CHAPTER 110

BEACH HAVEN AND LITTLE EGG INLETS, A CASE STUDY

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ABSTRACT

A comprehensive investigation of coastal processes active within and in the vicinity of Beach Haven and Little Egg Inlets was completed as part of the Coastal Processes Investigation for the proposed Atlantic Generating Station. The suspected complex nature of this dual natural inlet system was documented and a process-response model is presented to relate the more significant physical forcing functions to observed morphologic and hydraulic changes. A rising sea level, a net littoral drift from the north and the sediment scouring power of the flow in the two main channels serving the tidal basins are the principal factors related to the geographic and hydraulic stability of the system. The results of the study can be used to evaluate the potential impact, if any, of the proposed Atlantic Generating Station on the adjacent coastal environment.

INTRODUCTION

Beach Haven and Little Egg Inlets are juxtaposed natural tidal inlets located midway along the New Jersey Coast, U.S.A. (Figure 1). As part of the Coastal Processes Investigation, for the proposed Atlantic Generating Station, a study was made of these inlets and their adjacent beaches to obtain baseline data on the dynamic nature of this complex natural system. The necessity for a study of this type was noted by the Atomic Energy Commission (1973) in their report on the Workshop for Offshore Nuclear Power Siting. The inlet study included the following task investigations:

1. A study of the recent geomorphic history of the inlet complex using historical shoreline and bathymetric charts dating from 1840 to 1974, site aerial photographs dating from 1933 to 1974, and the biweekly monitoring of beach profiles in the vicinity of the inlet channels.

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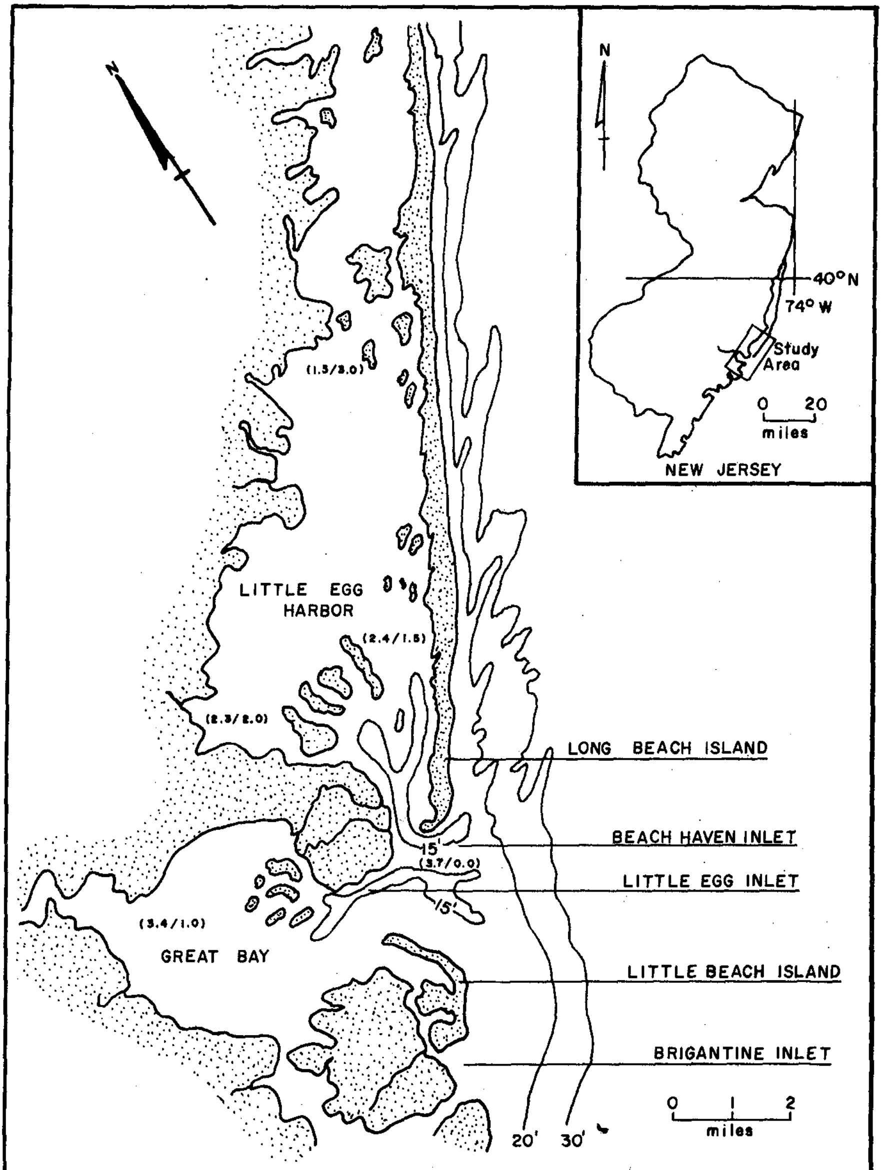


LOCATION MAP
BEACH HAVEN AND LITTLE EGG INLETS, NEW JERSEY
(MEAN TIDE RANGE IN FEET/ELEVATION PHASE LAG IN HOURS)

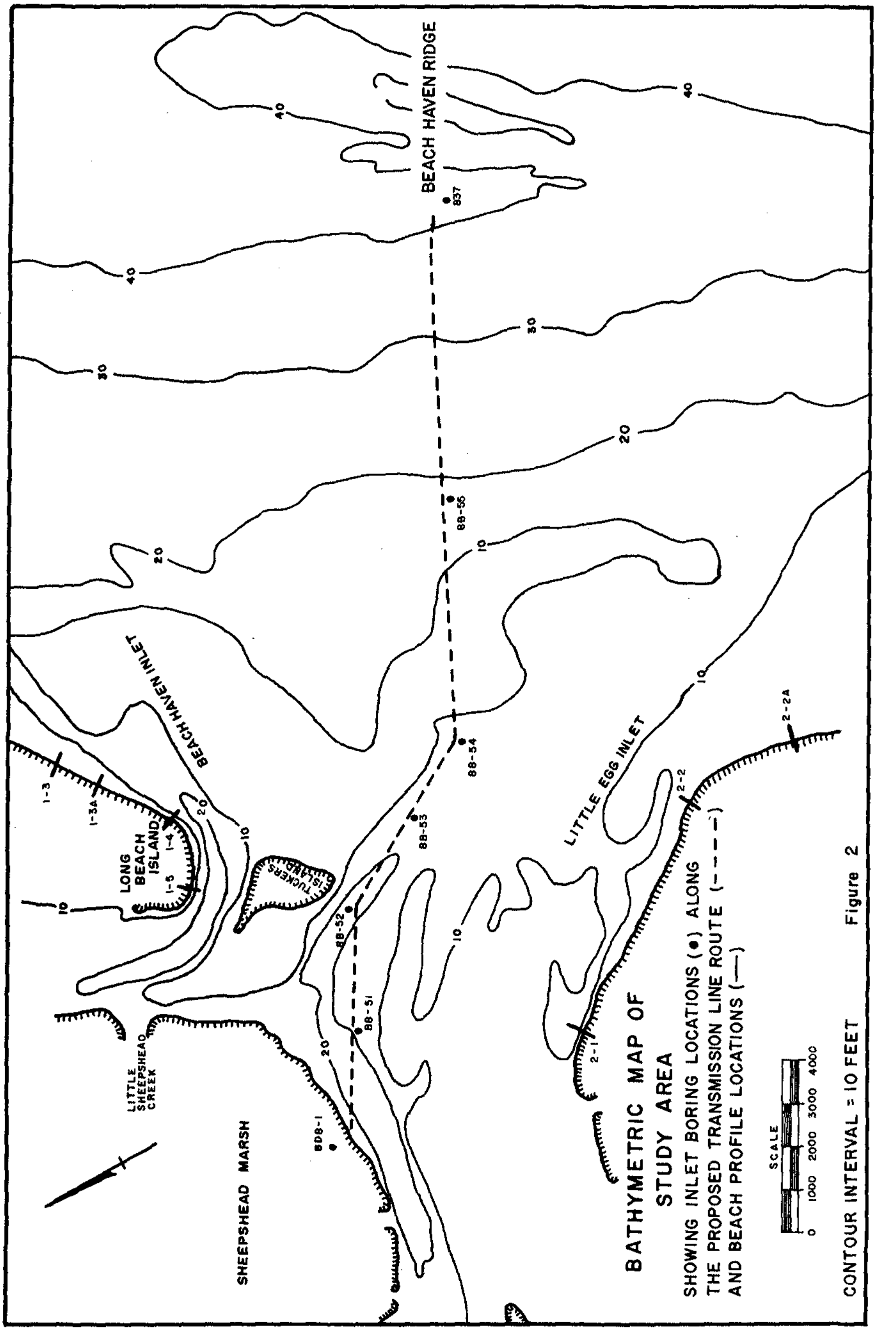
FIGURE - I

2. A study of the hydraulic characteristics of the inlet complex including analyses of short-term and long-term changes in the cross-sectional areas of the inlet throats, of the storage basin characteristics for each of the inlets, and tide and velocity measurements at the inlet throats.

The purpose of this paper is to present the methodology and results of these individual task studies and a process-response model for the long and short-term evolution of the inlet complex.

Previous studies in this area include the contributions of Shepard and Wanless (1971) which provides a general discussion of the coastal geological features and Charlesworth (1968) which discusses marine sedimentation processes in the inlets. Caldwell (1966) estimates the net littoral drift in this area to be approximately 500,000 cubic yards per year to the south. Fair weather waves in the study area are generally from the SE, are less than 3 feet in height, and have periods of 5 to 6 seconds, (Darling, 1968). Storm generated waves are generally from the NE, are greater than 3 feet in height, and have periods greater than 7 seconds. The mean ocean tide range at Atlantic City Steel Pier (10 miles to the south) is 4.1 feet; the spring tide range is 5.0 feet. The tides are semi-diurnal in nature. The Beach Haven-Little Egg Inlet system is located at a sharp boundary between two distinctly different sediment regimes in the New Jersey coastal sector (McMaster, 1954). The beaches to the north of the inlet system are characterized by medium to coarse sand with an opaque heavy mineral assemblage while the beaches to the south are characterized by fine sands with a hornblende heavy mineral assemblage. DeAlteris and Vespucci (1975) describe the quarternary stratigraphic sequence of the inlet complex based on the results of borings along the transmission line route (Figure 2).

The general limits of the study area included Beach Haven and Little Egg Inlets, their respective storage basins and the beaches adjacent to the inlet (Figures 1 and 2). The Beach Haven Inlet throat channel is located between the southern terminus of Long Beach Island and Sheepshead Marsh. The channel presently reaches a maximum depth of 48 feet (Referenced to MLW). The storage basin served by Beach Haven Inlet includes Little Egg Harbor and Manahawkin Bay. The overall dimensions of these bays are 15 miles long by 3 miles wide. The bays are flanked on the landward side by fringing upland marsh. The average depth of bays is 3 feet (Referenced to MLW). Within this storage basin, there are significant reductions in tidal amplitude and phase lags in the tide curve. Beach Haven Inlet channel is about 2 miles long and has large ebb and flood tidal deltas at each end.



BATHYMETRIC MAP OF STUDY AREA

SHOWING INLET BORING LOCATIONS (●) ALONG THE PROPOSED TRANSMISSION LINE ROUTE (– – – –) AND BEACH PROFILE LOCATIONS (—)

CONTOUR INTERVAL = 10 FEET

Figure 2

The Little Egg Inlet throat channel is located between the northern flank of Little Beach Island and Sheepshead Marsh. The channel presently reaches a maximum depth of 52 feet (Referenced to MLW). The storage basin served by Little Egg Inlet consists of Great Bay and the lower reaches of the Mullica River. Great Bay is a large open bay, approximately 4 miles in diameter, with an average depth of 6 feet (Referenced to MLW). There are no significant reductions of the tidal amplitude or phase lags in the tide curve within Great Bay. Great Bay is surrounded by fringing salt marsh that periodically floods on spring tides. The lower portion of the Mullica River is tidal in nature and is therefore included in the storage area. The mean annual discharge of the Mullica River is about 0.1% of the mean tidal discharge of the inlet and therefore has not been considered in the tidal hydraulic analysis. The Mullica River is flanked by fringing upland marsh. The outer inlet channels of Beach Haven and Little Egg Inlets are presently separated by Tuckers Island Shoal.

GEOMORPHIC HISTORY OF THE INLET COMPLEX

Using copies of the original hydrographic survey boat sheets available from the National Ocean Survey for the period 1840 through 1954 and the results of a bathymetric survey conducted in 1972 by E G & G, the history of the inlet channels and adjacent beaches was investigated. The individual charts were adjusted to a common scale and grid for comparison purposes and the results of these efforts are summarized in Figure 3.

In 1840, two inlets were present, separated by a large island called Tuckers Island. The primary channel was Little Egg Inlet between Little Beach and Tuckers Islands. The maximum depth of the channel was 59 feet. Some flow also passed between Tuckers and Long Beach Islands, but data are not available on the channel dimensions. Between 1840 and 1873, accretion on the southern end of Long Beach Island caused it to extend southward, overlapping Tuckers Island. Long Beach Island had grown almost 13,000 feet south of its 1840 location. Tuckers Island decreased from about 12,000 feet in length to less than 5,000 feet.

The closure of Beach Haven Inlet's outer channel in the 1870's, had a pronouned effect on the northern limb of the channel at Little Egg Inlet. Tidal flow from Little Egg Harbor was routed through the narrow passage between Tuckers Island and the peninsula to the west. Deep scour occurred over an area extending far into Little Egg Harbor. Depths to 50 feet were present in several places, showing the effect of increased constriction of the channel. By 1903, Long Beach Island had grown more than 7,000 feet and completely absorbed Tuckers Island. At this point, conditions seemed to reach a state of quasi-stability with a

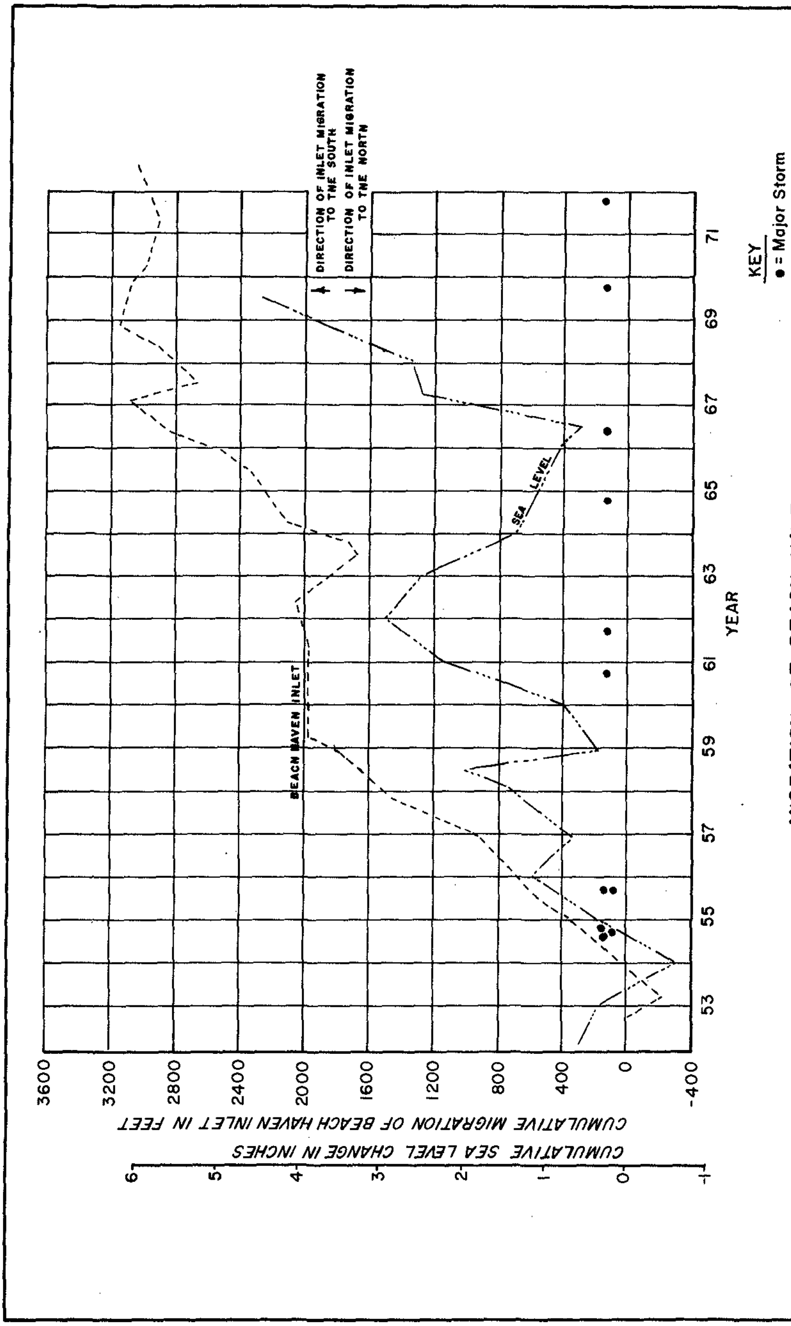
BEACH HAVEN AND LITTLE EGG INLETS
1840 - 1972

Figure 3

single inlet (Little Egg Inlet) relieving both Great Bay and Little Egg Harbor and with Beach Haven Inlet outer channel temprarily non-existent. With a single channel serving the two basins, tidal velocities were apparently sufficiently high to prevent further deposition or constriction of the channel. This semi-stable condition continued until 1920, with the maximum southerly extent of Long Beach Island occurring in 1915. The effect of the constriction was most apparent in the channel, which was now 3 miles long and had depths in excess of 60 feet.

In 1920, equilibrium was upset and Long Beach Island was breached at a point 20,000 feet north of the 1972 position of Little Egg Inlet. The new inlet established itself rapidly, eroding into Long Beach Island to form a major topographic feature. The previous cycle of southerly migration, closure of the northerly inlet, and subsequent growth to a semi-stable single inlet condition had been completed and the cycle begun anew. The survey of 1935 indicated that Long Beach Island had grown southward several thousand feet, while Tuckers Island had eroded considerably. This survey showed increased scour in the northern portions of Beach Haven Inlet. The inlet was narrower and the channel apparently deepened. Little Egg Inlet to the south, showed signs of shoaling. A deep gorge was maintained, but it was reduced to a very narrow breadth. The northern branch of the channel which lead into Little Egg Harbor had been completely buried. By 1954, Tuckers Island was reduced to an intertidal shoal, and the axes of the two channels were separated by about 7,000 feet at their closest point. By 1972, the separation had reduced to little more than 3,000 feet with Little Egg Inlet remaining in a stationary position. All movement can therefore be attributed to the southerly migration of Beach Haven Inlet.

Using aerial photographs dating from 1933 to the present, a more detailed study of the recent evolution of the inlet complex was accomplished. The most interesting result of this study is shown in Figure 4 and suggests a correlation between the rate of migration of Beach Haven Inlet and fluctuations in the rate of sea level rise and storm action. The sea level curve is taken from Hicks (1973) and the distance of inlet migration was determined by measuring on the aerial photographs from a fixed reference point on the barrier to the inlet channel. The periods of rapid southerly inlet migration correlate with periods of rapid sea level rise; while periods of minimal southerly inlet migration and short-term reversals correlate with periods of minimal sea level rise and lowering of sea level.



MIGRATION OF BEACH HAVEN INLET AND FLUCTUATION OF SEA LEVEL 1952-1972

Figure 4

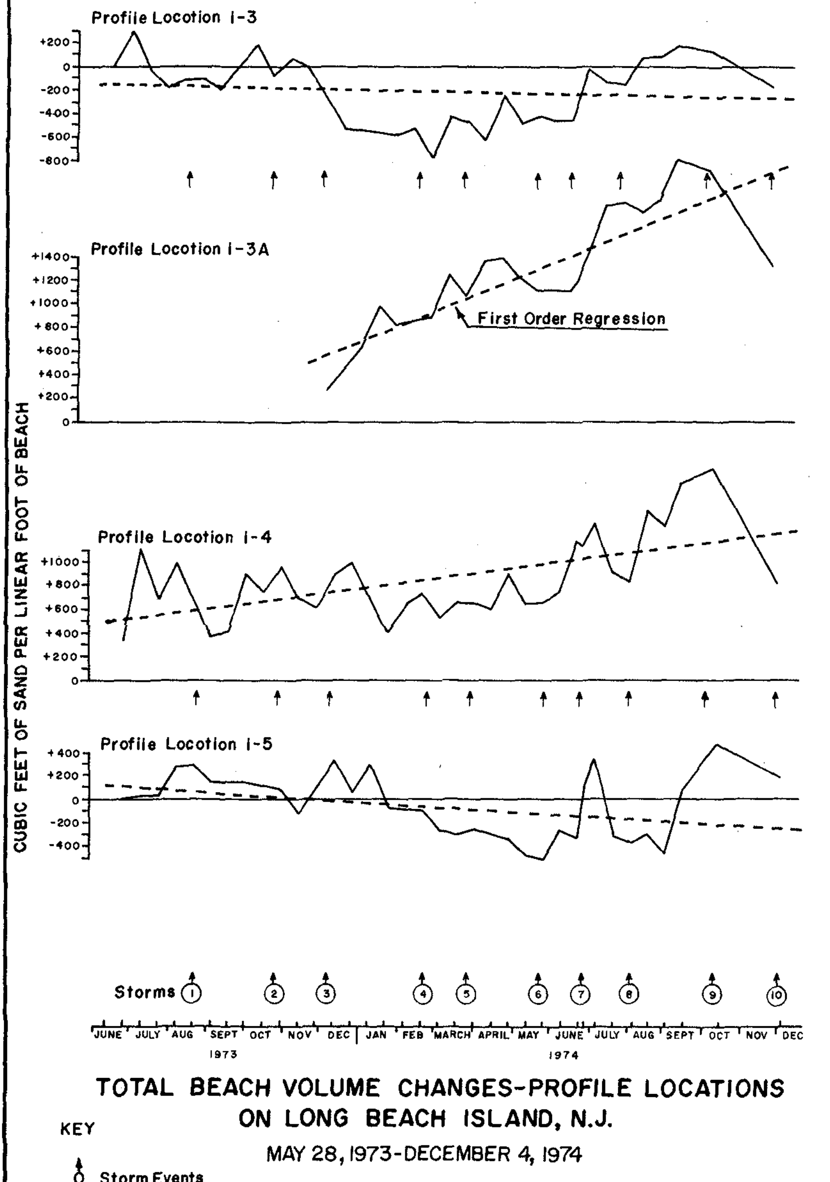
REFERANCE:
SEA LEVEL FLUCTUATION FROM HICKS (1973)

In order to provide data on short-term changes on the beaches adjacent to the inlets, a beach profiling program was initiated in the summer of 1973, and continued for a period of 18 months. Using a horizon leveling method adapted from Emery (1961), the beach profiles were measured on a bi-weekly schedule. The area under each profile was represented as cubic feet of sand per linear foot of beach. This was plotted as a time series and a first order regression line calculated for each profile to represent the trend, (Goldsmith and others, 1975). The results of the profiling program (Figures 5 and 6) indicate that the profiles which show the most dramatic trends of erosion and/or accretion are located in and adjacent to the inlets. The profiles located at the distal portions of both prograding spits on Long Beach and Little Beach Islands, (1-3, 1-3A, 1-4, 1-5,2-1) show accretional or relatively stable trends, suggesting continued inlet-directed drift along these beaches. Seaward of these segments, zones of significant erosional trends are noted on both Long Beach and Little Beach Islands. The exact mechanism of the erosional trend at Profile No. 2-2 on Little Beach Island spit is not clear, but the refraction pattern for waves from the northeast suggest that in addition to the suspected interaction of Little Egg Inlet flow, wave energy concentrations into this zone may also be an important factor. Most of the remaining ocean-facing portions of Little Beach Island show a slight erosional trend during the measuring period. Profile No. 2-2A on the north end of Little Beach shows a high accretional trend. This is also suggested by the shoal in the nearshore area as outlined by the 10 foot contour line (Figure 2). The shoal is elongated parallel to the trend of the outer channel of Little Egg Inlet. The details of the processes controlling this accretional nodal point are also lacking. However, it may represent the confluence of the northerly directed littoral drift derived from the eroding beaches to the south on Little Beach and the tidal ebb flow of Little Egg Inlet. The proximity to the dominantly erosional segment at Profile No. 2-2 also suggests a transport contribution from that source, perhaps aided as well by the tidal flow from Little Egg Inlet. In contrast to these inlet influenced beach profiles, the beach profiles facing the Atlantic Ocean are more subdued in both their short-term changes and long-term accretion/erosion trends. This is attributed to the more uniform wave energy distribution along this section of shoreline.

HYDRAULIC CHARACTERISTICS OF THE INLET COMPLEX

The tidal prism represents the volume of water entering the storage basin in a given tidal cycle. If the basin surface remains horizontal throughout the bay as the tide rises and falls, then:

$$P = \text{Tidal Prism} = H \times A_B \qquad (1)$$

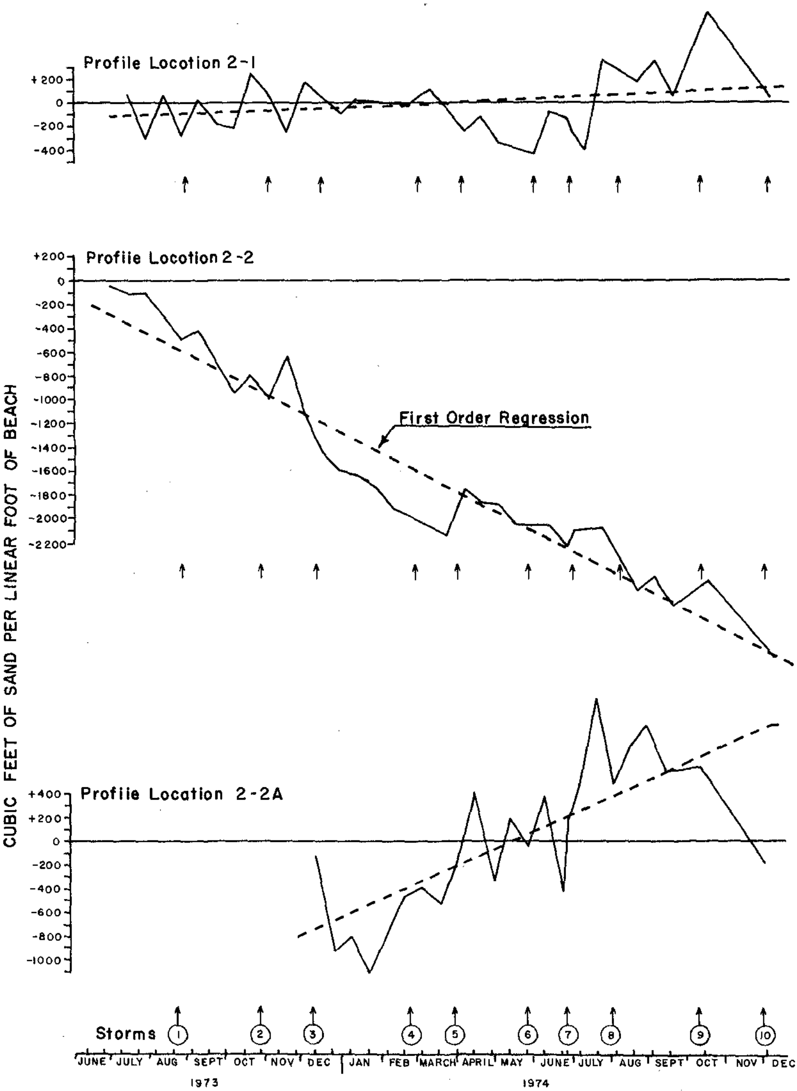


TOTAL BEACH VOLUME CHANGES-PROFILE LOCATIONS ON LONG BEACH ISLAND, N.J.

MAY 28, 1973-DECEMBER 4, 1974

REFERENCE: GOLDSMITH AND OTHERS, 1975

Figure 5



TOTAL BEACH VOLUME CHANGES-PROFILE LOCATIONS ON LITTLE BEACH ISLAND, N.J.

MAY 28, 1973 - DECEMBER 4, 1974

KEY

Storm Events

REFERENCE: GOLDSMITH AND OTHERS, 1975

Figure 6

where A_B is the basin area and H is the average difference between high and low tide elevations in the bay. In practice, however, there may be considerable differences in tide range within the bay accompanied by phase lags of several hours. Computation of tidal prism is then considerably more complex and a straightforward prism analysis is possible only by making discharge measurements at the inlet throat.

The tidal prisms for Beach Haven and Little Egg Inlets were first calculated from Equation 1 using average values for mean and spring tide ranges. For Little Egg Harbor, the basin was subdivided into eight sections for which the range was relatively constant and the total prism was taken as the summation of the sectional prisms. The result of this calculation is given in Table 1 for mean and spring tides. It is emphasized that this calculation is only a crude first approximation. There is a significant phase lag in surface elevation within Little Egg Harbor because of the time involved for the tidal wave to proceed up the shallow bay. For Great Bay, the phase lag is on the order of one hour, therefore the volumetric calculation of tidal prism should be reasonable (Table 1). However, for Little Egg Harbor, the phase lag between high water in the inlet and in the upper bay is about three hours and therefore the calculation of tidal prism simply based on storage basin area and tide range may be subject to considerable error.

Analyses of inlet throat discharges were made, based on measured velocity profiles and tide varying channel cross-sectional areas. Velocity data taken at hourly intervals at the surface, mid-depth and near bottom over an entire tidal cycle were obtained from the Corps of Engineers, Waterways Experimental Station. Cross-sectional areas for each section were evaluated from Alpine Geophysicals' 1974 bathymetry. The raw current data from each station were plotted as a function of time and smoothed by fitting a sinusoidal type curve to the data. From the velocity data and the channel cross-sections, the channel discharges were calculated. These values were then adjusted to be representative of a spring tide range and are shown in Table 1.

To a good approximatation, the hydraulic stability of a "sandy" inlet may be characterized by a unique relationship between the cross-sectional area at the entrance and the spring tidal prism. Based on a wealth of empirical data, O'Brien (1969) postulated,

$$A = (2 \times 10^{-5})\ P_{spring} \qquad (2)$$

	Little Egg Inlet	Beach Haven Inlet
Mean Tidal Prism (Volumetric)	$3.1\ (10)^9\ ft^3$	$1.9\ (10)^9\ ft^3$
Spring Tidal Prism (Volumetric)	$3.8\ (10)^9\ ft^3$	$2.3\ (10)^9\ ft^3$
Spring Tidal Prism (adjusted discharge)	$3.7\ (10)^9\ ft^3$	$2.4\ (10)^9\ ft^3$
Throat Cross Sectional Area, 1974 (Ref MSL)	$7.0\ (10)^4\ ft^2$	$4.3\ (10)^4\ ft^2$
Equilibrium Flow Area Based on O'Briens Relationship (Ref MSL)	$7.4\ (10)^4\ ft^2$	$4.8\ (10)^4\ ft^2$

HYDRAULIC CHARACTERISTICS

TABLE 1

where A = Cross-sectional area at the throat at MSL (ft^2), P_{spring} = Volume of tidal prism at spring tide (ft^3).

The implication is that tidal prism or "tidal power" is the forcing mechanism which maintains and determines the entrance channel. The term "stability" does not imply that the inlet will not change over time but rather that the system is in a state of dynamic equilibrium. A "stable" inlet implies a long-term balance between scour capability of tidal currents and depositional potential from littoral drift. Dramatic or permanent changes in storage basin characteristics of a tidal inlet system will then be manifested by a change of the entrance channel cross-sectional area. One such mechanism might be a geomorphic alteration of the storage basin which would change the tidal prism. A stable inlet will adjust to such changes with a new entrance channel which again permits a state of equilibrium.

Many inlets are not in fact totally "sandy". In a given inlet, one might expect to find a wide range of sediments, ranging from cohesive silts and clays on the channel flanks to shells and gravels on the channel bottom. Given some sand, however, it appears that the adjusting mechanism is generally sand transport as sands are most easily eroded (DeAlteris and Byrne, 1973). This explains, in part, why a unique maximum velocity (about 3.5 fps) is approximated in many inlets and a wide range of inlets may be characterized by Equation (2), (O'Brien, 1969). In particular, Little Egg and Beach Haven Inlets are at least partially sandy so that O'Brien's relationship should be a valid interpretation of their "stability".

Given the present spring tidal prism (adjusted discharge, Table 1), the equilibrium cross-sectional areas were computed from Equation (2). These results are shown in Table 1 and are compared with actual sections given by recent bathymetry. The results indicate that the measured cross-sections at Beach Haven and Little Egg Inlets are approximately equal to the "equilibrium cross-sections".

Within the accuracy of O'Brien's relationship and combined with the inaccuracies of the present analysis, one may conclude that Little Egg and Beach Haven Inlets are at present hydraulically in equilibrium or stable type inlets.

Historical changes in the bathymetry of Little Egg and Beach Haven Inlets were studied to gain some insight into the long-term stability or variability of the area. Hydrographic boat sheets showing both inlet channels, were available for 1903 and 1935 and Alpine Geophysical Associates' data for 1972 and 1974. A "throat" was identified for each inlet and the cross-sectional area was computed from the chart bathymetry. The cross-sectional areas of these sections are given in Table 2. Note that while a particular inlet may change drastically (even disappear), changes in the combined inlet area are relatively minor. For 1903 and 1935, the total Beach Haven and Little Egg cross-sectional areas were nearly identical at about 73,000 ft.^{2}, compared with recent cross-sections which average about 97,000 ft.^{2}. Adjacent geomorphic changes must therefore also be considered. Great Bay was formerly serviced by an additional inlet slightly north of Brigantine Inlet, commonly called Wreck Inlet. Since 1933, Wreck Inlet has migrated some 1,400 feet southward until merging with Brigantine Inlet in 1963. Wreck Inlet serviced Great Bay by means of Great Thoroughfare which is still present, but in a very reduced state. Simultaneously, Brigantine Inlet was narrowed from 3,000 feet in 1940 to its present width of 700 feet. One may conclude, therefore, that at one time, significant quantities of tidal flow were interchanged between the Wreck Inlet-Brigantine Inlet system and the southern portions of Great Bay. Great Thoroughfare is no longer an avenue for significant flow so that Great Bay is almost exclusively serviced by Little Egg Inlet. In view of the previous discussion of hydraulic stability, the changes in total entrance area from 1903-1935 era to present, seems at least qualitatively reasonable. The effective tidal prism for Little Egg Inlet is now considerably larger, encompassing all of Great Bay. As the storage basin area and tidal prism have increased during the last 30 years, the inlet cross-sectional area has increased to preserve hydraulic stability.

Short-term changes of the inlet channel cross-sections were also investigated by periodic bathymetric measurements along five transects across the Beach Haven and Little Egg Inlet channels. The measurements were made using a small boat, a precision fathometer and an electronic range finding device. The raw profiles were corrected to MSL with local tide data. Channel cross-sectional areas were computed using a limited baseline length that included the central channel and its flanks only, not the wide peripheral shoal areas. During the monitoring period, the area changes were minimal (less than 10 per cent of the average area). In all cases, the actual morphologic changes occurred on the seaward

YEAR	AREA AT BEACH HAVEN INLET (ft^2)	AREA AT LITTLE EGG INLET (ft^2)	COMBINED TOTAL (ft^2)
1903 (1)	-------	-------	72,480
1935 (1)	35,860	37,090	72,960
1972 (2)	35,650	58,900	94,550
1974 (2)	36,680	60,800	99,480

(1) From U.S.C.G.S. Boat Sheets, Reference MLW.

(2) From Alpine Geophysical 1974 Bathymetry, Reference MLW.

HISTORICAL INLET CHANNEL CROSS SECTIONAL AREAS

TABLE 2

flank opposite the marsh. This is due to the geology of channel cross-section, that is, sands occur on the seaward or updrift flank while cohesive sediments are found on the channel bottom and on the channel flank adjacent to the marsh.

SUMMARY AND CONCLUSIONS

The results of these inlet studies were directed toward assessments of the geomorphic and hydraulic stability of the inlet channels. Beach Haven Inlet is geographically unstable due to the steady southwestward elongation of Long Beach Island. During the last 20 years, Beach Haven Inlet has migrated southwest at a mean rate of 160 feet per year. Fluctuations in this rate along with mean shoreline recession rate, correspond well to fluctuations in the local rate of relative sea level rise. During the next 50 years, it is speculated that Beach Haven Inlet will merge with Little Egg Inlet forming a single entrance to the sea, after which a new break-thru inlet will form on the northern portion of Long Beach Island. This sequence occurred under identical circumstances between 1873 and 1923. This speculation presumes that there will be no attempt to stabilize this natural system. Hydraulically, Beach Haven Inlet appears stable. That is, during the last 75 years, the cross-sectional area of the inlet throat has remained relatively constant at approximately 36,000 square feet. The measured tidal prism for Beach Haven Inlet when plotted against the throat cross-sectional area, lies reasonably close to O'Brien's curve. Little Egg Harbor, the storage basin for Beach Haven Inlet, is long, narrow and shallow. Within this storage basin, there are significant reductions in tide range and phase lags in the tide curve. In contrast to Beach Haven Inlet, Little Egg Inlet is geographically stable; only the outer inlet channel thru the ebb tidal delta has migrated in the recent past. Little Egg Inlet appears hydraulically stable, that is, the inlet throat cross-sectional area has remained relatively constant. Both the calculated and measured tidal prisms when plotted versus the channel throat cross-sectional area, lie reasonably close to O'Brien's curve. Between the surveys dated 1936 and 1973, the inlet throat cross-sectional area increased from 37,000 square feet to its present size of 59,000 square feet. This increase in cross-sectional area can be related to an increase in tidal prism served by the inlet due to the closure of Wreck Inlet, a former inlet on the south side of Little Beach Island. Hydraulically, Little Egg Inlet is distinctly different from Beach Haven Inlet. There are no significant reductions of the tidal amplitude or phase lags in the tide curve within Great Bay.

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