BEACH AND SAND DUNE EROSION CONTROL
AT
CAPE HATTERAS NATIONAL SEASHORE

A Five Year Review (1956-1961)

Assembled By

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PROLOGUE

A Digest of Geology and Shore Processes

A knowledge of the historic present as well as the geologic past is important to an understanding of the Outer Banks. Let us turn back the pages of time briefly and review a barrier beach and its origin. First, prior to the last glacial age the sea level was much higher and the shore line was far back on the present mainland. Secondly, with the coming of the last glaciation, the water was trapped in sprawling mile deep ice caps and the sea level dropped several hundred feet to expose the wide area of the continental shelf and create a low lying plain of meandering streams. On this flood plain was deposited vast quantities of sand by the Chesapeake, its tributaries, and other streams. These sand deposits became the mother lode forming the outer banks. Winds shifted the sand into rolling dunes. Then another force came into play. About 5,000 years ago, with the melting of the continental ice sheet, the sea level slowly rose to approximately its present level, and a combination of long shore currents and wave action began to carry and shift the sand into barrier beach formation called the Outer Banks. The energy of currents and waves were utilized in carrying sand and the mother lode supplied the material with prodigous generosity to a point of glutting the litoral drift.

In the very recent past and the present, however, the mother lode is nearing depletion and the source of sediment material is greatly diminished. At the same time the sea is slowly rising. We are undergoing a period in which the sea water level is in fluctuation caused largely by the melting of the northern hemisphere glaciers. World sea level is currently rising at about 1.2 mm annually (1/25th of an inch approximately). These figures are world averages. Local trends may be more significant at Pensacola, Florida, for example, the 1948 level was 0.65 feet above 1931. The changes are uneven with dips and peaks; however, the trend is a rising one. During this past 2000-1500 years the rise has approximated 7 feet along the Southern Atlantic seaboard with the last 30 years showing a minor but rapid rise. This factor has grim significance when related to shore erosion. A rise of 1/10 foot may cause a recession of 15 feet of shoreline over a period of 5 to 10 years.

Another factor governing shore erosion is the height of off shore bars and profile of slope. These hidden underwater land forms exert a tremendous influence on wave forces as a means of dissipating wave energy. Whether or not the off shore bars and slope exert their normal drag and withdrawal of wave energy is dependent only upon a couple feet difference in sea level.

Thus, a combination of spring tide (full moon) and northeaster lows with high winds will raise the ocean tides so that they ride over the off shore bars and slopes with no loss of energy and strike the shore with kilo ton force. The results of such a combination of events can be seen in our recent March 7-9, 1962 storm.

Another factor governing what portions of the beach will be hardest hit lies in the undulating character of off shore bars and slopes. Where depressions exist off shore the wave impact against the land will be the greatest.

The shore process phenomena is dynamic, change is constant, off shore undulations shift overnight. There is tear down and build up of beach sand deposit; but the over all governing factors are such that the net long term results is loss of land mass. Thus, the Outer Banks are now in most places being eroded and moved toward the mainland by a combination of long shore currents, tide and wave action, and by wind movement which generally carries the sand inland.

Our job is to recognize these causes and to mitigate and alleviate the effects as best we may be able to with whatever means we can economically afford. Because ours is a great responsibility--as men and women of the 20th Century--we should turn over to our children of the 21st Century something of this glorious land which we have known and experienced. The beaches of our shores are an important part of that heritage we owe the future. We can do much with what we already know to safeguard this trust.

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Introduction

The Cape Hatteras National Seashore is one of the 181 areas administered by the National Park Service under the Department of the Interior. These comprise the outstanding scenic, scientific, and historical areas in America. Cape Hatteras is the first National Seashore in the National Park System. Extending from Whalebone Junction at the southern boundary of Nags Head, North Carolina, some 70 miles southward through Ocracoke Island, the National Seashore preserves 45 square miles of beach land. It is divided into three sections -- Bodie, Hatteras, and Ocracoke Islands. Lying between broad shallow sounds and the foaming ocean surf, this thin barrier of golden sand on the windswept Outer Banks provides stimulating recreational opportunities and rewarding experiences in both human and natural history.

Less than a hundred years ago the Outer Banks were covered with trees, shrubs, vines, grasses, and other types of vegetation from the sound almost to the edge of the ocean. Live oak, water oak, dogwood, pine, sycamore, pellitory, holly, persimmon, yaupon, and mulberry were the principal types of trees. At that time the inhabitants were primarily engaged in fishing and stock raising; small horses known as banker ponies, cattle, sheep, goats, and hogs were all raised in the area. Originally, the stock was kept in fenced enclosures and marsh grass was harvested to feed them during the winter months. As the population increased, the stock increased, fences were abandoned and soon the grasses and other vegetation began to disappear, leaving vast areas barren of all types of vegetation.

As time went on, the accumulation of sand from the beaches was blown across the barren areas and the vegetation not destroyed by over-grazing was covered up with drifting sand. Since most of the people were engaged in fishing, trees were used in the construction of fishing vessels, others were used for constructing buildings, and many others for firewood. So that eventually all of the sturdy trees, with the exception of a few left around the homes, were used up or swallowed by the moving sands. As a result, the storm tides began to wash across the barren beaches from the ocean to the sound.

During the depression years of the 1930's, emergency funds were made available for the purpose of stabilizing the sand dunes by planting grasses, shrubs, and trees throughout the barren areas and restoring the vegetation to most of the area. Much of this work was lost during the next 15 years thru negligence and lack of maintenance. With the establishment of the Cape Hatteras National Seashore in 1953, the dune rehabilitation conservation project was resumed.

THE DUNE STABILIZATION PROJECT

The problem is one of creating a barrier dune of sufficient (1) height to prevent storm tides from rolling across the land mass from ocean to sound; (2) width to withstand storm tide action and seepage of imponded sea areas without seriously weakening; (3) distance from ocean to permit easy slopes and also to limit storm damage and (4) vegetation to stabilize and establish the sand mass in the location desired. Buildup of the dune mass is accomplished by either fencing or bulldozing or a combination of the two. Vegetation of the dunes is done by transplanting native beach grasses.

The above are general statements setting up the problems and the methods used at the National Seashore. Specifically, the work is done as outlined below.

Sand Fence Method

During the years, improvements have been made in selecting fence types and methods of erection. In 1955, brush fencing was used with woodlot posts; in 1957, standard snow fence was first used; in 1958, standard snow fence became the main fence type media and 2"x4"x6'0" rough sawn oak was used for posts. No 12 wire bag ties were used to attach fence rolls together and to aid in attaching to posts. Final attachment is by $1\frac{1}{4}$" galvanized fence staples.

Along open beaches with little or no existing dunes, the initial fence line is laid out at about 150 to 400 feet from mean high tide. Four-foot fencing with posts at 8-foot centers and alternating (right and left of fence center line) at 16-foot intervals is the basic fence pattern used. Eight-foot wings are then placed perpendicular to the main fence, on alternate sides, 32 feet apart. Where fine beach sand exists, the fence may be covered in a few weeks; where coarse sand exists it may take several months or it may show little sand build-up even after a year or more. Drifting, blowing sand is a prerequisite to dune establishment by fencing and is an important factor in its location.

Along beaches where there is much fine sand, the fences are completely wrapped up in a sand mound within the year. Then base widening fences, or lift fences, can be placed on top of existing sand masses. The primary advantage lies in its low cost and the fact that no heavy equipment (dozers and earth movers) are necessary. It can be strictly a labor-truck proposition; and along suitable sand, it will create a dune four feet high with a 30' - 40' base. Thus, cubic yardage-wise, it is a relatively inexpensive method of dike building.

Theoretically, the use of fencing involves a multiple use arrangement whereby parallel fencing is placed in two or three rows about 16-20 feet apart. After these fences build up a low, broad, 4-foot dune, one or two rows are erected on top to build the final 8-foot dune. Such a build-up may take 3-5 years (allowing one year for each fence to gather sand.) Therefore, during this period of build-up it is vulnerable to storm damage.

Sand fences have certain disadvantages. They must be located along, or to the rear of, fine blowing sand areas which will gather and build up about the fences. Coarse sand, or so-called beach gravel, is a poor fence build-up media. Also, many times ideal sand conditions exist closer to the ocean front than it is desirable to locate fences.

Standard sand fence (or snow fence) comes with a 1½" slat with a 2" opening which works very well to control blowing sand to build up dunes. We have used a fence with a 1" opening and are now using a fence with a 1½" opening. All these fences will work satisfactorily and in general, it is largely a matter of using the type which is available. We believe that you will find the 2" open area between slats type of fence less costly and for sale at several retail outlets. Preservative treatment may have advantages, however, we specify untreated fencing in our contracts because it is satisfactory and less messy to handle.

Our specifications for standard fence are as follows:

> FENCE - snow standard; minimum lath size shall be 3/8" x 1½" x 48"; shall be No. 1 quality, sound Canadian spruce or equal, thoroughly dry with no twist or warp; wire shall be 12½ gauge soft galvanized industrial quality, five (5) double cables, 2½ full twist of wire with uniform 2" spacing between lath. Fence to be in fifty (50) foot rolls full footage and contain a minimum of 168 slats. NOTE No wood preservative treatment this contract.

The following specifications cover a fence which we are now using. We mention this for your information. It can be procured from the manufacturer on special order:

> FENCE - snow, special lath space ratio of 50% closed area to 50% open area or 1½" (lath) to 1½" (open space) as follows: wooden pickets to be No. 1 quality, 3/8" thick or better by 1½" wide spaced 1½" apart. Each 50 foot roll to have not less than 195 pickets. The following species of wood is acceptable: redwood, spruce, Douglas fir, ash, beech, white pine, cypress, and hard maple. Other species may be acceptable, but must be submitted to the Contracting Officer for approval. Wire may be 13-gauge soft galvanized industrial quality, with 2 twists or more between slats; 48" fence shall have four (4) double cables; end cables shall be approximately 4" from each end. Fencing shall be in fifty (50) foot rolls full footage. NO PRESERVATIVE TREATMENT.

Bulldozing Method

Another method of building dunes is by earth moving equipment such as bulldozers. At the National Seashore, a TD 18 is used the year around. This piece of equipment is used to build up easy sloping dunes about 6 - 8 feet high above the existing ground and between 150 and 400 feet from mean high water. The mean sea level elevation is usually between El. 15.0 and El. 18.0. For the most part, it is used along those portions of the beach where the existing dunes are too close to the ocean, badly eroded, or windblown. Depending upon available material, the back beach area is graded at a slope between 1:10 and 1:20.

Along the crest of the dozer-built dune is erected a 2-foot sand fence to gain additional height and also to keep wind from blowing out the sand and lowering the dozer-built dune elevation. On low elevation dozer-built dunes, 4-foot sand fencing is erected to gain additional height.

The swath of borrow uncovers fine sand; thus, a blow sand area is created which quickly wraps up the fence and spills over to build an easy, lee slope. Beach grass is planted on the ocean side of the 2-foot fences after about a foot of build-up has occurred. If the build-up is somewhat slow, it is planted anyway. The beach grass pushes up through the drifting sand, stabilizing and holding the sand in place. The time of planting is largely a matter of judgment and observation. Should the planting be done too early followed by a rapid deep build-up which completely covers the new plants before they become established, they will not survive.

The effectiveness of dozer-built dunes, immediate 8-10 foot high dikes, over that of recent installed fences, was sharply revealed after Hurricane Helene in September, 1958. The dozer-built dunes withstood the storm with only comparatively slight damage and few breakthroughs. Dozer-built dunes proved their value in a dollar-cents manner. Where existing eroding dunes and sand masses permit quick easy borrow and reshaping of beach slopes, dozer-built dunes have a great advantage over sand fencing. However, in low beach locations where borrow must be taken from the berm formed by high wave action, use of dozers to form a dike can be highly questionable.

Sand fencing used in conjunction with dozer-built dunes maintains and increases dune height at a low cost. Such fencing is located in an area conducive to rapid build-up; therefore, is an excellent method to achieve the maximum desired strength.

In any large scale project of dune building, dozers, dredges, and other types of earth moving equipment must be given top consideration. Such dunes followed by 2-foot high fencing along the dune crest and grassing of slopes will give immediate protection at the height and location desired. It is then only a question of maintenance to keep up this protective barrier.

Vegetation and Plantings

The Cape Hatteras National Seashore staff firmly believes that vegetation is the final sand stabilization media. Over 99% of all transplant grasses is composed of about six varieties: (1) American beach grass (Ammophila breviligulata), (2) salt-meadow grass (Spartina patens), (3) sea oats (Uniola paniculata), (4) running beach grass (Panicum amarum), (5) smooth cord grass (Spartina alterniflora), and (6) silver beach grass (Panicum amarulum).

Both the Seashore staff and planting crews are partial to American beach grass. This species grows best on the high dunes which have some sand movement. It is one of the last grasses to turn brown in winter and one of the first to turn green in spring. Its excellent characteristics are a fine stolon root system, growth from rhizomes, ability to stand summer heat and drought, and ease in gathering and transplanting. It is our first choice as a grass for beaches.

Salt-meadow grass is planted on the lower dunes and flats. It is a thriving species within the National Seashore. It has a lesser root growth, does not take sand burial too well, is easy to procure and plant, and is able to withstand considerable heat and drought. As an experiment, this species was machine planted during the summer months of 1959 on Ocracoke Island flats. Here the water is about six to twelve inches from the surface. Several inspections of this planting show about 70-80 percent success. Similar plantings will be made again this summer.

Sea oats is a dominant plant growth at the National Seashore. It is a tall, majestic plant growing to about 36 inches with spectacular fronds of grain which catch the tourists' attention in late summer and fall. It has all the good characteristics of beach grass, except ease of gathering (must be dug because of heavy root system) and tends to produce hump-backed dunes which are subject to wind erosion. It is used as a transplant along ocean frontal dunes because of its superior qualities in this location.

Panicums are now being heavily used, especially amarum, which is a common grass found on Bodie and Hatteras Islands, although not a dominating species. It has a fine root system, spreads by rhizomes, and is found back of dunes and along roadsides at low levels. It is not as easy to gather as beach grass or Spartina and does not feed into the planting machines as well. Its chief advantage is the fact that it spreads rapidly in favorable locations, and is very tolerant to salt spray and grows well on the frontal ocean dunes.

Smooth cord grass has been widely used on large, moist, low-lying flats to check blowing sand which sweeps across these flats, creating live dunes. Although this is one of the Spartinas common at the Seashore,it has not transplanted as successfully as the Spartina patens.

Silver beach grass is a tall clumpy, non rhizomous, type grass which is fairly tolerant to salt spray and does well in the back dune area.

Hand Planting Grasses

Transplanting of grass sprigs has proven the only effective method of bringing cover and final stabilization to dune masses and raw drifting sand. Hand planting is a laborious and costly method, Seeding, so far, has proven to be an unsuccessful means of providing vegetative cover. Although numerous varieties have been tried, they either fail to germinate or die soon after they sprout.

So far as we know commercial seed is not available for the above grasses. We plant sprigs or small clumps (about 1/2 dozen stems as a unit) by hand. The grasses are pulled or dug from existing healthy stands. All of these grasses except silver beach grass reproduces by seeds and by root rhizomes. Thus, obtaining these grasses for transplanting is largely a thinning process, and does not injure the existing stands. Care must be taken to have at least one node or joint which have roots and to secure as many secondary and fibrous rootlets as possible. The planting is usually by hand, about 15 inches on centers in a random staggered pattern. At the Seashore we use two man planting teams. One workman with a No. 2 shovel prepares the planting crevice into which the other slips the transplant before sand can fill the hole. Occasionally one man works alone but it appears to be a slower and more awkward method. Planting is usually done during the months of October through April into May. However, the best results will be obtained in colder months when the plants are dormant.

The amount of work per man day accomplished by National Seashore employees has a wide variation from 500 to 2150 square feet per day, with the average being 1250 square feet per man day (this includes pulling and planting). Weather, terrain, availability of grasses, and good supervision are basic factors in labor output. Certainly, an average 1250 square feet per man day should be considered only a satisfactory minimum with 2000 square feet per man day a realizable goal to reach.

For a comprehensive report on seaside vegetation and plantings, we refer you to Department of Army, Corps of Engineers, Beach Erosion Board, Technical Memorandum No. 101, which was prepared by Dr. John H. Davis, University of Florida, Gainesville, Florida. Dr. Davis visited the National Seashore several times during preparation of the Memorandum and most of the illustrations and a good part of the text was formulated from observations made during these visits.

If the area of planting is extensive, the use of grass planting machines may be practical. We can send further information for the type now in use at the National Seashore, if you so request. Basically these machines are modified root type planters (tobacco, tomatoes, etc.) pulled by small crawler tractors and only large scale plant operations can justify their initial cost. However, this machine planting will step up the man day effort 5 times and reduce your cost about 500 percent.

Machine Planting

The National Seashore project started using mechanical grass planters in March 1959. The machines were patterned after one used by Mr. Edward Brady, Department of Parks, New York City. The National Seashore machine is similar to the one which Mr. Brady had successfully used on the Long Island Beach Parks. It is our understanding that mechanical planters have also been used at Jones Beach State Park and Idlewild Airport, New York City. There are, no doubt, other places in which root type transplanters are being used to sprig grasses. Real estate developers in the Norfolk, Virginia area use this type planter to sprig Bermuda grass lawns.

Two similar planters, composed of three individual planting units joined together by a drawbar, are now in use at the National Seashore. These are standard root type transplanters normally used for such crops as tobacco, tomatoes, etc. Modifications were made to improve the handling of beach grasses and render more practical the operation over uneven dune terrain. The basic change was altering the rigid planter drawbar attachment to one which permitted considerable vertical and horizontal freedom to each of the three planting units. The change permitted wider usage on uneven ground, a very necessary prerequisite to dune planting. This type of equipment is manufactured by Holland Transplanter Company, Holland, Michigan for Model 1600 and Powell Manufacturing Company, Wilson, North Carolina for Model 44. Similar equipment is produced by other manufacturers.

Two small tractors are used in conjunction with the mechanical grass planters. One is a Fordson, Model 641, equipped with a step-down-down transmission, front wheel drive, and bombardier tracks. The driver is protected from blowing sand by a standard canvas cab which is provided as extra equipment by the manufacturer. The other tractor is a crawler-type International, Model T-340, equipped with all-weather cab and front dozer blade. Both tractors have a three-point hydraulic agricultural hitch for attaching the planters.

A low operating speed is necessary. Around 40 feet per minute is a normal working speed. The machines have been operated as high as 50-55 feet per minute and as low as 25-30 feet per minute. The high speed does not permit even planting and there are many skips. The low speed is used to orient new workers to the job. When one realizes that the normal machine planting is 12-inch spacing between plants, he can see that at a normal speed each operator plants 40 sprigs per minute. This is just about as fast and efficient as sustained planting can be maintained. The distance between rows is 26 inches.

A planting crew consists of five workers, a tractor driver, three planters, and one supplier. The supplier drives the truck or pickup in which the sprigs are transported and keeps the plant trays on the machine filled. It will normally take five additional workers to keep the machines supplied with planting material. Frequently, the crews gather grass sprigs in the morning and plant in the afternoon.

Fertilizer as a Plant Stimulant

Usually the sand beaches have poor fertility and a complete fertilizer (10-10-10) or (8-8-8), which is applied at the rate of 400 pounds per acre, and in two equal applications (about 200 pounds each) during the middle of April and June, will enhance the growth and strength of the plants. We are also hopeful that fertilizing will also stimulate seed and rhizome reproduction. An application of a nitrogen fertilizer in September will also enhance rhizome growth. Dr. W. W. Woodhouse, Professor of Soils, North Carolina State College, Raleigh, North Carolina has been conducting a study on the use of fertilizer as a stimulant to dune plant life and seed viability. The study has been in progress for only one year and although results are inconclusive, certain facts stand out. He reports as follows:

> We have been able to observe the beach and dune erosion problem much more intensively during the past 12 month period and our thinking has been clarified considerably as to the place of vegetation in a control program. It is obvious that vegetation will not solve all the problems. At the same time, it appears to be equally obvious that vegetation will be the most practical answer to many of them. It appears, at this stage, that nitrogen is the principal fertilizer constituent limiting growth of these grasses. Due in part, at least, to the high variability encountered, response to phosphorus and potassium is uncertain. Observations made throughout the season led to the impression that phosphorus was beneficial but that potassium had no apparent effect. This is about what might be expected with these plants under these conditions but additional study will be needed to confirm or deny these tentative conclusions. The following points may serve to summarize some of our present thinking on this:
>
> In summary, results from the first year of the study indicate that - -
>
> 1. Fertilization can be a very effective and relatively economical tool in the stabilization program. It seems probable that the full effect of a two or three year fertilization program will be much more pronounced than the first year results demonstrate.
> 2. The key factors in a practical fertilizer program appear to be
>   (a) Nitrogen applied at least 3 times during the growing season; on beach grass this would probably be in April, June and August or early September. It appears that for Spartina the initiation of the program should be delayed until early May.
>   (b) Phosphate, applied once a year, in the spring. Potash may or may not be needed.
> 3. Optimum rates of application are presently estimated at 100 lbs. of N and 30 to 50 lbs. of P_2O_5. This could probably best be obtained by applying 300 to 400 lbs. of 10-10-10 at the first or spring application, with the 2nd and 3rd applications each consisting of 100 lbs. of ammonium nitrate. Thus the annual fertilization would total 500 to 600 lbs. per acre at a cost for materials of about $15.00.
>
> It would be difficult, if not impossible, at this stage to predict, quantitatively the value for stabilization purposes of the increased growth from fertilization. Observations indicate, however, that both increased speed of establishment and of total growth greatly enhances the value of plantings and reduces the probability of loss of stands due to storm damage.

Engineering Survey Facts

As a part of the C.C.C. endeavor in the years 1932-37 a base line monumented every ½ mile was established and cross sections taken.

In April 1961 a field survey crew started re-establishment of the base line and cross sections duplicating the C.C.C. work and thus obtaining data relating to shore changes during the past 25 years. The purpose of this work is to learn the amount of shore erosion at closely controlled distances along the beach. The work on Bodie Island was completed before the March 7-9, 1962 storm.

The information below is offered as a sample of the findings to date and relate only to that portion of the Bodie Island ocean beaches included within the Cape Hatteras National Seashore.

Erosion - Bodie Island

	25 Year Loss		Storm Loss		Total
Feet	Mile	Lin.Ft.	Mile	Lin.Ft.	Lin.Ft.
0/00	0	156		107	263
620	0.11	326		207	533
2720	0.52	85		218	303
4740 #	0.90	198		192	390
5760 *	1.10	196		167	363
7945	1.50	230		159	389
8985	1.70	194		197	391
10,990	2.08	218		222	440
13,050	2.47	325		369	694
14,043	2.70	284		308	592
16,110	3.05	788		40	828
17,165	3.25	824		186	1,010
18,176	3.44	748		197	945
20,470	3.88	752		900	1,652
21,343	4.04	800		in inlet	channel

Bodie Island Headquarters *Coquina Beach Area

The above table indicates beach conditions at definite times of survey. The changes were not constant but variable as the dynamics of coastal processes undergoes its normal plus and minus actions. But in general, the table shows that the net result of wind and wave is beach loss, that the beach loss occurring during the last storm (3/7-9/62) was generally equivalent to that sustained during the previous 25 years, that the average acreage loss over a four mile distance was 293.3 acres in 25 years and 155.2 acres as a result of the storm. The total acreage loss was 448.5 acres.

The above are important facts to keep in mind in any long range planning of development projects along the Outer Banks.

The following is a progress and cost summary to date covering five years, 1956-1961.

Project	Unit	Quantity		Unit Cost	Total Cost
Erect Sand Fence	L/Ft.	561,180	@	0.4014	$225,294.73
Erect Brush Fence	L/Ft.	98,029	@	0.220	21,586.07
Build Brush Fence	L/Ft.	65,900	@	0.298	19,697.88
Sand Moval, Dozer	CYds.	519,754	@	0.103	54,009.17
Brush Layering	CYds.	8,180	@	2.061	16,859.31
Grassing (Hand)	Acres	119.8	@	620.597	74,347.63
Grassing (Machine)	Acres	268.5	@	136,735	36,713.41
Grassing Equipment Purchased	-----	------	-	-------	4,666.34
Other	-----	------	-	-------	5,889.19
Ramps	L/Ft.	2,126	@	1.664	3,539.00
Fencing (N.C. participation)	L/Ft.	35,000	@	0.083	2,925.00
Pine Seedlings	Each	21,000	@	0.035	738.00
Fascilitating Services	-----	------	-	-------	7,891.00
Engineering Research	-----	------	-	-------	15,250.00
Total					$489,406.73

Accumulative totals for five years

Labor	Supplies	Equipment	Other	Contract	Total
190,836.96	129,067.67	91,282.82	42,676.57	35,542.71	489,406.73

FIVE YEARS IN REVIEW

The highlights of the past five years have been as follows:

1. Improvements in fence types and erection methods.

2. Experimentation on fencing types using synthetic fiber materials.

3. Use of dozer-built dunes as a primary method of raising dune masses and also to obtain immediate dune mass and height at critical areas.

4. The use of fertilizer as a means of improving beach grass growth.

5. The use of mechanical grass planting equipment which makes beach grass transplanting feasible and economical.

6. The Dr. Per Bruun Report which explained the forces at work forming the Outer Banks and recommended ways and means to check these forces and protect man-made developments.

7. Experience gained during the past five years in the selection of types of grasses that are more adaptable to this particular area.

8. Experiment with modern seeding and mulching equipment (Finn Equipment Company, Cincinnati, Ohio).

9. N. C. State Study on grasses, use of fertilizer, and research and development of native grass and shrubbery materials for dune control use.

10. Engineering Survey which set up a series of controls to measure beach erosion, prepare base maps, and the datum to evaluate present operation, methods, techniques of sand fixation and building barrier dunes, and to provide the framework to plan future work on a sound basis.

C O N C L U S I O N

Beach and Sand Dune Erosion Control at the Cape Hatteras National Seashore is a difficult problem. Flanked by the salt waters of the Atlantic Ocean and Pamlico Sound, the long narrow ribbon of sand averaging less than one mile in width, is frequently covered with salt spray. Since most of the area is less than six feet above sea level, much of it is flooded with salt water during storms. On most of the flat areas, the brackish water table is within one foot of the surface.

Many types of vegetation grown successfully in other sea coast areas are unable to withstand the high salt content of the soil and atmosphere. The search continues for vegetative types that can be successfully adapted. As soon as grasses have been established, trees and shrubs native to the area will be reintroduced. Vegetation is the final stabilizer and anchor of the dunes.

It has been clearly demonstrated that live sand dunes can be halted temporarily with mechanical structures. Permanent stabilization can be accomplished only by complete vegetative cover. This has long been recognized. A hundred years ago, Henry David Thoreau said in his book Cape Cod, "This Cape is anchored to the heavens, as it were, by myriad little cables of beach grass, and if they should fail, would become a total wreck, and ere long go to the bottom."