SHORELINE CHANGES ALONG THE OUTER BANKS OF NORTH CAROLINA

Linwood Vincent and Robert Dolan

Technical Report 70-5

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INTRODUCTION

Aerial photography of the barrier islands of coastal North Carolina was analyzed for the period 1958 to 1969 to pinpoint areas of rapid change, and to indicate regions with high potential for serious erosion problems in the near future. The study extended from Nags Head north of Oregon Inlet on Bodie Island southward to Beaufort Inlet. This includes all or part of Bodie, Pea, Hatteras, Ocracoke, and Portsmouth islands, Core and Schackleford Banks, and Oregon, Hatteras, Ocracoke, Swash, Drum, and Barden inlets [Figure 1].

The barrier islands are best described as a series of land masses averaging in width between 2000 to 7000 feet, which are connected by narrow sand spits less than 1500 feet in width. The topographic sequence across the barrier islands consists of three principle elements: the ocean beach, 50 to 400 feet across; a barrier dune field up to 500 feet in width, and either a low, flat marsh, or a sequence of relic dune ridges with intervening marsh. Along the length of the islands, the land-sea interface may be fairly straight, or it may be sinuous and crescentic in form.

Along the Outer Banks, the principle settlement areas and transportation routes are all north of Ocracoke Inlet.

Included as villages, other than the Nags Head-Kitty Hawk complex, are Rodanthe, Waves, Salvo, Avon, Buxton, Frisco, Hatteras, and Ocracoke. These communities are heavily oriented toward recreational pursuits and tourism.

DATA

The aerial photography used in the survey consists of flight strips taken in October 1958, April 1964, July 1965, and April, June and August of 1969. The scale of the photographs varied from 1:6,000 to 1:24,000. The imagery was excellent. Features of the landscape, such as the swash zone, highwater mark, vegetation, as well as highways, drainage networks and buildings, were distinct.

The 1958 and 1969 strips covered the entire study area, but the 1964 and 1965 strips provided only partial coverage. Thus, for different sections of the Outer Banks differing sets of photography were used to estimate the change in the beach and sound shores. The 1958 to 1969 change was obtained from sets of photography that covered the entire region. In order to reduce errors inherent in reproduction of the photography, the scale was calculated for each measurement of change by measuring distances between fixed land points on the photography and reducing it to the 1958 scale.

METHODS

In order to examine and pinpoint change in a dynamic coastal system, indicators of change and a criterion for

determination of critical areas were essential.

For the ocean beach the high water line [HWL] and the water line [WL] were chosen as the best indicators of change. The high water line marks the greatest penetration of the swash zone onto the shore, and when used in measurement from a particular photograph it is the most continuous, distinct mark left by a tidal cycle other than the one during which the photography was taken. The water line is the line between the swash zone and the zone of near shore breakers. Bothe HWL and WL measurements involve a subjective selection on the part of the interpreter. In addition, the WL measurements are uncorrected for tidal cycle. However, as indicators of the overall position of the shoreline, they are sufficient.

Another indicator of beach change is the base or toe of the barrier dunes. This is, however, extremely difficult to find with appreciable accuracy from aerial photographs. Likewise, changes in dune stability and dune vegetation serve as indicators of change in the beach area, but are difficult to measure.

The criterion for classifying a region as one of concern is a combination of conditions, including [1] a significant erosion rate, [2] instability of the barrier dunes, [3] narrowness of the beach, [4] the width of the island, and [5] the proximity of buildings, and highways to the surf zone. In addition to long term erosion trends, short term oscillations, termed sand waves,

and seasonal fluctuation of the land-sea interface are important [see Appendix I]. The maximization of all these occur when [1] a storm with high waves over an extended period of time occurs with [2] the yearly low point in beach width, [3] the passing of the embayment of a sand wave coupled with [4] poor dune stability. Even if breaching of the dune does not occur, the dune can be severely damaged, and buildings or other cultural features near the beach are vulnerable.

SECTOR STUDIES

The barrier islands were divided into seven sectors for the study. The sectors are: Bodie Island, Pea Island, Hatteras Island (Rodanthe to Cape Point), Hatteras Island (Cape Point to Hatteras Inlet), Ocracoke Island, Portsmouth Island-Core Banks, and Schackleford Banks [Figure 1].

Each sector was examined for ocean and sound shore change, sand wave activity, and dune instability. Regions of concern were noted. The results of those studies, distributed as interim reports, are attached to this as an appendix, and should be consulted for greater detail. This paper summarizes the trends and conditions discovered.

REGIONS OF SIMILAR TREND

It is evident from the seven sector studies that the Outer Banks can be divided into two broad regions based upon the severity of erosion, and its accompanying problems.

The dividing point is Cape Hatteras.

North of Cape Point rates of erosion are much higher than to the south, although there are regions of moderate erosional activity along the entire coast. Severe winter storms, which occur more frequently to the north, generate winds and waves fields from the North to East quadrant. The northern sector has eastward facing beaches and is, therefore, subjected to the full force of those storms. The southern sector is oriented towards the south and southeast, and is less exposed.

North of Cape Hatteras:

This segment of the Outer Banks extends from Nags Head southward to Cape Hatteras, a distance of about 50 miles, and includes Bodie, Pea, and Hatteras islands. The principle tourist areas of the Cape Hatteras National Seashore are located in this region, as well as most of the private investment in recreational facilities.

Within this sector, erosion along the ocean beaches is particularly severe. Changes in the HWL for 1958 to 1969, based on the sector wide averages, ranges from -6.6 ft/yr to -20.1 ft/yr, with a maximum rate of -62.9 ft/yr recorded for a shorter period of time at one of the study points. The WL recession rates for 1958 to 1969 range from -8.7 ft/yr to -21.3 ft/yr, with a maximum of -78.6 ft/yr recorded. These high recession rates have exacted a heavy toll on the beaches as the present beach widths rarely exceed 300 feet, and some are as narrow as 60 feet. Accretion is rare.

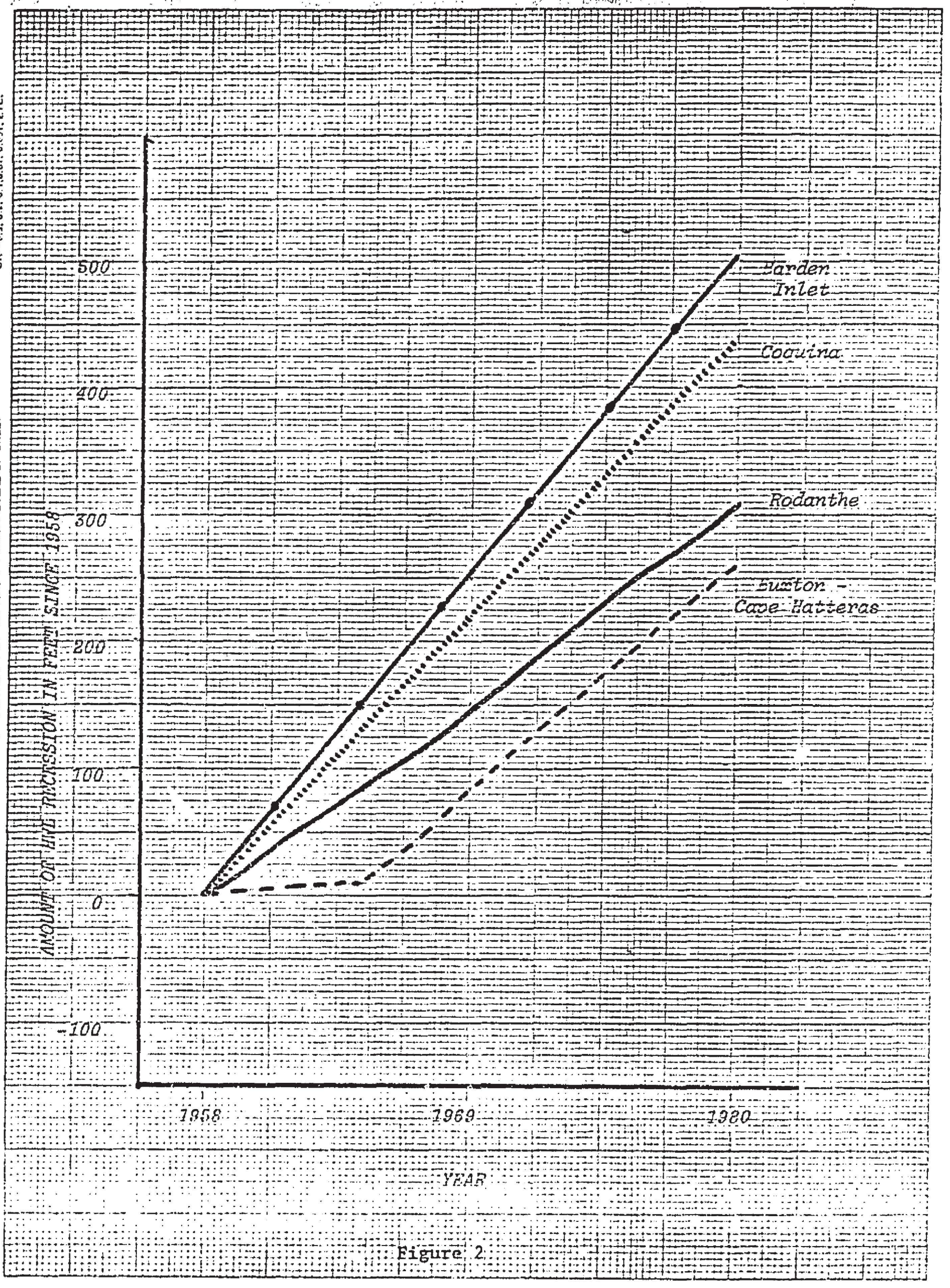


Figure 2

Along this entire reach sand wave activity is moderate to severe. Sand waves of amplitude 30 to 75 feet are common; so in terms of effective erosion, the beach can be temporarily narrowed (or widened) 60 to 150 feet by their passage. During a storm, these differences in width can determine, to a large extent, the degree of damage to both the dune field and beach. Reaches in this sector of heavy sand wave activity are near the Pea Island Refuge Ponds, Rodanthe Village, Salvo to Waves, and Buxton to Cape Point. The interim reports contained in the appendix delimits these areas more precisely; however, our analysis suggests that areas of intense sand wave activity may reflect locations within larger rhythmatic features with wave lengths approaching 7 to 10 miles.

Most of the barrier dune line in this area was reconstructed after the March 1962 storm. With few exceptions, the dunes are fairly stable, but not heavily vegetated. Reaches of dune instability include the Pea Island Refuge Ponds, Rodanthe, Avon, and Buxton to Cape Hatteras.

Five areas north of Cape Hatteras are of immediate concern and should be monitored continuously. These are near the Coquina Beach Comfort Station, Pea Island Refuge Ponds, Rodanthe, Avon, and Buxton.

Coquina Beach:

The HWL at the Coquina Beach Comfort Station receeded

at a rate of -13.4 ft/yr for the period 1958 to 1969 and rates of -33 ft/yr have been recorded for the HWL in this area. The maximum rate for the WL was -43 ft/yr. Sand waves of amplitudes from 30 to 50 feet were present in 1969. The dune line is continuous, but hummocky. The beach has narrowed 80 to 100 feet since 1958 and the dune field, in places, is only separated from the swash zone by 70 to 100 feet. The potential for storm damage is high [Figure 3].

The proximity of the Coquina Beach Comfort Station, the maintenance and housing facilities, and private development to the beach (in some cases less than 300 feet) couple to make erosion in this area very critical. Continued monitoring and consideration of a program of beach nourishment and dune stabilization is recommended. In addition, future investment near the beach-dune system should be cautiously considered.

Pea Island Wildlife Refuge Pond Area:

Erosion and dune instability in this reach combine to endanger facilities near the dune-beach system. The HWL recession rate was -8.7 ft/yr for 1958 to 1969, with a maximum of -20.7 ft/yr recorded. The beach is only 175 to 225 feet wide, placing the main highway along the Outer Banks about 325 to 400 feet from the surf zone. Sand wave activity is present with amplitudes of about 50 feet.

Planning should consider the feasibility of defending the present beach line by nourishment or dune reconstruction,

or relocation of the highway and modification of the Refuge ponds. Part of the erosion problem in this region is due to material lost to the littoral system at Oregon Inlet. This could be corrected by discharge of dredged material from the inlet onto the beaches of Pea Island.

Rodanthe:

Two miles north of Rodanthe, the main Outer Banks highway is located less than 275 from the swash zone, and the intervening barrier dune, which is not stable, is only 150 to 180 feet from the water line. The average HWL erosion rate for 1958 to 1969 was about -18.1 ft/yr, and sand waves with amplitudes of 35 to 45 feet (net change of 70 to 90 feet) are active in the area. This combination endangers the barrier dunes, the highway, part of which has already been relocated, as well as the continuity of the National Park Service land holdings [Figure 4]. The remainder of the roadway must be relocated. Beach nourishment or some less desirable form of protection may serve as a temporary check of recession.

Avon:

The area north of Avon has been eroding (HWL) at a rate of 25 ft/yr for the period 1965 to 1969. The barrier dune line is in good shape, that is, not too close to the surf, and the road is 750 to 1000 feet removed from the swash. Although no facilities are endangered at this time, the high rate of erosion demands continued observation and planning.

Buxton to Cape Hatteras:

This region of concern extends from the area of the 1962 "Ash Wednesday" inlet to Cape Point. The rate of erosion (HWL) near the U. S. Naval Facility for 1965 to 1969 has been -16.5 ft/yr. The barrier dunes, which are in very poor condition, are only 70 to 100 feet from the water. Buildings at the Naval Station are as close as 175 feet to the surf. Sand waves in the area have amplitudes of up to 45 feet (range 90 feet).

Farther north where the main highway passes from Buxton onto the narrow neck of land breached by the 1962 storm, the dunes are only 60 to 80 feet from the water and the highway is only 150 feet removed from the surf. With the dunes low and unstable, an erosion rate of -10 to -17 ft/yr, and the island only 500 to 600 feet wide [Figure 5], breaching is a distinct possibility. The combination of all these negative factors yield this as an extremely critical region. All efforts should be made to stabilize this area as soon as possible.

Cape Hatteras West:

This segment of the study area extends from Cape Hatteras southwestward to Beaufort Inlet. Included are Hatteras Island (southfacing beach), Ocracoke Island, Portsmouth Island - Core Banks - Cape Lookout, and the Schackleford Banks. Most of the land is administered under the control of the Cape Hatteras National Seashore and the Cape Lookout National Seashore. Only Hatteras and

Ocracoke islands have substantial settlements; otherwise, the landscape is essentially undeveloped. With the exception of the region from Drum Inlet north to Portsmouth Island, which is essentially a sandflat, the islands have a typical barrier island topographic sequence.

The reach from Drum Inlet northward to Portsmouth Inlet is a wide, sandflat. The interim report indicates the trend along this area has been erosion. The actual magnitude and severity are relatively minor, and subject to great variation due to the low, flat nature of the topography. No problem is seen here. The area remains undeveloped.

The general trend for the ocean beach in this segment is a minor amount of erosion. The sector average rates of change range from +1.2 ft/yr to -6.6 ft/yr. for the HWL; and +1.4 ft/yr to -11.7 ft/yr for the WL for 1958 to 1969. There are several areas of severe erosion, but these areas are not as critical as those in the North of Cape Hatteras segment.

The barrier dune fields in this sector are wide, hummocky, and moderately well vegetated. There are several narrow regions, notably near Sandy Bay on Hatteras Island, central Ocracoke Island, and north of Cape Lookout adjacent to Barden Inlet. Sand wave activity is minor. Amplitudes did not exceed 30 feet in 1969. Most of the beach is relatively free of sand wave activity.

There are four regions where action should be

considered to remedy problems which are near critical status. In most instances the severity of the problems are less than those in the North of Cape Hatteras reach. The four regions are: Sandy Bay, central Ocracoke, Cape Lookout-Barden Inlet, and central Schackleford Banks.

Sandy Bay:

Action should be taken to reduce the vulnerability to severe damage or breaching of the reach of Hatteras Island between Sandy Bay and the Atlantic Ocean. The road from Buxton to Hatteras Village is 300 to 350 feet from the water, and the dunes are only 120 feet removed. The rate of erosion (HWL) was about -2.5 ft/yr for the period 1965 to 1969, even though slight accretion has been the overall trend. With the island being 600 feet wide and with the narrowness of the dune field, this erosion provides cause for preventive action before the situation is irreversible [Figure 6].

Central Ocracoke Island:

In the central segment of Ocracoke Island, the rate of erosion and dune instability combine to necessitate immediate corrective action. Here, the road is less than 250 feet from the surf zone, with the intervening barrier dune breached in at least one place. The net erosion rate of the HWL for 1958 to 1969 was about -19 ft/yr; over 1965 to 1969, however, there has been accretion at +3.3 ft/yr. The proximity of the road to the surf zone without dune protection leaves it vulnerable to storm damage.

Action should consider nourishment, re-establishment of the dune, or relocate the road.

Cape Lookout to Barden Inlet:

The area near the Cape Lookout lighthouse needs immediate attention. The island width between the Atlantic Ocean and Barden Inlet is about 1500 feet (1969). The rate of erosion on the beach was -4 ft/yr for 1958 to 1969. Barden Inlet, however, has widened from 1830 feet in 1958 to 2067 feet in 1969, with most of the eroded channel bank north of the lighthouse, where 247 feet has been lost in 10.5 years [Figure 7]. Although the dune line appears stable, it is not well vegetated, or very distinct. The channel and beach erosion endangers both the lighthouse and the continuity of the island. Since most of the trouble is from the inlet, action should be considered there.

Central Schackleford Banks:

The central third of the Schackleford Banks is undergoing erosion (HWL) at a rate of -7 ft/yr, and the dune field is only 100 feet from the swash zone. The lack of buildings and roads make this region less critical than any of the others. Careful observation, however, is needed should more serious problems arise.

INLETS

Hatteras Inlet:

According to Knox (1953), Hatteras Inlet had widened from 0.5 to 1 mile from 1850 to 1953. On an 1883 map, the inlet was 2625 feet wide.

Aerial photography from October 1958 and April 1969 indicate that the inlet had widened from 8400 feet in 1958 to 8820 feet in 1969. The Hatteras Island spit has widened about 500 to 1000 feet (discontinuous shoals in 1958, sand flat in 1969), but Ocracoke Island had lost 300 feet. While there was only one island in the inlet in 1958, an additional one was present in 1969, with the other shifting 1500 to 2000 feet eastward.

The present trend is one of southwestward migration of the channel with continued widening. Hatteras Island should continue to gain land, while Ocracoke should lose it.

Ocracoke Inlet:

The flight lines for aerial photography taken in 1958, 1965, and 1969 do not cover the mouth of Ocracoke Inlet. Measurements of the change in the adjacent spits, however, indicate that from 1958 the western bank has lost about 750 feet, and the eastern bank has lost 270. This would imply a widening of the inlet. During this period several small islands have formed.

Figure 9, from the Combined Hurricane and Cooperative Beach Erosion Report for Ocracoke Island, illustrates change in the inlet from 1852 to 1956.

Oregon Inlet:

Knox (1953) indicated that Oregon Inlet had widened from one-half mile in 1848 to 1.25 mile in 1942, with the inlet having migrated 1 mile to the south of its 1848 position. Measurements from 1883 and 1937 maps, and 1958 and 1969 aerial photography indicate a width of 1800 feet in 1883 versus 3833 feet in 1937. From 1937 to 1969, the southern end of Bodie Island has grown 4200 feet southward, with all of the change but 600 feet occuring since 1958 [Figure 8]. The inlet was 3833 feet wide in 1937, but in 1958 it was 5160 feet. By 1969, the width had decreased to 2083 feet.

The northern end of Pea Island, however, has undergone severe erosion due to the southward migration of the channel. From 1937 to 1958, this bank, which was essentially a sand flat, receded 2100 feet, and since 1958 has receded at 36 ft/yr. Rates of erosion on northern Pea Island range from 23 to 67 feet per year.

Thus, the overall recent trend is one of inlet narrowing with continued southward migration. The severe erosion on Pea Island is likely to continue, endangering both the Coast Guard station, and the approach to the Oregon Inlet bridge. Bodie Island should continue its southward growth with the marina channel undergoing additional filling.

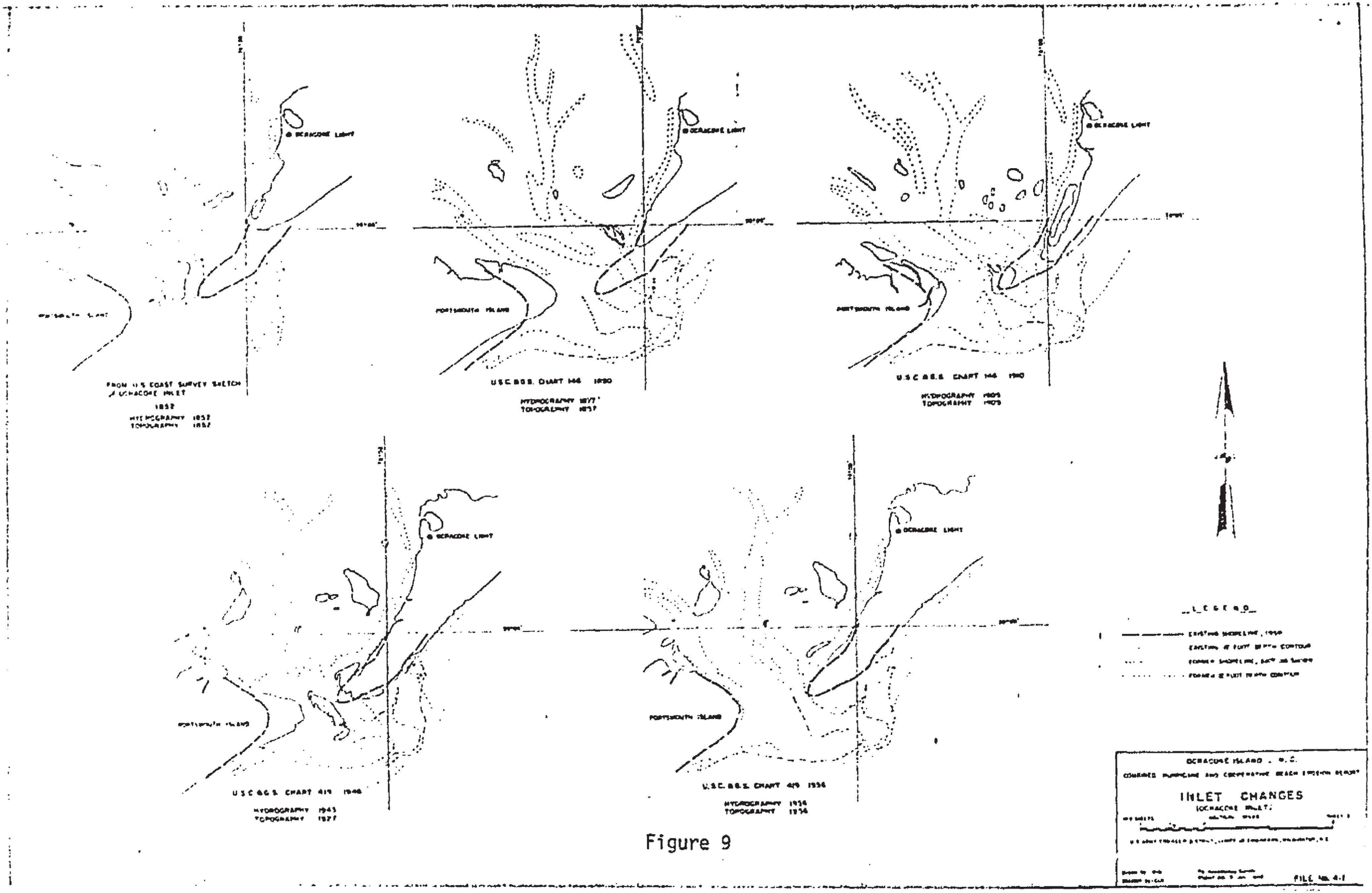

OCRACOKE LIGHT
FROM U.S. COAST SURVEY SKETCH
OCRACOKE INLET
1852
HYDROGRAPHY 1852
TOPOGRAPHY 1852
OCRACOKE LIGHT
PORTSMOUTH ISLAND
U.S.C.G.S. CHART 146 1930
HYDROGRAPHY 1877
TOPOGRAPHY 1857
OCRACOKE LIGHT
PORTSMOUTH ISLAND
U.S.C.G.S. CHART 146 1960
HYDROGRAPHY 1905
TOPOGRAPHY 1905
OCRACOKE LIGHT
PORTSMOUTH ISLAND
U.S.C.G.S. CHART 419 1946
HYDROGRAPHY 1945
TOPOGRAPHY 1927
OCRACOKE LIGHT
PORTSMOUTH ISLAND
U.S.C.G.S. CHART 419 1956
HYDROGRAPHY 1956
TOPOGRAPHY 1956
LEGEND
EXISTING SHORELINE, 1950
EXISTING 6 FOOT DEPTH CONTOUR
FORMER SHORELINE, 1852 AS SURVEYED
FORMER 6 FOOT DEPTH CONTOUR
OCRACOKE ISLAND, N.C.
COASTAL HURRICANE AND CONSERVATIVE BEACH EROSION REPORT
INLET CHANGES
(OCRACOKE INLET)
FILE NO. 4-1

Figure 9

Barden Inlet:

Barden Inlet widened from 1830 feet in 1958 to 2067 feet in 1969. Most of the erosion has been on the Core Banks side of the channel where 247 feet of recession of the island has occurred. There has been slight accretion on the Schackleford Banks side. This region has been mentioned as one of much concern.

Swash and Drum Inlets:

Aerial photography of 1958 and 1969 indicated that Swash Inlet had narrowed from 4500 feet in 1958 to 200 feet in 1969, with littoral drift almost closing the inlet. The inlet has shifted 500 feet to the southwest.

Drum Inlet, over the same period, narrowed from 1410 feet to 250 feet. The channel was well established in 1969 and likely to remain open. The inlet had shifted 6000 feet to the southwest due to spit growth from the northeast.

The width figures for 1958 are inflated because the photography was taken after a storm that breached the Core Banks from Drum Inlet northward in most places.

SOUND SHORE CHANGES

The magnitude of erosion along the sound side of the barrier islands of North Carolina is dependent upon the length of the over water fetch and the probability of storm winds over this fetch.

The reach of shore line from Oregon Inlet to just north of Buxton shows little change over the period 1958 to 1969 except where construction has altered the shore. Erosion rates are low, ranging from -0.5 to -1.5 ft/yr.

The narrow spit north of Buxton, breached in 1962, is undergoing more severe erosion. Rates over the period 1945 to 1969 are in the range of -3 ft/yr.

The Sandy Bay shoreline of Hatteras Island is generally stable with slight accretion being the dominant trend rather than erosion. Some areas of localized erosion are evident.

The Ocracoke Island sound shore is undergoing moderate erosion. The northeast shore of the island in the vicinity of Ocracoke Village has a severe erosion problem. The average annual recession rate is from -5 to -8 ft/yr in places for 1946 to 1969. The northwest shore in the village vicinity has lost land at a rate ranging from 0 to 2.5 ft/yr.

Change on the sound side from Portsmouth Island to Beaufort Inlet is minor. Regions of erosion and deposition are local in nature. Extensions of these islands into the sound are most often caused by overwash during storms.

SUMMARY AND RECOMMENDATION

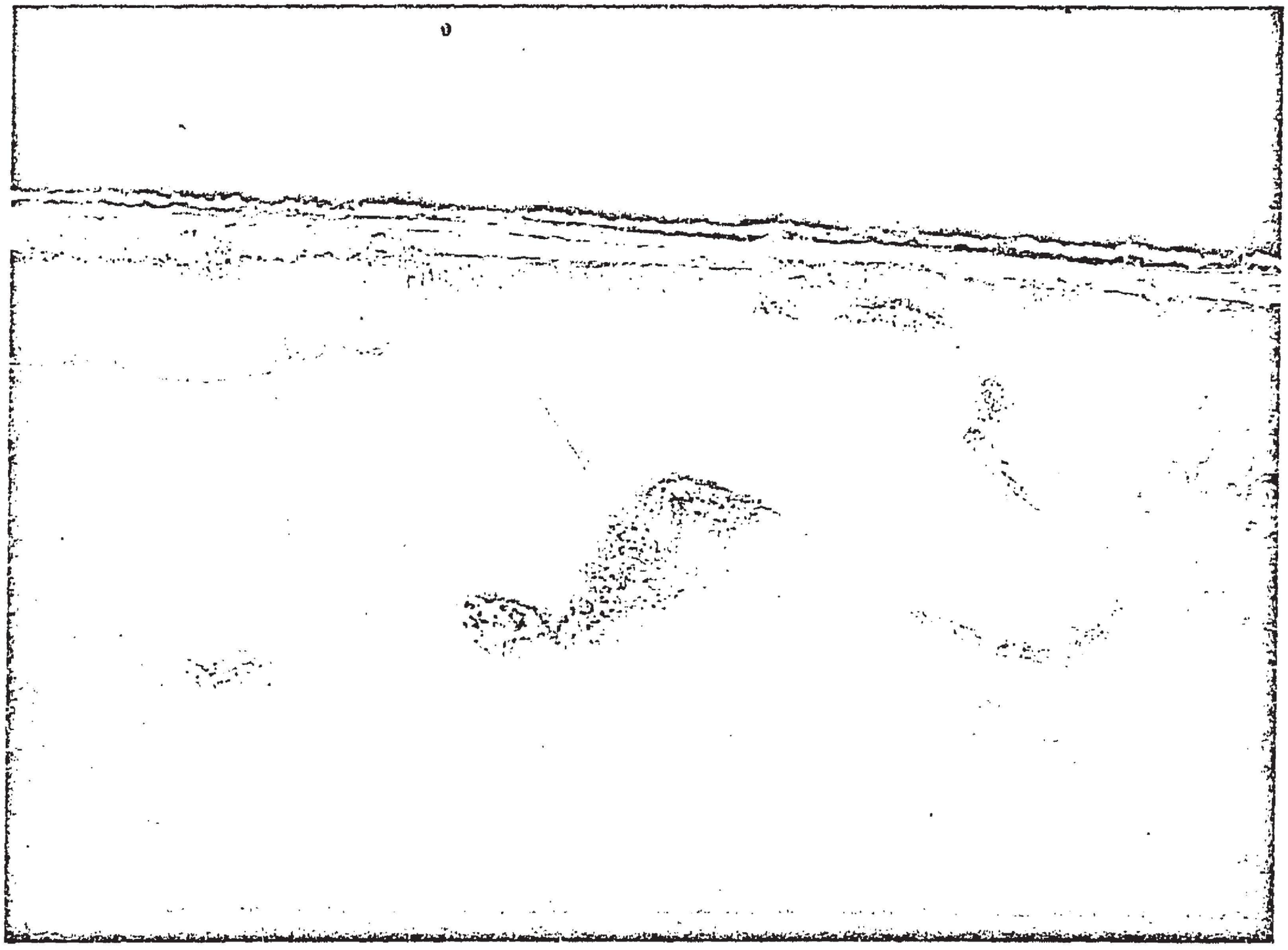
This report coupled with the attached interim reports indicate the major and minor trouble areas along the barrier islands of North Carolina. In most cases, suggestions have been submitted to indicate possible corrective actions.

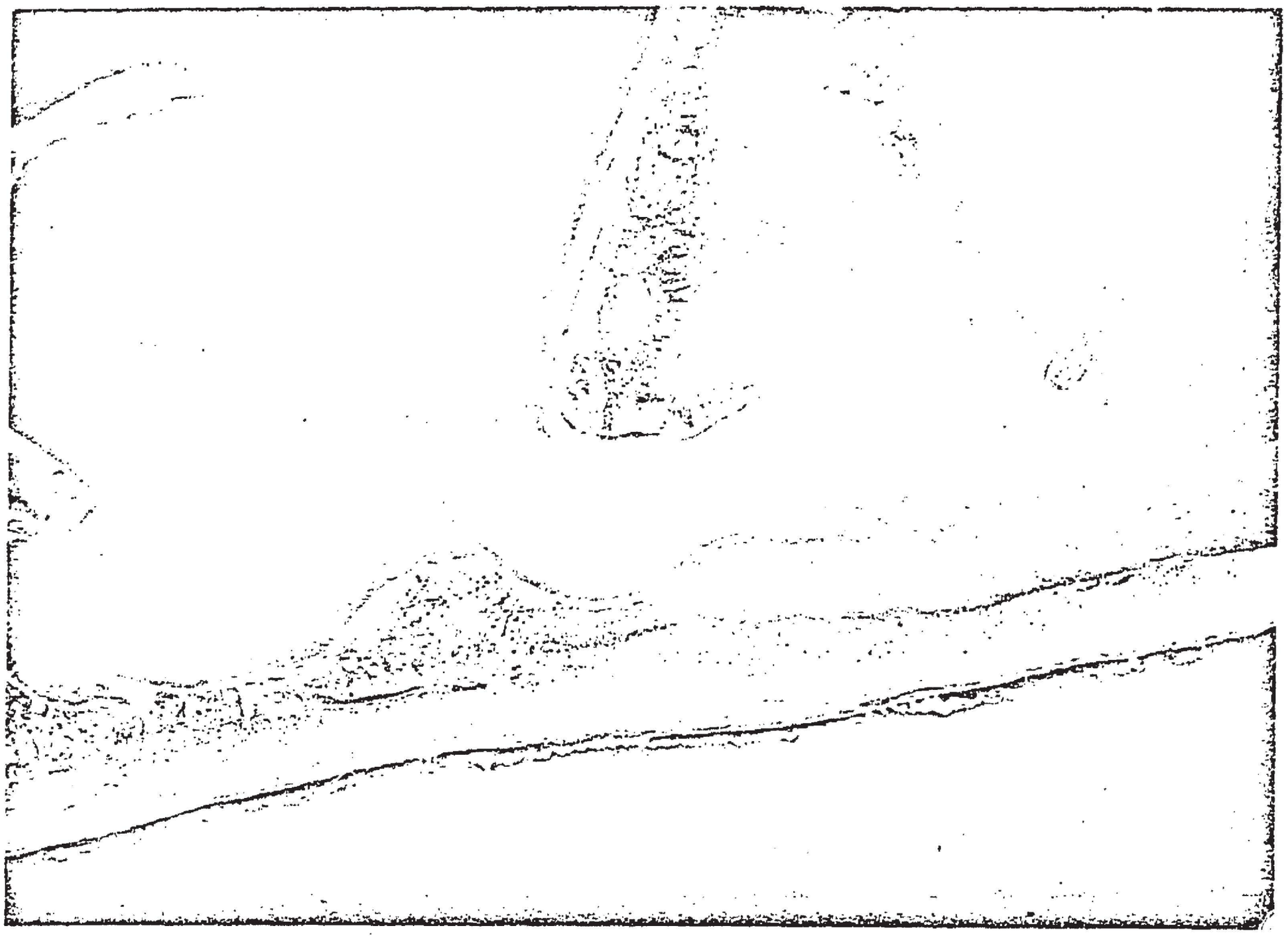
In the long term, however, a continuing program of careful observation and planning is needed to spot potential trouble areas, and to avoid the construction of facilities which might either upset the balance of the local erosion-deposition environment, or be destroyed or damaged due to improper placement of the facility. It is necessary to include the problem of a short life span in the cost and planning of these facilities.

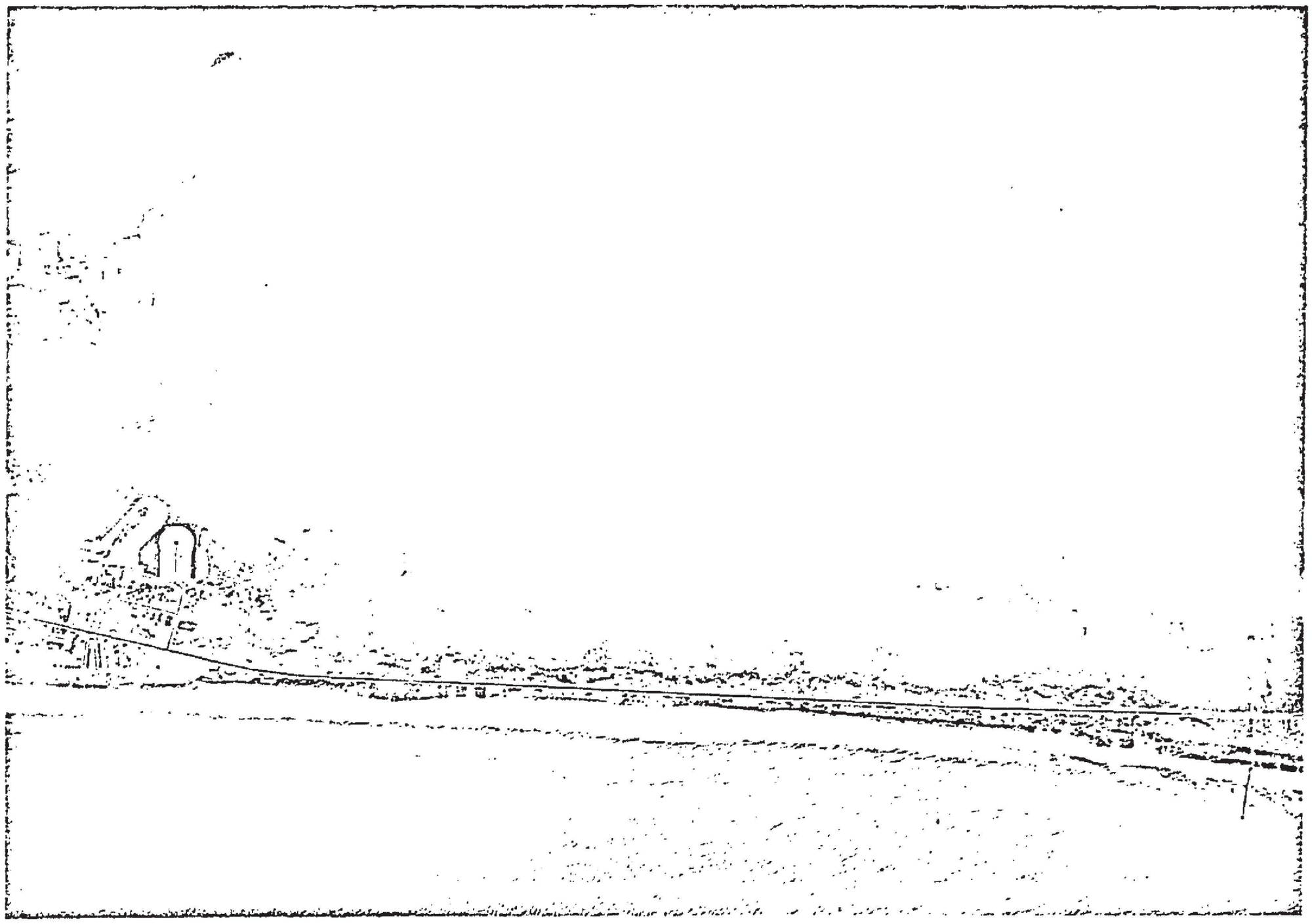
In addition, wherever protective measures are initiated, consideration should be given to planning the relocation of the facility over a period of years in such a manner that the cost of protection plus relocation over this period is minimized. This is based on the premise that the continued rise in sea level will cause eventual relocation of most facilities. This form of future contingent planning should be extended to the private sector as well as public.

The entire Outer Banks is undergoing severe erosion which requires that some immediate protective action be instituted, and that future planning should be based on careful observation of current trends, and sound long-range economic policy.

Sector	Shoreline Trend	Average Magnitude of Change (ft/yr)		Dune Field	Sand Wave Activity	Sand Wave Amplitude
		HWL	WL			
Bodie Island	Severe erosion	-20.1	-21.3	Continuous, but hummocky.	Moderate	25' to 50'
Pea Island	Moderate erosion, locally severe	- 8.7	-14.0	Poor, irregular, breached.	Severe	50'
Rodanthe-Cape Hatteras	Moderate erosion, locally severe	- 6.6	- 9.9	Local problems.	Severe	25' to 75'
Cape Hatteras-Hatteras Village	Almost stable	+ 1.3	- 2.7	Local problems.	Minor	30'
Ocracoke Island	Moderate erosion	- 6.6	-11.7	Generally stable.	Minor	25'
Portsmouth Island	Moderate erosion	- 4.1	- 3.6	Generally stable.	Minor	-
Schackleford Banks	Almost	- 0.4	+ 1.4	Stable.	Minor	-







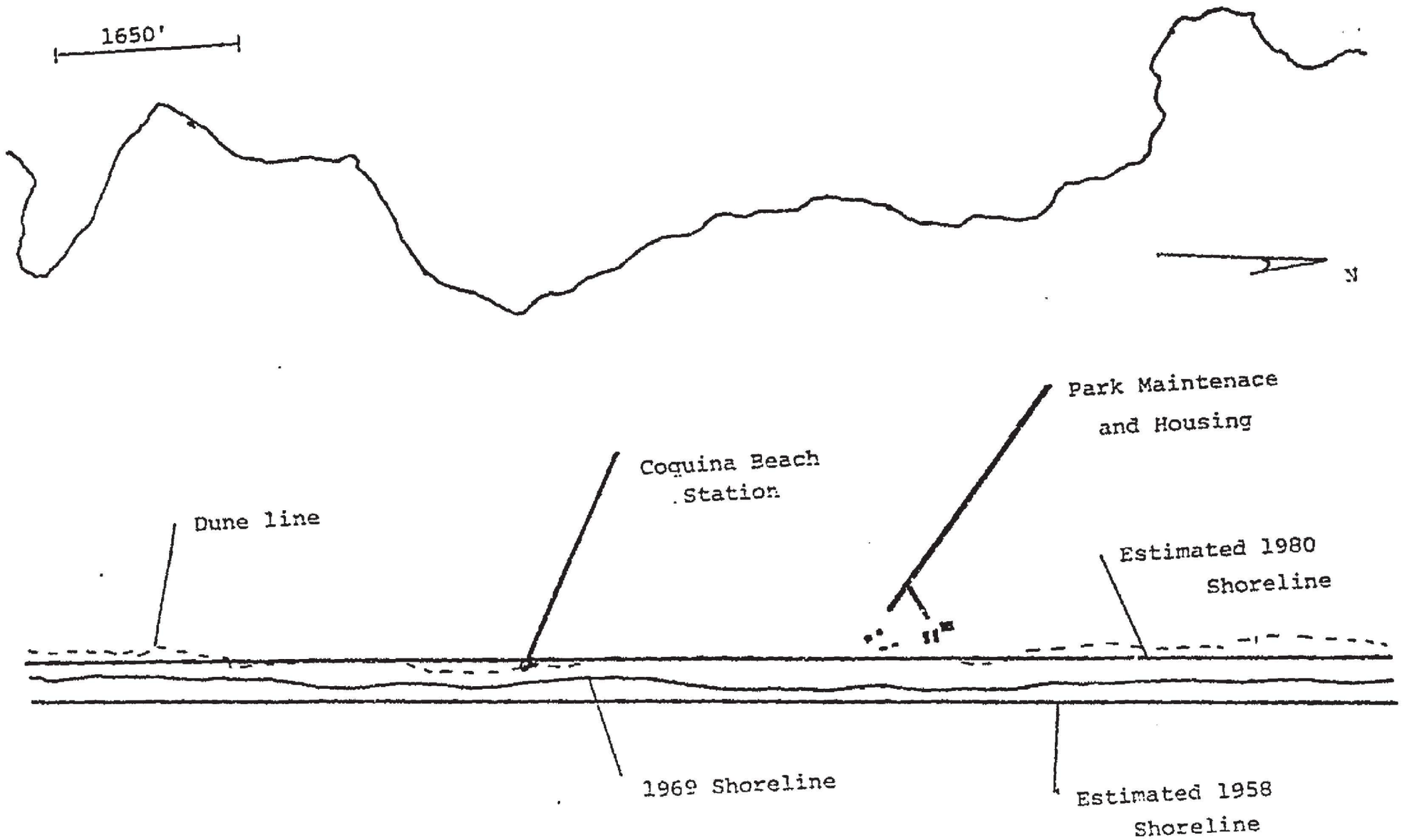

1650'
N
Park Maintenace
and Housing
Coquina Beach
Station
Dune line
Estimated 1980
Shoreline
1969 Shoreline
Estimated 1958
Shoreline

Figure 3

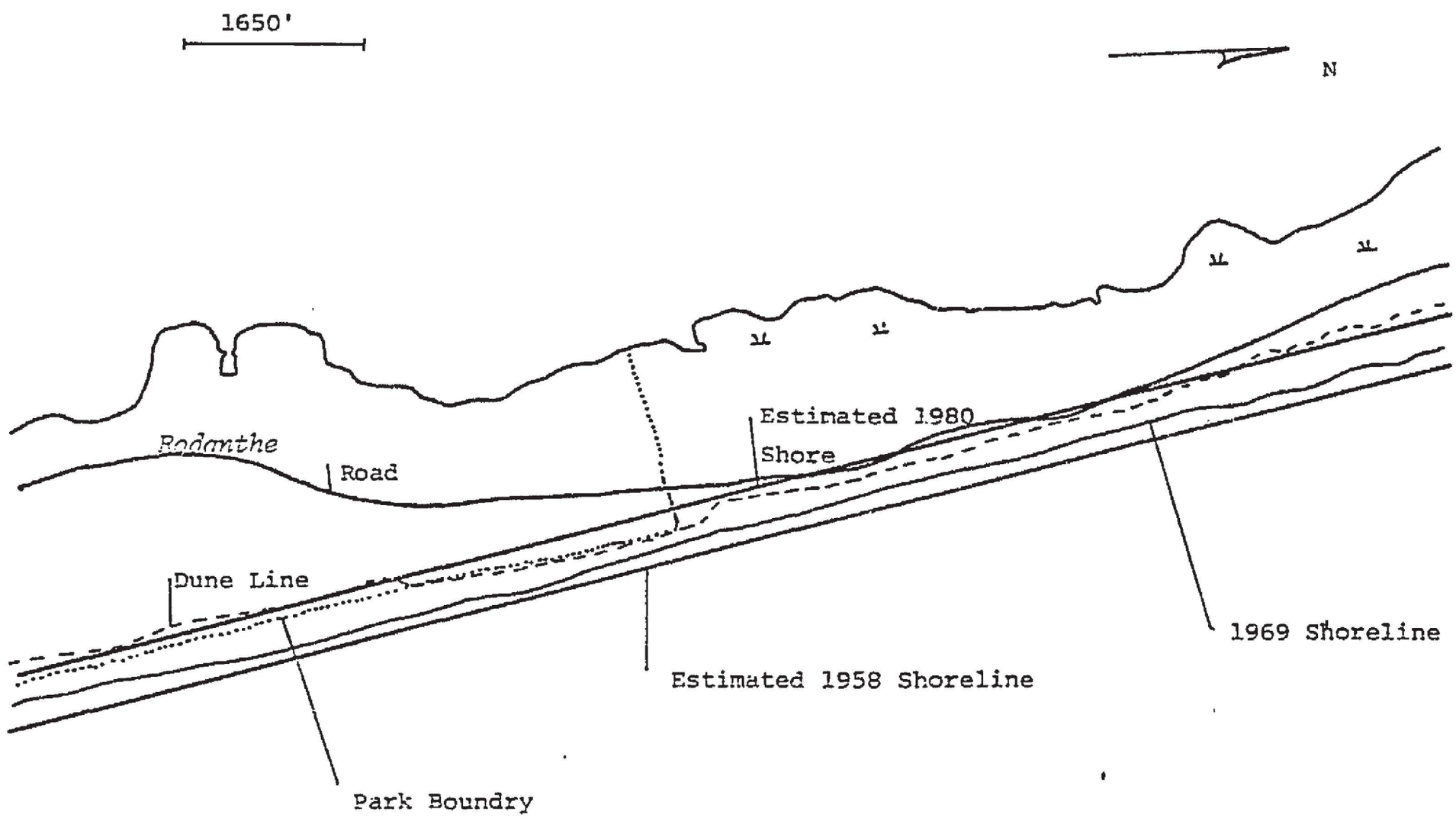

1650'
N
Rodanthe
Road
Estimated 1980
Shore
Dune Line
1969 Shoreline
Estimated 1958 Shoreline
Park Boundry

Figure 4

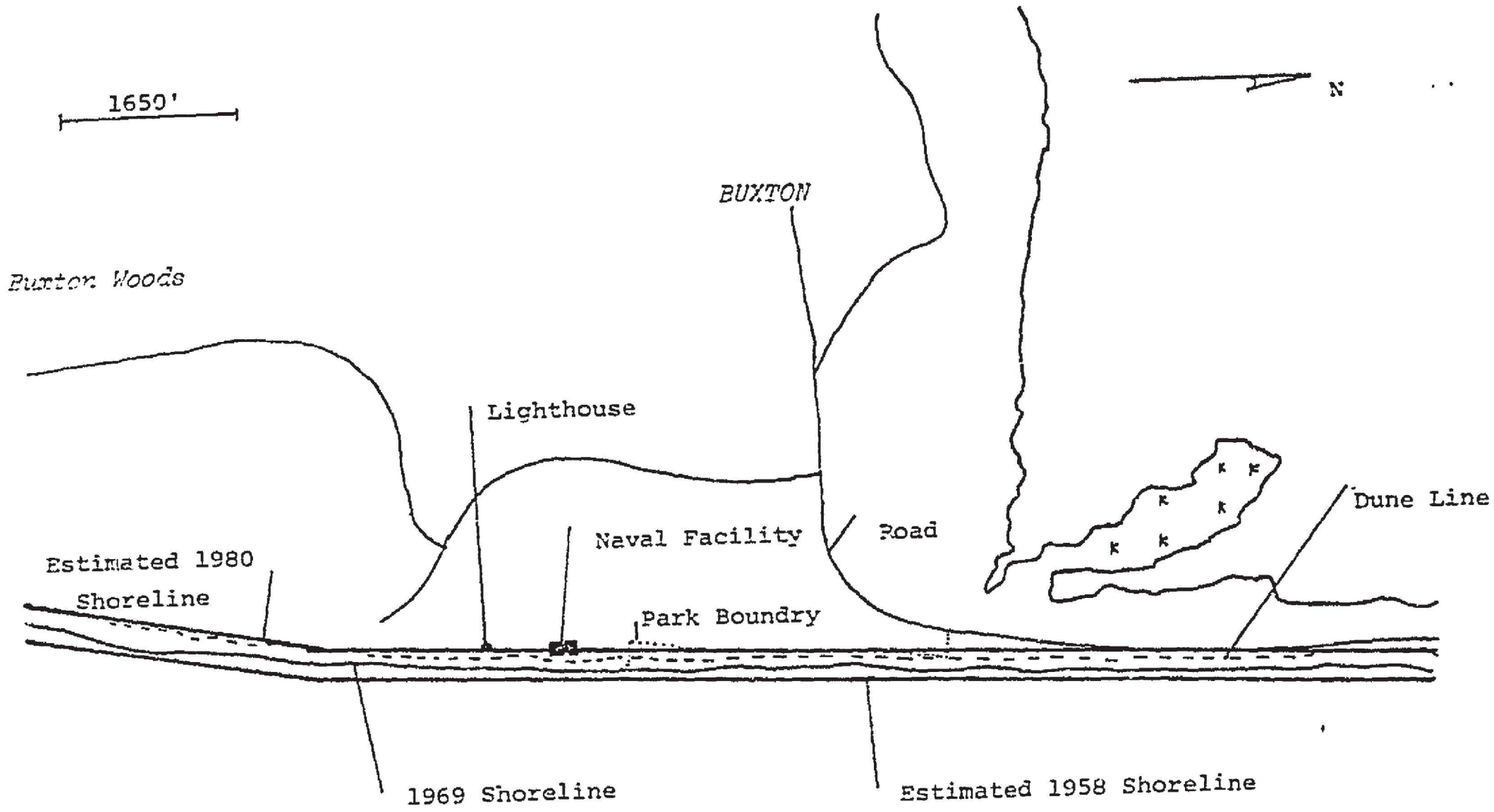

1650'
N
BUXTON
Burton Woods
Lighthouse
Naval Facility
Road
Dune Line
Estimated 1980
Shoreline
Park Boundry
1969 Shoreline
Estimated 1958 Shoreline

Figure 5

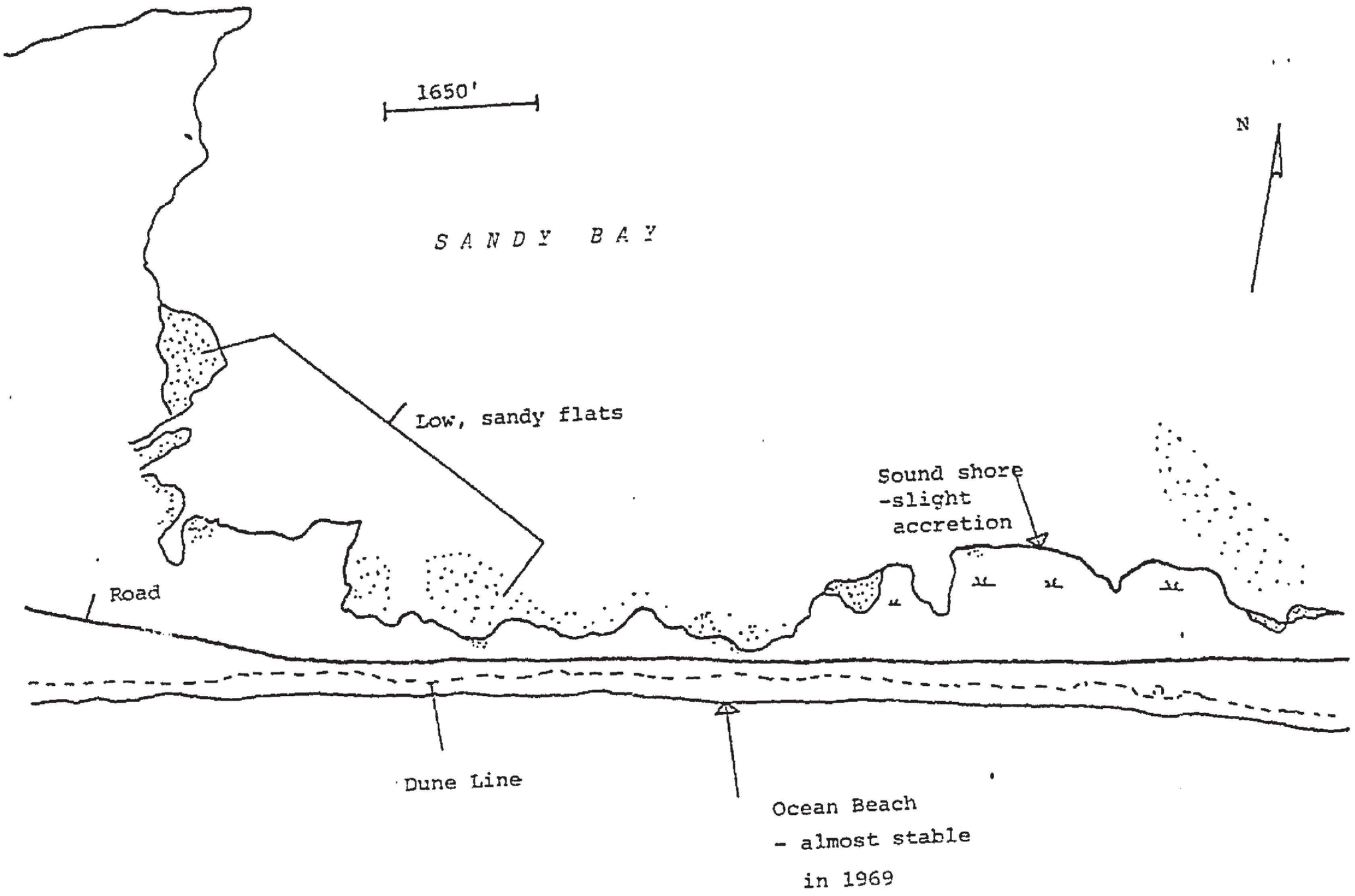

1650'
N
SANDY BAY
Low, sandy flats
Sound shore
-slight
accretion
Road
Dune Line
Ocean Beach
- almost stable
in 1969

Figure 6

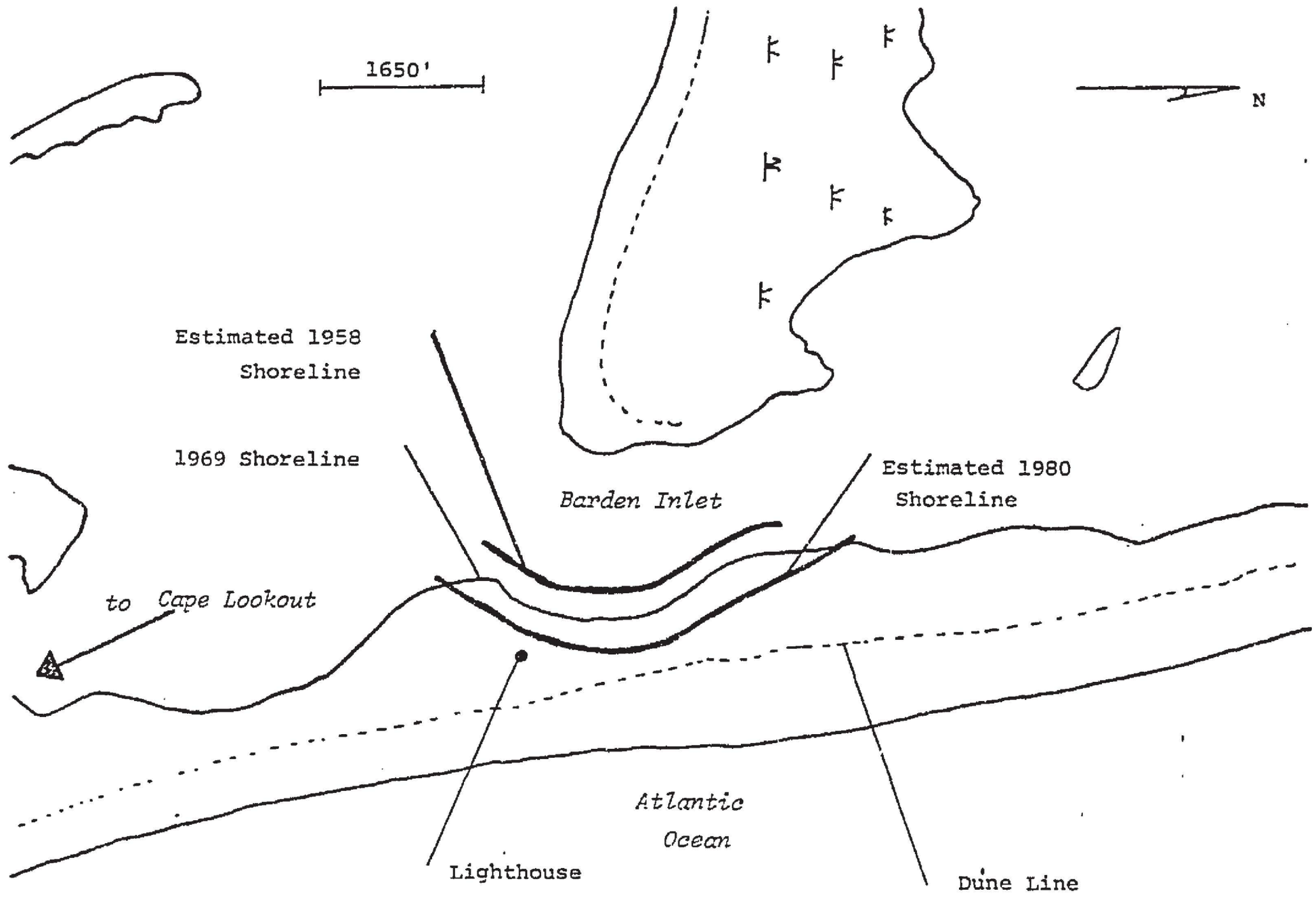

1650'
N
Estimated 1958
Shoreline
1969 Shoreline
Barden Inlet
Estimated 1980
Shoreline
to Cape Lookout
Atlantic
Ocean
Lighthouse
Dune Line

Figure 7

Bibliography

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