File Copy

BROADKILL BEACH: AN ASSESSMENT OF AN EROSION PROBLEM

by

Robert A. Dalrymple

Research Report CE-82-22

OCEAN ENGINEERING PROGRAM

DEPARTMENT OF CIVIL ENGINEERING
UNIVERSITY OF DELAWARE
NEWARK, DELAWARE
19711

BROADKILL BEACH:
AN ASSESSMENT OF AN EROSION PROBLEM

February, 1982

Submitted to

The State of Delaware

Department of Natural Resources

and Environmental Control

by

Robert A. Dalrymple

Department of Civil Engineering

University of Delaware

Newark, DE 19711

Ocean Engineering Program

Research Report CE-82-22

Table of Contents

List of Figures

List of Tables

INTRODUCTION

A section of South Broadkill Beach, in the vicinity of Tyler Avenue, has been eroding seriously over the past several years, so seriously that a beach house (owned by the Mihalik family) is in jeopardy. This erosion appears to be anomalous, as the erosion is very localized (extending about 500 m) and occurs at a location where, in the recent past, the shoreline has protruded bayward.

The purpose of this study was to evaluate existing data, obtain bathymetric data (with the Department of Natural Resources and Environmental Control (DNREC)) and to make recommendations for erosion abatement.

BACKGROUND

Geologic History

The shoreline at Broadkill Beach has undergone extensive changes over the past 150 years. Over this time span the location of the shoreline was advanced bayward about 300 m due to the northward migration of the Cape Lewes spit. Before Cape Henlopen acquired its present shape (early (1900's), vast quantities of Atlantic beach sand moved around it into the Delaware Bay, where it was moved along the south shore of the bay by the action of waves. The sand, bypassing Lewes Creek, took the form of a spit which migrated past the mouth of the Broadkill River almost to Prime Hook Creek. See Figure 1. The growth of the spit was arrested in about 1900 due

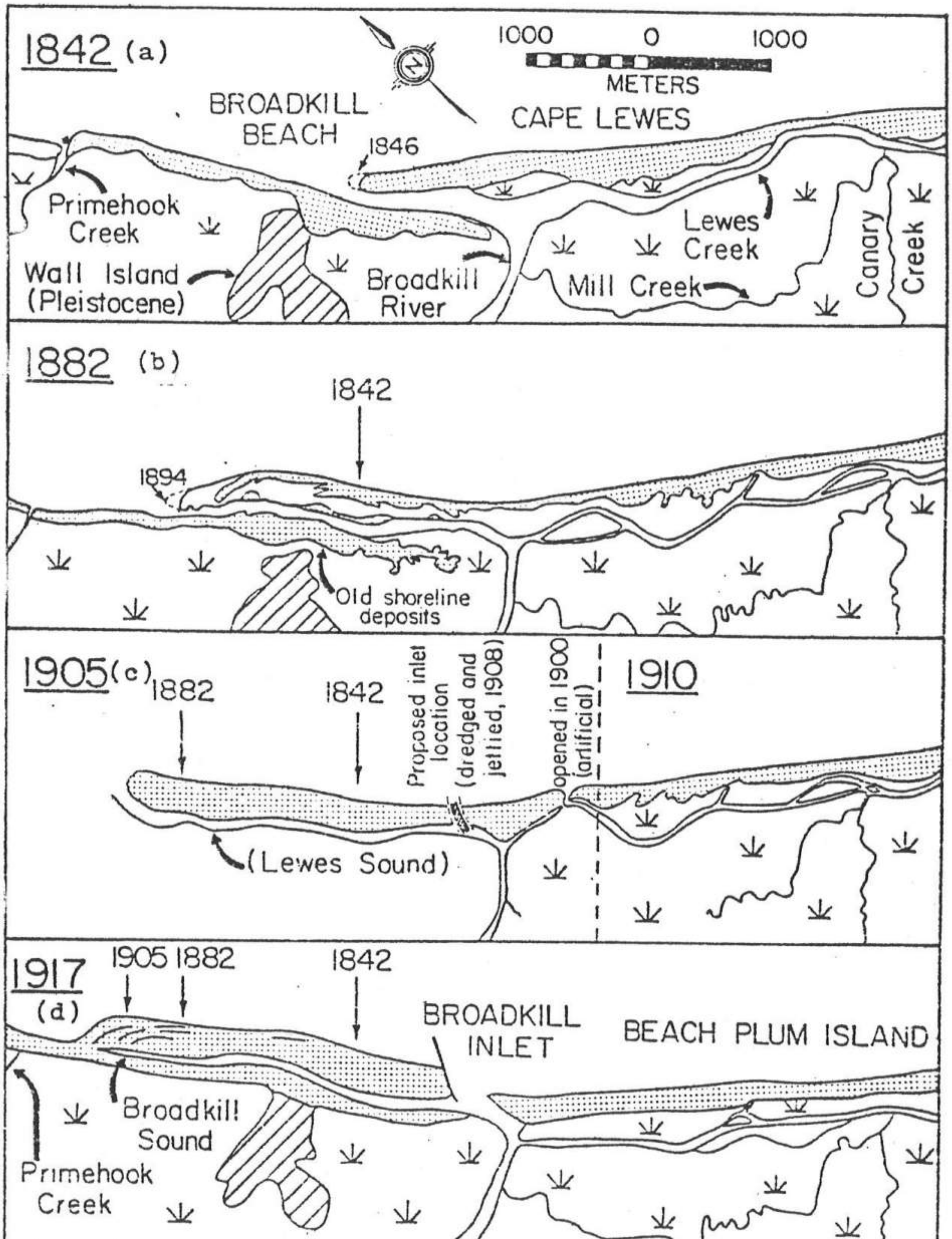

Figure 1. Shoreline changes at Broadkill Beach and Beach Plum Island, 1842-1917. (From Maurmeyer, 1978)

to several factors, the growth of Cape Henlopen bayward, the completion of the Inner Breakwater at Breakwater Harbor and the excavation of two inlets through the spit. One of these was cut in 1900 by local interests and shoaled rapidly and the other, Broadkill Inlet, was built by the U. S. Army Corps of Engineers in 1908 and stabilized with a north jetty. (High maintenance led the Corps to abandon Broadkill Inlet in favor of a third inlet, Roosevelt Inlet, at Lewes in 1937.) As the supply of sand to the spit decreased, it ceased migrating and, in the vicinity of Prime Hook Creek, it migrated shoreward and became attached to the former shoreline. This migration sealed off a section of the bay, now referred to as Broadkill Sound, which drains through Roosevelt Inlet.

This former spit, presently Broadkill Beach, has eroded over the past half century due to the lack of a sand supply. The U. S. Army Corps of Engineers (1972) has examined the accretion and erosion of Broadkill from 1894-1964 at 4 profile locations, shown in Figure 2, denoted lines 24-27. Table 1 shows their results which include the accretion due to the spit migration. From 1954-1964 the Corps noted a shoreline recession at an average rate of almost 6 m/year. Most of this recession, occurring on the old spit, appears due to the March 1962 storm. At the northernmost line (24), which was not affected by the Cape Lewes spit, shoreline recession has averaged 1.3 m/year. This shoreline retreat is largely due to sea level rise.

Erosion Control Measures

In 1950 the ongoing erosion of the beach resulted in the construction of three timber groins at the south end of Broadkill Beach. Erosion to the

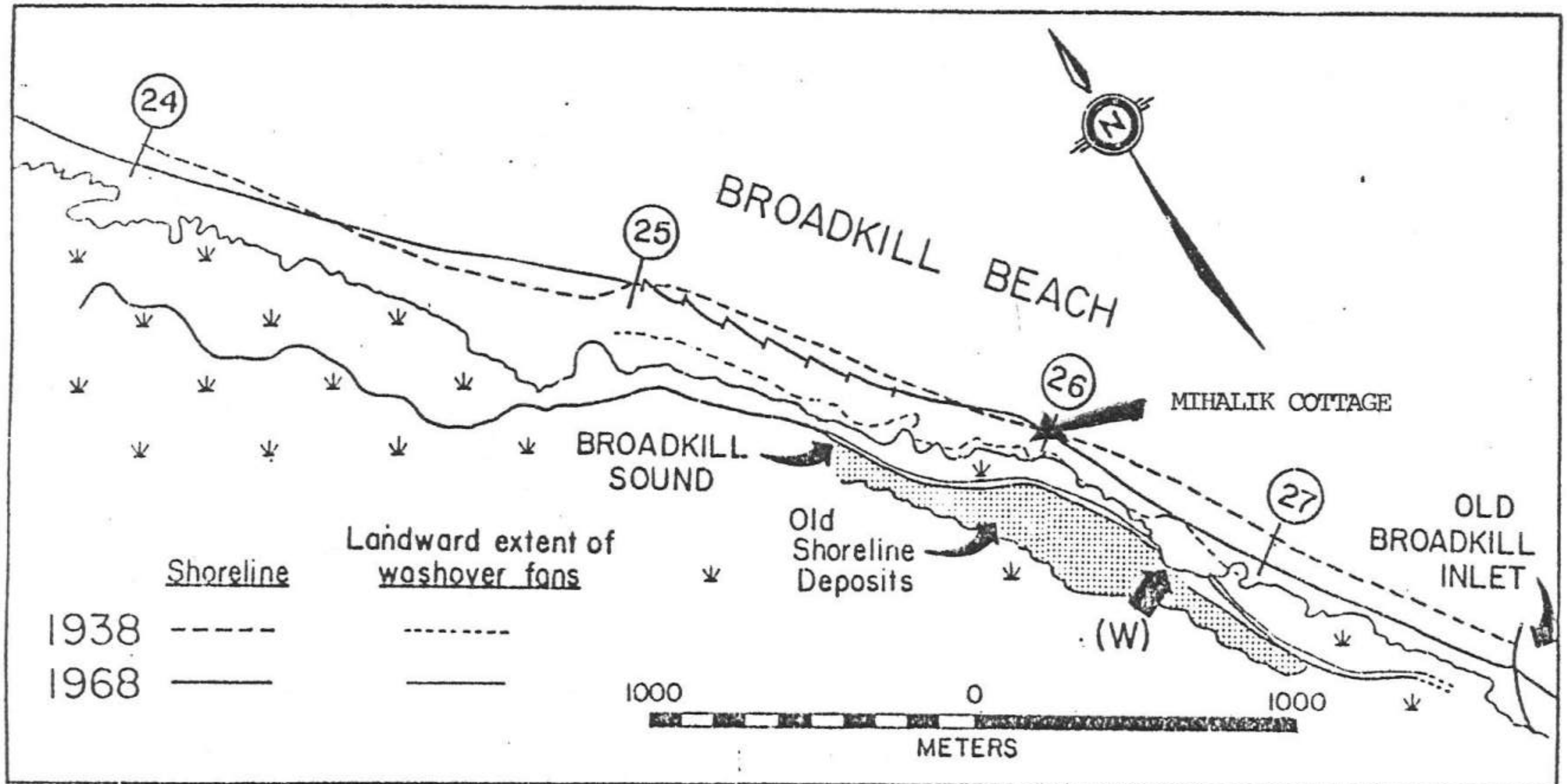

Figure 2. Shoreline changes at Broadkill Beach, 1938-1968. Erosion and accretion rates along Lines 24-27 are presented in Table 1. (W) denotes location of a breakthrough. (Figure from Maurmeyer (1978))

TABLE 1

Total annual shoreline changes at Broadkill Beach, Delaware, 1843-1964 (from U.S. Army Corps of Engineers, 1972). See Figure 1 for location of Lines 24-27.

	1843-1884		1884-1954		1954-1964	
Line	Total change (m)	Annual change (m/yr)	Total change (m)	Annual change (m/yr)	Total change (m)	Annual change (m/yr)
24	-76	-1.9	-69	-1.0	-9	-0.9
25	-427	-10.4	+274	+3.9	-109	-10.9
26	+213	+5.2	-107	-1.5	-54	-5.4
27	+396	+9.7	-145	-2.1	-64	-6.4

north of these resulted in the construction of two more groins in 1954. Continuing erosion to the north induced the State Highway Department to construct two rubble groins in 1964. The location of these groins can be seen on Figure 2. Presently, only the northward three groins are functional.

Concurrent with structural remedies, beach nourishment has been used to maintain the beach. In 1957, the State Highway Department placed 77,000 yds^3 of fill along 1500' of beach.[1] Another 120,000 yds^3 were placed in 1961.

In 1973, DNREC acted to repair Broadkill Beach which had suffered during the March 1962 storm. At this time 118,000 yds^3 were placed using an offshore borrow pit. In 1975 a major fill project was undertaken; 295,000 yds^3 were placed along the southern portion of the beach again using an off-shore borrow pit. In 1976, 60,000 yds^3 were placed by the State. An additional 127,700 yds^3 were placed in 1981 by the Corps of Engineers, again using an offshore borrow pit. The location of the borrow pits are shown in Figure 6 (page 14).

Wave Climate

There is very little historical wave data extant for Delaware Bay. Maurer and Wang (see Fig. 9 from Maurmeyer (1978)) report on significant wave height and directional data based on ship observations for 1969-1971. Their results indicate for Broadkill that there are significant waves in the bay from the northwest and north, particularly in the winter and very few from the southeast (including from the Atlantic). In the summer, however, the predominant waves are smaller than winter but from the southeast.

---

[1] These and subsequent fill data from R. Henry, DNREC.

Table 2

Beach Fill Quantities Placed on Broadkill Beach

Date	Fill Quarterly (yds^3)	Location
1957	77,000	central?
1961	120,000	central?
1973	118,000	central
1975	295,000	southern
1976	60,000	central
1981	127,700	central

A similar trend is seen by data prepared by A. H. Glenn in "Cost Study and Design of Marine Terminal Facilities." Again, the predominant waves are from the north and northwest, with the smaller summer waves coming from the southeast.

Planform Shoreline Changes

The U. S. Soil Conservation Service flew aerial photographic surveys of the Broadkill Beach shoreline in 1938, 1954, 1960 and 1968. In 1975 aerials were flown for the Department of Natural Resources and Environmental Control. The shorelines observed on these photos have been overlain in Figure 3 to provide a time history of shoreline change.

Several interesting features are readily seen in the figure. The uniform erosion that occurred from 1938 to 1954 is obvious. Here, the erosion can be determined as about -4.5 meters/yr. which corresponds well to the Corps' estimate for the 1954-1964 time period. Secondly, a migrating point of sand can be observed. This point with a shoreline amplitude of about 300' is more obvious in the 1968 aerial. This point, which is seen in all the aerials, has been slowly migrating northward. Its passage at any shoreline location is marked by a gradual increase in shoreline width and then apparent erosion as it moves past the given point. From 1960 to 1968, the sand point migrated past the existing Mihalik structure located at 22+95 B at a rate of about 70 ft per year.

Not visible from the aerials is an inlet which was cut through to Broadkill Sound by the March 1962 storm. This inlet, located about 3500 ft north of the old Broadkill inlet (about 41+00 B) gradually infilled and was closed between 1964-1968 (U. S. Army Corps, 1972), appearing as a wash-over in the 1968 aerial photograph. This inlet did remove a significant amount of sand from the beach.

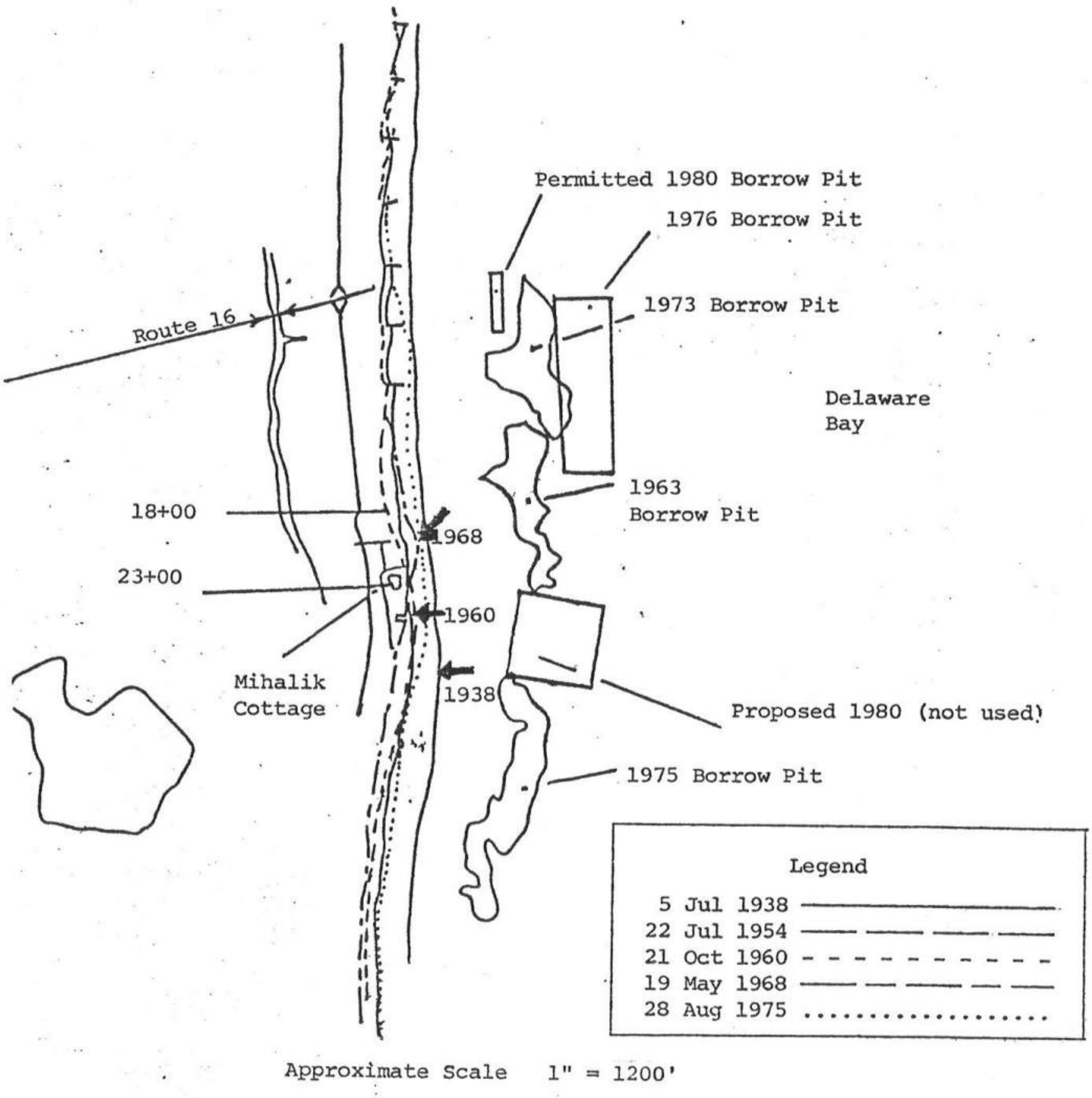

Figure 3. Overlay of aerial photographs. Offshore borrow pit locations are also shown. Dates on arrows indicate location of migrating sand point.

Historically sand has been eroding from Broadkill Beach and been moved both north and south: northward to fill in between the previous mainland shoreline and the head of the old spit (Fig. 1, north end), and to the south, south of the former Broadkill Inlet. The net drift direction is now apparently southward; however, the planform shapes of the fillets of sand in the groins at the north end of the beach would indicate a northerly drift. This anomaly is likely due to the large angles of wave attack from the stronger north waves which are reflected from the groins and do not erode the southern sand fillets as much as would be apparent at other beaches.

The Broadkill shoreline has been monitored fairly closely by DNREC, particularly since the beach fill project of 1975. Shortly after the fill was emplaced, a significant portion of the fill was lost very rapidly with recession rates of up to 33 m/year (22+00 B; from 4/10/75-1/15/76). As the fill stabilized, these rates decreased to a "more reasonable" 10 m/year at that location.

It is fairly clear from later aerial photographs that the rapid erosion of the beach fill was due to its migration under the action of the waves both northward and southward with the bulk of it in 1979 being just south of Del. Rt. 16 (4+00 B) and in the vicinity of station 40+00 B.

The shoreline changes (taken from DNREC supplied beach profiles) from 2/75 to 5/80 are shown in Figure 4. The increase in beach width due to the fill operation is shown as well as the subsequent erosion. The Mihalik cottage is shown in the figure also.

From the profiles, volumetric erosion rates can be estimated by integrating the area under the profile down to a base elevation

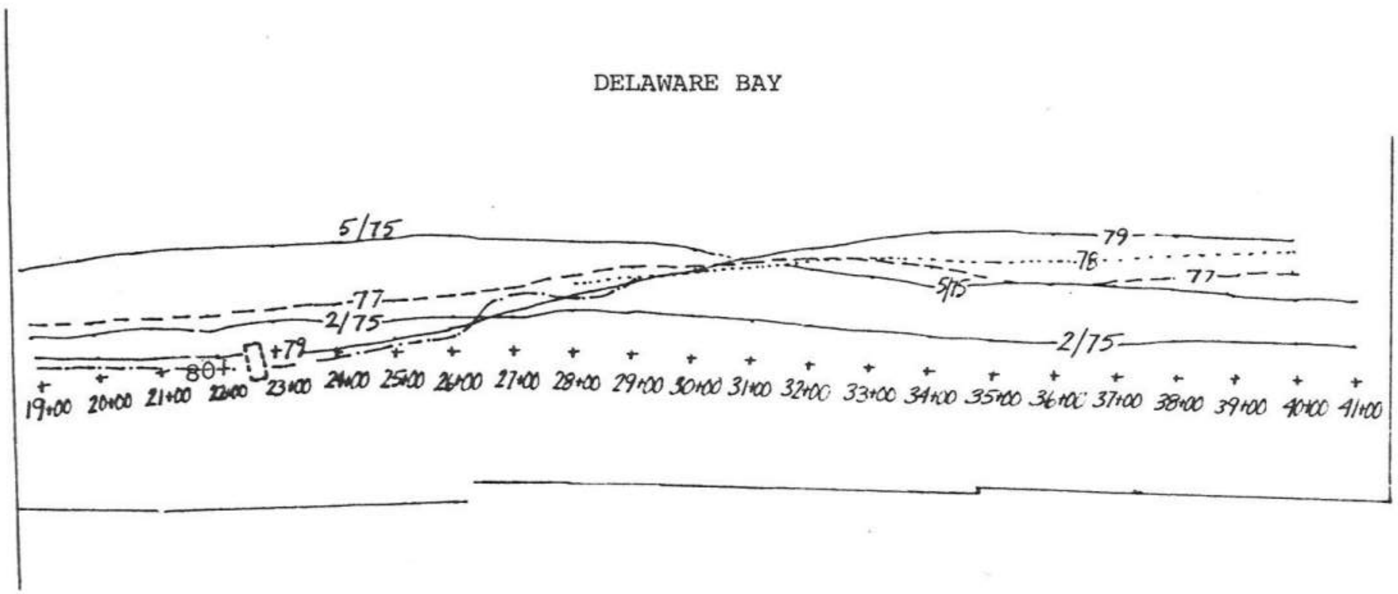

Figure 4. Recent shoreline changes between stations 19+00 B and 41+00 B. (The Mihalik cottage is marked between 22+00 and 23+00.)

(here taken arbitrarily at -5 ft.). Between surveys the differences in area can be related to the volume per ft. of beach. Using this technique, the volumetric erosion rate was calculated for a number of profiles (12+00-34+00 B). Clearly from Figure 5, the volumetric erosion is most significant in the vicinity of lines 20+00-27+00, which spans the Mihalik cottage at 22+95. From Figure 5 it is clear that north of station 30+00 erosion has removed beach fill, yet southward, accretion of material from the fill has occurred.

EROSION MECHANISMS

The shoreline at Broadkill is unusual in that it is affected both by wind generated waves from the north (down the Bay) which impinge upon the shore with large angles of incidence and by small eastward waves of local or Atlantic origin. The net result is a shoreline characterized by both northerly and southerly drift, of a magnitude difficult to assess. For the region bounded by stations 14+00-29+00 where the erosion is intense, integrating the area under the volumetric erosion curve (yds^3/ft-month), Figure 5, and multiplying by 12 yields a local erosion rate over the 1500' range of 20,000 yds^3/yr. (This number includes the intense erosion in the vicinity of the Mihalik cottage and, hence, is an overestimate of the littoral drift in the area.) There are several possible mechanisms to explain this localized erosion and they are elaborated below.

One obvious mechanism for the loss of beach material is the transport of sand from the beach face into the offshore borrow pits which are shown in Figure 6. For this reason, a bathymetric survey (DNREC, Figure 7) and cores (by the College of Marine Studies Marine Sediment Laboratory) were taken in the 1973, 1976, 1981 borrow pits. Most of the borrow pits were filled, with

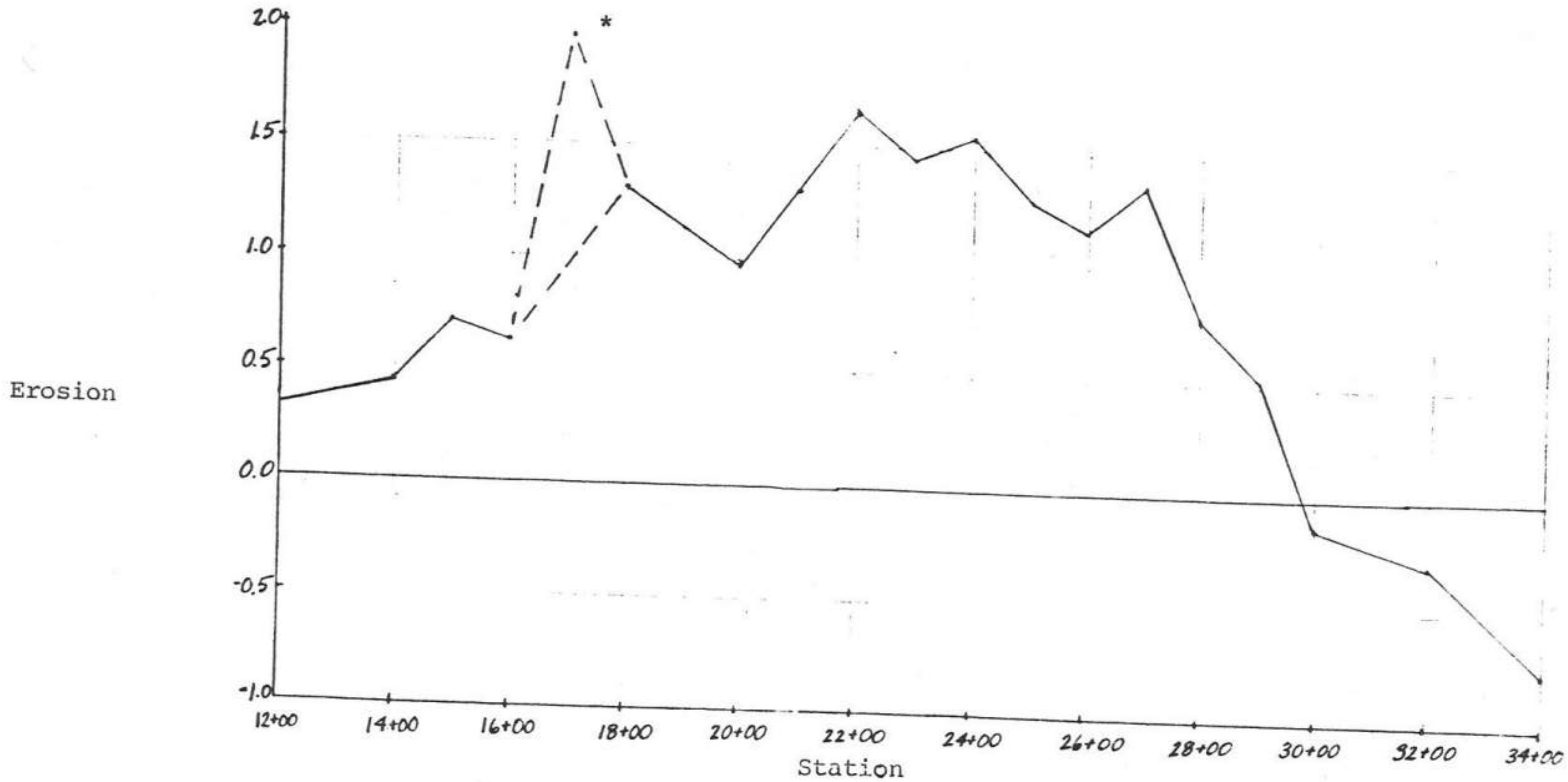

Figure 5. Average volumetric erosion since 1975.
(Units are yd^3/ft/month)

*Note: Based on only 1 point, lower line places lower bound on actual erosion rate.

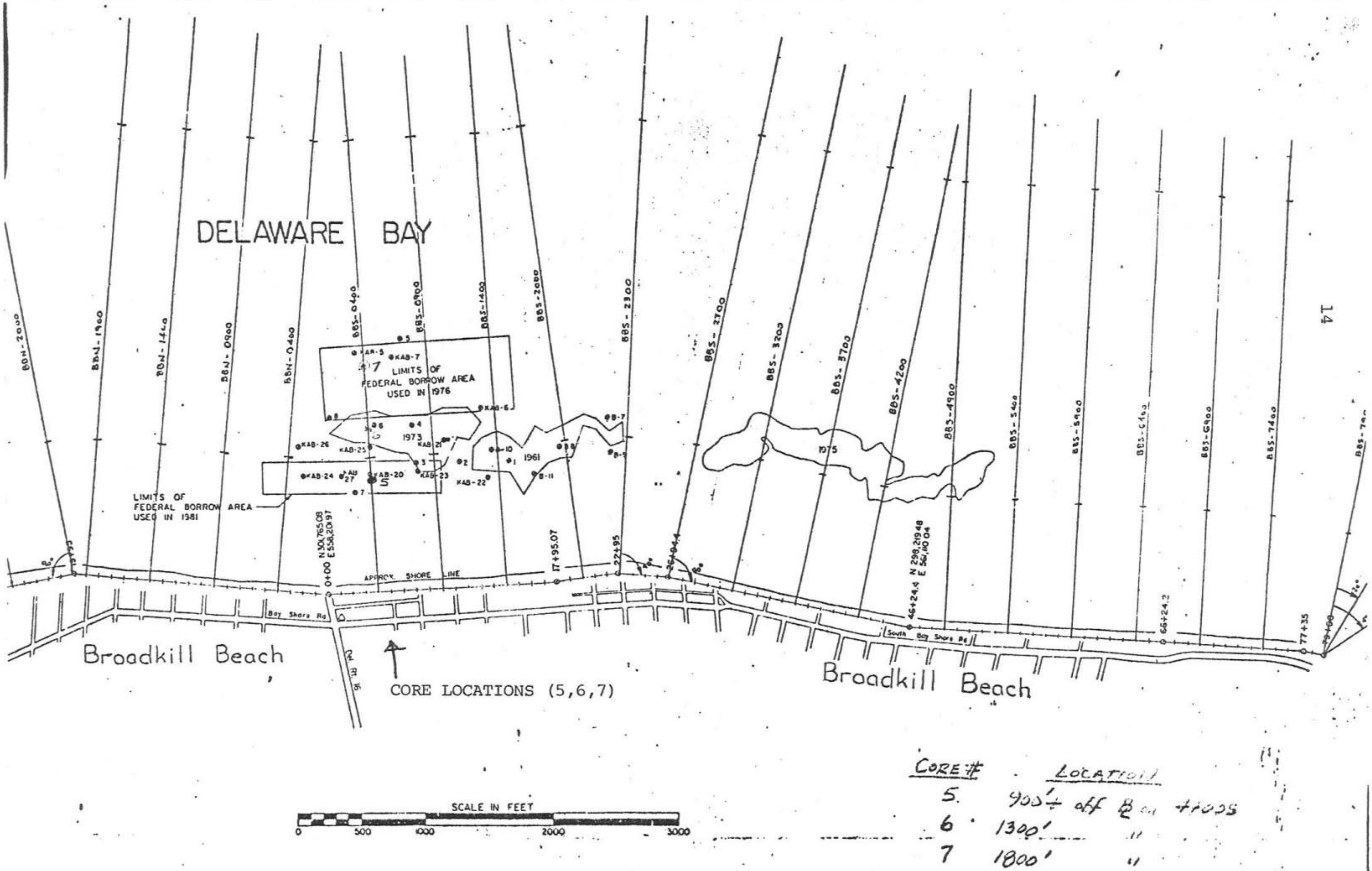

Figure 6. Location of core locations (offshore of arrow). The lines perpendicular to the shoreline are the transects used for the bathymetric survey.

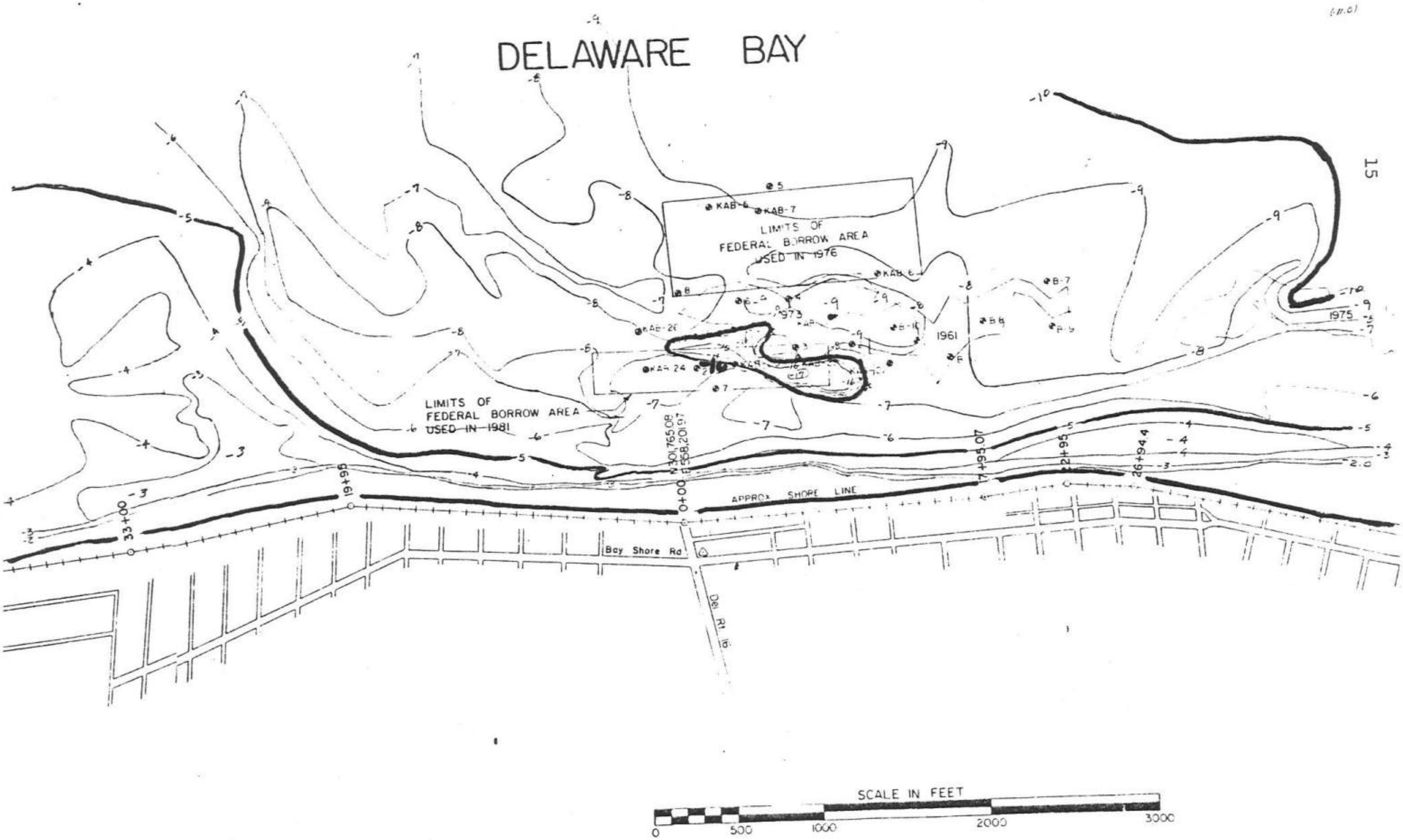

Figure 7. Bathymetric survey of Broadkill Beach.

the exception of the 1981 borrow pit, which still was 10' below the local bottom. Filling of the borrow pits is rapid, according to measurements made by E. H. Richardson in the 1975 borrow pit (over six feet of infilling in a month). However, most of the material appears to be silt, not sand. Figure 6 also shows the location of the core samples and the core logs, Appendix 1, show primarily mud.

While the loss of beach material to the borrow pits can be discounted as a mechanism for erosion, there still is the possibility that the borrow pits themselves aggravate the shoreline erosion by refracting waves in a manner which would force convergences and divergences of wave energy at the beach. This is an extremely likely possibility due to the shallow offshore regions and the relatively large holes created by the dredging. A wave refraction computer program was written for this project to analyse the refraction effects caused by the dredge pits as originally dredged (see e.g., Noda, 1974). As shown in Figures 8 and 9 which plot the paths of the wave, the wave directions are significantly changed resulting in a change in local littoral drift. It is impossible to quantify this effect without historical wave data. However, the large build-up of the beach in the vicinity of station 40+00 could indicate a tombolo is forming due to the offshore pit dredged in 1975 and a similar effect also occurs at 7+00 inshore of the 1981 borrow pit which is still very evident in the offshore bottom. This effect, however, is transitory as the pits fill rapidly and thus any shoreline response would dissipate after a year or two.

A third phenomenon which can be identified is the unstable nature of the shoreline with respect to the littoral drift. It can be shown that a shoreline with waves at an angle of incidence of 45° to the beach normal is unstable to small perturbations in the shoreline. Physically, this means that

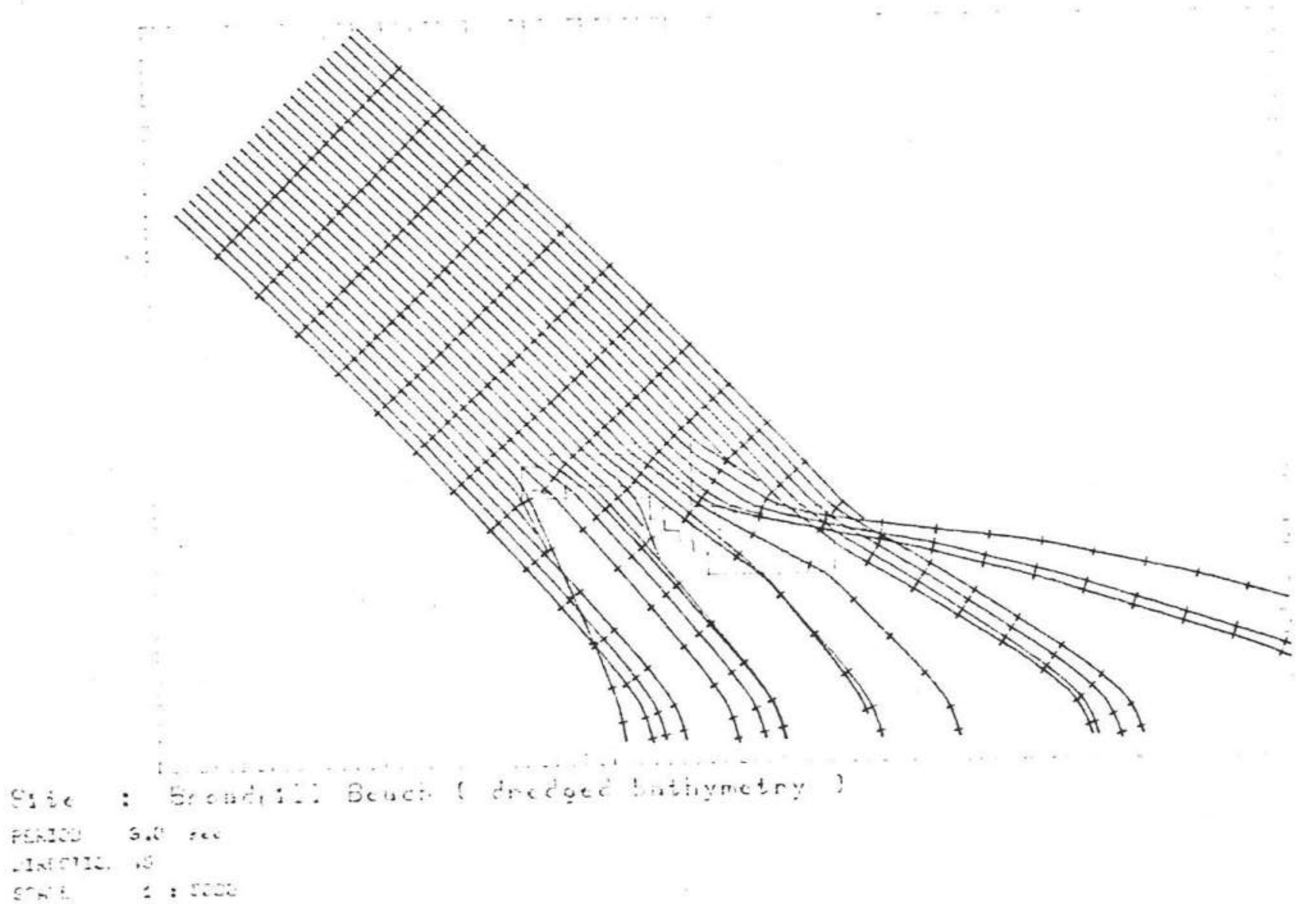

Figure 8. Refraction of waves from the northeast over the 1975 borrow pit.

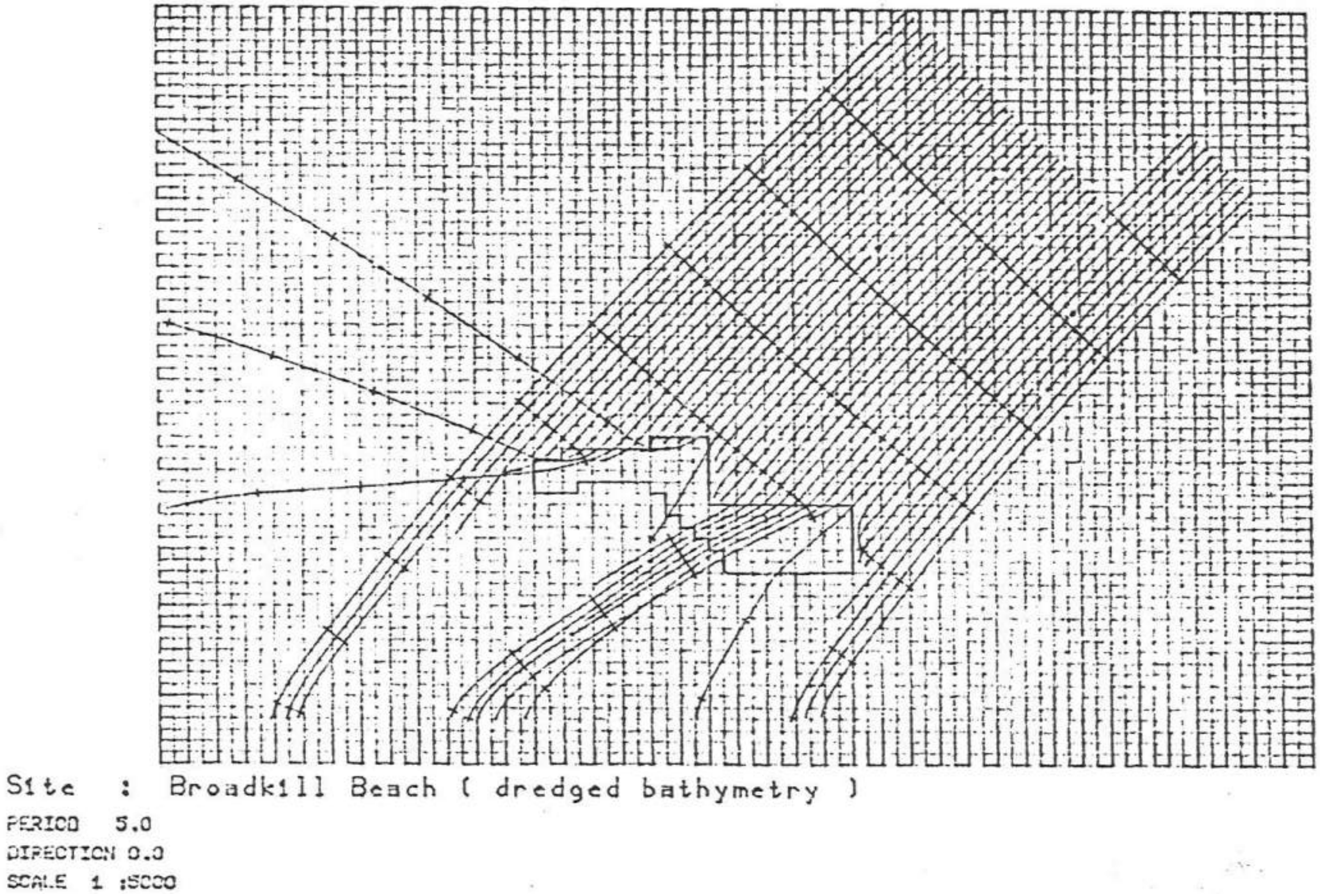

Figure 9. Refraction of waves from the southeast over the 1975 borrow pit.

beach fill after placement tends to form cuspate forelands (such as the migrating sand point mentioned previously) instead of gradually spreading over the length of the beach. While this is not what happens to beach fill at Broadkill, a similar effect can occur as depicted in the sequence of drawings in Figure 10 which compares the migration of beach fill under normal and stronger waves.

Erosion Control Measures

The localized erosion in the vicinity of stations 23+00 B at Broadkill Beach is likely due to both the influence of the remnants of the offshore borrow pits as well as the response of the beach fill to the oblique wave climate that influences Broadkill Beach. The detrimental refractive effect due to the borrow pits is ameliorated with time as the pits tend to fill rapidly with silt. Therefore no corrective measures are necessary. More study, however, is necessary for other coastal sites to attempt to quantify this problem, as shallow and wider borrow pits can mitigate the problem as well as dredging further offshore. These offshore dredging practices obviously entail higher costs; therefore, their necessity should be examined.

The unstable nature of the shoreline characterized by the migrating sand wave and the anomalous response of the beach fill can be addressed. The problem is generated by the placement of a large amount of fill on the beach face over a short length of beach. (A wider initial placement of fill should reduce the problem in beaches with wave climate similar to Broadkill.) Presently erosion in the vicinity of 23+00 can be mitigated by placement of enough fill in this erosion region (stations 16+00 to 28+00) to straighten the shoreline

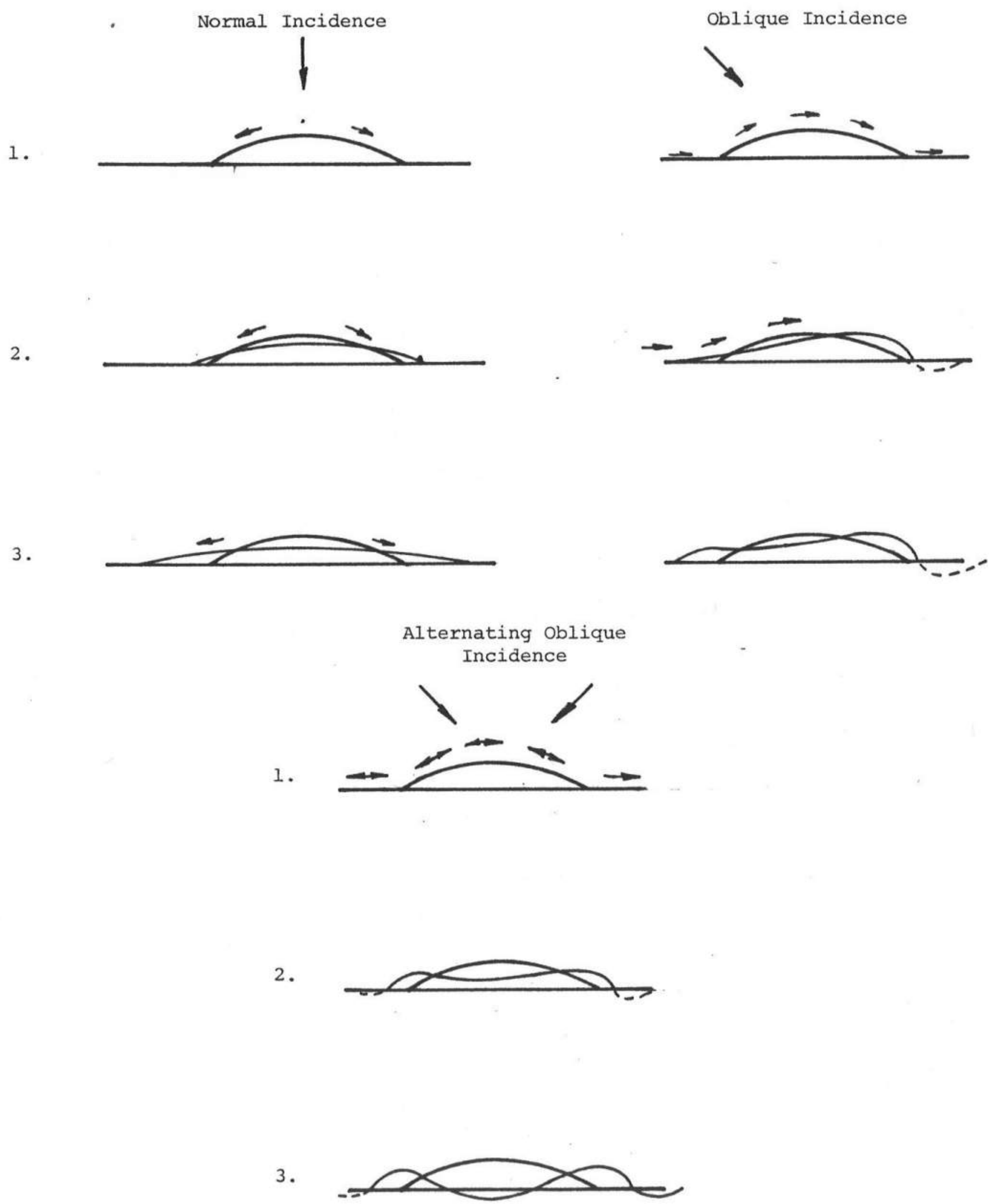

Figure 10. Beach fill planform changes with time under different wave regimes. Original planform shown in all 3 figures. Large arrows denote wave direction and small arrows are littoral drift directions.

and provide time for the sand waves (the heads of the fill in the vicinity of 7+00 B and 40+00 B to blend into the beach face.

Future large beach fills at Broadkill should be designed with several short temporary groins (sand bags perhaps) in the middle section to hold the sand in this region while the fill readjusts to the natural shoreline planform.

Long term solutions to the erosion at Broadkill would likely involve continuing periodic beach fills, with the recommendation of using wider placements and the temporary groins in the center of the fill.

CONCLUSIONS

The local erosion at Broadkill Beach (station 23+00) is apparently due to several causes: (1) a temporary modification of the nearshore wave climate by the offshore borrow pits and (2) the wave climate to which Broadkill is exposed, which caused the unusual response of the beach fill. The influence of the migrating sand wave appears to be less important as the human intervention (beach fill) is on the same scale; however, in the absence of the beach fill operation, erosion would have occurred along this section of beach anyway due to the passage of this large sand wave as it migrates northward.

For the present shoreline, the only suitable erosion control measure involves a small localized fill operation which would fill the shoreline indentation from station 20+00 to 27+00. It should be stressed that this only provides a temporary solution. Long term solutions involve large scale beach fill projects as well as temporary groins.

ACKNOWLEDGEMENTS

The funding and assistance provided by the Department of Natural Resources and Environmental Control is appreciated, specifically the help provided by Mr. Laurence R. Irelan, Director of the Division of Soil and Water Conservation and Mr. Robert D. Henry, Manager of the Beach Preservation Section.

Professor Robert G. Dean has been helpful in providing insight and help in this project. Mr. Claudio Neves programmed the wave refraction procedure and his help is appreciated.

REFERENCES

Glenn, A. H., "Design and Operational Data" in Cost Study and Design of Marine Terminal Facilities, Divcan Engineers, Inc., Houston, June, 1968.

Maurmeyer, E. M., Geomorphology and Evolution of Transgressive Estuarine Washover Barriers along the Western Shore of Delaware Bay, Ph.D. Dissertation, Dept. of Geology, University of Delaware, 1978.

Noda, E. K., "Wave-Induced Nearshore Circulation," J. Geophys. Res., Vol. 79, No. 27, 1974.

U. S. Army Corps of Engineers, Philadelphia District, "Detailed Project Report, Small Beach Erosion Control Project, Broadkill Beach, Delaware," February, 1972.

Appendix 1

Core Logs from Borrow Pits

Core Number	Borrow Pit
BB-5	1981
BB-6	1973
BB-7	1976

University of Delaware
College of Marine Studies
Marine Sediments Laboratory

CORING LOG

Project: DNREC Sand Sources
Location: Broadkill Beach

Core Number: BB - 5
Coring Date: 11/5/81

Investigator: C. Wethe
Driller: K. DeSombre

Core Length: 11.45 ft. (recovery)
Water Depth: 14 ft.

Coring by Vibracore using
3 inch O.D. Aluminum Core Pipe

Depth (ft)	Soil Classification	Remarks
0.00 - 1.25	Mud, Dark Olive Gray (5Y 3/2)	
1.25 - 10.25	Mud, Black (Color 5Y 2.5/1)	
10.25 - 11.46	Mud, with thin layers of Sand, Black (5Y 2.5/1)	
11.45 - 14.50	Lost out of bottom of pipe- Indications of Sand	

University of Delaware
College of Marine Studies
Marine Sediments Laboratory

CORING LOG

Project: DNREC Sand Sources
Location: Broadkill Beach

Core Number: B3 - 6
Coring Date: 11/5/81

Investigator: C. Wethe
Driller: K. DeSombre

Core Length: 14.67 ft.
Water Depth: 9.5 ft.

Coring by Vibracore using
3 inch O.D. Aluminum Core Pipe

Depth (Ft)	Soil Classification	Remarks
0.00 - 0.50	Mud, Dark Olive Gray (Color 5Y 3/2)	
0.50 - 3.71	Mud, with interlayering of Black (5Y 2.5/2) and Black (5Y 2.5/1)	
3.71 - 3.83	Organic (Plant) Material	
3.83 - 7.83	Mud, Black (N 2/0)	
7.83 - 8.75	Mud grading to Sandy Mud, Black (5Y 2.5/1)	
8.75 - 9.42	Muddy Fine Sand, 8 layers, Black and Light Gray in color	
9.42 - 10.50	Fine grading to Coarse Sand with Some Gravel, Gray (5Y 5/1)	
10.50 - 11.17	Very Coarse Gravel to Coarse Sand	
11.17 - 11.67	Medium Sand with Some Gravel	
11.67 - 12.29	Mud globules and Gravel in Coarse to Medium Sand	
12.29 - 14.67	Muddy Fine to Coarse Sand, White (N 8/0)	

University of Delaware
College of Marine Studies
Marine Sediments Laboratory

CORING LOG

Project: DNREC Sand Sources
Location: Broadkill Beach

Core Number: BB - 7
Coring Date: 11/5/81

Investigator: C. Wethe
Driller: K. DeSombre

Core Length: 18.38 ft.
Water Depth: 9.5 ft.

Coring by Vibracore using
3 inch O.D. Aluminum Core Pipe

Depth (ft)	Soil Classification	Remarks
0.00 - 0.92	Muddy Fine to Very Coarse Sand	
0.92 - 1.50	Interlayering of Mud and Very Coarse Sand	
1.50 - 2.17	Mud, Gray (Color 5Y 3/1)	
2.17 - 4.08	Muddy Sand grading to Very Coarse Gravel	Remnent of Dredging
4.08 - 7.83	Muddy Medium Sand with Some Very Coarse Gravel grading to Muddy Medium Sand with Fine Gravel	
7.83 - 8.00	Medium to Coarse Sand with Coarse Gravel	Thin Layer
8.00 - 11.58	Muddy Fine to Medium Sand	
11.58 - 11.75	Very Coarse Gravel in Muddy Fine Sand	
11.75 - 18.38	Muddy Fine Sand (2Y 8/1)	