AD 699 395

TEST OF NOURISHMENT OF THE SHORE BY OFFSHORE DEPOSITION OF SAND, LONG BRANCH, NEW JERSEY

J. V. Hall, et al

Corps of Engineers
Washington, D. C.

June 1950

AD699395

DEPARTMENT OF THE ARMY — CORPS OF ENGINEERS

BEACH EROSION BOARD
OFFICE OF THE CHIEF OF ENGINEERS

TEST OF NOURISHMENT OF THE SHORE BY OFFSHORE DEPOSITION OF SAND

LONG BRANCH, NEW JERSEY

TECHNICAL MEMORANDUM NO. 17

copy 5

Out of print

36

TEST OF NOURISHMENT OF THE SHORE BY OFFSHORE DEPOSITION OF SAND

LONG BRANCH, NEW JERSEY

TECHNICAL MEMORANDUM NO. 17
BEACH EROSION BOARD
CORPS OF ENGINEERS

JUNE 1950

PREFACE

This paper presents the results of a cooperative study between the New York District and the Beach Erosion Board, Corps of Engineers, designed to test the feasibility of nourishing eroded shores with dredge spoil.

The test included deposition, in 38 feet of water about ½ mile off Long Branch, New Jersey, of about 600,000 cubic yards of sand derived through maintenance dredging in New York Harbor channels; and a study of its movement by natural forces.

This report was prepared by J. V. Hall and W. J. Herron of the Field Research Section, Engineering and Research Branch, Beach Erosion Board, Corps of Engineers. The field work was done by Field Research Group No. 2 under the direction of R. L. Harris. The laboratory work was done by members of the Board's laboratory staff.

Acknowledgment is made of the earnest cooperation rendered to the Field Research Group during the course of the study by Mr. D. Mahr, owner of the Long Branch Fishing and Recreation Pier; Officials of the City of Long Branch, New Jersey; Woods Hole Oceanographic Institution; the United States Coast and Geodetic Survey; the Naval Reserve Squadron VPP-52, Willow Grove, Pennsylvania; the United States Geological Survey; and the United States Coast Guard, Monmouth Beach Station.

The opinions and conclusions expressed by the author are not necessarily those of the Board.

TABLE OF CONTENTS

TEST OF NOURISHMENT OF THE SHORE BY OFFSHORE DEPOSITION OF SAND
LONG BRANCH, NEW JERSEY

I. Authority

A cooperative study between the New York District and the Beach Erosion Board, Corps of Engineers, to test the use of dredged material deposited offshore to nourish eroded shores in the vicinity of coastal harbors was authorized by the Chief of Engineers by 6th Indorsement dated 3 February 1948, subject: Disposal of Dredged Material to Nourish Eroded Shores in the Vicinity of Coastal Harbors (Letter OCE to NAD 9 December 1947).

II. Location and Description of Area

The city of Long Branch is highly developed as a summer resort. It lies on a slight rise in the surrounding terrain, which slopes seaward to an elevation of 20 feet and terminates at the shore at the crest of a timber bulkhead which retains Ocean Avenue. The beach fronting the bulkhead is relatively steep and narrow, and is intersected by numerous heavy rubble mound groins. The Long Branch Fishing and Recreation Pier is 900 feet long and terminates in about 20 feet of water.

Northward from Long Branch the land lowers to an elevation of about 7 feet and the shorefront becomes a barrier beach less than 300 feet wide at its narrowest point. Along the greater part of this stretch of coast, the beach is backed by a high rubble mound sea wall designed to prevent storm waves from breaching the barrier.

The area covered by detailed studies in this investigation extends about 2 miles northward along the beach from the Long Branch Fishing and Recreation Pier to Shrewsbury Rocks opposite the Monmouth Beach Coast Guard Station.

III. Test Procedure

Hydrographic and other surveys defining conditions were made before the deposit of material. During the pre-deposit period a U. S. C. and G.S. primary tide station, a recording wave gauge, and a recording anemometer were installed on the seaward end of the Long Branch Fishing Pier.

The Corps of Engineers hopper dredge "Goethals" deposited the first load of material at the Long Branch site 30 April 1948. The material, dredged from New York Harbor entrance channels, was placed in a ridge about 7 feet high, 3,700 feet long, and 750 feet wide, lying about ½ mile from shore in 38 feet of water, mean low water, with its southerly limit on an eastwest line about 1,500 feet north of the Long Branch Pier. Dumping at the site continued throughout the summer to a total of 601,991 cubic yards of sand.

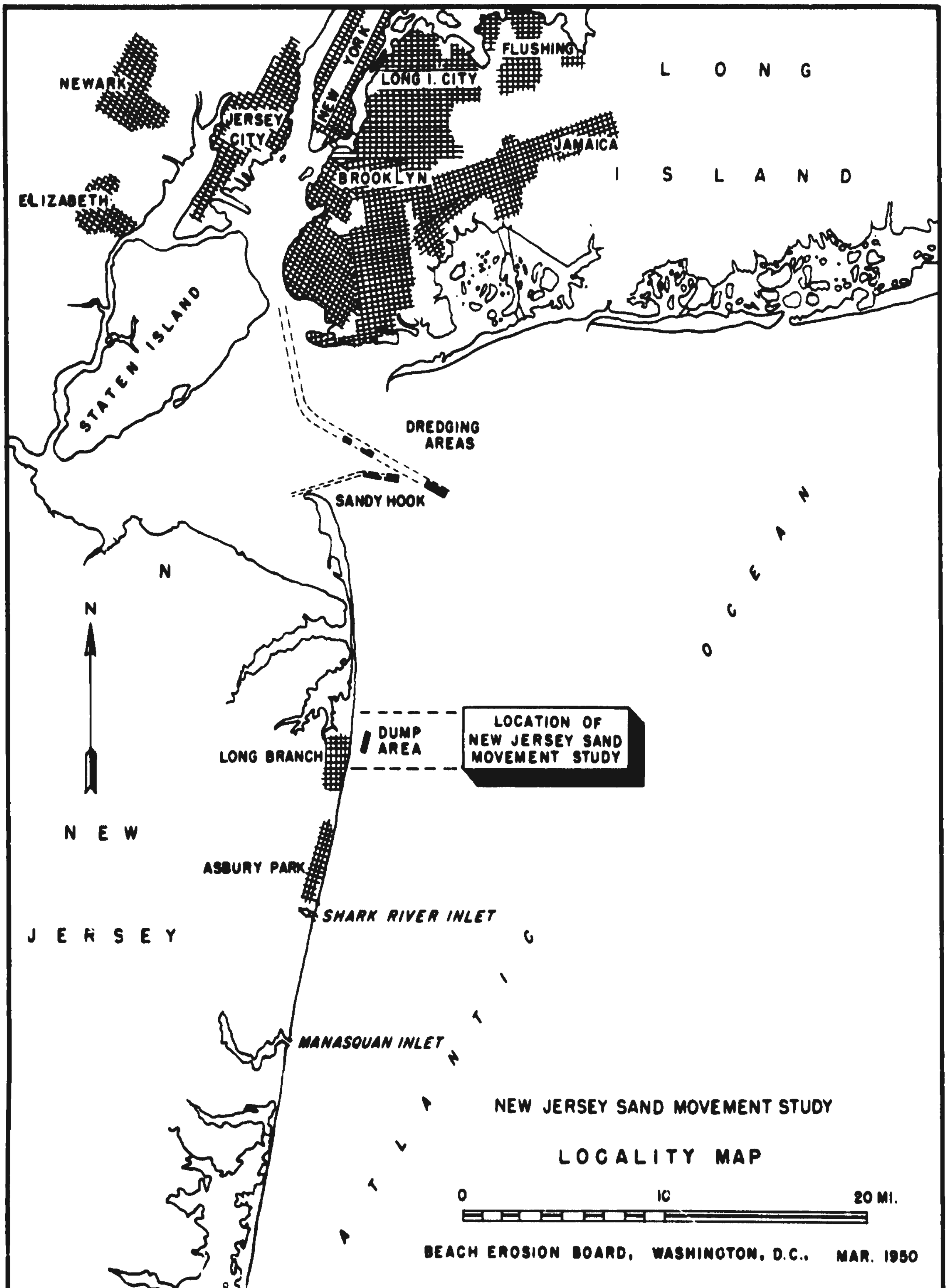

NEWARK
JERSEY CITY
NEW YORK
LONG I. CITY
FLUSHING
LONG ISLAND
JAMAICA
BROOKLYN
ELIZABETH
STATEN ISLAND
DREDGING AREAS
SANDY HOOK
N
OCEAN
LOCATION OF NEW JERSEY SAND MOVEMENT STUDY
DUMP AREA
LONG BRANCH
NEW JERSEY
ASBURY PARK
SHARK RIVER INLET
ATLANTIC
MANASQUAN INLET
NEW JERSEY SAND MOVEMENT STUDY
LOCALITY MAP
0
10
20 MI.
BEACH EROSION BOARD, WASHINGTON, D.C., MAR. 1950

PLATE I

Throughout the period of material deposit, surveys were made of the stockpile at about weekly intervals to determine the location of the sand dumped by the dredge and to insure the safety of the dredge in operations over the dumping grounds. Hydrographic surveys were made of the entire study area in April, July, and October 1948, and in April and October 1949. These surveys covered the area from the Long Branch Fishing Pier to Monmouth Beach Coast Guard Station and from the bulkhead line seaward 6,000 feet to about the 42-foot depth contour mean low water.

Sand samples of the offshore area were taken at selected locations along with samples from the beach at mid-tide level. A sample of each dredge load was taken before dumping at the Long Branch site. All samples were sent to the Beach Erosion Board laboratory for analysis and correlation. Selected beach and dredge samples were subjected to petrographic analysis by the U. S. Geological Survey.

Aerial photographs of the shore line under study were flown, for collateral information, by the U. S. Naval Reserve Squadron VPP-52, Willow Grove, Pennsylvania, 7 September 1948, 16 October 1948, 23 January 1949 and 21 May 1949.

IV. Waves

The Beach Erosion Board has maintained wave-measuring instruments in the Long Branch area continuously since the inception of the study in April 1948. On this date, a Beach Erosion Board step-resistance type wave gauge was installed on the seaward end of the Long Branch Fishing and Recreation Pier where the water was approximately 20 feet deep at mean low water. This gauge was continued in operation until 4 April 1949 when it was removed to make way for pier modifications. A pressure type wave gauge, supplied by Woods Hole Oceanographic Institution, was installed in about 20 feet of water northward from the pier as a replacement. The pressure gauge has been in continuous operation since its installation. Records of height and period are taken automatically for a period of seven minutes every four hours.

The records derived from the gauges have been analyzed for significant wave height and period[(1)], and the results have been tabulated seasonally in Table I, II, III, IV and V.

The tables give the per cent of time that waves within the indicated height and period groups occurred during the stated interval of observation.

Plate II has been prepared from the wave data tabulated in Tables I to V to show the cumulative frequencies of occurrence of wave height and period during the entire period of study. The curves show for any given wave height or period the percentage of time that the waves exceeded that height or period in the Long Branch area.

TABLE I

STATISTICAL WAVE SUMMARY SHOWING PERCENTAGE FREQUENCY OF WAVE OCCURRENCE

LONG BRANCH, N. J. — 22 APRIL 1948 TO OCT. 1948

T-SEC. / H-FEET	0-2	2-4	4-5	5-6	6-7	7-8	8-9	9-10	10-12	12-14	14+	TOTAL PERCENT	CUMULATIVE PERCENT
0-1.0					0.1	1.3	2.8	0.8	1.2	0.5		6.7	100.0
1.0-2.0			1.9	2.9	8.3	10.5	12.3	5.1	6.0	2.4		49.4	93.3
2.0-3.0		0.1	1.0	1.4	4.5	7.5	5.8	0.5	1.6	1.0	0.1	23.5	43.9
3.0-4.0			0.3	1.1	1.9	2.4	2.2	0.7	0.5	0.2		9.3	20.4
4.0-5.0			0.1	0.8	1.4	1.3	0.7	0.4		0.1		4.8	11.1
5.0-6.0				0.4	0.8	0.5	0.5		0.3			2.5	6.3
6.0-7.0					0.4	0.6	0.3	0.3				1.6	3.8
7.0-8.0			0.1			0.4	0.1		0.1			0.7	2.2
8.0-9.0					0.1	0.2	0.5					0.8	1.5
9.0-10.0					0.3							0.3	0.7
10.0-11.0						0.2						0.2	0.4
11.0-12.0							0.1	0.1				0.2	0.2
TOTAL PERCENT		0.1	3.4	6.6	17.8	24.9	25.3	7.9	9.7	4.2	0.1	100.0	

NOTE: FIGURES BELOW AND TO THE RIGHT OF THE SOLID AND DASHED LINES DEFINING THE BOUNDARIES OF HJULSTROM'S THRESHOLD VELOCITIES GIVE THE PERCENT OCCURRANCE OF WAVES OF A GIVEN HEIGHT AND PERIOD WHICH WILL MOVE SAND IN 40 FEET OF WATER.

TABLE II

STATISTICAL WAVE SUMMARY SHOWING PERCENTAGE FREQUENCY OF WAVE OCCURRENCE

LONG BRANCH, N. J.

1 NOV. 1948 TO 30 APRIL 1949

T-SEC. / H-FEET	0-2	2-4	4-5	5-6	6-7	7-8	8-9	9-10	10-12	12-14	14+	TOTAL PERCENT	CUMULATIVE PERCENT
0-1.0	1.9	2.1	0.9	1.2	1.9	4.5	8.5	6.3	3.3	0.9	0.1	31.7	100.0
1.0-2.0		1.4	1.9	3.9	6.3	9.8	14.5	6.7	5.5	0.9		50.9	68.3
2.0-3.0		0.1	0.5	1.1	1.1	1.7	2.5	1.8	0.9			9.7	17.4
3.0-4.0			0.1	0.2	0.9	1.5	0.5	0.4	0.5			4.1	7.7
4.0-5.0				0.1	0.2	0.7	0.5	0.3	0.2	0.2		2.2	3.6
5.0-6.0				0.1	0.1	0.1	0.4					0.7	1.4
6.0-7.0					0.1		0.2	0.1				0.4	0.7
7.0-8.0						0.2						0.2	0.3
8.0-9.0													0.1
9.0-10.0								0.1				0.1	0.1
10.0-11.0													
11.0-12.0													
TOTAL PERCENT	1.9	3.6	3.4	6.6	10.6	18.6	27.1	15.7	10.4	2.0	0.1	100.0	

NOTE: FIGURES BELOW AND TO THE RIGHT OF THE SOLID AND DASHED LINES DEFINING THE BOUNDARIES OF HJULSTROM'S THRESHOLD VELOCITIES GIVE THE PERCENT OCCURRENCE OF WAVES OF A GIVEN HEIGHT AND PERIOD WHICH WILL MOVE SAND IN 40 FEET OF WATER.

TABLE III

STATISTICAL WAVE SUMMARY SHOWING PERCENTAGE FREQUENCY OF WAVE OCCURRENCE

LONG BRANCH, N. J. — 1 MAY 1949 TO 31 OCTOBER 1949

H-FEET \ T-SEC	0–2	2–4	4–5	5–6	6–7	7–8	8–9	9–10	10–12	12–14	14+	TOTAL PERCENT	CUMULATIVE PERCENT
0-1.0					0.2	5.2	9.0	5.5	3.6	0.5		24.0	100.0
1.0-2.0				0.5	2.3	13.2	19.8	10.5	5.6	0.7		52.6	76.0
2.0-3.0				0.2	1.4	3.4	6.1	2.9	1.4	0.1		15.5	23.4
3.0-4.0				0 3	0.3	0.6	1.9	1.2	0.1			4.4	7.9
4.0-5.0						0.6	0.6	0.1				1.3	3.5
5.0-6.0							1.4	0.1				1.5	2.2
6.0-7.0						0.7						0.7	0.7
7.0-8.0													
8.0-9.0													
9.0-10.0													
10.0-11.0													
11.0-12.0													
TOTAL PERCENT				1.0	4.2	23.7	38.8	20.3	10.7	1.3		100.0	

NOTE: FIGURES BELOW AND TO THE RIGHT OF THE SOLID AND DASHED LINES DEFINING THE BOUNDARIES OF HJULSTROM'S THRESHOLD VELOCITIES GIVE THE PERCENT OCCURRENCE OF WAVES OF A GIVEN HEIGHT AND PERIOD WHICH WILL MOVE SAND IN 40 FEET OF WATER.

TABLE IV

STATISTICAL WAVE SUMMARY SHOWING PERCENTAGE FREQUENCY OF WAVE OCCURRENCE

LONG BRANCH, N.J. — 22 APRIL 1948 TO 30 APRIL 1949

H-FEET \ T-SEC.	0-2	2-4	4-5	5-6	6-7	7-8	8-9	9-10	10-12	12-14	14+	TOTAL PERCENT	CUMULATIVE PERCENT
0-1.0	0.9	0.9	0.4	0.6	1.0	2.6	5.5	3.3	2.2	0.7		18.3	100.0
1.0-2.0		0.7	1.9	3.4	7.3	10.2	13.3	5.8	5.8	1.8		50.2	81.7
2.0-3.0		0.1	0.9	1.3	2.9	4.8	4.3	1.2	1.2	0.5	0.1	17.3	31.5
3.0-4.0			0.2	0.7	1.4	1.9	1.4	0.6	0.5			6.7	14.2
4.0-5.0				0.4	0.9	1.0	0.6	0.3	0.1	0.2		3.5	7.5
5.0-6.0				0.3	0.5	0.3	0.5		0.1			1.7	4.0
6.0-7.0					0.3	0.3	0.2	0.2				1.0	2.3
7.0-8.0						0.3	0.1		0.1			0.5	1.3
8.0-9.0						0.1	0.3					0.4	0.8
9.0-10.0					0.1	0.1						0.2	0.4
10.0-11.0						0.1						0.1	0.2
11.0-12.0								0.1				0.1	0.1
TOTAL PERCENT	0.9	1.7	3.4	6.7	14.4	21.9	26.2	11.5	10.0	3.2	0.1	100.0	

NOTE: FIGURES BELOW AND TO THE RIGHT OF THE SOLID AND DASHED LINES DEFINING THE BOUNDARIES OF HJULSTROM'S THRESHOLD VELOCITIES GIVE THE PERCENT OCCURRANCE OF WAVES OF A GIVEN HEIGHT AND PERIOD WHICH WILL MOVE SAND IN 40 FEET OF WATER.

TABLE V

STATISTICAL WAVE SUMMARY SHOWING PERCENTAGE FREQUENCY OF WAVE OCCURRENCE

LONG BRANCH, NEW JERSEY — 22 APRIL 1948 TO 31 OCTOBER 1949

H-FEET \ T-SEC.	0-2	2-4	4-5	5-6	6-7	7-8	8-9	9-10	10-12	12-14	14+	TOTAL PERCENT	CUMULATIVE PERCENT
0-1.0	0.6	0.6	0.3	0.4	0.7	3.5	6.6	4.0	2.7	0.6		19.4	100.0
1.0-2.0		0.5	1.3	2.6	5.8	11.1	15.3	7.2	5.7	1.4		50.9	80.0
2.0-3.0		0.1	0.5	1.0	2.5	4.4	4.8	1.6	1.3	0.4	0.1	16.7	29.1
3.0-4.0			0.2	0.5	1.1	1.5	1.5	0.8	0.4			6.0	12.5
4.0-5.0			0.1	0.4	0.6	0.8	0.6	0.2	0.1	0.1		2.9	6.5
5.0-6.0				0.2	0.4	0.2	0.7	0.1				1.6	3.6
6.0-7.0					0.2	0.5	0.1	0.1				0.9	2.0
7.0-8.0						0.2	0.1		0.1			0.4	1.1
8.0-9.0						0.1	0.2					0.3	0.7
9.0-10.0					0.1							0.1	0.3
10.0-11.0						0.1						0.1	0.2
11.0-12.0								0.1				0.1	0.1
TOTAL PERCENT	0.6	1.2	2.4	5.1	11.4	22.4	29.9	14.1	10.3	2.5	0.1	100.0	

NOTE: FIGURES BELOW AND TO THE RIGHT OF THE SOLID AND DASHED LINES DEFINING THE BOUNDARIES OF HJULSTROM'S THRESHOLD VELOCITIES GIVE THE PERCENT OCCURRANCE OF WAVES OF A GIVEN HEIGHT AND PERIOD WHICH WILL MOVE SAND IN 40 FEET OF WATER

V. Characteristics of Sand.

Seven sets of sand samples, totaling 320 samples were taken over a five month period at 400-foot intervals, along the beach and along the profiles, to determine the character of the native materials at various times during the course of the study. The results of these sampling tests and mechanical analysis are on file at the Beach Erosion Board. The average geometric mean diameter of the sand samples taken along the beach varied from 0.35 mm. in the summer to 0.91 mm. in the winter with an annual average geometric mean diameter of 0.66 mm. The offshore area was not sampled seasonally; of the samples taken the average geometric mean diameter was found to be 0.39 mm. with limits of 0.16 minimum and 0.65 maximum. The material deposited in the study area was sampled while aboard the dredge; the average geometric mean diameter was 0.34 mm. with limits of 0.14 mm. minimum and 0.80 maximum. The dredge and offshore samples are similar in range and average geometric mean diameters, and do not offer a satisfactory criterion for determining sand movement.

Four composite samples were subjected to petrographic analysis to ascertain the existance of unique minerals which could be used as tracers. These samples were: #780 taken from material aboard dredge; #781 taken from the beach before dumping; #782 composite of samples taken from the beach up to 21 July, after 396,000 cubic yards of sand had been deposited in the dump area; and #783 representative of the native bottom material.

The analysis results are:

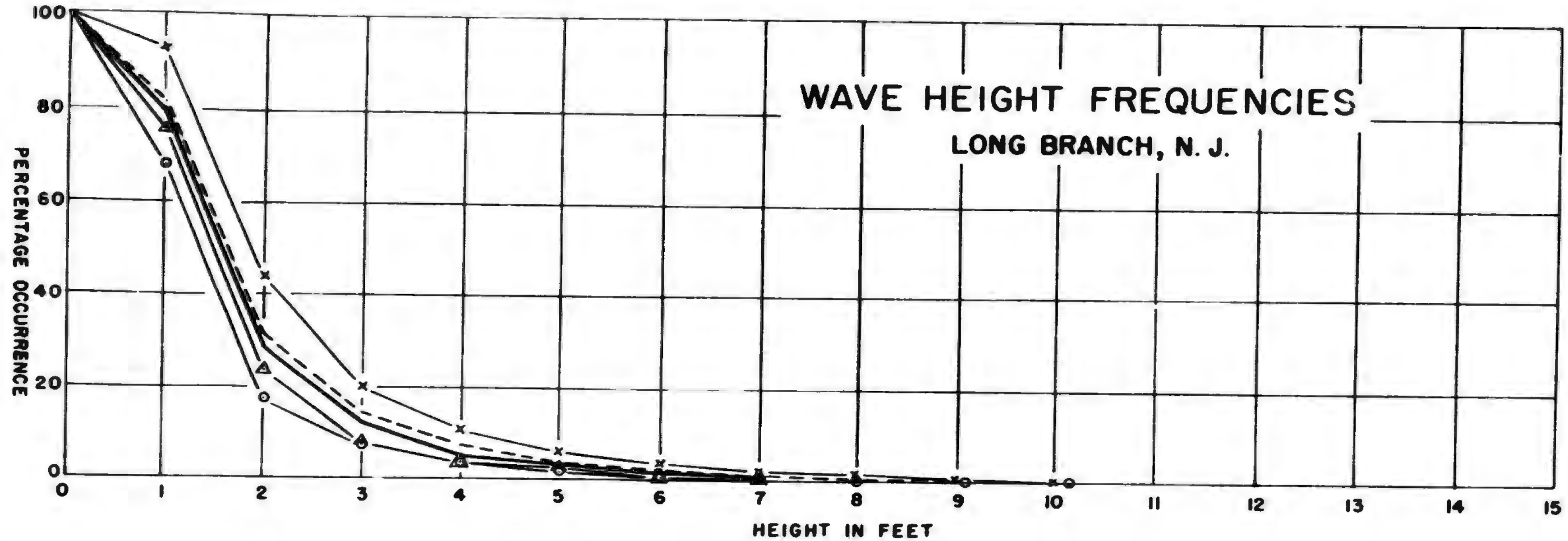
Bromoform Separation (% by weight)

Separation about 2.9 Specific Gravity

Sample No.	#780	#781	#782	#783
Heavy Fraction	3.6%	1.6%	1.36	4.43
Light Fraction	96.0%	97.3	97.5	95.2

Grain Count Percentages - Heavy Fraction

	#780 - Dredge	#781 - Before	#782 - After	#783 - Bottom
Opaques	31	23	35	41
Glauconite	9	48	25	14
Hornblende	12	5	11	10
Biotite	10	4	2	5
Garnet	7	5	5	6
Muscovite	7	-	3	5
Chlorite	9	-	3	3
Zircon	2	3	2	3
Hematite	4	4	4	2
Tourmaline	3	1	2	2
Hypersthene	3	4	2	2
Other	3	3	6	7
	100	100	100	100


WAVE HEIGHT FREQUENCIES
LONG BRANCH, N. J.
PERCENTAGE OCCURRENCE
HEIGHT IN FEET
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

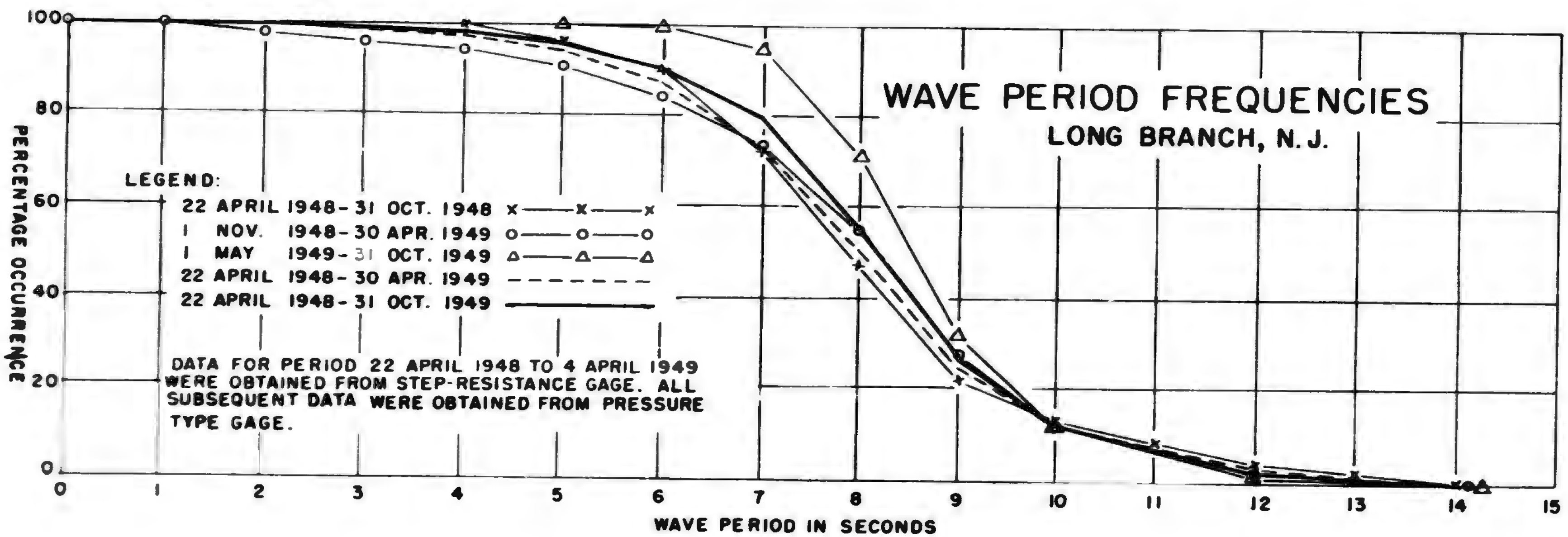

WAVE PERIOD FREQUENCIES
LONG BRANCH, N. J.
LEGEND:
22 APRIL 1948 - 31 OCT. 1948 x——x——x
1 NOV. 1948 - 30 APR. 1949 o——o——o
1 MAY 1949 - 31 OCT. 1949 △——△——△
22 APRIL 1948 - 30 APR. 1949 - - - - - -
22 APRIL 1948 - 31 OCT. 1949 ———
DATA FOR PERIOD 22 APRIL 1948 TO 4 APRIL 1949 WERE OBTAINED FROM STEP-RESISTANCE GAGE. ALL SUBSEQUENT DATA WERE OBTAINED FROM PRESSURE TYPE GAGE.
PERCENTAGE OCCURRENCE
WAVE PERIOD IN SECONDS
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

PLATE 11

Grain Count Percentages - Light Fraction

	#780 - Dredge	#781 - Before	#782 - After	#783 - Bottom
Quartz	79	76	75	77
Feldspar	2	3	7	4
Opaques	11	4	11	3
Glauconite	3	8	4	10
Other	5	9	3	6
	100	100	100	100

Distinctive criteria are lacking between the dredge, beach, and bottom samples; mineralogical composition is therefore not a satisfactory criterion for determining sand movement in this case.

VI. Relation Between Wave Orbital Velocities and Sand Movement

In order to establish the relation between wave orbital velocities and sand movement, a search was made of available literature on the subject. The article "Transportation of Detritus by Moving Water," by Filip Hjulstrom, appearing in the book "Recent Marine Sediments," published by the American Association of Petroleum Geologists appeared to best cover this field. A graph showing the velocities required to erode sand particles of various sizes, as developed by Hjulstrom, is shown on Plate III. Velocities are shown in feet per second with sand particle size in millimeters.

The lower portion of the graph is a chart showing the sand particle size distribution of the material dumped by hopper dredge in the deposit area. The percentages represent the average size distributions of 120 samples of the dumped material. The solid vertical line shows the average geometric mean diameter of the dumped material. The geometric mean diameter of the sand particles has been used in this study rather than other factors since in significance it appears to rank as a more important factor in sedimentary work(2).

The upper portion of Plate III shows the upper and lower limits of velocities capable of putting sand into motion, according to Hjulstrom. The average geometric mean diameter of the material dumped at the site coinsides very nearly with the diameter corresponding to the minimum eroding velocity as shown by Hjulstrom's curve. Therefore the intersections of the average geometric mean diameter line with the two curves show the range of minimum velocities required to erode sand at Long Branch. Hjulstrom's curves show that velocities of 0.48 to 0.79 feet per second will erode sand.

In order to determine the range of wave heights and periods which are capable of eroding sand in 40 feet of water, the depth surrounding the stockpile, the bottom velocities of a wide range of waves were computed. The resulting values have been applied, for demonstration purposes, to the wave heights and period tabulations

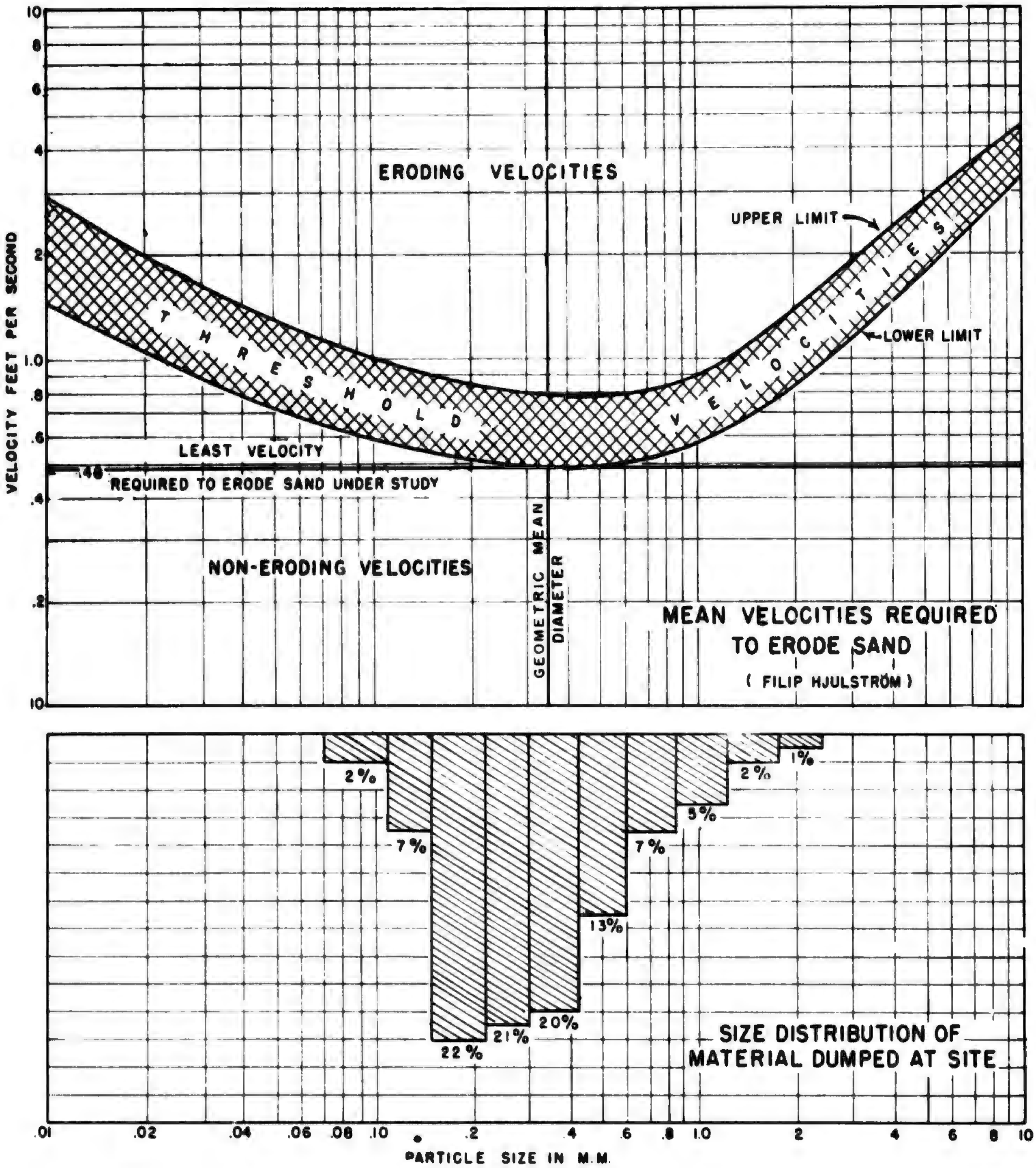

ERODING VELOCITIES
UPPER LIMIT
LOWER LIMIT
THRESHOLD VELOCITIES
LEAST VELOCITY
.48 REQUIRED TO ERODE SAND UNDER STUDY
NON-ERODING VELOCITIES
GEOMETRIC MEAN DIAMETER
MEAN VELOCITIES REQUIRED TO ERODE SAND
(FILIP HJULSTRÖM)
VELOCITY FEET PER SECOND
2%
7%
22%
21%
20%
13%
7%
5%
2%
1%
SIZE DISTRIBUTION OF MATERIAL DUMPED AT SITE
PARTICLE SIZE IN M.M.

PLATE III

of Tables I to V inclusive. All groups of wave heights and periods below and to the right of the solid line are capable of moving sand according to the lower limit of Hjulstrom's curves. All groups of waves below and to the right of the dashed line are capable of moving sand according to the upper limits of Hjulstrom's curves.

The following table gives the percentages of occurrences of recorded waves capable of moving sand over the survey area according to the lower and upper limits of Hjulstrom's curve.

TABLE VI

Percentage of Occurrences of Waves With Sand Moving Ability Sufficient to Move Sand In 40-foot Depths

Period	Lower Limit	Upper Limit
Apr 48 - Oct 48	79%	35%
Nov 48 - Apr 49	54	14
May 49 - Oct 49	73	22
Apr 48 - Apr 49	67	25
Apr 48 - Oct 49	69	24

VII. Comparative Shore Line and Depth Changes

The preceding section shows that there are waves of sufficient size, at Long Branch, to put sand in motion during an appreciable part of the study period. This does not necessarily mean however, that the bottom sand is transported over any great distance. At present there is not sufficient information available on sand transport by wave action to compute the quantity and direction. Comprehensive hydrographic and topographic surveys were made over the area to determine the movement of the sand over the ocean floor.

Surveys made in April, July, October 1948, April and October 1949, were used as a basis for determining changes in the position of the high water shore line and the 12, 24, 30, 36 and 42-foot depth contours. The April 1948 survey, herein referred to as the base survey, was made prior to the first dump; the July survey near the end of the dumping period; the October survey two months after all dumping had been completed; and the April and October 1949 surveys after the stockpile had been in place for 8 and 14 months respectively. The positions of the shore line and depth contours as determined at the time of each survey are shown on Plates IV, V, and VI. The primary purpose in presenting these superposed surveys is to aid in detecting any realignment of the depth curves and shore line resulting from the movement of the dumped material.

For convenience in describing the changes which have taken place along the shore line during the period of study, the beach has been divided into four sections. The first extends from a point 500 feet south of the Long Branch pier northward to the limit of the bulkheaded section of the shore; the second from the northern limit of the bulkheaded section to the Long Branch-Monmouth Beach jetty; the third from the Long Branch-Monmouth Beach jetty to the Monmouth Beach Club jetty and the fourth from the Monmouth Beach Club jetty to the end of the study area.

In order to show more clearly the movement of the high-water shore line in the various sections during the various periods of study, Table VII has been prepared by averaging the increments of change of horizontal position of the shore line, for each period, taken at 200-foot intervals along the shore.

TABLE VII

High-water Shore Line Changes

	Spring	Summer	Fall Winter	Spring Summer	18 mo.	15 mo.	12 mo.
Sections	Apr 48 Jul 48	Jul 48 Oct 48	Oct 48 Apr 49	Apr 49 Oct 49	Apr 48 Oct 49	Jul 48 Oct 49	Oct 48 Oct 49
1	-4'	+4'	-17'	+3'	-14'	-10'	-14'
2	-2'	-6'	-9'	-34'	-51'	-49'	-43'
3	-	-17'	-18'	+4'	-	-31'	-14'
4	-	-15'	-2'	-12'	-	-29'	-14'

The table shows that the history of the entire stretch of beach during the period of study is one of progressive erosion, averaging in one section as much as 43 feet per year. The table shows further that when erosion did occurr during the study period it occurred during the summer months.

Seaward from the shore line, a study of the depth curves shows that the 12-foot contour has, in general, moved toward the shore, substantiating the shore line erosion discussed above. The movements of the 24 to 42-foot contours are irregular and no definite trend of bottom movement is indicated. The movement of sand in these offshore areas will be discussed in the succeeding sections.

VIII. Sand Movement Diagrams

Sand movement in the study area from April 1948 to October 1949, the most recent examination period, is shown on Plates VII, VIII, IX, X, XI, XII, XIII, and XIV.

The diagrams were prepared by dividing the study area into 200-foot squares; computing the average change in elevation in each square, and contouring to show the extent of vertical change in the ocean floor between the various survey periods. The contours were drawn along the 0.2 and 0.5-foot depth changes and at 0.5-foot intervals for greater changes. The depth changes less than .2 of a foot were neglected as being of the order of the accuracy of the data.

Plate VII shows the changes in depth which have occurred in the study area between April and July 1948. During this period, the dredge Goethals deposited approximately 555,000 cubic yards of material, bin measure, within the stockpile area. During this period, there was a random shifting of the sands on the ocean floor due to natural forces. Nearshore erosion was prevalent along the central beach area with small areas of accretion near the pier and near the northern limit of the area.

Plate VIII shows the changes between July and October 1948. Approximately 47,000 cubic yards of sand, bin measure, were deposited in the stockpile during this period. Changes in depth again appear to be of a random nature. The dissimilarity of the patterns on this and Plate VII indicates a random shifting of the ocean bottom. An examination of the survey and dredge data indicate that at least one load of about 5,000 cubic yards was deposited about 700 feet seaward of the limits of the stockpile. Nearshore erosion has continued in the center of the study area, but other locations which formerly showed erosion during the April-July period now show accretion.

Plate IX shows the changes between April and October 1948. The entire stockpile of 601,991 cubic yards of sand, bin measure, was deposited by 19 August, two months before the latter survey date. Scattered areas of accretion and erosion are shown with the major changes appearing in the stockpile area as accretion resulting from the dumped material and erosion nearshore, in the center of the study area, resulting from natural causes.

Plate X shows the changes in depth from October 1948, two months after all dumping had been completed, to April 1949. The diagram shows that erosion took place over the center and northerly peaks of the pile and a greater part of the talus area surrounding it. The considerable accretion at the southwest corner of the dumped area is the result of a depression filling rather than the stockpile building. (See Plate IV). The accretion shown in the offshore area at the northern and southern limits of the study is believed to be due to the readjustment of the extensive shoals in these areas (See Plates IV and VI). An examination of the nearshore area shows that, in general, the area has continued to erode and the area of erosion has extended northward over the greater part of the shore line under study. Since it appears that the accretion in the study area overbalances the erosion it can only be assumed that the greater part of the accretion shown moved into the study area from outside of its boundaries. This assumption is supported by data in Table VIII.

Plate XI shows the changes in depth from April 1949 to October 1949. An examination of the plate shows that in general those areas which eroded during the previous period accreted and those which accreted have eroded. It appears from the diagram that the material eroded from the shoal at the southern end of the study area (see Plate IV) moved northward and the material eroded northward from the center of the study area was scattered about forming areas of accretion or was moved out of the study area. The large area of accreted material shown south of the center of the study area included but was not limited to the dump area. Although this area of accretion extends shoreward almost to the beach there is no indication that the mound is supplying material to the beach. It appears that the accreting material was supplied from continuous areas of the ocean floor. The long tongue of accretion extending from the shore seaward just north of the center of the area appears to support the belief that the material is supplied from contiguous areas of the ocean floor. Although there are areas of accretion nearshore, erosion predominates.

Plate XII shows the changes which have occurred from April 1948 the inception of the study, to April 1949, eight months after all dumping had been completed. In the offshore area, there appears to be a general readjustment of the bottom. Nearshore erosion has prevailed, the greatest recession occurring in the central beach area. In view of the erosion on the beach, it does not appear that the dumped material has had a beneficial effect on the beach.

Plate XIII shows the net bottom changes which have occurred during the periods October 1948 to October 1949. Although the intervening changes (see Plates X and XI) are considerable the net change appears to show a relative balance between accretion and erosion. The balance between accretion and erosion is supported by data in Table VIII. The net changes show accretion to be general over the offshore area including the mound except for an area of localized erosion near the center of the mound and erosion over the shoal at the southern limit of the study. Nearshore erosion has been extensive over the year. The general accretion over the mound coupled with the extensive erosion along the shore indicates that the deposited material has not benefited the beach.

Plate XIV shows the changes in depth from the inception of the study April 1948 to the last examination, October 1949, a period of 18 months. A comparison between this plate and Plate IX shows the mound to be nearly intact. In considering the entire area, it can be seen that if all differential contours of less than one foot are disregarded, there has been little change in the area except along the shore. Along the shore in the central area and northward, erosion has been progressive and extensive. The resultant changes in the shore line and the bottom from the inception of the study in April 1948 to the last survey in October 1949, show conclusively that the stockpile has not replenished the formerly eroding shore.

IX. Volumetric Sand Movement

The computations in this study were based on the system of 200-foot squares devised for the preparation of the sand movement diagrams. The change in elevation in each square was determined by averaging the difference in soundings at each of its four corners.

In order to simplify the study of the volumetric movement of sand, the surveyed area was divided into three zones; the area shoreward of the 18-foot depth contour; the area embracing the stockpile as delineated by the 0.2 foot contour around it as shown on the April to October 1948 sand movement diagram and the area seaward of the 18-foot depth contour excluding the stockpile.

The volume changes in these three zones were computed between the April 1948, October 1948, April 1949 and October 1949, surveys and are shown in Table VIII.

The history of the shore area at Long Branch, New Jersey, before the inception of this study, has been one of progressive erosion. The table shows that during the 18-month period of the study, the shore line continued to erode. During this period of 18 months, there has been a net loss in this zone of approximately 266,000 cubic yards of material between range 13 and 63 corresponding to an average annual rate of loss of 177,000 cubic yards. The rate of erosion was greatest during the winter months.

The area within the boundaries of the stockpile area, previously defined, shows considerable erosion during the winter months, but shows a greater accretion during the summer months. During the year October 1948 to October 1949, the stockpile area remained relatively stable, showing a net gain of approximately 39,000 cubic yards.

The area seaward of the 18-foot depth, excluding the stockpile, showed considerable accretion during the winter months and erosion during the summer months. Over the period of one year, from October 1948 to October 1949, there has been a net gain of 182,000 cubic yards of material over the entire area.

It is interesting to note that the total erosion and accretion over the entire area from range 13 to 63 showed a net change of plus 15,000 cubic yards from October 1948 to October 1949. Similarly, from range 13 to 80, the balance between accretion and erosion was even closer, showing a total net gain of only 1,000 cubic yards. It appears possible that the shoal areas on the north and south flanks of the study area act as barriers of a sort forming a bowl in which the sands shift with the season.

In view of the fact that the table shows a material balance within

TABLE VIII
VOLUMETRIC MEASURE OF BOTTOM CHANGES IN THE SURVEY AREA

	Date	Shoreward of 18 ft. Depth	Within Oct 1948 Boundary of Dump	Seaward of 18 ft. Depth Excluding Dump Area	Net Change Over Survey Area
Range 13-63	April 48 - Oct 48	-114,000 cu yards	∤605,000 cu yards	-81,000 cu yards	∤410,000 cu yards
	April 48 - April 49	-241,000 cu yards	∤483,000 cu yards	∤236,000 cu yards	∤478,000 cu yards
	April 48 - Oct 49	-260,000 cu yards	∤644,000 cu yards	∤47,000 cu yards	∤425,000 cu yards
Range 13-80	Oct 48 - April 49	-138,000 cu yards	-122,000 cu yards	∤441,000 cu yards	∤181,000 cu yards
	Oct 48 - Oct 49	-222,000 cu yards	∤39,000 cu yards	∤182,000 cu yards	-1,000 cu yards
Range 13 - 63	April 48 - Oct 48	-114,000 cu yards	∤605,000 cu yards	-81,000 cu yards	∤410,000 cu yards
	Oct 48 - April 49	-127,000 cu yards	-122,000 cu yards	∤317,000 cu yards	∤68,000 cu yards
	April 49 - Oct 49	-25,000 cu yards	∤161,000 cu yards	-189,000 cu yards	-53,000 cu yards
Range 13-80	Oct 48 - April 49	-138,000 cu yards	-122,000 cu yards	∤441,000 cu yards	∤181,000 cu yards
	April 49 - Oct 49	-84,000 cu yards	∤161,000 cu yards	-259,000 cu yards	-182,000 cu yards

the surveyed area over the period of observation, it is reasonable to believe that the littoral drift is also in balance; that is, the same quantity of material that is moved into the area by littoral forces is removed by littoral forces. It is doubtful that this area is devoid of littoral drift.

X. Discussion

A study of the data presented in this paper gives no evidence of any substantial movement of sand from the stockpile to the shore. This is confirmed by the fact that the stockpile remained in place or increased slightly in quantity, +39,000 cubic yards, over the period October 1948 to October 1949 while the shore line in the vicinity showed a marked erosion of about -222,000 cubic yards. See Table VIII.

One may question the choice of the site and of the depth of water at the placement area as being inherently unsuitable for study of the movement of sand by natural wave forces. The Long Branch area was selected due to its proximity to a source of material available by hopper dredging activity in New York Harbor and for its open exposure to ocean waves. The depth in which the material was placed was controlled by the draft of the dredge. Thus there was in actuality little in the way of choice of these two basic elements of procedure. However, it might be well to review the local factors to see if they imposed any condition that militated against a reasonable test of this method of beach replenishment.

The first point that must be considered is the representative character of the natural forces, principally waves, which affected the sand after it had been dumped. Although much of the time the wave action in the area was probably not sufficient to move sand in 35 to 40 feet of water the facts given in the body of the report shows that wave action did exist which produced significant changes in the 35 to 40 foot depths adjacent to the stockpile. The important point to note is that although the material moved, it did not move continuously in any one direction but moved haphazardly. The data in this paper shows that although 122,000 cubic yards of material moved out of the dump area to the surrounding bottom between October 1948 and April 1949, a larger quantity of 161,000 cubic yards moved into the dumped area from the surrounding bottom during the subsequent six months.

The movement of material within the stockpile area, as shown by the sand movement diagrams, indicates that this area is affected by natural forces in the same manner as the surrounding area. In other words it appears that the material deposited at the site formed so low a mound (5 to 9 feet) compared to the depth of water in which it was deposited (38 feet mean low water) and assumed such flat side slopes (1 on 30 to 1 on 54) it did not alter the natural trend of sand movement but became essentially an integral part of the topography of the ocean floor reacting in the same manner as contiguous areas.

It is also significant to note that during the period when the stockpile eroded October 1948 to April 1949 (-122,000 cubic yards) the beach area lost approximately -138,000 cubic yards of material during the same period. See table VIII.

In view of the fact that natural forces were extant which would move material over the ocean floor and along the beach it is considered that the test made in the Long Branch area was representative.

Since it has been shown that material moved in deep water but not toward the beach it might be well to consider for a moment the conditions under which sand does move in quantity from the offshore area to the beach. Little is known of the boundaries of a movement of this nature. It is known that during storms when waves of high steepness are striking the beach, the beach erodes and the material is pulled seaward forming an offshore bar. It is known further that when the wave steepness decreases, that is, when the wave height becomes small in comparison with the length the bar is moved onto the beach. It is evident from the findings of this test that the stockpile probably was outside the seaward boundary of this phenomenon. It appears from the above that if the sand had been placed in shallower water it might have been transported to the beach. An attempt to nourish an eroding beach by dumping dredge spoil in 15 to 25 feet of water (mean low water) was made by the Philadelphia District, Corps of Engineers. The results of the test are given in the following paragraph taken from a Beach Erosion Control Report on Cooperative Study of Atlantic City, New Jersey, approved April 8, 1947.

"Realizing that augmented nourishment of the beach would be beneficial, the sand removed from the channel by dredging was released by hopper dredges in the waters southwest of the Steel Pier and as near the beach as the dredge could operate in the hope that the spoil so discharged would move ashore by natural underwater processes. Evidence that any substantial quantity of sand moved onto the beach has not been found, despite the fact that 792,000 cubic yards of sand were so deposited off the beach in the period April 1935-March 1936, nearly 900,000 cubic yards in February-September 1937, more than 500,000 cubic yards in August-December 1938 and 1,362,000 cubic yards in the period August 1942 - September 1942".

Further a similar attempt at nourishment was made at Santa Barbara, California, where 202,000 cubic yards of sand were deposited by the hopper dredge in 20 feet of water (mean lower low water) in September 1935. The results are given in the Report on Cooperative Beach Erosion Study at Santa Barbara, California, District Engineer, Corps of Engineers, November 22, 1946 follows:

"The mound deposited by hopper dredge in 1935 has remained exceptionally stable. The profiles indicate that its present ridge elevation of 17 to 18 feet below mean lower low water is at no point more than a foot below the 1937 elevation. However, the shallow trough between the mound and the shoreward slope of the natural bottom has been filled to a depth of 2 to 3 feet in most places."

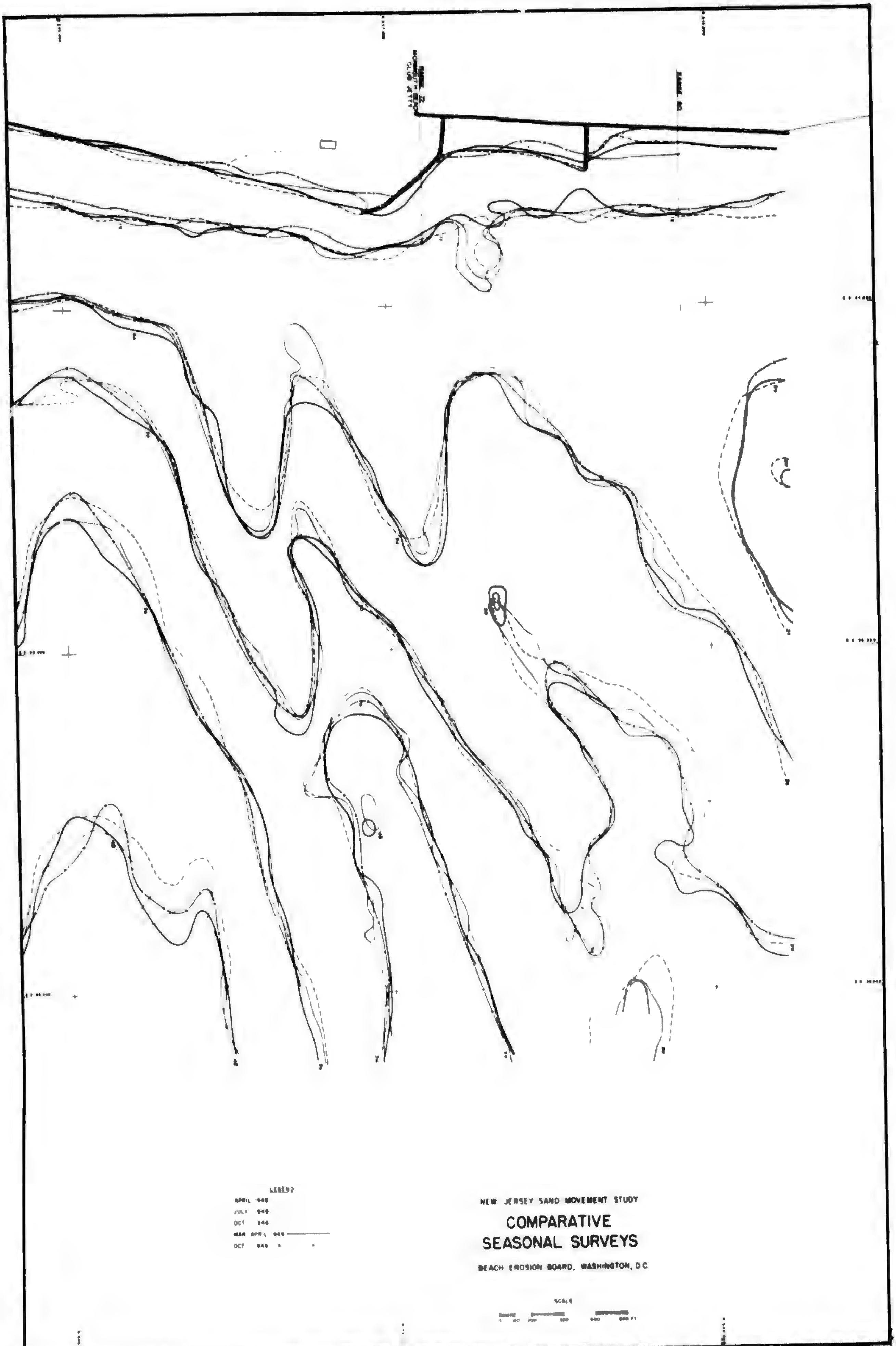
In view of the results of these studies, and especially the Santa Barbara, California, study where the crest of the mound was near the surface and there is a large percentage of waves with low steepness which are conducive to a shoreward movement of material, it is evident that if material is to be transported shoreward in any quantity it must be deposited in water shallower than that previously employed. How much shallower cannot be determined from this study but it is probable that it would have to be placed on or landward of the offshore bar.

* * * * * *

BIBLIOGRAPHY

(1) Procedure for Interpreting Pressure Records of Swell, R. G. Folsom, HE-116-56, 14 February 1945, University of California, Berkeley, California.

(2) Manual of Sedimentary Petrography, Krumbein and Pettijohn, page 240.



LEGEND
APRIL 1948
JULY 1948
OCT 1948
MAR APRIL 1949
OCT 1949
NEW JERSEY SAND MOVEMENT STUDY
COMPARATIVE
SEASONAL SURVEYS
BEACH EROSION BOARD, WASHINGTON, D.C.
SCALE

PLATE IV

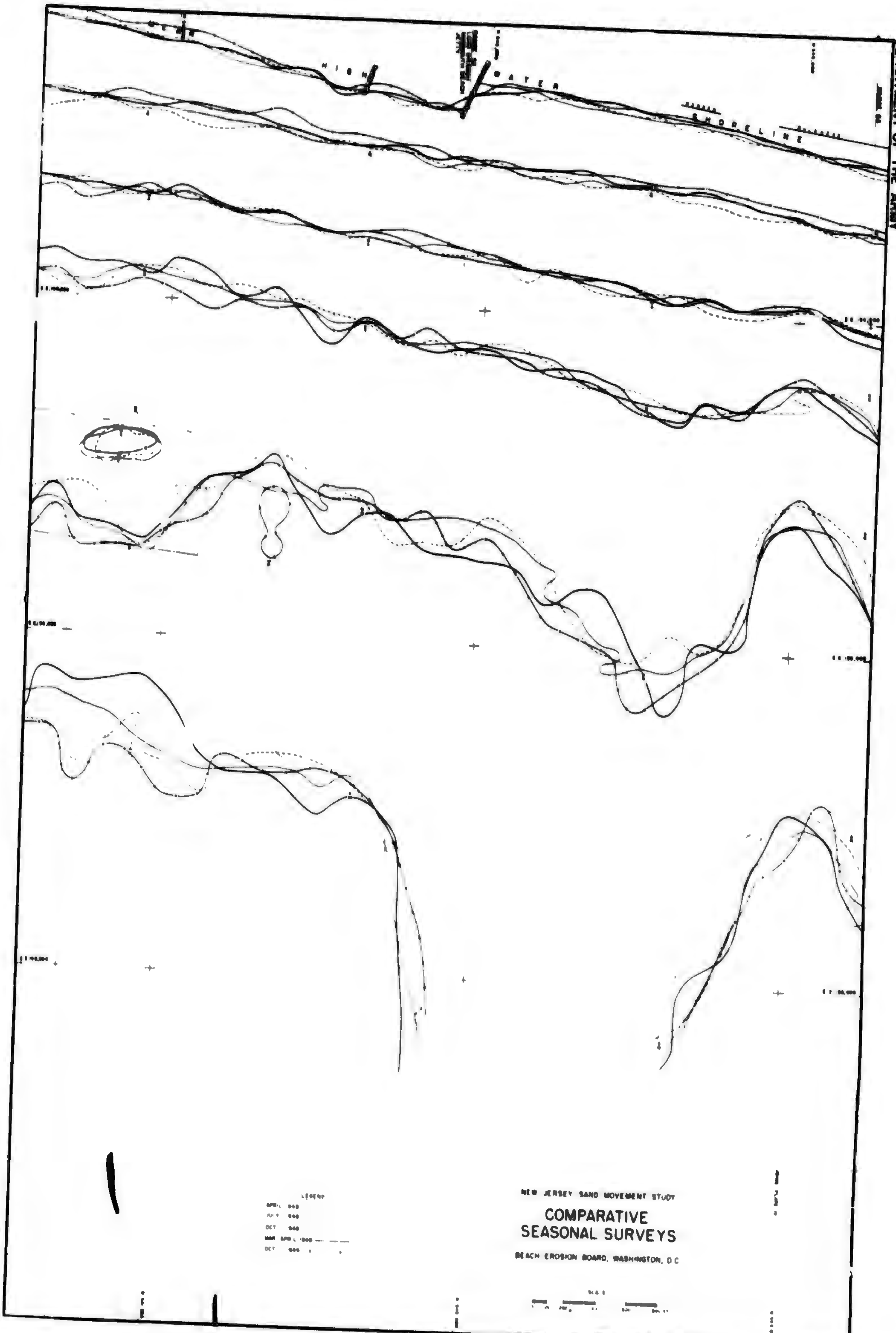

DEPARTMENT OF THE ARMY
HIGH WATER
SHORELINE
LEGEND
NEW JERSEY SAND MOVEMENT STUDY
COMPARATIVE
SEASONAL SURVEYS
BEACH EROSION BOARD, WASHINGTON, D.C.

PLATE V

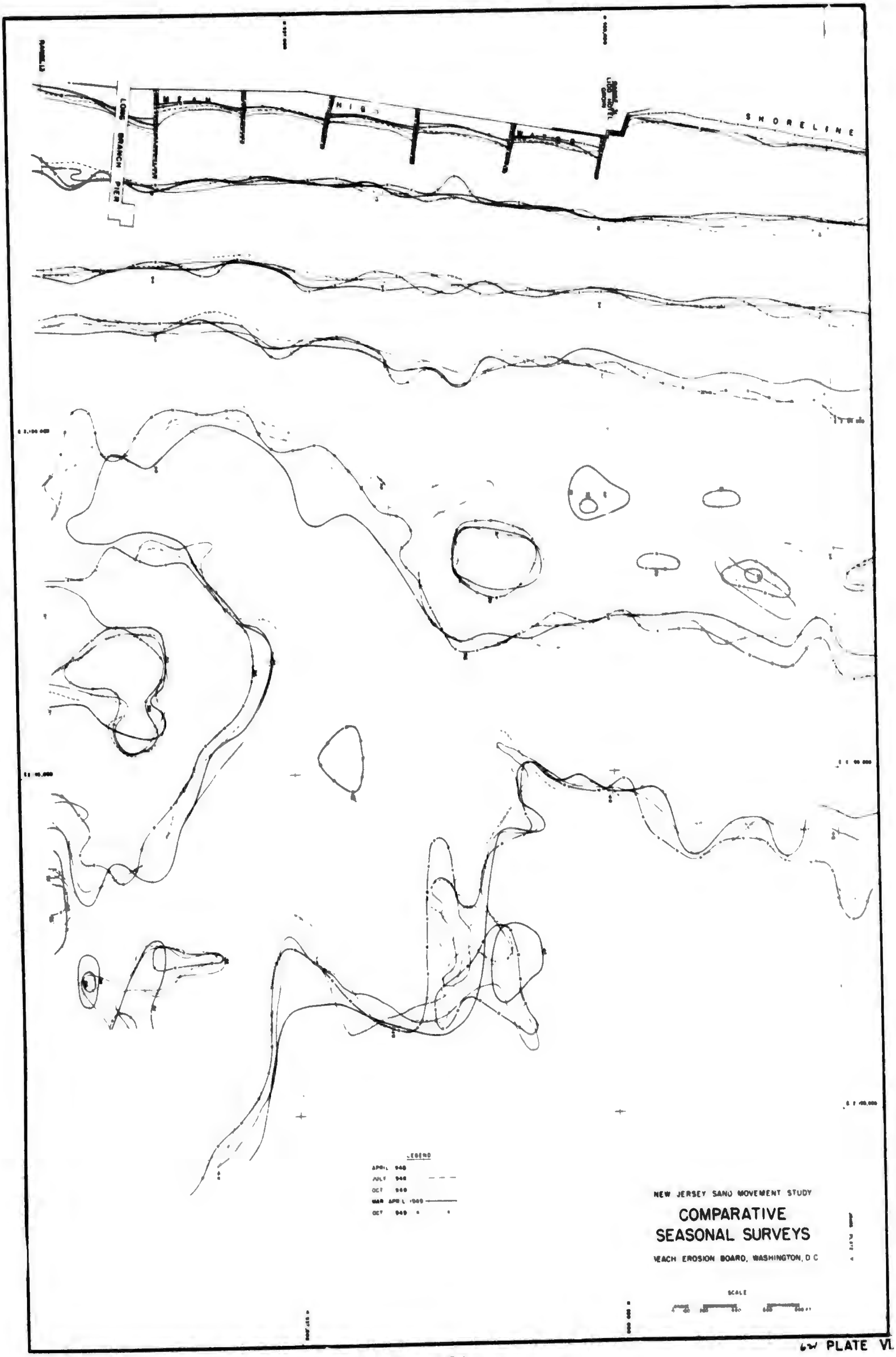

LONG BRANCH PIER
MEAN HIGH WATER
SHORELINE
LEGEND
SCALE
NEW JERSEY SAND MOVEMENT STUDY
COMPARATIVE
SEASONAL SURVEYS
BEACH EROSION BOARD, WASHINGTON, D C

PLATE VI

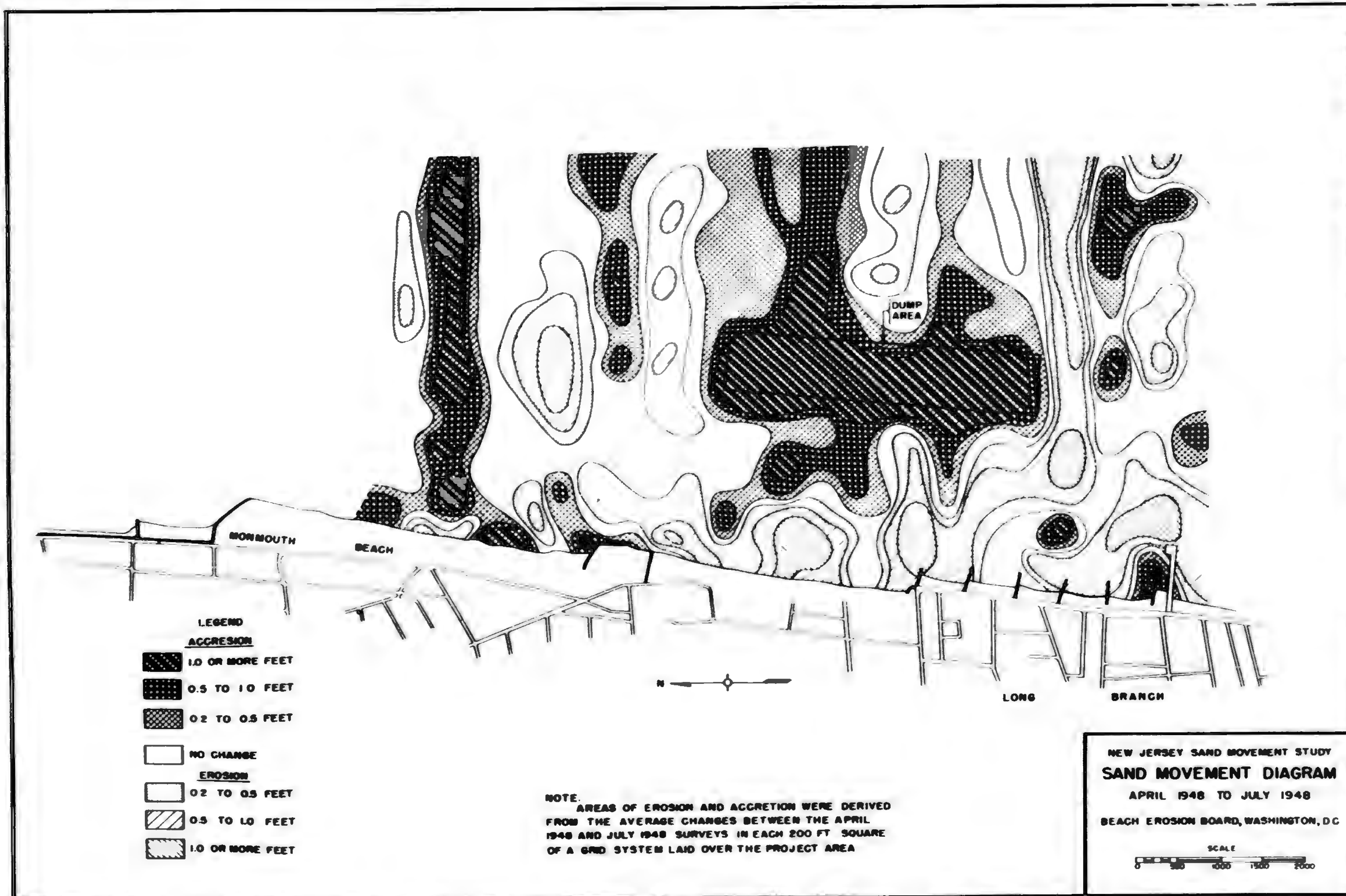

NEW JERSEY SAND MOVEMENT STUDY
SAND MOVEMENT DIAGRAM
APRIL 1948 TO JULY 1948
BEACH EROSION BOARD, WASHINGTON, D.C.
SCALE
0 500 1000 1500 2000
MONMOUTH
BEACH
LONG
BRANCH
DUMP AREA
N
LEGEND
ACCRESION
1.0 OR MORE FEET
0.5 TO 1.0 FEET
0.2 TO 0.5 FEET
NO CHANGE
EROSION
0.2 TO 0.5 FEET
0.5 TO 1.0 FEET
1.0 OR MORE FEET
NOTE.
AREAS OF EROSION AND ACCRETION WERE DERIVED FROM THE AVERAGE CHANGES BETWEEN THE APRIL 1948 AND JULY 1948 SURVEYS IN EACH 200 FT. SQUARE OF A GRID SYSTEM LAID OVER THE PROJECT AREA

PLATE VII

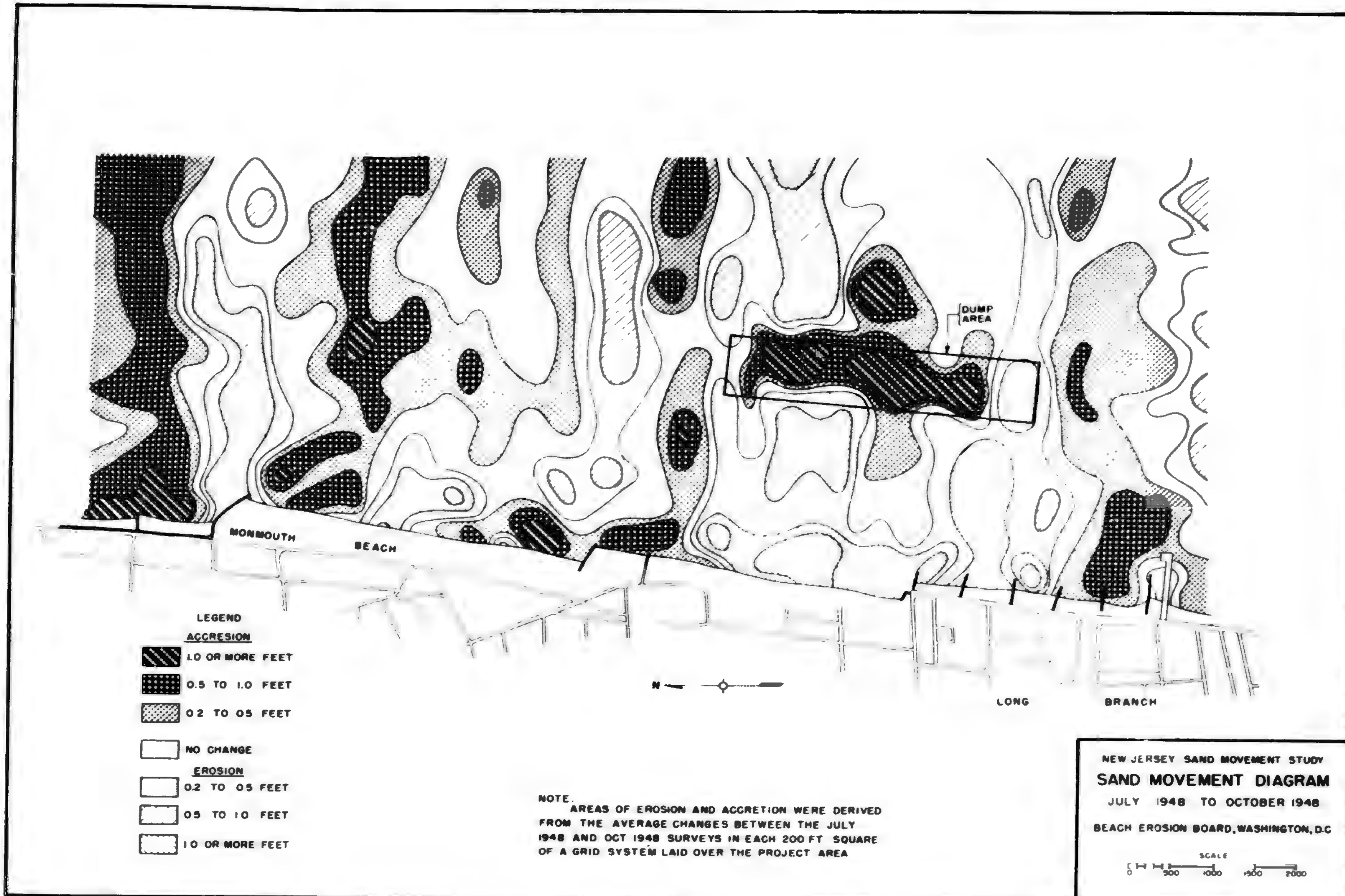

NEW JERSEY SAND MOVEMENT STUDY
SAND MOVEMENT DIAGRAM
JULY 1948 TO OCTOBER 1948
BEACH EROSION BOARD, WASHINGTON, D.C
SCALE
0 500 1000 1500 2000
DUMP AREA
MONMOUTH BEACH
LONG BRANCH
N
LEGEND
ACCRESION
1.0 OR MORE FEET
0.5 TO 1.0 FEET
0.2 TO 0.5 FEET
NO CHANGE
EROSION
0.2 TO 0.5 FEET
0.5 TO 1.0 FEET
1.0 OR MORE FEET
NOTE.
AREAS OF EROSION AND ACCRETION WERE DERIVED FROM THE AVERAGE CHANGES BETWEEN THE JULY 1948 AND OCT 1948 SURVEYS IN EACH 200 FT SQUARE OF A GRID SYSTEM LAID OVER THE PROJECT AREA

PLATE VIII

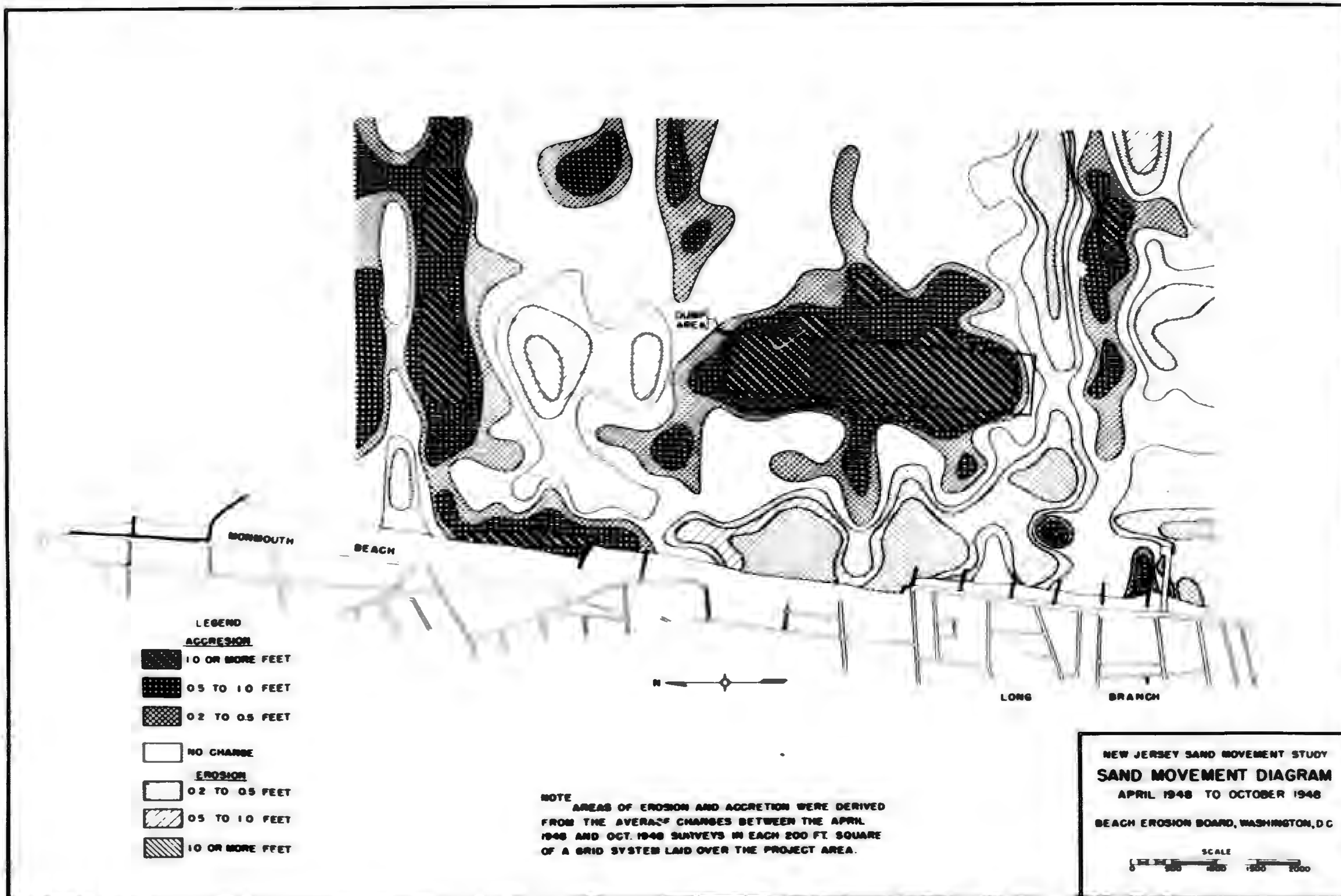
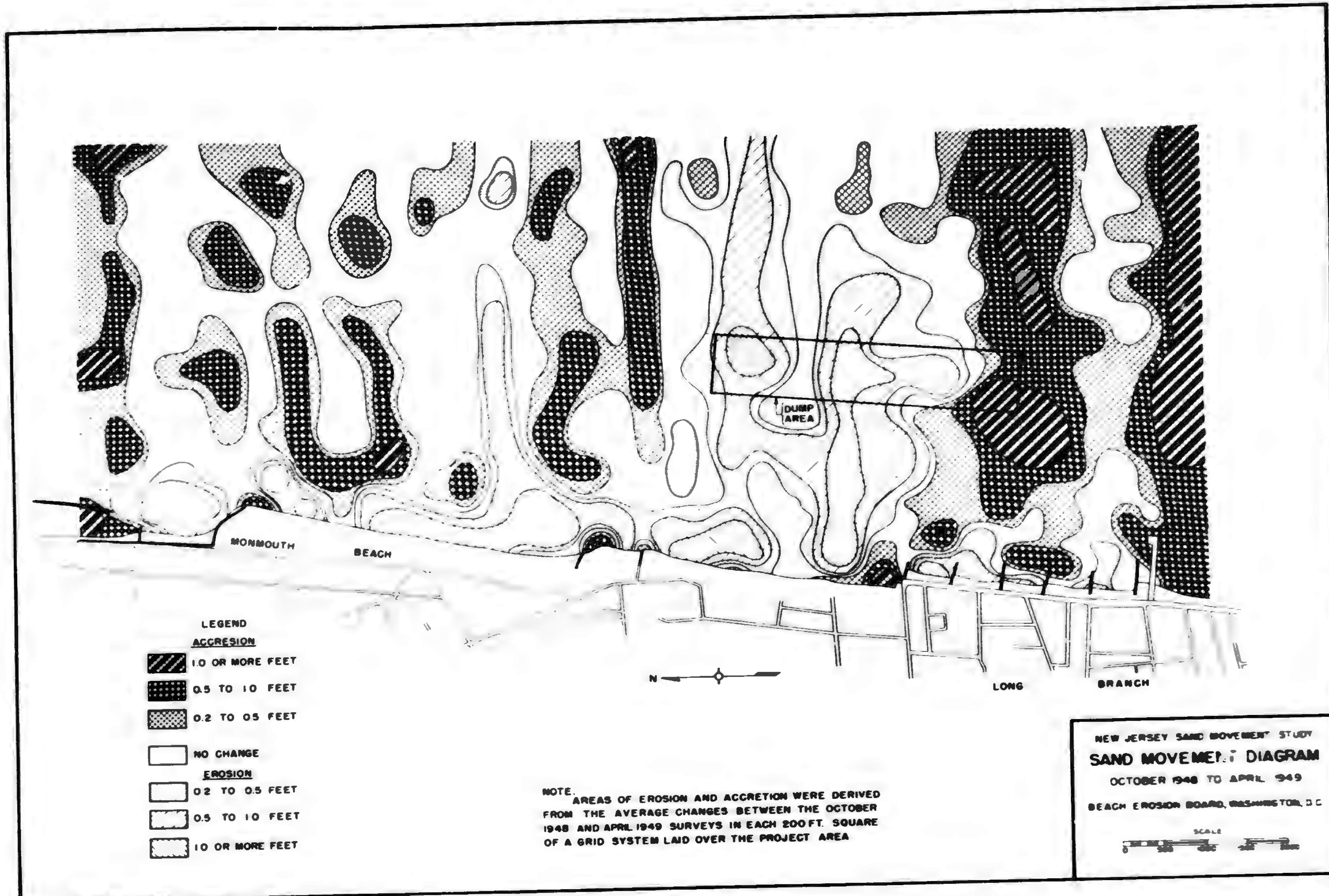

NEW JERSEY SAND MOVEMENT STUDY
SAND MOVEMENT DIAGRAM
APRIL 1948 TO OCTOBER 1948
BEACH EROSION BOARD, WASHINGTON, D.C.
SCALE
0 500 1000 1500 2000
MONMOUTH
BEACH
LONG
BRANCH
DUMP AREA
N
LEGEND
ACCRESION
1.0 OR MORE FEET
0.5 TO 1.0 FEET
0.2 TO 0.5 FEET
NO CHANGE
EROSION
0.2 TO 0.5 FEET
0.5 TO 1.0 FEET
1.0 OR MORE FEET
NOTE
AREAS OF EROSION AND ACCRETION WERE DERIVED FROM THE AVERAGE CHANGES BETWEEN THE APRIL 1948 AND OCT. 1948 SURVEYS IN EACH 200 FT. SQUARE OF A GRID SYSTEM LAID OVER THE PROJECT AREA.

PLATE IX



NEW JERSEY SAND MOVEMENT STUDY
SAND MOVEMENT DIAGRAM
OCTOBER 1948 TO APRIL 1949
BEACH EROSION BOARD, WASHINGTON, D.C.
SCALE
MONMOUTH BEACH
LONG BRANCH
DUMP AREA
N
LEGEND
ACCRESION
1.0 OR MORE FEET
0.5 TO 1.0 FEET
0.2 TO 0.5 FEET
NO CHANGE
EROSION
0.2 TO 0.5 FEET
0.5 TO 1.0 FEET
1.0 OR MORE FEET
NOTE. AREAS OF EROSION AND ACCRETION WERE DERIVED FROM THE AVERAGE CHANGES BETWEEN THE OCTOBER 1948 AND APRIL 1949 SURVEYS IN EACH 200 FT. SQUARE OF A GRID SYSTEM LAID OVER THE PROJECT AREA

PLATE X

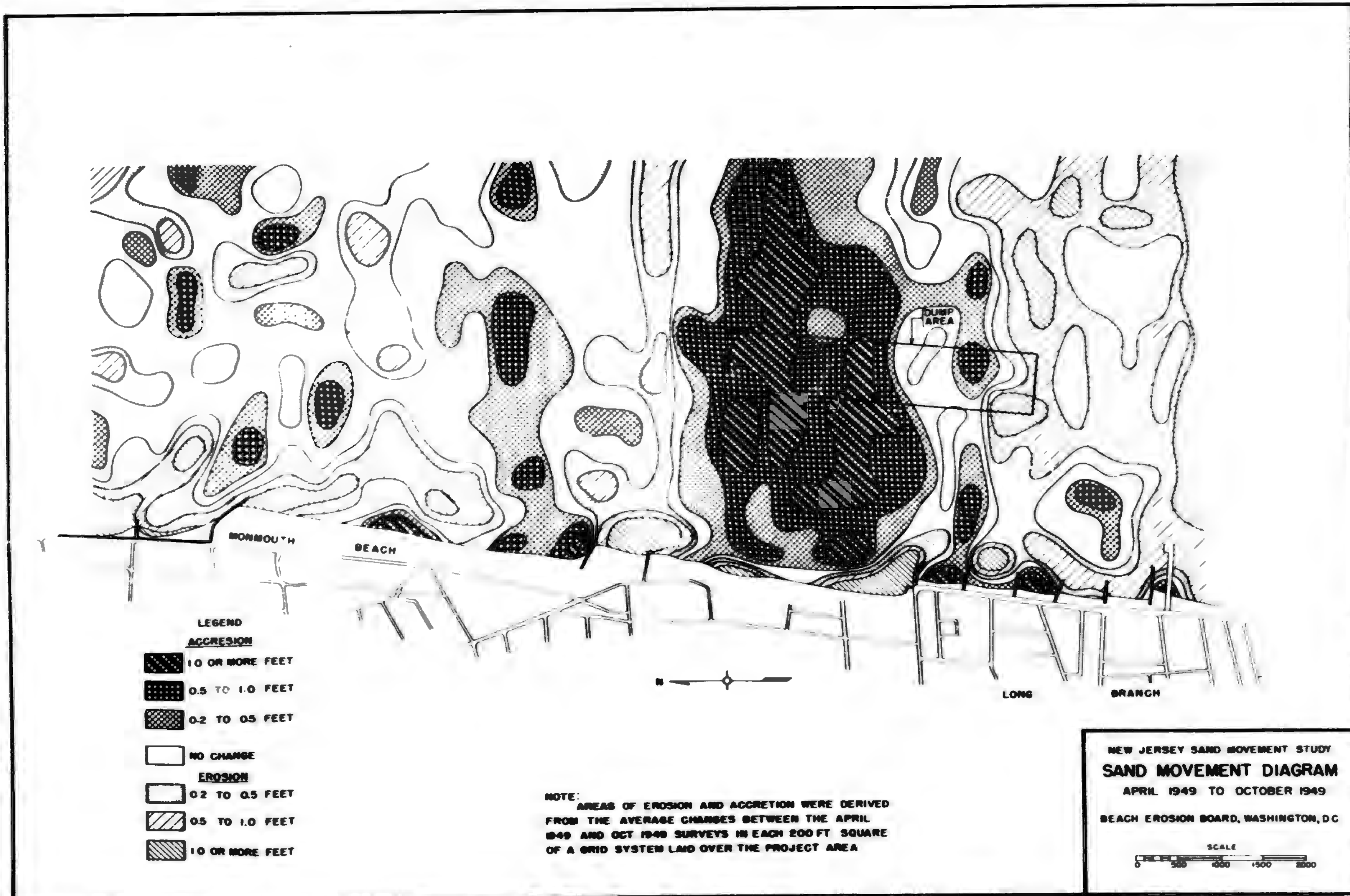

MONMOUTH
BEACH
LONG
BRANCH
DUMP AREA
N
LEGEND
ACCRESION
1.0 OR MORE FEET
0.5 TO 1.0 FEET
0.2 TO 0.5 FEET
NO CHANGE
EROSION
0.2 TO 0.5 FEET
0.5 TO 1.0 FEET
1.0 OR MORE FEET
NOTE:
AREAS OF EROSION AND ACCRETION WERE DERIVED FROM THE AVERAGE CHANGES BETWEEN THE APRIL 1949 AND OCT 1949 SURVEYS IN EACH 200 FT SQUARE OF A GRID SYSTEM LAID OVER THE PROJECT AREA
NEW JERSEY SAND MOVEMENT STUDY
SAND MOVEMENT DIAGRAM
APRIL 1949 TO OCTOBER 1949
BEACH EROSION BOARD, WASHINGTON, D.C.
SCALE
0 500 1000 1500 2000

PLATE XI

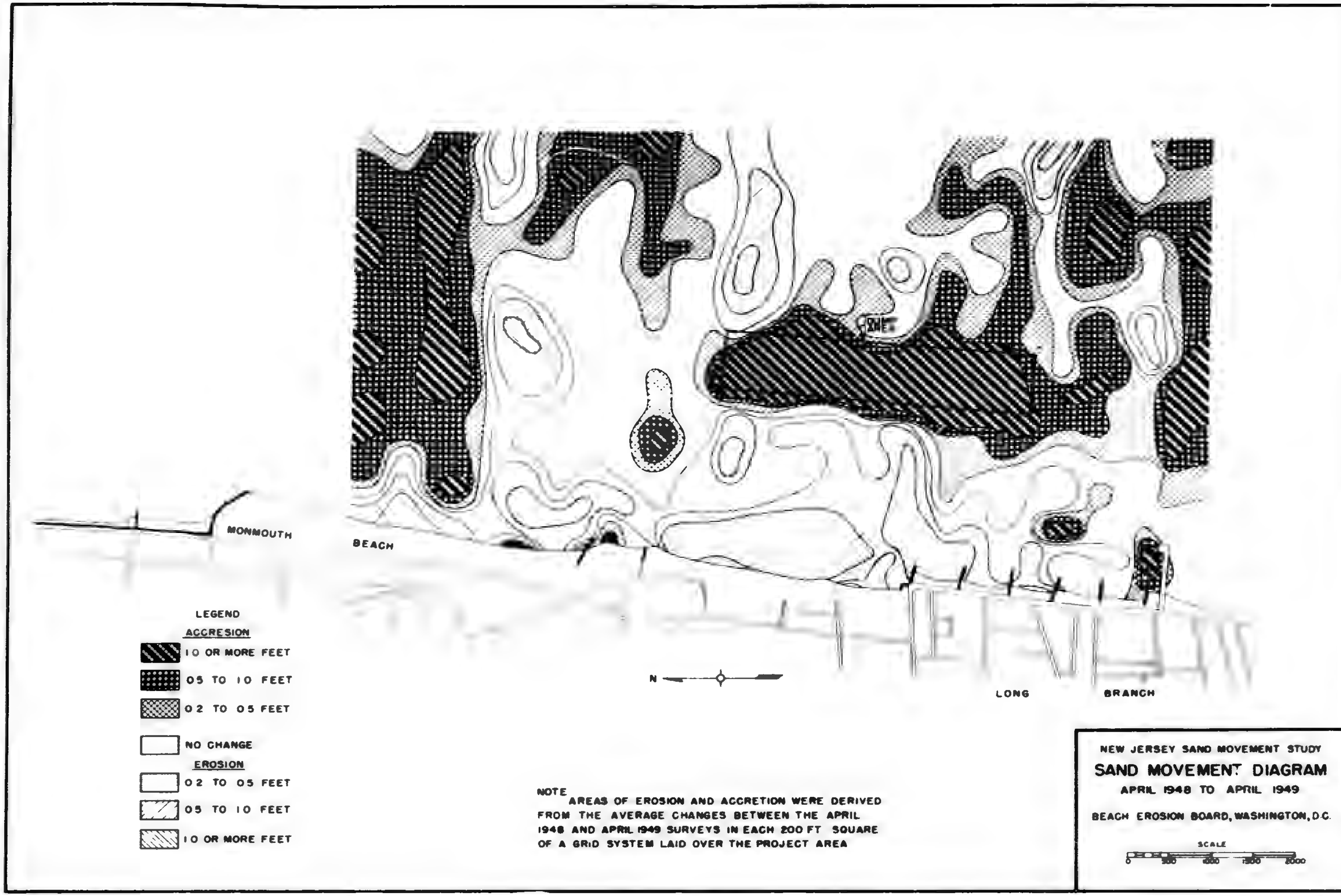

MONMOUTH
BEACH
LONG
BRANCH
N
LEGEND
ACCRESION
1.0 OR MORE FEET
0.5 TO 1.0 FEET
0.2 TO 0.5 FEET
NO CHANGE
EROSION
0.2 TO 0.5 FEET
0.5 TO 1.0 FEET
1.0 OR MORE FEET
NOTE
AREAS OF EROSION AND ACCRETION WERE DERIVED FROM THE AVERAGE CHANGES BETWEEN THE APRIL 1948 AND APRIL 1949 SURVEYS IN EACH 200 FT SQUARE OF A GRID SYSTEM LAID OVER THE PROJECT AREA
NEW JERSEY SAND MOVEMENT STUDY
SAND MOVEMENT DIAGRAM
APRIL 1948 TO APRIL 1949
BEACH EROSION BOARD, WASHINGTON, D.C.
SCALE
0
500
1000
1500
2000

PLATE XII

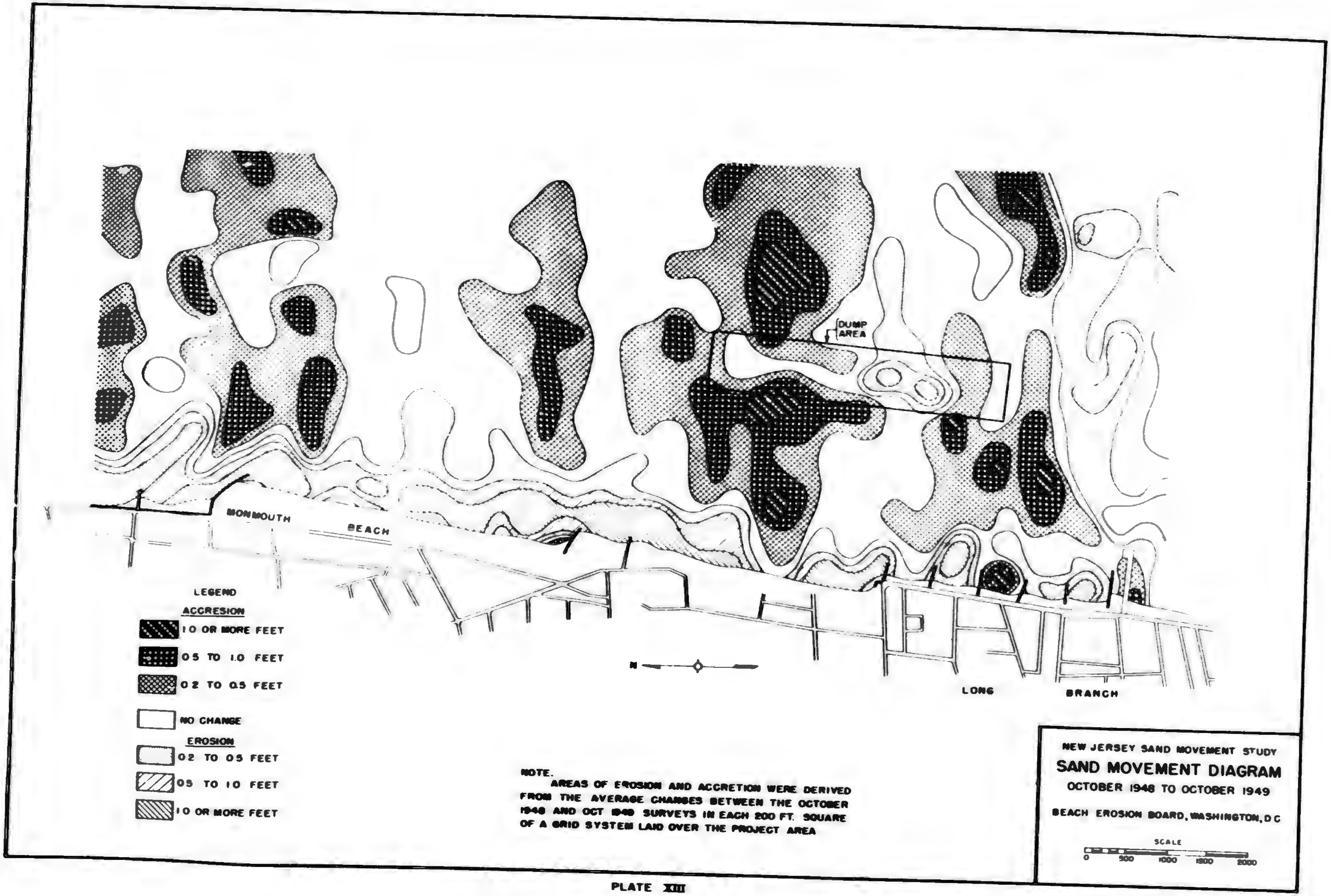

MONMOUTH
BEACH
LONG
BRANCH
DUMP AREA
N
LEGEND
ACCRESION
1.0 OR MORE FEET
0.5 TO 1.0 FEET
0.2 TO 0.5 FEET
NO CHANGE
EROSION
0.2 TO 0.5 FEET
0.5 TO 1.0 FEET
1.0 OR MORE FEET
NOTE.
AREAS OF EROSION AND ACCRETION WERE DERIVED FROM THE AVERAGE CHANGES BETWEEN THE OCTOBER 1948 AND OCT 1949 SURVEYS IN EACH 200 FT. SQUARE OF A GRID SYSTEM LAID OVER THE PROJECT AREA
NEW JERSEY SAND MOVEMENT STUDY
SAND MOVEMENT DIAGRAM
OCTOBER 1948 TO OCTOBER 1949
BEACH EROSION BOARD, WASHINGTON, D.C.
SCALE
0 500 1000 1500 2000

PLATE XIII

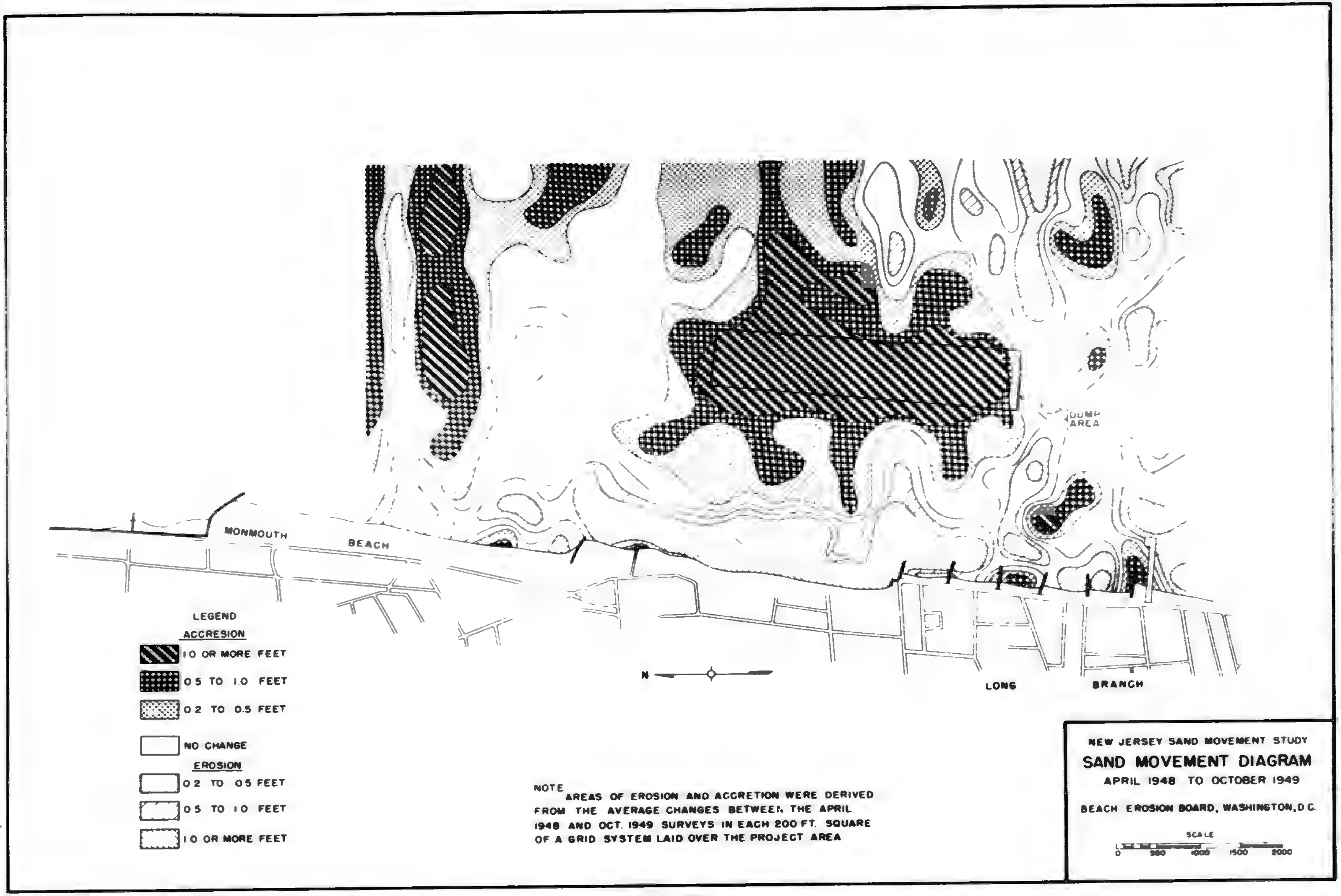

MONMOUTH
BEACH
DUMP AREA
LONG
BRANCH
N
LEGEND
ACCRESION
1.0 OR MORE FEET
0.5 TO 1.0 FEET
0.2 TO 0.5 FEET
NO CHANGE
EROSION
0.2 TO 0.5 FEET
0.5 TO 1.0 FEET
1.0 OR MORE FEET
NOTE
AREAS OF EROSION AND ACCRETION WERE DERIVED FROM THE AVERAGE CHANGES BETWEEN THE APRIL 1948 AND OCT. 1949 SURVEYS IN EACH 200 FT. SQUARE OF A GRID SYSTEM LAID OVER THE PROJECT AREA
NEW JERSEY SAND MOVEMENT STUDY
SAND MOVEMENT DIAGRAM
APRIL 1948 TO OCTOBER 1949
BEACH EROSION BOARD, WASHINGTON, D.C.
SCALE
0 500 1000 1500 2000

PLATE XIV