

Oceanfront Shoreline Change

Digitized historic oceanfront shoreline positions between 1973 and 2001 are depicted on Figures 11 through 13. Shoreline changes were measured along the 37 transects established (Fig. 2) on the digitized historic aerial photographs of Bogue Banks and Bear Island (Hammocks Beach). The average changes recorded for transects along the Bogue Banks oceanfront are depicted by Figure 16 and Figures 7-13, Appendix. Comparable oceanfront average shoreline changes recorded for the Bear Island oceanfront are depicted in Figure 17 and Figures 7-13, Appendix. Figures 5 and 6 in the Appendix also illustrate shoreline changes for the oceanfront segments most influenced by the inlet. The average shoreline changes recorded for the various time periods between 1973 and 2001 for both oceanfront shoreline segments are illustrated by Figures 7-13 in the Appendix.

Inspection of Figure 14 illustrates that there were dramatic net differences in the shoreline change patterns along the Bogue Banks and Bear Island (Hammocks Beach) oceanfront between 1973 and 2001. Significant net coastwise accretion (Fig. 14) has occurred along the Bogue Banks shoreline (Figs. 14 and 15 and Figs. 5 and 13, Appendix). The average progradation along this oceanfront shoreline segment (transects 1-14) ranged from 56 to 410 ft. The greatest shoreline accretion occurred along the oceanfront near the inlet between transects 10-13 (Fig. 15) and reached a maximum of 410 ft at transect 12 (Fig. 5 in the Appendix). The net progradation of the entire Bogue Banks shoreline and is directly attributable to the eastward movement of the ebb channel over the past several decades (Fig. 18).

In contrast to the net accretion recorded along Bogue Banks, chronic erosion has been the norm along the Bear Island oceanfront since 1973 (Fig 14 and 16 and Fig 6 in the Appendix). Net erosion ranged from 68 ft (at transect 37) to 531 ft (at transect 25). In general the net erosion increased toward the inlet and reached its maximum along the northeastern-most portion (transect 25) of the Bear Island spit (Fig. 14). The shoreline recession at the barrier segment (transect 32-37), west of the point of spit attachment (in vicinity of transect 31), ranged from 68 to 149 ft (Fig. 14). In contrast the net average shoreline erosion along the reach between transects

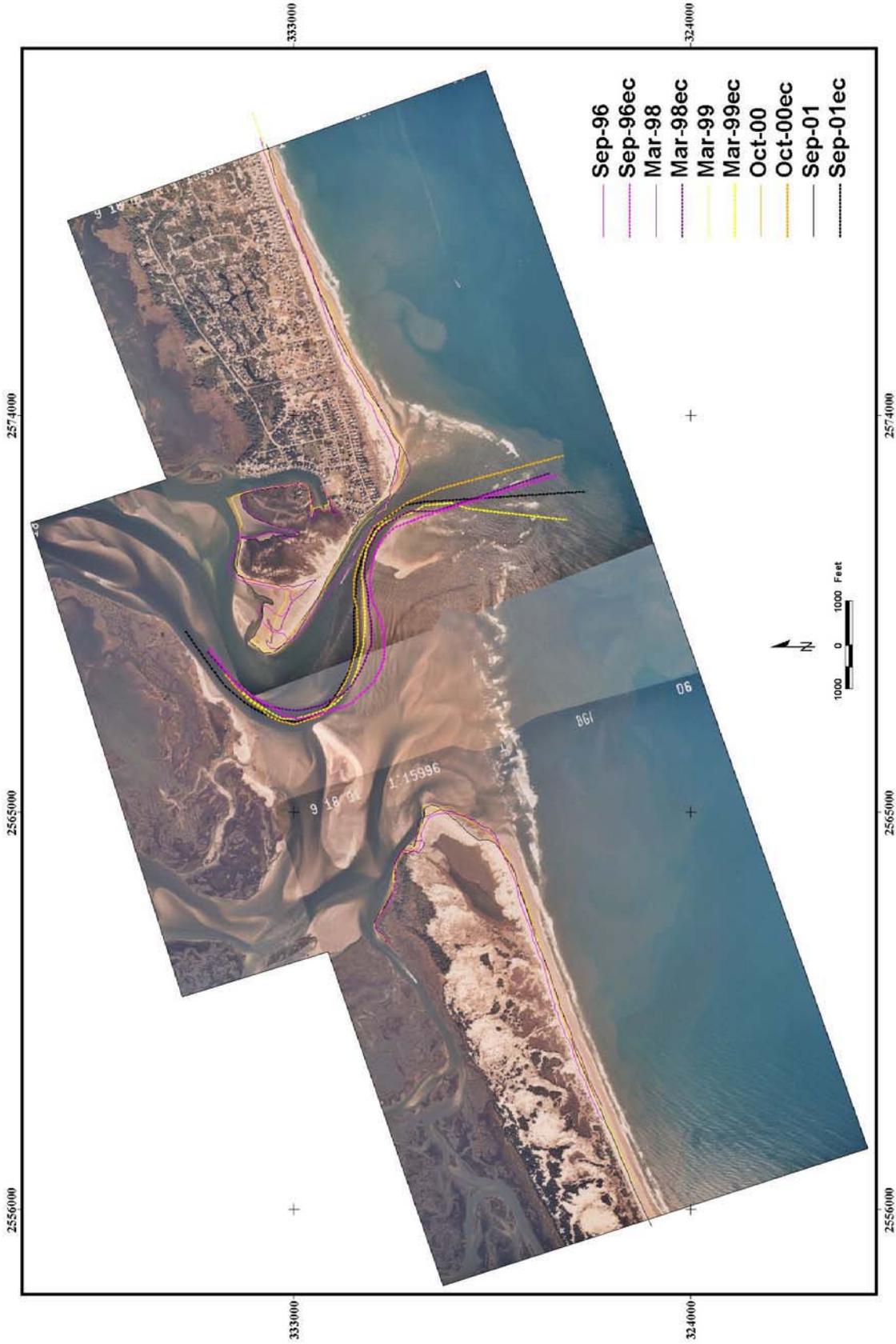


Figure 14. Aerial photograph mosaic (9/18/01) showing ebb channel and shoreline positions between September 1996 and September 2001. Note the complex eastward shift and reorientation of the ebb channel within the mid inlet shoal. The northwestern shift in the channel toward Dudley Island marsh complex is related to spit encroachment on the margin of East Channel (main feeder channel). Note the changing orientation of the outer bar channel.

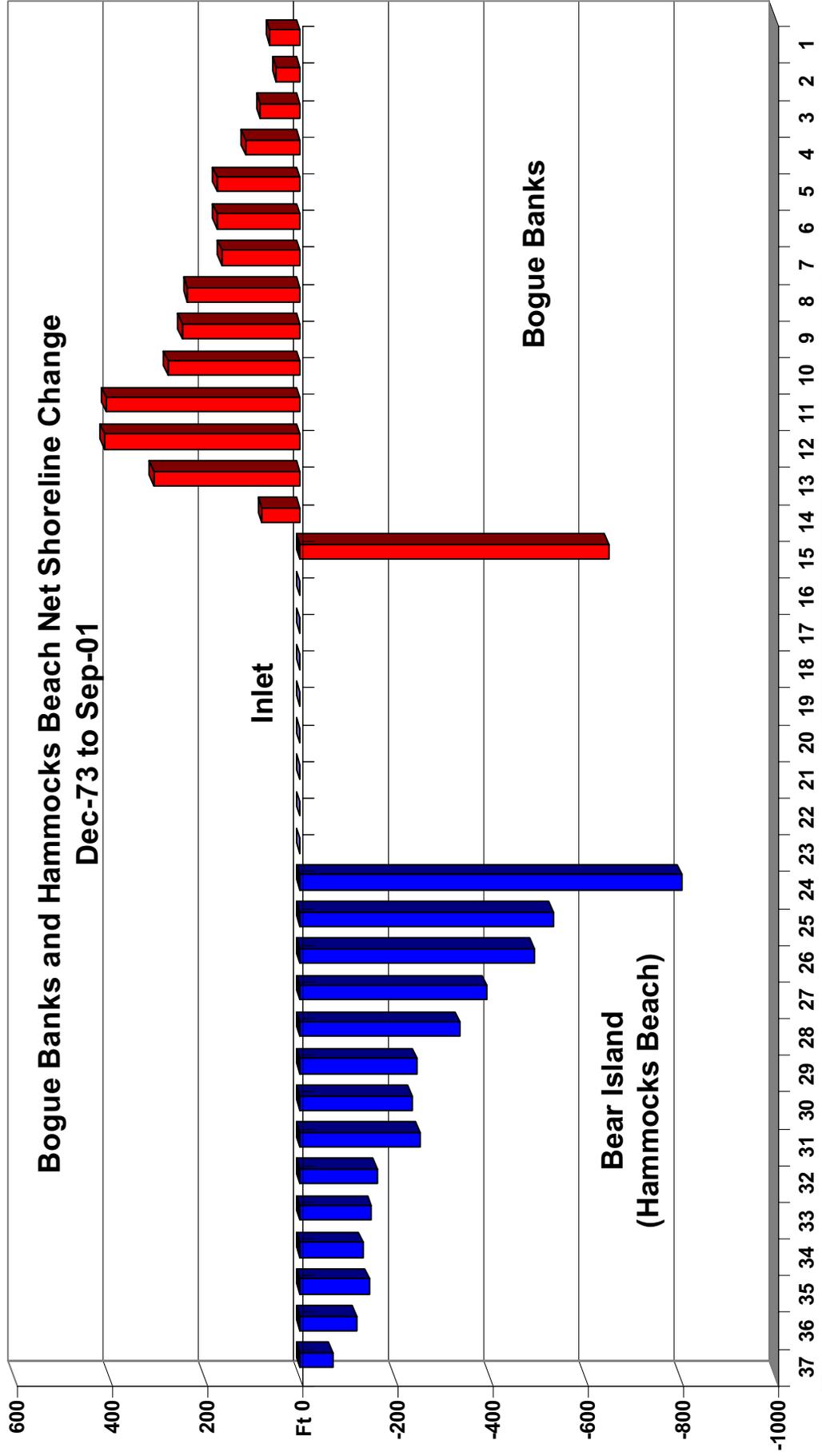


Figure 15. Graph depicting the net shoreline change along Bogue Banks and Bear Island (Hammocks Beach) oceanfront between 1973 and 2001. A contrasting pattern of change characterizes Bogue Banks (Transects 1-14) and Bear Island (Transects 25 - 37).

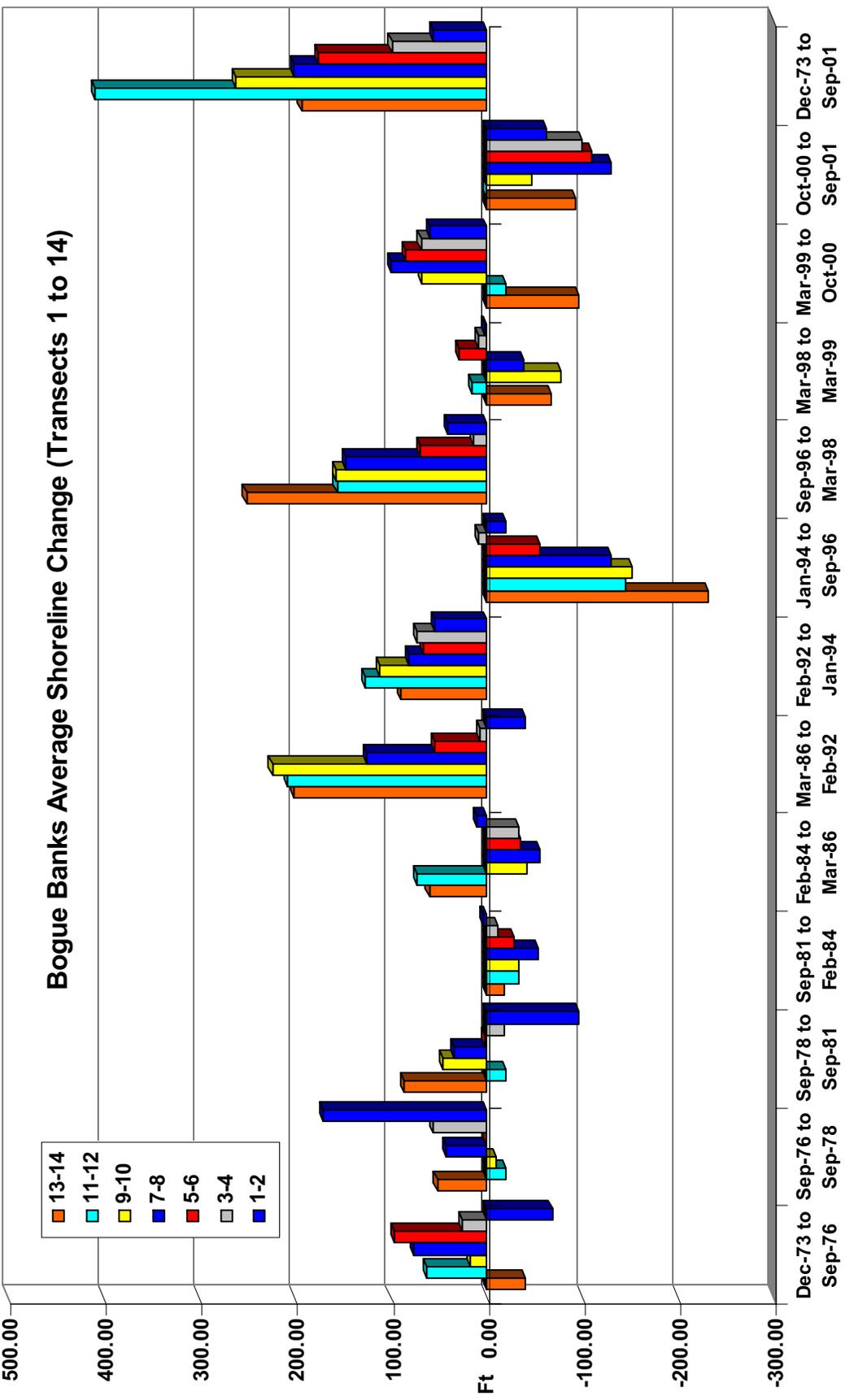


Figure 16. Graph depicting average shoreline changes along the Bogue Banks oceanfront. Shoreline change values for 1,000 feet long reaches are represented. Compare with Figure 17.

25 and 27, on the eastern margin of the spit, was considerably higher and ranged from 363 - 510ft (Fig. 14). The maximum shoreline erosion recorded occurred at transect 25 adjacent to the inlet (530ft) while the minimum net shoreline loss was recorded for transect 37 at the western boundary of the study area. The aforementioned relatively high values of shoreline recession along the spit reflect the negative influence of the easterly migration of Bogue Inlet (Fig. 18). It is interesting to note that the cumulative (average) erosion that occurred along the Bear Island oceanfront since 1973 is approximately equal to the net shoreline accretion along the Bogue Banks oceanfront (Fig. 18). A comparison of the average shoreline changes for both oceanfront segments and the shoreline reaches most influenced by the inlet (transects 7-14 and 25-32) reveal some complex and shoreline change patterns that are linked to the changes within the inlet shoal system (Figs. 15 and 16 and Figs. 7-13, Appendix). These temporal and spatial relationships are fully addressed in a following section.

Oceanfront change rates

Table 1 lists the average change rates for the oceanfront segments most influenced by the inlet (transects 7-14 and 26 -32). Between 1973 and 2001 the Bogue Banks average oceanfront erosion rates for the various time periods ranged from ~1.0ft/yr (2/84 - 3/86) to 64ft/yr (10/00 - 9/01). Some of the higher erosion rates recorded were related to the impact of storms such as Hurricanes Fran and Bonnie in 1996 and 1998 (Fig. 19). The average accretion rates ranged from 2.0ft/yr (9/76 -9/78) to 111ft/yr (9/96-3/99). The later value characterized a period of shoreline recovery following Hurricane Fran (9/96). The average net change rate for the Bogue Banks oceanfront was 10.6ft/yr (1973-2001). This accretion rate reflects the positive influence of the inlet on the Bogue Banks oceanfront as it migrated in an eastward direction (Fig. 19).

The average change rates for the Bear Island oceanfront between transects 26-32 also showed a wide range of values for the period 1973-2001. Average erosion rates ranged from 7ft/yr (9/78-9/81) to 66ft/yr (1/94 - 9/96). The highest erosion rate recorded reflected the impact of Hurricane Fran (9/96) while the highest accretion rate (44 ft/yr) reflected the subsequent shoreline recovery (9/96 -3/94) following the storm event (Fig. 19). The minimum accretion rate of 3.0 ft/yr was

	Bogue Avg Ocn Er Rate	Bear Is Ocn Er Rate	Chnl MP Migr Rate
Dec-73 to Sep-76	15.8	18	560
Sep-76 to Sep-78	2.2	-35	125
Sep-78 to Sep-81	9	-6.7	34
Sep-81 to Feb-84	-17.5	-13	-1040
Feb-84 to Mar-86	-0.86	8	-100
Mar-86 to Feb-92	32	-9.5	-61
Feb-92 to Jan-94	61	-43	-158
Jan-94 to Sep-96	-57	-66	-101
Sep-96 to Mar-98	111	44	-150
Mar-98 to Mar-99	-28.7	10	-49
Mar-99 to Oct-00	17	3	-53
Oct-00 to Sep-01	-64	-10	10
Dec-73 to Sep-01	10.6	-11	-76

Table 1. Bogue Banks and Bear Island Oceanfront Average Change Rates (Transects 7 - 14 and 26 - 32) and ebb channel mid point change rates.

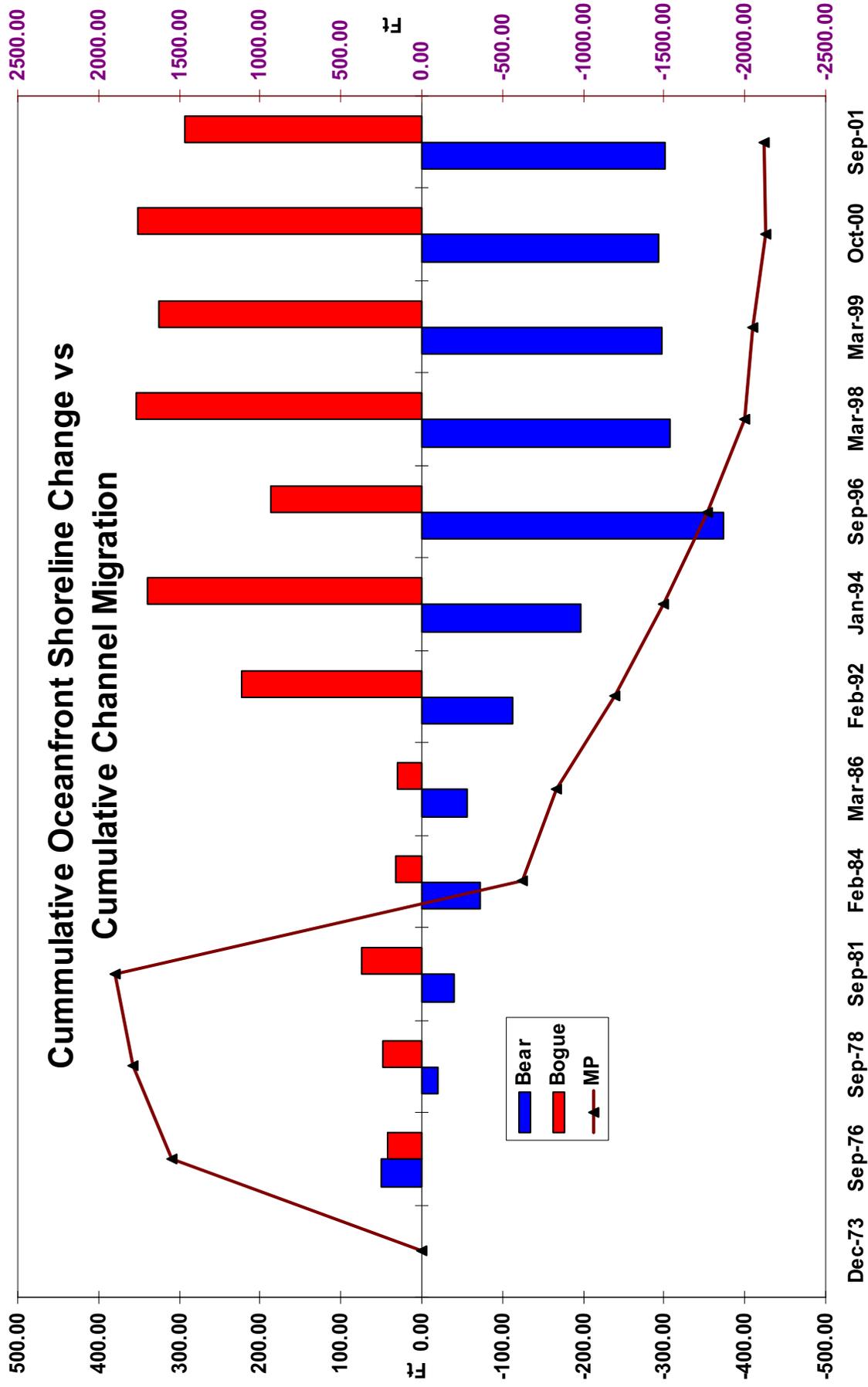


Figure 18. Graph comparing Bogue Banks and Bear island (Hammocks Beach) cumulative oceanfront shoreline (inlet influenced reach) and ebb channel mid point changes. Repositioning of the ebb channel to shore-normal (mid throat position) favored progradation on both shorelines (shoulders). Since the mid 1980s net accretion has characterized the Bogue Banks shoreline while erosion has occurred along Bear Island.

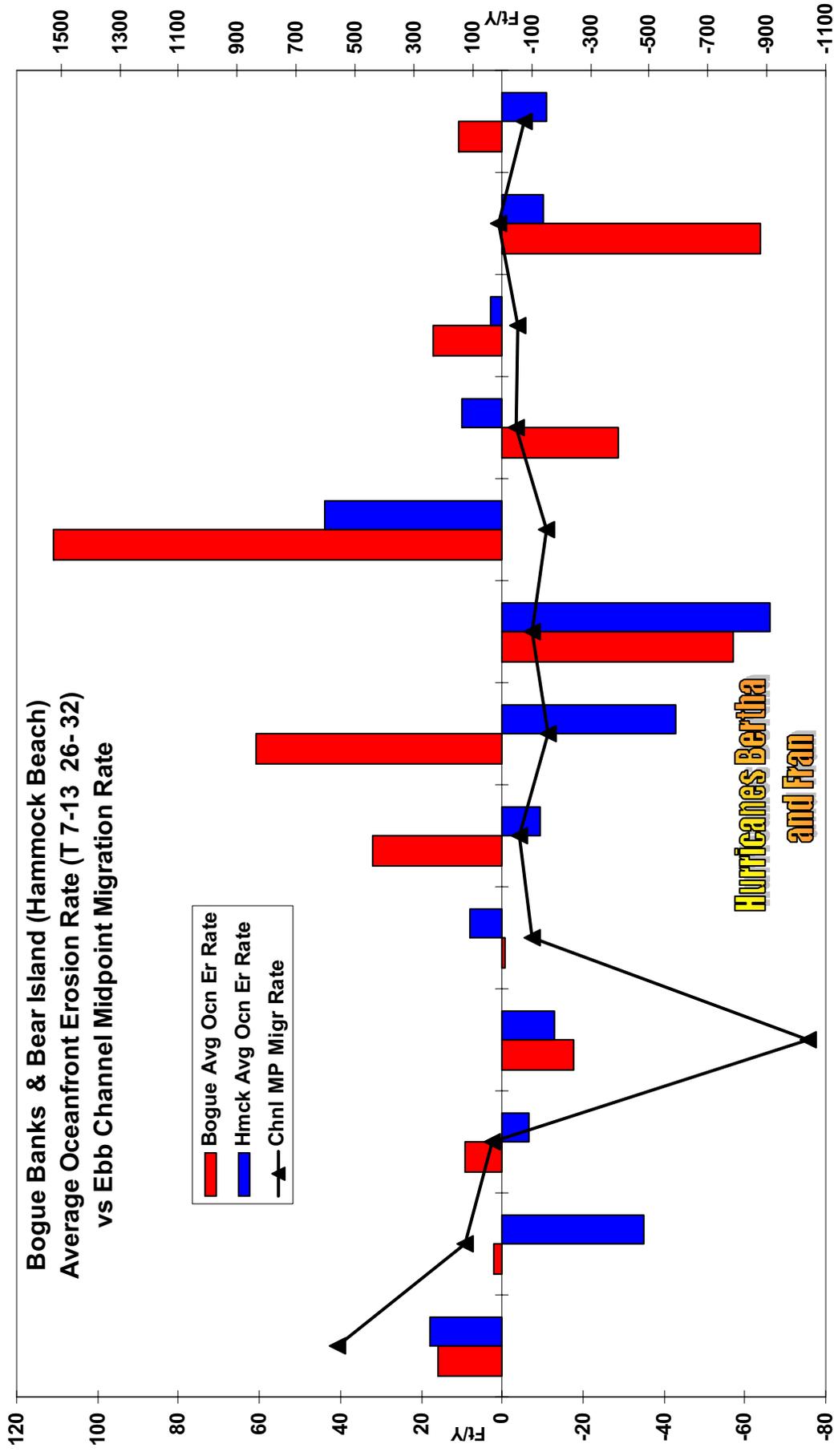
recorded for the interval October 2000 to September 2001. The average net change (erosion) for the Bear Island oceanfront (transects 7-14) since 1973 was -11 ft/yr, reflecting the negative influence of the inlet as it tracked toward Bogue Banks.

Impact of Ebb-Tidal Delta Changes on the Oceanfront

The size (surface area) and shape of the ebb-tidal delta have changed considerably since 1973 (Fig. 2, Appendix). Figure 14 (Appendix) which illustrates the changes in the surface area of the ebb delta since 1973, shows the surface area ranged from a maximum of ~ 29 million sq ft in 1973 to a minimum of 18 million sq ft in 1991. The wide range of values may reflect errors involved in the methodology, but the data do provide a means of assessing the relationship of ebb delta shape changes, the evolution of the inlet morphology and the various shoreline changes. The apparent surface area changes can be correlated with the three basic phases of the evolution of the inlet morphology that can be recognized upon inspection of historic aerial photographs (Figs. 5 - 8). The initial phase (1973 to 1981) was one of general instability characterized by a period of channel reorientation related to shoal breaching, an initial period of westward channel migration and the formation of a single ebb channel. The areal extent of the ebb shoals during this phase was initially high and steadily declined until the early 1980s.

The second phase of inlet evolution in the 1980s was characterized by an eastward migration of the ebb channel, development of a wide marginal flood channel on the western margin of the inlet (Bear Island) and growth of the mid inlet shoal. The surface area of the ebb delta during this interim stage of morphologic development was generally low (~ 19 million sq ft). Since the late 1980s until 2001 the apparent surface area of the ebb delta has generally increased as the ebb channel continued to migrate toward Bogue Banks. The morphology of the platform and the mid inlet shoal have changed little during this interval (Figs. 6-8).

The eastward trek of the ebb channel over the past two decades coupled with the alignment of the channel along the Bogue Banks margin have resulted in the development of a highly skewed ebb delta whose seaward most protrusion has shifted $\sim 2,500$ ft in an eastward



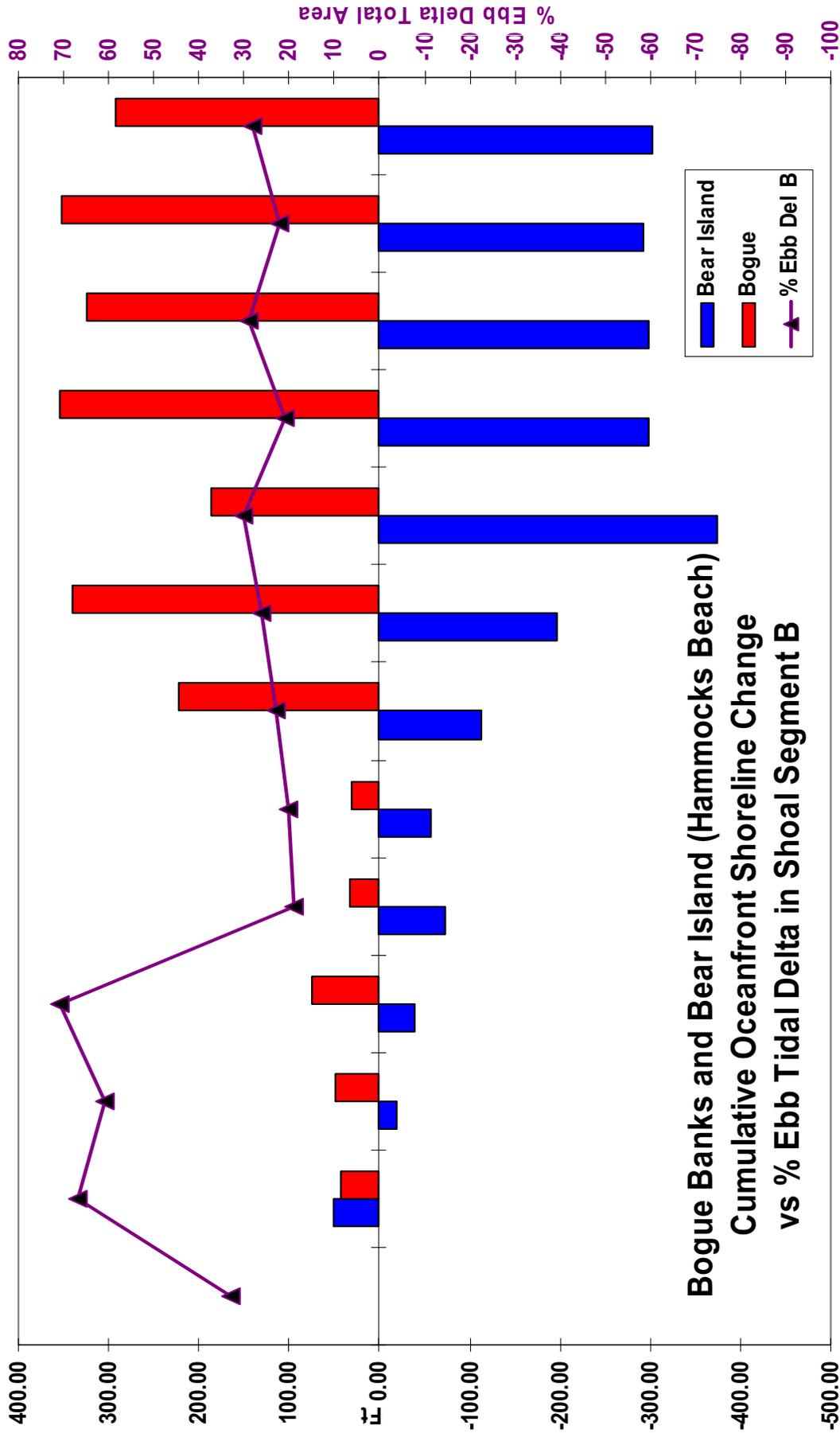
Dec-73 to Sep-76 to Sep-78 to Sep-81 to Feb-84 to Mar-86 to Feb-92 to Jan-94 to Sep-96 to Jan-99 to Mar-99 to Oct-00 to Dec-73 to Sep-76 Sep-78 Sep-81 Feb-84 Mar-86 Feb-92 Jan-94 Sep-96 Mar-99 Oct-00 Sep-01 Sep-01

Figure 19. Graph comparing Bogue Banks and Bear Island (Hammocks Beach) average oceanfront erosion rates (Transects 7-13 and 26-32 reaches) and ebb channel mid point migration rate. Note impact of 1996 hurricanes and subsequent shoreline recovery.

direction since 1978 (Fig. 2, Appendix). Figure 20 illustrates that since the mid 1980s, the percentage of the surface area of Bogue Banks' ebb delta segment ("B") has fluctuated between 19-30% of the total area of the entire offshore shoal (outer bar [ebb-tidal delta]). Incremental changes in the Bogue Banks shoal segment areal extent involved gains or losses that ranged from < -0.05 to ~2.2 million sq ft (Fig. 15, Appendix).

A slight shift in the orientation of the axis of the outer bar channel (ebb channel) generally causes a minor shift in the position of the apex of the ebb tidal delta (Fig. 2, Appendix and Figs. 6 - 8). The slight shift in an east or west direction controls the erosion or accretion along the extreme western oceanfront reach of Bogue Banks. The short-term shoreline change pattern is a function of the development of a secondary marginal flood channel on eastern margin of the main ebb channel. An eastward shift in the axis of the ebb channel resulted in the encroachment of the marginal flood channel on the Bogue Banks margin and the eventual erosion of the oceanfront (Fig.14). The continued eastward migration of the ebb channel and the associated development of the asymmetrically shaped ebb –tidal delta since the mid 1980s had a long-term positive influence on the net progradation along a 7,500 ft long oceanfront reach on Bogue Banks.

In contrast to the chronic erosion along the inlet shoreline, the Bogue Banks oceanfront continued to build seaward as the ebb channel migrated to the east (Fig. 18). The net oceanfront shoreline gains ranged from 63 ft (transect #1) to 410 ft at (transect # 12). The net gain for the shoreline reach most readily impacted by the inlet, (transects # 7 –13) prograded an average of 302 ft since 1973. The majority of this accretion has occurred since the early 1990s (Fig. 18 and Fig. 16, Appendix). The consequences of the easterly channel movement for the Bogue Banks oceanfront were twofold: first and foremost large swash bar complexes that formed on the eastern shoal segment, migrated landward, attached and nourished the immediate shoreline; secondly the highly asymmetric ebb-tidal delta afforded protection for the western end of the island from wave attack and simultaneously aided in the buildup of the western 7, 500 ft of Bogue Banks (Figs. 24 to 26). Wave refraction around the ebb delta, coupled with the presence of the linear margin bar/swash bar complex, that developed off the western end of the island



Dec-73 Sep-76 Sep-78 Sep-81 Feb-84 Mar-86 Feb-92 Jan-94 Sep-96 Mar-98 Mar-99 Oct-00 Sep-01

Figure 20. Graph depicting cumulative shoreline change along Bogue Banks and Bear Island (Hammocks Beach) and the percentage of the ebb tidal delta contained in the shoal segment B'fronting Bogue Banks.

(Figs. 8 A-D), produced a wedge shaped zone of accretion that developed at an average rate of 10.5ft/yr since 1986.

The eastward migration of the ebb channel and the attendant morphologic changes in the inlet system has not only controlled the shoreline change patterns along Bogue Banks, but concurrently they have played a significant role in the Bear Island oceanfront erosion (Fig. 18). The consequences of the complex morphological changes related to the easterly channel movement for the Bear Island oceanfront are the reverse of those for the Bogue Banks oceanfront. The data show there has been a net shoreline loss along the majority of the 7,500 long oceanfront. Shoreline losses ranged from 68 ft at the western margin of the study area to a maximum of 530 ft at transect 25 near the extreme eastern end of the island. Since 1973 the average net shoreline loss for the 3,000ft long section immediately west of the inlet is 308 ft. The greatest losses have occurred since the late 1980s when the ebb delta and the inlet throat began to assume their current morphologic identities. Figure 2 illustrates the ebb delta shape changes that have occurred since 1973. As ebb channel migration occurred, the entire offshore shoal complex was continuously being reconfigured along with the adjacent barrier shorelines as they responded to the changes in wave approach and sand supply.

The apex (seaward protuberance) of the ebb delta in 2001 was ~5,550 ft east of its 1976/78 position (Fig. 2, Appendix). The eastward shift of the bulge as previously mentioned is a by-product of the eastward migration of the ebb channel. The significant net morphologic changes that resulted from the channel's eastward migration were the widening of the inlet throat accompanied by the buildup of the mid inlet shoal as the western portion of the terminal lobe (zone of breaking waves) migrated landward. The complex interaction of the above variables combined to produce a reconfigured barrier that was increasingly exposed to increased wave activity and hence continued shoreline recession.

Dudley Island Shoreline Changes

The oceanfront along Bogue Banks and Bear Island are not the only areas to experience

shoreline erosion associated with the ebb channel and inlet configuration changes. The marsh and sandy shoreline segments that comprise the seaward portion of the Dudley Island complex also have been significantly impacted by configuration changes in the channel/shoal system (Figs. 21-23). Segments of this estuarine shoreline were subject to significant and rapid erosion. Figure 21 illustrates various shoreline positions (marsh scarp or w/d line on sandy shoreline segments) between 1973 and 2001. The complex pattern of shoreline change, which generally involved land loss along the this 6000ft wide complex, is primarily due to the eastward migration of the ebb channel, the attendant spit growth along the Bogue Banks shoulder and the consequent migration of the East Channel toward Dudley Island (Figs. 22-25). The complex pattern of movement of the ebb channel and its relationship to shoreline change along Dudley Island is apparent upon inspection of Figures 21 A-D – 23 A-D. The historic aerial photographs clearly show the above-mentioned relationship and the impact of the encroachment of the Bogue Banks upon the southern margin of East Channel. Elongation of the spit and the extension of its subaqueous platform had caused the thalweg of the large feeder channel to shift toward Dudley Island, resulting in erosion and overtopping of the landward bank.

Encroachment of the margin of East Channel on the eastern portion of the marsh complex has generally resulted in recession of the marsh shoreline (Fig. 24). With the exception of the shoreline buildup along transect 7 (+86 ft since 1973) erosion has been the norm along the 3000 ft wide eastern segment of Dudley Island. Erosion ranged from 18 ft (transect 5) to 500 ft (transect 3). The estuarine shoreline located immediately to the northwest of the Bogue Banks spit has eroded the greatest amount (288 –500 ft) since 1973 (Fig. 24). Erosion along the eastern marsh shoreline ultimately stemmed from the migration of East Channel as the spit platform extended into the eastern margin of the channel, resulting in deflection of the flow toward the Dudley Island shoreline. The majority of the marsh and sandy shoreline along the western portion of Dudley Island has also receded due to encroachment of various feeder channel segments. Generally the least amount of erosion and the greatest buildup occurred in the lee of the Island # 2 near the tip of the flood ramp (Figs. 21- 24).