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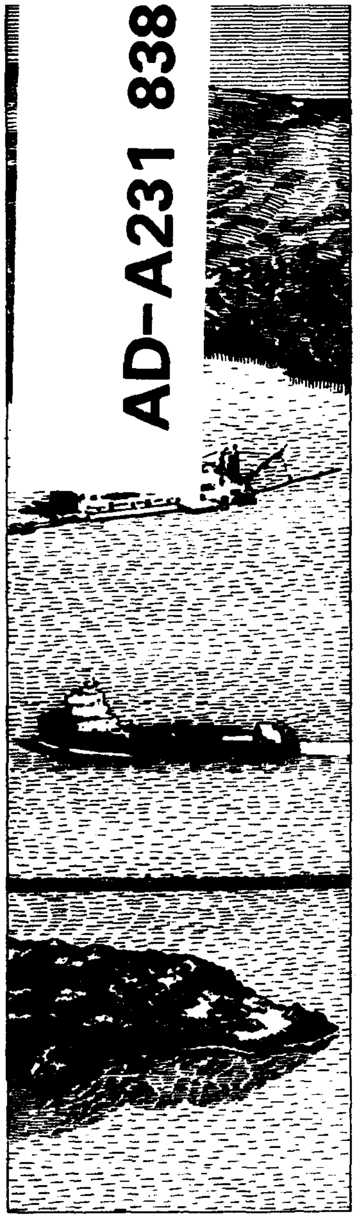


**DREDGING RESEARCH PROGRAM**

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(2)

# RESULTS OF MONITORING THE DISPOSAL BERM AT SAND ISLAND, ALABAMA

## Report 1

## CONSTRUCTION AND FIRST YEAR'S RESPONSE

by

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- Area 2 - Material Properties Related to Navigation and Dredging
- Area 3 - Dredge Plant Equipment and Systems Processes
- Area 4 - Vessel Positioning, Survey Controls, and Dredge Monitoring Systems
- Area 5 - Management of Dredging Projects

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The Directorate of Civil Works of the US Army Corps of Engineers, the US Army Engineer District, Mobile, and the US Army Engineer Waterways Experiment Station, Coastal Engineering Research Center, are engaged in a cooperative effort to construct and monitor experimental submerged berms on the open seafloor offshore of Sand Island, AL. Described herein are the experimental placement methods used along with a comparison between expected results and those actually achieved. Background site information and measured environmental conditions are summarized. Results of the first year's monitoring are discussed. Results of continued monitoring will be included in later reports.

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Nearshore nourishment
Onshore transport
Seabed drifters
Seafloor currents
Sediment dispersion
Shortened haul distances
Submerged disposal berms

## PREFACE

This is the first report on the Sand Island berm, an alternative dredged material placement test planned by the US Army Engineer District, Mobile (SAM); the US Army Corps of Engineers, Directorate of Civil Works; and the Coastal Engineering Research Center (CERC) of the US Army Engineer Waterways Experiment Station (WES). The work described herein was authorized as part of the Dredging Research Program (DRP) of Headquarters, US Army Corps of Engineers (HQUSACE), under Work Unit 32467, "Field Techniques and Data Analysis to Assess Open Water Disposal Deposits." The HQUSACE Technical Monitors and Advisors for the DRP are Messrs. Glenn R. Drummond, Rixie J. Hardy, John J. Parez, M. K. Miles, John Sanda, Gerald Greener, Tom Verna, Jim Crews, and David Mathis. Mr. E. Clark McNair, Jr., is the DRP Program Manager, and Ms. Carolyn M. Holmes is the DRP Assistant Program Manager. Dr. Nicholas C. Kraus, Senior Scientist, Research Division, CERC, is Technical Manager of Area 1, "Analysis of Dredged Material Placed in Open Waters," which includes Work Unit 32467. Mr. Edward B. Hands, Engineering Development Division (EDD), CERC, is the Principal Investigator.

Personnel from SAM and CERC collected field data. Mr. Hands analyzed the data and prepared this report with Mr. K. Paul Bradley, Study Manager, SAM. Together with a recently completed offshore berm in deeper water, the Sand Island berm is part of a national demonstration program intended to assess potential berm benefits. The specific purpose of the Sand Island berm is to test the concept for using dredged material to improve regional sediment balance. Messrs. Thomas W. Richardson, CERC; Charles C. Calhoun, Jr., CERC; Hugh A. McClellan, SAM; James M. Kelly, Jr., SAD; and David B. Mathis, CECW-D, form the management committee overseeing monitoring of berms. Mr. J. Patrick Langan, SAM, is committee chairman. Reviews of this report were provided by members of the Berm Committee.

Special thanks are extended to Mr. William L. Murden, retired Chief of the former Corps Dredging Division. His support of innovative improvements in dredging and his enthusiasm for constructing underwater berms were critical in the initiation of this study.

Work at CERC was under the general supervision of Dr. James R. Houston and Mr. Calhoun, Chief and Assistant Chief, CERC, respectively; and under the

direct supervision of Mr. Richardson, Chief, EDD; Ms. Joan Pope, Chief, Coastal Structures and Evaluation Branch, EDD; and Mr. Yen-Hsi Chu, Engineering Applications Unit, EDD.

Survey contractors were Pyburn & Odom, Inc., Baton Rouge, LA, and Browning, Inc., Jackson, MS. Mr. James W. Reaves, SAM, was contract monitor. The extra efforts of Mr. Reaves and Mr. Rex D. Wells to integrate research tasks with the more standard offshore survey tasks are greatly appreciated.

Messrs. James H. Nichols and David Bedford, SAM, assisted in preparation of field equipment. Mr. Thomas M. Nevels, SAM, calculated recovery coordinates for the seabed drifters. Mr. Darryl D. Bishop, CERC, coordinated seabed drifter releases and other field activities and supervised the preparation of figures, and Ms. Mary C. Allison, CERC, compiled and reduced field data.

Help from the Dauphin Island Fishery Research Branch of the US Public Health Service is acknowledged. The information they provided on local conditions greatly improved the planning of field tests. Also, they responded with equipment and personnel on several occasions when unforeseen conditions required prompt onsite assistance.

Commander and Director of WES was COL Larry B. Fulton, EN. Technical Director was Dr. Robert W. Whalin.

For further information on this report or on the Dredging Research Program, please contact Mr. E. Clark McNair, Jr., Program Manager, at (601) 634-2070.

CONTENTS

# CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

| Multiply | By | To Obtain |
|---|---|---|
| cubic feet | 0.02831685 | cubic metres |
| cubic yards | 0.7645549 | cubic metres |
| feet | 0.3048 | metres |
| inches | 2.54 | centimetres |
| knots (international) | 0.5144444 | metres per second |
| miles (US nautical) | 1.852 | kilometres |
| miles (US statute) | 1.609347 | kilometres |

SUMMARY

As part of a continuing improvement of economic and environmental aspects of dredging, the US Army Corps of Engineers is constructing submerged berms at various locations on the seafloor. Selected berms are being monitored to evaluate their stability and potential usefulness for reducing wave damage on the shore, increasing the coastal sand supply, and other purposes. The Sand Island berm was built with sand dredged from the entrance to Mobile Bay, Alabama. This report, the first of a series on that berm, describes design and placement methods, compares expected with observed berm dimensions, and summarizes results from the first year of monitoring.

The intent of the berm was not only to conserve sand at this site, but to increase understanding of bottom responses by forming a prominent deposit that could be tracked by repeated bathymetric surveys. Draft requirements for the placement vessels and the goal of retaining sand in the active littoral zone limited the placement to below 14- and above 20-ft mean lower low water (mllw) depth contours. A 19-ft depth was selected to accommodate a 6-ft-high berm. This height, plus the anticipated volume and side slopes, dictated a berm length of at least a mile. To simplify placement and avoid delays, a 500-ft-wide placement corridor was specified. The competing criteria of short haul distances and minimum risk of material returning to the channel were judged to be balanced for a site about 1.5 miles west of the channel. This is also an area where the natural ebb-tidal delta ridge, which protects the east end of Dauphin Island from wave attack, requires sand to reestablish its typical pre-1970 conditions.

The dredged material was a clean, fine-grained sand with a median diameter of 0.2 mm. Careful, but nonelaborate placement resulted in a prominent 6,000-ft-long berm with 6- to 7-ft relief and 500- to 700-ft width across the base. The measurements closely matched design estimates.

The Sand Island experiment provides new information on the response of fine-grained sand in intermediate depths, i.e., shallower than previous tests with stable berms, but deeper than previous feeder berms. The major question was whether sand at this depth would stay nearshore or be lost seaward. Bathymetric surveys, sediment samples, and side-scan sonar documented berm construction and the longer term fate of the feature. Aerial photography,

seabed drifters (SBD's), and meteorological, wave, and current meters monitored erosive processes so that the result could be applied to other sites.

Over the first year, natural currents smoothed the crest, flattening scattered peaks that rose above -13 ft mllw. The most extensive peaks and greatest erosion were along the southern (offshore) terminus. The gulfward end retreated less than 300 ft (<5 percent shortening). Changes elsewhere were minor. It was unclear where the small eroded volumes resettled. A small amount of silt was rapidly winnowed from at least the surface of the entire berm. However, the berm shape and size remained essentially unchanged. No evidence suggested offshore loss of sand.

A northerly current was often directed from the placement area to Dauphin Island, located 4-miles north of the release sites. This focused, shoreward current occurred through the year, but was strongest in the winter as indicated by increased SBD recoveries on Dauphin Island, reduced returns inside Mobile Bay, and a higher ratio of heavy-to-light drifters coming ashore on Dauphin Island. Currents toward the west were also more prominent in the winter. Extensive eastward flow was documented only once, in April. At that time eastward currents affected the whole study area, but only briefly, and may not have been capable of transporting dredged material back toward the channel.

Earlier measurements suggest that typical velocities measured over the long term may be much higher than those measured in 1987. Until additional onsite measurements are obtained, it may be prudent to avoid release of easily suspended material near the channel in the spring. However, movement of the sand berm was small enough so that subsequent surveys could be conducted less frequently, resulting in considerable savings on monitoring costs. This and other adopted monitoring improvements should clarify the long-term fate of the placed material, provide data for testing prediction methods, and confirm the apparent success of conserving sand resources at this site without adding to the cost of navigation maintenance.

# RESULTS OF MONITORING THE DISPOSAL BERM AT SAND ISLAND, ALABAMA

## CONSTRUCTION AND FIRST YEAR'S RESPONSE

## PART I: INTRODUCTION

### Background

1. In a continuing effort to conduct the national dredging program in an economically and environmentally sound manner, the US Army Corps of Engineers (USACE) is constructing experimental submerged berms on the open seafloor offshore of Sand Island, Alabama, and monitoring their fate. This project is a cooperative effort among the Directorate of Civil Works, USACE; the US Army Engineer District, Mobile (SAM); and the Coastal Engineering Research Center (CERC) of the US Army Engineer Waterways Experiment Station. The purpose is to evaluate methods of using dredged material to reduce wave damage and the rate of coastal sand losses to deep offshore waters.

2. Prediction of berm stability and onshore/offshore transport is difficult for natural sediments and even more complex for placed deposits for which no historic trends exist. Several earlier field tests indicated submerged berms constructed in depths of 20 to 38 ft* remain stable for many years. More recently, experimental berms in the 7- to 16-ft range near New River Inlet, North Carolina, and Fire Island, New York, dispersed quickly with some evidence of a shoreward component of transport. Proper berm design can promote preferential onshore transport by placing appropriately sized material in shallow water where a gently sloping seafloor is exposed to long period waves and offshore winds.

3. The present test, conducted in 1987 offshore of Sand Island, Alabama, expands experience using fine sand in intermediate depths, i.e., below depths where onshore transport has already been demonstrated, but shallow enough for potential movement. The major question is whether sand at this depth will be retained in the nearshore zone or lost seaward. Data are being gathered to determine the forces necessary for dispersion of the material.

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* A table of factors for converting non-SI units of measurement to SI units is presented on page 4.

4. The sand used in this test was dredged to maintain the navigation channel at the entrance to Mobile Bay. Split-hull dredges placed the material along the 19-ft contour west of the channel. Careful, but nonelaborate, control over the exact positioning of placement permitted the construction of a prominent berm about 6,000 ft in length with a typical relief of 6 to 7 ft and a base width of 500 to 700 ft. The USACE conducted one baseline and nine postplacement surveys the first year to monitor berm fate.

5. Bathymetry and grab samples were taken in an identic.. manner on each postplacement survey. Waves, tides, bottom currents, and winds were also measured.

6. During the first year, erosive forces smoothed the berm crest. Where peaks protruded above -13 ft, they were lowered 1 to 2 ft. No major dispersion occurred, and nothing indicated offshore sand loss.

## Objectives

7. This field study has two major objectives. First, SAM wants to evaluate the feasibility of conserving clean sands dredged to maintain the navigation channel into Mobile Bay. Conventionally, this sand would be disposed of in a designated offshore open-water site seaward of the littoral zone. Retention of the material in the nearshore sand prism or placement in the westward moving littoral stream may help alleviate regional erosion problems. Returning sand to the littoral system is a fairly simple task from the technical standpoint. The challenge is to accomplish the task without increasing the cost of channel maintenance.

8. The second objective is to extract general guidance. Districts nationwide are attempting to enhance existing nearshore profiles using sand dredged in a situation similar to that in Mobile Bay. This study is contributing additional data needed to generalize sand placement guidelines and to establish design criteria from several well-documented case studies covering various waves, currents, and bottom materials.

9. Monitoring of the Sand Island nearshore berm is continuing. Some modifications were made to improve the second year results. These limitations and modifications are described as they are relevant to monitoring being planned at other sites.

## PART II: PROJECT SETTING AND NEARSHORE PLACEMENT BENEFITS

### Regional Setting

10. Mobile Bay, in southwest Alabama, has a length in excess of 30 miles and a width at its southern end of close to 10 miles. The bay opens to the west into Mississippi Sound and to the south directly into the Gulf of Mexico through the main pass, a 3-mile-wide natural opening between Mobile and Pelican Points (Figure 1). The main pass carries an estimated 85 percent of the 14.6 billion cu ft of water that flows in and out of the bay on an average day (US Army Engineer District (USAED), Mobile 1978). South of this pass lies one of the larger ebb-tidal deltas on the gulf coast. The outer apex (defined by the 30-ft contour) lies 9 miles south of Dauphin Island.

11. The climate of the area is characterized by warm, humid summers and mild winters with occasional cold fronts. The average annual rainfall is

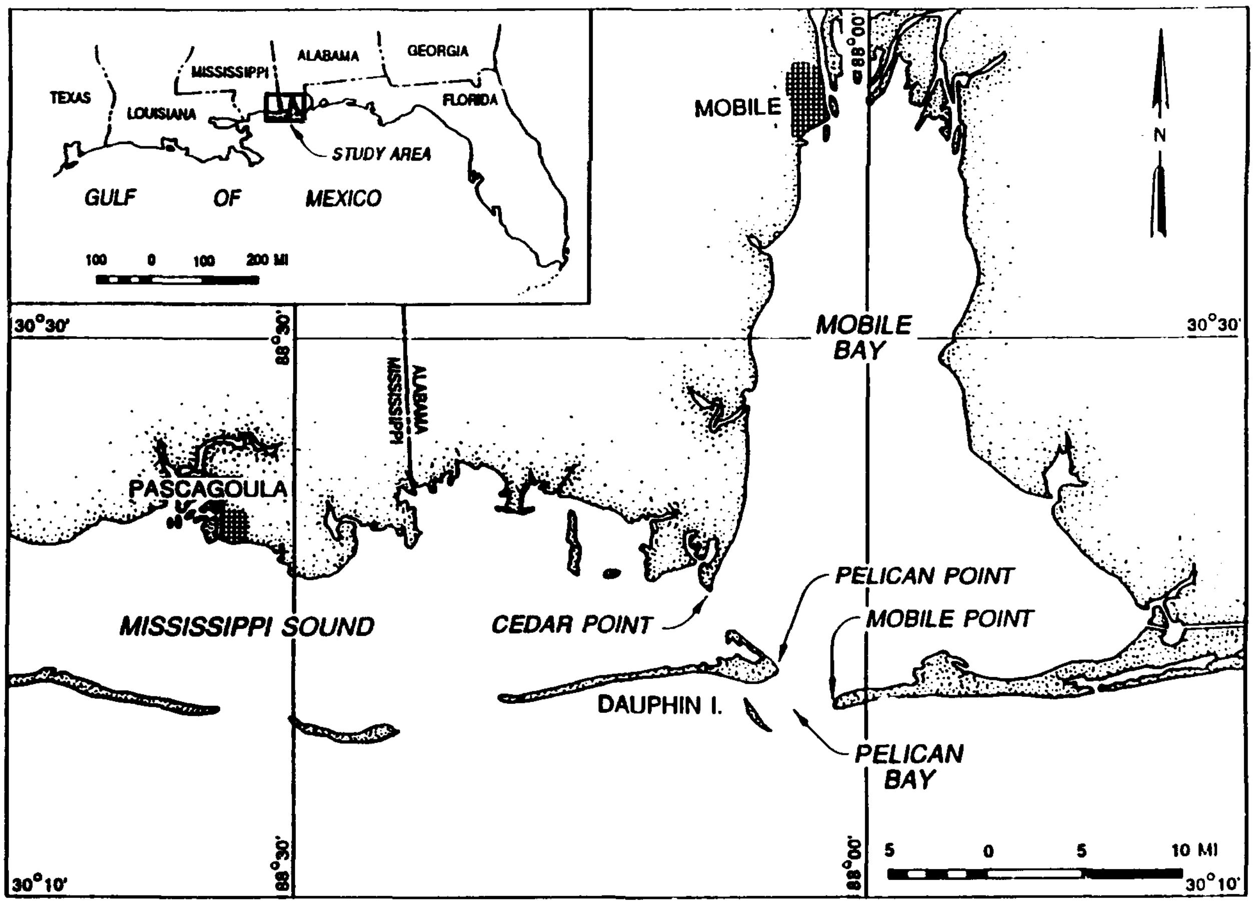


Figure 1. Mobile Bay location map

about 68 in. Prominent weather features include short duration, wind-intense thunderstorms mainly during the summer, with occasional tropical storms and hurricanes later in the year. Since 1711, hurricanes have affected the Alabama coast about once every 4 years (USAED, Mobile 1978). The worst storm on local record, Hurricane Frederic, hit Dauphin Island in 1979. Hurricanes Elena and Juan caused considerable damage in 1985.

12. The diurnal tidal range of Mobile Bay increases from 1.3 at the mouth to 1.6 ft at the head of the bay. Winds and tides are the major contributors to nearshore water circulation. Wind-induced nearshore waves are low to moderate with wave periods ranging from 3 to 8 sec and wave heights rarely over 7 ft (Hubertz and Brooks, 1989). However, hurricane or storm conditions can produce larger waves (USAED, Mobile 1985).

13. Prevailing south and southeast winds generate waves that produce a westward flowing current which is the primary factor transporting sediment along the Florida/Alabama coastline. Ebb-tidal currents combined with the littoral drift have formed the sand delta at the entrance to Mobile Bay. The western margin of the delta is characterized by narrow islands that change shape, disappear, and reappear due to the dynamics of wave action and water circulation patterns. Shoreline erosion on Dauphin Island has been explained in terms of increased exposure to the open gulf as these outer islands move or erode.

14. The nearshore gulf area is intensely utilized by man and aquatic organisms. A major spring, summer, and autumn migratory area for larval, postlarval, and juvenile fish and shellfish, it is fished extensively by both commercial and sport fishermen. Shrimp trawling, pet food trawling, artificial reef, and other sport fishing are common in the immediate project area. Additionally, the recent discovery of natural gas has resulted in establishment of numerous well platforms. All of these activities, including dredging and associated environmental monitoring, make it a challenge for multiple users to avoid interference. Opportunities likewise arise for mutual support. The Corps is especially interested in the use of dredged material to improve the environment and in field confirmation of innovative management techniques.

## Project Description

15. The Mobile Harbor project (Figure 2) consists of a 42- by 600-ft channel about 1.5 miles long across Mobile entrance bar and a 40- by 400-ft channel extending through Mobile Bay up to the mouth of Mobile River. A presently underway deepening operation will expand these dimensions to 47 by 600 ft at the entrance and 45 by 400 ft through the bay. The bar channel traps littoral drift. Historically, hopper dredges remove an average of 324,000 cu yd of material annually. Historically, material from the bar channel has been placed in an open-water site outside the active zone of littoral transport.

16. At various times, one to three islands of variable length appear offshore of the eastern end of Dauphin Island. Episodes of erosion on Dauphin Island have been explained in terms of increased exposure to the open gulf as these outer islands move or erode. Lamb (1987a and 1987b) observes that there was only a single island in an extreme western position in 1979 when Hurricane Frederic hit and in 1985 when Dauphin Island again sustained significant shore erosion during Hurricane Elena. He suggests that shore erosion would have been less severe if Sand Island had been in its more typical, eastern position. Schramm et al. (1980) note that shoreline retreat was at a minimum where the ebb-tidal delta broke the waves far offshore. Just west of the delta, two earlier hurricanes breached Dauphin Island in 1916 and 1947 (Nummedal and Otvos 1985). Though Hurricane Frederic did not breach Dauphin Island, the most severe overwash and maximum shore erosion occurred at the site of former breaching. Schramm et al. (1980) interpret this zone of vulnerability as an indication of wave energy focusing by the ebb-tidal platform. Beach width and dune growth on the east end of Dauphin Island have also varied with changes on the offshore islands.*

17. The 6-ft-depth contour can be used to define an unbroken ridge along the outer edge of the ebb-tidal platform extending from the offshore lighthouse east of the eastern end of Dauphin Island to within less than half a mile of Dauphin Island near the western end of the stable core. Coastal charts dating back to 1847 reveal this ridge to be a permanent, fairly continuous feature of the delta platform (Figure 3). In this context, when sections

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* Personal Communication, 1988, Dr. Robert G. Dean, Professor, University of Florida, Gainesville, FL.

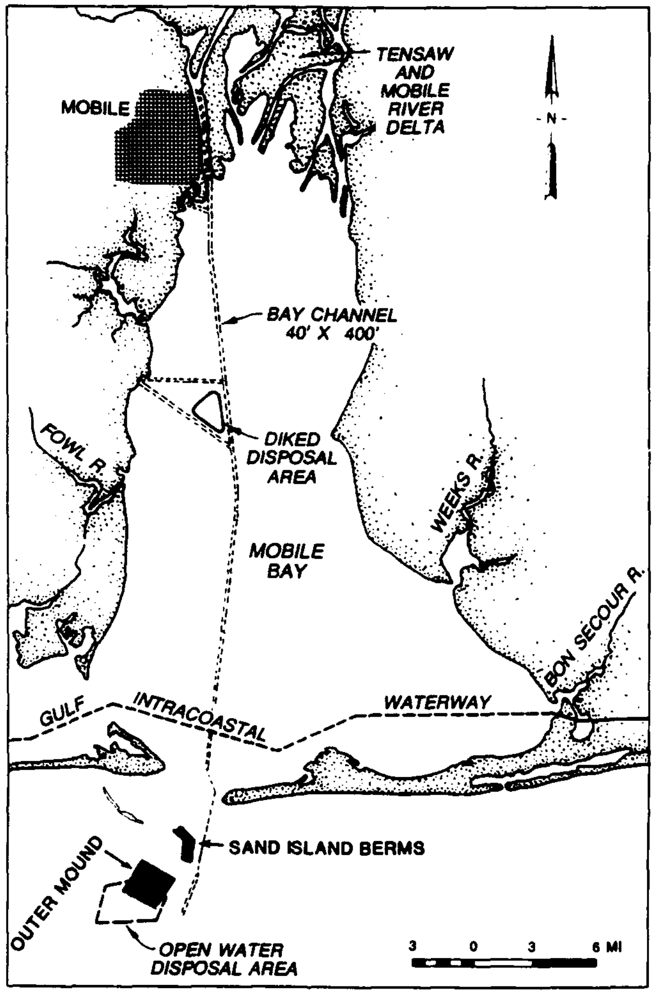


Figure 2. Map of Mobile harbor project. Material dredged from the bar has conventionally gone to the Open Water Disposal Area Offshore.

emerge above sea level, they are known as East and West Sand Island. Sections emerging even farther west are called Pelican Island.

18. The modern Sand/Pelican Ridge has thus been a permanent protective barrier throughout modern times. As various sections lose elevation or become breached, the pattern of wave penetration into Pelican Bay changes. Consequently, circulation in Pelican Bay is affected, causing local reorientations on the eastern beaches of Dauphin Island. The shoreline salient so prominent in 1987 (Figure 4) is probably a reflection of Sand Island dynamics. Similar salients have been shown to grow behind and migrate with ebb-tidal shoals near

Boca Grande Pass, Florida, and south of the entrance to Tampa Bay, Florida.* However, because the marginal ridge of Mobile Bay's ebb-tidal delta is a permanent feature, the dynamics of ephemeral islands on its crest has a more apparent than real effect on the stability of Dauphin Island.

19. Since 1979 most of the eastern end of the Sand/Pelican Ridge has been in a low, eroded state, with only a short western portion above sea level. The Sand Island berm was constructed gulfward of this low end of the ridge (last panel in Figure 3). The berm thus tends to reestablish wave energy dissipation away from shore similar to the way the natural Sand/Pelican Ridges did through most of the historic past.

20. Unless there was extensive sand loss to deep water, some of the berm benefits would continue even if it was flattened. The dredged material would no longer function as a discrete submerged breakwater but would increase the amount of sand in the low section of the Sand/Pelican Ridge. Monitoring is being conducted to identify any substantial offshore loss.

## Potential Benefits

21. Potential benefits of mounding sandy materials include:

- a. Enhance fisheries.
- b. Serve as stockpile for later use.
- c. Reduce damages of wave impact and runup.
- d. Augment the sand budget on an eroding coast.
- e. Serve as a barrier reducing offshore sand loss.
- f. Bolster foundation or form core of offshore structures.
- g. Channel the migration of fluid muds.
- h. Reduce haul distance and placement costs.
- i. Improve monitoring of material behavior.

The Corps of Engineers is evaluating the practicality of these potential benefits by conducting large-scale tests in association with required channel dredging. Information on the fate of material mounded at the Dam Neck disposal site in Virginia and off Gilgo Beach in Long Island, New York, may be found in Hands and DeLoach (1984) and McLellan, Truitt, and Flax (1988),

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* Personal Communication, 1988, Dr. Robert G. Dean, Professor, University of Florida, Gainesville, FL.

respectively. Cost reduction related to the shortened haul distance offsets some of the expense of these tests.

22. Coastal erosion occurs where sand is removed faster than it is replaced. Such imbalance often causes problems which can be reduced by placement of new material in the shore compartment. The value of such action will depend on the nature of the local problem plus the location, quantity, and rate of sand replacement. Man's concerns are usually at the shoreline. Traditional placement directly on the beach has an immediate benefit. The active sand prism, however, extends far offshore (e.g. Hands 1983, Bruun and Schwartz 1985, Wright 1987). Any addition of sand to the active prism tends to correct coastal sand deficiencies and eventually reduces regional erosion problems. Nearshore placement is a less expensive alternative to direct placement at the shore.

23. Schwartz and Musialowski (1980) and Hands (1987) indicate that the probability of onshore movement of sediment depends on profile shape, wave height, wave period, wind velocity, and grain size characteristics. Flat profiles, low steepness waves of moderate height, offshore winds, and a grain size similar to that landward of the placement site promote shoreward transport.

24. Only a few of the cited benefits may be appropriate at any single site. The design criteria for optimizing selected benefits have not been formulated. The objectives at the Sand Island site are simply to place sand in the active coastal zone rather than continue disposing in deep water and to monitor the fate of the resulting deposit as a basis for future guidance.

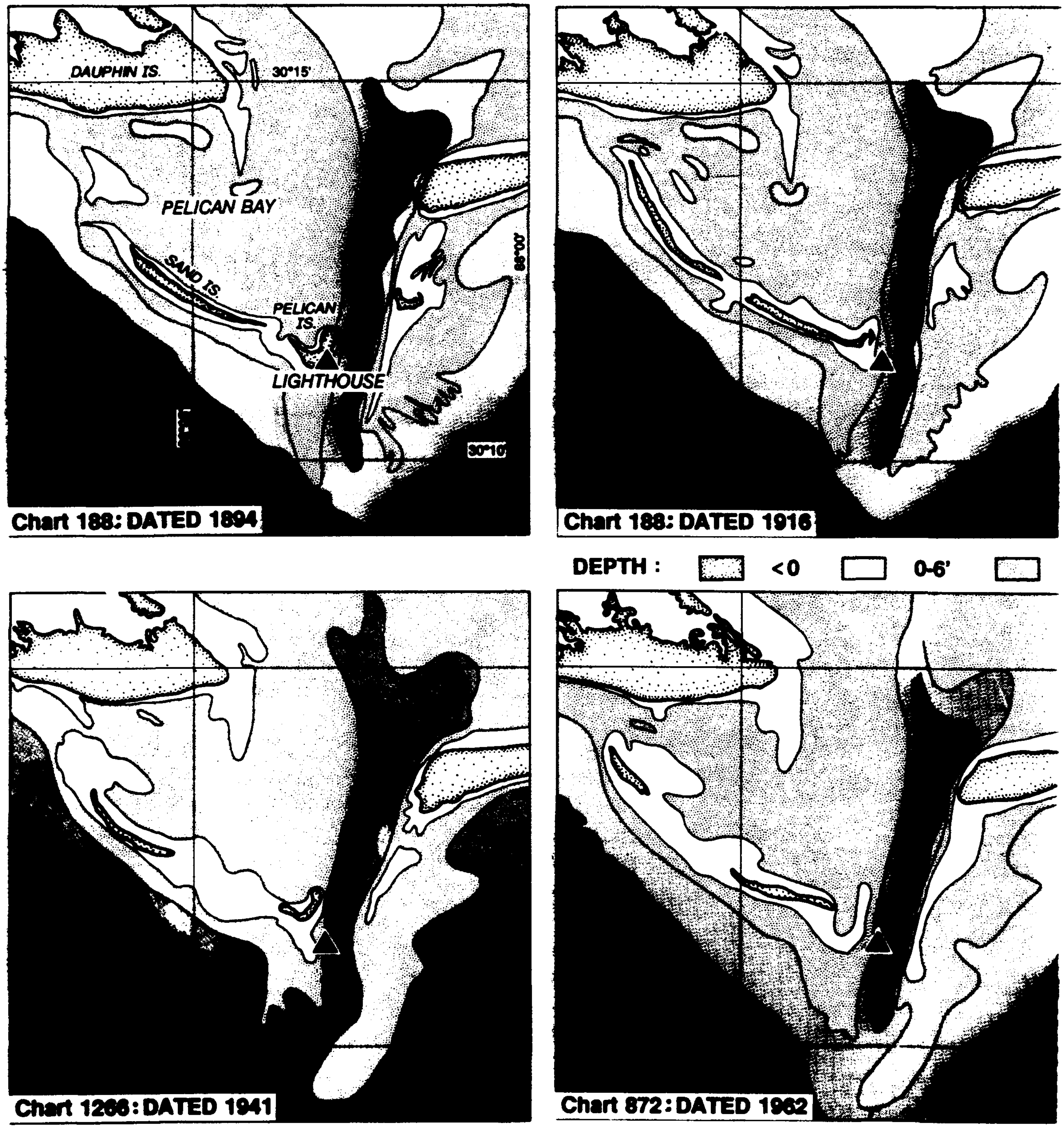


Figure 3. Historic charts of the Mobile Bay ebb-tidal delta and the
Mobile ebb-tidal delta is a massive shoal that has shielded Dauphin I
tively small changes in volume along the crest of this Sand/Pelican I
Ridge itself, however, is a permanent feature and relatively stable a
Island Feeder Bar was built along the presently diminished end of thi

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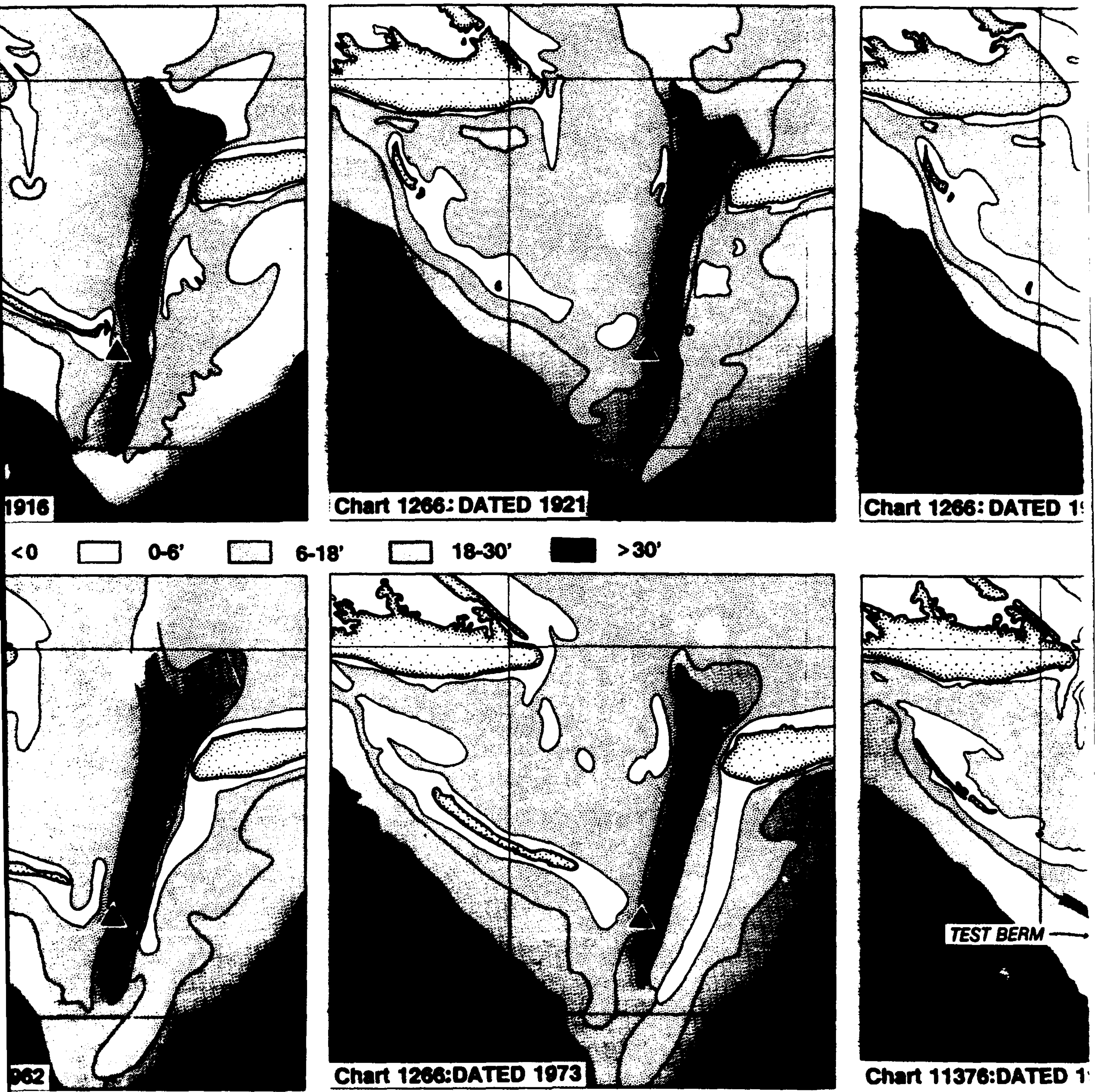


y ebb-tidal delta and the east end of Dauphin Island. The marginal ridge on the western side of the hat has shielded Dauphin Island from the brunt of direct wave attack throughout historic times. Rel est of this Sand/Pelican Ridge cause islands to appear, migrate, and disappear. The Sand/Pelican re and relatively stable as compared with the ridge on the eastern side of the tidal delta. The Sanc ntly diminished end of this Sand/Pelican Ridge.

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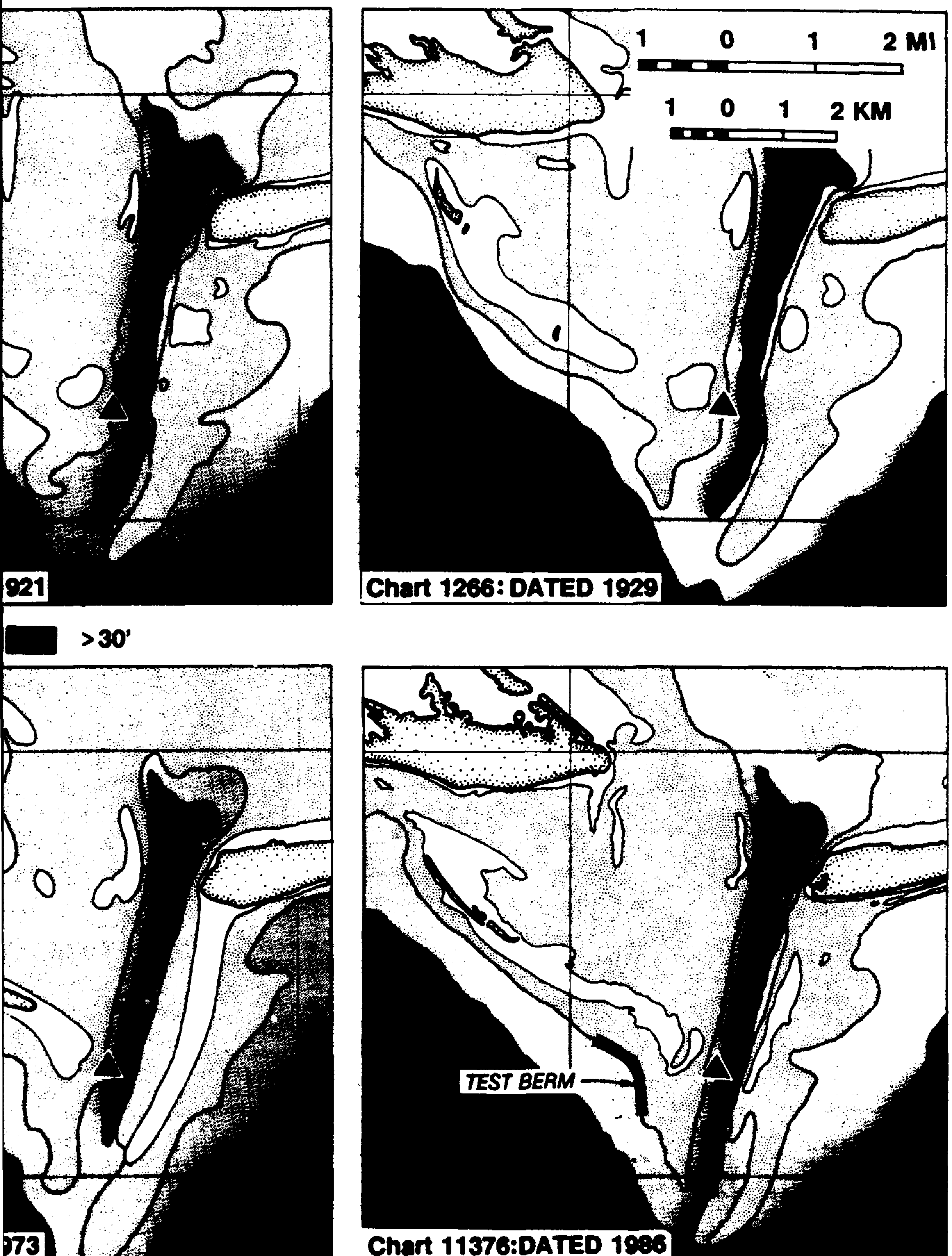



nd. The marginal ridge on the western side of the
direct wave attack throughout historic times. Rela-
pear, migrate, and disappear. The Sand/Pelican
e on the eastern side of the tidal delta. The Sand

3of3

Figure 4. Dauphin and Sand Islands from Système Probatoire d'Observation de la Terre (SPOT) imaging, 27 April 1987. Local reorientations on Dauphin Island's eastern beaches reflect the pattern of reformed and refracted waves transmitted over and around the Sand/Pelican Ridge. The nearshore berm was not detectable on this imaging

## PART III: BERM CONSTRUCTION

### Site Selection

25. Selection of a site for the dredged material berm was dictated by economic haul distance, direction of expected longshore movement, hopper-dredge draft restrictions, and the desire to retain the sand in the littoral system. There are no specific guidelines for site selection. The considerations will be described, but the reasoning depends heavily on engineering judgment. Documentation of additional experiences will lay the foundation for more specific future guidance.

26. To be within the littoral drift zone and still allow for passage of a shallow-draft hopper dredge, the Sand Island site had to be located between depths of 14 to 20 ft. Due to predominantly westward longshore transport and chronic erosion problems on Dauphin Island, the berm was placed west of the ship channel and close enough to minimize hopper haul distance but far enough away that the chance of material returning to the channel would be minimal. Fortunately, these criteria were compatible with nourishment of the eastern, low section of the Sand/Pelican Ridge (Figure 3).

27. Considering all factors, the material was placed along the 19-ft contour about 1.5 to 2 miles west of the entrance channel. It was calculated that this placement location could result in a 10- to 15-percent cost savings in hopper dredge travel time compared with placement at the conventional site (Figure 2).

### Conceptual Geometry

28. The berm was planned to accommodate monitoring by being prominent enough to be easily identified with conventional bathymetric surveys. Considering draft requirements and the need to retain sand in the active littoral zone, the maximum height achievable was about 6 ft.

29. To prevent serious delays in placement of material, a 500-ft-wide placement corridor was planned anticipating a potential spread of the material as much as 1,000 ft across the base. The placement of an expected 400,000 cu yd of dredged material was estimated to be sufficient to create a berm about 1 mile long.

## Placement Operations

### Equipment

30. The dredging and placement were conducted with two split-hull shallow-draft hopper dredges, the *Atchafalaya* and *Mermentau*. Each contract dredge had a 1,300-cu yd hopper and a fully loaded draft of approximately 14 ft. The light draft was approximately 5 ft. Dredging began on 12 January 1987.

31. Using a bottom overflow port and running on zero clearance, the dredges were able to achieve a peak berm elevation near -10 ft mean lower low water (mllw), considerably shallower than the fully loaded dredge draft. The highest peaks were created by propeller wash blowing sand on top of the previous release as the dredge backed away from a topping-off effort.

### Placement time

32. The added topping-off effort resulted in an average dumping and turning time at the placement site of 23 min per load as opposed to an historical average time of 14 min. While the maximum berm height is advantageous for monitoring, risk of grounding is unnecessary. Delays would be much less in future operations.

## Achieved Geometry

33. Berm construction was completed on 23 February 1987. Approximately 464,000 cu yd of sand was placed, resulting in a 6,000-ft-long berm with a characteristic relief of 6 to 7 ft. As indicated in Figure 5, a typical cross section from the first postplacement survey on 3 March 1987 shows a berm very closely resembling the conceptualized configuration.

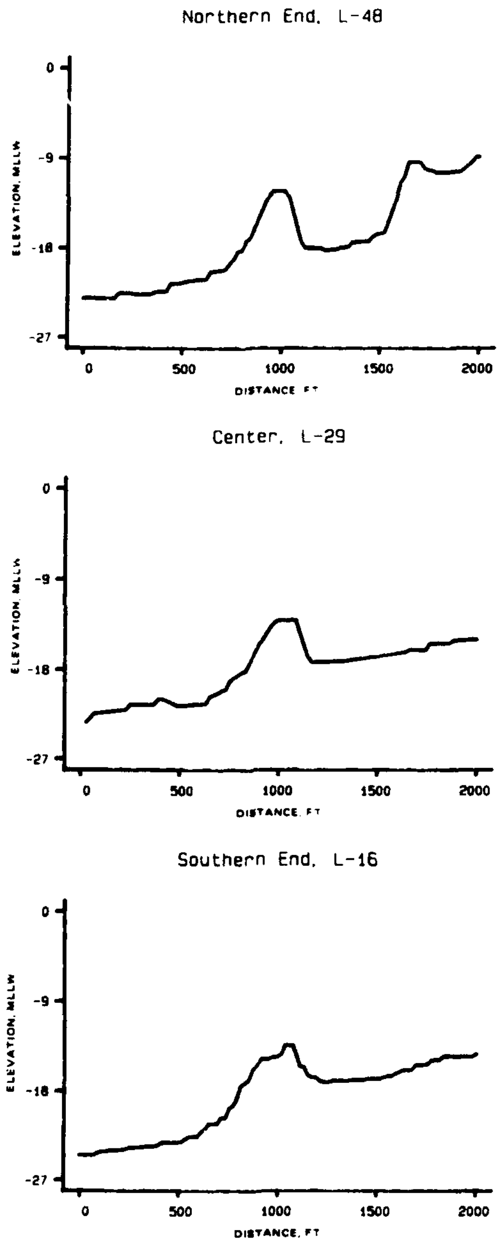



Figure 5. Typical cross sections 1 week after construction of the nearshore berm. The constructed berm appears in the center of each section. Shoals to the right of the berm are natural accumulations. The location of each cross section is keyed to line numbers shown in Figure 6

## PART IV: MONITORING PROGRAM

### Requirements

34. Postplacement monitoring was designed to determine if the placed material stayed in the littoral zone, as intended. Table 1 summarizes the techniques employed on the baseline survey and over the following 12 months.

Table 1

Multi-Element Techniques to Monitor the Nearshore Berm

| Technique | Coverage/Schedule |
|---|---|
| Bathymetric surveys | 23 miles, 200 kHz, Survey Nos. 0 through 9 |
| Side-scan sonar surveys | 500 kHz, Survey Nos. 1, 5, and 7 |
| Bottom grab samples | 25 on Survey No. 0, 23 from hopper, 31 on Survey No. 1 and Surveys 3 through 9, and more from Survey No. 2 |
| Aerial photography | 27 Apr 87, 1:12,000; 21 Sep 87, 1:24,000 |
| Waves offshore | Fairly continuously beginning 22 Apr 87 |
| Waves near berm | Intermittently beginning 3 Dec 87 |
| Currents near bed | 29 Apr to 7 May and 22 Sep to Oct 88 |
| Seabed drifters | None released on Survey No. 0, 300 released on all subsequent surveys |

35. Initial bathymetry was run to document geometry of the constructed feature. Subsequent bathymetric and side-scan surveys were intended to document changes in shape of the berm. Sediment samples were taken (a) to establish how the placed material differed from ambient sediment, (b) to help determine the predominant direction of migration, and (c) to find out whether transport affected only certain grain sizes.

36. Aerial photography was taken to investigate wave patterns and turbidity associated with potential erosion of the berm and to illustrate surrounding coastal and shallow-water features. Winds, waves, and bottom currents were measured to better understand the complicated interaction of

forces dispersing sediment. This information is necessary to translate observed responses to future management guidelines at this and other sites, and is not part of any requirement for normal dredged material management.

## Methods

### Bathymetric surveys

37. Pyburn & Odom, Inc., completed the baseline survey on 5 December 1986, 38 days before placement began (Table 2). The baseline bathymetry was

Table 2

Placement and First-Year Sounding Schedule

| Activity | Dates |
|---|---|
| Baseline 0 survey | 2 Dec 86 to 5 Dec 86 |
| Placement Operations | 12 Jan 87 to 23 Feb 87 |
| Postplacement 1 survey | 2 Mar 87 to 5 Mar 87 |
| Postplacement 2 survey | 16 Mar 87 to 19 Mar 87 |
| Postplacement 3 survey | 1 Apr 87 to 2 Apr 87 |
| Postplacement 4 survey | 16 Apr 87 to 17 Apr 87 |
| Postplacement 5 survey | 6 May 87 to 9 May 87 |
| Postplacement 6 survey | 20 Aug 87 to 21 Aug 87 |
| Postplacement 7 survey | 25 Oct 87 to 25 Oct 87 |
| Postplacement 8 survey | 1 Dec 87 to 2 Dec 87 |
| Postplacement 9 survey | 6 Jan 88 to 8 Jan 88 |

run roughly parallel to the bottom contours. As the berm was to be constructed in a zone of constant depth, the study area was elongated the direction of the contours. Survey lines were extended parallel to the long axis to minimize time lost in turning and between lines. However, the information content is maximized by transverse lines that run along the gradient. Therefore, line orientation was transposed and run between fixed geographic points on all postplacement surveys (Figure 6).

38. Browning, Inc., conducted nine postplacement surveys for the first year's monitoring. Forty-two 2,000-ft-long survey lines cross the berm on

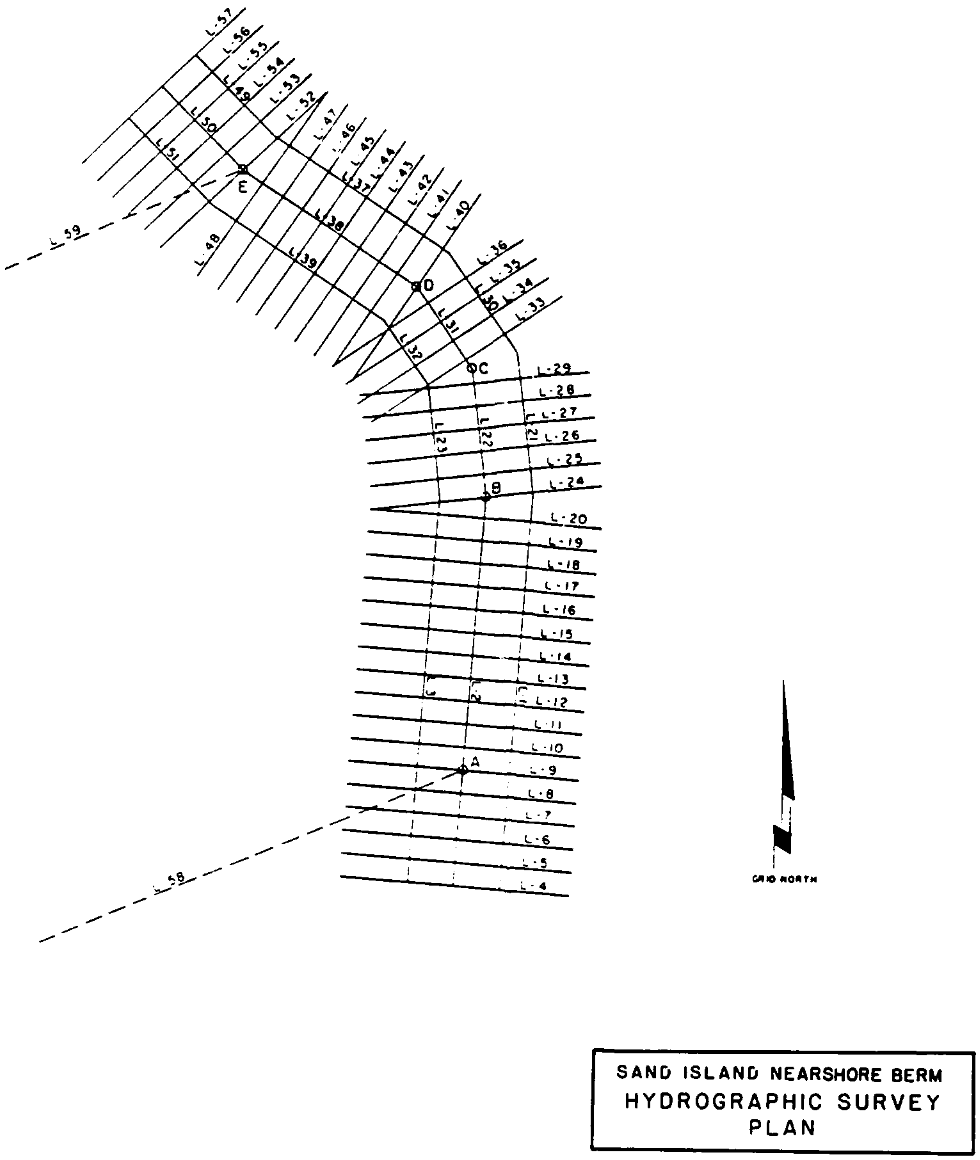



Figure 6. Layout of survey lines on 200-ft spacings. The lines were run between the same end points on all postplacement surveys

200-ft centers. Five survey line segments extend along the crest. Two additional sets of parallel segments run 400 ft to either side of the berm.

Side-scan sonar

39. Side-scan was used on several early surveys to look for the boundary between placed and native bottom material. It was used again on the seventh survey to test the feasibility of tracking bottom-current drogues equipped with special transmitters.

Grab sampling

40. Grab samples were taken with a modified Peterrson grab sampler to compare placed and ambient sediments as well as to document changes in bottom type as the material was either reworked or dispersed. Samples were obtained at 26 locations prior to placement. The same sites, plus six additional ones (SD-1 to SD-6) were resampled on subsequent surveys. Most sample locations were in the placement zone. A few were taken farther afield to assess temporal changes unrelated to placement. The layout of all 32 sample sites is shown in Figure 7. Preplacement samples were taken as the slurry was discharged into hoppers aboard the dredge.

Gage deployment

41. Sea Data 635-9 and 635-12 PUV gages were deployed throughout the year at several points seaward of the berm. Internal data loggers in both types of gages recorded waves and currents sensed by a Marsh McBirney two-component electromagnetic current meter (4-cm sphere) and a Paroscientific pressure sensor. The objective was to obtain information on bottom conditions during any major disturbance of the placed material. The gages were set to record for about 17 min every 6 hr with 1.0-Hz sampling of hydrostatic pressure and horizontal, orthogonal current velocities. In this mode these self-contained instruments can operate unattended for about 3 months. Before the end of this period, divers retrieved the instruments and replaced them with a new package containing fresh tape cassettes and batteries. Gages were mounted on blocks with sensors about 3 ft above the seabed in the 26- to 42-ft range (PUVSI 1 and 2, Figure 8). Historic wave data are available farther offshore from the National Data Buoy Center (NDBC) buoys (NDB 42009 and 42015) and the US Army Wave Information Study (WIS) hindcast site (WIS 27, Figure 8).

Wave hindcasting

42. Wave hindcasting is the process of using wind data to estimate past wave conditions. The USACE has a numerical model for hindcasting waves (Resio, Vincent, and Corson 1982). Historic barometric pressure maps and ship observations of air-sea temperature and winds are input to a wave generation and propagation model that develops wave fields. The data include seas generated by local winds and swell from the far field. Hurricanes are reported separately. The WIS is an ongoing effort to provide a data base of wave climatology for all US coasts. The two-dimensional wave spectra (energy by frequency and direction) for the Gulf of Mexico were recently completed for

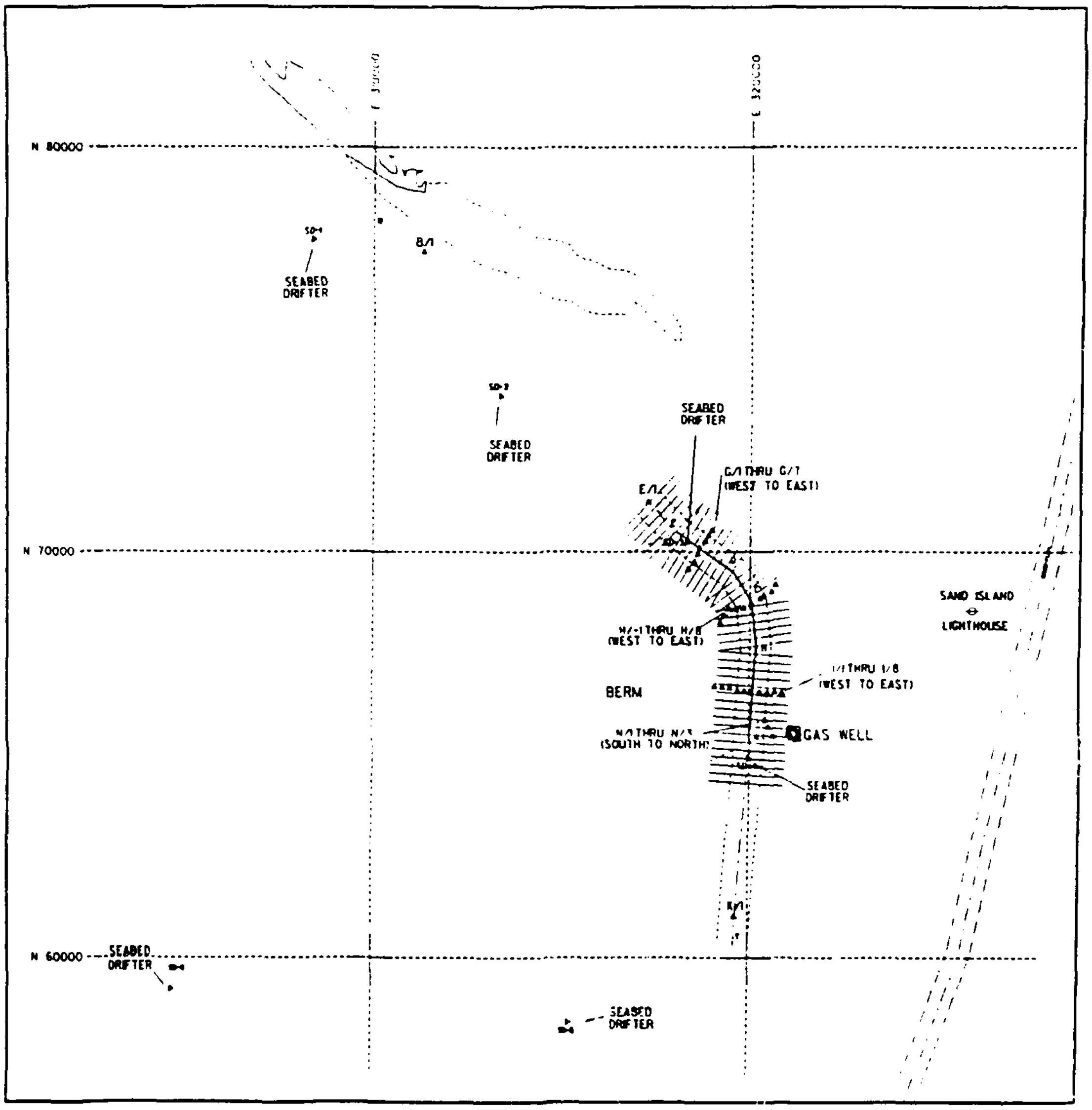



Figure 7. Sample locations, survey lines, and seabed drifter (SBD) release sites (SD-1 to SD-6). Sediment samples were taken at each SBD release site as well as at the other 26 points shown as triangles above

every 3 hr from 1956 to 1975 (Hubertz and Brooks 1989). Data for the nearest WIS station were accessed with the Sea State Engineering Analysis System (SEAS) (Ragsdale 1983) to cast onsite measurements in their historical perspective.

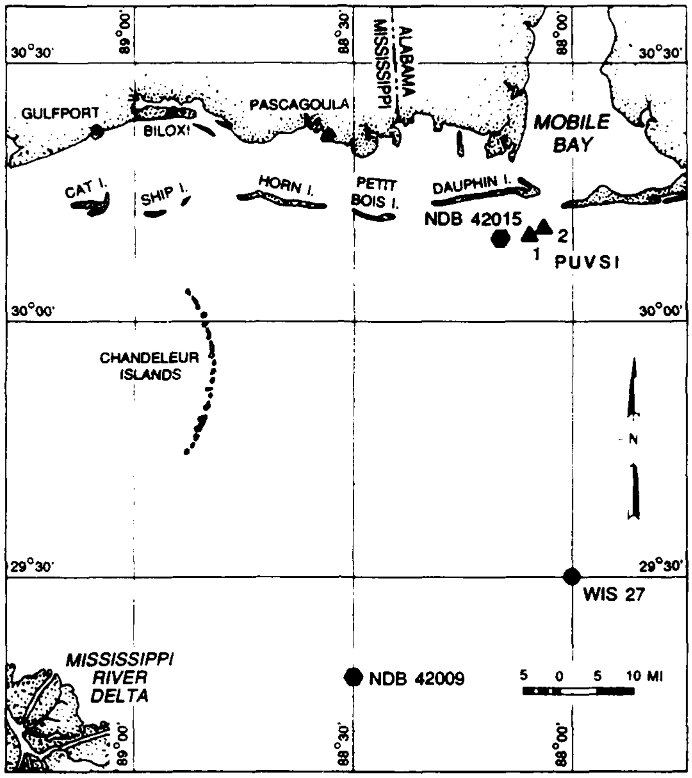



Figure 8. Wave data locations

Buoy deployment

43. A 3-m NDBC directional wave buoy station (NDB-42015) was established in August 1987 specifically to support Mobile Harbor offshore studies. Earlier deployment for testing and demonstration extends the record back to May 1987. The buoy, anchored southeast of the test berm (Figure 8) in a depth of about 52 ft, provided meteorological and directional wave data. The buoy contains a pitch-and-roll analyzer that records surface elevation and wave slopes. Calculated significant wave height, directional spectral coefficients, and period of the spectral peak are transmitted hourly to various shore stations through the Geostationary Operational Environmental Satellites (GOES). Details of the instrument and theory are given by Steele, Lau, and Hsu (1985). Buoys farther offshore predate these monitoring efforts and provide a basis for comparing CERC measurements with typical years. Summaries of the offshore data are available in a compilation by Gilhousen et al. (1986).

Seabed drifters

44. To investigate bottom current patterns in the vicinity of the berm and other nearby potential placement sites, current-following drogues were released throughout the year. The umbrella-shaped plastic drogues, known as SBD's, permit simple, direct, and inexpensive documentation of bottom currents. Drifters function well in weather damaging to many in situ instruments. However, only the SBD release and recovery sites are known. Paths between these two points must be inferred to obtain differences in relative speed and seasonal variations of flow patterns. Limitations can arise if only a small fraction of the released SBD's is recovered.

45. The SBD's have had extensive use in regional oceanographic and fisheries studies, especially in Europe where they were developed (Woodhead and Lee 1960). Coastal use is expanding as it is realized that nearshore deployments avoid many problems attendant to their deep-sea use. Prompt recovery of larger percentages reduces uncertainties in interpretation. Simple procedures for near-simultaneous release at several points facilitate field work (Hands 1987, Clausner 1988).

46. A fairly standard design known as the Woodhead (named for its principal British user) SBD was used for the tests described herein. The device consists of a brightly colored 22-in. stem and a 7-in.-diam cap with four 3/4-in. vent holes (Figure 9). Almost all SBD recovery data for the Mobile study have been provided by the public who discover SBD's on the beach or in their fishing nets, read a description of the study on an attached information card, complete a questionnaire, and return it by mail. Each card has a unique serial number relating it to the time and location of release (Figure 10).

47. During surveys 1 through 9, a bundle of 50 SBD's was dropped overboard at each of six sites (Figure 11). A sandbag tied to each bundle assured that it promptly sank directly below the release site. A salt ring, forming the weak link in a strap holding the bundle together, dissolved in 10 to 15 min, freeing the SBD's to move individually with the currents. Further details on procedures, results from other studies, and limitations of SBD's are discussed in Hands (1987).

48. Two differently weighted drifters were used. The light drifters had an average submerged weight in salt water of only 0.60 g. The heavy ones had a mean submerged weight of 6.6 g. The light weight resulted from

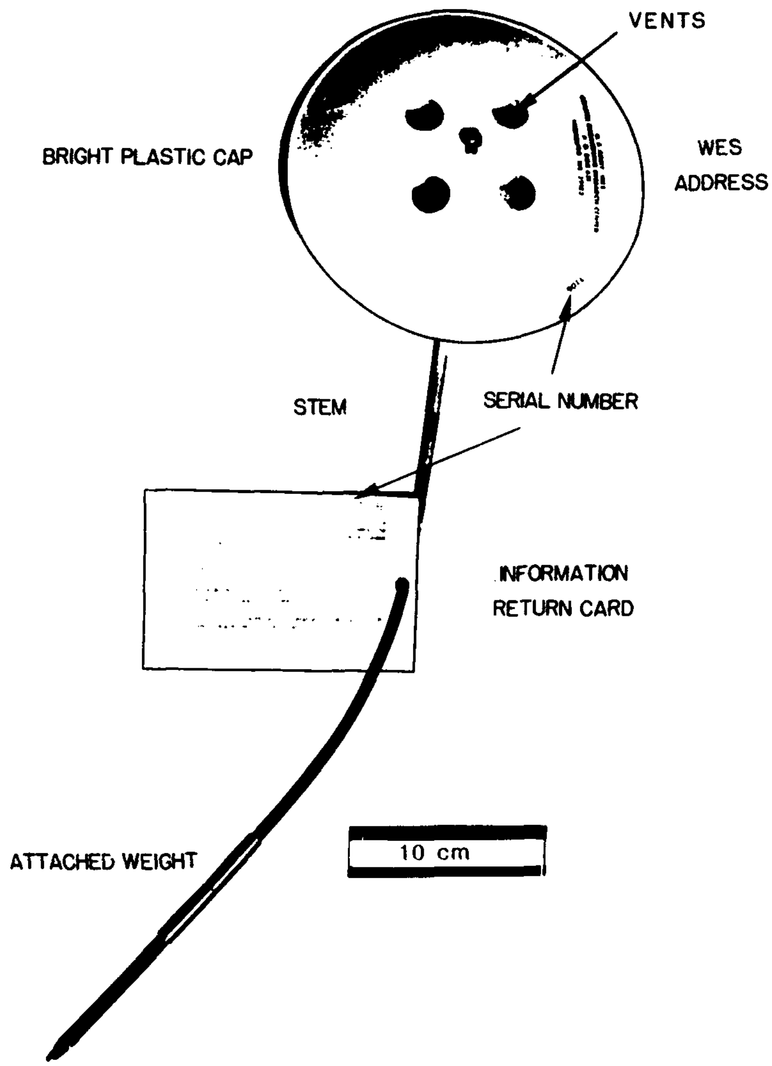
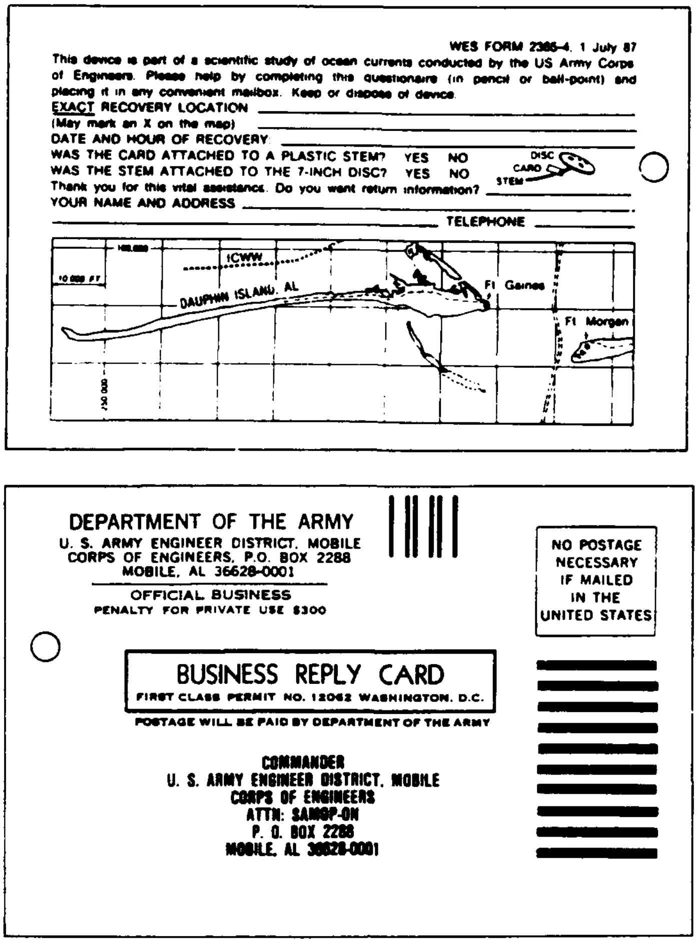



Figure 9. Woodhead SBD

attaching a commercially available brass ferrule with a nominal weight of 7 g to match the European design.

49. The first use of SBD's at the CERC's Field Research Facility in North Carolina revealed that the conventional weight (7 g) was too small to keep the SBD on the bottom especially when subjected to lift beneath approaching waves. Lacking other resources at the time, two weights were attached to half the releases. Doubling the attached weight resulted in a 6-g or tenfold increase in submerged weight. In spite of this enormous difference, the initial study showed that drifters of both weights sometimes behave identically. At other times the recovery patterns and elapse times are distinctly different depending on weight (Hands 1987). Part of the explanation is that the differently weighted SBD's travel at different heights above the seafloor. The


WES FORM 2365-4, 1 July 87

This device is part of a scientific study of ocean currents conducted by the US Army Corps of Engineers. Please help by completing this questionaire (in pencil or ball-point) and placing it in any convenient mailbox. Keep or dispose of device.

EXACT RECOVERY LOCATION ______

(May mark an X on the map) ______

DATE AND HOUR OF RECOVERY ______

WAS THE CARD ATTACHED TO A PLASTIC STEM? YES NO

WAS THE STEM ATTACHED TO THE 7-INCH DISC? YES NO

Thank you for this vital assistance. Do you want return information? ______

YOUR NAME AND ADDRESS ______

______ TELEPHONE ______



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Figure 10. Recovery card attached to each SBD

conventional 7-g attached weight results in near neutral buoyancy. These SBD's move freely throughout the water column if there is any vertical component to the current. The heavier SBD's require a higher threshold velocity to initiate motion, and they tend to remain near the seafloor with the lower end of their stem resting on or skipping over the bed surface. If suspended briefly by strong lift forces, they resettle with a fall velocity similar to medium to coarse-grained sand. Therefore, a weight invariant recovery pattern indicates quasi-uniform flow between the bed and the water surface. Efforts to further clarify weight related differences are under way. Meanwhile, two submerged weights provide more information than any single weight. Thus, a de facto standard arose: heavy and light SBD's (0.6- and 6.6-g submerged weights) are being released in equal numbers from each site. As characteristics of the plastic components vary from one purchase to the next, the attached weight is modified to preserve a constant submerged weight for the two standards.

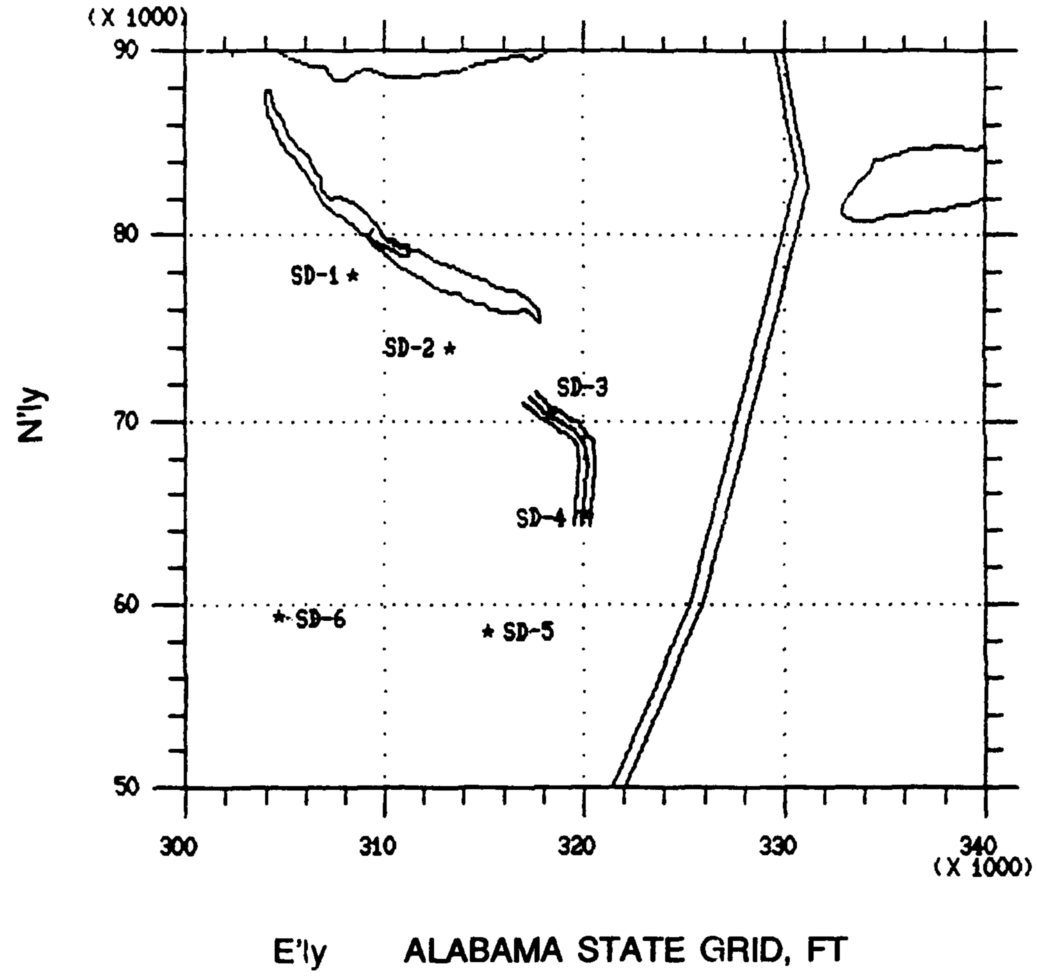



Figure 11. Seabed drifter release sites. Fifty SBD's were released at sites SD-1 through SD-6 during each of the 9 surveys

## PART V: INITIAL POSTPLACEMENT RESULTS AND DISCUSSION

### Bathymetry

50. The preplacement bathymetry of the Sand Island Study Area (SISA) is contoured in Figure 12. The bottom is relatively smooth. The steep area between -10 to -16 ft mllw in the northwest corner of the study area is the lower face of the Sand/Pelican Ridge. It slopes at about 1:20. The bottom gradually flattens to about 1:75 between -20 and -25 ft. An abrupt change in orientation of the bottom (from NW/SE on the left in Figure 12 to N/S on the right) can be considered the boundary between the relatively permanent tidal platform and its terminus in a north/south leveelike feature that has shrunk and regrown along the west side of the main ebb channel (refer to Figure 3).

51. An approximately 1,000-ft-diam mound was found at the southern end of the study area. It had been created earlier during work on a gas well platform and will be referred to as the Sand Island mound as distinguished from the Sand Island bar built with dredged material.

52. The dredged material bar was built to a typical elevation of -13 ft mllw with small areas peaking above -12 ft (middle panel of Figure 12). No postplacement elevations were above -10 ft mllw. The Sand Island bar was thus similar in depth, but much larger and more elongate than the preexisting Sand Island mound.

53. No major changes occurred in shape, size, or position of these berms over the first 12 months, as can be seen by comparing middle and lower panels in Figure 12. The crest of the bar was smoothed with a loss of about 2 ft from the peaks. The most extensive changes were erosional and along the southern end of the berm where it had been highest.

### Waves and Currents

54. Storm conditions in 1987 were not sufficient to cause any major bathymetric changes. To determine if this stability is likely to persist, historic data must be used as a guide to future conditions. The winter of

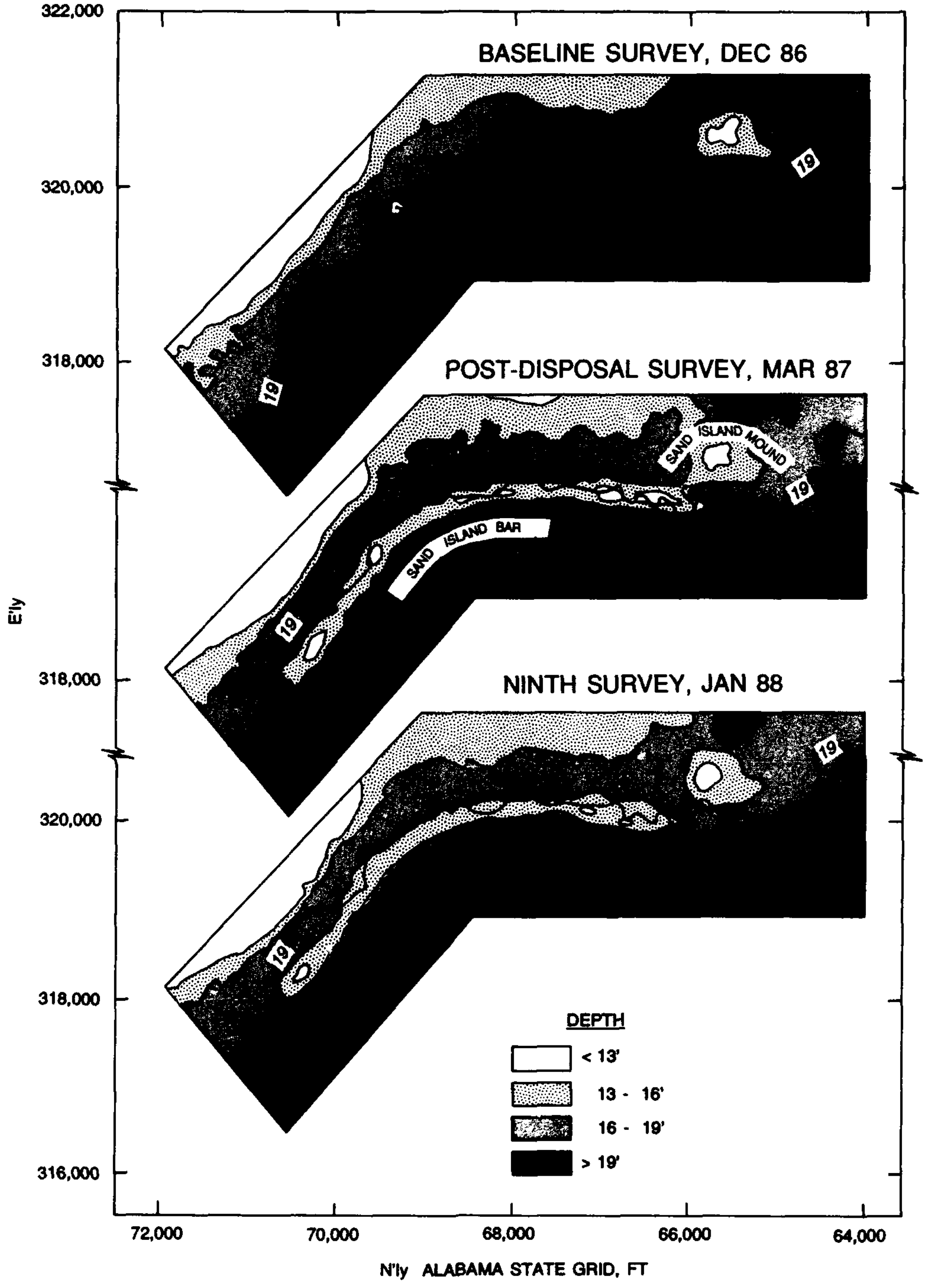



Figure 12. Measured bathymetry on baseline, first and ninth postplacement surveys document no significant dispersion of the berm during the first year. The 19-ft-depth contour from the baseline survey was transposed to later maps as a reference for berm position. Berm construction and survey dates were given in Table 2

1986/1987 was unusually calm.* In the fall of 1987, no hurricanes and only one tropical storm came into the northern Gulf of Mexico. This unnamed storm came ashore within 24 hr of forming near Galveston, TX. Maximum sustained winds were 45 knots (National Climatic Data Center 1987). After traversing Louisiana, the storm remnants passed north of Mobile. Fourteen inches of rain fell on Dauphin Island in the 48-hr period ending on 14 October 1987, but there were no severe winds.

55. Sources of quantitative data on waves are listed in Table 3. The first attempt to compare 1987 and long-term conditions is shown in the top panel of Figure 13. The monthly mean significant wave heights from the berm site (NDB-42015) are all well below average heights from the WIS hindcast study.

Table 3

Wave Information Sites

| Data Source | Latitude/Longitude, deg | | Depth, ft | Dates |
|---|---|---|---|---|
| PUVSI-1 | 30.16 | 88.11 | 42 | 12/86-5/87 |
| PUVSI-2 | 30.18 | 88.08 | 26 | 5/87-cont |
| WIS-27 | 29.50 | 88.00 | 150 | 1956-1975 |
| NDB-42015 | 30.14 | 88.17 | 52 | 5/87-cont |
| NDB-42016 | 30.19 | 88.08 | 42 | 5/88-cont |
| NDB-42009 | 29.30 | 87.50 | 210 | 1980-cont |
| NDB-42003 | 26.00 | 85.90 | 12,500 | 1976-cont |

56. It is not obvious if the height differences presented above are sufficient to substantiate that 1987 was an unusually calm year. Hubertz and Brooks (1989) report WIS heights slightly higher than measurements in each of five comparisons they made for the Gulf of Mexico. These differences probably reflect some combination of sampling variability, differences in methodology, plus real spatial and temporal differences between sites. Interpretation of differences at Sand Island are further complicated by WIS-27 being 40 miles south of NDB-42016 and in appreciable deeper water (150 versus 52 ft).

* Personal Communication, May 1987, Dr. William Schroeder, University of Alabama Laboratory, Dauphin Island, Alabama.

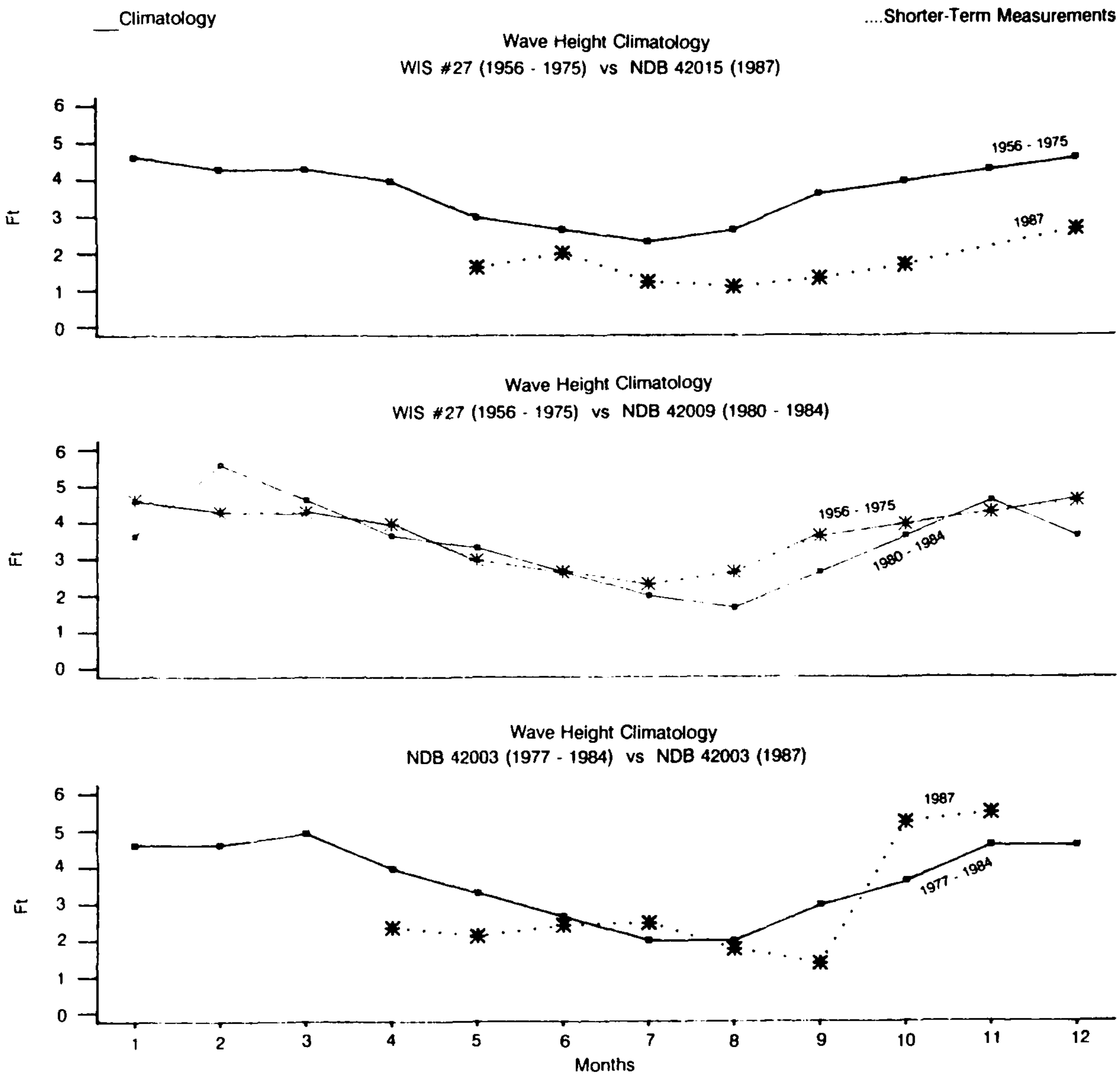



Figure 13. Monthly mean wave heights in 1987 appear below the long-term average in the top panel. However, WIS predictions are not directly comparable to onsite measurements in much shallower water. In the middle panel, comparable data from similar water depths lend credibility to both WIS and buoy measurements for long-term averages. Unfortunately, neither of these sources have 1987 data for comparison with the long term. Comparison of 1987 with longer term measurements is possible farther offshore (lowest panel). However, the offshore data fail to substantiate the suspected relative calm of 1987. Reasons are discussed in the text

Shoaling, refraction, bottom friction, and other energy losses would have to be evaluated for an unambiguous comparison between these two locations. A different NDBC buoy (42009) closer to the WIS station shows excellent agreement between these two sources for long-term climatology (middle panel, Figure 13). Unfortunately NDB-42009 operated only 1 month in 1987. So this comparison offers no clue as to whether the first year of monitoring was unusually calm.

57. The only long-term wave data continuous through 1987 comes from NDB-42003. Unfortunately, this buoy is approximately 240 miles south of the SISA, but for completeness the comparison of long-term and 1987 heights is shown in the last panel (Figure 13). In 1987, waves were clearly above their long-term average only in the winter months when winds and waves come out of the north. Such waves would have little or no effect on a berm near shore and close to the shallow ebb-tidal delta. So the higher waves in October and November of 1987 at NDB-42003 do not contradict the notion that the erosion potential at the berm may have been unusually low during this first year of monitoring.

58. Although presently available wave information is inconclusive, a study of bottom currents recently completed offshore of Pensacola, FL, does provide a good, direct indication of the berm's 1987 erosion potential. Currents were measured over an 8-month period in 1987 at locations 6 to 10 miles offshore in depths ranging from 66 to 80 ft. The highest average speeds at different meters ranged from 22 to 62 cm/sec. A numerical current model based on wind input was calibrated to fit the observations. The model was then run with 40 years of Pensacola wind measurements to generate a current climatology.*

59. Speeds from model-derived climatology far exceed the 1987 measurements. Figure 14 compares modeled and measured bottom currents. The solid line indicates probability of exceeding different speeds based on actual measurements 3 ft above the 66-ft-deep seafloor between 24 October and 26 November 1988. This is a period of the year when winds are usually near their maximum and strongest from the northeast quadrant (Schroeder and Wiseman

* R. L. Pickett, July 1988, "A Summary of the Currents Off Pensacola, Florida: Final Report," unpublished report, Naval Ocean Research and Development Activity, Stennis Space Center Station, Mississippi.

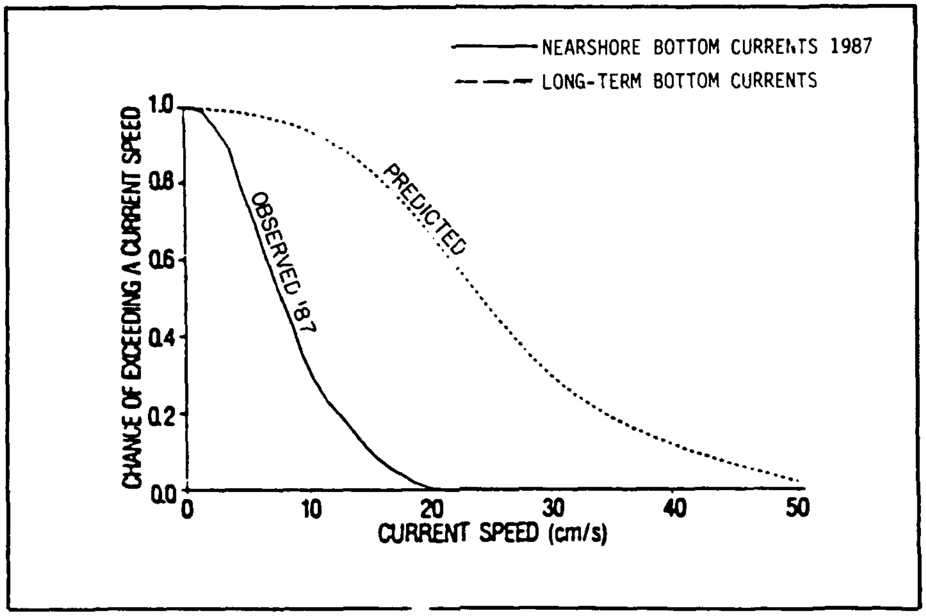



Figure 14. Currents measured in 1987 were much slower than expected from the long-term wind record. The solid line indicates the distribution of near-bottom currents observed offshore of Pensacola. The dashed line gives the distribution of much stronger currents predicted for the long-term at the same location by a three-dimensional numerical model. The relative calm of 1987 is vividly evident in this data set*

1983). The dotted line shows exceedance frequency for all speeds from the 40-year model. Both curves represent full-duration exceedances, i.e., calm periods were not excluded from either the measurements or calculations. Measurements from the solid state S4 current meter are averages from six readings per hour, and model results do not include tides. Both of these conditions tend to centralize the distributions slightly, i.e., less averaging and higher sampling rates would increase the chance of extreme measurements. Tidal effects would also increase both low and high predicted values.

60. All the 1987 observations were low and uniform relative to long-term predictions. The median current speed observed in the fall of 1987 was 8 cm/sec compared with 25 cm/sec predicted for the long term. The critical current necessary to erode sandy deposits depends on several factors, including character of bed material, roughness of the bottom, and the velocity

* Pickett, op. cit.

distribution and viscosity of the fluid or bottom shear stress. For unidirectional currents, abundant empirical data exist on the threshold velocity necessary to initiate sand motion on a flat bed. In accordance with the relationship of Miller, McCave, and Komar (1977), sand of a size equal to the median diameter of the Sand Island berm material would begin moving when unidirectional flow exceeds 40 cm/sec measured 1 m above the bed.

61. Initiation of bed movement under wave oscillations involves turbulence and flow accelerations in a time varying boundary layer with increased potential for particle entrainment. Published criteria for oscillatory flow thresholds exist but are less consistent than in the unidirectional case (Komar and Miller 1974). Hallermeier (1980) has evaluated 10 sets of data and derived a unified threshold criterion. Following his formulation, a peak near-bottom speed of 16 cm/sec should mobilize the grain sizes of interest. Hallermeier discusses many factors ignored in the theory that in nature would contribute to motion at even lower speeds: bed forms, nonuniform grain sizes, and bottom slope. Interacting wave trains, superimposed tidal and wind currents, and irregularities of the bed would further increase opportunities for sediment motion below the theoretical threshold for simple wave oscillations. So the value of 16 cm/sec could be viewed as an upper limit. Whenever instantaneous velocities exceed this limit, grains should be moving on the berm.

62. In this application, average, not instantaneous, velocities are presently being considered. Furthermore, mere grain motion, though necessary, is not sufficient for berm erosion. Net erosion requires that grains be significantly displaced before resettling and that the resulting transport away from the berm exceed transport to it from the "upstream side." A compromise is required between the relatively well-established threshold for simplified, steady conditions (40 cm/sec) and the heuristic, lower valued threshold for instantaneous velocities under oscillatory flow (16 cm/sec). Accordingly, episodes when the hourly averaged velocities exceeded 25 cm/sec are examined as indicative of vigorous berm erosion.

63. At Pensacola only 1 percent of the measurements exceeded this nominal dispersion threshold in 1987, while half the results exceeded it over the long term. So in the first cut, erosional conditions barely encountered in 1987 apparently occur regularly over the long run. The frequency of other speeds can be read from Figure 14. Clearly, the climatology model indicates

1987 was a relatively quiescent period at Pensacola.

64. Sand Island is about 45 nautical miles west of Pensacola. For wind-driven currents, this is not a large separation. Huyer et al. (1975) found currents of similar magnitude, direction, and timing at sites more than 100 miles apart on the Washington/Oregon coast. Noble and Butman (1984) demonstrate similar coherence off New York.

65. Bathymetric differences between the two shallow gulf sites (66 and 16 ft), the tidal currents from Mobile Bay, and the sheltering from southwest waves at the berm site could introduce differences in absolute velocities between the two locations. However, the relative calm of 1987 at Pensacola applies directly to the question of 1987 versus long term at the Sand Island berm site. Greater erosion of the berm can thus be expected in coming years.

## Tides

### Daily and monthly

66. Astronomical tides advance about 50 min from day to day in step with the Moon's revolution around the Earth. In the vicinity of Mobile Bay, the tide is diurnal. Only one high and low is regularly distinguishable each tidal day. The mean diurnal range at the mouth of the bay is 1.3 ft. Each month the diurnal range grows to about twice this average. The resulting tidal currents in the vicinity of the study area are accentuated by filling and discharging of the bay. The effect that monthly variations in ebb and flow from the bay have on coastal currents is discussed in a following section on SBD's.

### Yearly

67. There is also an annual component to the tide that amounts to about 0.8 ft at Mobile (Harris 1981). The daily mean water elevation averaged by month increases for half the year and then decreases over a range that is about the same amplitude as the diurnal range. This annual cycle level is more regular at Mobile than at most US tidal stations. The cause is not completely understood. Schroeder and Wiseman (1985) summarize and refer to processes that play a potential role in the annual tide: seasonal winds, river discharge, thermal expansion of the water, gulf-wide wind-stress curl, and variations in the loop current.

68. The significance for this study is that daily averaged water levels are lowest during precisely the time of year when winds, waves, and currents tend to be strongest. Daily means and highs are highest during the summer when waves tend to be lowest and least likely to initiate bottom motion. Daily low water tends to be lowest in the fall during hurricane season. Thus the major factors combine to increase berm erosion potential during fall and winter months and minimize it in the summer. Observations are presently too limited to address seasonal variations in berm stability, but continuing monitoring should clarify this relationship.

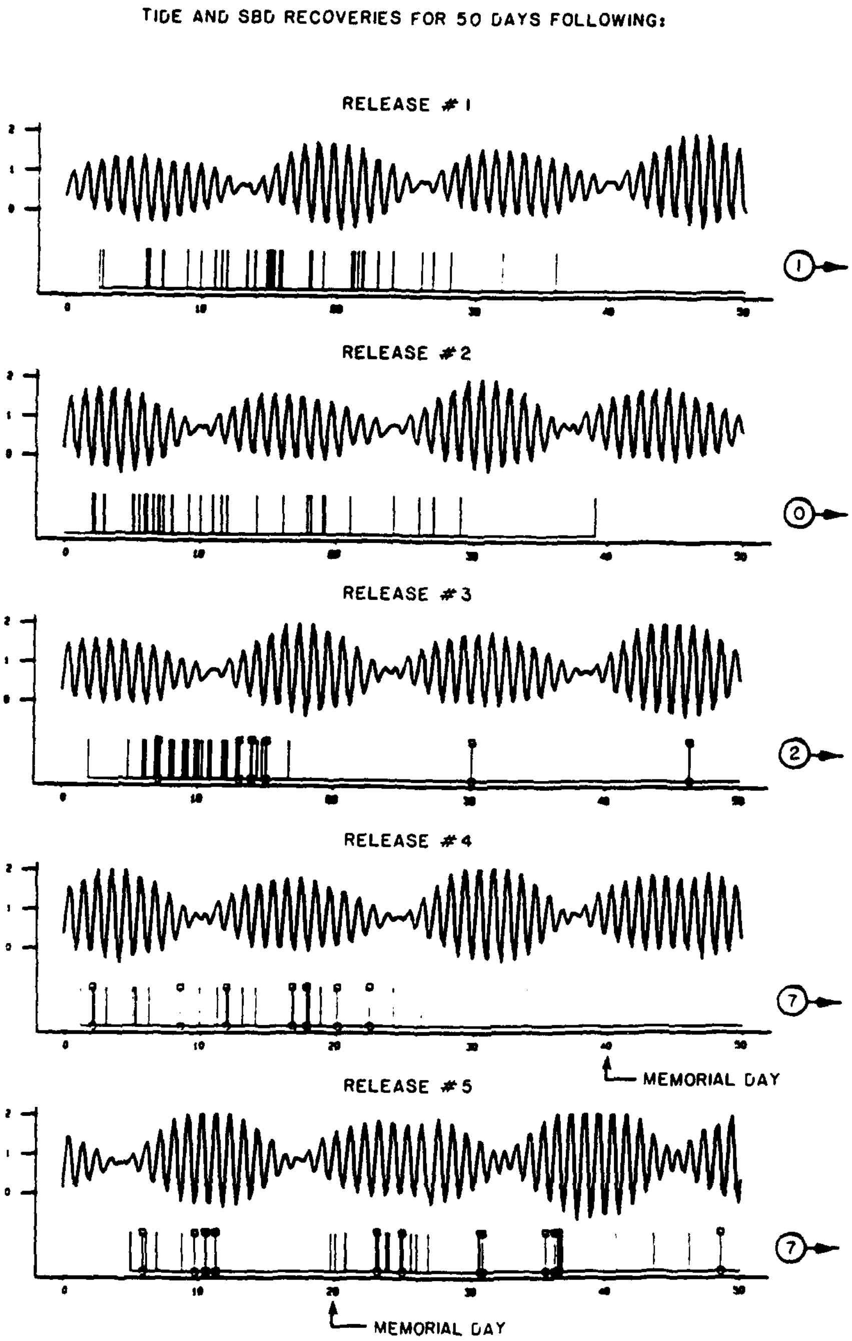
## Seabed Drifters

### Elapsed time between release and recovery

69. Many factors affect the time and place of SBD recovery. With proper consideration, some potential sources of variation can be eliminated. Others can be standardized to minimize bias and uncertainties in the results. For example, a short elapsed time between release and recovery suggests fast, direct currents. However, the stall time between arrival of an SBD at its recovery site and its discovery is generally unknown. Information on speed degrades as the stall time increases. For this reason, some workers infer speeds using only the shortest elapsed time. Alternately, constant vigilance at the recovery site can eliminate stall time, or periodic searches can fix an upper limit on this unknown.

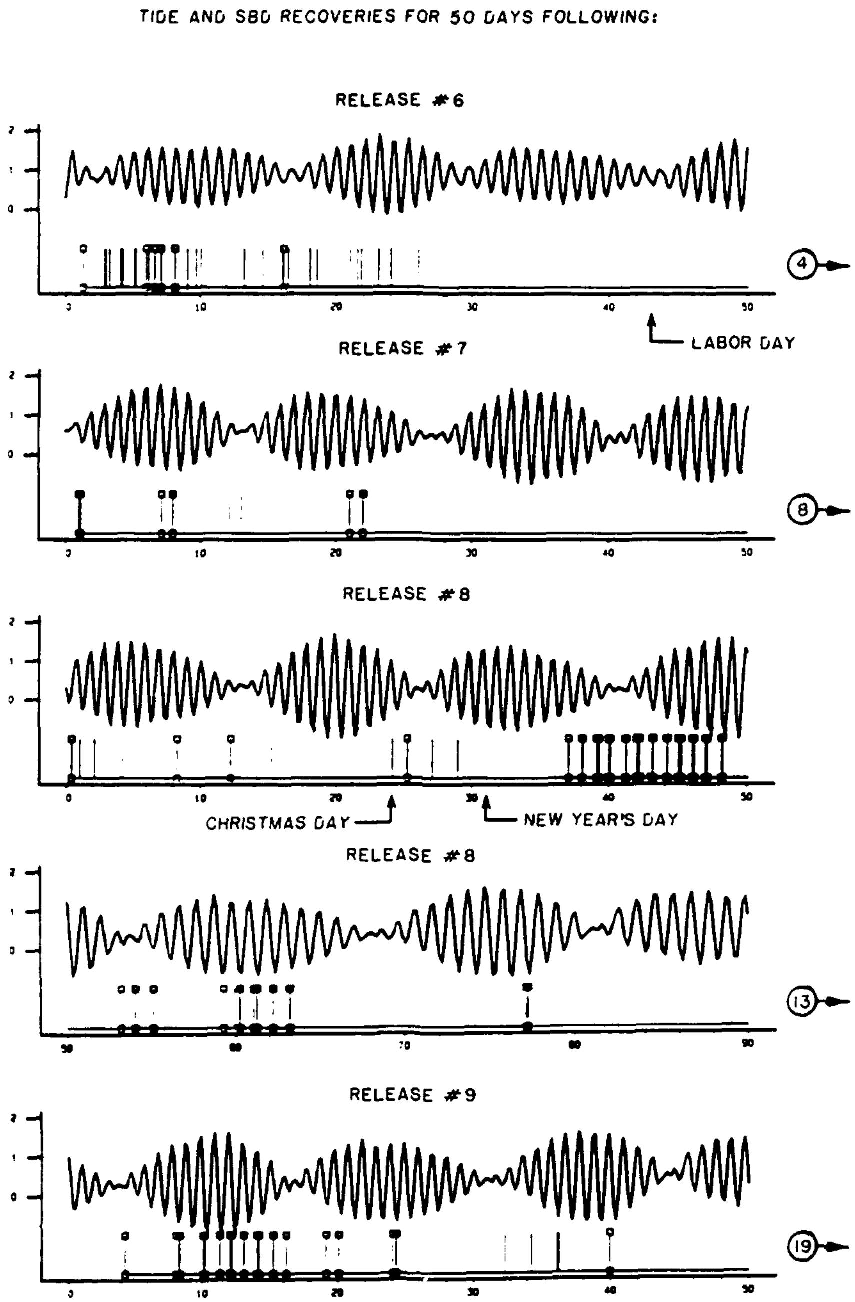
70. In the present study, Corps personnel searched the beaches only occasionally. The distribution of stall times could thus vary with public visitation on the beaches and trawling activity in adjacent waters. Figure 15 presents the elapse time for each batch of releases the first year. Tidal fluctuations and SBD elapse times are shown for 50-day periods following each of the nine releases of SBD's.

71. It would be reasonable to expect releases on a rising tide to result in a different initial trajectory than would have occurred during a contiguous falling tide. Even though Sand Island tides are diurnal (only one/day), the release sites are far enough from shore (Figure 11) that several tidal cycles elapse before SBD's begin to reach the beach. Therefore, no




a. The spring to neap tidal cycle has no clear effect on the time of SBD recovery. The only indication of a visitation bias is a slight increase in recoveries after Memorial Day weekend. Even if real, this effect would be too small to have any bearing on the overall patterns of interest in this study

Figure 15. Tides and SBD elapse time (Continued)




b. Tidal fluctuations are shown for 50-day periods following each of the nine releases of SBD's. Vertical tic marks below the tide curves indicate the number of days that elapsed between SBD release and recovery. Boxes at the end of tic marks indicate heavier (14-g) weighted SBD's. Circled numbers in the right margin indicate the number of recoveries made beyond the end of the time line

Figure 15. (Concluded)

effort was made to fix release times relative to the daily stage of the tide. As tide stages vary from release to release, there is a slight indication that releases on rising tides (episodes 1 through 8) result in shorter elapsed time averaged for all recoveries, but there is no indication that this affects final recovery percent (Figure 15).

72. The tidal range on successive days builds and diminishes in a cycle having a period near 29 days. The largest amplitudes coincide with the new and full moon (spring tide). When the moon is in the first and third quarters, the tides along the Alabama coast essentially vanish for a day or two (neap tide). Resulting monthly variations in strength of Mobile Bay ebb and flow could play a role in recovery patterns. Nine batches were released at different times in this monthly cycle. To date the monthly periodicity by itself does not seem to be of much importance to residual transport from these release sites.

73. Actual water levels are affected by phenomena other than the astronomical tide depicted in Figure 15. The other phenomena are significant for reduction of sounding depths to elevations and calculation of volume changes on the berm. They need not, however, be considered in this general examination of tidal effects on SBD recovery times.

74. Holidays affecting beach visitation also appear in Figure 15. It is noted that none of the SBD's from Release 5 were recovered the week before Memorial Day. Then, 15 were recovered over the following week. This recovery record may reflect an increase in beach combing after the holiday weekend. However, since the change in visitation would be most pronounced at this time of the year, bias at other times should be even smaller.

75. Since the gulf is at its calmest in the summer, no monitoring activities took place from May to August. The other events affecting visitation to Dauphin Island (e.g. Labor Day, the sailing regatta, and fishing rodeo) were in this period of no release and thus had no effect on SBD elapse times. So a few drifters from the fifth release suggest a few days' increase in stall time. Even this "worst case" is a minor effect that will have no bearing on the general patterns of return interpreted below.

Spatial bias

76. The chief enforcement officer for Alabama's Department of Marine Resources on Dauphin Island said that residents walk every foot of the eastern

half of the island daily and could be relied upon to report SBD's.* The western end is not walked as extensively but is patrolled by vehicles. Corps employees traversed the western half of the island after each survey and found only three drifters. The public returned many SBD's from this stretch. Thus almost all of the previously released SBD's were already recovered before Corps traverses. Evidently SBD's do not lie on Dauphin Island for weeks undiscovered. It appears most drifters arriving on Dauphin Island are recovered within a few days, even on its least visited sections, except perhaps during inclement weather.

Recovery location

77. Release sites and dates for all 2,700 SBD's deployed the first year are given in Table 4. Release and recovery sites are shown in Figure 16, which depicts the numbers of recoveries along 1-mile segments above a map of the Alabama coast.

Table 4

First Year's SBD Releases

| Release Period | Serial Number | Date of Release | Number of Recoveries |
|---|---|---|---|
| 1 | 5501 to 5800 | 3 Mar 87 | 60 |
| 2 | 5801 to 6100 | 19 Mar 87 | 50 |
| 3 | 6101 to 6400 | 31 Mar 87 | 58 |
| 4 | 6401 to 6700 | 15 Apr 87 | 37 |
| 5 | 6701 to 7000 | 5 May 87 | 46 |
| 6 | 7001 to 7300 | 11 & 17 Aug 87 | 40 |
| 7 | 7301 to 7600 | 20 Oct 87 | 18 |
| 8 | 7601 to 7900 | 1 Dec 87 | 83 |
| 9 | 7901 to 8200 | 7 Jan 88 | 56 |
| | | Illegible Serial No. | 5 |
| | | Total | 453 |

* Personal Communication, 1988, Major J. K. Waller, Chief Enforcement Officer, Department of Natural Resources, Dauphin Island, Alabama.

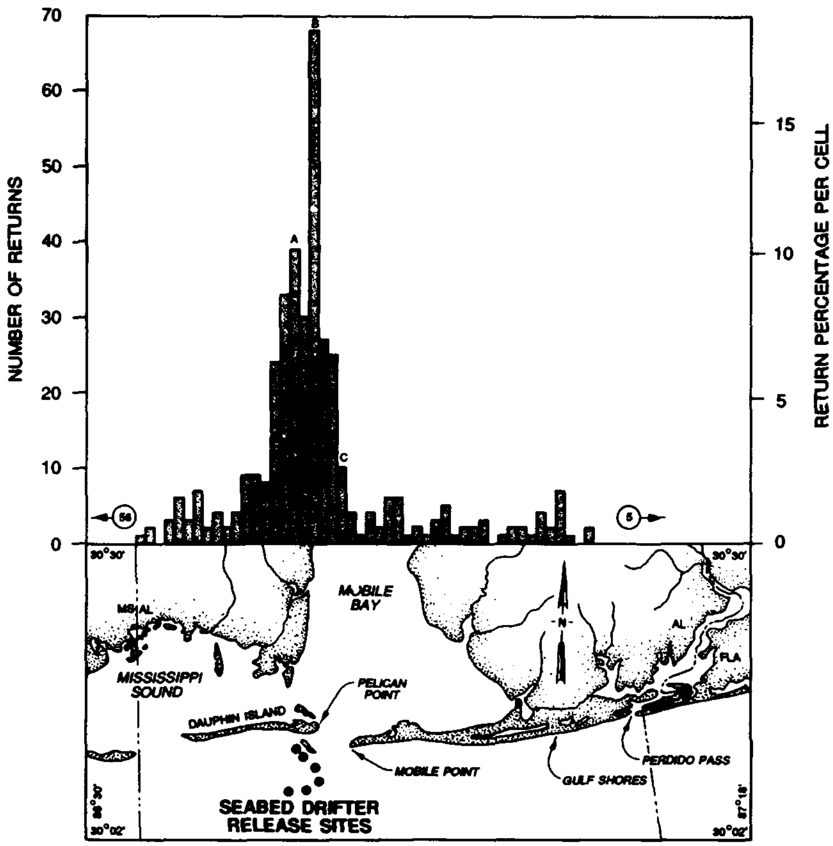



Figure 16. Alabama SBD recoveries. The numbers of recoveries along 1-mile segments are tabulated above a map of the Alabama coast. The greatest concentration of SBD returns was at Pelican Point on the eastern end of Dauphin Island, Cell B. A secondary maximum occurred at Cell A inshore of west end of Sand Island. Between A and B, the smaller number of recoveries include those from Dauphin Island and from offshore, principally on Sand Island. Cell C covers Mobile Point. Recoveries anywhere in the bay are tallied at the two cells between B and C. Circled numbers in the margins indicate the total number of returns beyond the Alabama state boundaries

78. Most of the recoveries were made on the beaches directly inshore from the release area. The Sand/Pelican Ridge on the outer edge of the ebb-tidal platform (Figure 3) represents a convex foil tending to divert northbound currents to either side. The major concentration for SBD recoveries, Cell B, is in approximate alignment with the eastern end of the Sand/ Pelican Ridge. The next highest concentration (Cell A, 3 miles west) is aligned with the western end of the Sand/Pelican Ridge. Evidently, there is

frequent bottom flow toward shore which is diverted around the Sand/Pelican Ridge but continues northward all the way to Dauphin Island. The lesser number of recoveries between maxima A and B in Figure 16 represents roughly equal numbers of recovery from Sand and Dauphin Islands (as shown in more detail in Figure 17).

79. Sand Island is below 6 ft in elevation. Although there is some grass on Sand Island, a considerable portion of it is barren sand subject to overwash. If not recovered promptly, SBD's initially beached on Sand Island, then, may be washed around or even over the island in a storm.

80. In Figure 16, Cell C covers Mobile Point. Recoveries from anywhere within Mobile Bay are tallied in the two cells aligned with the mouth of the bay, which was their route of entrance and the place where they crossed the shoreline trend. The 1-mile-wide cell west of C got all the bay recoveries east of an arbitrary dividing line, X = 326500 in the Alabama state plane system. The adjacent cell got all the remaining bay recoveries.

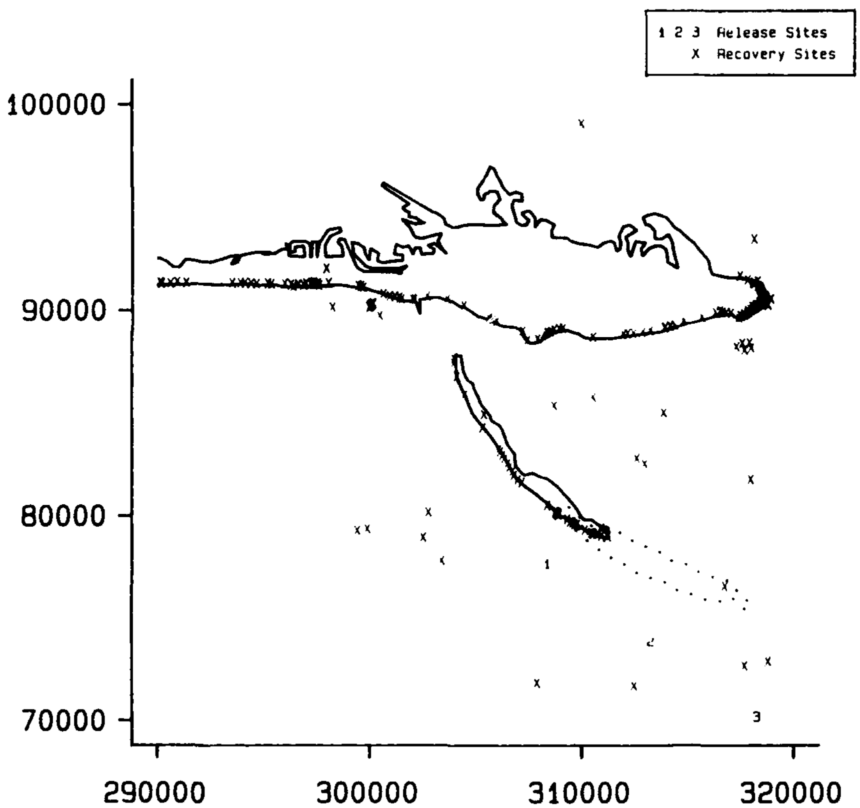



Figure 17. Recoveries of SBD's on and near Sand and Dauphin Islands

81. Most recoveries were along a span of beach less than 5 miles in length. The SBD's have come ashore in a remarkably tight cluster considering that the release sites extend 6 miles offshore, are spread over 3 miles parallel to shore, and the intervening bathymetry tends to split the northbound current into easterly and westerly components.

Variation in recovery by release site

82. The SBD's released from the shallower, more northerly four sites (Figure 11) came ashore on the east end of Dauphin island in greater numbers and in a tighter concentration than SBD's from the outer two sites (Figure 18). The recoveries from deeper sites 4 and 5 are fewer. Their longshore distribution is less peaked, but spread over the same stretch of shore. The distributions from all six release sites center on the east end of Dauphin Island.

83. Most of the SBD's crossing the channel to Mobile Point come from site 3, and most of these end up on Mobile Point (Cell C, Figure 16). Being on the crest of the more shoreward end of the berm, site 3 seems more susceptible to the flood tide. This is the simplest explanation of why more of the SBD's recovered east of the channel come from site 3 than from sites closer to the channel (4 and 5). All six release sites appear equally susceptible to infrequent transport farther east.

84. In sheer numbers, more far-west recoveries come from the inner four release sites, as shown by the circled numbers in the left half of Figure 18. When scaled to percent recovery, all sites except 1 and 2 seem equally susceptible to extreme westward deflection. The percentage of recoveries from release sites 1 through 6 that came in west of Alabama were 8, 7, 14, 17, 13, and 15, respectively.

Variation in recovery by season

85. Recoveries east of Dauphin Island indicate those SBD's moved across the navigation channel or bypassed inside the bay or out in the gulf. However, only a small fraction of the total recoveries came from east of the release area (Figure 16).

86. Figure 19 partitions SBD recoveries by release periods. The few recoveries east of Dauphin Island are seen here to come almost entirely from the third and fourth releases. Eastward movement was not only uncommon but restricted to a single period of the year. Eastward drift would have appeared

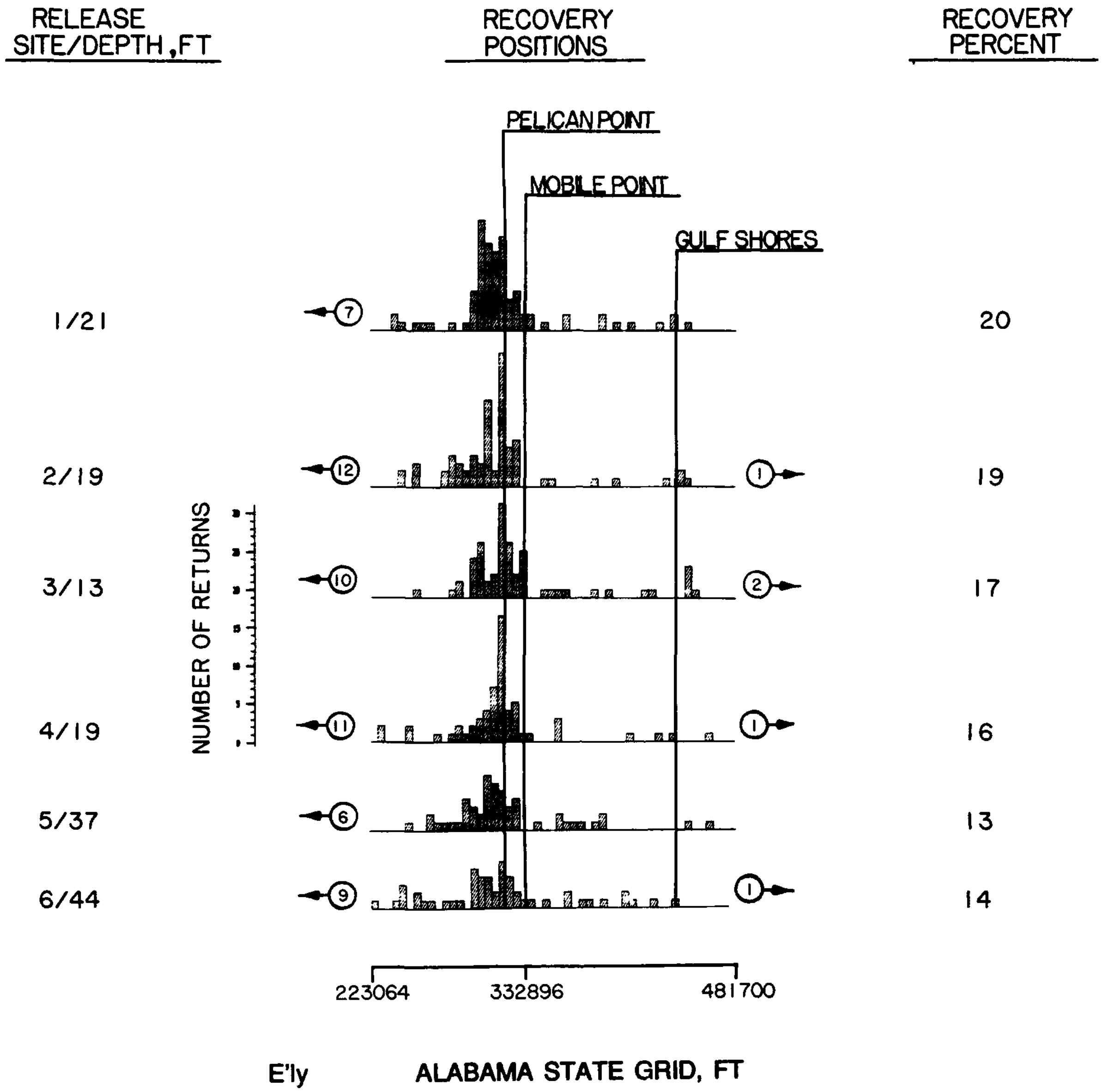



Figure 18. Distributions of SBD's from six different release sites are surprisingly similar. Recoveries from the outer two sites are slightly lower in number and less focused

even less important if two releases, less than 16 days apart, had not fallen in this period of eastward flow. Elapse time for the easterly recoveries from release 3 are shown in Figure 20. Almost all of these SBD's came ashore the second week after their release. In a typical Sand Island release, more than half of the recoveries will be made after the end of the second week. Eastward displacement is not only infrequent, but of brief duration.

87. Three hundred SBD's were released on each deployment. Fairly high recovery followed the first three releases in March. Then the number of

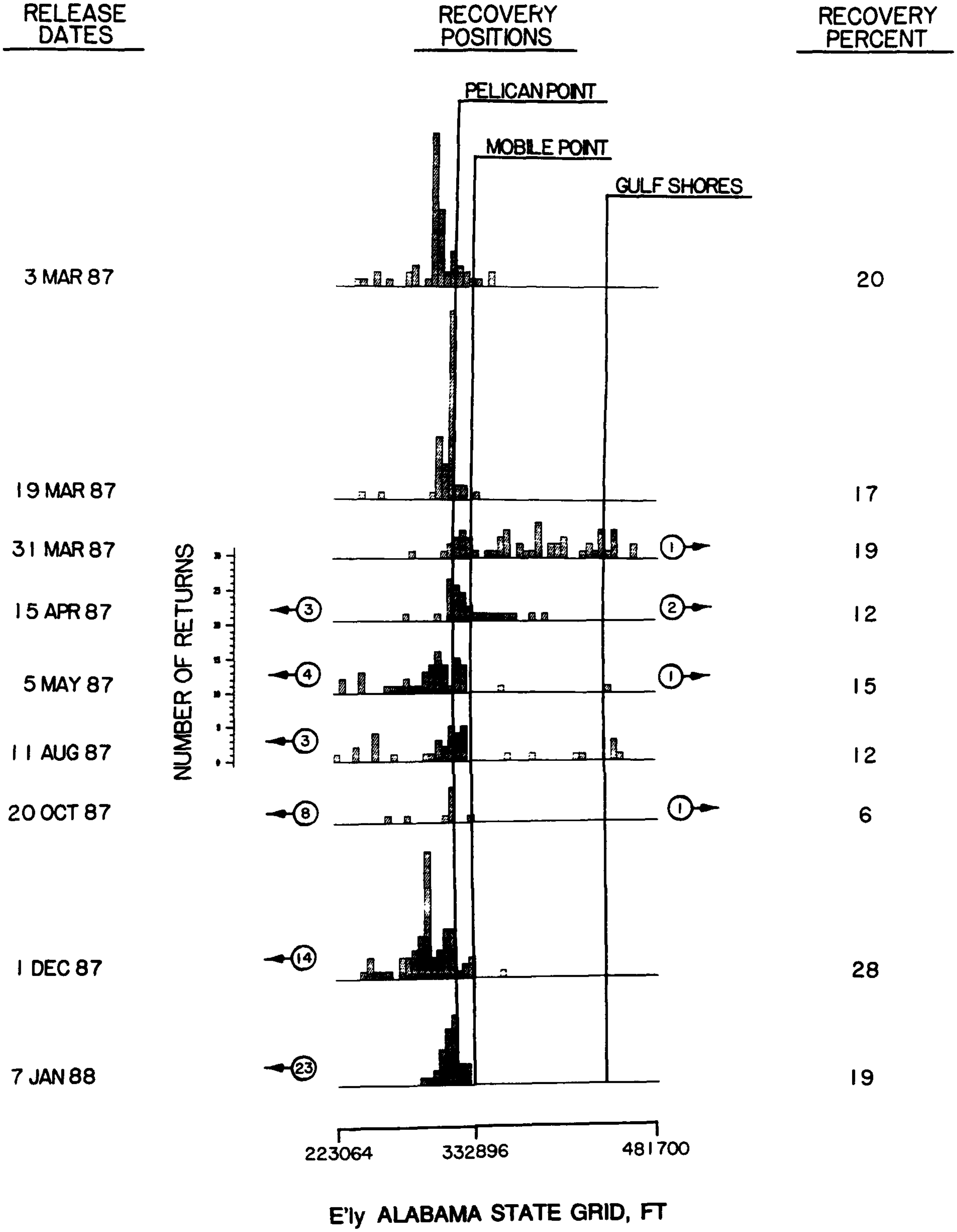



Figure 19. SBD recoveries by release periods. The highest concentration of recoveries were aligned with either the eastern or western ends of the Sand/Pelican Ridge (Figures 4 and 17), except after the passage of a strong cold front coinciding with the third release. Recoveries east of Alabama (circled numbers on the right) indicated no seasonal change. In contrast, far-west recoveries rose considerably in the winter

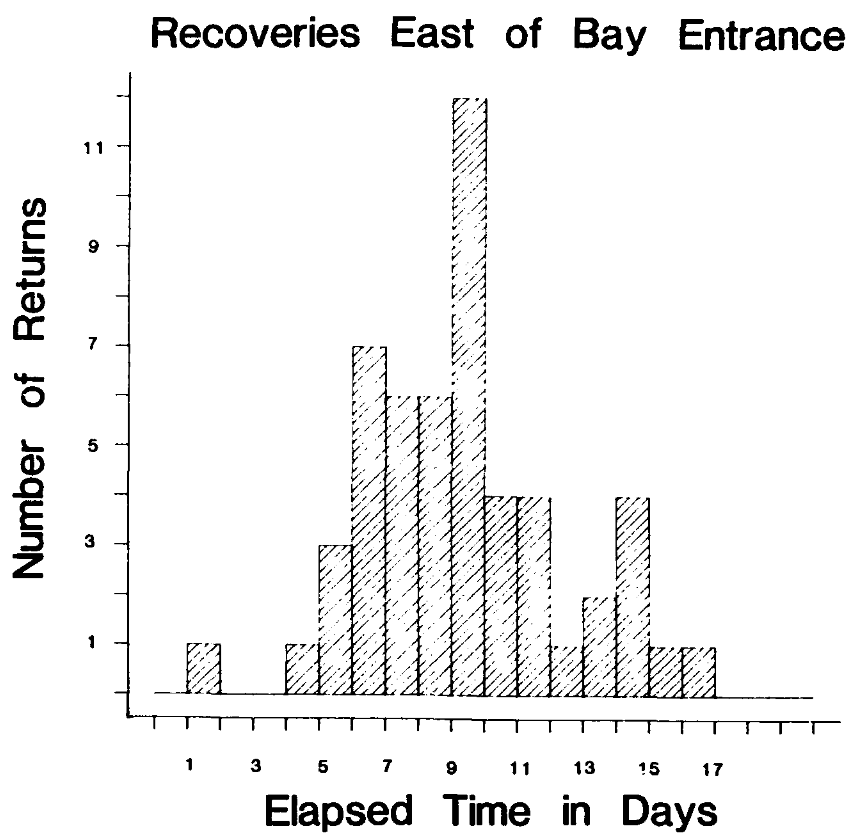



Figure 20. Elapsed time for April SBD's recovered east of Dauphin Island. Extreme eastward recoveries were made promptly after the third release, most within the second week, suggesting eastward flow is not only infrequent, but of brief duration

recoveries remained low for 8 months, dropping to their lowest in the fall. During winter the total number of recoveries rebounded even higher than after the initial March releases (Table 4 and Figure 19). The number of far-west recoveries, from Mississippi and Louisiana, rose considerably in the winter. The small number of recoveries east of Alabama shows no seasonal propensity. The recoveries outside Alabama are shown as circled numbers along the margins of Figure 19.

88. Of the two types of drifters released in equal numbers at each site, the heavier one was rarely found on the beach during the first 9 months of study. In the winter, the ratio of heavy to light increased phenomenally (Figure 15 and Table 5). Sometimes heavy SBD's were more common on the winter beach by a factor of 3 to 1. Onshore currents were thus not only more frequent in the winter of 1987 but also stronger near the bottom where the heavy drifters are confined by their tenfold greater submerged weight.

Table 5

Seabed Drifter Recovery Statistics

| Release Period | Date of Release | Percent Recovered | Ratio of Heavy/Light |
|---|---|---|---|
| 1 | 3 Mar 87 | 20 | NA |
| 2 | 19 Mar 87 | 17 | NA |
| 3 | 31 Mar 87 | 19 | 0.1 |
| 4 | 15 Apr 87 | 12 | 0.5 |
| 5 | 5 May 87 | 15 | 0.7 |
| 6 | 11 & 17 Aug 87 | 13 | 0.3 |
| 7 | 20 Oct 87 | 6 | 0.8 |
| 8 | 1 Dec 87 | 28 | 3.0 |
| 9 | 7 Jan 88 | 19 | 1.5 |
| | | Illegible Serial No. | 5 |

NOTE: NA = not available. On each date 300 SBD's were released; however, on the first two occasions each SBD had a submerged weight of about 0.6 g. Thereafter submerged weight was increased to 6.6 g for half of the SBD's released from each site.

## Sediment Samples

89. Target sites for sediment samples were 200 ft or more apart. Post-survey plots indicate that most grab samples fell within a circle of 25-ft radius around the target sites, as illustrated in Figure 21.

90. To examine bottom changes following placement, a subset of 21 samples was identified in the immediate vicinity of material placement. Composite grain size was calculated from this subset and compared with that of the calculated composite from hopper samples. The baseline samples were well-sorted fine sands. Material taken from the hoppers was well sorted but finer and skewed by the presence of 10-percent silt (Table 6).

91. The content of fine sand in the first postplacement samples was intermediate between baseline and hopper values. However, the silt and very

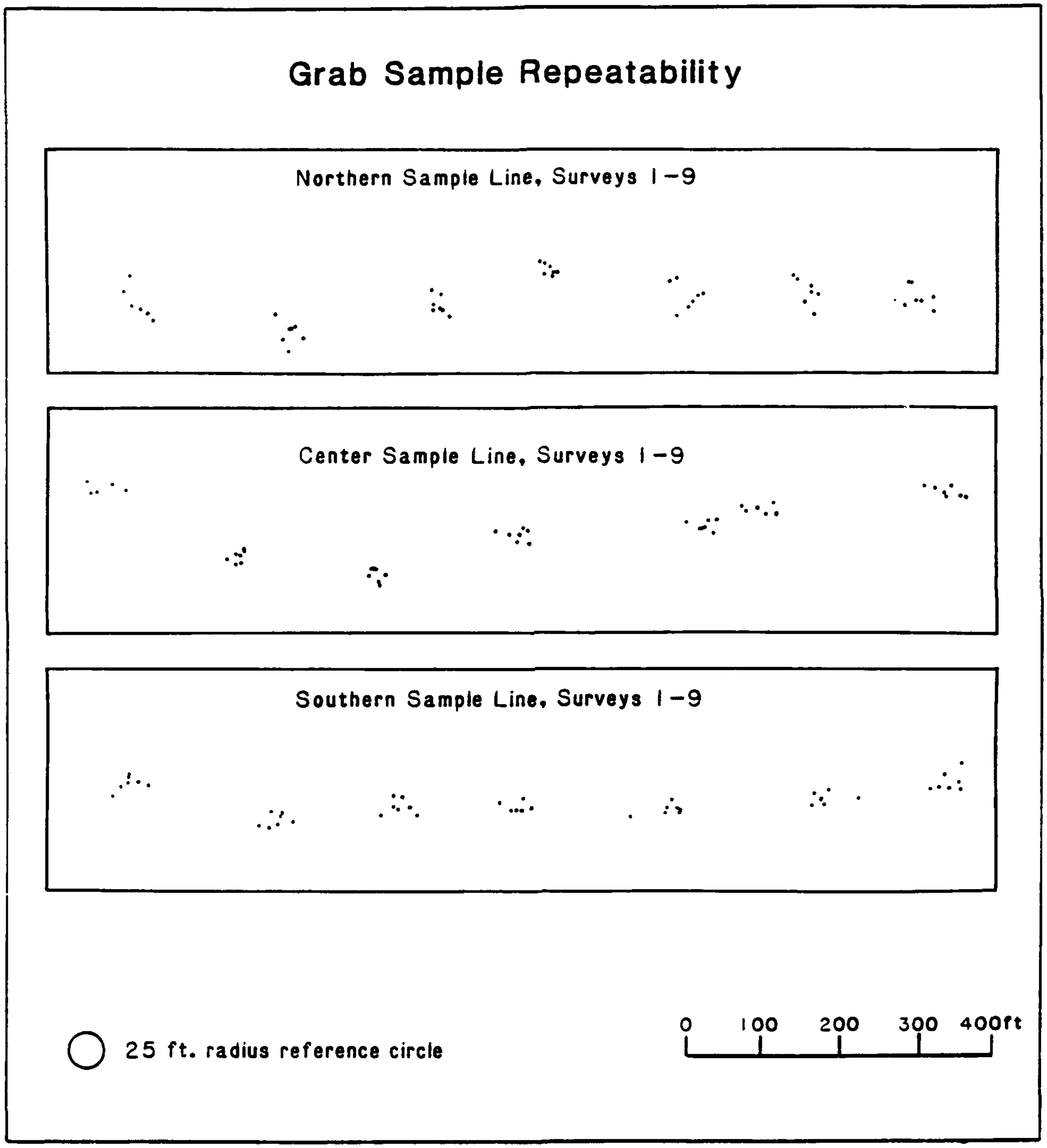



Figure 21. Repeatability of sampling locations on nine surveys from March 1987 to January 1988. Position and orientation of the three sample lines are shown in Figure 7

Table 6

Composite Grain Size Statistics

| Sample | | Median, $D_{50}$ | | Mean | |
|---|---|---|---|---|---|
| Dates | Numbers | mm | phi | phi | Sorting |
| Dec 86 | 21 | 0.22 | 2.20 | 2.26 | 0.40 |
| Jan/Feb 87 | 23 | 0.17 | 2.55 | 2.63 | 0.57 |
| Mar 87 | 21 | 0.22 | 2.20 | 2.28 | 0.44 |

NOTE: Predisposal samples (21 Dec 86) and first resampling (Mar 87) were from the immediate vicinity of the berm. Twenty-three samples from Jan/Feb 87 were from the hoppers of the dredge vessels. Conventional sample statistics are based on 16th, 50th, and 84th percentiles (Shore Protection Manual 1984).

fine sand (0.125 to 0.0625 mm size class) evident in the hopper samples were absent or much reduced in the first postplacement samples. Average grain size of bottom samples had reverted to the value observed prior to placement. Little change occurred over the following months. In fact, the composite characteristics remained essentially unchanged through the next winter.

92. On a conventional grain size plot, all composites would be indistinguishable except the one from the silt-rich hopper samples. An expanded sand scale used in Figure 22 clarifies the difference between baseline and hopper samples and illustrates the rapid reversion toward baseline characteristics before the first postplacement sampling. None of the subsequent composites differ much, so only the first and last postplacement (first and ninth) grain size curves are compared with the baseline and hopper composites. Preplacement and postplacement samples were taken with a Pettersson grab sampler; hopper samples were taken from the discharges aboard the dredges.

93. Assuming the samples are representative, silt must have been rapidly lost, either during hopper overflow, during material placement, or between completion of placement and the first postplacement sampling. If fines were lost during actual placement, much of the body of the deposit would be deficient in silt, especially beneath the center line of the berm because fluid muds would have flowed downslope away from the growing crest. Alternatively, if later reworking was the primary removal process, the loss of silt should be confined to the surface layer that has been reworked. This reworked

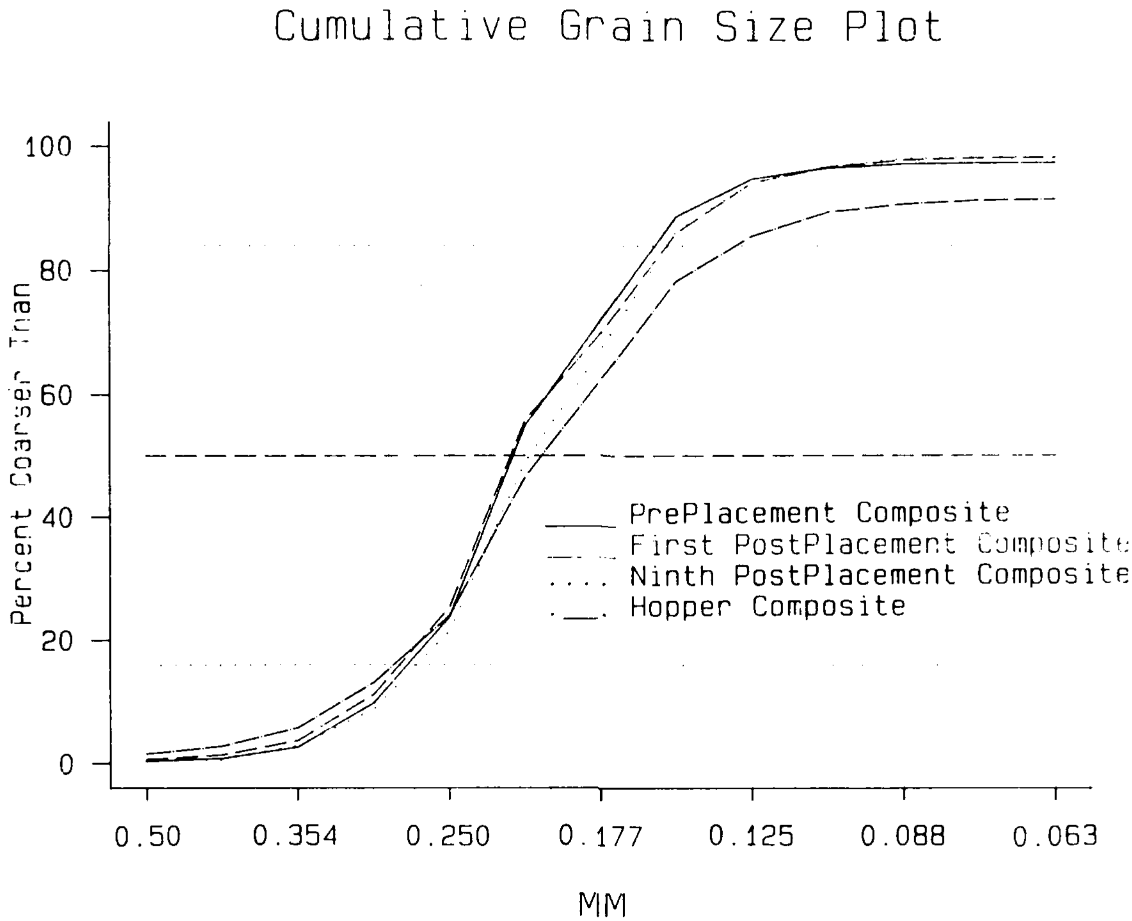



Figure 22. Changes in grain size in the immediate vicinity of the berm. Preplacement and postplacement samples were taken with a Pettersson grab sampler. Hopper samples were taken from the discharges aboard the dredges. The only change in bottom sediments with time was a rapid reversion to baseline characteristics as silt was lost from the berm

layer may be thickest along the crest but thinner on the leeward side than at similar depths on the gulfward side. Cores will be taken on later surveys to help resolve the time and mechanism of silt loss.

## Side-Scan Sonar

94. Side-scan sonar was used during the early surveys to determine the boundary between placed and native bottom material. A 500-kHz system failed to reveal any distinction. Because the quality of side-scan sonar records depends heavily on sea conditions, the scan was repeated but without improvement.

95. Side-scan sonar provided the best delineation of placed material at

the Dam Neck placement site offshore of Virginia Beach, Virginia (Hands, DeLoach, and Vann 1988), and has proven useful at a few other placement sites (Truitt 1986). The similarity of dredged and surface sediments at the Mobile nearshore berm placement site presented a more challenging situation that rendered side-scan sonar useless for monitoring the spreading outer boundary of the placed material.

96. Side-scan sonar was used on the seventh survey to test the feasibility of tracking SBD's equipped with special transmitters. This test proved successful. A hydrophone and side-scan sonar will be employed during the second year to track SBD's at intermediate points between release and recovery sites.

97. A 100-kHz sonar signal works best for SBD tracking while a 500-kHz signal is best for mapping of the bottom roughness. Unless dual frequency side-scan sonar is available, further attempts to map the Sand Island berm with side-scan sonar seem unwarranted.

## PART VII: CONCLUSIONS AND RECOMMENDATIONS

98. The apparent volume of material in the berm fluctuated significantly from survey to survey. Large apparent losses would be followed by pervasive rebuilding with no sign of lateral spread or major shifts in position. These erratic volume fluctuations probably arise from elevation errors that are small by most standards, but accumulate when summed for an individual survey and vary from survey to survey. A vertical offset averaging 1 ft is equivalent to nearly 1,000,000 cu yd over the survey area or 175,000 cu yd above the footprint of the berm. The most likely source of these errors seems to be the datum determinations. Transformation of measured depths to elevations assumed a constant water surface slope between the survey site and the tide gage 4 miles away on Dauphin Island. To improve volume calculations, water levels will be measured on offshore gages near the berm. This should increase datum reliability and provide a basis for meaningful calculations of volume changes with continued monitoring.

99. If dispersion remains low, the berm could be extended in the future to augment the natural wave-absorbing ridge on the outer margin of the ebb-tidal delta. Historic charts show that the east end of this marginal ridge was more extensive in the late 1800's and for most of the 1900's. Placement adjacent to the present berm would thus be reestablishing a condition closer to that which prevailed before the 1960's.

100. Placement in shallower water would promote quicker mobilization, but the increased risk of grounding disposal vessels may discourage industry dredgers. Extension of the berm westward along the same 19-ft contour would keep the material in a zone where SBD patterns suggest shoreward bottom currents focused on the eastern end of Dauphin Island. Return of the material to the channel should not be a concern judging from the first year's results. If landward sediment does not increase, at least prevailing currents the first year opposed offshore losses.

101. Landward bottom currents may strengthen in winter as suggested by an increased number of SBD recoveries on Dauphin Island, a westerly shift of the centroid of recovery, a lower percentage found inside the bay, and a marked increase in the ratio of heavy-to-light drifters reaching Dauphin Island. Future SBD releases will be more uniformly spaced through the year

for a clearer resolution of seasonal variations. The main purpose of drifters is to document the flow pattern of bottom water during mobilization of the berm. So far, major berm mobilization has not occurred. The ability to anticipate the important storm and to release drifters in its face will improve the value of this aspect of the study.

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