CHAPTER 213

AN ENGINEERING STUDY OF OCEAN CITY'S BEACHES, NEW JERSEY, USA

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INTRODUCTION

Ocean City, New Jersey is a major coastal resort in the heavily populated northeastern part of the United States. It is located on a 13 km-long barrier island about 13 km south of Atlantic City and 48 km north of Cape May, the southernmost point in New Jersey. See Figure 1. The barrier island, called Peck's Beach, is bounded on the north by Great Egg Harbor Inlet and on the south by Corsons Inlet.

Because wide recreational beaches are important to Ocean City's economy, an engineering study of the beaches was undertaken: a) to quantify natural and man-made shoreline changes, b) to quantify tides, sea level changes, waves, longshore sand transport rates, seasonal variations in beach width and Great Egg Harbor Inlet processes and incorporate them into a sediment budget for Ocean City, c) to determine why past attempts to maintain wide recreational beaches were only partially successful, and d) to recommend a plan to establish and maintain wide beaches.

EXISTING CONDITIONS

The northerly end of Ocean City is the most densely developed part of the city. Here the barrier island is at its widest at about 1.4 km. Heavily used commercial development and tourist facilities are also located in this area. Further southward the island narrows to about 0.9 km and development consists primarily of single and multiple family dwellings. The streets in Ocean City are numbered from north to south with 9th Street being about the commercial and tourist center. A boardwalk extends from First Street in the north, southward to 23rd Street. Timber sheet-pile bulkheading parallels the shoreline behind much of Ocean City's beach. In some areas, e.g. south of 47th

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Street, the bulkhead is fronted by rubble toe protection and the high water shoreline is up against the bulkhead. At the heavily used northern end of Peck's Beach the shoreline has been stabilized by a number of long, high, impermeable rubble-mound groins. Groin crest elevations vary but average about 2.5 m above the local mean low water datum which is 0.58 m below the mean sea level of 1929 (National Geodetic Vertical Datum, NGVD). There are 18 groins between the terminal groin at Great Egg Harbor Inlet and 21st Street. Groin spacing ranges from 225 m to 370 m and averages about 300 m. In addition, there is a terminal groin at 59th Street, the southern end of the developed part of the island. There are no groins between 21st Street and 59th Street. South of 59th Street the shore is characterized by natural sand dunes on the sand spit which comprises the northern boundary of Corson's Inlet.

HISTORICAL SHORELINE CHANGES

Historical shoreline changes at Ocean City were studied by analyzing 21 sets of controlled, vertical, aerial photographs taken between April 1952 and September 1984. Most photos had a scale of 1:4800. The "wet line" or the interface between the wet and dry beach was identified at 46 stations along Ocean City's shoreline. This line is easily identifiable and is close to the limit of wave runup during the preceding high tide and to the berm line. The location of the wet line relative to a local baseline, usually the centerline of a shore-parallel street, was noted. Most of the 46 stations were located close together along the more northerly beaches to define shoreline changes within the groin compartments there. Stations were spaced further apart along the southerly beaches where spatial variations were smaller. Linear regression lines were fitted to the plots of wet line location as a function of time.

Interestingly, with only minor exceptions, the analysis found that the shoreline in 1984 was in almost the same location as it had been 32 years earlier in 1952. In addition, the regression lines showed that the time-averaged erosion rate was small or nearly zero even though there had been significant fluctuations of the shoreline about the average. In at least two locations, narrowing of the beach was due to encroachment from the landward side rather than by beach erosion.

The air photo analysis incorporated into it the effect of beach nourishment activities carried out by the Corps of Engineers and the City of Ocean City between 1952 and 1984. During that time, 6.4 million cu m (8.4 million cu yd) of sand were placed on Ocean City's beaches in three major beach fills in 1952, 1959 and 1982 and in numerous smaller fills between 1970 and 1981. Watts (1956) documented the performance of the relatively successful 1952 fill, one of the earliest beach fills ever undertaken, in which 1.95 million cu m (2.6 million cu yd) of sand was placed on the beach. During the 11 year period from 1970 to 1981, the City of Ocean City operated a dredge behind the barrier island and pumped an average of 166,000 cu m (217,000 cu yd) of relatively fine sand onto the beaches each year. Thus the average rate of beach filling from all sources between 1952 and 1984, the period covered by the air photo analysis, was 198,000 cu m/yr (259,000 cu yd). While the 1952 fill was relatively successful, the 1982 fill, placed during September and October, was short-lived and most of it was lost during that first winter. The winter of 1982-83 was marked by 18 storms out of the northeast which contributed to the rapid loss of fill (Farrell & Inglin, 1988).

Ocean City's beaches are relatively stable, but only at the expense of placing an average of 200,000 cu m (262,000 cu yd) of fill per year on them. However, the problem is beaches that are too narrow rather than beaches that are experiencing excessive erosion. The solution is to initially widen Ocean City's recreational beaches and then to stabilize and maintain these wider beaches.

SEASONAL BEACH PROFILE CHANGES

Quarterly surveys of 17 beach profile lines were made in September 1985, December 1985, May 1986 and June 1986 to determine what seasonal changes might be typical of Ocean City's beaches. Horizontal movements of 25 m at the mean sea level shoreline were not unusual during this period. In fact, changes of about 35 m occurred near the center of the island between 14th and 22nd Streets. See Figure 2. Most changes occurred between the September survey and the December survey with a further, less dramatic, shoreline recession between December and May. In general, there was little change between May 1986 and June 1986. A dramatic loss of sand occurred along the Great Egg Harbor Inlet shoreline between September and December 1985. The wide beaches and large sand dunes in the inlet area were eroded during two storms that occurred in late September and October. Shortly after the September survey, hurricane "Gloria" threatened the New Jersey coast. While most of Ocean City's beaches were spared major damage because the hurricane was too far offshore, the Great Egg Harbor Inlet beaches of Ocean City were severely eroded. Large volumes of sand, stockpiled in dunes along the inlet shoreline, dissappeared and two groins, which had been constructed in 1979 and buried beneath the sand, were exposed. See Figure 3.

WAVE AND POTENTIAL LONGSHORE TRANSPORT ENVIRONMENT

The wave and longshore sand transport environment in the vicinity of Ocean City were investigated using the hindcast wave data developed under the Corps of Engineers' Wave Information Study (WIS) (Jensen, 1983). WIS Station 62, Peck Beach, is located approximately offshore of 40th Street and best represents the average wave conditions in Ocean City. The next station to the north (Station 61) is at Atlantic City while the next station to the south (Station 63) is at Seven Mile Beach. Maximum offshore wave heights in 10 meters of water for Station 62 are given in Figure 4 along with an estimate of their return period.

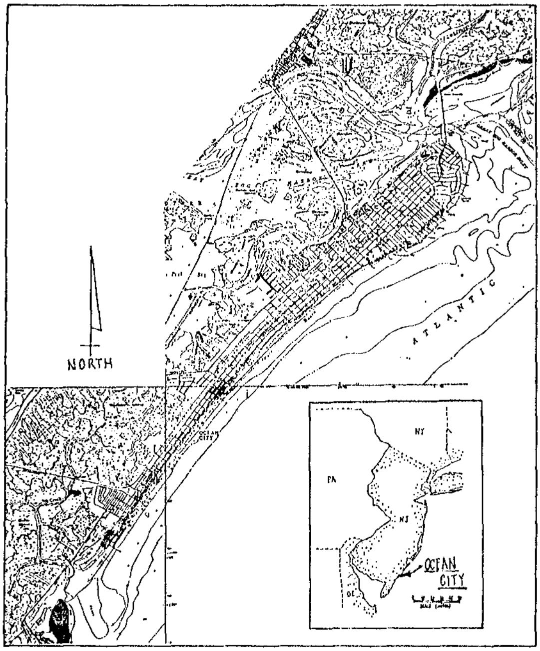

Figure 1 Location Map, State of New Jersey and Ocean City, New Jersey

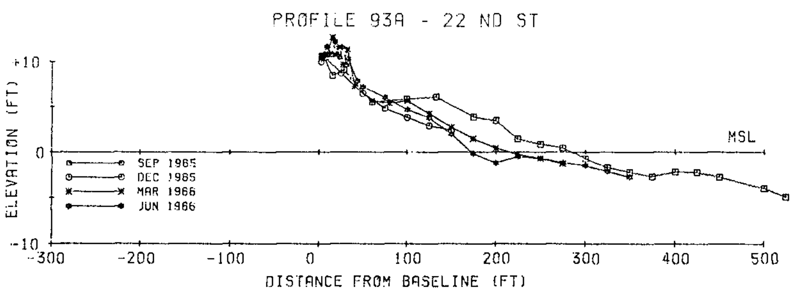

Figure 2 Beach Profiles at 22nd Street Showing Seasonal Shoreline Movement

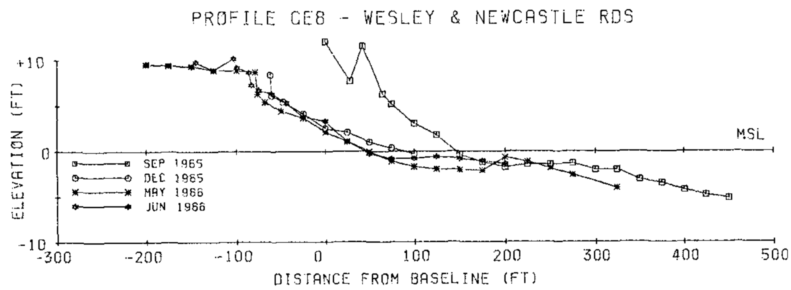

Figure 3 Beach Profiles at Great Egg Harbor Inlet Shoreline Showing Sand Losses between September and December attributable to Hurricane "Gloria"

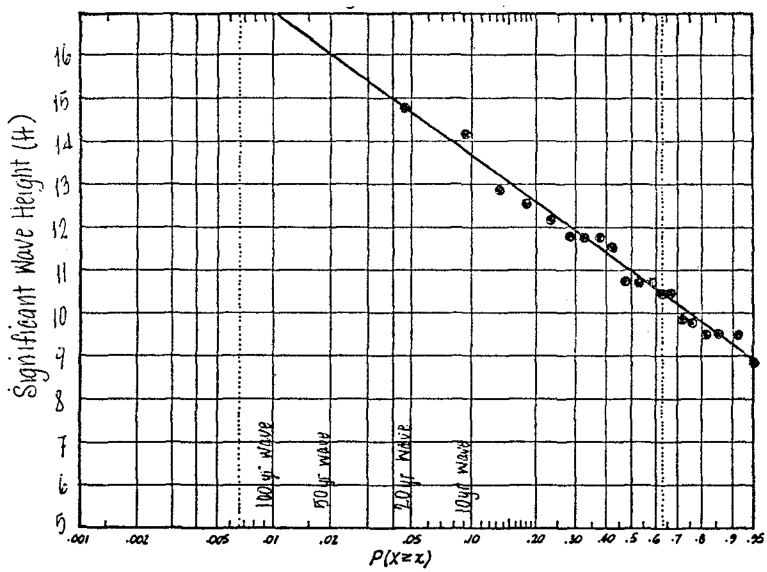

Figure 4 Frequency of Occurrence of High Waves in 10 Meters of Water at Station 62, Peck Beach (WIS Hindcast Data)

The WIS tabulated wave heights, periods and directions were used with the CERC formula to calculate potential longshore sand transport rates. In most cases calculated transport rates represent only potential transport because of: a) the effect of groins on transport, b) local reorientation of the shoreline, and c) the limited amount of sand available for transport in some areas. Transport rates calculated from the Station 62 WIS data were analysed statistically to determine how often given levels of transport are exceeded. The calculated transport rates were separated into two populations: positive transport (transport to the right for an observer looking seaward) and negative transport. Each data set was then listed in rank from the highest transport rate to the lowest. The number of hours that each transport rate prevailed was accumulated to obtain two freqency plots, one for positive transport and one for negative transport. The resulting longshore transport frequency data was plotted on log-normal probability paper to obtain the plots shown in Figure 5. Thus the longshore transport environment can be summarized by six parameters, the mean and variance of each of the two log-normal distributions (a positive transport distribution and a negative transport distribution) and the fractions of time the transport is positive, negative or calm (Weggel & Perlin, 1988; Weggel, Douglass & Tunnell, 1988). Driven by waves out of the northeast, sand moves southwestward only about 38% of the time at Station 62, Ocean City. Sand moves northeastward about 60% of the time. While northeastward transport occurs over a greater fraction of time, it is at a lower rate since it is driven by the relatively smaller waves out of the southeast during the summer months. Episodes of southwestward transport (northeasters), while less frequent, are more intense and carry more sand in the course of a year. This results in a net southwestward longshore transport. The potential net southwestward transport is estimated to be 56,000 cu m/yr (73,000 cu yd/yr). The northeastward transport is estimated at 540,000 cu m/yr (706,000 cu yd/yr) and the southwestward transport is 596,000 cu m/yr (779,000 cu yd/yr) for an annual gross transport rate of 1,136,000 cu m/yr (1,485,000 cu yd/yr). Obviously, these net and gross transport rates vary from year to year. The numbers given here are estimates of the 20-year average conditions summarized in the WIS hindcast data.

Similar analyses were performed for WIS Stations 61 and 63. Analysis of the Station 61 data, Atlantic City, predicts a northward net longshore transport on Absecon Island. This is contrary to evidence obtained from observations of sediment accumulation at structures on Absecon Island, particularly the terminal groin on the Longport side of Great Egg Harbor Inlet; consequently, Station 61 data was not used in the present analysis. This discrepancy between predicted and observed net transport rates shows that care must be exercised in interpreting transport rates computed from the WIS data and that other evidence to confirm or deny transport predictions should be sought. Quite often, as is the present case, net transport rates are the difference between large upcoast and large downcoast transport rates.

Small errors in estimating either the upcoast or downcoast rate can result in a large error in the net rate.

GREAT EGG HARBOR INLET PROCESSES

Great Egg Harbor Inlet has a significant effect on Ocean City's beaches, particularly those beaches adjacent to the inlet at the north end. However, even the beaches exposed to the ocean in the vicinity of the inlet are influenced by the effect of the inlet's ebb tidal shoal on incident waves. The prevailing southerly longshore sediment transport in the area causes the ebb tidal shoal to elongate so that it frequently extends southward from the inlet in the form of a shore-parallel offshore bar. This bar affords some protection from high waves to these beaches and thus influences the magnitude and direction of longshore transport near the inlet. In addition, Great Egg Harbor Inlet serves as a sediment trap for sand carried into it from both Longport's beaches to the north and Ocean City's beaches to the south. Historically, before construction of the stabilizing terminal groin/jetty on the Longport side of the inlet, the inlet was migrating northward. See Figure 6. Following construction of the jetty, the inlet's location stabilized but Ocean City's inlet shoreline has since been subjected to alternating periods of accretion and erosion as the channel thalweg moves back and forth in response to the influx and trapping of sand.

An analysis was made of the sedimentation patterns and of the volume of sediment trapped within the inlet. Extensive hydrographic surveys of the inlet had been made by the U.S. Army Corps of Engineers in 1965 and 1984. These two surveys coincided with the time period for which a sediment budget of the area was developed. Contours of the differences in depth between the two surveys were constructed as shown in Figure 7. The resulting contours show areas within the inlet where accretion occurred (solid lines) and areas where scour occurred (dashed lines). The figure demonstrates the southward movement of the channel thalweg since the accretion contours on the northeasterly side show filling of the old channel thalweg and the scour contours on the southwesterly side show the scouring of a new channel thalweg. The southward migration of the thalweg is also shown in Figure 8 which is a profile through the inlet's throat.

In addition to the southward migration of the inlet channel, there was an net increase of the volume of sand within the inlet. Between 1965 and 1984 the inlet accumulated approximately 3.6 million cubic meters (4.7 million cubic yards) of sand, presumably stripped from the Longport beaches to the north and Ocean City beaches to the south. This corresponds to an annual rate of trapping of 179,000 cu m/yr (234,000 cu yd/yr).

SEDIMENT BUDGET

A sediment budget for Ocean City's beaches was developed for the 19 year, 9 month period between 1964 and 1983. These

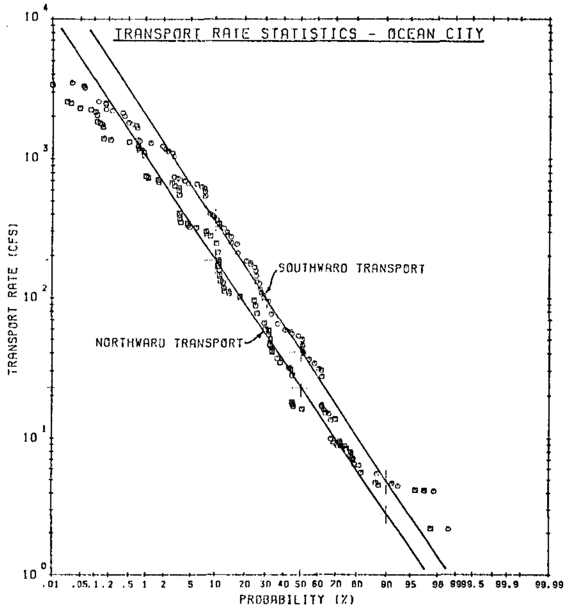

Figure 5 Log-Normal Probability Distributions for Positive and Negative Potential Longshore Sand Transport Rates at Station 62, Peck Beach (Computed from WIS Hindcast Data)

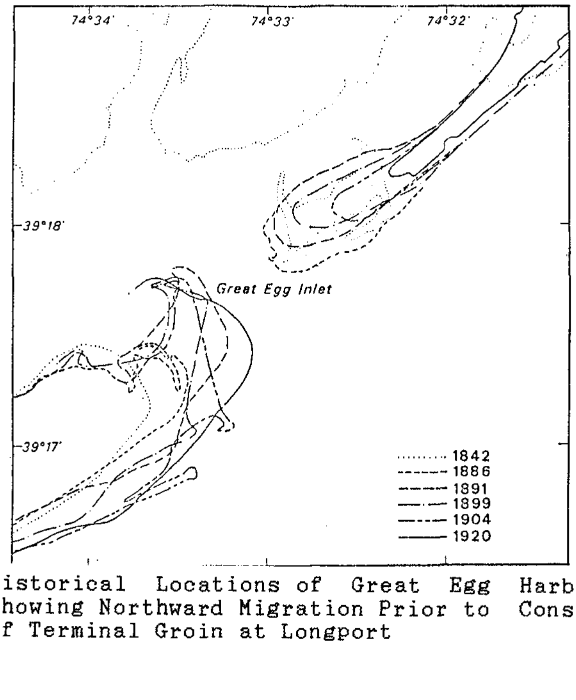

Figure 6 Historical Locations of Great Egg Harbor Inlet Showing Northward Migration Prior to Construction of Terminal Groin at Longport

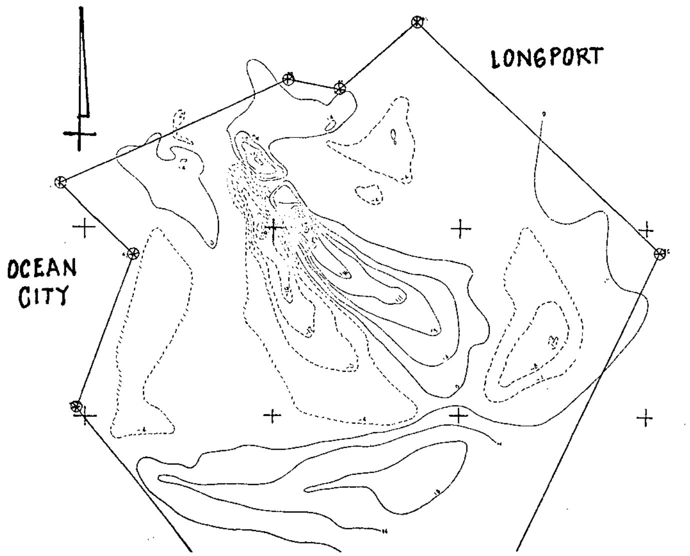

Figure 7 Bathymetric Changes Occurring within Great Egg Harbor Inlet Between 1965 and 1984

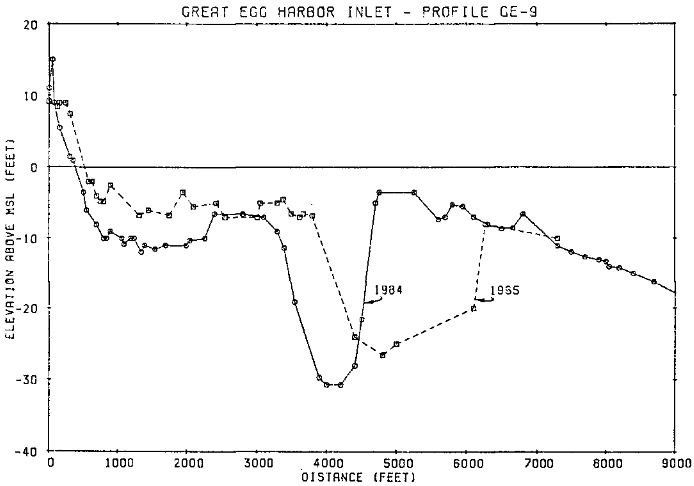

Figure 8 Profiles Through Throat of Great Egg Harbor Inlet Showing Southward Migration of Channel Thalweg

dates were dictated by the times for which both inlet bathymetric data and beach profile data were available. The area was divided into three cells and the transport of sediment into and out of each cell was balanced against the change in sediment volume within the cell. The three cells were: Ocean City's beaches from the inlet south to about 40th Street, Great Egg Harbor Inlet, and Longport's beaches on the southern end of Absecon Island just north of the inlet. See Figure 9. Sand volume changes on both Longport's beaches and Ocean City's beaches were determined from beach profile surveys obtained by the Philadelphia District of the Corps of Engineers. Sand volume changes in the inlet were obtained from two bathymetric surveys obtained in 1964 and 1983 by the Corps. Offshore losses were assumed to be caused by the long term increase in relative sea level as measured at Atlantic City. This rate is about 0.01 foot/year and is believed to be one-half due to sea level rise and one-half to local subsidence. Offshore losses were determined using the Bruun rule (Bruun, 1962) with the closure depth determined by the semi-logarithmic profile methodology outlined in Weggel (1979). The closure depth was estimated at about 7.9 to 8.5 meters (26 to 28 feet) below mean low water and erosion rates were estimated at between 7.0 and 9.3 cu m/m/yr (75 to 100 cu ft/ft/yr) yielding a shoreline recession rate of about 0.96 m/yr (2.5 ft/yr).

The results of a simplified sediment budget are shown in Figure 9. The three cells are shown schematically along with the contributions to and losses from each cell. Units on the figure are in thousands of cubic meters per year. The 7,000 m (23,000 ft) long Longport cell lost 47,400 cu m/yr (62,000 cu yd/yr) offshore, gained an unknown amount of sand from Atlantic City's beaches to the north and lost an unknown amount of sand to Great Egg Harbor Inlet to the south. The annual rate of increase in sand volume on Longport's beaches was 40,500 cu m/yr (53,000 cu yd/yr). The inlet lost an estimated 17,600 cu m/yr (23,000 cu yd/yr) offshore and gained unknown amounts of sand from Longport's and Ocean City's beaches. The net accumulation of sand in the inlet was at a rate of 178,900 cu m/yr (234,000 cu yd/yr). The Ocean City cell lost an unknown amount of sand to the inlet, 79,500 cu m/yr (104,000 cu yd/yr) offshore and 55,800 cu m/yr (73,000 cu yd/yr) to the beaches at the south end and the spit at Corsons Inlet. Ocean City gained 141,100 cu m/yr (195,000 cu yd/yr) through beach nourishment; however, there remained a net loss of 100,900 cu m/yr (132,000 cu yd/yr) from the beaches. Solving the three simultaneous equations that result, yields values for the three unknown transport rates: the transport into the Longport cell from Atlantic City is 169,700 cu m/yr (222,000 cu yd/yr), transport into the inlet from Longport is 81,800 cu m/yr (107,000 cu yd/yr), and transport into the inlet from Ocean City is 114,700 cu m/yr (150,000 cu yd/yr). Obviously, these results are sensitive to the quality of the data used to determine them. The longshore transport rates are most suspect; in fact, longshore transport into the Longport cell from Atlantic City should be known from the WIS wave hindcast longshore sand transport analysis. However, because the magnitude and direction of this longshore rate

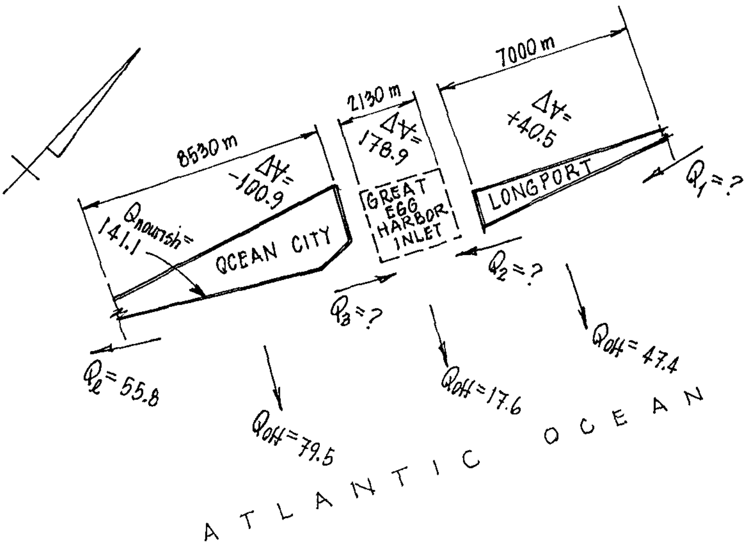

Figure 9 Schematic of Sediment Budget Analysis Showing Longport Cell, Great Egg Harbor Inlet Cell, and Ocean City Cell

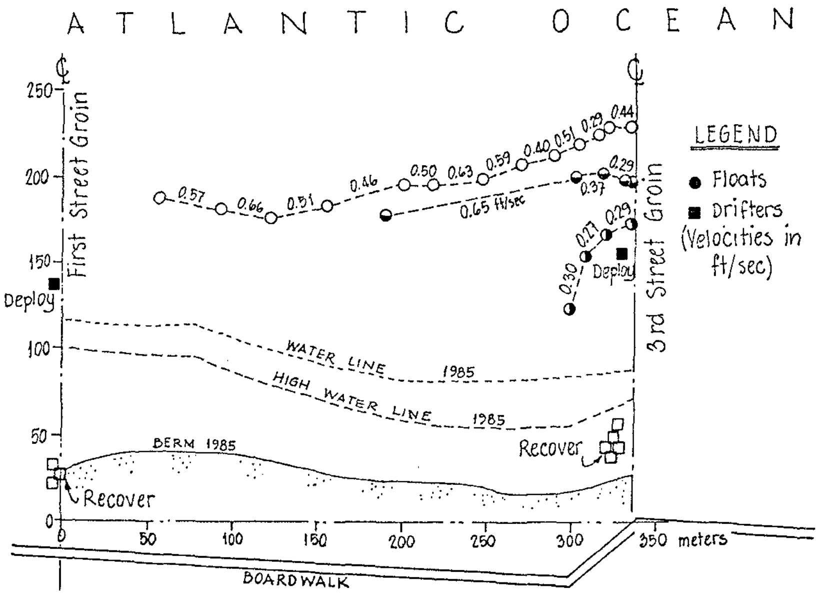

Figure 10 Current Patterns in Compartment Between Groins at First and Third Streets, Ocean City, New Jersey, 2 November 1986

is questionable, it was taken to be an unknown in the analysis. Actually, the rate of sand loss to the beaches south of Ocean City might also differ from the 55,800 cu m/yr (73,000 cu yd/yr) assumed here. Larger losses to downdrift beaches would result in larger transport rates into the Longport cell at the northern end of the analysis; smaller losses would result in smaller transport rates into the Longport cell.

CIRCULATION STUDY IN GROIN COMPARTMENT BETWEEN FIRST AND THIRD STREETS

The groin compartments along the northerly beaches of Ocean City are believed to induce circulation cells that exacerbate the loss of beach fill during storms. Even during high storm water levels, the high rubble mound groins block longshore transport and divert sand offshore in rip currents that form adjacent to the groins. A field study was undertaken offshore of the beach compartment formed by the groins at First and Third Streets to evaluate the circulation patterns that might arise within the groin compartments. Surface currents were measured by tracking plywood surface floats equipped with a small flag. (In subsequent tests, plastic milk bottles partially filled with sand and water were used instead of plywood floats. These proved easier to deploy and always floated with the flag upward since the body of the bottle was submerged.) The floats were released from the groins and followed using two surveyor's transits set up a known distance apart along a shore-parallel baseline. Simultaneous recording of the angle between the float's location and the baseline by the two transits along with the time of the observation allowed the pathlines of the floats to be plotted and their average velocity between observations calculated.

The results of a field test conducted on 2 November 1986 are shown in Figure 10. During that test, transport was northward with current velocities averaging about 0.15 m/sec (0.5 ft/sec). The wave period was about 8.5 sec and breaker heights averaged about 0.55 m (1.8 feet). Longshore current speeds, measured by throwing dye into the surf, were about 0.2 m/sec (0.66 ft/sec). Figure 10 shows no evidence of rip current development along the First Street groin; however, initial observations made with floats released from the First Street groin showed offshore movement. Unfortunately, the floats often became trapped within the rocks of the groin. The floats also capsized and could not be seen with the transits.

FINDINGS AND RECOMMENDATIONS

Ocean City's beaches have been relatively stable, at least over the period of observation covered by this study. In 1984 the beaches were in essentially the same location as they were in 1953. This is believed in part to be due to the high, impermeable, rubble-mound groins constructed to stabilize the northerly beaches, and in part to the occasional renourishment of the beaches. Over the 32 year period between 1952 and 1984, more than 6.4 million cu m

(8.4 million cu yd) of sand were placed on the beaches. Some of these beach nourishment projects were relatively successful, e.g. the 1952 fill, while others, such as the 1982 fill, were very short-lived. Between 50% and 90% of the beach fill placed late in 1982 was lost before the following summer (Farrell & Inglin, 1988). The existing beaches are not wide enough to accomodate the many beach users during the summer months. Also, in the commercially developed areas along Ocean City's narrow northerly beaches, the beach affords little protection to the area behind it. The problem is to widen the beach and to stabilize it in a new, equilibrium position that is farther seaward than the present equilibrium position.

The long, high, impermeable groins contribute a level of stability to the beaches by sheltering a length of the shoreline from northeast storms; however, they probably also contribute to the rapid loss of sand during storms by inducing the formation of rip currents. Following the placement of a beach fill, groin compartments are full of sand and the more-seaward, less-protected shoreline is exposed and vulnerable to wave attack during storms. During storm periods with high water levels and swift longshore currents, the longshore currents are deflected seaward as rip currents form along the groins. The rip currents quickly transport beach fill sand offshore. After the shoreline has eroded back to approximately its pre-fill location, it is again sheltered by the groins and a dynamic, near-equilibrium condition is again established.

Lowering and lengthening the existing groins was recommended to increase the residence time of future beach fills. Lower groins would allow sand to spill over them during high storm water levels rather than have the sand diverted seaward by rip currents. While the sand might not remain in the groin compartment in which it was placed, it would at least remain on the beach rather than be diverted offshore. The modified groin profiles would approximate the natural beach profile from about the +2.4 m (+8 foot) berm elevation out to the mean high water line; from here, the groin crest would extend seaward horizontally. See Figure 11. Stone removed by lowering the groins will be used to lengthen and extend them seaward. Also, several existing groin spurs (rock extensions to the groins that extend perpendicular to the groin axis) would be lowered or removed and the stone used to lengthen the groins.

Approximately 1.1 million cu m (1.4 million cu yd) of beach fill is required to provide at least a 30.5 m (100 ft) wide berm having an elevation of +3.0 m (+10 ft) between the northern end of the barrier island and about 20th Street. The Corps of Engineers has recommended a more extensive beach fill extending from the inlet southward to 59th Street. The fill proposed by the Corps will require about 3.8 million cu m (5 million cu yd) of sand. Construction of the groin modifications is scheduled to begin in late 1988 or early 1989 and the Corps of Engineers beaoh fill project is scheduled for 1990.

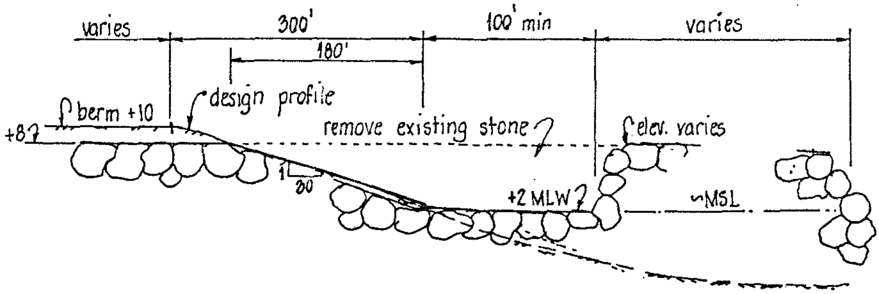

Figure 11 Proposed Modified Groin Profile

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