

**OCEANFRONT SANDBAG USE IN NORTH CAROLINA: MANAGEMENT REVIEW
AND SUGGESTIONS FOR IMPROVEMENT**

by

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ABSTRACT

North Carolina's 326 miles of oceanfront coastline is composed of barrier islands. Inherently transitory, the position of these islands and the profile of their beaches naturally fluctuate with the dynamic equilibrium established by waves, wind, storms, and sea level rise. The net result of this dynamic has been erosion of 75% of the coastline, putting oceanfront human development at risk. Erosion rates vary geographically and temporally, ranging from a state average of two feet per year to hundreds of feet in just a few stormy hours.

The risk posed to coastal development is ever increasing with the effects of climate change, specifically sea level rise and increased hurricane intensity. A geospatial analysis conducted for this project, incorporating the effects of erosion rates and sea level rise on the shoreline position of Dare County, NC, revealed that more than 97% of the first row, oceanfront homes will encounter waves within the next hundred years. Methods of combating this threat can be divided into three categories: hard stabilization, soft stabilization, and relocation.

Under the direction of the Coastal Resources Commission, North Carolina has adopted a progressive approach to regulating the use of erosion control strategies. It encourages relocation and, unlike many other states, it has banned the use of hardened structures on the oceanfront since 1985. The state also has strict rules governing the use of soft stabilization techniques such as sandbags and beach nourishment. However, the state's policies in practice are not necessarily as strong as in writing. Focusing on the erosion control strategy of sandbags, this paper provides a review of oceanfront sandbag management within North Carolina through analysis of the regulations that guide their use, comparison to alternate erosion control strategies, and recommendations for the future based upon literature review and interviews with professionals in the field.

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I. Introduction

I was introduced to the issue area of oceanfront sandbag use by Steve Roady in his fall 2007 Ocean and Coastal Law and Policy course taught at the Nicholas School. In a class discussion, the topic of the firm May 1, 2008 removal deadline for unauthorized sandbags was raised. It struck me as a very concrete and straightforward mandate, so I was interested to see if its application occurred on the ground. By October of 2008, it was clear that it had not, so I broadened my study to include recommendations for the future erosion control management.

My methods of inquiry were three fold. First I conducted a literature review during which I uncovered the regulatory history of the sandbag use in oceanfront North Carolina. This included references within scientific publications, as well as, those from the popular media. Alternative erosion control strategies were also researched as comparison points to sandbags. These included beach nourishment, relocation, and the use of hardened structures.

Next, I conducted semi-structured phone interviews with nineteen experts in the field. The experts came from government, academia, non-profit, and legal fields. Their opinions were solicited on several topics with a particular emphasis on the effectiveness of and preference for the different erosion control structures, as well as, what the future of regulations might be. To protect their identity, they are referenced as Expert A, Expert B, etc instead by name.

Third and finally, a geospatial analysis was conducted for Dare County to illustrate the pressing need for management of sandbag use.

The presentation of my research is as follows. Section II provides a brief background on the nature of the erosion problem. Section III describes the different strategies available to control erosion. Section IV outlines the regulatory history of oceanfront sandbag use in North Carolina. Section V delves into why the use of sandbags and other erosion control strategies has

generated such heated debate. Section VI contains the geospatial case study of Dare County, NC in which the interaction between the ocean and first row, oceanfront homes is projected. Section VII uses the information gathered from publications and personal interviews to isolate three management alternatives. Section VIII provides detailed summary of the findings of the interviews I conducted with experts in the field. Finally Section IX synthesizes all of my research to provide a set of management strategies I view to be preferable.

II. Background on the Issue

A. Defining the phenomena

Barrier island formations dominate much of the east coast of the United States (O. R. Pilkey, et al., 1998). This is especially true of the coastline of North Carolina (NC), where, with the exception of its 23 inlet areas, all 326 miles of coastline bordering the ocean is a series of barrier islands (S. R. Riggs, et al., 2008) (see Figure 1). Barrier islands are transitory geological features in nature. Since their emergence 18,000 years ago, they have been in constant in motion, rolling back and forth with sea level rise, storm activity, and normal wind and wave patterns (Beyer, 1991). The interaction between these forces is often described as a dynamic equilibrium (O. H. Pilkey, R. Turner, 1975). Other factors including subsidence, reduced beach material, and interference by man also affect the barrier island morphology (Finkl, 1981; O. H. Pilkey, R. Turner, 1975).

In North Carolina as a net result of these factors, 240 miles or 75% of the coastline is eroding (Cooney, 2003). Average erosion rates vary greatly geographically and temporally, but the overall trend is an erosion rate of two feet or more per year for 61% of the coastline (see Figure 2 as an example). Maximal annual erosion rates reach up to 20 feet and during storm

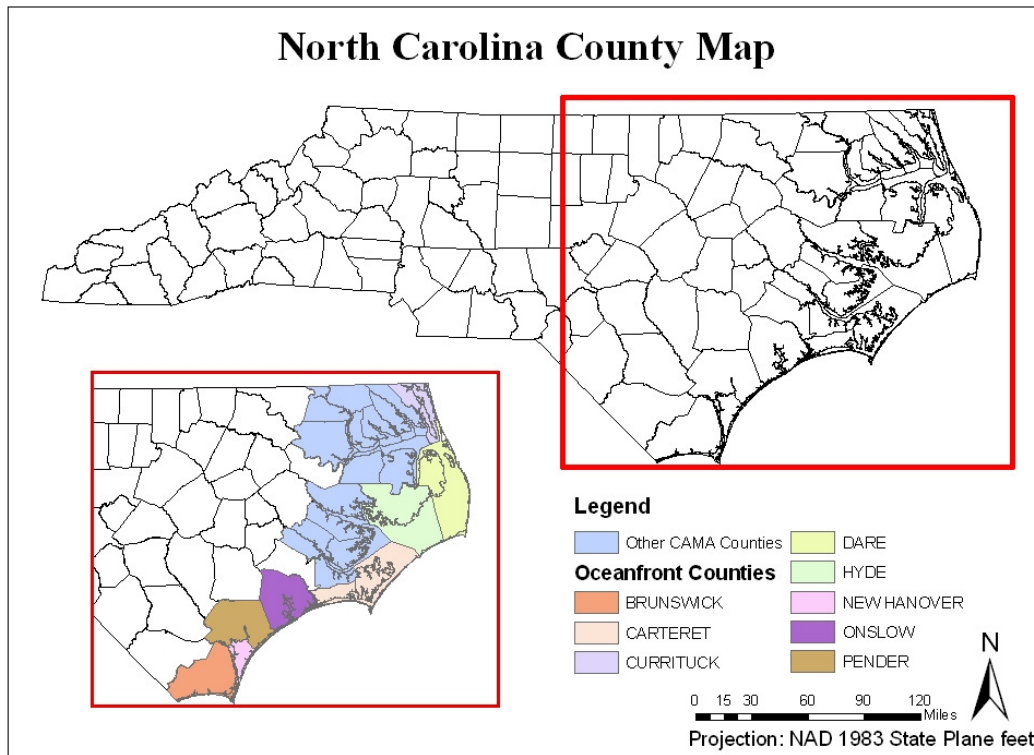


Figure 1. County map of North Carolina. CAMA refers to Coastal Areas Management Act which is described in Section IV.



Figure 2. Evidence of shoreline movement from paired historical photographs, specifically a home in Rodanthe, NC. Source:
<http://www.darylscience.com/graphics/CapeHatterasNC-Erosion.jpg>

periods hundreds of feet can be lost in just a few hours (Major, 1990; NCDRC, 2008c; North Carolina Real Estate Commission (NCREC), 2008). Inlet areas tend to experience these high rates of erosion (Riggs et al. 2008).

It is important to stress that *erosion* is a human construct term. Although erosion is the most frequently employed term both in the scientific literature and public vocabulary, it is infused with a negative connotation, reflecting human sentiments of the process' interference with their development. In reality, a more accurate descriptor of the change on the coastline is shoreline migration or evolution.

B. Why it is a problem

Before humans started to develop them, the fluctuant state of the barrier islands was not a problem. Coastal development began in the mid-1800s when small communities sprung up in Nags Head in 1830 and in Morehead City in 1850. It was not until after World War II that the North Carolina barrier islands started to be heavily developed (O. H. Pilkey, et al., 1980). The widespread use of the car (instead of reliance on mass transportation), increased salaries and vacation time, and the development of resorts encouraged this growth (Nordstrom, 2000; O. H. Pilkey, et al., 1980). Since 1970s development accelerated leaving virtually no undeveloped land on the oceanfront outside of protected lands such as the national seashore (National Research Council (NRC), 1995).

With this development, humans have demanded that the islands retain a constant location and shape. The permanent structures which have been placed along the shoreline such as homes, hotels, and businesses interact negatively with the natural processes which shape barrier islands, namely wave action and sediment transport (O. H. Pilkey, et al., 1980; O. R. Pilkey, et al., 1998).

In attempts to protect developments that are threatened by these processes, people typically erected barriers, such as seawalls, between their homes or businesses and the sea. These barriers, while affording buildings some protection from direct contact from wave energy, actually serve to further exacerbate the underlying problem by accelerating erosion rates and altering the natural transport of sediment down the beach (Baker, 1980; Leatherman, 1980). This so-called “straight-jacketing” of the beach has generated great controversy (Wallace, 1979) and is a focus of the rest of the discussion.

The conflict between natural barrier island movement and coastal development is only expected to increase in the coming decades as climate change exerts extra pressure on the North Carolina coast. The predicted sea level rise of 4.3 centimeter per decade will put the high tide water level and crashing waves in contact with more development (Pearsall, 2008). This increase in contact will occur rapidly since the barrier islands are low lying with a very gradual slope (O. H. Pilkey, et al., 1980). Coastal geologists have documented that for every incremental rise in sea level the shoreline retreat is two to three orders of magnitude greater (O. H. Pilkey, et al., 1980; O. H. Pilkey, R. Turner, 1975). The often-cited Bruun Rule states that horizontal erosion of the beach is 50 to 200 times the rate of sea level rise (Phillips, 2006).

Additional pressure will be exerted by the predicted increase in hurricane intensity (Kerr, 2005). A major hurricane typically hits the North Carolina coast every two to three years (O. H. Pilkey, et al., 1980). Over the course of the 20th century, 105 tropical storms were documented in North Carolina, 64 of which were hurricanes (S. R. Riggs, et al., 2008). Hurricanes can drastically change the shoreline in short periods of time; it is not unusual for hundreds of feet of beach to be lost over the course of 24 hours. The rate of return of this sand is not nearly as rapid, taking years, if not decades, to fully restore the beach width completely (Expert L, 2008).

Together with sea level rise, this means that more homes will be put in peril every year and thus there will be a greater demand for measures to slow or stop erosion.

Each of these increasing pressures is exacerbated by the increase in development that is occurring on the coast. The coast is a desirable place both to live and vacation. Coastal counties across the nation have seen population and development increases that exceed those of inland counties. Between 1983 and 1990, the population of coastal counties in the U.S. grew 3% faster than the rest of the country and the value of insured property increased by 69% on the Atlantic and Gulf coasts (The H. John Heinz III Center for Science Economics and the Environment, 2000). This flocking to the coasts increases the risk posed by chronic and acute erosion events as more investments and lives are in harm's way. A simple case study projecting the number of first row, oceanfront homes in Dare County, NC that will likely be affected by the erosion problem over the next 100 years can be found in Section VI.

The beaches of the barrier islands provide essential revenue to North Carolina. Beaches annually generate \$2.9 billion of the state's \$10 billion tourist revenue and provide 50,000 of the 180,000 state tourism-based jobs (Cooney, 2003; Legislative Research Commission (LRC), 2001). Beach erosion threatens this significant source of revenue and employment because when the beaches are gone, the tourists will have fewer reasons to visit.

III. Erosion control strategies

Strategies for combating oceanfront erosion are typically broken into three categories: hard stabilization, soft stabilization, and relocation. Listed in the order of decreasing invasiveness, each of these methods has different advantages and disadvantages. The three strategies are briefly discussed subsequently with reference to their historical use in North

Carolina. The primary focus of this paper is the second category with a particular emphasis on sandbags, however, in order for the reader to comprehensively understand issue, it is necessary to present a background on other available erosion control strategies.

A. Hard stabilization

Hard stabilization is the placement of permanent structures in or near the water to alter the natural flow of water and/or sediment. There are two primary categories of harden structures that get used along shorelines which need protection: those which are parallel to the shoreline and those which are perpendicular. In the former category are breakwaters, sills, and seawalls. In the latter are jetties and groins. For the purposes of this paper, the effects of only one example from each category will be discussed.

Coastal geology expert, Dr. Orrin Pilkey argues that seawalls, as shown in Figure 3, are the “worst thing to do to a beach to preserve it” (O. H. Pilkey, R. Turner, 1975) because they act to accelerate the erosion problem in three ways. First they reflect the wave energy which increases erosion at the base of the wall. This means a steeper beach profile is produced which in turn accentuates the erosion effect of the waves. In other words a positive feedback system is generated (Wallace, 1979). Second, seawalls prevent sand from blowing back onto the dune, a process that normally bolsters future island stability. Third, seawalls cause the curving of waves around their ends and thereby increase erosion on the edges of the wall in what is known as the “flanking effect” (Kraus, 1996; O. H. Pilkey, et al., 1980; O. H. Pilkey, H. L. Wright, 1988; O. H. Pilkey, R. Turner, 1975). Longshore transport, or the movement of sand parallel to the beach, has also been interrupted in front the seawall in some cases (Kraus, 1996). In North Carolina, the longshore current typically runs from North to South at an average rate of 5 miles per hour or

less (Douglass, 2002) and has been shown to transport an average of 139,000 to 727,000 cubic meters of sediment per year (Park, 2005).



Figure 3. Photos of typical seawall designs. Source:
http://www.cmiwaterfront.com/Seawalls/images/slate_seawall.jpg (left);
http://lh6.ggpht.com/_tVE2NcRYpSo/RqLCbTZW-gI/AAAAAAAAACUY/kyWGU7o39pY/P7210106.JPG (right)

An equally significant problem posed by seawall use is their effect upon the public. Post-installation, seawalls provide a false sense of security and leave people with the belief that no further action needs to be taken to combat the erosion problem (O. H. Pilkey, H. L. Wright, 1988). Seawalls are also typically unsightly and can prevent physical access to the beach and thus are a nuisance to the public. As the seawall causes the beach to disappear, the public loses its place of recreation.

Groins are used to trap sediment moving downstream with the longshore current. As a result, they deprive downstream areas of sand (O. H. Pilkey, R. Turner, 1975). This means that groins are rarely installed as a single unit but rather as a series down the beach, also known as a “field,” to counteract the effects of the adjacent upstream groin. The result is a series of scalloped beaches as sand accumulates on the upstream side of each of the groins and is lost on the

downstream side. This phenomena has come to be known as “New Jerseyization” as it is the strategy that was first extensively used in that state (O. H. Pilkey, et al., 1980) (see Figure 4). In addition to altering natural sand flow, groins have been known to create additional rip currents and produce debris that injures swimmers (Nordstrom, 2000).



Figure 4. Scalloping of beach that is seen in New Jersey as a result of the use of groins.

Source: http://farm1.static.flickr.com/187/470507242_8badbec926.jpg

The construction of hardened structures is relatively new in North Carolina. The first wooden bulkheads and groins were installed in the 1960s as opposed to the early 20th century in New Jersey (Rogers, 1993). With development ever increasing, North Carolina managers quickly realized the demand for hardened structures would increase. Having witnessed the devastating effects of hardened structures in New Jersey, they decided to halt the use of hardened structures before the same situation developed in NC. Accordingly, North Carolina banned the use of hardened structures in 1985 (15A NCAC 07H .0308). As a result only 3% of the NC coast has been hardened as opposed to 50% in New Jersey and Florida which lack similar bans (O. H.

Pilkey, H. L. Wright, 1988; O. R. Pilkey, et al., 1998). This policy will be discussed extensively in the Section IV.

B. Soft stabilization

The soft stabilization strategy consists of projects that temporarily stop or slow the effects of erosion. They are not intended to be long-term, one-time solutions. There are three primary techniques in this category: sandbags, beach scraping, and beach nourishment.

The first of these is the primary focus of this paper; sandbags are placed in front of and parallel to development to prevent the destructive forces of the sea reaching the structure (see Figure 5). In NC, the placement of sandbags, as will be discussed in depth in the following section, is regulated by the Coastal Resources Commission (CRC) through the Division of Coastal Management (DCM) under the authority of the Coastal Areas Management Act (CAMA). Given the evolving nature of technology, the sandbags used today are constructed of very durable material and thus act in the same manner as a seawall when in contact with the surf. Thus all of the negative consequences of seawall installations are also seen with sandbag structures. The sole difference is the “temporary” nature of the sandbags; they are more easily removed than the stone and concreted used in seawalls. The use of sandbags greatly increased after the 1985 hardened structure ban and remain quite prevalent today. A spring 2008 census revealed 369 sandbag structures along the North Carolina coast (Division of Coastal Management (DCM), 2008) which can be seen in Figure 6.



Figure 5. Photos of sandbag structures. Source: Aaron McCall (left); <http://psds.shutterfly.com/nccoastalcommunities/224?size=All&startIndex=0> (right)



Figure 6. GoogleEarth screen capture of the location of all sandbag structures, denoted by black and white circles, on the NC coast as of May 2008. Interactive data available from: http://www.nccoastalmanagement.net/sandbag_locations.htm

Geotextile tubes are an alternative version of sandbags which have gained attention since the late 1990s. Geotextile tubes are essentially a massive sandbag, 2-8 feet in diameter, that can be placed alone, instead of 10-15 of the bags currently used in a typical structure (Psuty, 2002) (see Figure 7). They have only been used once on the North Carolina coast at Bald Head Island

(Dean, 1999) but have been used more extensively in other areas of the nation such as Texas and Florida (ExpertB, 2008). The experts I interviewed, as described in detail in Section VIII, had mixed feelings about the benefits of geotextile tubes with some suggesting that tubes create less debris and are less mobile in storms while others argue that they are more unsightly and cause the same, if not worse, erosion problems.



Figure 7. Geotextile tubes. Source: <http://cache.daylife.com/imageserve/0dTTaZ67GXcCw/610x.jpg>

In beach scraping, “front-end-loaders” and bulldozers are used to transport sand from the lower beach at low tide to the upper part of the beach to create a secondary berm or to augment the dune line. Scraping must be performed very couple of weeks to sustain the beach profile as only a small amount of sand is moved each time to preserve the natural morphology of the beach. This method is only able to be used during certain environmental windows when sensitive coastal species, such as nesting turtles and shorebirds, are not using the beach (ExpertR, 2009).

The beach scraping method of erosion control was first used in the 1930s when the Civilian Conservation Corps (CCC) constructed dunes from the Virginia state line to Ocracoke in order to protect Highway 12 (O. H. Pilkey, K. L. Dixon, 1996). With this project, too much sand was moved at one time and the constructed elevated dunes actually acted to block normal

sand overwash and thus prevented the natural roll back of the barrier islands. As a result, today it is used on a smaller scale, meaning smaller amounts of sand being moved, in communities such as Topsail, which is exploring its use as a less costly alternative to beach nourishment (ExpertD, 2009).

Beach nourishment projects, the third and final soft stabilization technique, involve much larger volumes of sand movement than in beach scraping. Sand from offshore or inlet areas is added to eroded beaches by the Army Corps of Engineers (Corps) (see Figure 8). It is an inherently sacrificial process since the added sand does not eliminate the underlying erosion rate but rather is lost just as the original sand had been (National Research Council (NRC), 1995). Unlike many other states, North Carolina requires that this deposited sand be of similar quality to what is naturally found on the beach, with only 5% difference in the distribution of grain size. Like beach scraping, this too is a temporary process; the sand placed in nourishment projects typically only last 3-4 years in North Carolina before it needs to be replenished even under normal wind and wave patterns (Valverde, 1997). Catastrophic storm activity can shorten this lifespan to just a few months in some cases. Nourished beaches erode 1.5 to 12 times faster than natural ones (Leonard, 1990).



Figure 8. Aerial image of beach nourishment in progress in New Jersey. Source: <http://marine.rutgers.edu/geomorph/oceancityfill.jpg>.

Critics frequently describe the negative effects on local flora and fauna both in the removal of sediment from the source and then its deposition upon the beach (Dobkowski, 1998). At least 730 marine species have been identified on or close to North Carolina beaches. This is the highest for any U.S. Atlantic state excluding Florida. The reason for this abundance is the combination of the temperate latitude, the proximity to the Gulf Stream, and diverse habitat availability (Cooney, 2003). The beach nourishment process has the potential to threaten many of these species as it disturbs natural habitats. Burrowing animals can be dredged up with the sand and deposited onto the beach, out of water, where they cannot survive. Suspension feeder gills are clogged with suspended sediments. Differences in grain size of the nourished sand as compared to the natural beach can affect the nesting patterns of shorebirds and sea turtles (National Research Council (NRC), 1995). An additional, non-biological problem is taking sand from too close to the shoreline creates a depression that can potentially negatively affect the normal wave and current patterns (O. H. Pilkey, et al., 1980).

Beach nourishment first began in 1922 at Coney Island, NY (National Research Council (NRC), 1995). The first North Carolina project was in 1939 in Wrightsville Beach (Dobkowski, 1998). The aftermath of the 1962 Ash Wednesday storm that devastated the east coast spurred Congress authorize and fund nourishment for the first time with passage of the Water Resources Act of 1962 (Greene, 2002; O. H. Pilkey, H. L. Wright, 1988).

The typical nourishment process is as follows. A citizen raises the need for nourishment to his or her Congressman who then presents it to Congress to vote on an authorization bill to have the Army Corps of Engineers look at the project to determine if there is “federal interest.” If approved, the Corps conducts a federally funded, 12-month reconnaissance study to determine what the federal interest is and if the benefits are great enough to warrant action, i.e. is the

benefit to cost ratio greater than 1. If there is a positive finding, then Congress will authorize a feasibility study, typically with a duration of 3 years, to collect data and conduct detailed monitoring to weigh different project alternatives over a 50-year lifespan. The preferred alternative, also known as the National Economic Plan (NEP), is then presented to Congress for approval. Once authorized, the project must then be given appropriations in the Water Resources Bill. Only then, once the NEP has been both authorized and appropriated, can the Corps begin construction. Each subsequent nourishing event in the 50-year lifespan of the project must receive appropriations from Congress; it is not guaranteed that Congress will provide the funding each year.

Between 1962 and 2002, 176 miles or 55% of the NC coastline has been nourished. An additional 104 miles were in some state of the process of requesting nourishment projects (Greene, 2002). More than \$197 million has been spent on nourishment projects which have moved a total of 75 million cubic yards of sand onto the state's beaches (Program for the Study of Developed Shorelines (WCU), 2006). By 2009, every part of the developed coastline is in some stage of the nourishment process. Wrightsville, Carolina and Kure Beaches are already in nourishment cycles. Dare County has been authorized but not funded. The Cape Hatteras area is in the preliminary study phase. Bogue Banks, Surf City, North Topsail, and Topsail are finishing their feasibility studies and will likely be authorized in the coming year (ExpertR, 2009).

This prevalence in projects is particularly shocking as prior to 1990, only 12 miles of North Carolina beach was nourished (S. R. Riggs, et al., 2008). This is clear proof of the general trend that nourishment is viewed as the preferred solution to the erosion problem. This is problematic since, similar to the effects of seawalls on public perception, nourishment projects

build up the beach to give homeowners a false sense of security about their developments when in reality the new beach only lasts a few years (Greene, 2002).

C. Relocation

Relocation is the management strategy by which oceanfront structures are moved out of harm's way as the shoreline retreats. Structures can be relocated to a position on the same lot farther from the ocean or to a new location. This strategy is the least invasive as it allows for the natural beach movement to proceed normally and requires that humans adapt to nature instead of forcing nature to their will. It is also the first erosion control strategy that North Carolina employed when barrier island fishing villages were threatened in the early 20th century (Rogers, 1993).

Preventing the need for relocation has also been codified in North Carolina law since the passage of the 1974 Coastal Area Management Act (CAMA). As will be described in greater detail in Section IV, CAMA requires that new oceanfront homes be constructed at least 30 or 60 times the annual erosion rate from the mean high tide line if they are less than 5000 square feet or greater than 5000 square feet, respectively (15A NCAC 07H .0306(a)(1)). Since 1985, regulations have been increased, requiring structures that are within 20 feet of the erosion escarpment, defined as "the normal vertical drop in the beach profile caused from high tide or storm tide erosion" (15A NCAC 07H .0305(a)(8)), to be relocated within two years (15A NCAC 07H .0306(b)(k)).

In North Carolina, the relocation process is facilitated by the traditional design of coastal homes with the ground floor being elevated on stilts to prevent flooding accompanying normal storm activity (see Figure 9). This makes it easier to pick up the house and put it on a trailer for

transport to the new home site. Relocation is still practiced today although is becoming increasingly difficult as lots get smaller, preventing on-lot relocation, and as homes get bigger, preventing their transport on public roads (Rogers, 1993).



Figure 9. Elevated design of many NC oceanfront homes. Source: Aaron McCall.

D. General similarities

Each of these erosion control strategies has the major flaw of addressing only the symptoms and not the cause of erosion. This means that the erosion problem is not actually solved but rather just being staved off to a later date. However, the solution to the problem is virtually impossible; it would require either adding more sand to the system or ceasing the longshore transport system (van de Graaff, 1991). The rate of erosion could be slowed if steps were taken to address climate change but this would require a global effort which has failed in attempts to date, such as the Kyoto Protocol.

Another similarity is the scale at which these strategies are necessary. With the exception of relocation, each of the strategies needs to be employed at a large scale to be effective and/or to eliminate the negative effects resulting from an adjacent erosion control structure. In other

words, it is difficult for a single homeowner to use one of the erosion control strategies on his or her own and see lasting benefits. For example a beach nourishment project in front of a single home would quickly be washed away as the beach naturally evens itself and the installation of a seawall would likely induce similar installations by neighbors to prevent the negative impacts of flanking effect. Thus when thinking about erosion control strategies, it is necessary to think at a larger scale, at the level of whole communities, instead of at the level of the individual homeowner.

E. Economic comparison

Environmental management decisions are influenced not only by the effect of different approaches upon the natural world but also their economic impact. Accordingly it is important in comparing the effects of different erosion control structures to also address their relative costs. Since this project does not have an explicitly economic focus, I have only compiled a comparative table, compiled from a few existing sources (Table 1) (Dobkowski, 1998; Harper, 2009; National Research Council (NRC), 1990; Psuty, 2002; Randall, 2003; Rogers, 1993; Trembanis, 1999). It is not exhaustive and prices are likely to vary by location and scale of their implementation. In the table, I have also included information on some locations where the different techniques have been employed in case the reader wishes to learn more about their implementation in NC. It is important to note, however, that the listed prices are not specific to the example locations but rather are averages for the state as a whole.

Considerations of costs are especially pertinent given the current recession. The Division of Coastal Management, as all state agencies, has already had to cut its budget by 7% (Gregson, 2009). Such cuts effect enforcement and permitting personnel for local erosion control

structures. At the federal level, the cuts will mean reduced funds for Army Corps nourishment projects. Citizens will likely also be more resistant to tax increases to finance nourishment projects with state funds.

Table 1. Comparison of average costs for erosion control strategies on the NC coast.

Method	Cost	Duration (years)	Examples
Seawall	\$1000-2000 per linear foot	50-100	Fort Fisher
Groin	\$1000-2000 per linear foot	30-40	Oregon Inlet, Bogue Banks
Dune stabilization ¹	\$6-120 per linear foot	5-10	N. Topsail, Virginia-Ocracoke
Sandbags	\$450 per linear foot	5+ years	Coast wide, see Figure 6
Geotextile tubes	\$60-70 per linear foot	5-10	Bald Head Island
Beach nourishment	\$4-8 per cubic yard; \$2-6 million per mile	4-7* but NC typical max is 4-year interval	Carolina, Wrightsville, and Kure Beaches
Relocation	\$25,455-60,500 per home	Ideally indefinite	North Topsail, Nags Head

IV. Legal Mandates in North Carolina

North Carolina has been very proactive in identifying the emerging issue of oceanfront erosion and the problems associated with control structures. The state had the advantage of learning from the mistakes that had been made in other states such as New Jersey and Florida and implemented regulations better suited to maintain the natural beach morphology and minimize the hardening of the shoreline. A brief discussion of legislation and regulation that made this possible follows.

In 1972, the federal government passed the Coastal Zone Management Act (CZMA) which provides incentives for states to develop and implement management plans for their

¹ Dune stabilization was used as a proxy for beach scraping since information on beach scraping along was not readily available.

coastal regions. Among the first states to complete this recommendation, North Carolina passed the Coastal Area Management Act (CAMA) in 1974 with a stated purpose of using “state-mandated local planning as a means to improve local land use decision making, especially for the purpose of improving environmental protection” (Norton, 2005). As such it was a law that was “99% planning and 1% regulation” (Norton, 2005).

The regulations outlined in CAMA guide the behavior of the twenty coastal counties, eight of which are oceanfront (see Figure 1) and thus the focus of this discussion. The coastal counties are divided into two zones: areas of environmental concern (AEC) and other (Office of Ocean and Coastal Resource Management (OOCRM), 2006). All of the barrier islands fall into the former category and are further classified into ocean erodible areas, high hazard flood areas, inlet hazard areas, and unvegetated beach areas (15A NCAC 07H .0304). Ocean erodible areas and inlet hazard areas are the primary zones in which sandbags are installed.

As stated in its mission, CAMA’s regulations seek to restrict the use of these zones to ensure responsible use and protection of the natural environment. A 15 member, governor appointed body called the Coastal Resources Commission (CRC) is responsible for determining the regulations that are necessary to maintain this balance (“NCAC Article 7 Part 1 § 113A-104,”). Each of the 15 members holds a dedicated seat. This ensures representation of a diverse set of stakeholder interests when formulating regulations. Each member holds their post for a term of four years, with the opportunity for extension for several terms. A list of the current members along with the stakeholder group they represent can be found in Appendix I.

The CRC is supported by two bodies. The staff of the Division of Coastal Management (DCM) and the Coastal Resources Advisory Council (CRAC). DCM implements the regulations authorized by the CRC, meaning they permit and enforce. They also provide technical assistance

to the CRC upon request, in areas such as in drafting rule language or assessing competing scientific claims. The CRAC is a 45-member group that provides additional assistance through presentation of technical advice and personal perspectives (NCDCM, 2009a). The CRC is composed of representatives from local governments, state agencies, and the academic community. The CRC relies heavily upon the advice of both bodies but ultimately has the rule making authority regardless of their opinions or findings.

The CRC has passed two sets of regulations that are most notable for the discussion of erosion control strategies. The first is the setback regulations. North Carolina Administrative Code Title 15A Subchapter 07H Section .0306(a)(1) states that oceanfront development “shall be set at a distance 30 times the long-term annual erosion rate from the first line of stable natural vegetation” or 60 times if the annual erosion rate is less than 2 feet per year. The idea behind this regulation was to prevent homeowners from building in especially dangerous zones. The 30-year time horizon was selected since it is the average length of a mortgage (Coastal Hazards Information Clearinghouse (WCU), 2005).

Second, and of most interest to this paper, is the CRC’s regulation of hardened structures. In 1985, after a report from the Outer Banks Erosion Task Force, the CRC decided to implement a ban on the use of hardened structures on the oceanfront with an amendment to North Carolina Administrative Code Title 15 Subchapter 7H Section .0308 (Dhane, 2007). The only allowance was the use of temporary sandbag structures, which they considered “soft stabilization,” by permit when a building was “imminently threatened” (15A NCAC 07H.0308(a)(1)(H)(i)). Imminently threatened was defined as the building being within 20 feet of the erosion escarpment (15A NCAC 07H.0308(a)(2)(B)). This policy was very forward thinking at the time of implementation and was the envy of many other states (McGrath, 2008a).

Between 1985 and 1996, the sandbag permitting authority was delegated to the local governments and there was no uniform standard of record keeping (ExpertG, 2008). After 1996, the CRC, through the Division of Coastal Management (DCM), was responsible for permitting, at which point, there were set rules applied to the dimensions and duration of the structures which could be placed and a central permitting authority. Bags are required to be “tan in color and three to five feet wide and seven to fifteen feet long when measured flat” and the “base width of the structure shall not exceed 20 feet, and the height shall not exceed six feet” (15A NCAC 07H.0308(a)(2)(J)). When placed in front of the home, the sandbag structure may not extend laterally 20 feet beyond the foundation of the building that it is protecting and may only remain in place for two years if the building is less than 5000 square feet or five years if it is larger (15A NCAC 07H.0308(a)(2)(F)). If, at the end of the permitted time, the sandbags are covered with sediment and vegetated, then they are allowed to remain in place until they become uncovered. This allowance assures that to further disruption of the naturally re-accreted beach occurs with removal procedures. A sandbag structure can be permitted once in the lifetime of a property but extensions, so-called variances, can be granted on a case-by-case basis by the CRC.

In 2003, the North Carolina General Assembly codified the CRC ban on hardened structures with HB 1028. This bill stated that, “No person shall construct a permanent erosion control structure in an ocean hazard area. The Commission shall not permit the construction of a temporary erosion control structure that consists of anything other than sandbags in an ocean hazard area” (NCGS §113A-115.1). Therefore, the law still left the permitting authority and variance petitions to the CRC but strengthened the ban since it is harder to challenge legislation than an agency’s rules.

Despite being strong on paper, the rules and legislation were not effectively enforced. The DCM is the agency responsible for enforcing the rules established by the CRC. Their website states that they execute this enforcement through monthly aerial patrols of the coastal zone and routine inspections of permitted sites (NCDCM, 2008a). On their website, there are also listings of CAMA violations for the last five years which document only 10 sandbag structure violations (NCDCM, 2008b). From interviews with other professionals in the field, as described in Section VIII, this figure is not accurate; few people can actually recount times in which sandbags were removed when they were supposed to be. In fact, I have encountered several dramatic stories which indicate these structures are frequently placed in dimensions larger than allowed or without a permit at all. Most notably, this occurred when CRC members were taken on a field trip of barrier island sights and at one of their scheduled stops they saw a gargantuan, 14-foot structure that was visually unappealing and blocked public access (ExpertL, 2008).

In 2000, the CRC made a step to address the problem of non-compliance with permit durations. It issued a mandate that allowed all non-vegetated, uncovered sandbags to remain in place beyond their permitted time to May 1, 2008 if the community that they were located in was seeking a beach nourishment project (Pippin, 2008). After this date, however, all violating bags were to be removed. It was hoped that if given this reminder and ample notice to implement it, homeowners would voluntarily remove their non-compliant bags. Unfortunately, this is not what happened. Instead there were virtually no removals.

Anticipating this response, in the spring and summer of 2008 the DCM conducted a census of the 369 sandbag structures along the coast to determine how many were still in place and exposed and ranked their relative need for removal with categories such as percentage

blocking access, age, degree of exposure, degree of disrepair, etc (ExpertG, 2008). From this census they identified 150 structures for removal and gave each a sandbag removal index rating ranging from 0-71.² In September 2008, the DCM issued warning letters to the top 23 violations, giving homeowners 30 days to comply with the removal regulation. Those homeowners refused acceptance of the certified mail until early spring 2009 which meant in the eyes of the law they did not know they were out compliance. Despite this “ignorance” they did band together and hired Mack Paul of K & L Gates LLP to represent them as a group. They are predicted to apply to the CRC for variances at their April 2009 meeting and if denied, as is likely, will take the issue to administrative court. Should this happen, there will be at least two to three years before there is a resolution to this issue (ExpertG, 2008) after which 127 violators (and possibly more that have accrued in the intervening years) will still remain to be addressed. The decision made in this first court case will be incredibly influential in determining the course removal actions take in the future (ExpertF, 2008; ExpertO, 2008; ExpertQ, 2009).

V. Human Ecology

The crux of this problem is the conflict between public trust and private property interests in which the state is serving as the moderator. The public, through the guardianship of the state, owns the beach up to the mean high tide line (MHTL) and is guaranteed access through public trust easement to the dry sand just above the MHTL (Smith, 1989; Titus, 1998). This designation is more complicated than it might first seem as the MHTL is in a constant state of flux. In California, the courts approached this issue by assigning the designation according to the winter MHTL since that was the season during which the beach width was the narrowest (Collins, 1989).

² Information about these bags is available from: http://www.nccoastalmanagement.net/sandbag_locations.htm.

If non-compliant sandbag structures result in the loss of the beach as described in Section IIIB then the public has lost their resource for recreation. Even if sandbag structures do not completely eliminate the beach, they have the potential to inhibit the public's enjoyment of the beach either aesthetically or physically by blocking beach access. As such this conflict has the potential to be taken to court under the context of nuisance law.

Nuisance is defined as the “unreasonable, unwarrantable or unlawful use by a person of his own property working an obstruction of or injury to a right of another or the public and producing such material annoyance, inconvenience, discomfort or hurt that the law will presume a consequent damage” (Smith, 1989). More simply put this means that a property owner cannot alter their property so as to harm their neighbors or the public. The particulars of what constitutes a nuisance can and has evolved with time, but it is hard to argue that large sandbag structures are not a nuisance. Despite this available legal route, I was not able to locate any cases in which sandbags have been challenged under nuisance law in North Carolina nor did the nineteen experts I interviewed mention one.

The loss of enjoyment not only affects those individuals that live close to the beach but also all of those that visit on their vacations. In 2002, NC's eight coastal counties drew 11 million visitors and generated \$12.538 billion in beach related revenues (Ellis, 2004). Donna Moffitt, Director of the NCDCEM, succinctly captured the value of the beaches to the NC economy in a 2000 statement: “People want to come to the shore for a sandy beach. We can't sacrifice a sandy beach that is going to bring in lots of tourists and lots of tourists' dollars to protect one person's investment. Our goal is to protect the state's long-term investment, which means protecting sandy beaches” (NOAA Coastal Services Center (NOAA), 2000).

A secondary component of public trust is protection of the natural resources, or the other organisms that use the beach. Many species, as mentioned in Section IIIB, use the beach at some point in their life history, so if it is completely eroded away, then they will suffer. The scientific community provides the arguments typically used in favor of this aspect of the public trust side of the debate. As discussed in Section II, their studies have shown that the environment is in a state of flux and wants to push back towards the mainland. They therefore argue that as the ocean advances, the public trust areas should as well. This means structures that encounter ocean, thereby effectively eliminating public access, should be removed. As a result of removal, the public and other organisms using the beach will benefit.

On the other side of the debate are the oceanfront property owners. As the beach gets eroded away, their property and the development on it is lost which directly corresponds with depreciation of their assets. When the CRC denies them the right to protect their property against this threat, homeowners argue that the state is “taking” their property and therefore must give them some compensation. Property rights are one of the founding principles of the constitution of the United States (J. Kalo, W. Clark, 2006), so this is not an issue that is taken lightly, especially when the homes that are being lost are worth millions of dollars.

North Carolina adopts a rather unique stance on this divide, one which is different from many other states. In most states, the destructive power of water is viewed under the “common enemy rule.” This means that property owners are allowed to take all necessary steps to protect their property against the water, even if that protection is to the detriment of adjacent property owners. However in NC, the guiding principle is what is known as “civil law” which means that property owners are responsible for the injury that they cause neighbors if they alter the natural movement (J. Kalo, W. Clark, 2006). Since, by definition, sandbags or other hardened structures

alter the natural flow of water and sand on the beach, NC property owners do not have a common law right to construct them; instead, they are only allowed to if the state grants them permission, even if the consequence is their home falling into the sea.

This principle was upheld in the *Shell Island Homeowners Association v. Tomlinson* court case (134 NC App 217, 228 517 SE 2d 406, 414 (1999)). This is the only high profile hardened structure court case in NC that has been resolved to date. In it, the homeowners in a development that was threatened by the migrations of Mason Inlet were denied a permit by the CRC to construct a steel seawall to protect the development, after several rounds of sandbag structure approvals. Frustrated with this decision, the homeowners took the issue to court, hoping that a judge would approve their request. Instead both the Superior Court and Court of Appeals upheld the CRC's authority to make final decisions and deny the construction of a seawall (NOAA Coastal Services Center (NOAA), 2000).

The second most publicized case is still at trial but concerns a similar matter. The owners of the Riggings condominium complex in Kure Beach are challenging the CRC's variance denial for an extension of their sandbag structures. This situation is one of the most cited examples of egregious sandbag abuse as the sandbags have been in place since the start of the hardening ban in 1985. Furthermore, the Riggings had the opportunity to relocate its building to an empty lot it purchased across the street with the aid of a Federal Emergency Management Agency hazard mitigation grant but chose not to do so (McGrath, 2008b).

A third likely case to undermine the CRC's power to regulate sandbag use is anticipated in the spring of 2009. As previously mentioned, it is very likely that twenty-three property owners who have been given notice of their expired permits will be denied variances in the April 2009 CRC meetings. Unwilling to lose the investment of their homes without a fight, they will

take the issue to court. The decision of the court in this manner will guide the fate of sandbag use in the future; if upholding the CRC's authority, then the remaining 127 cases will likely be quickly resolved with removal but if the CRC's decision or authority is questioned, then the regulations will be weakened and more court cases will ensue.

These court cases drain the resources of the DCM. In the 2007-2008 fiscal year, the DCM spent \$79,820 on legal fees. The projections for 2008-2009 fiscal year are higher, \$116,734, in anticipation of contested cases being brought by the twenty-three homeowners (Stadiem, 2008). With budget cuts occurring due to the recession as mentioned previously, this increase in expense is poorly timed. At their November 2008 meeting, CRC members expressed concern that this increasing cost would influence their decisions in variance requests as they might more willing to grant a variance than drain the DCM's time and resources on litigation.

Regulation change is a likely a prospect. The DCM has already begun discussions about special extension rules for sandbag structures in inlet hazard areas (IHA)³ (ExpertP, 2008). The DCM, under the direction of Jeff Warren, have proposed new rule language to increase setback requirements and allow multiple sandbag permits in the IHA, instead of just one in the lifetime of the structure (McGrath, 2009). As inlet hazard areas are where most sandbags are located already, I think that this proposed change would have the effect of weakening the hardening ban and temporary status sandbag structures are supposed to fill. Similarly the public is pushing for a weakening of the hardened structure ban by introducing legislation several times over the last three years to the General Assembly calling for the conditional use of terminal groins.⁴

³ Inlet Hazard Areas are defined as: "This area shall extend landward from the normal low water line a distance sufficient to encompass that area within which the inlet shall, based on statistical analysis, migrate, and shall consider such factors as previous inlet territory, structurally weak areas near the inlet and external influences such as jetties and channelization." in 15A NCAC07H.0304

⁴ The most recent example of this was with Senate Bill 599, available from: <http://www.ncga.state.nc.us/sessions/2007/bills/senate/pdf/s599v2.pdf>.

Terminal groins are groins placed immediately adjacent to inlets, thus at the end of barrier islands (Carteret County Shore Protection Office (CCSPO), 2008). As described in Section 2A, they function to build up beach on the updrift side of the groin while depleting beaches on the downdrift side by inhibiting the natural longshore flow of sand. Due to the 2003 NC General Assembly legislation, the CRC is no longer allowed to permit terminal groins through the variance process. Instead, it is required that they receive permission via General Assembly legislation to consider such a petition. In anticipation of such legislation, the CRC has already begun to educate themselves on the effects of groins with a series of presentations by scientific professionals at their last meeting in February 2009 (NCDCM, 2009b).

VI. Dare County, NC case study

As described in Section II, the problem of coastal erosion is dynamic and increasing in scale. The number of structures that are going to be put in harm's way increases every year. This is due to two factors. The first is the effects of climate change as described in Section II, sea level is rising and hurricanes are increasing in intensity. These forces put extra pressures on the low lying beach and cause the loss of horizontal width of the beach. The second is that development restrictions established by CAMA and the CRC have reached the end of their initial lifetime. Guidelines for setbacks set in 1970s were designed to afford protection for 30 years, a time span which has been surpassed. Consequently many of the structures which were abiding by regulations are now finding themselves in harm's way (ExpertK, 2008; ExpertO, 2008).

To demonstrate the severity of the problem, I performed a geospatial analysis on the first row of oceanfront structures in Dare County, NC north of Cape Hatteras. The purpose of the analysis was to determine how many of these structures would be in contact with the ocean in 10,

25, 50, and 100 years. A brief description of the data and processes I used in this analysis are provided below while detailed information including Python scripts and ArcGIS model images can be found in Appendix II.

The model incorporates two elements, erosion rates and sea level rise, to determine when existing first row structures would come into contact with the ocean. I used 2007 LIDAR digital elevation model (DEM) data for Dare County, NC downloaded from the NCSU library (http://geodata.lib.ncsu.edu/dem/nc_20f) to determine the location of oceanfront structures. This was a high-resolution data set with a resolution of 20 feet. The boundaries of the first row of development were hand digitized using ArcGIS 9.3. This resulted in 2843 structures in the study area. Taking into account the imminently threatened definition described in Section IV, the digitized home perimeters were then buffered 20 feet for the final at-risk structure polygon. A visual of this process can be seen in Figure 10 and the final results of the digitization can be seen in Figure 11.



Figure 10. Example of the digitizing process map

Next I used the shoreline position data provided by the North Carolina Division of Coastal Management on their website (<http://dcm2.enr.state.nc.us/Maps/chdownload.htm>). I selected three years with the most comprehensive coverage of the study area to use for this

analysis (1980, 1998, 2004). The study area was split into 10 equal lengths, labeled zones 1-10, as seen in Figure 12, to create a more localized estimation of shoreline change/erosion rates. Zones 1-2 were eliminated in subsequent analysis since the aerial photography images used to digitize development did not extend northward of zone 3 (see Figure 11). Through a series of steps involving the Euclidean Distance and Zonal Statistics tool, the average rate of shoreline change was determined for each zone between 1980-1998 and 1998-2004 (see Appendix II). The two rates were then averaged to determine a final change rate used for the subsequent analysis (see Table 2). It is important to note that while the rate of change is positive, it actually indicates loss of beach due to the techniques I used in the modeler.

I used these predicted erosion values to erode the eastern edge of the barrier islands from the DEM using the 2004 shoreline as the base line. The final result was five new DEMs reflecting the new position of the shoreline in each of the future years and eliminating those areas from the original DEM that were predicted to be underwater.

Table 2. Erosion rates: average of the two time periods and the resulting horizontal loss for the five time periods. Measurements are in feet. Zones 1 and 2 are included merely for reference but were not ultimately used in the analysis.

Zone	Total average annual shoreline change	2007	2017	2032	2057	2107
1	5.35	16.06	69.60	144.56	283.77	551.48
2	3.29	9.87	42.77	88.83	174.38	338.88
3	3.32	9.95	43.11	89.54	175.77	341.60
4	3.34	10.03	43.46	90.27	177.19	344.35
5	3.52	10.56	45.74	95.01	186.50	362.44
6	19.10	57.29	248.24	515.58	1012.07	1966.86
7	9.17	27.50	119.16	247.48	485.80	944.09
8	8.75	26.24	113.73	236.20	463.66	901.07
9	8.15	24.45	105.96	220.06	431.97	839.50
10	13.42	40.26	174.46	362.35	711.27	1382.29

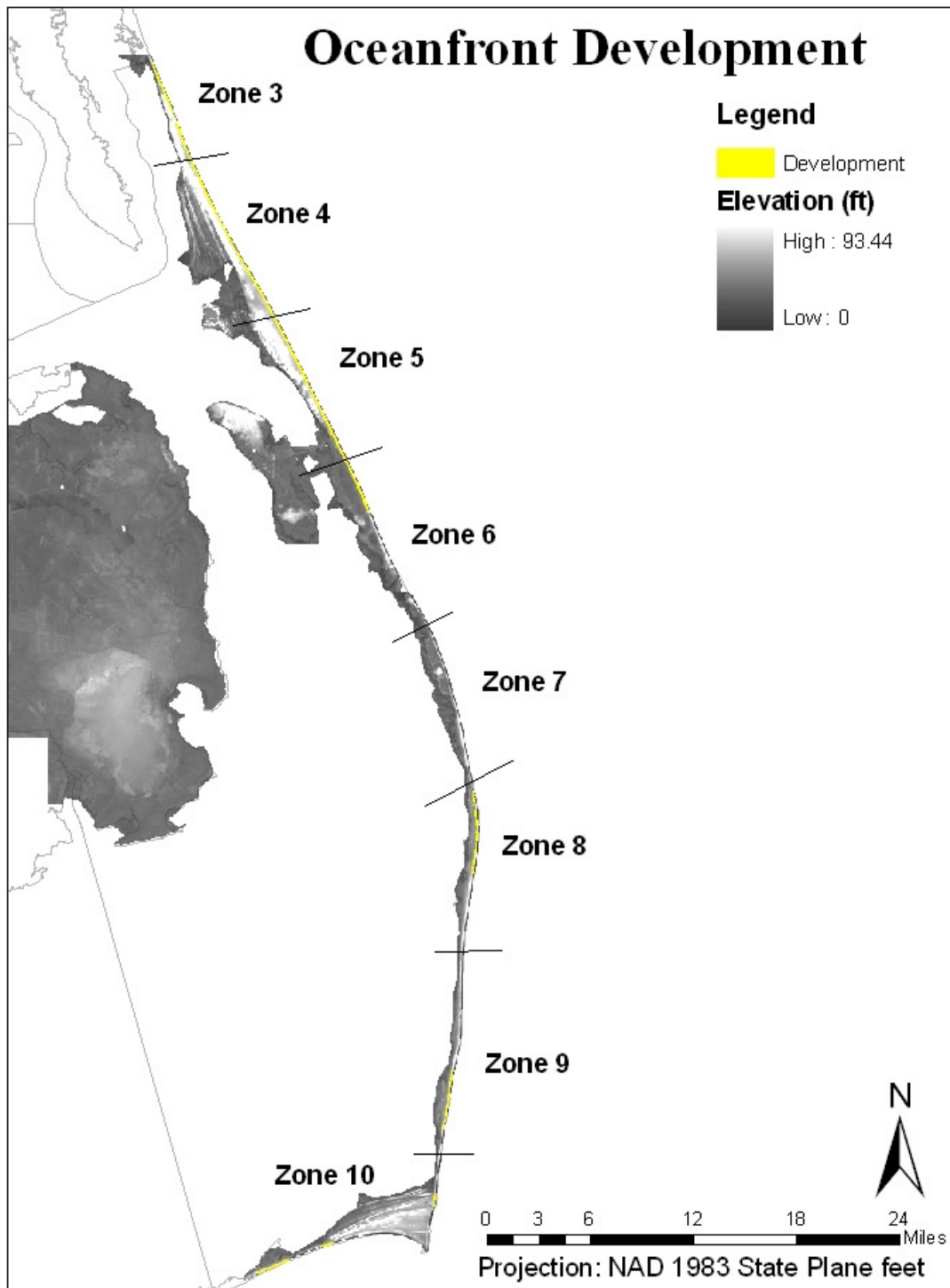


Fig. 11. The zones in relation to the presence of first-row development.

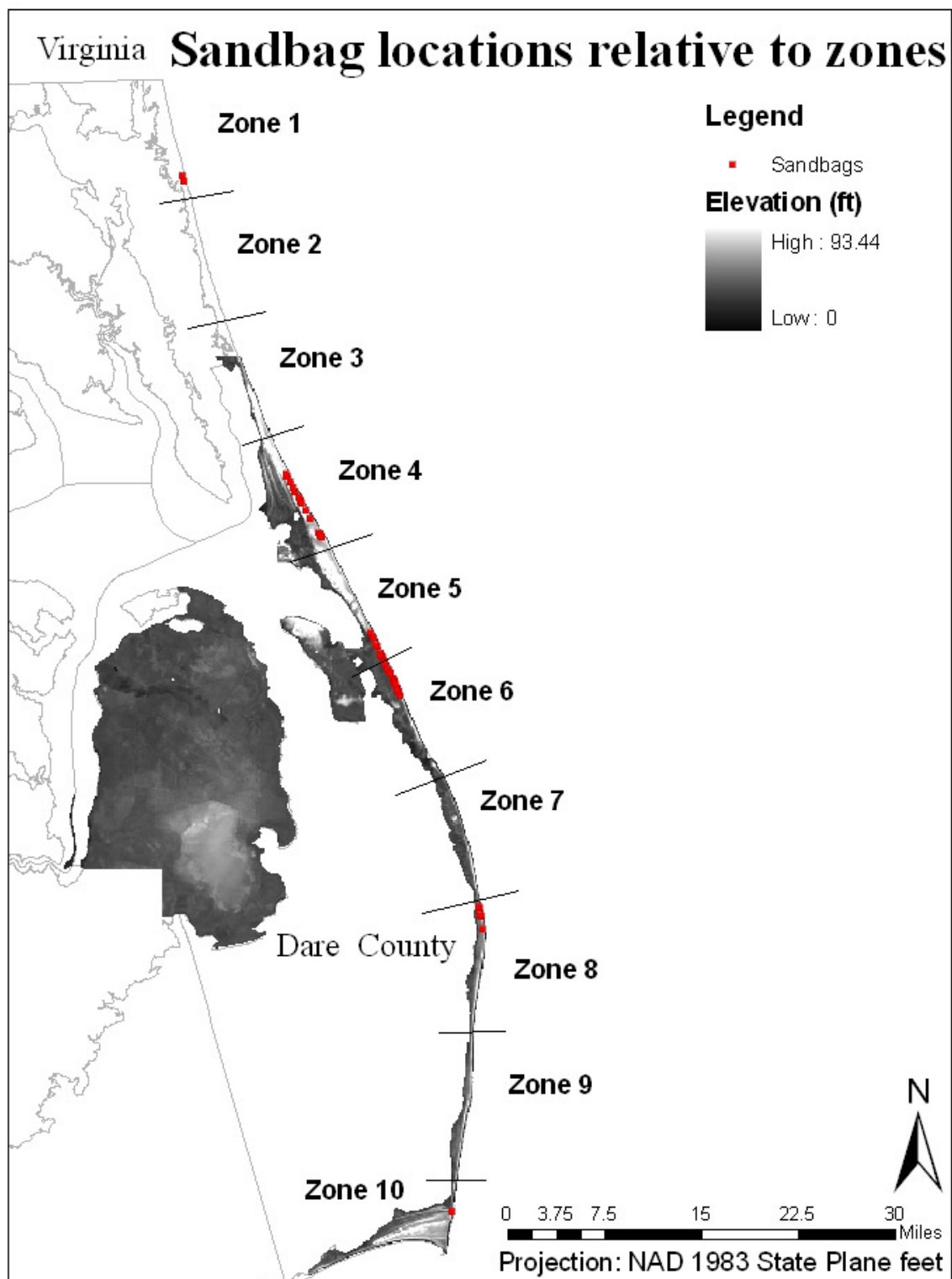


Fig. 12. Visual representation of the different zones with sandbag locations included.

Since I was interested in the cumulative effect of erosion and sea level rise, I used sea level rise average of 2.88 millimeters per year as determined from sea level recordings from 8 NC CO-OPS coastal water level stations in North Carolina (Zervas, 2004) to determine how much elevation would be lost in the five time periods. Using the DEM layers created for each of the years with the shoreline data, areas identified as underwater in the future year were eliminated.

Finally, the number of digitized structures encountering the water in the future years was determined by intersecting the sea level rise and erosion adjusted DEMs with the digitized structure layer. This identified those homes which were on dry land so it was necessary to use inverse logic to determine the number of homes that were in the water (see Table 3). (Note: This seemingly backwards way of conducting the analysis was necessary given the limitation of tool function in ArcGIS). The designation as in the water indicates only that some portion of the buffered structure perimeter encountered the water. In some cases it could only be a one-foot protruding edge of a home while in others the entire structure may be underwater. The lack of specificity in the degree of harm is a weakness of this type of modeling prediction.

Table 3. Homes in peril

Year	Number of homes	Percentage
2007	37	1.30
2017	313	11.02
2032	579	20.38
2057	1612	56.84
2107	2776	97.71
DCM 2008 data	79	2.78
Total	2841	

Table 4. Homes in peril by zone. Absolute numbers listed with percentages in parentheses..

Zone	2007	2017	2032	2057	2107	Total in entire study area, regardless of state of peril
3	0 (0.00)	0 (0.00)	1 (0.17)	187 (11.29)	353 (12.42)	359 (12.33)
4	0 (0.00)	2 (0.63)	61 (10.20)	290 (17.51)	635 (22.34)	662 (22.73)
5	1 (2.70)	11 (3.49)	53 (8.86)	407 (24.58)	807 (28.39)	843 (28.95)
6	30 (81.08)	247 (78.41)	349 (58.36)	361 (21.80)	361 (12.70)	361 (12.40)
7	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
8	6 (16.22)	20 (6.35)	85 (14.21)	172 (10.39)	369 (12.98)	369 (12.67)
9	0 (0.00)	0 (0.00)	0 (0.00)	160 (9.66)	239 (8.41)	239 (8.21)
10	0 (0.00)	35 (11.11)	49 (8.19)	79 (4.77)	79 (2.78)	79 (2.71)

As the reader can see, Dare County is likely to see a large increase in the use of sandbag structures to protect homes in the coming decades. It is important to contextualize the data beyond just looking at the final numbers by referencing erosion rates in Table 2 as well as the relative location of development shown in Figure 11. Certain areas of the coast such as Zones 6 and 10 (see Table 2) are particularly susceptible given their large annual erosion rate. The high erosion rate in Zone 6 is a result of the presence of Oregon Inlet and in Zone 10 it is as a result of the presence of the cape. As previously described, inlet areas and capes are particularly susceptible to large movements of sand. Other areas, such as Zones 4 and 5, are more susceptible in later years given their density of development. Overall the future does not look good for the first line of homes in the next 100 years as my work predicts 97.71% will be within the affected water zone.

The simplicity of the model does have notable drawbacks. It does not take into account storm effects, localized wave activity, or underlying geology all of which can influence the change in shoreline position. The model is designed to only provide one perspective on how the shoreline of Dare County will change in the next century and by no means represents an expert prediction as I am only trained in geospatial analysis at the intermediate level. Nonetheless, there is general consensus that homes will be lost at increasing rates the coming century. This is

reflected in the increased number of structures that have required sandbag protection since the 1990s; of the 369 sandbag structures documented on the NC coast in May 2008, 269 of them had been installed after 1996 (Walker, 2008). Accordingly preparatory planning and management action needs to be taken by the state to adapt to the coming changes.

VII. Management Alternatives

With the mandatory sandbag removal date come and gone, the state is facing a precedent setting management period. Its decision now will set the tone for the coming decades. In my opinion, there are three primary options available to the state: maintain the status quo, adherence to the law as it is written, and alternate measures. Each of these three is discussed below with a description of the likely effects each will have on the different stakeholder groups (private owners, public trust, the environment, the local economy).

The first option would mean proceeding with business as usual as has been done for the last 20 years in which sandbag permits are issued but the time durations are not enforced, or at least enforced in a relaxed manner. The DCM would continue to tackle the non-compliant bags in a piecemeal fashion in which it takes several years in contested cases before there is resolution. While this is the least costly option (at least in terms of the money it takes to initially implement), it is the least beneficial option for all stakeholders; homeowners are still in danger but in a state of denial about it while the public, natural environment, and local economy have lost their beach. Furthermore, this solution is one which does not fix the problem over any sustained period of time. Erosion will continue to proceed, houses will fall into the ocean, and the beach will be lost.

In the second option, there would be no difference from the rule on paper and the rule in practice. Bags would continue to be permitted but removal deadlines would be enforced, perhaps even by removal actions taken by the state. This would still afford private homeowners with the temporary relief that they need to buy time to decide upon a more long-term solution. It would also allow the beach to remain relatively unchanged so the public and tourists would still be able to reap the benefits. Similarly species using the natural environment would be able to continue to do so. However, this would only be a short-term solution since erosion would still continue to put more homes in danger. Under this management scenario, the private homeowner would bear the brunt of the cost since their homes would only be protected for the short duration of two or five years. It would also require that the DCM put more staff and time into ensuring compliance with the rules.

The third and final option is to pursue alternate measures. This would mean a de-emphasis on sandbags as temporary erosion control structures and their eventual phase-out. Instead the state would pursue alternate erosion controls, specifically relocation and nourishment projects. Each of these alternative measures has different consequences. Under a relocation program, the public, the natural environment, and the tourism economy would benefit because the beach would be protected. The local economy would potentially be harmed via a loss of tax base if homes could not be relocated in the same community. This is a likely outcome since barrier islands are essentially over developed. Private homeowners would also be negatively affected by this management choice since many of them would lose their oceanfront homes and would likely be required to bear a large portion of the cost of relocation. There are no good study estimates for how much a comprehensive relocation project would cost as it has never actually been considered a viable policy (ExpertB, 2008). However almost all of the costs would be borne

initially with the moving of houses but subsequent costs would be eliminated since the typical losses and rebuilding necessary after storms would be reduced. This solution best serves stakeholders in the long run as it allows the dynamics of barrier islands to proceed naturally.

Under nourishment projects, there is a different balance of benefits and costs. Unlike under a relocation program, private homeowners would benefit since their homes could remain in place. However this would occur at the expense of the public since it would be their tax dollars that helped to fund the expensive process. Typical nourishment plans are cited as costing as much \$6 million for every mile of beach nourished over the course of ten years (Randall, 2003). A specific study of the 4.5 mile stretch of Nags Head, NC revealed that to protect the same number of endangered homes nourishment projects cost \$9 million every 3 years whereas relocation is approximately \$2 million every 20-25 years (Coastal Hazards Information Clearinghouse (WCU), 2005).

Thus effect of nourishment on the local economy would be mixed; it would require local revenue to help fund the project but such projects would sustain the tourism industry revenue. While a very tempting management option because it benefits many stakeholders in some manner, this is still not a long-term solution to the problem because it is cost prohibitive and requires frequent renewal. As such it is referred to as an “ongoing” project by the Army Corps and as an “eternal” project by coastal geologists (O. H. Pilkey, et al., 1980).

Critics argue that beach nourishment is “little more than building sand castles to protect against an advancing sea”(National Research Council (NRC), 1995) and suggest that nourishment as the savior is the “fleecing of America” (Douglass, 2002). Alternatively nourishment is referenced to as a “mid term solution to a long term problem” (Gayes, 2009).

Beyond those problems, there is also a potential stumbling block of the availability of sand. While it may seem like North Carolina has an abundant supply of sand offshore, the number of beach nourishment projects that are demanding that sand is ever increasing. The shoals off the state's three capes are not yet feasible as sources because they are distant from many of the beaches that need the sand and the effects of large scale removal from these sources has not been well-studied. As such, there is potential that beach quality sand sources could be exhausted (ExpertK, 2008; J. Kalo, et al, 2009; S. R. Riggs, 2009). It has been suggested the 129 inland active sand and gravel pits in coastal North Carolina could be used to supplement the oceanic supply, however, transportation and processing cost of this sand supply make it uneconomical for medium-large projects (greater than 50,000 yd³) (Dobkowski, 1998).

VIII. Expert opinion on the future

A. Background

In addition to drawing my own conclusions from a literature review, I spoke with nineteen experts and decision-makers in the field to see how they viewed the issue and what they expected in the future. I spoke with all but four of the participants over the phone for durations ranging from fifteen to ninety minutes. An outline of type of questions that were asked can be found in Appendix III. This protocol was approved by the Institutional Review Board for the Protection of Human Subjects at Duke University as demonstrated by the exemption letter replicated in Appendix III. As part of the conditions of exemption, expert participant responses had to remain anonymous.

The experts had a wide variety of backgrounds but can be classified into three broad categories. Five are from academia, with specialties relating to coastal geology, coastal

engineering, or policy. Ten experts are affiliated with North Carolina government, either as staff members of state agencies or holding political posts with local governments or the Coastal Resources Commission. Four are employed by non-profit organizations active in North Carolina. Sixteen of these participants agreed to speak with me on topics about both science and policy. The remaining three preferred to limit their discussions to technical, scientific information so their responses have been excluded from this qualitative summary.

While I discussed many things with the participants, I have elected to focus on three topic areas: views of the use of the ban, predictions on the status of the ban in the future, and preferred erosion control strategy. The perspectives of the sixteen experts were discerned from written transcripts of the recorded interviews and are demonstrated herein with summary statements and a few direct quotations which illustrate key themes.

B. Views of the current and future ban

Thirteen (68%) of the experts were in favor of the current hardening ban. They believed that it was well founded and had served the state a great benefit in the avoidance of the problems seen in other states with heavily engineered shorelines, such as New Jersey. For example, Expert C commented, “I think our approach to hardened structures over the last 20 or so years has been a good one. That is to be very, very hesitant to allow hardened structures. It is still a very good approach.” Furthermore the consensus agreed that the temporary allowance of sandbags was a good idea but that it has not been enforced to the best of its capacity. This was well demonstrated by Expert F who stated, “The state was trying to help private property owners save their structure and give them a temporary fix. Unfortunately some property owners have abused that and refused to remove sandbags and not make serious efforts to relocate their structures. So we are

faced with a lot of “temporary sandbags” that have been there for decades. It’s a mess for the state to deal with. I know that they still think the sandbags are better than a hard structure, but you cant move the sandbags. They are hard as a wall.”

The remaining three experts (16%) did not demonstrate their dislike for the ban with an outright condemnation but rather indicated disapproval by endorsing the use of terminal groins. Each of the three experts stressed the need for “additional tools in the toolbox to help deal with erosion control” (e.g., Expert N). However, they were adamant that this desire for change did not mean that they wished for “armoring” of the coast. Their frustration at the limitation of sandbags was carried over into their projection about the hardening ban in the future. All three believed that there would be allowances that broke the ban. Their beliefs were shared by two additional experts who likewise believed that the ban would be weakened. These two cited the increasing lobbying power as the driving force behind the change.

Fourteen experts (74%) expressed varying degrees of confidence that the ban would remain in place. Five (26%) were hopeful but cautious in asserting this hope, qualifying their belief based on certain contingencies like funding for beach nourishment projects or sustained popular support. The remaining nine (47%) had overwhelming optimism that the ban would be retained. For support of their belief, a few individuals pointed to the codification of the hardening ban in 2003 as solidifying this direction; in other words, now that the regulation is in the North Carolina Administrative Code, it is much harder to change. Others referenced that “the state has such a long history of managing shorelines and showing that these structures do have negative impacts on the shorelines” (Expert B) that the ban would remain in place even in the face of the increasing pressure of climate change. Furthermore Expert S summarized a primary

concern of the pro-ban experts by equating the allowance of any hardened structure to “gateway drugs.”

C. Preferred erosion control strategy

The same sixteen experts who supported the current ban established that relocation or retreat was the preferred erosion control strategy. But while it was agreed “relocation is the only long term sustainable solution,” it was unlikely to happen in actuality as it is the erosion control strategy that has the “largest political hurdles” (Expert I). Expert A was more direct about the problem by saying, “Relocation doesn’t exist. There is nowhere to move them to. Relocation is a great idea if you’ve got land. But the barrier islands of North Carolina have no land left so I don’t know where we would relocate to.”

Three experts suggested that the solution to the threat poised by amendments to the ban was to increase education of the general public about the issue. They believed that if more people were aware of how their tax dollars were being spent, they could raise enough opposition to the beach homeowners/developer’s lobby to prevent any alteration of the ban.

Those against relocation as the primary erosion control strategy proposed beach nourishment as a preferable alternative. However whenever beach nourishment was proposed, the issue of cost was simultaneously raised. Thus feasibility was a concern for both sets of experts, those in favor of relocation or nourishment.

D. Implications

While there was consensus among the experts, this does not mean their predictions will come true. Many of the experts couched their responses with this sentiment and reminded me that they cannot guarantee the outcomes. Unpredictability has already been seen in the erosion

control issue with regard to human choice. In several instances, coastal users did not take the option that was the most logical in terms of long-term sustainability. Instead economic factors drove the decision making. For example, the Riggings Condominium (as mentioned in Section IV) received FEMA funding to move its structure across the street to a protected lot but turned it down since it was not sufficient to cover the full cost of the move (ExpertL, 2008). An oceanfront position is much more valuable to buyers, so the Riggings owners decided that the risk posed by the ocean was not sufficient to outweigh the economic loss that would be suffered by moving across the street. Now they are still in court to get a variance approved by the CRC (Surfrider Foundation, 2008). Similarly, during the period in which the Upton-Jones Amendment was active,⁵ many at-risk homeowners still did not ask for pre-emptive payments but rather waited until the ocean began to damage their structures; the perceived benefit of oceanfront property was high enough to outweigh the monetary value gained by taking responsible action (National Research Council (NRC), 1990). Thus even if the CRC continues to uphold its rigorous approach to erosion control, individual citizens can undermine it with economic incentives for risky behavior.

IX. Recommendation

My personal recommendation for addressing oceanfront erosion is three fold and a combination of two of the management approaches described previously. First, I recommend that the DCM uphold the sandbag regulations as they are written. This may seem like common sense, but it has not been executed to date in this manner. I agree with the CRC that sandbags should be

⁵ See Section IX for full description of Upton-Jones Amendment.

allowed on a permit basis to give private landowners the time to recover from acute erosion events, but they should not be used as a long-term solution to chronic erosion problems.

Since the DCM has struggled in the past with enforcing removal deadlines and is currently facing a particularly heavy load of non-compliant structures as a result of the passing of the May 1, 2008 deadline, it is my recommendation that a special task force be created to address all of the 150 structures that are in violation. This task force would consist of legal professionals who would tackle the mounting court cases that are predicted to arise when contesting CRC denial of variance requests. After these 150 structure violators were processed, the task force could be dismantled as the DCM's regular staff could likely handle the workload that would be presented by contemporary permits.

In addition to the creation of a task force, I believe that local governments and the state as a whole should begin looking into the development of a relocation program for vulnerable homes. This could include the identification and purchase of undeveloped areas to which the oceanfront homes could be transferred once they are imminently threatened and/or a buy-out program to compensate homeowners for the loss they incur when the CRC denies a variance to increase the duration of sandbag placement beyond the standard two or five years. This program could be modeled after the Upton-Jones Amendment (UJA) or Section 544 of the National Flood Insurance Program (NFIP).

The NFIP was established by the 1968 National Flood Insurance Act of 1968. Its purpose is to provide insurance for "damage and loss which may result from erosion and undermining of shorelines by waves or currents" (National Research Council (NRC), 1990). It insures 1200 coastal communities in the United States that have management regulations for new coastal developments. In 1987, representatives from North Carolina and Michigan, two states which

were battling high erosion rates, succeeded in passing the amendment. The UJA allowed for 110% reimbursement for the value of homes that were demolished and 40% for relocation of the home (excluding purchase cost of a new lot) (Coastal Hazards Information Clearinghouse (WCU), 2005; National Research Council (NRC), 1990; Rogers, 1993). This was revolutionary since prior to the UJA's passage, the NFIP only provided payments to structures that had already sustained damage (National Research Council (NRC), 1990).

The rationale behind the UJA was that it would act as a carrot for oceanfront homeowners by providing incentive for the proactive removal of homes from harm's way (National Research Council (NRC), 1990). It was thought that NFIP insurance payments would be cheaper for relocating or demolishing an endangered home that had not yet fallen into the sea rather than payments to restore a damaged home (Psuty, 2002). Prior to the UJA, homeowners were solely responsible for the costs of relocation and so it was felt that some homeowners allowed their homes to fall into the sea just to receive the NFIP payments (Rogers, 1993).

The amendment had many thoughtful considerations. Only homes that were insured prior to June 1, 1988 were eligible, the home had to be condemned or declared threatened by the state before a claim could be made, and if relocation was selected, the new home site had to comply with state setback rules (National Research Council (NRC), 1990; Rogers, 1993). However in practice, the UJA was not as influential or effective as hoped. Homeowners making claims were disproportionately located in certain states; by March 1995, 60% of the nation's claims (238 total) were made by NC residents with a third of which were from Nags Head alone (Coastal Hazards Information Clearinghouse (WCU), 2005). Furthermore, homeowners were not simply choosing to relocate but rather demolish their homes. This was the more costly of the two options with average settlement claims roughly twice as much for demolition (\$55,235) as for

relocation (\$25,455) (National Research Council (NRC), 1990). Finally, the average age of the homes was quite young, only 21 years, as compared to a typical home lifespan of 75 years. Moreover up to 22% of the homes were constructed after 1978 (Rogers, 1993). This indicated that states were not regulating coastal construction effectively and homeowners were allowing the allure of oceanfront property cloud their rational decision-making in building in a notoriously hazardous area.

Studies concluded that the “Upton-Jones Amendment will not induce voluntary, anticipatory action by owners and is insufficient to overcome individual, market, and regulatory incentives for oceanfront owners to remain on the coastline” (Davidson, 1993). Consequently, the UJA was actually increasing costs for the NFIP instead of its initial intention to decrease them. Accordingly, the UJA was repealed in September 1995 by the National Flood Insurance Reform Act of 1994 (Psuty, 2002). In its place the National Flood Mitigation Fund (NFMF) was established. This program provides grants to state and local governments to develop programs to reduce the risk of flood damage in NFIP areas. These programs can include beach nourishment, relocation or demolition, acquisition of flood-prone lands for public use, and technical assistance (Coastal Hazards Information Clearinghouse (WCU), 2005).

Recently there has been renewed interest in this type of program. At the February 2009 meeting of the CRC, the CRAC proposed submitting a resolution to the NC General Assembly for the establishment of trust fund dedicated to beach projects (Royal, 2009). Furthermore an employee of the NC Coastal Federation indicated that they were in talks about the development of a resolution for an Upton-Jones-like policy for the state.

Naturally, state aid in “bailing” out these homeowners who have built in a notoriously dangerous area will be controversial, but given the political power of these homeowners in the

past, I feel that North Carolina would be unlikely to pass alternate regulations which do not provide compensation. If the state and local governments do chose to adopt this measure, then subsidization practices for coastal development currently endorsed by the state through the North Carolina Insurance Underwriting Association's Beach Plan need to cease.

Finally, no additionally development, either in the form of new construction on empty lots or replacement of homes demolished by storms, should be allowed in the inlet hazard areas and other areas particularly susceptible to erosion regions of the coastal zone. The specific designation of the boundaries of these areas should be determined by the Science Panel on Coastal Hazards, a 12 member group of engineers and geologists who serve in a support role to the CRC (ExpertL, 2008).⁶ By eliminating new development in these highly volatile areas instead of just using setback limits to restrict development, the state would reduce the additional problem properties it would see in the coming decades instead of just postponing them.

As a final consideration, caution needs to be taken when adopting a uniform policy for the entire coastline. In reality each area should be treated separately since it has different dynamics (Overton, 2009), however, it is impractical to approach management on such a case-by-case basis. It requires too much time to study and just as one thinks he or she understand the dynamics, they change. For perceived justice issues, it is also necessary to adopt a uniform policy, or at least an approach that only has a handful of different designations.

X. CONCLUSION

North Carolina is facing a growing threat of coastal erosion. It has taken steps early to address this threat through CAMA regulations including the mandatory 30-year erosion setback

⁶ More information on this panel can be found at: <http://www.nccoastalmanagement.net/Hazards/scipanel.htm>.

and the 1985 ban on hardened structures. These policies have placed the state ahead of others in protecting the natural state of its barrier island beaches. However, the existing regulations as they are currently being enforced are not sufficient to address the looming peril that climate change poses. According it is my recommendation that stated preferences for relocation and only short term use of sandbags be implemented. This requires a shift in the government's emphasis away from the short-term protection and benefits afforded by beach nourishment projects and other soft stabilization towards an outlook that prioritizes long-term benefits. It is important that regulation of erosion control strategies remain consistent at the state level since the effects, both positive and negative, are felt in areas adjacent to those with direct implementation. It would be even more beneficial if this regulation could be expanded to the entire region as coastal processes are not restricted by political boundaries (National Research Council (NRC), 1995). This is not a far-fetched idea as recently there has been a push for the development of a South Atlantic Coastal Alliance, a partnership between North Carolina, South Carolina, Georgia, Alabama, and Florida. This idea is that this type of collaboration will aid in the attraction of federal funds for shared problems (Emory, 2009).

APPENDIX I

Current (2009) CRC members

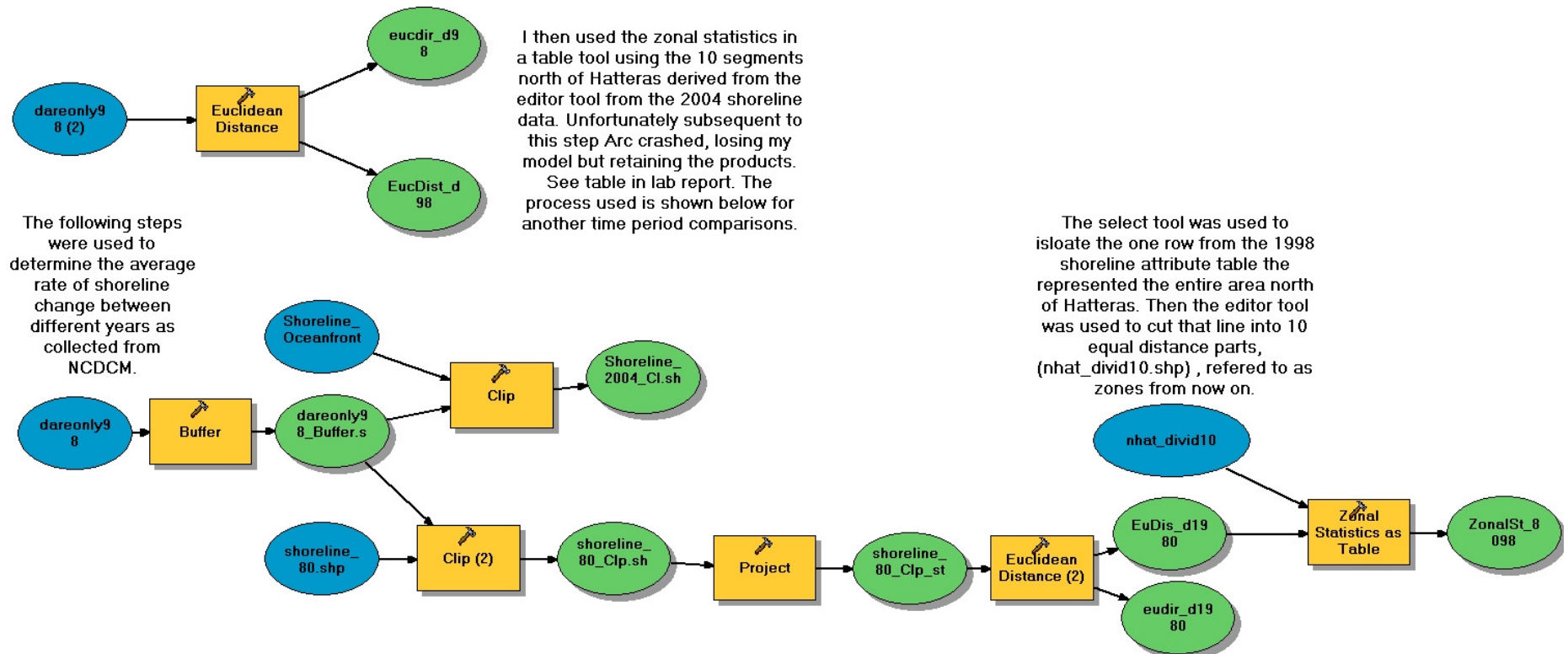
Member	Association	Term Ends
Bob Emory (Chair)	Coastal forestry	6/30/10
Joan L. Weld (Vice Chair)	State or national conservation organization	6/30/10
Charles B. Bissette, Jr.	Coastal engineering	6/30/12
Renee Cahoon	Local government	6/30/10
Veronica Carter	At-large	6/30/12
Charles M. Elam	Coastal land development financing	6/30/12
Dr. James R. Leutze	At-large	6/30/12
Ed Mitchell	Coastal land development	6/30/12
Jerry L. Old	Local government	6/30/12
William R. Peele III	Coastal agriculture	6/30/12
Wayland J. Sermons, Jr.	Sports fishing	6/30/10
Melvin M. Shepard, Jr.	Marine-related business	6/30/12
David Webster	Marine ecology	6/30/10
Robert O. Wilson	At-large	6/30/10
Lee Wynns	Commercial fishing	6/30/10

APPENDIX II

A. SHORELINE CHANGE

Part 1

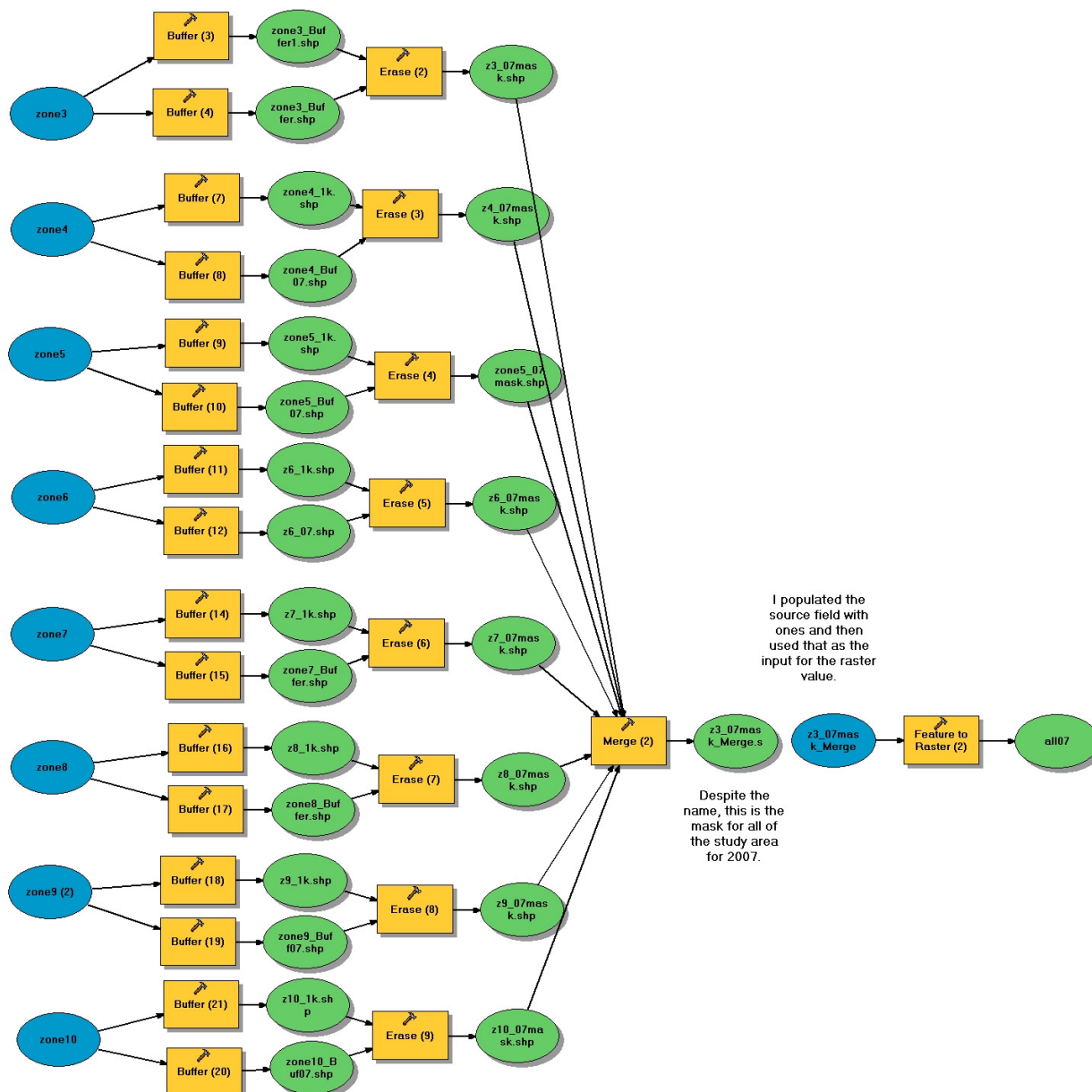
Calculating average shoreline erosion for the 10 different zones model graphic



Part 2

2007 Mask Model graphic (script is found as part of the larger Shoreline Change Model)

The following steps were done to isolate Dare County from the 2004 shoreline data which originally covered the entire NC coast. Only zones 3-10 were used since zones 1 and 2 were beyond the elevation data.



Python script for entire Shoreline Change Model

****Note** there are some parts of the model script which were not used in the ultimate analysis but I have left included (in the script but not the model graphics) because I thought they might be useful in future work. This includes the following tools: Buffer 2, 5, 6, 13; Erase 1; Feature to Raster 1, 4; Single Output Map Algebra 2; Merge 1**

```
# -----
# ShorelineChangeModel.py
```

```

# Created on: Thu Dec 11 2008 03:16:30 PM
# (generated by ArcGIS/ModelBuilder)
# -----

# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Set the necessary product code
gp.SetProduct("ArcInfo")

# Check out any necessary licenses
gp.CheckOutExtension("spatial")

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst
Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Conversion Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Data Management
Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Analysis Tools.tbx")

# Set the Geoprocessing environment...
gp.XYResolution = ""
gp.scratchWorkspace = "F:\\GIS_Project"
gp.MTolerance = ""
gp.randomGenerator = "0 ACM599"
gp.outputCoordinateSystem = ""
gp.snapRaster = ""
gp.outputZFlag = "Same As Input"
gp.qualifiedFieldNames = "true"
gp.extent = "DEFAULT"
gp.XYTolerance = ""
gp.outputZValue = ""
gp.outputMFlag = "Same As Input"
gp.geographicTransformations = ""
gp.ZResolution = ""
gp.workspace = "F:\\GIS_Project"
gp.MResolution = ""
gp.ZTolerance = ""

# Local variables...
dareonly98_Buffer_shp = "F:\\GIS_Project\\dareonly98_Buffer.shp"
dareonly98 = "dareonly98"
Shoreline_2004_C1_shp = "F:\\GIS_Project\\Shoreline_2004_C1.shp"
Shoreline_Oceanfront_2004 = "Shoreline_Oceanfront_2004"
EucDist_d98 = "F:\\GIS_Project\\EucDist_d98"
eucdir_d98 = "F:\\GIS_Project\\eucdir_d98"
dareonly98__2_ = "dareonly98"
zone1_Buffer_shp = "F:\\GIS_Project\\zone1_Buffer.shp"
zone1 = "zone1"
z1_07 = "F:\\GIS_Project\\DareShorelineSegments\\z1_07"
zone3_Buffer1_shp = "F:\\GIS_Project\\zone3_Buffer1.shp"
zone3_Buffer_shp = "F:\\GIS_Project\\zone3_Buffer.shp"
zone3 = "zone3"

```

```

all07 = "F:\\GIS_Project\\DareShorelineSegments\\all07"
nhat_divid10_r_shp = "F:\\GIS_Project\\nhat_divid10_r.shp"
nhat_divid10_shp = "F:\\GIS_Project\\nhat_divid10.shp"
zone9_Buff_1_shp = "F:\\GIS_Project\\zone9_Buff_1.shp"
zone9 = "zone9"
buffdare1000ft_shp = "F:\\GIS_Project\\buffdare1000ft.shp"
dre04bufbest = "F:\\GIS_Project\\dre04bufbest"
elev_pre04 = "F:\\GIS_Project\\elev_pre04"
dare20_int100 = "dare20_int100"
buffdare1000ft = "buffdare1000ft"
shoreline_80_Clp_shp = "F:\\GIS_Project\\shoreline_80_Clp.shp"
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EuDis_d1980 = "F:\\GIS_Project\\EuDis_d1980"
eudir_d1980 = "F:\\GIS_Project\\eudir_d1980"
zone4_1k_shp = "F:\\GIS_Project\\DareShorelineSegments\\zone4_1k.shp"
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z6_1k_shp = "F:\\GIS_Project\\DareShorelineSegments\\z6_1k.shp"
z6_07_shp = "F:\\GIS_Project\\DareShorelineSegments\\z6_07.shp"
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zone7 = "zone7"
zone8 = "zone8"
zone10 = "zone10"
zone9__2_ = "zone9"
z3_07mask_shp = "F:\\GIS_Project\\DareShorelineSegments\\z3_07mask.shp"
z4_07mask_shp = "F:\\GIS_Project\\DareShorelineSegments\\z4_07mask.shp"
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z7_07mask_shp = "F:\\GIS_Project\\DareShorelineSegments\\z7_07mask.shp"
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z9_07mask_shp = "F:\\GIS_Project\\DareShorelineSegments\\z9_07mask.shp"
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z3_07mask_Merge_shp = "F:\\GIS_Project\\DareShorelineSegments\\z3_07mask_Merge.shp"
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# Process: Buffer...
gp.Buffer_analysis(dareonly98, dareonly98_Buffer_shp, "1000 Feet", "FULL", "ROUND",
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# Process: Clip...
gp.Clip_analysis(Shoreline_Oceanfront_2004, dareonly98_Buffer_shp,
Shoreline_2004_Cl_shp, "")

```

```

# Process: Euclidean Distance...
gp.EucDistance_sa(dareonly98__2_, EucDist_d98, "", "20", eucdir_d98)

# Process: Buffer (13)...
gp.Buffer_analysis(zone1, zone1_Buf1000_shp, "1000 Feet", "RIGHT", "ROUND", "NONE",
"")

# Process: Buffer (2)...
gp.Buffer_analysis(zone1, zone1_Buffer_shp, "16.06 Feet", "RIGHT", "ROUND", "NONE",
"")

# Process: Erase...
gp.Erase_analysis(zone1_Buf1000_shp, zone1_Buffer_shp, z1_07clip_shp, "")

# Process: Feature to Raster...
gp.FeatureToRaster_conversion(z1_07clip_shp, "FEATURE", z1_07, "5")

# Process: Feature to Raster (2)...
gp.FeatureToRaster_conversion(z3_07mask_Merge, "SOURCE", all07, "20")

# Process: Buffer (5)...
gp.Buffer_analysis(nhat_divid10_shp, nhath_divid10_r_shp, "1000 Feet", "RIGHT",
"ROUND", "NONE", "")

# Process: Buffer (6)...
gp.Buffer_analysis(zone9, zone9_Buff_1_shp, "1000 Feet", "LEFT", "ROUND", "NONE", "")

# Process: Merge...
gp.Merge_management("F:\\GIS_Project\\nhath_divid10_r.shp;F:\\GIS_Project\\zone9_Buff_
1.shp", buffdare1000ft_shp, "SHR_DATE 'SHR_DATE' true true false 8 Date 0 0
,First,#,F:\\GIS_Project\\nhath_divid10_r.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\zone9_Buff_1.shp,SHR_DATE,-1,-1;FEATURE 'FEATURE' true true false
75 Text 0 0 ,First,#,F:\\GIS_Project\\nhath_divid10_r.shp,FEATURE,-1,-
1,F:\\GIS_Project\\zone9_Buff_1.shp,FEATURE,-1,-1;ANALYST 'ANALYST' true true false 3
Text 0 0 ,First,#,F:\\GIS_Project\\nhath_divid10_r.shp,ANALYST,-1,-
1,F:\\GIS_Project\\zone9_Buff_1.shp,ANALYST,-1,-1;SHR_YEAR 'SHR_YEAR' true true false
4 Short 0 4 ,First,#,F:\\GIS_Project\\nhath_divid10_r.shp,SHR_YEAR,-1,-
1,F:\\GIS_Project\\zone9_Buff_1.shp,SHR_YEAR,-1,-1;SOURCE 'SOURCE' true true false 50
Text 0 0 ,First,#,F:\\GIS_Project\\nhath_divid10_r.shp,SOURCE,-1,-
1,F:\\GIS_Project\\zone9_Buff_1.shp,SOURCE,-1,-1;BUFF_DIST 'BUFF_DIST' true true
false 19 Double 0 0 ,First,#,F:\\GIS_Project\\nhath_divid10_r.shp,BUFF_DIST,-1,-
1,F:\\GIS_Project\\zone9_Buff_1.shp,BUFF_DIST,-1,-1")

# Process: Feature to Raster (4)...
gp.FeatureToRaster_conversion(buffdare1000ft, "raster_val", dre04bufbest, "20")

# Process: Single Output Map Algebra (2)...
gp.SingleOutputMapAlgebra_sa("dare20_int100 * dre04bufbest", elev_pre04,
"F:\\GIS_Project\\dre04bufbest;dare20_int100")

# Process: Clip (2)...
gp.Clip_analysis(shoreline_80_shp, dareonly98_Buffer_shp, shoreline_80_Clp_shp, "")

# Process: Project...
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n_1983',DATUM['D_North_American_1983',SPHEROID['GRS_1980',6378137.0,298.257222101]],P

```

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RIMEM['Greenwich',0.0],UNIT['Degree',0.0174532925199433]],PROJECTION['Lambert_Conformal_Conic'],PARAMETER['False_Easting',2000000.002616666],PARAMETER['False_Northing',0.0],PARAMETER['Central_Meridian',-79.0],PARAMETER['Standard_Parallel_1',34.33333333333334],PARAMETER['Standard_Parallel_2',36.16666666666666],PARAMETER['Latitude_Of_Origin',33.75],UNIT['Foot_US',0.3048006096012192]]", "",
"GEOGCS['GCS_North_American_1983',DATUM['D_North_American_1983',SPHEROID['GRS_1980',6378137.0,298.257222101]],PRIMEM['Greenwich',0.0],UNIT['Degree',0.0174532925199433]]")

# Process: Euclidean Distance (2)...
gp.EucDistance_sa(shoreline_80_Clp_stpln_shp, EuDis_d1980, "", "20", eudir_d1980)

# Process: Zonal Statistics as Table...
gp.ZonalStatisticsAsTable_sa(nhat_divid10, "FEATURE", EuDis_d1980, ZonalSt_8098, "DATA")

# Process: Buffer (3)...
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# Process: Buffer (4)...
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# Process: Erase (2)...
gp.Erase_analysis(zone3_Buffer1_shp, zone3_Buffer_shp, z3_07mask_shp, "")

# Process: Buffer (7)...
gp.Buffer_analysis(zone4, zone4_1k_shp, "1000 Feet", "FULL", "ROUND", "NONE", "")

# Process: Buffer (8)...
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# Process: Erase (3)...
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# Process: Buffer (9)...
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# Process: Erase (4)...
gp.Erase_analysis(zone5_1k_shp, zone5_Buf07_shp, zone5_07mask_shp, "")

# Process: Buffer (11)...
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# Process: Buffer (12)...
gp.Buffer_analysis(zone6, z6_07_shp, "57.29 Feet", "RIGHT", "ROUND", "NONE", "")

# Process: Erase (5)...
gp.Erase_analysis(z6_1k_shp, z6_07_shp, z6_07mask_shp, "")

# Process: Buffer (14)...
gp.Buffer_analysis(zone7, z7_1k_shp, "1000 Feet", "RIGHT", "ROUND", "NONE", "")

```

```

# Process: Buffer (15)...
gp.Buffer_analysis(zone7, zone7_Buffer_shp, "27.5 Feet", "RIGHT", "ROUND", "NONE",
"")

# Process: Erase (6)...
gp.Erase_analysis(z7_1k_shp, zone7_Buffer_shp, z7_07mask_shp, "")

# Process: Buffer (16)...
gp.Buffer_analysis(zone8, z8_1k_shp, "1000 Feet", "RIGHT", "ROUND", "NONE", "")

# Process: Buffer (17)...
gp.Buffer_analysis(zone8, zone8_Buffer_shp, "26.24 Feet", "RIGHT", "ROUND", "NONE",
"")

# Process: Erase (7)...
gp.Erase_analysis(z8_1k_shp, zone8_Buffer_shp, z8_07mask_shp, "")

# Process: Buffer (18)...
gp.Buffer_analysis(zone9__2_, z9_1k_shp, "1000 Feet", "LEFT", "ROUND", "NONE", "")

# Process: Buffer (19)...
gp.Buffer_analysis(zone9__2_, zone9_Buff07_shp, "24.45 Feet", "LEFT", "ROUND",
"NONE", "")

# Process: Erase (8)...
gp.Erase_analysis(z9_1k_shp, zone9_Buff07_shp, z9_07mask_shp, "")

# Process: Buffer (21)...
gp.Buffer_analysis(zone10, z10_1k_shp, "1000 Feet", "RIGHT", "ROUND", "NONE", "")

# Process: Buffer (20)...
gp.Buffer_analysis(zone10, zone10_Buf07_shp, "40.26 Feet", "RIGHT", "ROUND", "NONE",
"")

# Process: Erase (9)...
gp.Erase_analysis(z10_1k_shp, zone10_Buf07_shp, z10_07mask_shp, "")

# Process: Merge (2)...
gp.Merge_management("F:\\GIS_Project\\DareShorelineSegments\\z3_07mask.shp;F:\\GIS_Pr
oject\\DareShorelineSegments\\z4_07mask.shp;F:\\GIS_Project\\DareShorelineSegments\\z
one5_07mask.shp;F:\\GIS_Project\\DareShorelineSegments\\z6_07mask.shp;F:\\GIS_Project
\\DareShorelineSegments\\z7_07mask.shp;F:\\GIS_Project\\DareShorelineSegments\\z8_07m
ask.shp;F:\\GIS_Project\\DareShorelineSegments\\z9_07mask.shp;F:\\GIS_Project\\DareSh
orelineSegments\\z10_07mask.shp", z3_07mask_Merge_shp, "SHR_DATE 'SHR_DATE' true true
false 8 Date 0 0
,First,#,F:\\GIS_Project\\DareShorelineSegments\\z3_07mask.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z4_07mask.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\zone5_07mask.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z6_07mask.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z7_07mask.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z8_07mask.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z9_07mask.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z10_07mask.shp,SHR_DATE,-1,-1;FEATURE
'FEATURE' true true false 75 Text 0 0
,First,#,F:\\GIS_Project\\DareShorelineSegments\\z3_07mask.shp,FEATURE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z4_07mask.shp,FEATURE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\zone5_07mask.shp,FEATURE,-1,-

```

```

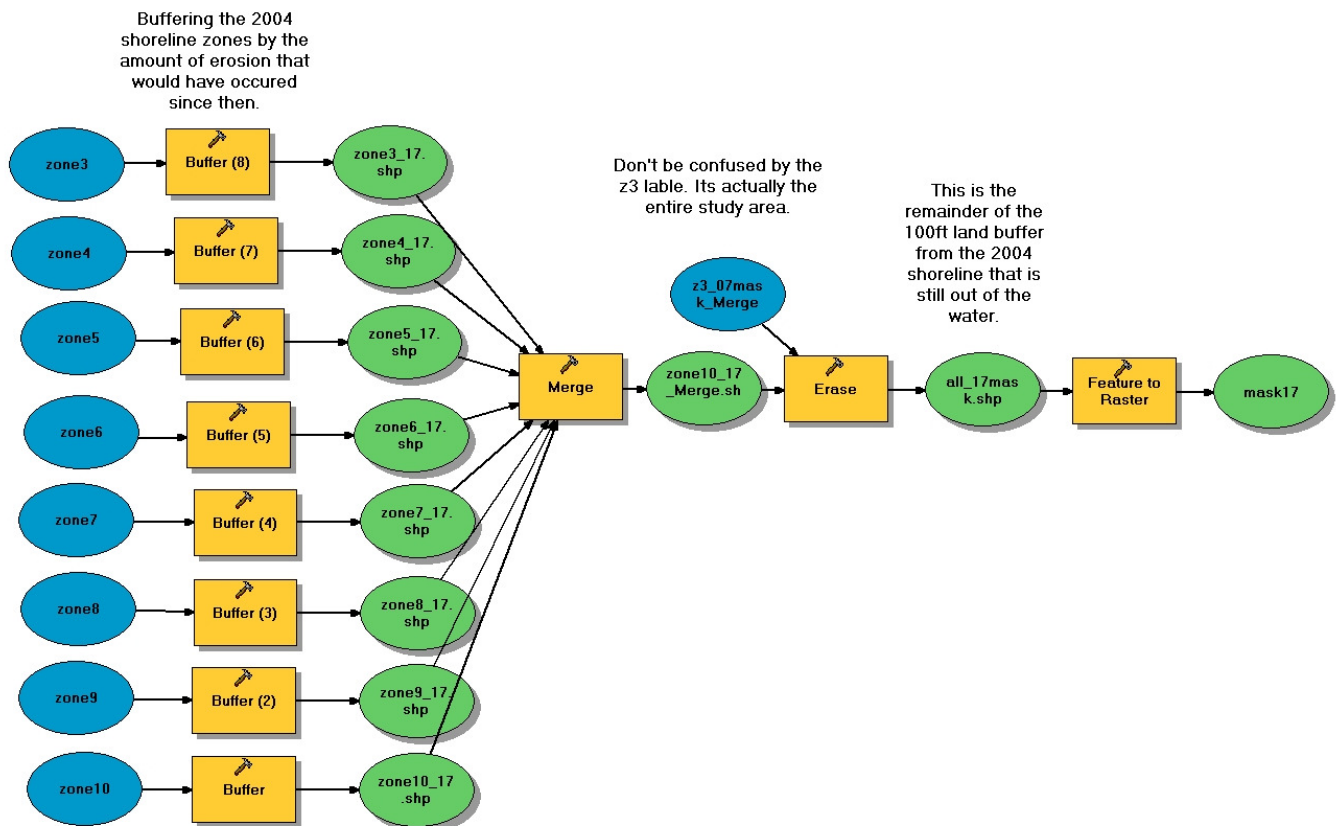
1,F:\\GIS_Project\\DareShorelineSegments\\z6_07mask.shp,FEATURE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z7_07mask.shp,FEATURE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z8_07mask.shp,FEATURE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z9_07mask.shp,FEATURE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z10_07mask.shp,FEATURE,-1,-1;ANALYST
'ANALYST' true true false 3 Text 0 0
,First,#,F:\\GIS_Project\\DareShorelineSegments\\z3_07mask.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z4_07mask.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\zone5_07mask.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z6_07mask.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z7_07mask.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z8_07mask.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z9_07mask.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z10_07mask.shp,ANALYST,-1,-1;SHR_YEAR
'SHR_YEAR' true true false 4 Short 0 4
,First,#,F:\\GIS_Project\\DareShorelineSegments\\z3_07mask.shp,SHR_YEAR,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z4_07mask.shp,SHR_YEAR,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\zone5_07mask.shp,SHR_YEAR,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z6_07mask.shp,SHR_YEAR,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z7_07mask.shp,SHR_YEAR,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z8_07mask.shp,SHR_YEAR,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z9_07mask.shp,SHR_YEAR,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z10_07mask.shp,SHR_YEAR,-1,-1;SOURCE
'SOURCE' true true false 50 Text 0 0
,First,#,F:\\GIS_Project\\DareShorelineSegments\\z3_07mask.shp,SOURCE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z4_07mask.shp,SOURCE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\zone5_07mask.shp,SOURCE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z6_07mask.shp,SOURCE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z7_07mask.shp,SOURCE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z8_07mask.shp,SOURCE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z9_07mask.shp,SOURCE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z10_07mask.shp,SOURCE,-1,-1;BUFF_DIST
'BUFF_DIST' true true false 19 Double 0 0
,First,#,F:\\GIS_Project\\DareShorelineSegments\\z3_07mask.shp,BUFF_DIST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z4_07mask.shp,BUFF_DIST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\zone5_07mask.shp,BUFF_DIST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z6_07mask.shp,BUFF_DIST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z7_07mask.shp,BUFF_DIST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z8_07mask.shp,BUFF_DIST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z9_07mask.shp,BUFF_DIST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\z10_07mask.shp,BUFF_DIST,-1,-1")

```

B. Masks for other time periods

Part 1.

Mask for 2017 Model graphic



Python script for Mask for 2017 Model

```
# -----  
# mask2017.py  
# Created on: Thu Dec 11 2008 03:30:01 PM  
# (generated by ArcGIS/ModelBuilder)  
# -----  
  
# Import system modules  
import sys, string, os, arcgisscripting  
  
# Create the Geoprocessor object  
gp = arcgisscripting.create()  
  
# Set the necessary product code  
gp.SetProduct("ArcInfo")  
  
# Load required toolboxes...  
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Conversion Tools.tbx")  
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Data Management  
Tools.tbx")  
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Analysis Tools.tbx")
```

```

# Set the Geoprocessing environment...
gp.XYResolution = ""
gp.scratchWorkspace = "F:\\GIS_Project\\DareShorelineSegments\\2017"
gp.MTolerance = ""
gp.randomGenerator = "0 ACM599"
gp.outputCoordinateSystem = ""
gp.snapRaster = ""
gp.outputZFlag = "Same As Input"
gp.qualifiedFieldNames = "true"
gp.extent = "DEFAULT"
gp.XYTolerance = ""
gp.outputZValue = ""
gp.outputMFlag = "Same As Input"
gp.geographicTransformations = ""
gp.ZResolution = ""
gp.workspace = "F:\\GIS_Project\\DareShorelineSegments\\2017"
gp.MResolution = ""
gp.ZTolerance = ""

# Local variables...
zone10_17_shp = "F:\\GIS_Project\\DareShorelineSegments\\2017\\zone10_17.shp"
zone9_17_shp = "F:\\GIS_Project\\DareShorelineSegments\\2017\\zone9_17.shp"
zone8_17_shp = "F:\\GIS_Project\\DareShorelineSegments\\2017\\zone8_17.shp"
zone7_17_shp = "F:\\GIS_Project\\DareShorelineSegments\\2017\\zone7_17.shp"
zone6_17_shp = "F:\\GIS_Project\\DareShorelineSegments\\2017\\zone6_17.shp"
zone5_17_shp = "F:\\GIS_Project\\DareShorelineSegments\\2017\\zone5_17.shp"
zone4_17_shp = "F:\\GIS_Project\\DareShorelineSegments\\2017\\zone4_17.shp"
zone3_17_shp = "F:\\GIS_Project\\DareShorelineSegments\\2017\\zone3_17.shp"
z3_07mask_Merge = "z3_07mask_Merge"
all_17mask_shp = "F:\\GIS_Project\\DareShorelineSegments\\2017\\all_17mask.shp"
zone10 = "zone10"
zone9 = "zone9"
zone8 = "zone8"
zone7 = "zone7"
zone6 = "zone6"
zone5 = "zone5"
zone4 = "zone4"
zone3 = "zone3"
zone10_17_Merge_shp =
"F:\\GIS_Project\\DareShorelineSegments\\2017\\zone10_17_Merge.shp"
mask17 = "F:\\GIS_Project\\DareShorelineSegments\\2017\\mask17"

# Process: Buffer...
gp.Buffer_analysis(zone10, zone10_17_shp, "174.46 Feet", "RIGHT", "ROUND", "NONE",
"")

# Process: Buffer (2)...
gp.Buffer_analysis(zone9, zone9_17_shp, "105.96 Feet", "LEFT", "ROUND", "NONE", "")

# Process: Buffer (3)...
gp.Buffer_analysis(zone8, zone8_17_shp, "113.73 Feet", "RIGHT", "ROUND", "NONE", "")

# Process: Buffer (4)...
gp.Buffer_analysis(zone7, zone7_17_shp, "119.16 Feet", "RIGHT", "ROUND", "NONE", "")

# Process: Buffer (5)...

```

```

gp.Buffer_analysis(zone6, zone6_17_shp, "248.24 Feet", "RIGHT", "ROUND", "NONE", "")

# Process: Buffer (6)...
gp.Buffer_analysis(zone5, zone5_17_shp, "45.74 Feet", "RIGHT", "ROUND", "NONE", "")

# Process: Buffer (7)...
gp.Buffer_analysis(zone4, zone4_17_shp, "43.46 Feet", "RIGHT", "ROUND", "NONE", "")

# Process: Buffer (8)...
gp.Buffer_analysis(zone3, zone3_17_shp, "43.11 Feet", "RIGHT", "ROUND", "NONE", "")

# Process: Merge...
gp.Merge_management("F:\\GIS_Project\\DareShorelineSegments\\2017\\zone10_17.shp;F:\\GIS_Project\\DareShorelineSegments\\2017\\zone9_17.shp;F:\\GIS_Project\\DareShorelineSegments\\2017\\zone8_17.shp;F:\\GIS_Project\\DareShorelineSegments\\2017\\zone7_17.shp;F:\\GIS_Project\\DareShorelineSegments\\2017\\zone6_17.shp;F:\\GIS_Project\\DareShorelineSegments\\2017\\zone5_17.shp;F:\\GIS_Project\\DareShorelineSegments\\2017\\zone4_17.shp;F:\\GIS_Project\\DareShorelineSegments\\2017\\zone3_17.shp",
zone10_17_Merge_shp, "SHR_DATE 'SHR_DATE' true true false 8 Date 0 0
,First,#,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone10_17.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone9_17.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone8_17.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone7_17.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone6_17.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone5_17.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone4_17.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone3_17.shp,SHR_DATE,-1,-1;FEATURE
'FEATURE' true true false 75 Text 0 0
,First,#,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone10_17.shp,FEATURE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone9_17.shp,FEATURE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone8_17.shp,FEATURE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone7_17.shp,FEATURE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone6_17.shp,FEATURE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone5_17.shp,FEATURE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone4_17.shp,FEATURE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone3_17.shp,FEATURE,-1,-1;ANALYST
'ANALYST' true true false 3 Text 0 0
,First,#,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone10_17.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone9_17.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone8_17.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone7_17.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone6_17.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone5_17.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone4_17.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone3_17.shp,ANALYST,-1,-1;SHR_YEAR
'SHR_YEAR' true true false 4 Short 0 4
,First,#,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone10_17.shp,SHR_YEAR,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone9_17.shp,SHR_YEAR,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone8_17.shp,SHR_YEAR,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone7_17.shp,SHR_YEAR,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone6_17.shp,SHR_YEAR,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone5_17.shp,SHR_YEAR,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone4_17.shp,SHR_YEAR,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone3_17.shp,SHR_YEAR,-1,-1;SOURCE
'SOURCE' true true false 50 Text 0 0
,First,#,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone10_17.shp,SOURCE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone9_17.shp,SOURCE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2017\\zone8_17.shp,SOURCE,-1,-

```

```

1,F:\GIS_Project\DareShorelineSegments\2017\zone7_17.shp,SOURCE,-1,-
1,F:\GIS_Project\DareShorelineSegments\2017\zone6_17.shp,SOURCE,-1,-
1,F:\GIS_Project\DareShorelineSegments\2017\zone5_17.shp,SOURCE,-1,-
1,F:\GIS_Project\DareShorelineSegments\2017\zone4_17.shp,SOURCE,-1,-
1,F:\GIS_Project\DareShorelineSegments\2017\zone3_17.shp,SOURCE,-1,-1;BUFF_DIST
'BUFF_DIST' true true false 19 Double 0 0
,First,#,F:\GIS_Project\DareShorelineSegments\2017\zone10_17.shp,BUFF_DIST,-1,-
1,F:\GIS_Project\DareShorelineSegments\2017\zone9_17.shp,BUFF_DIST,-1,-
1,F:\GIS_Project\DareShorelineSegments\2017\zone8_17.shp,BUFF_DIST,-1,-
1,F:\GIS_Project\DareShorelineSegments\2017\zone7_17.shp,BUFF_DIST,-1,-
1,F:\GIS_Project\DareShorelineSegments\2017\zone6_17.shp,BUFF_DIST,-1,-
1,F:\GIS_Project\DareShorelineSegments\2017\zone5_17.shp,BUFF_DIST,-1,-
1,F:\GIS_Project\DareShorelineSegments\2017\zone4_17.shp,BUFF_DIST,-1,-
1,F:\GIS_Project\DareShorelineSegments\2017\zone3_17.shp,BUFF_DIST,-1,-1")

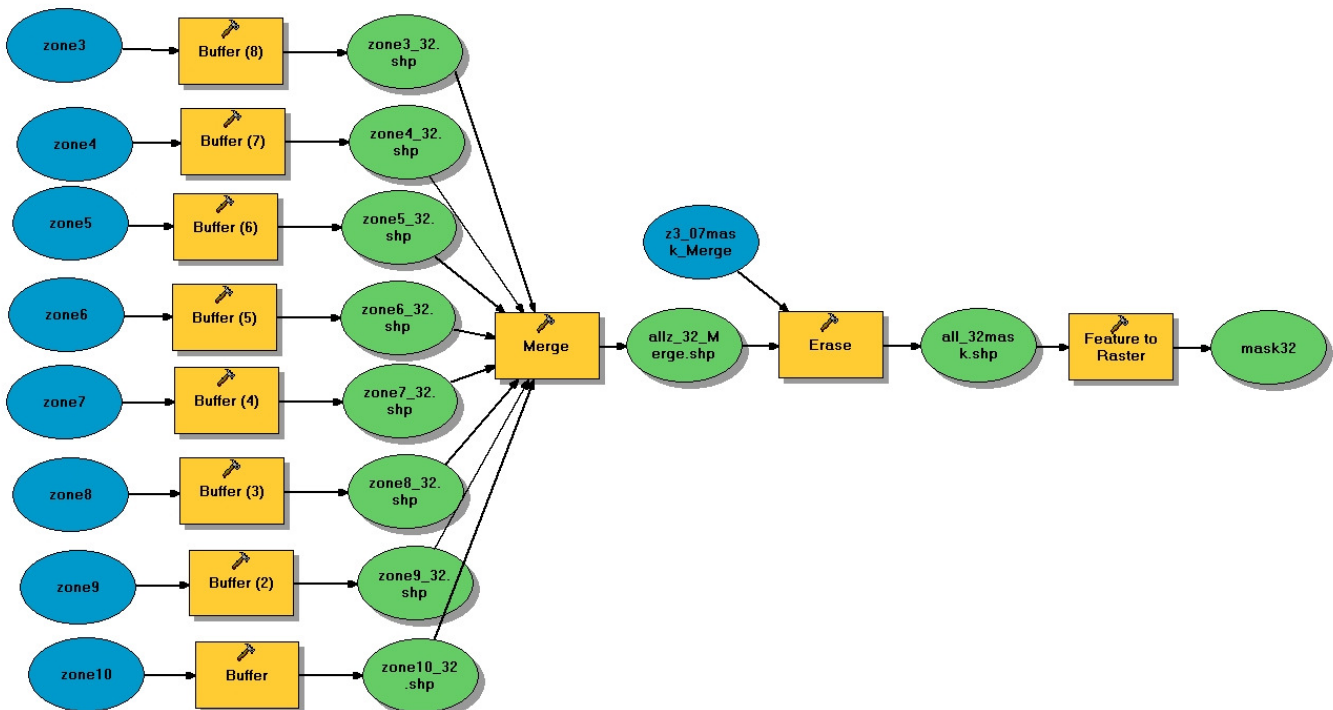
# Process: Erase...
gp.Erase_analysis(z3_07mask_Merge, zone10_17_Merge_shp, all_17mask_shp, "")

# Process: Feature to Raster...
gp.FeatureToRaster_conversion(all_17mask_shp, "SOURCE", mask17, "20")

```

Part 2. Mask for 2032

Mask for 2032 Model graphic



Python script for Mask for 2032 Model

```
# -----
# mask2032.py
# Created on: Thu Dec 11 2008 03:35:13 PM
# (generated by ArcGIS/ModelBuilder)
# -----

# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Set the necessary product code
gp.SetProduct("ArcInfo")

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Conversion Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Data Management
Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Analysis Tools.tbx")

# Set the Geoprocessing environment...
gp.XYResolution = ""
gp.scratchWorkspace = "F:\\GIS_Project\\DareShorelineSegments\\2032"
gp.MTolerance = ""
gp.randomGenerator = "0 ACM599"
gp.outputCoordinateSystem = ""
gp.snapRaster = ""
gp.outputZFlag = "Same As Input"
gp.qualifiedFieldNames = "true"
gp.extent = "DEFAULT"
gp.XYTolerance = ""
gp.outputZValue = ""
gp.outputMFlag = "Same As Input"
gp.geographicTransformations = ""
gp.ZResolution = ""
gp.workspace = "F:\\GIS_Project\\DareShorelineSegments\\2032"
gp.MResolution = ""
gp.ZTolerance = ""

# Local variables...
zone10_32_shp = "F:\\GIS_Project\\DareShorelineSegments\\2032\\zone10_32.shp"
zone9_32_shp = "F:\\GIS_Project\\DareShorelineSegments\\2032\\zone9_32.shp"
zone8_32_shp = "F:\\GIS_Project\\DareShorelineSegments\\2032\\zone8_32.shp"
zone7_32_shp = "F:\\GIS_Project\\DareShorelineSegments\\2032\\zone7_32.shp"
zone6_32_shp = "F:\\GIS_Project\\DareShorelineSegments\\2032\\zone6_32.shp"
zone5_32_shp = "F:\\GIS_Project\\DareShorelineSegments\\2032\\zone5_32.shp"
zone4_32_shp = "F:\\GIS_Project\\DareShorelineSegments\\2032\\zone4_32.shp"
zone3_32_shp = "F:\\GIS_Project\\DareShorelineSegments\\2032\\zone3_32.shp"
z3_07mask_Merge = "z3_07mask_Merge"
all_32mask_shp = "F:\\GIS_Project\\DareShorelineSegments\\2032\\all_32mask.shp"
zone10 = "zone10"
zone9 = "zone9"
zone8 = "zone8"
zone7 = "zone7"
```

```

zone6 = "zone6"
zone5 = "zone5"
zone4 = "zone4"
zone3 = "zone3"
allz_32_Merge_shp = "F:\\GIS_Project\\DareShorelineSegments\\2032\\allz_32_Merge.shp"
mask32 = "F:\\GIS_Project\\DareShorelineSegments\\2032\\mask32"

# Process: Buffer...
gp.Buffer_analysis(zone10, zone10_32_shp, "220.06 Feet", "RIGHT", "ROUND", "NONE",
"")

# Process: Buffer (2)...
gp.Buffer_analysis(zone9, zone9_32_shp, "236.2 Feet", "LEFT", "ROUND", "NONE", "")

# Process: Buffer (3)...
gp.Buffer_analysis(zone8, zone8_32_shp, "247.48 Feet", "RIGHT", "ROUND", "NONE", "")

# Process: Buffer (4)...
gp.Buffer_analysis(zone7, zone7_32_shp, "247.48 Feet", "RIGHT", "ROUND", "NONE", "")

# Process: Buffer (5)...
gp.Buffer_analysis(zone6, zone6_32_shp, "515.58 Feet", "RIGHT", "ROUND", "NONE", "")

# Process: Buffer (6)...
gp.Buffer_analysis(zone5, zone5_32_shp, "95.01 Feet", "RIGHT", "ROUND", "NONE", "")

# Process: Buffer (7)...
gp.Buffer_analysis(zone4, zone4_32_shp, "90.27 Feet", "RIGHT", "ROUND", "NONE", "")

# Process: Buffer (8)...
gp.Buffer_analysis(zone3, zone3_32_shp, "89.54 Feet", "RIGHT", "ROUND", "NONE", "")

# Process: Merge...
gp.Merge_management("F:\\GIS_Project\\DareShorelineSegments\\2032\\zone10_32.shp;F:\\
GIS_Project\\DareShorelineSegments\\2032\\zone9_32.shp;F:\\GIS_Project\\DareShoreline
Segments\\2032\\zone8_32.shp;F:\\GIS_Project\\DareShorelineSegments\\2032\\zone7_32.s
hp;F:\\GIS_Project\\DareShorelineSegments\\2032\\zone6_32.shp;F:\\GIS_Project\\DareSh
orelineSegments\\2032\\zone5_32.shp;F:\\GIS_Project\\DareShorelineSegments\\2032\\zon
e4_32.shp;F:\\GIS_Project\\DareShorelineSegments\\2032\\zone3_32.shp",
allz_32_Merge_shp, "SHR_DATE 'SHR_DATE' true true false 8 Date 0 0
,First,#,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone3_32.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone8_32.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone7_32.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone4_32.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone5_32.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone6_32.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone9_32.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone10_32.shp,SHR_DATE,-1,-1;FEATURE
'FEATURE' true true false 75 Text 0 0
,First,#,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone3_32.shp,FEATURE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone8_32.shp,FEATURE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone7_32.shp,FEATURE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone4_32.shp,FEATURE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone5_32.shp,FEATURE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone6_32.shp,FEATURE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone9_32.shp,FEATURE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone10_32.shp,FEATURE,-1,-1;ANALYST
'ANALYST' true true false 3 Text 0 0

```

```
,First,#,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone3_32.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone8_32.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone7_32.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone4_32.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone5_32.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone6_32.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone9_32.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone10_32.shp,ANALYST,-1,-1;SHR_YEAR
'SHR_YEAR' true true false 4 Short 0 4
,First,#,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone3_32.shp,SHR_YEAR,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone8_32.shp,SHR_YEAR,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone7_32.shp,SHR_YEAR,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone4_32.shp,SHR_YEAR,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone5_32.shp,SHR_YEAR,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone6_32.shp,SHR_YEAR,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone9_32.shp,SHR_YEAR,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone10_32.shp,SHR_YEAR,-1,-1;SOURCE
'SOURCE' true true false 50 Text 0 0
,First,#,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone3_32.shp,SOURCE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone8_32.shp,SOURCE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone7_32.shp,SOURCE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone4_32.shp,SOURCE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone5_32.shp,SOURCE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone6_32.shp,SOURCE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone9_32.shp,SOURCE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone10_32.shp,SOURCE,-1,-1;BUFF_DIST
'BUFF_DIST' true true false 0 Double 0 0
,First,#,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone3_32.shp,BUFF_DIST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone8_32.shp,BUFF_DIST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone7_32.shp,BUFF_DIST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone4_32.shp,BUFF_DIST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone5_32.shp,BUFF_DIST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone6_32.shp,BUFF_DIST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone9_32.shp,BUFF_DIST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2032\\zone10_32.shp,BUFF_DIST,-1,-1")

# Process: Erase...
gp.Erase_analysis(z3_07mask_Merge, allz_32_Merge_shp, all_32mask_shp, "")

# Process: Feature to Raster...
gp.FeatureToRaster_conversion(all_32mask_shp, "SOURCE", mask32, "20")
```

Part 3. Mask for 2057

Mask for 2057 Model graphic



Python script for Mask for 2057 Model

```
# -----  
# mask2057.py  
# Created on: Thu Dec 11 2008 03:35:59 PM  
# (generated by ArcGIS/ModelBuilder)  
# -----  
  
# Import system modules  
import sys, string, os, arcgisscripting  
  
# Create the Geoprocessor object  
gp = arcgisscripting.create()  
  
# Set the necessary product code  
gp.SetProduct("ArcInfo")  
  
# Load required toolboxes...  
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Conversion Tools.tbx")  
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Data Management  
Tools.tbx")  
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Analysis Tools.tbx")  
  
# Set the Geoprocessing environment...  
gp.XYResolution = ""  
gp.scratchWorkspace = "F:\\GIS_Project\\DareShorelineSegments\\2057"  
gp.MTolerance = ""  
gp.randomGenerator = "0 ACM599"  
gp.outputCoordinateSystem = ""
```

```

gp.snapRaster = ""
gp.outputZFlag = "Same As Input"
gp.qualifiedFieldNames = "true"
gp.extent = "DEFAULT"
gp.XYTolerance = ""
gp.outputZValue = ""
gp.outputMFlag = "Same As Input"
gp.geographicTransformations = ""
gp.ZResolution = ""
gp.workspace = "F:\\GIS_Project\\DareShorelineSegments\\2057"
gp.MResolution = ""
gp.ZTolerance = ""

# Local variables...
zone10_57_shp = "F:\\GIS_Project\\DareShorelineSegments\\2057\\zone10_57.shp"
zone9_57_shp = "F:\\GIS_Project\\DareShorelineSegments\\2057\\zone9_57.shp"
zone8_57_shp = "F:\\GIS_Project\\DareShorelineSegments\\2057\\zone8_57.shp"
zone7_57_shp = "F:\\GIS_Project\\DareShorelineSegments\\2057\\zone7_57.shp"
zone6_57_shp = "F:\\GIS_Project\\DareShorelineSegments\\2057\\zone6_57.shp"
zone5_57_shp = "F:\\GIS_Project\\DareShorelineSegments\\2057\\zone5_57.shp"
zone4_57_shp = "F:\\GIS_Project\\DareShorelineSegments\\2057\\zone4_57.shp"
zone3_57_shp = "F:\\GIS_Project\\DareShorelineSegments\\2057\\zone3_57.shp"
z3_07mask_Merge = "z3_07mask_Merge"
all_57mask_shp = "F:\\GIS_Project\\DareShorelineSegments\\2057\\all_57mask.shp"
zone10 = "zone10"
zone9 = "zone9"
zone8 = "zone8"
zone7 = "zone7"
zone6 = "zone6"
zone5 = "zone5"
zone4 = "zone4"
zone3 = "zone3"
allz_57_Merge_shp = "F:\\GIS_Project\\DareShorelineSegments\\2057\\allz_57_Merge.shp"
mask57 = "F:\\GIS_Project\\DareShorelineSegments\\2057\\mask57"

# Process: Buffer...
gp.Buffer_analysis(zone10, zone10_57_shp, "711.27 Feet", "RIGHT", "ROUND", "NONE",
"")

# Process: Buffer (2)...
gp.Buffer_analysis(zone9, zone9_57_shp, "431.97 Feet", "LEFT", "ROUND", "NONE", "")

# Process: Buffer (3)...
gp.Buffer_analysis(zone8, zone8_57_shp, "463.66 Feet", "RIGHT", "ROUND", "NONE", "")

# Process: Buffer (4)...
gp.Buffer_analysis(zone7, zone7_57_shp, "485.8 Feet", "RIGHT", "ROUND", "NONE", "")

# Process: Buffer (5)...
gp.Buffer_analysis(zone6, zone6_57_shp, "1012.07 Feet", "RIGHT", "ROUND", "NONE", "")

# Process: Buffer (6)...
gp.Buffer_analysis(zone5, zone5_57_shp, "186.5 Feet", "RIGHT", "ROUND", "NONE", "")

# Process: Buffer (7)...
gp.Buffer_analysis(zone4, zone4_57_shp, "177.19 Feet", "RIGHT", "ROUND", "NONE", "")

```

```

# Process: Buffer (8)...
gp.Buffer_analysis(zone3, zone3_57_shp, "174.77 Feet", "RIGHT", "ROUND", "NONE", "")

# Process: Merge...
gp.Merge_management("F:\\GIS_Project\\DareShorelineSegments\\2057\\zone10_57.shp;F:\\GIS_Project\\DareShorelineSegments\\2057\\zone9_57.shp;F:\\GIS_Project\\DareShorelineSegments\\2057\\zone8_57.shp;F:\\GIS_Project\\DareShorelineSegments\\2057\\zone7_57.shp;F:\\GIS_Project\\DareShorelineSegments\\2057\\zone6_57.shp;F:\\GIS_Project\\DareShorelineSegments\\2057\\zone5_57.shp;F:\\GIS_Project\\DareShorelineSegments\\2057\\zone4_57.shp;F:\\GIS_Project\\DareShorelineSegments\\2057\\zone3_57.shp",
allz_57_Merge_shp, "SHR_DATE 'SHR_DATE' true true false 8 Date 0 0
,First,#,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone3_57.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone4_57.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone5_57.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone6_57.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone7_57.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone8_57.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone9_57.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone10_57.shp,SHR_DATE,-1,-1;FEATURE
'FEATURE' true true false 75 Text 0 0
,First,#,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone3_57.shp,FEATURE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone4_57.shp,FEATURE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone5_57.shp,FEATURE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone6_57.shp,FEATURE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone7_57.shp,FEATURE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone8_57.shp,FEATURE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone9_57.shp,FEATURE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone10_57.shp,FEATURE,-1,-1;ANALYST
'ANALYST' true true false 3 Text 0 0
,First,#,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone3_57.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone4_57.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone5_57.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone6_57.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone7_57.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone8_57.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone9_57.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone10_57.shp,ANALYST,-1,-1;SHR_YEAR
'SHR_YEAR' true true false 4 Short 0 4
,First,#,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone3_57.shp,SHR_YEAR,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone4_57.shp,SHR_YEAR,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone5_57.shp,SHR_YEAR,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone6_57.shp,SHR_YEAR,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone7_57.shp,SHR_YEAR,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone8_57.shp,SHR_YEAR,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone9_57.shp,SHR_YEAR,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone10_57.shp,SHR_YEAR,-1,-1;SOURCE
'SOURCE' true true false 50 Text 0 0
,First,#,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone3_57.shp,SOURCE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone4_57.shp,SOURCE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone5_57.shp,SOURCE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone6_57.shp,SOURCE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone7_57.shp,SOURCE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone8_57.shp,SOURCE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone9_57.shp,SOURCE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone10_57.shp,SOURCE,-1,-1;BUFF_DIST
'BUFF_DIST' true true false 0 Double 0 0
,First,#,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone3_57.shp,BUFF_DIST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\2057\\zone4_57.shp,BUFF_DIST,-1,-

```

```

1,F:\GIS_Project\DareShorelineSegments\2057\zone5_57.shp,BUFF_DIST,-1,-
1,F:\GIS_Project\DareShorelineSegments\2057\zone6_57.shp,BUFF_DIST,-1,-
1,F:\GIS_Project\DareShorelineSegments\2057\zone7_57.shp,BUFF_DIST,-1,-
1,F:\GIS_Project\DareShorelineSegments\2057\zone8_57.shp,BUFF_DIST,-1,-
1,F:\GIS_Project\DareShorelineSegments\2057\zone9_57.shp,BUFF_DIST,-1,-
1,F:\GIS_Project\DareShorelineSegments\2057\zone10_57.shp,BUFF_DIST,-1,-1")

```

```
# Process: Erase...
```

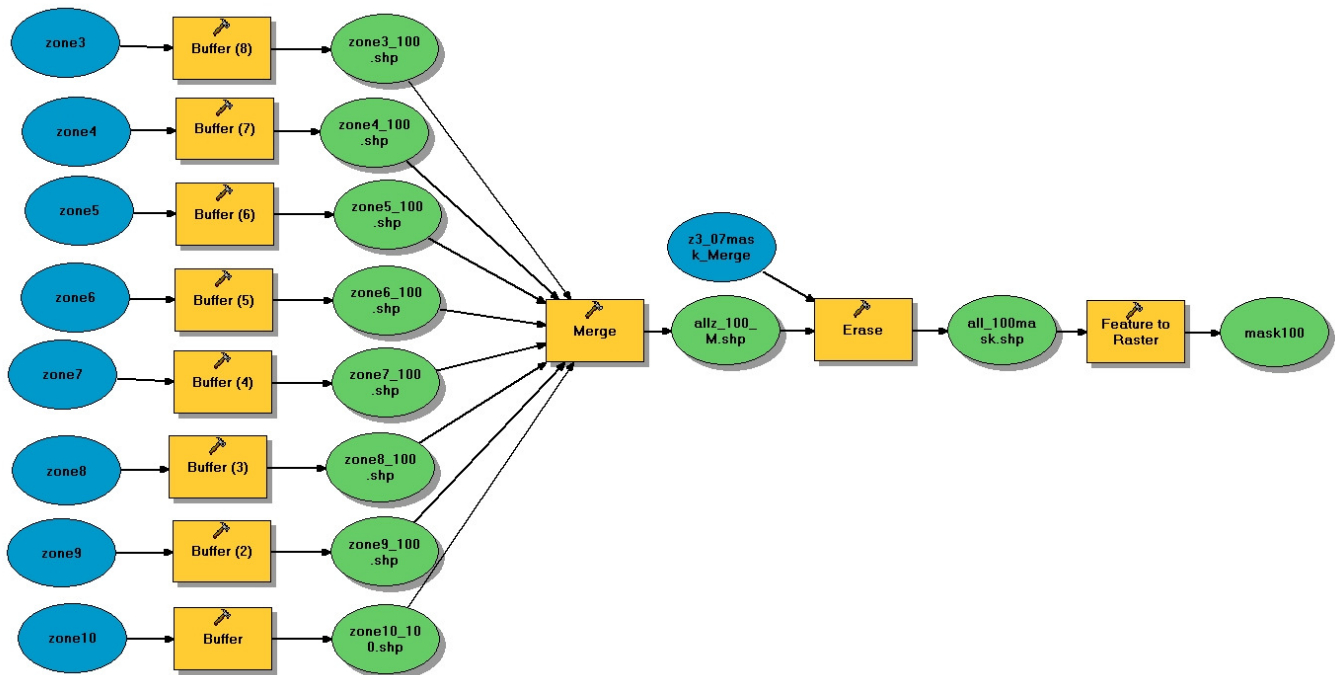
```
gp.Erase_analysis(z3_07mask_Merge, allz_57_Merge_shp, all_57mask_shp, "")
```

```
# Process: Feature to Raster...
```

```
gp.FeatureToRaster_conversion(all_57mask_shp, "SOURCE", mask57, "20")
```

Part 4. Mask for 2107

Mask for 2107 Model graphic



Python script for Mask for 2107 Model

```

# -----
# mask3007.py
# Created on: Thu Dec 11 2008 03:38:06 PM
# (generated by ArcGIS/ModelBuilder)
# -----

# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

```

```

# Set the necessary product code
gp.SetProduct("ArcInfo")

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Conversion Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Data Management
Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Analysis Tools.tbx")

# Set the Geoprocessing environment...
gp.XYResolution = ""
gp.scratchWorkspace = "F:\\GIS_Project\\DareShorelineSegments\\3007"
gp.MTolerance = ""
gp.randomGenerator = "0 ACM599"
gp.outputCoordinateSystem = ""
gp.snapRaster = ""
gp.outputZFlag = "Same As Input"
gp.qualifiedFieldNames = "true"
gp.extent = "DEFAULT"
gp.XYTolerance = ""
gp.outputZValue = ""
gp.outputMFlag = "Same As Input"
gp.geographicTransformations = ""
gp.ZResolution = ""
gp.workspace = "F:\\GIS_Project\\DareShorelineSegments\\3007"
gp.MResolution = ""
gp.ZTolerance = ""

# Local variables...
zone10_100_shp = "F:\\GIS_Project\\DareShorelineSegments\\3007\\zone10_100.shp"
zone9_100_shp = "F:\\GIS_Project\\DareShorelineSegments\\3007\\zone9_100.shp"
zone8_100_shp = "F:\\GIS_Project\\DareShorelineSegments\\3007\\zone8_100.shp"
zone7_100_shp = "F:\\GIS_Project\\DareShorelineSegments\\3007\\zone7_100.shp"
zone6_100_shp = "F:\\GIS_Project\\DareShorelineSegments\\3007\\zone6_100.shp"
zone5_100_shp = "F:\\GIS_Project\\DareShorelineSegments\\3007\\zone5_100.shp"
zone4_100_shp = "F:\\GIS_Project\\DareShorelineSegments\\3007\\zone4_100.shp"
zone3_100_shp = "F:\\GIS_Project\\DareShorelineSegments\\3007\\zone3_100.shp"
z3_07mask_Merge = "z3_07mask_Merge"
all_100mask_shp = "F:\\GIS_Project\\DareShorelineSegments\\3007\\all_100mask.shp"
zone10 = "zone10"
zone9 = "zone9"
zone8 = "zone8"
zone7 = "zone7"
zone6 = "zone6"
zone5 = "zone5"
zone4 = "zone4"
zone3 = "zone3"
allz_100_M_shp = "F:\\GIS_Project\\DareShorelineSegments\\3007\\allz_100_M.shp"
mask100 = "F:\\GIS_Project\\DareShorelineSegments\\3007\\mask100"

# Process: Buffer...
gp.Buffer_analysis(zone10, zone10_100_shp, "1382.29 Feet", "RIGHT", "ROUND", "NONE",
"")

# Process: Buffer (2)...
gp.Buffer_analysis(zone9, zone9_100_shp, "839.5 Feet", "LEFT", "ROUND", "NONE", "")

```

```

# Process: Buffer (3)...
gp.Buffer_analysis(zone8, zone8_100_shp, "901.07 Feet", "RIGHT", "ROUND", "NONE", "")

# Process: Buffer (4)...
gp.Buffer_analysis(zone7, zone7_100_shp, "944.09 Feet", "RIGHT", "ROUND", "NONE", "")

# Process: Buffer (5)...
gp.Buffer_analysis(zone6, zone6_100_shp, "1966.86 Feet", "RIGHT", "ROUND", "NONE",
"")

# Process: Buffer (6)...
gp.Buffer_analysis(zone5, zone5_100_shp, "362.44 Feet", "RIGHT", "ROUND", "NONE", "")

# Process: Buffer (7)...
gp.Buffer_analysis(zone4, zone4_100_shp, "344.35 Feet", "RIGHT", "ROUND", "NONE", "")

# Process: Buffer (8)...
gp.Buffer_analysis(zone3, zone3_100_shp, "341.6 Feet", "RIGHT", "ROUND", "NONE", "")

# Process: Merge...
gp.Merge_management("F:\\GIS_Project\\DareShorelineSegments\\3007\\zone10_100.shp;F:\\
\\GIS_Project\\DareShorelineSegments\\3007\\zone9_100.shp;F:\\GIS_Project\\DareShoreli
neSegments\\3007\\zone8_100.shp;F:\\GIS_Project\\DareShorelineSegments\\3007\\zone7_1
00.shp;F:\\GIS_Project\\DareShorelineSegments\\3007\\zone6_100.shp;F:\\GIS_Project\\D
areShorelineSegments\\3007\\zone5_100.shp;F:\\GIS_Project\\DareShorelineSegments\\300
7\\zone4_100.shp;F:\\GIS_Project\\DareShorelineSegments\\3007\\zone3_100.shp",
allz_100_M_shp, "SHR_DATE 'SHR_DATE' true true false 8 Date 0 0
,First,#,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone3_100.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone10_100.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone9_100.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone8_100.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone7_100.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone6_100.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone5_100.shp,SHR_DATE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone4_100.shp,SHR_DATE,-1,-1;FEATURE
'FEATURE' true true false 75 Text 0 0
,First,#,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone3_100.shp,FEATURE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone10_100.shp,FEATURE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone9_100.shp,FEATURE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone8_100.shp,FEATURE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone7_100.shp,FEATURE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone6_100.shp,FEATURE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone5_100.shp,FEATURE,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone4_100.shp,FEATURE,-1,-1;ANALYST
'ANALYST' true true false 3 Text 0 0
,First,#,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone3_100.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone10_100.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone9_100.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone8_100.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone7_100.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone6_100.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone5_100.shp,ANALYST,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone4_100.shp,ANALYST,-1,-1;SHR_YEAR
'SHR_YEAR' true true false 4 Short 0 4
,First,#,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone3_100.shp,SHR_YEAR,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone10_100.shp,SHR_YEAR,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone9_100.shp,SHR_YEAR,-1,-
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone8_100.shp,SHR_YEAR,-1,-

```

```

1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone7_100.shp, SHR_YEAR, -1, -
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone6_100.shp, SHR_YEAR, -1, -
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone5_100.shp, SHR_YEAR, -1, -
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone4_100.shp, SHR_YEAR, -1, -1; SOURCE
'SOURCE' true true false 50 Text 0 0
,First,#,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone3_100.shp, SOURCE, -1, -
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone10_100.shp, SOURCE, -1, -
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone9_100.shp, SOURCE, -1, -
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone8_100.shp, SOURCE, -1, -
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone7_100.shp, SOURCE, -1, -
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone6_100.shp, SOURCE, -1, -
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone5_100.shp, SOURCE, -1, -
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone4_100.shp, SOURCE, -1, -1; BUFF_DIST
'BUFF_DIST' true true false 0 Double 0 0
,First,#,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone3_100.shp, BUFF_DIST, -1, -
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone10_100.shp, BUFF_DIST, -1, -
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone9_100.shp, BUFF_DIST, -1, -
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone8_100.shp, BUFF_DIST, -1, -
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone7_100.shp, BUFF_DIST, -1, -
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone6_100.shp, BUFF_DIST, -1, -
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone5_100.shp, BUFF_DIST, -1, -
1,F:\\GIS_Project\\DareShorelineSegments\\3007\\zone4_100.shp, BUFF_DIST, -1, -1")

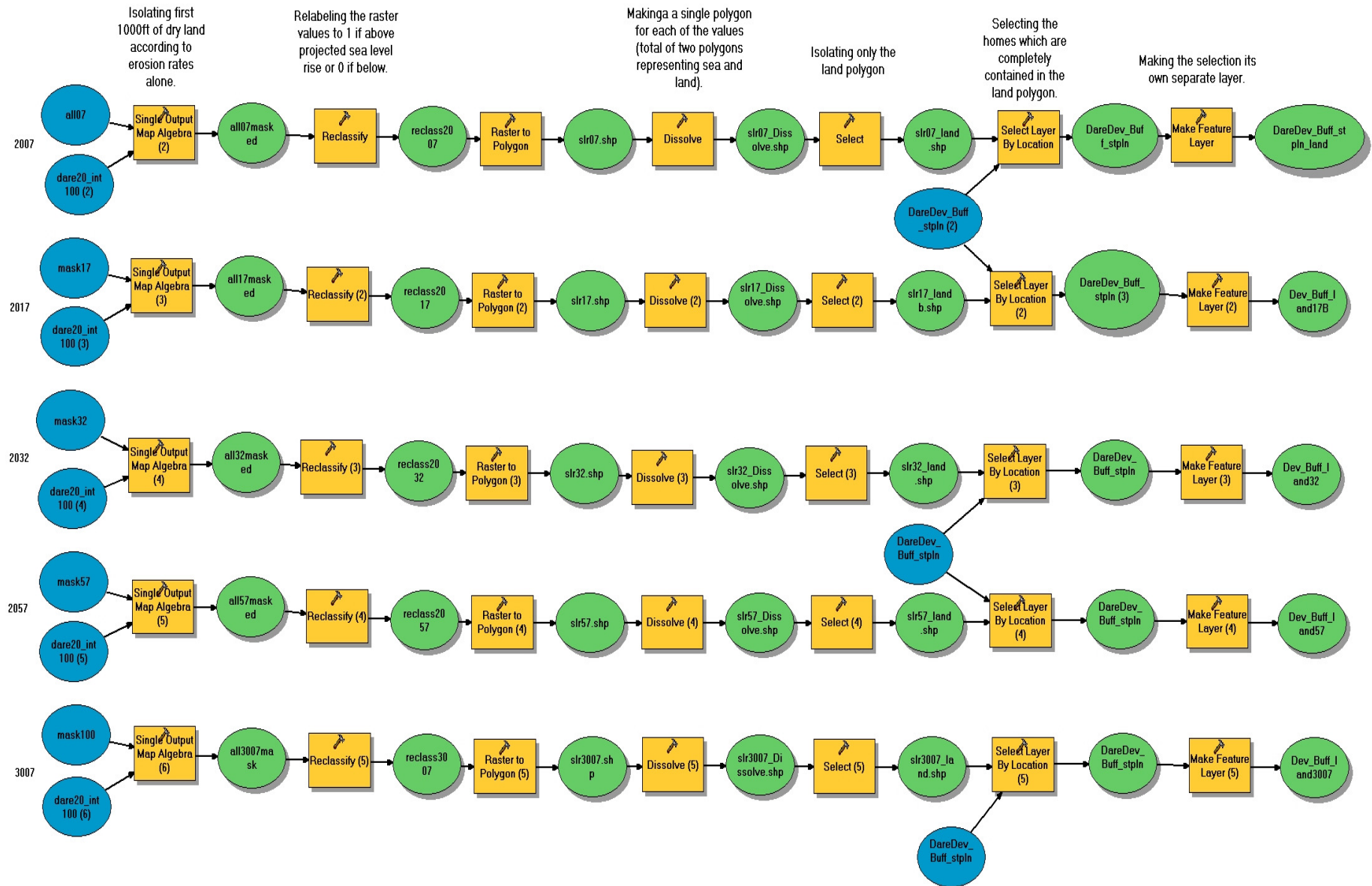
# Process: Erase...
gp.Erase_analysis(z3_07mask_Merge, allz_100_M_shp, all_100mask_shp, "")

# Process: Feature to Raster...
gp.FeatureToRaster_conversion(all_100mask_shp, "SOURCE", mask100, "20")

```

C. Sea Level Rise

Sea Level Rise Model graphic



Python script for Sea Level Rise Model

```
# -----
# SeaLevelRiseBest.py
# Created on: Thu Dec 11 2008 02:37:27 PM
# (generated by ArcGIS/ModelBuilder)
# -----

# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Check out any necessary licenses
gp.CheckOutExtension("spatial")

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst
Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Conversion
Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Data Management
Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Analysis
Tools.tbx")

# Set the Geoprocessing environment...
gp.XYResolution = ""
gp.scratchWorkspace = "F:\\GIS_Project\\seaLevelRise"
gp.MTolerance = ""
gp.randomGenerator = "0 ACM599"
gp.outputCoordinateSystem = ""
gp.snapRaster = ""
gp.outputZFlag = "Same As Input"
gp.qualifiedFieldNames = "true"
gp.extent = "2880000 540000 3060000 920000"
gp.XYTolerance = ""
gp.cellSize = "MAXOF"
gp.outputZValue = ""
gp.outputMFlag = "Same As Input"
gp.geographicTransformations = ""
gp.ZResolution = ""
gp.mask = ""
gp.workspace = "F:\\GIS_Project\\seaLevelRise"
gp.MResolution = ""
gp.ZTolerance = ""

# Local variables...
all07masked = "F:\\GIS_Project\\seaLevelRise\\all07masked"
all07 = "all07"
dare20_int100__2_ = "dare20_int100"
all17masked = "F:\\GIS_Project\\seaLevelRise\\all17masked"
all32masked = "F:\\GIS_Project\\seaLevelRise\\all32masked"
all57masked = "F:\\GIS_Project\\seaLevelRise\\all57masked"
dare20_int100__3_ = "dare20_int100"
```

```

mask17 = "mask17"
all3007mask = "F:\\GIS_Project\\seaLevelRise\\all3007mask"
mask32 = "mask32"
dare20_int100__4_ = "dare20_int100"
mask57 = "mask57"
dare20_int100__5_ = "dare20_int100"
mask100 = "mask100"
dare20_int100__6_ = "dare20_int100"
reclass2007 = "F:\\GIS_Project\\seaLevelRise\\reclass2007"
slr07_shp = "F:\\GIS_Project\\seaLevelRise\\slr07.shp"
slr07_Dissolve_shp = "F:\\GIS_Project\\seaLevelRise\\slr07_Dissolve.shp"
DareDev_Buff_stpln = "DareDev_Buff_stpln"
DareDev_Buff_stpln__2_ = "DareDev_Buff_stpln"
DareDev_Buff_stpln_land = "DareDev_Buff_stpln_land"
slr07_land_shp = "F:\\GIS_Project\\seaLevelRise\\slr07_land.shp"
reclass2017 = "F:\\GIS_Project\\seaLevelRise\\reclass2017"
slr17_shp = "F:\\GIS_Project\\seaLevelRise\\slr17.shp"
slr17_Dissolve_shp__2_ = "F:\\GIS_Project\\seaLevelRise\\slr17_Dissolve.shp"
DareDev_Buff_stpln__3_ = "DareDev_Buff_stpln"
slr17_landb_shp = "F:\\GIS_Project\\seaLevelRise\\slr17_landb.shp"
Dev_Buff_land17B = "Dev_Buff_land17B"
reclass2032 = "F:\\GIS_Project\\seaLevelRise\\reclass2032"
slr32_shp = "F:\\GIS_Project\\seaLevelRise\\slr32.shp"
DareDev_Buff_stpln__4_ = "DareDev_Buff_stpln"
slr32_land_shp = "F:\\GIS_Project\\seaLevelRise\\slr32_land.shp"
Dev_Buff_land32 = "Dev_Buff_land32"
DareDev_Buff_stpln__6_ = "DareDev_Buff_stpln"
reclass2057 = "F:\\GIS_Project\\seaLevelRise\\reclass2057"
slr57_shp = "F:\\GIS_Project\\seaLevelRise\\slr57.shp"
DareDev_Buff_stpln__5_ = "DareDev_Buff_stpln"
slr57_land_shp = "F:\\GIS_Project\\seaLevelRise\\slr57_land.shp"
Dev_Buff_land57 = "Dev_Buff_land57"
DareDev_Buff_stpln__8_ = "DareDev_Buff_stpln"
reclass3007 = "F:\\GIS_Project\\seaLevelRise\\reclass3007"
slr3007_shp = "F:\\GIS_Project\\seaLevelRise\\slr3007.shp"
DareDev_Buff_stpln__9_ = "DareDev_Buff_stpln"
slr3007_land_shp = "F:\\GIS_Project\\seaLevelRise\\slr3007_land.shp"
Dev_Buff_land3007 = "Dev_Buff_land3007"
slr32_Dissolve_shp = "F:\\GIS_Project\\seaLevelRise\\slr32_Dissolve.shp"
slr57_Dissolve_shp = "F:\\GIS_Project\\seaLevelRise\\slr57_Dissolve.shp"
slr3007_Dissolve_shp = "F:\\GIS_Project\\seaLevelRise\\slr3007_Dissolve.shp"

# Process: Single Output Map Algebra (2)...
gp.SingleOutputMapAlgebra_sa("all07 * dare20_int100", all07masked,
"all07;dare20_int100")

# Process: Reclassify...
gp.Reclassify_sa(all07masked, "VALUE", "-440 2.8300000000000001
0;2.8300000000000001 5373 1", reclass2007, "NODATA")

# Process: Raster to Polygon...
gp.RasterToPolygon_conversion(reclass2007, slr07_shp, "SIMPLIFY", "VALUE")

# Process: Dissolve...
gp.Dissolve_management(slr07_shp, slr07_Dissolve_shp, "GRIDCODE", "",
"MULTI_PART", "DISSOLVE_LINES")

```

```

# Process: Select...
gp.Select_analysis(slr07_Dissolve_shp, slr07_land_shp, "\"GRIDCODE\" = 1")

# Process: Select Layer By Location...
gp.SelectLayerByLocation_management(DareDev_Buff_stpln__2_,
"COMPLETELY_WITHIN", slr07_land_shp, "", "NEW_SELECTION")

# Process: Make Feature Layer...
gp.MakeFeatureLayer_management(DareDev_Buff_stpln, DareDev_Buff_stpln_land,
"", "", "OBJECTID OBJECTID VISIBLE NONE;AREA AREA VISIBLE NONE;PERIMETER
PERIMETER VISIBLE NONE;CB100SL_ CB100SL_ VISIBLE NONE;CB100SL_ID CB100SL_ID
VISIBLE NONE;FIPS FIPS VISIBLE NONE;CO_NAME CO_NAME VISIBLE NONE;CO_ CO_
VISIBLE NONE;CO_ABBR CO_ABBR VISIBLE NONE;SL_ID SL_ID VISIBLE NONE;BUFF_DIST
BUFF_DIST VISIBLE NONE")

# Process: Single Output Map Algebra (3)...
gp.SingleOutputMapAlgebra_sa("mask17 * dare20_int100", all17masked,
"dare20_int100;mask17")

# Process: Reclassify (2)...
gp.Reclassify_sa(all17masked, "VALUE", "-440 12.279999999999999
0;12.279999999999999 5373 1", reclass2017, "NODATA")

# Process: Raster to Polygon (2)...
gp.RasterToPolygon_conversion(reclass2017, slr17_shp, "SIMPLIFY", "VALUE")

# Process: Dissolve (2)...
gp.Dissolve_management(slr17_shp, slr17_Dissolve_shp__2_, "GRIDCODE", "",
"MULTI_PART", "DISSOLVE_LINES")

# Process: Select (2)...
gp.Select_analysis(slr17_Dissolve_shp__2_, slr17_landb_shp, "\"GRIDCODE\" =
1")

# Process: Select Layer By Location (2)...
gp.SelectLayerByLocation_management(DareDev_Buff_stpln__2_,
"COMPLETELY_WITHIN", slr17_landb_shp, "", "NEW_SELECTION")

# Process: Make Feature Layer (2)...
gp.MakeFeatureLayer_management(DareDev_Buff_stpln__3_, Dev_Buff_land17B, "",
"", "OBJECTID OBJECTID VISIBLE NONE;AREA AREA VISIBLE NONE;PERIMETER
PERIMETER VISIBLE NONE;CB100SL_ CB100SL_ VISIBLE NONE;CB100SL_ID CB100SL_ID
VISIBLE NONE;FIPS FIPS VISIBLE NONE;CO_NAME CO_NAME VISIBLE NONE;CO_ CO_
VISIBLE NONE;CO_ABBR CO_ABBR VISIBLE NONE;SL_ID SL_ID VISIBLE NONE;BUFF_DIST
BUFF_DIST VISIBLE NONE")

# Process: Single Output Map Algebra (4)...
gp.SingleOutputMapAlgebra_sa("mask32 * dare20_int100", all32masked,
"mask32;dare20_int100")

# Process: Reclassify (3)...
gp.Reclassify_sa(all32masked, "VALUE", "-440 26.48 0;26.48 5373 1",
reclass2032, "NODATA")

# Process: Raster to Polygon (3)...
gp.RasterToPolygon_conversion(reclass2032, slr32_shp, "SIMPLIFY", "VALUE")

```

```

# Process: Dissolve (3)...
gp.Dissolve_management(slr32_shp, slr32_Dissolve_shp, "GRIDCODE", "",
"MULTI_PART", "DISSOLVE_LINES")

# Process: Select (3)...
gp.Select_analysis(slr32_Dissolve_shp, slr32_land_shp, "\"GRIDCODE\" = 1")

# Process: Select Layer By Location (3)...
gp.SelectLayerByLocation_management(DareDev_Buff_stpln__6_,
"COMPLETELY_WITHIN", slr32_land_shp, "", "NEW_SELECTION")

# Process: Make Feature Layer (3)...
gp.MakeFeatureLayer_management(DareDev_Buff_stpln__4_, Dev_Buff_land32, "",
"", "OBJECTID OBJECTID VISIBLE NONE;AREA AREA VISIBLE NONE;PERIMETER
PERIMETER VISIBLE NONE;CB100SL_ CB100SL_ VISIBLE NONE;CB100SL_ID CB100SL_ID
VISIBLE NONE;FIPS FIPS VISIBLE NONE;CO_NAME CO_NAME VISIBLE NONE;CO_ CO_
VISIBLE NONE;CO_ABBR CO_ABBR VISIBLE NONE;SL_ID SL_ID VISIBLE NONE;BUFF_DIST
BUFF_DIST VISIBLE NONE")

# Process: Single Output Map Algebra (5)...
gp.SingleOutputMapAlgebra_sa("mask57 * dare20_int100", all57masked,
"mask57;dare20_int100")

# Process: Reclassify (4)...
gp.Reclassify_sa(all57masked, "VALUE", "-440 50.0799999999999998
0;50.0799999999999998 5373 1", reclass2057, "NODATA")

# Process: Raster to Polygon (4)...
gp.RasterToPolygon_conversion(reclass2057, slr57_shp, "SIMPLIFY", "VALUE")

# Process: Dissolve (4)...
gp.Dissolve_management(slr57_shp, slr57_Dissolve_shp, "GRIDCODE", "",
"MULTI_PART", "DISSOLVE_LINES")

# Process: Select (4)...
gp.Select_analysis(slr57_Dissolve_shp, slr57_land_shp, "\"GRIDCODE\" = 1")

# Process: Select Layer By Location (4)...
gp.SelectLayerByLocation_management(DareDev_Buff_stpln__6_,
"COMPLETELY_WITHIN", slr57_land_shp, "", "NEW_SELECTION")

# Process: Make Feature Layer (4)...
gp.MakeFeatureLayer_management(DareDev_Buff_stpln__5_, Dev_Buff_land57, "",
"", "OBJECTID OBJECTID VISIBLE NONE;AREA AREA VISIBLE NONE;PERIMETER
PERIMETER VISIBLE NONE;CB100SL_ CB100SL_ VISIBLE NONE;CB100SL_ID CB100SL_ID
VISIBLE NONE;FIPS FIPS VISIBLE NONE;CO_NAME CO_NAME VISIBLE NONE;CO_ CO_
VISIBLE NONE;CO_ABBR CO_ABBR VISIBLE NONE;SL_ID SL_ID VISIBLE NONE;BUFF_DIST
BUFF_DIST VISIBLE NONE")

# Process: Single Output Map Algebra (6)...
gp.SingleOutputMapAlgebra_sa("mask100 * dare20_int100", all3007mask,
"mask100;dare20_int100")

# Process: Reclassify (5)...
gp.Reclassify_sa(all3007mask, "VALUE", "-440 97.3199999999999993
0;97.3199999999999993 5373 1", reclass3007, "NODATA")

```

```

# Process: Raster to Polygon (5)...
gp.RasterToPolygon_conversion(reclass3007, slr3007_shp, "SIMPLIFY", "VALUE")

# Process: Dissolve (5)...
gp.Dissolve_management(slr3007_shp, slr3007_Dissolve_shp, "GRIDCODE", "",
"MULTI_PART", "DISSOLVE_LINES")

# Process: Select (5)...
gp.Select_analysis(slr3007_Dissolve_shp, slr3007_land_shp, "\"GRIDCODE\" =
1")

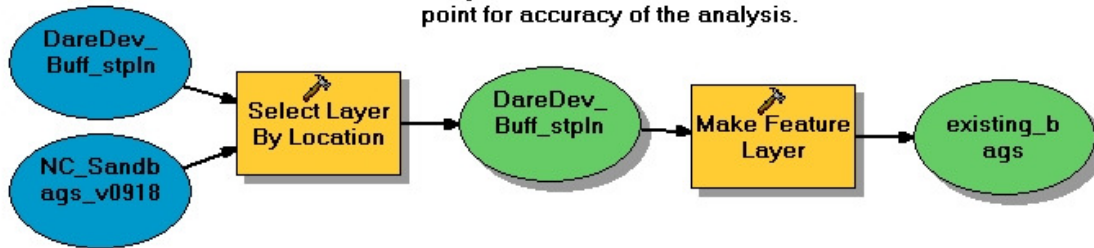
# Process: Select Layer By Location (5)...
gp.SelectLayerByLocation_management(DareDev_Buff_stpln__8_,
"COMPLETELY_WITHIN", slr3007_land_shp, "", "NEW_SELECTION")

# Process: Make Feature Layer (5)...
gp.MakeFeatureLayer_management(DareDev_Buff_stpln__9_, Dev_Buff_land3007, "",
"", "OBJECTID OBJECTID VISIBLE NONE;AREA AREA VISIBLE NONE;PERIMETER
PERIMETER VISIBLE NONE;CB100SL_ CB100SL_ VISIBLE NONE;CB100SL_ID CB100SL_ID
VISIBLE NONE;FIPS FIPS VISIBLE NONE;CO_NAME CO_NAME VISIBLE NONE;CO_ CO_
VISIBLE NONE;CO_ABBR CO_ABBR VISIBLE NONE;SL_ID SL_ID VISIBLE NONE;BUFF_DIST
BUFF_DIST VISIBLE NONE")

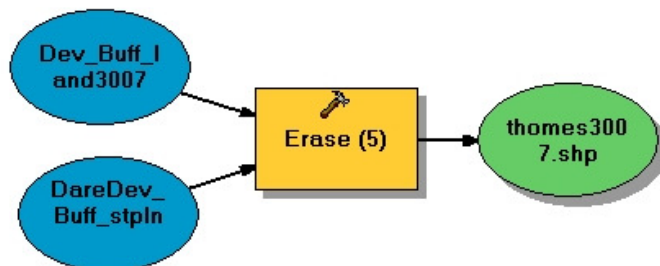
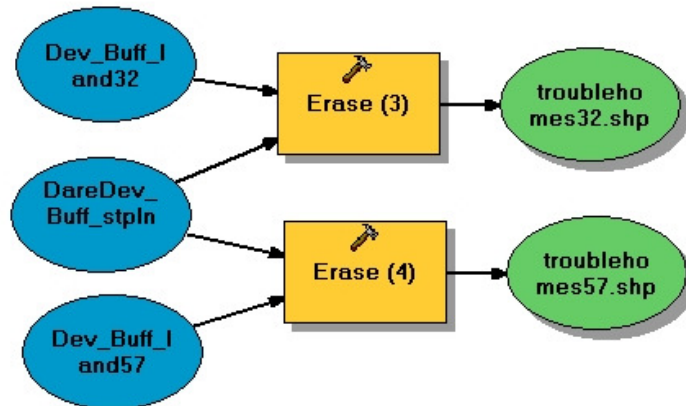
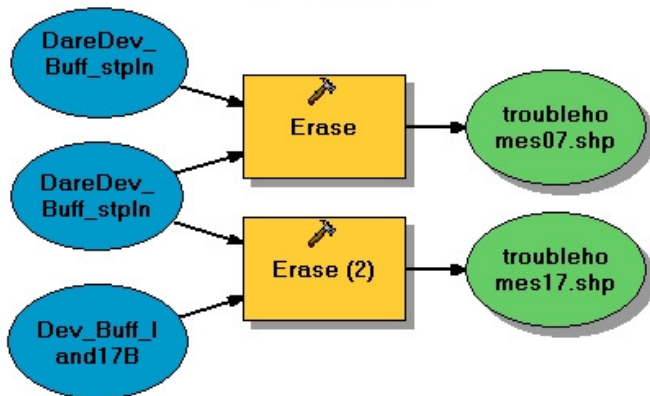
```

D. Development Effected Homes in Peril Model graphic

Homes within 25 feet of exisiting sandbags as of May 2008. This was used a reference point for accuracy of the analysis.



Isolating those homes which will need sandbags or be underwater in each of the 5 time periods.



Python script for Homes in Peril Model.

```
# -----
# finalhomesmodel.py
# Created on: Thu Dec 11 2008 02:23:35 PM
# (generated by ArcGIS/ModelBuilder)
# -----

# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Set the necessary product code
gp.SetProduct("ArcInfo")

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Data Management
Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Analysis
Tools.tbx")

# Set the Geoprocessing environment...
gp.XYResolution = ""
gp.scratchWorkspace = "F:\\GIS_Project\\HomesInPeril"
gp.MTolerance = ""
gp.randomGenerator = "0 ACM599"
gp.outputCoordinateSystem = ""
gp.snapRaster = ""
gp.outputZFlag = "Same As Input"
gp.qualifiedFieldNames = "true"
gp.extent = "DEFAULT"
gp.XYTolerance = ""
gp.outputZValue = ""
gp.outputMFlag = "Same As Input"
gp.geographicTransformations = ""
gp.ZResolution = ""
gp.workspace = "F:\\GIS_Project\\HomesInPeril"
gp.MResolution = ""
gp.ZTolerance = ""

# Local variables...
Dev_Buff_land3007 = "Dev_Buff_land3007"
Dev_Buff_land32 = "Dev_Buff_land32"
Dev_Buff_land57 = "Dev_Buff_land57"
DareDev_Buff_stpln_land = "DareDev_Buff_stpln_land"
DareDev_Buff_stpln = "DareDev_Buff_stpln"
troublehomes07_shp = "F:\\GIS_Project\\HomesInPeril\\troublehomes07.shp"
troublehomes17_shp = "F:\\GIS_Project\\HomesInPeril\\troublehomes17.shp"
troublehomes32_shp = "F:\\GIS_Project\\HomesInPeril\\troublehomes32.shp"
troublehomes57_shp = "F:\\GIS_Project\\HomesInPeril\\troublehomes57.shp"
thomes3007_shp = "F:\\GIS_Project\\HomesInPeril\\thomes3007.shp"
DareDev_Buff_stpln__2_ = "DareDev_Buff_stpln"
DareDev_Buff_stpln__3_ = "DareDev_Buff_stpln"
```

```

Dev_Buff_land17B = "Dev_Buff_land17B"
DareDev_Buff_stpln__4_ = "DareDev_Buff_stpln"
DareDev_Buff_stpln__5_ = "DareDev_Buff_stpln"
NC_Sandbags_v09182008 = "NC_Sandbags_v09182008"
existing_bags = "existing_bags"

# Process: Erase...
gp.Erase_analysis(DareDev_Buff_stpln, DareDev_Buff_stpln_land,
troublehomes07_shp, "")

# Process: Erase (2)...
gp.Erase_analysis(DareDev_Buff_stpln, Dev_Buff_land17B, troublehomes17_shp,
"")

# Process: Erase (3)...
gp.Erase_analysis(DareDev_Buff_stpln__2_, Dev_Buff_land32,
troublehomes32_shp, "")

# Process: Erase (4)...
gp.Erase_analysis(DareDev_Buff_stpln__2_, Dev_Buff_land57,
troublehomes57_shp, "")

# Process: Erase (5)...
gp.Erase_analysis(DareDev_Buff_stpln__3_, Dev_Buff_land3007, thomes3007_shp,
"")

# Process: Select Layer By Location...
gp.SelectLayerByLocation_management(DareDev_Buff_stpln__5_,
"WITHIN_A_DISTANCE", NC_Sandbags_v09182008, "25 Feet", "NEW_SELECTION")

# Process: Make Feature Layer...
gp.MakeFeatureLayer_management(DareDev_Buff_stpln__4_, existing_bags, "", "",
"OBJECTID OBJECTID VISIBLE NONE;AREA AREA VISIBLE NONE;PERIMETER PERIMETER
VISIBLE NONE;CB100SL_ CB100SL_ VISIBLE NONE;CB100SL_ID CB100SL_ID VISIBLE
NONE;FIPS FIPS VISIBLE NONE;CO_NAME CO_NAME VISIBLE NONE;CO_ CO_ VISIBLE
NONE;CO_ABBR CO_ABBR VISIBLE NONE;SL_ID SL_ID VISIBLE NONE;BUFF_DIST
BUFF_DIST VISIBLE NONE")

```

APPENDIX III

Duke University Institutional Review Board for the Protection of Human Subjects

FWA No. 00000265 Notice of Approval of Exemption Request

Investigator(s): Jennie Dean
Advisor: Rafe Sagarin
Title: Sandbag Use in North Carolina and the Midwest
Exemption Number: 2573
Approval Date: Wednesday, November 26, 2008
Sponsor: None
Sponsor Number
(if applicable):

Please note: Approval is contingent upon maintaining certification to conduct research with human subjects.

This research is exempt from further review by the IRB unless a proposed change in the research makes it no longer eligible for an exemption. For example:

-- The researchers find that there is an unanticipated risk to the subjects. (There can be no risk to subjects in exempt research.)

-- The researcher wishes to add a protected subject population such as students in the Psychology Department Subject Pool or students of the researcher.

-- The researcher wishes to change the methodology so that it no longer fits an eligible category of research activity.

If the research is no longer eligible for exemption, please contact the Human Subjects Specialist at 684-3030.

Duke University adopted a set of ethical principles to cover all research with human subjects, even exempt research, regardless of the source of funding. The principles, respect for persons, beneficence, and justice, described in the Belmont Report, can be found at
<<http://ohrp.osophs.dhhs.gov/humansubjects/guidance/belmont.htm> >

Data Retention

In accordance with Duke's Data Retention Policy, signed consent forms and other research records must be maintained for five years after the completion of the research.
< <http://www.ors.duke.edu/policies/datarete.htm> >

Completed Research

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Please inform the Office for Protection of Human Subjects when the research is completed. You may send notice of completion to ors-info@duke.edu. *Generated by Admin on 1/26/2009 1:32:02 PM*

Semi-structured Interview Guide

I. Introduction and Study Background

Hello, my name is Jennie Dean and I am masters student at Duke. For my master's project, I am investigating the use of sandbags on the oceanfront shorelines in North Carolina. I have completed background research on the legislative history of sandbag use and the natural science of barrier islands but now I am talking with important stakeholders and parties involved in the policy development and management/implementation process. My goal in this is to determine what factors are contributing to the sandbag/hardened shoreline management process and specifically how things are to proceed in the future. I have a particular interest in the mandatory removal deadline of May 1, 2008 which has come and gone.

I would like to inform you that I am taping your responses but I do not intend to replay them for anyone but myself. Furthermore any responses you provide will not be attached to your name in my final project but rather to the group which you represent, for example the DCM or NSCU. I will destroy the recordings upon completion of the project. I do want to make you aware however that all Duke masters projects are made available to the general public upon completion, so the main themes of this interview and others will be presented in a such a format. If any of this information makes you uncomfortable please let me know so that I can address your concerns. Feel free to do so at any point during the interview as well.

II. Sandbag Legislation

How do you feel about the current approach to hardened shorelines on the oceanfront in NC and why?

Specifically relating to sandbags?

Do you think that this reflects a general consensus of the people in your field or at your organization?

Do you think that this method can be sustained in the coming years? For how long?

What are the pros and cons of sandbag use in your eyes? And which side outweighs the other?

Are you familiar with the legislation which guides sandbag use. If yes, what is your opinion of the legislation?

Is it good in its current form?

What improvements could be made?

Are too many people receiving variance permits?

Is the permitting process transparent enough?

How well are the permits enforced and who is that a reflection of?

Who do you perceive as the most powerful, vocal, or influential stakeholders in this issue? Please differentiate between these descriptors and elaborate on how you have come to your conclusions.

Have concerns about contamination of the sand contained within the bags been raised in any of your discussions of the issue?

What about the damage the broken bags do to surrounding shorelines and estuaries?

Is there anything that can be done about that damage?(alteration in design of bags, placement restrictions, etc)

What about alternate technologies to make the sandbags more biodegradable? Smaller in size, different materials, reduced total structure size?

Are you aware of anyone doing studies on these aspects or trying to implement them in the permitting process?

III. The Future

May 1, 2008 was supposed to mark the end of all un-vegetated, expired permit sandbag structures. From my research, this failed. Do you hold the same opinion? Why?

If yes, what was the cause of the failure to remove?

What, if anything, can be done now to induce removal?

Does this non-removal suggest that there needs to be a change in the legislation and/or enforcement body?

Is there too much political pressure to actually enforce removal?

Should property owners be responsible to compensate the State if the State has to conduct the removal themselves?

Do you foresee any point in the future when there will be no sandbags? Why?

Do you think that the legislation will be altered? in a manner to weaken or strengthen it? By whom? (CRC or NC General Assembly)

Typically there are three adaptations to shoreline erosion. Retreat/relocation, nourishment and erosion control structures. Sandbags obviously fall into the final category. Given the projections of sea level rise and highly volatile nature of the NC shore, which approach do you think will prevail in the coming decades? Why? If sandbags aren't the solution, then when do you think the change will be made?

IV. Section specific to CRC members

How many permit applications do you receive a year? Of those how many are accepted?

How has the transfer of permitting power from the local governments to the CRC in 1996 changed the process?

Was this an improvement?

Has documentation been better?

What about enforcement? The DCM website lists only 10 sandbag violations in the past 5 years which seems abnormally low. Is this an accurate statistic? What is being done to

enforce permits, both in terms of only installing sandbags with one and then removing them when the permit expires?

Who typically brings the permits? Private land owners, commercial land owners, contractors?

What are the typical arguments and how do you weigh the judgments?

Is it voted upon by majority or unanimous decision?

Is there pressure to change the regulations? And if so, when do you think that they will be changed and in what manner?

Can you describe the prioritizing system that was devised to determine which bag structures need to be targeted for removal first? What stage of the process are you in now?

I have not read of any bag removal in any circumstance. Can you describe an instance of when a homeowner has voluntarily removed their sandbags? Or when they have done so at the request of the State or CRC?

V. Conclusion

Thank you very much for your time. You have provided some input that will be very valuable for my project. If you would like, I would be happy to send you a copy of the final product in April. Is that something you would be interested in?

As a final question, is there anyone you can think of who would be good to talk to about this issue?

Are there any facets of the topic which we have not addressed but about which you would like to make a statement or comment?

Well thank you again for your time. It has been quite helpful. Would it be alright for me to contact you in the future if I have any additional questions?

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