CHAPTER 215

Littoral Impact of Ocean City Inlet, Maryland, USA

Julie Dean Rosati[1], M. ASCE, and Bruce A. Ebersole[2], M. ASCE

ABSTRACT

Ocean City Inlet, Maryland presents a data-rich site for evaluating the total littoral impact of an inlet system with a significant adjacent beach response. Analysis of adjacent beach and bay shoreline data, adjacent beach profiles, ebb and flood shoal evolution, and dredge/fill history provided a database with which the inlet's littoral impact to adjacent beaches was quantified. The even/odd method, which decomposes shoreline changes into their symmetric (even) and antisymmetric (odd) components about a point of significance, was applied to the volume change dataset. This analysis indicated a present-day (1996) alongshore impact distance of 8 to 13 km from the centerline of the inlet. A second method, which relates the total "inlet sink" volume to adjacent island (ocean and bay) volume change, was also applied. The total inlet sink volume ranged from 10.8 to 15.6 million m^3, and reflects the volume of material captured by the inlet which is assumed to have been derived from adjacent beaches. The inlet sink method indicated that, at most, 10.8 million m^3 can be realized within $\pm$14.2 km (data limit). The paper concludes that the alongshore impact of Ocean City Inlet most likely extends beyond $\pm$14.2 km.

1.0 EVOLUTION OF OCEAN CITY INLET

Ocean City Inlet is located on the Atlantic coast of the United States (Figure 1), and was created by a hurricane on 25 August 1933 which breached the outer barrier island. In 1922, groins were constructed on Fenwick Island (to the north) to stabilize this increasingly-popular beach resort. Assateague Island (to the south) remained in a natural state, and, in February 1920, Sinepuxent Inlet breached the island approximately 4.8 km south of the existing inlet, and had migrated southward about 0.8 km until it was closed by another storm in May 1928. After the hurricane of August 1933, jetty construction commenced in September and the inlet quickly scoured to 3 m depth and 76 m width (Underwood and Hiland 1995).

A study by Dean and Perlin (1977) and Dean, Perlin, and Dally (1978) documented sediment transport moving north along northern Assateague Island, which deposited in the inlet channel. As a result of the study, in 1985 the south jetty was raised and

[1]Research Hydraulic Engineer, [2]Supervisory Hydraulic Engineer, US Army Engineer Waterways Experiment Station, Coastal and Hydraulics Laboratory, CEWES-CR-P, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199

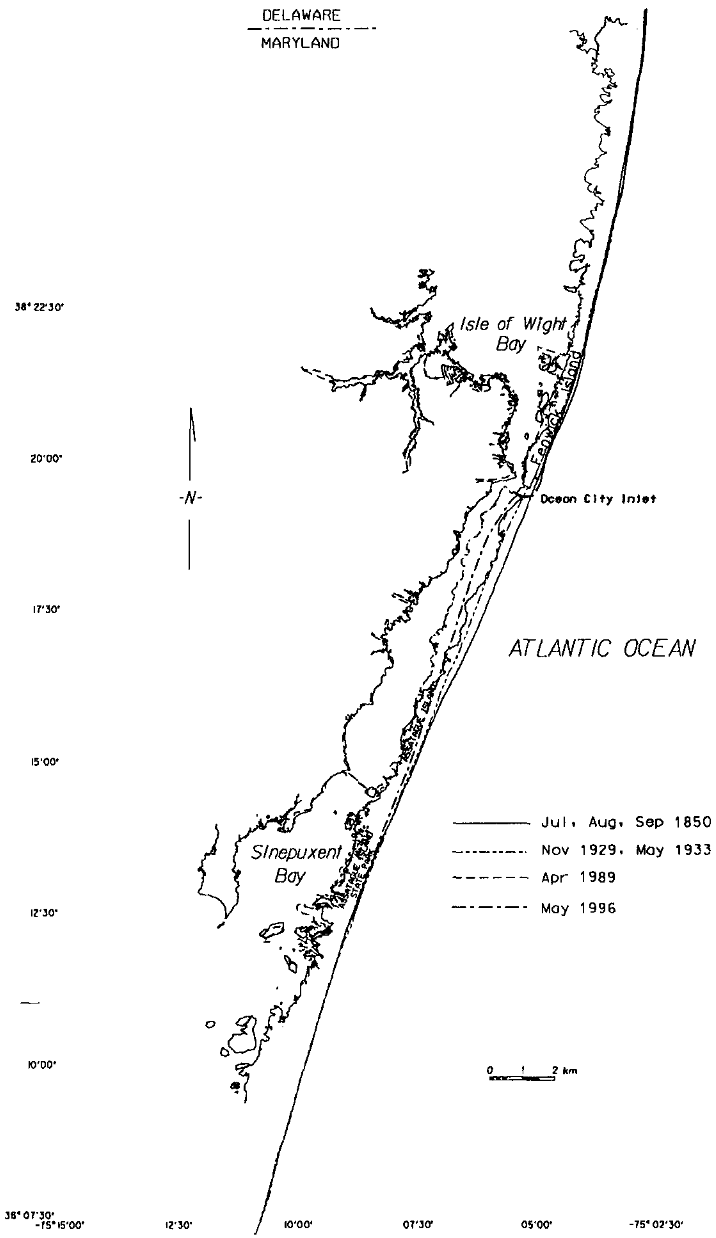

Figure 1. Historical shorelines, Ocean City Inlet, Maryland, USA

tightened, and the northern Assateague Island channel bank was stabilized with three detached breakwaters. The most recent significant engineering event affecting the littoral system has been the placement of approximately 7.4 million m^3 of beach fill on Fenwick Island from June 1988 through April 1995, which extended from the just north of the inlet to the Maryland-Delaware state line.

2.0 DATA ANALYSIS

Shoreline position, adjacent beach profile, ebb shoal bathymetry, and flood shoal data sets as well as dredging events were analyzed and used to create a volume change database. A range of parameters which were applied in sensitivity evaluations were also defined, and are discussed below.

2.1 Variation of Shoreline Position with Time

Both ocean and bay shoreline position were recorded with respect to an alongshore coordinate, x, which was set to zero at the centerline of the inlet and used a right-handed coordinate convention (i.e., negative x indicates north; positive x indicates south). The shoreline position represents the high water line, and was calculated for each time period at a 50-m alongshore cell spacing. Results of the shoreline change analysis are presented in Table 1.

Table 1. Summary of Shoreline Change Analysis: Average Rates and Associated Standard Deviation (m/yr)

Time Period	Alongshore Extent: Ocean (km)	Alongshore Extent: Bay (km)	Fenwick Island		Assateague Island	
			Ocean	Bay	Ocean	Bay
1850-1929/33	-15.1 to 14.2[1]	-13.7 to 3.3	-0.37 ± 0.98	~0[2]	-1.5 ± 1.7	2.8 ± 1.8
1929/33-1995/96	-15.1 to 14.2	Varies; range -13.5 to 16.6	0.44 ± 0.80[3] -0.21 ± 0.91[4]	0.75[5]	-2.9 ± 2.2[3] -2.9 ± 2.7[4]	2.5[6]

[1] Full extent was -19.4 to 23.5 km; the analysis was limited here to equal the alongshore extent for the post-inlet period.
[2] Calculated value was a small negative number. Because it is not likely that pre-inlet bay processes would erode the bay shoreline, a near-zero bayshore change rate was assumed for the pre-inlet time period.
[3] Shoreline change rate reflects advancement due to beach fill.
[4] Adjusted shoreline change rate to remove advancement due to beach fill.
[5] Calculated by prorating 1929-1965 and 1965-1980 bay shoreline change rates. Standard deviation values are unavailable.
[6] Calculated by prorating 1933-1965, 1965-1980, 1980-1989, and 1989-1995 bay shoreline change rates. Standard deviation values are unavailable.

Ocean shoreline change rates for Assateague Island extending 14.2 km south of the inlet nearly doubled from a pre-inlet (1850-1929/33) erosion rate averaging -1.5 ± 1.7 m/yr to an average post-inlet (1929/33-1996) erosion rate averaging -2.9 ± 2.7 m/yr (latter rate excludes shoreline advancement due to documented beach fill of 0.9 million m^3). For both the pre- and post-inlet time periods, overwash processes were significant along Assateague Island, with bay shoreline change indicating accretion. For the Fenwick shoreline extending approximately 15.1 km north of the inlet, the ocean shoreline responded to construction of the jetties by decreasing the pre-inlet erosion trend (-0.37 $\pm$ 0.98 m/yr for the pre-inlet time period to -0.21 $\pm$ 0.91 m/yr in the post-inlet time period (latter rate excludes shoreline advancement due to documented beach fill of 8.1 million m^3)). For the pre-inlet time period, the bay portion of Fenwick Island was comparably stable. The post-inlet time period reflects some bay shoreline accretion, which occurred prior to 1980 (a majority of the Fenwick bay shoreline in the vicinity of the inlet has been developed since 1980).

2.2 Profile Data

Beach profile data were analyzed to provide a relationship to convert shoreline change rates into volumetric change rates. Shoreline change within a given alongshore cell is estimated to represent a horizontal translation of the profile over its active depth. The absolute sum of the berm elevation and the depth at which profile changes are insignificant, the closure depth, is one method of estimating the active profile depth. A second method relates the profile volume change to shoreline movement for a given time period. Sensitivity testing of values from both methods indicated that the difference was not significant (less than 2-percent difference in total volumes). Thus, the first method was applied herein. For Fenwick and Assateague Islands, ocean beach profile data were analyzed to estimate active depth. Fenwick Island pre- and post-fill profile data were also analyzed to estimate the percentage of Fenwick Island beach fill remaining in 1996, which was required to correctly account for alongshore movement of this material from Fenwick Island into other regions of the project.

In evaluating the initial performance of the Fenwick Island beach fill, Stauble et al (1993) estimated the depth of closure for Fenwick Island using profile data measured from the spring of 1988 through the winter of 1992, and concluded that 6.1 m relative to National Geodetic Vertical Datum (NGVD) was a representative value. Because coastal processes at this depth are most likely similar offshore of Fenwick and Assateague Islands, this depth was also assumed to be representative of Assateague Island. However, this active depth was not used for southern regions of Fenwick Island and northern region of Assateague Island which were sheltered by the ebb tidal shoal. For these regions, the depth at the shoreward edge of the ebb shoal was used in active depth calculations. Volume change within the ebb shoal was accounted for separately.

Stauble et al (1993) estimated the active berm elevation for Fenwick Island as 3.0 m NGVD, resulting in an estimate of active depth for regions of Fenwick Island outside the shelter of the ebb shoal equal to 9.1 m. For Assateague Island, the sensitivity of applying pre- versus post- rehabilitation jetty berm crest elevations was insignificant; therefore, post-rehabilitation jetty berm crest elevations were applied herein. The estimate of active depth for the regions of Assateague Island unaffected by the ebb tidal shoal (from 2 to 14 km south of the inlet) ranged from 8.3 to 8.5 m.

Seven profiles from June 1988 (immediately pre-fill) and May 1996 (present-day condition) were analyzed to determine the rate of beach fill "loss" from the profile.

Volume change for each profile was multiplied by an alongshore distance represented by that profile to properly "weight" results at each profile location. Results from this analysis indicated that approximately 17 percent of the placed material was lost over the active depth. An additional 10 percent of material was originally placed in a dune feature (above 3.0 m NGVD), and this entire volume was assumed to remain on the profile. Because the fill material was similar to or coarser than the native sediments, it was assumed that any fill loss moved alongshore rather than offshore. The portion of the 1988-1995 Fenwick Island beach fill that was assumed to move alongshore, totaling approximately 1.7 million m^3, was assumed to deposit and remain within the inlet sink. Shoreline change calculations assumed a beach fill "loss" rate of approximately 2-percent per year.

Profile data for the bay shoreline were only available for the northwest corner of Assateague Island (Dean, Perlin, and Dally 1978), and represented conditions prior to sand-tightening and raising of the south jetty and construction of the detached breakwaters. These data extended into the channel, and reflect stronger current conditions than the rest of the bayshore. Based on estimates of bay active depth of approximately 4 m for this small, higher energy, region of the bayshore, the sensitivity of results to a range of slightly smaller bay shoreline active depths, thought to be more representative of conditions along the majority of the bay (1 m, 2 m, and 3 m) was evaluated. The sensitivity of volume calculations to the choice of bay active depth was found to be significant for certain cases (see Section 3.4).

2.3 Ebb Shoal Evolution

Bathymetric data from 1933, 1976, and 1995 were utilized to define the ebb shoal planform "footprint," depth at the landward edge of the footprint (used in estimating active depth), and volume. Visual inspection of a bathymetric data set or a bathymetric contour plot to delineate an ebb shoal is rather subjective. For this study, the availability of a pre-inlet (1933) bathymetry enabled application of a more objective procedure, as modified from that discussed by Hicks and Hume (1996). First, an idealized "non-inlet" bathymetry was created by using the 1933 bathymetric data set, but replacing the 1933 shoreline and nearshore beach profile data along the northern region of Assateague Island with present-day shoreline and bathymetry which were typical of that found outside the influence of the ebb tidal shoal. Using this idealized non-inlet bathymetry, "residual" topographies were created by subtracting it from the subsequent time periods. Next, the ebb tidal shoal footprint for each residual topography was estimated by four different individuals, and residual ebb shoal volumes were calculated. Four independent estimates of the ebb shoal footprint gave an indication of the error associated with personal subjectivity.

Estimates 1, 2, and 4 applied similar methods of using the 1-m residual contour to delineate the ebb shoal footprint. This contour appeared to provide a planform shape of the ebb tidal shoal that reflected onshore and alongshore evolutionary trends of the shoal as evidenced from bathymetric data. Estimate 3 used the 0-m residual contour to delineate the shoal, and therefore these volume and area estimates are higher. Estimate 3 chose the 0-m residual contour to fully capture bathymetric regions which may have accreted. These regions resulted in a footprint which included more of the areas reflecting growth and lengthening of finger shoals, and deposition in troughs, which are probably only partly represented by Estimates 1, 2, and 4. All residual volumes were calculated by using the selected footprint and determining the volume above a 0-m residual contour within this polygon. Bathymetric data from 1995 did not fully cover the ebb tidal shoal. Therefore, 1933-1976 residual ebb shoal data were used to complete coverage on the outer edges of the ebb tidal shoal for the 1933-1995 residual bathymetry. Results are presented in Table 2.

Table 2. Ebb Tidal Shoal Changes, 1933-1995

Estimate Number	Volume (million m^3)	Area (million m^2)	Volume Change Rate (m^3/yr)
1, 2, 4	9.8, 9.9, 9.9	3.0, 3.0, 3.0	158,000, 159,000, 158,000
3	12.9	4.2	207,000

For estimates of total ebb shoal volume from 1933 to 1996, two ebb shoal volumes were used: a minimum value was obtained by extrapolating the average of Estimates 1, 2, and 4 to 1996 (approximately 10 million m^3); and a maximum value was obtained by extrapolating Estimate 3 to 1996 (approximately 13 million m^3) . For each estimate, depths at the landward edge of the ebb tidal shoal footprint were applied in calculating active depth for regions of Fenwick and Assateague Islands sheltered by each ebb shoal. In sensitivity testing, the differences between active depths for the 10 and 13 million m^3 ebb tidal shoal footprints were found to have an insignificant impact on final calculations. Therefore, results are presented herein for active depths as indicated by the 10 million m^3 ebb shoal footprint.

2.4 Flood Shoal Evolution

Information about deposition in the bay is necessary to account for losses to the littoral system. Unfortunately, detailed bathymetric data provide only partial coverage for Isle of Wight and Sinepuxent Bays. For this study, the flood shoal/bay accretion rate calculated by Dean and Perlin (1977) and Dean, Perlin, and Dally (1978) using 1931 to 1972 bathymetry was used, 19,600 m^3/yr. It is likely that the 1972 through 1996 flood shoal accretion rate has decreased somewhat, perhaps half this value, for a present-day estimate of total flood shoal/bay volume equal to 1 million m^3. This estimate is based on the belief that flood shoal accretion would probably be greatest during the initial years after inlet formation, and would decrease with time. The sensitivity of calculations presented herein was evaluated with two other flood shoal/bay accretion estimates. A maximum estimate assumed that the original rate continued through the present, for a total flood shoal/bay volume of 1.2 million m^3. A minimum volume of 0.76 million m^3 was estimated by assuming that no additional bay/flood shoal accretion has occurred since 1972.

2.5 Dredging History
Various sources were culled to determine the dredging and placement history for Ocean City Inlet. A total of 24 dredging events between 1947 and 1995 indicated a channel shoaling rate of approximately 56,000 m^3/yr, with many dredge placements on northern Assateague Island. For this study, a minimum channel shoaling volume between 1933 and 1996 was calculated by assuming that only the documented dredging events occurred (2.7 million m^3). A maximum channel shoaling volume assumed that the 56,000 m^3/yr rate continued from 1933 through 1996 (3.5 million m^3). Adjacent beach placement of the dredged material was accounted for in the shoreline change database.

3.0 LITTORAL IMPACT OF OCEAN CITY INLET

3.1 Volume
The "inlet sink volume" captured by Ocean City Inlet is defined as the volume of material within the inlet which is assumed to have been derived from adjacent ocean and bay beaches. A range of volumes representing the Ocean City Inlet sink was calculated by summing the minimum and maximum estimates for ebb shoal volume, flood shoal volume, and channel shoaling volume, subtracting maximum and minimum estimates for the original 1933 Ocean City Inlet breach, and subtracting the volume of Fenwick Island beach fill which was assumed to move alongshore and deposit in the inlet. The initial loss of material due to the island breach in 1933 was estimated using typical ocean and bay profile shapes (best estimate: 0.53 million m^3, with a range between 0.43 and 0.97 million m^3).

The minimum inlet sink volume was estimated as 10.8 million m^3 (ebb shoal: 10 million m^3 + flood shoal: 0.76 million m^3 + shoaling volume: 2.7 million m^3 - initial breach: 0.97 million m^3 - alongshore movement of Fenwick Island beach fill: 1.7 million m^3). The maximum inlet sink volume totaled 15.6 million m^3 (ebb shoal: 13 million m^3 + flood shoal: 1.2 million m^3 + shoaling volume: 3.5 million m^3 - initial breach: 0.43 million m^3 - alongshore movement of Fenwick Island beach fill: 1.7 million m^3). Thus, **the total volume of material captured by Ocean City Inlet which can be attributed to adjacent beaches is estimated to be between 10.8 and 15.6 million m^3.**

3.2 Alongshore Impact: Overview. Two methods were used to estimate the distance alongshore for which the inlet has affected adjacent beaches: the even/odd procedure (Section 3.3), and an examination of the inlet's net sink effect and adjacent island response (Section 3.4). Both methods accounted for a background erosion rate, and assumed that pre-inlet volume change trends would have continued through the present if the inlet had not been created. Thus, pre-inlet (1850-1929/33) volume change rates were subtracted from post-inlet (1929/33-1996) volume change rates. The effect of beach fill (which is reflected in the shoreline position) was removed from the signal by subtracting an estimate of the beach fill volume remaining from the volume in each 50-m shoreline calculation cell. An estimate of beach fill reflected in the shoreline position was estimated by assuming a beach fill "loss" (or alongshore movement) rate of approximately 2-percent per year (discussed in Section 2.2).

The assumption of a background erosion rate is reasonable, as evidenced from the Fenwick Island shoreline change rates from 1929/33-1996 (Table 1 with beach fill advancement removed), and the trend for relative sea level rise in this region of the U.S. (1.1 mm/yr for Lewes, Delaware, north of Ocean City Inlet, Marine Board 1987). In addition, the 1850 to 1929/33 reorientation of the Fenwick-Assateague Island barrier island from a convex to a more "linear" shoreline orientation (see Figures 1 and 3a) most likely is a long-term, large-scale response which is continuing through the present.

3.3 Alongshore Impact: Even/Odd Method. The even/odd method is a simple analytical procedure discussed and applied by Dean and Work (1993) and Bodge (in preparation) among others, and can be solved from the linearized treatment of shoreline evolution (Pelnard-Considere 1956). The method decomposes shoreline change (or, as applied in this case, volume change) data into their symmetric (even) and anti-symmetric (odd) components about a point of significance. For application at Ocean City Inlet, the center of the inlet was chosen as the point about which data were decomposed into even and odd components. Volumetric change data were used so that the effects of beach fill could be removed, and so that the alongshore variation in active depth could be incorporated. Due to space limitations herein, the reader is directed to Dean and Work (1993) or Bodge (in preparation) for a description of even/odd calculation procedures.

The even and odd functions are indicators of those shoreline or volumetric changes which have been symmetric or anti-symmetric, respectively, about the point of significance. For an inlet with the centerline chosen as the point of significance, the even function reflects changes in shoreline position (or volume change rate) which have occurred symmetrically about the inlet, such as shoreline retreat or advance due to cross-shore transport (due to storms and relative sea level change), and symmetric shoreline retreat due to sediment feeding the ebb and flood tidal shoals. An example of an anti-symmetric change common to stabilized inlets, which is reflected by the odd function, is impoundment on the updrift beach at the expense of the downdrift beach. The alongshore point at which the odd function returns to a zero value is an indicator of the alongshore distance influenced by the anti-symmetric effects, such as impoundment, which is a project-induced impact. The alongshore point at which the even function approaches a constant value is an indication of the alongshore distance influenced by symmetric inlet-induced effects such as shoreline retreat due to feeding the ebb and flood tidal shoals.

Figure 2a shows the post-inlet (1929/33-1996) even/odd analysis, and Figure 2b shows results for the post-inlet rate adjusted by the background erosion rate as defined by the pre-inlet (1850-1929/33) data set. Negative distances indicate shoreline to the north along Fenwick Island. For both Figures 2a and b, the "total" curve shows the updrift

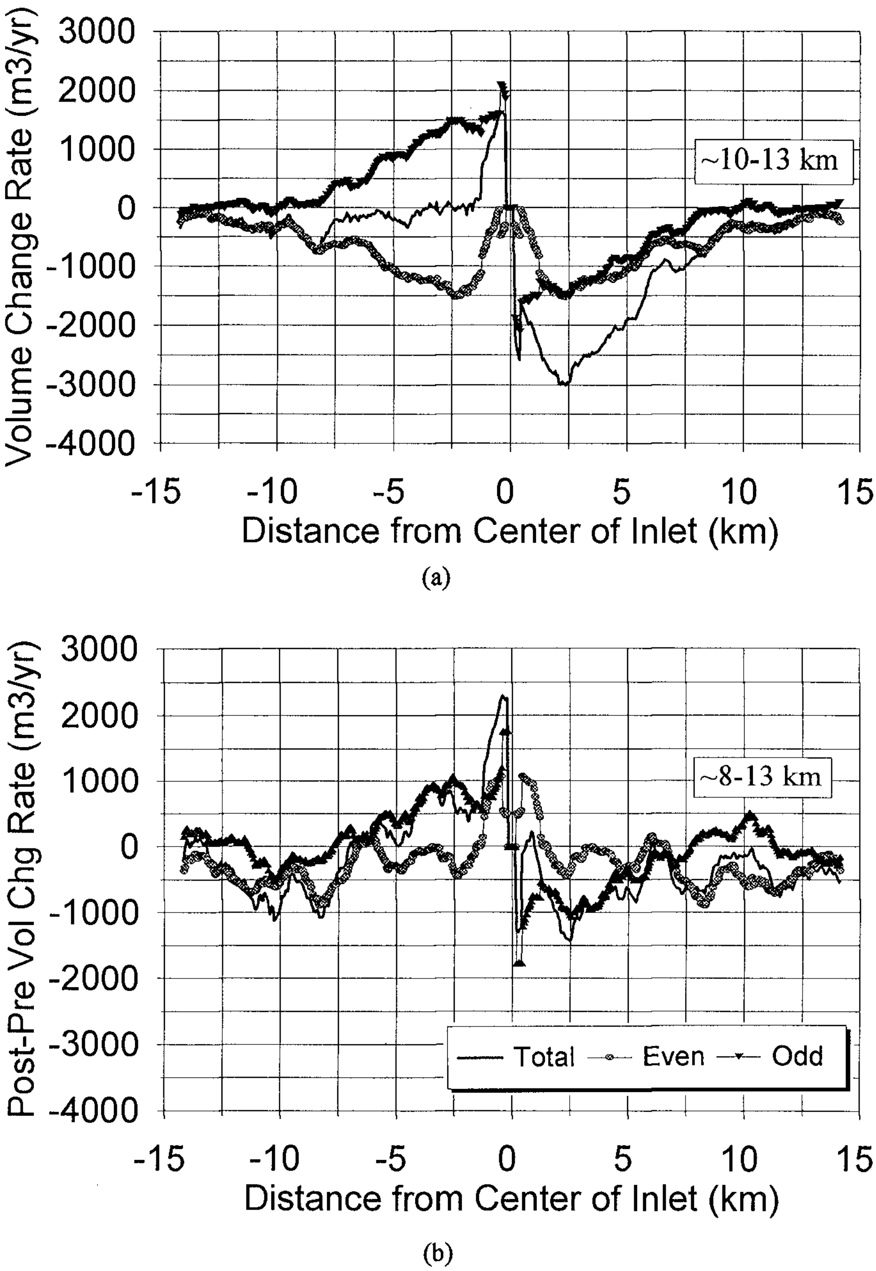

Figure 2. Total volumetric change, even, and odd functions for (a) post-inlet volume change rates (1929/33-1996); and post-inlet minus pre-inlet (1850-1929/33) volume change rates

accretion that has occurred as a result of inlet stabilization and the groin field along Fenwick Island. It is interesting to note the erosional peak in the post-inlet volume change rate ("total" curve in Figure 2a) at approximately 8 km updrift of the inlet, which agrees in concept with a longshore sediment transport nodal point in the vicinity of York Beach, Delaware (approximately 18 km north of the inlet), with a variation of 10 km (Mann and Dalrymple 1986). For Assateague Island, except for a peak in the total adjusted volume change curve at approximately 1 km (Figure 2b), the entire shoreline response has been erosional. The peak at approximately 1 km in Figures 2a and b agrees well with the presently-observed bridging of the ebb tidal shoal to the downdrift beach. The "odd" function indicated in Figures 2a and b illustrates the strong alongshore impact that the inlet and Fenwick Island groin field have incurred on the adjacent beaches. This function returns to a zero value approximately 10 km from the inlet in Figure 2a, and at approximately 8 km in Figure 2b. The "even" function in Figure 2a returns to a near-constant value at approximately 13 km from the inlet, and approaches a constant value in this region for Figure 2b. If Figure 2a were taken to represent the inlet's impact (i.e., no background erosion existed from 1933 to 1996), then the alongshore impact distance would be interpreted as between 10 and 13 km. However, we have evidence that background erosion has occurred during the post-inlet time period. Thus, considering both the even and odd functions, **the alongshore impact distance of the inlet (and Fenwick Island groin field) is estimated to be between 8 and 13 km from the centerline of the inlet.**

3.3 Alongshore Impact: Net Sink Effect

Overview. A second method of determining alongshore impact distance is discussed by Bodge (in preparation). This method calculates the alongshore variation in total volume change, and determines the alongshore distance for which the total inlet sink volume can be accounted. Alongshore impact distance as determined through application of this method is very sensitive to the total sink volume estimate, due to the fact that the alongshore volume changes due to the inlet will decrease with distance from the inlet.

Pre- and Post-Inlet Volumetric Change. Shoreline change from August/September 1850 to November 1929/May 1933 indicated that the pre-inlet Fenwick-Assateague barrier island in the region $\pm$ 7 km from the centerline of the existing inlet was in an erosive state (Figure 3a). The island (ocean and bay) cumulative volume change rate for what would become Fenwick Island (extending 14.2 km north of the inlet location) was -42,500 m^3/yr during this time period (independent of bay active depth; the bay shoreline change rate was approximately zero during this period, see Table 1). The cumulative island pre-inlet volume change for 14.2 km of Assateague Island ranged between -137,700 and -59,300 m^3/yr, depending on bay active depth.

In the post-inlet (November 1929/May 1933 through March 1995/May 1996) time period, Fenwick Island stabilized with cumulative island volumetric change rates ranging from -16,500 to +4,400 m^3/yr, depending on bay active depth. However, cumulative

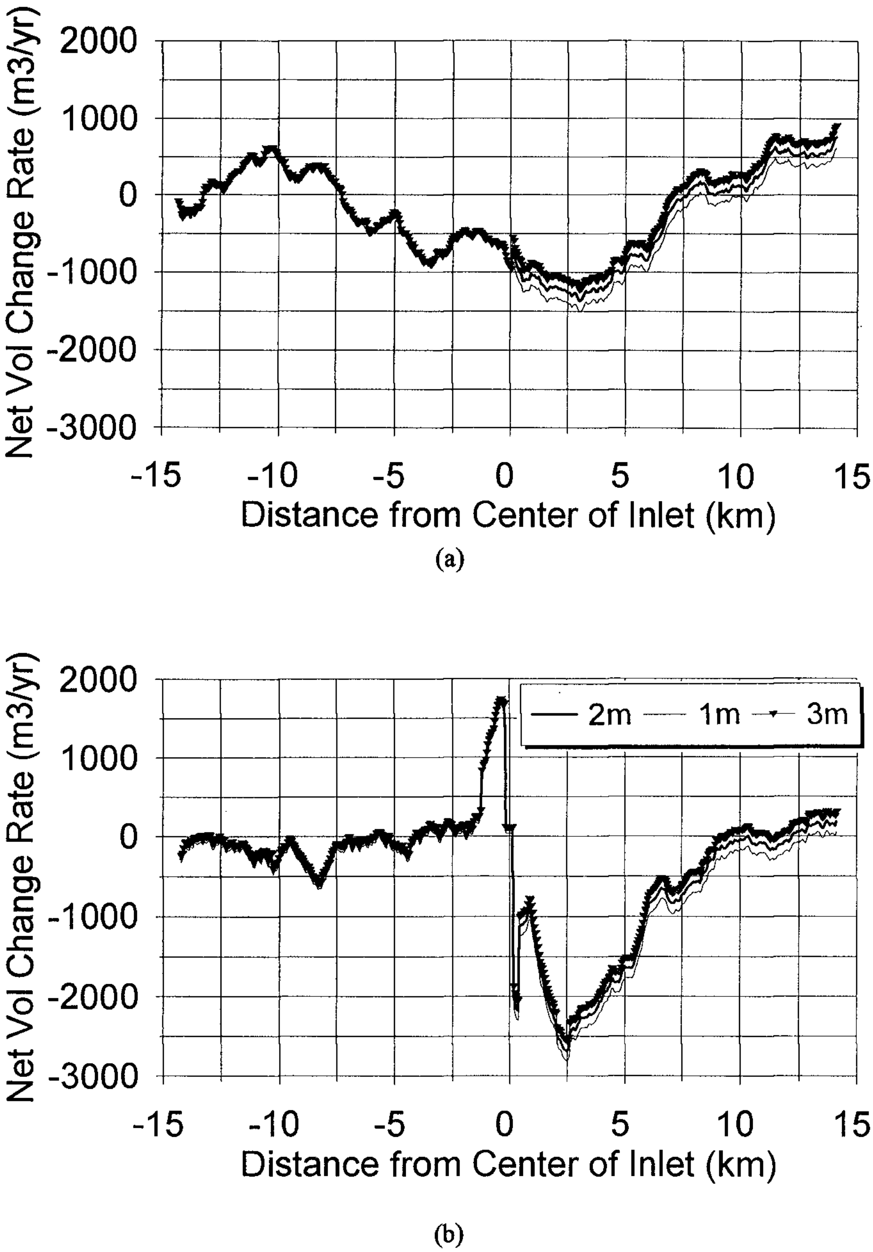

Figure 3. (a) Pre-inlet (1850-1929/33) and (b) post- inlet (1929/33-1996) island (bay and ocean) volumetric change rates as a function of bay active depth (1, 2, or 3 m)

volumetric erosion rates along Assateague Island increased, ranging from -293,000 to -224,000 m^3/yr depending on bay active depth (Figure 3b). The first four columns of Table 3 summarize these results.

Table 3. Pre- and Post-Inlet Net Island Volume Change for 14.2 km Up- and Downdrift of Ocean City Inlet

Island	Bay Active Depth (m)	Net Island[1] Volume Change Rate (m^3/yr)		Present-Day Normalized[2] Cumulative Volume (million m^3)
		Pre-Inlet (1850-1933)	Post-Inlet (1933-1996)	
Fenwick	1	-42,500	-16,500	+1.6
	2	-42,500	-6,000	+2.3
	3	-42,500	+4,400	+3.0
Assateague	1	-137,700	-293,000	-9.8
	2	-98,500	-259,000	-10.1
	3	-59,300	-224,000	-10.4

[1] Net ocean and bay volume change.
[2] Post-inlet minus pre-inlet rate multiplied by the number of years since inlet creation (1996-1933=63 years).

Present-Day Impact Accounting for Background Erosion. The fifth column of Table 3 presents the cumulative volume change, accounting for "background erosion" which was defined by the pre-inlet condition, at $\pm$14.2 km of the inlet. The degree to which the bay active depth assumption influences magnitudes of cumulative impact can be evaluated from these data. For Fenwick Island, the bay active depth assumption can alter the normalized cumulative volume by nearly a factor of two. For Assateague Island, ocean volumetric change dominates the volumetric impact and the influence of bay active depth is less significant.

Summing the Fenwick and Assateague Islands cumulative volumes for a given bay active depth gives ***total adjacent beach impact volumes*** which vary at most by 10-percent as a function of bay active depth (-8.2, -7.8, and -7.4 million m^3 for 1, 2, and 3 m bay active depth, respectively). Note that only 0.9 million m^3 of dredged material is documented as being placed on Assateague Island, whereas between 2.7 and 3.5 million m^3 were dredged. If it is assumed that this entire dredged volume was placed on Assateague Island (as has been standard practice), and (to be conservative) that this entire volume moved alongshore or was lost to the profile and is not reflected in the shoreline data, then an additional loss of 1.8 to 2.6 million m^3 can be assigned to the adjacent island losses. Using the upper value of 2.6 million m^3, it can be concluded that the volumetric impact of Ocean City Inlet realized on adjacent ocean and bay shores within 14.2 km from the inlet, is *at most* 10.8 million m^3. This estimate approaches the minimum total inlet sink volume, which was estimated to range from 10.8 to 15.6 million m^3. (However, note that the 10.8 million m^3 adjacent island loss was developed with the *upper* dredge volume estimate, whereas the 10.8 million m^3 sink volume was developed with the *lower* dredge volume estimate.) Thus, with a pre-existing background erosion rate which is defined by the pre-inlet condition, it is likely that the inlet's influence exceeds the available data limit (14.2 km).

4.0 SUMMARY AND CONCLUSIONS

A database representing 146 years of beach response in the vicinity of Ocean City Inlet, Maryland, was created to reflect adjacent beach, bay, and inlet volume change. Analyses were conducted to evaluate the total sink volume of the inlet, and the alongshore distance associated with this volumetric impact. The total inlet sink, defined as the volume captured by the inlet which can be attributed to the adjacent ocean and bay shorelines, was estimated to range between 10.8 and 15.6 million m^3. The even/odd method was applied to ocean shoreline change (adjusted by a background erosion rate) since inlet formation, and indicated an alongshore impact distance (which includes the effects of the Fenwick Island groin field) of approximately 8 km from the centerline of the inlet. The inlet sink analysis, assuming that pre-inlet trends continued through the present, indicated, *at most*, that 10.8 million m^3 can be realized along 14.2-km of up- and downdrift ocean and bay shorelines. This analysis indicated that the alongshore impact distance most likely exceeds the available data limit ($\pm$14.2 km from the centerline of the inlet).

5.0 ACKNOWLEDGEMENTS

The research discussed herein was partially supported by the *Inlet Channels and Shorelines* work unit of the Coastal Inlets Research Program, Coastal and Hydraulics Laboratory, Waterways Experiment Station, US Army Corps of Engineers (USACE), and by the *Ocean City Water Resources Study* funded by the USACE District, Baltimore. Permission to publish this paper was granted by the Chief of Engineers. Thanks to reviewers Mark B. Gravens and Nicholas C. Kraus.

6.0 REFERENCES

Bodge, K. R. 1996 (in preparation). "Sediment Management at Inlets/Harbors," draft Coastal Engineering Manual Chapter V-6, USACE Waterways Experiment Station, Coastal and Hydraulics Laboratory, Vicksburg, MS (draft dated August 21, 1996).

Dean, R. G., and Perlin, M. 1977. "Coastal Engineering Study of Ocean City Inlet, Maryland," *Proceedings*, Coastal Sediments '77, American Society of Civil Engineers, pp. 520-540.

Dean, R. G., Perlin, M., and Dally, W. 1978. (March). "A Coastal Engineering Study of Shoaling in Ocean City Inlet," prepared for USAED, Baltimore, under contract with the University of Delaware, Newark, DE, 135 p.

Dean, R. G., and Work, P. A. 1993. "Interaction of Navigational Entrances with Adjacent Shorelines," ***Journal of Coastal Research***, Vol 18, p. 91-110.

Hicks, D. M., and Hume, T. M. 1995. "Morphology and Size of Ebb Tidal Deltas at Natural Inlets on Open-sea and Pocket-bay Coasts, North Island, New Zealand," *Journal of Coastal Research*, Vol 12(1), pp 47-63.

Mann, D. W., and Dalrymple, R. A. 1986. "A Quantitative Approach to Delaware's Nodal Point," ***Shore and Beach***, Vol 54, No. 2, pp 13-16.

Marine Board. 1987. "Responding to Changes in Sea Level: Engineering Implications," National Academy Press, Washington, D.C.

Pelnard-Considere, R. 1956. "Essai de theorie de l'evolution des formes de rivage en plages de sable et de galets," *4th Journees de l'Hydraulique: Les Energies de la Mer*, Question III, No. 1, pp. 289-300.

Stauble, D. K., Garcia, A. W., Kraus, N. C., Grosskopf, W. G., and Bass, G. P. 1993. "Beach Nourishment Project Response and Design Evaluation: Ocean City, Maryland, Report 1, 1988-1992," Technical Report CERC-93-13, USAE Waterways Experiment Station, Vicksburg, MS 39180-6199.

Underwood, S. G., and Hiland, M. W. 1995. "Historical Development of Ocean City Inlet Ebb Shoal and its Effect on Northern Assateague Island," final draft report prepared for the USACE Waterways Experiment Station under Work Order No. DACA39-92-M-198 and the US Department of the Interior, National Park Service under Inter-agency agreement IA4000-1-0022.