LAND CLEARING IN THE COASTAL PLAIN

by

John R. Clark

Environmental Guidance Group

Washington, D.C.

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October 9, 1981

TABLE OF CONTENTS

TC 345 .N55 C55 1981

INTRODUCTION

This report was commissioned by the Office of Coastal Management of the North Carolina Department of Natural Resources and Community Development in order to get an independent opinion on the matter of land conversion in the coastal lowlands by clearing and draining. The Office of Coastal Management has numerous responsibilities for resource conservation and environmental protection in the coastal counties of the state where land conversion has skyrocketed in recent years. Some troublesome side effects have been produced by conversion of land for farming, tree harvest, and strip mining for peat.

One particularly damaging side effect of land clearing and draining is the accelerated surge of storm water runoff into shallow estuarine "nursery areas" -- shallow sanctuaries where young fish and shellfish find food and protection. The surges -- increased fourfold over natural runoff -- push out vital brackish water and substitute fresh water, an unsuitable medium for propagation of estuarine fish. The surges also bring down nutrients washed off croplands to cause eutrophication of estuaries. Wetlands and

other types of essential wildlife habitat are rapidly disappearing under the blade and the backhoe.

The purposes of this report are to provide a background of fact, to examine the impacts and to consider remedies. It was prepared in tandem with a slide show on the subject which is also available from the sponsoring agency.

Several terms used herein need clarification. "Lowlands" means land fringing the coast that is especially low and subject to storm flooding. "Wetlands" refers to areas with soils that are saturated or inundated most of the year and have vegetation especially adapted to wet soils (marshes, swamps). "Moistlands" are a version of wetlands with soils that are inundated or saturated seasonally and which are often dry at the surface for a good part of the year (pocosins, bogs, river bottomlands). "Land conversion" means the alteration of land from one condition to another to facilitate a particular use -- specifically clearing, draining, and grading the wet lowlands of the North Carolina coast.

The author is appreciative for the dedicated efforts of his associate, Ms. Catherine Lochner and for the close attention given to this project by Kenneth Stewart, Director, and David Owens, Ralph Cantral, and Steve Benton of the Office of Coastal Management. We enjoyed the cooperation and assistance of so many people it is not possible to name them all. The following colleagues were particularly generous: Steve Benton, Charles Daniel, Linda Gantt, Ralph Heath, Paul Lilly, Preston Pate, Don Philen, Joseph Phillips, Jim Smith and Anne Taylor.

John R. Clark
Environmental Guidance Group
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The conversion of swamp and bog lands to fertile farmland goes back two centuries in North Carolina's history. Why then should controversy over land clearing and draining be high on the state's list of current environmental concerns in the 1980s? One reason is the very intensity of clearing activity that is now underway. Another reason is the push to extend clearing into the wetter lands which gives rise to greater environmental problems. A further reason is the potential consequences of a new enterprise, strip mining for peat to be marketed as fuel or as biomass for fuel production (alcohol). Also, the renewed land clearing program of the 1970s and 1980s faces a public environmental awareness not present in the clearing and draining campaigns of the 1950s. At stake are wildlife, fisheries, water supplies and hurricane flooding.

Another important factor in the current controversy over coastal land clearing is the shift in incentive from income to investment. In the past, the main purpose of buying and clearing lowlands was to generate income from sales of farm and forest products. But lately the purpose has shifted toward

land improvement for investment potential. Corporate "super farms" are replacing smaller family farms.

Large scale land clearing activities, along with wetlands drainage and peat mining, substantially alter the coastal landscape, its water cycles, and the condition of adjacent rivers and sounds. Therefore, the benefits of clearing must be balanced against the resource losses that inevitably follow. This section of the report provides background for considering these tradeoffs by examining the extent of land clearing to date and projecting what may come in the future.

Two Hundred Years of Land Clearing

The clearing and drainage activities of today are not taking place on virgin lands so much as on lands that were cleared in earlier years for farming or drained to facilitate logging operations.[1/] As economic conditions became less favorable, these lands were idled and began a reversion back to their previous wetland state. In fact, most of the land now involved in clearing was at one time part of a giant bog and swamp complex that covered much of the coastal plain of North Carolina. This huge wetland has challenged land entrepreneurs since the time of our national independence.

To quote J. Paul Lilly on the history of land clearing and drainage:

> Development of swamps in North Carolina has occurred over a long period of time with periods of enthusiasm alternating with periods of inactivity....Easily drained land on the edges of swamps was being developed by the late 1600's, but the first large scale drainage of deep organic soils was in the 1790's north of Lake Phelps. 1/
>
> Development of North Carolina swamp lands began as early as 1700, first for timber production and later for agriculture. Swamp lands were considered more fertile than upland soils and agricultural successes at Lake Phelps and Lake Mattamuskeet in the early 1800s caused the state to drain swamp land to raise money for public education. Canals were dug at considerable expense but little land was sold. The Civil War halted swamp land development but, by the late 1800s intense logging had begun and timber companies were acquiring much land. The 1909 drainage act enabled land owners to fund area-wide drainage projects and greatly accelerated development. In the 1930s paper companies began buying timber company land, Croatan National Forest and Hofmann Forest were formed, and the remaining state owned swamp lands were preserved for wildlife. 2/
>
> Since World War II there has been steady development of swamp lands for agriculture and forestry. It was found that successful production of pine trees on poorly drained soils required drainage, and paper companies began extensive canaling and ditching. By the 1960s most of the swamp land not in public ownership belonged or had belonged to paper companies. In recent years, pressure for land has increased again and large acreages are being developed for agriculture 2/
>
> The area of most intense development is the Albemarle peninsula, also the area with the smallest proportion of land in public ownership.

> Land clearing has not proceeded as rapidly as Heath .... projected, but it is likely to be as extensive eventually. It is quite likely that the swamp lands in private ownership will be cleared and drained for agriculture and forestry as long as current investment opportunities exist. 2/

Present Inventory of Cleared and Drained Land

One third of North Carolina's coastal land has been drained (see Figure 1). It is technically possible for another 45 percent of the land to be drained. The remaining 25 percent is either dry or publicly owned and therefore not subject to drainage. Altogether, 1.8 million acres has been drained in 17 coastal counties according to a recent survey (Table 1. 4/

The survey concludes that another 2.5 million acres are potentially drainable in the following categories:

Lands Potentially Drainable	Acres	Percent of Land in 17 Counties
1. Farmland	94,000	1.7
2. Forestland	2,197,000	39.4
3. Miscellaneous	183,000	3.3
	2,474,000	44.4

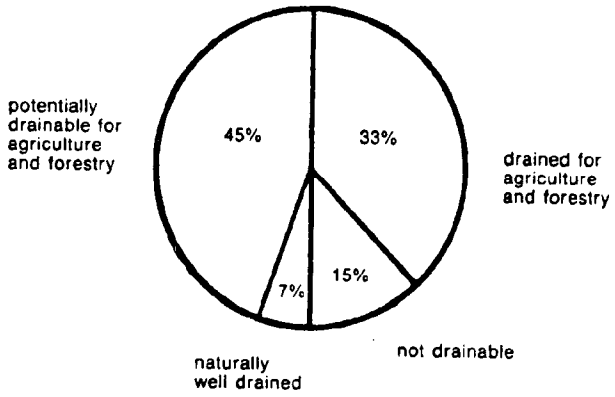


Fig. 1. Extent of coastal land drainage based on 1978 survey. Total land area is 5.6 million acres. (Source: Ref. 3.)

Table 1. Farmland and forestland drainage in 17 coastal counties.[a] (Source: Ref. 4.)

Land Use and Drainage Status	Acres	Percent of Land Use
Farmland		
1. Extensively drained[b]	513,000	33.2
2. Partially drained[c]	541,000	35.1
subtotal	1,054,000	68.3
3. Potentially drainable	94,000	6.1
4. Well drained, no drainage required	396,000	25.6
Total Farmland	1,544,000	100.0
Forestland		
1. Partially drained	780,000	26.2
2. Not drained and suited for drainage	2,197,000	73.8
Total Forestland	2,977,000	100.0

a. The 17 counties are: Beaufort, Bertie, Brunswick, Camden, Carteret, Craven, Dare, Gates, Hertford, Hyde, New Hanover, Onslow, Pamlico, Pasquotank, Pender, Tyrrell and Washington counties.

b. Extensively drained is land with subsurface tile drainage systems combined with surface drainage measures and an adequate outlet.

c. Partially drained means the use of surface drainage measures such as bedding, mounding and ditching, or land smoothing combined with drainage ditches.

d. All well drained land is assumed to be in farmland for the purpose of this estimate. The actual proportion of farmland that is naturally well drained is smaller than this figure.

That suitable lands can be put into production rapidly is shown by a doubling of acres in corn on the Albemarle-Pamlico peninsula in the 1970s. This trend reflects the extensive clearing and draining of lowlands that occurred during the last decade. Similar trends exist for land in soybeans and other crops and for grazing and forestry lands.

It appears that 100,000 acres of wet, lowlying land have been cleared and drained, or re-cleared and re-drained in the last 10 to 12 years on the Albemarle-Pamlico peninsula. The U.S. Soil Conservation Service can account for over 200 million feet of ditches and 80 million feet of tile drains in recent years.[5] A hydrologist's view of the peninsula today shows a criss-cross web of interconnecting canals and ditches that looks like the street map of a Chicago suburb.[6]

In 1979 the Soil Conservation Service determined that only 39 percent of all the land drained for agriculture and forestry in the coastal area is adequately engineered.[7] But much of the inadequately drained land is presently abandoned and lying fallow.

Much of the land clearing and draining has been done in large-scale campaigns by well-funded investment combines. The most ambitious is First Colony Farms

which purchased 372,000 acres on the Albemarle-Pamlico peninsula in the early 1970s (see Figure 1). In 1974, the 10-year plan released by First Colony called for 150,000 acres of row crops, 140,000 acres of pasture, and 10,000 acres of vegetables -- 300,000 acres in all.[8] By 1976, 55,000 acres had been cleared and only 65,000 acres more were planned, the remainder having been designated as poor quality, low-yield, forestland. Thus, First Colony abandoned 60 percent of their program, apparently because the land was unsuitable. They later sold off parcels to other investment combines, most notably 83,000 acres in Dare County to Prulean Joint Venture (Prudential Life Insurance as major investor) and began to concentrate on the peat mining potential of their land. As of February, 1981, First Colony had sold all but 163,000 acres.[9] (See Table 2).

Another large venture is the 35,000 acre Mattamuskeet Farms, owned by the John Hancock Mutual Life Insurance Co. and American Cyanamid in Hyde County (Fig. 2). In Carteret County, Italian investors are developing the 45,000 acre Open Ground Farms around the South River. The remaining farms are mostly 10,000 acres or less.

Table 2. Current large land holdings, Albemarle-Pamlico region. (Source: Ref. 9.)

NAME	ACRES
First Colony Farms	163,000
Mattamuskeet Farms	35,000
Prulean Partnership	83,000
Tyson Carolina	11,000
Winslow	10,000*
Georgia Timberlands	10,000*
Rich Farms	13,000*
SJE Investments	14,000*
Timberlake Columbia Farms	10,000*
Buckeridge	17,000*

*The source listed the last six as holding "more than" the numbers shown.

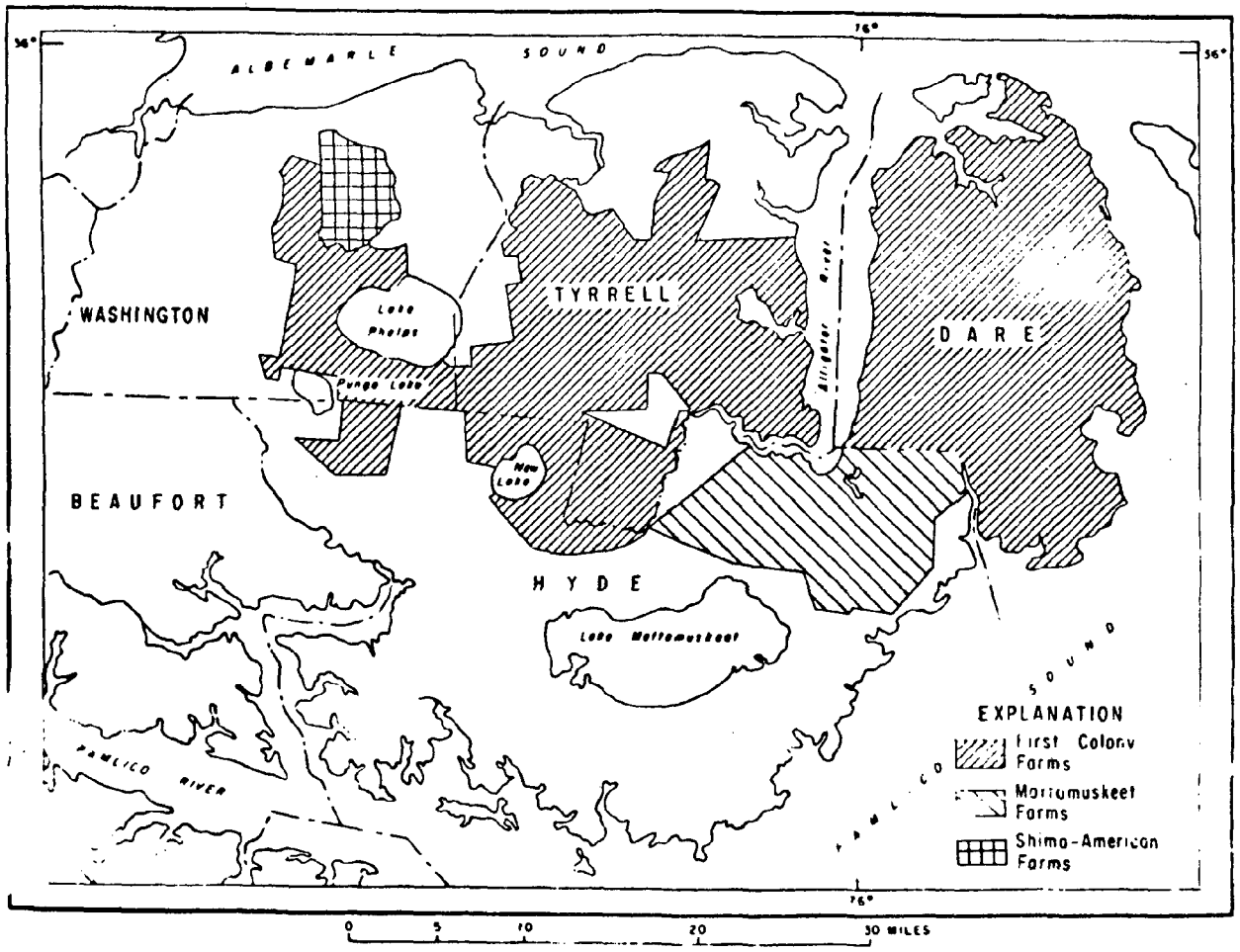


Fig. 2. Land owned by First Colony Farms and other large corporate farms as of 1974. (Source: Ref. 10.)

Future Prospects

No authority has been willing to predict the future extent of land clearing and draining in the coastal plain. While 44.4 percent of the land -- 2.5 million acres -- in the 17 coastal counties was listed in the 1978 survey as "potentially drainable,"[4] much of this may have poor to marginal potential for agriculture. Economic and environmental considerations will substantially govern clearing and draining enterprises in the future.

The 1978 survey showed that the trend is toward "more coastal land drainage for agriculture and forestry" and continued as follows:[7]

> The rate at which new lands are drained and brought into production during the 1980s will vary according to commodity prices and export policies, but generally is expected to be slower than in the 1970s.
>
> Future crop land drainage is also influenced by the kinds of crops grown. The dominant Coastal Zone crops grown on soils needing drainage are cash grain corn and soybeans. Cash grain operations have historically increased in size to reduce costs and to maintain profitability. For Coastal North Carolina this increase in size can occur 1) by purchasing new land or 2) bringing into production land not currently used for crops.

But big investors may play a stronger role than farm prices and the driving force may be inflation conditioned by the recent attractiveness of the money market.

The principal commodity in coastal Carolina may become the land itself, not the products the land produces. Quoting J. Paul Lilly, "Farm land is seen as a desirable investment and it is likely that land clearing will continue at a rapid rate so long as the current economic....conditions exist."[1/] The benefit of holding coastal farmland as a hedge against inflation is clear -- the average value of an acre of land in a 12-county area around Albemarle and Pamlico sounds increased 824 percent between 1959 and 1978.[11/] If inflation continues at a high rate, one would expect U.S. and foreign investors to continue purchasing blocks of land and developing the more suitable areas.

Heath determined that 100,000 acres of the Albemarle-Pamlico peninsula were cultivated in 1956 and 270,000 acres in 1973.[12/] He also projected that over 640,000 acres would be cleared by 1980, a considerable overestimate as it turns out. However, the areas identified by Heath (Figure 3) are a good indication of future possibilities (except for southern Dare County, recently purchased by the military for an air target range).

The promise of fortunes to be made at peat mining has also encouraged coastal land investment and conversion through clearing and draining. As long as this promise remains, investment pressure will continue.

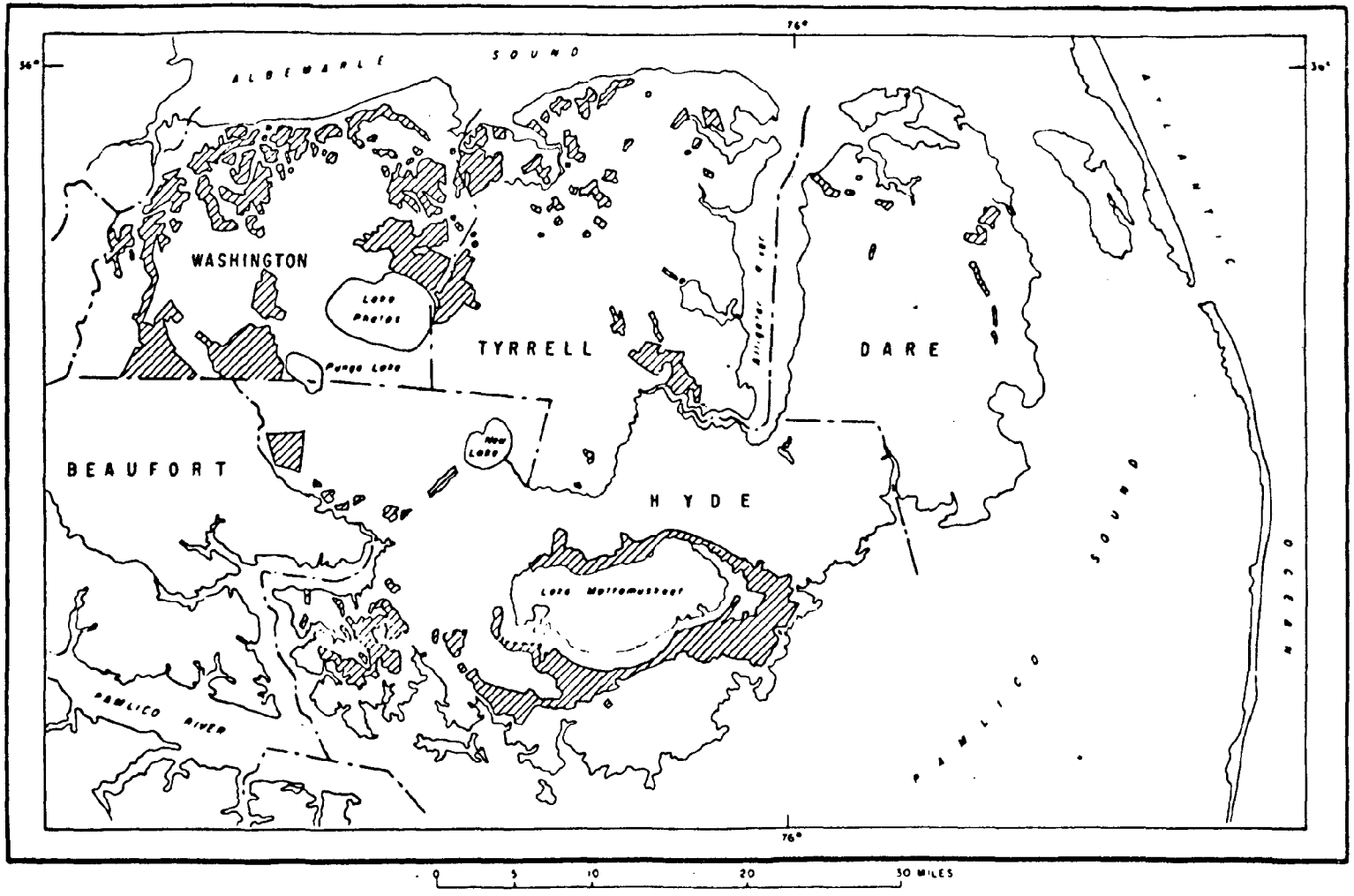


Fig. 3A. Cultivated land, 1956. (Source: Ref. 12.)

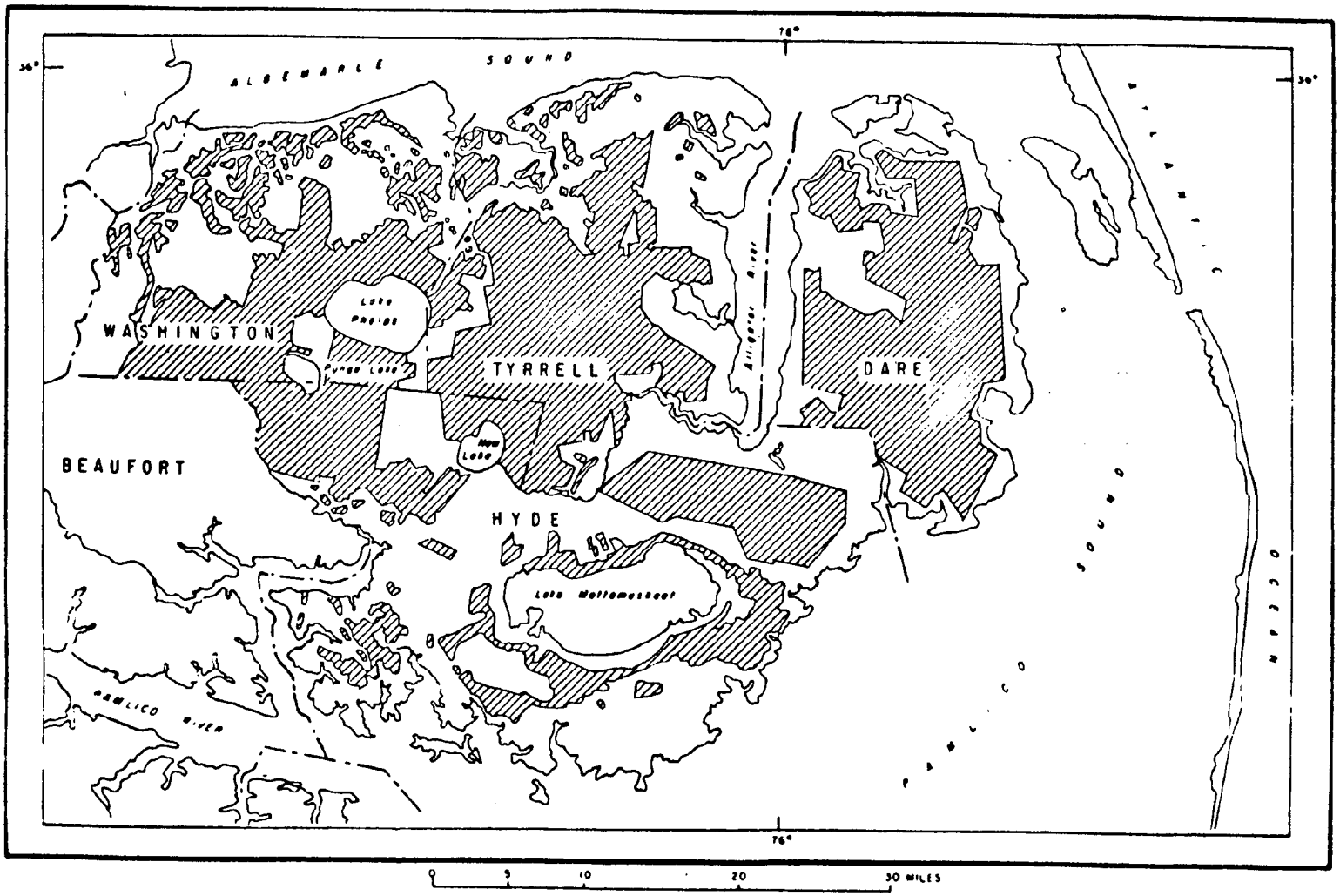


Fig. 3B. Cultivated land projected to 1980. (Source: Ref. 12.)

By September 1981, five mining permits for peat had been granted for tracts totalling over 16,000 acres and two more permits for over 10,000 acres were pending.[13] Trial mining is underway on some of these tracts with production approaching 2,000 tons per week (of 30% moisture peat) by August, 1981.[13] Market demand and profitability for full scale operations are unknown, but it appears that the most promising market is for methanol produced from peat by gasification.[13] Whatever the future may hold, the peat potential is buoying the present value of lands that are poorly suited for agriculture.

Current trends suggest that coastal forest industries of the future may be based on cultivation of loblolly pine. Native pines are more of a nuisance than a resource in modern land clearing and they are typically piled and burned rather than harvested when land is cleared. A Weyerhauser representative is quoted as saying recently they "would not log the area if the timber were given...free...."[3] However, harvesting and culturing of pine trees can be profitable as a single purpose activity in which all factors are maximized for the one purpose -- e.g., the areas for harvest are drained up to two years in advance so that the soils are dry enough to support heavy machinery.[3]

One would expect to see the continued advance of higher technology, single-purpose pine culturing and harvesting. From Table 2, one can see that the major holdings -- 2.2 million acres -- of undrained coastal land are in forest and only 780,000 acres have been drained at some time in the past. If some favorable change in technology or market demand occurs, hundreds of thousands more acres could be drained and prepared for loblolly pine tree farms in the near future.[5/]

There appears to be a dimmer future for white cedar (juniper) and cypress -- the prime forest species of the past. Available stands are nearly gone and it seems not to be practicable to culture them at the current state of the art of silviculture. However, a technological breakthrough could change the picture.

MAJOR USES OF CLEARED LAND

The coastal plain of North Carolina is a rural area with a predominance of farming, forest industries, and fishing. There is tourist recreation development along the ocean beaches and shipping connected industry in the ports. The fortunes of farmers, foresters, and fishermen have a major effect on the economic life of the coastal communities. The trend toward corporate farms adds a new factor. While the long term employment benefits of both super farm and tree farm operations are minimal, the indirect and short-term benefits to the local economy -- including employment in land clearing-- are significant. Major shifts in land use are of great importance to coastal communities. Their economy, environment and life style are keyed to the use of land. In this section we review the major potential uses of cleared land in the coastal plain of North Carolina -- agriculture, forestry , and peat mining. The emphasis is on the Albemarle-Pamlico peninsula.

Agriculture

Lowlands converted for agriculture -- that is, cleared and drained -- are used primarily to produce corn and soybeans along with wheat and sorghum. Some of this land is used for vegetables and some for pasture. Very little tobacco is grown. The past 10 years has witnessed a great increase in land conversion. For example, Tyrell County had only a few thousand acres of cultivated land in the early 1960s but 27,000 acres were converted for row crops in the 1970s.

Accelerated lowland conversion has been associated with a marked increase in the total amount of agricultural land in production. For example, in Table 3, Donald Philen shows trends in harvested acreage of corn for 12 coastal counties. (Corn, traditionally the major crop of coastal plain farms, is now second to soybeans.) A general slump in the 1960s was followed by an increase in the 1970s as land was put back into production. The increases were particularly striking for Hyde, Tyrell, and Washington counties in the Albemarle-Pamlico peninsula. These were the only counties which gained significantly over 1959 acreages -- from 35

Table 3. Acres of corn harvested in various years for all purposes. (Source: Ref. 11)

COUNTY	1959	1964	1969	1973	1978
BEAUFORT	47,223	28,506	24,177	41,820	47,659
BERTIE	34,004	25,500	28,747	35,350	42,225
CARTERET	2,691	1,446	1,616	3,060	5,918
CRAVEN	24,589	12,875	11,557	16,120	22,409
DARE	7	8	*	50	*
HYDE	13,883	12,472	14,004	25,920	23,962
JONES	24,768	14,899	15,856	18,130	27,272
MARTIN	32,183	22,230	22,424	28,350	32,485
PAMLICO	9,802	6,728	4,545	6,620	8,738
PITT	76,384	51,600	55,759	62,190	68,046
TYRRELL	7,018	4,931	3,890	7,300	14,149
WASHINGTON	13,931	8,979	13,819	28,710	30,686

* Data not available.

to 69 thousand acres overall. Carteret also doubled its considerably smaller total acreage. On the peninsula, 142,000 acres -- 8 percent of the state total -- were in corn by the end of the 1970s. [14]

On the peninsula, 193,000 acres -- 10 percent of the state total -- were in soybeans by the end of the 1970s. The growing world demand for soybeans has caused both a shift from corn and an increase in the rate of land conversion.

Regarding livestock, at the end of the 1970s, the peninsula had 180,000 hogs and 25,000 cattle, respectively 6.8 and 2.3 percent of the state total.

Technology of Land Clearing and Draining

Because the Albemarle-Pamlico peninsula -- and much of the rest of coastal North Carolina -- is a giant bog of organic (peat) soils, it was not characterized by much in the way of natural streams and swales to drain the land. Rainfall drained off the

surface as a flowing sheet of water moving slowly toward the sounds. To drain this bog meant cutting a complete system of artificial drainageways and outlets to the sea -- not too difficult technologically in an area where the land runs flat and uninterrupted for miles. However, since the slope falls from only 20 feet to zero elevation over distances of 15 to 50 miles, a major problem is to get the drainage water to flow. Giant electric pumps are coming into common use to aid the flow, to reverse it, or to pump out areas of falling land surface.

Water penetrates the peaty bog soils very poorly, tending to stand on the surface in shallow puddles and ponds. Therefore, it is important to shape the fields so that water runs off the surface as well as drains from underneath. The capacity of the ditches and canals must be adequate to handle major downpours as well as regular rains. Even with the best drainage, there are many crops that the peninsula's organic soils cannot support.

According to Doucette and Phillips:[4/]

> The majority of field crops and plantation grown trees require an unsaturated root zone for optimal growth. When the root zone is saturated either by a rising water table or the infiltration of ponded rainwater, the roots are deprived of oxygen and suffocate (drown!). Some field

> crops can withstand temporary wetness longer than others. Soybeans, for example, can withstand wet conditions longer than corn. Tobacco will be hurt with short periods of wetness while wetland rice is planted and grown almost under water. Drowning can stunt the growth of a plant and severely reduce grain yields or eventually kill it.

In the simplest view, agricultural drainage involves lowering the water table to below the root zone and increasing the rate of surface water removal to prevent ponding.

The technology of clearing and draining of coastal lowlands by the open ditch method has become rather standardized. According to Heath[12] the ideal drainage system consists of three different types of drainage channels (see Figure 4). The first is the main canal which extends into the interior from the coast or from major natural streams like the Scuppernong River.... The material removed from these canals forms the principal highways and roads in the area. The second type is the collector ditch, generally spaced about half a mile apart along each side of the main canals. Width and depth depends primarily on the amount of material needed for field roads. The third type is the field ditch which runs parallel to the collector ditch and provides the direct conveyance of water from the field.

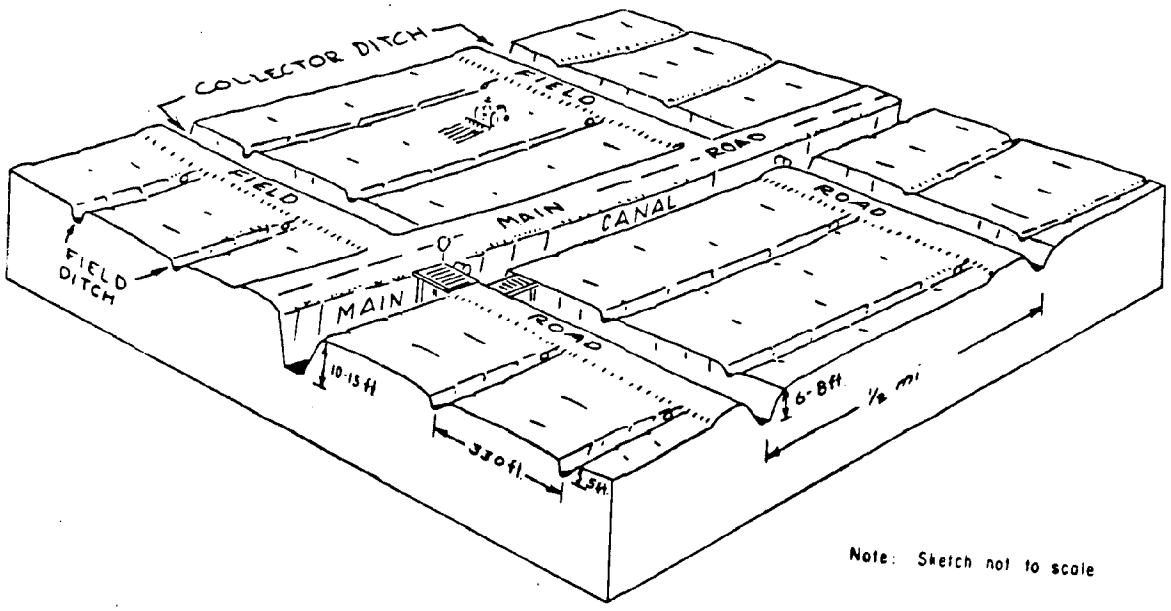


Fig. 4. Typical artificial drainage system of the Albemarle-Pamlico peninsula. (Source: Ref. 12.)

Upon completion of the drainage channels, each square mile is drained through 16 to 20 miles of field ditches and three miles of collector ditches. The average for the area under cultivation is about 20 miles of channel per square mile. The U.S. Soil Conservation Service has assisted property owners to install 208 million feet of open ditches affecting about 4.2 million acres of land in coastal North Carolina.[5/]

Most large-scale clearing and draining enterprises conform generally to the following steps of construction outlined by Heath:[12/]

1. Construction of drainage canals - In areas not previously drained, major canals are spaced about a mile apart. Depending on the terrain, they are dug 10 to 15 feet deep and 15 to 25 feet wide at the top. All dirt is piled on one side where it serves as a road foundation and, where additional material is needed for the road bed, the canal may be dug both wider and deeper than normal. In low-lying areas, collector ditches and field ditches are also constructed at this time. (Note: Where there are natural drainageways, these may be "channelized" and used in place of the straight canals.)

2. Removal of pulpwood and saw timber - This step is facilitated by the roads built along the major drainage canals and by the somewhat dryer conditions provided by the canals.

3. Clearing of remaining vegetation - Bulldozers and other power equipment are used to uproot the remaining vegetation and pile it in windrows which

are burned as soon as wind and moisture conditions permit. Because large amounts of soil are removed with the roots only the outer part of the windrow burns at this stage.

4. Construction of field ditches - If not dug earlier, power shovels equipped with a triangular shaped bucket are used to dig field ditches (or "V" ditches) parallel to and midway between the windrows. The field ditches are five feet wide at the top and one foot wide at the bottom. They are spaced from 260 to 330 feet apart. (Note: Subsurface drain tiles are sometimes used in place of field ditches.)

5. Preparation of fields for crops - This step includes further burning of the windrows, and "shaping" the fields so that they slope towards the field ditches at a rate of about 0.5 percent. Thus, where field ditches are 330 feet apart the center of the field is about 10 inches higher than the edges. The fields are shaped to avoid ponding of water on the surface. During this step 5 to 6 tons of limestone are added per acre to the soil to neutralize the strongly acid condition of the swamp soils.

The more advanced method of field drainage is the installation of subsurface tile drain systems. While initially more expensive, subsurface drains leave the fields clear of ditches and make them easier to plow. Tiles are placed four to eight feet deep, spaced the same as ditches or somewhat closer, and pitched to flow into collector ditches. In the"past few years" the U.S. Soil Conservation Service has "...assisted in the total installation of approximately 82 million feet of tile affecting almost one-half million acres..." in the North Carolina coastal plain. 5/

There may be a fourth level of drainage involving "hoe drains", small, shallow ditches running at right angles to the field drains, dug each year by small tractors as part of field preparation. Hoe drains are particularly needed where the individual rows are bedded -- that is, raised from the general surface of the field -- to drain the water from the furrows.

Much of the recently converted land is too low to drain by gravity flow, requiring that the water be pumped up into the canals. Land less than four feet above sea level is particularly difficult to drain and on the Albemarle-Pamlico peninsula drainage may be complicated by storms and tides. According to Heath: [12] "Development plans for these areas involve the construction of protective dikes to avoid storm flooding from the sounds and the Alligator River and the installation of pumping stations for water level control. In the lowest areas, canal levels may be maintained below sea level during the growing season as is now done in the Gum Neck area."

Excess water is not the only problem facing lowland farmers, drought is still another. Plant roots do not penetrate deeply in the "blacklands" of the coast.

The water table lies low in dry weather. Subsurface soils remain acidic even while the surface 6 to 8 inches is neutralized with lime.

Nor does water easily move upward through the peaty organic soils to reach the shallow plant roots.[1/] Consequently, there may be serious drought losses of crops in the cleared and drained lands unless efforts are made to maintain the water table during dry periods. This can be done by constructing ditches or tile drains at the right level to make it feasible to reverse the drainage process when necessary and to feed water back into the soil. Pumps may be needed to accomplish this reversal of flow along with water level weirs to impound water. In this system, the ditches may require considerably more maintenance to remove sediment and vegetation and the additional construction and operation costs may bring profits down to the marginal range unless the result is extremely productive land.

Forest Industries

In the North Carolina coastal plain there are several categories of land harvested for wood products:

1) pinelands owned and harvested by wood products manufacturers (often converted to agriculture after harvest); 2) plantations where loblolly pines are cultured for maximum production; 3) natural swampland forests of cypress and white cedar (juniper); and 4) miscellaneous holdings of woodlands by investors, farmers and others. The first and second categories are the ones of primary economic importance. Most of the 2.2 million acres of forest land of the 17 coastal counties that have conomic potential have been logged at least once in the past. Much of it is of marginal value for agriculture, having deep organic soils and severe drainage problems. Nevertheless, if the investment potential of improved land continues to increase, many thousand additional acres may be cleared and drained.

In general, coastal lowland forests run about 14½ cords of merchantable wood per acre of pine, gum, other hardwoods, some white cedar. Another 30 tons per acre of biomass is windrowed and burned when land is cleared for farming.[3/]

Major companies, such as Weyerhauser, have invested extensively in pine culture. Authorities consider these ventures an economic success and

expect to see them expanded in the future.[5/] If loblolly tree farms do succeed, one would expect to find them on land of low value for agriculture . Forestry expert J.D. Gregory claims that "Loblolly pine makes its best long term growth on poorly drained soils high in clay," but that drainage and "extensive site preparation" are needed for "vigorous stands" of loblolly in pocosin areas.[5/]

Technology of Land Drainage and Pine Culture

Gregory notes two major objectives for drainage of forest lands in the coastal area:[5/]

> The objective of the earliest forest land drainage in eastern North Carolina was to facilitate logging. Lowering of water tables and reduction of the water content of surface soils improved trafficability for heavy equipment. Soil from the drainage ditches was used to build access roads for logging trucks and for use in subsequent management activities. Forest fire control was especially enhanced by the system of roads that provided access to formerly remote forested areas and served as firebreaks.
>
> The second objective of land drainage is to improve the potential productivity for pine. Many poorly drained organic soils are much more suited for the growth of pines after water tables are lowered. Loblolly pine is the species of choice for the forest industry, not only because of the market requirement for pine pulpwood, but because of the demonstrated growth potential on lower coastal plain sites.

In relation to drainage techniques, Gregory states:[5]

> Drainage systems being installed on previously undrained forest lands in eastern North Carolina are carefully designed to conform with the natural drainage pattern as much as possible and to provide adequate soil drainage throughout the area to be planted....Common site preparation practices include shearing and piling of large residual material when necessary, drum-chopping, burning, and finally, bedding. Experience has shown that providing raised beds for the seedlings is needed to produce a well-aerated rooting zone even on drained land. Fertilization with phosphorus or nitrogen plus phosphorus has become a common practice because most poorly drained soils of the lower coastal plain are highly acid and low in available nutrients.

Experience shows that 80-foot loblollies can be grown in 25 years under culture, *versus* only 45-foot trees in nature.[15] The total productivity per acre may be two to three times the rate of non-cultured stands.[3] However, the costs for complete clearing, drainage and field preparation can run to $1,000 per acre for loblolly farms. Also, fertilizer and herbicides must be applied at intervals and the ditches must be maintained. Strategic water management may also be required, according to Gregory, because loblollies do best if started in relatively dry soil and finished in relatively wet soil.[5]

Peat Mining

For all the publicity about peat mining in coastal North Carolina, full scale mining lies in the future. Surveys have been made, harvesting machines tested, products analyzed, markets reviewed and trial production commenced. Four state permits are active 16,600 acres) and two more are pending (10,600 acres).[13] Clearly, Carolina peat can be mined and the product would be salable. The question is whether peat mining can show a profit within today's costs and sales parameters.

The projections for the peat market do look promising. According to a recent state task force report:[16]

> There is not yet an established market for North Carolina peat, but a major market is expected to develop within five years as proposed methanol plants and peat-fired generating plants are built. The first peat sold, perhaps within six months (from March, 1981) will probably be bought by Weyerhauser to fuel its new boiler at Plymouth.

The state has about 1,000 square miles of peatland (640,000 acres) containing 600 million dry tons of peat. Three hundred sixty square miles, with 210 million tons, are on the Albemarle-Pamlico peninsula. (See Figures 5 and 6.)[17] The peat lies in deposits averaging about 4½ feet deep but it can range from a

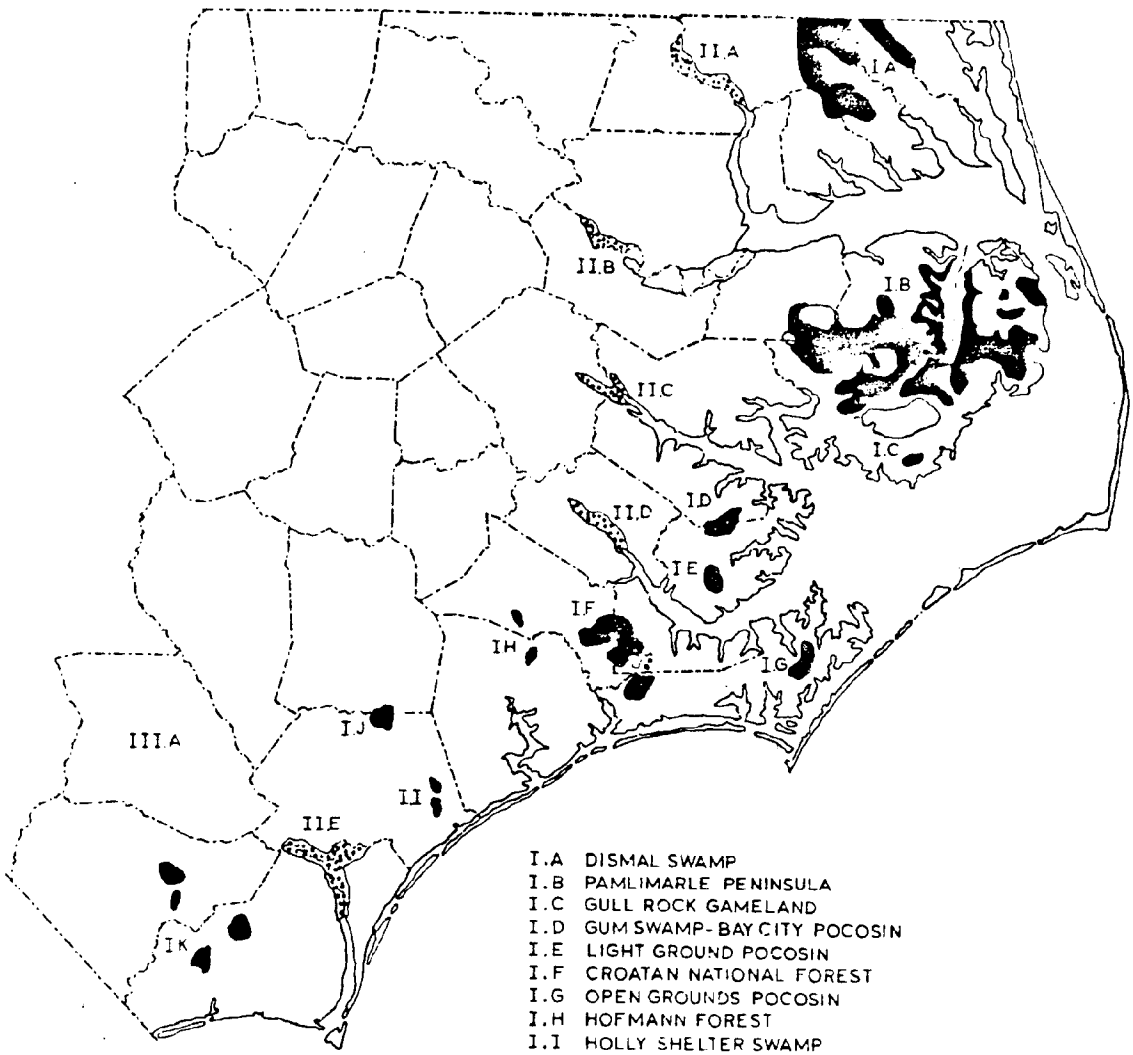


Fig. 5. Map showing location of North Carolina peat deposits. (Source: Ref. 17.)

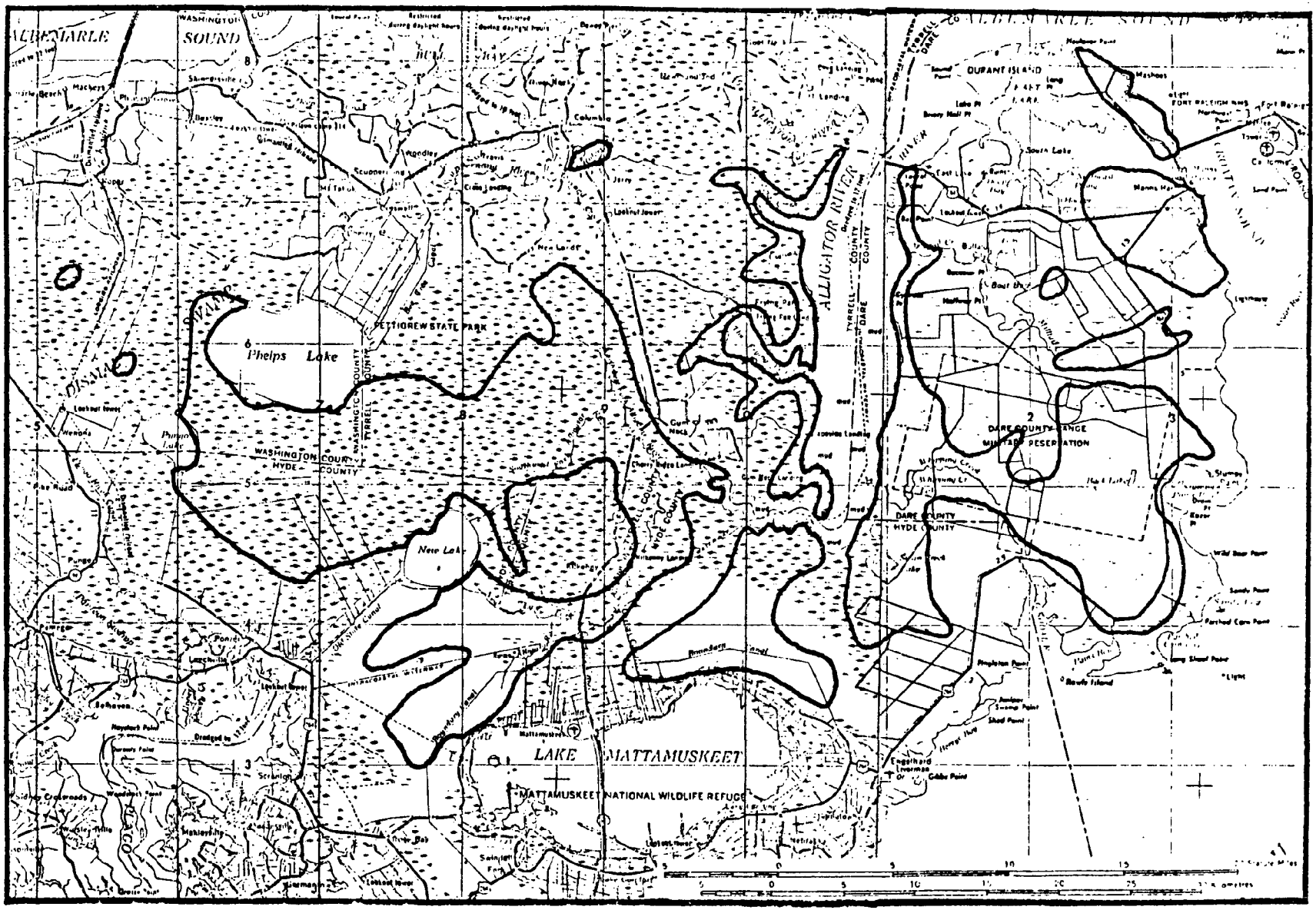


Fig. 6. Peat deposits of the Albemarle Pamlico peninsula. (Source: Ref. 17 .)

thin slice to over 16 feet deep (over relict stream beds). Mining of deposits as shallow as 2 feet has been proposed.[13]

The quality of the peat is adequate for use as an industrial fuel. Sulphur content is low, ash is around 5 percent While peat is far bulkier than coal, its BTU output, pound-for-pound is comparable to eastern bituminous coal -- peat rates from 10,000 to 10,500 BTU/lb (dry weight) while coal contains 10,000 to 13,000/lb. It is wet and heavy as it comes out of the ground and drying it is a big job since it must be reduced from around 90% moisture to about 30-50% in order to burn right[18] or to 0-3% moisture for gasification (in a methanol plant).[13] Because of its bulk (four times that of coal) transport is expensive and stockpiling and handling at the use point is somewhat cumbersome. A severe problem is that much of the peat contains masses of logs that remain undecomposed at depths of 2 to 3 feet beneath the surface. European peat harvesting equipment is not designed to work in such fields but modified asphalt paving equipment appears to be working in North Carolina for peat mining. Equipment has been the major deterrent to profitable mining.

The peat is usually deepest in bog areas where it restricts growth of plants and trees Thus, peat is

often located in pocosin bogs associated with a dense shrub thicket and stunted pond pines. These deep peat soils are marginal to unsuitable for row crops, even at the state-of the art of drainage engineering and pH manipulation. But with all but 10-14 inches of the peat removed, the underlying mineral soil base can be very productive. Consequently a major incentive to strip mining of peat is to improve the land for crop production. If the peat mining operation only breaks even, the value added to the deep peat land may turn a good investment profit. In considering the economics of land clearing and drainage, one must realize that the large corporations operating in coastal North Carolina are ultimately concerned with land values from an investment standpoint more than they are with revenue generation.

Technology of Strip Mining for Peat: The technology for clearing and draining peat lands in preparation for strip mining is similar to that for agriculture. According to one source, the field ditches may be spaced more closely than for crops (e.g. 165 feet compared to 300 feet) and the field is sloped to an even 0.5 to 1.0 percent, grading toward the drainage ditches.[18/]

Harvesting methods tested are: 1) "milling," whereby the top 4 to 10 inches are disturbed, left to dry a few days, and recovered with a vacuum or conveyor harvester 1 to 2 inches at a time, 2) "sod cutting," whereby a wheel cutter removes chunks and extrudes them through an auger back onto the field for drying and recovery, and 3) modified asphalt paving removal equipment which can cut through the buried logs (too recent to evaluate). Ideally, the processes would continue through many cuts until mineral soils are approached.

In many cases, stripping the peat will create shallow pits. These will often lie below the existing water table, causing the ground to become inundated much of the year. The remedy -- especially needed after mining deep peat deposits -- is the continual pumping of water up to higher level canals where it can flow away by gravity. This need for perpetual pumped drainage increases the costs of farming the land after stripping is finished (variously $10-15 per acre or 3-5 percent of costs) and intensifies the hazards (2-3 days of water logging can cause extreme crop damage).[18/] However, these drawbacks may often be offset by the general high productivity of mineral soils exposed by stripping.

IMPACTS OF CLEARING COASTAL LAND

The consequences of coastal land conversion have been studies by state agencies, engineers, scientists and others since 1974. Great progress has been made in understanding the effects of clearing and draining and their impacts on the economy, environment, resources and the quality of life of coastal North Carolina. These studies have identified the following as the probable major impacts: 1) substantial loss to fisheries by disruption of the sounds and bays; 2) much increased hazard of hurricane flooding as the land surface drops lower; 3) dramatic loss of habitat of bears and other key species; 4) severe reduction in wetlands -- swamps, marshes, and pocosin bogs; 5) increased threat of salt water pollution of groundwater; and 6) general deterioration of coastal environmental quality by smoke, dust, and loss of natural amenities.

Impacts on Land

The character of the coastal landscape is dramatically changed by land clearing and draining. While the fact of change is obvious to the eye, the effects of change are not so easy to see. Our knowledge of major changes to the land is reviewed below.

Land Surface: It is known around the world that when peaty wetlands are cleared and drained for conversion to farmlands, the land surface begins to fall -- North Carolina is no exception. The causes are shrinkage and consolidation of the soil, compaction from tractor operation, oxidation of the peat, wind erosion and wildfires. The land has only one way to go, down. It is only a question of how far, how fast. Equilibrium comes only when all the peat is gone and the mineral soil level is reached. Once peat soil has subsided, it does not rise again Subsidence is a real threat to large areas of coastal land that lie close to sea level. For example, most of Tyrell, Dare, and Hyde Counties are less than 5 feet above sea level. Any further subsidence could subject such areas to extreme hurricane damage and pose further difficulties in land drainage (Figure 7).

Because much of the lowlands of coastal North Carolina were drained for forestry or agriculture years ago, much of the dramatic initial shrinkage, consolidation, and subsidence of the land occurred in the past.[1/] Consequently, the initial subsidence of such land now reconverted may be on the order of inches rather than feet.

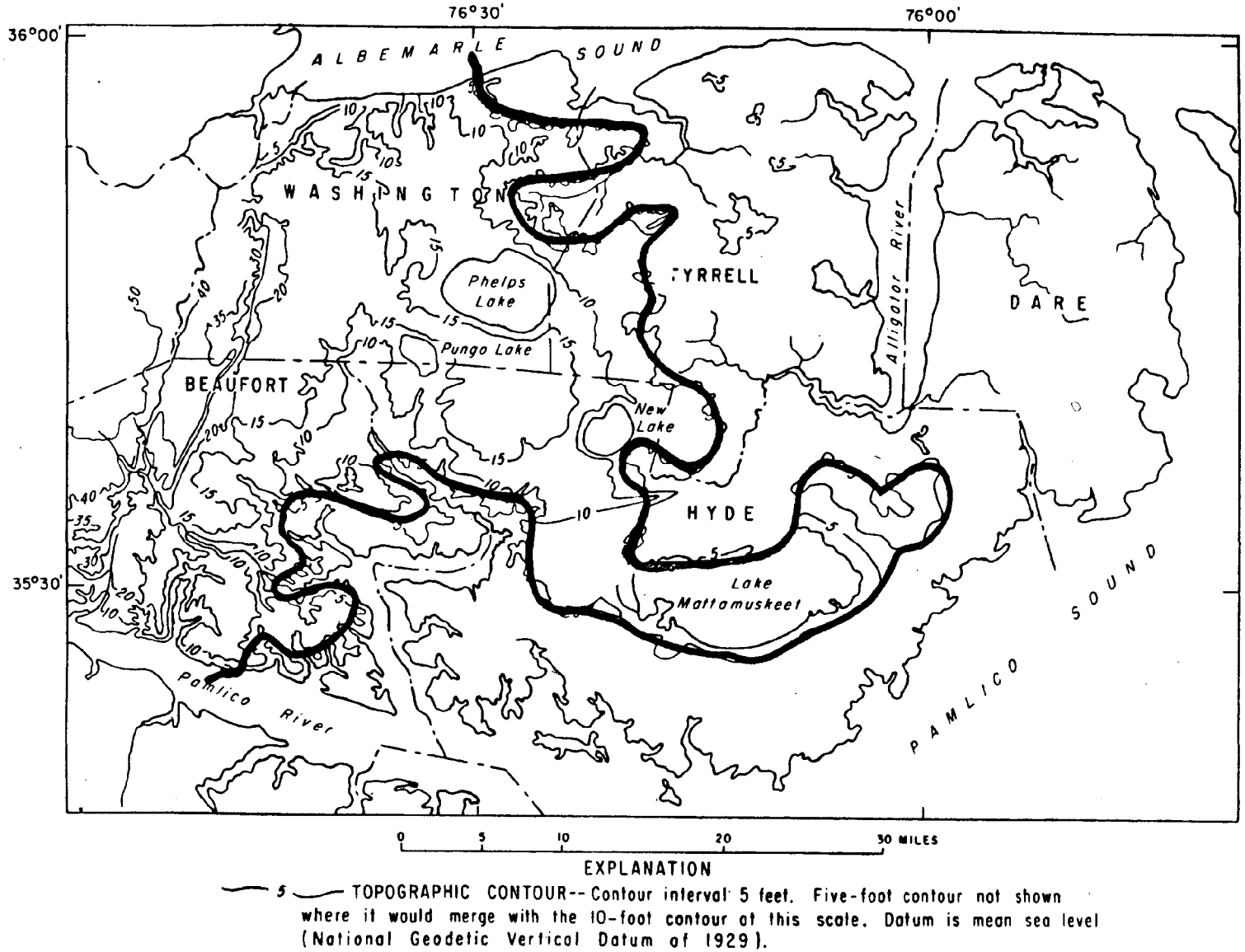


Fig. 7. Generalized position of the 5 foot contour on the Albemarle Pamlico peninsula shown by heavy line; most land east of the line lies lower than 5 feet above mean sea level (base map from Ref. 6).

After the initial period the rate of subsidence may fall to less than ½ inch per year, according to some studies.[1/] This is attributable to oxidation principally, the natural decay of organic soils when dried and exposed to air. From the studies done in North Carolina recently (e.g. See Ref.19), it appears that the rate of persistent oxidation is low and does not cause the extent of subsidence that it does in other areas. Based upon information available, it would be appropriate to say that oxidation alone would not be expected to lower the land surface more than two or three feet in a hundred years in the typical peat soils of the coast.

However, when adding up all causes, the potential for reduction may be greater than two or three feet per hundred years. For example, Figure 8 illustrates subsidence up to six feet in one location on the Albemarle peninsula. Wildfire in the peat soils may be responsible for much of the effect in such areas of severe subsidence. Once started, peat fires burn down to the level of water saturation. Fire threat is seriously increased by clearing, draining, and working the land. Peat fires are difficult to stop because water to inundate the burn areas is not easy to come by in dry

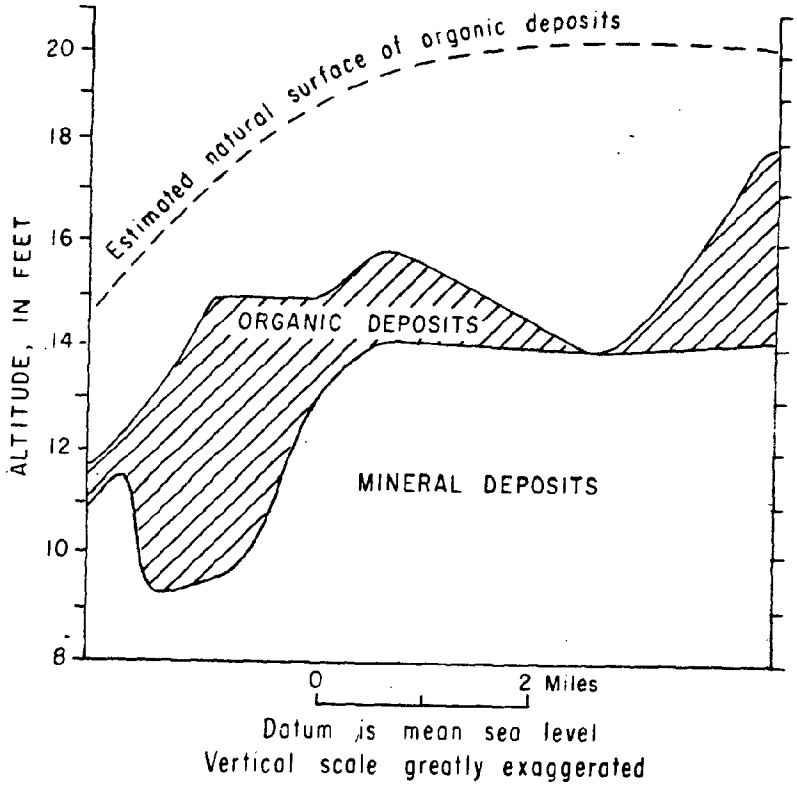


Fig. 8. Subsidence of the peat surface caused by drainage in an area west of Lake Phelps (after Dolman and Buol). (Source: Ref. 12.)

periods. Nevertheless, removal by fire may be considered advantageous in areas of deep organic soil where crop production is enhanced by removal of peat down to the mineral soils. In past years, peatlands were burned intentionally, after drainage, to get at the mineral soils.

If the potential for peat mining is realized in coastal North Carolina, land lowering will be greatly accelerated in the areas stripped. This will often create a need for pumping and deepening of canals as well as an increase in the hazards to crops of waterlogging when equipment fails (operators are required to reclaim stripped land -- for agriculture or other purpose.) The question also arises as to who will maintain the pumps and canals if the owner chooses to abandon the mine site after it has been stripped.

Flood Hazards: The problem of subsidence is especially serious in the lowland areas subject to severe flooding by hurricanes. For example, Figure 9 shows that large parts of the Albemarle-Pamlico peninsula would lie below sea level if stripped of their peat. Such areas would have to be surrounded by high dikes for protection from storm tides and would have

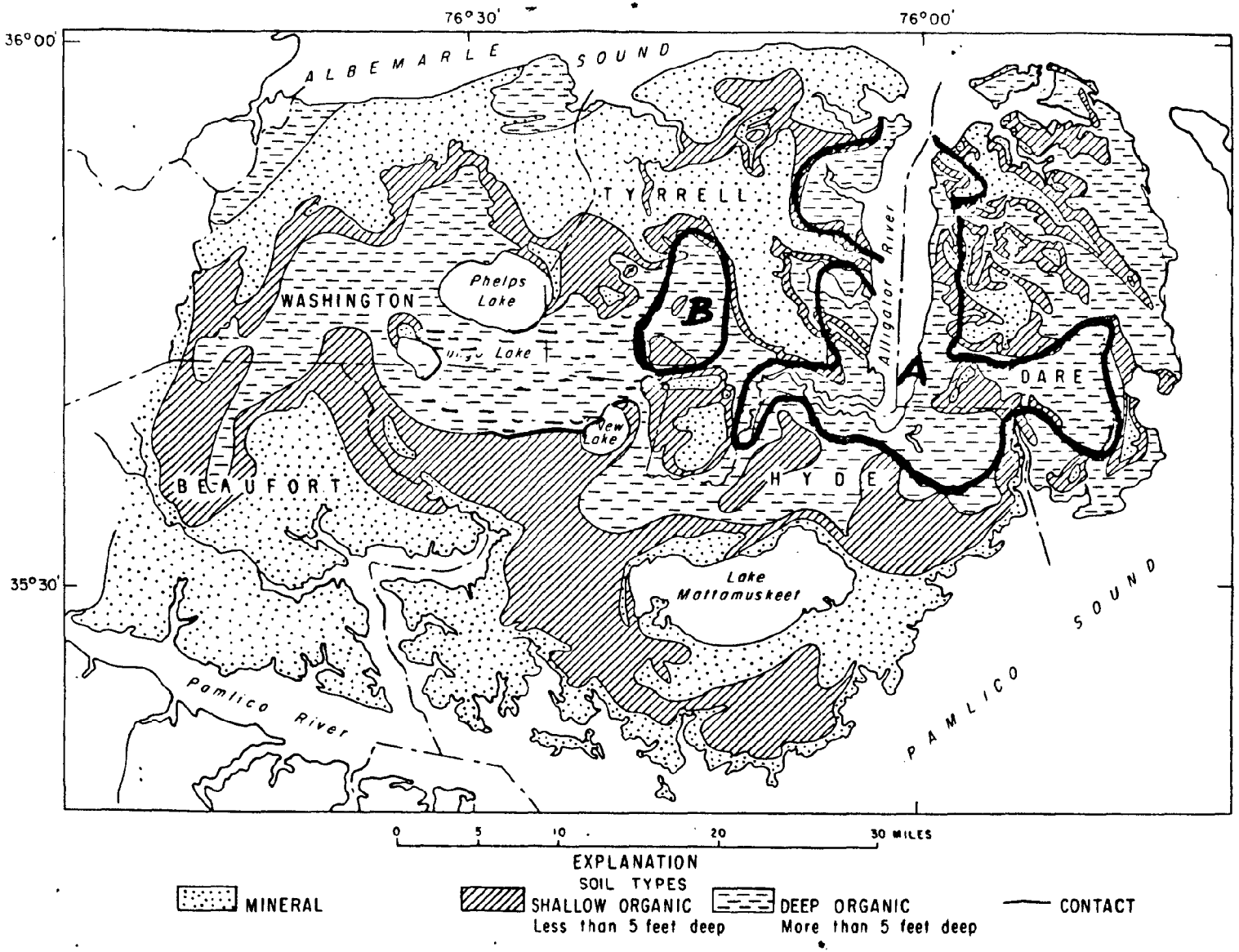


Fig. 9. Potential peat mining areas that will fall to elevations below sea level with all peat removed include: all of A and the eastern third of B according to a recent study. (Data from Ref. 18 ; base map from Ref. 6).

to be furnished with large, powerful pumps to routinely discharge rainwater and prevent damaging floods. A large hurricane which breached or overflowed the dikes would cause extensive flood damage and pollute croplands with salt water making them unusable for several years to follow.

That hurricanes are a real threat to coastal North Carolina is shown by the extensive areas flooded when "Hazel" hit in 1954 (see Figure 10). A still larger (giant) hurricane would have done considerably more damage. Hurricanes in 1955 caused damages of $131 million to coastal agriculture.[20/] Losses today would be much higher because of the extent of new farmland created by clearing and draining coastal lowlands, and the extensive clearing of forests which are a natural buffer against hurricane surges and waves. The coast immediately east of the Albemarle-Pamlico peninsula has a one-in-ten chance of a hurricane strike every year.

In the future, hurricane damage could be astronomical if coastal lands are lowered further, allowing storm driven salt water to sweep over hundreds of square miles. The public liability for disaster assistance and rehabilitation of services would be extremely high.

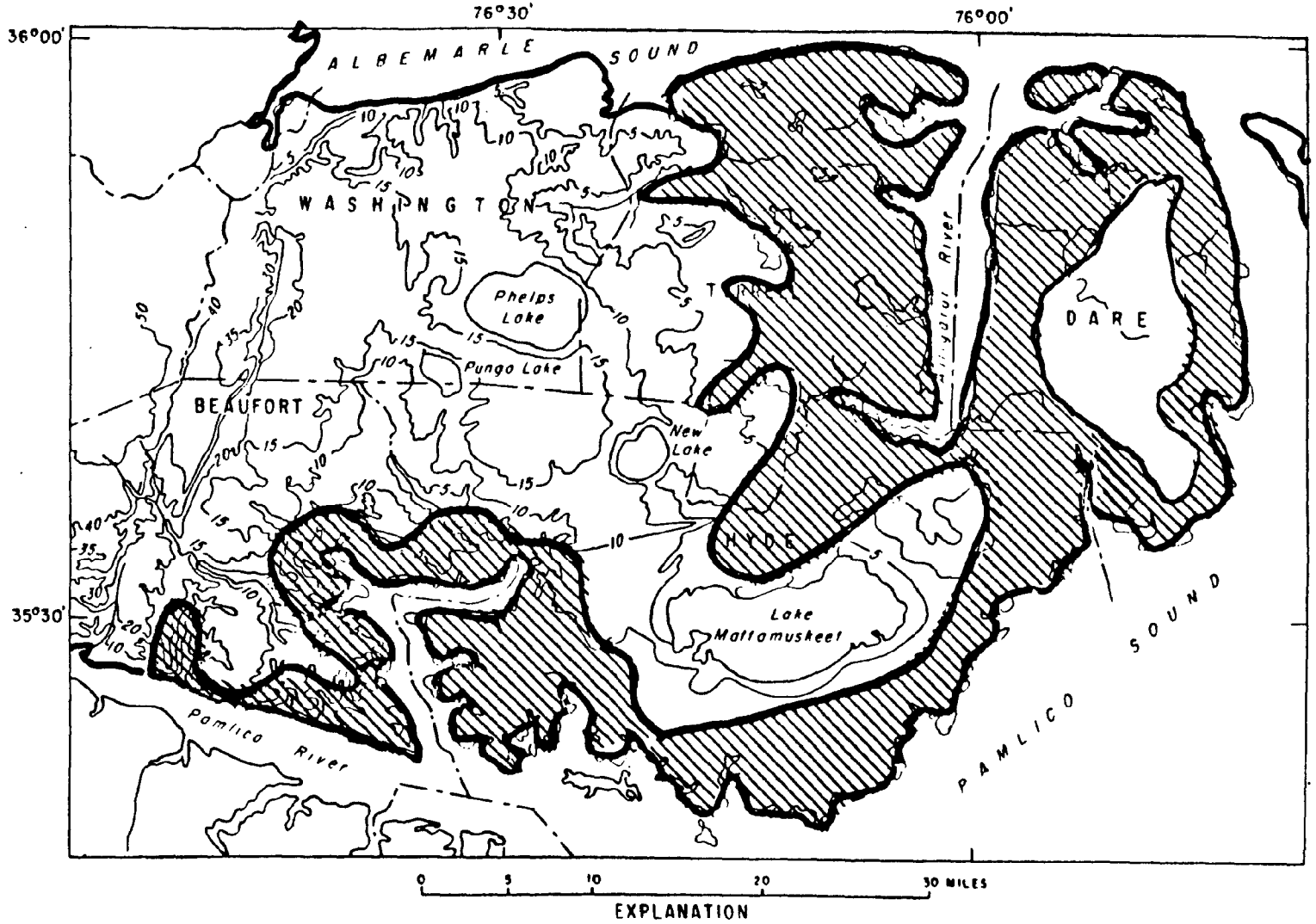


Figure 10. Areas of the Albemarle Pamlico peninsula that were flooded with salt water during hurricanes of 1954 and 1955. (Data from Ref. 20; base map from Ref. 6.)

To add to the hazards, sea level is relentlessly rising and increasing the height of tides; someday the sea will cover all the lowest of coastal lands (several hundred to one thousand years) as this trend continues.

Examples from the West: In California, 700,000 acres of peat moistlands were drained and diked in the Sacramento-San Joaquin Delta area in the 1800's and 1900's. While the peat soils were deeper -- one-third of the area had peat depths of 20 feet or greater -- the Delta is of some interest here. A study by the state Department of Water Resources shows subsidence of 12 to 20 feet for the tracts with deeper peat deposits.[21/] Over the period 1911-1952, a rate of subsidence of about three inches per year was measured for 17 large tracts that had been drained.

Fortunately, 3 inches per year (10 feet in 40 years) is a greater rate of subsidence than one would expect for North Carolina lowlands, because this has led to severe economic problems in California. In the last five or ten years there has been continuing failure of the drainage works in the Delta, particularly

the dikes that come under increasing hydraulic pressure as the land level falls. The cost to the government for disaster aid payments was $45 million for just one year (September 1980 to September 1981).[22/] But it is doubtful that the Federal government will continue to pay the tab. Many huge farms remain flooded under many feet of water today because the repairs are just too expensive. One effect is that sales of Delta farm land to foreign investors have dropped from a previous high of $22 million per year to a recent low of $3.7 million per year.

Other states, such as Minnesota[23/] and Florida have had considerable experience with draining of peat bogs that can benefit North Carolina in preparing to manage its lowland resources.

Industrialization: One must always look to the full range of effects of any major development to fully assess its effects. For example, it appears that there will be very little peat mining in the lowlands without industrial growth. The reason is that peat is too bulky to ship any distance and therefore must be used near where it is mined. An existing Weyerhauser

plant appears to be the only customer at present. Consequently, sustained peat mining would be accompanied by a large power plant, a large methanol plant, or both. If these or similar industries do not locate in the lowlands vicinity, there may be too low a demand for peat to sustain substantial production.

It is clear, therefore, that any consideration of approval for peat mining must also consider the effects of industrial growth: traffic, noise, smoke, water pollution, heavy demand for ground water, and so forth. Moreover, industrial growth in rural areas is usually accompanied by major social changes as farmers become millhands, rural institutions become urbanized, and local tradition and political style shift to the mode of the industrial community.

Impacts on Water Resources

Coastal land conversion by clearing and draining has pronounced effects upon surface and ground waters. In fact, the main purpose of drainage is to alter the existing water balance. The major effects on water to be considered in this section are pollution, alteration of basic hydrology and salt water intrusion into fresh water systems. How the adjacent estuaries are impacted by these effects is discussed in a later section.

Surface Water Pollution: Clearing and draining cause pollution of surface waters in ditches, canals and natural waterways. Because of the extreme variation in conditions, it is difficult to make general statements about the severity of pollution effects. It is probably safe to say that the short-term pollution problems from clearing and ditch construction are not nearly as severe as the continuing pollution from agricultural operations.

A variety of pollutants issue from farmlands and, to a lesser extent, from tree farms, forest harvest operations, and peat mine sites. The following are considered to be damaging to aquatic (fresh water) and estuarine systems:

- Nitrogen (N) and Phosphorus (P): Released from drained farmlands in significant amounts (N loadings were increased by 3 to 8 times normal in one test!). Both N and P have a high potential for eutrophication (over-fertilization of surface waters. The worst for aquatic systems is P (in the inorganic form) which tends to attach to sediments.[19] (N may be the worst for estuaries.) Major sources of N and P are fertilizers and soil contents.

- Pathogens: Fecal coliform enter surface waters from pasture lands in high concentration[19] and constitute a major pollution problem.

- Pesticides: Pollution of surface waters by pesticides (e.g. alachlor) is partially attributed to careless spraying; i.e. over ditches or too close to them.[19] (In a 1979 study scientists estimated that 25-50% of the alachlor applied to one field "reached the surface of the water .."[24]).

A number of other pollutants which are generally regarded as potentially damaging have not been shown convincingly to have degraded coastal aquatic systems in North Carolina.

- Heavy Metals: While copper is applied heavily to newly converted lands, it appears to be held tightly by the organic soils and -- along with other heavy metals -- does not appear in the surface waters in high concentrations.[19/]

- Sediment and Turbidity: Soil erosion, sedimentation and water turbidity are not reported to have created severe problems.[19/]

- Other Substances: There seems to be little problem with acidity or B.O.D., or with calcium, sodium, potassium, etc.

Some pollutants, like pesticides and heavy metals, can do extensive damage without visible sign or obvious effect. Consequently, an aquatic ecosystem can become gradually unproductive and depleted of beneficial life without the appearance of any dramatic event. This type of invisible pollution is probably well advanced in certain of the coastal canals, streams and lakes. For example, the fish resources of the

Scuppernong River (Tyrell) are greatly degraded, probably by agricultural runoff.[16]

More obvious and dramatic is the effect of excessive phosphorus (P) and nitrogen (N) nutrients on aquatic systems. Therefore, one can look to eutrophication caused by excess P and N for a more obvious signal of pollution damage to aquatic systems. The reports are ominous. Many coastal rivers are already eutrophic because of N and P (e.g., the Chowan and the Neuse). Outbreaks of nuisance algae are prevalent with resulting surface scums, fish kills, and ecologic deterioration.[9] [25] [26]

While the devastating effects of P and N pollution are obvious when the blooms suddenly strike, the specific combination of chemical factors precipitating a bloom may be puzzling but warm, calm days are the trigger. Researcher Hans W. Paerl explains the effects as they apply to Pamlico Sound and the Neuse River as follows:[27]

> Recent (1978 and onwards) nuisance algal blooms, dominated by blue-green algal genera have been a particularly troublesome symptom of accelerated eutrophication of the river. Blooms have been found to be common on a 60 mile section between Kinston and New Bern,

where the river empties into the Pamlico Sound. July and August 1980, yielded the worst blooms on record in the river...Blooms were most often present as surface scums, effectively restricting algal growth (O_2 evolution) in underlying waters....anoxic conditions were promoted in the bottom sediments and extremely low dissolved O_2 content of waters overlying sediments resulted.... A general comparison of current vs. past chemical and biological data indicate that the Neuse River is at the threshold of experiencing serious water quality deterioration.

A particularly troubling aspect of the river's accelerated eutrophication problems is the fact that algal blooms are dominated by nuisance blue-green algal genera.... In addition to deoxygenation of underlying and bottom waters and the promotion of fish kills, scums can cause toxicity, foul odors and tastes, chemical and physical/chemical alteration of sediments as a substrate and nutrient source/sink. Invariably rapid deterioration of water quality (in terms of the onset of undesirable plant and animal species as well as lower aesthetic values of affected waters) will result.

A report on the Chowan River provides the following general account:[25/]

For the last decade, the blooms have depressed waterbased recreation activities, caused odor problems, fouled swimming beaches with...deep piles of decaying algae, caused tourism to slacken, and are suspected of being linked to the drastic decline in fishing success. In addition to the fish kills, the important commercial herring fishery in the river is down 60 percent over normal catches, stripped (sic) bass catches are down 80 percent, and catfish catches are down 50 percent according to studies by the North Carolina Division of Marine Fisheries...

> Moreover, the eutrophication problem in the Chowan River is only part of the overall decline in water quality that is apparent in the entire Chowan River-Albemarle Sound area. In addition to the algal blooms, epidemics of red sore disease have devastated fish populations in the area in 1976 and 1979. Caused by a bacterial infection, the disease causes lesions to develop on the fish and commonly results in death. During the epidemics, many commercial and game fish catches had to be discarded due to 70-100 percent contamination with the disease In 1976, the death of over 95 percent of one commercially important species - yellow perch - in the sound was attributed to the disease....

Clearly, centers of intensive agriculture in the coastal lowlands are potential sources of damaging N and P pollution and their runoff into canals, streams, and estuaries must be carefully controlled.

Hydrologic Balance: The natural water cycle of the coastal area is severely altered by clearing and draining. Instead of slow release of rainwater from the land to the receiving watercourses via sheet-runoff

and numerous small drainageways, the water flow is shortcircuited by tile drains, ditches and collectors, and is quickly flushed off the land. This water then moves directly and rapidly through canals to bays and sounds with a peak rate of discharge up to four times greater than would be the case under natural conditions (that is, without clearing and artificial drainage).

The total runoff to the estuary may increase because the water moves off so fast that less of it is evaporated or transpired away. Also, less water may be intercepted by seasonal crops on farmlands than by the original perennial vegetation, allowing more to run off the land.[28/]

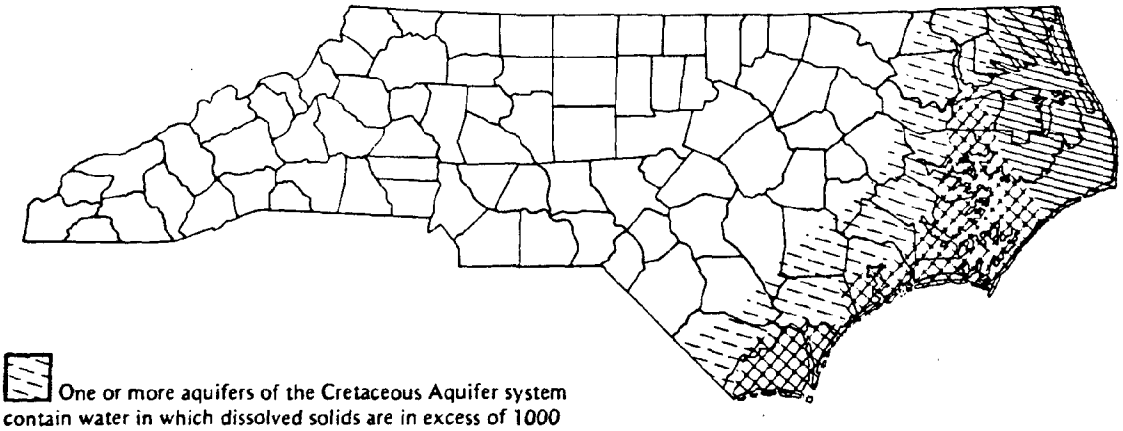
The ecological effect of these hydrologic changes is to create a stressful aquatic ecosystem, one that changes too fast to accomodate abundant life. This, coupled with degraded water quality, substantially reduces aquatic productivity.

A contributing problem is the channelizing of natural stream courses to increase their flow capacity and to lower water levels in adjacent bottomlands. This is ecologically unwise for many reasons including

the acceleration of fresh water discharge and diminished water quality. A stream that winds slowly through the lowlands tends to release water more slowly and to sequester more of its pollutants (in adjacent wetlands, for example) than a straightened and channelized one.

Groundwater Effects: The North Carolina coast is dependent on ground water aquifers for its water supply. Groundwater aquifers can be over-pumped or polluted leading to serious problems. At the coast, intrusion of salt water into groundwater aquifers can render them brackish and unusable (Figure 11). Heath summarizes the situation as follows: "Conditions in the Albemarle-Pamlico region, both natural and manmade, are such that salty water will inevitably move into zones now containing fresh water. Whether this movement poses a problem in a hundred years or in a decade cannot now be determined."[12/]

On the Albemarle-Pamlico peninsula, deep groundwater supplies are not now being overpumped (less than 2 million gallons/day are used) but the situation could be reversed if large scale crop irrigation were begun or if heavy demands were made by new industry



One or more aquifers of the Cretaceous Aquifer system contain water in which dissolved solids are in excess of 1000 mg/1.

All or most aquifers of the Cretaceous Aquifer system contain water in which dissolved solids are in excess of 1000 mg/1.

Area in which all or most aquifers in the Cretaceous and Tertiary Limestone Aquifer systems contain water in which dissolved solids are in excess of 1000 mg/l.

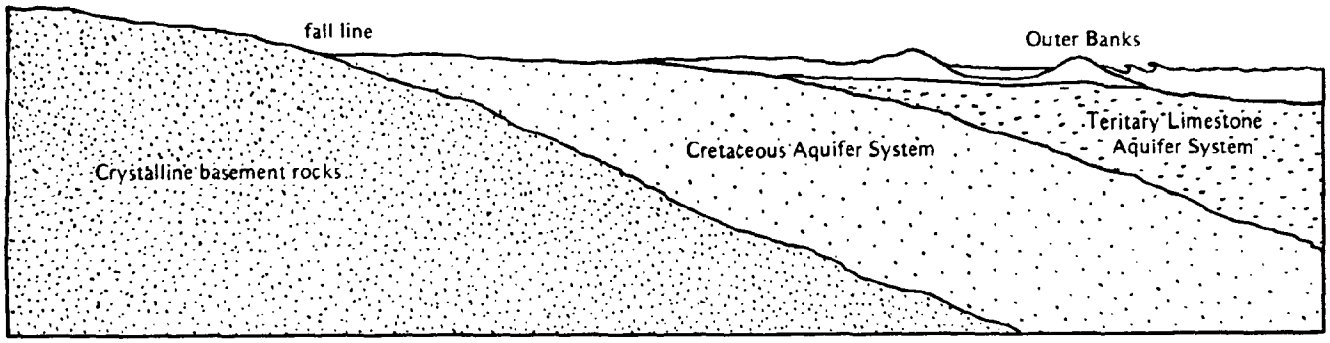


Fig. 11. Approximate extent of brackish groundwater in the coastal plain. (Source: Ref. 29)

such as proposed methanol factories, electric power generation plants, or phosphate mining operations. This could cause municipal or private wells to become defunct. The state has recognized the problem and is considering extension of groundwater controls to the peninsula and other parts of the coast.

Some experts fear that the freshwater lakes in the coastal lowlands will fall and become diminished and poor in quality if the groundwater table is lowered too far. A recent state report[16] poses the question: "What will be the effects of lowered water tables...on the water levels of nearby natural bay lakes."

Another concern is that stripping of peat in the low lying eastern areas of the peninsula will lower the surface water table and reduce the head pressure that keeps salt water from penetrating up toward the land surface. This could result in salinification of shallow groundwater and the soils in a wide band around the edge of the peninsula. Other routes for salt water penetration deeper inland are found in the drainage discharge canals that may be cut to depths as deep as 4 to 6 feet below sea level in the lowest areas (prevalent in Dare and Hyde Counties). However, the biggest threat is salt water inundation of hundreds of square miles of low country by a large hurricane surge as previously mentioned.

Fisheries and Estuarine Waters

The economic vitality of the commercial fisheries of North Carolina is said to be seriously jeopardized by conversion of coastal lowlands. The loss to the fisheries may already figure well into the millions of dollars per year for both commercial and recreational fisheries. Fish populations go up and down for many reasons, making it hard to pin changes on any one factor. But, no impact of land conversion has been more convincingly and incontestably proven than the depletion of fisheries caused by surges of fresh water into primary nursery grounds of the estuary.

The whole of Pamlico Sound and its salty tributary bays and rivers is an estuary (an enclosed coastal water body with salinity intermediate between fresh and ocean waters). The eastern part of Albemarle Sound is also an estuary as is the Cape Fear River and other smaller lagoons and tidal rivers of the North Carolina coast. Estuaries are recognized universally as being the most productive of water types throughout the world. As critically valuable resources, their conservation is a public matter of the highest concern wherever they occur.

Tide, salinity, shallowness, and abundant flats and salt marshes, combine to give estuaries their high potential. If healthy, they support an extraordinarily rich community of life from microscopic algae and plankton to the largest of game fish. The forms of life are closely related and highly dependent upon each other through the natural food chain and in other ways. There is within the estuary a critical zone of intermediate salinity (about ½ to 1/10 ocean strength) which serves as the primary sanctuary and feeding area for the young stages of fish and shellfish -- this zone is called the estuarine "nursery area." (See Figure 12). If it is not maintained in productive condition, fishery stocks will be severely depleted. Conservation of these areas requires protection of such key elements as water quality, tideflats, marshes, water circulation, grassbeds and, particularly, the salinity balance. The state's Coastal Management office has identified the most critical breeding areas as "primary nursery areas."

Salinity imbalance: The salinity balance can be upset by either too much salty sea water or too much fresh water from land runoff . In North Carolina sounds, considerable damage is being done by rapid surges of farmland runoff water which changes the

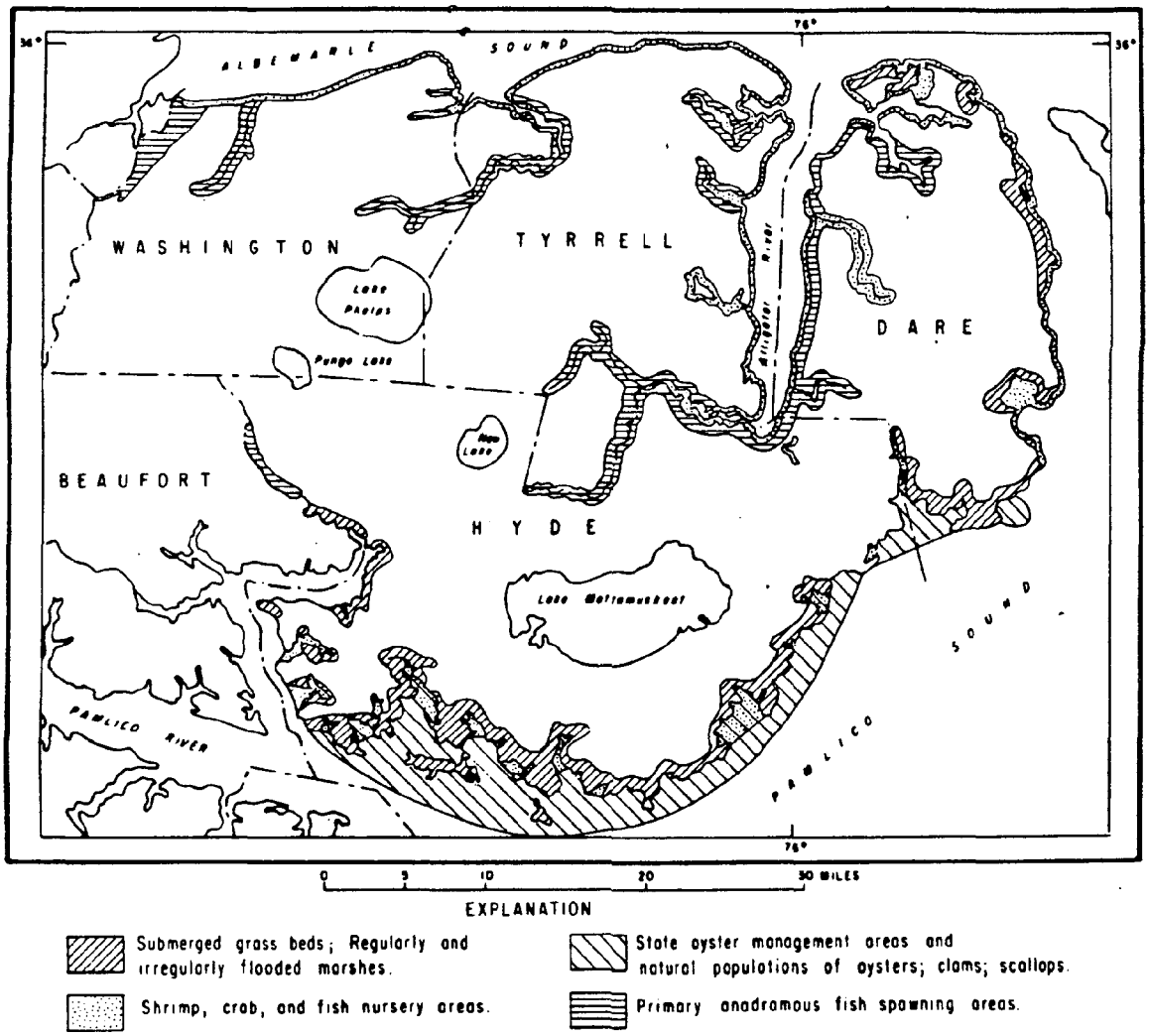


Fig. 12. Fish nursery areas and other critical areas determined by the Department of Natural Resources and Economic Development to be so important for seafood production that there is a high priority for their protection. (Source: Ref. 12 .)

brackish waters of nursery areas to fresh water, driving some tiny young fish and shrimp out of their sanctuaries, immobilizing some and killing others. When the young of the species do not survive well, the fishable stocks are gradually depleted.

Oysters, too, have been depleted by increased fresh water inflow and by pollution. They need intermediate salinities and are most sensitive to conditions in the estuarine shallows. Repeated heavy surges of polluted runoff water prevent them from surviving and reproducing. For example, the rich oyster fisheries of the southern peninsula around Rose Bay and Swansboro have been nearly eliminated and the dealers must import Chesapeake oysters. A recent report notes the following:[9/]

> Rose Bay, Swan Quarter Bay, lower Pamlico River and Pungo River were well known for their oysters prior to the 1960s. Production from these areas is negligible today.

Aquatic scientists who have studied North Carolina estuarine nursery areas can now report in detail on the problems with fresh water runoff. On shrimp nurseries, for example, biologist James Brown reports:[5/]

> Rapid freshwater run-off into a primary shrimp nursery changes the hydrological characteristics and can adversely affect shrimp in one or more of at least three ways: (1) Larval shrimp utilize the transport flow characteristics of certain incoming currents to reach essential nursery areas. This inward flow is usually a bottom current having greater specific gravities and salt concentrations and as these currents are sometimes drastically changed by heavy rainfall and run-off, the larval shrimp may be carried away rather than into the nursery area: (2) The corresponding drop in salinity can prevent successful establishment of larvae that have already reached the area, and (3) If heavy rainfalls occur after larval shrimp have established in an area, these larvae may be killed by sudden metabolic change or prematurely forced into secondary nursery areas where less of the needed nutrients are available and predation is greater. Either way, the production of commercial shrimp is reduced.

From the most intensive research on the nursery area situation, biologists R.A. Jones and T.M. Sholar reached the following detailed conclusions:[30/]

1. Drainage of surface water from upland areas into primary estuarine nursery areas through man-made ditches and canals creates unstable salinity conditions in the nursery areas. The unaltered nursery areas showed much more stable salinity patterns. Following heavy rainfall, altered areas experienced wide fluctuations in salinity while the unaltered systems remained quite stable.

2. Extensive drainage into a single nursery area reduces its value as nursery habitat by reducing average salinities and making it more sensitive to the effects of rainfall within the drainage basin.

3. Relative productivity of economically important estuarine organisms was lower each year in nursery areas receiving extensive drainage compared to natural areas.

4. The data did not show any mass or complete movements of juvenile shrimp from the nursery areas as a response to rapid changes in salinity. The most serious effects of drainage into nursery areas appear to be the degree of alteration and that alterations will be severe enough to create an unsuitable habitat even during periods of low or normal rainfall.

5. Salinity alterations appear to affect food organisms important in the production of economically important species.

Economics: The fisheries of North Carolina are valued at $150 to $250 million.[29/] with the catch hitting over 100 million pounds. The catch in the estuary (bays and sounds) around the Albemarle-Pamlico peninsula -- the part most threatened by land conversion -- sometimes reaches half of the total for the state. The most recent summary statistics show the state total to be 136 million pounds (1979) and the estuary total to be 56 million (1980).[31/] (Catches of fish for fish meal, oil and other "industrial" purposes are excluded in the above.)

There are 23,600 licensed commercial fishing boats in North Carolina according to the most recent count,[29/] an imposing investment of capital and a strong commitment to individual enterprise which keeps 50,000 North Carolinians off the unemployment lines for part of the year.

Sport fishing is also big business with boat, bait and tackle sales an important component of the coastal counties. It is surprising to find that more than one million North Carolinians sport fish each year in coastal waters. In addition, there are numerous out-of-state visitors who come to fish at the coast and add a much needed spring and fall boost to the tourist industries.

Clearly, industry of this magnitude should not be jeopardized by careless development of coastal lowlands or shortsighted planning. Fisheries are conducted in a "commons," that is, in public waters. Since the public, not private individuals, owns the estuaries, the public must take action to conserve their resources.

Pollution: When freshwater runoff surges into the estuarine nursery areas it brings with it much of the farmland pollution that enters the ditches and canals (see previous section). Some of the chemicals remain behind in the bottom of the ditches and canals but a high proportion are carried into the estuaries along with silt and debris. This results in several types of pollution problems:

* Eutrophication (over-enrichment), caused by excess phosphorus or nitrogen in the water which

leads to de-oxygenation and to algae blooms that have plagued the state's tidal rivers lately.

* Toxification, caused by heavy metals and pesticides dissolved in the water which degrade the life support capacity of the nurseries.

* Siltation, caused by sediment carried into the nurseries with runoff which can degrade estuary bottoms and make the water excessively turbid.

* Pathogens, originating with fecal matter from livestock which cause oyster beds to be closed.

No one is certain how much damage any one of these pollutants has done. According to a recent report, "An accurate assessment of the effect of continued clearing and development in the area between the Albemarle and Pamlico estuaries will have upon.. phosphorus reaching the estuaries cannot be made." However, the report adds the ominous note, "There is no question that fertilized organic soils will lose high amounts of phosphorus." Pollution may be responsible for much of the depletion of North Carolina's estuarine fisheries and shellfisheries.

Impacts on Air Quality

The major concerns for air quality are dust and smoke. Dust is a condition of life that rural communities don't welcome but must tolerate. It is doubtful that further land clearing and draining would create unacceptably worse dust conditions, although during dry times the converted lands of the coast are impressive dust producers.

Conversely, smoke pollution from debris burning during land clearing has caused intolerable air conditions including reduced visibility and multiple auto accidents. The problem was summarized recently in the following unofficial statement of the state task force on land clearing:[3/]

> The problem is caused by smoke created in the piling and burning of timber and other vegetation and peat in windrows. Since peat burns for extremely long periods (sometimes months) of time, weather conditions at the time of ignition have little effect on the creation of smoke. The smoke has caused the closing of schools, automobile accidents and other disruptions of normal operations in the area. Numerous complaints have been received from citizens in the area.

Impacts on Habitats and Natural Areas

The very wetness of the low country of the coast has created special types of natural areas and wildlife habitats that are highly valued by the people of North Carolina. Until recently, this wetness also discouraged large-scale development in much of this area and kept it from being permanently altered. And while there was considerable drainage for forest harvest, the areas gradually reverted to semi-natural between cuttings and many of them acquired a feeling of wilderness. The lowlands converted permanently to agriculture were a small enough proportion to leave large areas in forest, swamp, marsh, or pocosin. But the present and projected rates of accelerated conversion to agriculture threaten the whole natural system of the coast with dire consequences for wildlife, ecosystem integrity, and the quality of the coastal landscape. No public management system presently exists to comprehensively handle this whole situation, but the prospects are too grim to ignore.

Wetlands: The category of natural system called wetlands includes the pocosin bogs, white cedar cypress swamps, salt marshes, river bottomlands and fresh water marshes of the North Carolina coast. Wetlands are characterized by high water tables and special vegetation adapted to live in saturated soil conditions. They are quite clearly distinct from other natural areas and have unique and highly valuable functions to perform in hydrology, natural stability, biotic diversity, wildlife productivity and landscape integrity.

For these reasons, wetlands conservation became a goal of most states and the federal system in the 1970s. Wetlands conversion was sharply curtailed through regulatory programs. But these were aimed more at the wettest categories -- swamps and marshes -- than at the moistlands of bogs and river bottomlands. As it now stands, one must accept that all swamps and marshes should be fully preserved while development of all bogs and bottomlands should be controlled so as to prevent major reduction of their beneficial functions.

Any drainage, diking, filling or general clearing of swamps and marshes constitutes an unwise change in

these vital natural areas. Such changes vastly diminish their capacity: 1) to store and hold back storm water discharge; 2) to purify agricultural runoff; 3) to furnish vital wildlife habitat; and 4) to provide amenities.

Any alteration of pocosin bogs and river bottomlands which conflicts with their primary natural functions constitutes a major adverse impact and a dubious use of these wetlands. A principal function of bogs and bottomlands is to store and hold back stormwaters to preserve the quality of surface waters and to protect the estuaries against massive surges of fresh water. A second function is to hold the water table high enough to keep salt water from intruding into the surface soils. A third function is to provide for natural productivity, diversity and special habitats for wild species. A fourth function is to slow the rush of hurricane surges over the low country. Those who would alter bogs and bottomlands should make provisions to maintain these functions through state-of-the-art mitigation methods.

River bottom wetlands and pocosins have been heavily depleted in the past, leaving these resources in critical scarcity today. For example, Figure 13 shows that most pocosins of North Carolina are either totally developed or in development transition. The same could be shown for river bottoms. The vital swamp and marsh resources of the coastal area are also in need of protection. Therefore, a strong thrust toward conservation in the North Carolina coastal area seems appropriate, with emphasis on restoration of the natural functions of as much area as possible.

A survey of 17 coastal counties identified 1,800,000 acres of wetlands, 32 percent of the total land surface. Figure 14 shows that about 1/3 of these wetlands have been drained and that another 1/3 are subject to drainage in the future (although little of this could be considered wilderness).

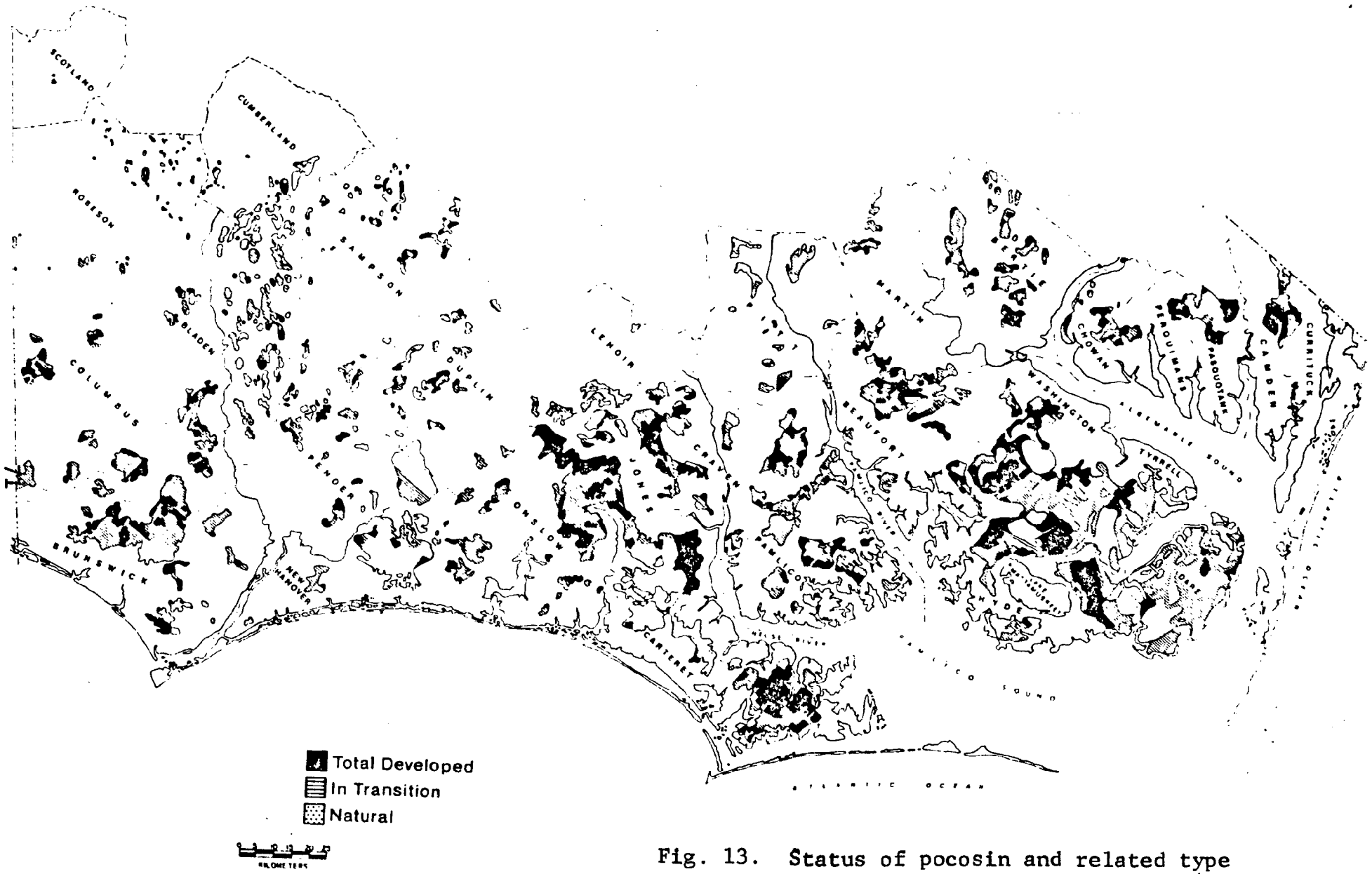


Fig. 13. Status of pocosin and related type wetlands in North Carolina. 32/

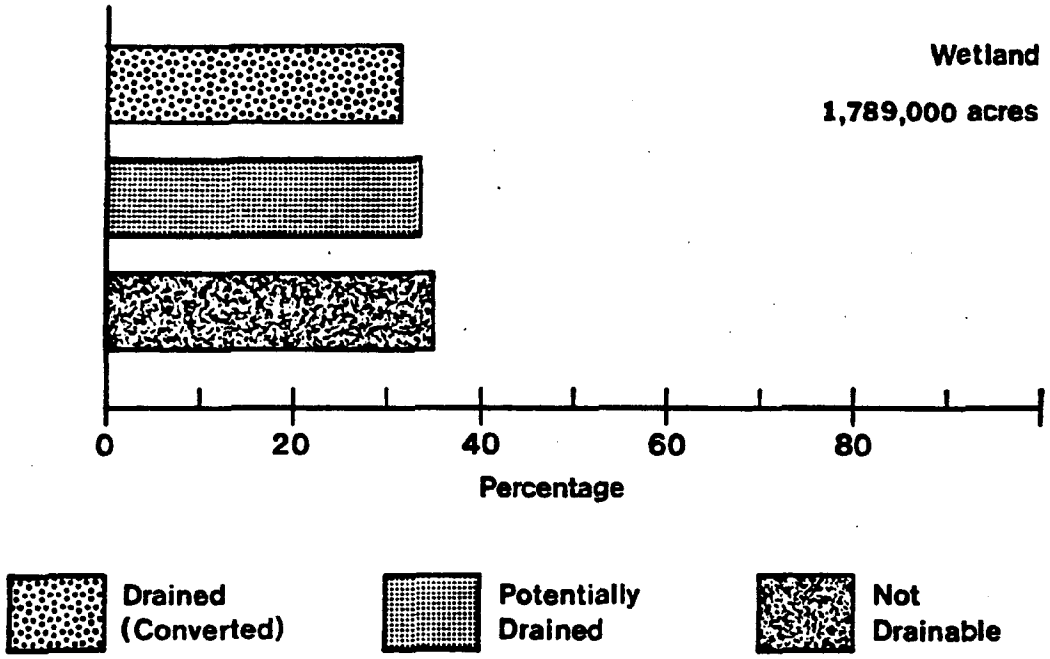


Fig 14. The percentage of wetland drained potentially drainable, and not drainable for agriculture and forestry (Source: Ref. 4)

Wildlife Habitat: The rapidity of clearing and draining coastal lowlands is progressively eliminating vital habitat for game species, endangered species and other valuable species. Stuart Critcher recently summarized the game species problem as follows:[16/]

> The impacts of land clearing operations which are required for peat mining and for large-scale agricultural production (soybeans for export) are similar and cumulative. Further, these impacts are a certainty, and cannot be considered a "potential problem." The process involves the complete removal of all existing forest and shrub vegetation, thereby eliminating the habitat for certain wildlife species, including the black bear, cougar, bobcat, deer and other forest-dwelling species. In turn, these species are eliminated or so reduced in numbers as to render these populations unsuitable for recreational hunting. *

The situation regarding the black bear is critical. Black bear are particularly prone to inhabit pocosin bogs and the disappearance of these wetlands is threatening the very existance of huntable stocks.

The coastal area in general, and the Albemarle-Pamlico peninsula in particular, are important to the state as habitat for many game species. For example, coastal counties support much of the deer population of the state (Figure 15). It should not be surprising that many of the officially endangered

*Note: There is some disagreement over the existence of cougar in the lowlands.

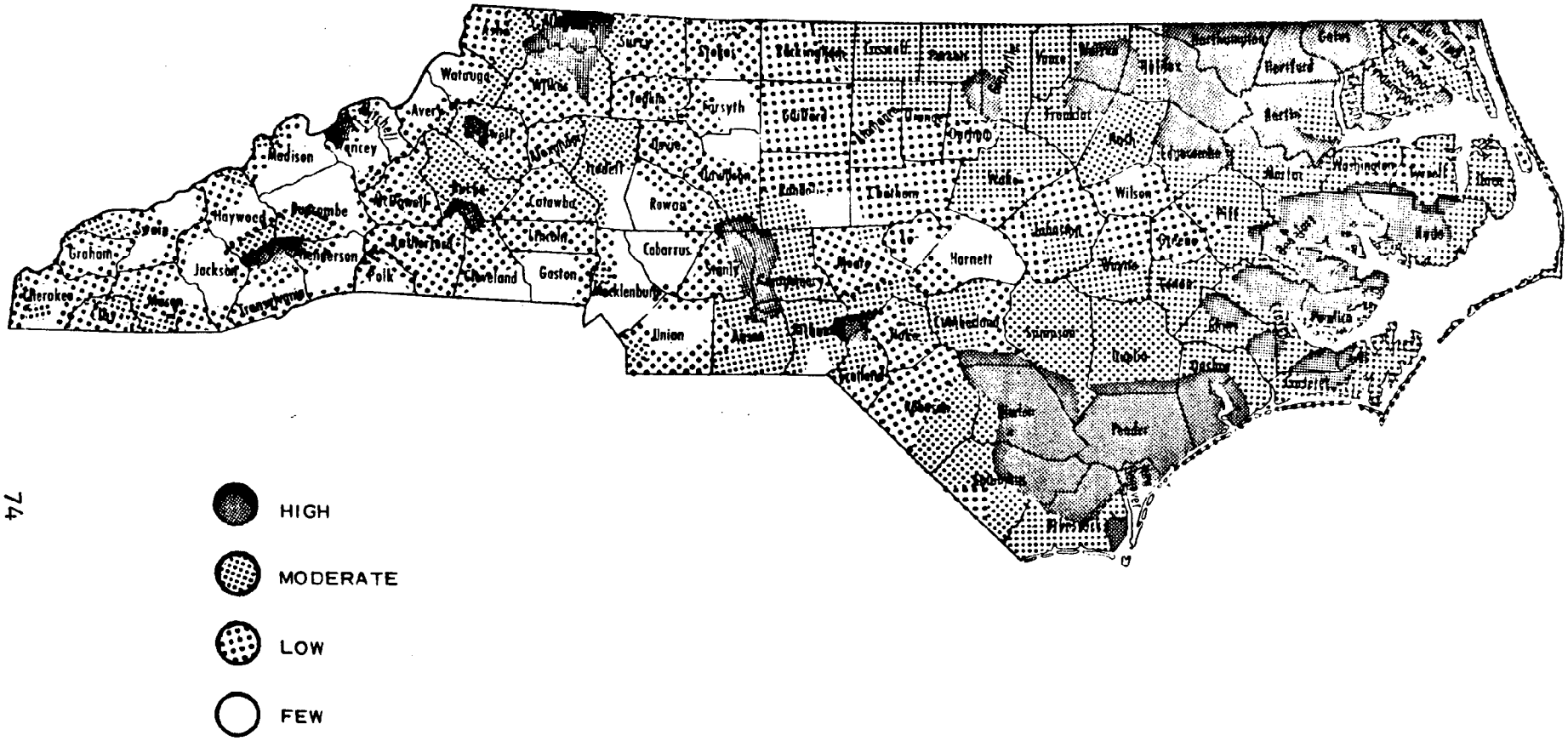


Fig. 15. North Carolina deer distribution map, July, 1979. (Source: North Carolina Department of Natural Resources and Community Development.)

species of the state are critically dependent upon the wetland and moistland habitats of the coastal area. The alligator, for one, has its northernmost habitat in the Alligator River on the Albemarle-Pamlico peninsula and could easily be extirpated there if the swamps are depleted or the aquatic areas highly disturbed. Other species recognized as needing protection throughout the state and critically dependent upon the conservation of lowland habitats are bobcat, cougar, osprey and otter.

It should be noted that there are a number of other terrestrial species that could either lose or gain on clearing and draining of coastal, depending on the outcome: dove, quail and wild turkey.

SOLUTIONS

Conversion of hundreds of thousands of acres of watery lowlands in coastal North Carolina has created a most complex environmental situation. It has brought fishermen into conflict with farmers; hunters with foresters; and environmentalists with strip miners. The impacts on natural systems and the human environment are widespread and serious. Some impacts, like heavy smoke, are obvious to the man in the street. Others, like pollution of bays and sounds, are difficult even for scientists to trace. Moreover, what may be acceptable for 10,000 acres may be unacceptable when 100,000 acres are involved. Who should decide how much is too much? Certainly not the individual land owner whose motive is to maximize profit and not to look after the public's interest or to protect the fisherman's livelihood. Clearly, if the problems are to be solved, public agencies must intercede. State agencies will need to be involved because the problems are too complex for local government.

Exercise of Authority

The chance of finding a miracle solution in which everyone wins is nil. The chance of finding a reasonable accomodation between conflicting interests is very good. Landowners will have to give up some short term profit for long term protection of resources and environment, setting aside land for buffer strips and wildlife sanctuaries. Fishermen will have to accept some further risk to future stocks of fish and shellfish. Farm drainage districts may have to expand their functions to include flood protection. Many adjustments will have to be made to ensure that continuing land conversion does not exceed the threshold of good sense. Beyond that threshold lies a nightmare of species obliteration, hurricane holocaust and ruined fisheries.

The complexity of the problem is such as to stretch the concept of coordination and cooperation among agencies. First, the Governor may have to focus state efforts through establishment of a more centralized review authority. Second, the area itself should be designated as a "critical area" with unique circumstances and strong threats. Thirdly, funds must be provided to support the needed technical studies and monitoring actions (funds could be obtained from severance tax on peat or

other special levy). Experience from the many states that have"critical area" programs suggests that, if done right, they can indeed solve difficult problems (e.g. see Jon Kusler's "Regulating Sensitive Lands", Ref. 33) just as North Carolina's areas of environmental concern mechanism has aided coastal management.

A special critical area authority for land conversion would organize technical studies, consolidate the review processes for permits and approvals, establish criteria and performance standards, coordinate state and federal agency interests, help opposing interests find common ground, facilitate public education on the issues and guide public works projects. It would have to approve all land conversion projects (subject to appeal) in the critical area of coastal lowlands in accordance with an appropriate balance of interests.

The Leading Issues

There is a well publicized set of conservation and environmental issues to be resolved before the present controversy over coastal land conversion dies down. It is good that a state task force is now in a position to give them more concentrated attention. Issues of

greatest concern are briefly reviewed in this concluding section.

1. How can runoff be controlled so as not to disable estuarine nursery areas with surges of storm water?

This is a matter of restoration as well as prevention of future damage -- some way of controlling the runoff surges that now disrupt the estuary must be implemented. Drainage enterprises should be delayed until solutions are found. Two main approaches have been advanced: 1) increase water storage capacity, and 2) route the runoff to discharge at the least vulnerable estuarine shoreline locations. To measurably increase storage will require a centralized plan for use of storm water routing into fallow areas, strip mine pits, and so forth (probably including many pumps and water level weirs). Such a system should be capable of storing the average highest yearly rainfall. Relocation of discharge points requires reworking the existing networks of canals according to a central strategy (beyond the ability of local drainage districts to accomplish). Optimum would be a combination of the two approaches, that is, increase water retention through storage and discharge if in the safest manner possible.

2. How far can the land surface subside without creating major hazards?

As it now stands, any further lowering of the land surface in certain floodable areas does threaten life and property. There are insufficient dikes, pumps and such,to prevent massive salt-water flooding in a major hurricane. In spite of the huge damage brought by hurricanes of the 1950's, little has been done to protect the coastal lowlands. Damage in the hundreds of millions is expected from the next large hurricane to hit coastal North Carolina.

Any activity which would measurably lower the land surface in hurricane threatened areas (see Figure 10) should be delayed until a central plan is created. The plan would specify the type, size and location of hurricane dikes, outlet structures, and pumps. It might also limit the amount and type of drainage entering the system.

The end result (particularly after another 2 or 3 feet of sea-level rise) is a coastal zone, which, like Holland's, lies behind dikes and where rain water must be pumped out. The intensity of need and value of land in Holland make it possible to create a huge

acreage of these "polders," or diked lands. But in Holland the national government owns the land, builds the polders, maintains the canals and operates the pumps. Also, Holland does not get hurricanes.

The key point here is that hundreds of thousands of acres of coastal lowlands are going toward gradual submergence. This trend is now being counteracted by uncoordinated and totally inadequate building of weirs, pump-stations and dikes by private interests and drainage districts. None of this protects against large hurricanes. North Carolina is already in a countdown to disaster and further land lowering will add to the damage. One solution is a comprehensive state hurricane protection project for the lowlands.

3. How can wildlife be protected without undue intervention in private property rights?

People own land but not wildlife. The species of wildlife are common property and free to move about on private lands. Property owners have no greater right to hunt or capture species than anyone. Nor are they under obligation to enhance wildlife on their property. Unless an endangered species is involved, owners may strip their property of wildlife habitat whenever

they wish to. Wildlife interests depend to great extent upon the voluntary efforts of property owners to maintain wildlife and to allow access to the public. Unfortunately, this voluntary system is seriously threatened in the coastal lowlands by large scale corporate land conversion. Many species, including bear, are seriously in danger of losing most of their habitat.

The main solutions are: 1) public acquisition of key parcels of habitat (such as pocosins for bears) and 2) requirement by law that some natural habitat be spared in the conversion process. Both should be employed in a comprehensive wildlife plan for the coastal lowlands.

State natural resource agencies have recommended that a minimum 10 percent of land be left in natural area in the clearing and draining process. The plan would create a 300-foot-wide natural area buffer around each mile-square block of cleared land, providing both habitat and migration pathways for wildlife. One major problem is: How do you keep the buffer strip protected over the years?

The gridwork of buffers would secure some much needed habitat but would not solve the whole problem. Public acquisition of larger blocks of habitat will be needed for some species, like the black bear. A comprehensive wildlife plan can identify the areas to be acquired. An agressive acquisition program -- of state-Federal purchase, of securing land gifts, of obtaining easements and leases -- can put it together.

4. How much of the coastal lowlands should be protected as bonafide wetlands?

Wetlands are highly regarded resources and given considerable protection by federal and state law. Restrictions apply to privately owned wetlands much to the chagrin of some owners who are told they cannot fill, dredge, or build there. The restrictions are upheld in court, usually, to prevent public harm to water and water-dependent resources from private actions. As a rule, the wetter the wetlands are, the tighter the protection. For example, a marsh which is always wet may be more highly regarded than a flood plain which is inundated once every year or two. The white cedar swamp will usually be more highly regarded than a pocosin bog.

Clearly, marshes and swamps should not be cleared or drained nor impounded or otherwise subject to alteration of natural function. Even the thin borders of marsh that lie along streams and waterways are worth protecting for water quality and other benefits. Swamps and marshes are simple to identify and there is little to argue about in placing their boundaries.

Conversely, floodplains and bogs are often difficult to delineate and hard to conceptualize as wetlands; that is, as water areas rather than land areas. Also, the wetland-type values for these bog and floodplain "moistlands" tend to be lower than for marsh and swamp wetlands. Nevertheless, the state should incorporate into its program standards for protection of the essential water-related functions of bogs and sporadically inundated floodplains. The state should cooperate closely with wetland protection activities of the U.S. Army Corps of Engineers (under Section 404 of the Clean Water Act).

5. <u>What restrictions have to be placed on land conversion to protect water quality</u>?

The main pollution problem is the runoff of chemicals (fertilizer, pesticides, etc.) and some silt into canals and down to the estuary. This problem needs to be recognized during the layout of croplands, tree farms,

and strip mine restorations so that green strips (5 feet width recommended) can be left along the sides of the field ditches and collectors to hold back eroded soil and filter out pollutants. These green strips (also called filter strips or buffer strips) are the presently favored solution. Also, more skill, or care, by spray operators (plane or ground) to keep chemicals from falling on water surfaces would help. Any storage reservoirs set up for water retention (see 1. above) will improve water quality by also acting as settling basins.

If these remedies prove inadequate, there may have to be controls on the types and amounts of chemicals applied to the land. Any large industrial facilities attracted by the peat resource (e.g. power plants, methanol factories) could create serious new pollution problems.

6. What controls are needed to protect groundwater?

Realizing that overpumping of groundwater can have serious consequences, the state requires permits for amounts greater than 100 thousand gallons/day. One presumes that due care will be exercised so that power plants, methanol factories and so forth will not over-pump aquifers.

Hydrologists are concerned that too much drainage may lower the surface water table, reduce hydraulic head pressure and allow salt water to penetrate into the soil along estuarine shores and canals. Some biologists are afraid that lake levels might also fall if the land is "over-drained." Conversely, drought is not an unfamiliar visitor to the coastal lowlands and any well engineered system will provide for water level management as well as drainage. Such management will keep the water table from falling too far. It is now possible and soon may be necessary, for the state to require maintenance of the groundwater at a certain specified level.

Past Experience

State agencies, using their existing resources and powers seem to have done the best they could to control land conversion over the past decade. But their efforts have obviously fallen short, leaving wildlife, fisheries, wetlands, water quality, and flood prone areas without sufficient protection. How could this happen? Five possible reasons are given below:

1) Complexity: Solutions are difficult to create in a situation with such a complexity of environmental impacts, of economic considerations, of technical details and of policy aspects .

2) Lack of technical information: Scientific studies have been spotty, uncoordinated and inadequate for decision purposes until just recently when some more useful information has emerged.

3) Lack of authority: State agencies have not been given sufficient authority to deal with some important aspects of land conversion.

4) Lack of focus: Without a mechanism to centralize efforts, the existing authority to control

land conversion has been scattered among various agencies -- each with its own mission, its own constituency, and its own expertise -- rather than sharply focused.

5) Lack of mandate: The state resource agencies have not yet been instructed to put fisheries and wildlife conservation or ecological protection at a higher priority than the types of land utilization or exercise of property rights which degrade the environment.

To make better progress, the state will have to take the problem more seriously and devote more attention and resources to its solution. This should be done right away, before any further permits are given for large scale land conversion in the lowlands and before the U.S. Army Corps of Engineers and Interior Department get too far along with their current studies of coastal land clearing in North Carolina. It may be hoped that the Governor's task force on coastal water management, now presently reviewing the subject, will recommend an accelerated and higher priority program.

BIBLIOGRAPHY

1. Lilly, J. Paul, 1981. The Blackland Soils of North Carolina: Their Characteristics and Management for Agriculture. North Carolina Agricultural Research Service, Tech. Bul. No. 270. North Carolina State University. Raleigh, North Carolina.

2. Lilly, J. Paul. 1980. "A History of Swamp Land Development in North Carolina." Prepared for Richardson, C.J., Ed. 1981. Pocosin Wet Lands; A Conference on Alternative Uses of Coastal Plain Freshwater Bogs of North Carolina. Dowden, Hutchinson & Ross, Stroudsburg, Pa.

3. Land Clearing Steering Committee. 1981. "Alternative Solutions to Pamlico Land Clearing Problem Smoke Management and Fire Control Viewpoint." Discussion Paper, Land Use Steering Committee, North Carolina Department of Natural Resources and Community Development. Raleigh, North Carolina.

4. Doucette, William H., and Phillips, Joseph A. 1978. Overview: Agricultural and Forest Land Drainage in North Carolina's Coastal Zone. Center for Rural Resource Development Report No. 8. North Carolina State University, Raleigh, North Carolina.

5. Doucette, William H. and Phillips, Joseph A. 1979. Proceedings: 1978 Workshop on Coastal Land Drainage for Agriculture and Forestry. Center for Rural Resource Development Report No. 13. North Carolina State University, Raleigh, North Carolina.

6. Daniel, Charles C. 1978. "Land Use, Land Cover, and Drainage on the Albemarle-Pamlico Peninsula, Eastern North Carolina, 1974." (Maps) U.S. Geological Survey, Water Resources Investigation 78-134. Raleigh, N.C.

7. Doucette, William H. 1980. "Coastal Land Drainage for Agriculture and Forestry." The North Carolina Agricultural Extension Service. North Carolina State University at Raleigh, North Carolina.

8. Land Quality Section. ....."Permit for the operation of a mining activity, Peatco, Inc. (Draft). " North Carolina Department of Natural Resources and Community Development, Division of Land Resources, Land Quality Section.

9. Water Quality Planning Branch. 1981. DEM Assessment of Water Quality in Coastal North Carolina. Division of Environmental Management, Department of Natural Resources and Community Development. Raleigh, North Carolina.

10. Kirby-Smith, William W., and Barber, Richard T. 1979. The Water Quality Ramifications in Estuaries of Converting Forest to Intensive Agriculture. Water Resources Research Institute. University of North Carolina, Raleigh, North Carolina.

11. Philen, Don. 1981. "The North Carolina Coastal Plain." Summary of a presentation to the North Carolina Peat Task Force. North Carolina Department of Natural Resources and Community Development. Raleigh, North Carolina

12. Heath, Ralph C. 1975. Hydrology of the Albemarle-Pamlico Region North Carolina; A Preliminary Report in the Impact of Agricultural Developments. U.S. G.S. Geological Survey, Water Resources Investigations 9-75.

13. James Smith, North Carolina Department of Natural Resources and Community Development, personal communication. (September, 1981.)

14. North Carolina Crop & Livestock Reporting Service. 1980. Agricultural Statistics. Number 141. North Carolina Crop and Livestock Reporting Service, Raleigh, North Carolina.

15. Campbell, R.G. and Hughes, J.H. 1981 "Forest Management Systems in North Carolina Pocosins: Weyerhauser." In Richardson, C.J., Ed. 1981. Pocosin Wet Lands; A Conference on Alternative Uses of Coastal Plain Freshwater Bogs of North Carolina. Dowden, Hutchinson & Ross, Stroudsburg, Pa.

16. NRCD Peat Mining Task Force. 1981. "Report of Peat Mining Task Force." Submitted to Secretary Howard N. Lee, N.C. Department of Natural Resources and Community Development. Raleigh, North Carolina.

17. Otte, Lee J., and Ingram, Roy L., 1980. 1980 Annual Report on Peat Resources of North Carolina. North Carolina Energy Institute. U.S. Department of Energy.

18. Straley, Joseph P. 1980. "Peatlands Development and the Impact on the Estuarine Waters of the Albemarle pamlico Peninsula." (Student of Dr. C. Smallwood, Paper, Dec. 8, 1980.)

19. Skaggs, R.W., Gilliam, J.W., Sheets, T.J., and Barnes, J.S., 1980. Effect of Agricultural Land Development on Drainage Waters in the North Carolina Tidewater Region. Water Resources Research Institute, The University of North Carolina, Raleigh, North Carolina

20. Council of Civil Defense. 1955. North Carolina Hurricane Rehabilitation Project. Governor's Office, Raleigh, North Carolina.

21. State of California. 1980. "Subsidence of Organic Soils in Sacremento-San Joaquin Delta." State of California, Department of Water Resources.

22. Personal communication. Russ Franson, Department of Water Resources, State of California. October, 1981.

23. Boelter, Don H. and Verry, Elon S. 1977. Peatland and Water in the Northern Lake States. USDA. Forest Service. Gen. Tech. Rep. NC-31.

24. Gilliam, J.W., Skaggs, R.W., and Sheets, T.J. n.d. Fertilizer and Pesticide Movement in Surface Water. North Carolina State University, Raleigh, North Carolina.

25. Duda, Alfred M., and Klimek, Alan. n.d. Significance of Non-Point Sources of Nutrients to Eutrophication in the Chowan River. North Carolina Department of Natural Resources and Community Development. Raleigh, North Carolina.

26. Hobbie, John E. and Smith, Nathaniel W. 1975. Nutrients in the Neuse River Estuary, North Carolina. Sea Grant Publication UNC-SG-75-21. Raleigh, North Carolina.

27. Paerl, Hans W. 1981. Unpublished statement.

28. Daniel, Charles C., 1980. Hydrology, Geology, and Soils of Pocosins: A Comparison of Natural and Altered Systems. Prepared for Richardson, C.J., Anderson, S.A. and Thompson, W.A., 1981. Pocosins: An Integrated Analysis of Coastal Plain Freshwater Wetlands in North Carolina. Dowden, Hutchinson and Ross, Inc., Stroudsburg, Pa.

29. Department of Natural Resources and Community Development. 1981. North Carolina's Environment, 1981 Report. Department of Natural Resources and Community Development. Raleigh, North Carolina.

30. Jones, Robert A., and Sholar, Terry M., 1981. The Effects of Freshwater Discharge on Estuarine Nursery Areas of Pamlico Sound. North Carolina Department of Natural Resources and Community Development. Division of Marine Fisheries, Morehead City, N.C.

31. Data supplied by Preston P. Pate, Jr. Department of Natural Resources and Community Development. Marine Fisheries, Morehead City, North Carolina. July, 1981.

32. Courtesy of Dr. Curt Richardson, Duke University.

33. Kusler, Jon A. 1980. Regulating Sensitive Lands. Ballinger Publishing Company, Cambridge, Mass.

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