Background

In June 2002 William J. Cleary (WJC) was authorized by Coastal Planning and Engineering (CPE, Inc.) to initiate a Geographic Information System (GIS) based analysis of the recent history of Bogue Inlet (1973-2001). The primary focus of the 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. Data from this study will be used in conjunction with other information generated by engineering oriented investigations to better plan the activities associated with the proposed ebb channel relocation effort.

Chronic erosion along the western end of Bogue Banks, specifically in the vicinity of the Pointe, has been the subject of concern and debate for the past several decades. The deterioration of this shoreline segment reached a critical level several years ago when several homes were endangered by the retreat of the inlet shoreline. Subsequent to onset of the rapid loss, individual homeowners along Inlet Drive and Bogue Court stabilized the eroding shoreline with a series of sandbags in an attempt to protect the threatened homes. The land loss in this area is a result of a number of variables that act in concert to produce the complex erosion pattern. The Town of Emerald Isle is also experiencing erosion along much of its oceanfront; and as a result, it has initiated an extensive 11.2 miles long nourishment project. 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 with Coastal Planning and Engineering of North Carolina (CPE of NC) to finalize the design of a recommended project involving the relocation of the main inlet channel.

Subsequent to receiving the authorization to initiate the GIS based study, a plan was devised that focused on the movement of the ebb channel and its linkage to inlet morphologic changes as the principal causes of the observed shoreline changes. This report presents the data from the GIS-based analysis of aerial photographs (1973 to 2001) that describes movement of the ebb channel and the influence it has on the Bogue Banks and Bear Island (Hammocks Beach) inlet and oceanfront shorelines.

Inlets and Shoreline Change

During various time scales, inlets play a major role in the coastal sediment budget by retaining large volumes of sand impounded from the littoral system (Walton and Adams, 1976). The extent to which these inlet systems interrupt the alongshore transport and store sand depends largely upon the hydrodynamics and the potential tidal exchange capacity of the system (Nummedal, et al., 1977; Hayes, 1980; FitzGerald, 1993; Hayes, 1994). Inlet systems are also important from a management viewpoint because the great majority of the critical erosion zones that have been identified along North Carolina's coast are associated with inlets (Cleary, 1996; Cleary and Marden, 1999).

Inlets dictate the oceanfront shoreline patterns over long shoreline stretches many times the current dimensions of the adjacent inlet. The length of a shoreline segment influenced by an inlet is a function of throat size, ebb shoal shape and migration habit. Numerous studies have shown that the dynamics of inlets are site specific with each system exhibiting individualized responses to the local environmental and geological factors and the interaction of man. Therefore, effective long-term management and specific modification plans require an understanding of the natural inlet-induced shoreline changes.

The Role of Ebb Deltas in Shoreline Change Patterns

Ebb-tidal deltas, the seaward shoals of an inlet, are formed through the interaction of waves and tidal currents. Changes in the size or shape of ebb-tidal deltas can have a significant effect on adjacent shorelines. Regardless of size, the offshore shoals influence the ends of the adjacent barriers, acting as natural breakwaters and modifying the wave energy impinging upon the shorelines. Waves approaching the islands are refracted in such a manner that a region of sediment transport reversal occurs in the vicinity of the inlet (Hayes, et al., 1973; Hayes, 1994). This mechanism of transport reversal had been proposed to account for the bulbous shoreline segment immediately downdrift of some inlets. Additionally, episodes of sand bar-welding events account for a major portion of the observed progradation (FitzGerald, 1984; Cleary, 1996,

Figure 1. Location map and aerial photograph mosaic (9/18/01) depicting major features.

Kana, et al., 1999). When the symmetry of the ebb-tidal delta changes there is a concomitant change in the pattern of erosion or accretion on the adjacent barrier shorelines. Often times alternating erosion and accretion episodes produce dramatic changes in the planform of adjacent oceanfront shoreline segments (FitzGerald, 1984; FitzGerald, 1993; Cleary and Marden, 1999; Kana, et al., 1999; Gaudiano and Kana 2001).

Moreover, erosion and accretion along shorelines bordering relatively stable inlets such as Bogue Inlet are related to complex and poorly understood cyclical changes in the shape of the ebb-tidal deltas (Kana, et al., 1999; CS & E, 2001). Cycles are associated with the repositioning of the ebb channel and the corresponding position and size changes in the marginal flood channels and where swash bars welded onto the adjacent shorelines (FitzGerald, 1984; Cleary, et al., 1989; Cleary, 1994 and 1996; Cleary and Marden, 1999; Kana, et al., 1999; CS & E, 2001). The cycles are of variable length (years to decades) and the actual cycle length appears to be correlated with inlet size and possibly storm history. Additional variables governing cycles are backbarrier channel hydraulics. Cycles are typically longer and more complex at larger systems. Hundreds of meters of accretion/erosion can be recorded on the inlet shoulders subsequent to channel and ebb tidal delta changes. Progradation or erosion may continue for more than several decades depending upon the size of the inlet and inlet history.

General Setting

Bogue Inlet, one of the larger inlets in southeastern North Carolina, is located approximately 55km west-southwest of Cape Lookout in the northeastern portion of Onslow Bay (Fig. 1). The inlet separates Bogue Banks in Carteret County and Bear Island (Hammocks Beach) in Onslow County. The inlet drains an expansive marsh filled lagoon where two large, relatively deep tidal creeks, Eastern and Western Channels, connect the inlet to the Atlantic Intra-Coastal Waterway (AIWW) and the White Oak River Basin. The eastern feeder channel that connects the AIWW to the outer bar has been maintained on an annual basis by the USACE since 1981. The one-mile long channel is maintained to a depth of –8ft (MLW). The average annual maintenance dredging efforts generally involves the removal of 150,000 cy of material

from the corridor.

The inlet has been a relatively stable feature over the past several centuries and has been confined to a 500-800m wide zone. The ultimate origin of the inlet is related to the ancestral channel of the White Oak River, which controlled the location of the inlet as sea level rose during the past four thousand years. The contemporary inlet's main ebb channel currently lies approximately 3 km to the east of the incised ancestral channel that can be traced across much of the shoreface (Steele, 1981; Hine and Snyder, 1985). The large drainage area that includes portions of the bar built lagoon and the White Oak River estuary enhanced the inlet's stability.

Bogue Inlet has been classified as a wave-influenced transitional inlet with an exceptionally wide throat (~8,500 ft), a relatively narrow ebb channel (~700 ft), and a large mid inlet shoal that occupies most of the western portion of the floodway (Cleary and Marden, 1999 CS & E, 2001). The ebb channel is unstable and has a history of migration related to spit growth on opposing shoulders. Breaching of the inlet shoals has also 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 elevated water level associated with Hurricane Hazel (1954) was the likely trigger mechanism that led to the shoal-breaching event. The rapid realignment of the ebb channel promoted large-scale changes on the Bear Island shoulder as extensive portions of the offshore shoals migrated and welded onto the adjacent shoreline (Cleary and Marden, 1999; CS & E, 2001). A similar but smaller scale event occurred in the mid 1970s. The direction and rate of channel migration has varied considerably since 1938. During the past three decades the channel has steadily migrated in an easterly direction at an average rate of ~75ft/yr.

An October 2001 bathymetric survey (CS&E, 2001) indicated the 750 ft wide 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 and observations indicated it was only exposed during spring tide conditions. Data recorded across the mid inlet shoal during the October 2001 survey led CS & E to conclude that the surface of the feature had been raised by 1-

2 ft since 1999. CS& E (2001) defined several inlet cross-sections using the bathymetric survey data. Data from a combined cross-section showed the outer throat had a section of 16,400 ft^2 (MSL).

Utilizing data from a hydrographic survey conducted in October, 2001 CS & E concluded that the main (ebb) channel was ebb dominant. The ebb discharge averaged 30,000 cfs in comparison to the flood discharge of 25,000cfs. 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 (9,000 vs 6,000cfs). The discharge characteristics of the various channel segments suggested that the ebb channel handled ~60 % of the discharge during the tidal cycle while the section across the mid inlet shoal carried ~ 20 % of the flow during the cycle.

Methodology

Contemporary changes in the inlet and along the adjacent oceanfront shorelines (Fig. 1) were determined through an analysis of a series of representative historic aerial photographs that date from 1973. Twenty-five sets of photographs were initially examined for trends; and on the basis of these observations, 13 sets of aerial photographs covering a large spatial and temporal scale (1973 –2001) of Bogue Inlet, adjacent Bogue Banks, Hammocks Beach (Bear Island) and neighboring marshes (Dudley Island) were scanned and orthorectified using both ERDAS Image Analysis and SmartImage extensions. The images were manipulated utilizing ArcView GIS 3.2a. Ground control points (GCPs) were selected from 1998 digital orthophotos obtained from the North Carolina Division of Coastal Management. A minimum of 15 control points for each 9" x 9" frame were used in the rectification process. The wet/dry line (shoreline), ebb delta, and ebb channel(s) of each newly created orthophoto were digitized and projected to a common projection of North Carolina State Plane, NAD 83 datum, feet units, and GRS1980 spheroid as ArcView shapefiles.

An 18,500 feet long baseline was established landward of all digitized shorelines and 37 transect lines were erected perpendicular to the baseline at a 500ft spacing for purposes of measuring and calculating the various shoreline changes (Fig. 2). The baseline transects were established to intersect the digitized shoreline themes and position data were recorded in a GIS database. Shoreline changes were calculated using the Endpoint Rate Method (EPR) by exporting the GIS database to Microsoft Excel for further manipulation and analysis.

A second baseline was established by constructing a line from a stable reference position on Bogue Banks extending across the inlet to Hammocks Beach. The baseline was utilized for purposes of measuring and calculating ebb channel midpoint changes, inlet width, and shoulder changes associated with ebb channel migration (Fig. 2). The location of the mid-point and axis of the ebb channel were digitized for purposes of tracking the temporal and spatial changes in the position and orientation of the ebb channel within the inlet system. The distance from the reference position to various features that intersected the baseline was measured and recorded in the GIS database. The inlet minimum width, a conventional parameter, was also measured at the narrowest portion of the throat and the data recorded.

The surface area of ebb tidal delta was calculated utilizing polygon shapefiles that were created by digitization of the aerial extent of shoals defined by the zone of breaking waves. The areas of each of the polygons, that intersected the established inlet baseline, were then determined. An ArcView script was used to perform the calculation of area into the GIS database. The data were then exported to MS Excel for further manipulation.

Results and Discussion

Map Evidence

Historic map evidence indicates that Bogue Inlet has been in existence since pre-Colonial times. The inlet has been identified on historic coastal charts dating from the mid 1600's. Historic map data suggest the inlet system is confined to a relatively narrow migration pathway.

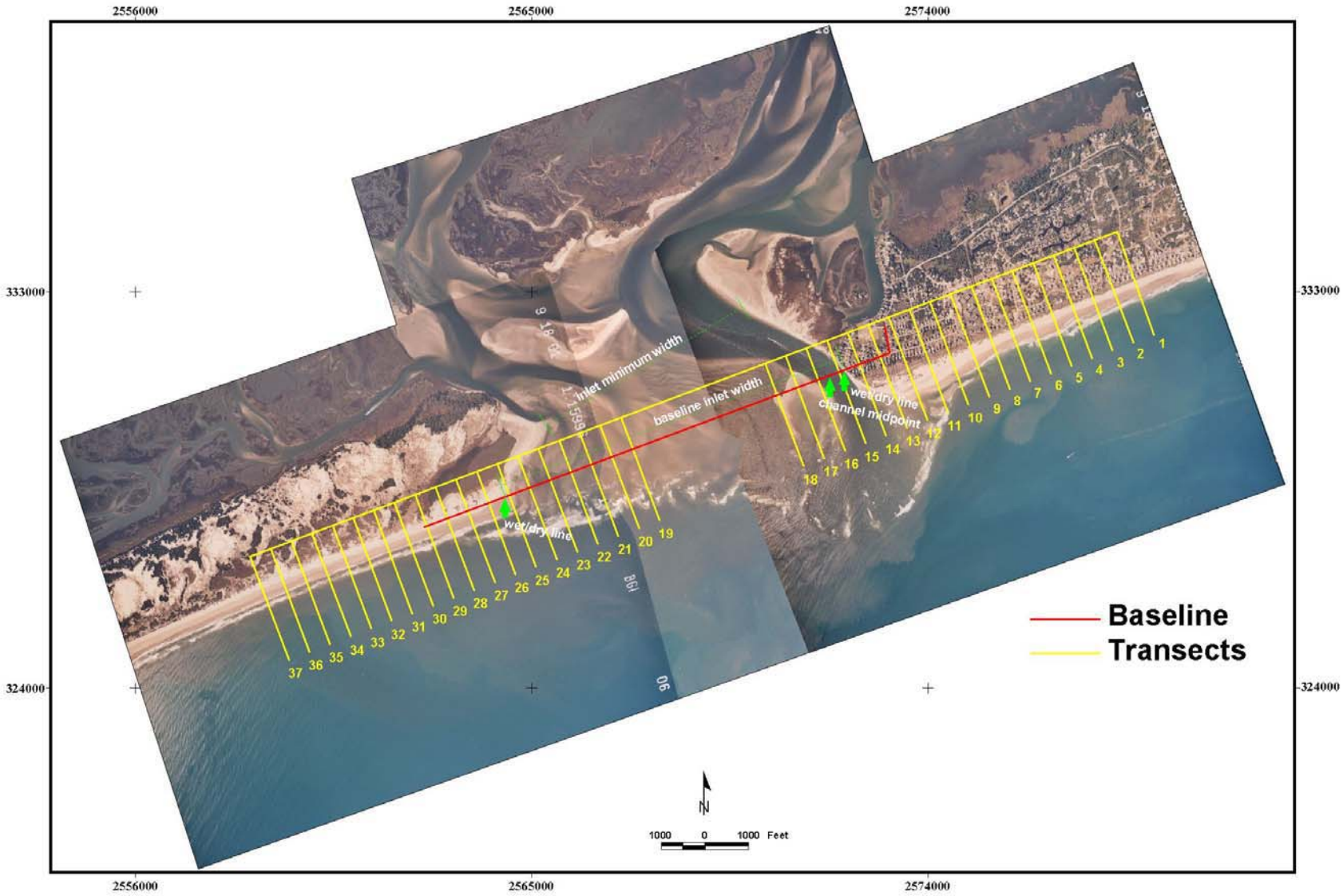

Figure 2. Aerial photograph mosaic (9/18/01) with inlet and oceanfront baselines and transects locations.