REPORT BY

BOARD OF COMMERCE AND NAVIGATION

NEW JERSEY

ON THE EROSION AND PROTECTION OF THE NEW JERSEY BEACHES

1930

REPORT

BY

Board of Commerce and Navigation

New Jersey

ON THE

Erosion and Protection of the New Jersey Beaches

1930

J. SPENCER SMITH, *President*
RICHARD C. JENKINSON, *Vice-President*

WILLIAM LAWRENCE SAUNDERS
WILLIAM T. KIRK
AUGUSTUS SMITH
JOHN MURTLAND
FRANK DORSEY
THOMAS H. THROPP

VICTOR GELINEAU, *Director and Chief Engineer*

TRENTON, N. J.
MACCRELLISH & QUIGLEY CO., STATE PRINTERS.
1930

TABLE OF CONTENTS

ILLUSTRATIONS

LETTER OF TRANSMITTAL

TRENTON, N. J., March 8, 1930.

To the Legislature:

GENTLEMEN—This report brings up to date the reports submitted to your Honorable Body by the Board of Commerce and Navigation, January 10, 1923, and February 17, 1925, respectively.

In those earlier documents figures were quoted to indicate the enhancement in the valuations of the coastal resort communities of this State as well as the strength of the resort industry as a factor in the economic structure of the Commonwealth. Following this precedent it is submitted that the valuations have increased from $57,000,000.00 in 1899 to approximately $600,000,000.00 in 1929.

At the outset of the studies on which these various reports were based, computations which were supported by the best maps and records available reveal that despite accretion in some localities, there had been a net loss of over two thousand acres of land on the oceanfront of New Jersey since 1835.

This tendency toward erosion is almost universal. Coast lines are continually changing, but more often than otherwise the tendency all over the world is toward recession. If the land fronting on the ocean has any substantial value, the owner is usually required at some time or other to decide whether he will permit continued recession or whether he will assume the expense of protection. This report is believed to demonstrate that coast protection is primarily for the community and not for the individual landowner.

In the present report the subject matter is presented rather in the form of which the lawyers term the "case method" as distinguished from the text-book system of general rules. The object is to present for detailed consideration and study several significant types of structures, leaving the reader to concur or dissent from the conclusions submitted. This tends to reduce generalizations to the minimum but involves considerable repetition which is perhaps unavoidable in the case method. It will not do to assume that in discussing jetties, the reader will necessarily recall and apply all of the relevant statements that have been uttered in connection with sea walls or sand dunes, for example.

The detailed surveys constitute a fund of most valuable definite and pertinent information. Unfortunately, they have become so voluminous that the decision has been reached to postpone until a later report their publication. Incorporation of these maps would increase the bulk of this report to undesirable proportions.

Respectfully submitted,

VICTOR GELINEAU,
Director.

EROSION AND DEFENCE OF SEA BEACHES

Beaches Increasing Source of Attraction

Paralleling the growth in wealth and population we have witnessed a demand for leisure and recreation. It is therefore natural that with increased facilities for travel such as the automobile, our people are responding at a greatly accelerated rate to the appeal of the beaches. Perhaps some one will write an epic on the transformation within the last few years of countless thousands of acres of marsh and sand dune into beautiful resort and residential sections on our oceanfront. The attractions of the more temperate climate adjacent to the ocean, the sea breezes and the opportunities for bathing, boating, fishing and other sports make the strongest appeal to the dwellers of the cities and inland regions. In the State of New Jersey alone, one of the smallest of the American Commonwealths in area whose oceanfront extends about one hundred and twenty-five miles from Cape May Point, on the south, Latitude North 38° 56′ to Sandy Hook in Latitude North 40° 28′ on the north, the advance in wealth and population of the municipalities fronting on the ocean has been far greater than the advance in wealth and population of the State as a unit. In fact, in 1929 the net valuation taxable of these oceanfront municipalities on this stretch of coast of New Jersey exceeded $600,000,000.00.

New Developments Bring New Problems

The assertion by man of dominion over these beaches has, in many places, resulted in operations that violated some of the fundamental operations through which nature built up these beaches. As a result the ocean at times shows a tendency to lash to destruction some of the works that man places in the ocean's domain. The beaches are not the result of a fleeting action or process, but have been built up through countless centuries of the operation of wind and wave and tide. Some of the processes which are destructive to structures erected by human hands are manifestations of nature working to build up the beaches. For example, an extremely high storm tide occasionally piles up a vast tonnage of sand upon low lying streets and properties. Yet this is merely one of the processes by which low lying beaches have been raised to a safe level. The formation of sand dunes by wind action is probably nature's final process in the building up of a high beach. Unfortunately, one of the first activities of the men who build upon these beaches is to level down the sand dunes, the finest and most beautifully moulded barrier that nature can erect short of rock upheavals. In general we can safely accept the prediction that troubles from erosion will begin with the lowering of these sand dunes.

The etymology of this word "erosion" is very interesting. Its literal meaning is "to gnaw" (Latin *e* + *rodere*). The word and its derivation are most apt. When beaches are in a natural condition it is relatively seldom that great areas are suddenly shifted. That does happen occasionally where an inlet breaks through a very narrow low-lying strip, or more accurately the seas break over a low-lying strip and form an inlet. But in general the extensive shifting of beach lines constitutes a gradual not strictly continuous process and should be measured wherever possible with relation to accurate surveying operations and not merely by observations without reference to fixed monuments.

Obviously even very slow, gradual operations of nature, if they press in one dominant direction, will, over many centuries, have far-reaching effects.

Erosion of Sea Beaches

The word beach is used indiscriminately to mean a sandy and fairly level place where it is readily possible to enter the water. Barrier beaches are areas of varying width which separate the ocean from an inshore lagoon which lies adjacent to the mainland. We can divide the two beach types into barrier beaches and headland beaches. A headland beach we can define as the talus in front of a bluff or cliff that can be denominated as a headland. A headland beach, then, is attached to the mainland and does not front on any lagoon.

The headland beach is, as we say, the slope or talus of a mainland cliff or bluff and is composed largely of material washed down from the headland. We must remember at the outset that sandy or gravelly headlands have not emerged from the water in their present condition. The existence of cliffed headlands on sandy beaches as distinguished from cliffs of rock of volcanic origin is pretty safely to be interpreted as an outstanding characteristic of erosion. Land-forms emerge very slowly from the ocean and with a very flat slope. Some idea of the form or position of the beach in front of a headland can be gained by tracing in an oceanward direction the slope of the land running back from the headland. Leaving out of consideration the former barrier beaches in front of this headland, the intersection of this slope of headland or surface profile with the water-level will approximate the position of this former shore line in front of the eroded headland. It seems unnecessary to caution the reader that this rule can apply only to real mainland headlands and not to sand dune areas. Sand dunes are an ambulatory feature of topography with which we will deal later on.

There are various theories of the origin of sea beaches. The first point of consideration is the material of which the beaches are formed. Normally the surface that we see is composed partly of shell particles and partly of sand or gravel. Sand is a ground-up rock, as are pebbles, for that matter, although of a different degree of fineness. The proportion of shell material is often larger than may be supposed. In fact, some of our southern beaches seem to be very largely composed of shell particles. Headland beaches we can readily dismiss by repeating the statement that they form merely the talus or slope of the headland. But of barrier beaches, the origin is a matter only of speculation and hypothesis. There are three general outstanding theories: First, that the barrier beaches mark upheavals; Second, that the barrier beaches were formed by the actions of wind and wave; and, Third, that the barrier beaches mark the remaining portions of larger submerged areas. These theories are interesting, but only limited discussion should be given in a work of this nature to matters so entirely hypothetical. They are discussed in somewhat greater detail hereafter.

One outstanding fact we should remember, which is that in general wherever waves beat upon a shore their tendency is to flatten down the land-forms to water-level. As this process continues, the wave attack becomes more and more enfeebled, with a flattening out of the foreshore slope. The further consideration of these theories properly belongs in a work on geology and physiography.

The engineer's primary object is to mould and guide, as far as possible, the operation of natural forces, with a view to arresting the destruction of land areas which in general the forces of the ocean are seeking to level down. A combined number of processes in operation continue without cessation. Every wave, every alteration of the tidal level has some effect on the ocean beaches. The energy of a breaker or of a small wavelet, as the case may be, breaking upon a shore is absorbed by that land and some distortion is to be expected. Conditions, as affected by natural or artificial structures, will determine whether the wave effect will be checked or victorious, or be made to yield beneficial protection to the immediate locus.

This is the field of the engineer and only of the engineer who is a specialist in this field, one with the qualities of discernment and observation, who realizes that theory is not really theory unless it is predicated upon sound physical facts. Pure theory and elaborate calculations have little application in this field where the engineer's task is to combat the forces of the ocean. If resistance is to be offered to the onslaught of heavy seas no trifling construction will serve, and on the other hand, if the object is to guide the forces of wave and tidal current, then the types of works adopted must be carefully chosen. The engineer planning coast works must, like the agriculturalist, to a certain extent gamble upon what the weather conditions will be during the course of construction; it is perhaps the most critical time in which coast works are exposed. Hence the strong advisability, wherever possible, of beginning and planning construction so that the more critical and hazardous stages of the work will be completed and protected before the onset of the season of heavy storms.

Perhaps it can be accurately said that this field of engineering work has not reached the stage of development that marks the construction of other works. Undoubtedly this is true. It can also be said that the field is much more difficult. The conditions are not static, as they are in the case of, let us say, bridges, roads and other land constructions. One reason is that the engineers have not been called upon to perform any real large amount of work in this field. The total amount of coast protection work that has been performed in recent times is almost negligible in comparison with any other field of civil engineering construction.

The reason is perfectly obvious. It is only in very recent times that we have witnessed the construction of fine buildings, roads and other works upon our beaches. Furthermore, when these buildings were first constructed they were normally located at a reasonable distance back from the shoreline of that time. Apparently it seldom if ever entered the minds of builders on the beaches that erosion is a normal process. There are exceptional places where large land areas have been captured from the ocean, but this is not the normal result to expect. Even today, with the fund of knowledge that has been gathered, the tendency is to build rather too close to the ocean on the assumption that nothing detrimental will occur.

The engineer is seldom called in until conditions are acute and immediate construction is required. There is rarely an opportunity afforded for comprehensive planning to permit the highest economy in the distribution of the funds to protect a given area. Usually works have to be designed to save certain structures, and to protect limited frontages. Furthermore, only the most heartbreaking losses and discouragements will, as a rule, convince land owners and public bodies that the protection of the beaches where the attack is heavy requires the highest engineering skill in this field, with adequate funds to construct adequate structures. The community has learned that to build good roads takes vast sums of money, that modern traffic requires adequate bridges, but it seems difficult to emerge from the idea that flimsy fences, erected without regard to sound engineering knowledge, will arrest the mightiest forces of nature. Those who have witnessed the huge seas of the North Atlantic beating against an obstruction to their path, the impact hurling skyward enormous volumes of water and causing a quivering of the ground, should have a wholesome respect for these forces. Yet structures can be designed and built to arrest erosion and ultimately the Commonwealth does, when the danger becomes sufficiently great, find the money to build the necessary works. But these protective measures are seldom applied until valuable structures have been actually undermined. One of the objectives of the engineer and other public officials, interested in this field, should be to point out the needlessness of suffering these great losses which can be avoided while the beaches are in a relatively fair position by lighter and infinitely less expensive structures than those that are required when valuable buildings are actually in danger.

Obviously, there must be a rule of reason. There is very little interest in the question of erosion of a wild sandy waste, but we know that the worthless beach strip of today may be the splendid community of twenty years hence, and that in so many instances it is simple and inexpensive to provide measures that will tend to prevent the unnecessary breaking through of the sea over low places which could very readily have been protected at trifling expense. Inlets seldom break through a beach unless there are low glades which form a ready passage for the water in abnormal times. A very slight obstruction across these glades operating to check the water and catch the drifting sand can usually be provided at very slight expense. Here, too, is a splendid field for the building of sand dunes, nature's finest protection against erosion.

When a heavy wave breaks upon a shore it runs up the shore as far as the force of the wave permits, and then retires, usually carrying some of the beach material back into the water. This operation is repeated with tremendous rapidity and varying force an almost incalculable number of times daily, and the effect of waves may be either to tear down a beach or to build it up. While we have pointed out that the normal effect of the sea beating on land-forms is unfavorable, on the other hand, taking another view of the subject, we are face to face with the fact that the forces of nature have built up the barrier beach.

A particular beach may be progressing oceanward or retreating. The engineer is never called in while the beach is progressing oceanward — there is no malady here. The land owner's tendency then is to thrust his construction oceanward just as far as possible. This building-up process rarely continues indefinitely. There may be a swing of the cycle marking raising of the shoreline, or while there may be a general stability, the beach in question may be attacked by abnormal storm conditions. In either of these two events some destruction and damage ensues, and it is the prevention of this destruction which forms the problem confronting the engineer.

We can dismiss, then, the beach where accretion is in progress, with the caution that this advance probably will not continue indefinitely and apply our attention to the situation where the conditions are unfavorable—that is, where land is being lost.

The wave, then, falling upon the shore, brings back in suspension a certain amount of beach material, sand, shell, etc. Much space and time and talent have been devoted to arguing whether the wind or wave or currents alongshore form the real destructive agency. Destruction is in fact caused by all three of these agencies, and the degree of effect resulting from any one is a matter that varies with every beach and probably every moment of time. We have considered the wave action already and have described the process of the wave washing up on the beach and after expending its energy the water returns to the lower level taking some beach material with it.

In every large body of water, and certainly in the ocean water, there is tidal influence, or changes in level somewhat analogous thereto. The flood tide normally sets in one dominant direction. This direction is usually what marks the direction of beach drift. It must be understood that the sand and shell particles that we see in looking at the beach strip are not the same particles that were there, let us say, the previous year. Obviously, we cannot identify the finer particles, but we know that in fact these particles shift, not always in the same direction, but over a long course of time, say one year, there is a definite shift in one dominant direction year after year, and this direction is normally that at which the flood tide component impinges upon a coast. This is fundamental and explains many prominent elements in the study of beach contours. It is to be noted that at most inlets there is a point at which there is a reversal or division in direction of the drift of beach material. This simply means that the flood component splits or divides at this point.

Once having loosened this beach material and having it in suspension, the wave direction, complicated with the wind motion, tends to set this suspended material a little further along the beach in the direction of the beach drift. It is not a direct question of prevailing winds nearly so much as the direction of the wind and tide component. It is true that tremendous storms will temporarily reverse the direction of beach drift; but the result of non-spectacular weather conditions, having a much longer application of their forces, is much more pronounced than is the effect of these striking storms which are of limited duration. Whether the motion of the particles of the beach as the waves break and run up the beach is parabolic or zigzag or follows a sine curve in their path is probably not fundamental. The fact remains that there is a dominant movement of the material in one direction for every beach of considerable length and any reasonable period of permanence. If this beach current resulting from the flood tide were effective only to move the beach particles one foot in a month, the effect over a long period of time would obviously be pronounced.

Many of the beaches situated on sea islands are accessible only by boat until the lagoons which separate the islands from the mainland are bridged. When a bridge is constructed from the vicinity of a wealthy seashore resort to an outlying barrier island, a rapid transformation generally takes place. The worthless sandy waste immediately becomes valuable and attracts the real estate operator.

Now the characteristic appearance of a barrier beach can briefly be described as follows: There is a row of sand hills or dunes, or perhaps several such rows, near the ocean, and in back of these sand dunes a more or less extensive plot of salt marsh. The dunes are of irregular contour and normally too high and irregular in profile for the street layout that the developer contemplates and the salt marsh belt is too low for drainage and habitation.

The developer thereupon seeks to equalize and grade the land level by cutting down the dunes to fill out the low places and probably dredges by hydraulic machine the surplus material required to raise the elevation.

It can be confidently predicted, although we know of some exceptions to this statement, that when the sand dunes are levelled down, coast erosion troubles begin. This statement has already been made but is worthy of repetition. In the first place the promoter, with a view to the utmost economy, seldom incurs any unnecessary expenditure in raising the elevations very high. He sells the ocean front lots which are deemed the most valuable, and the buyer of such lots, proud of his new possession, ordinarily viewing the property only under favorable conditions, let us say in the Summer of the year, builds his house right on the beach just as he would on an inland lake. It never occurs to him that the ocean, on certain occasions, looks very different from what it does in the Summer season.

We then have a difficult situation. The land elevation is lowered in order to grade out the low lots and the sand reservoir which constituted the sand dunes, Nature's best protection during fluctuations has been depleted. Furthermore, any erosion or overflow by the high storm tides now becomes a serious matter, for here are beautiful dwellings right on the beach within range of these high seas, and in all probability there is a marginal boulevard not any too far from the shoreline.

If the beach in question happens to be a section where prograding rather than erosion is in progress, there is no trouble except that it is almost inevitably the rule that as this high water line recedes oceanward, land improvement and development follows very closely. Ultimately there may be a reversion in the cycle and the buildings pushed out under favorable conditions of accretion are then endangered. In other words, there is almost never any allowance for these fluctuations. Favorable conditions are regarded as permanent, and there is no preparation for the storms and fluctuations of the shoreline that are almost inevitable.

This situation has thus brought into being a new branch of engineering, namely, that concerned with the erosion and protection of the sandy beaches. It is probably the most difficult field of engineering work. The engineer is seldom called in until the ravages of the sea have brought about an acute situation and he is seldom permitted to plan for adequate works. This is singular but true. We have learned that light, cheap bridges cannot carry the heavy railroad and highway freights of today, hence it is taken as a matter of course that good permanent bridges cannot be built with negligible appropriations. Furthermore, it has become recognized that engineering applied to the construction of such bridges must necessarily be a specialty requiring particular training and experience.

But this is hardly the situation with respect to Coast Protection. Here there is a very deplorable lack of recognition of the fact that we are dealing with one of the most serious situations that can confront an engineer, where works must be adequate or they will fail, where the work must be prosecuted too frequently under adverse conditions with danger of loss while construction is in progress, yet there is no hesitation to throw out the flimsiest work solely with a view to present cheapness, almost always designed without regard to sound engineering principles or experience in this most difficult of all engineering fields.

The result is deplorable losses with a consequent feeling that nothing is known about this division of engineering activity. There is no more reason for some of the structures that are constructed at large expense than there would be for erecting bridges or buildings in an earthquake country without due regard to what may be expected. This comparison is rather apt for coast protection works are at times subject to processes that are just as severe as those that would be encountered by structures on lands that are subject to severe earthquake shocks.

We know that along the North Atlantic coast of the United States there is in general throughout the Summer an accumulation of sand. Usually the losses occur during the Winter under severe conditions of onshore wind. Too often flimsy structures have been erected in the Spring, photographs taken at the beginning of the work and then photographs taken, let us say, in September when the beaches would naturally fill up, and these structures then paraded as the solution for the problem. The advocates of these structures seldom if ever exhibit photographs of conditions after the first Winter. Now a coast protection structure may be good for 99% of the time of its first two years of service, but if it fails during a storm it is a total failure and represents an absolute waste of money. If the structure does not protect during times of stress, it is just as unsuited for its purpose as is a bridge that will stand up until it is loaded.

Theory alone without experience in this particular field is very likely to lead to trouble, yet the principles that govern the construction of coast protection works are purely sound engineering principles. It is the failure to recognize and make allowance for some of the situations that will arise in times of stress that are responsible for the losses.

Geographic and Geologic Elements Directly Involved

While it is out of the question for the average engineer to obtain a profound equipment in the study of geology, it is certainly advisable for the engineer to prepare himself as well as possible to apply upon inspection the elementary principles to a given coast that forms the subject of study. It should be a relatively easy matter for the engineer upon first inspection of a shore to determine whether that particular frontage is part of a new land form recently arisen from the sea or whether the coast has attained the stage of maturity. This will tell him whether erosion or accretion has been operative. Every mainland frontage as distinguished from barrier beaches has probably been the situs of more or less pronounced elevations and depressions. In fact a scrutiny of the maps issued by the State or Federal Geological Surveys or by the U. S. Coast and Geodetic Survey will yield highly valuable information preparatory to the detailed study of the coast in question. It may well be argued that a grounding in the elements of geology will not of itself aid appreciably in the design of jetty or sea wall, but it is submitted that the engineer earnestly undertaking this class of work can not afford to ignore the studies of the geologists. In the absence of anything better the Federal and State geological reports and maps will furnish valuable information in respect of the substrata. While this will not supply a satisfactory substitute for actual borings, nevertheless, it will in a general way indicate what can be expected when the detail examinations are undertaken.

The study of geology indicates what earth moulding processes are or have been active. It is unfortunate, however, that much which has been written by some able professional geologists is presented in such technical language as to repel the engineer or other layman and the general elementary works are for the greater part not sufficiently detailed. There are, however, a number of good readable works available to the engineer. The writer has supplemented his study of elementary geology with particular attention to "Shore Processes and Shore Line Development," by D. W. Johnson, and "Shore Line Topography," by F. P. Gulliver. Professor Johnson has furnished a splendid summary of earlier works and in addition has definitely enriched the store of knowledge by his own field studies and observations. F. P. Gulliver wrote "Shore Line Topography" as a candidate for the degree of Doctor of Philosophy at Harvard University. This is a work of great value. Unfortunately, so far as the writer knows, Mr. Gulliver did not write any subsequent books. His clearly written thesis most assuredly formed a highly valuable contribution to the fund of knowledge on shore formations.

The observer of a shore front can be assured of the fact, that the beach front under inspection has not existed indefinitely in its present contour, profile and general appearance. Gulliver in "Shore Line Topography," at page 151, quotes from Shakespeare:

> "When I have seen the hungry ocean gain
> Advantage on the kingdom of the shore
> And the firm soil win of the watery main,
> Increasing store with loss and loss with store;
> When I have seen such interchange of state,
> Or state itself confounded to decay;
> Ruin hath taught me thus to ruminate."
> (Sonnet LXIV)

"The shoreline, the line formed by the intersection of the plane of the sea with the land, is in a geographic sense a most inconstant line. Though for a geographic minute, a generation of men, it is practically in the same position, yet even in the short period of historic time records show that villages have been submerged, or that seaport towns have been turned into inland places."

Again on page 154:

"Land forms go progressively through a series of successive stages of development, to which have been applied names taken from various stages of life, thus suggesting that forms as seen today began as something else, and will as time advances become systematically still further developed. Stages of the cycle follow one another from birth to death in the ideal case, where the land stands still long enough for the completed development. The initial stage, or birth, is succeeded in turn by infancy, youth, adolescence, maturity, past-maturity, old age, and finally by death.

"A new cycle is inaugurated by each oscillation of any considerable amount, minor changes of level being included as epicycles, or divisions of a cycle. Land forms advance successively from infancy toward old age in each cycle, while any stage of development may be arrested by elevation or depression of the land and a second cycle begun. An essential conception is that a region will be finally reduced to a peneplain if the base leveling action of the streams, and the other forces of subaerial degradation, be allowed to continue long enough to reduce the land forms to extreme old age. Insequent, consequent, subsequent, and obsequent streams all play their part in the development of the land forms, captures of one stream by another follow unequal chances, while superposed streams often come unexpectedly upon a difficult piece of work. * * *

"At the beginning of a cycle the subaerial forces of degradation enter upon a new piece of work. Similarly the sea has to begin anew its attack upon an initial coast. A series of coastal forms would be expected to result, and these may be grouped in stages analogous to those of land forms. On account of the many variables which control topographic form, it would not be expected to find the inland area and the coast of the same region in homologous stages of development. The general surface of a coastal plain may be in youth or maturity when its coastline has advanced to adolescence. Because the coastline has reached an adolescent stage of development, it does not follow that the surface of the coastal plane further inland is also in adolescence."

He continues at page 173:

"The ocean, however, tends to convert irregular to straight or gently swinging coasts. If the land therefore remains at the same level there will come a time when the increased cutting upon the exposed promontory will equal the lessened wearing of the softer material in the re-entrants on either side."

In other words, the sea operates on land-forms to produce easy curves in plan or in profile and will tend to smooth off the promontory, fill in the bays and to smooth off vertical projections exactly as it does projections in plan. As to the cutting upon the exposed promontory, note the analogous action of the sea upon the outer end of jetties or groins.

At page 178, Gulliver discusses the very significant features of offset, overlap and stream deflection. He defines these as the three criteria of form by which the dominant current alongshore may be inferred. He says that the three usually occur together, but each may be found by itself. His decription, though rather brief, is worthy of careful study, but the writer feels that with respect especially to the offset his analogy should not be carried too far, particularly if inlets like Absecon, Barnegat, Great Egg Harbor and some others be considered. In general, the stream deflection feature accurately indicates the direction of the dominant drift. This feature has been rather fully discussed with respect to Manasquan Inlet which has occupied a great deal of the writer's attention during the past few years.

Perhaps a reference to the behavior of these inlets with pronounced stream deflection would not be amiss. The ocean shoreline at and near Manasquan Inlet is normally roughly north and south and the dominant drift is definitely and strongly to the north. The shortest distance for the Manasquan River water to travel in finding egress to the ocean was along a line approximately at right angles to the beach. The various United States works and the jetties built by local interests which are fully described in the 1924 report need not be discussed here. The behavior of the inlet exhibited a very clear case of stream deflection. After one of its periodic closings, which occurred during the summer, and when a good head of water piled up in the Manasquan River (really a drowned valley or small bay), interested parties would cut a small ditch across the bar usually at the time of low tide in the ocean. The impounded waters of the river, much higher than the ocean level, quickly scoured out an inlet gorge which might maintain itself for many months. Invariably, however, the gorge would depart from its straight alignment and form a roughly shaped "S" with the south point of beach building forward and the north point receding due to the northerly drift. Ultimately a point would be reached where the length of the gorge would be relatively very great in consideration of the other hydraulic factors involved and the inlet would close. A number of other inlets prior to their permanent closing, exhibited the same behavior. They were affected of course by the relatively small tidal area and prism, inadequate to maintain a good inlet. This in turn was influenced by the small volume of drainage run-off. A considerable excess of ebb-tide would maintain an inlet of some sort.

The primary point is that these land-forms, if not of a fleeting nature due to a recent severe storm, indicate at a glance the pronounced direction of the shore drift and guide the engineer in his planning.

Johnson, at page 307 of "Shore Processes and Shore Line Development," discusses Gulliver's reference to the three features of offset, overlap and stream deflection. He very properly points out the failure of application of the offset theory of shore drift to the inlets on the southern shore of New Jersey. The dominant current on that frontage is very clearly to the southward as evidenced by all of the writer's observations, except, however, that there is a reversal of drift at the inlets and in a few restricted isolated spots remote from the inlets.

In considering the stream deflection feature, the writer has noted that in general, meagre, attenuated points or sand spits at the inlets usually indicate erosion; whereas a full rounded point of beach at the inlet indicates the favorable condition of accretion. The map of Great Egg Inlet shows the north (Longport) point full and rounded in 1886, subsequent to which it narrowed steadily. Despite fluctuations the growth of the south (Ocean City) point has been marked, and the contour has always been much more ample and rounded than the Longport point.

Gulliver devotes considerable space to the discussion of the land-form known as "tombolo" which is a connecting bar tying an offshore island to another island or to the mainland. On the ocean front of the Atlantic Coast of United States, south of Massachusetts, there are few, if any, islands lying offshore of the barrier beaches to which this feature is an appurtenant. The fact of earth material collecting in the lee of exposed islands is a familiar characteristic in inland waters and as shown by Gulliver and Johnson, Marblehead, Nahant at Massachusetts and at various points on the Italian coast, where the name comes from, and Alaska.

While the geologic feature of the tombolo and its allied formation, the lee bar in itself is of slight interest on our Atlantic Middle and Southern Ocean Coast, it is nevertheless the analogy in nature to the proposed offshore barrier type of protection that is urged by some engineers. See article by Mr. Henry C. Ripley in Vol. LXXXVII, Transactions American Society of Civil Engineers, entitled "Beach Erosion, Its Causes and Cure." The offshore island affords the conditions to form a lee just as would the artificial offshore barrier for the collection of drift material. A possible point of distinction is that the offshore island itself in the localities mentioned probably furnished a considerable volume of the material of which the lee barrier or tombolo is constituted. A brief allusion has been made in describing the origin of sea beaches and the offshore bar and beach channel to the various theories for the formation of the offshore bar. Johnson, beginning on page 348, gives a most commendable review of the theories, and at page 356 presents a deductive study of offshore bar profiles to test the application of the various arguments. He summarizes the result of a deductive study of profiles on page 360, to which the reader interested in the further study of this interesting field is referred.

The Origin of Sea Beaches

There are various definitions of the word "beach." Some of the courts have defined the beach as the zone marked by the limits of high water and low water. Ries and Watson in "Engineering Geology" define the beach as the belt or zone occupied by the moving shore drift. Normally, we think of a beach as a sandy or gravelly belt of land which forms the boundary of the ocean or any other body of water, the width of which varies with the height of the water levels.

For practical purposes beaches are divided into two classes, the headland beach which is part of and forms the sea boundary of the solid mainland and barrier beaches which consist of islands or peninsulas which are bounded on one side by the ocean or other major body of water and on the other side by lagoon or other secondary or tributary body of water. For example in New Jersey, the frontage between North Long Branch and Bay Head is a headland beach while the section which extends northward from North Long Branch to Sandy Hook and the section which extends southward from Bay Head to Cape May are classified as barrier beaches. Gulliver in "Shore Line Topography" defines the New Jersey coast as a winged headland. It is an important question whether the material of which these wings or barrier beaches are composed was not in large part derived from the headland section. That this headland section in former times extended much further oceanward than at present is almost certain.

While the distinction between the two classifications of beaches appears to be of primary interest to the geologist rather than to the engineer, it is to be recalled that the headland beach is not subject to overflow and breaching by extreme tides, as is the case with low-lying barrier beaches.

The forces and agencies which have created the sandy islands and peninsulas which we call barrier beaches have always perplexed engineers and geologists. Various theories have been advanced to explain their creation but human records do not extend back far enough to aid in testing any of these theories. There are perhaps three principal theories to which brief references may be made.

The first is that advanced by Mr. F. J. H. Merrill, that the bars were formed and built up under the water by wave and current action. (See article "Barrier Beaches of the Atlantic Coast," Popular Science Monthly, Vol. 37 of 1890.) The second theory is that advanced by W. J. McGee, entitled "Encroachments of the Sea," in the Forum Magazine, Vol. 9, page 443, of 1890, which explains the existence of the offshore bars and barrier beaches as a proof of coastal subsidence in which these barrier beaches had lagged behind the mainland in the area in its sinking movement. The third theory is that advanced by Elie De Beaumont in "Leçons de Geologie Pratique," pp. 223-252, Paris, 1845, who suggests that wave action piles up the movable material in a ridge parallel to the shore. He suggests that the operations of the sea result in establishing a profile of equilibrium and that the offshore bar is thus created. (See D. W. Johnson, "Shore Processes and Shore Line Development," for an excellent summary on the views advanced by these various writers.)

The theory advanced by De Beaumont is worthy of very close study by the engineer engaged in these works. There is no question that the sea is constantly moulding and operating on the profile of the foreshore to accommodate itself to the forces of the sea. Every wave is operating in just this manner. The contour of the sea bottom is changing with every change of the wind and tide although sometimes the changes are so slight that their measurement is difficult. To the trained eye these changes are readily discernible by the action of the waves approaching the shoreline.

G. K. Gilbert, in the 5th Annual Report of the United States Geological Survey, says that the material of which the offshore bars are composed consists of shore drift which is being moved parallel to the coast by alongshore currents. Some other geologists have disagreed with Gilbert's theory, but perhaps it is because they have not examined closely enough his reasoning. There is no question that the operation suggested by Gilbert has a powerful influence. How else are we to account for the removal of vast volumes of beach material in front of clift headlands? The forces suggested by Gilbert and De Beaumont and Shaler are all effective. It may be argued that the engineer engaged in coast protection works is not particularly interested in geological processes; that his work is primarily a matter of design. But with this view we do not entirely agree. Here surely is a field for the open mind, for an eager search for the truth if we are to prepare ourselves for our task in protecting the shoreline.

It is argued by geologists that coast protection is a losing battle; that the ocean's forces inexorably tend to level down the land-forms. Probably this is true but allowance must be made for the difference in viewpoint. The engineer has to meet the situations of the immediate present and the near future. A thousand years may be a short period in a geological study, but mortgages never run that long, nor will the materials which we put in our coast protection works endure for that period. And against this theory, too, we can point out large areas of ocean frontage where conditions are distinctly unfavorable, where nevertheless land had been held and enlarged in area. From the standpoint of erosion one of the most unfavorably situated sections is the northerly part of the clift headland of North Long Branch, and yet here coast protection works have been erected within the last few years which have resulted in reclaiming a large area of land and have postponed indefinitely the action of the ocean.

Offshore Bar and Beach Channel

One of the characteristic and for our purpose highly significant features of sandy ocean beaches is represented by a bar some distance offshore, between which and the shore runs a more or less sharply defined trough or channel, approximately parallel to the beach. The bar is a sort of ridge which the channel or gully separates from the beach.

None of these terms is entirely satisfactory or descriptive. The importance of these land-forms is that the trough too often forms a tide race or channel which presents hydraulic elements which may not be ignored.

The profile of the beach trough and its adjoining bar varies with the operation of a large number of forces, but primarily with the range of tide, velocity of alongshore currents, intensity of wave attack and mass and specific gravity of the material of which the beach is composed.

The manner in which these bars and channels have been formed—and there is nothing static about them—has been the subject of much study and speculation by many of the ablest geologists. There is no lack of supporters for a number of doctrines among which are—

(1) that the bar is washed up by the waves from the sea bottom;

(2) that it is washed down from the main beach by the waves;

(3) that it is composed of material transported by shore channels from other regions.

In any event, the engineer called upon to design coastal works cannot afford to ignore these critical features of the land-forms.

Heavy waves, always to an important degree waves of translation on a sandy foreshore, move toward the land and break over the bar. This trips the sea and great masses of water fall into a pool or channel of relatively smooth water on the landward side of the bar. The wave is broken and cannot in its original form return oceanward over the bars; yet the water thus catapulted must return oceanward. Some of the water does, in fact, flow back oceanward directly over the bar but much of it follows a path along the line of the trough or low or beach channel, as it is variously termed, until it reaches an outlet through an opening in the bar. This operation with the shifting of the outlet and bar itself explains many cases of apparently mysterious and sudden localized cutting of sandy beaches.

Some of the bars, in fact, work into positions where they constitute highly effective contraction works—employing the terms of the river engineer — which drive the cutting channel against the easily eroded beach. When the beach bar contour is seriously broken up by the channels which cut across the bar, a situation is created which is highly favorable for erosion. The heavy seas, breaking over the bar, dislodge and beat into suspension the lighter material such as shell particles and fine sand. Here, also, as in rivers, though to a lesser extent, a selection and sorting out of materials is taking place through the motion of the water currents and waves; the lighter materials being more readily transported. All observers are familiar with the discoloration of the water during storms, caused by the large quantities of sand and other material carried in suspension.

The bar may or may not—depending on the elevation of its crest and slope of its front with relation to the wave heights—almost completely absorb the wave impact. The profile of the bar will be subject to change and the bar itself will tend to shift under these conditions of heavy attack. A heavy break is simply evidence that the waves and the foreshore profile are not suited to each other; the forces of attack and of resistance are not in equilibrium.

In any event, the storm waves, with crests elevated greatly above the mean or average level of the sea at the moment, hurl enormous volumes of water into the pool. The level of that pool, assuming that the bar fairly completely breaks down the waves, more closely approaches but should exceed the average level of the sea. The bar to a marked degree operates as a submerged weir or sill, with a more or less pronounced head of water on its landward side, if comparison is made between mean levels.

The water in the pool is then going to seek the most favorable path to return oceanward and restore this level. That proportion which does not move back oceanward over the bar will follow a channel through a breach in the bar.

Actually the force and direction of the elements of the hydraulic problem are complex. The direction of the tide movement and the angle of incidence of the waves enter into the planning. But the ocean is emphatically not a body of still water in which waves mysteriously move shoreward without lateral movement of the water and then fall, leaving the water particles in place.

This prepares for consideration of a most significant feature of coastal forms which is comprised in these breaks through the bar. There is apparently no satisfactory descriptive term for them but the most common is "sea puss"; also "sea purse." Webster's Dictionary gives this definition:

> SEA PUSS—A dangerous, whirlpool-like form of undertow, due to the combined effect of several breakers; also an undertow setting along shore; called also sea purse.

The sea puss is, in fact, the most effective force in creating the undertow which is often dangerous to surf bathers, especially unskillful swimmers who exhaust themselves swimming against the current. Hopkinson Smith, in the novel "Tides of Barnegat," gives a highly dramatic description of the "sea puss."

The presence of this feature is readily discernible by the break in the continuity of the line of breaking waves and often by the different shade of the deeper water of the trough. A scalloped shoreline frequently attests its existence.

The prominence of the different features, the bar or the trough or the sea puss, may be relative. The bar may be so high and broad in expanse as to mask somewhat the existence of the sea puss, or the bar feature may be less noticeable than that of the sea puss. But their influence will be felt. Later in this report it is shown that breaches or orifices in offshore barriers operate precisely as do these sea pusses and the barriers themselves—cribs, sea-walls or bulkheads—operate in analogy to the offshore bars.

The profile across the beach bar, the adjacent beach channel and the beach proper is the result of forces in operation. The waves and currents are always moulding this friable material. It is not surprising that change does occur but rather that conditions are relatively so stable, considering the magnitude of the forces at work. It is the delicacy of adjustment of the forces that is wonderful.

Tides

Tides are variously defined as "An elastic or viscous periodic deformation of a solid or viscous globe under the action of tide-generating forces." (Encyclopedia Brittanica, 11th Edition.)

"The alternate rising and falling of the surface of the ocean and of gulfs, bays, rivers, etc., connected with the ocean." (Webster's Dictionary.)

Volumes have been written on the subject of tides. An elementary understanding of the ordinary and more important tidal phenomena is vitally necessary to the coastal engineer. It is not necessary, however, for the practical engineer to devote much labor to the study of profound mathematical treatises written on this subject. The many hours so spent by the writer could have been far more profitably employed on the beaches. The tidal day has a duration of approximately 24 hours and 50 minutes. Therefore there is an interval of about 12 hours and 25 minutes between successive high waters, with a low water intervening. This is stated in extremely simple terms, and omits consideration of the complex tides of some localities. The maxima and minima, extreme high and extreme low tides, generally require closest attention. The elevation attained by the water of the sea at high or low water varies somewhat from the elevation attained at the previous high or low water. Therefore recourse is had to calculated high water and low water elevations, which are based on observed elevations and are denominated "Mean high water" and "Mean low water." Necessarily the engineer works from local mean high water and local mean low water and not the elevation at some distant reference station. He will be required to refer his local readings of the tide to a reference station unless local bench marks have been established by some authority.

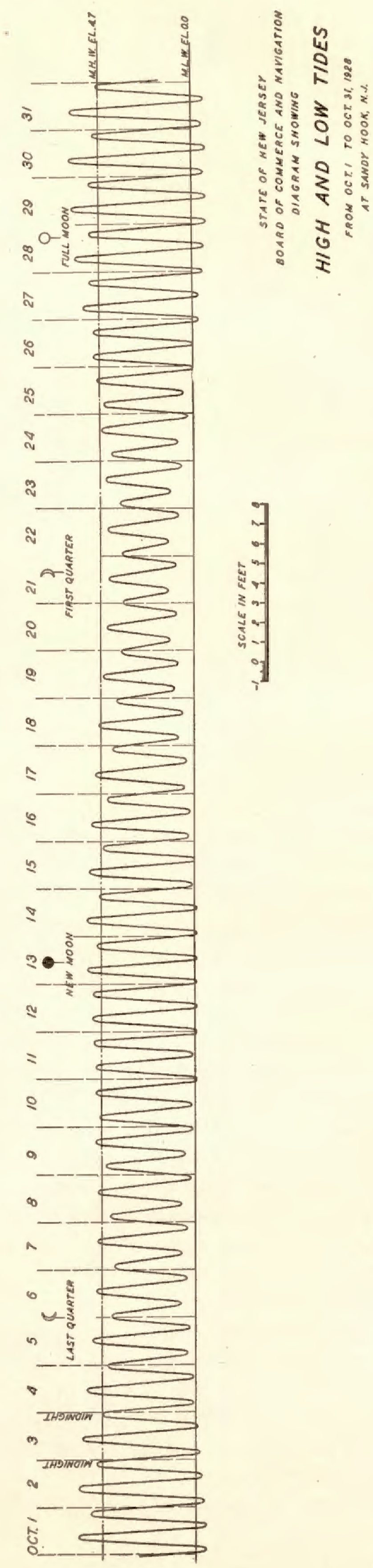
As high water and low water do not occur simultaneously at different points on a coastal region, differences in level exist which create a hydraulic head. This in turn generates currents alongshore and particularly at the inlets leading into the lagoon areas of barrier beach regions or into the estuaries. These currents are often responsible for accelerated erosion (or accretion), as they transport large volumes of beach material, beaten up by the waves.

The engineer must work out mean low water level because that is approximately the elevation at which the exposure to the air will cause timber work to decay and because he will find it necessary to carry down to that level the supporting details such as platforms, wales, and similar parts of the structure. This particular elevation may cause trouble in its determination because the contractor has a most limited time at low water slack tide in which to install the parts like the bottom wales in a groin, or bulkhead. It is essential in the ordinary timber groin or bulkhead to place the bottom wale at as low an elevation as possible because the sheeting is unsecured and the piles are not mutually supporting below the lower wales. Actually mean low water is about the minimum elevation at which this work can be performed unless the extra cost is assumed of employing elaborate apparatus to work below water-level.

Mean high water and storm tide levels must be established if protection is to be obtained. Groins should be designed with regard to mean high water, but sea walls should be designed with regard to storm conditions. The tendency seems to be, with sea walls, to build too low for onshore storm conditions; which is frequently unavoidable. The storm levels must be ascertained in any event.

Heights of storm waves and of still water levels are matters of local information and observation. Waves may impinge much more heavily at a given point than on the same shore a quarter of a mile distant, where conditions do not seem upon casual observation to be materially different. Much depends on the existence of offshore bars and shoals.

Successive tides are not of constant or uniform elevation. The range of the spring tides greatly exceeds that of the neap tides. Even night and daylight tides of the same day vary greatly in height. Spring tides occur at or shortly after new moon and full moon, whereas neap tides occur at the quarters when the moon is in quadrature. That is to say, the Spring tides occur when the sun and moon are working together in respect to the gravitational forces exerted on the earth. Neap tides are due to the sun and moon not working in unison, so to speak. The proximity of the moon, particularly whether in apogee or perigee, exerts a very con-



siderable influence. In short, nothing could be more complex than a study of all of the forces that affect the tides. But these complexities do not come within the field that is assigned to the engineer.

The moon exerts the more important force because of its greater proximity to the earth, despite the fact that its mass is so much inferior to that of the sun. This accords with the elementary physical law that the attraction between two bodies varies directly as their mass and inversely as the cube of their distance apart.

Curve Diagram

The above diagram shows the heights of mean low and mean high water predicted in the U. S. Coast and Geodetic Survey tide tables for the month of October, 1928, at Sandy Hook Station, New Jersey.

Note that the predicted elevations above the datum of mean low water vary from 5.9 feet on October 1st (full moon, September 29th) to 3.6 feet on October 21st, when the moon is in the first quarter. The difference of 2.3 feet is roughly one-half the mean tidal range (4.7 feet).

These are predicted tides based on the various meteorological and other factors, and necessarily omit from consideration a most important element from the standpoint of coastal works, the onshore and offshore gales. It is the coincidence of Spring tides with onshore gales of protracted duration or great intensity that produces the abnormally high tides and the heavy waves that cause the most serious damage. More accurately perhaps, the Spring tides raise the water level to the maximum and the gales generate large waves and of themselves pile up the water alongshore. These conditions permit the water to attain abnormal limits shoreward and subject structures to increased force of attack by the waves.

For a highly interesting and useful contribution on this subject, written in non-mathematical language, the reader is referred to "Tides and Their Engineering Aspects," by G. T. Rude, M. Am. Soc. C. E., in the August, 1927, Proceedings of the American Society of Civil Engineers.

The article "Tide" in the Encyclopedia Britanica is interesting and complete and contains much of practical interest. Much of the matter is necessarily mathematical, and this part, while of essential application in other fields of activity, is of limited practical value to the engineer designing coastal works.

The flood tide is the important feature to the engineer. It is the set of flood tide that controls the direction of littoral drift; it is the dominant feature but is somewhat modified and affected by the winds, particularly storm winds. There are many situations where the drift will fluctuate more or less from one side of an embayment to the other. But on a large scale and in a broad sense the direction of the flood tide movement controls the direction of littoral drift.

This photograph shows the abnormal height attained by the sea during an exceptionally severe storm, February 18, 1927, the wave rolling in high and striking the floor of the pier.

Comber striking floor of pier. February, 1927.

The destruction of the floor of piers and other structures of this nature is a familiar occurrence at almost every point of the oceanfront. The better practice is, therefore, to build wherever possible so that the floor fastenings will give way before endangering the caps and piling. Oftentimes damage to a pier or boardwalk that seems disastrous at first sight is quickly repaired with the expenditure of a few pounds of nails and a few hours of labor.

The outshore end of this particular structure was destroyed during the storm in question. It had endured many years and probably the piling had seriously deteriorated. But something has to give when these big combers begin to lift the solid structure. In any event, the elevation should be high if solid flooring is used, as will be required in a pavilion or casino. These costly solid floor structures should be given a good elevation, using other structures as a criterion. Also the waves should either be tripped outshore of the pier or else allowed to roll in freely. They should not be tripped, suddenly, under the floor by any form of obstruction.

Waves

On the subject of Waves there is no end of literature. Matthews, in "Coast Erosion and Protection," says that it is very desirable that those designing coast protection works should have a knowledge of the laws under which waves operate. With this statement, there should be no dissent. But it is submitted that the way to obtain that knowledge is to conduct the studies in the field.

The writer has read everything obtainable on this subject and has derived very little profit from that reading, in point of applicability to practical operations on the oceanfront and bays.

At the outset of the detailed studies of the New Jersey Board of Commerce and Navigation it was felt very desirable to conduct experiments that would expand the field of knowledge on waves. Many attempts have elsewhere been made to measure the wave characteristics and particularly the impact of waves on sea walls. The New Jersey experiments on wave characteristics, begun with high hope and conducted at a considerable outlay of time and money, yielded practically nothing of any value. The apparatus installed failed utterly in times of storms. While disappointing, the operations were not entirely valueless because, doubtless, it would have been necessary, in the state of knowledge of the time when these experiments were undertaken, to carry out these observations.

Most engineers desire formulas but formulas are always to be used with caution and in the light of experience. Matthews in his book says there are two matters in connection with wave action which are of extreme importance in designing sea walls or breakwaters—one, the force of impact of a wave; second, height to which a breaking wave will rise. He then quotes approvingly the eminent engineer, Smeaton, who said, "They are subject to no calculation." Thus is the marine engineer's task made difficult. Matthews is correct in saying that the force with which a wave strikes a plane surface can not be accurately measured because, while the marine dynamometer which has been utilized will give a certain record, this does not correctly represent the force of impact against the upright face of the sea wall because the wall is rigid; whereas the dynamometer is fitted with springs or plungers which creates a very different state of facts. The plate of the dynamometer against which the wave impinges necessarily yields, but the face of the wall can yield only by fracturing. Various writers have referred to the tremendous impact of waves and illustrated their statements with references to the dislodgement of huge rocks or concrete in breakwaters and jetties. While doubtless much of this movement of heavy rocks or concrete blocks has been due to undermining and consequent settlement of the rock units, nevertheless the writer has been impressed with the lifting of five or six ton rocks on the New Jersey coast which could only be attributed to lifting by the concentrated and "pocketed" force of the waves.

D. W. Johnson, in "Shore Processes and Shore Line Development," quotes Hagen, a German writer, as concluding that when an unbroken oscillatory wave strikes a vertical wall or cliff the base of which reaches down to deep water, the wave is reflected back. He points out that boats have been observed to rise and fall with successive waves without touching the vertical wall a few feet distant. Hagen therefore concludes that under such circumstances debris must accumulate at the base of the wall and that therefore the prejudice against vertical sea walls and harbor walls, based on the fear of undermining by wave action, is ill-founded.

Hagen's statements can be accepted in those situations where the depth of water is relatively very great compared with the height of the waves. He had in mind, undoubtedly, a situation where the oscillatory wave striking the vertical wall is merely lifted back on a cushion of water sufficiently deep. The reflection of this wave is caused by a hydrostatic pressure as it rises to a great height, stated to be twice its normal height. The wall or cliff must then be able to offset this pressure, but compared to heavy wave impact, this hydrostatic pressure alone is unimportant. This does not refer to the impact of vast volumes of water falling directly on the wall after a wave is broken. That is very different.

To the engineer, the important element of the height of waves is not the mathematical analysis but actual observation during the storms at the point in question. There will always be landmarks on a beach which will aid the engineer in determining this important element.

The person interested in the subject will obtain much information of practical value by making his own observations while bathing or boating.

Incidentally, the work by Matthews contains some very fine photographs of waves striking sea walls on the English coast.

Waves in the sea are described as waves of oscillation and waves of translation. The wave of oscillation is distinguished by the fact that it can occur only in deep water and the water particles through which it travels do not suffer any permanent displacement but are merely rotated through an orbit. Inasmuch as waves in the water are generated by the wind, it seems probable that there is no true wave of oscillation. In nature, high winds, at least, must blow forward some of the water from the crest of the wave. Floating objects in water which is subjected to the action of waves of oscillation will appear to move up and down as successive waves pass but have very little or no apparent lateral movement. Any wave approaching a sea wall before it breaks is for all practical purposes a wave of oscillation and may travel up the face of the vertical wall and return seaward for a very appreciable distance until it is encountered by a wave moving shoreward. Some of the pictures in this report illustrate this action.

Aside from this situation of the cliff or wall in deep water—deep with respect to the wave which may impinge on the particular shore—the wave of oscillation has no interest to the engineer. Waves of oscillation approaching a shelving shore gradually lose their form and assume the familiar curving profile before they break. Vast volumes of water are projected shoreward and must return seaward by one route or another.

The various formulas for calculating the height of waves are useful only in the absence of actual measurements on the beach in question. The point at which the waves break is a very important element in the calculation of the designer, but actual observation on a beach is infinitely superior to any calculation that may be devised. As an illustration, an onshore storm lasting two or three days or perhaps a week will inevitably modify the profile of the sandy shore. The point of breaking will be accordingly modified with this change in profile and with the generation in intensity of the storm with its effect upon the size of the waves and increase of still water-level. Johnson, in "Shore Processes and Shore Line Development," gives an excellent summary of the literature on the subject, and the Encyclopedia Britannica presents a fine mathematical treatment which few practical engineers will understand and probably none could apply usefully in design.

Sand Dunes

The high importance of sand dunes, elsewhere referred to as an ambulatory feature of the beaches, has not been sufficiently appreciated. On this subject much has been written. A highly interesting and valuable work on the subject of sand movement is Bulletin No. 68 of the U. S. Department of Agriculture, entitled "The Movement of Soil Material by the Wind," by E. E. Free.

Whenever the sea, by its wash and particularly by operation of onshore storm tides, throws up a ridge of sand above the mean tide and, in fact, above the wash of the few succeeding tides, it creates a situation that renders possible dune building. Sand deposited by the wind blowing from the sea on the familiar tidal salt marsh is favorably situated for the beginning of dune formation.

The sand layer, drying out as the tide recedes, is moved by favorable winds, blowing from the ocean, to form a bed or bank in a new situation, usually against plants or other obstructions. The offshore winds blowing from the land also carry back large volumes of sand. Their operation is particularly noticeable because they occur and, in fact, are largely responsible for the low levels of the sea as well as the subdued waves. But this sand does not travel far, as it is quickly trapped in the water or on the wet strand.

Actually in most cases where the engineer is called upon to design protective works, sand dunes no longer constitute an element in the landscape. Their destruction is to be lamented but becomes inevitable when the locality is developed beyond a certain degree. As between a row of sand dunes—beautiful and helpful as they are in resisting the forces of littoral attack—and a number of palatial hotels, each representing an investment of one to five million dollars, any locality will choose the hotels. As a consolation for the loss of the sand dunes, the valuations of the hotels and the rest of the community will support the cost of effective sea protection structures.

In this report under the caption, "Nature of Attack," a warning is given against leveling down the sand dunes. This caution is absolutely sound but must be considered only within the dictates of common sense. It is the elimination of the sand dune before the municipality becomes financially able to take care of its coastal problem that is to be avoided. Obviously, sand dunes must be removed when a large dwelling or hotel is to be constructed on the site. The dunes would be out of place in Atlantic City or Miami Beach or Asbury Park.

Again, the writer has satisfied himself that the dune formation will in all probability change as houses are constructed in close vicinity to the dunes, the houses and fences and hedges deflecting and contracting the wind currents somewhat as a similar obstacle affects water currents. Then the formation of glades is a possibility.

The first essential to the formation of a dune is an area of moist ground to hold the sand in place or else an obstruction such as a fence or house or trees or grass. The operation of the wind will not be very effective as long as the sand over which it blows is wet or moist. Mr. Free in the Bulletin above referred to says that surface tension in moist ground is a potent factor in resisting the dislodging force of the wind. The grasses, brushes, etc., form a lee where the sand particles are deposited out of the wind or in the case of a structure such as a house or fence form in addition to the lee an obstruction to catch the drift.

Situations often arise which call for the stimulation of dune growth. All barrier beaches that are of low elevation or intersected by an occasional transverse glade or slash should be regarded as potentially dangerous, because an inlet may form, either permanent or temporary, causing serious damage to property values and undermining an important highway. As an example, Professor Lewis M. Haupt issued the warning that a breach would probably occur where Beach Haven Inlet did break through some years later. The point is that dune building would in all likelihood have prevented this breach with its attendant loss of property values.

Much can be accomplished at such little cost that the possibilities should not be ignored. The growth of grasses, which should be encouraged, is very important, and stockades of the cheapest lumber and brushwood often yield remarkable results at an insignificant cost.

The Policy of Granting State Aid in Beach Protection

Each State is a sovereign with respect to its internal activities which are limited by a parliamentary or legislative contract or charter which is known as the State Constitution. Practically, then, the only limit upon the law-making powers of the State Legislature is the State Constitution, which in turn is limited only to the extent that the States have agreed by the adoption of the Federal Constitution. For our purpose, the State has supreme control over the beaches without interference by the Federal government excepting for the authority granted by the States to the Federal government for the regulation of navigation. This is contained in what is known as the commerce clause of the Constitution, which says, "The Congress shall have power: * * *

3—to regulate commerce with foreign nations, and among the several States, and with the Indian tribes;"

This is the Federal government's only control over coast protection works. If the proposed jetties or sea walls do not in fact constitute an interference with navigation, the Federal government has no authority in the premises.

The question, then, is whether a State may lawfully and as a matter of policy participate in the development and protection of the beaches situate within its boundaries. As most of the lands known as beaches belong to individuals or corporations or municipalities as distinguished from the State itself, the policy of the State's entering upon such lands and expending money for their protection is very likely to be criticized. The essence of the criticism is that the land owner should protect his own property and when the land owners are exhausted then each municipality should protect its own frontage. But what is to be the answer when the municipality has become intolerably burdened?

The questions had to be met in New Jersey where a liberal attitude has been adopted by the State government. That Commonwealth recognizes that whatever redounds to the benefit of its coastal communities must necessarily benefit the State at large; and, furthermore, that the State has a direct interest in the welfare of these divisions of the State. But it required much time and effort to bring about the present situation. It required in addition the staggering losses of years ago, when valuable properties, notably in the Boroughs of Longport, Monmouth Beach and Sea Bright, were destroyed, to convince the authorities that the State had an immediate interest in this broad question.

Obviously, reasonable regulations should control, and the tendency is defining itself that State appropriations should be limited to those frontages where the public will have free access to the beach. It has been ruled repeatedly that the intent of the State aid statutes was to authorize the State to aid the municipality in protecting the taxable, hence, privately owned, properties. Nevertheless, the conviction has become firmly established that public monies should be expended only for the protection of those beaches which are accessible to the public. It should be said that in New Jersey under "Park Act" legislation almost all the municipalities have acquired title to all of the beach lands lying outshore of an established line such as the inshore boundary of the boardwalk or other public thoroughfare.

The writer asserts without qualification that had the knowledge of coast protection in 1910 been comparable with what it is today and had the State established the legislative machinery and funds for participation in protective measures, many hundred thousands of dollars of ratables could have been saved from destruction. The great losses in Monmouth Beach and Sea Bright in the northerly part of the State occurred in the winter of 1913-1914. These losses were calamitous but they were not unforeseen. As a matter of fact, there is seldom anything sudden or unforeseen about losses through erosion by the sea. The beaches wear down gradually until the water actually undermines the structures that are ultimately destroyed. Seldom is any attention paid to the situation; the unfavorable tendency is ignored until actual losses are incurred. Enlightened communities should, of course, arrest erosion before structures are endangered, acting on the unfavorable tendency and forestalling the catastrophe. In New Jersey, for example, the resort industry is probably the outstanding single industry of the State. It is a serious matter if the destruction of buildings is permitted because with it is destroyed the confidence of investors and home owners and hotel operators.

Thus, at Longport, while this Winter 1913-1914 caused severe losses, as it did over much of the Atlantic seaboard, the erosion had been rapid for some time previous and continued for several years thereafter. Each private owner sought to protect his own property, but the attack was too heavy and unremitting to offer any hope of success from this procedure. The Borough also expended large sums in the construction of groins and bulkheads prior to the construction of the concrete sea wall. At the risk of repetition, it is stated here that Longport lost approximately 184 acres between 1880 and 1920.

The losses in these small boroughs culminated in the breach of the reinforced concrete sea wall at Longport, the construction of which had imposed so heavy a burden on that municipality. It must be remembered that this was all prior to the extensive improvements and developments that have occurred in Longport within the last nine years. These small boroughs finally became financially unable to proceed without help. Confidence in the very existence of Longport and Sea Bright was seriously shaken. The beach north of Sea Bright had been pierced before and a large number of houses in Sea Bright and Monmouth Beach had been undermined so that the situation was highly acute. These municipalities had shown the utmost courage in protecting themselves and had virtually reached the end of their resources. Representatives of the municipalities supported by civic bodies pointed out to the Legislature the acuteness of the situation and submitted that the State should lend its support.

These efforts were rewarded by the enactment of Chapter 318 of the Laws of 1920, which is entitled "An Act appropriating from the State fund a sum of money to be expended by and under the direction of the Board of Commerce and Navigation for the construction in whole or in part of such works and structures including sea walls, bulkheads and jetties and other approved devices necessary and proper to protect the riparian lands and taxable property of this State in municipalities within any county bordering on the Atlantic ocean, from destruction by encroachments of the Atlantic ocean and other destruction agencies of the sea." Briefly, the law grants to the State board complete control of the operation of constructing such sea walls, bulkheads, jetties and other devices as are necessary and proper, leaving the board to determine whether it shall of itself let the contract or allow the municipality to contract for the work. It limits the State's contribution to 50% of the cost of construction. Under this act $250,000.00 was appropriated, and several statutes in similar terms had since been enacted to permit additional appropriations. In addition, the Legislature has for a number of years past made annual appropriations to defray the expenses of carrying on repeated observations and surveys to determine the tendency on the beaches and the effectiveness of various types of structures.

The question of State participation in the development and protection of the sea beaches has been considered abroad (see the report of the British Royal Commission on Coast Erosion and Afforestation, published in 1911). That commission very carefully considered whether and to what extent government funds should be expended for the protection of the shore lands against erosion. The report contains this:

"We recommend that the Board of Trade should be constituted the Central Sea-Defence Authority for the United Kingdom for the purpose of the administration of the coastline in the interests of sea-defence, and that further powers should be conferred upon that board enabling it (a) to control the removal of materials and the construction of works on the shores of the Kingdom, and (b) to supervise and assist, where necessary, existing authorities concerned with coast protection, and to create new authorities representing all interests affected in particular areas where they may be found requisite for the purpose of sea-defence."

* * * * * * * *

"The changes that we have suggested in the law and administration of the foreshore in the interests of the public, and in the control of the coastline generally in the interests of sea-defence, will, we think, if adopted, afford great assistance to local authorities and private owners in dealing with the difficulties which many of them experience in connection with sea-defence. We are not prepared, on the evidence laid before us, to recommend that there is any case for going further and for making grants from public funds in aid of sea-defence. We think that the evidence to the effect that there is an alleged obligation upon the Crown to defend the coasts of the United Kingdom from the inroads of the sea does not prove that there is any settled principle of the Common and Statute Law to support the contention that there is a responsibility for sea-defence 'resting primarily upon the nation at large.' The main question appears to us to be whether there is sufficient evidence that the defence of the United Kingdom from 'the outrageous flowing, surges, and course of the sea,'—to adopt the picturesque description in the preamble to the Statute of Sewers of 5 Henry VIII—is a national service which should be undertaken and paid for by the State. We cannot see that there is any ground for the contention that sea-defence is a national service; it is true that there is serious erosion in places, but this erosion does not affect the nation at large. We do not think that the case calls for any intervention by the State beyond that resulting from the extended administrative assistance which we have suggested; any adoption by the State of a general policy of giving grants in aid of sea-defence would, in our opinion, subject the State to serious difficulties. We therefore recommend on this question that the making of grants from public funds in aid of sea-defence should not be encouraged, although we think that the provisions of the Development, etc., Act of 1909 might in some cases be reasonably used so as—while primarily directed to public purposes—to give incidental assistance to some poor communities whose land is in danger of being destroyed by the sea, —particularly where the authorities affected have done their utmost to provide adequate defence.''

Testimony adduced before the Royal Commission indicated that some of the Continental countries, notably Holland and Belgium, support coast protection operations from the government funds.

Types of Jetties

As in the case of groins, or perhaps in even greater degree, there is no limit to the variety of methods of assembling at a given site the rock, timber, concrete, hardware or other materials employed in the construction of a jetty. The simplest jetty is a mound of rock, sand bags or concrete blocks thrown out in the water and comprising in effect an artificial promontory. The Longport jetty, the Sea Bright jetties, and the first Asbury Park jetty are of this type—large, costly structures of the simplest elements. These jetties were built without impervious diaphragm or core. In the case of the Longport jetty, a broad massive structure with material widely assorted as to size and subjected to rapid cutting currents at its outer end as it proceeded seaward, the omission of the core proved no detriment as the jetty is perfectly tight and impervious. The amount of material used, however, was enormous, due to the necessity for filling the pool which formed ahead of the jetty. For the same reason, settlement has not been nearly so pronounced in this jetty as in others where less material was used.

The omission of the core in the first Sea Bright jetty did not for a long time result in serious seepage; in fact, the jetty performed satisfactorily.

The large jetty at the northerly boundary of Asbury Park, heretofore fully described, though it reached a state of severe depreciation prior to its rebuilding, functioned very satisfactorily from the standpoint of protection. However, progressive deterioration had before its rebuilding permitted the formation of seepage pools.

Nevertheless, with these examples before us, it is submitted that a core should be provided in these large jetties, unless it is possible, as in the case of Longport jetty, to use enormous quantities of material widely assorted as to size. Note the conditions at an inlet with the sea wall acting as a training wall. The Monmouth Beach jetty is one of the structures that demonstrates the necessity for a good tight core. The picture shows this structure and the pool that has formed because of its broken core.

Monmouth Beach jetty showing effect of leaks, September 17, 1927.

The marine borers severely attacked this core but something happened to pierce the core in its earlier stages because the pool that runs crosswise of the broken core never filled up with sand. The seepage through the jetty became more and more pronounced as time went on and although a good bar formed alongside of the outshore part of the jetty, the work can not be said to have functioned satisfactorily.

This operation points to one precaution that should be taken, and that is to preserve the core against breakage by the rocks or by submerged obstructions. Omitting from consideration those cases where the core is broken by poor workmanship or faulty operations, it is possible for one of the large rocks weighing three to seven tons to settle in such a manner as to break one of the planks which form the core. This would suggest a substantial core and for an ideal construction the use of small stone against the core fortified by outer banks of heavier rock. It must be remembered that the rock in a jetty will always settle to a greater or lesser degree. It has been urged that rushing the construction will obviate or greatly reduce the settlement but that statement is not yet proved. The settlement will come sometime. It can be said with confidence that the rock in a jetty will find a suitable slope whether the engineer prescribes that slope or one that is too steep. Furthermore, the laying of heavy rock on sand washed by every high tide, or low tide, for that matter, or as in the Monmouth Beach case, placing the rock on the mud stratum, the sand having been entirely denuded, will surely result in settlement. The heavy rock will lay itself a suitable foundation.

The first requirement, imperviousness, is sought to be met by the incorporation of a timber or steel or concrete or composite core. The core by itself is nothing more or less than a substantially built groin. This quality of imperviousness can be obtained without providing the core of timber or other material if a sufficient quantity of well assorted sizes of stone or slag or other massive material be employed. There is relatively little hazard from the contractor's standpoint, other than bidding too low, in merely depositing rock at the unit price of so much per ton in this type of construction (not considering the ever-present danger of damage to plant by storms).

But the construction of the core presents a very difficult situation involving real risk and requiring experience and skill. The core work must necessarily proceed ahead of the rock placement, yet if the depth of water is considerable, the core will require the support of the rock. In practice, therefore, the core work is kept just slightly in advance of the rock. The outer end of the core might well be damaged or wrenched by tumbling or carelessly swung rocks or if carried too far ahead of the rock, supports might be damaged by waves or wreckage.

Inasmuch as the problem of building the core of the jetty consists essentially of first building a groin and then supporting it with rock, it seems unnecessary to describe the core construction since the details are fully described under the heading of "Groin Operations."

The great cost of the rock and its tendency to bed down and to spread under the wash and buffeting of heavy seas have led to the adoption of various expedients to reduce the volume of rock.

The primitive type of jetty, the rock structure without core, needs no further description. The operation of building the trestle for transferring and depositing the rock is familiar to everybody. Next in order comes the jetty type which has a central core of timber or steel or both combined with rock placed on each side of the core with suitable elevation and width of top and side slopes. The cross-section of one of these jetties is similar to a trapezoid bisected vertically by the core. In this type various artifices for bonding and placing the rock are resorted to with the object of preserving steep side slopes but they usually fail.

Next in order may be considered the various crib types which are designed by eliminating side slopes and spreading of rock to effect an economy over the previous type by reducing the volume of stone. In this crib variety, the rock is restrained by rows of piling at the outer sides, thus eliminating the side slopes as well as the scattering tendency of the rock. The core may be in the center, in which case the stone is restrained by two exterior rows of timber piling well tied with tie rods and running parallel to the core. Another design consists of one tight core and parallel to it a row of piling closely spaced with the chamber between filled with rock. As the rock thrusts against the outer timber work, good ties extending across the structure between the two rows of piling are necessary.

Still another departure consists of two parallel tight groins well fastened together with tie rods, the intermediate spaces being filled with rock.

Examples of all of these types are now in use in various places on the New Jersey coasts.

With respect to the stone itself, the essential requirement is to obtain a material that will not float away or dissolve or be otherwise lost. Granite, gneiss, sandstone and to a limited extent trap-rock are available within reasonable access of the New Jersey coast. The source of the rock used on a given job depends chiefly on the freight rate. The stone itself possesses no magic properties although there is some plausibility to the argument that the rough sides of a jetty with rock exterior and center core are more effective in trapping the sand, in that the voids and interstices operate gradually to break up the waves and reduce the back rush of the water after the waves break.

But the outstanding value of stone lies in its weight and resistance to dislodgement by the waves. It is to be employed when the wave attack and depth of water transcend the limits permissible with groins. The rock furnishes the necessary superior artificial holding bottom in situations where the timber groin without such fortifications would be floated out and it shortens the loaded beam which is formed by the groin elements under wave or current or sand pressure.

On the height of jetties there is no general universally applicable rule. The engineer must be guided by experience and existing conditions. The ideal would be to build groins or jetties high enough to prevent undue erosion by the waves cascading over to leeward and low enough to permit the sand to pass into the next bay as the zone protected by the jetty fills up. The types of high massive jetties suitable for the most exposed sections of the northern New Jersey coast are neither effective nor economic on the greater part of the flat beaches of the southern part of the State. Excessive height represents not only a waste of money but results in comparative inefficiency. Furthermore, while jetties or groins can be raised within limits, it is practically impossible to reduce their height in the event that an error is made in determining the elevation.

As to the angle of the jetty, it is submitted that in general the jetty should be laid with its alignment at right angles to the line of the beach. Only exceptional circumstances warrant the various hooks, fins, spurs, sharp and flat deflection angles and other complexities of alignment. If any of these complex plans of alignment are considered, attention should be given to the possibility of repercussion and other interferences with other jetties and sea walls. In support of the adoption of alignment other than the right angle system, it is argued that the line of the groin or jetty should be vertical to the line of the waves; but the fact is that the angle of wave impingement varies somewhat with the wind and tide and is certain to change as the jetty begins to function and modifies the shore contours.

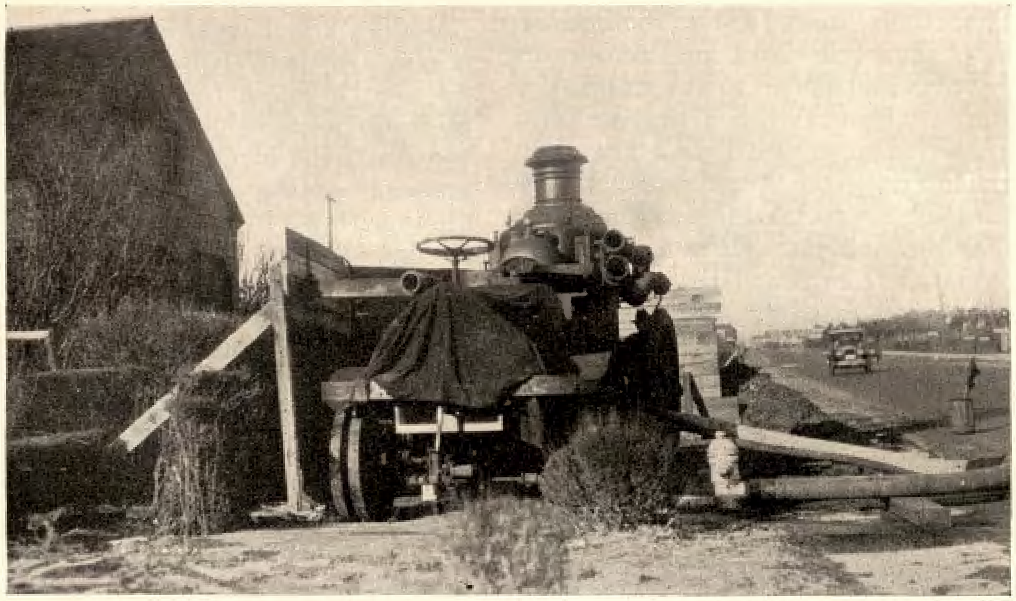
Every angle in the alignment of a framed structure of the bulkhead or groin type, most of which will be underground or submerged, introduces difficulties in construction and hazards in regard to effectiveness of operation. The angle creates a break in the continuity of the timber pieces. Hence, a plane of weakness. Plates and gussets strengthen the wales but no practical means are known for insuring tightness of the timber sheeting below low water mark. Furthermore, excessive bolting at angles often reduces the timber cross-section to a highly undesirable degree.

Practical Operations

It seems hardly worth while to devote much time or space to the treatment of the practical work of constructing groins and bulkheads. The actual details do not differ from those involved in the construction of bridges, wharves and similar structures. The essential element consists of round or king piles usually of timber but occasionally of reinforced concrete or steel which, acting as beams, form the primary support of the groin or bulkhead. The next necessary element consists of the stringers or wales which are bolted to the piling. The third element consists of lighter but continuous material known as sheeting, which acts as an impervious curtain or diaphragm and is either bolted or spiked to the wales. None of these operations differ in any respect from those involved in the construction of cofferdams. The wales are laid horizontal and the round piles and sheeting are usually driven vertical but may be driven at any desired angle or batter. The contractor may employ either some form of hammer for driving or the use of a water jet which acts to displace the sand or other material and thus permits the necessary penetration with the piling and sheeting. Frequently, it is found advantageous to use both hammer and jet. The method to employ in the given case to obtain the desired penetration into the earth is determined by the existing conditions and it would be futile to offer any general rule for the determination of these practical questions. The engineer and the principal will surely not confide work of this nature to a contractor who lacks necessary plant and experience. The experienced contractor will have his own ideas of attacking the problem. Of course, where there is a considerable range of tide the contractor will necessarily shift his plant and force with a view to obtaining the utmost economy. It is submitted, however, that whenever subsoil conditions permit the feasibility of employing the water jet, it should be given consideration, for great economy may be frequently realized through the use of this appliance, as well as far greater accuracy in placing the piles and sheeting. It is a matter of common experience that there is far less tendency to drift when the water jet system is applied. However, coarse substrata through which the water propelled by the jet would be too rapidly dissipated, hard material and other conditions will argue for the adoption of the hammer method. On the other hand, closely packed fine sand which tends to retain the water propelled by the jet and is thereby easily displaced for the penetration of the piling, would indicate the advisability of employing the jet. Perhaps it is safe to offer the general statement that on the Atlantic coast of the United States extending southward and westward from Montauk Point, except where there are rock strata to be encountered, the water jet system should be employed for all but final penetration. There are, of course, localized conditions where rock outcrops or hardpan strata will call for the use of the hammer, or hammer and jet, but normally the presence of a substratum which approaches rock in hardness will require blasting operations before attempting to drive piles. Even then, round piles will probably require the use of a shoe, and penetration with sheeting will probably be out of the question.

The forms of appliances for jetting are infinite in number. There is a great diversity of opinion among contractors and engineers as to the relative merits of water jetting plants. Some contractors use steam plants very successfully while others prefer pumps driven by internal combustion engines. A similar diversity of opinion will be noticed in comparing the relative merit of piston drive and centrifugal pumps. Conditions are not uniform and the contractor will employ what he can get in the way of plant. The competent contractor will necessarily determine these things for himself, being guided to a high degree by the availability of plant and the necessity for keeping down expenses. The primary object to be sought is to secure a sufficient volume of water and an adequate pressure to obtain the necessary penetration at the most economical outlay of money and time. It is proper to stress the necessity for obtaining an adequate volume of water as well as sufficient pressure. This point is frequently overlooked. As a matter of fact, in the large operations the contractor frequently modifies his plant and operations as the work progresses.

Obviously, the measure of useful pressure is the pressure at the nozzle and not at the pump, which may, with extended operations, be rather remote from the actual jetting. While in some situations it is perfectly feasible to employ salt water from the sea, in others it is preferred to use fresh water taken from wells or in settled sections from the municipal water supply system. It must be recognized, of course, that the water taken from the municipal hydrants must be paid for—which forms a considerable item of cost; whereas the contractor is free to use the sea water if his machinery will permit. To offset the cost of the city water or of driving wells as against the use of sea water it is to be remembered that the city water is free from sand or grit or other objectionable matter, whereas the sea water may require straining in order to be sufficiently clear. Another advantage offered by the use of fresh water taken from the municipal hydrant is that the pressure need only be boosted to the required limit above the stipulated city pressure. This may, under some circumstances and particularly if obtaining adequate pressure, be an important consideration but well worth considering because city pressures are often held at forty pounds or more. Usually where a series of groins or jetties or a long sea wall is to be constructed, the contractor will find it necessary to provide a mobile pumping plant of which a number of types are obtainable. Some very efficient plants in operation today include old-fashioned horse-drawn or automobile steam fire engine pumps. One or more jets can be utilized in order to obtain the necessary volume of water at the available pressure.



Mobile Pumping Plant.

Piling and Sheet Piling

Piling, whether of timber or plain or reinforced concrete, are usually thought of as bearing posts or columns which are intended to aid in the support of loads that are otherwise too heavy for the soil in question. But actually this function as a post or column as distinguised from a beam has little application in Coast Protection operations except in respect to masonry sea walls; and even with masonry sea walls it can accurately be said that the sand or other beach material of which most beaches are composed can and does support very heavy masses as long as the sand is undisturbed or confined. The piling is intended primarily to prevent unequal settlement of the masory wall, and until such disturbance of the soil is occasioned by undermining in some manner, the piling may play a relatively secondary part in supporting the wall. However, it is true that piling should always be provided in the construction of a sea wall or any other structure of moment on a sandy or gravelly beach that is subject to overflow.

But the major function of piling in Coast Protection structures is to act as beams—cantilever in groins or jetties and either cantilever or supported at the upper end and fixed in the ground just below the ground surface in sea walls of the bulkhead or sheet wall type. The engineer must decide what beam formula to employ. The ordinary sheet wall or bulkhead can be described roughly as consisting of one or two rows of round timber or reinforced concrete piles as the major support and acting, as aforesaid, as beams and connected one to another for mutual support, preservation of alignment and distribution of impact with longitudinal framed members known as wales or stringers. Efficient design requires that these wales or stringers be securely fastened by bolts or otherwise to the pile. The other function of the wales, but a vital one, is to serve as the support of the impervious lighter members known as sheeting or sheet piles. Some writers prefer to apply the name "sheeting" to light boards two inches or less in thickness, and "sheet piling" to the planks of greater thickness. This is purely arbitrary matter. Obviously, the round timber or reinforced concrete members that act as the main piles could be dispensed with and the entire structure built of heavy sheet piles securely fastened together by the wales. This is a familiar procedure in certain cofferdams where different conditions often render that type of construction feasible. However, the light sheet piles with heavy round timber or concrete piles acting as supports are much more economical, which explains their wider use in bulkheads. The sheeting is almost always a very important factor in the cost and never to be skimped.

It is a very important matter in driving piles to secure a good penetration into a firm substratum, particularly if the structure is to serve as a sheet wall subject to the thrust of earth or water; failure through pushing out at the toe must be eliminated from possibility. The piles which are employed to carry the weight of a wall are termed bearing or master or king piles. They act as posts or columns to support a superimposed load. In the bulkhead or sheet wall type of structure the pile acts, as has already been indicated, as a beam. The first consideration in planning the pile elements of any structure is to obtain sufficiently accurate knowledge of the soil. Borings should be obtained whenever possible and in the absence of borings the engineer must drive test piles at suitable places to obtain the necessary information. To ignore these essentials in planning is doubtful economy. The necessity for ordering the lumber well in advance of the work, particularly if creosoted lumber is specified, requires that the length of piling and of the sheeting be accurately determined before the specifications are drawn.

Almost any kind of wood within reason will serve as piling. Naturally some varieties are preferable to others. Yellow pine is readily obtainable commercially, as is Oregon fir along the seaboard. Hence these varieties are more freely used. White oak or mixed oak are frequently used, and, of course, have many well known favorable qualities. Local experience and individual preferences and perhaps above all other considerations, availability, have much influence in determining the choice of timber. Oak with its high specific gravity and great strength and toughness naturally has many advocates. It is more durable but in general is not as well formed as the pine or fir.

REMOVING BARK FROM PILES

The writer believes in leaving the bark on piles unless the bark is obviously loose. No advantage results from peeling. Certainly where the driving is not hard enough to strip off the bark it should be retained in place. This, of course, applies to untreated piling.

DRIVING PILES

Modern pile drivers are still largely operated by steam, although internal combustion engines are used to an increasing extent. The use of the water jet is treated elsewhere in detail, and frequently the hammer and jet are used simultaneously or the jet may be used to lower the pile to within a few feet of final penetration and the final driving carried out with a hammer. Provided no deformation of the pile is incurred, it is of little interest to the designing engineer whether the contractor use a drop hammer or a steam hammer. In many situations nearly all of the driving will be effected with the water jet, but it is highly important to require that the pile top shall not be injured in the driving and it is important in the writer's opinion always to obtain the final penetration with some form of a hammer, even though the water jet is used.

POINTING PILES

It is usually required that the foot of a timber pile shall be cut off square with its axis, particularly in hard ground as it is easier to adhere to alignment. There is much dispute among practical pile driving men as to whether there is any advantage in pointing piles for driving into hard material. Undoubtedly for certain degrees of compaction of substratum pointing does offer some advantage. In many situations the only method of obtaining required penetration with timber piles is to attach a metal shoe.

DRIVING PILES WITH BUTT DOWNWARD

It is almost invariably the custom to drive or jet timber piles with the small end downward, but there are engineers and contractors who advocate driving the piles in some situations with the large end downward to resist lifting out by floating. There is no question that this argument has some merit, but the writer has seen its application carried to absurd extremes in the construction of groins and as a result a poor structure was obtained; the supporting upper parts of the piles above the ground line being virtually meagre sticks. Obviously the thrust of the water or floating wreckage is resisted by the upper end of the piling acting as a beam and if these are of poor section and weak, anchoring the piling against flotation by driving the butt end down will nevertheless leave the structure open to destruction as the result of the weakness of the piles acting as beams above the sand line. Instead of the piles which act as cantilever beams having a diameter of thirteen or fourteen inches, they will have a much smaller diameter—six or seven inches; and the section modulus varies with the cube of the diameter, $\frac{I}{C} = \frac{\pi d^3}{32}$

PRESERVATION OF TIMBER

It is recommended that in general treated timber should be employed both in groins and bulkheads to protect against both marine borers and decay. It would serve no useful purpose to pad this report with standard specifications for creosoting. There is no doubt, however, of the advisability of using treated timber.

Those interested in this particular phase are referred to such works as "Marine Structures, Their Deterioration and Preservation," by Messrs. Atwood & Johnson, published by the National Marine Council of Washington, D. C.; "Wood Construction," by the National Committee on Wood Utilization, published by the McGraw Hill Book Company, and to the reports of the Forest Products Laboratories.

In the warmer southern waters the danger of marine borer attack is so great that only the most unusual circumstances as to finances or other reasons would warrant the use of untreated timber in salt water. The danger, however, is much greater than is generally supposed even in the northern waters of New Jersey, New York and New England. The attack is very erratic. Untreated piling or other timber may endure for fifteen or twenty years in a given waterway without appreciable damage from borers; whereas new timber may be riddled within a season or two. This has happened within the writer's experience. It was never supposed that borer attack was unduly severe at the mouth of Clam Creek, Atlantic City. Old wharves and piling of untreated timber had lasted almost indefinitely. Yet at this very point the wooden drain covers installed by the city were completely destroyed by borers in one season. Untreated timber groins were first attempted under the State aid projects at Cape May City and were riddled the first season by the teredo, so that some of the jetties had to be strengthened with steel sheet piling and the later projects and subsequent designs have specified creosoted lumber and steel sheet piling. It seems needless to issue the customary caution against bruising or damaging treated lumber. Nevertheless, it is often handled in a very careless manner in unloading from cars or by bruising with crowbars and canthooks.

Of marine borers there are two principal classes — Crustacea and Mollusca. Limnoria, Chelura, Sphaeroma belong to the Crustacea, and the Teredo, Bankia and Martesia belong to the Mollusca. The primary importance of dividing the two classes, stated roughly, is simply that the one type eats away the wood from the exterior while the other works entirely inside of the timber. The determination of the various species belongs in the field of the biologist and not of the engineer. The scientific names of the various classes of borers are not of primary interest to the engineer except possibly that the attack of the Teredo type, which enter the wood as larvæ and grow to a large size entirely inside of the timber, is perhaps more insidious since the depredations of this type are less readily evident than the attack of the borers which work from the outside of the timber and visibly reduce the cross-section of the timber.

Certain harbor authorities, where serious attacks have been suffered within recent years, have issued regulations designed to eliminate as far as possible wreckage of wharfs, or structures that would form breeding places and centers of diffusion of the various marine borers. This seems to be well founded as it should tend to reduce the available areas for breeding.

Professor Thurlow C. Nelson of Rutgers University, who has for years conducted an experimental station in Barnegat Bay in latitude North 39° 55′ under the auspices of the New Jersey State Shell Fish Commission, has in connection therewith extended the studies to the operations of the various types of borers which attack wood structures as well as those which attack shell fish. Professor Nelson during these experiments has constructed rafts of different kinds of timber ranging from balsam at one end to greenheart at the other. These experiments have disclosed that in seasons when the ship worms are very active they work from the balsam through all of the varieties of the wood, even the greenheart being subjected to heavy attack. On the other hand, when the worm attack is not so severe it was found that the worm worked through the other woods but did not attack the greenheart. In other words, it was found that when there is a heavy crop of these borers, they will attack anything in the timber line.

Professor Nelson found that in this latitude the activities of these marine borers lasted only from six weeks to two months, the sets coinciding with attainment of a certain degree of temperature of the water. It was found that with a late spring the spawn would be thrown off very slowly and would be destroyed by their enemies, such as the jelly fish, which consumed vast quantities of these sea worms as well as of oyster spawn. It was found that attack by the borers is very light in those years when the oyster spawn failed to set, indicating conclusively the similarity of conditions required to support these varieties of marine life.

The essential requirement is to prevent the borers of any kind from beginning work on the timber. They may be repelled mechanically by means of coating with metal or concrete or by burlap and asphaltum casings of the timber or by the chemical method which consists of impregnating the timber with solutions which will be distasteful or poisonous to the borers.

The various expedients of covering piling with large headed nails have been treated in various books, as has the method of covering with galvanized metal or copper. But these expedients are very expensive. The writer has been apprised of and will follow with interest the installations in southern waters, including Miami Beach (Biscayne Bay), where untreated local timber piling was employed, using as a protection wire mesh and concrete coating.

In the chemical system it is essential that the preservative with which the timber is impregnated shall repel the borers and shall not quickly leach out. Various toxic agents have been employed but the writer's experience extends only to the creosote treatment. This creosote system has great merits but it is fair to say that there may be a good deal of deception among the more unscrupulous dealers, and the engineer should require that the treatment be applied by thoroughly reliable dealers or be sure that he obtains real inspection. Contracts are generally let on a competitive price basis with consequent strong temptation to beat the specifications or at least crowd them to the very limits.

Hardware in Groins, Jetties and Bulkheads

Hardware embraces the tie rods, bolts, nuts, collars and other metal appliances that form so important a group of items in the design of groins, jetties and bulkheads. It would serve no useful purpose to add to the bulk of a report of this nature by incorporating standard specifications for metal work. Whether to use galvanized metal for the various operations has been the subject of considerable differences of opinion, primarily because the galvanized material is more expensive. There is no question, however, that galvanized metal tends toward greater durability and should be specified certainly in those works where superior lumber is specified as distinguished from jobs where cheapness is the controlling essential. It is sometimes urged against the adoption of galvanized bolts or tie rods particularly, that the threading is performed subsequent to the galvanizing process with the result that the threaded portion, which is really the vital part of the bolts or ties, is just as much exposed to corrosion as in the case of non-coated steel or wrought iron.

This particular objection, which is perfectly sound, can be met by specifying that the bolts and nuts shall be galvanized after threading, but, on the other hand, it must be recognized that this procedure requires the use of oversize nuts which in turn renders it difficult to fasten up the work to a tight, firm bearing.

These arguments can be continued indefinitely. It must be recognized that it is economically most unsound to allow a costly jetty or bulkhead to be jeopardized by allowing the bolts and nuts to deteriorate without adequate maintenance. These details represent no very great part of the costs of materials, yet their preservation is vital to the integrity of the structure. Every means possible should be taken to retard their depreciation and adequate maintenance should be provided for.

General Discussion of Timber Bulkhead Walls

The ordinary bulkhead wall is a rather stereotyped form of construction. It is essentially a strong board fence resembling the side of a simple cofferdam in its elements and when high enough to require it, has the additional feature of a tie rod to prevent excessive outward deflection from the thrust of the backfill. It is supposed to be supported in the rear by an earth fill which resists the wave impact. The pile, acting as a beam fixed or cantilever in one case and simple beam in the other, is thereby supported against undue deflection in either direction. When constructed of good material by competent workmen and employed in situations where the exposure from the waves is not too severe and backfill pressure is not excessive, this form of sheet wall or bulkhead may yield gratifying results at moderate cost. The design of a bulkhead should be undertaken with due recognition of the fact that it must act as a retaining wall with respect to the earth fill and as a dam with respect to the water in front. It seems to be customary to build a wall fourteen feet high with the same materials as would be used in a wall five feet high, disregarding the greatly increased pressure.

No skimping in the dimensions or quality of the wales should ever be countenanced because it can effect no real saving, and it will incur great risk. Since the round piling is generally recognized as the primary element in the support of the sheet wall, this factor is usually amply provided for in the conventional designs, but too often there is a tendency to cut down the size of the wale pieces. As the wales form a very small proportion of the bill of materials, any reduction in their dimensions will effect the cost of materials very slightly. This is never worth while in view of the fact that the wales are important parts of the work, serving the important function of distributing pressure or impact. Adequate wales may well preclude the danger of partial failure due to the incorporation of an occasional weak round pile in the wall.

The wale shown on the outer face of the bulkhead is indicated primarily for the purpose of criticism, recognizing, however, that it will constitute an element of sound designing in many different situations. In the exposed situation under consideration, however, it is unfortunately an element of weakness because it is liable to destruction by storm waves with consequent danger of damage to the rest of the structure. It is particularly vulnerable to damage by floating wreckage, such as logs or heavy timbers, which, when lifted by strong waves may strike it a concentrated blow with tremendous power. Obviously, the force of this criticism varies with the degree of exposure to waves and to wreckage. For example, the statement has relatively little application if the bulkhead wall is constructed well inshore and serves primarily as a retaining wall and only incidentally and occasionally as a sea wall. The point is illustrated by the photograph of the Margate City bulkhead taken after a storm when the tide had fallen.

Margate City Bulkhead, after storm.

strong board fence resembling the side of a simple cofferdam in its elements and when high enough to require it, has the additional feature of a tie rod to prevent excessive outward deflection from the thrust of the backfill. It is supposed to be supported in the rear by an earth fill which resists the wave impact. The pile, acting as a beam fixed or cantilever in one case and simple beam in the other, is thereby supported against undue deflection in either direction. When constructed of good material by competent workmen and employed in situations where the exposure from the waves is not too severe and backfill pressure is not excessive, this form of sheet wall or bulkhead may yield gratifying results at moderate cost. The design of a bulkhead should be undertaken with due recognition of the fact that it must act as a retaining wall with respect to the earth fill and as a dam with respect to the water in front. It seems to be customary to build a wall fourteen feet high with the same materials as would be used in a wall five feet high, disregarding the greatly increased pressure.

No skimping in the dimensions or quality of the wales should ever be countenanced because it can effect no real saving, and it will incur great risk. Since the round piling is generally recognized as the primary element in the support of the sheet wall, this factor is usually amply provided for in the conventional designs, but too often there is a tendency to cut down the size of the wale pieces. As the wales form a very small proportion of the bill of materials, any reduction in their dimensions will effect the cost of materials very slightly. This is never worth while in view of the fact that the wales are important parts of the work, serving the important function of distributing pressure or impact. Adequate wales may well preclude the danger of partial failure due to the incorporation of an occasional weak round pile in the wall.

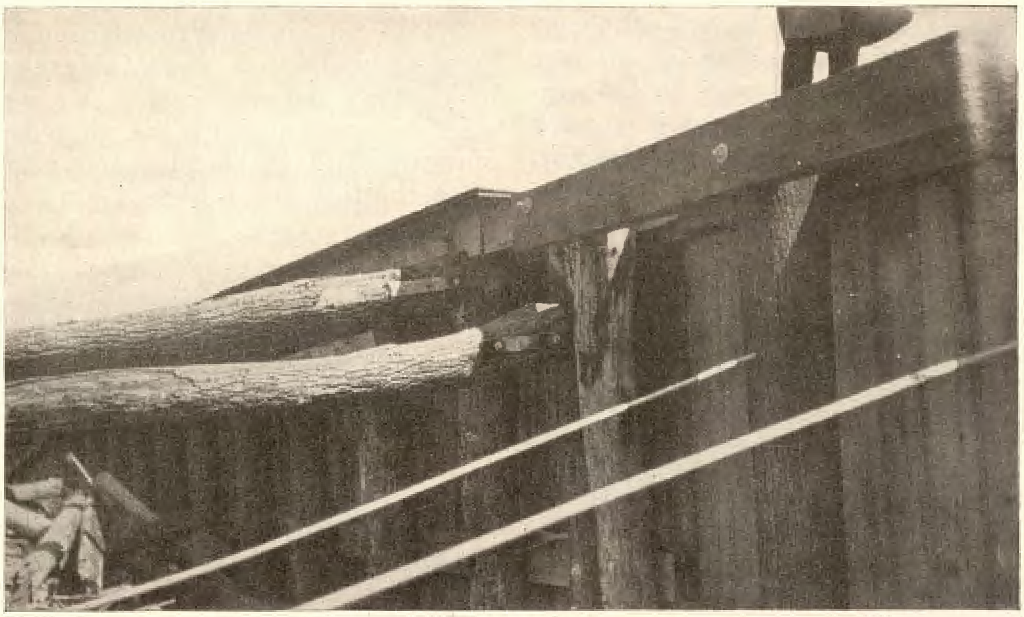
The wale shown on the outer face of the bulkhead is indicated primarily for the purpose of criticism, recognizing, however, that it will constitute an element of sound designing in many different situations. In the exposed situation under consideration, however, it is unfortunately an element of weakness because it is liable to destruction by storm waves with consequent danger of damage to the rest of the structure. It is particularly vulnerable to damage by floating wreckage, such as logs or heavy timbers, which, when lifted by strong waves may strike it a concentrated blow with tremendous power. Obviously, the force of this criticism varies with the degree of exposure to waves and to wreckage. For example, the statement has relatively little application if the bulkhead wall is constructed well inshore and serves primarily as a retaining wall and only incidentally and occasionally as a sea wall. The point is illustrated by the photograph of the Margate City bulkhead taken after a storm when the tide had fallen.

Margate City Bulkhead, after storm.

This unfortunate feature of probable damage by floating wreckage may be obviated to a large degree by using a beveled lower edge for the timber wale or by using a metal strap in place of the timber wale. The fitting of the holes to be drilled or burned in the metal plate to the bolts through the round piles is a detail that will considerably affect the cost and must therefore be worked out carefully. Both of these expedients have been adopted in various places on the New Jersey coast where the desirability and expediency of making the highly exposed bulkhead faces as smooth as possible is coming as the result of experience to be regarded as axiomatic.

In many other cases bulkheads are constructed without exterior wales, entire dependence being placed on the bolts which hold in place the sheeting. Were it not for the hazard of wave action and wreckage attacking these projections, it would be highly desirable from the structural designing standpoint to place the piles and wales outshore of the sheeting, as is customarily the practice in wharf structures of the relieving platform type and other works erected in less exposed situations. This plan, with outside wales, yields the more favorable condition of having the earth thrust compress the sheeting against the heavier timbers, the piles and the wales, instead of placing the bolts in tension. The omission of the outer wale and consequent reliance on the bolts will necessarily result in depreciation of the structure as the bolts rust.

An improvement over the above described type of bulkhead is that in which brace logs are utilized both as compression and tension members. Naturally this type of construction is somewhat more expensive than the preceding type. Theoretically, the tension members should extend shoreward of the line of natural slope for the particular material which composes the backfill. Just what that slope may be under the varying conditions of moisture in the backfill is a matter for the individual to estimate for himself. Obviously, the length of the brace logs will affect their original cost and handling and effectiveness in acting as struts. While the backfill remains effective, it will tend to support the strut throughout its length, which in turn will influence the effect of lengthening the strut.



Strut log strap-fastened acting as tie.

It is to be observed that the length of the metal strap in this type without tie rod especially should be sufficient to develop reasonable resistance to longitudinal shearing in the timber brace log. The attachment of the collar strap can be worked out by a number of methods but that shown in the photograph is about as simple as can be conceived. The labor of fitting the bolts to the holes in the strap is tedious and is reflected as a rather considerable item of the cost. Lag screws might be substituted for bolts to reduce this labor cost, but it is questionable whether the results would be as satisfactory. A wall thus braced is capable of a high degree of resistance to the waves, but, like all sheet walls, really requires the support of a backfill of earth or suitable material and must not be expected to endure indefinitely without it. Racking and vibration from wave pounding cannot be endured indefinitely. Deprived of this backfill, the structure is supported as to wave attack only by the vertical piles acting as cantilever beams—supported, of course, by the brace logs acting as struts. Nevertheless, the resistance of some of these structures on the New Jersey coast to heavy wave attack after losing backfill through destruction of neighboring sea walls has been rather remarkable. Good waling pieces are essential to distribute the pressure or impact among the vertical or main piles.

A better wall, structurally, can be obtained often at little or no greater cost by substituting one of the newer types of deep arch steel sheet piling for the timber sheeting. The Miami Beach and Sea Bright sea walls are examples. The deep arch sheet piling with its high section modulus possesses great strength. Furthermore, with particular respect to the pressure below the bottom wale, it possesses great advantages because of the continuous interlocking feature which is less certain and less impressive as to strength in the standard tongued and grooved or splined or certain other types. In other words, the engineer is assured with the steel interlocking system that the lower parts of the sheeting are in good contact; unless the driving is so unskillfully performed as to strip the interlock.

Steel Sheet Pile Seawall.

Sand-Tight vs. Permeable Groins

There has been considerable conflict and disagreement among engineers as to whether sand-tight or permeable groins offer the greater promise of success in arresting littoral drift. It is certain, however, that if the engineer adopts the sand-tight principle, he must so design and build the groin as to attain sand-tightness. If there is any breach or gap in the groin, the chances are very slight that any success can be looked for. The very principle of the sand-tight groin is that it must be impervious.

The permeable or open groin, on the other hand, seeks not to arrest immediately but to check the drift. It has for its object the checking of the movement of the water that carries the sand in suspension, so that the sand will pass through the groin and be deposited equally on both sides. Unquestionably, this offers a great advantage over the sand-tight system when success is attained, but it requires that the spacing between the piles in the permeable groin be exactly suited to meet the existing natural conditions.

It is evident that the advocates of the open, permeable groin system are, in effect, seeking generally the ultimate impermeability as to sand; that is to say, the system of groins, not the individual groin, must arrest the sand drift within the area protected by the groins. The idea seems analogous to the well known fact that an infinite number of small sticks or blades of grass will check the flow of the waterway if the surface of the obstructions be so great that the friction offered to the flow of water will overcome the head which induces the flow of water. This even distribution of sand is only one of the advantages that are claimed by the advocates of the permeable groin system, who also urge the much greater cost of sand-tight groins.

It should be said at the outset that many of the so-called open groins that have been built on the New Jersey coast were not open in fact. While the piling and braces were driven in accordance with the conventional permeable system, that is, merely rows of closely set piling bolted and fastened together without any sheeting, in many instances the groins were loaded with brush and rock. Whatever merits may be argued for these particular structures cannot be claimed as belonging to the permeable system. Nevertheless, on the Ocean City and Sea Isle frontage some of these open structures seem to have worked very well. On the Brigantine City frontage it was reported by the engineer for the Island Development Company, Mr. W. I. Eaton, that the open groins gathered beach during the summer but were largely destroyed by the winter storms.

It would be a great boon if the shore frontage could be protected in exposed localities with groins of the open system because the sheeting in the sand-tight system as a rule represents the major item of expense. Furthermore, the leeward side of the sand-tight system of groins too frequently shows a lowering of the beach as compared with the elevation to windward.

The coast of New Jersey has been the testing ground for almost every type of construction that can be devised for the purpose of halting erosion or inducing accretion of beach material. It is necessary to preserve the scientific standpoint of seeking only the truth. That requires making careful allowance for many factors in appraising the results obtained by various types of construction. It would be unfair to criticize or to praise unduly any type of construction without affording an equal chance for rebuttal. However, excepting in the Ocean City and Sea Isle frontage of New Jersey, the tendency has been to abandon the open type and rely on the impervious form of jetty or groin.

Ventnor Crib Wave Breaker

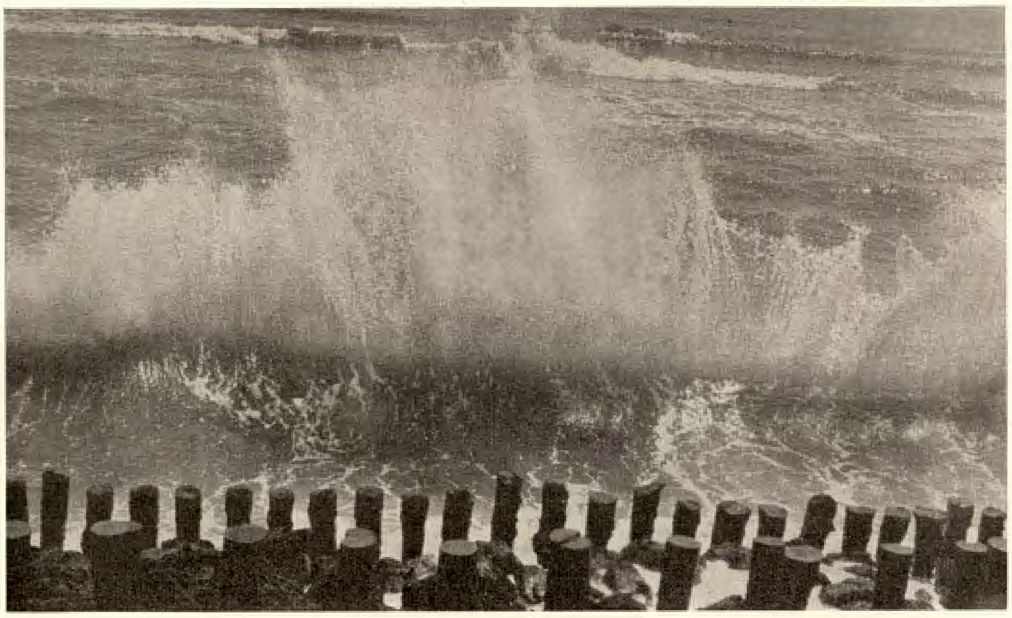
The elements of this structure are so clearly indicated by the plan and photographs that no extended verbal description is required. Briefly, it consists of a row of closely spaced round piles on the seaward face connected by tie rods to an ordinary timber and sheeting bulkhead on the inshore face, the space between being filled with rock. Originally with a view to saving cost of material, cedar brush was used as filling material weighted down with the rock. From the shore building standpoint it is much less favorably situated than the Ventnor bulkhead wave breaker above described, in that this crib structure is at or oceanward of ordinary low water mark. Therefore the waves impinge upon it during the entire normal tidal swing, consequently leaving no rest period. It is unattractive in appearance, particularly since it is now covered by marine growth, mussels, etc., although it was not unattractive when first constructed and filled up to grade. Its cost is necessarily much greater than that of the low bulkhead type already described, but it is only fair to say that by reason of its more substantial construction it would survive wave battering that would wreck the lighter structure. As it is shoreward of ordinary low water mark it utterly destroys the frontage as a bathing beach except for children who bathe in the shoreward pool of the structure when the tide is sufficiently low. A breach in the sheeting marks the widest and deepest part of this backwater pool.

The presence of a number of jetties with which this wave breakwater is coordinated should be noted. It is not clear at this time why the jetties other than that at the leeward end were extended shoreward of the wave break structure. It is submitted that these windward jetties, at least while the filling material was at grade, tended to prevent the entrance of the littoral drift from the northeast. Probably the intention was to prevent the water thrown over by the waves from racing out laterally. On the subject of structures of this kind, Professor Lewis M. Haupt, in the Annual Report of the

Ventnor Crib Wave Breaker. Looking N. E. (windward).

Ventnor Crib Wave Breaker, July 14, 1928. Rock and timber covered by heavy growth of mussels.

Ventnor Crib Wave-Breaker, July 14, 1928. Depression in right background caused by break in sheeting.



Ventnor Crib Breakwater, July, 1928. Meeting of incoming and reflected waves. Sea calm.

State Geologist of New Jersey for the year 1905, at page 88, says:

"The crest of the counterscarp is manifestly the best location for a series of wave breakers so placed as to cause the overfall to cushion on the water behind them, which will be comparatively still. Such structures should rise somewhat above the high water-level and be curved in plan to decompose the waves. Openings should also be left to admit detritus and pass fishing boats and other small craft. These devices do not interrupt the use of the beaches for driving, bathing or other purposes, as is the case with spur-jetties."

It should be noted, however, that the wave breaker forms a straight line in plan, whereas Professor Haupt suggests that the structure should "be curved in plan to decompose the waves."

The use of brush weighted down with rock in jetties and wave breakers of this type had considerable vogue for some years prior to and following 1910. It undoubtedly furnishes relatively inexpensive means of providing the filling material necessary, but the results have been disappointing in too many instances. The structure is impressive at first but the brush work quickly settles as the foliage is destroyed and the boughs are occasionally washed out, creating more or less of a nuisance on the bathing beaches. The boughs remaining in place as they are lowered may be quickly destroyed by marine borers. In any event, the brush quickly wastes away from one cause or another. If the grade first established with the brush and stone is determined as correct and necessary, then obviously this feature is lost when the brush is destroyed and the rock settles.

Ventnor Bulkhead Breakwater

This is a timber structure of very simple construction, the details of which are so clearly shown on the plan and photographs that no extended description is necessary. It was constructed by the municipality.

It is relatively inexpensive, and while in no sense novel is nevertheless interesting in operation and doubtless suitable for many localities. It is important to notice the L-plan—the connection to the shore being at the leeward and open at the windward. The basic idea which controlled its adoption is correct — the waves should, when conditions permit, be broken and weakened offshore instead of being allowed to rush with undiminished force against the shore walls and bulkheads which form the immediate and ultimate protection for the roads and dwellings.

If correctly located, and this is highly important, it serves as a first line of defense by definitely precluding the heavy storm seas from crashing with all their force upon the land structures. It is inferior in perhaps every re-

Ventnor Bulkhead Breakwater, May, 1928. Looking southwest from Municipal Pier.

Ventnor Bulkhead Wave Breaker. Looking west from Municipal Pier, May, 1928.

Ventnor Bulkhead Breakwater, May, 1928. Looking southwest, Municipal Pier in background.

Ventnor Bulkhead Breakwater, May, 1928. Looking north from Municipal Pier.

spect to the breakwater created by nature—a high wide beach — but some situations are affected by circumstances that urge its use. The protection of roadways running along the sea could frequently be obtained by constructing an offshore bulkhead, supplemented by a relatively inexpensive wall or bulkhead at the roadway. It does seem as if a change is due in the almost universal practice followed by highway authorities, of limiting their protective works to the actual boundaries of the road proper. This is like refusing medical aid until a patient is desperately ill. Modern pavements and the property right of adjacency to major highways are too valuable to be endangered and lost because of a fear that public money will be employed for the protection of private property. The destruction of a beachfront hotel or dwelling through attack by the sea is not only a private loss; it is a public calamity in any municipality. It results in direct immediate financial loss to every property owner in the taxing district, who must assume his share of the burden, which is necessarily shifted from the owner of the destroyed building to the remaining property owners. The resulting discouragement of prospective investors and builders may entail a loss that is enormous, although necessarily impossible to measure.

It should be noted that this wave breaker is of tight impermeable construction and, as noted above, it is securely attached at its southwesterly end (leeward) to a crosswall or return of similar construction which extends well inshore. This is intended to act as a jetty, trapping the littoral drift. It is therefore not an insular wave breaker.

This form of device has its defects and objectionable features, some of which may be serious. This is to be expected of any such structure which has no counterpart in land-forms as they emerge from the sea. The waves ever seek to establish smooth profiles; to this law a work like that under consideration does violence by abruptly tripping and reflecting the incoming waves. Only too frequently the backwash from the reflected waves scours a trough in front, while the overfall cuts a depression at the back of the bulkhead. At the same time the welling and surging of the partially impounded water is likely to prevent deposition of sand. The extent and result of these disagreebale features depends very largely upon the position of the bulkhead with respect to low water and high water line; in other words, the effects of the backwash and other adverse features will decrease in direct proportion with the length of the rest periods during which the waves do not reach the breakwater; the most favorable situation for a sea wall structure of any type, having regard only to the profile of the beach, being well back of high water line. Yet the engineer may have to disregard this principle in some situations because if a breakwater is required it is usually advisable to construct it well oceanward of buildings to be protected, otherwise there will be no leeway, and the seas, breaking over, will damage the buildings to a greater or less extent. Proximity to an inlet will have a very considerable influence also, because the flood tide current especially will operate to move the sand that is stirred up by the breakers and backwash. This is very important.

Attention is particularly invited to the pool formed inshore of the breakwater. This condition, which is often observed in connection with structures of this sort, is not to be wondered at. The water which breaks over is necessarily higher than the mean level of the sea at the time and must return oceanward by some avenue. Any breach or leak in the structure is made evident by pronounced scouring. The constant motion of the impounded water is unfavorable to the accumulation of sand which results in the formation of a pool on the landward side of the breakwater. But, of course, this is only one factor which may be outweighed by other forces.

Any marked excess of depth or width of a part of these pools over the average depth or width is to be taken as evidence of a breach through the barrier. In the present structure the enlargement of area of the pool is the result of fixing the elevation of the top wale a few inches below the wale adjacent, by which the point of outflow of the water which breaks over is definitely fixed. A breach or leak would have a similar but more pronounced effect.

Advocates of this type of protection argue that in addition to breaking the waves, it operates to gather sand, urging in support of this contention that the waves are more or less heavily charged with sand as they strike the breakwater and that this sand is deposited in the allegedly still water in back of the structure. This seems plausible and is to a certain extent true, but the truth is that the water in the pool is anything but still while the waves are breaking over the barrier. All the water that is thrown over by the waves necessarily returns oceanward, and much beach material is carried out with this outflowing water. It is believed that the major movement of wave-driven sand takes place along and near the bottom, and that if the breakwater projects appreciably above the beach profile this movement is seriously interfered with. Sand in suspension is certainly lifted over, but this is largely fine material much of which returns with the backwash.

Whether to construct a breakwater or a series of groins or jetties cannot be determined by any general rule. It is largely a question of what goal is sought and the possibilities presented. Pressing necessity for immediate protection of valuable structures facing on a depleted shore may require the protection of an artificial barrier; in that case it might be impossible to await the action of groins and jetties. In the work under discussion the objectionable features inherent in sea walls and breakwaters have been minimized by choosing a location well inshore of low water line and by fixing the height at a very conservative elevation above the beach. Obviously this favorable condition is frequently lacking.

A comparison between this wave barrier and the Ventnor Crib Breakwater is highly interesting as the two works are in close proximity.

Sea Walls

GENERAL

A sea wall is defined by Webster as "a wall or embankment to resist encroachments of the sea." It may therefore be constructed of a single material such as rock or earth or it may partake of a composite character and include two or more building materials such as wood, stone, steel, concrete, etc.

The simple mounds of rock or earth need not be considered further except that the artificial earth embankment might require a facing of wood, steel or concrete. The construction of such works is simple and their location with respect to and the shoreline and the incorporation of a core or cut-off wall may be the only question that would require special experience.

But the sea walls which are composed of concrete or of the other prepared materials of construction are a more complex matter, as numerous failures attest. In its essentials, this form of construction consists of the sea wall proper, a more or less massive structure which is faced with material impervious to water,—usually masonry or wood or steel sheeting. The quality of massiveness must usually be present whether the wall be of the gravity type of masonry or of masonry reinforced with steel. In the gravity type the masonry itself is present in such volume as to furnish the weight necessary whereas in the reinforced masonry type, the high strength of steel is utilized with a view to economy of construction and the massiveness desired in obtained from the backfill.

In many respects the design of sea walls is similar to that of retaining walls and dams. A sea wall with respect to the earth fill in back of it is a retaining wall and must be designed from that standpoint. It must be made secure against sliding or toppling into the sea as a result of the pressure exerted upon it by the earth fill which in turn supports it on the landward side against the impact of the seas which strike its ocean face. This is the ordinary problem of retaining wall design which so frequently confronts the engineer on railroad or highway construction.

Of course, the backfill pressure against a sea wall may be very high at times, particularly during on-shore storms when the waves and spray, thrown up high on striking the wall, are blown landward by high winds. Then the backfill may be saturated, with a low angle of repose. Ordinarily, however, the backfill is composed of clean sand which is easily drained. Another dangerous situation may be created when the backfill is deposited immediately against the wall by hydraulic dredging. Even with hydraulic dredging a dike should be built so that only dry material will be placed against the sea wall.

This hydraulic dredging method which is frequently employed should be applied with great care not alone because of the thrust of the saturated earth, but because of the necessity for taking care of the runoff water. Various expedients will suggest themselves to any engineer or contractor. Obviously, much depends upon the relative height of the fill and the facility with which the back fill drains itself.

But there is one important difference between sea wall and retaining wall design aside from the feature of wave and water pressure and that is in respect of the foundations. Ordinarily the earth that will support a retaining wall can readily be prepared to preclude undermining or serious settlement; on that vital point the designer can rest secure. But this is not true of sea walls, except in those unusual cases where the structure can be founded upon and hooked into good rock or carried down to a hard substratum below any possible settlement. Since sea walls are usually constructed on sandy coasts and unconfined wet sand is not dependable as a foundation, the design should proceed on the assumption that the foundation of sand or gravel or mud will occasionally be lowered to such an extent as to cause failure, unless some protection is provided. To meet this requirement it is customary to drive bearing piles to carry the weight of the wall temporarily during a wash out of the sand.

The impervious diaphragm known as sheet piling should also be regarded as a vital adjunct of most sea walls. It may be of timber or steel or reinforced concrete. It is analogous to the cut-off walls in dams. It must be securely incorporated into the wall to prevent leakage at the joints.

Both the bearing piles which are intended to support the weight of the sea wall and the sheet piling cut-off are essential features of a sea wall. As both of these parts of the structure will be invisible after the sea wall is completed and as they entail a large part of the cost of construction, it is only to be expected that they are most likely to be slighted.

But this neglect of these vital elements is a grave error for it is to inadequate foundations that most failures of sea walls are due. It is not intended to imply that ample provision should not be made for wave impact which is encountered by the visible part of the sea wall, i. e., the face or sea wall proper, but it seems advisable in view of the many failures from undermining to suggest that the most rugged and impressive masonry structure will almost certainly fail if any considerable settlement takes place in the underlying material.

It is certainly inconsistent to stress the wave impact feature while ignoring other considerations such as the foundations, that are at least equally important. In the first place with sensible supervision added to adequate design, it is not unduly difficult to provide for the wave impact if the position of the wall with respect to high water mark is first determined.

Assuming a tight impervious face wall securely backed with clean sand or gravel and we have a structure that can resist considerable wave hammering—as long as the face wall is not distorted, and the backfill remains in place. The estimates and such measurements as we have of wave impact are rather impressive but so is the bearing power of confined sand or gravel. (See American Civil Engineers' Handbook, 1920 Edition, page 607).

The chief weakness of the light structures known as sheet walls or bulkheads, placed in

Seawall, Sea Bright.

Steel Sheet Pile Seawall, Sea Bright.

highly exposed situations, is that any serious racking or twisting will permit the escape of the backfill, which usually results in quick failure. That bane of coastal engineers, heavy wreckage catapulted against a light face wall, often causes disaster. In a timber face bulkhead type wall, so much depends on the tightness of the sheeting and the holding of the bolts; but the bolts rust, decay of the wood alongside of the bolts and especially the tops of the piles is always imminent, the sheeting may warp. In the light reinforced concrete type dependence is necessarily placed upon setting the steel accurately and upon obtaining a concrete that is highly resistant to the effect of sea water. If the steel becomes exposed the loss of this vital element, the reinforcing, quickly follows.

It is to be remembered that a sea wall is attacked by many atmospheric agencies and in addition suffers from the vibration caused by the waves.

The steel sheet piling bulkhead or sheet wall type, when supported by creosoted timber piles or in some situations by reinforced concrete piles, is attractive from the structural standpoint, on the basis of cost per lineal foot of wall, compared with the all-timber or lighter reinforced concrete systems.

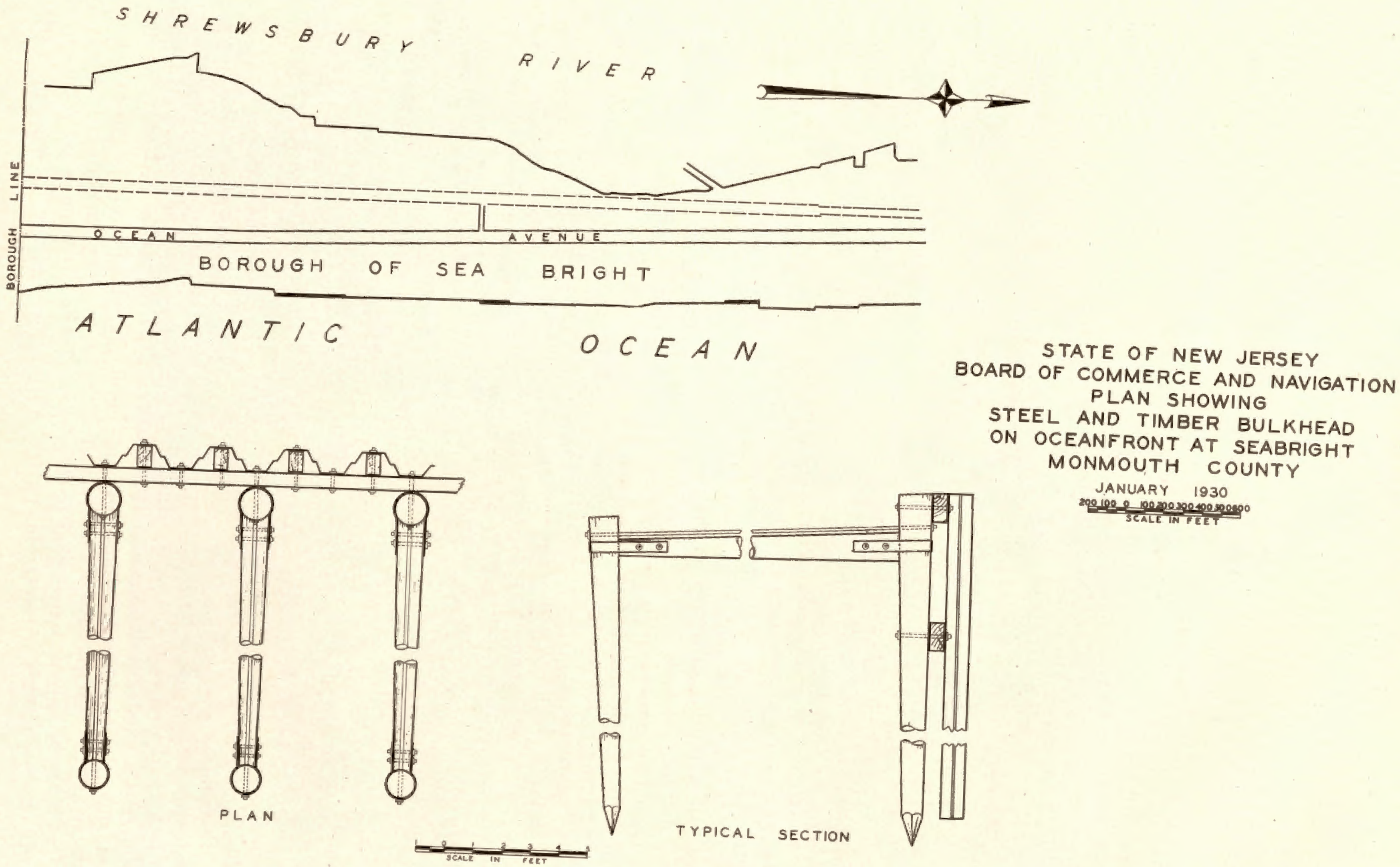
No wall should be constructed unless protection of building or roads or other structures require it or unless the beach is low and bounded by a lagoon, thus presenting the possibility of an inlet breaking through. A wall unsupported by groins or jetties is seldom of great value in beach building and only too often detrimental. But usually a wall is required because communities as well as land owners almost never undertake protection until buildings and roads are undermined and serious damage has actually occurred.

If it is decided that a wall is needed, the type of structure is then to be selected. While the first consideration from the engineering standpoint is to keep the wall back on shore as far as possible, this desired condition may have to yield to other necessities such as freedom from spray and wash during on-shore winds. If the wall can be placed well shoreward of ordinary high water line so that it will be required only during storms, the problem is simplified and almost invariably an inexpensive structure will serve. But if the situation is such that protection of valuable structures requires placing the wall where it is exposed to heavy wave action during a great part of the day with normal tides, then a substantial structure is necessary. It is a case of choosing between construction of an adequate wall on the one hand and inviting destruction of property exceeding in value the cost of a good wall, on the other.

There is no hard and fast rule that will control the selection of the type of sea wall for a given frontage. Almost always the engineer is placed under serious financial limitations. Furthermore, the characteristics of an extensive frontage will vary to such a degree that it is a question whether in the interest of economy a single design should be planned for the entire frontage. It is all a question of degree of exposure. The detailing of an efficient joint between two sections of widely different design requires the utmost care to avoid the creation of a plane of weakness at the junction.

Bulkheads and sea walls are often opposed when the question arises for protecting an ocean beach against erosion. There is no denying that the erection of a more or less elevated structure along a beach presents some objectionable features such as the blocking of the ready access to the beach, impairment of the view, etc. Nevertheless, it is a fact that must be faced that when serious erosion is occurring and roadways and structures are in imminent danger or have already been damaged by undermining, there is frequently no substitute for a sea wall structure. The unfavorable features inherent in this type of construction may be minimized but can not be altogether avoided. It should be remembered that a good timber or steel sheet piling bulkhead may be infinitely superior to a poorly designed masonry sea wall however massive and imposing in appearance. Too often the masonry sea wall by its very appearance conveys a false impression of security. The masonry work must be absolutely well supported by piling together with a first class cut-off wall. The bulkhead type, of course, is primarily a cut-off wall.

There is no evidence that the profile of the face of a wall exerts any considerable influence in arresting the movement of along-shore drift. However, in many instances where walls are well placed back of the mean high water line there is no denying that they have been effective in catching drifting wind blown sand. Therefore, the statement that sea walls intensify


SHREWSBURY RIVER
BOROUGH LINE
OCEAN AVENUE
BOROUGH OF SEA BRIGHT
ATLANTIC OCEAN
STATE OF NEW JERSEY
BOARD OF COMMERCE AND NAVIGATION
PLAN SHOWING
STEEL AND TIMBER BULKHEAD
ON OCEANFRONT AT SEABRIGHT
MONMOUTH COUNTY
JANUARY 1930
SCALE IN FEET
PLAN
SCALE IN FEET
TYPICAL SECTION

erosion or frequently act as the agencies of their own destruction while true in certain situations should be taken with caution. It is perfectly true, however, that a sea wall whether its face be vertical, battered or elliptical, if placed outshore of mean high water line, particularly adjacent to an inlet where hydraulic currents are active, may accelerate the deepening of a trough or flood tide channel along its toe. This operation if carried far enough will ultimately result in undermining the wall. That danger which confronted the Longport sea wall in 1923 was met by the deposition of riprap at the foot of the wall. The details of this operation are fully covered in the Board of Commerce and Navigation Coast Protection Report of 1924 and need not be reviewed here. At a matter of fact the work involved no particularly interesting or unusual features.

The contracting effect of a sea wall erected on ocean frontage adjacent to an inlet must be given due consideration but seems to have been generally ignored. On a frontage where there is a measurable range of tide, the flood tide especially tends to impinge against the shore and follow the shore into the inlet. This operation usually results in the creation of more or less well defined troughs or deeps which may be defined as flood tide channels. Consider, therefore, the operation of a relatively smooth faced wall planted at about low water mark on the frontage under discussion. The tide is rising, enormous volumes of water are moving on the flood to the inlet. The flood wave has worked into the shore and there may well be a head or difference in level of two or three feet or more operating on a distance of less than one-half mile. The waves, whatever be the quarter of the wind, strike the wall and are thrown back, tending in many instances to dislodge and scour out the sand at the toe of the wall. The wall then acts to a very pronounced degree as a training wall or harbor improvement jetty because the water is flowing toward the inlet. The height of the water at the foot of the wall and the angle at which it is reflected should be noticed.

This plan and photographs show a very substantial sea wall. The general view indicates that exposure to the sea is severe, the beach has been entirely denuded and substantial structures are required.

Margate Sea Wall

This interesting structure consists essentially of a timber bulkhead supported and weighted with concrete, braced and tied back to two sets of brace piles in the rear. Long timber piles, the tops of which extended nearly to the elevation of the top of the wall, were driven on three-foot six-inch centers. These long piles were connected by three sets of wales, the upper wale a six-inch by six-inch timber located about two feet below the top of the wall, the middle wale system being composed of two three-inch by ten-inch planks spiked together and then bolted to the pile, at about mean high water level. The bottom wale consisted of a six-inch by six-inch timber at about ordinary low water level. These long piles were then braced back to a vertical pile with two two-inch by ten-inch planks spiked together, at a point about four and one-half feet below the top of the wall and just above the middle wale braced back by a long strut to a low supporting pile well in the rear. A one-inch tie rod helped to hold this lower brace pile in place and operated as a tension member in resisting the forces tending to slide or topple the wall into the sea.

To carry the weight of the wall, close spaced round timber piles were driven to approximately low water mark. Two rows of two-inch by ten-inch timber sheeting, jointed at the middle wale and spiked to the three sets of wales, protected the face of the concrete wall.

The wall was built by a land company which reclaimed large areas of marsh and beach front in the period between 1910 and 1913. A great length of this wall was destroyed in the severe storms of the winter of 1913-1914, but a considerable frontage of the wall is still standing.

It is very difficult to analyze a structure of this character because of the number of assumptions that must be made in computing the effectiveness of the various members. Exposure is fairly severe, and the attempt was made to break up the waves with two rows of closely spaced round piles six feet and nine feet from the face of the wall. The wave impact, after being reduced somewhat by the low piling in the front, would be taken by the mass of the concrete, the backfill, the brace log and the brace planks near the top of the work, and the resistance to shearing of the long piles. The reason for the great extent of this wall failing while the frontage near the old Winchester School did not fail is not clear at this time. The writer, however, believes that the two rows of piles acting as a wave break are too close to the wall for effective service with heavy seas as the crest of the wave with an on-shore wind, high tide level and large waves, would still strike the wall a terrific blow. Furthermore, the writer does not approve of relying upon the timber work above low water mark or at least one foot above low water mark, and has never been favorably impressed with the idea of relying upon timber work imbedded in concrete. The shrinkage or decay of timber will ultimately destroy the bond between the reinforcing material, timber in this case, and the concrete. If concrete is to be reinforced, steel is the proper material for that purpose. The section of the concrete is none too impressive as a retaining wall, particularly with a depleted beach in front, a saturated backfill, and, as probably happened in the storms of 1914, large quantities of water piling up in back of the wall. Of course, this is not an ordinary gravity wall. Failure of this structure required shearing off the long piles which acted as beams. Whether the blanket of earth in front of the wall under these conditions was sufficient to prevent a blowout is always a serious and pertinent question. When this condition is approached the blanket at the toe of the wall must be increased, preferably with rock. It is a significant fact that much of the frontage where the wall is still standing is protected by good quantities of riprap held in place by the low closely spaced rows of piles.

On at least one large section northeast of Cedar Grove Avenue the wall sheared off at the middle wale. With a condition of severe depletion of the beach in front of the wall and a heavy thrust from the earth and water in back of the wall, the resistance to overturning by toppling into the sea would come from the one-inch tie rod, the plank braces four and one-half feet from the top of the wall and the resistance offered by the beam fixed in the ground and supported by the tie rod formed by each of the long piles. The low piles are of very little help in this particular section in this regard. They penetrate only slightly into the concrete and are intended to act as bearing piles and not as beams.

The foregoing is offered in no carping spirit of useless criticism. The officers of the company which developed this property were earnest men who applied their talents and risked their capital and finally suffered great losses. The engineers were capable, experienced men who merit and have received the highest respect of the community.

The development which was of a high order comprised a large tract extending from the ocean to the inland waterway. Unproductive and unsightly areas were reclaimed and beautified. As property oceanward of the trolley line was highly valued, land was reclaimed from the ocean by building the sea wall and raising the grade with sand dredged from the inland waters.

The storms of the Winter 1913-1914, which destroyed the greater part of this wall were extremely severe and caused the greatest losses in the history of the New Jersey Coast. Three storms occurred in close succession, the last occurring when the beaches had been depleted by the two preceding disturbances. Large sections of the broken wall were carried back half way to the trolley tracks by the heavy waves. The most serious loss, that of the fill and surfacing, quickly followed.

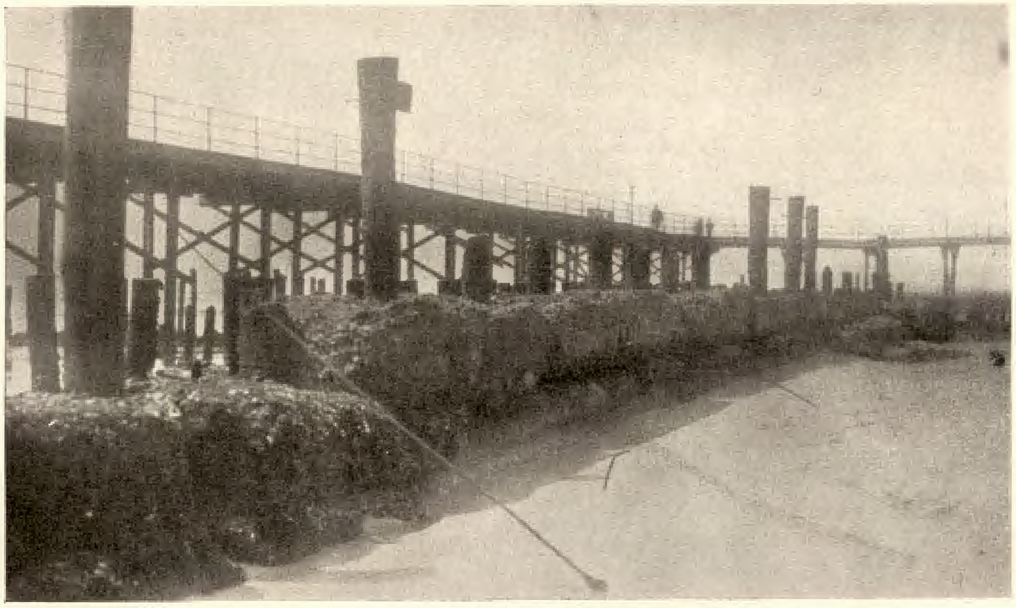
The lesson is that if land is reclaimed from the ocean and dependence is placed on a vertical wall to retain the area, then it is necessary to build strongly and well. In this case, it is believed that much of the concrete was poured in extremely cold weather, but whether this contributed to the rather poor endurance of the concrete is not certain.

It is interesting and perhaps not entirely futile to speculate on the probable causes of failure and how the trouble might have been avoided. At to the type of wall, it must be said that much of the Margate section of the work is still standing (January, 1930), and large frontages in Ventnor are protected by identical construction. The probability is that the actual collapse was confined to a very limited section; but loss of backfill followed.

Was the collapsed section attacked at some point by floating wreckage? Was it subjected to an extremely heavy and abnormal wave and current onset? Might a combination of defective material such as frozen concrete and unsatisfactory workmanship at one point, have invited a localized weakening which grew into

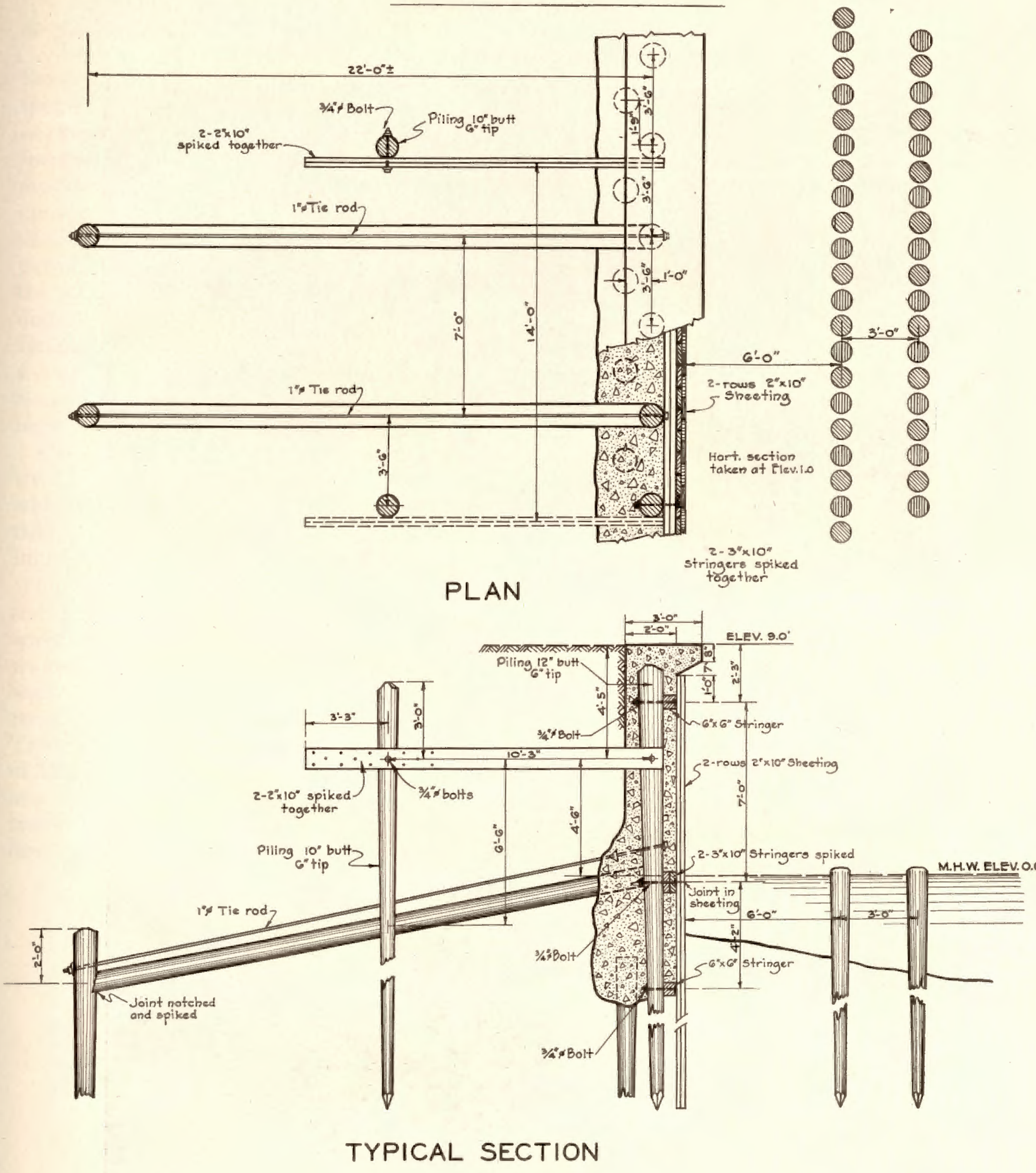
Margate Seawall, July, 1928. Original construction. Concrete deteriorating.

Margate Seawall, July, 1928.



Margate Seawall from rear, July 15, 1928.

Margate Seawall, July 15, 1928. Note shearing at middle wale.



MARGATE SEAWALL
MARGATE, N.J.

1 1/2 0 1 2 3 4 5 10
SCALE IN FEET

Margate Seawall, remains.

Margate Seawall, remains.

the destruction? These are all materials for speculation but will never be answered.

The writer who, on a few occasions, witnessed the construction operations, recalls that at certain localities the depth at the toe of the wall on normal high waters was sufficient to carry in a fairly heavy wave. True, the wave screen or stockade composed of two rows of closely spaced round piling, six feet and nine feet outshore of the wall was supposed largely to disperse the wave forces before the wave reached the wall. But these stockade piling at six-foot distance from the foot of the wall are none too remote; there is an instant in the breaking of a wave when it strikes with a terrific smash. Something has to absorb the energy of that blow.

Consider the conditions during normal fair weather on high water spring tide. The still water level might be 0.8 feet above mean high tide and the wave crest would be somewhat higher, depending on the swell. Under these conditions the danger to the wall would be negligible so far as immediate effects of the waves are to be considered. Even then, the waves throw very considerable volumes of water into the lane which is bounded by the wall and the inshore row of wave screen piles. That water will not remain inert at the foot of the wall, except to the extent that the waves are reflected and hurdle the screen as they travel oceanward, and for the immediate flow due to superior elevation of the water at the foot of the wall which wells over the piling, the wave-thrown water must return seaward through the interstices between the screen piling. Depending on the volume of this wave hurled water with respect to the effectiveness of the openings between the screen piling, a varying proportion of the water will follow a more or less indirect route in returning seaward. In other words, if the piling are so closely spaced as very effectually to retard the seaward flow of the wave water, the lane between the screen piling and the wall will be converted into a tide race. This condition with sand agitated by the waves is only too favorable for cutting.

This situation would naturally suggest the provision of cross-jetties or groins and riprap at the toe of the wall.

But with conditions of stress—on-shore gales at spring tide—the wave attack would be of primary interest. An elevation and off-shore spacing of screen piling adequate for the reduction of ordinary waves to limits that will not endanger the structures or the stability of beach levels may be ineffective when heavy seas generated by on-shore gales roll in on the flood of spring tides.

Private Sea Wall at Ventnor, N. J.

The sea wall shown in the photograph evidences determination on the part of the owner to secure protection.

Private Seawall, Ventnor.

The wall is above the line of ordinary high tide. The structure at the rear consists of the ordinary timber bulkhead in front of which there is a timber plank apron which slopes down to a concrete sea wall which is supported on piling. The concrete wall in turn is protected and fortified with a bank of broken concrete.

Assuming that the concrete wall is adequately supported by piling and generally meets the requirements of gravity walls, this type of structure should yield satisfactory results. It indicates however the inherent weakness in all isolated sea wall structures, namely, that the owner is compelled either to build expensive returns or cross walls at each end of this structure or else run the risk of being flanked if adjacent properties are denuded.

Margate Seawall, July, 1928. Coping replaced with reinforced concrete.

Concrete Seawall, Ventnor, N. J.

The Concrete Sea Walls at Ventnor, N. J.

These concrete structures were built by the owners to protect highly valuable properties. The details of construction cannot be determined without recourse to the plans which are not available. They make a rather impressive and attractive appearance.

These structures are above the reach of ordinary high tide.

Concrete Seawall, Ventnor, N. J.

The Longport Sea Wall

This interesting structure was built under contract by the Borough of Longport. The plans called for the erection of approximately three thousand five hundred lineal feet of wall with a series of low timber groins extending oceanward from the toe and at right angles to the direction of the wall. The wall construction, which was begun at 11th Avenue had been completed to a point between 23d and 24th Avenues

Seawall, Longport, after erosion.

and for a considerable additional distance the piling and cut-off bulkhead had been placed, when a severe storm in 1920 caused the loss of a section more than four hundred feet in length, between 14th and 17th Avenues. Another section which was destroyed during the early stages of the operation was rebuilt and is in good condition today, January, 1930.

Longport is the southernmost municipality of Absecon Island of which Atlantic City occupies the northernmost portion. Perhaps no other municipality in New Jersey has been obliged to sacrifice so much in comparison with its resources in order to protect the properties on its ocean front. The development in real estate of the last few years vastly increased the municipality's tax ratables but the cost of the sea wall under discussion represented a large proportion of the ratables of 1919-1920. But conditions had become desperate when the borough officials decided to adopt this type of protection.

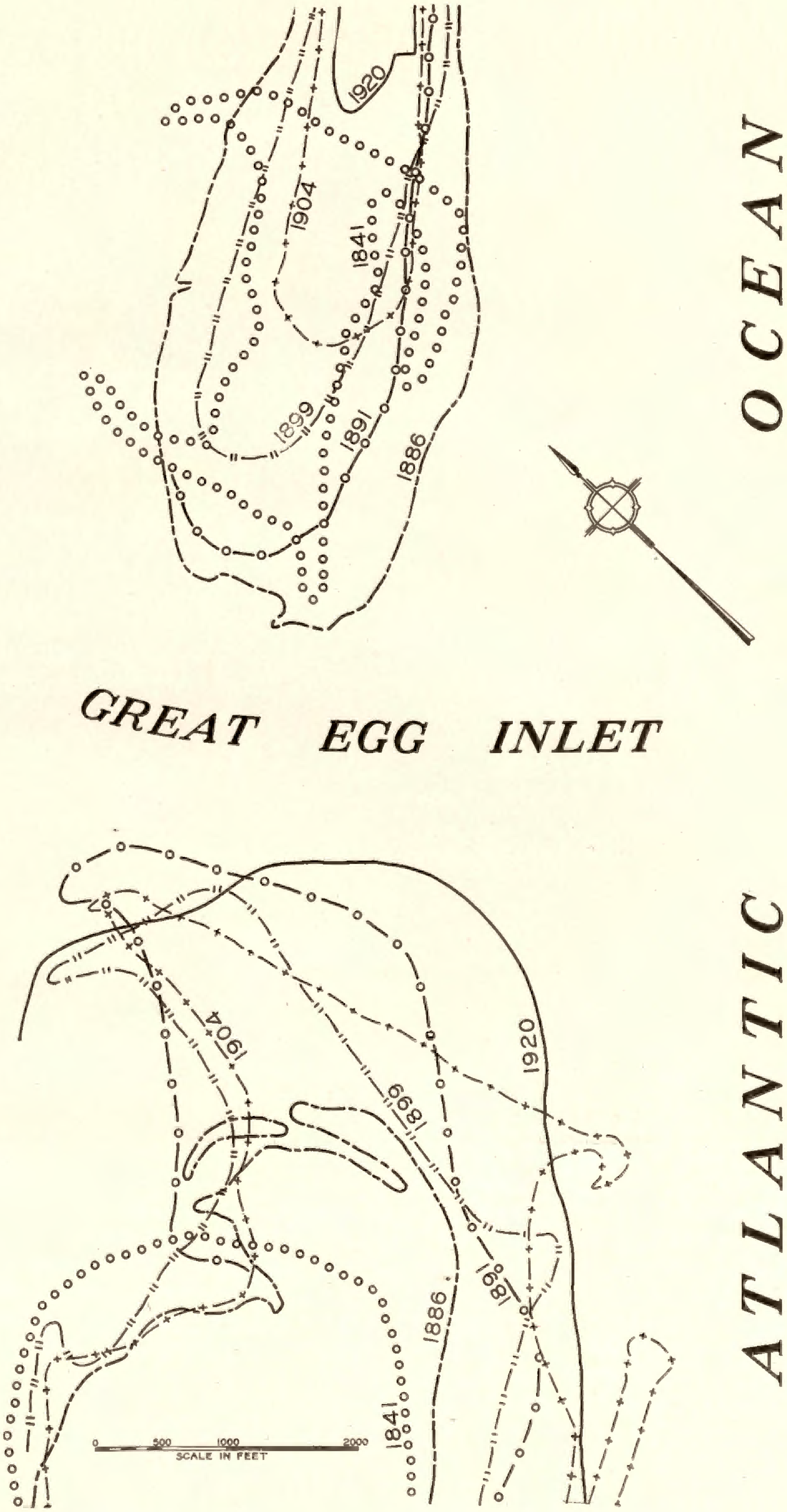
The difficulties at Longport have been obscure but are undoubtedly to a great extent the result of shifting of Great Egg Inlet or perhaps more accurately, the inlets, because at times in the past Great Egg Inlet has had two branches, with a large sand island between. While the northerly branch has been closed for perhaps more than forty years, nevertheless the tendency to reopen has frequently asserted itself. The fact is that almost the entire area of the borough south of 22nd Avenue is a recent emergence from the sea. The large sand island delineated on the U. S. Coast and Geodetic survey of 1841 is indicated on the riparian survey of 1881 as attached to the main beach. Some of the most impressive changes in the shoreline since 1841, are shown on the following map.

The relatively low elevation of the land together with the close proximity of the deep, rapid tidal waterway known as Risley's Channel presented a condition that was only too favorable for the formation of an additional inlet. Serious erosion has occurred on the Risley's Channel banks with resulting loss of buildings and lands and the borough found itself under attack on both sides. The railroad company's tracks were finally undermined. The company thereupon restored its roadbed by depositing vast quantities of rock, until the erosion by Risley's Channel was arrested. How far this cutting by the channel would have continued but for these protective works, placed by the railroad company it a serious question; but the deep rapid flow impinged on Longport which is on the concave bank of this waterway.

Until the construction of this ocean sea wall Longport had no general plan of defence, or at least it had no general plan which rested on the solid basis of substantial works adequate to meet the severe attack to which this littoral was subjected. The engineer of the borough knew that light or isolated structures would not serve but the taxpayers could not be induced to pay the price or to take concerted action until there were heartbreaking losses and actual disaster to the improved central section of the borough was imminent.

It is doubtful, however, if any one supposed that the erosion would proceed to the limits it had attained when the sea wall construction was begun. Loss of land become marked perhaps about 1904, but for several years following 1909 the erosion was particularly severe, the result, probably, as has already suggested, of extensive shifting of the inlet channels. The writer, comparing the recent maps with the earlier surveys, calculated that since 1881 an area of approximately one hundred and eighty-four acres of land has been eroded from the southerly end of the island. While in superficial area little change has occurred since 1920, real improvement of the beach has followed the construction of the massive 11th Avenue jetty and the other improvements toward which the State contributed.

Prior to the construction of the sea wall neither the borough nor the land owners were idle. Timber groins, small jetties and breakwaters of every kind of material and almost every sort of structure that could be suggested were tried, by the land owners or by the municipality. No doubt some of the structures were well designed; but erosion on a large scale can seldom if ever be combatted successfully by individual owners and this frontage was no exception. Ultimately even well constructed walls or jetties would be flanked as adjacent works failed.



Map showing shorelines, years 1841 to 1920, Longport and Ocean City.

Longport, February, 1926. Southwesterly end.

Longport, June, 1922. Southwesterly end.

This photograph taken at Longport in June, 1922 shows some of the various means that were adopted in the attempt to check erosion near the inlet. It includes the off-shore stockade or open piling wave screens and the conventional jetty composed of two rows of piling held together with occasional ties, the space between the two rows being filled with cedar brush weighted down with stones. Notice that the sheet piling groin has been flanked, that is, the sea runs inshore of its inshore end. This, of course, means that the jetty is rather a hindrance than a help because cutting is accelerated by the contracting effect of the groin. The wave screens have been extensively used in this section.

Excepting the portion of the concrete sea wall that failed in 1920, practically the entire structure remains in place today, December, 1929, in fair to good condition. A very good quality of concrete was obtained. The exposure is perhaps more severe than at the Margate sea wall which is discussed elsewhere because of the more active tidal currents through the inlet. A view of the two structures forces one to the conclusion that the quality of the concrete in the Longport sea wall was greatly superior to that in the Margate wall, even after making allowance for the greater age of the Margate structure.

The sequence of operations in the construction of the Longport wall was as follows:

The timber sheet-pile cut-off, which is actually a low bulkhead, and the timber bearing piles at the joint between the step and the curved sections of the wall were jetted into place; the details of fastening the component parts of the cut-off and the drift-bolting the timber cap to the bearing piles necessarily being controlled largely by the stage of the tide; this timber cap, of 8″ x 12″ material, being intended as a seat for the precast step section.

The reinforced concrete bearing piles and the step (washboard) sections were in the meantime cast and cured inshore at suitable points. When these precast concrete sections had been sufficiently cured they were conveyed to the site on an industrial railway which was laid on a trestle at the rear of the wall line. By means of U bars embedded in the concrete the step sections with reinforcing bars protruding upward were readily lowered into position, seating on the cut-off bulkhead at the toe and on the timber 8″ x 12″ cap which is supported on timber piles.

Longport, October, 1928.

The remaining operations of sealing the joint between the contiguous step sections and of pouring the concrete ingredients into collapsible steel forms to mould the upper curved section involved nothing of special interest.

The sequence of operations is well indicated by these photographs of uncompleted portions of the work just about as they were left at the cessation of work. Details while slightly blurred because of the dense growth of black mussels and other marine growth can be readily traced out.

The wall when first built made an attractive structure as in fact it does today, and when the concrete apron at the back of the wall was in place presented an appearance more impressive and suggestive of strength than the plans would indicate. The width of the top of the wall with its good coping helped to make this impression of massiveness. The back-fill and the apron covered the substructure. Its height is none too great during severe storms, but then

At break, Longport Seawall.

At break, Longport Seawall.

it must be recognized that some water is certain to go landward during severe onshore gales. It would have been desirable to make the wall somewhat higher from the coast protection standpoint, but reasonable limits must be fixed in a situation like this. Attention is called to the profile of the face of the wall, the object being gradually to break up the wave on the steps before the water strikes the curved section. The profile appears to form a portion of an ellipse.

But the security of a wall of this character and type of construction is made to depend on a number of factors, any one of which may fail. Some of the details are worthy of careful study. In the first place, the joint between the timber sheet pile cut-off at the toe and the bottom of the precast step section is a serious source of weakness. The original plans indicated a cut-off of reinforced concrete sheet piles, but for some reason, doubtless financial, revision was made to the timber piles and sheet piling cut-off. As a matter of fact, it is a difficult matter to obtain with certainty a good joint between precast concrete sections and work in place. But even admitting this difficulty a better key could have been obtained at slight expense. In this construction the toe of the wall is merely laid on the timber cut-off without notch or joint and abutting against the sheeting. Any appreciable sliding of the wall or undue pressure or blow from any source such as falling columns of water or wreckage might easily loosen up the sheeting from the cut-off wale. Presumably the expectation was that sand would build up on the step section and form a blanket to help hold the step in place but this was taking too great a risk. Certainly these timber groins were too low and failed to bring about this hoped for rapid building of the beach. Conditions became steadily worse until in 1923, with much of the remaining sea wall seriously in danger, the State and Borough united in repairing and extending the jetty at 11th Avenue, in depositing rock at the toe of the wall and in other measures.

The timber bearing piles and the caps which serve as a seat under the joint between the curved and step sections strike one as another source of weakness. True, the two sections of

At break, Longport Seawall.

concrete, step and upper, are bonded by the reinforcing rods which were left protruding from the precast step section. However, if concrete is deemed necessary and desirable as compared with other materials, notably timber, why not carry on to a logical conclusion and use concrete in place of these timber piles and caps, at least above the level of plus 1.0 foot above mean low water elevation? Decay and shrinkage of this cap and of the top of the pile is inevitable if they are exposed to the air, and when this occurs the vital support at the joint is lost. If necessary at all this support should have been more adequately preserved against decay. A glance at the details of the wall shows that this brace is required. Here again it is probable that dependence was placed upon the sand fill which was deposited by hydraulic dredging at the back of the wall supporting the wall at its level.

But the weakness at the toe represents poor detailing; and failure usually results from poor detailing. In the event of severe wave shock or blow from wreckage, it appears that the wall is likely to fall backward. Settlement of the piles would cause a similar result. Undoubtedly the backfill was relied on to aid the wall proper to take the wave shock and brace the wall, but with the slightest aperture at the toe the backfill which consists of fine sand dredged from Risley's Channel would be lost and trouble naturally follow. The toe of the wall with heavy masses of water or wreckage falling on the wall may have exerted an unexpected thrust against the sheeting in the cut-off, thereby creating an aperture for escape of the sand fill as well as permitting the step section to shift from its seat on the timber cap. This condition required highly accurate placing of the timber cap with respect to the timber cut-off. It is not certain whether creosoted material was used in the bulkhead cut-off, but it should have been employed in any event.

It may perhaps be significant that the breach occurred at a pronounced re-entrant angle in the wall as the wall is viewed from the seaward side. Perhaps this fact did not contribute materially to the failure but such re-entrant angles should be avoided whenever possible as they do tend powerfully to concentrate the vigor of wave attack. If conditions prevent easy alignment and render re-entrant angles unavoidable they should be regarded as danger points and the details worked out accordingly. Salient angles also require special detailing of the joint but at least the waves are not, as in the case of re-entrants, concentrated but rather dispersed to an appreciable degree.

The introduction of deflection angles in the alignment of a wall built of precast sections presents another pertinent question,—was the concrete step section on each side of the joint at the angle carefully moulded with contact planes so beveled as to give full contact of the concrete? A special form was required, else merely the edges of the precast section would have contact instead of the full plane surfaces. A heavy wave impact at the angle joint would tend to force the sections apart, leaving a fissure.

The necessity for obtaining a tight joint in the timber cut-off wall is equally vital, because with a backfill of fine sand the least weakness or crevice may cause disaster. This condition of danger will be present when the tide falls after an onshore gale which has saturated the backfill with rain and with spray blown over the wall. Veering of the wind from onshore to offshore (N. E. to N. W.) often takes place with startling suddenness. But it requires careful detailing and construction to obtain a tight reinforced angle in a timber or precast concrete cut-off wall. The unmodified design will leave a broken joint or seam right through the structure with resulting plane of weakness. If it is necessary to obtain imperviousness on the straight part of the work it is doubly so at the angle joint. Obviously, reinforcement around the angle point was required.

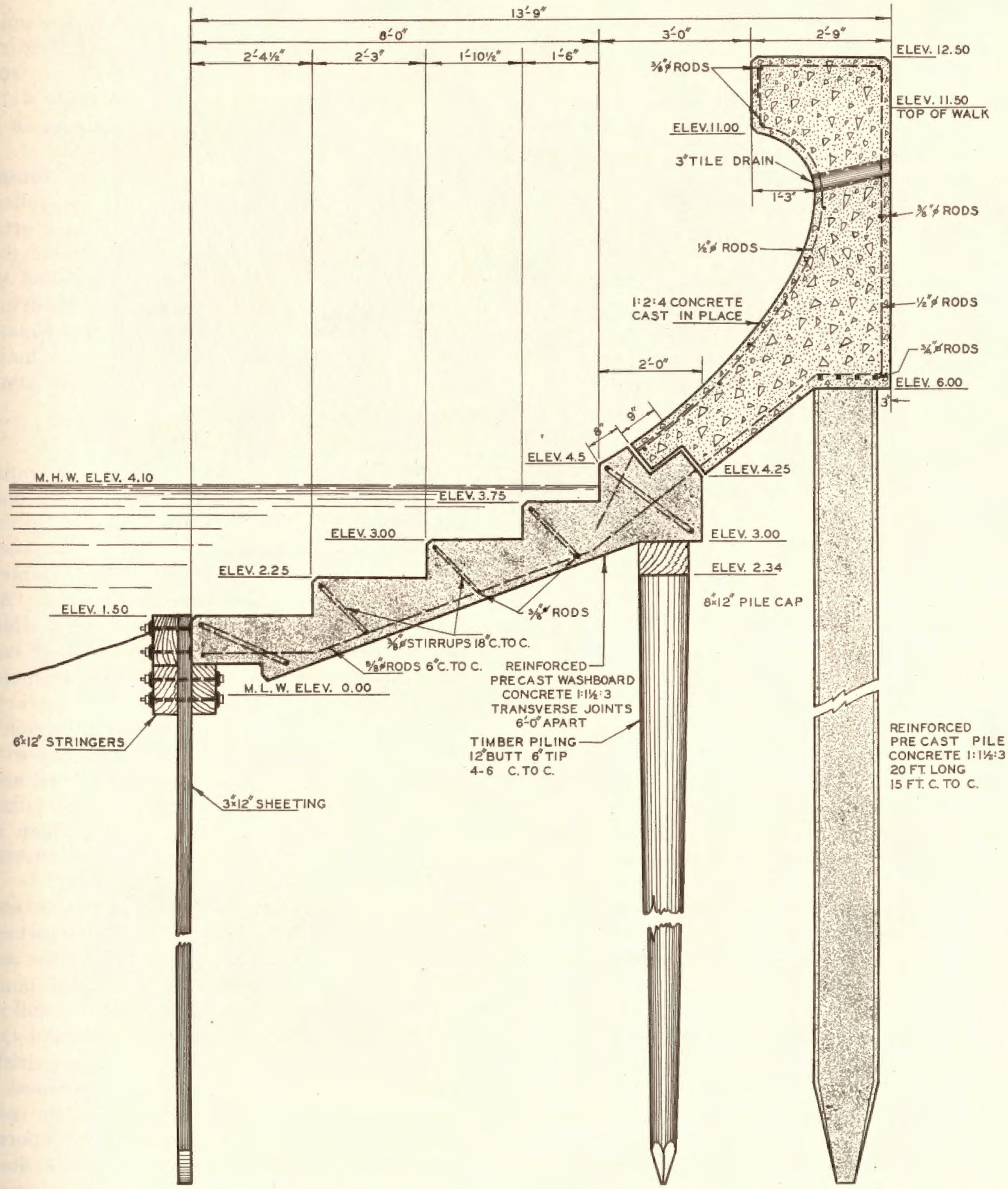
In a large number of the sections that failed, the concrete sheared off in the step (washboard) section in a vertical plane with the riser which extends from elevation 3.00 to elevation 3.75.

Attention is invited to the fact that the fracture occurred in this vertical plane even in certain sections, the toe of which remained in position on the cut-off bulkhead. The wall tilted backward; and it may be that the step section failed on this plane as the weakest cross section in the wall acting as a beam, in the absence of reinforcing metal on the tension side. But this is mere conjecture. The loss of back-fill was first required to permit the tilting of the wall. Then the wave hammering would quickly pound the wall from its seat on the 8″ x 12″ cap.

This wall suggests that by no means novel discussion as to the relative merits of precast and cast in place concrete. Here the portion below high water line was precast as a matter of sound engineering economics. Otherwise, a costly cofferdam would have been required. The upper part of the wall was cast in place primarily because it was necessary in order to unify into one monolithic structure the wash board (step) section and the concrete piles with the rounded face wall.

There can be no question that precast sections offer many advantages in the facilities for careful work in a suitable location, for adequate curing, inspection, etc. But the use of precast sections exclusively requires extreme precision, extreme precautions in handling to obtain perfect joints and impervious connections. Grouting and other modes of obtaining perfect seals in these joints may or may not result in entire satisfaction.

It is unfortunately impossible to determine precisely where the failure first occurred. The original weakness may have developed in a more limited and restricted section, but with a breach once open the backfill rapidly washed out and the waves poured over the breach. Probably the outstanding weakness of this particular structure is to be found in the junction between the wall and the cut-off. On the other hand, failure of the timber pile under



TYPICAL SECTION OF

LONGPORT SEAWALL

LONGPORT, N.J.

the joint between the precast and cast in place section, or of the concrete piles would pull the toe of the wall away from the cut-off and provide the vent for the backfill. The step section feature has received much favorable attention, but like all other engineering propositions should be subjected to careful analysis and full consideration of the requirements to be met. A long gently sloping step section, the top of which will attain the highest limit of the waves, presents one problem, but the building of a wall with just a few steps, adequate enough for the ordinary tidal swings and normal waves might not prove wholly effective because it should, to carry out the step plan to a logical conclusion, break up the storm waves. It is not a simple matter to provide adequate reinforcing material on the upper side of the step section profile yet the wall may under conditions readily visualized be required to act as a beam. The impracticability of providing continuous horizontal metal reinforcement through the step section for the entire length of the wall always impressed the writer as a source of weakness.

Reinforced Concrete Sea Wall at 48th Street, Ocean City

The design of this structure is obviously intended to produce a strong, highly resistant wall. It is difficult now to acount for the completeness with which it has suffered destruction. It is interesting to study the design and particularly the counterfort feature. Essentially, the wall along the front consists of a concrete structure reinforced with one inch rods, the top of the wall being one foot four inches wide, the back vertical and the front with a batter of one to four. As it is not excessive in height and was supported by backfill, it was rather good looking.

The concrete is seriously depreciated, but this may be a result of racking and wave vibration and not, primarily, of deterioration because of the action of the sea water. The evidence of this lies in the good condition of the concrete in the return or cross wall at the northeast end. Admittedly this is weak evidence because the return is most of the time above the reach of the waves. It is suggested, therefore, that the wall was undermined and that one or more weakened portions caused the destruction of the adjoining parts. This is only guesswork however, because along the entire front, the destruction is almost complete. One could argue with more confidence if there were portions of the main wall still remaining in a fair degree of preservation.

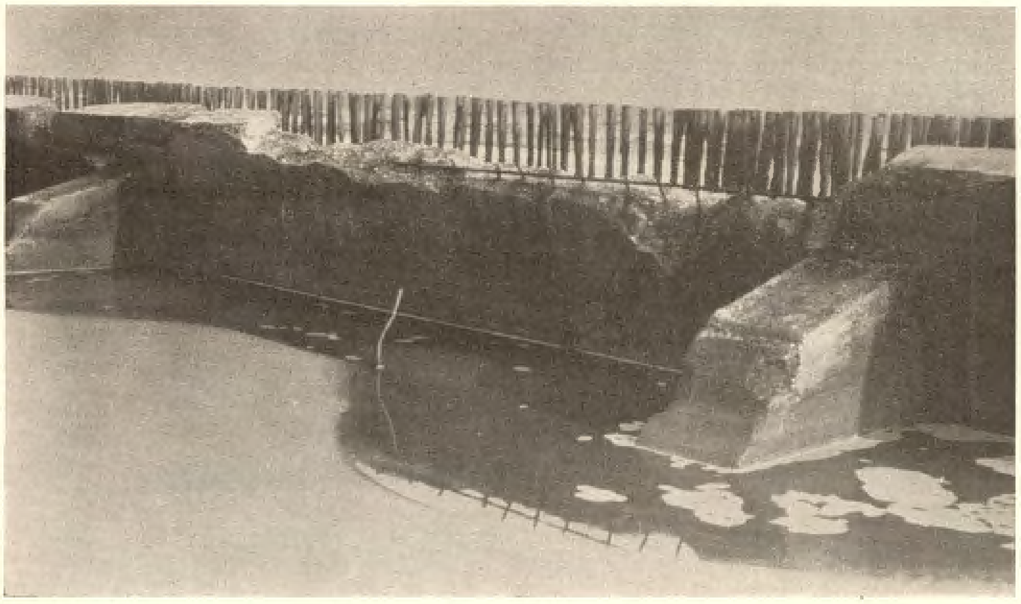
It is impracticable to determine the dimensions or the supporting power of the piling underneath the main wall and the counterforts, but such examination as could be made of the sheet pile cut-off indicates that it was not at all impressive. In any event, if the bearing piles were weak or the sheet piling inadequate in themselves or not well bonded into the main wall, steel reinforcement and counterforts avail little.

Groins and Jetties

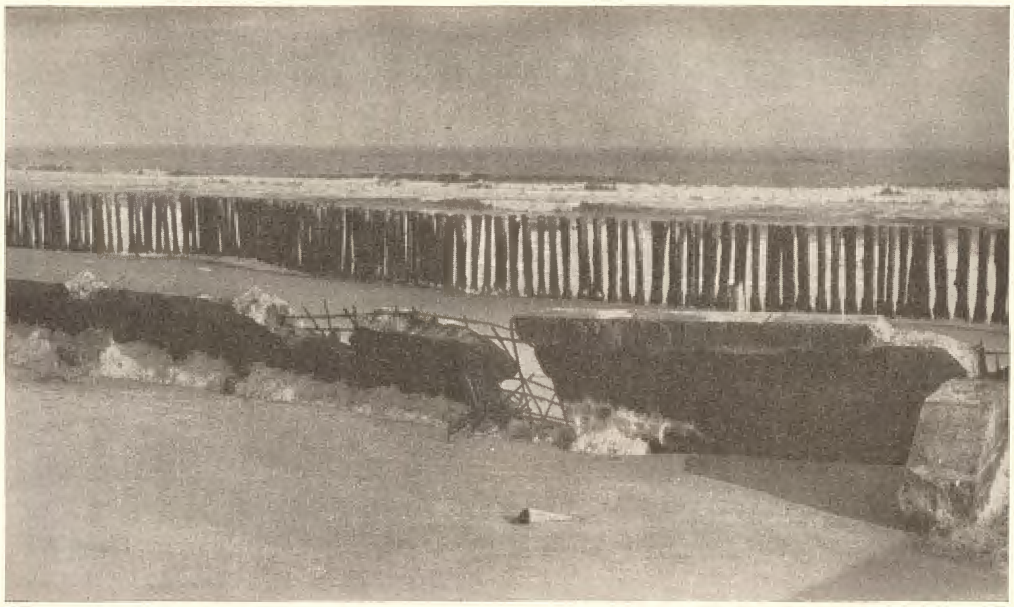
A groin is defined by Webster as "A frame of woodwork across a beach to accumulate and retain shingle." The definition of jetty by the same authority applies primarily to harbors rather than to coast protection. In this country the two terms are used interchangeably. As a matter of fact it is difficult if not impossible, whatever definitions are adopted, to mark out a satisfactory line of demarcation. Perhaps any definition must be somewhat arbitrary. The writer suggests applying the term "groin" to the timber or steel or concrete or composite structures which are unsupported by rock and the term "jetty" to the rock works extending into the sea. Thus a timber groin which is subsequently reinforced with rock would thereby be transformed into a jetty.

Groins or jetties are structures which extend at a suitable angle, more frequently than otherwise at right angles to the beach, into the sea from points above high water line in the land. Their function differs from that of a sea wall in that they are intended to arrest and hold the sand and other material known as littoral drift. Therein lies the essential distinction between a sea wall and a groin. Sea walls do not accumulate beach material although by operation of other causes material sometimes does gather at the foot of a sea wall. The quantities of wind-blown sand that gather against seawalls, etc., are greatly underestimated. Inasmuch as groins are usually spaced several hundred feet apart groins do not directly break up or resist the waves in any appreciable degree. As they are usually approximately

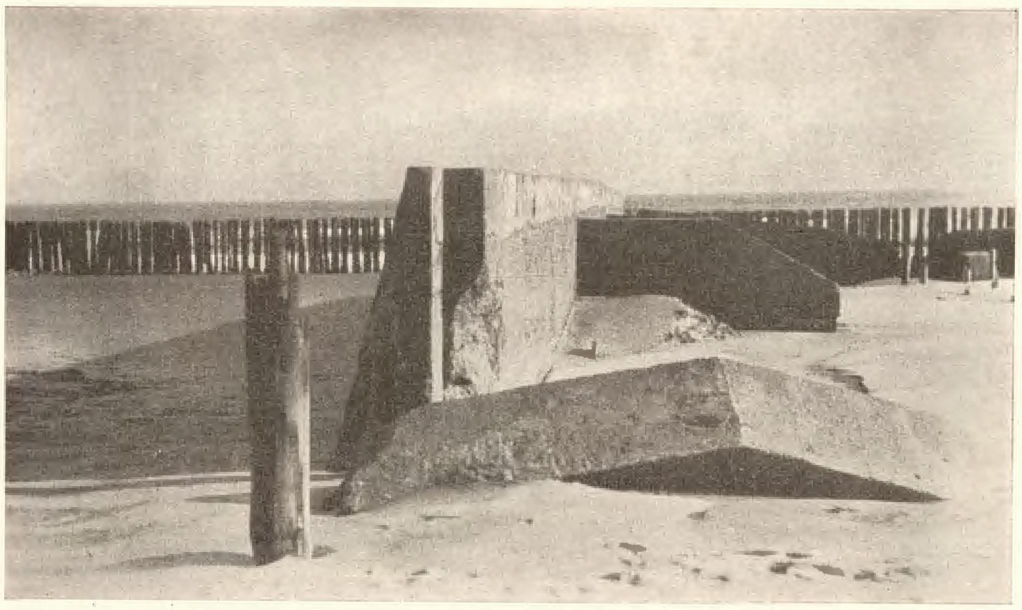
Reinforced Concrete Seawall, 48th Street, Ocean City.



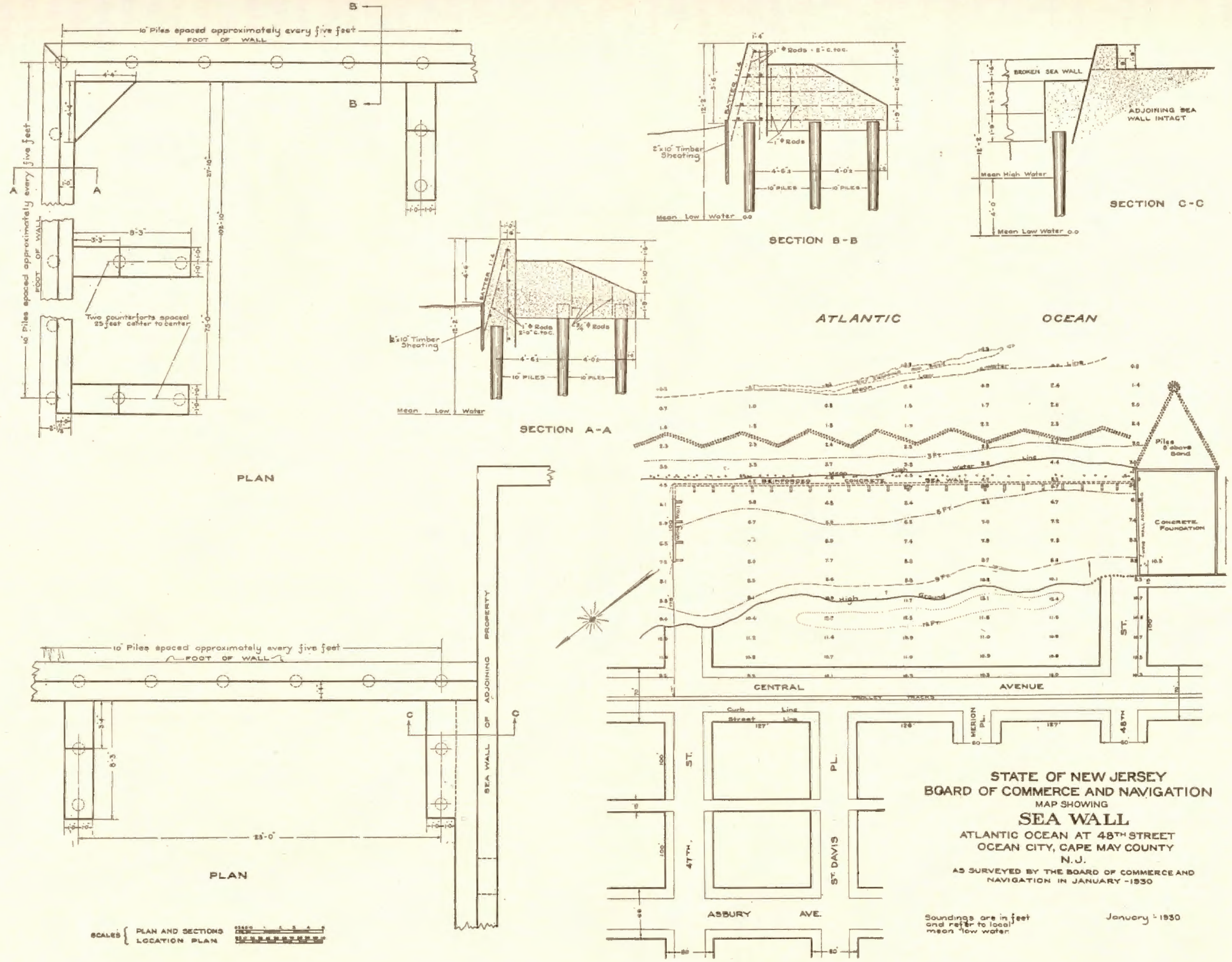
Reinforced Concrete Seawall, 48th Street, Ocean City.



Reinforced Concrete Seawall, 48th Street, Ocean City.



Reinforced Concrete Seawall, 48th Street, Ocean City.



10" Piles spaced approximately every five feet
FOOT OF WALL
Two counterforts spaced 25 feet center to center
PLAN
SECTION A-A
SECTION B-B
SECTION C-C
BATTER 1:4
1" ϕ Rods
2"x10" Timber Sheeting
10" PILES
Mean Low Water 0.0
Mean High Water
BROKEN SEA WALL
ADJOINING SEA WALL INTACT
ATLANTIC
OCEAN
REINFORCED CONCRETE SEA WALL
CONCRETE FOUNDATION
Piles 9' above Sand
CENTRAL
AVENUE
TROLLEY TRACKS
Curb Line
Street Line
MERION PL.
48TH ST.
47TH ST.
ST. DAVIS PL.
ASBURY AVE.
SEA WALL OF ADJOINING PROPERTY
PLAN
SCALES { PLAN AND SECTIONS
LOCATION PLAN
STATE OF NEW JERSEY
BOARD OF COMMERCE AND NAVIGATION
MAP SHOWING
SEA WALL
ATLANTIC OCEAN AT 48TH STREET
OCEAN CITY, CAPE MAY COUNTY
N.J.
AS SURVEYED BY THE BOARD OF COMMERCE AND NAVIGATION IN JANUARY -1930
Soundings are in feet and refer to local mean low water.
January - 1930

normal to the line of the beach they knife through the waves; remembering that the angle of waves approaching the shore varies somewhat. If successful they hold or build up the best of protection, a wide, high beach.

The object of a groin or jetty is to trap and retain beach material which would otherwise pass on. It is an artificial promontory. A series of such artificial promontories should normally result in the creation of a corresponding number of pocket beaches in the little embayments or bays as they are called by engineers. The shifting of beach material which cannot be entirely prevented is largely confined to the individual bay.

If it is possible to gather sand or other beach material in this manner—and it usually is possible if the beach is not entirely denuded of mobile material—the reason is that the beach material is at times put into motion by natural forces, and that this motion is checked by the inert groins or jetties which absorb the necessary energy. This motion is caused by the winds, waves and tidal currents. And to the student of these matters the wonder is not that sandy beach lines shift in the course of the years—and the changes in some areas are highly impressive—but that the changes should be relatively so slow in view of the tremendous forces always at work. The marvel is that these tremendous forces incessantly in operation are held in such delicate adjustment.

There is nothing mystical or particularly mysterious about groins, as such. In respect of accumulating sand any type of recognized tight, impervious groin construction will differ relatively little from another type of the same length, alignment and elevation. A light board fence if it were impervious and strong enough to resist the thrust of the sand and wave and tide current on the windward side would serve. Then why build the expensive structures of rock and steel at three or four or ten times the cost of a light groin. Simply because the light structure may be, and if it protrudes much above the sand, almost surely will be pushed over or floated out in severe storms. This type, unfortunately, from the economic standpoint, has its limitations.

The outer end of a groin is apparently in a position of severe stress during storms but the blow struck by a wave rolling against a groin normal to the beach is a glancing blow, not a direct crashing impact as in the case of a sea wall which must arrest the wave then and there. Again, at high water the groin is always backed up by water on the leeward side though there may be a fleeting difference in level as the wave rolls in. This refers to waves and not to the alongshore current. But the deeper water at the outer end of a groin renders that part of the structure more vulnerable to the forces which tend to float it out or push it over.

The scour that usually takes place at the outshore end of a groin or jetty should never be disregarded, for it is the projection above the earth line that normally limits the choice of the groin type. This scour is a phenomenon that is easily understood when it is realized that groins in the sea act rather similarly to groins in the rivers. The latter are erected for the purpose of confining the flow of the river to the channel section. Though it is not always realized, the flow of water along the beach is a very real and important fact which must not be ignored. With the rising tide the water follows the shore toward the nearest inlet (nearest in point of tidal attraction, not necessarily nearest in distance). The flow is barred by the groins or jetties from flowing immediately along the shore and is therefore contracted and concentrated at the ends of the groins or jetties. This is the principal reason that the estimates of engineers of limited experience almost always fall far short in respect of the actual amount of rock required to construct a jetty of given dimensions. Underestimating the length of piles and sheeting results from the same cause.

It is agreed that groins do not "make sand" although that expression is frequently used in statements that they build up the beach. Actually all that they can possibly do is to alter the profile of the shore by providing a resting place in quiet water for sand that is set in motion by the waves and currents. The groin or jetty does not by any mysterious process induce beach material from other places. But it does tend to arrest the movement of the sand along the beach and as to that immediate locality the gain in beach material is net.

Yet with all the limitations that they have, there is in many situations no substitute for groins or jetties. Most impressive results are often obtained from the construction of a series of groins.

If a beach is eroding the explanation is that waves and currents and the winds are transporting the beach material to other places. The material is not lost or consumed. That the beach material shifts to and fro along the shore is true but only in a qualified sense. In a broad sense, it is steadily, though not continuously, and perhaps very slowly, moving in one dominant direction. It is a fact familiar to everybody that along a given stretch of beach the sand normally piles up against one side of a groin, but that storms from the opposite direction occasionally pile the sand against the opposite side of the groin where it remains only for a limited period.

Much time and talent have been applied to the argument as to whether the wave action or tidal currents is more potent in shifting the beach material which is eroded and on the trace of a pebble or shell or grain of sand as it is moved along the shore. But what difference does it make? If the wave after breaking washes and lifts sand or gravel into suspension (and this is a familiar fact) and there is a tidal current, however slow, and discontinuous along the beach, this current will operate to shift the suspended material elsewhere. And whether the particles of beach material travel along a sine curve or parabola or zigzag line is not practically important to the engineer.

This tidal current which runs along the shore of every tidal sea is probably the most important agent in shifting the beach material, although it is doubtless true that in most localities the velocity of this current of itself unaided by the wave-beating is insufficient to move anything but the finest of material. Furthermore, this current is not continuous and constant in direction. But the breaking waves loosen the unconsolidated sand or pebbles which, once lifted, are given an impetus in the direction of the set of the tidal current. At points relatively remote from inlets or from deep channels this motion fluctuates more or less, hence the net resulting movement is relatively very slow. At the inlets the tidal current velocities may be very high and shifting of shore lines is particularly pronounced at inlets. But whatever the velocity is, even if it be hardly measurable with instruments, yet if it be actually present the set or current will move the beach material at a corresponding rate. And the resultant of all the currents, shifting as they are, will be in the direction of the flood tide pressure.

Jetties or groins are limited in their operation inshore to about the swash line or perhaps the line attained by storm tides. Omitting consideration of their effect upon wind-driven sands, it would appear that there is no advantage but many disadvantages in building them unduly high. If constructed at too high a level they are either useless or in many instances detrimental and certainly they are unsightly.

But when is a groin or jetty too high or too low, and how can the engineer determine the proper height? There will never be any standard that will apply everywhere any more than there will be a standard foundation for bridge abutments, because there are too many diversities to be encountered. Every beach has its own characteristics,—range of tide, coarseness and supply and other qualities of beach material, holding power of substrata, degree of exposure to heavy waves, angle of wave approach, presence or absence of rapid tidal current, and of marine borers, slope, width and elevation of beach; and these characteristics modified by availability of construction materials determine the type of groin or jetty.

However, these suggestions are tentatively offered for the construction of a groin on a beach the slope of which is 1:15 or 1:50 or flatter with a mean range of tide of two to six feet and a fair holding bottom (sand or gravel). Begin the inshore end above and inshore of the highest storm tide, then fix the grade of the top of the groin three feet above and parallel to the grade of the beach extending the structure out to low water line or usually just outshore of it. But it is a mistake to fix the grade too steep at the inshore end, even if the beach grade is very steep. The groin must be run well back on shore or if necessary be tightly joined to a sea wall. Some means must be found for preventing the wash from flanking the groin, therefore in the absence of a sea wall the groin must be extended shoreward beyond the wash line of storms. A groin that has been flanked is worse than useless for it concentrates the waves and shore currents against the beach.

The suggested elevation of three feet above the sand is not sacred. Four feet may serve as well in many localities, while two feet might be preferred in others. It is usually not difficult to plan for adding one foot of elevation in the future, either by leaving an extra foot of piling above the top wale or by bolting on flash-boards or nailing on planks laid flat, and the height should not be so great as to preclude the material from spilling over as a bay fills. But it is a mistake to build simple groins too high for that is chiefly what makes them vulnerable. Consider that each pile in the groin is the principal support, acting as a cantilever or fixed beam, for a panel of the groin in two senses—first, in resisting the push of the waves and current and secondly, in serving as an anchor in preventing flotation; however, the friction on the sheeting may help in resisting flotation, if good penetration has been obtained.

If the conditions present are more severe than indicated then timber groins will probably fail; consideration should be given to steel groins or jetties. Failure may result from an infinite number of causes. Floating wreckage is responsible for many losses, the wave and current pressure may cause the structure to fall over or the loss of frictional holding power of the soil through excessive wearing and vibration may cause the structure to fall over, or the loss of frictional holding power of the soil through excessive wearing and vibration may permit the timber to be lifted out by reason of the floating quality of this material. The "weaving" of a groin subjected to heavy waves and currents is impressive.

Distortion of outer end of groin.

Partial destruction of groin.

CONCRETE GROINS OR JETTIES

Reinforced Concrete Jetty, Long Branch.

Seaview Avenue, Long Branch, November 10, 1922.

These photographs show the remains of a series of reinforced concrete jetties that were constructed along the ocean front at Long Branch. Several of the jetties have entirely disappeared. They were built under the direction of the city engineer by skillful and experienced contractors, but, whatever the reason, they were not at all successful. The writer in fact recalls no reinforced concrete jetties along the New Jersey Coast that have given any satisfactory service except those that were constructed at the mouth of Shark River.

These Shark River jetties which serve to maintain a navigable channel have been fully discussed heretofore in the former reports and that discussion need not be reviewed at this time. In view of their endurance for a considerable length of time, it is only fair to cite their performance as well as the failure of other jetties. The Shark River jetties were built under Chapter 305 of the Laws of 1911. The north jetty was seriously breached in January, 1924, and repaired with timber bulkheads and rock. The advocates of the reinforced concrete system are therefore warranted in advancing the performance of this concrete jetty in support of their arguments. The exposure from Northeast storms is severe and inasmuch as the jetty curved in plan acted as a training wall in preserving navigability of the inlet it was subject to undermining.

Long Branch, November 10, 1922.

Just as in approaching any other problem of magnitude, there are certain questions, not all of an engineering nature, which must first be solved.

The first question is, how much money is available? This will present the greatest difficulty in many cases because the necessity for beach protection is seldom admitted until serious damage has occurred. The chief difficulty in municipal projects is that the owners of property remote from the beach are often reluctant to contribute toward the cost of protecting the beach front. This is particularly true where the beach front is privately owned even though the beach front is occupied by a number of hotels and villas which represent a large proportion of the municipality's ratables and whose owners employ a large number of residents.

The next question bears upon the suitability and availability of the various materials of construction. The human element will be present in this connection because the vendors of the materials—timber, steel, and concrete ingredients—will have been active, and properly so, in urging the merits of their respective commodities.

Having resolved these two questions as well as practicable, the engineer can apply himself to the engineering aspects of the project.

The first requirement is a good map on a sufficiently large scale, perhaps 200 to 400 feet to 1 inch, based on accurate surveys. The map should show the street system, if any, all groins, piers, jetties and sea-walls and wrecks, contours of elevation from the bluff to deep water based upon a suitable datum, such as mean high or mean low water. Sufficient borings should be taken to develop the availability of sand or other mobile beach material as well as the holding power against flotation and penetrability of the soil where piling are to be driven. The range of tide and the heights attained by the water during extreme storm tides are matters of local record.

Of paramount importance on many sandy beaches are the beach channels and inshore bars and the breaches in the bar which are colloquially called "sea-pusses". This seems to be a poor, inexpressive term, but the writer has not found any suitable name in the nomenclature. Actually it is marked by a break in the continuity of the inshore bar and acts as an outlet for the beach channel. The inshore bar has been defined as the "Counterscarp".

The profile of a typical beach of this character can be followed descriptively in this manner—starting at the top of the bluff there is a sharp decline to the swash line, then a more gentle slope where the waves break, extending into a more or less well defined channel. The outer limit of this channel is marked by a bar approximately parallel to the shore line, which may be only slightly submerged at low water. The position of this bar will be indicated by soundings but is apparent by the coloring in the water and the breaking of the waves.

If the escarpment were continuous and practically level, it would serve as a natural breakwater as in fact it does to a certain degree in any event. But the sea-puss or breach at intervals in the escarpment forms an orifice and outlet for the beach channel. This is the complication in the breakwater scheme.

The waves striking as rollers or waves of oscillation break on the bar, throwing vast quantities of water into the beach channel. The most favorable avenue of return for a large proportion of this water is along the channel and then seaward through the breach or "sea-puss"; because where the wave dissipates itself on a sloping shore there is no return wave running oceanward to hurdle the bar. This refers to waves which break, not to waves reflected from a sea-wall or other obstruction in deep water.

The beach channel is sometimes termed "a tide race" or adjacent to inlets "the flood channel". The presence of the sea-puss manifests itself by the absence of breakers which is an indication of relatively deep water and by an intensified undertow which is so frequently an element of danger to bathers. It is the crest of the wave breaking on the bar that supplies the head for the beach channel or tide race and consequently, the sea-puss.

The first consideration on this type of beach is to close the beach channel. In a majority of cases the most effective means of procedure, in the writer's opinion, is to throw out a series of groins or jetties extending to the escarpment.

The profile of the beach may be a simple slope of relatively flat gradient or else of the more complex type, just described, in which there is a pronounced escarpment and beach channel. In more severe situations there may be a sea-wall or cliff in front of which no beach sand is ever visible.

The range of tide is important because if the depth at high tide is so great that the groins would be entirely submerged unless their height were made so great as to endanger their stability the timber groins must be discarded. In general, the inshore end of a groin should have an elevation well above mean high water because the waves hammering against a bulkhead or sea wall are thrown up and tend to cascade over the groin. This in turn would accelerate washing out of the beach material on the leeward side of the groin.

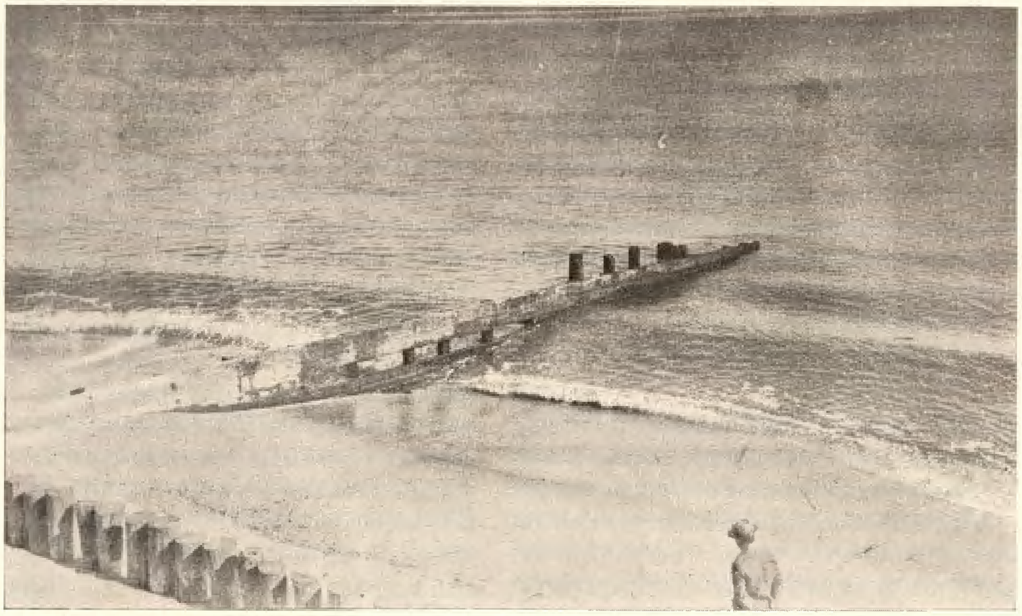
There is an infinite variety to the methods by which an assortment of piling, stringers, sheeting and hardware may be assembled together to form a groin. The engineer as in every other situation will endeavor to obtain the necessary stability at the lowest cost to his principal.

A very simple type consists of a single row of round piles, 3′ center to center with one lower and one or two upper wales of 6″ x 8″ material well bolted to the piles and a single row of 4″ x 10″ tongue and groove or spline and groove sheeting, dressed. This type has been employed where it was necessary to hammer the piling to obtain necessary penetration. The writer prefers when conditions permit, spacing the piles in two rows, staggered, instead of the single row; but hard driving material tending to throw the piles out of alignment may render the single row advisable. It is suggested that if this single row of piling type of construction be adopted the sheeting should be placed on the windward side so that the pressure of the sand naturally higher on the windward side, will hold the sheeting against the stringers, which are directly fastened to the piling. If the sheeting is placed on the leeward side of the piles, the bolts are subjected to direct tensile stress; and it is well understood that the bolts depreciate rapidly due to rusting.

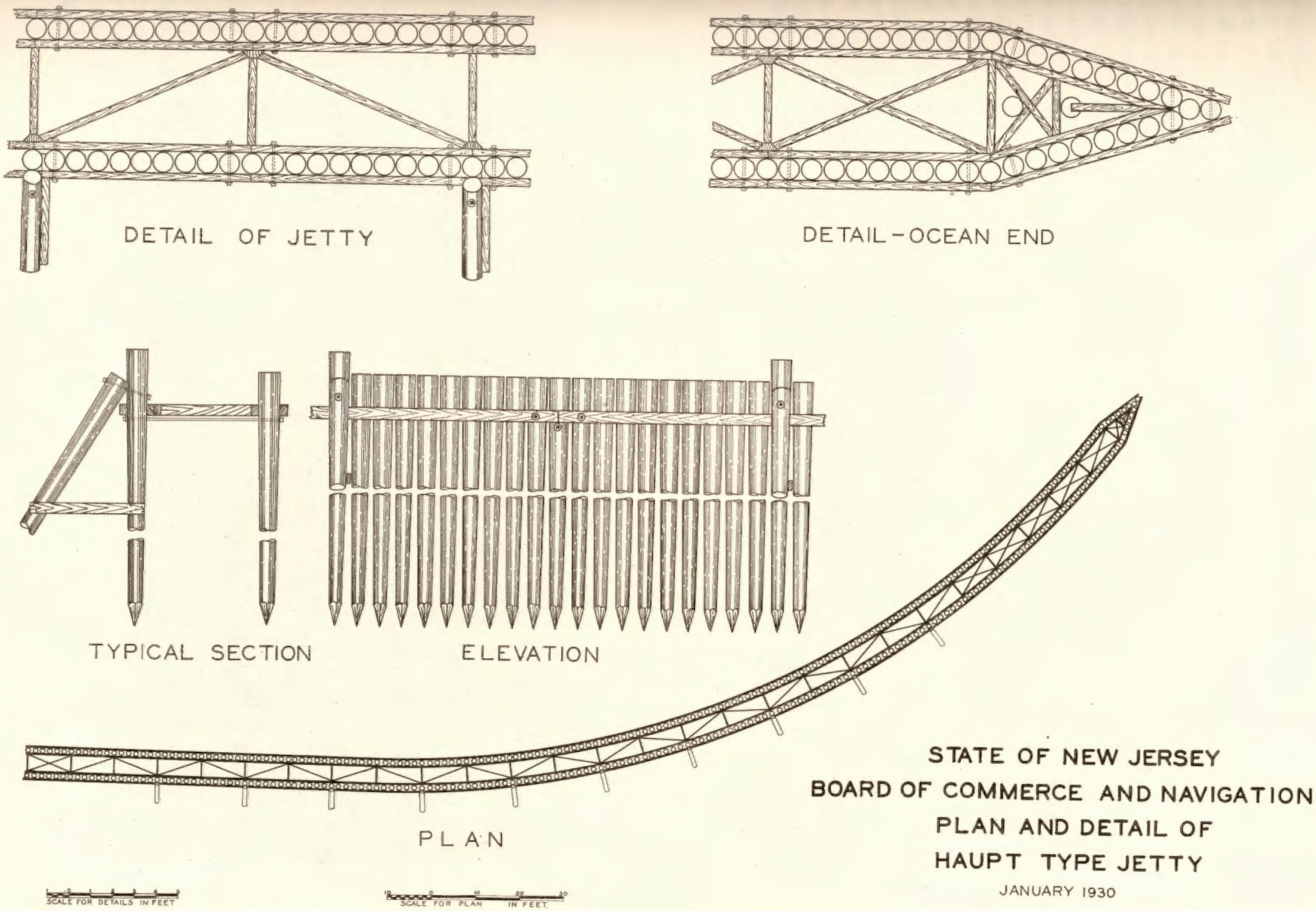
Another type differing somewhat in details from the preceding has been widely adopted on the New Jersey shore. Some of these structures have given great satisfaction at moderate cost. It comprises two rows of piles each spaced 5′ center to center thus giving a pile support at 2′6″ intervals. There may be one pair, but frequently two pair of upper wales placed one above the other and one pair of lower wales. If only one pair of upper wales is employed then both wale systems will be of heavier material than are used where the two upper wales are employed. The wales are secured to each pile by a 1¼″ galvanized wrought iron bolt. Two rows of 3″ x 10″ or one of 3″ x 10″ and one of 4″ x 10″ sheeting are spiked to the wales. In other designs of sheeting such as a single row of 5″ tongue and groove or spline might be used. These are details on which there is considerable diversity of opinion among practical men. The writer believes, however, that the standard tongue on 4″ material or lighter is very weak. The writer further believes that sheeting of less than 3″ nominal thickness is too light except in triple lap, like the Wakefield sheet piling. A practical method of procedure that may be followed in constructing a groin of this kind, using the water jet is described as follows:

One row of round piles is driven to approximately final penetration. Specified alignment having been obtained and the necessary notching completed, the proper wales, three in this case are fastened to the first row of round piles with two 6″ or 7″ spikes for each wale. Next the nearer row of sheeting is jetted to position keeping a firm, tight bearing between adjacent planks and then fastened to the wales with 6″ or 7″ spikes, two to a plank and staggered. A good bearing must be obtained between the adjacent sheet piles and the wales and sheeting.

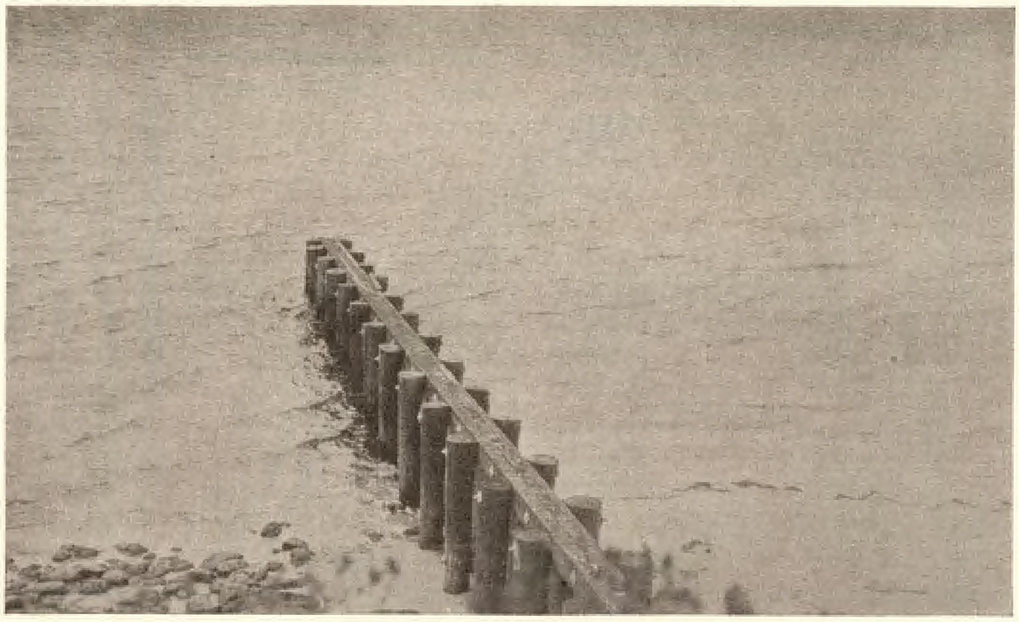
The second row of sheeting is then jetted down to grade, breaking joints with the first row and fastened with two 6″ or 7″ spikes to the first row of sheeting. These spikes are staggered with respect to the spikes previously driven. Care must be taken while butting each plank against the neighboring planks in the same row to avoid bruising the lumber, particularly if it is creosoted material. Next the last sets of wales are spiked to the sheeting already driven. Following this, the second row of piles is jetted down. The final detail is the boring for and tightening up the bolts and where specified, sawing the piles down to grade. The writer submits that sawing off creosoted material is subject to criticism. For satisfactory work, the timber should be square



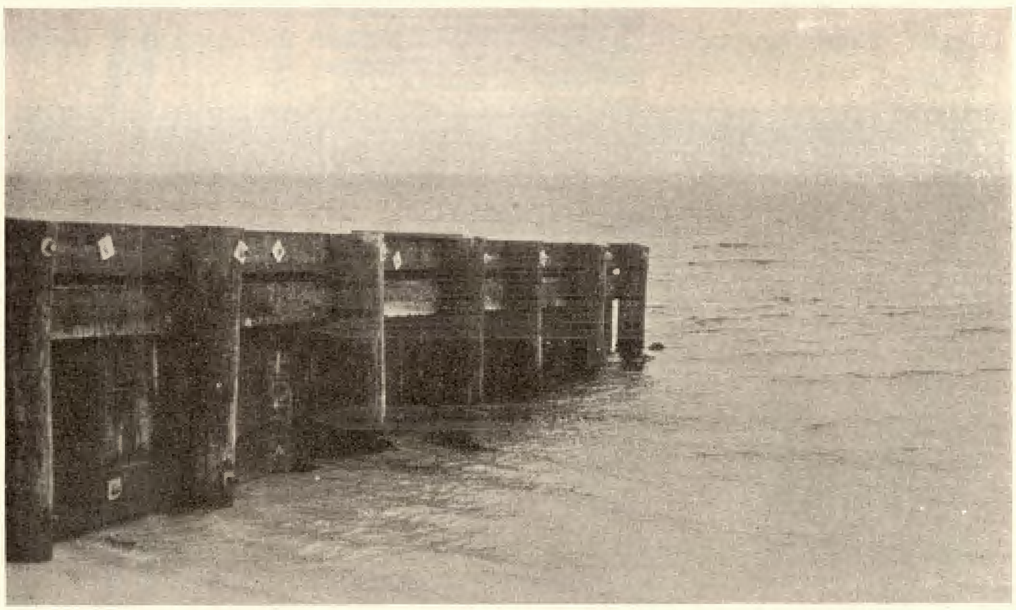
Long Branch, November 10, 1922, No. 5.



See text, page 77.



Pile and timber groin.



Pile and timber groin.

edged so as to obtain good bearing particularly for the sheeting, as good bearings are necessary for a tight job.

Whenever possible, timber groins should be constructed of lumber treated with preservative. Sometimes the inshore ends are, from motives of economy, constructed of untreated lumber, but in some cases, this is doubtful economy. It is true that creosoted lumber for example will increase the cost by roughly one-third to one-half as compared with untreated lumber, but the preservation of timber against decay and attacks by marine borers is well worth while, particularly, in view of the great reluctance of responsible officials to provide adequate maintenance.

A third type is that known as the reaction jetty, the original designer of which is believed to be Professor Lewis M. Haupt. A typical example is shown on page 75. Briefly, it consists of two rows of round piles, 6′ apart on centers, the leeward row of piling being in turn supported by batter piles bolted and braced to the vertical pile. In addition each row of vertical piles carries two 4″ x 8″ wales. For rigidity the two rows of piles are tightened together at 10′ intervals with a tie rod and braced with a 4″ x 8″ strut. In addition these cross members are braced with 4″ x 8″ diagonals. This is the permeable type to which reference is made elsewhere in this report. An essential feature is the curving plan or hook which swings up to windward. There would be no profit in continuing indefinitely the description of the details of groins. When groins will serve, it is not economy to specify the more expensive structures which are denominated as jetties, but when the water is too deep or the exposure is too severe for the lighter works, more substantial and necessarily more expensive construction is required.

This photograph shows the failure of the outer end of a timber groin during the storm of February, 1927.

Failure of outer end of groin. Storm of February, 1927.

The seemingly small size of the round piles is due to the fact that they were fitted into place, butt downward, in an attempt to reduce the tendency to lift out as the result of wave action and flotation. Obviously, however, if this procedure is followed, due allowance should be made for the fact that the effectiveness of the round piling acting as beams, each supporting a panel is correspondingly reduced because the larger section is buried in the ground and the thrust from waves or other impact must be taken by these very small timbers.

The following photograph shows one of the groins that were built as a part of the same operation as the previous structure.

Groin, partly destroyed in place, partly floated out.

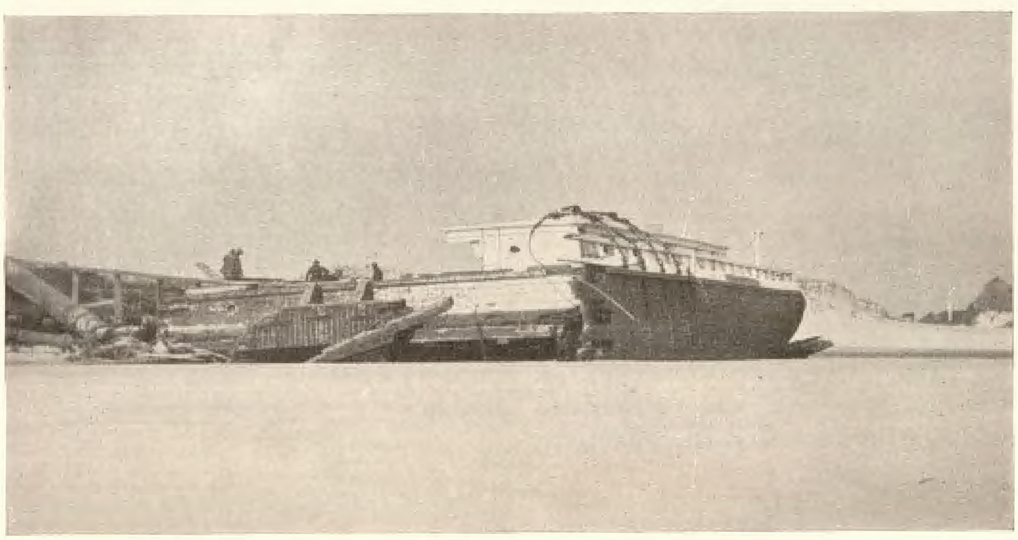
In this case a section of the groin was destroyed by floating out and a part destroyed but remaining in place.

The third photograph shows the hulk of the schooner which came ashore during the same storm, February, 1927, and presumably struck these groins.

Of course no type of groin could resist the impact of such a floating mass of wreckage as this schooner or heavy scow. This illustrates the need for enlightened action in preventing the grounding of hulks in the bays or other waterways where they can be easily floated during abnormal high tides. Every large timber or part of a boat grounded near an inlet should be regarded as a potential menace to every groin or jetty in the locality. The writer has, on more than one occasion, witnessed the great damage caused by a lighter lost or cast loose in a towing operation, follow along the beach for several miles, mowing down piers and other structures.

Timber Groin With Vertical Main Piles and Batter Pile Bracing

This plan is designed to produce a structure well braced against lateral pressure from drift or current. It is practically an ordinary groin fortified with the additional bracing of a batter pile every five feet, staggered. The main piles are driven to eighteen feet average penetration and extend on an average of nine feet out of the earth. The 5″ x 10″ creosoted tongue and groove sheet piling indicates with the other details sturdy and not cheap construction. The



Grounded hulk.

vertical piles are spaced five feet apart on the leeward side of the sheeting. Three 4″ x 10″ wales bolted to each vertical pile are utilized to guide and provide bearing for the sheeting. The batter piles are driven to a penetration of eighteen feet below the bottom on a batter of one and one-half to one and are secured by a one-inch galvanized bolt driven through the batter pile and the vertical pile and extending to the opposite wale. 6″ x 10″ wales bolted through the vertical piles and the sheeting provide a bearing for the batter piles against the vertical piles.

While this makes a very good looking structure, the writer's experience is that batter piles are objectionable in many respects where there is strong wave action. If the waves are heavy enough to set up a serious vibration, there is danger that the structure will weave more or less and when that condition occurs friction between the batter pile and the earth is reduced with consequent probability that the batter pile may be lifted out. Once they are loosened the batter piles operate as agencies for loosening the vertical pile. There is no particular difficulty in driving batter piles with a hammer, as everyone knows but there is difficulty in obtaining good penetration with a water jet because the water tends to rise from the jet in a vertical direction and not in the diagonal direction of the batter pile. As a consequence the pile or the jet pipe may in some conditions be "frozen" at the ground surface. To avoid this it is necessary to open up a large area of disturbance by the water jet with the consequent probability that firm bearing may not be obtained for a long time. That is to say, so much sand and other material may be washed out to obtain the necessary penetration that the necessary recompacting of the earth after the jetting processes terminate will take a long time. Jetting, unlike hammering, does not compress the earth, but quite the contrary, and if there is a clay or mud substratum which is washed out in the jetting operation, there is always a question whether the area thus disturbed is quickly refilled with good earth material that will furnish the necessary holding power. Normally, the jet should be so employed that the disturbance of the substrata will be reduced to a minimum.

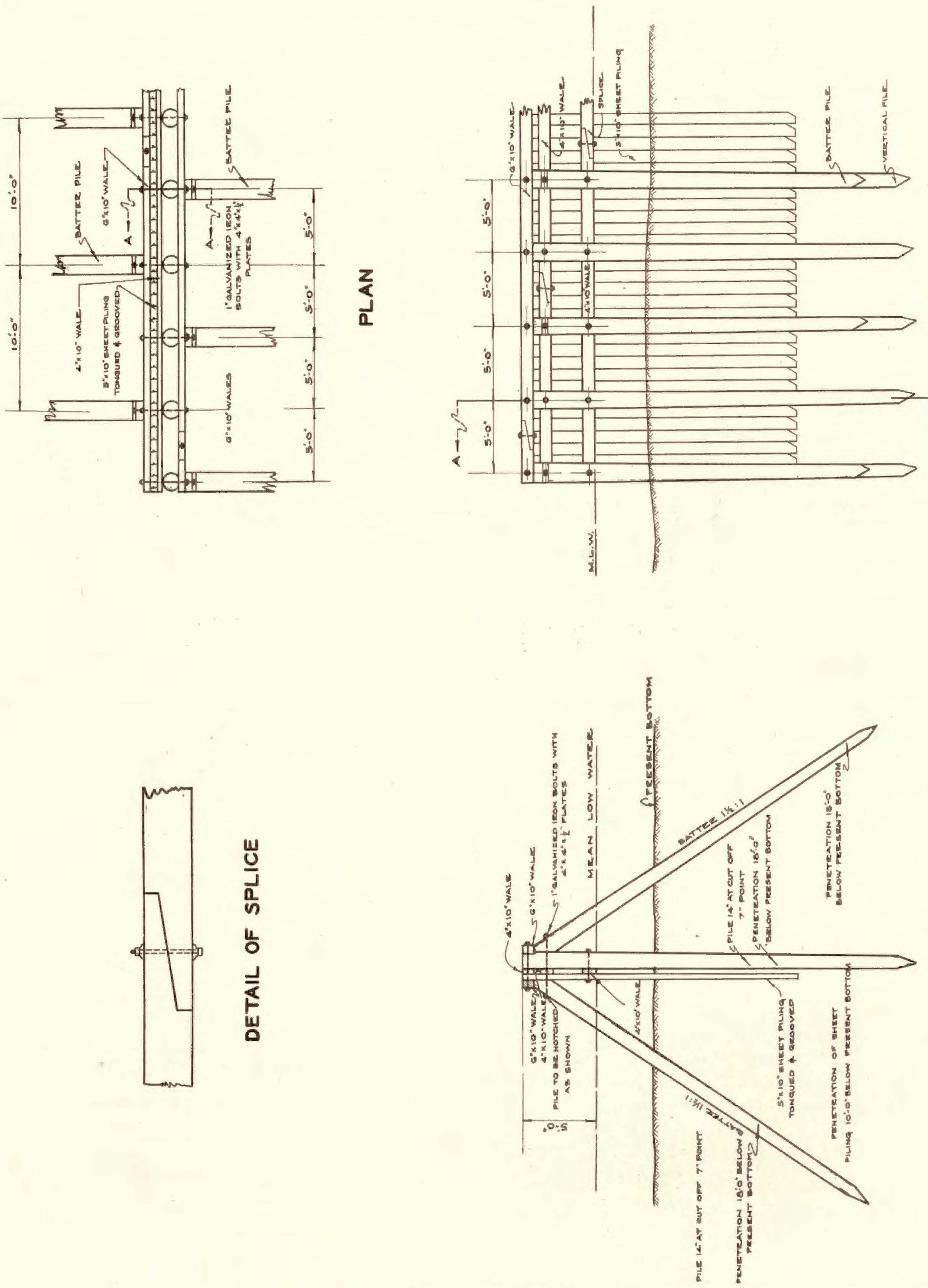
Batter piles in a seaway are subject to another weakness, and that is the very great probability that floating logs or other wreckage will wedge in under the batter piles and knock them loose when raised by waves. It is only necessary for the blow to be hard enough to shear the timber in the batter pile from the upper end to the bolt; in this case from the one-inch galvanized iron bolt on the batter pile to the bottom of the 6″ x 10″ wale.

The writer therefore suggests that the structure shown on this plan is very expensive for the results it would yield in a situation where the reversal of the current as in a tidal inlet requires double bracing and where there is serious wave action and floating wreckage. And floating wreckage is always to be expected on sea beaches, particularly in the neighborhood of harbors. The structure shown has too great a projection above the surface of the ground compared with its penetration. It is very difficult to put enough timber, buoyant as it is, into an exposed single line structure like a groin to make it strong enough to resist much wave action. A double line structure giving necessary width and opportunity for bracing will probably promise better results at the same cost. But in any event, penetration into the earth to obtain necessary anchorage of the piling against flotation when vibrated by the waves is one of the first considerations. If the structure projects far into a tide-way scouring on the leeward side is probable.

Therefore, if the water is too deep, or the wave attack too severe, or the holding power of the earth inadequate or other unfavorable conditions indicate probable failure of the single line groin, recourse must be had to rock reinforcement or a double line structure.

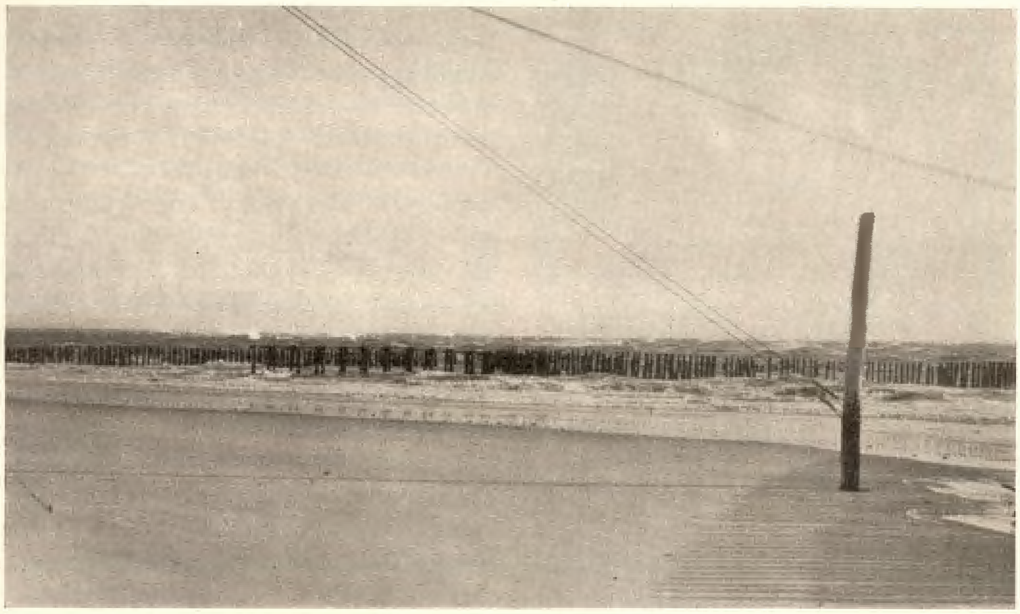
Timber Piling or Wave Screen Stockades

Various plans and photographs show the open sand fence or stockade, a very popular system of protection, or alleged protection that has been extensively used in many sections of the country, including the New Jersey Beaches. In general this type of construction consists of round piling, generally the cheapest type available, closely spaced in one or two parallel rows. In plan, they are laid approximately parallel



Plans of groin with batter pile bracing.

to the shore line and may be on a straight or zigzag alignment. In appraising the effects of this type of construction, the observer should sharply distinguish between stockades placed above the high water mark which act primarily to arrest wind-blown sand and the wave screen stockade which, as its name indicates, is intended to break the force of the waves before they reach the bulkheads or upland beach.

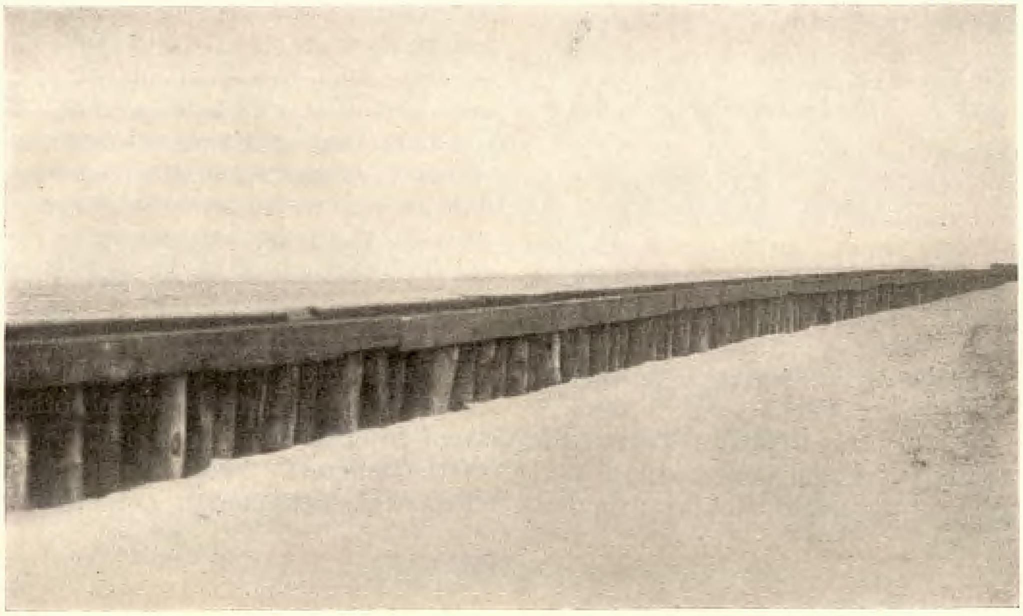


Wave screen, Longport, February, 1926.

This photograph shows the typical wave screen rather seriously depreciated.

In weighing the merit of cheapness that is argued for this type of open construction, it is not fair to compare their cost with the cost of standard bulkheads or groins for which the usual specification requires first class material well fastened together and adequately treated with preservative. The advocates of this type of construction in pointing out its cheapness have not stressed this point; but it should not be overlooked.

This photograph shows a typical sand fence made of old piling salvaged in the reconstruction of a highway bridge.



Sand fence, Seaside Park.

Old railroad ties are often used. This particular structure has been very successful and is in fact one of a series of screens by which the shore line has been successively moved out. It was constructed twenty-five to fifty feet back of mean high water mark and, in the writer's opinion, is supported and aided by a bulkhead underneath the boardwalk inshore.

The writer is firmly convinced that the sand fence stockade of this type when placed above ordinary high water mark, is a cheap form of protection, which has yielded highly gratifying results in many situations. It often piles up a ridge or windrow which is very effective. With regard to the wave screen type necessarily placed well outshore of high water mark, he is not so optimistic. He does not recall a single instance of it demonstrating any great value on a shore front adjacent to an inlet.

The theory that supports the use of the wave screen stockade seems rather plausible. The idea is that the wave rolling in from the ocean is in large part dissipated by the wave screen, thus reducing its effectiveness in striking a sea wall or other structure placed inshore of the wave screen. It is well known that as the waves roll in, the water as it advances shoreward is necessarily contracted into the small spaces between the piling. Here is a favorable situation for cutting out the sand in these spaces. That sand is necessarily driven shoreward as the wave, partly broken by the stockade, rushes in. So far the theory is very good, but it is necessary to carry it another step further. This sand, dislodged by the water, is necessarily carried in suspension. All of the water thrown inshore in the waves will return and as it returns carry some or much of the suspended sand with it. Furthermore, the water rushing oceanward after the wave is spent is again favorably trained and driven so as to scour out sand between the piling. The argument is advanced that this sand is again driven shoreward in the next wave. In other words, the water will be more or less seriously agitated, carrying a very considerable volume of sand in suspension.

If there were no lateral component in the movement of the sea water or if it were so evenly fluctuating as to compensate, this situation on a flat beach would be subject to little comment because the sand would ultimately come to rest in periods of fair weather. Unfortunately, however, we know that there is a strong lateral component to the movement of sand which is highly active in proximity to the inlets. The reader is invited to distinguish sharply between this type of construction and the bulkhead type or offshore crib type which are discussed elsewhere in this work. The bulkhead type or the crib type filled with rock or tightly sheathed is frankly intended to catch and retain the sand as it is driven shoreward by the waves which hurdle the barrier. For examples of this type of construction see the Ventnor offshore crib and bulkhead plans and photographs in this report. For the open type see reference to the Beach Haven hurdles and flying buttresses.

Sea Walls vs. Timber or Steel Bulkheads

In considering a project of any magnitude which includes the erection of a structure running along the shore which is designed to arrest the tidal and wave forces, we are confronted, if it is required to exceed a certain stage of height, with the necessity for choosing between a very expensive timber or steel bulkhead on the one hand and a rock or concrete wall on the other. Each of the types and materials has its advantages and disadvantages. The concrete structure within certain limits is more expensive but it normally can be constructed of more attractive appearance than is the case with a heavy timber structure, particularly after the timber begins to lose its alignment. The concrete in many situations is relatively durable if the wall be properly constructed. On the other hand it is not as easily repaired in case of a breach.

Furthermore, a timber or steel bulkhead if properly designed and constructed is a self-supporting structure with considerable elasticity or resilience, whereas the concrete bulkhead or sea wall is a monolithic structure highly rigid which must be more adequately braced; otherwise a defect or breach even in a very restricted portion, is likely to carry with it much other material which otherwise would have resisted the attack. The greater weight of the concrete structure, particularly in situations where the soil is not any too good with respect to bearing power, is an important element to consider. On the other hand, this very weight or massiveness may be highly advantageous with respect to resisting the wave impact.

The concrete sea wall and the bulkhead as well must be provided with first class cut-off walls underneath. The certainty that the backfill will become more or less saturated during periods of high waves and onshore gales and that possibly some seepage will pass under the structure render the provision of an adequate cut-off imperative. Furthermore, it is highly unsafe to rely upon the bearing power of the soil of the beaches to carry a masonry sea wall unless the construction can be carried down to solid rock. Therefore, among the primary essentials are these,—

1st. Provide enough piling to support the concrete structure even though considerable removal of the underlying sand take place;

2d. Provide a buried bulkhead or cut-off securely joined to the wall structure to prevent as far as possible this washing out of the underlying material;

3d. Brace the sea wall or bulkhead with returns or cross walls at frequent intervals in effect forming compartments in order to localize the effect of a breach.

There is no rule to control definitely the selection of the type of wall or bulkhead. This is all a matter of judgment and experience. A variation of fifty to one hundred feet at right angles to the beach line in the location of the structure may determine whether it is necessary to construct a heavy sea wall or whether a lighter and much more economical structure can be safely specified.

Evidently therefore supervision of the beaches and observations of the prevailing tendencies should be provided for because a light structure perfectly adequate to meet the conditions of the given time may in a few years be subjected to forces for which it was not designed in the event that the erosion continues.

The Wildwood Bulkhead

This structure, the details of which are clearly indicated on the plan was designed by the City Engineer, Mr. Harry E. Weir. Situated on the ocean front, it is intended to protect a section of the city which was in part reclaimed by the hydraulic fill method with sand dredged from the lagoon which lies to the west of the city. For this fill, it acts as a retaining structure as well as a protective device against the waves and tide.

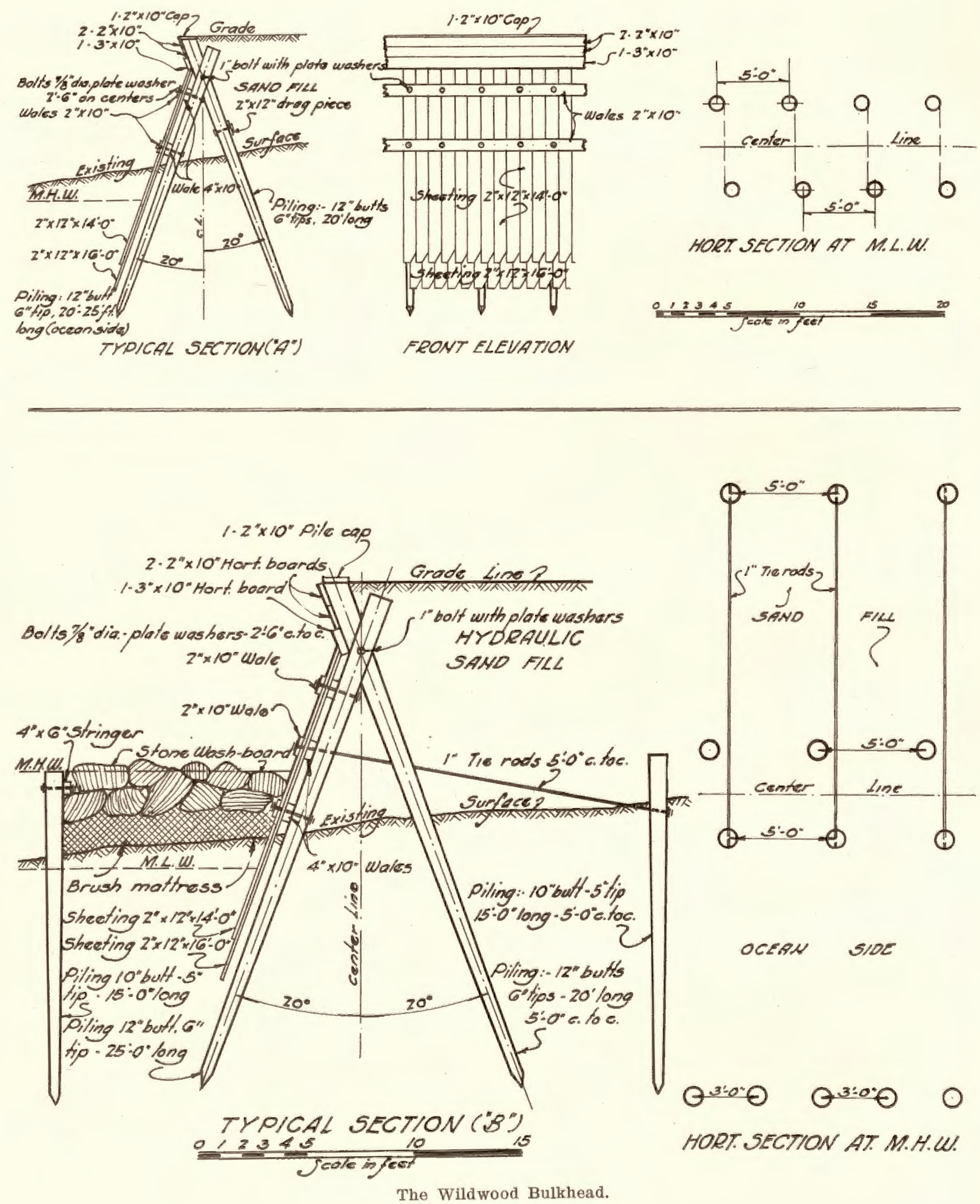
It is to be noted that there are really two classes of construction; section B. differs from Section A. in that it has the additional protection and fortification of the rock and brush mattress at its toe. This auxiliary support and protection to the timber bulkhead represents an excellent precaution and in the present instance must be regarded as an element of sound designing, in considering the cheap and light elements of the timber work. As shown by the location plan its incorporation in the work is due to the greater exposure of section B. which extends outshore at mean high water mark. This design is predicated upon the highly favorable conditions which obtain on this frontage, namely, a naturally flat foreshore,—a tendency toward accretion which has been particularly marked since the construction of the navigation jetties at Cold Spring Inlet, a few miles to the south,—a remoteness from inlets, a new condition which arose following the closing by the State and County authorities in 1923-4. Normally the process of building out into the ocean to enlarge the land areas constitutes an operation which is attended with hazard, but in this instance, the risk from this angle was regarded as worth taking, in view of the favorable factors adverted to, the flat foreshore which caused the storm seas to break well outshore,—the well established tendency toward accretion and the remoteness from inlets which implies freedom from the troublesome flood channel and other alongshore currents.

This work was completed in November, 1926. Following are the details:

BULKHEAD SYSTEM

Cost of the Bulkhead proper (length, 3,081 feet)	$53,265.00
Sand Fill (hydraulic), 209,970 cu. yds.	71,389.00
Brush, 1,524 cords	12,954.00
Sand Cement Bags, 35,792	17,896.00
Stone, 582 tons (2,000 lbs.)	3,490.00
Total Cost	$158,994.00

Cost per lineal foot, $51.60.



The Wildwood Bulkhead.

JETTIES

As an adjunct to this bulkhead, jetties were constructed in 1927 at Montgomery, Rio Grande, Bennett and Cresse Avenues. The costs were as follows:

Jetty, 1,050 feet	$8,925.00
Brush, 600 cords	5,400.00
Stone, 1,200 tons (2,000 lbs.)	6,000.00
Sand Bags, 4,000	2,400.00
Total Cost	$22,725.00

Cost per lineal foot, $21.64

Brush weighted down with one-man stone was extensively used in coast protection works on the New Jersey beaches twenty or thirty years ago, and it is still used in sections of the southerly coast line of the state where conditions are highly favorable. Its use elsewhere in the state has been largely abandoned. It produces a rather impressive looking jetty at relatively small cost, but the maintenance features must be faced unless conditions are extremely favorable.

It settles quickly as the foliage is destroyed and the foliage is rather quickly removed but is required in the work as it is the primary factor in furnishing imperviousness. Furthermore, the branches are likely to be quickly riddled by marine borers. All of this can not be taken as a valid criticism of the system but must be faced in view of the extreme difficulty in inducing officials to provide for adequate maintenance.

DETAILS OF STATE AID COAST PROTECTION OPERATIONS

* * *

The following reviews in detail the State Aid Coast Protection Operations completed or undertaken since the submission of the 1924 Report.

Additional details of the earlier projects may be obtained by reference to the 1922 and 1924 Reports.

Allenhurst Borough—Monmouth County

Net valuation taxable, $4,233,450.00
Ocean frontage, ½ mile

The total allotments of State aid to date amount to $70,000.00. State aid actually paid over to December 31, 1929, $67,474.91. Total cost of State aid improvements to December 31, 1929, $200,763.80. As indicated in the previous reports the tendency on this frontage has been unfavorable, a comparison of recent maps with the survey of 1839 indicating considerable erosion. This recession is also clearly indicated at a glance by the cliff formation.

The municipality has a highly attractive shore front occupied by a high concrete sea wall, beautiful homes and the Casino.

This frontage in addition to being subjected to a general tendency toward erosion for many years, was probably unfavorably influenced to a certain extent by the breakwater jetty constructed at the northerly boundary of Asbury Park in 1923. Certainly the breakwater jetty trapped an enormous volume of sand.

On May 17, 1926, the Board formally allotted $50,000.00 for the construction at the Borough's north boundary of a jetty with timber core, the contract having been awarded on previously approved plans to Thomas Procter in March, 1926. On August 18, 1927, the Board authorized extension of the jetty an additional two hundred feet. The final estimate of November 15, 1927, showed the following quantities at the prices bid:

694.5 lineal ft. of timber core @ $20.00 per ft.	$13,890.00
33,025.83 tons of stone @ $4.80	158,523.98
Total cost	$172,413.98

This jetty begins at the northerly end of the sea wall, this point marking the division of the Boroughs of Allenhurst and Deal and extends seaward in a southeasterly direction at an angle of approximately 60° with the concrete sea wall. At the time of beginning the work this concrete sea wall, a gravity structure of attractive appearance, had been badly undermined and the Borough was compelled to reinforce it and at the point of severest attack and actual collapse to build a boardwalk.

The rock was obtained from Raven Rock in the northwestern part of the State. The core consists of 16″ white oak piling with 4″ x 10″ stringers and one row of 6″ x 12″ sheeting, tongue and groove. All timber in the core except the oak piling being of creosoted Southern Yellow Pine.

The details of the State Aid payments are as follows: $25,000.00 approved December 27, 1926, $25,000.00 approved December 12, 1927. The enabling act was Chapter 39, of the Laws of 1925. This jetty did not function as satisfactorily as was hoped and the fortification and extension of the jetty at the foot of Corlies Avenue was decided upon.

The Board had previously agreed to contribute $20,000.00 toward the installation of a Brasher compressed air system; to be installed and operated on a contingent basis. As agreement could not be reached between the Borough and the Brasher interests, the Corlies Avenue jetty was determined upon and the $20,000.00 State Aid allotted therefor.

The latter is of the conventional type of piling, thirty feet in length, two rows of wales, 3″ x 10″ and double row of 2″ x 10″ sheeting. The contract was awarded to Thomas Procter, October 29, 1928, and in the final estimate covered the following items:

100 linear ft. timber core @ $32.28	$3,228.00
5,371.45 tons of stone @ $4.70	25,245.82
200 linear ft. of timber core @ $32.38 per linear ft.	6,476.00
Total cost	$34,949.82

State Contribution, 50%—$17,474.91

The Corlies Avenue jetty has functioned with considerable satisfaction, particularly in protecting the frontage of the Casino and south thereof.

City of Asbury Park—Monmouth County

Net valuation taxable $36,050,913.00
Ocean frontage, 1 mile
State aid allotted, $60,000.00
State aid payments to January 31, 1930, $25,000.00
Cost of State aid improvements to January 31, 1930, $217,790.00

The primary work executed as a State aid project in this municipality is fully described in detail in the 1924 report. Briefly, the specifications called for the construction at the northerly boundary of the city, of a stone jetty without core to be 800 feet long. The payment included a contingent clause as the specifications required building up the beach eighteen inches above mean high water mark. This does not apply to the eighth section of one hundred feet.

The work suffered severely during construction—a storm of December 28, 1922, causing serious damage. Depreciation continued, but it is fair to say that the jetty even in its depreciated condition was very effective in trapping sand. The State's contribution of $25,000.00 was paid in 1923. This jetty was subsequently restored in large part by the city and is very effective at this time.

On December 19, 1927, the Board under Chapters 114 and 318 of the laws of 1927, voted the allotment of $15,000.00 for the construction of a stone jetty with timber core at 6th Avenue; this jetty is of straight alignment at right angles to the shore for the inshore 400 feet and there deflects $52\frac{1}{2}°$ to the right (southeast). The contract was awarded February 16, 1928, to Thomas Procter of Long Branch, whose bids on this operation were as follows:

16,000 tons of derrick rock @ $4.80		$76,800.00
Creosoted timber core for the 1st 200′ @ $24.80	$4,960.00	
Creosoted timber core for the 2nd 200′ @ $34.40	6,880.00	
Outshore 100′ timber core @ $54.00	5,400.00	
		17,240.00
Total		$94,040.00

The total bid was actually $117,790.00 but this included in addition to the 6th Avenue Jetty, 5,000 tons of derrick rock for the rebuilding of the first jetty above described at a unit price of $4.75 per ton. The State aid contribution applied to the 6th Avenue jetty.

The Board under Chapter 166 of the Laws of 1928 and Chapter 263 of the Laws of 1929, allotted $20,000.00 for the construction of an extension without timber core to the existing jetty at the foot of 6th Avenue and the construction of a new timber and stone jetty at the foot of 4th Avenue.

Bids were opened November 12, 1929, and rejected by the municipality allegedly on the ground that the low bidder would not have completed the work prior to May 1, 1930. New bids were asked for and opened on December 17, 1929. The low bidder in this case was O'Brien Brothers, Inc., of New York City. The details are as follows:

	14,000 tons Derrick Rock 6th Ave.	17,000 tons Derrick Rock 4th Ave.	300 lin. ft. Type "A" core	250 lin. ft. Type "B" core	50 lin. ft. Type "C" core	Total
O'Brien Brothers	$4.15	$4.15	$24.40	$34.00	$60.00	$147,470.00
Woolley & Howland	4.02	4.02	32.10	48.83	58.00	148,857.50

Actual construction had just begun on January 1, 1930.

Atlantic City—Atlantic County

Net valuation taxable, $313,316,459.00
Ocean frontage, 3½ miles
State aid allotted to January 1, 1930, $24,000.00
State aid paid to January 1, 1930, $9,000.00
Expenditures on State aid improvements to January 1, 1930, $23,361.01

Atlantic City is the most northerly of the municipalities situate on Absecon Island. Its situation is radically different from Longport, which is at the southernmost extremity of Absecon Island. Heretofore, in this region, the southern points of the inlets have shown a general tendency toward accretion. As in every other shore front section, local recessions and cuts occur occasionally, but these are closely watched and guarded by the municipality. In general on this frontage the tendency continues favorable.

The beach excepting in the Inlet section is flat; that is, it has a very slight gradient which with the four-foot normal range of tide exposes a broad expanse of shore between swings of the tide. With this flat beach, heavy seas are broken up before they can do any damage to shore structures. Under the circumstances erosion is not greatly to be feared and marked accretion is not desired.

This municipality was the pioneer in New Jersey in proceeding under what is known as the general "Park Act" which authorizes ocean front municipalities to acquire the beach and hold that beach in trust as a public playground. There are a few properties such as Young's Old Pier and the Garden Pier and one or two other frontages which were exempted from the operations of this statute by the simple expedient of failure to condemn or otherwise acquire the parcel. The City under the foregoing legislation has with the aforesaid exceptions acquired title to all lands outshore of the inshore line of the boardwalk. Under the agreements with the owners, the title to the lands inshore of the boardwalk immediately passes to the abutting properties upon the extension oceanward of the boardwalk site. As the property fronting on the boardwalk in the central part of the City is highly improved extension at this time would be almost impracticable and is probably not desired by anybody.

Notice that the Park Act and the agreements thereunder provide for shifting oceanward but not for recessions. Recessions have never been contemplated on this frontage. The City is wealthy and to its credit it must be said that it would not permit any serious erosion without taking prompt and active measures for correction. It has been fortunate but vigilant as well.

The low jetty has in the past been the standard of protection in this frontage and has in general yielded very satisfactory results, it being understood that conditions have been favorable. The first State Aid project on this frontage was undertaken when the Board of Commerce and Navigation on January 16, 1927, allotted to Atlantic City $9,000.00 State aid on the following two projects:

(a) Placing additional stone on the ends of the existing jetties at Illinois and Tennessee Avenues respectively.

(b) Construction of a low stone jetty with timber core 260 feet in length situated 150 feet west of New York Avenue.

On (a) the contract was awarded to Anthony P. Miller, April 7, 1928. The final estimate was for the payment of $16,746.42. The unit price of rock was $10.73 per ton.

On (b) the contract was awarded April 4, 1928, to Barker-Somers, Inc. The structure cost $6,614.59. Quantities per 100 feet of lineal structure are itemized as follows:

77 bolts, washers, etc., galvanized—1"
26 round piles, S. Y. P.
7,000' B. M. sheeting, double row
0.8 M. ft. B. M. wales
208.6 tons of stone:—75%—300 lbs., 25%—25 to 300 lbs.

The prices on this jetty were very low.

Under Chapter 301 of the Laws of 1928, an additional $15,000.00 State aid allotment was granted for the construction of three low level stone and timber core jetties, at Drexel, Madison and Vermont Avenues, respectively. None of this work had been completed at January 1, 1930.

The Drexel and Madison Avenue operations were awarded to Eastern Engineering Company and the Vermont Avenue contract awarded to Vincent Jafolla on the following prices:

DREXEL AVENUE JETTY
72′ in length
Timber core $510.00 complete
Rock in place $8.90 per ton

MADISON AVENUE JETTY
84′ in length
Timber core $450.00 complete
Rock in place $8.90 per ton

VERMONT AVENUE JETTY
100′ in length
Timber core $5,000.00 complete
Rock in place $5.50 per ton

Avalon Borough—Cape May County

Net valuation taxable, $3,115,348.00
Ocean frontage, 2 miles

State aid allotment $5,000.00, under Chapter 303 of the Laws of 1928, for the construction of two timber, brush and stone jetties at 8th and 12th Streets, Avalon. Only the 8th Street jetty was contracted for and built.

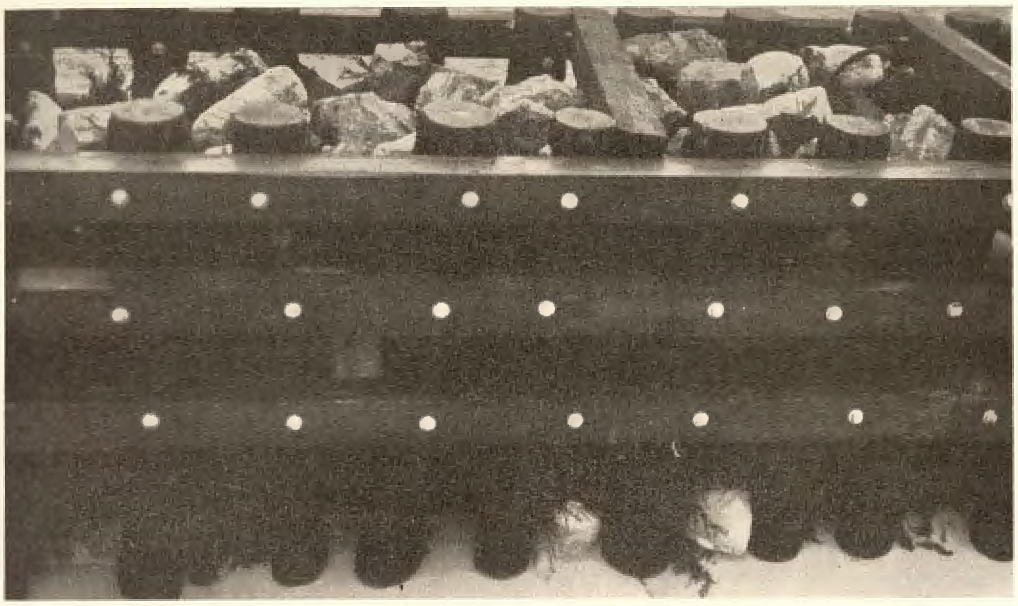
Contract awarded to Wright Brothers on the following described materials and prices:

600 round pine piles @ $4.00
22 M. ft. of lumber (stringers, struts, braces, etc.) @ $90.00 per M.
1,800 galvanized bolts & washers @ $1.00
70 tie rods—1½″ diameter @ $3.00
700 lin. ft.—10″ channel iron @ 30c.
600 tons 1 man and 2 man stone @ $4.50
180 cords Cedar brush tied in bundles with galvanized wire @ $1.50

This jetty can be described as of the crib type with two rows of piling on two-foot centers; each row of piling carrying three wales; the two rows being well tied with tie rods and braced with struts.

The space between being filled with brush weighted down with small stone. The jetty follows approximately the slope of the beach up to mean high water line and from that point extends seaward, at elevation of about one foot above mean high water. This work was approximately 50% completed January 1, 1930.

Avalon Jetty from the Boardwalk.



Avalon Jetty showing details of construction.

Avalon jetty inshore end.

Avon Borough—Monmouth County

Net valuation taxable, $3,657,929.00
Ocean frontage, ¾ mile
No State aid has been granted on this frontage.

Timber core and rock jetties were built by the borough without State aid and in fact without having applied for State aid. The application having been submitted subsequent to completion of the jetties was rejected.

Barnegat City—Ocean County

Net valuation taxable, $188,647.00
Ocean frontage, more than two miles

The Board of Commerce and Navigation has voted to allot for new work $17,500.00 made available under Chapter 192 of the Laws of 1929, a State Aid Statute, and the County of Ocean has appropriated $17,500.00 to meet the State's appropriation. Plans were in preparation January 1, 1930.

The large breakwater jetty on the oceanfront at the foot of Barnegat Light and the three timber groins on the bay front were constructed by the Board of Commerce and Navigation under Chapter 159 of the Laws of 1926. The primary object of this operation was to protect the lighthouse from destruction by the sea. This lighthouse and curtilage have been ceded by the United States to the State of New Jersey.

The inshore end of the existing breakwater jetty and the three bay side groins were built under contract by Woolley & Howland, of Long Branch. Owing to the long haul of about nine miles from the nearest railroad point, Surf City Junction, and the relatively small appropriations plus the necessity for building and maintaining a long runway for the trucks, the unit costs which follow were necessarily high:

Under Chapter 231 of the Laws of 1925, appropriated $75,000.00

5,459.665 tons of stone @ $9.80	$53,504.72
2,196 lin. ft. piling @ $1.25	2,745.00
47,421⅔ ft. B. M. Lumber untreated, @ $150.00 M.	7,113.25
2,662 lin. ft. creosoted Piling @ $1.65	4,392.30
28,616⅔ ft. B. M. creosoted Lumber @ $178.00 M.	5,093.77
Total of original contract	$72,849.04

The State House Commission subsequently appropriated $25,000.00 additional. This was all expended under supplemental contract with Woolley & Howland for extension of the rock jetty, 2,551.02 tons of rock at the unit price of $9.80 per ton.

The second supplemental contract was entered into for the expenditure of the $45,000.00 appropriated under Chapter 24 of the Laws of 1928, which was all expended for 4,591.84 tons of additional rock on the stone breakwater jetty at $9.80 per ton.

Just as in the case of the Longport jetty, the high velocity of the tidal currents scoured a pool ahead of the jetty which required enormous quantities of rock for filling. This unfortunate condition which was fully anticipated was aggravated by the delay between the second and third allotments. At the time the estimate was made for closing the gap between the end of this jetty and the old government rock pile, the depth of the gorge was fourteen feet. In the months succeeding that elapsed before the $45,000.00 became available the depth increased to twenty-seven feet.

The $75,000.00 originally appropriated with the subsequent appropriation of $25,000.00 and the later State House Commission's grant of $45,000.00 brought the total cost of the work as it stands to $145,000.00. Considering the very limited amount of money expended at the high unit prices and a severe degree of exposure, highly satisfactory results have been obtained. The lighthouse and the premises which are now owned by the State as the result of cession by the United States Government were preserved from destruction and are in no immediate danger. It is necessary to face the fact however, that despite the large amount of sand gathered by the breakwater jetty chiefly to south but noticeably also in the north and the favorable results obtained by the three bay side groins, the job is not completed. Severe erosion has continued to the south beyond the zone of influence of the jetty and the short gaps at the inshore ends of the bay side groins should be closed as abnormal tides will circle around the inshore ends of the bay groins. This formation of these gaps was expected at the time the jetties were built but their further extension into the sand hills at that time would have been highly expensive.

Sea Dog Shoal as it continues to grow becomes increasingly effective in directing the currents against the south side of the inlet gorge.

Bayhead Borough—Ocean County

Net valuation taxable, $2,108,094.00
Ocean frontage, exceeding one mile

Bayhead (head of Barnegat Bay) marks the northerly limit of the offshore bar or barrier beach which we have already described as extending southward to Cape May.

The old timber groins referred to in the 1924 report have seriously deteriorated.

No State aid coast protection works have been carried out on this frontage.

Beach Haven Borough—Ocean County

Net valuation taxable, $2,160,367.00
Ocean frontage, 2 miles
State aid allotted to January 1, 1930, $50,000.00
State aid actually paid to January 1, 1930, $35,000

Total expenditures on improvements to date $92,624.31.

HOLYOKE AVENUE JETTY

The Board under Chapter 114 of the Laws of 1927 allotted $25,000.00 in aid of the construction of a timber core rock jetty at Holyoke Avenue. This jetty which extends straight seaward at right angles to the beach within the extension of the lines of Holyoke Avenue is of the conventional type, with top five feet above mean low water, ten feet wide.

Three bids were received as follows:

Bidder	Stone Per Ton	Round Piling Per Lin. Ft.	Lumber Per M. B. M.
J. A. Howland	$5.98	$1.00	$180.00
Woolley & Howland	6.15	1.25	150.00
Thos. Procter	7.00	1.25	160.00

Contract awarded to Jesse A. Howland, December 8, 1927.
Total cost under contract, $53,980.66.
First State aid payment $12,500.00, approved May 22, 1928.
Second State aid payment $12,500.00, approved August 14, 1928.
Total State aid, $25,000.00 paid from funds appropriated year ending June 30, 1928.
Total length of finished structure, 400 lineal feet.

The structure has operated very successfully but the erosion continues on the unprotected south (leeward) and will ultimately require consideration. Pool cutting at the end of the jetty was active as the construction progressed seaward.

CHATSWORTH AVENUE JETTY

The Board of Commerce and Navigation allotted $25,000.00 State aid under Chapter 301 of the Laws of 1928 for the construction of a stone and timber jetty at the end of Chatsworth Avenue. This operation had not been completed January 1, 1930. It resembles closely the Holyoke Avenue, but as it is to the north (windward) of Holyoke Avenue this Chatsworth Avenue jetty is constructed at a lower elevation to permit the sand to pass over into the Holyoke Avenue bay. Pool cutting and settlement as the work progressed oceanward were not nearly so pronounced as in the case of the Holyoke Avenue jetty. The piling and lumber outshore of low water mark are all treated with creosote (twelve pounds per cubic foot). The length of piling varies from twenty-five feet to thirty feet according to depth. The specifications and quantities and lowest price are indicated in the following summary:

6,600 tons of stone @ $5.40
830 lin. ft. round piling @ $0.90
1,450 lin. ft. treated round piling @ $1.35
17,577 ft. B. M. untreated sheet piling @ $110.00 M.
34,894 ft. B. M. treated sheet piling @ $150.00 M.
2,733 ft. B. M. untreated wales @ $150.00 M.
3,280 ft. B. M. treated wales @ $175.00 M.
Hardware included in timber bid.
State aid paid to January 1, 1930, $10,000.00
Work 85% completed January 1, 1930.

Belmar Borough—Monmouth County

Net valuation taxable, $6,937,662.00
Ocean frontage, 1½ miles
State aid allotted to January 1, 1930, $65,000.00
State aid actually paid to January 1, 1930, $42,715.63

Under Chapter 250 of the Laws of 1922, $25,000.00 was appropriated and reappropriated under Chapter 165 of the Laws of 1923 for the construction of a rock jetty with wooden core on the south side of Shark River Inlet. Conditions were very bad, the sand being so denuded that the highway bulkhead extending southward from the Ocean Boulevard bridge had become seriously weakened. The contract was awarded to Thomas Procter, April 19, 1924. The final estimate is as follows:

5,670.2 tons of rock @ $6.30	$35,722.26
2,050 lin. ft. piling @ $3.00	$6,150.00
32,302 ft. B. M. lumber (sheet piling and wales) @ $252.80 M.	$8,165.95
Extra carting of broken concrete, filling in voids back of concrete bulkhead and providing sand fill at cost plus 15%, $369.15	$50,407.36

State contribution, $25,000.00, approved for payment February 13, 1925.

Under chapter 114 of the Laws of 1927, $20,000.00 State aid was appropriated for the extension and regrading of this same jetty. Contract was awarded to Thomas Procter, October 19, 1928. Final estimate was as follows:

Inshore 300' of jetty reclaiming rock for regrading jetty	$2,750.00
Additional rock in place, 1,596 tons @ $5.85	9,336.60
Outshore 280' of jetty reclaiming rock for regrading jetty	2,900.00
Additional rock in place 3,426 tons @ $5.833	19,983.86
Repairs to core wall, 3,840' B. M. Yellow Pine @ $120.00 M.	460.80
Total cost	$35,431.26

State Share, $17,715,63. paid October 25, 1929.

Under Chapter 166 of the Laws of 1928 and Chapter 263 of the Laws of 1929, $20,000.00 was allotted for the construction of a jetty at 8th Avenue. Bids have been received but the contract has not been awarded—January 1, 1930.

The jetty at the south side of the inlet has been successful in the highest degree, gathering a large area of beach and furnishing protection to structures that suffered serious damage every year. This municipality needs additional protection to the south and is making provision therefor as rapidly as possible.

An incidental benefit of great moment to this region is the improvement in the Inlet Channel which has followed upon the construction of this jetty.

Bradley Beach—Monmouth County

Net valuation taxable, $7,548,860.00
Ocean frontage, 1 mile

State aid allotted to January 1, 1930, $25,000.00
State aid paid to January 1, 1930, $12,335.46

On September 11, 1928, the State House Commission granted an emergency appropriation of $15,000.00 which was later reimbursed to the Revolving Fund by Chapter 301 of the Laws of 1928. This State aid was applied to the construction of two timber and rock jetties of the crib type. Prices are as follows under the contract dated October 13, 1928:

126 lin. ft. Type "A" core @ $34.50
102 lin. ft. Type "B" core @ $38.50
1,518.3 long tons rock @ $5.35
Total cost North Jetty, $12,582.36
Total cost South Jetty, $12,088.55
All lumber is Long Leaf Yellow Pine

Parts of the work called for twelve pound penetration and the balance for sixteen pound penetration of creosote.

Under Chapter 263 of the Laws of 1929 the $10,000.00 additional was allotted for the construction of six timber groins, each 200 feet in length. The supplemental contract was awarded to Woolley & Howland on the unit price of $27.00 per lineal foot on an emergency basis.

This municipality suffered a sudden erosion from storms in the summer of 1928, which destroyed the old bulkhead under the boardwalk. Hence the emergency action taken by the State House Commission.

Brick Township—Ocean County

Net valuation taxable, $1,247,670.00
Ocean frontage, 1¼ miles

No jetty work of any kind has been undertaken either with or without State aid.

Brigantine City—Atlantic County

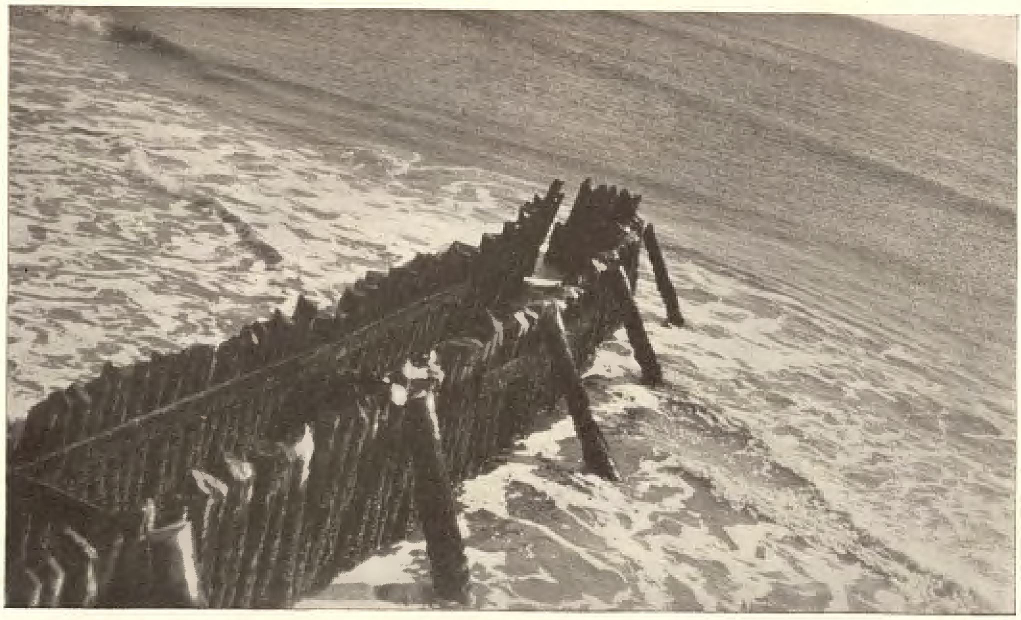
Net valuation taxable, $14,308.995.00
Ocean frontage, 5½ miles

The 1924 report gives the net valuation taxable in this municipality as $916,025.00, the population as twelve in number and refers to a company then engaged in developing portions of this beach as having undertaken the construction of a highway bridge to connect this wild desolate area with Atlantic City. All of this increase of taxable value and wealth has been created in this five years, and in place of the wild, trackless sand hills, there are now well paved streets and fine homes and a beautiful hotel. Brigantine City has not as yet felt the need for coast protection works although they did construct a number of cheap open type groins which are elsewhere referred to. These groins have in general suffered serious depreciation.

Brigantine City. Showing extension of hook jetty south of Hotel.

Brigantine City hook jetty.

Looking northeast from hook jetty shown above.



Outshore end of jetty extension south of Hotel.

Brigantine Hook Jetty, February 11, 1930.

Brigantine City, hook jetties largely destroyed by floating out. February 11, 1930.

Looking northeast from end of boardwalk.

This picture shows a condition typical of large numbers of the series of open jetties built on Brigantine Beach. The outer ends are almost always quickly destroyed. Without considering the theory of this type of jetty, it is obvious that such poor construction has no justification on the Atlantic Ocean.

Cape May City—Cape May County

Net valuation taxable, $7,867,589.00
Ocean frontage, 3½ miles
State aid allotted to January 1, 1930, $63,000.00
State aid paid to January 1, 1930, $53,567.73
Total expenditures on State aid improvements to date, $108,167.01

Cape May is one of the oldest resorts on the New Jersey oceanfront. Its beach which is very flat and firm is one of the most celebrated bathing beaches in the country.

Erosion was not altogether unknown here because old groins have been unearthed within recent years well inshore of the existing shore line. Nevertheless, it must be conceded that serious erosion followed the construction of the United States government jetties at Cold Spring Inlet to the north. The situation became acute with much of the formerly splendid beach denuded down to the mud line and in 1925 the State allotted $27,000.00 to aid this municipality in protecting its shore frontage. A larger amount would have been granted had the City been willing to meet the additional amount. With the vast expanse to be protected the municipality's officials felt constrained to spread the money out as far as possible and submitted plans for the construction of fourteen timber groins of untreated material.

The Board of Commerce and Navigation urged that work be undertaken as far south (to leeward) as practicable as the fine sand and currents into Delaware Bay presented a real problem; and that creosoted material be used. Financial considerations were finally allowed to govern and the construction of untreated lumber was undertaken. The contract was awarded to John W. Corson on the following basis:

1,278 piles @ $9.80
45.81 M. B. M. wales @ $97.00
367.3 M. B. M. sheet piling @ $102.00 (Wakefield)
Total cost, $54,728.16
State's contribution $27,000.00 paid, $13,500.00, December 4, 1926; $13,500.00, February 28, 1928.

An additional allotment of $10,000.00 State aid was granted under Chapter 39 of the Laws of 1925. The contract was awarded to Craythorn and Nickerson for the construction of five timber groins at the bid price of $16.259 per lineal foot.

The teredo manifested great activity and riddled the outer end of some of the groins within a few months. This necessitated the repair of the outer ends of the damaged structures which was effected by using steel sheet piling (Larssen section #1 A). Cost of this work was $6,256.27 and required the placing of the following materials:

64.03 tons of steel sheet piling
320 ft. B. M. creosoted lumber
Hauling, handling and placing materials, $345.76
Threading and cutting bolts, $16.20

As the foregoing work was largely placed to the northeast (windward) in order to protect existing structures and build up the beach in the most denuded portions, the work had to continue and the State under Chapter 114 of the Laws of 1927 allotted an additional

Cape May City. Sand totally gone, mud showing, February 27, 1926.

Cape May groin showing south of coast guard station. February 27, 1930.

Doubling up piling. Cape May pilot boat is in the distance, February 27, 1926.

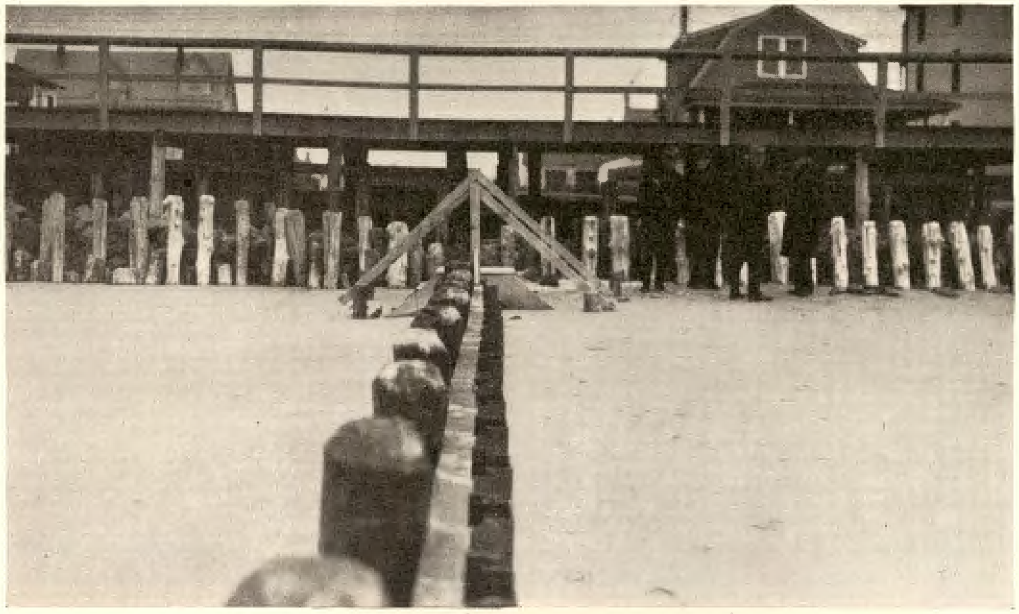
Cape May City, February 27, 1930.

1. Cape May City showing old Cape May Hotel in left background. February 27, 1926.

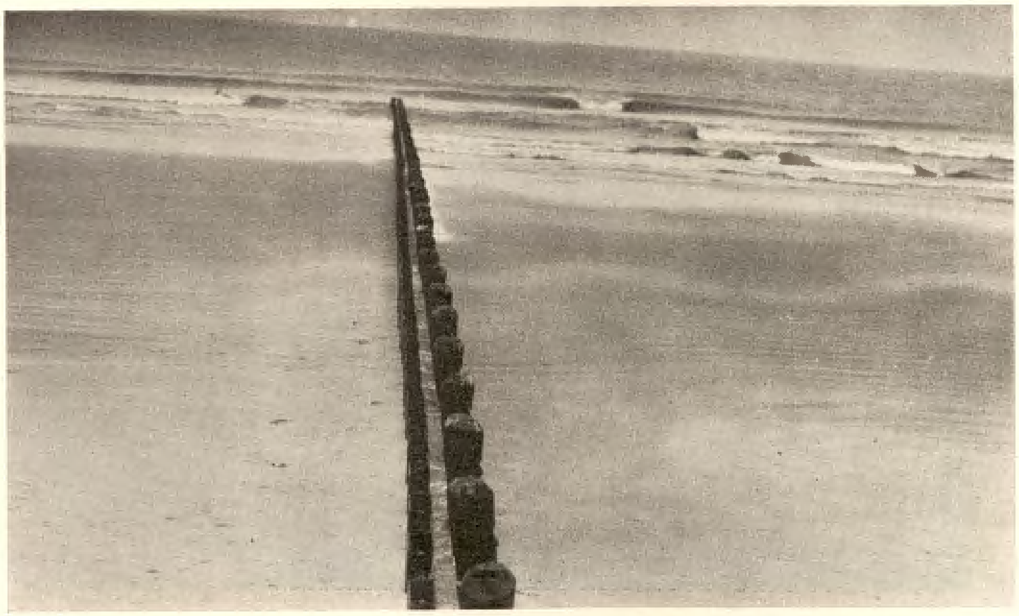
2. February 27, 1926. Beach almost denuded of sand.

3. May 23, 1928.

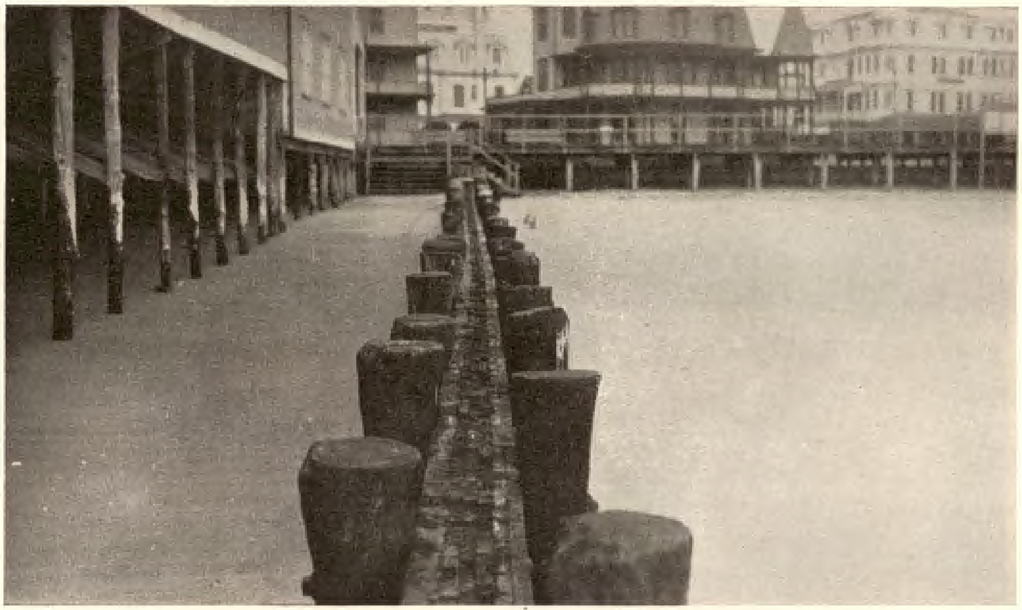
4. February 27, 1930. Fine sand beach restored.



Cape May groin south of Casino showing pronounced accretion. February 27, 1930.



Cape May groin south of Casino, February 27, 1930.



Cape May groin north of Casino.

Cape May City, groin of original contract showing steel sheet piling encasement due to attack by teredo.

Cape May City south of Casino. Remarkable accretion where conditions were very serious prior to construction of groins. February 27, 1930.

Cape May City, February 27, 1930.

$20,000.00. The contract was awarded to L. A. Hafeman & Company, February 5, 1929, for the construction of five timber pile and steel sheet pile groins between Paterson Avenue and Third Avenue. The prices and the final estimate are indicated as follows:

241 creosoted round piles in place	$4,660.94
1 untreated round pile	6.00
5,125 B. M. wales @ $304.00 M.	1,558.00
19,408 Sq. ft. steel sheet piling (Larssen #1) @ 74c.	14,361.92
581 hrs. labor @ 60c.	348.60
Extra work	200.00
5,000 lbs. steel sheet piling taken off contractor's hands	150.00
Total cost	$21,285.46

The steel sheet piling indicated as taken off the contractor's hands was not allowed as part of the contract cost and the State's share was paid accordingly in the amount of $10,567.73.

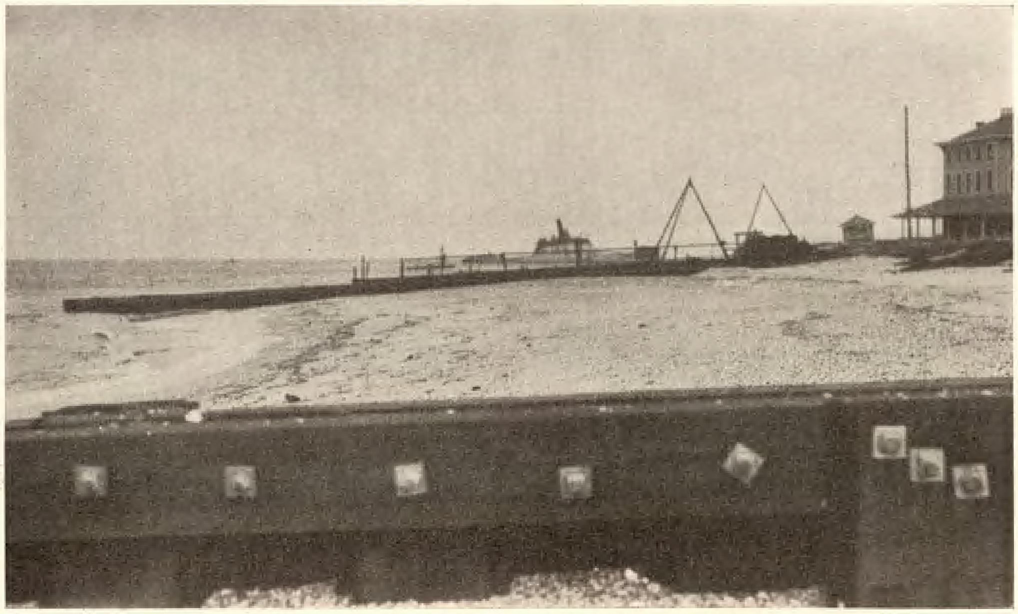
These operations have resulted in a gratifying improvement in the beach, much of the denuded mud bank sections now being covered with a good layer of sand. Conditions on the northerly frontage north of the groin system are still unsatisfactory and it would doubtless be difficult to gather any considerable volume of sand while the Cold Spring Inlet jetties to the north trap all the southward littoral drift.

Cape May Point Borough—Cape May County

Net valuation taxable, $406,080.00
Ocean frontage, 1 mile

Cape May Point forms the southernmost extremity of the State at the junction of Delaware Bay with Atlantic Ocean. This little borough has suffered severely from erosion for a long time. It seems so unfortunate that the small poorer municipalities are those where erosion has been most severe. Attack that would be quickly and effectually met by one of the most opulent municipalities may well prove entirely too serious to be encountered by one of these smaller boroughs with small ratables.

Various expedients were resorted to in the past including the construction of a system of permeable groins with their various hooks and hurdles. The situation became increasingly acute, plans were prepared in the forepart of 1929 and contract was awarded to L. A. Hafeman & Company, June 20, 1929, for the construction of four steel groins. The most interesting feature is that the usual timber round piles have been supplanted with steel piling driven on a batter as the main supports. The center of the groin is composed of steel sheet piling and the only wood members are the two wales. Unit prices on the lowest bid were as follows:



Cape May Point showing old concrete ship in background. February 27, 1930.

Cape May Point, southeasternmost steel jetty. February 27, 1930.

Cape May Point Steel Jetty, February 27, 1930.

Item	Length Per Pile in Lin. Ft.	Total Lin. Ft. Piling	Unit Price
Steel Master Piling	21	693	$0.99
" " "	25	750	1.13
" " "	31	868	1.40
Interlocking Steel Piling	13	2,952 sq. ft.	0.68
"	17	3,347 " "	0.76
"	23	2,415 " "	0.87

529 lin. ft. Timber waling including bolts and washers @ $2.00

Total cost, $10,458.90

Deal Borough—Monmouth County

Net valuation taxable, $8,790,381.00
Ocean frontage, 1½ miles
State aid allotted to January 1, 1930, $30,500.00
State aid actually paid to January 1, 1930, $22,926.30
Total expenditures to January 1, 1930, $47,558.10

The comparison of recent surveys with those of 1839 show that serious recession of the shore line has taken place in that interval on this frontage. Further attestation of this fact is given by the high-bluff formation.

The first State aid operation is reviewed in the 1924 report from which the following is quoted: The State in 1924 appropriated a grant of $8,000.00, under Chapter 318 of the Laws of 1920 to aid this borough in constructing protection devices. The contract was awarded to Thomas Procter, of Long Branch, with the approval of the Board for the construction of two timber jetties or groins at the Casino. These extend oceanward at right angles to the beach for a distance of 225 feet measured from the concrete retaining wall. The cost of the work is itemized as follows:

JETTY "A"

4.600 ft. B. M. stringers @ $119.50	$549.70
141 piling @ $20.50	2,890.50
21.600 ft. B. M. sheathing @ $113.00	2,440.80
743 bolts, washers, &c., @ $1.50	1,114.50
Removal of old jetty	800.00
144 ft. new C. I. pipe @ $11.00	1,584.00
81 ft. pipe relaid @ $1.50	121.50
Total cost	$9,501.00

JETTY "B"

21.600 ft. B. M. sheathing @ $113.00	$2,440.80
4.600 ft. M. B. M. stringers @ $119.50	549.70
95 piling @ $20.50	1,947.50
283 bolts, washers, &c., @ $1.50	424.50
Total cost	$5,362.50

The charge for the cast-iron pipe was not considered by the Board to be part of the coast protection devices, hence no contribution was made toward these two items of $1,584.00 and $121.50 respectively.

The Board on November 25, 1924, paid the borough $6,559.00 representing 50% of the cost of the work strictly designed for coast protection measures.

The State under Chapter 39 of the Laws of 1925, allotted $15,000.00 which was applied to the construction of six timber groins. The construction was awarded to J. A. Howland, February 27, 1927. The total expenditures under this contract amounted to $25,648.00 of which the State paid $12,824.00. The unit prices bid by the low bidder were as follows:

570 piling @ $16.00	$9,120.00
1,674 bolts @ $1.10	1,841.40
26.9752 M. B. M. stringers @ $105.00	2,832.40
118.542 M. B M sheeting @ $100.00	11,854.20
Total	$25,648.00

The specifications were substandard in that untreated lumber was used throughout but the State's approval was given upon the agreement by the municipality's officials to set aside a fund annually to insure proper maintenance in the event of attack by the teredo.

As there was an unexpended balance of $1,141 from the $8,000.00 appropriated under Chapter 240 of the Laws of 1924, as well as a balance of $2,176.00 from the aforesaid $15,000.00 appropriated, as contract was awarded to Jesse A. Howland, March 28, 1928, for the construction of two additional timber groins which cost $7,086.60 of which the State contributed $3,543.30. Itemizations on this contract are as follows:

110 white oak round piles @ $18.75	$2,062.50
318 bolts @ $1.80	572.40
22.256 M. B. M. sheathing @ $150.00 (12 lb. creosote L. L. Y. P.)	3,338.40
7.422 M. B. M. stringers @ $150.00 (12 lb. creosote L. L. Y. P.)	1,113.30
Total cost	$7,086.60

The State allotted an additional $7,500.00 under Chapter 166 of the laws of 1928 and Chapter 263 of the Laws of 1929, toward the construction of a creosoted timber bulkhead, 2,191 feet in length extending from Roseld to Marine Place and from Monmouth Avenue to Neptune Avenue located at average distance of twenty-three and thirty-six feet respectively outshore of the high water line. The contract was awarded to Thomas Procter, Long Branch, October 10, 1929, on the following price basis:

All material in place
White oak piling @ $18.32
Wales, Yellow Pine, 12 lb. creosote, per M. B. M., $125.00
Bolts @ $1.00
Tie rods @ $3.74
Sheathing, Yellow Pine, 12 lb. creosote, $123.00
Anchor Piles @ $4.40
Sandfill not included in State aid @ 24c. per cubic yard
Lump sum bid, $51,372.65

Harvey Cedars Borough—Ocean County

Net valuation, taxable, $292,365.00
Ocean frontage, 2 miles
Total State funds allotted, $10,000.00
State aid paid to January 1, 1930, $8,761.50
Total cost of State aid improvements, $17,523.00

The $10,000.00 allotment was made pursuant to Chapter 39 of the Laws of 1925. Contract was awarded to Jesse A. Howland, June 19, 1926, for the construction of four timber groins of untreated material. The bid was for 900 lineal feet of groin at the unit price of $19.47 per lineal foot. Quantities for 100 feet of groin are as follows:

34 white oak piles, 646 lin. ft.
Sheeting and wales, 8.75 M. B. M.
68 bolts, nuts and washers
Untreated timber of Long Leaf Yellow Pine

Some of these groins were subjected to attack by wreckage with consequent loss of the outer ends of the work during the storm of February, 1927. It is assumed that the drifting wreckage damaged the outer ends of the groins but as a matter of fact, it is submitted that it was unsound practice to construct the groins with some of the round white oak piling driven with butts down. There were two instances of State aid structures in which loss of the outer ends of groins occurred; this operation and that at Margate City, in both of which the expedient of jetting the round piles to position with butts down was adopted. This artifice certainly not novel, was in each case suggested by the local engineer and at first discouraged by the State engineers. The reason urged in support of this departure from standard practice was that the outer ends of the groins would be less likely to destruction by lifting out if the piling were driven butt down. This seemed plausible but did not take into account sufficiently the great loss in strength arising from the fact that the strength of the primary support of the groin structures, the round piling, was measured by sticks of six and seven inches diameter, the thickness near the points, instead of twelve or thirteen inches in diameter, the thickness near the butt. Photographs of these damaged groins are shown in the general description entitled "Groins and Jetties".

Lavallette Borough—Ocean County

Net valuation taxable, $964,235.00
Ocean frontage, 1 mile

This municipality has not undertaken any State aid coast protection works.

Long Beach Township—Ocean County

Net valuation taxable, $3,031.076.00
Ocean frontage, 11 miles

This municipality has not undertaken any State aid coast protection works.

Long Branch City—Monmouth County

Net valuation taxable, $20,847,500.00
Ocean frontage, 5 miles
State aid allotted to January 1, 1930, $100,000.00
State aid paid to January 1, 1930, $76,324.00
Cost of State aid projects to January 1, 1930, $225,644.76

Long Branch is one of the old coastal resorts of New Jersey, hence the records of the erosion on this frontage are more complete and enlightening than is the case in some of the newer municipalities. Conditions have so greatly improved since the 1924 report that the description of 1924 seems impossibly pessimistic.

As early as 1868 the late Professor George H. Cook, State Geologist of New Jersey, reported that erosion had become very serious. He refers in his report of that year to the fact that the site of the boarding house which existed thirty years before and the road which ran to the west of it were entirely washed away.

Stories by the older men that their fathers cultivated fields far outshore of the present roadway seem to be well supported by the records.

North Long Branch marks the northerly point of the headland formation which extends to Bayhead and the theory of the geologists is that the material which forms the barrier beaches, the wings of the headland, originated on this headland frontage. The elevation and slope of the ground at Long Branch indicate a serious recession amounting to probably two or three miles. In 1886 or thereabout, the road along the beach between Seaview Avenue on the south and a point near Atlantic Avenue on the north was destroyed and travel routed over the street one block west.

In the face of all this, it is most gratifying to say, that the last six years have witnessed a most notable accretion on the entire northerly frontage of the city from Atlantic Avenue to points south of Seaview Avenue. In fact the reconstruction of the roadway lost in 1886, between Seaview Avenue and Atlantic Avenue is now being considered.

The State in 1922 appropriated $25,000.00 to aid Long Branch in providing coast protection. The municipal officers desired to expend this money at Seaview Avenue and south thereof in order to protect the boardwalk and roadway of Ocean Avenue. The Board of Commerce and Navigation declined to approve this plan but insisted that the protection works should be constructed at the northerly end of the city, that is, far to leeward of Seaview Avenue with a view to building up the beach in the deeply indented cove which existed between Seaview Avenue and Atlantic Avenue. There was difference in opinion also as to the type of jetty, the State insisting on timber core with rock exterior and the city desiring the confined stone type with timber exterior and rock between the lines of timber.

Finally the State agreed to approve the city's plan for the construction of two jetties, A and B, to be located just south of Atlantic Avenue. The situation was so acute at Atlantic Avenue and just south thereof, that the reinforced concrete roadway wall was under severe attack and to prevent its complete destruction it was necessary to deposit large quantities of rock at its foot. A contract was let to Woolley & Howland, Long Branch, October 30, 1923, for the construction of jetties A. and B. The detail statement given in the 1924 report is not complete as the work had not been finished at that time, and the final costs to the city greatly exceeded the figures there given. It was found as a matter of fact that the crib type of jetty without rock exterior would not resist the attack and large quantities of rock were required, in excess of the city's estimate. The pool cutting in front of the work as it progressed seaward was extremely severe and it seems incredible now that conditions are so greatly improved that such large volumes of rock were required. Nevertheless, the results obtained have been satisfactory in the highest degree. The final costs of the work on jetties A. and B. including rock deposited in front of the sea wall are as follows:

JETTY A.

400 lin. ft. timber work @ $58.00	$23,200.00	
134 round piles, sections 1, 2, 3, 4 @ $25.00	3,350.00	
6,084.82 tons of stone @ $6.00	36,508.92	
		$63,058.92

JETTY B.

300 lin. ft. timber work @ $43.00	$12,900.00	
49 round piles, sections 1, 2, 3 @ $25.00	1,225.00	
2,222.66 tons of stone @ $6.00	13,335.96	
		27,460.96
Total cost		$90.519.88

All lumber and piling treated with 12 lb. creosote.

Jetties A. and B. being situated several hundred feet southward of the city boundary afforded no protection to a number of properties which continued to be subjected to hazard from the seas on the frontage between Jetty A. on the south and the city boundary on the north. This photograph taken May 4, 1926, indicates the condition at that time. The house on the extreme left was in fact subsequently undermined in the storm of February, 1927.

Plans were therefore drawn for the construction of two rock jetties of the timber core type to be constructed on the frontage in question. Contract was awarded to Jesse A. Howland, November 16, 1926, but only one jetty was built, No. 1, at the north boundary at the cost of $112,475.82 of which the State paid $40,000.00. Details are given by the following estimate.

23,909.76 tons stone @ $4.00	$95,639.04
79,904 M. B. M. sheathing @ $160.00	12,784.64
11.4884 M. B. M. wales @ $160.00	1,838.14
3,690 lin. ft. piling @ $0.60	2,214.00

Sheathing and wales given 12 lb. creosote
Length of structure, 600 feet

Payment of the State's first half of contribution, $20,000.00, approved March 9, 1927. The second half, $20,000.00, was paid August 29, 1927.

Jetty No. 1 like Jetties A. and B. has built up a splendid beach to the south. Had this jetty been constructed just a few months sooner the deplorable loss of Mr. Richard's house could probably have been avoided. The breach left in the bulkhead is clearly shown in the picture of May 4, 1926, and this of itself invited disaster.

Long Branch, near north boundary, May, 1926.

Twenty thousand dollars State aid was allotted under Chapter 166 of the Laws of 1928, and Chapter 263, Laws of 1929, for the construction of a stone breakwater jetty at Laird Street. The contract was awarded to Jesse A. Howland, March 19, 1929. The total cost of the work was $22,649.06, of which the State paid 50%, $11,324.53, and was paid September 6, 1929. Details of final estimate are as follows:

300 lin. ft. creosote timber core @ $23.70	$7,110.00
3,943.3 tons stone @ $3.90	15,379.06
.8 M. B. M. creosoted stringers @ $200.00	160.00
Total cost	$22,649.06

This jetty has performed very satisfactorily.

Fifteen thousand dollars was approved under Chapter 301 of the Laws of 1928, for the construction of a rock jetty with timber core three hundred feet in length and the extension of the existing crib jetty on the frontage between Madison Avenue and North Broadway. Contract had not yet been awarded January 1, 1930.

Longport Borough—Atlantic County

Net valuation taxable, $4,390,818.00
Ocean frontage, .71 mile
State aid allotted to January 1, 1930, $50,000.00
State aid paid to January 1, 1930, $50,000.00
Cost of State aid improvements, $107,205.85

No State aid work has been undertaken at Longport since the work that is fully reviewed in the 1922 and 1924 reports. Elsewhere in this report there is a detailed review of the Longport sea wall which was not a State aid project.

Since 1924 the borough whose ratables have greatly increased since that time has built a number of confined stone jetties at its own expense. Conditions in general are much better on this frontage than they were prior to the State aid operations.

Northwest from outer end of Jetty A. Jetty No. 1 in right background. February 4, 1930.

Looking north from Jetty A to Jetty No. 1. Shortly after completion of Jetty No. 1. Compare this with photograph of February 4, 1930.

Jetty No. 1. Note pool cutting at end exposing the core. February 4, 1930. Same view as above. Stockade nearly buried.

Looking shoreward along the north side of Jetty A. May 4, 1926. This bulkhead was destroyed in the storm of February 20, 1927, and Mr. Richard's house lost.

Looking southward from Jetty A's outer end past Jetty B toward Seaview Avenue. May 4, 1926.

February 4, 1930. Looking southwest from Jetty A. Jetty B almost entirely covered with sand is dimly discernible in line with pavilion.

Looking west along south side of Jetty A. May 4, 1926.

Same view, February 4, 1930. Piling stockade shown prominently in photograph of May 4, 1926, is almost entirely covered.

Looking shoreward along Jetty B.—May 4, 1926.

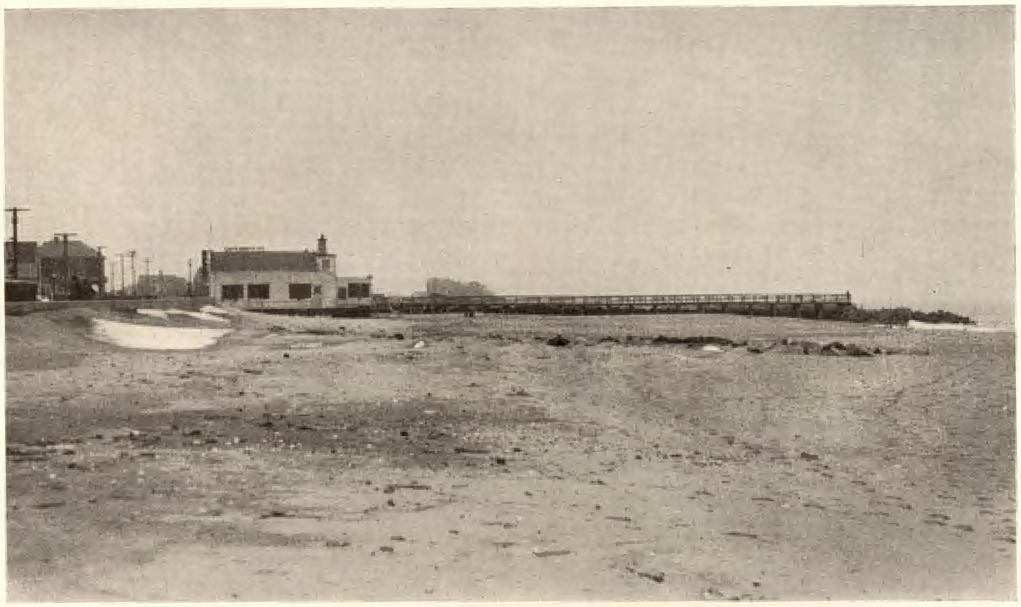
Same view—February 4, 1930. Sand has almost entirely covered Jetty B and has banked up against sea wall that was being undermined in 1923-1924.

On Jetty A looking southwest to inshore end of Jetty B. February 4, 1930.

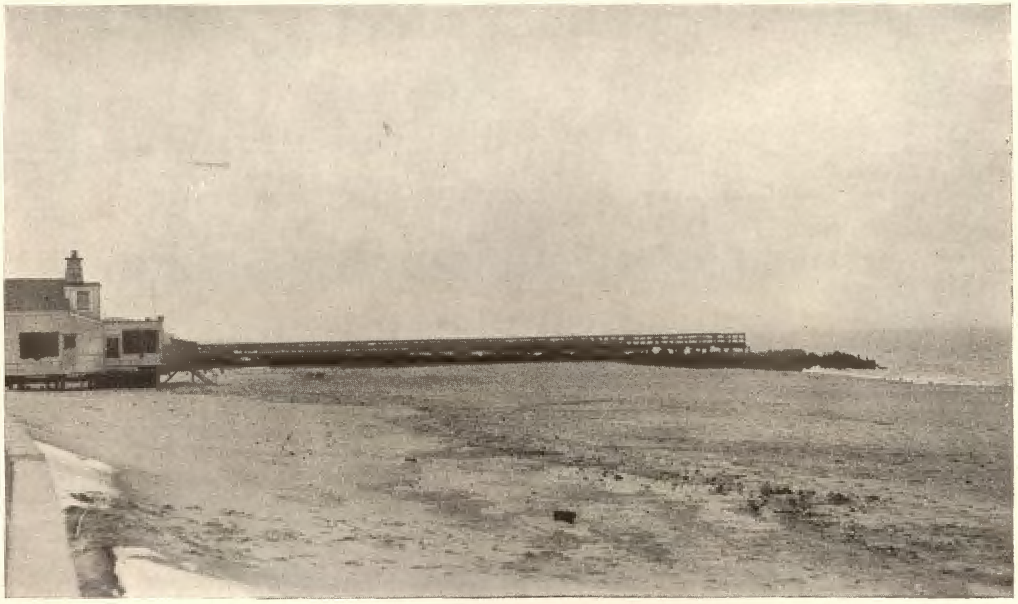
Jetty B, outshore end, May 4, 1926.

Jetty B looking oceanward, May 4, 1926.

From outshore end of Jetty B looking north. Jetty A appears in background. May 4, 1926.



Looking north from pavilion. Note sand bank against reinforced road wall. In middle ground Jetty B and in background Jetty A. February 4, 1930.



Looking north to Jetty A from inshore projection of Jetty B now almost entirely buried. February 4, 1930.

Looking northeast at Jetty A. February 4, 1930.

Storm of February 19-20, 1927. Jetty A and at extreme right the outshore end of Jetty B. Courtesy Johnson Brothers

Looking west northwest from outer end of Jetty A. February 4, 1930. Note growth of sand against bulkhead and wave stockade since 1926 pictures.

Manasquan Borough—Monmouth County

Net valuation taxable, $3,442,644.00
Ocean frontage, 1 mile

This municipality has not undertaken any coast protection works. It has in general been very fortunate in respect to erosion, particularly since the closing of Manasquan Inlet. The opening of Manasquan Inlet which forms the south boundary of the borough will doubtless be followed by a change in this condition because the Manasquan Inlet plan calls for the construction of large jetties. With the drift on this section moving south to north, erosion on this Manasquan frontage is to be guarded against.

The operations of opening Manasquan Inlet, disposal of sand dredged out, etc., should as far as possible be so carried out as to aid this frontage.

Mantoloking Borough—Ocean County

Net valuation taxable, $1,288,660.00
Ocean frontage, approximately 2½ miles

No State aid coast protection works have been carried out on this beach.

Margate City—Atlantic County

Net valuation taxable, $17,507,694.00
Ocean frontage, 1¾ miles
State aid allotted to January 1, 1930, $40,000.00
State aid paid to January 1, 1930, $40,000.00

Ten thousand dollars ($10,000.00) was allotted by the State under Chapter 114 of the Laws of 1927. This was paid January 10, 1928. An additional $10,000.00 was appropriated under Chapter 301 of the Laws of 1928, and this was paid January 4, 1929. Twenty thousand dollars was appropriated under Chapter 263 of the Laws of 1929 and paid by the State, August 26, 1929. Contract was awarded to Jesse A. Howland, February 9, 1927, for the construction of seventeen timber groins.

The inshore ends of these groins described as Type B construction cost $10.00 per lineal foot and the outer portion described as Type A cost $17.00 per lineal foot. The main difference in detail is that the sheeting in Type A was treated with twelve pounds of creosote per cubic foot while that in Type B was untreated and the round piles of white oak were spaced six feet center to center in Type B and three feet center to center in Type A. Materials per 100 feet of groin were as follows:

Type A.	Type B.
834 ft. Piling	417 ft. Piling
8. M. B. M. sheathing	8. M. B. M. sheathing
1.6 M. B. M. stringers	1.6 M. B. M. stringers
67 bolts & washers	34 bolts & washers

Total cost of Jesse A. Howland contract of February 9, 1927.

4,436.8 lin. ft. of Type A groin @ $17.00	$75,425.60
268.8 lin. ft. of Type B groin @ $10.00	2,688.00
Total	$78,113.60

This was followed by contract with C. L. Frye, September 25, 1928.

260 lin. ft. timber groin @ $16.50	$4,290.00
1,617.45 tons stone @ $6.00	9,704.70
Total	$13,994.70

This added to the expenditure under the Jesse A. Howland contract gives a total of $92,108.30, the figures enumerated in the latest State aid bill dated August 26, 1929. Other expenditures incurred by the city but not the subject of State aid are as follows:

1,836.35 tons stone @ $5.73	$10,522.29
Contract of Frank P. Gandy:	
97 ft. of bulkhead @ $7.00	$679.00
50 ft. of bulkhead @ $12.00	$600.00
Jesse A. Howland removing old jetty at Adams Street, cost plus 14%	$2,505.27
Labor by City employees	$8,102.66

The results of the groins and jetties have not been very strongly pronounced as yet.

The Margate Sea Wall is discussed in detail elsewhere in this report.

Middletown Township—Monmouth County

(East Keansburg)

Net valuation taxable, $10,108,045.00
Ocean frontage, 2½ miles
State aid allotted to January 1, 1930, $5.000.00

State aid appropriated $5,000.00 under Chapter 263 of the Laws of 1929 for the construction of three timber groins with an aggregate length of 475 feet and timber bulkhead totaling 310 feet. Contract was awarded to Jesse A. Howland at a lump sum bid of $8,290.00.

The work which is considerably lighter than would be countenanced on the ocean frontage, has been completed in a manner satisfactory to the Board but the State's payment had not been made at the close of the year 1929, awaiting the submission of the voucher.

Monmouth Beach—Monmouth County

Net valuation taxable, $1,911,474.00
Ocean frontage, $1\frac{1}{2}$ miles
State aid allotted to January 1, 1930, $55,000.00
State aid paid to January 1, 1930, $54,700.00
Total cost of State aid improvements to January 1, 1930, $183,993.06

This borough lies to the south of Sea Bright Borough and like it has suffered severely from attack. Landowners have been required to pay out large sums for individual protection. The municipality during the severe storms of 1913-1914 suffered very great losses.

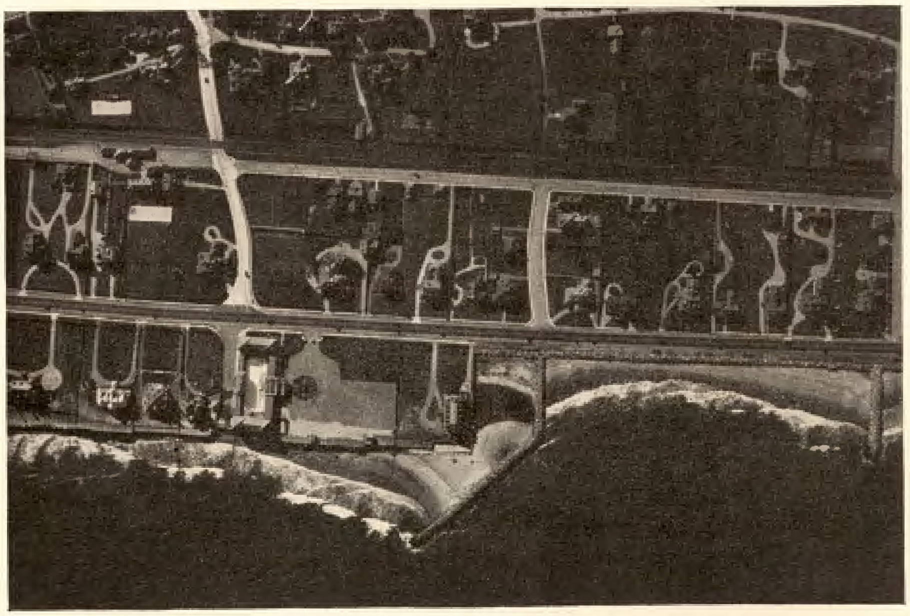
In 1924, $25,000.00 was allotted under Chapter 318 of the Laws of 1920. The details of cost of the rock breakwater jetty then constructed with plans and photographs are given in full in the 1924 report and need not be treated here.

For a time this jetty gathered up a very considerable area of beach to the south although the zone of influence did not extend over a very great frontage. From very early in the history of this jetty, a gully persisted near the inshore end. That gully has never closed, apparently due to damage to the core.

The core was constructed of untreated timber which has been riddled by marine borers. The jetty has not retained all of the sand it gathered in 1923-1924. It was urged that the jetty did not extend sufficiently far outshore past the bulkheads and it was agreed to undertake the construction of the 200 feet extension of the above described existing stone jetty at the foot of Cottage Road. Thirty thousand dollars ($30,000.00) was allotted under Chapter 301 of the laws of 1928. Contract was let to Jesse A. Howland, December 20, 1928, for the placing of 12,000 tons of rock. Prices per bid were as follows:

J. A. Howland	$4.95 per ton
T. Procter	5.35 per ton
Woolley & Howland	6.00 per ton

The State's share, $29,700.00 representing 50% of the total cost of the work was approved for payment July 8, 1929.



An air view of a section of Monmouth Beach. Courtesy Johnson Brothers

North Wildwood Borough—Cape May County

Net valuation taxable, $9,345,333.00
Ocean frontage, $1\frac{1}{2}$ miles

No State aid coast protection work has been undertaken on this frontage.

Ocean City—Cape May County

Net valuation taxable, $37,530,700.00
Ocean frontage, $7\frac{3}{4}$ miles
State aid allotted to January 1, 1930, $57,000.00
State aid paid to January 1, 1930, $50,248.00
Total cost of State aid improvements, $142,070.60

Contract was awarded to Jesse A. Howland, November 23, 1925, by the City of Ocean City for the construction of a stone jetty timber core, 600 feet in length at 59th Street. Detail costs were as follows:

600 lin. ft. timber core @ $21.11	$12,666.00
13,876.25 tons stone @ $5.10	70,768.87
Extra wing piles at ends	
Lump sum	995.00
Total contract was	$84,429.87

Main piles were of white oak
Wales and sheet piles of L. L. Y. P. untreated

The State aid payment of $30,000.00 was approved September 21, 1926.

The jetty extends seaward, not at right angles but almost due east at an angle of about 45° with the bulkhead. It has been moderately successful in operation but cost far more than necessary, first, because of the loss in projection due to the acute angle of the bulkhead and second, to the excessive amount of rock employed for the effective length of the structure.

An additional $20,000.00 was allotted under Chapter 303 of the Laws of 1928 for patching up and extension of various protective works between 49th and 59th Streets. This operation included removal of old piling, extending jetties, replacement of bulkheads, placing stone and brush outside of bulkheads, etc.

Contract was awarded to Kolyn Construction Company, November 7, 1928, at the cost of $54,611.00. On February 18, 1928, the Board voted to allot $20,248.00 which represented 50% of all the foregoing work that could be considered to be coast protection work. The operation included the following details:

1,195 lin. ft. of bulkhead @ $16.00
500 lin. ft. timber jetty @ $20.00
2,930 lin. ft. stone breakwater @ $3.20
Removing old piling—Lump sum of $2,000.00

The stone jetty at 59th Street was well constructed but is believed to be unnecessarily expensive for the situation. The State aid was granted after work had begun upon appeal by the local representative in the legislature who pressed for the State's contribution on the ground that he had secured the appropriation from the legislature for this specific operation.

Point Pleasant Beach Borough—Ocean County

Net valuation taxable, $3,279,014.00
Ocean frontage, 2 miles

The Board allotted $75,000.00 of the monies made available by Chapter 192 of the Laws of 1929 for the construction of groins and bulkheads on the ocean frontage. The Board having discretion under this statute in the matter of allocating the funds appropriated, required the Borough to acquire and dedicate the beach as a public park. Apparently this has proved the obstacle, although local opinion as to going ahead is much divided, to undertaking the work. Although bids were opened June 20, 1929, and the contract awarded to Jesse A. Howland, no work has begun.

Conditions have been unfavorable since the closing of Manasquan Inlet. The building up of the beach prior to that was accompanied by crowding out as far as possible. The possibility of recession was never considered.

The storms of the spring of 1929 caused severe damage, including the collapse of the front of a beachfront hotel and undermining of a number of cottages on the front.

Sea Bright Borough—Monmouth County

Net valuation taxable, $1,850,967.00
Ocean frontage, 2 miles
Total State aid allotted to January 1, 1930, $65,000.00
Total State aid paid to January 1, 1930, $55,000.00

This borough is situated on a very narrow off-shore bar, bounded by the Shrewsbury River lagoon on the west, and the ocean on the east. The attacks it has received from the sea have been more severely felt than on any other section of the State. It lies just south of Sandy Hook Reservation, and is exposed to easterly storms and to the wind and tide waves and currents which flow toward Lower New York Bay. The flood tide impinging on this shore as it works toward the Narrows obviously forms a very potent factor; the writer is convinced that the effluent waters from the New York Harbor estuary also induce effective secondary currents which affect this frontage. The beach is of low elevation, which with the other natural features described, combined to render its existence very precarious until adequate protection was provided by the Central Railroad Company of New Jersey, and by the municipality. It is fortunate for Sea Bright that the railroad company has taken and maintained energetic measures to protect its line by constructing along the oceanfront a heavy rock wall which is supported by low groins which extend seaward normal to the line of the wall. In the winter of 1913-1914 three severe storms in close succession wrought havoc with a greater part of the oceanfront property of Sea Bright. A number of houses were undermined and other property damage was very severe.

On the bay side of Sandy Hook, to the south of the spit, the changes are not rapid. Sandy Hook Peninsula was formerly an island—it is so shown on the old map by J. F. W. Des Barres of 1779, and the map of Lieutenant John Hills dated 1792; the inlet at the southerly end of the island being that referred to by the novelist, J. Fenimore Cooper, in his work "The Water Witch." This opening which was in the vicinity of what is now Island Beach, has been closed for many years. The beach, however, has been breached a number of times. In 1835-1836 Sandy Hook was connected to the mainland by a narrow strip of land which extended due north from the pronounced angle in the shore line, between Water Witch and Highlands. This strip formed the westerly boundary of an inlet the east point of which terminated, in 1836, just north of the present Highlands bridge at Highland Beach. This breach was closed in, or prior to, 1850. The breach in the vicinity of Highland Beach and south has been opened on various occasions. The Railroad Company, in 1856, closed the breaches opposite the Navesink and Shrewsbury Rivers. The maps show at a glance how readily and naturally the Navesink may be expected to break through unless protective measures are maintained.

In 1896-1897 the sea broke through the neck of Sandy Hook Peninsula, nearly opposite Island Beach. This was closed by the Government by 1900-1901 by the deposit of stone along the Government railroad trestle, and the placing of dredged sand immediately adjacent thereto. These various breachings of the ocean beach have undoubtedly resulted in the carrying of beach sand into the navigable channel of the Shrewsbury River, to the great detriment thereof.

The attack continuing, the Borough on July 10, 1921, began work on a large breakwater jetty beginning at the Peninsula Hotel property and extending oceanward on an acute angle with the shoreline to the south. The jetty was completed October 1, 1921. This is supported by a heavy riprap wall further south which runs approximately along or parallel with the old high water mark as this existed at the time of beginning construction. This breakwater jetty and the wall to the south form in effect a sand trap which has been very successful. In addition to protecting a part of the Borough, this construction has built up a wide beach sheltered from easterly storms on which a large colony of fishermen are enabled to land their boats. In addition it meets a real need as a bathing beach. The contractor was Jesse A. Howland, of Sea Bright.

Under Chapter 318 of the Laws of 1920, $25,000.00 was allotted by the State for Sea Bright. Inasmuch as the above described rock jetty at the foot of Peninsula Avenue had been completed prior to the appropriation, this money was not used but a supplemental appropriation was provided by the legislature in 1923. This was applied to reimburse the Borough part of the cost of the aforesaid breakwater jetty.

Thirty thousand dollars ($30,000.00), State aid was allotted under Chapter 39 of the Laws of 1925 and Chapter 325 of the Laws of 1926.

The contract was awarded to Jesse A. Howland, June 8, 1927, for the construction of a stone jetty without timber core at the foot of East Center Street. As a matter of fact there was so much old wreckage at the site that it would probably have been impossible to drive a timber core. The total cost of this work was

Aerial view, Sea Bright.

Courtesy Curtiss Flying Service.

$63,883.33. The final estimate was for 13,887.68 tons of rock at $4.60 per ton.

This particular jetty, while it protects a limited frontage can not be said to have functioned with any remarkable degree of success with respect to protecting extensive shorefront. To overcome as much as possible the absence of a core, the central portion was composed of small rock.

An additional $10,000.00 was appropriated under Chapter 166 of the Laws of 1928. The contract was awarded to Jesse A. Howland, November 1, 1929, for the construction of a timber core stone jetty, 200 feet long, located 400 feet north of the railroad station. The work is not yet completed but the bids are as follows:

Bidder	Timber Core Per lin. ft.	Stone Per Ton
Jesse A. Howland	$20.00	$3.90
Woolley & Howland	27.75	5.10

Sea Girt Borough—Monmouth County

Net valuation taxable, $2,254,729.00
Ocean frontage 1½ miles
State aid allotted to January 1, 1930, $25,000.00
State aid paid to January 1, 1930, $20,000.00
Total cost of State aid improvements, $52,440.50

In 1926 plans were prepared for a comprehensive groin system for the entire frontage of this municipality with a view to building the structures as rapidly as was financially practicable. The groins are numbered beginning with No. 0 at Seaside Avenue to No. 13 north of Beacon Boulevard.

Groins No. 4 and No. 5 were constructed entirely at the cost of the municipality, that is, without State aid contribution. Numbers 1 and 3, 260 and 275 feet long respectively, were constructed under contract with Woolley & Howland, at the cost of $26.18 per lineal foot. The total cost was $13,875.40. Numbers 0, 10, 11, 12, 13 cost $25.90 per lineal foot and were constructed under contract dated September 13, 1927, by Woolley & Howland. All of these groins are of standard construction. All timber being of long leaf yellow pine treated with twelve pound creosote per cubic foot.

The State payments were as follows:

$10,000.00 ....February 10, 1928
$10,000.00 ....September 5, 1928

This $20,000.00 was allotted to this municipality under Chapter 114 of the Laws of 1927.

These groins which have functioned in a highly satisfactory manner have gathered and held a fine strip of beach on a frontage that has suffered seriously for many years.

The municipality had constructed without State aid the groins No. 4 and No. 5 of the same type of construction as that already described.

Chapter 263 of the Laws of 1929, allotted pursuant to Chapter 166 of the Laws of 1928, an additional $5,000.00 toward the construction of two timber groins of the conventional type, numbers 8 and 9 between Baltimore and Brooklyn Avenues, at an estimated cost of $15,000.00. Bids have not been received up to January 1, 1930, awaiting settlement of litigation on boardwalk development.

Sea Isle City—Cape May County

Net valuation taxable, $3,445,563.00
Ocean frontage, 6 miles

No State aid coast protection work has been undertaken on this frontage. The borough has constructed a number of open jetties of the Haupt type at various times.

Seaside Heights Borough—Ocean County

Net valuation taxable, $1,326,850.00
Ocean frontage, ¾ mile

No State aid has been granted and no coast protection works of any great moment have been undertaken on this beach.

Seaside Park Borough—Ocean County

Net valuation taxable, $2,426,887.00
Ocean frontage, 2 miles

No State aid coast protection works have been undertaken on this frontage. The Borough has obtained very satisfactory results from the construction of sand fences consisting of a single row of closely spaced piling erected twenty-five to fifty feet inshore of mean high water mark. This construction is undoubtedly well supported by a bulkhead under the boardwalk, a short distance inshore. The sand is coarse and yet mobile enough to collect in the zone between the bulkhead and the sand fence from which it grows oceanward.

Spring Lake Borough—Monmouth County

Net valuation taxable, $7,010,491.00
Ocean frontage, 2½ miles
State aid allotted to January 1, 1930, $20,000.00
State aid paid to January 1, 1930, $20,000.00

Twenty thousand dollars ($20,000.00) was allotted under Chapter 318 of the Laws of 1920 and Chapter 240 of the Laws of 1924. Contract was awarded to Woolley and Howland, July 23, 1924, for the construction of a timber bulkhead and three groins of the same type as the Sea Girt groins. All of long leaf yellow pine treated with twelve pound creosote.

Fill for the bulkhead was taken from Wreck Pond Inlet with a very small suction dredge erected in place. The results obtained from these groins have been satisfactory in the highest degree.

Stone Harbor Borough—Cape May County

Net valuation taxable, $2,953,493.00
Ocean frontage, approximately 3 miles

No State aid construction has been undertaken on this frontage and in fact no coast protection works have been undertaken for many years.

Surf City—Ocean County

Net valuation taxable, $492,618.00
Ocean frontage, 1½ miles

No State aid coast protection operations have been undertaken on this frontage.

Ventnor City—Atlantic County

Net valuation taxable, $34,164,356.00
Ocean frontage, 1¾ miles

No State aid coast protection structures have been erected on this beach. For many years Ventnor City has been very fortunate but twenty years ago, due partly to pushing out the reclamations, extensive works were required. Typical examples are the Ventnor Crib Breakwater and Ventnor Bulkhead Breakwater described and illustrated in detail in this report.

Wildwood City—Cape May County

Net valuation taxable, $21,918,385.00
Ocean frontage, 1 mile

No State aid structures have been erected on this beach front. Wildwood is one of those fortunate municipalities with a very fine, broad, flat beach where conditions have been favorable rather than otherwise.

Some coast protection or more correctly perhaps reclamation works have been undertaken in the past, but entirely at the expense of the local interests.

The closing of Turtle Gut Inlet, a project in which the State Board of Commerce and Navigation joined with the County of Cape May, has had a highly favorable effect on this municipality's beach front.

Wildwood Crest Borough—Cape May County

Net valuation taxable, $5,735,554.00
Ocean frontage, 2½ miles

No State aid coast protection work has been undertaken on this frontage. Conditions have been highly favorable for years, particularly since the closing of Turtle Gut Inlet to the south.