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Management and Erosion Mitigation Issues Related to Ebb Channel Repositioning: Rich Inlet, North Carolina, USA

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ABSTRACT

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Natural inlets have the ability to promote significant oceanfront shoreline changes through movements of the ebb channel and the attendant shape changes in the ebb-tidal delta. Rich Inlet is one of the larger, more dynamic inlets in southeastern NC where cyclical oceanfront erosion related to this complex linkage is a primary management concern. A GIS-based study of 17 sets of aerial photographs covering the period 1938 to 2003 suggest channel migration is restricted to an ~ 460 m wide pathway. The orientation of the channel as it passes through the outer bar has ranged between ~ 83° to 181°. The cyclic nature of changes in the ebb channel's position has promoted variations in the oceanfront erosion and accretion patterns. The northern 2 km long segment of Figure Eight Island's shoreline has eroded ~ 90 m due to a combination of channel migration and realignment over the past 7 years. The optimum channel orientation is ~ 145° when the ideal channel alignment approximates the position of the ebb channel depicted on the 1938 and 1980 aerial photos. In this arrangement the most favorable configuration is attained for accretion along the oceanfront shoreline. These analyses are essential for the development of sand management strategies and long-term inlet/shoreline management plans.

ADDITIONAL INDEX WORDS: *Shoreline change, inlet-induced, ebb delta, ebb channel, channel orientation, swash bars.*

INTRODUCTION

In the southwestern portion of Onslow Bay, six of North Carolina's 20 inlets border the developed retrogradational barriers that comprise the shoreline. These transitional inlets are wave-influenced and vary in terms of locational stability from highly unstable migrant systems such as Mason Inlet to artificially stabilized features such as Masonboro Inlet. In spite of their stability index, all natural inlets have the capability to promote considerable oceanfront shoreline changes through complex linkages to ebb channel movement and ebb-tidal delta shape changes. Several coastal communities in North Carolina are dealing with serious management issues that concern inlet hazard zones and the cyclical erosion that is characteristic of these systems. Rich Inlet, one of the larger inlets in southeastern North Carolina, is an exemplary site where severe recurring oceanfront erosion is a major management concern.

Rich Inlet, located 55 km northeast of Cape Fear, separates Figure Eight Island, a private residential island, from Hutaff Island, an undeveloped barrier (Figure 1). Even though the inlet has been a fairly stable feature since the early 1900's there have been substantial shoreline changes along both inlet shorelines or shoulders and the adjacent oceanfront. A GIS-based analysis of historic aerial photographs dating from 1938 to 2002 was undertaken to quantify shoreline change and its connection to the migration habit and system changes of Rich Inlet. The study focused on the migration of the various segments of the ebb channel, changes in orientation of the outer bar channel and the associated shape changes in the ebb-tidal delta in an effort to ascertain the extent of the inlet's influence.

Background

Tidal inlets in southeastern North Carolina are primarily wave-influenced transitional systems (HAYES, 1994). Even though many inlet systems display well-developed ebb-tidal deltas, sand bodies tend to be concentrated within the inlet throat. OERTEL (1972) and HAYES (1980) described the morphology of tidal inlets, the associated sand bodies and the processes responsible for their development. Previous work has shown that minor changes in the symmetry of ebb-tidal deltas can have a profound effect on adjacent barrier island shorelines (FITZGERALD and HAYES 1980; FITZGERALD, 1988; CLEARY *et al*., 2000; CLEARY, 2001). Ebb delta morphology affects the refraction of waves and promotes local reversals of sediment transport downdrift of the inlet leading to buildup on the downdrift shoulder (HAYES, 1980, FITZGERALD, 1988). These reversals of sediment transport together with bar welding events play a vital role in the accretion of the adjacent oceanfront shorelines (FITZGERALD, 1988).

PREVIOUS STUDIES OF RICH INLET

Previous studies of shoreline changes due to inlet influence include those of BROOKS (1988), CLEARY (1996), and JOHNSON *et al.* (1999). A general overview of the influence of inlets on adjacent shorelines including those within the study area can be found in a pictorial atlas of North Carolina Inlets by CLEARY and MARDEN (1999). CLEARY (2002) addressed the potential management concerns associated with the use of the inlet's sand resources for nourishment purposes. Combined, these studies provide a general outline for the interpretation of Rich Inlet's influence on adjacent shoreline changes of both Figure Eight Island and Hutaff Island. The current study provides an added quantitative approach to the analyses of shoreline change through a comprehensive GIS-based examination of inlet system changes.

METHODOLOGY

In preparation for the analyses, 17 representative sets of aerial photographs with dates spanning a period from 1938 to 2003 of Rich Inlet and adjacent barrier islands (Table 1) were scanned and rectified using ground control points that were selected from 1998 digital orthophotos from the North Carolina

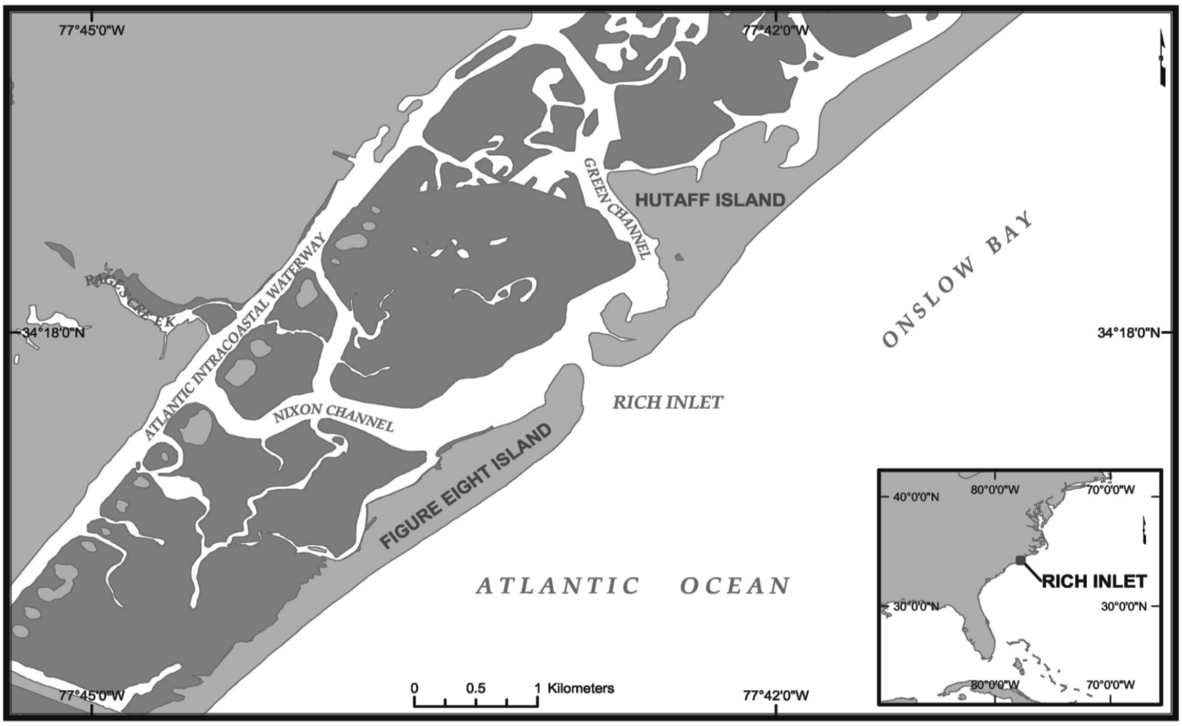

Figure 1. Location map of Rich Inlet, North Carolina and study area.

Department of Environmental and Natural Resources. The wet/dry line (shoreline), ebb delta, and ebb channel(s) of each newly created rectified photo along with digital orthophotos were digitized and projected to a common map datum.

A shoreline change analysis was performed using both SCARPS! (Simple Change Analyses of Retreating and Prograding Systems) and Digital Shoreline Analysis System (DSAS) (THIELER and DANFORTH 1994 a & b) ArcView extensions. In both extensions, a baseline was established landward of all shorelines and transect lines were erected perpendicular to the baseline in order to capture and calculate shoreline change (Figure 2). A separate shoreline change analysis was conducted on LIDAR data spanning 1996 to 2000 so as to not mix shoreline datums. Tables were extracted and imported into Microsoft Excel for further data display and treatment. Another baseline was erected from a fixed reference position on Figure Eight Island across the inlet to Hutaff Island for measurements of changes in the position of channel orientation, channel midpoint, inlet width, and ebb delta change (Figure 2).

RICH INLET SETTING

Rich Inlet drains an extensive estuary filled with tidal marsh where two large tidal creeks, Nixon and Green Channels, connect the inlet to the Atlantic Intracoastal Waterway (AIWW) (Figure 1). Its ultimate origin is likely related to the ancestral channel of Pages Creek that presumably controlled the location

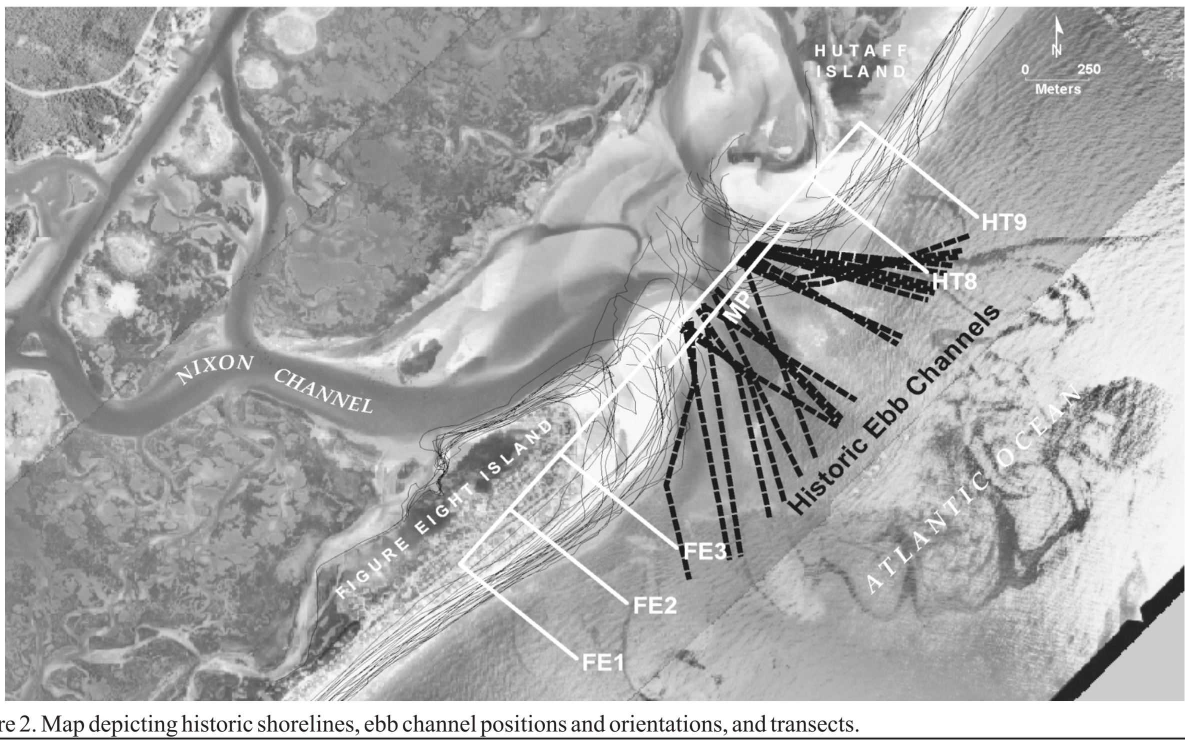

Figure 2. Map depicting historic shorelines, ebb channel positions and orientations, and transects.

Table 1. *Shoreline change and ebb channel migration rates.*

Time Period (month/year)	# years	FE1 (m/yr)	FE2 (m/yr)	FE3 (m/yr)	HT8 (m/yr)	HT9 (m/yr)	Channel MP (m/yr)	Channel Movement
03/38 - 01/45	6.8	-0.8	-1.3	-2.1	2.3	0.0	4.4	northeast
01/45 - 11/49	4.8	0.7	3.0	-0.7	-2.2	0.7	9.4	southwest
11/49 - 03/56	6.4	1.5	1.7	3.7	-4.1	-1.8	0.8	northeast
03/56 - 08/59	3.4	-1.2	2.7	4.3	12.4	-	16.0	northeast
08/59 - 03/66	6.6	0.3	-0.6	-1.7	-	-	2.9	southwest
03/66 - 12/74	8.7	0.6	0.6	0.6	-	-	1.5	southwest
12/74 - 09/84	9.8	-0.2	-0.6	-1.6	0.2	-	1.8	northeast
09/84 - 10/89	5.1	-0.7	-0.2	5.3	1.0	1.2	1.3	northeast
10/89 - 01/93	3.2	0.1	2.9	8.3	-4.5	-3.5	8.1	southwest
01/93 - 08/96	3.6	2.7	3.1	-2.2	2.5	2.9	27.8	northeast
08/96 - 01/98	1.4	33.4	-41.7	-10.3	88.2	-	102.2	northeast
01/98 - 06/98	0.5	89.5	100.9	23.5	-	-	211.8	northeast
06/98 - 03/99	0.7	-8.3	-116.9	-78.1	226.4	333.4	91.3	southwest
03/99 - 10/00	1.6	-19.1	-43.1	-97.6	-76.8	114.4	95.2	southwest
10/00 - 02/01	0.3	6.4	-116.5	-92.9	216.4	-391.0	123.6	southwest
02/01 - 05/02	1.3	1.2	-4.0	-4.5	-31.9	-45.5	12.7	southwest
Average	*4.0*	*6.6*	*-13.1*	*-15.4*	*33.1*	*1.1*	*44.4*	-

of the paleo-inlet as sea level rose during the past several thousand years. The inlet's stability is enhanced by the expansive drainage area, which includes portions of the lagoon and Pages Creek estuary. As a result, it has been a relatively stable feature for the past century. The recent movement of the ebb channel has been confined to a ~ 0.5 km wide pathway. The ebb-tidal delta is situated on Oligocene siltstone that crops out along the ebb delta's outer margin thus forming hardbottoms in water depths of approximately 9 m.

Inlet Characteristics

Rich inlet is one of the larger inlets in southeastern North Carolina. The inlet minimum width (IMW) reached a maximum of 815 m in October of 1989 and minimum of 280 m in February of 2001 (CLEARY, 2002). The average IMW since 1938 was ~ 600 m. Data collected from the latest Acoustic Doppler Current Profiler (ADCP) survey conducted in October 2002 estimated the tidal prism to be 18 x 10^6 m^3 (KNIERIM and CLEARY 2003). It is also estimated that the ebb-tidal delta contains 7.2 x 10^6 m^3 of sediment material to a depth of about -6 m.

The orientation and position of ebb channel have repeatedly changed since 1938. Measurements taken from rectified aerial photography suggest the orientation of the ebb channel as it crosses the outer bar has ranged from ~ 83° to 181° (Table 2). The channel was oriented principally in a southeasterly direction from 1938 to 1993 when it aligned in a more easterly manner. The channel was oriented in its most northeasterly alignment throughout the summer of 2000. In later months of 2000 a breach of the ebb-tidal delta encouraged the shore-normal shift of the ebb channel. Since 2001 the outer bar channel has been deflected southwest toward Figure Eight Island and continues to maintain this shift.

The ebb channel has migrated a net distance of approximately 460 m since 1938. The ebb channel reached its maximum southerly position in late 1981 when it began to track to the northeast at a rate of ~ 1.5 m/yr. A relatively low migration rate characterized the inlet for the next decade. Conversely, from 1989 to the summer of 1998 the rate of northeasterly migration was highly erratic. Ebb channel migration rates increased from 8.1 to 27.8 m/yr during the period from 1989 to 1996. During the period of 1996 to 1998 the inlet accelerated in its northeasterly movement to ~ 150 m/yr in the aftermath of Hurricane Fran. The inlet switched its migration direction in early 1998 and tracked in a southwesterly direction at ~90 m/yr. Even though the landward portion of the ebb channel migrated to the southwest, the outer portion continued to deflect to the northeast. A maximum easterly alignment of ~ 83° was reached in 2000. In recent years the channel migration rates decreased to ~12.7 m/yr. Figure 3 illustrates representative aerial photographs that depict changes in the inlet system.

Oceanfront Shoreline Change

The consequences of movement and realignment of the ebb channel during the past seven years for the Figure Eight Island oceanfront were significant and twofold: first and foremost, swash bar complexes no longer nourished the island's developed segment; and secondly, the ebb-tidal delta no longer afforded protection from wave attack. As a result, the northern 2.0 km of oceanfront, which had a 70-year history of accretion, experienced severe erosion (80-100 m) (Figure 4). The Hutaff oceanfront by contrast experienced rapid accretion (40-110 m) along a 1.5 km reach updrift of the inlet (Figure 4).

A cursory inspection of the aerial photographic data suggests a direct relationship exists between the ebb channel orientation and position and oceanfront shoreline change. Information pertaining to optimum channel orientation and position that promotes accretion along Figure Eight Island shorelines was derived from an analysis of trends within the dataset. The optimum channel orientation is ~ 145° when the preferred channel alignment approximates the position of the ebb channel imaged on the 1938 and 1980 photos. This type of analysis is important for the development of a sand management strategy and long-term inlet/shoreline management plan currently being formulated for Figure Eight Island.

In the Fall of 2000 an ebb delta breaching event occurred that repositioned and realigned the ebb channel and initiated a southwestward trek of the inlet and a slow reversal of the previously established shoreline change patterns. Although the inlet was tracking to the SW the asymmetry of the large ebb-tidal delta continued to promote erosion along the downdrift Figure Eight Island shoreline. Between August 2000 and February 2001 as much as 150 m of erosion occurred along the downdrift barrier. In the Spring 2001, ~200,000 m^3 of fill material was placed along the erosion hot spot in an effort to mitigate the recession. Much of the beach fill was lost by November 2001 due to exposure of the former accretion zone.

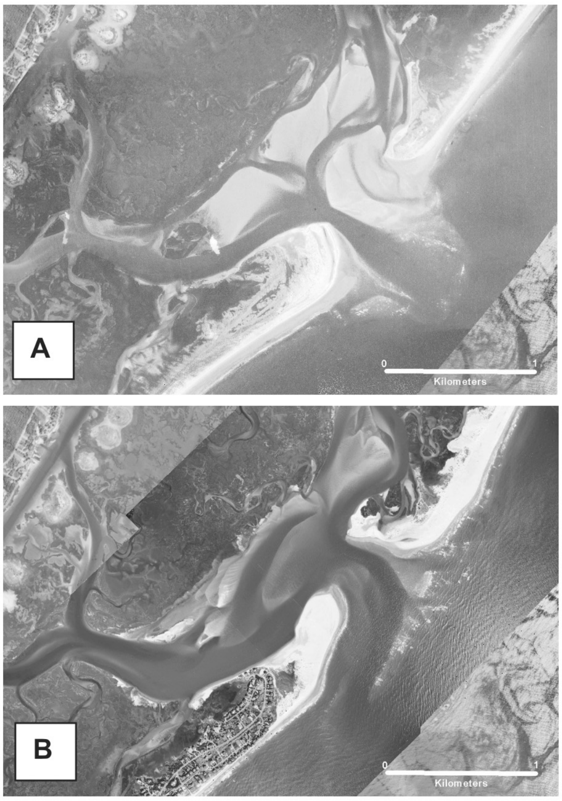

Figure 3. Representative rectified aerial photographs of Rich Inlet showing (a) 1938 and (b) 2002. Note changes in position and orientation of the ebb channel and shape of the ebb delta.

Table 2. *Historic ebb channel orientations.*

Date	Throat (azimuth)	Outer Bar (azimuth)
Mar-1938	56.7	123.4
Jan-1945	42.2	137.8
Nov-1949	359.7	180.3
Mar-1956	27.7	152.3
Aug-1959	40.5	139.5
Mar-1966	7.9	172.1
Dec-1974	10.3	169.7
Sep-1984	56.6	123.4
Oct-1989	24.2	155.8
Jan-1993	18.0	162.0
Aug-1996	76.6	103.4
Oct-1996	76.2	103.8
Sep-1997	57.1	122.9
Jan-1998	73.8	106.2
Jun-1998	76.0	104.0
Sep-1998	84.1	95.9
Mar-1999	87.1	92.9
Sep-1999	80.7	99.3
Aug-2000	91.5	88.5
Oct-2000	96.2	83.8
Feb-2001	64.4	115.6
May-2002	19.0	161.0
Average	*69.4*	*127.0*

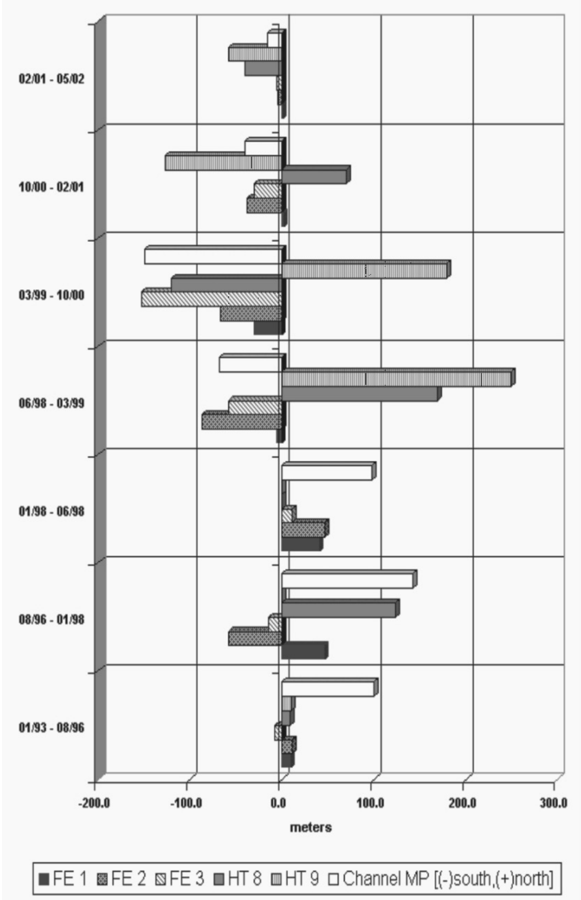

Figure 4. Graph showing shoreline change and channel migration direction of representative time periods during 1993 to 2002.

Figure 5. Photographs of the northern Figure Eight Island, NC: (a) Low oblique aerial photo looking north to Rich Inlet showing accretion of swash bars to southern Hutaff Island (November 2nd, 2002). (b) Emplacement of more sandbags on oceanfront properties (September 19th, 2003 Post Hurricane Isabel).

Since late 2001 erosion has continued and reached such critical proportions that large sand bags front all of the homes in the area. These sandbags continue to fail during increased water levels in minor storms and spring tides (Figure 5). Due to State regulations the sand bags must meet certain height specifications and must be removed by 2006. Efforts are currently underway to obtain a variance to allow larger bags to be placed along the shoreline to protect the endangered homes. If the request for the variance fails the only solution involves channel relocation. However relocation efforts will be confronted with many issues including the time necessary to complete such a controversial project. As a consequence, a rapid reconfiguration of the ebb-tidal delta must occur shortly in order to afford the degree of natural protection needed for the homes now protected by this narrow wall of failing sandbags.

The current alignment of the ebb channel favors a breach of the outer bar and the consequent bypassing of large packets of sand to the affected shoreline. However when the ebb delta-breaching event does occur the majority of the sand contained in the asymmetric ebb-tidal delta will still be located offshore the updrift shoulder of the inlet.

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LITERATURE CITED

BROOKS, W.B., 1988. A historic and morphologic study of Mason and Rich Inlets, North Carolina. Wilmington, North Carolina, University of North Carolina at Wilmington, M.S. Thesis, 87p.

CLEARY, W.J., 1996. Inlet induced shoreline changes: Cape Lookout to Cape Fear. In: Environmental Coastal Geology: Cape Lookout to Cape Fear, NC. Cleary, W.J., (Editor), Carolina Geological Society Field Guidebook, 49-59.

CLEARY, W.J., 2002. Variations in inlet behavior and shoreface sand resources: Factors controlling management decisions, Figure Eight Island, NC. Special Issue 36, *Journal Coastal Research*, 148-163.

CLEARY, W.J. and MARDEN, T.P., 1999. Shifting Shorelines: A Pictorial Atlas of North Carolina Inlets. NC Sea Grant Publication, 99-4. Raleigh, NC, 60pp.

CLEARY, W.J., RAUSCHER, M.A., MCLEOD, M.A., JOHNSTON, M.K. and RIGGS, S.R., 2000. Beach nourishment on hurricane impacted barriers in southeastern NC, USA: Targeting shoreface and tidal inlet sand resources, Special Issue 34, *Journal of Coastal Research*. 232-255.

COASTAL SCIENCE AND ENGINNERING (CSE), 2001. Analysis of alternatives for Bogue Inlet channel realignment and beach nourishment along western Emerald Isle, NC. Summary Report, 72 pp.

FITZGERALD, D.M. and HAYES, M.O., 1980. Tidal inlet effects on barrier island management. *Proceedings of Coastal Zone '80*, ASCE Press. 2355-2379.

FITZGERALD, D. M., 1988. Shoreline erosional-depositional processes associated with tidal inlets. Vol 29, New York, Springer-Verlag. Lecture notes on Coastal and Estuarine studies, p 186-225.

HAYES, M.O. 1994. CHAPTER 7: Georgia Bight: in *Barrier Islands* (R.A. Davis, Jr., Ed.), Springer Verlag, N.Y., 233-304

HAYES, M.O. 1980. General morphology and sediment patterns in tidal inlets, *Sedimentary Geology*. 26.139-156.

JOHNSEN, C.D.; CLEARY, W.J.; FREEMAN, W.C. and SAULT, M., 1999. Inlet induced shoreline changes on the high energy flank of the Cape Fear Foreland, NC. *Proceedings of Coastal Sediments '99*. ASCE Press.1402-1418.

KNIERIM, A.C. and CLEARY, W.J., 2003. Hydrographic investigation of a wave-influenced transitional inlet: Rich Inlet, North Carolina. *Proceedings of Coastal Sediments '03*. CD-Rom.

OERTEL, G.F., 1972. Sediment transport of estuary entrance shoals and formation of swash platforms. *Journal of Sedimentary Petrology*. 42.857-863.

THIELER, R.E. and DANFORTH, W.W., 1994a. Historical shoreline mapping (I): improving techniques and reducing position errors. *Journal of Coastal Research*, Vol. 10, No. 3, pp. 549-563.

THIELER, R.E. and DANFORTH, W.W., 1994b. Historical shoreline mapping (II): application of the Digital Shoreline Mapping and Analysis Systems (DSMS/DSAS) to shoreline change mapping in Puerto Rico. *Journal of Coastal Research*, 10(3), 600-620.