typically designated 'foul' on navigation charts.

Newly deposited peat retains much of its matted texture, but, after years of burial it becomes more pulpy. A typical section through the marsh reveals a thin crust of densely intertwined living stems and roots. Several feet of soft saturated fibrous peat may occupy the space between the surface crust and underlying sandy soils. Ordinary wave action loosens and erodes this soft peat creating a cavity beneath the living grass layer. The marsh surface thus slopes sharply downward along the waters edge and large sections often break off producing a jagged edge of consecutive 'U'-shaped notches (Figure 31). Waves entrained by the notch walls are focused into the small end of the notch thus cutting it deeper. Eventually the notch walls are undermined and cave in, thus initiating a new cycle of erosion. This pattern of erosion is especially evident in smooth cordgrass marsh and needle-rush marsh fringed by smooth cordgrass.

Marshland is most extensive in the low land east of the Suffolk Scarp. Along the Chowan River this scarp intersects along a line between Colerain on the Bertie County side and Cannon's Ferry on the Chowan County side. A



Figure 31. Erosion of the grass marsh cuts notches into the peat soil. Undercutting of the resulting tongues of marshland between successive notches causes blocks of peat to break off into the estuary.

comparable line in the Pamlico River would lie between the mouth of Durham Creek on the south side and Belhaven to the north, in Beaufort County (Figure 8).

Marshlands function as effective natural barriers between waves and easily eroded sandy soils. When flooded by storm waters they dissipate wave energy before it reaches the sandy bank. Their unique ability to remain in elevation equilibrium with changing sea level makes them the first line in the natural defense mechanism of lowlands against drowning. Since marsh underpinnings are softest where the marsh is deepest, it is not surprising that maximum rates of estuarine erosion, in terms of annual increment lost, are recorded for marshland.

COPING WITH ESTUARINE EROSION

It is now clear that shoreline erosion within North Carolina's estuaries is the rule rather than the exception and that it has been a continuing process for the last several thousand years. Once this fact is accepted, and indeed many people are reluctant to do so, the obvious question is what can be done about it?

As explained elsewhere in the text the continued erosion of the estuaries is caused by a gradual, worldwide rise in sea level which is locally modified by regional sinking or uplift of the land. There is really nothing that man can do to change this. There are however, several options available to man for dealing with estuarine shoreline erosion which are not possible along the higher energy ocean shorelines. These options fall into three categories: 1) shoreline protection structures, 2) enhancement of natural erosion barriers, and 3) setback regulation.

Shoreline Protection Structures

Perhaps one of the more important conclusions drawn from the project thus far is that artificial protection measures such as bulkheads, sea walls, groins, and revetment are effective, if properly constructed, in preventing estuarine erosion. In fact, if it were desirable and economically justifiable, virtually all estuarine erosion could be eliminated using these techniques. For economic and ecological reasons most of the marsh and swamp forest will not be bulkheaded. Much of the sand and clay bank shoreline has already been protected, and tabulation of the monthly permit requests to the U. S. Army Corps of Engineers for bulkheading or other types of shoreline protection give a figure of eight miles per year for North Carolina. Shoreline protection is justified as it does permit maximizing the resource potential of these shorelines.

Unfortunately, shoreline protection measures result in a rather serious problem which must be considered. It is the eroding clay-sand bank shorelines which supply the bulk of the sand for the stretches of sandy beach within the estuaries. As bulkheading continues and erosion is checked, more and more of the source material for these sandy beaches is cut off. It is conceivable then, since it has already happened in several localities, that a point could be reached where there simply would be no more sandy beach! Hopefully, existing and future legislation will consider this problem carefully. The sandy beach is an area of environmental concern; paradoxically, unless man plans carefully he will end up eliminating that very resource he is trying to preserve.

A detailed analysis of the engineering and installation aspects of the various types of shoreline modification structures is beyond the scope of this project.¹ It is useful, however, to briefly consider the relative effectiveness of the structures presently being used. Examination of Table 4 illustrates man's resourcefulness when it comes to attempting to stop shoreline erosion. Unfortunately, the success rate is not comparable to his innovation. During this study we have seen every conceivable type of material used in an attempt to check erosion--up to, and including, the proverbial kitchen sink! In some instances extremely modest and inexpensive structures are over protected by literally thousands of tons of broken concrete riprap (Figure 32); while in others, exclusive permanent homes are left virtually unprotected by shoreline emplacement of unsightly and completely ineffective piles of trash and debris (Figure 33). Such disparity

¹An excellent recent publication dealing with engineering aspects of shoreline erosion, which is highly recommended for the layman is "Help Yourself-A Discussion of the Critical Erosion Problem on the Great Lakes and Alternative Methods of Shore Protection". This pamphlet has been prepared by Department of the Army, Corps of Engineers and is available free of charge from the Department of the Army, North Central Division Corps of Engineers, 536 South Clark Street, Chicago, Illinois 60605. Although specifically prepared for shoreline erosion along the Great Lakes, much of the material contained in this pamphlet is applicable to the North Carolina estuaries.

Table 4 Shoreline protection structures currently employed in the Albemarle Sound-Pamlico Sound region

I. SEAWALL and BULKHEAD	
<p>A. Poured concrete</p> <ol style="list-style-type: none"> 1. Wooden form casting 2. Inflated cloth bag casting 	<p>B. Masonry</p> <ol style="list-style-type: none"> 1. Concrete block 2. Brick 3. Cemented stone or concrete slab
<p>C. Wooden</p> <ol style="list-style-type: none"> 1. Creosoted plank and piling with steel cable or rod anchors 2. Stacked logs or creosoted telephone poles 3. Stacked creosoted railroad ties 4. Plywood sheets and pilings 	
II. REVETMENT or RIPRAP	
<p>A. Asphalt</p> <p>B. Poured concrete</p> <p>C. Broken concrete slabs</p> <p>D. Concrete blocks, castings, and brick</p> <p>E. Stone</p> <p>F. Sand bags</p>	<p>G. Tires</p> <ol style="list-style-type: none"> 1. Loose 2. Strung on rope, rods or stakes <p>H. Automobiles</p> <p>I. Assorted brush, trash and debris</p>
III. GROINS	
<p>A. Concrete and masonry</p> <ol style="list-style-type: none"> 1. Wooden form casting 2. Broken concrete slabs 3. Loose brick and concrete block <p>B. Stone</p>	<p>C. Wooden</p> <ol style="list-style-type: none"> 1. Creosoted plank and piling 2. Pilings side by side <p>D. Sand bags</p> <p>E. Tires</p>



Figure 32. Along some portions of the estuarine shoreline massive structures protect rather modest investments. . .

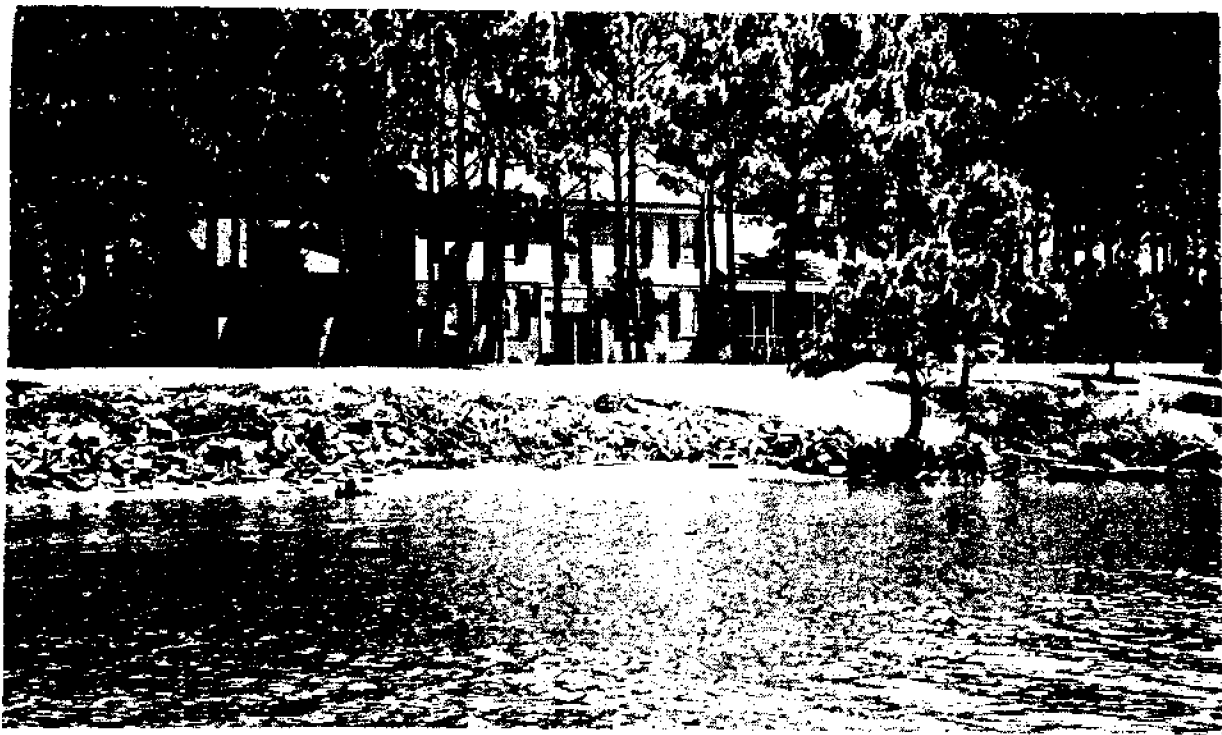


Figure 33. . . while at other locations major investments are left unprotected or ineffectively protected by heaps of trash and debris.

in approach demonstrates a rather general lack of understanding of the erosion controlling processes and reflects the psychological 'man-against-the-sea' syndrome.

Seawalls and Bulkheads

Seawalls are designed to stop wave action and erosion of the shore, while bulkheads prevent the sliding or slumping of the shore into the water. Both serve the same purpose and within the estuaries bulkhead is perhaps the preferred term.

Poured concrete bulkheads are the most durable but are also the most expensive, costing \$100 and up linear foot (Figure 34). The most important factor in the construction of concrete bulkheads is that they extend deep enough beneath the bottom (at least two or three feet in most areas), so that undermining and subsequent collapse will not occur. Masonry bulkheads of concrete blocks, brick, or cemented stone are difficult to construct in this manner and will generally fail when constructed right on top of the ground.

Wooden bulkheads are the simplest and cheapest (\$15-20/linear foot) type of structure to install. The preferred construction is the familiar post or piling with three-layer, 1 X 6 inch facing planks (Figure 35). When constructed of properly treated, quality lumber, which has been driven or washed several feet into the bottom and securely tied back into the shoreline with anchor cables or rods before backfilling, this type of structure can effectively stop shoreline erosion for 20 to 30 years. Other materials such as telephone poles and railroad ties sometimes work but generally fail because of poor installation design. Such materials as plywood, sheet metal, and fiberglass panels are useless.

Revetment or Riprap

Revetment and riprap are terms often used interchangeably to designate a



Figure 34. This low, poured concrete bulkhead was constructed well up on the beach near the base of the bank. It has a deep foundation and follows the natural contour of the beach. Poured concrete 'quilting' behind the low bulkhead prevents erosion from splashing waves. Bulkheads following this design are very effective, aesthetically pleasing, minimize loss of shallow water habitat, and are very expensive. Photo taken near Greenfield Plantation, Chowan County, N. C.



Figure 35. The most frequently encountered bulkhead in the Albemarle-Pamlico region is this treated wood design. Pilings are connected by a three-layer wall of vertical 1 x 6's secured by a cap and anchored behind by metal cables. Bulkheads of this type cost about \$20.00 per linear foot and are estimated to provide twenty to thirty years of protection.

layer or protective facing placed along the beach to prevent erosion. Revetment is generally quick and inexpensive but has the drawback of being unsightly and less effective than bulkheading. Costs are as varied as the materials used. The availability of 'free' materials such as demolished buildings, old tires, junked cars, and other debris all too often leads to really bizarre shorelines (Figures 36, 37 and 38). While none of the materials can be considered aesthetically pleasing, broken concrete slabs are perhaps the most effective.

Groins

Groins serve a somewhat different purpose than bulkheads or revetment in that they are designed to trap beach sand moving along the shore by waves and currents. In North Carolina most groin systems are employed along with bulkheading as a means of preserving some semblance of a sandy beach in front of one's property (Figure 39). Wooden, broken concrete, and stone groins are the most common materials used and appear to perform with equal effectiveness. Wave and current stress upon the groins is generally much less than that on the bulkhead within the estuaries, so that installation is relatively simple.

Enhancement of the Natural Erosion Barriers

Cypress Fringe Inducement

Each shoreline type recognized within the Albemarle-Pamlico region exhibits several kinds of natural barriers to shoreline erosion. These natural barriers include such phenomena as cypress knee and root 'bulkheads', fallen tree 'groins' (Figure 40), and offshore shoal and sandbar 'breakwaters'. A detailed treatment of the function of these natural barriers is presented under the sections on shoreline types and will not be repeated here. It does seem worthwhile to discuss examples of ways in which man might enhance such natural barriers to erosion as an alternative to bulkheads, revetment, or groins.



Figure 36. Cropland is usually not protected by bulkheads because costs of installation far exceed the benefits to be gained. Nevertheless many farm managers have attempted to deal with shoreline erosion with whatever low cost materials are available. Junked automobiles are readily available in coastal North Carolina, but their effectiveness in protecting estuarine shoreline has been unsatisfactory. It is questionable whether they retard erosion to any measurable extent. This defensive measure can bring only temporary relief at best because automobile bodies usually corrode to useless scraps of rust within five years after first exposure to brackish water.



Figure 37. Bulkheads of original design such as the one illustrated here are moderately successful if constantly maintained with back fill and restacking of blocks. Many waterfront owners consider such structures to be unsightly. Certainly they are a real nuisance to maintain.



Figure 38. Great variations in bulkhead design features, materials, and effectiveness along contiguous segments of beachfront attest to man's failure to respond in a coordinated manner to the problem of beach erosion. Each individual attempts to solve his own immediate problem with little attention given to how his decisions might affect the local sediment transport process or to the cumulative effects of several adjacent projects. Photo taken near Hornblow Point, Chowan Co., N. C.



Figure 39. Groins constructed perpendicular to the shoreline are often effective in trapping sand transported along the beach. Groins become progressively less effective as new ones are added because all groins must compete for the limited amount of sand being moved by nearshore currents. In a very real sense the decision of one landowner to install groins will affect the rate of erosion of adjacent properties. Groin effectiveness is dependent upon continual input of fresh supplies of sediment eroded from the shoreline. Bulkheading eliminates the source of sediments needed to make groins effective. Photo taken along north shore of the Pamlico River, Beaufort County, N. C.



Figure 40. In this photo the cypress fringe (upper left) has been breached with subsequent erosion of the second growth pine upland behind it. Mature trees often fall perpendicular to the shoreline where they function as natural groins. Sands eroded from the bank are temporarily stored behind such 'groins', thus retarding the rate of erosion. Photo taken on north shore of Albemarle Sound in Chowan County, N. C.

As a long term protection device a program of cypress seedling plantings offers considerable merit. In areas where rapid erosion discourages such planting, a low (1-2 foot) wooden bulkhead could be installed and cypress seedlings started. This method could be easily accomplished on a low bank shoreline and possibly on a bulldozed high bank shoreline. After twenty or thirty years the trees should then be well enough established that bulkhead maintenance could be discontinued, and the natural cypress barrier could take over.

Multiple Bulkheads

A three to four foot wooden bulkhead is a cheap and effective erosion prevention technique, but for water access and general aesthetics it has its drawbacks. An alternative, more natural, but also more expensive method of bulkheading would be a multiple, stepped arrangement of bulkheads. In this arrangement the bulkhead at the waters edge would be only a few inches above mean water. Behind this bulkhead could be placed sand, gravel, or perhaps natural marsh grasses planted which would provide a more enjoyable water experience. The higher bulkhead or bulkheads would serve to absorb storm energy.

Discussion

Innovative shoreline modification programs which build upon concepts of natural erosion barriers should be encouraged. In most cases initial costs would be higher than the standard techniques of shoreline protection; however, the long term effects should be well worth the additional expenditure.

Setback Regulations

In areas where shoreline protection structures or natural erosion barriers prove unsuccessful or are unfeasible due to ecological or economic considerations, set back regulations may provide the only solution. Setback simply involves

prohibiting development or construction within a specified distance of the shoreline. Voluntary setback is rarely achieved for obvious reasons, and legislation to that effect is not popular because of lost real estate potential and the public animosity that is aroused through the necessary condemnation or grandfathering-in rulings. Nevertheless, in some cases it may prove to be the wisest choice; particularly along undeveloped, but critically erosion prone, shorelines. Since all shorelines are not eroding at the same rate an important question at present is, if setback lines are to be established, how far back is enough? This legitimate question is not easy to answer at this point in that each area is different. Perhaps, for the present the best solution would be for those in the planning stage to use the county data contained in Shoreline Erosion Inventory, North Carolina (1975) recently published by the USDA Soil Conservation Service, Raleigh, N. C. If for each stretch of shoreline in question the maximum annual reported values are used for a hundred year period, a conservative setback line could thus be established. This general setback limit could then be subjected to detailed shoreline erosion studies on a local basis as developmental interests dictate and revised accordingly.

Recommendations

At the rate that the estuarine waterfront is being developed it is imperative that stringent regulatory guidelines be imposed regulating the type of shoreline protection structures that can be emplaced. The alternative is unacceptable ecological, economic, and visual chaos as each property owner does 'his own thing'. An important factor to be considered in such planning is the fact that within broad stretches of shoreline there exist smaller segments or coves of eroding shoreline which are separated by more resistant headlands. Within a

single segment erosion rates may vary considerably, but every stretch of beach within that segment is related to the next. Thus every modification of the shoreline within a segment will have an effect on the adjacent property. Thus, if one property owner employs bulkheads or groins, then his neighbor may be forced to do the same, even if he prefers a shoreline with enhanced natural barriers. Natural beach segments must, therefore, be planned as units. Fortunately, each headland separated segment behaves quite independently of the adjacent segment, and so diversified shoreline planning is possible.

SIGNIFICANCE OF OBSERVATIONS REPORTED HERE TO COASTAL PLANNING AND SHORELINE DEVELOPMENT

Our survey shows that erosion rate is often highly variable even along adjacent reaches of estuarine shoreline. Estimates of average erosion rate are of limited value to someone who wants to know the erosion potential at a particular location. This problem becomes more acute if the site in question lies between two points of widely differing erosion rate. Individuals can refine the accuracy of their estimates of shoreline erosion rate by acquiring an elementary knowledge of the basic processes causing erosion and learning to recognize on-site clues regarding erosion potential. The descriptions, diagrams, and photos included in this publication are designed to summarize our study of the Albemarle-Pamlico region and to serve as an interim guide until we can publish more detailed maps and mile-by-mile descriptions of that shoreline. Detailed shoreline analyses for each coastal county will be published by North Carolina Sea Grant during the next two years as field work is completed and prepared for publication.

1. Estuarine waterfront can be expected to experience increased development pressures as developable ocean frontage becomes increasingly scarce and expensive. Even a disastrous ocean storm which might temporarily discourage ocean front development would only emphasize the greater security of building away from the ocean beach.
2. Cypress headlands, resistant clay bluffs, cypress fringe, swamp forest, and peat marshlands all function as natural barriers to shoreline erosion. Such areas should be declared Areas of Environmental Concern (AEC) and modification permitted only under guidelines established by the Coastal Area Management Act of 1974.

3. Whole stretches of the beach erode as a unit. Usually such units occur as coves of varying size between naturally resistant land features as clay bluffs or cypress headlands. Within any one cove only one strategy for responding to erosion can be employed. The requirement of short lots protected by bulkheads upon which are located expensive permanent homes or cottages is inconsistent with that of individuals who wish to locate temporary or inexpensive structures and avoid shoreline protection costs. Coves where extensive bulkheading already exists must continue such measures and will primarily serve more affluent individuals. Some coves, as yet essentially undeveloped, should be designated for development by persons who do not choose to make a large investment. This type of planning permits wide social and economic access to the market and at the same time allows otherwise conflicting strategies for dealing with shoreline erosion to be employed.
4. Although there appear to be few sites along the estuaries where shoreline protection structures such as groins and bulkheads could not be effective, the alternative of accepting erosion as a natural process should be seriously considered at many locations. There are two effective strategies for dealing with shoreline erosion. Protection through construction of bulkheads and other shoreline modifications necessarily commits the individual employing these methods to their continued maintenance. Unfortunately, once these methods are used they disrupt shoreline sediment transport mechanisms, thereby committing adjacent land owners to employ similar measures out of self defense. Shore protection construction thus spreads in a random pattern

utilizing a variety of materials and techniques. Such individual initiative can be aesthetically unpleasing, but more important it constitutes inefficient use of money and materials and results in something less than the ideal solution to the common problem. Lot owners should also know that extensive bulkheading will result in loss of sandy beach front. Once initiated shore protection construction commits lot owners along an entire stretch of beach to expensive initial installation and maintenance costs. Currently effective bulkheading costs average about \$20.00 per linear foot. Often this cost of beach front ownership is not anticipated, and the sudden outlay of \$1,000.00 to protect a 50 foot beach front containing a modest second home or trailer can constitute a considerable hardship. Added costs for beach protection may price many individuals right out of the market.

Establishment of appropriate set back lines and a requirement for deep lots would allow many people, who otherwise could not afford it, to own beachfront property. Another alternative for trailer owners would be term leases. When the shoreline reached a trailer, the leasee would renegotiate a deeper lease with the landowner or move to a new lease location. The 'do nothing' alternative would also preserve sandy beaches and be less expensive.

5. In most situations, owners of cropland fronting on estuarine shoreline will not find it economically feasible to employ structural methods such as bulkheading to protect their land from erosion. Cropland owners will encourage strip development of their river front property as a means of establishing a defensive buffer between their cropland and continued shoreline erosion. Planners should insure that lot size

remains large enough for access and will adequately provide for utilities and services. Lot owners should understand that responsibility for shoreline erosion control transfers to them along with ownership of the land. It is imperative that the prospective lot owner be given adequate information concerning erosion rate and costs of protection at the same time that he is negotiating for the land.

6. Estuarine shoreline erosion rates have recently been measured at numerous points along our rivers by the Soil and Water Conservation Service. This data, including estimates of average county shoreline loss, is available in the recent publication Shoreline Erosion Inventory, North Carolina, USDA Soil Conservation Service, Raleigh, N. C.

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GLOSSARY

- accretion-An accumulation or build-up of sand along the beach produced by waves or currents.
- Area of Environmental Concern-(AEC) Especially fragile or ecologically unique areas of the North Carolina Coast where development should occur only if it is in harmony with natural processes. Areas of the coast where the public welfare might be endangered by unwise manipulation of the environment.
- backfill-Fill materials used to bring the space behind a bulkhead or seawall up to a desired grade, usually the top of the bulkhead. Bulkheads are often constructed several feet out from the waterline and then the river bank is bulldozed to grade behind it.
- bathymetry-Water depth, underwater topography. Navigation charts typically indicate bathymetry in feet or fathoms. Nearshore bathymetry is an important factor in shoreline erosion because it controls the breaking pattern of storm waves. Deep near-shore water allows wave energy to be dissipated on the beach.
- bulkhead-Any structure or wall designed to stop bank collapse and resist erosive forces. Bulkheads are typically placed parallel to the shore and tied in on the landward side to prevent tipping as a result of backfill pressure. Treated wood or masonry bulkheads are the most frequently encountered erosion control structures along North Carolina estuaries.
- canopy-'cypress canopy' A layer of leaves and braches formed by the interlocking mosaic of tree tops in a forest. Cypress swamps often have a dense canopy during summer. Thus the microclimate beneath the canopy is much darker, cooler, and more humid than in surrounding areas.
- Coastal Area Management Act of 1974-An act passed by the North Carolina legislature in 1974 intended to promote wise development of North Carolina's coastal resources. Among other provisions this act calls for the designation of certain especially sensitive areas as 'Areas of Environmental Concern'.
- cypress fringe-A straight or curved line of cypress running parallel to the shoreline. Older cypress fringe has its trees standing in water while young cypress fringe occupies sandy beaches in front of eroding sand or clay banks.
- cypress headland-A cluster of cypress trees which juts out into the estuary. Typically called points, cypress headlands are particularly resistant to erosion and function in stabilizing drifting sediment.
- drift line-Linear accumulation of floating debris which collect in windrows along the beach at the high tide or storm tide line. Drift often consists of sticks leaves, and aquatic plant remains. The drift line collects seeds of trees and weeds which often germinate and grow in this moist matted drift.
- ecological succession-The natural process by which one community of living organisms is gradually replaced by another. Usually each successive community is more stable than the last, thus leading toward a final community especially well suited to the particular environmental conditions existing at that location.

erosion rate-A measurement of how fast shoreline is being lost at any given point. Erosion rate is usually given as 'feet per year' or 'cubic yards per year'.

estuarine shoreline-The 'river bank' to many North Carolinians. This is the zone of contact between brackish tidal water and the land.

fetch-The distance across open water which a prevailing wind travels before reaching shore.

flood plain-Lowlands adjacent to a river or stream which become channels during periods of unusually high flow. Flood plains are a natural component of the river system and function as overflow storage areas.

grass marsh-Low grass meadows subject to tidal flooding. Smooth cord grass and black needle-rush marshes cover many acres of coastal North Carolina and are ecologically valuable as shell fish breeding areas and as refuges for water fowl.

long shore sediment transport-Sand, silt, and clay which is carried parallel to the shoreline along the beach by waves and currents.

Miocene Epoch-That period of earth history which saw the coastal plain of the Eastern U. S. covered by a vast, warm, shallow sea. Deposits are rich in marine fossils and phosphate. It is considered to have taken place between 15 and 20 million years ago.

Pamlico Terrace-A low, flat, featureless, topographic surface extending over the Coastal Plain of the Southeastern U. S. at elevations less than 10 feet above sea level. It is considered the relict sea floor of the Sangamon Interglacial.

peat-Accumulations of slowly decomposing plant remains. Peat is formed in swamps and marshes. Erosion of peat soils releases suspended organic matter into coastal waters as well as certain 'humic acids' which give water a tea colored stain.

Pleistocene Epoch-That period of earth history which saw the advance and retreat of the four great Ice Ages. It is generally considered to have begun between 1 and 2 million years ago and to have continued up until about 18,000 years ago.

relict beach ridge-Throughout the Southeastern U. S. ancient shoreline areas detected at various elevations inland from the coast. These shorelines are often manifested as continuous ridges and are considered a product of higher stands of the sea during the Pleistocene Ice Ages.

river swamp-see Swamp Forest

Sangamon Interglacial-A period of deglaciation (no continental ice sheets) during the Pleistocene Epoch between the Illinoian and Wisconsin Ice Ages. This period is generally considered to have taken place about 80-100,000 years ago.

shoreline modification-Any activity or structure undertaken by man in the coastal zone which disrupts the natural ecological shoreline system.

shoreline setback-An arbitrary line chosen on the basis of local erosion rates which is established to prevent development in hazard prone coastal areas.

'smooth sheet'-The detailed work sheets from which the U.S. Coast and Geodetic Survey coastal navigation charts are constructed. Coverage in much of the Eastern U. S. goes back to the mid-1800's.

Suffolk Scarp-A topographic ridge rising from 15 to 40 feet above sea level which runs parallel to the coast throughout North Carolina. It is considered an ancient shoreline formed during the Pleistocene Epoch. It is also referred to as the Pamlico Shoreline.

swale-A topographic low or troughlike depression.

swamp forest-Type of forest characterized by seasonal flooding and water saturated organic soils. Water tupelo (swamp gum) and bald cypress are dominant tree species. In coastal North Carolina, Swamp Forests usually occur along river or stream flood plains. Synonyms include: 'Southern River Swamp', 'dismal', 'cypress swamp', 'gum swamp', etc.

Talbot Terrace-A rather flat but stream dissected surface lying at an average elevation of 40-45 feet throughout Southeastern United States. It is considered to have been the sea floor during the Pleistocene Epoch and was subsequently elevated to its present position. In North Carolina it lies west of the topographic ridge known as the Suffolk Scarp.

Yorktown Formation-An ancient deposit of clay and clayey sand which typically contains abundant marine fossils including clams, snails, whale vertebrae, and shark teeth. It occurs extensively over eastern North Carolina and is generally considered a depositional product of the Miocene Epoch which took place 15-20 million years ago.