**History of Islands # 1 and # 2**

Islands # 1 and # 2 represent extremely small sand accumulations located within the Mid Inlet Shoal complex. The islands are ephemeral in nature and of low relief (<2ft NGVD). Figures 5 B, 5F and 6A illustrate the ephemeral nature of these features. The transitory nature and recent evolution of Island # 2, the larger of the two islands, is documented by inspection of Figures 7 and 8 that show Island # 2 began to develop in 1995/96 along the western margin of the ebb channel. Since 1996 the feature has increased in size and extent (Fig. 8 A-D). The extremely shallow depths across the landward portion of the mid inlet shoal favored the development of Island # 2 through a combination of processes associated with breaking waves and the associated swash that partially or completely overtops the low relief island. Extreme wave action during elevated water levels will likely erode a portion or the entire feature. Although no measurements were made, it appears that the eastern margin of the feature is being eroded due to the westward migration of a portion of the ebb channel (Fig. 8 C – D).

Island # 1, located along the eastern seaward margin of the Mid Inlet Shoal, formed during the mid to late 1990s. This feature probably represents a series of complex sand bars that merged in late 2000 (Fig. 8A - D). The eastern portion of the feature appears to have developed along the channel margin linear bar that forms the western margin of the ebb channel. The growth and decay of this portion of the feature is imaged on Fig 8A –D. The initial stage of development of the western arm of Island # 1 is visible on the March 1999 aerial photograph (Fig. 8 B).

## Impact of Proposed Channel Relocation

During the conduct of a regional investigation of North Carolina's inlets in the mid 1990s Cleary and Marden (1999) predicted that a natural shoal breaching and realignment of the ebb channel would occur at Bogue Inlet. This prediction was based on the previous history of the inlet since the mid 19$^{th}$ C and the morphologic features imaged on the historic aerial photographs dating from the mid 1990s. As indicated in a subsequent in depth study of the inlet (CS & E,

2001), the breaching event did not occur primarily due to the impacts of subsequent hurricanes (1996-1999) and the vertical buildup of the mid inlet shoal complex. The proposed channel relocation effort would basically mimic the predicted natural breaching event that has occurred three to four times since the mid 1800s and twice since 1938 (~ 1955 and 1975). Data from the above-mentioned report (CS & E, 2001) suggests the presence of the inlet's expansive floodway, that is ten times the width of the ebb channel, favors a more hydraulically efficient location than currently exists. Historical information supports this contention.

The overall goal of the current investigation was to develop an understanding of the relationship between the inlet's temporal and spatial morphologic changes and the changes that occurred along the adjacent oceanfront segments since 1973. A secondary goal was to then utilize this understanding to better evaluate the impacts of the proposed channel relocation effort on the various components of the system. The detailed analysis of the historic changes that have taken place since 1973, clearly show that the movement of the ebb channel and the attendant ebb-tidal delta symmetry changes are the forcing variables that dictate the erosion and accretion trends along the inlet and oceanfront shorelines of both Bogue Banks and Bear Island. The erosion of the eastern inlet shoreline in the vicinity of the Pointe (Bogue Banks) and the concurrent progradation of the adjacent oceanfront, for a coastwise distance of 7,500 ft, are directly related to the eastward migration of the ebb channel. The data also indicate that the inlet and oceanfront erosion along adjacent Bear Island stem directly from the complex morphologic changes related to the eastward migration of the ebb channel and the associated shoal shape changes (Fig. 2, Appendix). The data, its derivatives (maps) and a simple visual inspection of the historic aerial photographs suggests there is a felicitous inlet (ebb channel) configuration that provides mutual benefits for both shoulders and oceanfront shoreline segments that flank the inlet. The proposed channel relocation site falls within this optimum zone (Fig. 26).

The discussion that follows provides information describing two different channel relocation scenarios. Both scenarios involve channel relocation to a shore-normal, mid-throat position. However the first scenario relies upon natural sediment transport processes to infill the existing ebb channel (Option #1, CS & E 2001) while the second scenario involves disposal of

dredge materials within a segment of the ebb channel in the vicinity of Island # 1. It is assumed that the newly relocated channel in each scenario is of sufficient dimensions to satisfy the tidal flow requirements of the inlet as described by CS & E (2001).

The location of the proposed channel lies along the approximate axial position of the ebb channel imaged on the 1978 aerial photograph used in the conduct of this investigation. Relocation of the ebb channel to this mid inlet location (Fig. 26) will alter the sediment transport patterns dramatically on both shoulders and ultimately result in the significant reconfiguration of the ebb tidal delta. After an initial period of adjustment, the apex of the ebb delta will eventually shift ~2,500-3,000ft in a westward direction. During this period of equilibration, which may last several years, a significant volume of the ebb-tidal flow will be redirected from the erosion hot spot along the eastern shoulder. During the time interval when the former ebb channel continues to remain a viable pathway for tidal flow, additional erosion (albeit at slower rates) may occur along the eastern inlet shoreline.

The gradual collapse of the ebb shoal segment (‘B”) fronting the Bogue Banks oceanfront will lead eventually to infilling and abandonment of the existing ebb channel along the eastern inlet margin. Concurrent with the reorganization of the eastern ebb delta segment; bar bypassing events will eventually promote spit growth on the eastern shoulder. Elongation of the estuarine portion of the existing Bogue Banks spit may continue and as a result further erosion of the Dudley Island shoreline will occur as the spit builds into the eastern feeder channel (Fig. 25). The eventual infilling of the seaward segment of the former ebb channel will lead to westward growth of the Bogue Banks oceanfront. Figure 2 in the Appendix, illustrates the 1978 and 2001 respective positions of the ebb channel, ebb tidal delta and the corresponding shorelines. Given sufficient time, the oceanfront shoreline along Bogue Banks will erode and recede to a position that is approximated by the location of the 1978 shoreline depicted on Figure 2. The amount of erosion is predicted to range from 20ft along the eastern end of the historic accretion zone to ~310 ft along the western extremity of the oceanfront.

The westward repositioning of the ebb channel and the associated reconfiguration of the

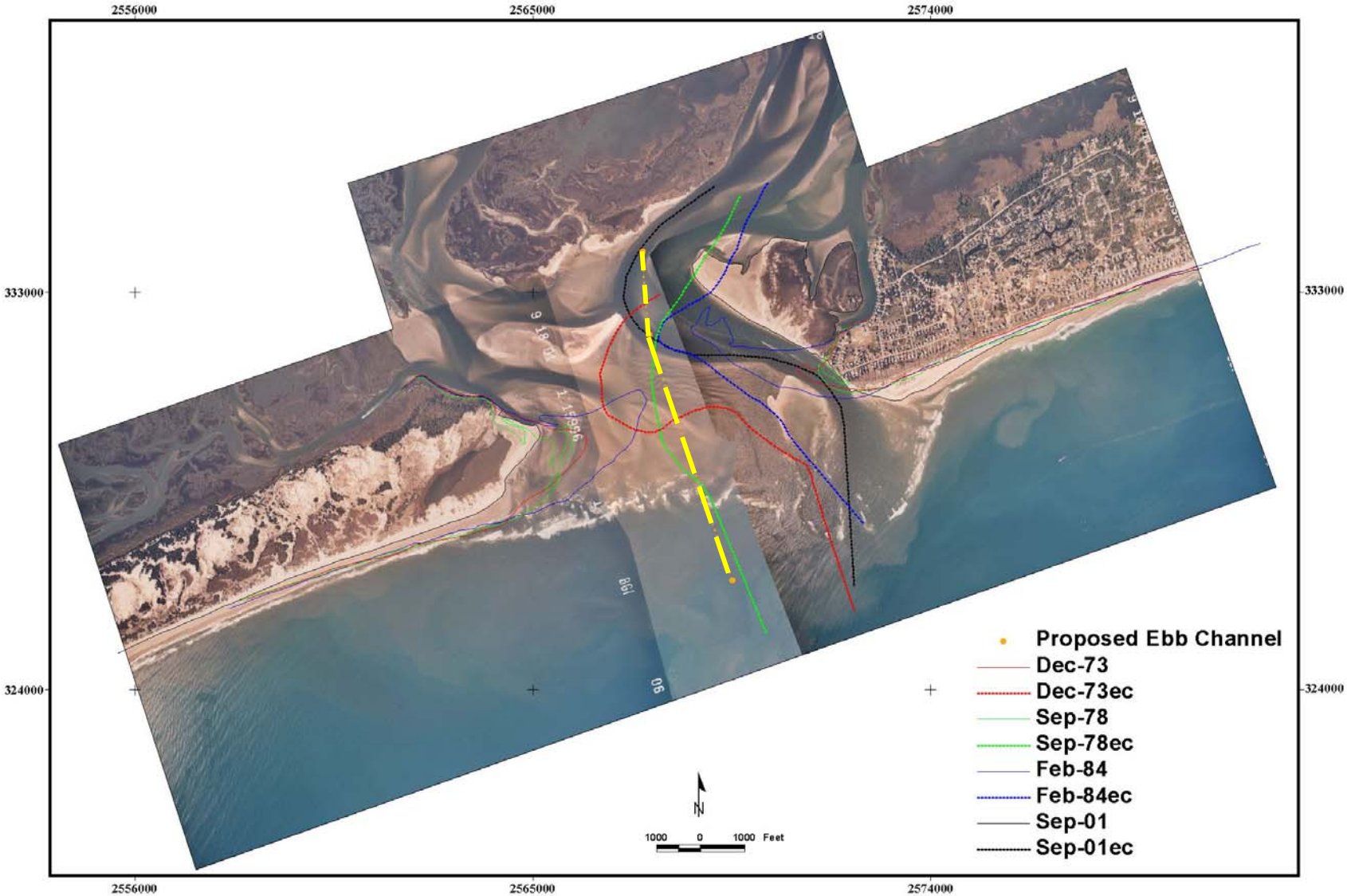


Figure 26. Aerial photograph mosaic (9/18/01) with historic shoreline and associated ebb channel positions. Note axis of the proposed relocated channel coincides with the 1978 ebb channel position. After an initial period of adjustment, the newly relocated channel will promote an inlet/oceanfront shoreline configuration similar to 1978 configuration.

ebb-tidal delta will have the opposite effect on the Bear Island shoulder. The movement of the ebb delta's apex farther to the west will probably lead to a seaward movement of the ebb delta's western segment outer margin (zone of breaking waves). This seaward extension of the platform will have a positive influence on the adjacent Bear Island oceanfront by altering the wave refraction patterns and ultimately leading to a reversal of the historic shoreline change trend. It is anticipated that oceanfront shoreline progradation will range from ~60 ft along the mid barrier portion of Bear Island to as much as 450 ft along the eastern extremity of the existing spit. It is likely the current extensive mid inlet shoal will erode as inlet reconfiguration tales place. A relatively wide marginal flood channel will probably develop that will separate the evolving ebb channel from the Bear Island inlet shoreline. As a consequence, eastward spit growth on the western shoulder of the inlet (Bear Island) will be very limited.

If design plans include plugging the existing ebb channel with dredge materials or involve a placement of a sheet pile structure of some sort, then the likelihood of additional erosion along the inlet shoulder in vicinity of the Pointe would be significantly reduced. A "plug" would forcibly redirect the ebb flow toward the new channel and aid in the demise and abandonment of the former ebb channel. The temporary cessation of ebb tidal flow within the channel would accelerate the reorganization and eventual collapse of the fronting ebb delta segment. The relatively rapid landward transport of the materials comprising the shoal segment would result in rapid spit growth on the Bogue Banks shoulder and infilling of the seaward portion of the former ebb channel. The aforementioned post-relocation scenario will also involve a significant transport of sand into the estuary through the marginal flood channel that will develop between the newly relocated ebb channel and the eastern shoulder. This evolving sediment transport pathway will continue to provide additional nourishment for the complex spit that currently is extending into East Channel. Erosion of the Dudley Island marsh will likely continue.

It is likely that neither scenario will have a direct negative impact on the integrity of Island # 2. Although the continued westward growth of the estuarine portion of the Bogue Banks spit may eventually lead to the deflection of the ebb channel and juxtaposition of the channel's

margin and the eastern portion of Island # 2. The erosion of the ephemeral island will likely occur with or without channel relocation.

## Overview and Summary

The primary focus of this investigation was the linkage between the movement of the ebb channel and the shoreline change patterns on the Bogue Banks (Emerald Isle) and Bear Island (Hammocks Beach) shorelines. Chronic erosion specifically in the vicinity of the Pointe is a result of a number of variables that act in concert to produce the complex shoreline change patterns. In an effort to support the restoration of a portion of the eroding oceanfront shoreline and to provide a long-term solution to inlet-related erosion, the Town has contracted to finalize the design of a recommended project involving the relocation of the main inlet channel.

During the past three decades the morphology of the inlet has changed substantially. Three distinct periods of change can be recognized, each with unique migration trends and morphologic characteristics. The initial phase covered the period between 1973 and 1981 when the ebb channel was moving to the west. The second stage of inlet evolution occurred between 1981 and ~1988 when the ebb channel migrated to the east and the marginal flood channel expanded dramatically on the western margin of the floodway. The expansion of the flood channel promoted the development of the large mid-inlet shoal. The third phase of morphologic development covers the period from 1988 to present. Since ~1988 the ebb channel has continued to migrate to the east and little significant change has occurred in the morphology of the inlet during this phase with the exception of the emergence of Islands # 1 and 2.

Although the three phases of morphologic development are recognized, the changes in the inlet system and their impact on the adjacent shorelines are presented for two distinct time intervals that reflect the direction of net movement of the ebb channel between 1973 and 2001. The first interval covers the period between 1973 and 1981 when the ebb channel was migrating to the west. The most significant event that occurred during this period was the breaching of the ebb shoals in 1975 that led to the repositioning and reorientation of the primary ebb channel. The net westward shift of the ebb channel during this portion of the inlet's history was 1,895 ft.

Migration rates were variable and ranged from 34 to 125 ft/yr. The most rapid rates characterized the interval between 1973 and 1976, a period characterized by instability following the breach of the ebb shoals. The apparent surface area of the ebb-tidal delta steadily decreased during this phase of westward migration from ~ 29 million $ft^2$ in 1973 to ~ 22 million $ft^2$ by 1981. During this period of instability the percentage of the surface area of the Bogue Banks ebb delta segment ("B") fluctuated from 33 % in 1973 to 71% in 1981.

During this period the shoreline changes along the shoulders of the inlet reflected the migration of the ebb channel and the expansion and constriction of the flood channels due to spit growth. Between 1973 and 1981 the inlet initially widened (1973 - 1978) and then narrowed (1978 - 1981) from 6,315 ft in 1973 to 5,714 ft in 1981. Between 1973 and 1978 the Bogue Banks margin eroded 509 ft and then subsequently prograded 390 ft by 1981. The net change during the period amounted to 119 ft of erosion. Accordingly erosion and accretion rates varied considerably from - 81 ft/yr to - 143 ft/yr (1973 - 78) to 150 ft/yr (1978 - 81). The Bear Island inlet shoreline changes are somewhat similar to those for the Bogue Banks, but the scale of change is significantly greater. The movement of the west shoulder follows a pattern of recession between 1973 and 1978 (-183 ft) and then rapid eastward progradation of 1,443ft by 1981. Due to the spit growth on the western margin of the inlet, net progradation amounted to ~1,260 ft.

The oceanfront changes along both barriers during the period 1973 to 1981 were highly variable. In general, the Bogue Banks oceanfront prograded during the period; shoreline accretion averaged ~ 75ft (cumulative change) along Transects 7-13. Oceanfront accretion rates varied from an average of 2.0 ft/yr for the period 1976 - 78 to ~16.0 ft/yr for the interval between 1973 and 1976. In contrast to the net buildup of the Bogue Banks oceanfront, the Bear Island shoreline was the site of chronic erosion. The barrier experienced an average net loss of 39 ft for the oceanfront segment between Transects 26 and 32. Oceanfront shoreline change rates from +18ft/yr for the period between 1973 and 1976 to –35 ft/yr for the interval 1976to 1978.

A reversal in the direction of channel migration occurred in the early 1980s. The data show the throat channel segment began its eastward trek in 1981/82. Between September 1981 and February 1984 the ebb channel migrated very rapidly to the east a distance of 2,514 ft at an annual rate of 1,040 ft/yr. Since 1984 the channel has shifted a net distance of ~1,500 ft to the east at an average rate of 155 ft/yr. Since 1998 the migration rates have decreased to ~30 ft/yr. The ebb channel was relatively stable between October 2000 and September 2001when it moved <10 ft in a westerly direction.

The major inlet shoreline changes that were recorded during the period 1981 to 2001 reflect the migration of the ebb channel in an easterly direction and the initial growth and subsequent erosion of the extending spits. Between September 1981 and February 1984 the Bogue Banks inlet shoreline accreted ~ 567 ft. The pattern of shoreline accretion was dramatically reversed during the period February 1984 to September 1994 when net shoreline losses amounted to 335 ft. The average rate of erosion during this period was ~ 34 ft/yr. A major episode of shoulder erosion occurred between January 1994 and September 1996 when the inlet shoreline retreated an additional 576 ft. During the subsequent two and one-half years (September 1996 to March 1999) the inlet shoreline prograded 108ft; and erosion again became the norm between March 1999 and September 2001 when the inlet shoreline retreated 161 ft. The net eastern shoulder erosion since 1981 was ~ 400 ft. Since 1973 the cumulative change along the Bogue Banks inlet margin has amounted to ~ 520 ft of erosion.

Significant changes also occurred along the western margin of the inlet as the ebb channel shifted to the east. The Bear Island spit elongated an additional 166 ft during the period between September 1981 and February 1984. With the exception of a brief interval between September 1996 and March 1998 the spit has continued to erode as the ebb channel has migrated to the east. A shift in the apex of the ebb delta to the east coupled with the expansion of the western marginal flood channel has resulted in ~ 2,190 ft of erosion of the spit between February 1984 and January 1994. The average rate of erosion during the decade was ~219 ft/yr and an additional 528 ft of erosion occurred between January 1994 and September 1996. Presumably a portion of the recession during the aforementioned period can be attributed to increased water

levels and wave activity associated with Hurricane Fran. A brief period of shoulder accretion (161 ft) occurred between September 1996 and March 1998. Between March 1998 and September 2001 the spit eroded an additional 415 ft. Since 1981 the net erosion of western shoulder was ~ 2,808 ft. Thereby evidencing that since 1973 the cumulative change along the Bear Island inlet margin has amounted to ~ 1,548 ft of erosion. During the initial phase of the channel's eastward migration, spit growth on the shoulders resulted in dramatic constriction of the throat; and by February 1984, the inlet's width had narrowed to 4,440 ft. Since the mid 1980s the inlet has generally expanded to its current maximum width of ~ 8,380 ft.

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 ~ 19 million $ft^2$. 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 the past decade.

The eastward trek of the ebb channel since 1981 coupled with the alignment of the channel along the eastern margin of the inlet have resulted in the development of an asymmetric ebb delta whose apex has shifted ~ 2,500 ft in an eastward direction. As a consequence, the smaller of the two segments ("A" and "B") that comprise the ebb delta has fronted the Bogue Banks oceanfront since the channel began its eastward trek. Since 1981, the percentage of the surface area of ebb delta segment "B" that fronted Bogue Banks has fluctuated between 19 - 30% of the total area of the ebb-tidal delta. The position of the ebb channel, coupled with the configuration of the ebb delta, has promoted dramatic shoreline changes along the oceanfront of both Bogue Banks and Bear Island. The combined configuration of the channel and the offshore shoal segment had a long-term positive influence on the net progradation along a 7,500 ft long shoreline segment. The net accretion for the shoreline segment between Transects 7 and 13 ranged from a minimum of 34 ft near the eastern margin of the reach to a maximum of 397 ft along the western portion of the Bogue Banks oceanfront. The average net accretion for the reach

was 219 ft. The average accretion rate for all transects within the reach for period 1981 - 2001 was 10.9 ft/yr. Rates ranged from 1.7 ft/yr to 19.85 ft/yr.

The eastward migration of the ebb channel and the attendant morphologic changes in the inlet continued to dictate the shoreline recession along the Bear Island oceanfront. The consequences of the complex 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 ft long oceanfront included in the study. The net erosion along the oceanfront between Transects 26 and 32 ranged from a minimum of 97 ft along the western portion of the reach to a maximum of 336 ft along the eastern extremity of the spit. The average net erosion along the entire reach was 262 ft. Average change rates varied from – 66 ft/yr for the period January 1994 to September 1996, reflecting the impact of hurricane Fran, to +44 ft/yr for the subsequent period September 1996 to March 1998. The most significant change for storm-free periods occurred between March 1986 and January 1994 when as much as 280 ft of erosion occurred. The entire reach retreated an average of 70 ft during this period. The average erosion rate for the shoreline segment between transects 26 and 32 for the period 1981-2001 was 13.1 ft/yr. Since 1973 the cumulative erosion for the reach was ~ 302 ft. The average erosion rate for the aforementioned period was 11.0 ft/yr.

Chronic erosion along the western end of Bogue Banks, specifically in the vicinity of the Pointe, has been the focus of concern and debate since the early 1970s. The deterioration of this shoreline segment reached a critical level in the mid 1990s when a number of homes were endangered by the retreat of the inlet shoreline. Subsequent to onset of the rapid land loss, individual homeowners along Inlet Drive and Bogue Court attempted to stabilize the shoreline with sandbags. The land loss in the vicinity of the “Pointe” is a result of a number of variables that act in concert to produce a very complex inlet and oceanfront shoreline change pattern. The erosion of the inlet margin and the concurrent accretion on the immediate oceanfront shoreline is related to the easterly migration of the ebb channel, the eastward shift of the apex of the ebb delta, and the juxtraposition of the ebb channel and the eastern inlet margin.

The early 1990s marked the onset of major erosion along the inlet shoreline. Since 1992 ~ 845 ft of erosion (net) has occurred along the eastern margin of the inlet. Erosion rates were highly variable varied over the past decade. Rates ranged from a minimum of 49 ft/yr (1998 - 99) to a maximum of 158 ft/yr (1992 – 94). The average erosion rate for the period 1992 – 2001, excluding the impacts of Hurricane Fran, was 91/3 ft/yr. In contrast to the chronic erosion along the inlet shoreline, the Bogue Banks oceanfront has continued to accrete since 1992. During the past 10 years accretion along the 2,000 ft long shoreline segment east of the "Pointe" (Transects 10 - 13) ranged from 37 ft near the inlet to 158 ft at Transect 11, located 1,500 ft east of the inlet. Since 1992, this 2,000 ft long oceanfront segment shoreline has accreted an average of 80 ft. Rates of accretion varied and reached a maximum of 15.8 ft/yr at Transect 11.

The zone of maximum accretion along the oceanfront has generally shifted eastward through time as the ebb channel has migrated to the east. The easterly shift of the channel has dictated the shape of the highly asymmetric ebb-tidal delta that affords protection for the western end of the island from wave attack and simultaneously aids in the buildup of the immediate oceanfront. The position of the ebb channel as well as the deflection of the outer bar channel has also dictated the zone where large (100 - 300 ft) swash bar complexes attach to shoreline. The zone of maximum buildup related to bar welding events has been typically located ~ 1,500 ft east of the inlet since the ebb channel was juxtaposed on the eastern shoulder in the mid 1980s.

A variety of concerns have been raised about the impacts of the proposed relocation of the ebb channel to a mid inlet position. Concerns focus on the impacts the relocation efforts will have on adjacent oceanfront shorelines and the erosion of Dudley Island as well as Islands # 1 and 2 located within the throat area. Regardless of which relocation scenario is selected, the relocated channel will alter the sediment transport patterns and lead to a reconfiguration of the ebb-tidal delta. The consequences will involve an ~ 3,000 westward shift of the apex of the ebb delta and repositioning of the marginal flood channels. Given sufficient time, the oceanfront along Bogue Banks will erode (20 - 410 ft) to a position that is approximated by the position of the 1978 shoreline. The westward repositioning of the ebb channel will have a contrasting impact on the Bear Island shoulder. The shift of the ebb delta to the west will have a positive influence

on the adjacent Bear Island oceanfront. It is anticipated that progradation on Bear Island will be substantial (60 - 450 ft) along a segment from the mid barrier portion to eastern extremity of the existing spit. Neither channel relocation scenario will have a direct negative impact on the integrity of Islands # 1 and # 2. It is predicted that prior to the onset of relocation efforts both islands will erode and reform with different configurations and in different locations within the throat and interior areas.

Although a variety of environmental issues have been raised about the impacts of the project on the interior shorelines, the relocation of the ebb channel will in all likelihood have a positive impact on the Dudley Island marsh complex. Historically the easterly movement of the ebb channel has caused significant erosion of the marsh shoreline. The erosion was due to the complex movement of the throat and interior channels. The eastward migration of the ebb channel and the attendant spit growth along the Bogue Banks shoulder has resulted in a shift of East Channel toward Dudley Island. Encroachment of East Channel on the eastern portion of the marsh shoreline has resulted in chronic erosion. Shoreline recession has generally been the norm along the eastern 3000 ft of Dudley Island where erosion ranged from 18 ft to 500 ft. The estuarine shoreline located immediately northwest of the Bogue Banks spit has eroded the greatest amount (288 - 500 ft) since 1973. Erosion directly stemmed from the migration of East Channel as the spit platform extended into the channel, resulting in deflection of the flow toward Dudley Island. Relocation of the channel will likely reduce the growth of the spit and may lead to a reversal of the historic erosion trends along Dudley Island.

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