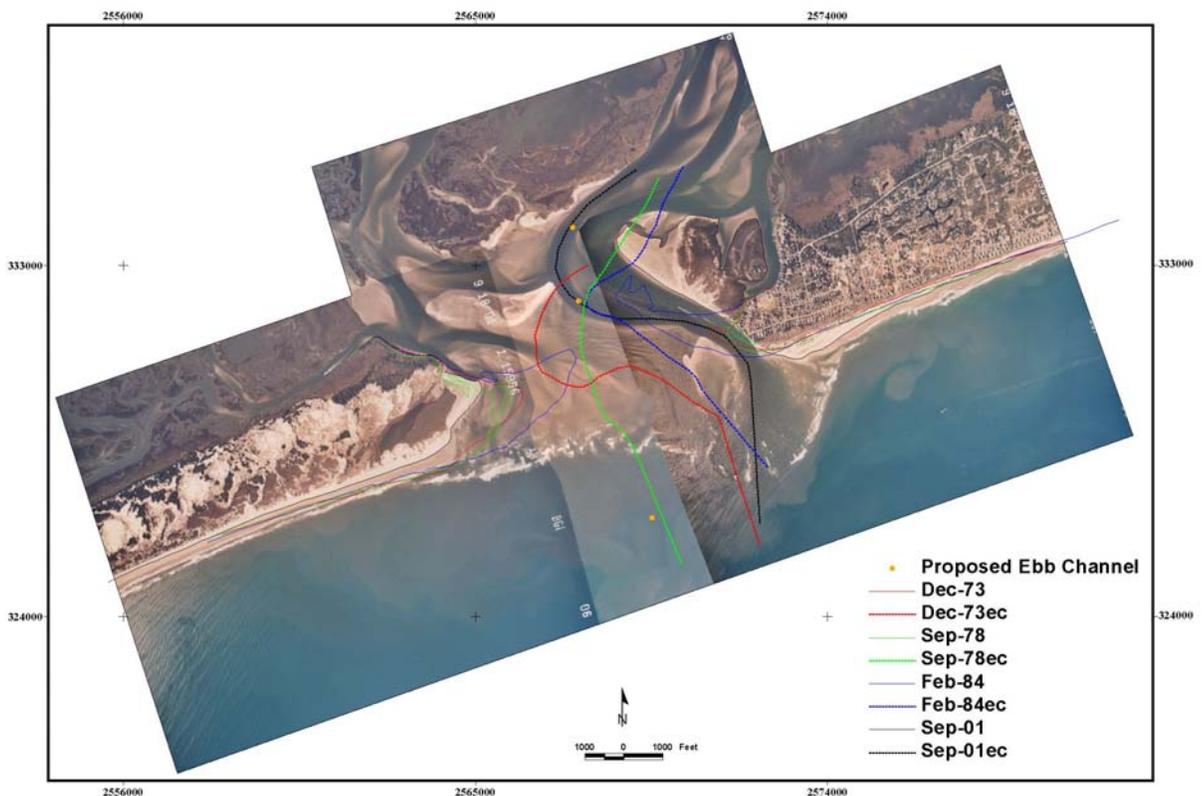


APPENDIX A
GEOMORPHIC ANALYSIS

Bogue Inlet, NC: A GIS Based Investigation of Inlet-Induced Shoreline Changes



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Executive Summary

In June 2002 William J. Cleary (WJC) was authorized by Coastal Planning and Engineering (CS&E) to initiate a Geographic Information System (GIS) based analysis of the recent history of Bogue Inlet (1973-2001). The focus of this investigation was the movement of the ebb channel and its influence on the shoreline change patterns on the Bogue Banks and Bear Island (Hammocks Beach) shorelines. Chronic erosion in the vicinity of the Pointe and along a portion of the Emerald Isle oceanfront prompted the need for remedial action.

Bogue Inlet separates Bogue Banks and Bear Island (Hammocks Beach). The inlet has been classified as a wave-influenced transitional system with an exceptionally wide throat (~8,500 ft) and a large mid-inlet shoal that occupies most of the floodway. The ebb channel is unstable and has a history of migration related to spit growth on opposing shoulders. Breaching of the inlet shoals has led to rapid repositioning of the ebb channel during several time periods since the late 19th century. The most dramatic realignment event occurred in the mid 1950s when the ebb channel was repositioned ~3,000 ft east of its 1938 position. The rapid realignment of the ebb channel promoted large-scale changes on the Bear Island shoulder. A similar but smaller-scale event occurred in the mid 1970s. The direction and rate of channel migration has varied considerably since 1938.

An October 2001 bathymetric survey by CS&E indicated the ebb channel had a maximum depth of -24 ft near the Pointe. The survey showed that the large, shallow (0 – 2 ft NGVD) mid-inlet shoal was generally subtidal. Data showed the outer throat had a cross-sectional flow area of 16,400 ft² (MSL). CS & E (2001) concluded that the main channel was ebb dominant. An ebb bias was also confirmed at other flow cross-sections with the major exception of the channel section across the mid inlet shoal where the flood discharge was dominant.

Bogue Inlet is a large inlet compared to the majority of other inlets in the area.

Since 1973 the inlet width has ranged from a minimum of 4,439 ft to a maximum of 8,383 ft. The changes recorded reflect the expansion and constriction associated with storms, realignment of the ebb channel and subsequent spit development on one or both shoulders. Since the early 1980s there has been a general widening of the throat. The orientation of the outer bar channel has ranged from 143° to 185° . From 1973 to 2001, the outer bar channel has generally been aligned in a SE to S orientation (143 - 185°). The position and orientation of the outer bar channel have controlled the shape of the terminal lobe and the size/shape of the eastern segment of the ebb delta that fronts Bogue Banks.

Findings of this study indicated that during the period 1973 to 2001, the ebb channel moved a net distance of 2,117ft in an easterly direction. Between December 1973 and September 1976 the channel moved 1543 ft toward Bear Island. Over the next five years the channel continued to move westward, a distance 352 ft. The inlet began its eastward trek in 1981/82. Between September 1981 and February 1984, the channel migrated rapidly to the east at a rate of 1,040ft/yr. During this period of initial reconfiguration, a large complex spit began to develop on the Bogue Banks shoulder. Rapid spit growth on both shoulders resulted in severe constriction of the throat and in February 1984 the inlet narrowed to 4,440 ft. Between February 1984 and March 1986 the ebb channel migrated east 210 ft. Between March 1986 and February 1992 the channel shifted east 364 ft. Slower migration rates (61 ft/yr) characterized this period. Migration rates increased substantially to 158ft/yr between 1992 and 1994. Subsequently (January 1994 to September 1996) migration rates decreased to 102 ft/yr. The basic configuration of the inlet remained unchanged between September 1996 and September 2001. Between March 1998 and October 2000 the channel migrated toward Bogue Banks a distance of 133 ft at a rate of ~ 50 ft/yr. The ebb channel remained essentially stable between October 2000 and September 2001. Since 1978 the ebb channel has shifted east a net distance of 2,117 ft at an average rate of 76 ft/yr.

Between 1978 and 1984 the Bogue Banks inlet shoreline prograded 957 ft. The pattern of shoulder accretion was reversed by 1984 when erosion became the norm. Between February 1984 and September 1996 the Bogue Banks shoulder eroded 912 ft.

The majority of the losses occurred between January 1994 and September 1996, a period of time characterized by increased storm activity (Hurricanes Bertha and Fran). The net inlet shoreline change amounted to 446 ft of erosion. An additional 46 ft of shoreline loss occurred between September 1996 and September 2001. Since 1973, ~520 ft of erosion has occurred along the Bogue Banks inlet shoreline.

Following a period of minor erosion (183ft) between 1973 and 1976, the western margin of the inlet prograded 1,609 ft during the interval 1976 to 1984. In general the Bear Island inlet shoreline has continued to recede. The recession of the Bear Island shoulder coupled with erosion of the Bogue Banks shoulder has effectively led to a widening of the throat since 1984. Since the mid 1980's the Bear Island shoulder has eroded ~2,975 ft. The cumulative change along the western shoulder of the inlet has amounted to 1,549 ft of erosion.

Dramatic net differences exist in the shoreline change patterns along the Bogue Banks and Bear Island oceanfront. Progradation along the Bogue Banks oceanfront shoreline segment ranged from 56 to 409 ft. The greatest shoreline accretion occurred along the oceanfront near the inlet. The average accretion rates ranged from 2.0 ft/yr (9/76 – 9/78) to 111 ft/yr (9/96-3/99). The average net change rate for the Bogue Banks oceanfront was 10.6ft/yr (1973-2001). The accretion reflects the positive influence of the inlet on the Bogue Banks oceanfront as the inlet migrated eastward.

In contrast to the net accretion recorded along Bogue Banks, chronic erosion has been the norm along Bear Island. Erosion ranged from 68 ft to 531 ft. In general the erosion increased toward the inlet and reached its maximum along the eastern-most portion of the spit. The relatively high values of recession along the spit reflect the negative influence of the easterly migration of the inlet. The average change rates for the Bear Island oceanfront also showed a wide range of values for the period 1973-2001. Average erosion rates ranged from 7 ft/yr (9/78- 9/81) to 66 ft/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). The average net erosion since 1973 was – 11ft/yr.

The area and shape of the ebb tidal delta have changed considerably since 1973. The initial phase (1973 to 1981) of morphologic change 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 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 and growth of the mid inlet shoal. The area of the ebb delta during this interim stage was generally low (~ 19 million ft²). Since the late 1980s the 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 changed little during this interval.

The eastward trek of the ebb channel coupled with the alignment of the channel along the Bogue Banks margin have resulted in the development of a highly skewed ebb delta whose apex has shifted eastward ~ 2,500 ft since 1978. 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. The net oceanfront shoreline gains ranged from 63 ft to 410 ft. The net gain for the shoreline reach most readily impacted by the inlet, prograded an average of 302 ft since 1973. The majority of this accretion has occurred since the early 1990s. Wave refraction around the ebb delta, coupled with the presence of the linear margin bar/swash bar complex produced a wedge-shaped zone of accretion that developed at an average rate of 10.5 ft/yr since 1986.

The eastward migration of the ebb channel and the attendant morphologic changes in the inlet has played a significant role in the erosion of Bear Island. Shoreline losses ranged from 68 ft at the western margin of the study area to a maximum of 530 ft 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 was 308 ft. The greatest losses have occurred since the late 1980s. As ebb channel migration occurred, the ebb-tidal delta was continuously being reconfigured along with the adjacent barrier shorelines. The apex of the ebb delta in 2001 was ~5,550 ft east of its 1976/78 position.

The marsh that comprises the seaward portion of the Dudley Island complex also has been significantly impacted by changes in the channel/shoal system. The pattern of erosion is due to the eastward migration of the ebb channel, the attendant spit growth along the Bogue Banks shoulder and the consequent migration of East Channel toward Dudley Island. Encroachment of East Channel on the eastern portion of the marsh complex has resulted in significant shoreline recession. Erosion has generally been the norm along the 3000 ft wide eastern segment of Dudley Island and has ranged from 18 ft to 500 ft. The estuarine shoreline located immediately to the northwest of the Bogue Banks spit has eroded the greatest amount (288 –500 ft) since 1973. Erosion stemmed from the extension of the spit platform into the eastern portion of the channel. Continued spit growth resulted in deflection of the flow toward the Dudley Island shoreline.

Islands # 1 and # 2 represent extremely small sand accumulations located within the Mid Inlet Shoal complex. The islands are low-relief ephemeral features that began to develop in 1995/96. Since 1996 Island # 2 has increased in size and extent and migrated further into West Channel. Island # 1 formed during the mid to late 1990s and represents a series of complex sand bars that merged in late 2000. It is an extremely ephemeral feature.

Two different proposed channel relocation scenarios involve repositioning the ebb channel to a shore-normal, mid-throat position. 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 channel in the vicinity of Island # 1. The location of the proposed channel lies along the approximate axial position of the ebb channel imaged on 1978 aerial photographs. Relocation of the channel 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. Given sufficient time, the oceanfront shoreline along Bogue Banks will erode and recede to a position that is approximated by the position of the 1978 shoreline. The amount of erosion is predicted to range from 20 ft along the eastern end of the historic accretion zone to ~ 410 ft along the western extremity of the oceanfront.

The westward repositioning of the ebb channel will have the opposite effect on the Bear Island shoulder. The movement of the ebb delta's apex farther to the west will lead to a seaward movement of the ebb delta's western segment outer margin. This seaward extension of the platform will have a positive influence on the adjacent Bear Island oceanfront. It is anticipated that oceanfront shoreline progradation will range from ~ 60 ft along the mid barrier portion of to as much as 450 ft along the eastern extremity of the existing spit. Neither scenario will have a direct negative impact on the integrity of Islands # 1 and # 2.