DEPARTMENT OF THE ARMY CORPS OF ENGINEERS

BEACH EROSION BOARD
OFFICE OF THE CHIEF OF ENGINEERS

ARTIFICIALLY NOURISHED AND CONSTRUCTED BEACHES

TECHNICAL MEMORANDUM NO. 29

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CORPS OF ENGINEERS

DECEMBER 1952

FOREWARD

This paper was prepared by Mr. Jay V. Hall, Jr., Chief of the Engineering Division of the Beach Erosion Board, and was originally given at the Third Conference on Coastal Engineering held at the Massachusetts Institute of Technology in October 1952.

The presentation and discussion of pertinent criteria for design of artificially nourished beaches are considered to be of sufficient value and general interest to merit publication as a Technical Memorandum. The opinions and conclusions of the author are not necessarily those of the Beach Erosion Board.

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The authority for publication of this report was granted by an Act for the improvement and protection of beaches along the shores of the United States, Public Law No. 166, 79th Congress, approved 31 July 1945.

ARTIFICIALLY NOURISHED AND CONSTRUCTED BEACHES

Jay V. Hall, Jr.
Chief, Engineering Division, Beach Erosion Board
Department of the Army, Washington, D. C.

INTRODUCTION

Construction, improvement and maintenance of beaches through the artificial deposition of sand on the shore is rapidly gaining prominence in the field of shore protection engineering. The trend toward this type of shore improvement has resulted from our changing economy, modes of transportation and recreational habits. As our mode of transportation improved and people had more time for recreation, beach resorts developed and grew to proportions typified by Atlantic City, New Jersey. Numerous factors control the growth of a resort of this size but undoubtedly all will agree that it is the beach which is the resorts' primary asset. This fact was recognized very early in resort development and every effort was made to preserve the beaches from the ravages of the sea. Unfortunately the science of shore protection lagged behind resort development and beaches soon became covered with a maze of structures which discouraged rather than encouraged their use. At this point something had to be done to restore the beaches to their original attractiveness. The obvious means for this improvement was to eliminate all structures as far as possible and to replace the beach material which had been removed. Careful study convinced a number of engineers that beach restoration employing artificial nourishment had possibilities and in some instances might be the most economical as well as best method of improvement. More importantly, there has developed a growing recognition of the fact that preventing erosion by means of protective structures is a dangerous practice, in the sense that in many cases such protection is secured at the expense of producing an ever expanding problem area. Artificial nourishment, on the other hand, benefits not only the shore upon which it is placed but adjoining shores as well. The economic merit of this type of treatment has often been difficult to evaluate because of uncertainties in prospective maintenance cost and in determination of the extent of shore which would be benefited. It is needless to say here that although the method has been employed without a complete understanding of all the factors controlling an ideal installation the results have been gratifying.

It is the purpose of this paper; first, to outline the criteria pertinent to the design of artificially nourished beaches and explain how each is derived and used; second, to present a brief history of five areas where the four types of artificial nourishment have been tried; namely the offshore dumping method, the stockpiling method, the continuous supply method, and the direct placement method; and third, to present a tabular record of a great number of artificially nourished and constructed beaches including factors relating to their placement and economic life.

DESIGN CRITERIA

At the present time although the design of artificially nourished and constructed beaches has not been firmly established on a scientific basis, advances have been made in the field of wave motion and the effect waves have on the shore which have established it on better than a rule of thumb basis. In the following paragraphs criteria for the design of artificially nourished and constructed beaches will be enumerated and their derivation and use will be explained.

The first task in approaching a design problem of this nature is to determine quantitatively the deficiency in material supply in the problem area. This is the rate of loss of beach material and is the rate at which the material supply must be increased to balance the transport capacity of littoral forces so that no net loss will occur. If there is no natural supply available, as may be the case on shores down drift from a major littoral barrier, the deficiency in supply will be equal to the full rate of littoral drift. If the problem area is part of a continuous and unobstructed sandy beach, it is likely that the deficiency will be relatively small compared with the drift rate. Comparison of surveys over a long period of time is the only accurate means of determining the rate of nourishment required to maintain stability of the shore. Since surveys in suitable detail for volumetric measurement are rarely available at problem areas, approximations computed from changes in the shore position determined by air photo or any other suitable records are often necessary. For such approximations a rule of thumb equation wherein one square foot of surface area equals one cubic yard of beach material appears to provide acceptable values on exposed seacoasts. For less exposed shores this ratio would probably result in volumetric estimates somewhat in excess of the true figure and would thus produce conservative values.

The next and equally important task is the determination of the predominant direction of littoral drift. This is most generally determined by studying the shore configuration at groins, jetties or other littoral barriers. The major accumulation of littoral material occurs on the updrift side of such barriers, however, in the case of minor barriers such as short groins, seasonal variability or storm effects may obliterate the predominant trend. Care must be taken to avoid misinterpretation in such cases. Seasonal trends should be determined and evaluated where doubt exists on the basis of available evidence.

Unfortunately, or maybe fortunately, the engineer has not covered each sector of our entire shore line with structures whereby this determination of the rate of drift can be made. In the event that structures are not available on a sandy beach, or an area is to be improved that is devoid of littoral materials, another method of determining these factors must be employed. A rather long laborious method is available for use, which indicates the direction of the predominant littoral forces quite accurately, but indicates only the relative strength of the littoral forces along selected stretches of the shore.

This method of procedure involves the use of the techniques of hindcasting wave data from synoptic weather charts to determine the wave climate over a period of years in a given area; the use of refraction diagrams to bring this wave budget into shallow water; and the use of vector diagrams to determine the resultant direction and magnitude of the wave energy which establishes the predominant direction and relative strength of the littoral movement. The predominant direction of the littoral drift is considered to coincide with the direction of the resultant of the flow of wave energy, and the relation between the strength of the littoral movement is determined to be the longshore component of the wave energy acting along its established direction toward the beach. In view of the lack of knowledge of the characteristics of the boundary conditions imposed by the surf zone it is not possible at the present time to actually relate the longshore component of the wave energy to a quantitative determination of littoral drift. In other words only the relative strengths of the littoral forces in the various related locations along a stretch of beach under study should be used.

Having established the direction and magnitude of the forces that will operate on a proposed fill the next problem to be encountered is that of selecting a suitable beach material. Unfortunately adequate criteria have not been established for evaluating the qualities of beach materials. However, a limited amount of information pertaining to the sorting of beach sands and the relation of grain size to beach slope are of value in selecting materials for artificial nourishment. When sand is deposited on a shore the waves operating in the area immediately start a sorting action on the surface layer of the fill moving the finer particles seaward, leaving the coarser material shoreward of the plunge point. This sorting action continues until a layer of coarse particles compatible with the wave spectrum of the area armors the beach and renders it relatively stable. However, if the armor is broken due to a storm, the underlying material is again subjected to the sorting process. In view of this sorting process beach materials containing clay lenses or discolored particles may be used with the assurance that natural processes will clean the sand and make it an entirely suitable material for nourishment. Experience with the fills at Anaheim Bay, California, and Palm Beach, Florida, both of which contained foreign matter confirm this statement.

During the period of sorting, the beach slope is also adjusted until it becomes compatible with the grain size distribution of the sorted material. In view of this fact, a desired beach slope may be obtained by randomly placing material of a gradation that will assume the desired slope after sorting and slope adjustment. The selection of a material of the proper gradation to produce the desired slope as far as is known at the present time can only be determined by analyzing the sand taken from a beach in the surrounding area which has a similar orientation and is acted upon by the same wave forces. Sand selected for artificial nourishment should ideally contain the same gradation of materials as those found on the beach to be nourished if the original beach slope is to be maintained.

Material of coarser characteristics may be expected to produce a steeper than normal beach. Material finer than that occupying the natural beach will, when exposed on the surface, move seaward to a depth compatible with its size. Almost any source of borrow near the shore will produce some material of proper beach size. Since the source of artificial nourishment will control the cost to a major degree, evaluation of material characteristics is an important factor in economic design. At present such evaluation must be made largely on a basis of experience at other localities.

The beach crest height will be established ultimately by natural forces, that is, the cyclic changes in water level and the wave pattern. The foreshore and nearshore slopes will affect wave behavior and thus influence the natural beach crest height. If the beach fill is placed to an elevation lower than the natural crest height a ridge will subsequently develop along the crest. Concurrent high water stage and high waves will overtop the crest and cause ponding and temporary flooding of the backshore. Such flooding, if undesirable, may be avoided by fixing the berm height slightly above the natural beach crest height. If there is an existing beach at the site, the natural crest height can be determined therefrom. Otherwise determination must be made on a basis of comparison with other sites possessing similar exposure characteristics and beach material. There is at present no acceptable theoretical basis for predicting beach crest height.

Criteria for specifying berm width depends upon a number of factors. If the purpose of the fill is to restore an eroded beach damaged by a major storm, where inadequate natural nourishment is not a factor in the problem, the width may be determined by the protective width which experience has demonstrated to be required. Where the beach fill is to serve as a stockpile, the berm width should be sufficient to provide for expected recession during the intervals between artificial replenishment. It is generally considered that the toe of fill of a stockpile beach should not extend to such depth that transport of any material forming the surface of the fill would be retarded. There are no firm specifications I this limiting depth at present but available data indicate, that depths of twenty feet below low water datum on seacoasts and twelve feet on the Great Lakes may be used safely. It is obvious that the initial slope of any beach fill must be steeper than that of the natural shore area upon which it is placed. Subsequent behavior of the slope depends principally upon the characteristics of the fill material. Fills composed of material coarser than that found on the native beach will maintain a steeper than normal slope. Finer material tends to form a flatter slope. In ordinary practice the initial fill slope is designed parallel to the local or comparable natural beach slope above low water datum, and slopes of 1:20 to 1:30 from low water datum to intersection with the existing bottom.

It is unnecessary to artificially grade beach slopes below the berm crest for they will be naturally shaped by wave action.

The length of a stockpile beach may vary greatly depending upon local conditions. Lengths from a few hundred feet to a mile have been employed successfully. Since the updrift end of a stockpile beach will be depleted first, long stockpiles are usually most suitable where a bulkhead or seawall exists to protect the backshore as erosion progresses along the stockpile.

The foregoing general discussion of the derivation and use of the basic criteria pertaining to the artificial placement of sand to maintain, rehabilitate or construct a beach clearly indicates the lack of the present knowledge and consequently presents a challange to investigators to direct their work toward this phase of shore protection work. The principal factors which appear to warrant detailed study in order to establish more rigorous design criteria are the relations between the characteristics of beach and nearshore materials and their modes of transport; the relations between beach materials, exposure, and the resulting geometry of naturally formed beaches; and more accurate methods of determining the deficiency in material supply on an eroding beach. In the present state of knowledge laboratory experimentation may be expected to contribute only to a limited degree to the solution of these problems. It is believed that emphasis must be placed on field investigation for this purpose, particularly in the form of follow-up studies of artificial beach fills.

TYPES OF ARTIFICIALLY NOURISHED AND CONSTRUCTED BEACHES

OFFSHORE DEPOSIT METHOD

This method of beach nourishment is constantly coming to the mind of the shore protection engineer since a large supply of beach material could be made available at comparatively low cost in connection with hopper dredge operations in coastal harbors.

A test of this type of nourishment was made in 1948 and 1949 by the Beach Erosion Board and the New York District, Corps of Engineers, Department of the Army at Long Branch, New Jersey (reference 1). The city of Long Branch is located near the northern tip of New Jersey adjacent to the entrance to New York harbor. (Figure 1) 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 retaining Ocean Avenue. The beach fronting the bulkhead is relatively steep and narrow and is intersected by numerous heavy rubble mound groins.

The history of the Long Branch area has been one of progressive erosion caused by the stabilization of updrift areas which formerly eroded and supplied abundant littoral material to down drift areas.

The purpose of this test was to determine the feasibility of restoring an adequate littoral drift to nourish the shore by employing natural forces to move material, dumped in relatively deep water, shoreward toward the beach.

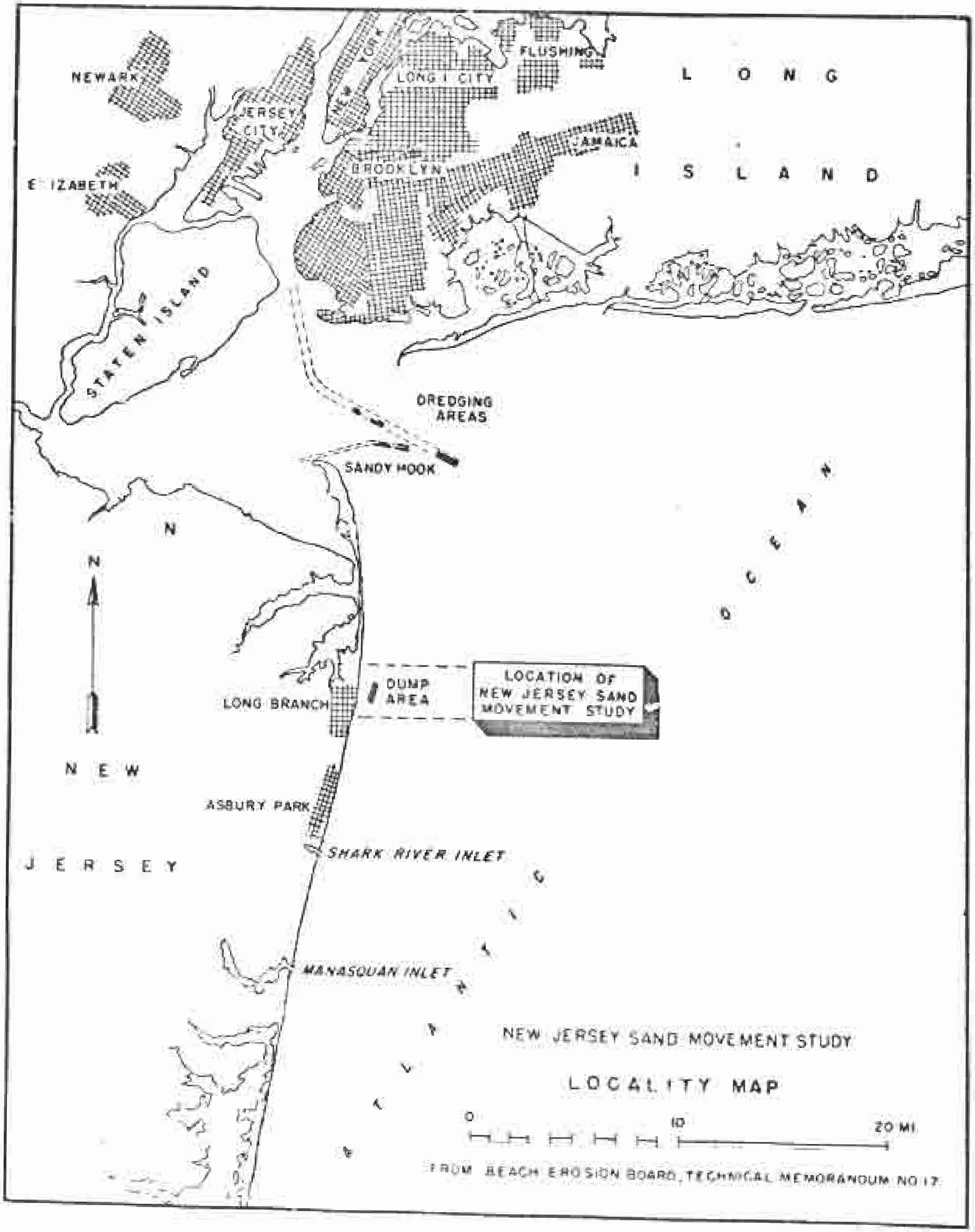
NEWARK
JERSEY CITY
NEW YORK
LONG I. CITY
FLUSHING
L O N G
BROOKLYN
JAMAICA
I S L A N D
ELIZABETH
STATEN ISLAND
DREDGING AREAS
SANDY HOOK
N
O C E A N
N
LOCATION OF NEW JERSEY SAND MOVEMENT STUDY
DUMP AREA
LONG BRANCH
N E W
ASBURY PARK
SHARK RIVER INLET
J E R S E Y
MANASQUAN INLET
A T L A N T I C
NEW JERSEY SAND MOVEMENT STUDY
LOCALITY MAP
0
10
20 MI.
FROM BEACH EROSION BOARD, TECHNICAL MEMORANDUM NO. 17

FIG. I

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 a depth of 38 feet below mean low water, with its southerly limit on an east west line about 1500 feet north of the Long Branch Pier. Dumping at the site amounted to a total of 602,000 cubic yards of sand. (Figure 1)

During the entire period of study, oceanographic forces effecting sand movement were recorded and the sand movement was traced by periodic hydrographic surveys covering the area from the Long Branch Fishing Pier northward to Monmouth Beach Coast Guard Station and from the bulkhead line seaward 6,000 feet to about the 42 foot de[illegible]ntour (mean low water). An effort to trace sand movement through dissimilar minerals in the beach and dumped sand failed. At this point one may question the suitability of the Long Branch site for a study of this nature. Oceanographic and hydrographic data collected at the site proved its suitability since natural forces were found which were capable of moving material over the ocean floor in 35 to 40 feet of water and along the beach.

The result of the sand movement during the period October 1948 after all dumping had been completed to October 1949 are depicted by net bottom changes and are shown on Figure II. The bottom changes show accretion to be general over the offshore area including the mound. An area of localized erosion developed near the center of the mound and erosion occurred over the shoal at the southern limit of the study area. 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, during the period of observation, has not benefited the beach. While observations over a longer period may indicate some benefit, it may be concluded from present evidence that this method will not provide nourishment at a suitable rate to justify its general use.

The conclusions reached in this study confirm the findings of two similar studies, one made at Santa Barbara, California where 202,000 cubic yards of sand were deposited in 20 feet of water (mean lower low water) in September 1935, and the other at Atlantic City, New Jersey where 3,554,000 cubic yards of sand were deposited off the beach in 18 to 20 feet of water (mean low water) during the period April 1935 - September 1943.

Although the results of this test to artificially nourish the beach at Long Branch, New Jersey, were negative, it is felt that they have a place in this paper to guide future work along these lines.

STOCKPILE METHOD

Probably the first shore protection project designed specifically for employment of this method was that developed at Santa Barbara, California (Figure III). This project has been in successful operation

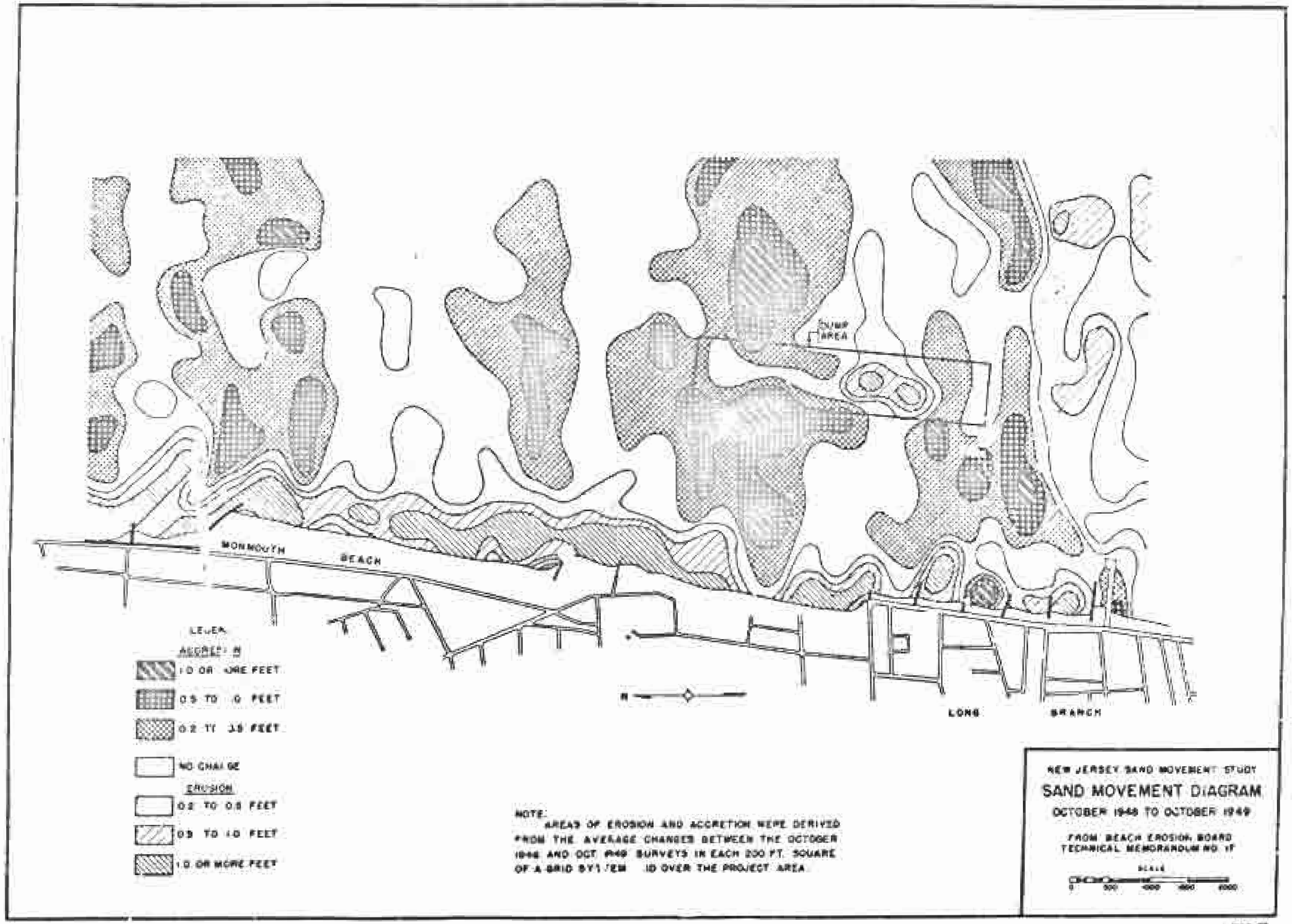
MONMOUTH
BEACH
DUMP AREA
LONG
BRANCH
N
LEGEND
ACCRETION
1.0 OR MORE FEET
0.5 TO 1.0 FEET
0.2 TO 0.5 FEET
NO CHANGE
EROSION
0.2 TO 0.5 FEET
0.5 TO 1.0 FEET
1.0 OR MORE FEET
NOTE:
AREAS OF EROSION AND ACCRETION WERE DERIVED FROM THE AVERAGE CHANGES BETWEEN THE OCTOBER 1948 AND OCT. 1949 SURVEYS IN EACH 200 FT. SQUARE OF A GRID SYSTEM ... OVER THE PROJECT AREA.
NEW JERSEY SAND MOVEMENT STUDY
SAND MOVEMENT DIAGRAM
OCTOBER 1948 TO OCTOBER 1949
FROM BEACH EROSION BOARD
TECHNICAL MEMORANDUM NO. 17
SCALE
0
500

FIG II

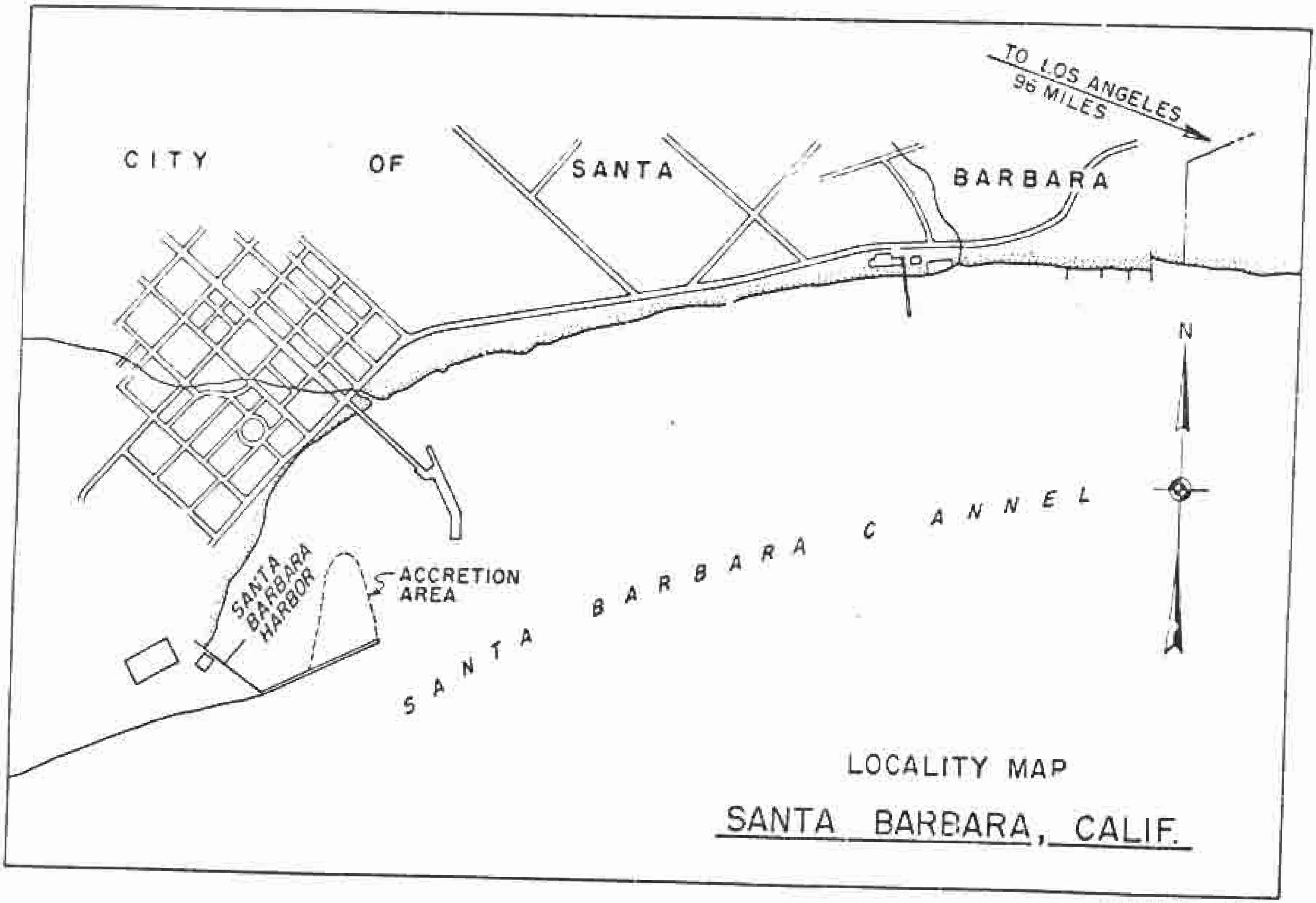
TO LOS ANGELES
96 MILES
CITY OF SANTA BARBARA
N
SANTA BARBARA HARBOR
ACCRETION AREA
SANTA BARBARA CHANNEL
LOCALITY MAP
SANTA BARBARA, CALIF.

FIGURE III

since 1938. Details of the plan are contained in references 2 and 3 and only a summary will be presented herein.

The problem at Santa Barbara was created by construction of a breakwater, completed in 1929, which effectively blocked the movement of littoral drift. Material accumulated on the updrift side of the breakwater at a rate in the order of 300,000 cubic yards a year. By 1934 the impounding capacity above the breakwater was reached, and the zone of entrapment shifted to the protected waters within the harbor.

Meanwhile beaches downdrift from the harbor, being deprived of normal nourishment, were progressively eroding. By 1938 the erosion area had denuded the down drift beaches for a distance of ten miles, to a location where a large natural sand deposit served to maintain shores beyond. Offshore deposit of sand removed from the harbor by hopper dredge in 1935, described earlier, failed to aid the shore. Damages mounted and hastily built shore protection structures provided little relief.

In 1938 a cooperative project was developed on recommendation of the Beach Erosion Board providing for establishing a stockpile beach fill along 4000 feet of shore down drift from the harbor, to be initially filled and periodically maintained with material dredged from the harbor. The first fill was completed in July 1938 and replenishment has been accomplished at two or three year intervals since that date. The seventh repetitive nourishment operation is in progress at this time. (October 1952).

By 1945, seven years after initiation of the project, stable conditions had been restored over the entire ten miles of previously eroding beach. No additional shore protection measures have been required since that date. The average rate of artificial nourishment in round figures, has been 300,000 cubic yards a year. The average cost is 21 cents a cubic yard. Harbor maintenance as well as shore protection is accomplished and under the terms of the project the United States pays the cost of the former by the cheapest method (hopper dredging) at an established price of cents a cubic yard. The work is accomplished with conventional pipe line dredging plant and equipment. Local interests contribute the added cost of depositing the material on the stockpile beach, an average of 8 cents a cubic yard or $24,000 a year. Considering the length of frontage receiving protection in this project, the average annual cost is about 50 cents a linear foot. This is a minor fraction of the cost experienced where defensive works are employed for shore protection.

A more recent example of stockpiling sand on a beach to be distributed along the down drift shore by the natural forces is the project undertaken several years ago at Palm Beach, Florida.

Palm Beach is located on the coastal lowlands of the east coast of Florida about 300 miles south of Jacksonville and 70 miles north of Miami Beach. (Figure IV) The barrier beach on which the town has been

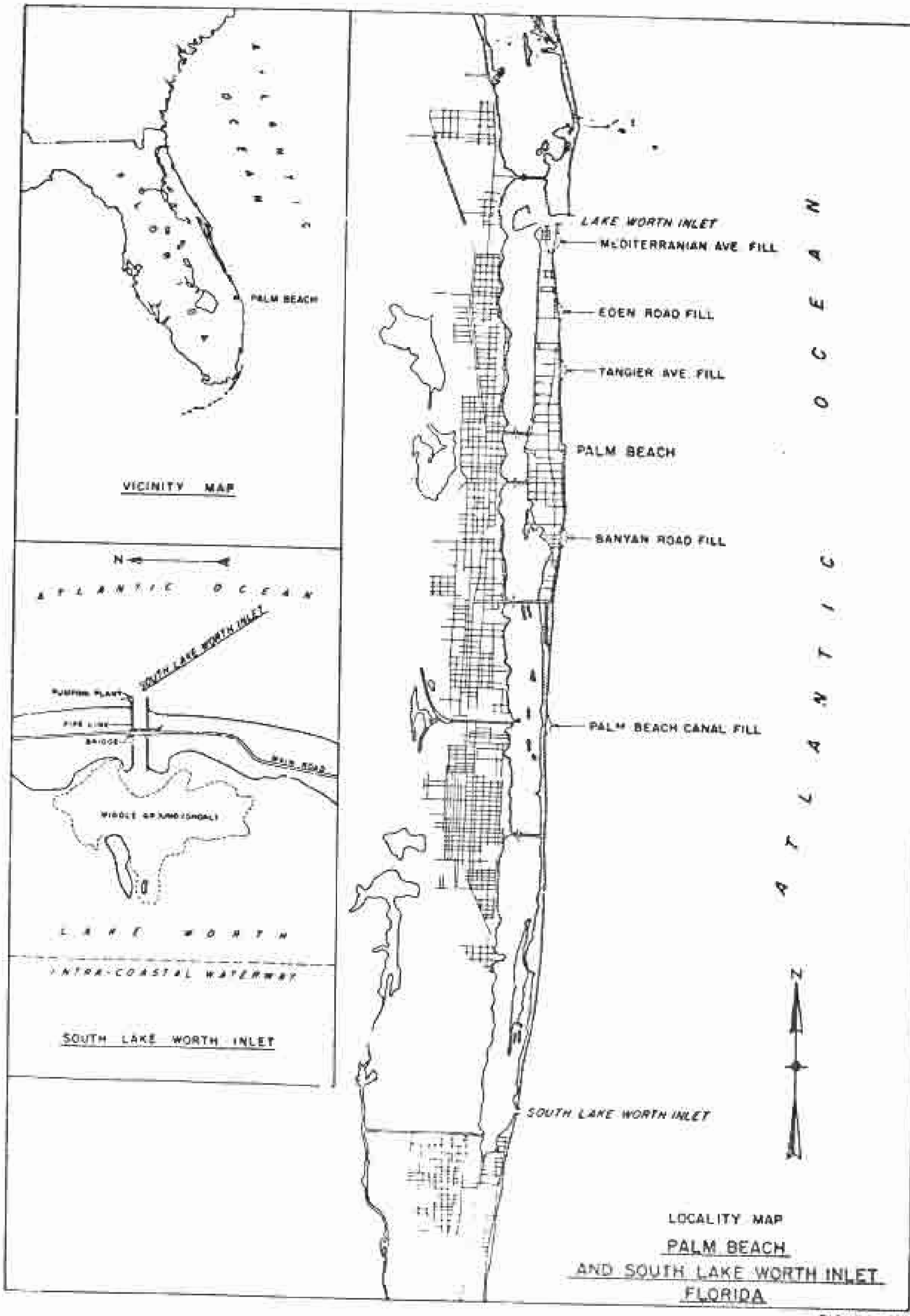
PALM BEACH
VICINITY MAP
N
ATLANTIC OCEAN
SOUTH LAKE WORTH INLET
PUMPING PLANT
PIPE LINE
BRIDGE
MAIN ROAD
MIDDLE GROUND (SHOAL)
LAKE WORTH
INTRA-COASTAL WATERWAY
SOUTH LAKE WORTH INLET
LAKE WORTH INLET
MEDITERRANIAN AVE. FILL
EDEN ROAD FILL
TANGIER AVE. FILL
PALM BEACH
BANYAN ROAD FILL
PALM BEACH CANAL FILL
SOUTH LAKE WORTH INLET
ATLANTIC OCEAN
N
LOCALITY MAP
PALM BEACH
AND SOUTH LAKE WORTH INLET
FLORIDA

FIGURE IV

built separates Lake Worth from the Atlantic Ocean and is breached by two inlets, Lake Worth Inlet and South Lake Worth Inlet, about 15.5 miles apart. The barrier is composed principally of sand, part of which is artificial fill over former marsh areas. There are occasional outcroppings of coquina on the barrier and in the offshore area.

Lake Worth Inlet was dredged through the barrier and two protective jetties were constructed between 1918 and 1925. The construction of the jetties have caused changes in the adjacent shore lines similar to those at a number of other inlets along the east coast of Florida where jetties have been constructed; namely, accretion north of the north jetty and erosion south of the south jetty. An accurate estimate of the rate at which the littoral drift has been impounded by the north jetty cannot be made from available historical records but a number of rough estimates have been made utilizing available information. These estimates although rough, indicate the limits of the range between which the true value probably lies. They indicate that during the 14 year period immediately following completion of the inlet and jetties, material was impounded at a rate averaging 150,000 to 225,000 cubic yards per year and that during the next seven years the rate approximated 130,000 cubic yards per year.

The removal of this quantity of material from the littoral stream which formerly nourished the Palm Beach shores has resulted in continuous erosion. The rate of erosion has been retarded by the construction of a fairly uniformly spaced field of groins but in general the groins have not maintained as wide a beach as desired, primarily because of the lack of sufficient littoral drift.

Studies made by the Beach Erosion Board in cooperation with the Port of Palm Beach District to develop a plan or plans for the rehabilitation and future protection of Palm Beach resulted in the conclusion that because of the absence of an assured natural supply of beach material an artificial supply must be furnished. (reference 4). It was also concluded that the best method of nourishing this shore would be to pump sand from Lake Worth and place it in stockpiles along the beach. The decision to use this method of nourishment was due in part to a satisfactory test of stockpile nourishment made on the beach immediately south of Lake Worth Inlet in 1944.

The recommendations made by the Board were accepted by the cooperating agency and four stockpiles of sand were placed on the beach between May and November 1948. An additional stockpile of 100,000 cubic yards of sand was placed on the beach opposite the West Palm Beach Canal by Palm Beach County in 1949. The quantity of material placed in each of the stockpiles together with previous and subsequent placements near the northern end of the beach and the locations of the piles are shown on Figure IV and in the following table.

Location	Date of Placement		No.Cu.Yds.	Cost per Cu.Yd.
Mediterranean Ave.	Aug	1944	300,000	35.0¢
	May-Nov	1948	215,690	32.2¢
	July	1949	380,000	
Eden Road	May-Nov	1948	630,600	19.3¢
Tangier Ave.	May-Nov	1948	454,640	19.3¢
Banyan Road	May-Nov	1948	1,035,000	19.3¢
West Palm Beach Canal		1949	100,000	

The results obtained through the use of stockpiles to nourish the beach in the Palm Beach area can best be described by the following statements made by Mr. Norman C. Schmid, Engineer, Town of Palm Beach. "It is my opinion that artificial sand supply is the best method of beach protection that we have found in Palm Beach. The only trouble is that we have only supplied the beach with two and one half million yards and it is estimated that the project would require six million yards to bring the beach line to the 1928 location." Mr. Schmid further states that past experience shows that, "The northernmost stockpile should be replenished yearly, the others to the south every two or three years depending upon storm conditions." He concludes ".....that the sand has moved as expected, also that the experiment even to the layman's eye has proven quite successful."

CONTINUOUS NOURISHMENT METHOD

One of the best examples of continuous nourishment to a beach down drift from an inlet is the sand bypassing plant at South Lake Worth Inlet, Florida. The factors pertinent to the installation of and the results obtained with this bypassing plant were thoroughly covered by Mr. Joseph M. Caldwell in the first Coastal Engineering Conference but since it is the intent of the writer to make this paper as complete as possible in the field of artificial nourishment the highlights of this installation will be briefly reviewed.

South Lake Worth Inlet is located on the east coast of Florida near the southern limit of Lake Worth which separates the mainland from the sand barrier on which the town of Palm Beach is located. (Figure IV).

This inlet was dredged through the barrier in 1927 by the South Lake Worth Inlet District to create a circulation of water in the southern end of the lake to relieve the stagnant condition of the waters. The inlet was fixed by two short jetties about 250 feet long. Due to the abundant littoral drift from north to south in this area the littoral reservoir formed by the north jetty was quickly filled and sand was carried around its outer end into the inlet where it dropped out of suspension forming a middle ground shoal.

Concurrently with the filling of the impounding area behind the north jetty and the formation of the shoal, the beach south of the inlet eroded. Property owners faced with the loss of valuable land and homes constructed numerous protective structures but due to the impounding of the natural supply by the inlet, these structures did not help in holding or building a protective beach. The failure of the structures to protect the area clearly indicated the necessity of rebuilding the beach as a protective barrier through the restoration of the littoral drift in the area. This was done by establishing a pumping plant on the north jetty to bypass the sand across the inlet to the eroding shore. The distribution down beach of this material was left to the action of natural forces. This method had the added advantage of reducing the sand available to be carried into the inlet to be deposited on the middle ground shoal.

The pumping plant was not designed to bypass the entire quantity of littoral drift but rather to supply the quantity of material required to restore the beaches to the south. During the first five years of operation prior to World War II about 250,000 cubic yards of sand were supplied to the beach. The benefit derived from this operation was felt almost immediately and at the end of the five year period the beach south of the inlet was entirely restored. During this period shoaling decreased over the middle ground.

The cost of moving the sand including operation, maintenance, and depreciation was about 9 cents per cubic yard. Based on current prices the figure would still be well under the 19.3 cents to 35.0 cents per cubic yard cost of the stockpile nourishment placed on Palm Beach from Lake Worth.

It is recognized that although the sand has been moved economically with a fixed plant at South Lake Worth Inlet periodic nourishment using a floating plant may be more economical at other littoral barriers.

DIRECT PLACEMENT METHOD

It differs from the stockpile method in that the fill is completed at one time over the entire shore to be protected. In effect it may subsequently take the form of a stockpile project since it will serve as a supply source for the down drift shore, and future maintenance may be accomplished by artificial nourishment of those areas which first demonstrate supply deficiency by erosion.

This type of beach rehabilitation was used at Atlantic City, New Jersey in 1948 to quickly restore the ocean beach which was eroded to a point where it furnished little protection during fall and winter storms to the boardwalk and valuable real estate investments. (reference 5).

Atlantic City is located on the coast of New Jersey about 45 miles northeast of Cape May, the southern tip of the State at the entrance to Delaware Bay. (Figure V) It comprises nearly one-half of the length of the barrier beach known as Absecon Island. Absecon Inlet is the northeastern boundary of the city and Island.

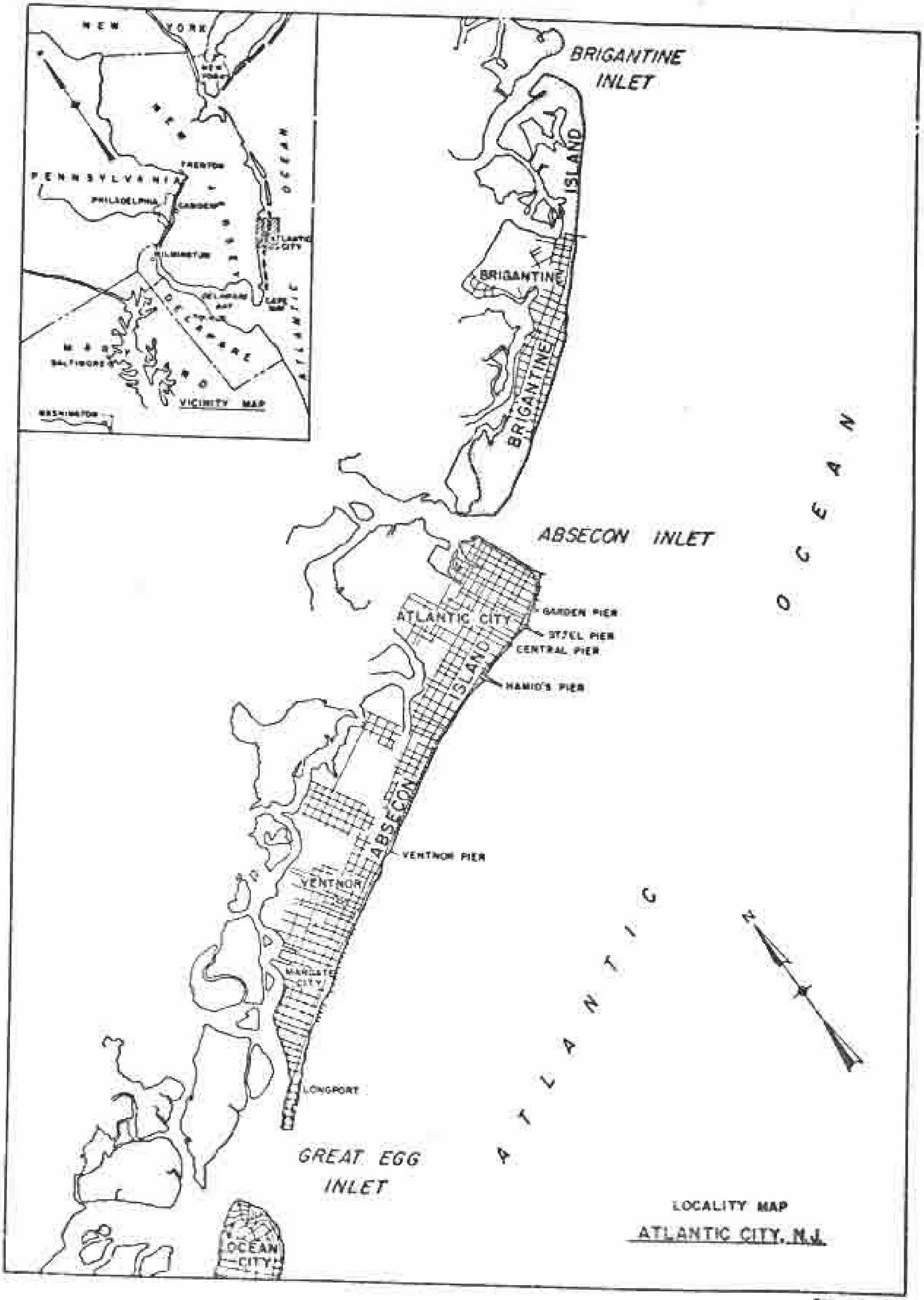
NEW YORK
NEW YORK
NEW JERSEY
PENNSYLVANIA
TRENTON
PHILADELPHIA
CAMDEN
WILMINGTON
ATLANTIC CITY
DELAWARE BAY
CAPE MAY
DELAWARE
MARYLAND
BALTIMORE
WASHINGTON
ATLANTIC OCEAN
VICINITY MAP
BRIGANTINE INLET
BRIGANTINE ISLAND
BRIGANTINE
ABSECON INLET
ATLANTIC CITY
GARDEN PIER
STEEL PIER
CENTRAL PIER
HAMID'S PIER
ABSECON ISLAND
VENTNOR PIER
VENTNOR
MARGATE CITY
LONGPORT
GREAT EGG INLET
OCEAN CITY
ATLANTIC OCEAN
N
LOCALITY MAP
ATLANTIC CITY, N.J.

FIGURE V

Because of its location near extensively developed and densely populated urban areas being about 60 miles from Philadelphia and 125 miles from New York City, it has rapidly become the most popular resort of its kind in the country.

The ocean beach is generally wide and flat; supplied with material transported southward along Brigantine Island. The volume of sand moving along this shore cannot be accurately determined but dredging figures indicate that it may be about 400,000 cubic yards per year. The part of this quantity moved onto the Atlantic City beach by natural forces is not known. Studies show that the beach remained relatively stable prior to 1940 and then started to erode progressively for a distance of about 6,000 feet southwest of the inlet. In view of the natural condition extant in the area and the immediate need for a protective beach southwest of the inlet, the State of New Jersey and the City replenished the beaches with sand moved by hydraulic dredge and pipe line from the point of Brigantine Island across the inlet. Approximately 700,000 cubic yards of sand were deposited on the beach from the Oriental Avenue Jetty to a point about midway between Central and Heinz's Piers during the summer of 1948. This material was placed on the beach over its 6,000 foot length at a cost of 77 cents per cubic yard.

Immediately prior to placing the fill a stone jetty was constructed on the south side of the inlet to divert the channel eastward away from the beach.

Subsequent to placing the artificial fill, an existing groin was repaired and five others were constructed to retard the loss of sand from the beach. Replenishment of the material placed on the beach has not been made but will be made when necessary.

The results obtained through the direct placement of sand to the beach at Atlantic City have been as successful as the studies had indicated. Observations made at various intervals following the period of beach slope adjustment show the beach to be relatively stable. It is too early to determine maintenance requirements and costs, but indications to date are that maintenance by periodic nourishment will be both feasible and economically preferable.

In summary, it is believed that artificial nourishment is firmly established as a practicable and economic means of shore protection which must be considered and evaluated in comparison with alternative measures in the study of any erosion problem. The long term benefit of this method of protection with respect to very substantial lengths of shore is an important aspect to be considered. Extensive additional research is needed to establish proper design criteria and a more accurate basis for economic analysis of this method.

ARTIFICIALLY NOURISHED BEACHES IN THE UNITED STATES

The purpose of this section of the paper is to assemble in one document all information available in the records of the Beach Erosion Board including published references 6 to 12 pertaining to those beach areas of the United States which have been artificially nourished or constructed. The data is presented in three parts in tabular form; the first outlines basic information on the beach required for the design of its nourishment; the second outlines information pertaining to the material available for the nourishment; and the third outlines information pertaining to the stabilized beach. Although an effort has been made to include all of the known artificially nourished beaches in the United States in the table there are undoubtedly many that have been overlooked. In several of the cases listed the purpose of the beach fill was not shore nourishment but simply selection of a convenient disposal area for dredged material. Those have been included for possible future use of the data presented.

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ARTIFICIALLY NOURISHED AND CONSTRUCTED BEACHES

DESCRIPTION OF NATURAL CONDITIONS									
Coastal area	Pacific Ocean	Pacific Ocean	Pacific Ocean	Pacific Ocean	Pacific Ocean	Pacific Ocean	Pacific Ocean	Pacific Ocean	Pacific Ocean
Name	Morro Bay Beach, California	Santa Barbara, California	Santa Barbara, California	Santa Barbara, California	Santa Barbara, California	Santa Barbara, California	Santa Barbara, California	Santa Barbara, California	Santa Barbara, California
Length of Problem Area		10.0 miles	10.0 miles	10.0 miles	10.0 miles	10.0 miles	10.0 miles	10.0 miles	10.0 miles
Exposure	SW thru W to NW, Clear	SE thru S to SW, Channel Islands to South	SE thru S to SW, Channel Islands to South	SE thru S to SW, Channel Islands to South	SE thru S to SW, Channel Islands to South	SE thru S to SW, Channel Islands to South	SE thru S to SW, Channel Islands to South	SE thru S to SW, Channel Islands to South	SE thru S to SW, Channel Islands to South
Slope - Foreshore Nearshore	1 on 10 1 on 25 - 1 on 100	1 on 15 1 on 40 - 1 on 75	1 on 15 1 on 40 - 1 on 75	1 on 15 1 on 40 - 1 on 75	1 on 15 1 on 40 - 1 on 75	1 on 15 1 on 40 - 1 on 75	1 on 15 1 on 40 - 1 on 75	1 on 15 1 on 40 - 1 on 75	1 on 15 1 on 40 - 1 on 75
Beach Material Characteristic	Coarse to fine sand	Medium to fine sand	Medium to fine sand	Medium to fine sand	Medium to fine sand	Medium to fine sand	Medium to fine sand	Medium to fine sand	Medium to fine sand
Rate of Littoral Transport per year		300,000 cu. yds.	300,000 cu. yds.	300,000 cu. yds.	300,000 cu. yds.	300,000 cu. yds.	300,000 cu. yds.	300,000 cu. yds.	300,000 cu. yds.
Dir. of Littoral - Winter Transport - Summer	South South	East East	East East	East East	East East	East East	East East	East East	East East
MATERIAL AVAILABLE FOR NOURISHMENT									
Location	Morro Bay Entrance Channel	Harbor	Harbor	Harbor	Harbor	Harbor	Harbor	Harbor	Harbor
Distance from Fill	0.1 to 2.0 miles	2.0 miles	0.1 to 2.0 miles	0.1 to 2.0 miles	0.1 to 2.0 miles	0.1 to 2.0 miles	0.1 to 2.0 miles	0.1 to 2.0 miles	0.1 to 2.0 miles
Character of Material	Coarse to fine sand	Medium to fine sand and silt	Medium to fine sand and silt	Medium to fine sand and silt	Medium to fine sand and silt	Medium to fine sand and silt	Medium to fine sand and silt	Medium to fine sand and silt	Medium to fine sand and silt
Quantity Available	Ample	Ample	Ample	Ample	Ample	Ample	Ample	Ample	Ample
NOURISHMENT ACCOMPLISHED									
Type of Nourishment	Direct placement with hydraulic dredge	Offshore placement by a hopper dredge in 20' water	Stockpile by hydraulic dredge	Stockpile by hydraulic dredge	Stockpile by hydraulic dredge	Stockpile by hydraulic dredge	Stockpile by hydraulic dredge	Stockpile by hydraulic dredge	Stockpile by hydraulic dredge
Primary Purpose	Disposal of dredged Material	Beach restoration	Shore nourishment	Shore nourishment	Shore nourishment	Shore nourishment	Shore nourishment	Shore nourishment	Shore nourishment
Slope of - Before Adj Foreshore - After Adj	1 on 5 1 on 10		1 on 10 1 on 15	1 on 10 1 on 15	1 on 10 1 on 15	1 on 10 1 on 15	1 on 10 1 on 15	1 on 10 1 on 15	1 on 10 1 on 15
Dimensions of Fill	0.5 mi x 400' South 0.3 mi x 400' North	0.4 mi x 200'	2.0 mi x 100'	1.0 mi x 200'	1.0 mi x 200'	1.0 mi x 200'	1.0 mi x 200'	1.0 mi x 200'	1.0 mi x 200'
Total No. of cu. yds.	2,000,000	202,300	606,427	497,715	600,110	717,773	642,977	838,152	
Cost per cu. yd.	15.5 cents	13 cents	21 cents	17.8 cents	21.9 cents	23.7 cents	17 cents	19.8 cents	
Date placed	1941-1943	September 1935	May-June 1938	June-July 1940	Jul-Aug 1942	Jun-Sept 1945	May-June 1947	May-June 1949	
Estimated Life of Fill									

TABLE I

ARTIFICIALLY NOURISHED AND CONSTRUCTED BEACHES

DESCRIPTION OF NATURAL CONDITIONS

Coastal Area	Pacific Ocean	Pacific Ocean	Pacific Ocean	Pacific Ocean	Pacific Ocean	Pacific Ocean	Pacific Ocean	Pacific Ocean
Name	Port Hueneme, Calif.	Port Hueneme, Calif.	Santa Monica, Calif.	Venice, Calif.	El Segundo, Calif.	El Segundo to Ocean Park, Calif.	Redondo Beach, Calif.	Cabrillo Beach, Calif.
Length of Problem Area		3.0 miles	13.0 miles	10.5 miles	6.5 miles	11.0 miles	1.0 miles	0.7 mile
Exposure	SE thru S to W, Channel Islands to SW Offshore Islands to S	SE thru S to W, Channel Islands to SW Offshore Islands to S	S thru SW to W Offshore Islands to S	S thru SW to W, Offshore Islands to S	SW to W, Offshore Islands to S	SW to W Offshore Islands to S	SW to W Offshore Islands to S	SE thru S to SW, Offshore Islands to S
Slope - Foreshore / Nearshore	1 on 15 / 1 on 60	1 on 15 / 1 on 60	1 on 30 / 1 on 240	1 on 30 / 1 on 250	1 on 20 / 1 on 230	1 on 20 / 1 on 230	1 on 10 / 1 on 25	1 on 25 / 1 on 100 - 1 on 150
Beach Material Characteristics	Medium to fine sand	Medium to fine sand	Medium to fine sand	Medium to fine sand	Medium to fine sand	Medium to fine sand	Medium to fine sand	Fine sand, clay, and silt
Rate of Littoral Transport per year	1,000,000 cu. yds.	1,000,000 cu. yds.	165,000 cu. yds.	165,000 cu. yds.	165,000 cu. yds.	165,000 cu. yds.		
Dir. of Littoral Transport - Winter / Summer	South / South	South / South	Southeast / Southeast	Southeast / Southeast	Southeast / Southeast	Southeast / Southeast		Southeast / Southeast

MATERIAL AVAILABLE FOR NOURISHMENT

Location	Harbor	Harbor	Harbor	Sand Dunes	Sand Dunes	Sand Dunes	Sand Dunes	Los Angeles Outer Harbor
Distance from Fill	0.2 to 1.0 mile	0.2 to 1.0 mile	0.06 to 0.5 mile	5.0 to 6.0 miles	2.0 miles	1.0 to 6.5 miles	3.0 miles	1.0 to 4.0 miles
Character of Material	Medium to fine sand & silt (Harbor spoil)	Medium to fine sand & silt (Harbor spoil)	Medium to fine sand with silt	Medium to fine sand	Medium to fine sand	Medium to fine sand	Medium to fine sand	Fine sand, clay and silt
Quantity Available	Ample	Ample	Ample	Ample	Ample	Ample	Ample	Ample

NOURISHMENT ACCOMPLISHED

Type of Nourishment	Direct placement with hydraulic dredge	Direct placement with hydraulic dredge	Direct placement and stockpile by hydraulic dredge	Direct placement by trucks	Direct placement sluicing from dunes	Direct placement hydraulic giants with ejector & dredge pumps	Direct placement by trucks	Direct placement with hydraulic dredge
Primary Purpose	Disposal of dredged material	Beach restoration and disposal of material	Shore nourishment	Beach restoration	Disposal of material and Beach restoration	Disposal of material and beach widening	Beach restoration	Beach restoration
Slope of - (Before Adj / After Adj	1 on 25 / 1 on 15	1 on 25 / 1 on 15	1 on 10 / 1 on 20	1 on 3 / 1 on 20	1 on 10 / 1 on 15	1 on 5 / 1 on 15	1 on 3 - 1 on 5 / 1 on 10	1 on 60 / 1 on 30
Dimensions of Fill	0.8 Mi x 450'	0.3 Mi x 200'	3.0 Mi x 300'	0.6 Mi x 75'	1.8 Mi x 200'	4.5 Mi x 600'	0.5 Mi x 50'	0.2 Mi x 200'
Total No. of Cu. Yds.	[illegible]	175,000	1,000,000	450,000	1,400,000	14,000,000	87,000	400,000
Cost per Cu. Yd.	20 cents	20 cents	25 cents	67 cents		26.5 cents	$1.00	20 cents
Date Placed	1939	1943	1950	1945	1938	1948	1947	1927
Estimated Life of Fill			7 to 10 years	10 years				

TABLE II

ARTIFICIALLY NOURISHED AND CONSTRUCTED BEACHES

DESCRIPTION OF NATURAL CONDITIONS

Coastal Area	Pacific Ocean	Pacific Ocean	Pacific Ocean	Pacific Ocean	Pacific Ocean	Pacific Ocean	Pacific Ocean	Pacific Ocean
Shore	Cabrillo Beach, Calif.	Long Beach, Calif.	Anaheim Bay, Calif.	Anaheim Bay, Calif.	Newport Bay, Calif.	Mission Beach, Calif.	Ocean Beach, Calif.	Ocean Beach, Calif.
Length of Problem Area	0.7 mile	5.0 miles	15.5 miles	15.5 miles	[illegible] miles		1.5 mile	1.0 mile
Exposure	SE thru S to SW, Offshore Islands to S	Sheltered by Los Angeles - Long Beach Breakwater	SE thru S to W, Offshore Islands to SW	SE thru S to W, Offshore Islands to SW	SE thru S to W, Offshore Islands to SW	SW thru W to NW, Channel Islands to W	SW thru W to NW, Channel Islands to W	SW thru W to NW, Channel Islands to W
Slope - Foreshore / Nearshore	1 on 25 1 on 100 - 1 on 150	1 on 25 1 on 150	1 on 7 1 on 70	1 on 7 1 on 70	1 on 25 1 on 35 - 1 on 75	1 on 7 1 on 50	1 on 7 1 on 50	1 on 7 1 on 50
Beach Material Characteristic	Fine sand, clay and silt	Medium to fine sand	Fine to Med. sand with small % of silt & clay	Fine to Med. sand with small % of silt & clay	Coarse to fine sand	Medium to fine sand	Medium to fine sand	Medium to fine sand
Rate of Littoral Transport per year			300,000 cu. yds.	300,000 cu. yds.				
Dir. of Littoral - Winter / Transport - Summer	Southeast Southeast	Nil Nil	South - Predominate North	South - Predominate North	SE - Predominate Northwest	South South	South South	South South
MATERIAL AVAILABLE FOR NOURISHMENT								
Location	Los Angeles Outer Harbor	Mouth of Los Angeles River	Anaheim Bay behind the Barrier Beach	Anaheim Bay behind the Barrier Beach	Newport Bay	Mission Bay	Mission Bay	Mission Bay
Distance from Fill	1.0 to 4.0 miles	5.0 miles	0.06 to 0.6 mile	0.06 to 0.6 mile	1.0 to 2.0 miles	2.0 to 3.0 miles	2.0 to 3.0 miles	2.0 to 3.0 miles
Character of Material	Fine sand, clay and silt	Medium to fine sand	Fine to medium sand, silt and clay	Fine to medium sand, silt, and clay	Coarse to fine sand and silt	Medium to fine sand	Medium to fine sand	Medium to fine sand
Quantity Available	Ample	Ample after each flood	Ample	Ample	Ample	Ample	Ample	Ample
NOURISHMENT ACCOMPLISHED								
Type of Nourishment	Direct placement with hydraulic dredge	Direct placement with hydraulic dredge	Direct placement and stockpile with hydraulic dredge	Direct placement and stockpile with hydraulic dredge	Direct placement with hydraulic dredge	Direct placement with hydraulic dredge	Direct placement with hydraulic dredge	Direct placement with hydraulic dredge
Primary Purpose	Beach restoration	Beach restoration	Shore nourishment	Shore nourishment	Disposal of material and beach restoration	Disposal of dredged material	Beach restoration	Beach restoration
Slope of - Before Adj / foreshore - After Adj	1 on 60 1 on 30	1 on 10 1 on 20	1 on 7 1 on 10	1 on 7 1 on 10	1 on 20 1 on 15	1 on 5 1 on 7	1 on 5 1 on 7	1 on 5 1 on 7
Dimensions of Fill	0.4 Mi x 500'	4.5 Mi x 300'		0.8 Mi x 1000' Wedge Type	2.0 Mi x 300'	1.0 Mi x 100'	0.6 Mi x 500'	0.5 Mi x 500'
Total No. of Cu. Yds.	2,886,000	4,000,000	202,000	1,097,000	7,090,000	[illegible]25,000	64,400	67,000
Cost per Cu. Yd.	40 cents	24 cents		23 cents	20 cents	21 cents	17 cents	17 cents
Date Placed	1948	1942 and 1946	1944	Oct 1947 to Jan 1948	1934 - 1935	September 1946	1949	May 1950
Estimated Life of Fill				3 to 5 years				

TABLE III

ARTIFICIALLY NOURISHED AND CONSTRUCTED BEACHES

DESCRIPTION OF NATURAL CONDITIONS

Coastal Area	Pacific Ocean	Pacific Ocean	Pacific Ocean	Atlantic Ocean	Atlantic Ocean	Atlantic Ocean	Atlantic Ocean	Atlantic Ocean
Beach	Coronado Beach, Calif. (North Island)	Coronado Beach, Calif. (Silver Strand)	Waikiki Beach, Honolulu, T. H.	Hampton Beach, N.H.	Napatree Beach, R.I.	West Haven, Conn.	Oak Neck & Center Is. Causeway, L.I. N.Y.	Orchard Beach, N.Y.
Length of Problem Area	2.0 miles		2.0 miles	1.3 miles	0.4 mile	1.5 miles	2.1 miles	0.4 miles
Exposure	S to SW. Point Loma to W. Los Coronados Islands to S	S thru SW to W.Los Coronados Islands to S	S thru SW to W.Clear	E to SE. Clear	S to SW. Sheltered in Block Island Sound	SE thru S to SW, sheltered in L.I.Sound	NW thru N to NE, sheltered in L.I.Sound	E thru SE to S, sheltered in L.I. Sound
Slope - Foreshore Nearshore	1 on 20 1 on 75 - 1 on 200	1 on 20 1 on 75 - 1 on 200	1 on 7 - 1 on 10 1 on 70 - 1 on 160	1 on 7 1 on 60	1 on 5 1 on 20 - 1 on 50	1 on 7 1 on 100	1 on 4 1 on 30	1 on 5 1 on 60
Beach Material Characteristic	Medium to coarse sand and shell	Medium to fine sand and shell	Coral sand and shell	Sand and shell	Sand and shell	Medium to fine sand and shell	Sand and shell	Sand and shell
Rate of Littoral Transport per year			10,000 cu. yds.					
Dir. of Littoral Transport - Winter Summer	Northeast Northeast	Northeast Northeast	South South	North North	West West		West East	
MATERIAL AVAILABLE FOR NOURISHMENT								
Location	Channel to San Diego Bay	San Diego Bay	Bellows Field Kaneohe N.A.S.	Hampton Harbor Inlet	Narragansett Bay, Watch Hill Cove	New Haven Harbor Inlet	Long Island Sound	Sand barged N side L.I. pumped on beach
Distance from Fill	0.2 to 1.0 mile	2.0 to 3.0 miles	2.0 miles	0.1 to 1.0 mile	0.6 to 1.0 mile	1.8 miles	0.2 to 0.8 mile	0.2 to 0.6 mile
Character of Material	Medium to coarse sand and shell	Medium to fine sand and silt	Coral sand	Medium to fine sand silt and shell	Sand, shell and silt	Medium to fine sand shell and silt	Sand, shell and silt	Sand, shell, and silt
Quantity available	Ample	Ample	Ample	Ample	Ample	Ample	Ample	
NOURISHMENT ACCOMPLISHED								
Type of Nourishment	Direct placement with hydraulic dredge	Direct placement with hydraulic dredge	Direct placement by trucks	Stockpile hydraulic dredge	Direct placement by hydraulic dredge	Direct placement by hydraulic dredge	Direct placement by hydraulic dredge	Direct placement by hydraulic dredge
Primary Purpose	Disposal of material and shore nourishment	Disposal of dredged material	Beach restoration	Shore nourishment	Beach restoration	Beach restoration	Beach restoration	Beach restoration
Slope of - (Before adj) Foreshore (After adj)	1 on 15 1 on 25	1 on 40 1 on 45	1 on 3 1 on 5 - 1 on 7	1 on 5 1 on 7	1 on 7 1 on 5	1 on 7 1 on 5	1 on 14 1 on 10	1 on 20 " on 10
Dimensions of Fill	1.0 Mi x 300'	3.0 Mi x 1500'	0.5 Mi x 150'	0.3 x 0.4 x 0.3 Mi. Triangle Shaped	0.4 Mi x 80'	1.5 Mi x 250'	0.7 Mi x 100'	
Total No. of Cu. Yds.	3,500,000	19,000,000	110,000	535,000	170,000	1,000,000	507,000	78,313
Cost per Cu. Yd.	15 cents	12.5 cents		25 cents		75 cents	37 cents	69 cents
Date Placed	1938 - 1939	1944	Dec 1951 to Jul 1952	1935	Oct 1948 - Feb 1949	Jul 1948 to Jan 1949	1947	1936 or 1937
Estimated Life of Fill								

TABLE IV

ARTIFICIALLY NOURISHED AND CONSTRUCTED BEACHES

DESCRIPTION OF NATURAL CONDITIONS

Coastal Area	Atlantic Ocean	Atlantic Ocean	Atlantic Ocean	Atlantic Ocean	Atlantic Ocean	Atlantic Ocean	Atlantic Ocean	Atlantic Ocean
Name	Jacob Riis Park Long Island, N.Y.	Coney Island, N.Y.	Long Branch, N.J.	Atlantic City, N.J.	Atlantic City, N.J.	Atlantic City, N.J.	Atlantic City, N.J.	Atlantic City, N.J. Absecon Inlet
Length of Problem area	0.9 mile	0.7 mile	13.0 miles	Indefinite	Indefinite	Indefinite	Indefinite	0.5 miles
Exposure	E thru S to SW. Clear	E thru S to SW. Sheltered in Lower New York Harbor	N thru E to S	NE thru SE to SW. Clear	NE thru SE to SW. Clear	NE thru SE to SW. Clear	NE thru SE to SW. Clear	NE to E
Slope – Foreshore / Nearshore	1 on 5 1 on 75	1 on 5 – 1 on 7 1 on 30 – 1 on 200	1 on 7 1 on 30 – 1 on 35	1 on 5 1 on 150	1 on 5 1 on 150	1 on 5 1 on 150	1 on 5 1 on 150	1 on 5 1 on 20
Beach Material Characteristic	Sand and shell	Medium to fine sand and shell	Medium to fine sand	Medium to fine sand and shell	Medium to fine sand and shell	Medium to fine sand and shell	Medium to fine sand and shell	Medium to fine sand and shell
Rate of Littoral Transport per year			177,000 cu. yds.	400,000 cu. yds.	400,000 cu. yds.	400,000 cu. yds.	400,000 cu. yds.	
Dir. of [illegible]ward-Winter / Transport Summer	West West	East and West East and West	North North	Southwest Southwest	Southwest Southwest	Southwest Southwest	Southwest Southwest	

MATERIAL AVAILABLE FOR NOURISHMENT

Location	Jamaica Bay, N. Y.	New York Harbor	New York Harbor	Absecon Inlet	Absecon Inlet	Absecon Inlet	Absecon Inlet	Absecon Inlet
Distance from Fill	[illegible].0 mile	0.3 to 1.0 mile	3.0 miles	1.0 to 2.0 miles	1.0 to 2.0 miles	1.0 to 2.0 miles	1.0 to 2.0 miles	0.1 to 0.8 mile
Character of Material	Sand, shell and silt	Medium to fine sand shell, and silt	Medium to fine sand and silt	Medium to fine sand and shell	Medium to fine sand and shell	Medium to fine sand and shell	Medium to fine sand and shell	Medium to fine sand, shell, and silt
Quantity available	Ample	Ample		Ample	Ample	Ample	Ample	Ample

NOURISHMENT ACCOMPLISHED

Type of Nourishment	Direct placement by hydraulic dredge	Direct placement by hydraulic dredge	Stockpile in water by hopper dredge	Offshore placement by a hopper dredge in 16' to 20' water	Offshore placement by a hopper dredge in 18' to 20' water	Offshore placement by a hopper dredge in 18' to 20' water	Offshore placement by a hopper dredge in 18' to 20' water	Direct placement by hydraulic dredge
Primary Purpose	Beach restoration	Beach restoration	Beach restoration and shore nourishment	Disposal of Material and beach restoration	Disposal of Material and beach restoration	Disposal of material and beach restoration	Disposal of material and beach restoration	Beach restoration
Slope of (Before adj) Foreshore (After adj)	1 on 7 1 on 5	1 on 5 – 1 on 10 1 on 4 – 1 on 7						1 on 7 1 on 5
Dimensions of Fill	0.9 Mi x 200'	0.7 Mi x 500'	0.7 Mi x 750'					0.8 Mi x 200'
Total No. of Cu. Yds.	900,000	1,700,000	602,000	792,000	900,000	500,000	1,362,000	900,000
Cost per Cu. Yd.	15 cents	21 cents						22 cents
Date Placed	Sep 1935 – Oct 1935	Aug 1922 – May 1923	Apr 1948 – Oct 1948	Apr 1935 – Mar 1936	Feb 1937 – Sep 1937	Aug 1938 – Sep 1938	Aug 1942 – Sep 1943	July 1948
Estimated Life of Fill								

TABLE V

ARTIFICIALLY NOURISHED AND CONSTRUCTED BEACHES

DESCRIPTION OF NATURAL CONDITIONS

General Area	Atlantic Ocean	Atlantic Ocean	Atlantic Ocean	Atlantic Ocean	Atlantic Ocean	Atlantic Ocean	Atlantic Ocean	Atlantic Ocean
Name	Atlantic City, N. J.	Ocean City, N. J. Surf Road - 12th St.	Virginia Beach, Va.	Wrightsville, N. C.	Palm Beach, Fla. Garden & Eden Roads	Palm Beach, Fla. Via Del Mar & Dunbar Rd.	Palm Beach, Fla. Tangier Ave	Palm Beach, Fla. Mediterranean Ave.
Length of Problem Area	Indefinite	Indefinite	Indefinite	23.0 miles	Indefinite	Indefinite	Indefinite	Indefinite
Exposure	NE thru S to SW	NE thru E to SW, Clear	N thru E to SE, Clear	E thru S to SW, Clear	NE thru E to S, Clear	NE thru E to S, Clear	NE thru E to S, Clear	NE thru E to S, Clear
Slope - Foreshore / Nearshore	1 on 5 / 1 on 150 - 1 on 200	1 on 5 / 1 on 50 - 1 on 100	1 on 15 / 1 on 50	1 on 7 / 1 on 15 - 1 on 20	1 on 10 / 1 on 50	1 on 10 / 1 on 50	1 on 10 / 1 on 50	1 on 10 / 1 on 50
Beach Material Characteristics	Medium to fine sand and shell	Medium to fine sand and shell	Medium to fine sand and shell	Medium to fine sand	Sand and shell	Sand and shell	Sand and shell	Sand and shell
Rate of Littoral Transport per year	400,000 cu. yds.	400,000 cu. yds.			225,000 cu. yds.	225,000 cu. yds.	225,000 cu. yds.	225,000 cu. yds.
Dir. of Littoral Transport - Winter / Summer	Southeast / Southwest	Southeast / Southwest	South - Predominate / North	South - Predominate / North	South - Predominate / North	South - Predominate / North	South - Predominate / North	South - Predominate / North

MATERIAL AVAILABLE FOR NOURISHMENT

Location	Absecon Inlet	Great Egg Inlet	Lake Rudee	Banks Channel	Lake Worth and Inland Waterway	Lake Worth and Inland Waterway	Lake Worth and Inland Waterway	Lake Worth and Inland Waterway
Distance from Fill	0.2 to 1.3 miles	0.6 to 2.0 miles	0.1 to 1.0 miles	2.0 to 3.0 miles	0.2 to 2.0 miles	0.2 to 2.0 miles	0.2 to 2.0 miles	0.2 to 2.0 miles
Character of Material	Medium to fine sand, shell, and silt	Medium to fine sand and shell	Medium to fine sand, shell and silt	Medium to fine sand and silt	Sand, shell, and silt	Sand, shell, and silt	Sand, shell, and silt	Sand, shell, and silt
Quantity Available	Ample	Ample	Ample	Ample	Ample	Ample	Ample	Ample

NOURISHMENT ACCOMPLISHED

Type of Nourishment	Direct placement by hydraulic dredge	Direct placement by hydraulic dredge	Direct placement by hydraulic dredge	Direct placement by hydraulic dredge	Stockpile by hydraulic dredge	Stockpile by hydraulic dredge	Stockpile by hydraulic dredge	Stockpile by hydraulic dredge
Primary Purpose	Beach restoration	Beach restoration	Beach restoration	Beach restoration	Shore nourishment	Shore nourishment	Shore nourishment	Shore nourishment
Slope of -(Before Adj / (After Adj	1 on 7 / 1 on 5	1 on 10 / 1 on 5	1 on 5 / 1 on 7	1 on 10 / 1 on 7	1 on 5 / 1 on 7 - 1 on 10	1 on 5 / 1 on 7 - 1 on 10	1 on 5 / 1 on 7 - 1 on 10	1 on 5 / 1 on 7 - 1 on 10
Dimensions of Fill	1.1 Mi x 200'	1.8 Mi x 300'	3.2 Mi x 300'		0.8 Mi x 400'	0.8 Mi x 400'	0.8 Mi x 400'	0.6 Mi x 390'
Total No. of Cu. Yds.	300,000	1,900,000	1,878,850	600,000	930,000	1,035,000	954,640	300,000
Cost per Cu. Yd.	77 cents	75 cents	60 cents	14 cents	14.2 cents	10.3 cents	10.3 cents	35 cents
Date Placed	July 1948	1952	1952	1939	May 1948 - Nov 1948	May 1948 - Nov 1948	May 1948 - Nov 1948	Aug 1944
Estimated Life of Fill	5 years				5 years	5 years	5 years	5 years

TABLE VI

ARTIFICIALLY NOURISHED AND CONSTRUCTED BEACHES

DESCRIPTION OF NATURAL CONDITIONS

Coastal Area	Atlantic Ocean	Atlantic Ocean	Atlantic Ocean	Atlantic Ocean	Gulf of Mexico (Mississippi Sound)	Lake Michigan
Name	Palm Beach, Fla. Mediterranean Ave.	Palm Beach, Fla. Mediterranean Ave.	Palm Beach, Fla. Opp W Palm Beach Canal	South Lake Worth Inlet, Fla.	Harrison County, Miss.	Chicago Park, Ill. North & Fullerton Aves.
Length of Problem Area	Indefinite	Indefinite	Indefinite	Indefinite	Indefinite	1.0 mile
Exposure	NE thru E to S. Clear	NE thru E to S. Clear	NE thru E to S. Clear	NE thru E to S. Clear	NE thru S to SW, Cat Is. 1.3 Mi South Ship Is. 7.3 Mi. South	N thru E to SE Clear
Slope - Foreshore / Nearshore	1 on 10 / 1 on 50	1 on 10 / 1 on 50	1 on 10 / 1 on 50	1 on 5 / 1 on 25 - 1 on 50	1 on 10 / 1 on 150 - 1 on 300	1 on 7 / 1 on 50
Beach Material Characteristics	Sand and shell	Sand and shell	Sand and shell	Medium to fine sand and shell	Medium to fine sand, shell and clay	Sand and gravel
Rate of Littoral Transport per year	225,000 cu. yds.	225,000 cu. yds.	225,000 cu. yds.	225,000 cu. yds.		12,500 cu. yds.
Dir. of Littoral Transport	Winter South - Predominate Summer North	South - Predominate North	South - Predominate North	South - Predominate North		South South

MATERIAL AVAILABLE FOR NOURISHMENT

Location	Lake Worth and Inland Waterway	Lake Worth and Inland Waterway	Lake Worth and Inland Waterway	North side of Inlet	Mississippi Sound	Lake Michigan
Distance from Fill	0.2 to 2.0 miles	0.2 to 2.0 miles	0.2 mile	0.1 mile	1.1 mile	0.05 to 0.6 mile
Character of Material	Sand, shell, and silt	Sand, shell and silt	Sand, shell and silt	Medium to fine sand and shell	Medium to fine sand, clay, and silt	Medium to fine sand, gravel and silt
Quantity Available	Ample	Ample	Ample		Ample	

NOURISHMENT ACCOMPLISHED

Type of Nourishment	Stockpile by hydraulic dredge	Stockpile by hydraulic dredge	Stockpile by hydraulic dredge	Continuous - Stockpile Bypassing Plant	Direct placement by hydraulic dredge	Direct placement by hydraulic dredge
Primary Purpose	Shore nourishment	Shore nourishment	Shore nourishment	Shore nourishment	Beach restoration	Beach restoration
Slope of Foreshore - (Before Adj / After Adj)	1 on 5 / 1 on 7 - 1 on 10	1 on 5 / 1 on 7 - 1 on 10	1 on 5 / 1 on 7 - 1 on 10	1 on 7 / 1 on 7	1 on 5 - 1 on 7 / 1 on 7 - 1 on 10	1 on 5 / 1 on 7
Dimensions of Fill	0.6 Mi x 390'	0.6 Mi x 390'			24.0 Mi x 300'	
Total No. of Cu.Yds.	265,690	380,000	100,000	90,000	6,000,000	250,000
Cost Per Cu. Yd.	30.2 cents			12 cents	12.5 to 14.5 cents	
Date Placed	May 1948 - Nov. 1948	July 1949	1949	Each year	1951 - 1952	1938 - 1939
Estimated Life of Fill	5 years	5 years	5 years			

TABLE VII

AD - 9480

UNCLASSIFIED