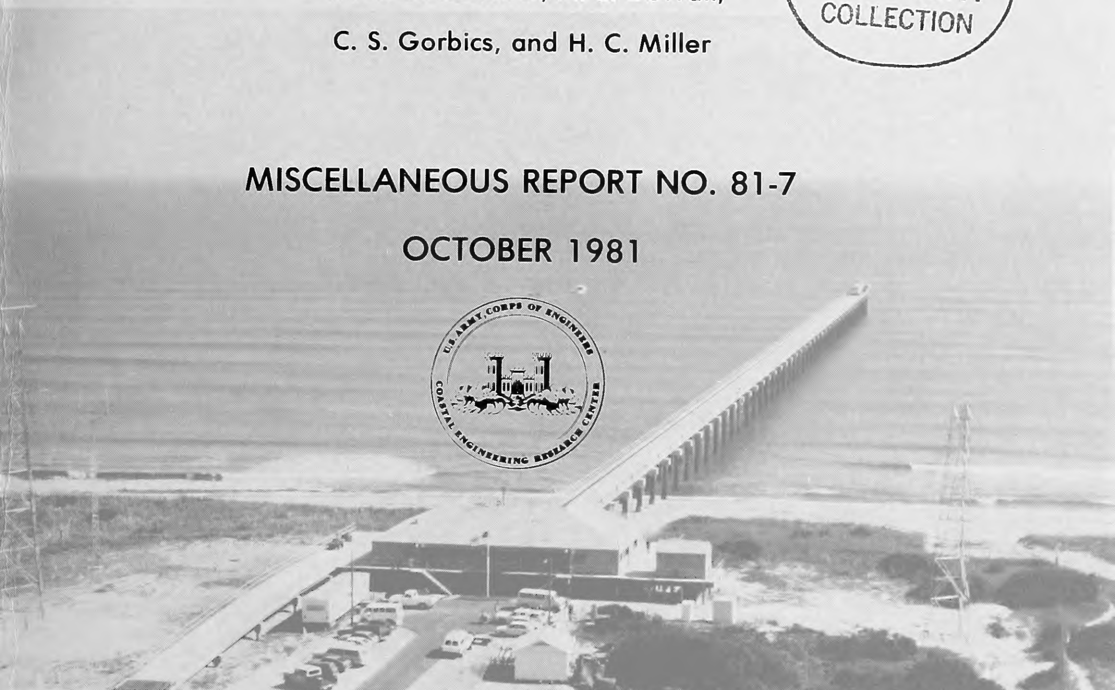
A User's Guide to CERC's Field Research Facility

by

W. A. Birkemeier, A. E. DeWall,
C. S. Gorbics, and H. C. Miller



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Kingman Building
Fort Belvoir, Va. 22060

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Duck, North Carolina
Field Research Facility-CERC
User's guide

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

The Coastal Engineering Research Center's (CERC) Field Research Facility (FRF) at Duck, North Carolina, is a 561-meter-long (1,841 feet) pier and laboratory dedicated to basic and applied coastal research. This report, which describes the facility, the instrumentation and data being collected, and the local area, is designed to be used as a tool in planning experiments to be conducted at the facility. (Use of the FRF by outside researchers is encouraged.)

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PREFACE

This report is published to provide basic information about the Coastal Engineering Research Center's (CERC) Field Research Facility (FRF) at Duck, North Carolina. Although the primary purpose of the facility is to support CERC's research programs, use by other agencies and organizations of both the facility and the data being collected is encouraged. The work on this report was carried out under CERC's waves and coastal flooding program.

The report was prepared by William A. Birkemeier, Hydraulic Engineer, under the supervision of C. Mason, Field Research Facility Group, Research Division; sections of the report were prepared by Allan E. DeWall, Carol S. Gorbics, and H. Carl Miller.

The authors acknowledge the assistance of the following members of the CERC staff: G. Bichner, C. Judge, and R. Townsend for collecting much of the data; J. Miller, J. Headland, and M. Lester for their analyses of beach profile and sand sample data; K. Jacobs for compiling the bibliography; H. Klein for her acute knowledge of the local area; and C. Mason, R.P. Savage, D. Berg, C. Judge, G. Bichner, H. Klein, A. Hurme, and J. Pullen for their reviews which contributed greatly to the quality of the final report.

Comments on this publication are invited.

Approved for publication in accordance with Public Law 166, 79th Congress, approved 31 July 1945, as supplemented by Public Law 172, 88th Congress, approved 7 November 1963.

Ted E. Bishop

TED E. BISHOP
Colonel, Corps of Engineers
Commander and Director

CONTENTS

TABLES

FIGURES

CONTENTS

FIGURES--Continued

CONTENTS

FIGURES--Continued

CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	by	To obtain
inches	25.4	millimeters
	2.54	centimeters
square inches	6.452	square centimeters
cubic inches	16.39	cubic centimeters
feet	30.48	centimeters
	0.3048	meters
square feet	0.0929	square meters
cubic feet	0.0283	cubic meters
yards	0.9144	meters
square yards	0.836	square meters
cubic yards	0.7646	cubic meters
miles	1.6093	kilometers
square miles	259.0	hectares
knots	1.852	kilometers per hour
acres	0.4047	hectares
foot-pounds	1.3558	newton meters
millibars	1.0197×10^{-3}	kilograms per square centimeter
ounces	28.35	grams
pounds	453.6	grams
	0.4536	kilograms
ton, long	1.0160	metric tons
ton, short	0.9072	metric tons
degrees (angle)	0.01745	radians
Fahrenheit degrees	5/9	Celsius degrees or Kelvins[1]

[1] To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use formula: C = (5/9) (F -32).

To obtain Kelvin (K) readings, use formula: K = (5/9) (F -32) + 273.15.

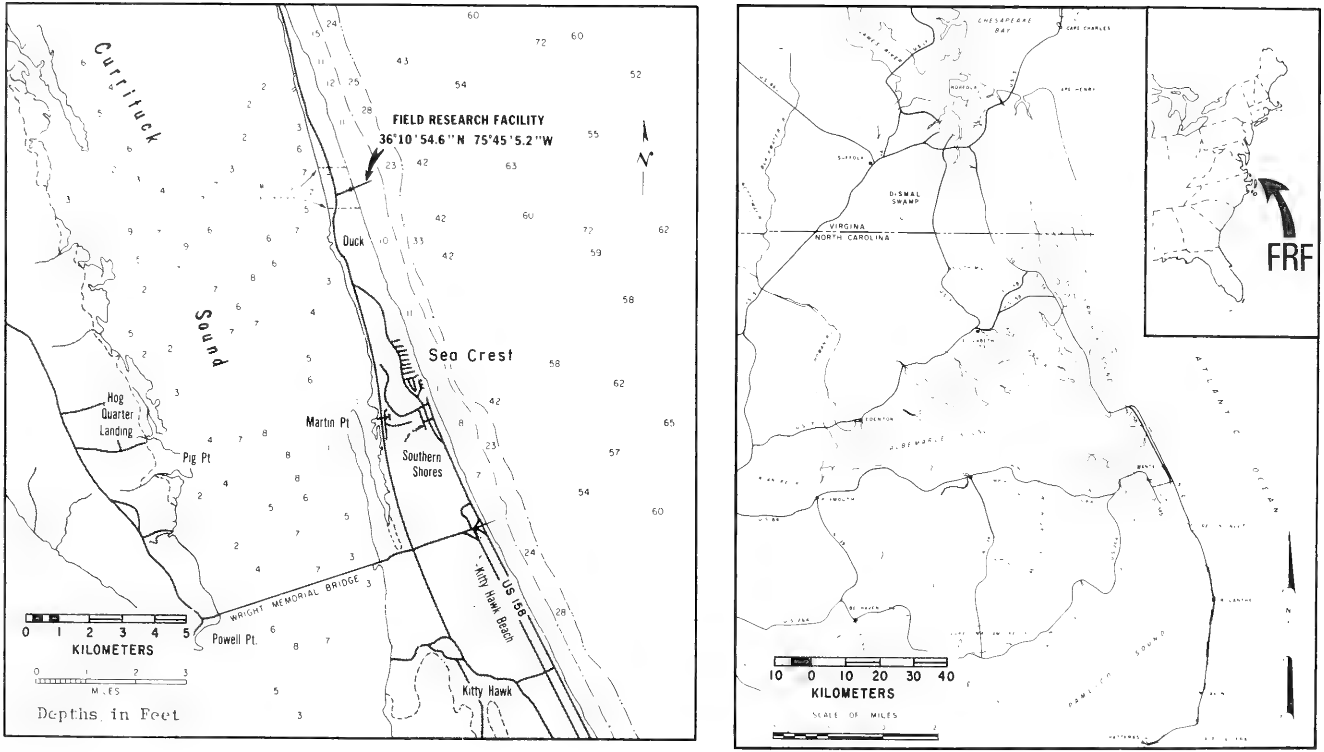


Figure 1. Location of the Field Research Facility.

A USER'S GUIDE TO CERC'S FIELD RESEARCH FACILITY

by
W.A. Birkemeier, A.E. DeWall,
C.S. Gorbics, and H.C. Miller

I. INTRODUCTION

Federal interest in coastal engineering began in the 1920's as a result of the increasing shoreline erosion along the recreational beaches in New Jersey. This concern led to the formation of the Beach Erosion Board (BEB) in July 1930 as a part of the civil works program of the U.S. Army Corps of Engineers. The BEB functioned largely as an advisor to the States with coastal erosion problems; however, the increasing need for research became evident. In recognition of that need, the BEB began expanding to include an official research program. In 1963, Congress established the Coastal Engineering Research Center (CERC), abolishing the BEB, and broadened the BEB's general investigation responsibilities to form the research mission of CERC.

CERC's mission, as the principal research and development facility of the U.S. Army Corps of Engineers in the field of coastal engineering, is to conceive, plan, conduct, and publish the results of data collection and research in coastal engineering and nearshore oceanography to provide a better understanding of the waves, winds, water levels, tides, coastal currents, and the coastal processes resulting from these littoral forces. CERC's research focuses on shore and beach erosion control; coastal flooding and storm protection; navigation improvements; recreation; and the design, construction, operation, and maintenance of coastal and offshore structures.

Much of CERC's past research in coastal engineering has consisted of laboratory experimentation and theoretical investigations. Supportive fieldwork has been hampered by a lack of dependable means of obtaining high-quality wave, beach, and water level data, including data during storms. To overcome this deficiency, CERC constructed the Field Research Facility (FRF) on 175 acres at Duck, North Carolina (Fig. 1). Located at 36°10'54.6" N. and 75°45'5.2" W. (landward end), the FRF consists of a 561-meter-long (1,840 feet) pier (Fig. 2), which was completed in August 1976, and a 418-square meter (4,500 square feet) laboratory and office building (Fig. 3) completed in March 1980. The FRF is designed to fulfill four major objectives:

(a) To provide a rigid platform from the land, across the dunes, beach, and surf zone out to the 6-meter (20 feet) water depth from which waves, currents, water levels, and bottom elevations can be measured, especially during severe storms;

(b) to serve as a permanent field base of operations for physical and biological studies of the site, the adjacent sound, bay, and ocean region by CERC, other Federal agencies, universities, and private industry;

(c) to provide CERC with field experience and data that will complement laboratory and analytical studies and provide a better understanding of the influence of field conditions on measurements and design practices; and

(d) to provide a manned field facility for testing new instrumentation.

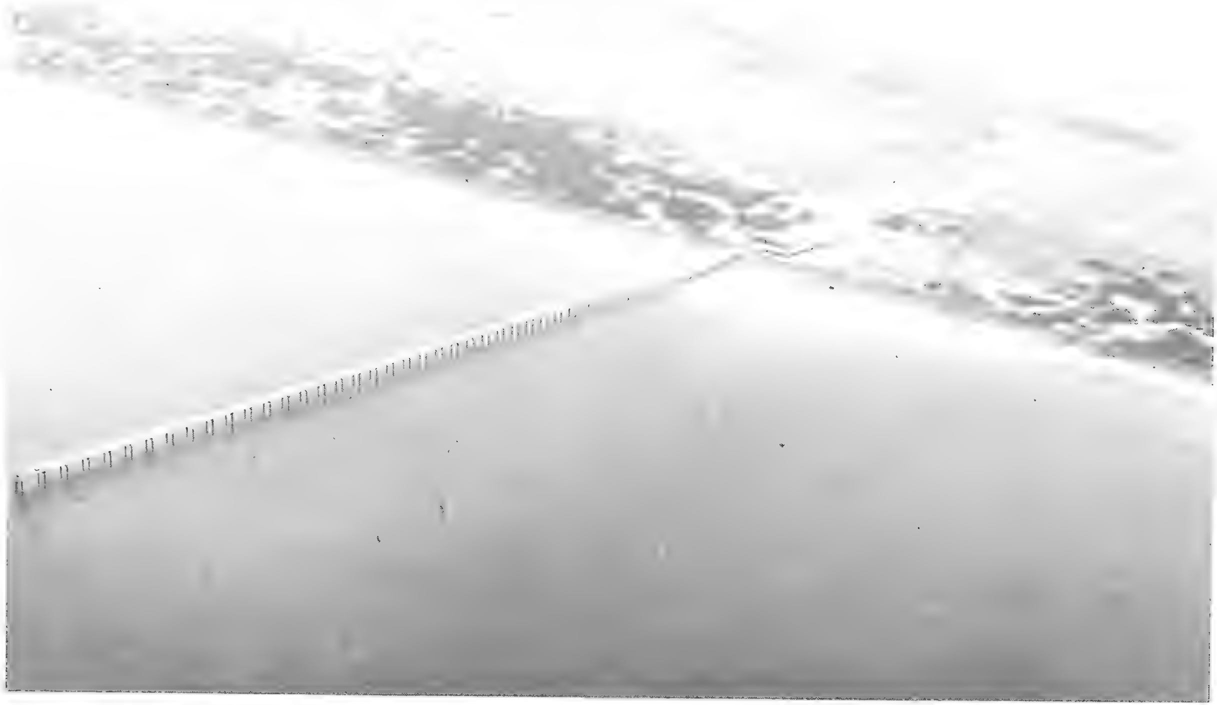


Figure 2. CERC Field Research Facility.

Figure 3. The laboratory building.

Although primarily intended for CERC research studies, other research organizations' use of the FRF and the data collected thereby is encouraged. This report provides potential users of the facility with useful information about the facility, the area, the climate, and the data being collected. Any questions which are not addressed in this guide should be directed to:

Chief, Field Research Facility
S.R. Box 271
Kitty Hawk, NC 27949
(919) 261-3511
Local dialing from Washington D.C. area;
370-6423

1. Use of the FRF.

a. Obtaining Permission. It is necessary to obtain written permission to use the FRF. This can be done by sending a synopsis of the research to:

Commander and Director
U.S. Army Coastal Engineering Research Center
Kingman Building
Fort Belvoir, VA 22060

Included in this letter should be the following information:

(1) Description of the planned research;

(2) dates;

(3) the approximate number of participants;

(4) a statement of the use, requirements, and expectations of the FRF; and

(5) other pertinent information.

Because of the occasionally harsh environment that exists at the FRF, it is imperative that potential users are aware of the prevailing conditions at the time of their experiment and have good advance planning (with regard to both people and equipment). Although this user's guide will help in that respect, any experiment should be discussed with the FRF staff before a formal request for use is submitted.

Particular attention will be given to those experiments requiring equipment to either be mounted directly on the pier or placed in the water. The area seaward of the FRF is a popular commercial fishing area with heavy use from October to December. Because of this, experimental equipment placed in this area should be marked with a pinger (acoustic beacon) and a large, lighted radar reflective buoy. Experiments within the pier length should be marked by a buoy (a pinger is desirable). Any installation requiring diver maintenance should be marked by a buoy or be attached by a handline to a nearby buoy for easy locating. Mooring lines should be large diameter rope or steel cable. The U.S. Coast Guard should be informed of all navigational obstructions. Experiment plans must also include plans for removal of equipment.

b. Costs and Funding of Research. If the planned research relates to the CERC mission, use of the facility and of the data being collected there is free. Costs for projects not relating to the CERC mission will be assessed according to the user's purpose and resources. Reimbursement will be required for out-of-the-ordinary use of FRF staff and equipment.

Although availability varies considerably from year to year, limited CERC funding may be available for contract (not grant) work. CERC funding of research by nongovernmental organizations may be applied for either by submitting an "unsolicited proposal" or by responding to a "Request for Proposal (RFP)" issued by CERC.

Unsolicited proposals are formal proposals, developed by the researchers, which address a research topic relevant to CERC's mission. The proposal should, at the minimum, include the following:

- Title page
  - Title
  - Proposed starting date
  - Duration
  - Principal investigator (name, title, phone number)
- Abstract of study
- Study description
  - Research objectives
  - Research application
  - Site description (if applicable)
  - Procedure
  - Research results and reports
  - Cost estimate (detailed)

Unsolicited proposals should be sent directly to:

Commander and Director
U.S. Army Coastal Engineering Research Center
Kingman Building
Fort Belvoir, VA 22060

An RFP is a request for proposals, issued by CERC, which addresses a topic of specific interest to CERC. To receive copies of future RFP's, a copy of Standard Form 254 (Architect-Engineer and Related Services Questionnaire) must be submitted to:

Commander and Director
Coastal Engineering Research Center
ATTN: CERRM-PC
Kingman Building
Fort Belvoir, VA 22060

Please note that it is neither necessary to submit an unsolicited proposal nor to respond to an RFP in order to use the FRF. Government agencies desiring CERC funding should contact the FRF Chief.

c. Liability. Users of the FRF are responsible for their own liability and will be asked to sign a release form (see App. A).

2. Description of the Area.

The FRF is located near Duck, North Carolina, along a 100-kilometer (62 miles) unbroken stretch of shoreline extending south from Rudee Inlet to Oregon Inlet. It is bordered by the Atlantic Ocean to the east and Currituck Sound to the west. An aerial view of the area is shown in Figure 4. Except for five fishing piers and the FRF pier, there are no major coastal structures or littoral barriers along the entire reach.

This location, one of 12 sites originally considered, was selected because it best satisfied (but not completely) the following list of desirable physical characteristics:

(a) Sand size typical of U.S. coasts and sufficient depth of sand to prevent exposure of underlayers;

(b) a wave climate and storm exposure representative of U.S. coasts;

(c) regular offshore bottom topography free of features which may affect the wave climate;

(d) a tidal range of 0.5 to 2.0 meters (1.5 to 6 feet);

(e) a representative nearshore slope such that the 6-meter depth contour is not appreciably more than 600 meters (2,000 feet) from shore;

(f) a straight coastline outside the range of the effects of any significant littoral barrier;

(g) easy access by vehicle;

(h) control of the pier and surrounding area by CERC to avoid interruptions in research programs;

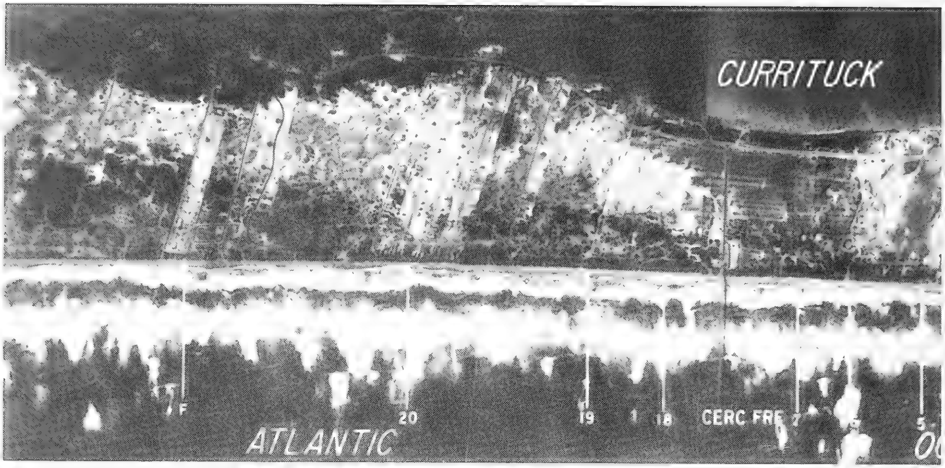
(i) an adjacent sound or estuary area;

(j) availability of commercial power and communication facilities;

(k) usually free of fog or cloud cover to permit frequent use of aerial remote sensing;

(l) a stable coastline (on a time scale of 50 years); and

(m) natural dunes.



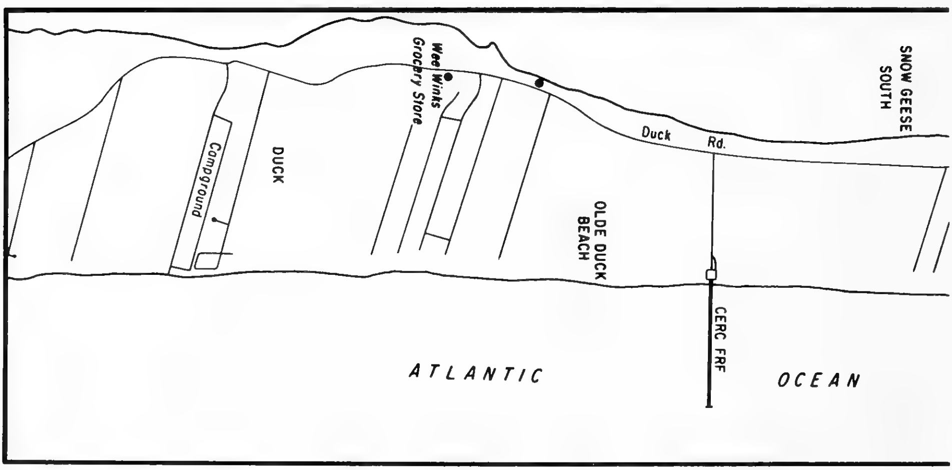


Figure 4. Aerial mosaic and map of pier site (numbers refer to profile line locations; see Table 4).

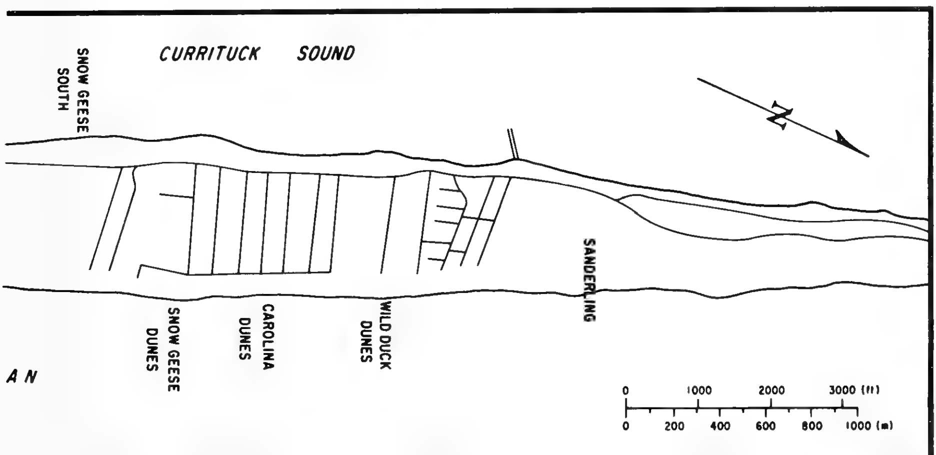


Figure 4. Aerial mosaic and map of pier site (numbers refer to profile line locations; see Table 4).--Continued

Details of the Duck site as it pertains to these items are discussed further in this guide.

Duck, North Carolina, was established in about 1909, as a small fishing village with eel and carp the predominant fishery resources. When CERC selected the Duck site in 1972 there were relatively few homes in the area; however, this situation has changed considerably. Duck has become a popular summer resort, and fast-growing resort communities are located both north and south of the area. The site had also been used previously by the Navy as a practice bombing range. Although there is evidence of the practice rounds of ammunition used during that time, there are no high explosives in the area.

Construction of the FRF pier began in August 1975. The pier was constructed in two phases, using a temporary second pier with closely spaced bents (pile groups 4.9 meters (16 feet) apart with four piles per bent) located along the south side of the FRF (Fig. 5). During the first phase of construction, 183 meters (600 feet) of pier was completed and the construction pier was removed. The second phase began in March 1976 with the reconstruction of the second pier. The entire FRF pier was completed by August 1976, and the second pier was removed in January 1977.

Figure 5. The FRF during construction, with second pier in foreground.

3. FRF Specifications.

A cross section of the pier is shown in Figure 6. The 561.1-meter-long (1,840.9 feet) pier is a reinforced concrete structure supported on concrete-filled steel pilings spaced 12.2 meters (40 feet) on center along the pier length and 4.6 meters (15 feet) on center across the width (Fig. 5). Inshore bents (numbered 6 to 20) are supported on 76-centimeter-diameter (30 inches) piles; the outer piles (bents 21 to 52) are 91 centimeters (36 inches) in diameter. The piles are embedded about 15 to 18 meters (50 to 60 feet) into the ocean bottom. Concrete erosion collars 120 and 137 centimeters (48 and 54 inches) in diameter, protect the pilings from sand abrasion, and a cathodic system provides protection from corrosion. The pier deck is 6.1 meters (20

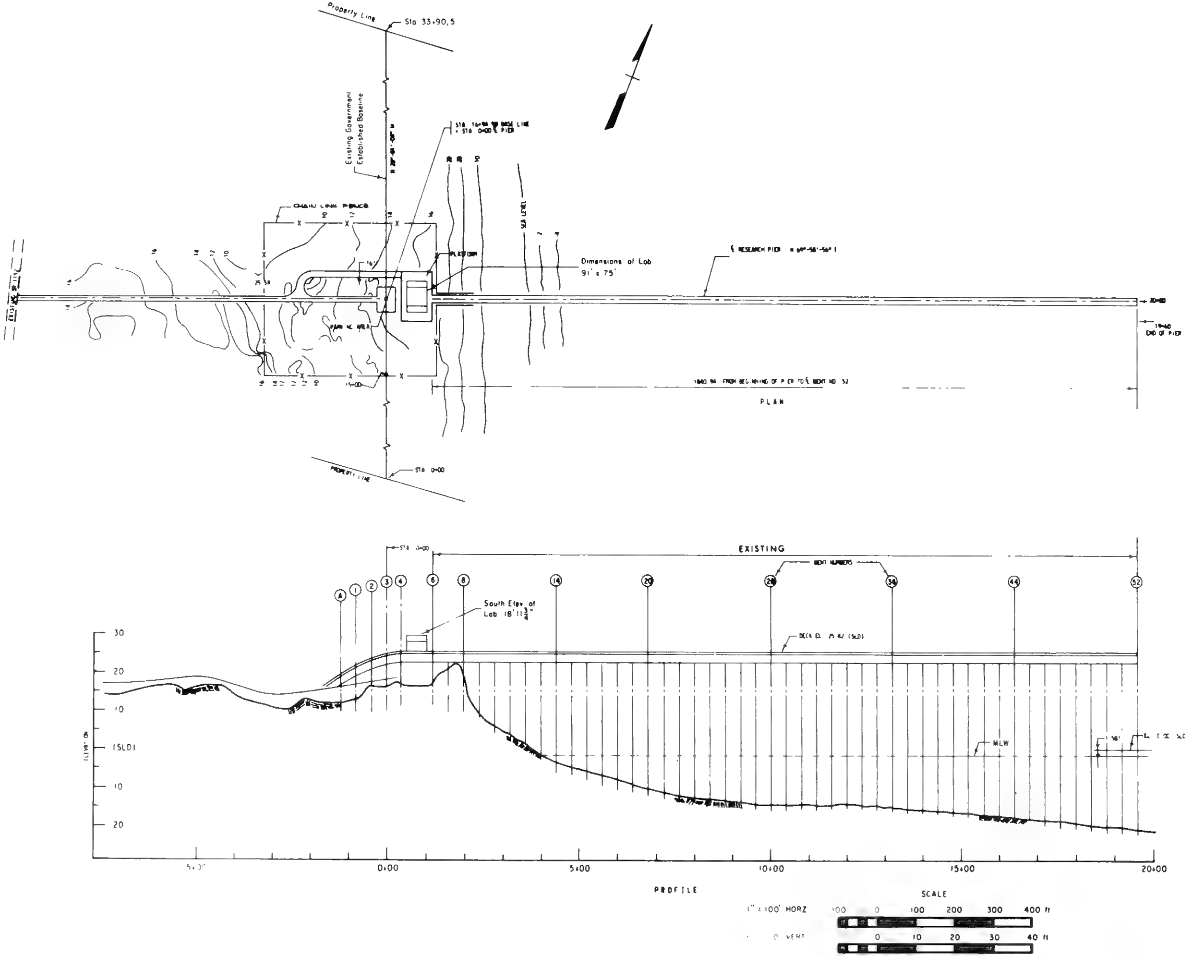


Figure 6. Plan and profile views of the FRF.

feet) wide, extends from behind the dune line to about the 6-meter depth contour, and is 7.7 meters (25.4 feet) above mean sea level (MSL). One set of railroad rails, 3.1 meters (10 feet) apart and extending from the garage of the laboratory building to the end of the pier, is used to transport heavy loads. Instrumentation cables run the length of the pier in a trough along the north side of the deck. Outlet boxes for both 220 and 115 volt power are located at 12-meter (40 feet) intervals along the south side. Removable gratings in the pier deck can be used for lowering instrumentation. There are two telephones on the pier--one at the end and one midway.

Locations on the pier are referenced by distance in feet from a monumented base line located landward of the laboratory and perpendicular to the pier centerline; e.g., the end of the pier is at station 19+40 (see Fig. 5) and the midpier telephone is at station 10+80.

Five steel piles (o.d. 6-5/8 inches) suitable for mounting instrumentation are located midway between the piles at stations 7+00, 7+80, 9+00, 10+60, and 14+20. These piles extend from the pier deck to the sea bottom.

The laboratory building includes offices, a kitchen, a library, a computer center, a garage, and a diving locker. The computer center (Fig. 7) houses a Data General NOVA-4 minicomputer. An emergency generator provides backup power for lighting and data collection equipment. The roof of the building provides a flat observation deck with an elevation of 12.4 meters (40.8 feet) above MSL.

Figure 7. The FRF computer center, showing the Data General NOVA-4 minicomputer.

II. LOCAL INFORMATION

This section addresses both the available research support and the living accommodations. Please note that much of the information has been obtained from the local telephone directory, the Dare County Tourist Bureau, and the Outer Banks Chamber of Commerce, and that CERC does not endorse any of the businesses listed.

1. Research Support.

The FRF staff of 10 includes the Chief, 3 scientists, 4 technicians, a computer operator, and a secretary. Requests for personnel assistance should be directed to the FRF Chief. The use of FRF personnel will require reimbursement of salaries and overhead.

a. Hours of Operation. Normal hours of operation of the FRF are from 0700 to 1700 weekdays. Special arrangements can be made for extended hours (including round the clock) and for weekends.

b. Laboratory Space. A 50- by 10-foot (15 by 3 meters) trailer with electricity, heat, and air-conditioning (no water) is available to visiting scientists. An effort will also be made to accommodate sensitive instruments and recording or computing equipment inside the laboratory. Nearby rental cottages may provide adequate temporary space. Free laboratory space is available at the North Carolina Marine Resources Center in Manteo, North Carolina (see Fig. 8), located 54 kilometers (34 miles) from the FRF. For further information contact:

Director
North Carolina Marine Resources Center
Manteo, NC 27954
(919) 473-3493

c. Airports and Plane Rentals. The nearest major airport is in Norfolk, Virginia, approximately 113 kilometers (70 miles) from the facility. Manteo Airport, the nearest local airport, has commuting service to Norfolk (Fig. 8). Facilities include aviation gas, keyed lighting for night flights, and ADF approach (refer to Charlotte Sectional). Aircraft can also land at First Flight Air Strip located in Kill Devil Hills just 23 kilometers (14.5 miles) south of the FRF (Fig. 8). Ground time is limited to 24 hours and the only accommodation is a telephone booth. With prior approval from the FRF, helicopters may land at the pier site. Local charter air service is available from:

(1) First Flight Air Service, Inc.
Manteo Airport
Manteo, NC 27954
(919) 473-3000

(2) Kitty Hawk Aero Tours
Nags Head, NC 27954
(919) 441-6247

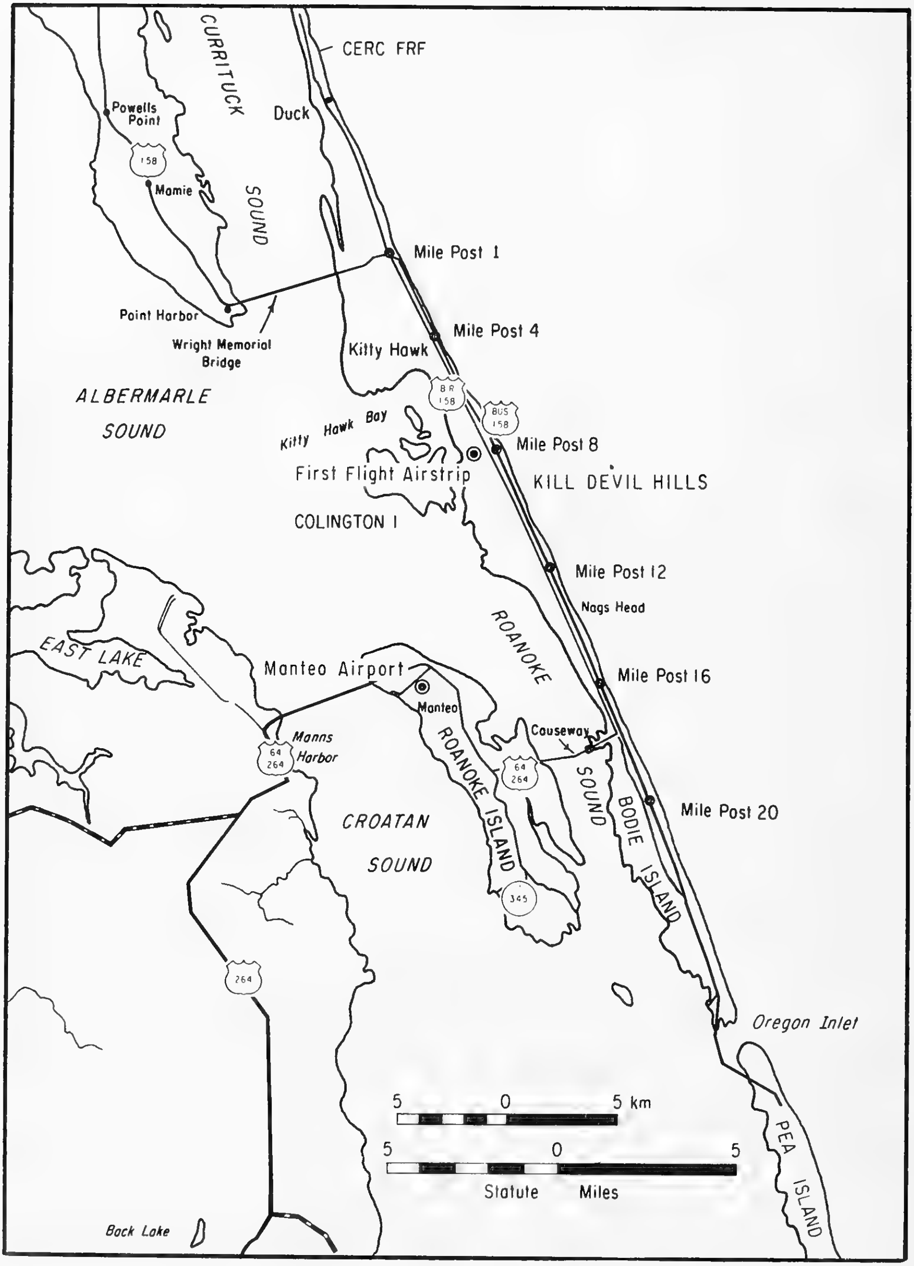


Figure 8. Map of local area (modified from U.S. Geological Survey, USGS, maps NJ 18-8, -11; NI 18-2).

d. Vehicle Use and Rentals. Vehicles with an axle width less than 3.1 meters and a weight under 900 kilograms (2,000 pounds) per wheel may be driven on the pier with permission of the FRF Chief. Beach access is provided just south of the pier. To minimize any adverse effects to the beach, all dune and beach vehicular traffic is restricted to permanent trails. During special studies or experiments, vehicular traffic will be detoured off the beach and around the property. Beach travel in Dare County is prohibited from Memorial Day to Labor Day. Rental automobiles are available at the Norfolk Airport, and may also be obtained at the Manteo Airport by contacting:

First Flight Air Service, Inc.
Manteo Airport
Manteo, NC 27954
(919) 473-3000

Between 15 May and 15 November it is also possible to obtain rental cars at the First Flight Air Strip in Kill Devil Hills by contacting:

National Car Rental System
Kill Devil Hills, NC 27948
(919) 441-5488

e. Boats. Except under special circumstances, visiting scientists should plan to provide their own boats. Small boats for ocean use must be launched from the shore. Larger boats must use Oregon Inlet, 56 kilometers (35 miles) south of the facility. A boat ramp for Currituck Sound is located about 1.6 kilometers (1 mile) south of the FRF. Large charter boats are available, and arrangements may be made by contacting:

Oregon Inlet Fishing Center
Box 533
Manteo, NC 27954
(919) 441-6301

f. Scuba Diving. All nongovernment scuba diving at the pier must comply with OSHA Commercial Diving Regulation (Department of Labor, 1977). Copies of the regulation may be obtained from the Diving Officer at the FRF. Divers are required to sign a statement that they have read this regulation and are in compliance. Specialized equipment required by the regulation (e.g., first aid kit, resuscitator) is available at the FRF.

Before diving permission at the pier is granted, a written dive plan (see sample in App. B) must be submitted 2 weeks in advance to the FRF Diving Officer for approval. Only no-decompression diving is permitted. In addition, the FRF Diving Officer or his assistant may cancel any diving activity if conditions warrant doing so.

Diving conditions around the FRF vary considerably. Visibility ranges from 0 to 6 meters with marginal visibility being the norm. Monthly mean water temperatures range from a mean of 4.4° Celsius (40° Fahrenheit) in February to 24.3° Celsius (75.7° Fahrenheit) in July (based on daily measurements from 1960 to 1966 at Virginia Beach, Virginia). Environmental conditions are discussed further in Section IV. Although ladders are planned, there is currently no way for divers to enter or leave the water from the pier.

g. Onsite Data Processing. The FRF is equipped with an onsite Data General NOVA-4 minicomputer with the primary function of collecting, editing, and analyzing the environmental measurements routinely collected. This computer has the capacity to handle 64 channels of analog-digital data. While this computer will not normally be available to outside users, it will be used to obtain near real-time analysis of the basic environmental measurements. This will permit users to obtain required data summaries while their experiment is underway.

Provisions have been made for users to record the output signal of a particular CERC gage or instrument. It may also be possible to have a special magnetic tape created of the data from one or a number of the CERC sensors. As mentioned previously, accommodations will be made (space permitting) for sensitive instruments inside the laboratory building. If a long period of recording of a special instrument is required, it may be possible to obtain a channel in the NOVA-4. For additional information concerning the use of data collection equipment at the FRF, contact the FRF Chief.

2. Living Accommodations.

Because of the resort nature of the area, it is important when planning an experiment to arrange for accommodations as early as possible, particularly for the months of June, July, and August. There are sufficient year-round facilities (hotels, restaurants, shopping centers) in the area to accommodate any size group and budget. Table 1 summarizes some basic detils about the 20 motels closest to the FRF. The milepost values given in the table refer to the local reference system shown in Figure 8. Milepost 1 is the point where route 158 divides into 158-Business, which follows along the ocean, and 158-Bypass. Table 2 is a partial list of companies which handle house rentals. Many of them have brochures describing their listings. The nearest campground is located 1.6 kilometers south of the FRF. For further information contact:

Ocean Beach Campground
Box 223D
Kitty Hawk, NC 27949
(919) 261-2200

More complete information on the area facilities is available in annual brochures published by:

(1) Outer Banks Chamber of Commerce
P.O. Box 90D
Kitty Hawk, NC 27949
(919) 261-2626 and (919) 261-2033

(2) Dare County Tourist Bureau
P.O. Box 399
Manteo, NC 27954
(919) 473-2138

During the tourist season, the Outer Banks Chamber of Commerce also operates a vacancy referral service which identifies the motels with vacancies.

Table 1. Motels closest to the FRF.

Motel and telephone No.	Address[1]	Relative cost[2]	Distance to FRF (mi)	Milepost[3]	Comments[4]
Sea Hawk (919) 261-2424	SR-Box 130T Kitty Hawk, NC	L-H	6.6	1	CYLTA
Sea Kove Motel (919) 261-9771	Box 168B Kitty Hawk, NC	L-M	7.8	3	SCLTA
The Buccaneer (919) 261-2030	SR-Box 53 Kitty Hawk, NC	L-M	10.1	5.25	SCYLTA
Bel Air Motel (919) 441-6132	Box 37T Kill Devil Hills, NC	M-H	10.6	5.8	SCLTA
Tan-A-Rama Motel (919) 441-7315	Box 1325T Kill Devil Hills, NC	H-E	11.1	6.5	SCLTA
Kill Devil Manor (919) 441-5356	Route 1, Box 418 Kill Devil Hills, NC	M-H	11.2	6.5	CYLTA
Mariner Motel (919) 441-7255	Box 407T Kill Devil Hills, NC	H-E	11.8	7	SCLTA
Sea Ranch Motel (919) 441-7126	Box 633T Kill Devil Hills, NC	H-E	11.8	7	SCYLRTA
Nettlewood Motel (919) 441-5039	Box 367 Kill Devil Hills, NC	L-M	11.9	7	CYLTA
Chart House Motel (919) 441-7418	Box 432T Kill Devil Hills, NC	M-H	11.9	7	SCLTA
The Croatan Inn (919) 441-7232	Kill Devil Hills, NC	L-H	12.5	7.5	LRTA
Colony IV Motel (919) 441-5581	Box 287R Kill Devil Hills, NC	H-E	13.6	8.5	SCYLTA
The Cavalier (919) 441-5584	Box 385 Kill Devil Hills, NC	L-H	13.6	8.5	SCYLTA
First Flight Inn (919) 441-5007	Box 698 Kill Devil Hills, NC	M-H	13.8	9	SCLTA
Holiday Inn (919) 441-6333	Box 308T Kill Devil Hills, NC	H-E	14.6	10	SCYLRTA
Outer Banks Motor Lodge (919) 441-7404	Box 747T Nags Head, NC	M-E	14.6	10	SCLTA
Ocean House Motel (919) 441-7328	Box 12 Kill Devil Hills, NC	M-E	14.7	10	SLTA
John Yancey Motor Inn (919) 441-7141	Box 422D Kill Devil Hills, NC	M-H	14.8	10	SCYLTA
Carolinian (919) 441-7171	Box 370 Nags Head, NC	M-H	15.3	10.5	SYLRTA
Cabana East Motel (919) 441-7106	Box 969T Nags Head, NC	---	15.9	11	SCYLRTA

[1]All motels are located along route 158-Business. Zip codes include: Kitty Hawk, 27949; Kill Devil Hills, 27948; Nags Head, 27959.

[2]L, low; M, moderate; H, high; E, expensive.

[3]Refers to reference system in Figure 8.

[4]S, swimming pool; C, cooking; Y, open all year; L, low offseason rates; R, restaurant; T, television; A, air-conditioned.

Table 2. Rental companies.[1]

Company and telephone No.	Address[2]	Approx. No.	
		cottages	apts.
Britt Real Estate (919) 261-3566	S.R. Box 272 Kitty Hawk, NC	15	16
Century 21 - Anchorage Realty (919) 441-6800	P.O. Box 14 Kill Devil Hills, NC	---	--
Cobia Realty (919) 441-6391	Rt. 1, Box 775 Nags Head, NC	55	--
Kitty Dunes Realty (919) 261-2171	P.O. Box 275 Kitty Hawk, NC	110	--
Kitty Hawk Realty & Rentals (919) 441-7166	Box 69T Kill Devil Hills, NC	---	--
Joe Lamb, Jr. & Associates (919) 441-5541	Box 609 Nags Head, NC	200	--
Midgett Realty (919) 441-6666	Box 1066 Kill Devil Hills, NC	44	--
Marvin Minton Real Estate Co. (919) 441-6422	Box 515 Nags Head, NC	35	--
Nags Head Realty (919) 441-4311	Box 726 Nags Head, NC	10	--
Ocean Acres Realty, Inc. (919) 441-5528	Box 656 Kill Devil Hills, NC	30	--
Outer Banks, Ltd. (919) 441-5000	Box 129T Nags Head, NC	132	--
Real Escapes (Frost Morrison Realty) (919) 261-3211	Box 299F Kitty Hawk, NC	28	--
Rollason & Wood Realty, Inc. (919) 441-5551	Box 326 Kill Devil Hills, NC	105	--
Sanderling (919) 261-2181	Box 1111 Kill Devil Hills, NC	10	--
Southern Shores Realty Co., Inc. (919) 261-2000	Box 150 Kitty Hawk, NC	200	--
Twenty Twenty Realty, Ltd. (919) 441-6306	Box 2020 Nags Head, NC	13	--
Wright Realty (919) 261-2186	Box 166 Kitty Hawk, NC	85	--
Robert A. Young & Associates (919) 441-5544	Box 285 Kill Devil Hills, NC	350	--
Twiddy and Company (919) 261-3521	S.R. Box 232C Kitty Hawk, NC	---	--

[1]This alphabetical list of licensed rental agents is taken from the 1979 Dare County and Outer Banks Chamber of Commerce Accommodation Directories. Not all agents necessarily have rentals near the FRF.

[2]Zip codes include: Kitty Hawk, 27949; Kill Devil Hills, 27948; Nags Head, 27959.

III. BASIC ENVIRONMENTAL MEASUREMENTS

A variety of oceanographic and meteorological instruments have been installed at the FRF in support of a basic environmental measurements program established in late 1977 to collect data on local conditions. The program consists of daily measurements of wave, current, water level, water temperature and salinity, wind and weather conditions, quarterly aerial photographic missions, and periodic beach and bathymetric surveys. In addition, daily photos and visual observations and weekly bottom surveys along the pier are collected. The data are available to anyone interested and may be obtained by writing to:

U.S. Army Coastal Engineering Research Center
Technical Information Division
Coastal Engineering Information and Analysis Center (CERTI-CE)
Kingman Building
Fort Belvoir, VA 22060

The requestor will be responsible for reproduction and mailing costs; requests should be specific. Questions may be directed to the Technical Information Division by telephoning (202) 325-7386. Monthly data reports, starting with October 1980, are available the month following collection. Annual reports summarizing a year of data collection will also be prepared. Near real-time data summaries will be available to researchers working at the FRF. Miller (1980) describes the instrumentation at the FRF.

1. Instrumentation.

Table 3 summarizes the instrument installations presently included in the measurement program; locations are shown in Figure 9. Of particular interest is the X-band radar used to obtain wave directions. The radar unit is located on the laboratory roof. Details of the system are reported by Mattie and Harris (1979).

Not included in Table 3 is an Sxy gage installed by Scripps Institute of Oceanography in September 1980. It consists of a four pressure-gage array capable of measuring near real-time directional wave spectra. The data and analysis are available interactively via a computer terminal and in monthly data reports.

The visual observation program consists of data collected daily at the pier end, pier nearshore, and on the beach. These observations supplement the instrument records by providing information on the type of breaker, direction of wave approach, width of the surf zone, littoral currents, beach slope, the presence of rip currents, water quality, and prevailing weather conditions.

Lead-line surveys are made weekly along both the north and south sides of the pier, using a graduated surveying tape with a 5-pound weight attached. The same positions along the pier are measured midway between the pier bents, to minimize the effect of the scour around the pilings. Periodic surveys to a depth of 9 meters are also made of profile lines located approximately 500 meters north and south of the pier.

Table 3. Summary of instrumentation.

Sensor No.	Type of sensor	Type of data	Location	Elevation of sensor (MSL) (ft)	(m)	Data record	Initial installation	Major gaps in data
615	Continuous-wire staff (Baylor Co.)	Wave	Station 6+20 FRF pier	-7.5	-2.8	20-min digital record 4 pts/s: 4 times/day	Nov. 1977	June 1978
625	Continuous-wire staff (Baylor Co.)	Wave	Station 19+00 FRF pier	-27	-8.2	20-min digital record 4 pts/s: 4 times/day	Nov. 1977	June 1978
610	Waverider buoy (1-m diam.) (Datawell)	Wave	220 m (721 ft) north, 200 m (656 ft) east of seaward end of FRF pier	-23	-7.0	20-min digital record 4 pts/s: 4 times/day	July 1978	---------
620	Waverider buoy (1-m diam.) (Datawell)	Wave	2.1 km (1.3 mi) east of seaward end of FRF pier	-59	-18.0	20-min digital record 4 pts/s: 4 times/day	July 1978	Nov.-Dec. 1978
611	Pressure gage	Wave	23 m (75 ft) east of seaward end of FRF pier	-18.4	-5.6	20-min digital record 4 pts/s: 4 times/day	Nov. 1977	Oct. 1978-Aug. 1980
621	Pressure gage	Wave	170 m (560 ft) north of seaward end of FRF pier	-17.7	-5.4	20-min digital record 4 pts/s: 4 times/day	July 1980	-----------
619, 629 Channels X, Y	Electromagnetic current meter (Marsh-McBirney)	Mean and wave-induced bottom currents	23 m (75 ft) east of seaward end of FRF pier	-18.4	-5.6	20-min digital record 4 pts/s: 4 times/day	To be installed	-----------
639, 649 Channels X, Y	Electromagnetic current meter (Marsh-McBirney)	Mean and wave-induced bottom currents	170 m (560 ft) north of seaward end of FRF pier	-17.7	-5.4	20-min digital record 4 pts/s: 4 times/day	July 1980	To present intermittent
865-1370	Float-activated tide gage (Leupold-Stevens)	Water level	Station 19+60 FRF pier end	-27	-8.2	Digital record One sample/6 min	Oct. 1978	-----------
865-1376	Bubbler (pressure) tide gage	Water level	305 m (1,000 ft) west, Currituck Sound shore	-5	-1.5	Continuous analog strip chart	Oct. 1977	Installation terminated, Feb. 1978
865-1376	Pressure tide gage (Metercraft)	Water level	305 m west, Currituck Sound shore	-4	-1.2	Continuous analog strip chart	July 1978	Feb. 1979, Feb.-July 1980
	X-band radar	Wave direction	Station 19+00 FRF pier	-----	----	1-min film record 4 times/day	June 1978	-----------
	F420 anemometer (National Weather Service)	Wind speed and direction	76 m (250 ft) landward of dune	-----	----	Daily by technician	Feb. 1978	Installation terminated, Sept. 1980
	F420 anemometer (National Weather Service	Wind speed and direction	FRF laboratory	62	19	Continuous analog strip chart	Oct. 1980	-----------
	F420 anemometer (National Weather Service)	Wind speed and direction	Station 14+00 FRF pier	46	14	Continuous analog strip chart	Oct. 1980	-----------
	Microbarograph (Belfort Inst. Co.)	Atmospheric pressure	FRF laboratory (inside)	-----	----	Continuous analog strip chart	Mar. 1978	-----------
	Aneroid Barometer (National Weather Service)	Atmospheric pressure	FRF laboratory (inside)	-----	----	Daily by technician	Mar. 1978	-----------
	Weksler thermometers (National Weather Service)	Max./min. air temperature	Instrumentation shack, 90 m (300 ft) landward of dune	-----	----	Daily by technician	Mar. 1978	-----------
	12-in weighing rain gage (Belfort Inst. Co.)	Precipitation	87 m (288 ft) landward of dune	-----	----	Continuous analog strip chart	Mar. 1978	-----------
	6-in rain gage (Edwards Mfg. Co.)	Precipitation	82 m (270 ft) landward of dune	-----	----	Daily by technician	Mar. 1978	-----------
	Weksler sling psychrometer (National Weather Service)	Dew point	Instrumentation shack	-----	----	Daily by technician	Dec. 1978	-----------
	Mechanical pyranograph (Weather Measure Corp.)	Solar radiation	Instrumentaion shack	-----	----	Continuous analog strip chart	Jan. 1979	-----------
	Conductivity/temperature (Hydrolab Corp.)	Water conductivity and temperature	Station 14+20 FRF pier	-----	----	Continuous analog strip chart	July 1981	-----------

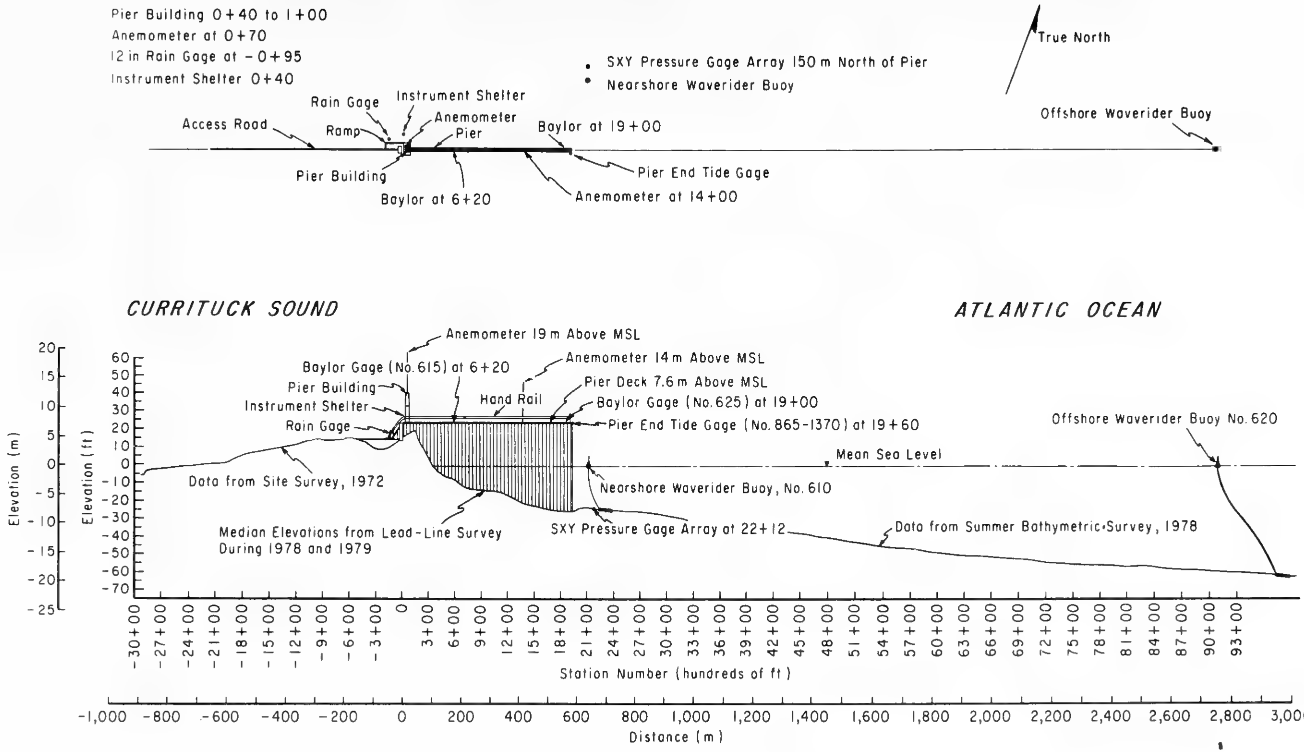


Figure 9. Instrument locations at the FRF.

2. Surveying Control.

a. Local Control. There is extensive monumentation on both the sound and ocean sides of the FRF site (Fig. 10). Large-scale versions of Figure 10 with complete monumentation are available from the FRF. The primary oceanside monuments are along a base line located landward of the laboratory and perpendicular to the pier centerline. U.S. Army Engineer District, Wilmington (SAW), has established a series of concrete monuments along this base line at 45.72- and 152.4-meter (150 and 500 feet) intervals. Other monuments at varying intervals have been established in support of CERC beach and bathymetric surveys. Many of the monuments along the base-line have permanent pipe monuments (front and back) to define profile azimuths perpendicular to the base line. Table 4 provides a summary of the base line monumentation according to distance along the base line and distance from the pier centerline. All these have been surveyed to third-order accuracy. Documentation on each monument is available.

One concrete monument and two series of profile lines have been established on the sound side to monitor sound changes. Further details about these lines are given in Section VI.

A series of very stable monuments, which will eventually be tied into first-order control, has been established by the National Oceanic and Atmospheric Administration (NOAA) in support of the tide gaging program. Information about these monuments is available at FRF.

Because of the profusion of monuments at the FRF, users are requested to use established monuments if possible. Temporary monuments, stakes, pipes, etc., must be clearly labeled as to owner and must be removed on completion of study. To ensure that valuable monuments are not removed or lost during extended studies, the monuments should be documented as to location, markings, date of installation, etc., using form DA 1959 (copy in App. C); a copy of the form is then given to the FRF Chief. Special care should be taken to minimize pedestrian effects on the dune and beach.

b. Island Control. The CERC monuments indicated in Table 4 are part of the series of 62 profile lines shown in Figure 11. Each line has three monuments: a brass disk on a concrete post and two pipes (front and rear) to define the profile azimuth. Additionally, third-order vertical control has also been established on each of the five fishing piers. Complete documentation for the profile lines may be obtained from the FRF Chief. All the lines are on private property, so written permission to survey must be obtained in advance from the owners. Data collected at these lines under CERC's Beach Evaluation Program (BEP) from May 1974 to January 1977 are discussed in Section V and summarized in Section VIII.

3. Bathymetric Surveying.

The accuracy of the bathymetric surveys depends on the survey methods used. The current procedure consists of dividing the survey lines into beach and nearshore zones.

The area from the beach to the 9-meter (30 feet) contour is surveyed using the innovative three-legged vehicle, the Coastal Research Amphibious Buggy (CRAB), shown in Figure 12. Designed and constructed by the Wilmington

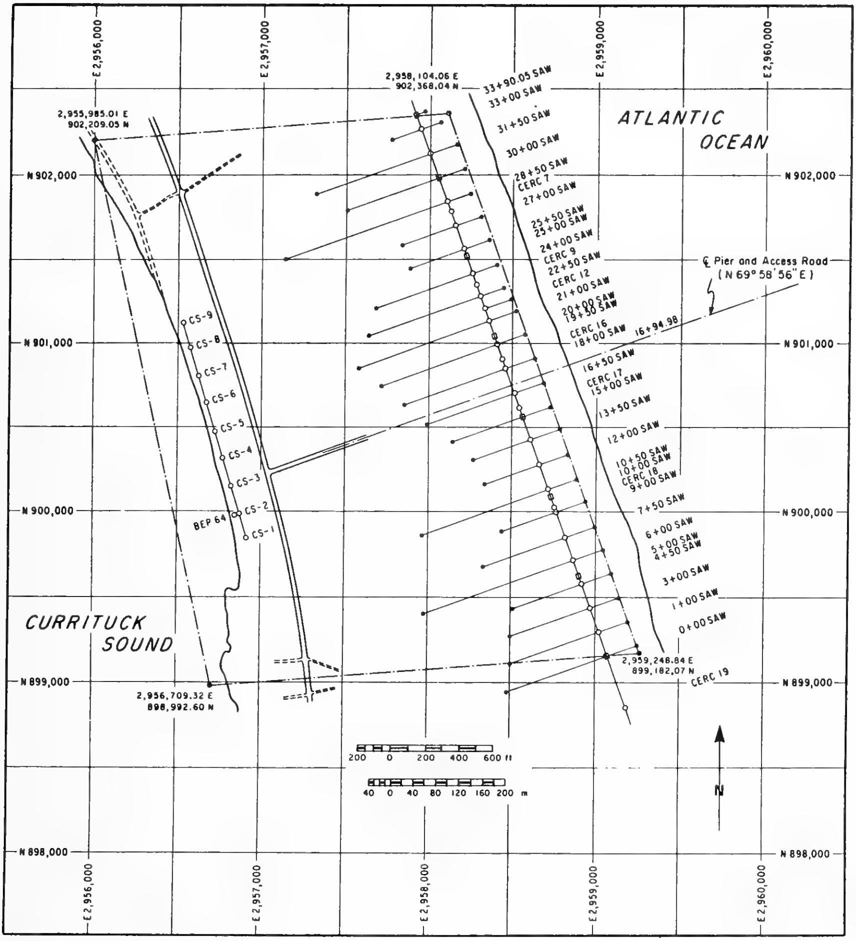


Figure 10. Map of FRF site showing location of primary survey monuments. Large-scale copies with more complete documentation are available.

Table 4. FRF base-line monumentation.

Profile No.	Pre-1980 designation	Distance along base line (ft)[1]	Distance from ℄ of pier (ft)[2]	Elevation NGVD (ft)	Type of monument[3]
25	A	14,195 [4]	-12,500 [4]	12.55	C1
30	CERC 3	10,476.91[4]	-8,781.93[4]	13.41	C1
40	CERC 4	7,163.73	-5,468.75	15.85	C1
50	CERC 5	4,663.73	-2,968.75	14.79	C1[5]
60	CERC 6	3,413.73	-1,718.75	12.36	D
61	SAW 33+90.05	3,390.05	-1,695.07	14.45	C
62	SAW 33+00	3,300.00	-1,605.02	13.15	P1
64	SAW 31+50	3,150.00	-1,455.02	12.52	P1
66	SAW 30+00	3,000.00	-1,305.02	14.70	P1
67	SAW 28+50	2,850.00	-1,155.02	12.36	P1
70	CERC 7	2,788.73	-1,093.75	12.92	C1
73	SAW 27+00	2,700.00	-1,005.02	13.14	P1
76	SAW 25+50	2,550.00	-855.02	12.00	P1
78	SAW 25+00	2,500.00	-305.02	12.33	C
80	CERC 8	2,476.23	-781.25	12.75	C1
85	SAW 24+00	2,400.00	-705.02	12.24	P1
90	CERC 9	2,319.98	-625.00	12.51	C1
95	SAW 22+50	2,250.00	-555.02	13.26	P1
100	CERC 10	2,241.86	-546.88	13.31	C1
110	CERC 11	2,202.80	-507.82	14.99	C1
120	CERC 12	2,163.73	-468.75	12.50	C1
130	CERC 13	2,124.66	-429.58	13.04	C1
135	SAW 21+00	2,100.00	-405.02	16.14	P1
140	CERC 14	2,085.60	-390.62	13.45	C1
150	CERC 15	2,007.48	-312.50	12.88	C1
151	SAW 20+00	2,000.00	-305.02	13.10	C
155	SAW 19+50	1,950.00	-255.02	13.80	P1
160	CERC 16	1,851.23	-156.25	14.18	C1
161	SAW 18+00	1,800.00	-105.02	15.76	P1
162	B	1,769.98	-75.00	16.05	P2
163		1,725.00	-30.02	17.77	
164	CERC 68	1,704.98	-10.0		NP
165	SAW 16+94.98	1,694.98	℄	17.56	D

Table 4. FRF base-line monumentation.--Continued

Profile No.	Pre-1980 designation	Distance along base line (ft)[1]	Distance from ℄ of pier (ft)[2]	Elevation NGVD (ft)	Type of monument[3]
166	CERC 69	1,684.98	10.0		SP
167	SAW 16+50	1,650.00	44.98	19.04	P1
168	C	1,619.98	75.00	17.55	P2
169		1,575.00	119.98	16.65	P1
170	CERC 17	1,538.73	156.25	14.11	C1
171	SAW 15+00	1,500.00	194.98	15.10	C1
173	D	1,375.00	319.98	16.97	P2
174	SAW 13+50	1,350.00	344.98	14.89	P1
175	E	1,295.00	399.98	14.71	P2
176	SAW 12+00	1,200.00	494.98	17.59	P1
178	SAW 10+50	1,050.00	644.98	16.15	P1
179	SAW 10+00	1,000.00	694.98	15.70	C
180	CERC 18	913.73	781.25	14.36	
181	SAW 9+00	900.00	794.93	14.23	P1
182	SAW 7+50	750.00	944.98	16.24	P1
183	SAW 6+00	600.00	1,094.98	14.16	P1
184	SAW 5+00	500.00	1,194.98	13.48	C
185	SAW 4+50	450.00	1,244.98	14.76	P1
186	SAW 3+00	300.00	1,394.98	15.10	P1
187	SAW 1+50	150.00	1,544.98	14.90	P1
188	SAW 0+00	0.00	1,694.98	15.14	C1
190	CERC 19	-336.27	2,031.25	16.14	C1
200	CERC 20	-2,836.27	4,531.25	16.05	C1
207	F	-5,805 [4]	7,500 [4]	16.44	C1
220	CERC 22	-10,884 [4]	12,579 [4]	19.16	C1

[1]Distances given along the base line are relative to a monument on the south property line (positive to the north).

[2]Pier coordinate system: positive distance seaward and to the south.

[3]Monument types: C, concrete; C1, concrete with front and rear pipes; D, monument destroyed; NP, north pier edge; P1, capped pipe with front and rear pipes; P2, pipe with front pipe only; SP, south pier edge.

[4]Monument not on base line; distance approximate.

[5]Monument buried.

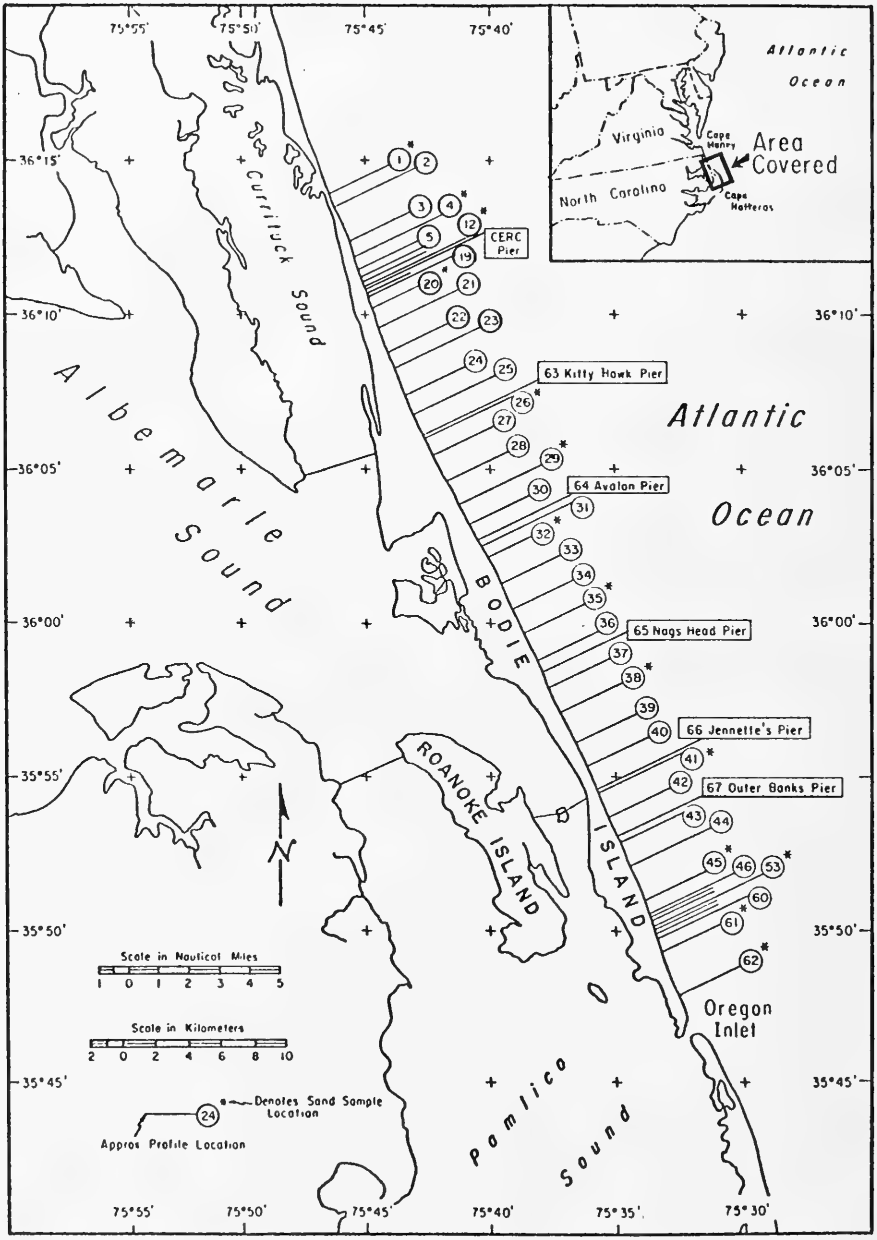


Figure 11. CERC profile line locations (pre-1980 designations).

Figure 12. Coastal Research Amphibious Buggy (CRAB).

District for nearshore surveying, the CRAB provides a stable platform in wave heights up to 1.8 meters (6 feet). Top speed is 3 kilometers (2 miles) per hour. Position and elevation are determined by targeting a prism mounted on the CRAB with an electronic survey system which also produces computer compatible data.

Surveying of the beach from the base line to the water line is done using the same system but using a person holding a prism at each survey point.

Pre-1981 surveys used more conventional surveying procedures. Generally, a sea sled or fathometer was used for the nearshore (out to 700 meters) and a fathometer for the offshore (out to 3,000 meters).

IV. ENVIRONMENTAL CHARACTERISTICS

This section summarizes available environmental data and information useful for planning studies at the FRF.

1. General Weather.

The FRF has a favorable marine climate with mild winters and warm temperate summers. The nearest weather stations with long periods of record are Cape Hatteras, North Carolina, and Norfolk, Virginia. Table 5 provides a NOAA summary of the normal, mean, and extreme meteorological data for each of these stations. More detailed information including monthly summaries and three-hourly measurements can be obtained from:

Environmental Data and Information Service
The National Climatic Center
Federal Building
Asheville, NC 28801

Figure 13 is a plot of monthly wind roses compiled from 1,853 observations at Sea Crest, North Carolina, 5 kilometers (3 miles) south of the FRF (see Fig. 1), using a hand-held Dwyer wind meter, from January 1972 to December 1978. Note the predominant winds from the northeast and southwest with the highest percentage of strong winds from the north and northeast. Wind distribution varies considerably from month to month.

2. Waves.

a. Ocean. Thompson (1977) summarized the wave climate for the area using measurements collected by a wave gage on Jennette's Fishing Pier (Fig. 11) from December 1968 to January 1975. This data set has been updated to include measurements to December 1979.

Figure 14 shows the seasonal variation in mean and standard deviation of the monthly wave height and period. Peak waves occur in October and February. Joint monthly distributions of significant wave height and period distributions are given in Appendix D. Table 6 is a summary of the distribution for the entire period, indicating the mean average wave height is 0.88 meter (2.9 feet) and the mean period is 8.9 seconds. Higher waves have been measured in the deeper water at the FRF. Figure 15 shows wave action during an October 1980 storm when the significant wave height reached 3.8 meters (12.5 feet). Measurements have also been made of breaking waves. Average monthly values for 7 years of observations at Sea Crest are shown in Figure 16.

The only historic wave direction information available is taken from LEO observations. Wave roses are shown in Figure 17. Predominant wave directions are shore normal (90°) and just right of shore normal (90° to 95°). Waves tend to approach the shore from the right in summer and from the left in the winter.

b. Sound. Because of the limited fetch across Currituck Sound, waves on the sound shore are usually an irregular chop of less than 15 centimeters (0.5 foot). The average fetch is 7.3 kilometers (4.4 miles); the longest fetch is 8.9 kilometers (5.3 miles). The sound is extremely shallow and gently sloping (less than 1 percent). The deepest areas, which average only 2.7 meters (9 feet) in depth, are on the western shore. Wave heights and setup during extreme events have not been documented.

Table 5. Meteorological data: normals, means, and extremes.

Norfolk, Virginia

Station NORFOLK, VIRGINIA 13737 — INTERNATIONAL AIRPORT — Standard time used: EASTERN — Latitude 36° 54' N — Longitude 76° 12' W — Elevation (ground) 24 feet — Year 1979

Month	Temperature °F Averages Daily maximum	Daily minimum	Monthly	Extremes Highest	Date	Lowest	Date	Degree days Base 65 °F Heating	Cooling	Precipitation in inches Water equivalent Total	Greatest in 24 hrs.	Date	Snow, Ice pellets Total	Greatest in 24 hrs	Date	Relative humidity pct Hour 01 (Local time)	Hour 07	Hour 13	Hour 19	Wind Resultant Direction	Resultant Speed m p h	Average speed m p h	Fastest mile Speed m p h	Fastest mile Direction	Fastest mile Date	Percent of possible sunshine	Average sky cover tenths, sunrise to sunset	Number of days Sunrise to sunset Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog visibility ¼ mile or less	Temperature °F Maximum (b) 90° and above	Maximum 32° and below	Minimum 32° and below	Minimum 0° and below	Average station pressure mb Elev 30 feet m s l
JAN	47.9	30.8	39.4	71	1	14	4	787	0	6.47	1.78	2-3	1.0	1.0	31	68	73	60	61	30	4.6	11.9	33	25	21	48	6.3	8	4	19	11	1	1	1	0	2	17	0	1015.6
FEB	41.5	25.1	33.3	63	25	14	18	879	0	5.01	1.75	25-26	12.7	6.7	18	70	72	62	65	31	5.4	11.4	32	33	19	51	7.0	7	4	17	10	2	0	4	0	6	21	0	1020.3
MAR	59.4	36.8	49.1	81	31	29	16	499	11	5.13	2.69	6	T	T	11	75	77	51	62	23	1.7	10.5	35	31	14	69	5.3	9	13	9	7	0	1	4	0	0	7	0	1019.6
APR	67.8	48.3	58.1	83	22	40	7	213	13	7.00	2.76	13-14	0.0	0.0		76	71	53	60	26	0.5	10.5	33	32	6	56	6.4	7	9	14	8	0	1	0	0	0	0	0	1016.3
MAY	75.0	58.4	66.7	85	9	43	6	52	112	10.12	2.12	13-14	0.0	0.0		82	79	60	69	19	2.6	[illegible]	38	02	18	48	6.8	5	9	17	15	0	7	4	0	0	0	0	1015.9
JUN	79.4	61.3	70.4	90	23	52	21	5	171	2.97	1.44	11	0.0	0.0		77	71	55	64	15	1.4	9.2	29	04	11	56	6.5	6	10	14	7	0	2	1	1	0	0	0	1018.0
JUL	85.3	68.9	77.1	93	29	54	7	0	365	4.69	2.16	29	0.0	0.0		81	78	58	69	27	1.5	9.1	32	34	13	45	7.1	1	16	14	11	0	9	0	5	0	0	0	1016.6
AUG	86.5	70.5	78.5	98	10	61	16	0	426	1.79	0.84	11-12	0.0	0.0		84	82	59	73	22	1.0	8.3	46	35	8	56	5.5	6	13	10	11	0	7	0	10	0	0	0	1016.6
SEP	79.0	66.6	72.8	91	6	57	18	0	239	13.80	4.36	5-6	0.0	0.0		84	82	68	81	09	4.1	10.1	36	05	23	57	7.1	5	8	17	12	0	7	1	3	0	0	0	1016.6
OCT	70.5	50.3	60.4	83	22	39	15	190	54	1.74	0.75	23	0.0	0.0		82	80	54	72	26	2.3	8.4	25	22	5		4.6	16	9	6	7	0	2	3	0	0	0	0	1016.3
NOV	66.1	46.6	56.4	83	10	26	30	272	22	5.26	1.96	11-12	0.0	0.0		75	80	56	69	30	0.8	9.8	25	22	26		5.2	12	6	12	7	0	1	0	0	0	1	0	1020.0
DEC	53.6	36.1	44.9	71	24	22	18	616	0	3.98	0.37	6	0.0	0.0		73	73	55	69	32	2.7	9.4	29	25	25		5.5	9	11	11	5	0	0	3	0	0	11	0	1020.7
YEAR	67.7	50.1	58.9	98	AUG 10	14	FEB 18	3513	1433	64.96	4.36	SEP 5-6	13.7	6.7	FEB 18	77	77	58	68	30	0.7	[illegible]	46	35	AUG 8		6.1	93	112	160	111	3	39	21	19	8	57	0	1017.7

Cape Hatteras, North Carolina

Month	Temperatures °F Normal Daily maximum	Daily minimum	Monthly	Extremes Record highest	Year	Record lowest	Year	Normal Degree days Base 65 °F Heating	Cooling	Precipitation in inches Water equivalent Normal	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs	Year	Snow, Ice pellets Maximum monthly	Year	Maximum in 24 hrs	Year	Relative humidity pct Hour 01 (Local time)	Hour 07	Hour 13	Hour 19	Wind Mean speed m p h	Prevailing direction	Fastest mile Ø Speed m p h	Direction	Year	Pct of possible sunshine	Mean sky cover, tenths, sunrise to sunset	Mean number of days Sunrise to sunset Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog visibility ¼ mile or less	Temperatures °F Max (b) 90° and above	Max 32° and below	Min 32° and below	Min 0° and below	Average station pressure mb Elev 30 feet m s l
(a)				31		31					31		31		31		31		31		31	31	31	31	31	15	7	7		29	31	31	31	31	31	31	31	31	31	31	31	31	7
J	48.6	32.2	40.5	78	1970	5	1977	760	0	3.35	6.47	1979	1.60	1949	3.80	1967	14.2	1966	9.1	1973	73	75	59	67	11.6	SW	39	23	1978	57	6.2	9	7	15	10	1	*	2	0	3	17	0	1017.9
F	50.0	32.7	41.4	81	1976	8	1965	661	0	3.31	5.72	1956	0.86	1950	1.87	1970	12.7	1979	6.7	1979	72	74	56	65	12.0	NNE	44	36	1973	59	6.1	9	5	14	10	1	1	3	0	1	14	0	1017.6
M	57.3	38.9	48.1	85	1968	20	1950	532	8	3.42	7.80	1978	1.34	1967	3.18	1958	7.9	1960	7.5	1974	72	74	54	62	12.3	SW	46	22	1973	63	6.1	9	7	15	11	*	2	2	0	*	6	0	1016.6
A	67.7	47.9	57.8	97	1960	28	1964	226	10	2.71	7.00	1979	0.99	1976	2.76	1979	1.2	1964	1.2	1964	73	73	50	61	11.7	SW	39	06	1978	65	5.8	9	9	12	10	*	3	1	1	0	*	0	1015.8
M	76.2	57.2	66.7	97	1956	36	1966	53	106	3.34	10.12	1979	1.46	1965	2.94	1961	0.0		0.0		81	78	57	68	10.3	SW	38	02	1979	65	6.1	8	10	13	10	0	5	2	1	0	0	0	1014.7
J	83.5	65.5	74.5	101	1964	45	1967	0	285	3.62	9.77	1963	0.37	1954	6.85	1963	0.0		0.0		83	79	57	68	9.6	SW	46	30	1977	69	5.8	8	11	11	9	0	6	1	6	0	0	0	1015.8
J	86.6	69.9	78.3	103	1952	54	1979	0	412	5.70	13.73	1975	1.69	1961	5.64	1969	0.0		0.0		85	82	60	71	8.8	SW	46	34	1973	65	6.0	7	12	12	11	0	9	1	11	0	0	0	1015.8
A	84.9	68.9	76.9	102	1977	52	1965	0	369	5.92	11.19	1967	0.74	1975	11.40	1964	0.0		0.0		86	85	62	75	8.8	SW	46	35	1979	65	5.8	8	12	11	11	0	7	1	9	0	0	0	1017.3
S	79.6	63.9	71.8	98	1954	45	1967	9	213	4.20	13.80	1979	0.36	1958	6.79	1959	0.0		0.0		84	84	62	76	9.6	NE	30	06	1979	65	5.7	9	10	11	8	0	3	1	3	0	0	0	1017.0
O	70.1	53.3	61.7	95	1954	27	1976	141	38	3.06	10.12	1971	0.93	1967	4.38	1971	0.0		0.0		82	83	60	75	10.3	NE	30	04	1977	60	5.3	12	7	12	8	0	1	2	*	0	*	0	1018.2
N	60.5	42.6	51.6	86	1974	20	1950	402	0	2.94	7.01	1951	0.49	1965	3.35	1952	0.6	1950	0.6	1950	76	79	56	70	10.6	SW	32	21	1973	59	5.4	11	8	11	8	0	1	2	0	0	3	0	1018.9
D	50.6	34.0	42.3	80	1978	14	1962	734	0	3.11	5.83	1973	0.98	1979	2.12	1958	14.7	1958	11.4	1958	73	75	58	68	11.0	SW	35	18	1976	57	5.9	10	7	14	9	*	*	2	0	1	14	0	1018.2
YR	68.0	50.6	59.3	103	JUL 1952	5	JAN 1977	3488	1441	44.68	13.80	SEP 1979	0.36	SEP 1958	11.40	AUG 1964	14.7	DEC 1958	11.4	DEC 1958	78	78	58	69	10.6	SW	46	35	AUG 1979	63	5.8	109	105	151	115	2	37	22	30	5	55	0	1017.0

(a) Length of record, years, through the current year unless otherwise noted, based on January data.
(b) 70° and above at Alaskan stations.
* Less than one half.
T Trace.

NORMALS - Based on record for the 1941-1970 period.
DATE OF AN EXTREME - The most recent in cases of multiple occurrence.
PREVAILING WIND DIRECTION - Record through 1963.
WIND DIRECTION - Numerals indicate tens of degrees clockwise from true north. 00 indicates calm.
FASTEST MILE WIND - Speed is fastest observed 1-minute value when the direction is in tens of degrees.

Ø record 1973 to 1979.

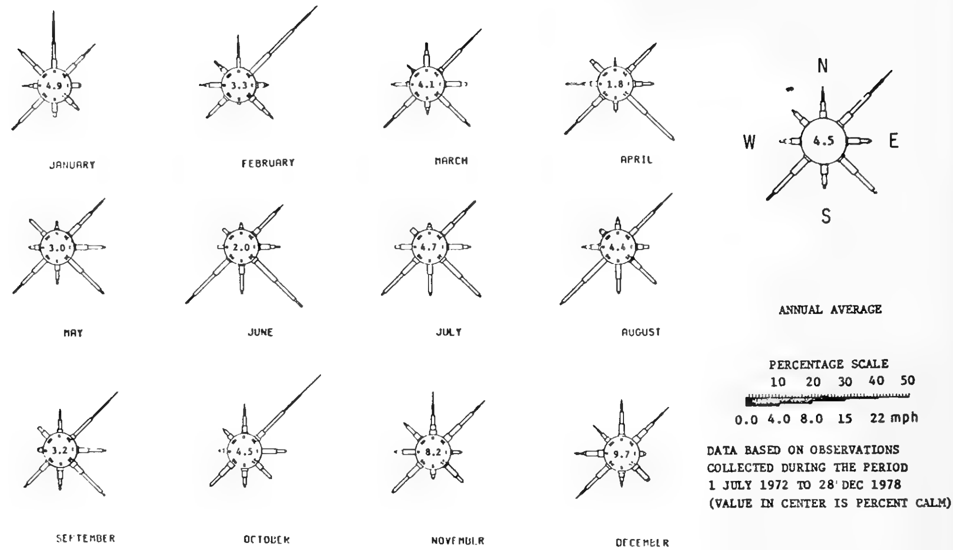


Figure 13. Wind roses at Sea Crest, North Carolina.

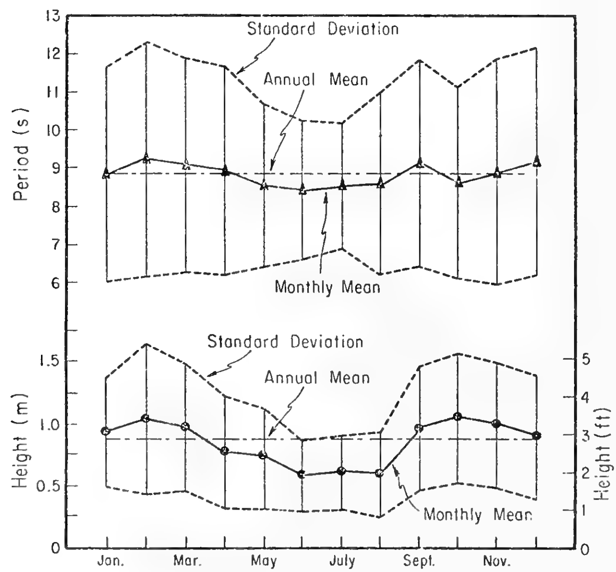


Figure 14. Seasonal variation in mean significant wave height and mean peak spectral period (from the CERC wave gage at Nags Head, North Carolina).

Table 6. Summary of wave statistics for Nags Head, North Carolina.

DISTRIBUTION OF SIGNIFICANT HEIGHT VS PERIOD (IN OBSERVATIONS PER 1000 OBS)
5653 OBSERVATIONS SUMMARY FOR 62 MONTHS FROM DEC. 1968 TO DEC. 1979

PERIOD (SECS) / SIG. HEIGHT (FT)

PERIOD (SECS)	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13 +	TOT.*	CUM. TOT.*	ROW AVG.*
0.0 - .9																1000	0.00
1.0 - 1.9																1000	0.00
2.0 - 2.9		2													2	1000	1.64
3.0 - 3.9		5	9	3											18	996	2.41
4.0 - 4.9		6	13	11	3	1									33	980	2.87
5.0 - 5.9	1	16	26	28	16	5	3								94	946	3.24
6.0 - 6.9	2	16	25	23	18	9	5	1	1						100	852	3.46
7.0 - 7.9	3	24	19	13	12	8	3	2							84	751	3.16
8.0 - 8.9	15	111	70	29	21	12	5	3	1	1					267	668	2.53
9.0 - 9.9	3	50	38	23	10	6	2	3	1						136	401	2.75
10.0 -10.9	3	31	27	17	8	7	6	1	1						101	265	3.03
11.0 -11.9																164	0.00
12.0 -12.9	4	29	20	14	11	6	6	3	1						96	164	3.20
13.0 -13.9																68	0.00
14.0 -14.9	4	22	9	4	3	2	3	3	1						50	68	2.85
15.0 -15.9																18	0.00
16.0 -16.9	1	7	3	1		1	1	1							15	18	2.92
17.0 -17.9																3	0.00
18.0 -18.9																3	0.00
19.0 -19.9																3	0.00
20.0 -20.9		1	1	1											3	3	2.72
21.0 +																	0.00
TOTAL	38	317	260	167	103	58	32	17	7	1							2.92
CUM. TOTAL	1000	902	645	385	218	115	57	25	8	1							
COL. AVG.	9.75*	9.50	8.59	8.17	8.36	8.87	9.04	10.23	10.56	8.25	0.00	0.00	0.00	0.00	8.87		

AVERAGE SIG. HEIGHT = 2.89 FT
VARIANCE OF SIG. HEIGHT = 2.60 FT SQ
STANDARD DEVIATION OF HEIGHT = 1.61 FT

AVERAGE WAVE PERIOD = 8.89 SEC*
VARIANCE OF WAVE PERIOD = 7.33 SEC SQ*
STANDARD DEVIATION OF PERIOD = 2.71 SEC*

RESULTS OBTAINED FROM 1024-SECOND DIGITAL RECORDS TAKEN WITH A STEP RES. AND CONT. WIRE WAVE GAGE LOCATED AT JENNETTES PIER.
* CALMS ARE OMITTED.

Figure 15. Storm waves breaking along the FRF, 25 October 1980.

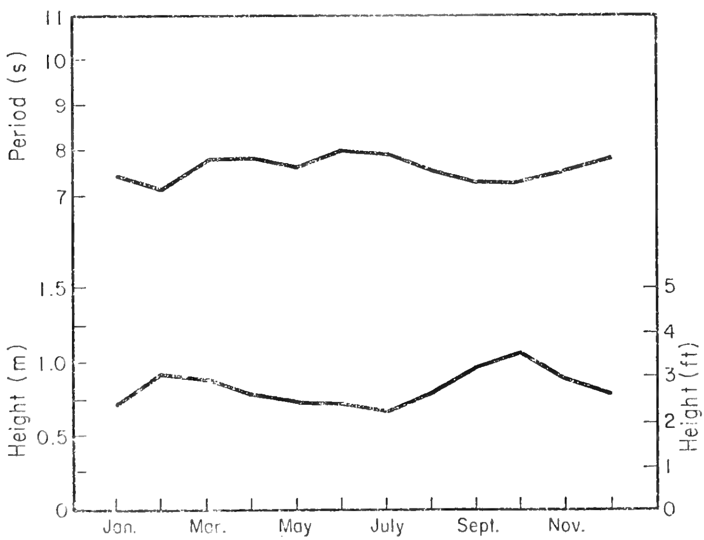
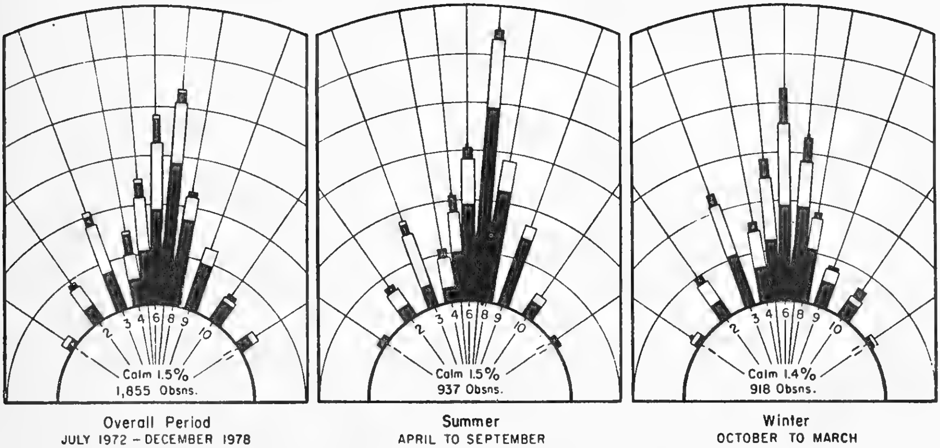


Figure 16. Seasonal variation in visually observed mean breaking wave height and mean period from Sea Crest, North Carolina (July 1972 to December 1978, 1,855 observations).



WAVE DIRECTION
(Relative to Shore Parallel)

CODE	ANGLE (deg.)	CODE	ANGLE (deg.)
1	$\theta < 55$	7	$90 < \theta \leq 95$
2	$55 \leq \theta < 70$	8	$95 < \theta \leq 100$
3	$70 \leq \theta < 80$	9	$100 < \theta \leq 110$
4	$80 \leq \theta < 85$	10	$110 < \theta \leq 125$
5	$85 \leq \theta < 90$	11	$125 < \theta$
6	$\theta = 90$		

WAVE HEIGHT (ft)

0–2 2–4 4–6 6–8 >8

0 10 20 30 40

PERCENT

Figure 17. Distribution of breaking wave directions at Sea Crest, North Carolina.

3. <u>Currents.</u>

Visual observations of longshore currents have been made at Sea Crest (see Fig. 1) since 1972 by timing the movement of floating foam in the surf zone. A sample year of data (1973) is plotted in Figure 18. Although reversals are common, the mean current from July 1972 to December 1978 was to the north. This is in contrast to the predicted direction of longshore transport, based on the visual wave data, which was predominantly to the south (see Sec. IV,5). Other currents which affect the area are rip currents, low salinity water masses, and Gulf Stream eddies.

Rip currents are frequently found at varying locations including under the pier. The low-salinity water masses, believed to originate in the Chesapeake Bay, are huge slugs of lower salinity water which move southward along the shore at an estimated velocity of about 0.23 meter (0.75 foot) per second. The edge is clearly discernible by both water color and turbulence. Two views of the phenomena are shown in Figure 19. Warm, clear water masses presumably resulting from Gulf Stream eddies have also been observed. These masses sometimes have a foam-line edge and can contain tropical fish.

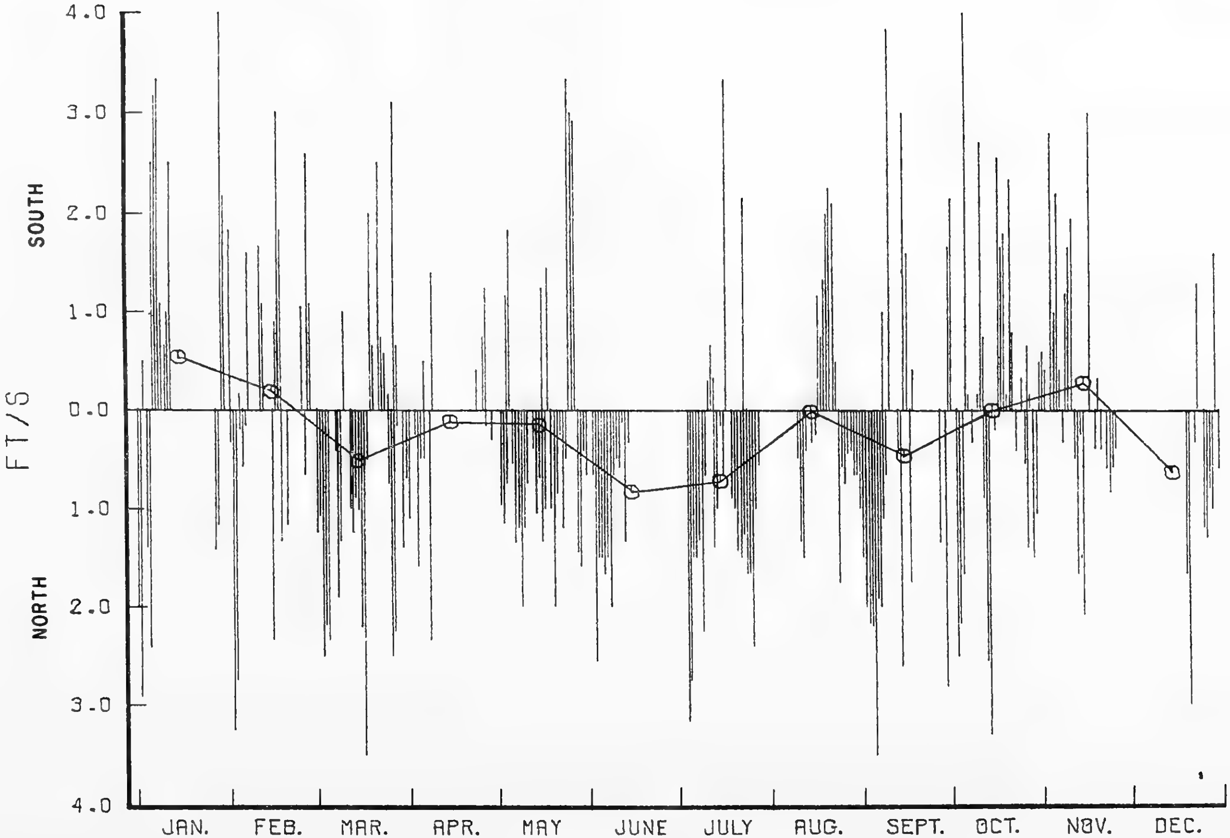


Figure 18. Longshore current at Sea Crest, North Carolina, 1973.

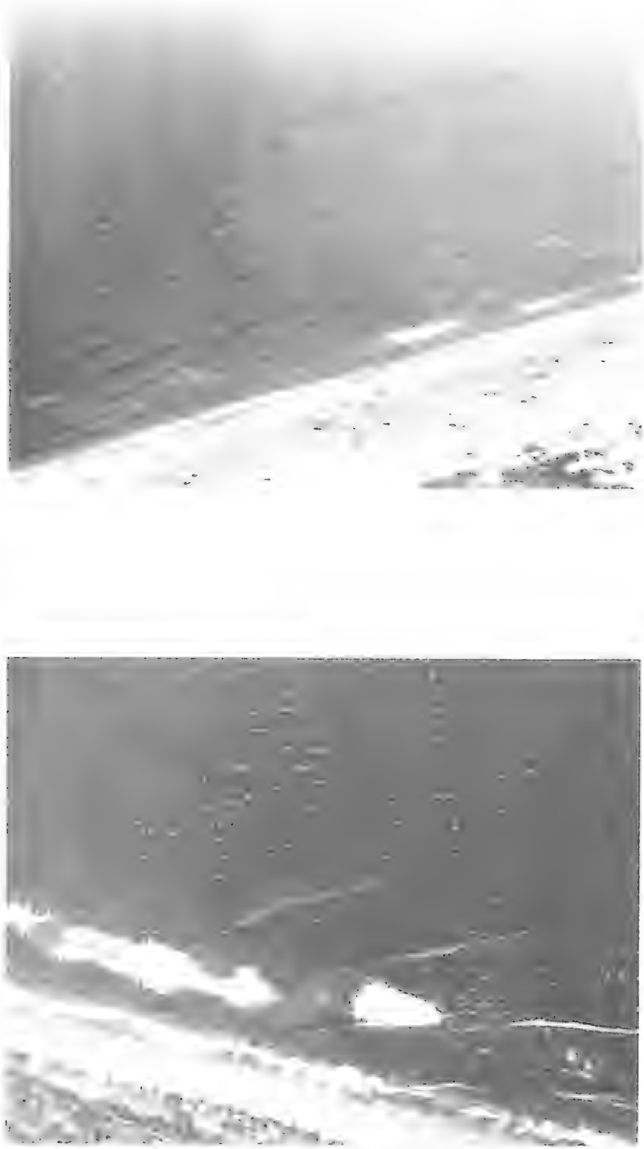


Figure 19. Two views of southward-moving edge of fresh-water mass. Photos taken from a point south of Carolla, North Carolina.

4. Storms.

The area is affected by both extratropical (northeasters) and tropical (hurricanes) cyclones. Bosserman and Dolan (1968), who examined the intensity and frequency of extraptropical storms affecting North Carolina, classified 857 storms according to the 10 tracks shown in Figure 20; note that seven of the tracks pass the FRF site. The most damaging storms follow the three widest arrows (2, 3, and 4). The severest situation occurs when the movement of a track 2 storm is slowed by a blocking high-pressure system to the north. This occurred during the Great East Coast Storm of March 1962 and resulted in strong northeasterly winds of long duration over a long fetch.

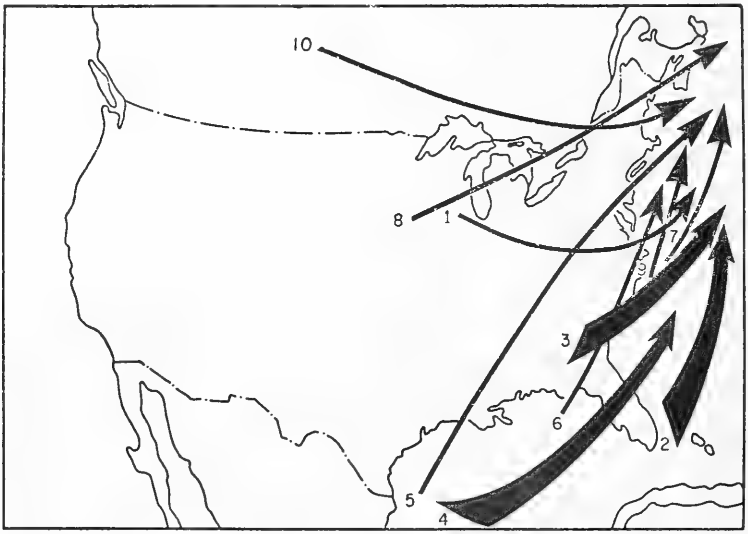


Figure 20. Storm tracks affecting the east coast (from Basserman and Dolan, 1968).

Storm occurrence prediction is somewhat difficult since cyclogenesis (storm formation) frequently occurs offshore of Cape Hatteras. Bosserman and Dolan (1968) found that about 19 percent of all storms affecting the Outer Banks develop in this manner. They also hindcasted wave heights for each storm studied. Storm frequencies (all tracks) by wave height and month are summarized in Table 7 and are shown in Figure 21.

Between 1901 and 1926, 31 hurricanes at full strength made either landfall along coastal North Carolina or passed close enough to affect the area (Baker, 1978). The frequency of occurrence of these hurricanes varies considerably (Fig. 22). The area between Cape Hatteras and Cape Lookout has the highest hurricane occurrence while the area around the FRF has the lowest with a hurricane reaching the area once every 42 years. Tracks of historic hurricanes passing within 50 nautical miles (90 kilometers) of the FRF are shown in Figure 23 (Ho and Tracey, 1975).

Table 7. Summary of storms (all classes), 1942 to 1967 (Bosserman and Dolan, 1968).

Year	Month												Wave height (m)						
	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	1.6-2.4	2.4-3.4	3.4-4.3	4.3-5.2	5.2-6.1	6.1-7.0	7 > 7.0
1966-1967	1	-	4	4	2	4	4	3	2	3	1	3	31	10	5	-	-	-	-
1965-1966	1	1	2	5	1	3	6	6	3	1	3	2	34	7	3	1	-	-	-
1964-1965	1	1	-	4	5	3	4	5	6	4	1	1	35	14	4	2	-	-	-
1963-1964	2	2	3	1	3	4	6	8	4	2	3	2	40	18	5	-	-	-	-
1962-1963	-	1	3	-	3	2	6	7	1	4	2	-	29	20	5	2	-	-	-
1961-1962	-	-	1	3	1	2	6	3	4	2	-	2	24	9	3	1	1	1	1
1960-1961	-	2	1	1	2	5	5	9	5	5	2	1	38	16	3	-	-	-	-
1959-1960	-	1	2	4	5	4	4	6	9	4	2	1	42	13	4	1	1	1	-
1958-1959	-	-	2	2	5	5	3	4	7	2	1	-	31	12	6	1	-	-	-
1957-1958	1	3	3	3	6	2	5	2	6	5	1	2	39	9	2	-	-	-	-
1956-1957	1	2	2	4	-	2	6	5	4	4	1	1	32	11	4	-	-	-	-
1955-1956	1	-	4	4	2	2	2	9	7	6	8	3	48	12	3	1	-	-	-
1954-1955	1	1	-	3	2	4	2	5	3	2	4	1	28	8	3	1	-	-	-
1953-1954	2	1	3	1	3	4	2	1	3	3	2	1	26	11	3	2	1	1	-
1952-1953	1	2	5	3	3	5	3	4	4	5	2	2	39	18	2	1	-	-	-
1951-1952	-	3	3	3	4	5	3	4	5	4	-	1	35	14	6	3	2	-	-
1950-1951	1	-	2	2	3	4	3	7	7	5	1	2	37	11	2	-	-	-	-
1949-1950	2	2	2	3	1	3	2	4	8	3	2	2	34	14	2	1	-	-	-
1948-1949	1	-	2	4	3	4	3	3	5	4	3	2	34	15	3	1	1	-	-
1947-1948	1	1	1	2	5	5	10	4	7	6	-	3	45	23	9	3	1	-	-
1946-1947	3	1	1	3	4	3	3	1	5	5	3	2	34	8	2	2	1	-	-
1945-1946	-	-	1	1	3	6	4	3	2	5	4	1	30	14	5	3	1	1	-
1944-1945	-	1	2	3	1	4	7	2	2	3	2	1	28	9	2	-	-	-	-
1943-1944	-	1	3	2	4	3	5	4	8	5	-	1	36	9	3	1	-	-	-
1942-1943	-	3	2	-	4	3	3	1	5	4	3	-	23	12	5	-	-	-	-
Totals	20	29	54	65	75	91	107	110	122	96	51	37	857	317	94	27	9	4	1
Averages	0.8	1.2	2.2	2.6	3.0	3.6	4.3	4.4	4.9	3.8	2.0	1.5	34.3	12.7	3.8	1.1	0.4	0.1	-

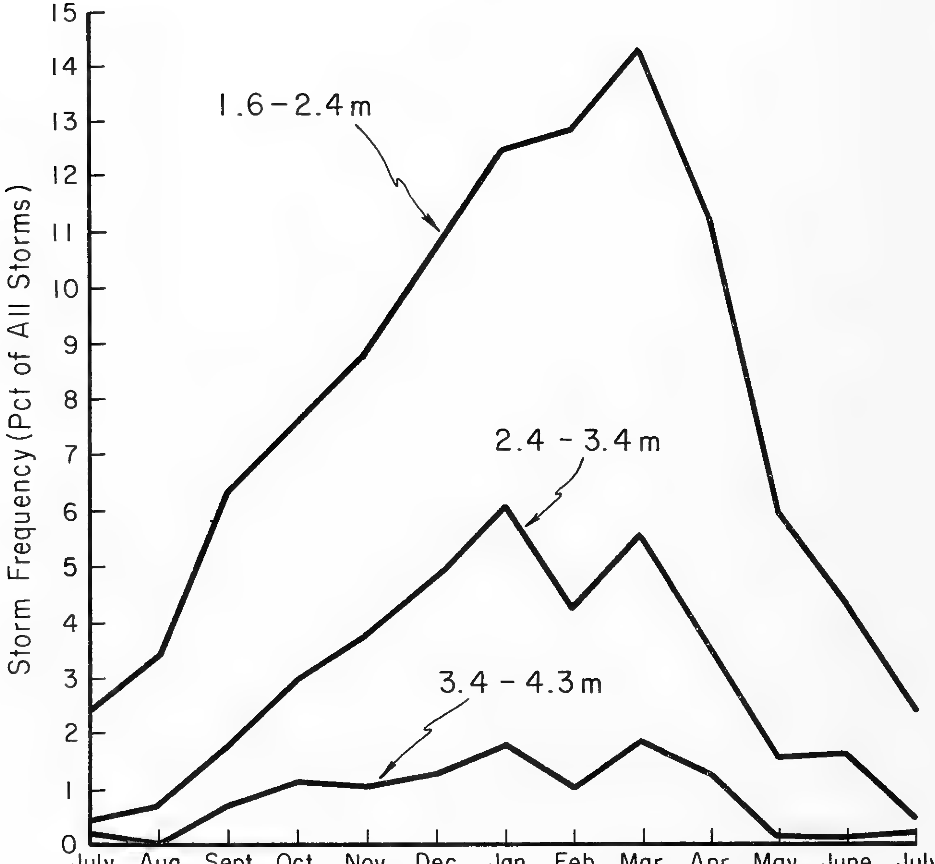


Figure 21. Monthly storm frequency and hindcasted wave height, based on a total of 857 storms (adapted from Basserman and Dolan, 1968).

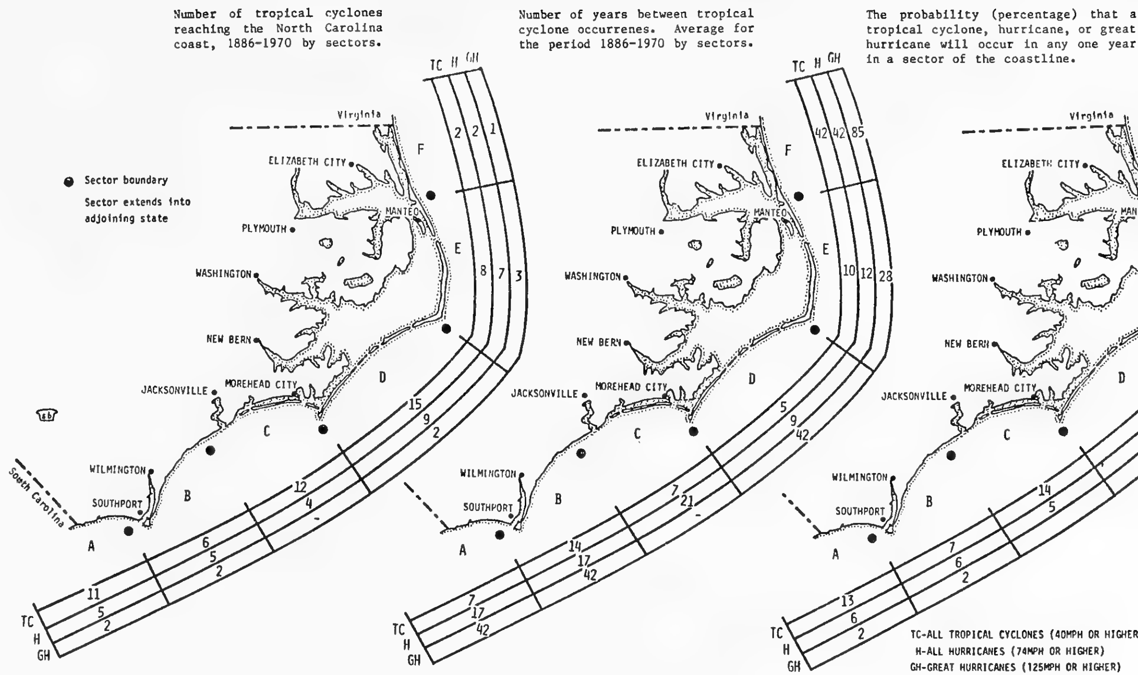


Figure 22. Hurricane statistics for North Carolina (adapted from Baker, 1978).

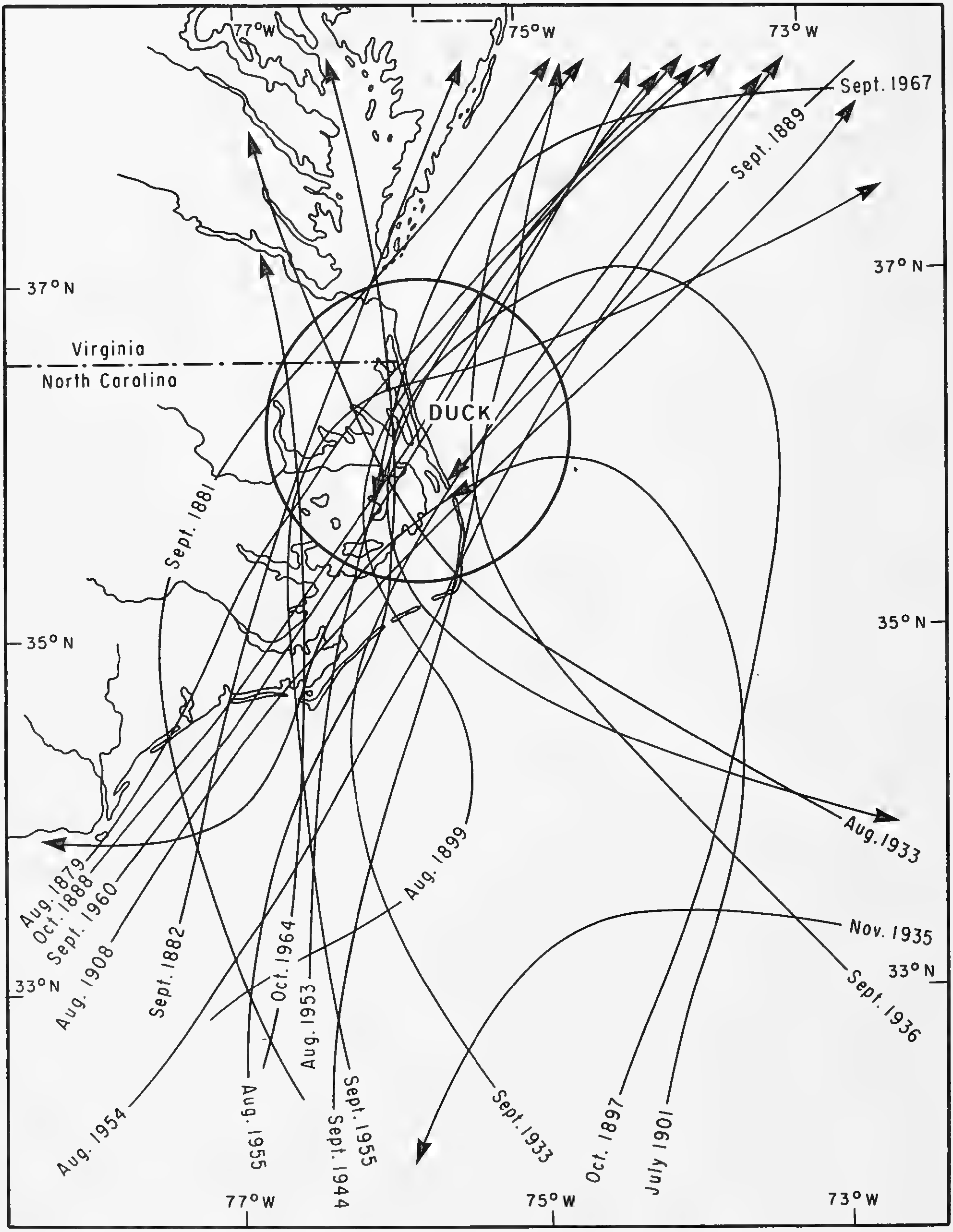


Figure 23. Major hurricanes passing within 50 nautical miles of FRF (adapted from Ho and Tracey, 1975).

Miller (1980) examined the duration of storms using measurements from the CERC Nags Head wave gage. He defined a storm as an event which caused the measured wave height to exceed a critical height equal to the sum of the annual mean significant wave height (0.88 meter) and one standard deviation (0.49 meter). This definition was used to compute Figure 24 which indicates 35 percent of all storms were of 1-day duration or longer while only 1 percent exceeded 6.8 days.

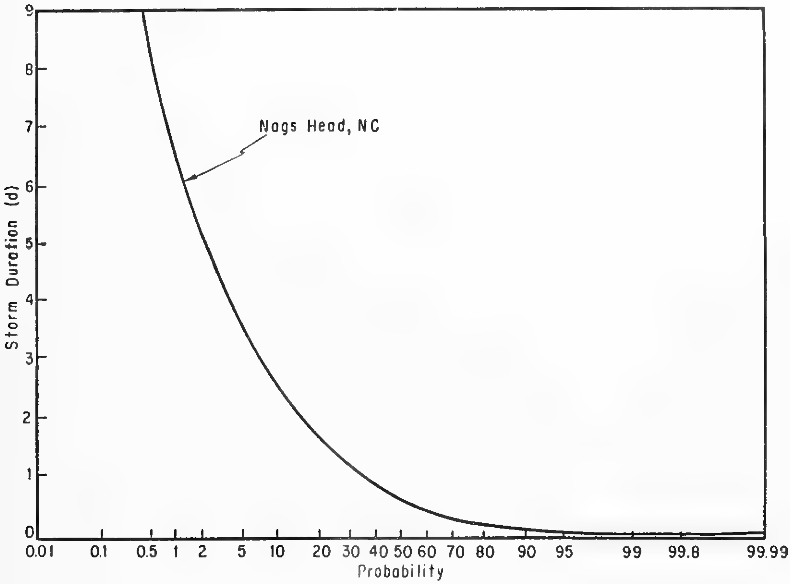


Figure 24. Storm duration probability based on wave data recorded by the CERC gage at Nags Head, North Carolina.

5. Sediment Transport.

The net longshore transport direction along the northern Outer Banks has been reported as toward both the north (Langfelder, Stafford, and Amein, 1968) and the south (Goldsmith, Sturm, and Thomas, 1977). Jarrett (1978) determined a net southerly transport along the beaches north of Oregon Inlet.

Although a detailed sediment budget has not been prepared for the FRF area, the longshore sediment transport rates can be estimated based on the visual observations of wave height and direction given in Section IV,2.

Average monthly and annual predicted transport rates based on the method recommended in the Shore Protection Manual (SPM) (U.S. Army, Corps of Engineers, Coastal Engineering Research Center, 1977) are given in Table 8. Note that the values use a dimensionless proportionality constant, k, equal to one. Generally accepted values of this constant are given at the end of the table. Annual and seasonal variations in net transport, based on the proportionality constant, are shown in Figure 25.

Table 8. Summary of estimated longshore transport at Sea Crest, North Carolina, based on LEO observations.

DATA FROM 39010 SEA CREST
OBSERVATION PERIOD 7/ 1/72 TO 12/28/78

MONTHS	1	2	3	4	5	6	7	8	9	10	11	12
MEAN NET ENERGY (FT-LBS/FT)	46.	71.	4.	41.	20.	21.	19.	59.	122.	147.	98.	15.
MEAN GROSS ENERGY (FT-LBS/FT)	90.	151.	145.	106.	89.	125.	69.	144.	197.	253.	164.	136.
IMMERSED WEIGHT NET(LBS)X10000	11995.	18606.	1140.	10658.	5172.	5412.	4930.	15635.	32108.	38739.	25835.	3984.
IMMERSED WEIGHT GROSS X10000	23668.	39609.	38075.	27886.	23458.	32829.	18063.	37804.	51901.	66525.	43052.	35833.
BULK VOLUME TO LEFT (CU YDS)	35777.	64379.	113214.	52809.	56050.	84039.	40256.	67952.	60671.	85168.	52775.	97625.
BULK VOLUME TO RIGHT (CU YDS)	109314.	178442.	120203.	118145.	87760.	117216.	70479.	163802.	257504.	322655.	211152.	122046.
BULK VOLUME NET (CU YDS)	73537.	114063.	6989.	65337.	31709.	33177.	30223.	95849.	196834.	237487.	158378.	24421.
BULK VOLUME GROSS (CU YDS)	145092.	242820.	233417.	170954.	143810.	201254.	110735.	231754.	318175.	407823.	263927.	219672.
NUMBER OF OBSERVATIONS	163.	121.	169.	111.	168.	152.	191.	138.	156.	202.	158.	124.

TOTAL TRANSPORT (SUM OF MONTHLY)

IMMERSED WEIGHT NET(LBS)X10000	174214.
IMMERSED WEIGHT GROSS X10000	438704.
BULK VOLUME TO LEFT (CU YDS)	810715.
BULK VOLUME TO RIGHT (CU YDS)	1878718.
BULK VOLUME NET (CU YDS)	1068004.
BULK VOLUME GROSS (CU YDS)	2689433.

NB-PROPORTIONALITY CONSTANT OF 1.00 USED IN COMPUTATIONS.
ACCEPTED VALUES ARE 0.25(INMAN AND FRAUTSCHY), 0.35(DAS), 0.77(KOMAR)

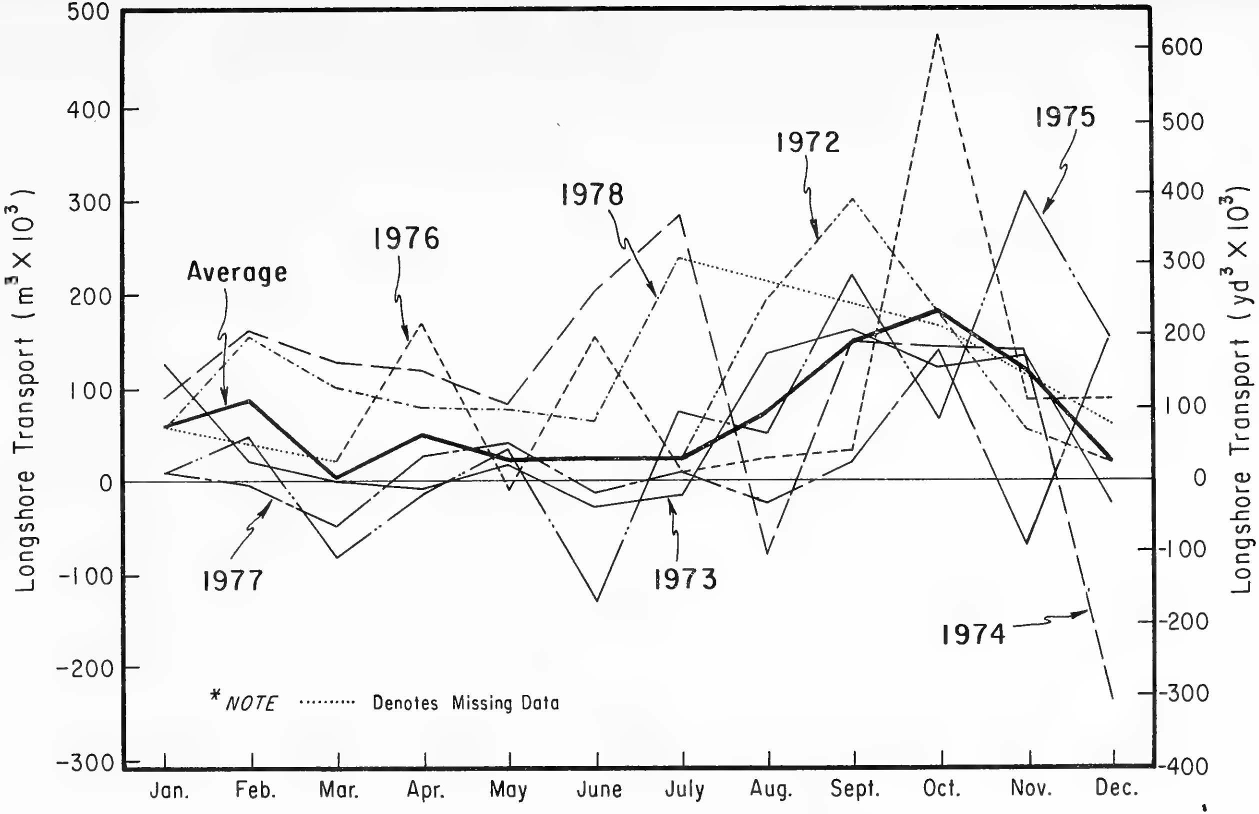


Figure 25. Potential net transport versus time, based on visual wave observations at Sea Crest, North Carolina (k = 1.0).

Using a proportionality value of 0.77 (Komar and Inman, 1970), the estimated gross transport at Sea Crest is 1,583,400 cubic meters (2,071,000 cubic yards) per year. The predicted net transport is to the south with a north-to-south transport ratio of 0.43. The annual net transport to the south at Sea Crest is estimated at 625,000 cubic meters (822,000 cubic yards) per year.

6. Tides and Sea Level Rise.

Ocean tides are semidiurnal with a spring range of 1.16 meters (3.8 feet) and a mean range of 0.97 meter (3.2 feet). Water levels in Currituck Sound are wind-dominated: high during periods of southwest winds, low during northeast winds. Mean water level in the sound is about 0.27 meter (0.9 foot) above MSL. Normal wind-induced setup is about 0.6 meter (2 feet) and setdown is -0.2 meter (-0.7 foot).

Ho and Tracey (1975) investigated the frequency and magnitude of storm tides for the northern North Carolina coast. Their results for 10-, 50-, 100-, and 500-year return period storms are shown in Figure 26. Note that at the Wright Monument, 23 kilometers south of the FRF, the expected 100-year surge height is 2.77 meters. Tide frequencies for several classes of storms are shown in Figure 27.

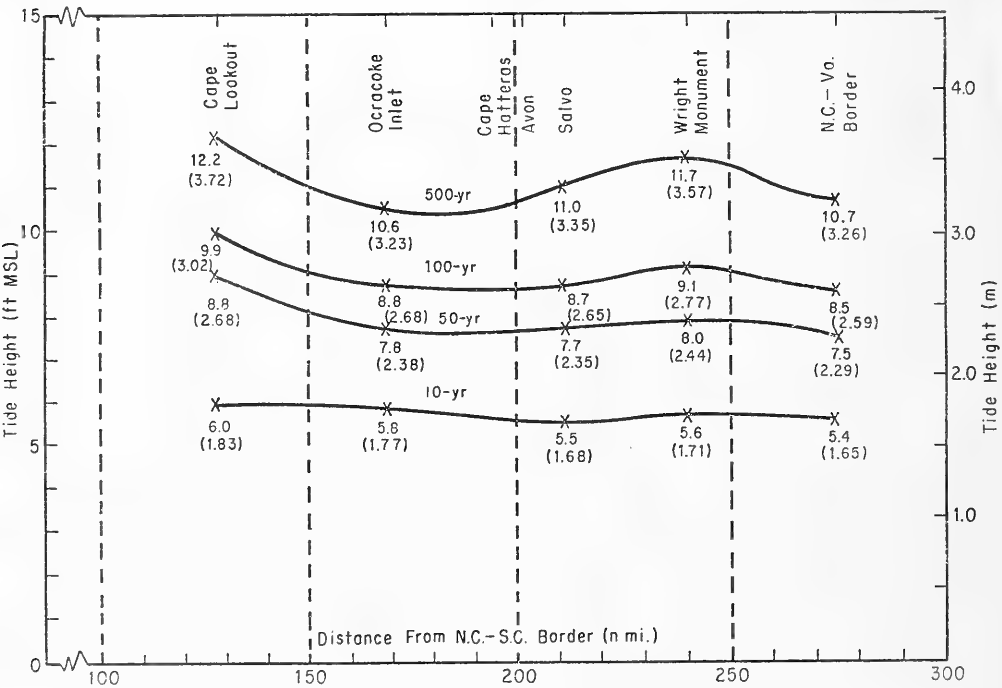


Figure 26. Coastal storm surge frequencies north of Cape Lookout, North Carolina. Numbers in parentheses are values in meters (from Ho and Tracy, 1975).

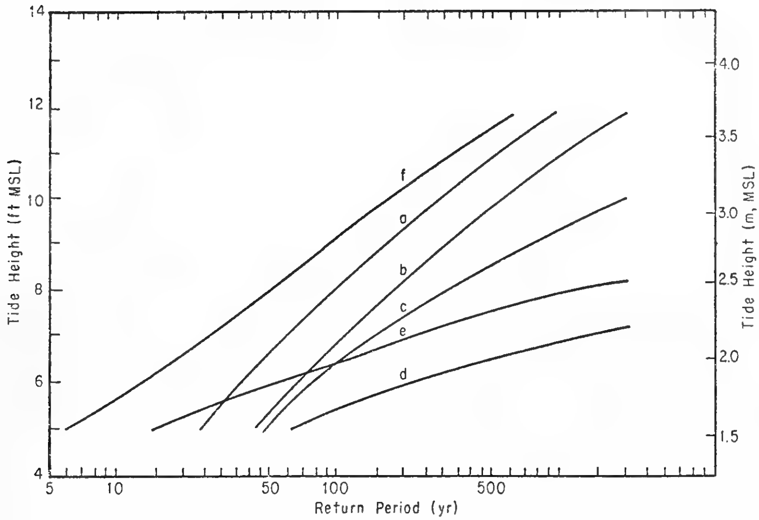


Figure 27. Tide frequencies at Wright Monument, North Carolina, for the following classes of storms: (a) landfalling, (b) alongshore, (c) inland, (d) exiting hurricanes and tropical storms, (e) winter storms, (f) all storms (from Ho and Tracey, 1975).

Hicks (1981) examined the recent rate of sea level rise for a number of east, gulf, and west coast beaches. For the closest station to the FRF, Hampton Roads, Virginia (near the mouth of the Chesapeake Bay), Hicks calculated a rate of sea level rise equal to 0.4411 centimeter (0.0144 foot) per year based on the period 1928 to 1978.

7. Surface Water Temperatures.

Table 9 gives monthly mean surface water temperatures at Virginia Beach based on observations between 1960 and 1966 (Department of Commerce, 1968).

Table 9. Monthly mean surface water temperatures.[1]

Month	°C.	°F.	Month	°C.	°F.
January	5.7	42	July	22.7	73
February	4.4	40	August	23.9	75
March	6.4	44	September	22.5	72
April	10.7	51	October	18.1	65
May	16.1	61	November	14.1	57
June	20.3	69	December	8.4	47

[1]Annual mean = 14.4 °C. (58°F.).

V. BEACHES AND GEOLOGY

The FRF, located along a barrier spit forming the eastern edge of the Coastal Plain, is the northernmost part of a complex series of barrier islands which extend south to Cape Lookout. Though there are currently four inlets along this stretch (Oregon, Hatteras, Ocracoke, Drum), the area is dynamic and includes many relic inlets (Fig. 28).

1. Origin.

The origin of this series of barrier islands is both complex and slightly controversial. Judge (1980) provides a summary of the following significant theories. De Beaumont (1845) suggested that the islands formed by bar building. Gilbert (1885) theorized that longshore drift and spit building were the primary cause of formation. Hoyt (1967) postulated that rising sea levels (or land submergence) could flood the flats behind the dunes and form a long subaerial ridge. Hoyt and Henry (1971) noted that the capes coincided with historic river deltas which were isolated by rising sea levels. Using stratigraphic interpretation of core samples, Pierce and Colquhoun (1970, 1971) found that 39 percent of the original 200-kilometer coast was primarily dune and that the islands formed by shoreline submergence. Field and Duane (1976) postulated that the barriers formed on the Continental Shelf during low sea levels and moved shoreward under the influence of sea level rise. Riggs (1978) postulated that the islands were formed by submergence and had been modified by coastal processes (waves, tides, and currents) to form their present shape and alinement.

The general consensus is that the barrier islands are comprised of recent (Holocene) sediments overlying Pleistocene deposits.

2. Shoreline Changes.

Historically, the ocean shoreline at the FRF has been relatively stable. This was documented by Wahls (1973), who found a mean annual accretion rate of 0.91 meter (3 feet) per year for the period 1955 to 1971. More recently, Dolan's (1979) analysis of shoreline changes north and south of the FRF showed long-term stability from 1940 to 1975 (Fig. 29), and overall erosion from 1977 to 1979. These results are based on shoreline measurements from photos at 50-meter (164 feet) intervals over the 28-kilometer (45 miles) reach. Average rates of change are computed based on the rates of change for each set of successive photos. The following sets of photos were used in the analysis:

1940 to 1975	1977 to 1979
21 October 1940	2 February 1977
29 March 1955	11 November 1977
3 May 1962	16 May 1978
5 September 1975	2 December 1978
	20 September 1979

Three rates were averaged to compute the 1940 to 1975 rates; four rates were averaged to obtain the 1977 to 1979 rates. The air photo analysis procedure is described in Dolan, et al. (1979). Errors can be significant, and average rates of change less than 1.0 meter (3.3 feet) per year over 40 years are difficult to measure.

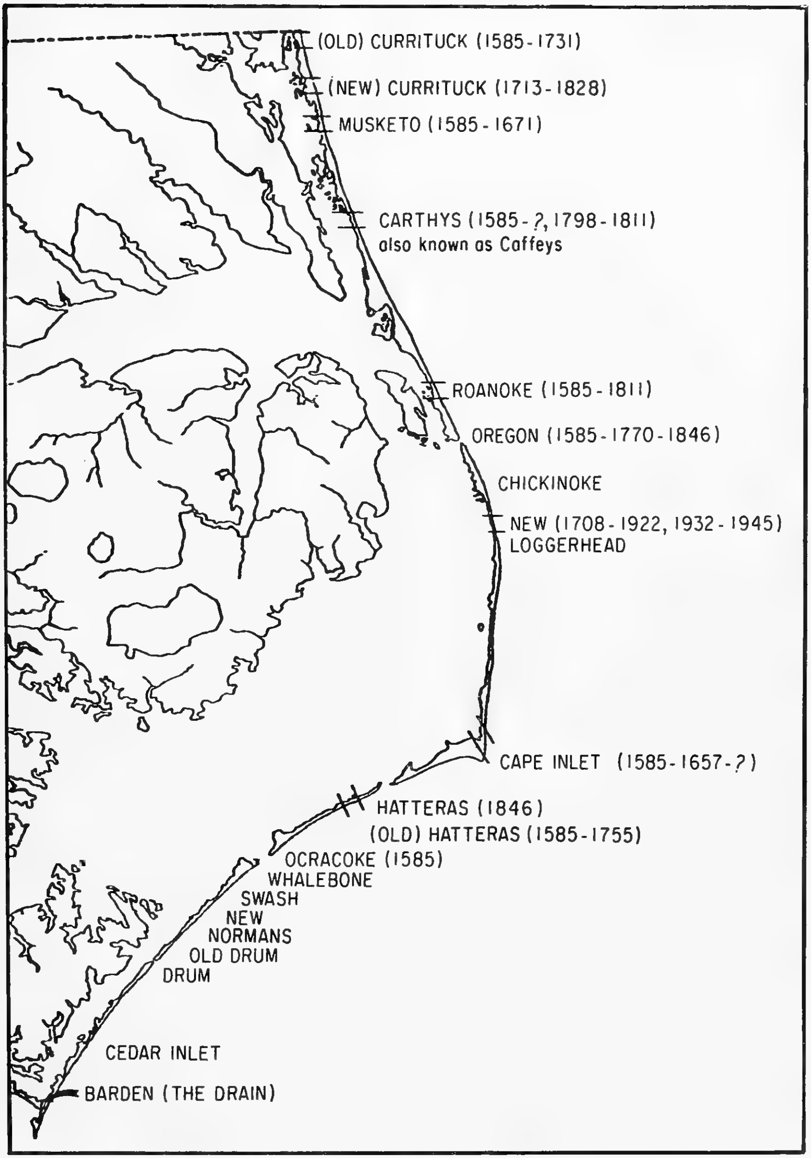


Figure 28. Present and historic inlets from the Virginia-North Carolina border to Cape Lookout (adapted from U.S. Congress, 1935, and Dunbar, 1958).

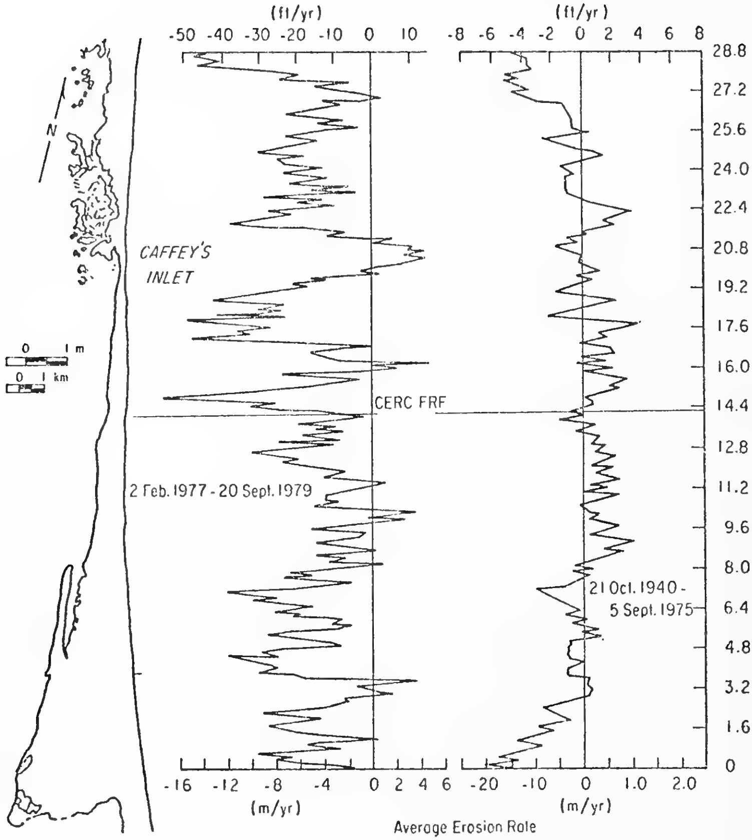


Figure 29. Average preconstruction and postconstruction erosion rates for 28 kilometers of shoreline near the FRF.

Because long time intervals tend to smooth the data, two different horizontal scales were used in Figure 29. The 1940 to 1975 data show accretion or stability near the FRF and erosion at the northern and southern ends of the study area. Between 1977 and 1979, erosion predominated with only a few areas showing accretion. Interestingly, the area with the most noticeable accretion is located around Caffey's Inlet. The area just south of the pier appeared to be stable, while peak erosion of 17.1 meters (56.1 feet) per year was found 183 meters (600 feet) north of the pier.

3. Topography.

A contour map of the FRF site is shown in Figure 30. The island is 680 meters (2,200 feet) wide at the FRF and is bordered on the sound side by a brackish water marsh (described in Section VI,6). The area is typified by dunes which reach heights of more than 14 meters above MSL; the beach is

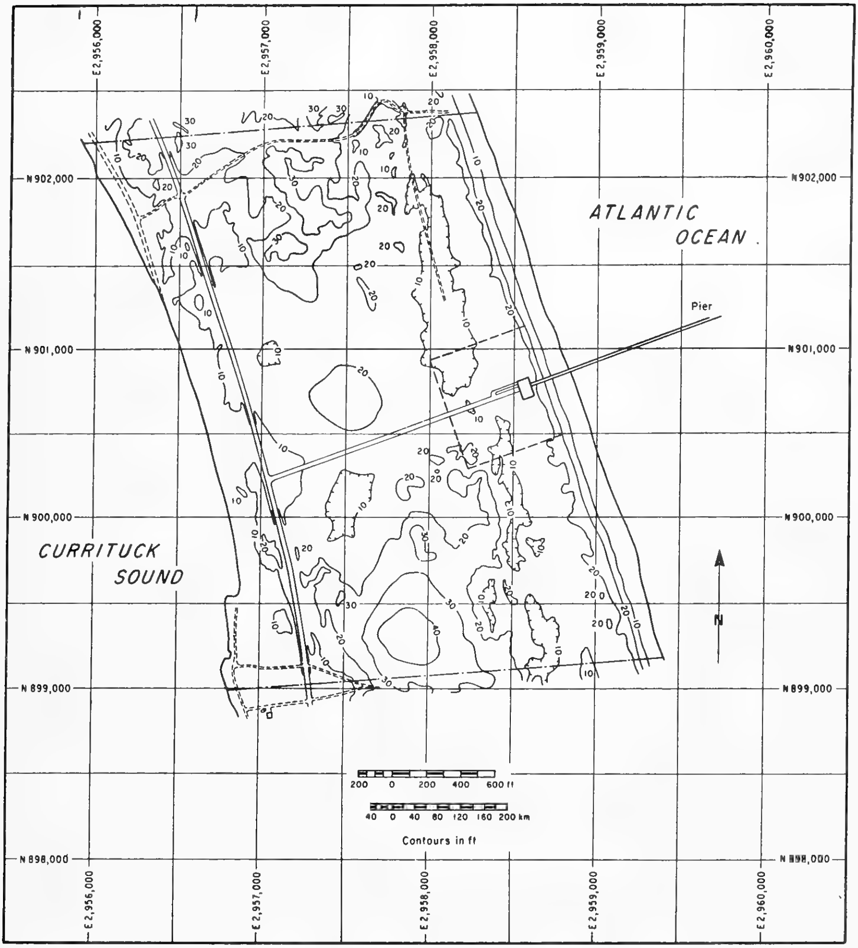


Figure 30. Contour map of the FRF site (contours in feet).

backed by a dune which reaches a height of 7 meters (22 feet) above MSL. Beach width varies but averages about 40 meters (130 feet). Berms, with crest elevations of 2.4 meters (8 feet), and beach cusps are common. The beach tends to be wider immediately south of the pier than north of it. Foreshore slopes vary from 0.023 to 0.345, averaging 0.108.

4. Beach Changes.

In May 1974, before the pier was constructed, CERC began surveys to wading depth of the 62 profile lines shown in Figure 11. Surveys were conducted monthly and immediately after storms. Thirty-four profile lines (4 to 20 and 45 to 61) were surveyed daily for three separate 30-day studies. The last complete survey of the 62 profile lines was conducted in January 1977.

Birkemeier (1979a) reported on short-term changes for profile lines 1 to 6 and 18 to 23 (Fig. 31). For a relatively severe northeaster, which occurred 2-3 December 1974, the average volume change on the above MSL beach was -5.8 cubic meters per meter (-2.3 cubic yards per foot). Prestorm and poststorm profiles are plotted in Figure 32. Note that 2 of the 12 profile lines (18 and 22) gained sand as a result of this storm. Significant wave heights of 2.8 meters were recorded during the storm by the CERC gage at Nags Head.

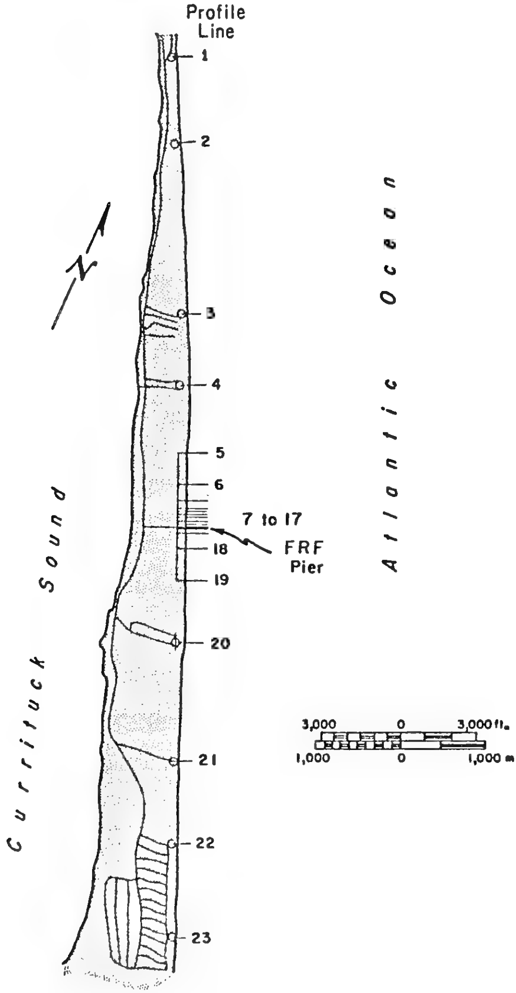


Figure 31. Profiles in the vicinity of the FRF pier.

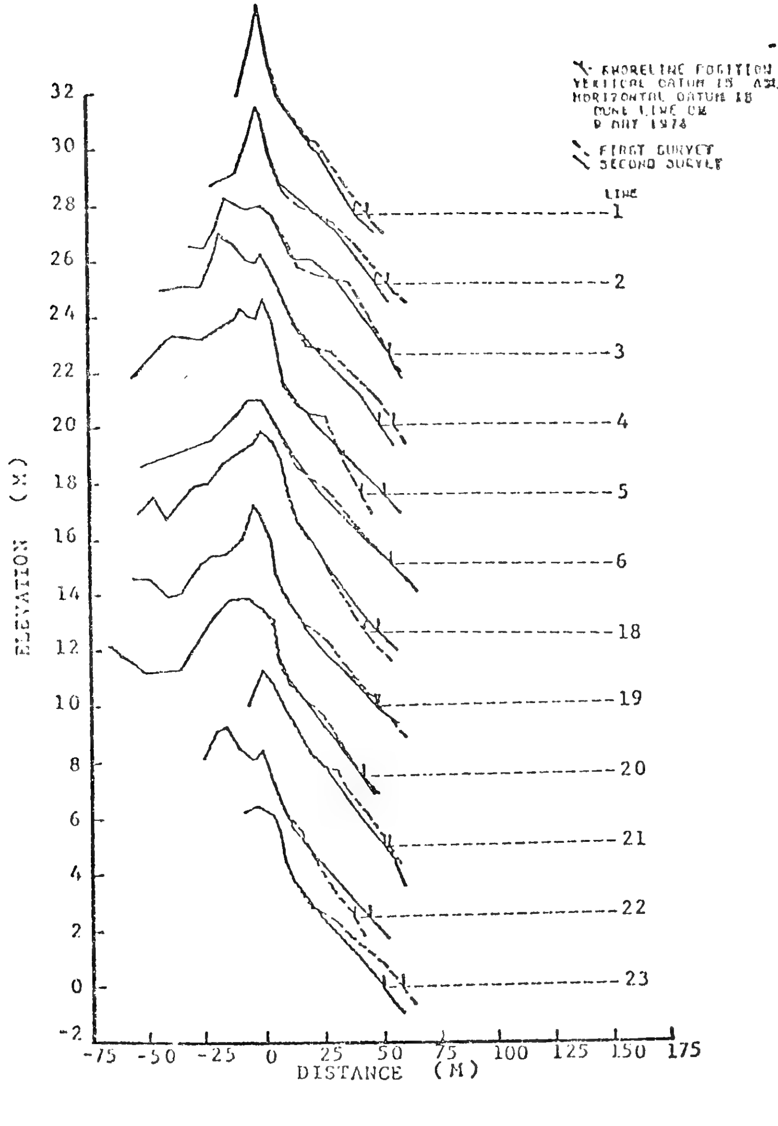


Figure 32. Typical storm changes, 4 November to 4 December 1974 ($\overline{\Delta v}$ = 5.8 m^3/m).

Birkemeier (1979a) reported the average monthly variation in mean shoreline position and unit volume for the same above MSL profiles (see Figs. 33 and 34). These data show no clear-cut seasonal variation. The subaerial beach has the least amount of sand during March and December and the greatest amount during April and November. These data do not provide the below MSL profile changes.

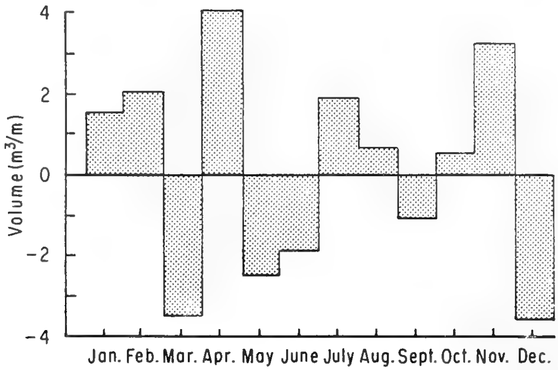


Figure 33. Monthly variations in mean profile volume (profile lines 1 to 6, 18 to 23, from May 1974 to January 1977).

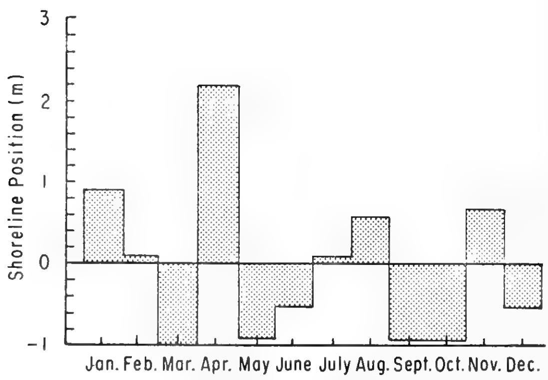


Figure 34. Monthly variations in mean shoreline position (profile lines 1 to 6, 18 to 23 from May 1974 to January 1977).

Changes in unit volume and MSL shoreline position from May 1974 to January 1977 for each of 15 profile lines are shown in Figures 35 and 36. These figures include Birkemeier's data and additional data from more closely spaced profile lines on the FRF property (lines 7, 8, 16, and 17). Profile lines 16 and 17 are located 48 meters (160 feet) north and south, respectively, of the FRF pier. Unit volume changes are referenced to the average volume above MSL.

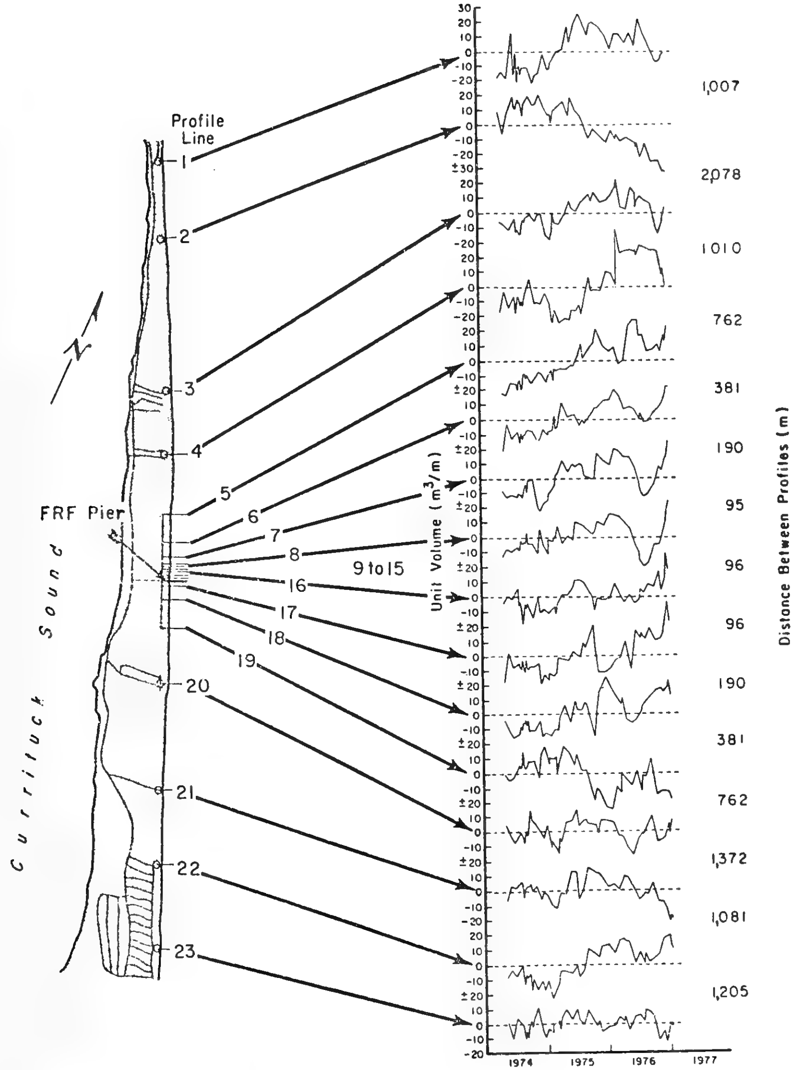


Figure 35. Variation in unit volume above MSL on 16 profile lines near the FRF.

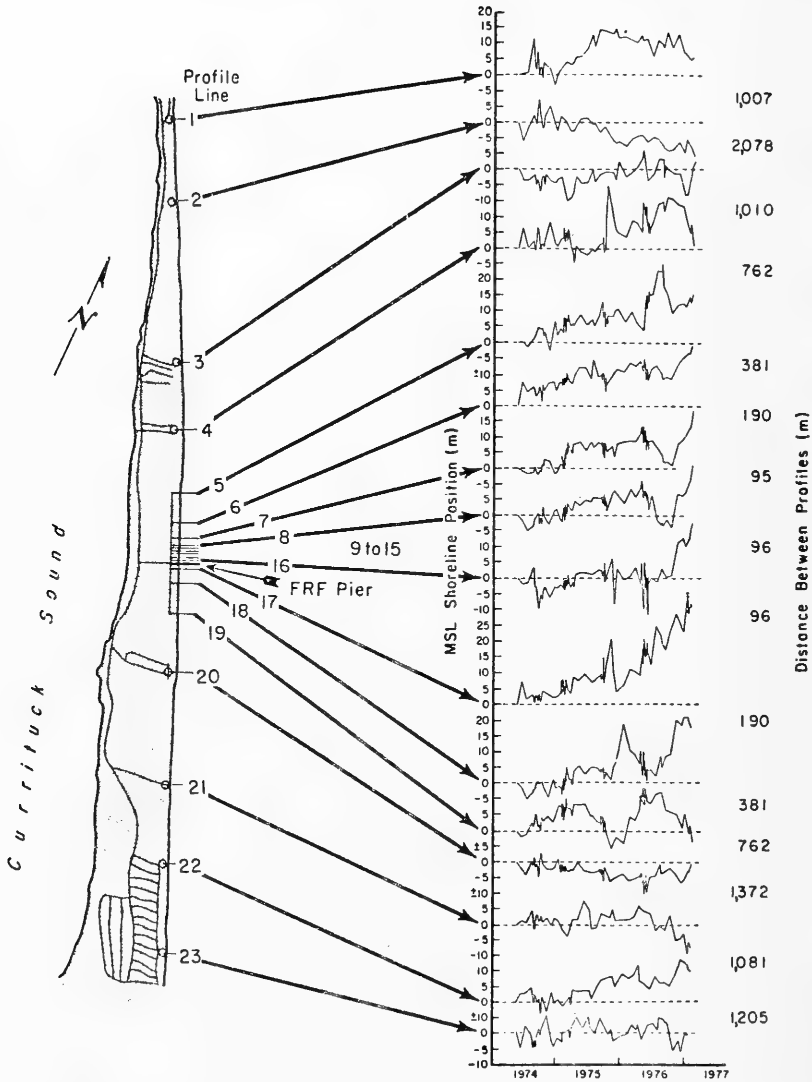


Figure 36. Variation in MSL shoreline position on 16 profile lines near the FRF.

Shoreline position is referenced to the shoreline position of the profile during the first survey. A linear regression fit to these data indicates that on the average the profile lines accreted at a rate of 3.49 cubic meters per meter (1.39 cubic yards per foot) per year and the shoreline advanced at a rate of 1.66 meters (5.4 feet) per year during this time period (Table 10). Only profile lines 2, 19, 20, and 21 underwent a net erosion. With the exception of profile line 16, profile lines immediately to the north of the pier displayed a sharp erosional trend during the second phase of pier construction (March to August 1976), which reversed in September 1976. Profile lines immediately to the south of the pier and profile line 16 underwent general accretion during this period.

Table 10. Rates of change for profile lines in vicinity of the FRF, May 1974 to January 1977.

Profile line No.	Distance from FRF[1] (m)	MSL shoreline change[2] (m/yr)	Above MSL unit volume change[2] (m^3/m/yr)
1	-5,762	+3.36	+8.32
2	-4,755	-3.94	-15.87
3	-2,677	+1.58	+6.47
4	-1,667	+4.19	+15.10
5	-905	+5.31	+14.60
6	-524	+3.57	+9.88
7	-333	+4.22	+7.70
8	-238	+3.42	+3.26
16	-48	+2.58	+7.16
17	+48	+9.59	+11.29
18	+238	+5.42	+10.21
19	+619	+2.40	-7.63
20	+1,381	-2.36	0.00
21	+2,753	-1.46	-2.87
22	+3,834	+3.97	+10.43
23	+5,039	+1.85	+0.92
Mean (distance-weighted)		+1.66	+3.50

[1]Positive distance is south, negative north.

[2]Positive value indicates accretion, negative erosion.

5. Bathymetry.

Except immediately adjacent to and underneath the FRF, bottom bathymetry is regular with a mild offshore slope. Offshore bathymetry is shown in Figure 37. Nearshore bathymetry, surveyed in November 1981, is shown in Figure 38. A noticeable feature at the end of the FRF is a 8.0-meter (26 feet) hole, slightly skewed to the south, which is the result of the pier's effect on the waves, currents, and bottom sediment movements. Figure 39 shows the development sequence of this hole and plots soundings taken along the FRF centerline from 24 September 1973 to 5 January 1977 (before and after construction). Though the data are incomplete, between 24 November 1974 and 5 January 1977, the profile shape changed markedly with 2 to 3 meters of scour along the outer section of the FRF.

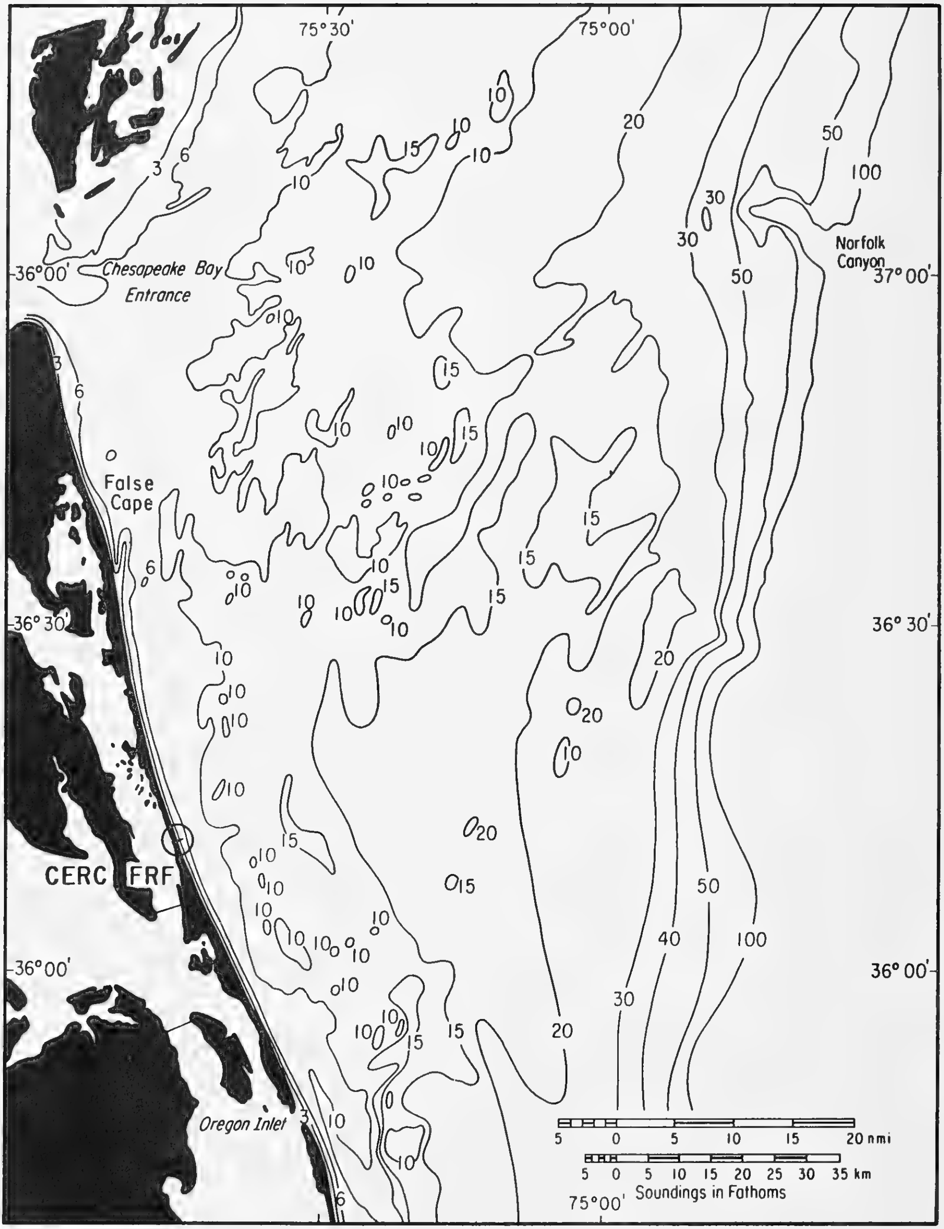
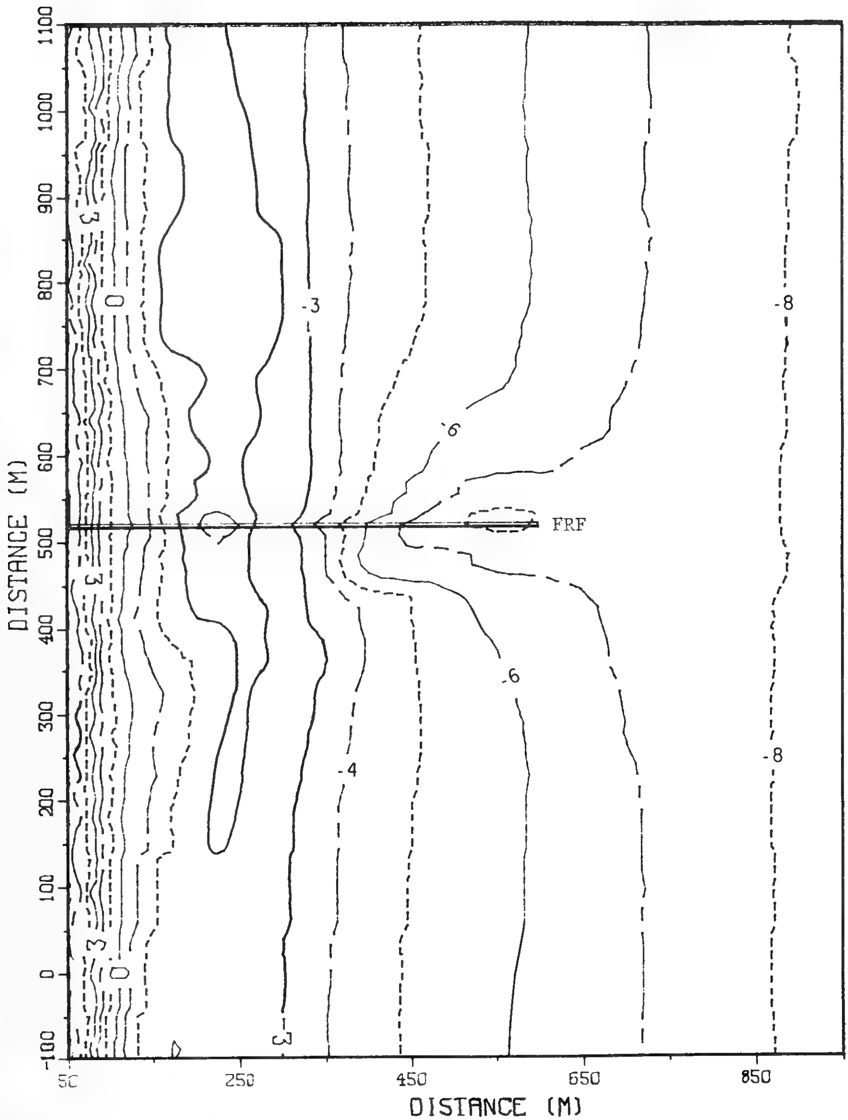


Figure 37. Deepwater contours offshore of the FRF.



FRF BATHYMETRY 3 NOV 81

CONTOURS IN METERS

Figure 38. Nearshore contours.

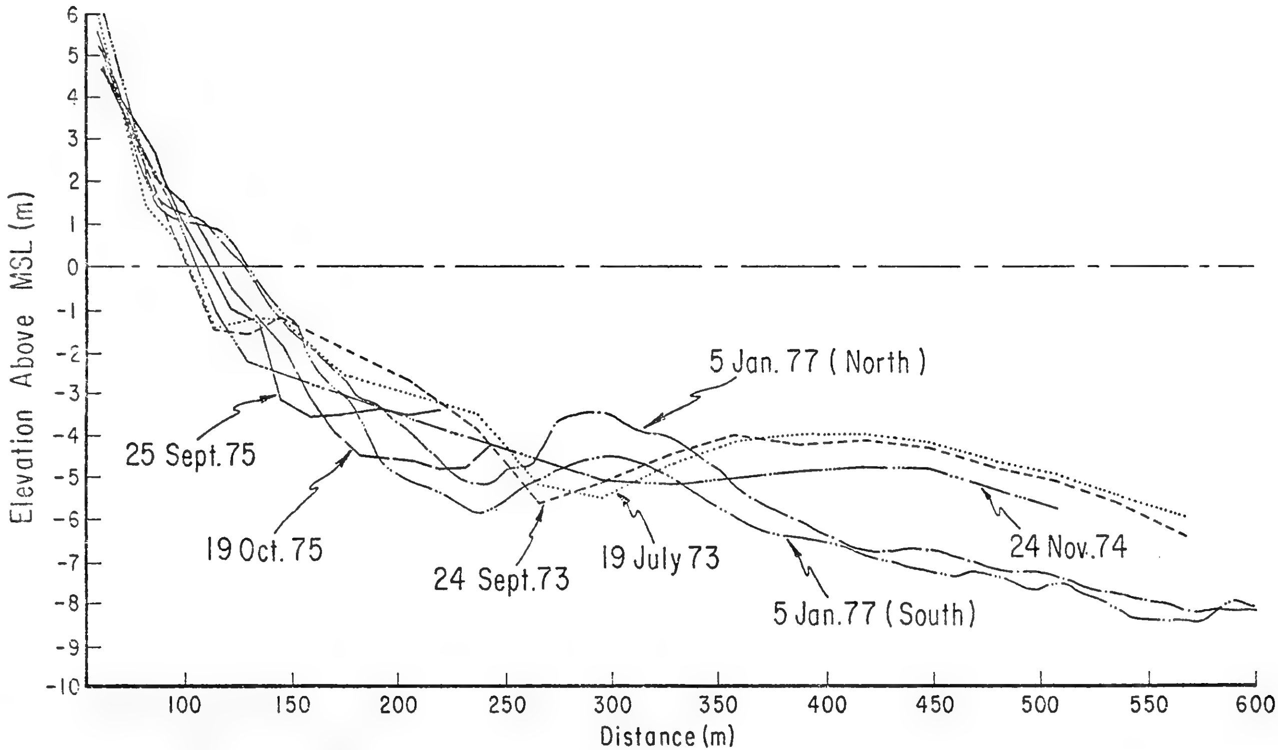


Figure 39. Preconstruction and postconstruction surveys along the FRF centerline (relative to the CERC base line).

Nearshore changes, particularly during storm conditions, can be large. Weekly soundings along both sides of the pier have been collected since July 1977. The profile envelope of surveys from July 1976 to December 1979 for the south side of the pier is shown in Figure 40. The maximum sand level change was 4.3 meters measured at 175 meters out; a 1.5-meter change was measured at the end of FRF.

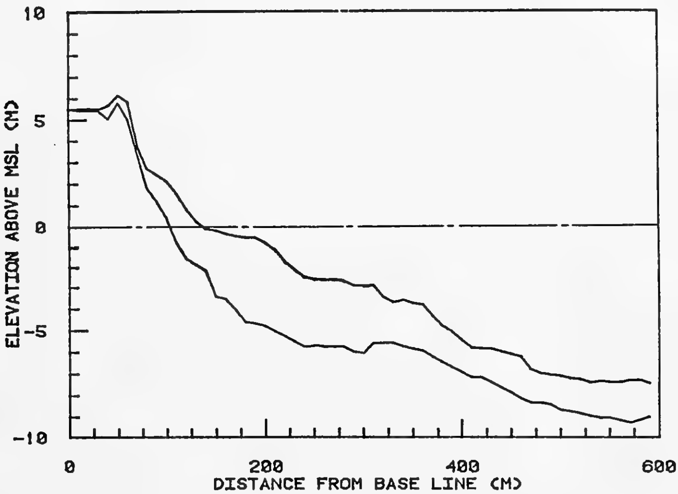


Figure 40. Profile envelope of soundings taken along the south side of the FRF pier from July 1976 to December 1979.

Birkemeier (1979b) reported that during a storm which produced maximum significant wave heights of 3.8 meters (12.5 feet), 234.3 cubic meters per meter (93.4 cubic yards per foot) eroded along the length of the pier. The storm also produced a relatively flat 200-meter-long terrace at a depth of -6 meters (-19.5 feet).

The localized scour around the pier piles and the concrete abrasion collars was investigated by DeWall and Christenson (1979). A maximum scour depth of 1 meter below the surrounding bottom was measured. The maximum width of holes was 7.3 meters (24 feet). Maximum pile scour was found at 243.8 meters (800 feet) along the pier relative to the base line.

6. <u>Longshore Bars</u>.

Lester (1980) examined the frequency and movement of longshore bars, using aerial photos from five overflights, and found that two different bar patterns existed. From Duck north 75 kilometers to Cape Henry, there was a single, uninterrupted bar. However, from Duck south to Oregon Inlet there was a sequence of seven sandbars. These bars had a trisectional formation, in that each bar tended to propagate at an angle from the shore, then continued southward parallel to shore for a considerable distance until only remanent indications of the bar remained. The trisectional bar formation is defined as

(a) the proximal, the section that propagated from shore; (b) the body, the section that was parallel to shore; and (c) the distal or transitional, the section where only remanent indications of the bar remained, and the proximal segment of a new bar was starting. Three bars with this configuration are shown in Figure 41.

Figure 41. Aerial view looking north from Kill Devil Hills, showing three distinct longshore bars.

These bars showed a strong indication of seasonal, shore-normal migration. During the summer and winter months, the average distance of the bar from shore was 137 meters (450 feet) and 290 meters (960 feet), respectively. The total length of the bars ranged between 6.4 and 9.6 kilometers. The average length of each proximal section was 1.2 kilometers, each body segment 7.2 kilometers, and each distal segment 1.4 kilometers. There was very little indication of shore-parallel migration. Instead, there appeared to be a very consistent location for the initiation of bar propagation from shore.

7. Sediment Characteristics.

a. Beach Material. As part of the BEP mentioned in Section III, a series of 915 sand samples was collected quarterly from 14 transects along the beach, above mean low water (MLW) between 1974 and January 1977 (Fig. 42). Headland and DeWall (1979) reported on the analysis of these samples. Each sample consisted of about 200 grams (7 ounces) taken by a specially constructed sampler from the top 1 centimeter (0.4 inch) of the beach. The location and elevation of each sample was carefully determined using tape and level techniques. Samples were collected from the landward side of the dune, the dune crest, the dune toe, the berm, and the foreshore.

Splits of the samples were analyzed on the CERC Rapid Sediment Analyzer (RSA). Ten percent of the samples were also run at 0.5-phi intervals through a standard sieve analysis for control. A subset of 60 foreshore samples collected during 1976 was analyzed for carbonate content. The results were then analyzed for variations in mean size as a function of (1) position along each profile line, (2) position along the beach, (3) season, (4) percent carbonate, and (5) foreshore slope. An average of all profile lines indicated the mean grain size decreased landward from 0.52 millimeter (0.9 phi) on the foreshore to 0.38 millimeter (1.4 phi) at the dune (Fig. 43). Profile lines to the north show a much wider range of sizes than the lines in the vicinity of Oregon Inlet, due to a secondary mode in the coarse fraction on the berm and foreshore (Fig. 44). The mean size of the dune sand remains nearly constant and ranges between 0.3 and 0.4 millimeter (1.7 and 1.3 phi). Figure 45 shows the bimodal distribution for a sample taken from the foreshore at profile line 20 (south of the FRF).

Figure 46 illustrates the change in average sample mean and standard deviation alongshore and confirms a decrease in sand size from north to south. The coarsest material occurs in the vicinity of the FRF (between lines 12 and 20) where the mean sand size on the foreshore averages 0.6 to 0.8 millimeter (0.7 to 0.3 phi).

Figure 47 summarizes the seasonal mean sand size, averaged by position on the profile line. Sand size on the dune remains generally unchanged, while the foreshore material (MHW to MSL) tends to become finer during the summer months. Sand size on the berm is coarser during the summer than during the rest of the year. Seasonal trends were not uniform from profile to profile.

The carbonate fraction of the foreshore samples, which consists of whole and broken shell material, ranges from 0 to 20 percent of the sample by weight (Fig. 48). The highest percentages occurred during the fall survey of profile lines 35 to 41. Mean grain size was found to have a positive correlation (0.4) with percent carbonate.

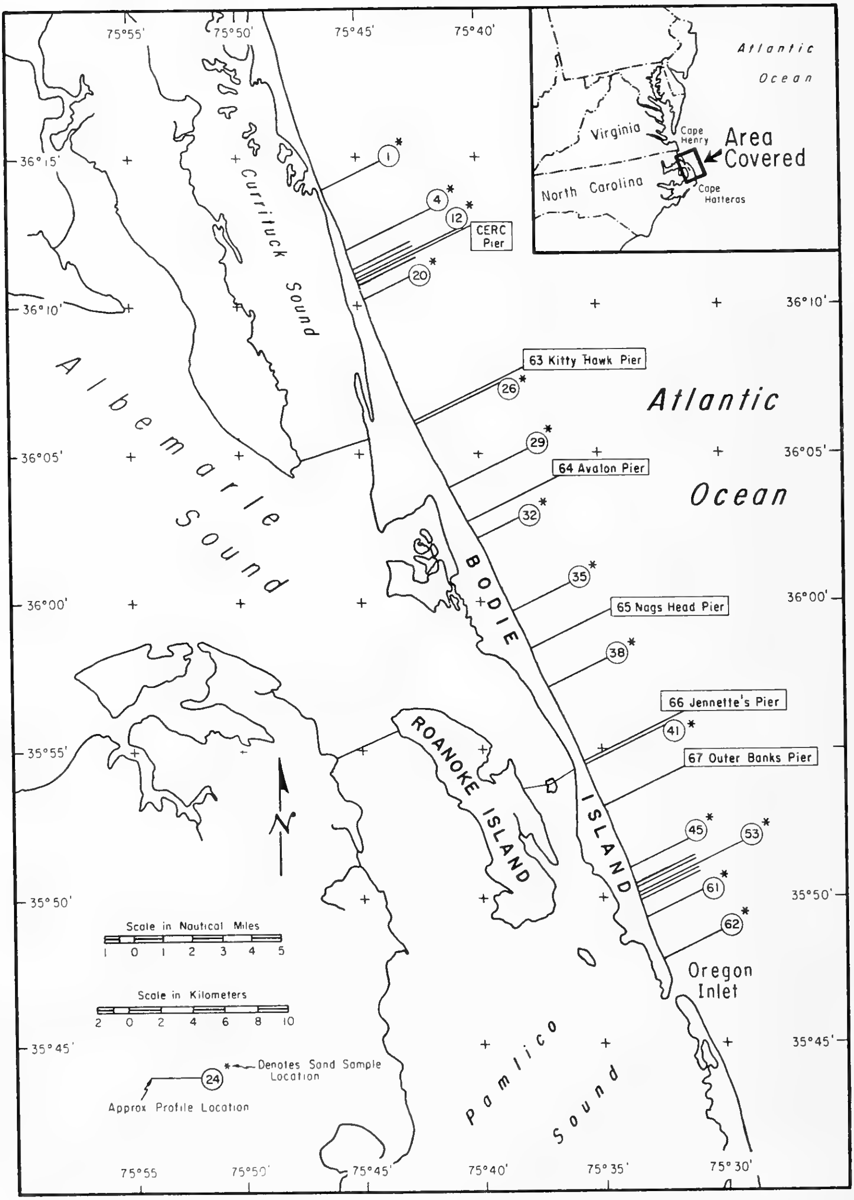


Figure 42. Location of sand sample profile lines.

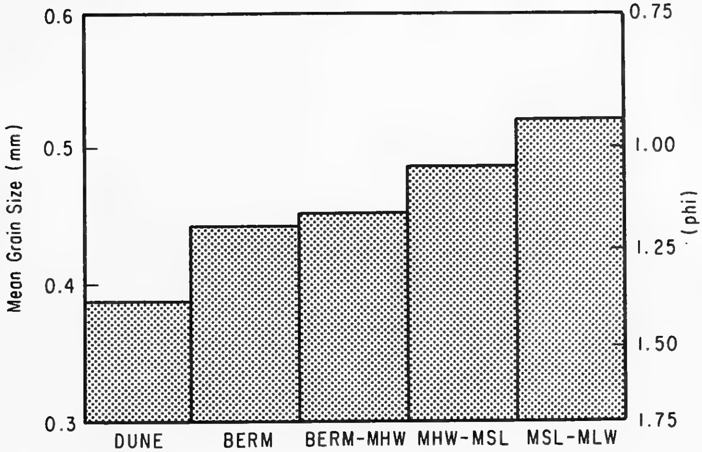


Figure 43. Average mean grain size (all samples) by profile position.

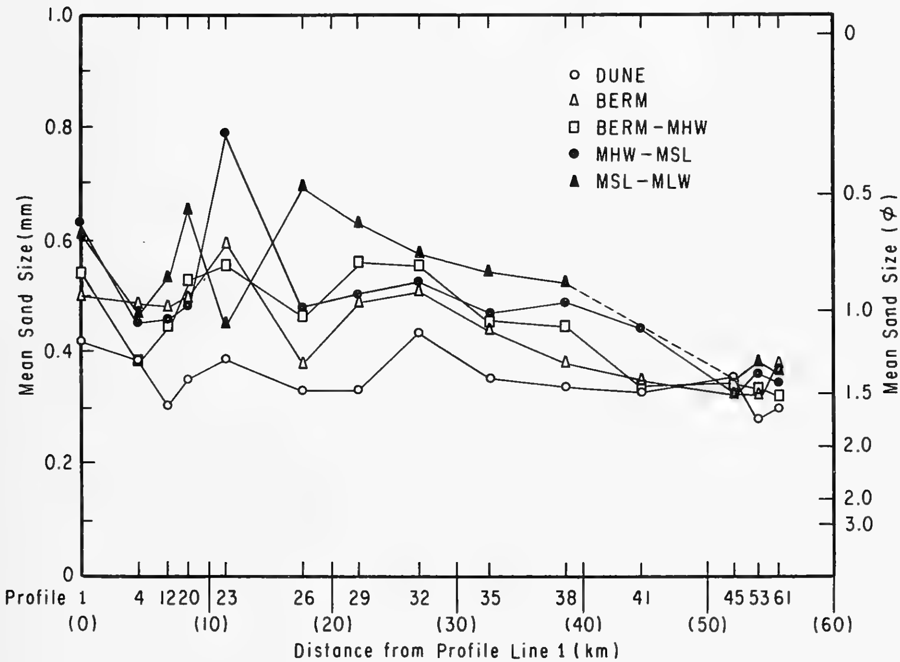


Figure 44. Alongshore variation in mean grain size by profile position.

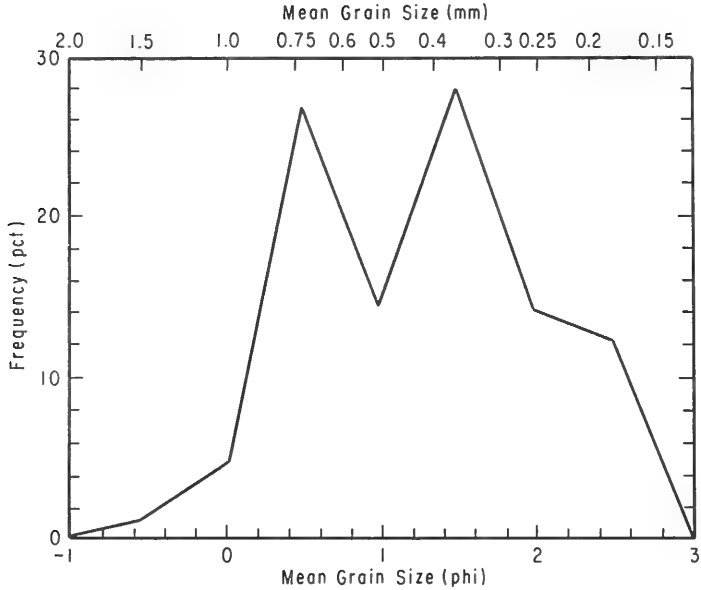


Figure 45. Example of bimodal foreshore sand-size distribution, collected at profile line 20 on 7 May 1976 (elevation +0.2 meter MSL).

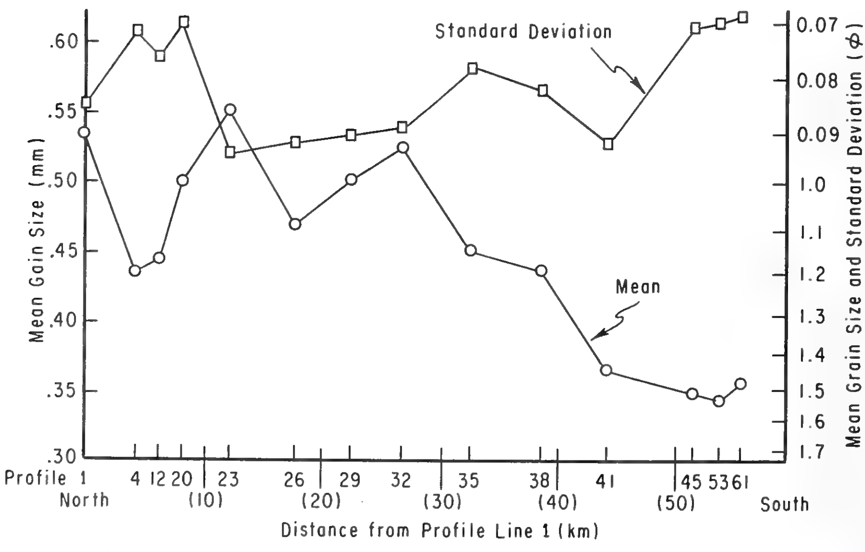


Figure 46. Alongshore variation in average mean grain size and standard deviation.

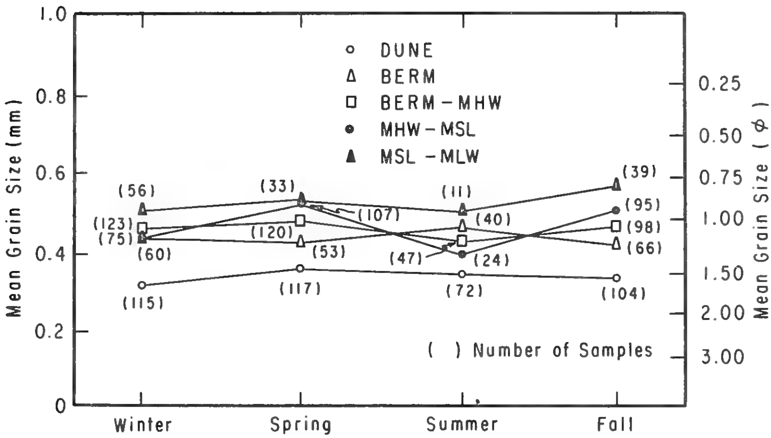


Figure 47. Mean grain size averaged by season and profile position.

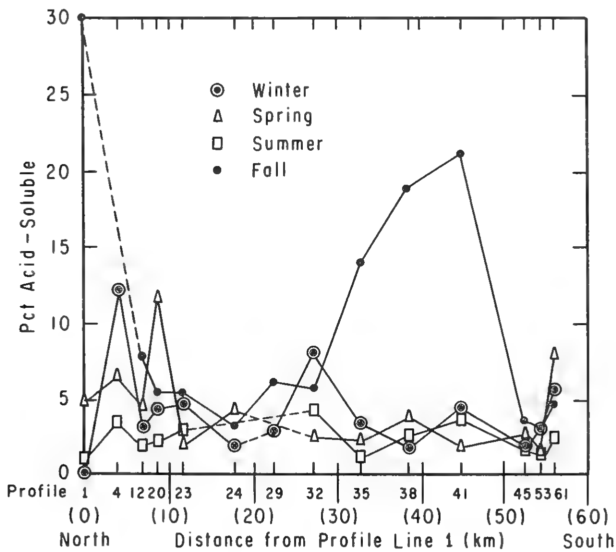


Figure 48. Carbonate percentage in foreshore samples by season.

Foreshore slope was determined at the same time each sample set was taken. Figure 49 shows the strong positive correlation coefficient (r = 0.88) between the average mean grain size and the average foreshore slope for each of the 15 profile lines; Figure 50 shows the decrease in average foreshore slope from north to south.

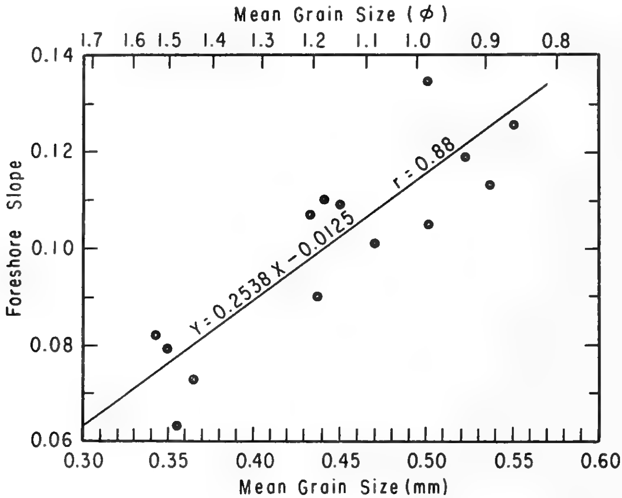


Figure 49. Average foreshore slope versus average mean grain size.

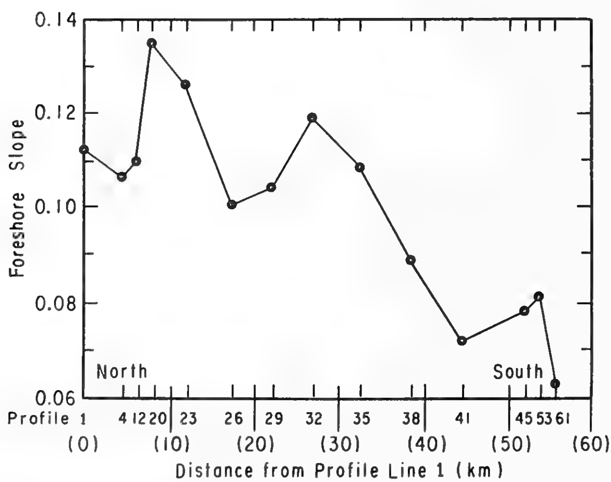


Figure 50. Alongshore variation in average foreshore slope.

The north-to-south decrease in mean grain size confirms earlier findings by Swift, et al. (1971) and Shideler (1973). A downdrift decrease in sand size has been noted at other localities along the east coast (e.g., Ramsey and Galvin, 1977). The coarse sand along the northern section of the study area is characterized by a bimodal-size distribution. The northward-coarsening trend does not continue northward of the study area (Goldsmith, Sturm, and Thomas, 1977), but appears to be localized between Caffey's Inlet and the vicinity of Duck. Swift, et al. (1971) attributed this coarse anomaly to a local source of gravel which is excavated from the former Albemarle River channel.

b. Nearshore Sediments. In August 1979 scuba divers collected a set of 35 short-core sediment samples on three shore-normal transects--along the pier centerline and along parallel lines 75 meters both north and south of the pier centerline. The results of the settling tube (RSA) analysis of these samples are plotted as box plots in Figure 51. Each sample is plotted relative to its distance (in meters) from the FRF base line, along the shore-normal transect. Values of the 10th, 16th, 25th, 50th (median), 75th, 84th, and 90th percentiles of the cumulative size distribution are also plotted for each sample. Sample depths, as determined by lead-line soundings and corrected to MSL elevations, are plotted for each transect. The statistics are summarized in Table 11.

According to Folk's (1965) classification, the bottom material is generally moderately well sorted, medium to fine sand. Median grain size ranges from 0.28 to 0.12 millimeter (1.85 to 3.11 phi) with sorting values ranging between 0.74 and 0.40 millimeter (0.44 and 1.31 phi) (Table 11). A zone of sandy silt is encountered at 13- to 15-meter (45 to 49 feet) depths. No gravel was directly observed, although one sample (Table 11, transect I,13) taken 43 meters (140 feet) directly seaward of the pier end did contain a secondary mode in the 1.4- to 1.0-millimeter (-0.5 to 0 phi) size fraction (very coarse sand).

The bottom was generally observed to be rippled, except in the surf zone where ripples were wiped out by surging breakers. Ripples were generally shore parallel with wavelengths ranging from 4 to 12 centimeters (1.5 to 5 inches) and heights from 1 to 4 centimeters (0.4 to 1.5 inches). At a 2.9-meter water depth megaripples were observed to be the primary bed form with smaller ripples superimposed. Megaripple wavelength was 2 meters (6.5 feet); height was 15 centimeters (6 inches).

c. Subbottom Sediments. Field (1973) summarized the results of a subbottom geophysical survey conducted at the site in 1972-73. His analysis of four nearshore vibracores and five drill holes (Figs. 52 and 53) showed that the beach is underlain by more than 15 meters of sand at the shoreline, thinning to about 1.5 meters at the 12-meter contour. Sediments vary from coarse sand with gravel layers to dense, poorly graded (well-sorted), fine sand. Alternating silts, clays, and silty sands are common below this sand prism. Geophysical records show a nearly horizontal reflector (layer) at -12 meters MSL nearshore that appears to intersect the bottom and become exposed at about -14 meters MSL. The depth of this major reflector was found to correlate with the change from sand with gravel layers to silts and clays noted in the core logs (Fig. 53). The surface samples and visual observations discussed above confirm an outcrop of the silt layer at -13 to -15 meters MSL. Detailed core logs and geophysical records are on file at CERC.

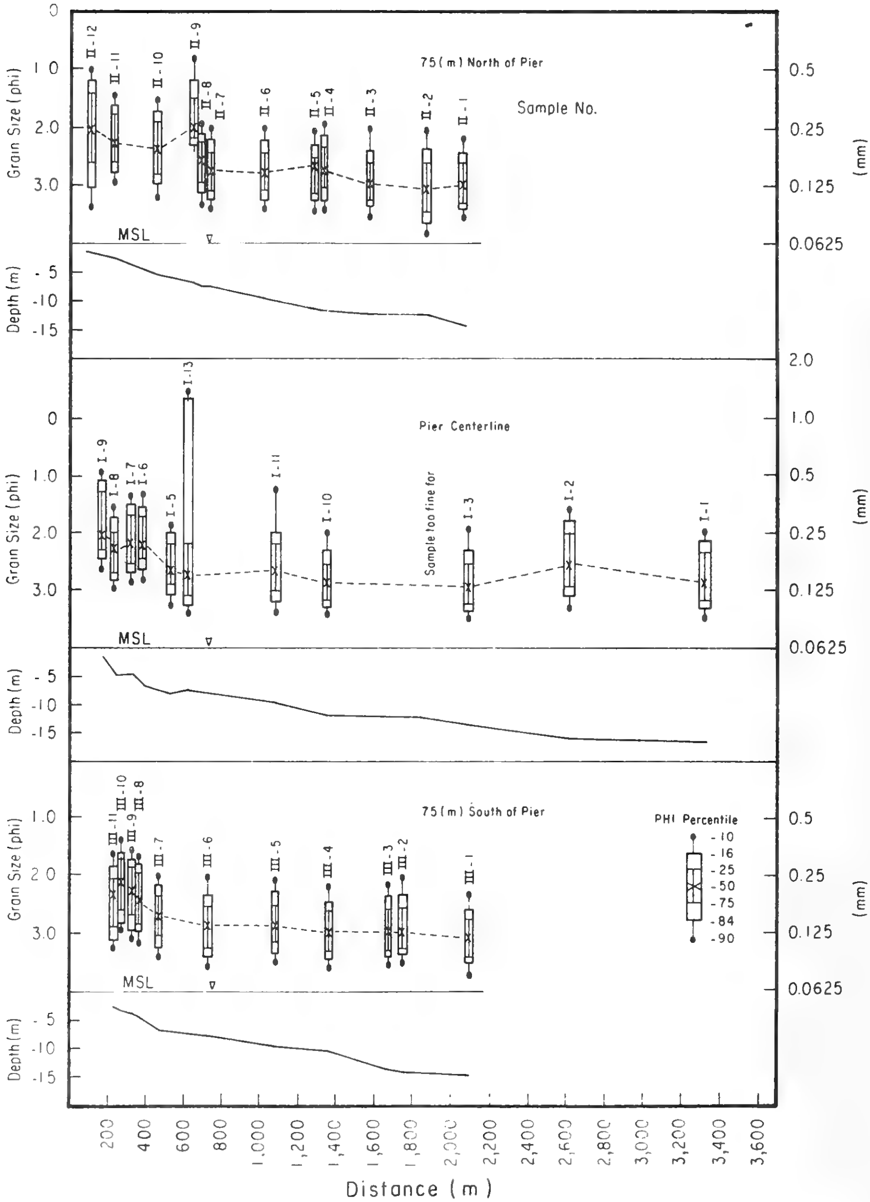


Figure 51. Size distributions of sediment cores collected along three transects near the FRF, 7 to 9 August 1979.

Table 11. FRF offshore sand samples, 7 to 9 August 1979.

Sample No.	MSL depth (m)	Mean grain size (phi)	Mean grain size (mm)	Median grain size (phi)	Median grain size (mm)	Std. dev. (phi)	Distance from base line (m)
TRANSECT I (pier centerline)							
1	16.4	2.76	0.15	2.86	0.14	0.51	3,341
2	15.8	2.48	0.18	2.55	0.17	0.59	2,610
3	13.7	2.83	0.14	2.95	0.13	0.56	2,085
4	11.99	----[1]	----	----	----	----	1,838
5	8.1	2.47	0.18	2.62	0.16	0.64	550
6	6.5	2.05	0.24	2.18	0.22	0.63	410
7	4.7	2.03	0.24	2.16	0.22	0.70	350
8	4.7	2.31	0.20	2.39	0.19	0.48	250
9	1.4	1.80	0.29	1.89	0.27	0.66	210
10	11.3	2.77	0.15	2.87	0.14	0.54	1,366
11	9.40	2.47	0.18	2.67	0.16	0.83	1,093
13	7.30	2.27	0.21	2.74	0.15	1.31	640
TRANSECT II (75 meters north of centerline)							
1	14.5	2.96	0.13	3.01	0.12	0.44	2,090
2	12.7	2.97	0.13	3.08	0.12	0.70	1,890
3	12.2	2.83	0.14	2.96	0.13	0.62	1,647
4	11.7	2.64	0.16	2.75	0.15	0.58	1,361
5	11.4	2.77	0.15	2.85	0.14	0.51	1,340
6	9.8	2.71	0.15	2.79	0.14	0.55	1,085
7	7.6	2.69	0.15	2.77	0.15	0.57	787
8	7.6	2.60	0.16	2.61	0.16	0.46	736
9	6.9	1.79	0.29	1.97	0.26	0.61	704
10	5.3	2.32	0.20	2.37	0.19	0.64	497
11	2.7	2.14	0.23	2.24	0.21	0.63	283
12	1.5	2.03	0.24	2.01	0.25	0.91	159
TRANSECT III (75 meters south of centerline)							
1	14.7	2.99	0.13	3.11	0.12	0.62	2,090
2	14.1	2.78	0.15	2.93	0.13	0.76	1,750
3	13.6	2.89	0.13	2.98	0.13	0.58	1,675
4	10.4	2.86	0.14	2.94	0.13	0.64	1,370
5	9.6	2.80	0.14	2.86	0.14	0.47	1,088
6	7.8	2.86	0.14	2.87	0.14	0.50	743
7	6.5	2.68	0.16	2.70	0.15	0.54	491
8	4.1	2.44	0.18	2.45	0.18	0.51	379
9	3.8	2.26	0.21	2.29	0.20	0.55	343
10	3.0	2.15	0.23	2.13	0.23	0.59	275
11	2.5	2.46	0.18	2.41	0.19	0.61	251

[1]Too fine for RSA.

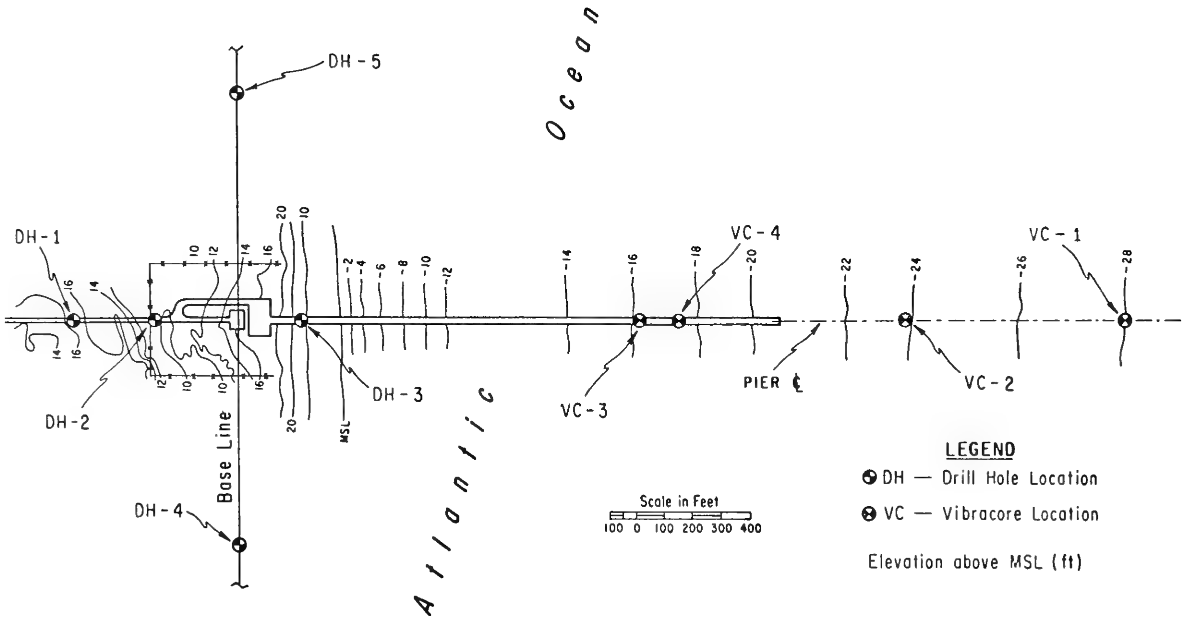


Figure 52. Location of drill holes and vibracores.

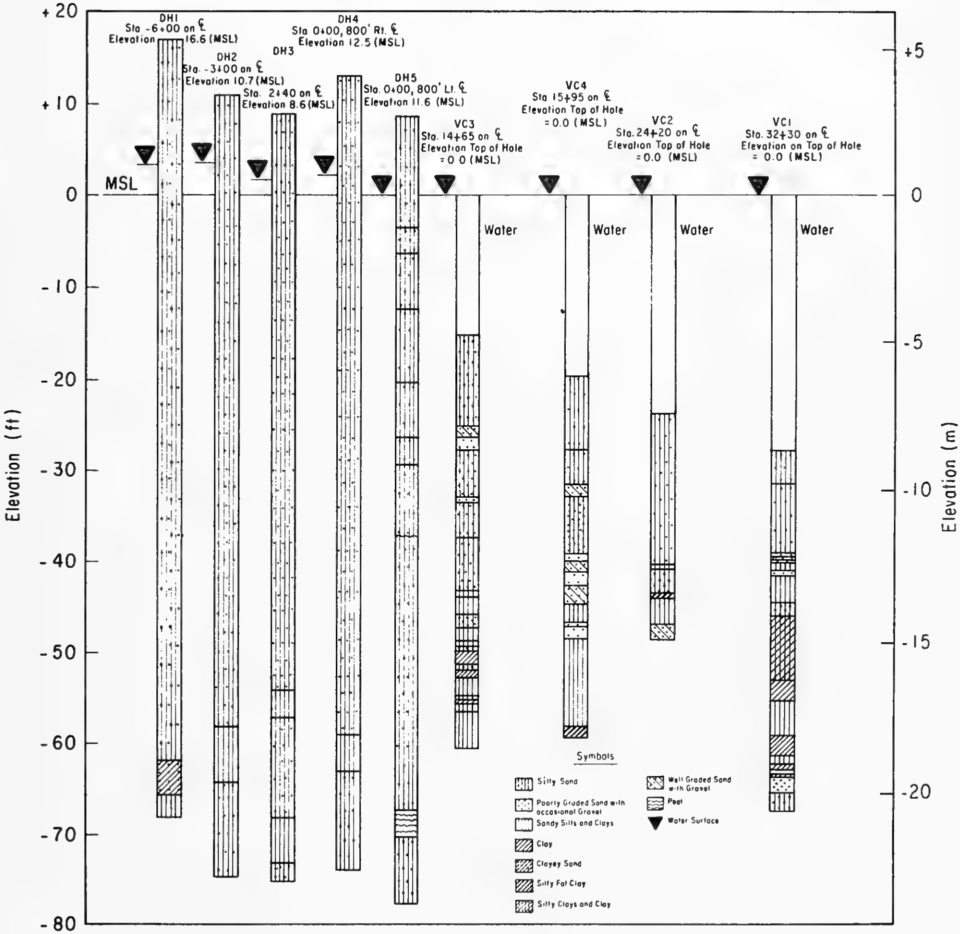


Figure 53. Summary of drill hole and vibracore logs.

VI. ECOLOGY OF THE FRF SITE

The mid-1600 settlement of the Outer Banks drastically changed the vegetation and topography of the region. Forests were diminished for fuel and building, and grass and shrubs were uprooted by grazing livestock which continued into the beginning of the 1900's. Once vegetation was disrupted the sandy soils became susceptible to movement by wind and storm tides. The blowouts and sand dunes seen today are results of these forces.

In 1935 the Works Progress Administration and the Civilian Conservation Corps began stabilizing the foredune from the Virginia border to approximately the middle of Ocracoke Island. Some of these foredunes now exceed 8 meters in height. The ocean beach, foredunes, arborescent (tree- and shrub-dominated) and sound-side marsh zones are the most characteristic features of the Outer Banks profile (Levy, 1976). The most variable zone is between the foredune and the arborescent zone. This is particularly evident at the FRF site.

1. Vegetation.

Levy (1976) conducted a complete vegetation study of the FRF site. A vegetation map of 11 different communities in the area is shown in Figure 54. Permanent plots were located in each of the designated communities. The results of the study showed the flora to be composed of about 178 species and 132 genera representing 58 families (App. E). Six of the plant communities correlate with the communities generally common to the Outer Banks: foredunes, wetlands, oceanside shrub, sound-side shrub, low dune grass, and bare sand. The remaining five communities are relatively unique to this site: sound-side disturbed, planted American beachgrass (*Ammophila breviligulata*), planted bitter panicum (*Panicum amorulum*), sandgrass-buttonweed (*Triplasis purpurea-Diodia teres*), and spurge-sandgrass (*Euphorbia polygonifolia-Triplasis purpurea*).

In September 1978, CERC reestablished approximately two-thirds of the previous plots, which could be located, and added more. Plant species were collected and identified, and the vegetation was mapped for comparison with aerial photos at scales of 1:2000 to 1:34000. Optimum scales for identifying vegetative species, associations, communities, and zones were also determined in the comparison.

a. Dune Vegetation. In April 1972, before CERC obtained the FRF site, the U.S. Navy sprigged the area with American beachgrass. In 1973 and 1974, North Carolina State University conducted experiments on propagation, handling, processing, and planting of bitter panicum, American beachgrass, and sea oats (*Uniola paniculata*) in the northern part of the site about 300 meters inland. By the fall of 1974, bitter panicum was the most successfully established. Fertilizer applications were necessary to retain the vigor of the planted stands. The results of this study were reported by Seneca, Woodhouse, and Broome (1976). Although the actual plantings are no longer clearly delineated, the general area is still identifiable from the air (see Fig. 4).

b. Marsh Vegetation. Experimental marsh plantings were established between April and September 1973 on the sound-side shore of the site to

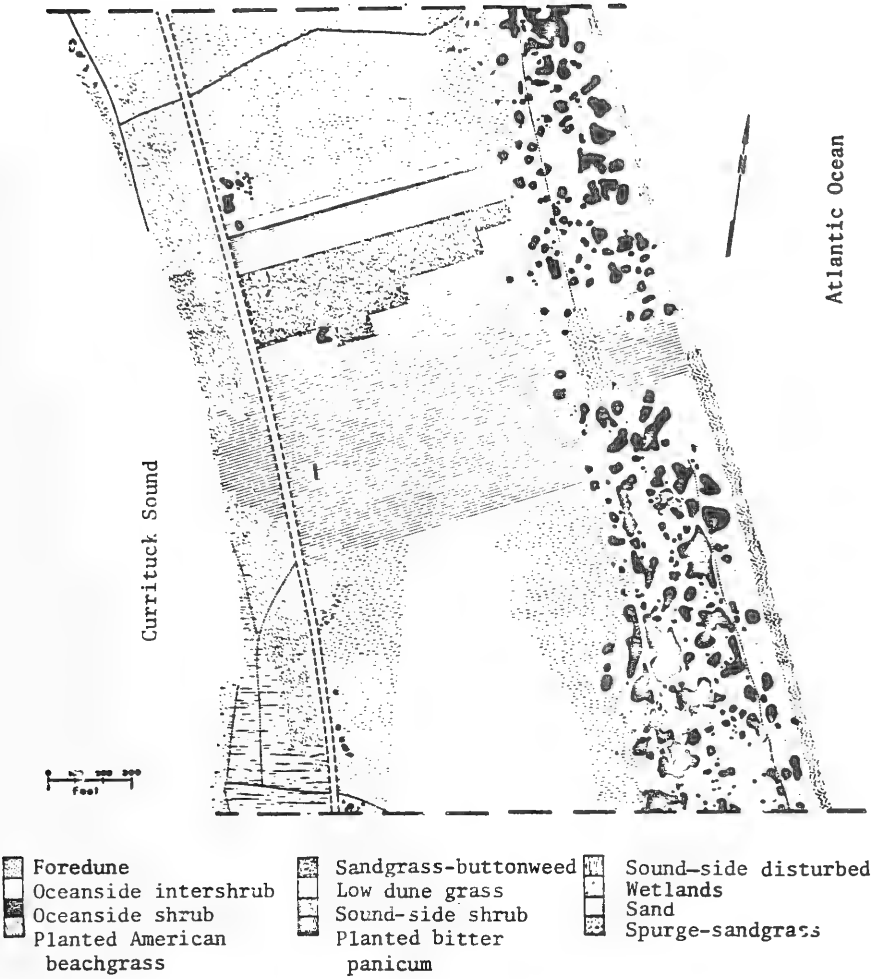


Figure 54. Vegetation map of the FRF (Levy, 1976).

stabilize the eroding shore (Fig. 55): a nursery area to the south and an unplanted control area to the north. Four species were planted: smooth cordgrass (*Spartina alterniflora*), black needlerush (*Junus roemerianus*), narrow- and broad-leaved cattails (*Typha* spp.), and common reed (*Phragmites australis*). Plant density and dry weight for the marsh were determined in June and October 1979. The results of this experiment show that the optimum planting time is April, May, and June. CERC, in conjunction with the Soil Conservation Service (SCS), has planted 10 species of freshwater marsh plants on the sound side to determine their erosion control potential, and 11 accessions of saltmeadow cordgrass (*Spartina patens*) in the dunes to determine those most suited for dune stabilization in the Outer Banks area.

Figure 55. Experimental marsh in Currituck Sound before planting (April 1973).

Profile lines in the marsh were surveyed in 1973, 1978, and 1979. Between September 1973 and September 1978, the 1- to 1.5-meter bank eroded at a rate of about 1.5 meters per year. Between 1978 and 1979, 1.06 cubic meters per meter of sediment began to accrue in the planting area, while the unplanted area eroded -1.68 cubic meters per meter. The marsh is now well established (Fig. 56). Many new species, mostly freshwater species, have invaded the marsh as the salinity is negligible, varying between 1 and 5 parts per thousand. Sediments in the sound are composed of medium sand.

2. Fauna Studies.

Matta (1977) conducted an intensive seasonal study of the FRF ocean and sound beach fauna. On the ocean beach, 23 species of macrofauna in 5 phyla and 19 families were collected (see App. E); all but four of these species were polychaetes or crustaceans. Several types of meiofauna were also quantitated but were not identified to the species level. On the sound beach 23 species of macrofauna in 4 phyla and 23 families were collected (see App. E), with the phylum Arthropoda dominating the macrofauna, the phylum Annellida the most numerous.

Figure 56. Experimental marsh in September 1975.

The land fauna were surveyed over a period of a year from August 1975 to September 1976 (Gorbics and Hurme, 1978). Identification was made on the basis of tracks, scats, visual observation, and trapping. Thirteen different species were documented; however, the study was not intensive enough to provide a complete fauna list.

For further information concerning ecological studies at the FRF, contact:

U.S. Army Coastal Engineering Research Center
ATTN: Chief, Coastal Ecology Branch
Kingman Building
Fort Belvoir, VA 22060

VII. OTHER AVAILABLE DATA

This section provides lists of some of the data available for the FRF, including aerial photography (Table 12), LEO data (Table 13), beach survey data (Table 14), and ecological data (Table 15). Refer to Table 3 for information about available data from sensors located on the FRF pier.

Table 12. Duck aerial photography.

Date	Format	Scale	Source	Project
21 Oct. 1940	B & W 9" × 9"	1:24,000	USGS	Barrier Reefs, N.C. coast (F9885)
29 Mar. 1955	B & W 9" × 9"	1:20,000	NOAA	55W
5 Dec. 1958	B & W 9" × 9"	1:20,000	ASCS	AOL
13 Mar. 1962	B & W 9" × 9"	1:5,000	USGS	MATS 62-1
3 May 1962	B & W 9" × 9"	1:20,000	USGS	MATS 62-1/MISS-77
25 June 1963	B & W 9" × 9"	1:5,000	NOAA	62 W
Aug. 1971	B & W 9" × 9"	1:12,000	CERC	
1 Nov. 1971	B & W 9" × 9"	1:12,000	CERC	VT33TRTS013-UNC
6 Nov. 1972	B & W 9" × 9"	1:12,000	CERC	VT33TRTS090-AGMU
30 Jan. 1973	B & W 9" × 9"	1:130,000	NASA	73-013C
13 Feb. 1973	Color IR 9" × 9"	1:12,000	CERC	
Sept. 1973	B & W 9" × 9"		CERC	
2 Feb. 1977	Color/ color IR 9" × 9"	Varies	CERC	Quarterly
29 July 1977	Color 9" × 9"	1:6,000/ 1:12,000	CERC	Quarterly
10 Aug. 1977	Color 9" × 9"	1:6,000	CERC	Quarterly
11 Nov. 1977	Color 9" × 9"	Varies	CERC	Quarterly
8 Feb. 1978	Color 9" × 9"	Varies	CERC	Quarterly
16 May 1978	B & W 9" × 9"	1:2,000/ 1:6,000/ 1:12,000	CERC	Quarterly
12 Sept. 1978	Color/ color IR 9" × 9"	Varies	CERC	Duck-X flight
13 Sept. 1978	B & W 9" × 9"	1:12,000	CERC	Duck-X flight
18 Oct. 1978	B & W 9" × 9"	1:12,000	CERC	Quarterly
2 Dec. 1978	B & W 9" × 9"	1:12,000	CERC	Quarterly
21 Apr. 1979	B & W/ color IR 9" × 9"	1:6,000/ 1:12,000	CERC	Quarterly
20 Sept. 1979	B & W/ color IR 9" × 9"	1:6,000/ 1:12,000	CERC	Quarterly
15 Oct. 1979	B & W 9" × 9"	1:12,000	CERC	Quarterly
25 Oct. 1979	B & W/ color IR 9" × 9"	1:6,000/ 1:12,000	CERC	SEAP
16 Jan. 1980	B & W/ color IR 9" × 9"	1:6,000/ 1:12,000	CERC	Quarterly
3 Mar. 1980	Color 9" × 9"	1:12,000	SAW	Poststorm
15 Apr. 1980	B & W/ color 9" × 9"	1:6,000/ 1:12,000	CERC	Quarterly
15 July 1980	B & W 9" × 9"	1:6,000/ 1:12,000	CERC	Quarterly
15 Oct. 1980	B & W 5" × 5"	1:12,000	CERC	Quarterly
24 Mar. 1981	Color 9" × 9"	1:12,000	CERC	Quarterly

Table 13. Summary of visual Littoral Environment Observations (LEO).

Year	No. per month											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Sea Crest (see Fig. 1)												
1972							36	29	30	34	49	43
1973	33	37	59	29	57	25	43	35	34	54	27	11
1974	27	29	26	12	27	26	30	9	15	30	25	16
1975	22	24	30	12	21	27	16	19	26	19	26	24
1976	30		31	29	26	29	25	16	22	30	24	11
1977	31	4	9	11	26	28	30	30	29	14	7	4
1978	20	27	14	18	11	17	11			21		15
1979	13	5	18	12					3	24	16	7
Avalon pier (see Fig. 11)												
1973										8	60	52
1974	60	56	62	60	55	57	62	62	59	62	4	40
1975	62	56	61	60	62	60	62	61	60	60	60	62
1976	62	58	61	60	62	61	61	56	80	62	60	54
1977		18	62	28	34	63	62	62	58	63	48	31
1978	31	28	31	31	31	30	31	31				
1979	31	29	30	16								
FRF pier end												
1977							6	25	16	16	16	21
1978	18	18	22	16	17	22	19	20	20	22	20	20
1979	22	16	25	21	21	18	21	23	19	21	19	31
1980	28	28	29	30	31	30	30	31	21	24	19	21
1981	25	25	31	30	28							
FRF beach												
1977							4	23	9	11	16	21
1978	21	18	21	18	20	18	19	20	21	20	18	19
1979	23	16	20	19	20	18	21	22	19	21	18	16
1980	28	28	30	30	31	29	29	30	22	23	19	19
1981	25	25	31	30	28							

Table 14. Beach profile survey and sand sampling dates (for the profile lines and piers shown in Fig. 11).

Survey No.	Date	Task code[1]	Survey No.	Date	Task code[1]	Survey No.	Date	Task code[1]	Survey No.	Date	Task code[1]
1	7 May 74	2	36	7 Feb. 75	1, 2	72	12 Sept. 75	1, 2	109	2 May 76	1, 2
2	3 June 74		37	8 Feb. 75	1, 2	73	13 Sept. 75	1, 2	110	3 May 76	1, 2
3	1 July 74		38	9 Feb. 75	1, 2	74	14 Sept. 75	1, 2	111	4 May 76	1, 2
4	6 Aug. 74		39	10 Feb. 75	1, 2	75	15 Sept. 75	1, 2	112	5 May 76	1, 2
5	12 Aug. 74		40	11 Feb. 75	1, 2	76	16 Sept. 75	1, 2	113	6 May 76	1, 2
6	19 Aug. 74		41	12 Feb. 75	1, 2	77	17 Sept. 75	1, 2	114	7 May 76	1, 2
7	16 Aug. 74		42	13 Feb. 75	1, 2	78	18 Sept. 75	1, 2	115	8 May 76	1, 2
8	3 Sept. 74	2	43	14 Feb. 75	1, 2	79	19 Sept. 75	1, 2	116	9 May 76	1, 2
9	9 Sept. 74		44	15 Feb. 75	1, 2	80	20 Sept. 75	1, 2	117	10 May 76	1, 2
10	16 Sept. 74		45	16 Feb. 75	1, 2	81	21 Sept. 75	1, 2	118	11 May 76	1, 2
11	23 Sept. 74		46	17 Feb. 75	1, 2	82	22 Sept. 75	1, 2	119	12 May 76	1, 2
12	30 Sept. 74		47	18 Feb. 75	1, 2	83	23 Sept. 75	1, 2	120	13 May 76	1, 2
13	7 Oct. 74		49	3 Mar. 75		84	24 Sept. 75	1, 2	121	14 May 76	1, 2
14	4 Nov. 74		50	15 Mar. 75		85	25 Sept. 75	1, 2	122	15 May 76	1, 2
15	3 Dec. 74		51	19 Mar. 75		86	26 Sept. 75	1, 2	123	16 May 76	1, 2
16	17 Jan. 74		52	31 Mar. 75	2	87	27 Sept. 75	1, 2	124	17 May 76	1, 2
17	6 Jan. 75	2	53	28 Apr. 75		89	28 Oct. 75	2	125	18 May 76	1, 2
18	20 Jan. 75	1, 2	54	2 June 75		90	10 Nov. 75		126	19 May 76	1, 2
19	21 Jan. 75	1, 2	55	2 July 75		91	26 Nov. 75	2	127	20 May 76	1, 2
20	22 Jan. 75	1, 2	56	14 July 75	2	92	5 Jan. 76	2	128	21 May 76	1, 2
21	23 Jan. 75	1, 2	57	11 Aug. 75		93	10 Feb. 76		129	8 June 76	
22	24 Jan. 75	1, 2	58	29 Aug. 75	1, 2	95	11 Mar. 76		130	7 July 76	2
23	25 Jan. 75	1, 2	59	30 Aug. 75	1, 2	96	6 Apr. 76	2	131	2 Aug. 76	
24	26 Jan. 75	1, 2	60	31 Aug. 75	1, 2	97	11 Apr. 76		132	4 Aug. 76	
25	27 Jan. 75	1, 2	61	1 Sept. 75	1, 2	98	21 Apr. 76	1, 2	133	10 Aug. 76	
26	28 Jan. 75	1, 2	62	2 Sept. 75	1, 2	99	22 Apr. 76	1, 2	134	31 Aug. 76	
27	29 Jan. 75	1, 2	63	3 Sept. 75	1, 2	100	23 Apr. 76	1, 2	135	27 Sept. 76	2
28	30 Jan. 75	1, 2	64	4 Sept. 75	1, 2	101	24 Apr. 76	1, 2	136	1 Nov. 76	
29	31 Jan. 75	1, 2	65	5 Sept. 75	1, 2	102	25 Apr. 76	1, 2	137	30 Nov. 76	
30	1 Feb. 75	1, 2	66	6 Sept. 75	1, 2	103	26 Apr. 76	1, 2	138	15 Dec. 76	
31	2 Feb. 75	1, 2	67	7 Sept. 75	1, 2	104	27 Apr. 76	1, 2	139	5 Jan. 77	2
32	3 Feb. 75	1, 2	68	8 Sept. 75	1, 2	105	28 Apr. 76	1, 2	140	11 Jan. 77	
33	4 Feb. 75	1, 2	69	9 Sept. 75	1, 2	106	29 Apr. 76	1, 2	141	24 Jan. 77	
34	5 Feb. 75	1, 2	70	10 Sept. 75	1, 2	107	30 Apr. 76	1, 2			
35	6 Feb. 75	1, 2	71	11 Sept. 75	1, 2	108	1 May 76	1, 2			

[1] Blank indicates monthly or weekly surveys of all profiles; 1, daily surveys of profiles 4-20 only; 2, sand sample taken.

Table 15. Ecological data for FRF.

Data	Survey dates	Remarks
1. Sound-side marsh and control area profile lines	Sept. 1973, Sept. 1978, May 1979, Oct. 1979, Apr. 1980, July 1980, Sept. 1980, May 1981-July 1981, Nov. 1981	See Section VI,1,b for preliminary results
2. Currituck sound profiles (nine profile lines located every 51.8 meters (170 feet) along sound shore)	June 1979, May 1980	Lines are labeled "CS" in Figure 10
3. Herbarium specimens (collection of plant species)	Plant study (Levy, 1976)	Available at CERC Coastal Ecology Branch
4. Beach fauna reference collection	Fauna study (Matta, 1977)	Available at CERC Coastal Ecology Branch

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- Atlases
- Beach Processes
- Bibliographies
- Ecology
- Geology
- Hydraulics
- Inlets
- Miscellaneous
- Sediments
- Shoreline Changes

Because some of these topics overlap (e.g., Beach Processes and Shoreline Changes) and citations are not cross referenced, the references under all pertinent topics should be checked.

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APPENDIX A

EXAMPLE OF LIABILITY RELEASE

Safety and Liability Statement

I, ______________________________, representing ______________________________
(printed name) (agency/organization)
______________________________ have been briefed on the safety aspects of my work at the Field Research Facility, Duck, North Carolina. I have also read and understand the safety regulations concerning work on and around the pier.

I agree to hold the Government harmless against any claims, demands, or liabilities arising out of the use or operation of the facility during the following term of the experiment or study: _______________ to _______________.
(date) (date)

____
(signature)

____
(date)

CERC FORM 134
1 August 1978

APPENDIX B

DIVE PLAN

Nongovernment Diving Operations Plan
Field Research Facility
Duck, North Carolina

1. Description of Mission:

a. Diving operations are scheduled to be conducted from ______________ to ______________ at the Field Research Facility (FRF), Duck, North Carolina.

b. The diving operation is being conducted by personnel from

____
(organization)

c. Briefly describe purpose of operation.

____
____
____

d. Describe in detail proposed underwater work.

____
____
____
____
____
____
____
____
____
____

e. Describe location of operation (if available include any coordinates, transit angles, etc.) in relation to the pier.

____
____
____

f. If equipment is to be left in place, provide a diagram on a separate page of the general layout including distances, instrumentation, handlines, pipes, buoys, etc.

g. Total expected bottom time for each diver for entire operation is ______ hours.

h. Maximum expected depth is ________ feet.

2. Description of Diving Apparatus/Equipment to be Used.

a. Open-circuit scuba, SAS, other (describe).

____

____

b. Wet suit, unisuit.

c. Tanks.

(1) Single - double.

(2) Steel - aluminum.

(3) Number being brought to FRF ___________.

d. Diving craft or platform.

(1) Craft.

(a) Make ________________.

(b) Length _________________.

(c) Outboard hp _________________.

(d) Number of personnel (including divers) to accompany craft ____.

(2) If craft is not being used, briefly describe

(a) Means by which divers will enter and exit the water.

(b) Approximate distance from entry and exit point(s) to dive location.

3. Safety Requirements.

a. Diving.

(1) A standard diving flag will be displayed when diving operations are underway.

(2) All dives will be no-decompression dives.

(3) The minimum number of personnel on a scuba dive team will include: a diver, a buddy diver or standby diver (if diver is line tended) and a tender/timekeeper.

(4) Divers will maintain either visual or physical contact when submerged.

(5) A buoyancy compensator will be worn by each diver.

(6) Dives will not be made when steady currents exceed 1 knot.

(7) All dives will be accomplished in accordance with OSHA Commercial Diving Regulation, Part 1910, Subpart T.

b. One diver in each dive team will be designated as the "senior diver" with the following responsibilities:

(1) Maintain a first aid kit.

(2) Notify the FRF Chief when diving operations are underway and when they are secured.

(3) Insure that emergency support and facilities are available prior to commencement of dive.

(4) Give an operations briefing to all divers prior to the start of operations.

(5) Conduct a pre-dive check on divers prior to entering the water.

c. Diving craft.

(1) Breaking waves 4 feet or higher will preclude launching of craft through the surf zone.

(2) Normal safe boating practices will be followed.

4. Personnel.

Position	Name	Certification (type and date) divers only
Onsite supervisor (if other than senior diver)	____________	____________
Senior diver	____________	____________
Divers	____________	____________
	____________	____________
	____________	____________
Support personnel	____________	____________
	____________	____________
	____________	____________
	____________	____________

Place an asterisk (*) beside any personnel who are first aid and/or CPR qualified.

If for any reason the dive plan, as approved, is altered in mission, depth, personnel or equipment, the FRF Group Diving Coordinator shall be contacted in order that he may review any revision prior to actual operations.

SUBMITTED BY: ______________________________ ______________________
name (please print) date

____

ADDRESS: ______________________________
____
____

PHONE NO: ______________________________

RECOMMENDED FOR APPROVAL:

______________________________ ______________________
FRF Group Diving Coordinator date

APPROVED: ______________________________ ______________________
Chief, Field Research Facility date

BENCH-MARK DOCUMENTATION FORM

COUNTRY	TYPE OF MARK	STATION	
LOCALITY	STAMPING ON MARK	AGENCY (CAST IN MARKS)	ELEVATION (FT) (M)
LATITUDE	LONGITUDE	DATUM	DATUM
(NORTHING)(EASTING) (FT) (M)	(EASTING)(NORTHING) (FT) (M)	GRID AND ZONE	ESTABLISHED BY (AGENCY)
(NORTHING)(EASTING) (FT) (M)	(EASTING)(NORTHING) (FT) (M)	GRID AND ZONE	DATE / ORDER

TO OBTAIN GRID AZIMUTH, ADD ° ' " TO THE GEODETIC AZIMUTH

TO OBTAIN GRID AZ. (ADD)(SUB.) ° ' " TO THE GEODETIC AZIMUTH

OBJECT	AZIMUTH OR DIRECTION (GEODETIC)(GRID) (MAGNETIC)	BACK AZIMUTH	GEOD. DISTANCE (METERS) (FEET)	GRID DISTANCE (METERS) (FEET)
	° ' "	° ' "		

N

SKETCH

DA FORM 1959, 1 OCT 64. REPLACES DA FORMS 1959 AND 1960, 1 FEB 57, WHICH ARE OBSOLETE.

DESCRIPTION OR RECOVERY OF HORIZONTAL CONTROL STATION

For use of this form, see TM 5-237; the proponent agency is U.S.Continental Army Command.

APPENDIX D

MONTHLY JOINT WAVE HEIGHT-PERIOD DISTRIBUTIONS

WAVE CLIMATOLOGY FOR NAGS HEAD, NORTH CAROLINA
DISTRIBUTION OF SIGNIFICANT HEIGHT VS PERIOD (IN OBSERVATIONS PER 1000 OBS)
573 OBSERVATIONS SUMMARY FOR JAN 72, 73, 75, 77, 78

PERIOD (SECS) / SIG. HEIGHT (FT)

PERIOD (SECS)	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13 +	TOT.*	CUM. TOT.*	ROW AVG.*
0.0 - .9																1000	0.00
1.0 - 1.9																1000	0.00
2.0 - 2.9		2													2	1000	1.50
3.0 - 3.9		2	7	5	2										16	998	2.94
4.0 - 4.9		10	24	5	2	2									44	983	2.58
5.0 - 5.9		19	33	37	24	7									120	939	3.22
6.0 - 6.9		19	24	45	28	14	3								134	818	3.53
7.0 - 7.9		7	23	12	14	7	7								70	684	3.58
8.0 - 8.9	7	51	70	21	23	21	2								197	614	2.91
9.0 - 9.9		45	23	24	16	2	3	3							117	415	2.90
10.0 -10.9	2	24	26	19	16	5	2		2						96	298	3.08
11.0 -11.9																202	0.00
12.0 -12.9	2	26	40	31	17	10	7	3							138	202	3.32
13.0 -13.9																65	0.00
14.0 -14.9	2	21	9	2	2		5	2							42	65	2.75
15.0 -15.9																23	0.00
16.0 -16.9	2	19		2											23	23	1.58
TOTAL	14	246	279	204	143	58	30	9	2								3.10
CUM. TOTAL	1000	986	740	461	257	108	40	10	2								
COL. AVG.	11.00*	9.78	8.44	8.27	8.29	8.57	10.26	11.70	10.50	0.00	0.00	0.00	0.00	0.00	8.83		

AVERAGE SIG. HEIGHT = 3.07 FT AVERAGE WAVE PERIOD = 8.86 SEC*
VARIANCE OF SIG. HEIGHT = 2.03 FT SQ VARIANCE OF WAVE PERIOD = 8.12 SEC SQ*
STANDARD DEVIATION OF HEIGHT = 1.43 FT STANDARD DEVIATION OF PERIOD = 2.85 SEC*

WAVE CLIMATOLOGY FOR NAGS HEAD, NORTH CAROLINA
DISTRIBUTION OF SIGNIFICANT HEIGHT VS PERIOD (IN OBSERVATIONS PER 1000 OBS)
498 OBSERVATIONS SUMMARY FOR FEB 69, 72, 73, 76, 77

PERIOD (SECS) / SIG. HEIGHT (FT)

PERIOD (SECS)	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13 +	TOT.*	CUM. TOT.*	ROW AVG.*
0.0 - .9																1000	0.00
1.0 - 1.9																1000	0.00
2.0 - 2.9			2												2	1000	2.50
3.0 - 3.9		4	8	8											20	998	2.70
4.0 - 4.9	2	8	6	14											30	978	2.57
5.0 - 5.9	2	16	33	23	22	10	2								119	948	3.26
6.0 - 6.9		10	28	13	33	14	14	4							127	829	4.10
7.0 - 7.9		12	8	10	18	6	2	4							60	702	3.83
8.0 - 8.9	6	62	22	22	15	10	18	4	4						171	641	3.24
9.0 - 9.9	2	56	23	16	2	4		8	2						119	470	2.70
10.0 -10.9	4	36	12	24	8	4	14	2		2					107	351	3.33
11.0 -11.9																244	0.00
12.0 -12.9	4	28	22	14	6	14	14	14							117	244	3.86
13.0 -13.9																127	0.00
14.0 -14.9		36	22	6		2	6	26	2						101	127	3.92
15.0 -15.9																26	0.00
16.0 -16.9		12	2					2	2						18	26	3.06
17.0 -17.9																8	0.00
18.0 -18.9																8	0.00
19.0 -19.9																8	0.00
20.0 -20.9			8												8	8	2.50
21.0 +																	0.00
TOTAL	20	252	214	161	111	65	71	65	10	2							3.43
CUM. TOTAL	1000	980	698	484	323	212	147	77	12	2							
COL. AVG.	9.10*	10.00	9.11	8.06	7.43	8.75	9.70	12.06	11.50	10.50	0.00	0.00	0.00	0.00	9.24		

AVERAGE SIG. HEIGHT = 3.41 FT AVERAGE WAVE PERIOD = 9.26 SEC*
VARIANCE OF SIG. HEIGHT = 3.93 FT SQ VARIANCE OF WAVE PERIOD = 9.93 SEC SQ*
STANDARD DEVIATION OF HEIGHT = 1.98 FT STANDARD DEVIATION OF PERIOD = 3.15 SEC*

RESULTS OBTAINED FROM 1024-SECOND DIGITAL RECORDS TAKEN WITH A STEP RES. AND CONT. WIRE WAVE GAGE LOCATED AT JENNETTES PIER.
* CALMS ARE OMITTED.

WAVE CLIMATOLOGY FOR NAGS HEAD, NORTH CAROLINA
DISTRIBUTION OF SIGNIFICANT HEIGHT VS PERIOD (IN OBSERVATIONS PER 1000 OBS)
705 OBSERVATIONS SUMMARY FOR MAR 69, 72, 73, 75, 76, 77, 78

PERIOD (SECS)	SIG. HEIGHT (FT) 0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13 +	TOT.*	CUM. TOT.*	ROW AVG.*
0.0 - .9																1000	0.00
1.0 - 1.9																1000	0.00
2.0 - 2.9		1													1	1000	1.50
3.0 - 3.9		1	13	6	1										21	999	2.83
4.0 - 4.9	1	6	11	10											28	977	2.55
5.0 - 5.9	1	10	31	35	18	1	1		1						101	949	3.27
6.0 - 6.9		13	18	24	13	11	4		3						87	843	3.71
7.0 - 7.9		11	18	18	16	7	3	3							77	762	3.61
8.0 - 8.9	3	71	57	43	34	10	1	4	1						224	685	2.94
9.0 - 9.9		50	50	23	11	10	3	1	1						155	461	2.83
10.0 -10.9	3	45	38	21	4	7	9		3						130	306	2.89
11.0 -11.9																176	0.00
12.0 -12.9	1	24	17	17	18	7	9	3	3						99	176	3.64
13.0 -13.9																77	0.00
14.0 -14.9	1	16	9	6	3	4	7	3	4						52	77	3.91
15.0 -15.9																24	0.00
16.0 -16.9		4	3		3	3		6	1						20	24	4.86
17.0 -17.9																4	0.00
18.0 -18.9																4	0.00
19.0 -19.9																4	0.00
20.0 -20.9		1	3												4	4	2.17
21.0 +																	0.00
TOTAL	11	254	263	209	122	61	37	20	18								3.22
CUM. TOTAL	1000	989	735	467	258	136	75	38	18								
COL. AVG.	9.38*	9.59	8.66	8.17	8.74	9.59	10.69	12.14	10.96	0.00	0.00	0.00	0.00	0.00	9.05		1

AVERAGE SIG. HEIGHT = 3.21 FT AVERAGE WAVE PERIOD = 9.08 SEC*
VARIANCE OF SIG. HEIGHT = 2.79 FT SQ VARIANCE OF WAVE PERIOD = 7.92 SEC SQ*
STANDARD DEVIATION OF HEIGHT = 1.67 FT STANDARD DEVIATION OF PERIOD = 2.81 SEC*

WAVE CLIMATOLOGY FOR NAGS HEAD, NORTH CAROLINA
DISTRIBUTION OF SIGNIFICANT HEIGHT VS PERIOD (IN OBSERVATIONS PER 1000 OBS)
658 OBSERVATIONS SUMMARY FOR APR 69, 71, 72, 73, 74, 75, 76, 77

PERIOD (SECS)	SIG. HEIGHT (FT) 0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13 +	TOT.*	CUM. TOT.*	ROW AVG.*
0.0 - .9																1000	0.00
1.0 - 1.9																1000	0.00
2.0 - 2.9		3	2												5	1000	1.83
3.0 - 3.9		11	11	2											23	995	2.10
4.0 - 4.9		12	9	18											40	973	2.65
5.0 - 5.9		38	23	15	11	5	2								93	933	2.70
6.0 - 6.9	3	25	32	12	14	5	3								94	840	2.85
7.0 - 7.9	2	21	15	5	6	6	3								58	746	2.89
8.0 - 8.9	15	123	63	15	11	2	3	5	2						243	688	2.22
9.0 - 9.9	8	58	65	32	9	9	3	3	2						188	445	2.72
10.0 -10.9	2	40	24	15	9	9	3	2							103	257	2.37
11.0 -11.9																153	0.00
12.0 -12.9	5	38	12	8	6	6	9		2						85	153	2.93
13.0 -13.9																68	0.00
14.0 -14.9		32	14	6	3										55	68	2.14
15.0 -15.9																14	0.00
16.0 -16.9		6	5			2									12	14	2.38
17.0 -17.9																2	0.00
18.0 -18.9																2	0.00
19.0 -19.9																2	0.00
20.0 -20.9		2													2	2	1.50
21.0 +																	0.00
TOTAL	33	409	280	128	68	43	26	9	5								2.59
CUM. TOTAL	1000	967	558	278	150	82	40	14	5								
COL. AVG.	9.14*	9.09	8.53	8.30	8.57	9.32	9.74	9.17	10.17	0.00	0.00	0.00	0.00	0.00	8.86		

AVERAGE SIG. HEIGHT = 2.58 FT AVERAGE WAVE PERIOD = 8.91 SEC*
VARIANCE OF SIG. HEIGHT = 2.03 FT SQ VARIANCE OF WAVE PERIOD = 7.22 SEC SQ*
STANDARD DEVIATION OF HEIGHT = 1.43 FT STANDARD DEVIATION OF PERIOD = 2.69 SEC*

RESULTS OBTAINED FROM 1024-SECOND DIGITAL RECORDS TAKEN WITH A STEP RES. AND CONT. WIRE WAVE GAGE LOCATED AT JENNETTES PIER.
* CALMS ARE OMITTED.

WAVE CLIMATOLOGY FOR NAGS HEAD, NORTH CAROLINA
DISTRIBUTION OF SIGNIFICANT HEIGHT VS PERIOD (IN OBSERVATIONS PER 1000 OBS)
539 OBSERVATIONS SUMMARY FOR MAY 69, 71, 72, 73, 76, 77

PERIOD (SECS)	SIG. HEIGHT (FT) 0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13 +	TOT.*	CUM. TOT.*	ROW AVG.*
0.0 - .9																1000	0.00
1.0 - 1.9																1000	0.00
2.0 - 2.9		6													6	1000	1.50
3.0 - 3.9		9	13	2											24	994	2.19
4.0 - 4.9		6	7	11	9										33	970	3.22
5.0 - 5.9		6	17	17	7		2								48	937	3.19
6.0 - 6.9	7	11	26	4	13										61	889	2.56
7.0 - 7.9	6	37	33	9	7	2			2						96	827	2.42
8.0 - 8.9	20	197	126	63	17	6	2								430	731	2.23
9.0 - 9.9	6	48	39	33	11	7									145	301	2.63
10.0 -10.9	4	19	11	9	19	7	2	2							72	156	3.32
11.0 -11.9																63	0.00
12.0 -12.9	11	22	9		6		2	2							52	83	2.18
13.0 -13.9																32	0.00
14.0 -14.9	4	17	4						2						26	32	2.00
15.0 -15.9																6	0.00
16.0 -16.9		2	4												6	6	2.17
TOTAL	58	376	289	148	69	22	7	4	4								2.47
CUM. TOTAL	1000	942	504	275	126	37	15	7	4								
COL. AVG.	9.53*	8.79	8.22	8.04	8.25	9.42	9.25	11.50	11.00	0.00	0.00	0.00	0.00	0.00	8.55		

AVERAGE SIG. HEIGHT = 2.43 FT
VARIANCE OF SIG. HEIGHT = 1.61 FT SQ
STANDARD DEVIATION OF HEIGHT = 1.27 FT

AVERAGE WAVE PERIOD = 8.56 SEC*
VARIANCE OF WAVE PERIOD = 4.65 SEC SQ*
STANDARD DEVIATION OF PERIOD = 2.16 SEC*

WAVE CLIMATOLOGY FOR NAGS HEAD, NORTH CAROLINA
DISTRIBUTION OF SIGNIFICANT HEIGHT VS PERIOD (IN OBSERVATIONS PER 1000 OBS)
348 OBSERVATIONS SUMMARY FOR JUN 71, 72, 76, 77

PERIOD (SECS)	SIG. HEIGHT (FT) 0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13 +	TOT.*	CUM. TOT.*	ROW AVG.*
0.0 - .9																1000	0.00
1.0 - 1.9																1000	0.00
2.0 - 2.9																1000	0.00
3.0 - 3.9				6											6	1000	3.50
4.0 - 4.9		3	20	9											32	994	2.68
5.0 - 5.9		11	29	14											55	963	2.55
6.0 - 6.9	3	17	29	11	9										69	908	2.58
7.0 - 7.9	9	63	26	6	3										106	839	1.85
8.0 - 8.9	40	345	72	17	14	3	3								494	733	1.77
9.0 - 9.9	3	92	29	3	3	3									132	239	1.89
10.0 -10.9	3	43	14	3	3										66	106	1.89
11.0 -11.9																40	0.00
12.0 -12.9		11	6			3									20	40	2.36
13.0 -13.9																20	0.00
14.0 -14.9	3	11													14	20	1.30
15.0 -15.9																6	0.00
16.0 -16.9		6													6	6	1.50
TOTAL	60	603	224	69	32	9	3										1.95
CUM. TOTAL	1000	940	336	112	43	11	3										
COL. AVG.	6.69*	8.82	7.74	6.67	8.14	10.17	8.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.41		

AVERAGE SIG. HEIGHT = 1.90 FT
VARIANCE OF SIG. HEIGHT = .82 FT SQ
STANDARD DEVIATION OF HEIGHT = .91 FT

AVERAGE WAVE PERIOD = 8.44 SEC*
VARIANCE OF WAVE PERIOD = 3.26 SEC SQ*
STANDARD DEVIATION OF PERIOD = 1.81 SEC*

RESULTS OBTAINED FROM 1024-SECOND DIGITAL RECORDS TAKEN WITH A STEP RES. AND CONT. WIRE WAVE GAGE LOCATED AT JENNETTES PIER.
* CALMS ARE OMITTED.

WAVE CLIMATOLOGY FOR NAGS HEAD, NORTH CAROLINA
DISTRIBUTION OF SIGNIFICANT HEIGHT VS PERIOD (IN OBSERVATIONS PER 1000 OBS)
112 OBSERVATIONS SUMMARY FOR JUL 69

PERIOD (SECS)	SIG. HEIGHT (FT) 0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13 +	TOT.*	CUM. TOT.*	ROW AVG.*
0.0 - .9																1000	0.00
1.0 - 1.9																1000	0.00
2.0 - 2.9		9													9	1000	1.50
3.0 - 3.9		9													9	991	1.50
4.0 - 4.9			9	9											18	982	3.00
5.0 - 5.9		27	9												36	964	1.75
6.0 - 6.9	9	36	18		9										71	929	2.00
7.0 - 7.9	18	27	9		27										80	857	2.39
8.0 - 8.9	18	339	89	18		18									482	777	1.87
9.0 - 9.9		71	71	45	18										205	295	2.54
10.0 -10.9		54													54	89	1.50
11.0 -11.9																36	0.00
12.0 -12.9		27													27	36	1.50
13.0 -13.9																9	0.00
14.0 -14.9	9														9	9	.50
TOTAL	54	593	205	71	54	18											2.03
CUM. TOTAL	1000	946	348	143	71	18											
COL. AVG.	8.33*	8.51	8.33	8.63	8.00	8.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.47		

AVERAGE SIG. HEIGHT = 2.01 FT
VARIANCE OF SIG. HEIGHT = 1.04 FT SQ
STANDARD DEVIATION OF HEIGHT = 1.02 FT

AVERAGE WAVE PERIOD = 8.53 SEC*
VARIANCE OF WAVE PERIOD = 2.73 SEC SQ*
STANDARD DEVIATION OF PERIOD = 1.65 SEC*

WAVE CLIMATOLOGY FOR NAGS HEAD, NORTH CAROLINA
DISTRIBUTION OF SIGNIFICANT HEIGHT VS PERIOD (IN OBSERVATIONS PER 1000 OBS)
333 OBSERVATIONS SUMMARY FOR AUG 69, 72, 75, 77

PERIOD (SECS)	SIG. HEIGHT (FT) 0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13 +	TOT.*	CUM. TOT.*	ROW AVG.*
0.0 - .9																1000	0.00
1.0 - 1.9																1000	0.00
2.0 - 2.9																1000	0.00
3.0 - 3.9		12	3												15	1000	1.70
4.0 - 4.9		6	15	9	3										33	985	2.77
5.0 - 5.9		9	30	18	9	6									72	952	3.13
6.0 - 6.9	3	27	24	9	6										69	880	2.33
7.0 - 7.9	12	84	21												117	811	1.58
8.0 - 8.9	51	234	84	18		9	6								402	694	1.84
9.0 - 9.9	3	93	12	12	9										129	291	1.97
10.0 -10.9	6	30	18	3	3										60	162	1.95
11.0 -11.9																102	0.00
12.0 -12.9	3	15	12		3	3									36	102	2.33
13.0 -13.9																66	0.00
14.0 -14.9	15	33	6				3								57	66	1.61
15.0 -15.9																9	0.00
16.0 -16.9		3	3												6	9	2.00
17.0 -17.9																3	0.00
18.0 -18.9																3	0.00
19.0 -19.9																3	0.00
20.0 -20.9				3											3	3	3.50
21.0 +																	0.00
TOTAL	93	547	228	72	33	18	9										2.00
CUM. TOTAL	1000	907	360	132	60	27	9										
COL. AVG.	9.58*	8.84	8.16	7.75	7.77	8.17	10.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.64		

AVERAGE SIG. HEIGHT = 1.95 FT
VARIANCE OF SIG. HEIGHT = 1.16 FT SQ
STANDARD DEVIATION OF HEIGHT = 1.08 FT

AVERAGE WAVE PERIOD = 8.60 SEC*
VARIANCE OF WAVE PERIOD = 5.63 SEC SQ*
STANDARD DEVIATION OF PERIOD = 2.37 SEC*

RESULTS OBTAINED FROM 1024-SECOND DIGITAL RECORDS TAKEN WITH A STEP RES. AND CONT. WIRE WAVE GAGE LOCATED AT JENNETTES PIER.
* CALMS ARE OMITTED.

WAVE CLIMATOLOGY FOR NAGS HEAD, NORTH CAROLINA
DISTRIBUTION OF SIGNIFICANT HEIGHT VS PERIOD (IN OBSERVATIONS PER 1000 OBS)
489 OBSERVATIONS SUMMARY FOR SEP 69, 71, 72, 74, 75

PERIOD (SECS)	SIG. HEIGHT (FT) 0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13 +	TOT.*	CUM. TOT.*	ROW AVG.*
0.0 - .9																1000	0.00
1.0 - 1.9																1000	0.00
2.0 - 2.9		4													4	1000	1.50
3.0 - 3.9		2	6	4											12	996	2.67
4.0 - 4.9			8	18	2					2					31	984	3.70
5.0 - 5.9		14	25	20	18	6	4								88	953	3.38
6.0 - 6.9	2	14	35	25	12	6	6								100	865	3.23
7.0 - 7.9		14	10	18	10	12			2						67	765	3.59
8.0 - 8.9	10	67	88	31	20	10	4		2	2					235	697	2.74
9.0 - 9.9	2	33	37	22	16	4	6	8							129	462	3.25
10.0 -10.9	4	29	45	14	16	14	16	2	4						145	333	3.56
11.0 -11.9																188	0.00
12.0 -12.9	6	35	35	14	25	6	6	4	4						137	188	3.23
13.0 -13.9																51	0.00
14.0 -14.9	8	14	8	2	4										37	51	1.94
15.0 -15.9																14	0.00
16.0 -16.9			6	2											8	14	2.75
17.0 -17.9																6	0.00
18.0 -18.9																6	0.00
19.0 -19.9																6	0.00
20.0 -20.9			2	2	2										6	6	3.50
21.0 +																	0.00
TOTAL	35	227	305	174	127	59	43	14	12	4							3.15
CUM. TOTAL	1000	965	738	434	260	133	74	31	16	4							
COL. AVG.	11.03*	9.36	9.06	8.15	9.27	8.74	9.40	10.50	10.33	6.50	0.00	0.00	0.00	0.00	9.09		

AVERAGE SIG. HEIGHT = 3.13 FT AVERAGE WAVE PERIOD = 9.11 SEC*
VARIANCE OF SIG. HEIGHT = 2.75 FT SQ VARIANCE OF WAVE PERIOD = 7.31 SEC SQ*
STANDARD DEVIATION OF HEIGHT = 1.66 FT STANDARD DEVIATION OF PERIOD = 2.70 SEC*

WAVE CLIMATOLOGY FOR NAGS HEAD, NORTH CAROLINA
DISTRIBUTION OF SIGNIFICANT HEIGHT VS PERIOD (IN OBSERVATIONS PER 1000 OBS)
536 OBSERVATIONS SUMMARY FOR OCT 69, 71, 72, 74, 75, 76

PERIOD (SECS)	SIG. HEIGHT (FT) 0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13 +	TOT.*	CUM. TOT.*	ROW AVG.*
0.0 - .9																1000	0.00
1.0 - 1.9																1000	0.00
2.0 - 2.9		2													2	1000	1.50
3.0 - 3.9		6	11	2											19	998	2.30
4.0 - 4.9			13	11	2	4									30	979	3.33
5.0 - 5.9		9	21	45	17	11	4	2							109	950	3.67
6.0 - 6.9	4	15	19	28	17	11	6	4	2						104	841	3.70
7.0 - 7.9		24	30	22	7	9	2	4		4					103	737	3.41
8.0 - 8.9	13	56	62	39	39	26	11	4	2						272	634	3.19
9.0 - 9.9		24	43	21	15	11	7	6	2						129	362	3.50
10.0 -10.9	4	17	22	13		17	7	4		2					86	233	3.67
11.0 -11.9																147	0.00
12.0 -12.9	2	13	15	26	22	6	4	9	6						103	147	4.12
13.0 -13.9																45	0.00
14.0 -14.9		9	13	6	4				2						34	45	2.94
15.0 -15.9																11	0.00
16.0 -16.9		6	2												7	11	1.75
17.0 -17.9																4	0.00
18.0 -18.9																4	0.00
19.0 -19.9																4	0.00
20.0 -20.9				2	2										4	4	4.00
21.0 +																	0.00
TOTAL	22	181	271	215	125	95	41	32	13	6							3.46
CUM. TOTAL	1000	978	797	526	312	187	91	50	19	6							
COL. AVG.	8.83*	8.99	8.51	8.22	8.90	8.36	8.32	9.56	10.93	8.50	0.00	0.00	0.00	0.00	8.66		

AVERAGE SIG. HEIGHT = 3.44 FT AVERAGE WAVE PERIOD = 8.65 SEC*
VARIANCE OF SIG. HEIGHT = 2.98 FT SQ VARIANCE OF WAVE PERIOD = 6.68 SEC SQ*
STANDARD DEVIATION OF HEIGHT = 1.73 FT STANDARD DEVIATION OF PERIOD = 2.58 SEC*

RESULTS OBTAINED FROM 1024-SECOND DIGITAL RECORDS TAKEN WITH A STEP RES. AND CONT. WIRE WAVE GAGE LOCATED AT JENNETTES PIER.
* CALMS ARE OMITTED.

WAVE CLIMATOLOGY FOR NAGS HEAD, NORTH CAROLINA
DISTRIBUTION OF SIGNIFICANT HEIGHT VS PERIOD (IN OBSERVATIONS PER 1000 OBS)
431 OBSERVATIONS SUMMARY FOR NOV 71, 72, 74, 75, 76

PERIOD (SECS)	SIG. HEIGHT (FT) 0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13 +	TOT.*	CUM. TOT.*	ROW AVG.*
0.0 - .9																1000	0.00
1.0 - 1.9																1000	0.00
2.0 - 2.9		2													2	1000	1.50
3.0 - 3.9	2	7	12	2											23	998	2.10
4.0 - 4.9		5	19	5	9										37	974	3.00
5.0 - 5.9	2	19	23	53	19	7	5								128	937	3.34
6.0 - 6.9		5	21	42	23	32	9	2	2						137	810	4.28
7.0 - 7.9	2	9	7	12	19	30	5	5							88	673	4.39
8.0 - 8.9	7	51	35	21	9	9	5								137	585	2.65
9.0 - 9.9		39	35	19	7	7		5							111	448	2.83
10.0 -10.9	5	21	44	35	9	7	3	2							128	336	3.08
11.0 -11.9																209	0.00
12.0 -12.9	7	37	35	14	7	12	9	2							123	209	2.97
13.0 -13.9																86	0.00
14.0 -14.9	14	19	2	5	2	12	12								65	86	3.18
15.0 -15.9																21	0.00
16.0 -16.9	5	2				2	5								14	21	3.50
17.0 -17.9																7	0.00
18.0 -18.9																7	0.00
19.0 -19.9																7	0.00
20.0 -20.9	2			5											7	7	2.50
21.0 +																	0.00
TOTAL	46	216	232	211	104	118	53	16	2								3.27
CUM. TOTAL	1000	954	738	506	295	190	72	19	2								
COL. AVG.	12.05*	9.51	8.61	8.23	7.03	8.83	10.67	9.07	6.50	0.00	0.00	0.00	0.00	0.00	8.92		

AVERAGE SIG. HEIGHT = 3.28 FT
VARIANCE OF SIG. HEIGHT = 2.83 FT SQ
STANDARD DEVIATION OF HEIGHT = 1.68 FT

AVERAGE WAVE PERIOD = 8.95 SEC*
VARIANCE OF WAVE PERIOD = 9.25 SEC SQ*
STANDARD DEVIATION OF PERIOD = 3.04 SEC*

WAVE CLIMATOLOGY FOR NAGS HEAD, NORTH CAROLINA
DISTRIBUTION OF SIGNIFICANT HEIGHT VS PERIOD (IN OBSERVATIONS PER 1000 OBS)
533 OBSERVATIONS SUMMARY FOR DEC 68, 71, 72, 74, 76, 77

PERIOD (SECS)	SIG. HEIGHT (FT) 0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13 +	TOT.*	CUM. TOT.*	ROW AVG.*
0.0 - .9																1000	0.00
1.0 - 1.9																1000	0.00
2.0 - 2.9																1000	0.00
3.0 - 3.9	2	2	9	2											14	1000	2.28
4.0 - 4.9		8	11	11	3										33	986	2.79
5.0 - 5.9	2	13	24	30	21	5	8								101	953	3.50
6.0 - 6.9	2	13	24	32	27	8	6	2	2						114	852	3.69
7.0 - 7.9	3	16	17	25	24	11	5	2							103	738	3.58
8.0 - 8.9	19	46	60	24	27	21		8	2	3					209	635	3.11
9.0 - 9.9	11	36	25	17	8	6		2							106	427	2.51
10.0 -10.9	5	23	36	21	3	6	3								103	321	2.70
11.0 -11.9																218	0.00
12.0 -12.9	6	54	21	19	6	3	3								112	218	2.39
13.0 -13.9																106	0.00
14.0 -14.9	5	32	11	6	8	5		2							68	106	2.55
15.0 -15.9																38	0.00
16.0 -16.9	2	13	9	5		2	6								36	38	3.02
17.0 -17.9																2	0.00
18.0 -18.9																2	0.00
19.0 -19.9																2	0.00
20.0 -20.9		2													2	2	1.50
21.0 +																	0.00
TOTAL	55	201	248	191	126	66	32	14	3	3							3.01
CUM. TOTAL	1000	945	664	436	245	118	52	21	6	3							
COL. AVG.	9.73*	10.42	8.88	8.39	7.99	8.98	9.40	8.94	7.50	8.50	0.00	0.00	0.00	0.00	9.14		

AVERAGE SIG. HEIGHT = 2.99 FT
VARIANCE OF SIG. HEIGHT = 2.50 FT SQ
STANDARD DEVIATION OF HEIGHT = 1.58 FT

AVERAGE WAVE PERIOD = 9.17 SEC*
VARIANCE OF WAVE PERIOD = 8.92 SEC SQ*
STANDARD DEVIATION OF PERIOD = 2.99 SEC*

RESULTS OBTAINED FROM 1024-SECOND DIGITAL RECORDS TAKEN WITH A STEP RES. AND CONT. WIRE WAVE GAGE LOCATED AT JENNETTES PIER.

* CALMS ARE OMITTED.

APPENDIX E

LISTS OF FLORA AND FAUNA AT THE FRF

Table E-1. FRF floristics list (Levy, 1976).

Family and species	Common name
Family Aceraceae	
Acer rubrum L.	Red maple
Family Aizoaceae	
Mollugo verticillata L.	Carpet weed
Family Alismataceae	
Sagitaria graminea var. *weatherbiana* (Fernald) Bogin	Arrowhead
Family Amaranthaceae	
Alternanthera philoxeroides (Martins) Grisebach	Alligator weed
Family Anacardinaceae	
Rhus copallina L.	Winged sumac
R. radicans L.	Poison ivy
Family Apiaceae	
Centella asiatica (L.) Urban	
Eryngium aquaticum L.	Eryngo
Hydrocotyle umbellata L.	Marsh pennywort
Lilaeopsis carolinensis C. & R.	
Ptilimnium capillaceum (Michaux) Ref.	
Sium suave Walter	Water parsnip
Family Aquifoliaceae	
Ilex opaca Aiton	American holly
I. vomitoria Aiton	Yaupon
Family Asclepiadaceae	
Asclepias lanceolata Walter	Milkweed
Family Aspleniaceae	
Asplenium platyneuron (L.) Oakes	Ebony spleenwort
Family Asteraceae	
Achillea millefolium L.	Yarrow
Ambrosia artemisiifolia L.	Ragweed
Aster tenuifolius L.	Aster
Baccharis halimifolia L.	Groundsel tree
Bidens mitis (Michaux) Sherff	Beggar ticks
Carduus spinosissimus Walter	Yellow thistle
Crepis vesicaria ssp *taraxifolia* (Thuillier) Thellung	Hawk's beard
Eclipta alba (L.) Hasskar	Yerba-de-tago
Erigeron canadensis var. *canadensis* L.	Horseweed
E. candensis var. *pusillus* (Nuttall) Ahles	Horseweed
Eupatorium capillifolium var. *capillifolium* (Lam.) Small	Dog fennel
E. serotinum Michaux	Thoroughwort
Gaillardia pulchella Foug.	Blanket flower
Gnaphalium obtusifolium L.	Rabbit tobacco
Hieracium gronovii L.	Hawk weed
Heterotheca adenolepis (Fernald) Ahles	
H. gossypina (Michaux) Shinners	
Iva frutescens L.	Marsh elder
I. imbricata Walter	Seashore elder
Krigia virginica (L.) Willd.	Dwarf dandelion
Lactuca canadensis L.	Wild lettuce
Mikania scandens (L.) Willd.	Climbing hempweed
Pluchea foetida (L.) D.C.	Marsh fleabane
P. purpurascens (Swartz) D.C.	Salt marsh fleabane
Pyrrhopappus carolinianus var. *carolinianus* (Walter) D.C.	False dandelion
Solidago rugosa var. *rugosa* Miller	Goldenrod
S. sempervirens L.	Goldenrod
S. tenuifolia Pursh	Goldenrod
Xanthium strumarium var. *strumarium* L.	Cocklebur
Family Bignoniaceae	
Campsis radicans (L.) Seemann	Trumpet vine
Family Brassicaceae	
Cakile edentula (Bigelow) Hooker	Sea rocket
Lepidium virginicum L.	Peppergrass
Family Cactaceae	
Opuntia compressa (Salisbury) Macbride	Prickley pear
O. drummondii Graham	Fragile prickley pear
Family Campanulaceae	
Lobelia elongata Small	Marsh lobelia
Specularia perfoliata (L.) A. D.C.	Venus' looking glass
Family Caprifoliaceae	
Lonicera japonica Thunberg	Japanese honeysuckle
L. sempervirens L.	Coral honeysuckle
Family Chenopodiaceae	
Chenopodium ambrosioides L.	Mexican tea
Family Cornaceae	
Cornus florida L.	Dogwood
Family Convolvulaceae	
Calystegia sepium (L.) R. Brown	Hedge bindweed
Family Cucurbitaceae	
Melothria pendula L.	Creeping cucumber
Family Cyperaceae	
Carex alata Torrey	Sedge
Cyperus dentatus Torrey	Sedge
C. erythrorhizos Muhl.	
C. filicinus Vahl	
C. haspan L.	
C. ovularis (Michaux) Torrey	
C. rivularis Kunth	
C. sesquiflorus (Torrey) Mattfeld and Kukenthal	
C. strigosus L.	
C. surinamensis Rottboell	
Eleocharis tuberculosa (Michx.) R. & S.	Spike rush
Fimbristylis autumnalis (L.) R. & S.	Sand rush
F. dichotoma (L.) Vahl	
Fuirena squarrosa Michaux	Umbrella grass
Scirpus americanus Persoon	Chair maker's rush
Family Ebenaceae	
Diospyros virginiana L.	Persimmon
Family Euphorbiaceae	
Croton glandulosus var. *septentrionalis* Muell.-Arg.	Croton
C. punctatus Jacquin	Croton
Euphorbia polygonifolia L.	Beach spurge
Family Fabaceae	
Apios americana Medicus	
Cassia fasciculata Michaux	Partridge pea
Centrosema virginianum (L.) Bentham	Butterfly pea
Desmodium paniculatum (L.) D.C.	Beggar lice
D. pauciflorum (Nuttall) D.C.	Beggar lice
D. strictum (Pursh) D.C.	Beggar lice
Lespedeza capitata Michaux	Bush clover
Family Fabaceae (concl'd.)	
L. cuneata (Dumont) G. Don	
L. striata (Thunberg) H. & A.	Japanese clover
L. virginica (L.) Britton	
Strophostyles helvola (L.) Ell.	Wild bean
Family Fagaceae	
Quercus virginiana Miller	Live oak
Family Gentianaceae	
Sabatia dodecandra var. *dodecandra* (L.) B.S.P.	Sea pink
Family Hamamelidaceae	
Liquidambar styraciflua L.	Sweet gum
Family Hypericaceae	
Hypericum gentianoides (L.) B.S.P.	St. John's wort

Table E-1. FRF floristics list (Levy, 1976).--Continued

Family and species	Common name	Family and species	Common name
Family Juncaceae		Family Poaceae (concl'd.)	
Juncus coriaceus Mackenzie	Rush	*Panicum amarulum* Hitchcock and Chase	Bitter panicum
J. megacephalus M.A. Curtis	Rush	*P. amarum* Ell.	Panic grass
J. roemerianus Scheele	Black rush	*P. dichotomiflorum* Michaux	Fall ronieum
		P. scoparium Lam.	
Family Juncaginaceae		*P. vaginatum* Swartz	
Triglochin striata R. & P.	Arrow grass	*P. virgatum* L.	Switch grass
		Polypogon monspeliensis (L.) Desf.	Rabbit foot grass
Family Lamiaceae		*Sacciolepis striata* (L.) Nash	
Monarda punctata L.	Horsemint	*Setaria geniculata* (Lam.) Beauvois	Fox tail grass
Salvia lyrata L.	Sage	*Sorgum halepense* (L.) Persoon	Johnson grass
Stachys nuttallii Shuttlew	Hedge nettle	*Spartina cynosuroides* (L.) Roth	Giant cord grass
		S. patens (Aiton) Muhl.	Salt meadow grass
Family Lauraceae		*Sphenopholis obtusata* (Michaux) Scribner	Wedge grass
Persea borbonia (L.) Spreng.	Red bay	*Triplasis purpurea* (Walter) Chapman	Sand grass
		Trisetum pensylvanicum (L.) Beauvois ex R. & S.	
Family Liliaceae			
Smilax bona-nox L.	Greenbrier	*Uniola paniculata* L.	Sea oats
Yucca filamentosa L.	Bear grass	*Zea mays* L.	Corn
Family Linaceae		Family Polygonaceae	
Linum virginianum var. *medium* Planchon	Flax	*Polygonum hydropiperoides* var. *opelousanum* (Riddell ex Small) Stone	
Family Loganiaceae		*P. pensylvanicum* L.	Knot weed
Polypremum procumbens L.		*P. sagittatum* L.	Tear thumb
		Rumex acetosella L.	Sheep sorrel
Family Lycopodiaceae		*R. verticillatus* L.	Swamp dock
Lycopodium appressum (Chapman) Lloyd and Underwood	Club moss	Family Pontederiaceae	
		Pontederia cordata L.	Pickerelweed
Family Lythraceae			
Lythrum lineare L.	Loosestrife	Family Primulaceae	
		Samolus parviflorus Raf.	Water pimpernel
Family Malvaceae			
Hibiscus moscheutos L.	Rose mallow	Family Ranunculaceae	
Kosteletskya virginica (L.) Presl.	Sea shore mallow	*Ranunculus sardous* Crantz	Buttercup
Family Myricaceae		Family Rosaceae	
Myrica cerifera var. *cerifera* L.	Wax myrtle	*Amelanchier arborea* var. *laevis* (Wiegard) Ahles	June berry
M. pensylvanica Loisel	Bayberry	*Prunus serotina* var. *serotina* Ehrhart	Black cherry
		Rubus betulifolius Small	Blackberry
Family Onagraceae			
Oenothera biennis L.	Evening primrose		
O. fruticosa L.	Sundrops	Family Rubiaceae	
O. humifusa Nuttall	Evening primrose	*Diodia teres* Walter	Buttonweed
		D. virginiana L.	
Family Orchidaceae			
Spiranthes cernua (L.) Richard	Nodding ladies' tresses	Family Rutaceae	
		Zanthoxylum clava-herculis L.	Hercules' club
Family Pinaceae			
Pinus taeda L.	Loblolly pine	Family Salicaceae	
		Salix nigra Marshall	Black willow
Family Phytolacaceae			
Phytolacca americana L.	Pokeweed	Family Scrophulariaceae	
		Agalinis purpurea (L.) Pennel	Gerardia
Family Plantaginaceae		*Linaria canadensis* (L.) Dumont	Toad flax
Plantago lanceolata L.	Plantain	*Verbascum thapsus* L.	Mullein
Family Poaceae		Family Solanaceae	
Andropogon elliottii Chapman	Broom straw	*Physalis viscosa* ssp *maritima* (M.A. Curtis) Waterfall	Ground cherry
A. virginicus L.	Broom sedge	*Datura stramonium* L.	Jimson weed
Ammophila breviligulata	American beachgrass		
Bromus secalinus L.	Brome grass	Family Urticaceae	
Cenchrus tribuloides L.	Sandspurs	*Boehmeria cylindrica* (L.) Swartz	False nettle
Cynodon dactylon (L.) Persoon	Bermuda grass		
Digitaria filiformis var. *villosa* (Walter) Fernald	Crab grass	Family Verbenaceae	
D. ischaemum (Schreber) Schreber ex Muhl.	Crab grass	*Callicarpa americana* L.	French mulberry
D. sanguinalis (L.) Scopoli	Crab grass	*Lippia nodiflora* (L.) Michaux	Frogbit
Echinochloa walteri (Pursh) Heller	Walter's barnyard grass		
Eleusine indica (L.) Gaertner	Goose grass	Family Vitaceae	
Elymus virginicus L.	Wild rye grass	*Parthenocissus quinquefolia* (L.) Planchon	Virginia creeper
Eragrostis elliottii Watson	Love grass	*Vitis aestivalis* var. *aestivalis* Michaux	Summer grape
E. spectabilis (Pursh) Steudel	Love grass	*V. rotundifolia* Michaux	Muscadine
Erianthus giganteus (Walter) Muhl.	Beard grass		
Festuca sciurea Nuttall	Fescue	Family Xyridaceae	
Leptoloma cognatum (Schultes) Chase	Witch grass	*Xyris jupicai* Richard	Yellow-eyed grass

Table E-2. Faunistic list of the ocean beach at the FRF (Matta, 1977).

Phylum NEMERTEA
- *Tubulanus pellucidus*

Phylum ANNELLIDA
- Class Polychaeta
  - Family Spionidae
    - *Scolelepis squamata*
    - *Spiophanes bombyx*
  - Family Nephtyidae
    - *Nephtys bucera*
  - Family Megalonidae
    - *Megalona rosea*
  - Family Hesionidae
    - *Microphthalmus sczelkowii*
  - Family Opheliidae
    - *Travisia carnea*
  - Family Phyllodocidae
    - *Eteone heteropoda*
  - Family Glyceridae
    - *Glycera* sp.

Phylum MOLLUSCA
- Class Bivalvia
  - Order Heterodontida
    - Family Donacidae
      - *Donax* sp. (probably *variablis*)
    - Family Solenidae
      - *Ensis* sp.
  - Order Prionodontida
    - Family Arcidae
      - *Anadara ovalis*

Phylum ARTHROPODA
- Class Crustacea
  - Order Amphipoda
    - Family Haustoriidae
      - *Parahaustorius longimerus*
      - *Amphiporeia virginiana*
      - *Bathyporeia quoddyensis*
    - Family Ischyroceridae
      - *Jassa falcata*
  - Order Mysidacea
    - *Metamysidopsis mexicana*
  - Order Cumacea
    - Family Leuconidae
      - *Leucon americanus*
      - *Eudorellopsis deformis*
    - Family Pseudocumidae
      - *Petalosarsia declivis*
  - Order Decapoda
    - Family Paguridae
      - *Pagurus longicarpus*
    - Family Portunidae
      - *Ovalipes ocellatus*
    - Family Hippidae
      - *Emerita talpoida*
- Microcrustacea
  - Subclass Ostracoda
    - Order Myodacopoda
      - Species A
    - Order Podocopa
      - Species A
  - Subclass Copepoda
    - Order Harpacticoida
      - Species A
      - Species B

Phylum CNIDARIA
- Class Anthozoa
  - Order Actiniaria
    - Species A (immature)

Table E-3. Faunistic list of the sound beach at the FRF (Matta, 1977).[1]

Phylum NEMATODA
- Order Dorylaimida

Phylum ANNELLIDA
- Class Polychaeta
  - Order Spionida
    - Family Spionidae
      - *Scolecolepides viridis*
  - Order Phyllodocida
    - Family Nereidae
      - *Laconereis culveri*
  - Order Terebellidae
    - Family Ampharetidae
      - *Hypaniola grayi*
- Class Oligochaeta
  - Order Prosopora
    - Family Lumbriculidae
      - *Lumbriculus* sp.
  - Order Plesiopora
    - Family Tubifisidae
      - *Peloscolex* sp.

Phylum MOLLUSCA
- Class Bivalvia
  - Family Mactridae
    - *Rangia cuneata*
- Class Gastropoda
  - Order Pulmonata
    - Family Physidae
      - *Physa* sp.
    - Family Ancylidae
      - *Ferrissia* sp ?

Phylum ARTHROPODA
- Class Crustacea
  - Order Amphipoda
    - Family Haustoridae
      - *Lepidactylus dysticus*
    - Family Gammaridae
      - *Gammarus* sp.
    - Family Photidae
      - *Leptocheirus plumulosus*
    - Family Oedicerotidae
      - *Monoculodes* sp.
  - Order Isopoda
    - Family Anthuridae
      - *Cyathura polita*
    - Family Idoteidae
      - *Chiridotea* sp.
  - Order Decapoda
    - Family Cambaridae
      - *Cambarus* sp ? (immature)
    - Family Portunidae
      - *Callinectes sapidus*
- Class Insecta
  - Order Odonata
    - Family Coenagrionidae
      - *Enallagma* sp.
  - Order Collembola
    - Species A
  - Order Coleoptera
    - Family Dytiscidae
      - *Uvarus* sp.
  - Order Diptera
    - Family Tabanidae
      - Species A (immature)
    - Family Chironomidae
      - (Immatures)
    - Family Cerotopogonidae
      - (Immatures)

[1] Species above 0.5 millimeter only.

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[119] p. : ill., map ; 28 cm.--(Miscellaneous report / Coastal Engineering Research Center ; no. 81-7)
Cover title.
"October 1981."
Bibliography: p. 91.
The Coastal Engineering Research Center's (CERC) Field Research Facility (FRF) at Duck, North Carolina, is a 561-meter-long (1,841 feet) pier and laboratory dedicated to basic and applied coastal research. This report, which describes the facility, the instrumentation and data being collected, and the local area, is designed to be used as a tool in planning experiments to be conducted there.
1. Coastal Engineering Research Center (U.S.). Field Research Facility. 2. Duck (N.C.)--Description. I. Birkemeier, William A. II. Title. III. Miscellaneous report (Coastal Engineering Research Center (U.S.)) ; no. 81-7.
TC203 .U581mr no. 81-7 627

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[119] p. : ill., map ; 28 cm.--(Miscellaneous report / Coastal Engineering Research Center ; no. 81-7)
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