Appendix D. ii.
Flood Insurance, Erosion and Coastal Development
Executive Summary

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Rapid economic growth in coastal areas has sparked debate about government's role in attenuating the risks of property damage from coastal storms. One issue is whether government programs, such as federal flood insurance, that reduce property owners' expected losses from coastal storm damage encourages significant "induced economic development" along coastal shorelines. Recent attention has also been focused on the effects of erosion in these areas.

Some people believe that the availability of flood insurance in beachfront areas has been a major factor in encouraging shoreline development. Others, however, argue that the rate and pattern of beachfront development has been shaped by "fundamental" economic factors that have little to do with the availability or terms of insurance. This study examines how exposure to erosion hazards and the availability of federal flood insurance affects the pattern of development in coastal beachfront areas.

The survey of structures completed as part of the FEMA Erosion Hazards Study provides a unique opportunity to examine the effects of erosion and flood insurance on the "decision to build or not to build" at a truly micro level. This level of detail allows the information obtained from the survey to be used to measure patterns and trends in development *within* coastal communities.

Creating Longitudinal Panels of Development Within Communities

The inventories of structures undertaken for the Erosion Hazards Study provide a *single -year snapshot* of structures that are observed to be in place at each site in the study. These snapshots contain information on structures — primarily residential property — that include: the year in which a structure was built, the square footage of the structure, the square footage of the parcel on which the structure is built, and other relevant information such as the current and future (projected) distance of the property from the erosion reference line as portrayed in the maps. The data also identify whether structures are currently located in the AE, VE, or other zones and whether they will be located in such zones in the future.

These community snapshots can be transformed into within-community development histories that track: (1) the *pattern* of development *at given moments in time* observed in different parts of the community with varying exposure to erosion and flood hazards*;* and (2) *trends over time* in development in different parts of the community. Data from the inventory of structures were sufficiently complete to allow development histories to be created for seven sites: portions of Dare County, North Carolina; Glynn County, Georgia; Brevard County and Lee County, Florida; Georgetown County, South Carolina; Galveston County, Texas; and Santa Cruz, California.

Data from these seven sites were used to construct measures of development density that track patterns of development in over 160 different blocks over a 35 year period from 1963 to 1998. The blocks are distributed among the seven sites as shown in the table below.

Observations on Capital-Land Ratios					
Site	**Communities within Site**	**# of Rectangles or "T's"**	**# of Blocks**	**Yrs.**	**# of Obs. (Yrs. X # of Blocks)**
Glynn, Ga.	Jekyll Island, Sea Island, St. Simon's Island	4 (Rectangles)	14	35	490
Dare, N.C.	Avon, Duck, Kill Devil Hills, Kitty Hawk, Nags Head, Rodanthe, Southern Shores, Waves	18 (T's)	51	35	1785
Brevard, Fla	Melbourne Beach, Cocoa Beach	3(T's)	9	35	315
Lee, Fla.	Boca Grande, Sanibel, Ft. Myers Beach	11 (T's)	28	35	980
Georgetown, SC.	Garden City Beach, Litchfield Beach, Debidue	4 (T's)	12	35	420
Galveston, Tx.	Crystal Beach, Galveston, Jamaica Beach	11(T's)	33	35	1155
Santa Cruz, Ca.	Aptos, Live Oak, Capitola, Watsonville	7(T's)	17	35	595

Results

Statistical analysis was performed on the longitudinal panels that result from creating the development histories in order to answer the following questions.

- How is the pattern of development within coastal communities affected by differing exposure to erosion and flood hazards?

- Does greater exposure to flood and erosion hazards cause the density of development to be lower than it otherwise would be?

- Do public policies that reduce the exposure to these hazards increase the density of development?

Statistical Analysis

The basic framework used to address these questions is a multivariate regression model in which the dependent variable to be explained is the density of development in each block, as measured by the *capital-to-land ratio,* which is the ratio of building square feet to total square feet of land in each block. The results of the analysis for the communities examined in the study can be summarized as follows.

- There has been a generally upward trend in development density over time.

- Development density increases with rising demand for beachfront recreation, as measured by employment in establishments providing recreation-related services and a time trend.

- In the absence of flood insurance, development density is roughly 20 to 30 percent less in areas that are prone to flood risks than it is in safer areas.

- The degree of setback from the erosion hazard has mixed effects. On balance, greater setback had a positive and statistically significant effect on development density *inside the 30 year erosion hazard area* (30 year EHA), but a negative and significant effect on development density outside the 30 year EHA, especially in areas outside the 60 year EHA. These results suggest that property owners view setback away from the erosion reference feature (which typically is close to the shoreline) as as an *amenity* in areas where the threat from erosion is seen to be more immediate (i.e. inside the 30 year EHA); but as.a *disamenity* in areas where the risk of erosion is perceived to be more remote (i.e. outside the 60 year EHA). The quantitative magnitude of the coefficients on the setback variables seem to be modest, however. For example, inside the 30 year EHA, a reduction of 10 years in setback from the erosion reference feature is estimated to reduce development density by roughly 7 percent.

  There is also statistical evidence that, in the sample of coastal areas analyzed, reducing the exposure of property owners to risks of flooding affected development patterns.

- Federal flood insurance has had the effect of increasing development density in areas close to the ocean, while decreasing it in inland areas. Providing subsidized flood insurance under both the Emergency and Regular phases of the NFIP is estimated to have increased development density "at the water's edge" by roughly 40 percent.

- Federal flood insurance has had the effect of increasing development density in areas that are prone to flood risk. Compared to the case in which there was no federal flood insurance, providing flood insurance under the Emergency Flood Insurance Program increased development density in V zones by roughly 18 percent, while the Regular Insurance Program increased development density by 11 percent.

- Designation as a CBRA area is estimated to have reduced development density by between 40 to 60 percent.

- Beach nourishment activities do not increase development density across the board, but do raise density in beachfront areas and in V zones.

The finding that participation in the regular flood insurance program (the regular NFIP) increased development density close to the shoreline and in V zones deserves further comment. One might expect that participation in the regular NFIP would have offsetting effects on development in areas prone to flood risks. Better information about flood risks provided by a community flood map might be expected to reduce development density in areas identified as having higher flood risks. But, completing a flood map also prompted many communities to enact building codes intended to mitigate risks of flood damage. These regulations made it more costly to build; but there is evidence that these higher costs were less than the expected damages avoided by implementing the more stringent building codes. Tougher building codes may thus actually have lowered the net cost of building in areas prone to flood risk, which would encourage more development.

In addition, although efforts were made to charge actuarial rates in the regular NFIP, it is arguable that property owners continued to benefit from subsidized insurance under the regular program, and indeed were able to insure larger amounts against loss. Administrators of the NFIP have observed that, although premiums paid to the NFIP cover losses from floods experienced over the past twenty years, many experts believe that the past twenty years have been characterized by "below-average" risk of storm damage. The implication is that current premiums would need to be higher to cover "expected" risks from storms. Premiums charged for private insurance coverage in CBRA areas, where federal flood insurance is unavailable, are also higher than premiums charged under the NFIP.

The statistical evidence suggests that increased availability of flood insurance affected the pattern, if not the level, of development in the sample of communities analyzed in this study. On balance, the results show that the combination of flood insurance and tougher building codes increased the density of development in areas subject to "higher than average" risks of damage from coastal floods.

Flood Insurance, Erosion and Coastal Development

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Introduction

Rapid development of shore areas with their unique ecological attributes is apparent to all observers as beach front communities from Maine to Texas have experienced high rates of residential growth compared to inland communities. The rapid economic growth in coastal areas has sparked debate about the government's role in attenuating the associated risks faced by property owners in these areas, which are frequently at risk from property damage cost by major storms, as well as by beach erosion. One issue is whether government programs that reduce property owners' expected losses from coastal storms, such as federal flood insurance, encourage significant "induced economic development" along coastal shorelines. Recently, attention has also been focused on the effects of erosion in these areas, both because erosion can magnify potential damages from flooding, and because erosion poses additional risks in its own right.

Effects of Insurance on Economic Development

As noted by Leatherman (1997), the issue of whether flood insurance causes property to be put in "harm's way" is not settled. Some believe that the availability of flood insurance in beachfront areas has been a major factor in encouraging shoreline development. Others, however, argue that beachfront development has been shaped by "fundamental" economic factors that have little to do with the availability or terms of insurance.

The rising cost of insurance claims, both private and government sponsored, in the last decade has stimulated substantial interest in various aspects of the provision of insurance against losses from natural disasters. Two important questions are: (1) To what extent do owners of property in high-risk areas purchase insurance and invest in mitigation efforts; and (2) How do insurance, mitigation expenditures, and post disaster aid interact and affect economic development.

Behavior and Perceptions of Property Owners in High Risk Areas

Significant efforts have been made to assess whether individuals in high risk areas accurately perceive those risks and act upon them in their insurance and mitigation decisions. The National Flood Insurance Program (NFIP) has served as a poster child for non-participation. Kunreuther (1978) noted that, in the first four years on the program (1968-72), only 3,000 of 21,000 eligible communities with substantial flooding history participated in the program and fewer than 300,000 homeowners voluntarily purchased a policy. In spite of the fact that NFIP was subsidized, participation was initially achieved only by threatening to withhold federally-assisted or guaranteed construction from non-participating communities, and by denying mortgage loans to property owners in on-participating communities that were identified as special flood hazard areas.[1] (Palm, et al (1990) have documented a similar failure of homeowners and even mortgage lenders to seek earthquake insurance in high risk areas.)

To some, the observed failure to insure raises questions about the applicability of standard economic models of the decision to insure in the special case of natural disasters. Kunreuther and Kleffner (1992) and Kunreuther (1996) have argued that homeowners do not behave as if they were maximizing expected utility in their decisions to purchase insurance or engage in private mitigation efforts. They contend that instead observed behavior most closely resembles the contingent weighting model in which individuals place different weights on the probability of a hazard event and on the contingent loss should it occur. If individuals place low weights on the probability of infrequent natural hazard events, they will act as if the expected utility of insurance and mitigation is lower than that perceived by experts.[2] (The failure of the public to use seat belt restraints has been rationalized this way.) Kunreuther and Kleffner (1992) consider simple benefit cost estimates of a loss mitigation measure, bracing pre-1940 homes in California so that they would not slide off their foundations, and find that low rates of mitigation appear to suggest low probabilities of hazard events, or low weighting of those probabilities.

Overall, it appears that property owners in areas subject to natural hazard risk appear to underspend on insurance and mitigation efforts compared to standards that appear justified by sound benefit-cost analysis.[3] Even where building codes require cost-effective mitigation efforts, Kunreuther (1996) reports serious cases of under-investment and failure to comply, resulting in significant additional damage, for example, in the case of hurricane Andrew.

Although property owners in high-risk areas appear to ignore those risks, there is evidence that behavior changes "after the fact" with additional information. Most dramatic is the finding by Palm, et al (1990) that, prior to the Loma Prieta earthquake, there was no relation between proximity to the San

[1] While the subsidy component of the NFIP for structures constructed under the regular program is likely small, older structures receive a significant subsidy and yet have significant non-participation rates. This in spite of requirements that lenders require flood insurance as a condition for giving a mortgage because owners have allowed policies to lapse after a modest period without having experience hazard losses. Overall, only about one-fourth of homeowners in flood-hazard areas have purchased NFIP insurance.

[2] Kunreuther (1978) first argued that property owners fail to purchase insurance and spend for mitigation some time ago. See also Brown (1972) and Kunreuther and Roth (1998).

[3] See Palm, *et. al*. (1990) for survey evidence on the failure of property owners to adopt any mitigation actions in earthquake-prone areas of California.

Andreas fault and the rate of purchase of earthquake insurance; but that after the earthquake the purchase of insurance increased and that insurance rates fell with distance from the fault. Survey evidence indicated further that attitudes toward the importance of earthquake insurance shifted substantially after the Loma Prieta earthquake. There is also evidence that market prices reflect learning behavior. Brookshire, Thayer, Tschirhart, and Schulze (1985) find that publication of information on the distance from properties and established fault lines causes house prices to fall within the earthquake prone zone. Shilling, Benjamin, and Sirmans (1985) have found that NFIP subsidies to pre-FIRM structures were capitalized into house values. As noted in some detail above, Yezer and Rubin (1987) find that housing prices respond to unanticipated disaster events, i.e. to differences between the frequency of floods, windstorms, etc during a given period and the previous history of such events. Thus it may be individual are motivated by changes in expected risk and the variance in expected risk to change their behavior in expected ways, but only with a lag. That is, changes in disaster events have the predicted effect on property owner's perceptions and behavior as well as on market prices, but only *after the event*.

Thus, the responses of property owners in high hazard risk areas with high exposure to hazards are only partly consistent with standard expected utility models employed to explain expenditures for insurance and mitigation. One possible explanation for observed behavior is that property owners are selected into high hazard areas based on their perceptions of risks. If markets provide price discounts for properties in areas with greater hazard risk, those properties will be differentially attractive to individuals who fail to perceive the risks. Alternatively, if there is a risk distribution, those whose expectation of actual risk is at the low end of expert opinion will likely occupy properties in areas rated as highest risk by the experts. With low probability events, where expert opinion on frequency has high variance, it would not be surprising if property owners in the highest risk areas believed that risks were at the low end of the distribution of expert opinion. Subsequent occurrence of an event, however, could still have a dramatic effect on these expectations as survey evidence and behavior have shown.

Interaction Among Insurance, Mitigation, and Post-Disaster Aid

From the point of view of the property owner, insurance, mitigation, and post-disaster aid are all substitutes, providing either funds to cover losses or lowering losses contingent on a natural disaster event occurring. As noted by a number of authors, establishment of public subsidies for insurance or mitigation, or the provision of post-disaster relief have the effect of shifting the burden of loss, both loss expected ex-ante and loss experienced ex-post, from the property holder to others.[4]

It is widely recognized that a key issue is whether the insurance is subsidized or not. Unsubsidized insurance shifts the burden of loss *ex-post* to those who have purchased the contingent liability but does not

[4] Note particularly the extensive discussion in Kunreuther (1996).

shift expected costs *ex-ante* as actuarially sound premiums reflect expectations of loss. In contrast, government-subsidized insurance and mitigation followed by post-disaster aid are predicted to encourage over-development and under- mitigation in high-risk areas because such programs lower the expected *ex-ante* cost of hazard. For example, Frame (1998) shows, using a general equilibrium model, that disaster insurance subsidies raise land and house prices and increase the density of development.

Estimating Effects of Insurance and Erosion on Development: Choosing the Unit of Analysis

Although theory predicts that providing subsidized insurance or undertaking other risk mitigation efforts tends to increase the density of real property development in high hazard areas, there is limited empirical evidence on the size of these real development effects, or indeed on whether they exist. Schilling, Sirmans, and Benjamin (1984) find that the availability of subsidized flood insurance is capitalized into land values; and most recently, Cordes and Yezer (1998) consider whether flood insurance through the NFIP, and mitigation in the form of beach enhancement by the U.S. Army Corps of Engineers can explain differences in development among communities that include beachfront areas.

Cordes and Yezer estimate a reduced-form model of economic development for beach communities. The general form of the estimating equation was: $\mathbf{Y = f(X_1, X_2, X_3) +} e$, where Y is the change in development in shoreline areas, as measured by new housing starts, $\mathbf{X_1}$ is an exogenous demand shifter based on proximity-weighted employment in nearby metropolitan areas, a vector of state dummy variables and variables indicating recent storm damage problems, and $\mathbf{X_2}$ and $\mathbf{X_3}$ are vectors of variables that measure effects of federal flood insurance, and shore protection projects, respectively.

To estimate this equation, the authors assembled a pooled cross-section, time series of data from coastal communities. The data included variables that measure economic development in shoreline areas, demand for recreation services, exposure to storm damage, and the effects of federal flood insurance and shore protection projects.

Forty-two beachfront communities which constituted the sample of interest for the Corps of Engineers were selected to provide variation both over time, and among communities in: beachfront economic development, demand for beachfront services, exposure to storm damage, and the scope of federal involvement in attenuating the economic losses from storm damage, either through federal flood insurance, or through Corps of Engineers shore protection projects. The time period covered was from 1960 to 1992, yielding 33 observations for each area. Within the panel of communities, it was possible to observe economic development in the same community before and after the provision of flood insurance and/or Corps shore protection projects, as well as among different communities with and without such federal programs.

Cordes and Yezer find that the main cause of growth in beachfront communities has been increased demand for recreation caused by rising income and employment in inland areas. But, they also find evidence that initial participation in the Federal flood insurance program encouraged a significant amount of additional development.

This finding contrasts with the relative paucity of evidence from other studies that the availability of flood insurance (or lack thereof) has a noticeable affect on beachfront development (Leatherman, 1997). The results reported by Cordes and Yezer may seem surprising because only a modest fraction of property owners in beachfront communities have chosen to maintain insurance in force. Nevertheless, insurance availability appears to have encouraged new owners while beach enhancement failed to do so. One possible explanation is that at the time that flood insurance was introduced, the federal government made an explicit attempt to tie access to federal funds for infrastructure development to participation in the flood insurance program. In that case, the findings reported in Cordes and Yezer may reflect the combined effects on development of flood insurance and infrastructure aid "tied" to community participation in the flood insurance program.[5]

Limitations of Community-Level Data

Using the community as the unit of analysis, however, has an important limitation. Namely, community-level data cannot capture shifts in development patterns *within* a community that economic models predict are likely to result from changes in the exposure of property owners to natural hazards — either because of nature, or because of man-made public policies. It is quite plausible that the main effect of different exposure to natural hazards is to alter the *pattern* of development *within* a community -- e.g. by causing development to shift out of "safe" inland areas into otherwise attractive areas that have relatively high risk of flooding and/or erosion. This may or may not affect the level of development in the community at-large, which is made up of areas with varying degrees of exposure to erosion hazards.

Measuring Development Patterns and Trends Within Communities

The survey of structures that is part of the FEMA erosion study provides a unique opportunity to examine the effects of flood insurance on the "decision to build or not to build" at a truly micro level. This level of detail allows the information obtained from the survey to be used to measure patterns and trends in development *within* each of the FEMA sites that are surveyed.

Transforming the "raw data" from these inventories is a rather complicated process that requires using information from maps as well as the electronic data on the spreadsheets. A detailed description of how these data were constructed is provided in Appendix 1. This section summarizes the steps involved

[5] This point was made by Frank Reilly at the initial advisory board meeting.

in creating what we shall term *within-community-development histories* for Glynn County, which was the first county for which complete data from the FEMA project became available. The same process was subsequently used to create comparable data from the structure inventories that were undertaken at six other sites.

Characteristics of the Inventories of Structures

The inventories of structures undertaken as part of the Erosion Hazards Study provide a *single - year snapshot* of structures that are in place at each of the sites. This snapshot provides information on structures — primarily residential property — that includes: the year the structure was built, the square footage of the structure, the square footage of the parcel (as created on the FEMA maps), and other vital information such as the current and future (projected) distance of the property from the erosion reference line as portrayed in the maps. The data also identify whether structures are currently located in the AE, VE, or other zones and whether they will be located in such zones in the future.

Research Questions to be Answered

The task is to transform the community snapshots into within-community development histories that provide information about:

- The *pattern* of development that is observed in different parts of the community with varying exposure to erosion hazards *at given moments in time.*

- *Trends* in development *over time* in different parts of the community, as a function both of changes in exposure to erosion hazards, and of changes in public policies.

In short, the data from the inventories need to be transformed into longitudinal data for each site that describe how development has unfolded over time, in different parts of the community.

Before describing the steps that are involved in creating these within-community development histories, it is useful to review *why* these data need to created. Broadly speaking, we are interested in answering two research questions.

- How do differing exposures to erosion hazards affect the pattern of development within coastal communities? In particular, is there evidence that greater exposure to erosion hazards causes the density of development to be lower than it otherwise would be?

- Do public policies that reduce the exposure to this hazard increase development density?

Longitudinal data on patterns of development over time within communities are well-suited to answering each of these questions. *At any point in time*, such data allow one examine whether there is a relationship between the density of development in different parts of the community and the spatial distribution exposure to erosion hazards, holding other factors constant. *Over time*, these data allow one to examine whether the relationship between development density and hazard exposure is affected by policy changes, such as the introduction of flood insurance, the implementation of a beach nourishment project, the drawing of a flood-map, or designation as a CBRA area.

Defining the Unit of Observation

Transforming the inventory of structures into longitudinal panels requires reorganizing these data in two major ways.

- Communities (e.g. the FEMA study sites) need to be "broken-down" into smaller geographical units of analysis that reflect spatial differences within the community to exposure to erosion hazards.

- For each within-community geographical unit of analysis, a time-series of how the unit has been developed over time needs to be created from the single snapshot.

Step 1: Defining "Rectangles," "T's" and "Blocks"

The original data encompass aerial maps for 1997 for the various sites in the Erosion Hazards Study. These maps are arranged according to grids along different beaches. The maps identify current and future erosion reference lines, current and future AE, and VE zones, and have the beach sectioned into parcels with both developed and undeveloped land. Most parcels comprise roughly the same land areas.

In the case of Glynn County, the maps were first used to identify rectangles in which the structure inventory contained complete information about all structures within the rectangle. Although the general quality of the data from Glynn County data was good, there were enough structures with missing information on year built and building square footage, so that only 4 rectangles were identified that contained complete information about structures in those rectangles. These rectangles were located in Glynn County Map Grids 2, 10, 18, and 19 (which contained two rectangles).

Using the FEMA maps, these rectangles were then further subdivided into three smaller geographical units, or *blocks* intended to capture variation in exposure to erosion hazards within each rectangle.

- The area within each rectangle designated as “Block 1" comprised a collection of (developed and undeveloped) parcels within each rectangle furthest from the beach.

- The area within each rectangle designated as “Block 3" comprised a collection of (developed and undeveloped) parcels at the beachfront.

- The area within each rectangle designated as “Block 2" comprises a collection of developed and undeveloped parcels located between Blocks1 and Blocks 3.

A simple schematic representation of how map grids, rectangles, and blocks are related is provided in Figure 1. In subsequent rounds of the inventory surveys, it was decided to use

“Glynn Co. Map Grid 2"

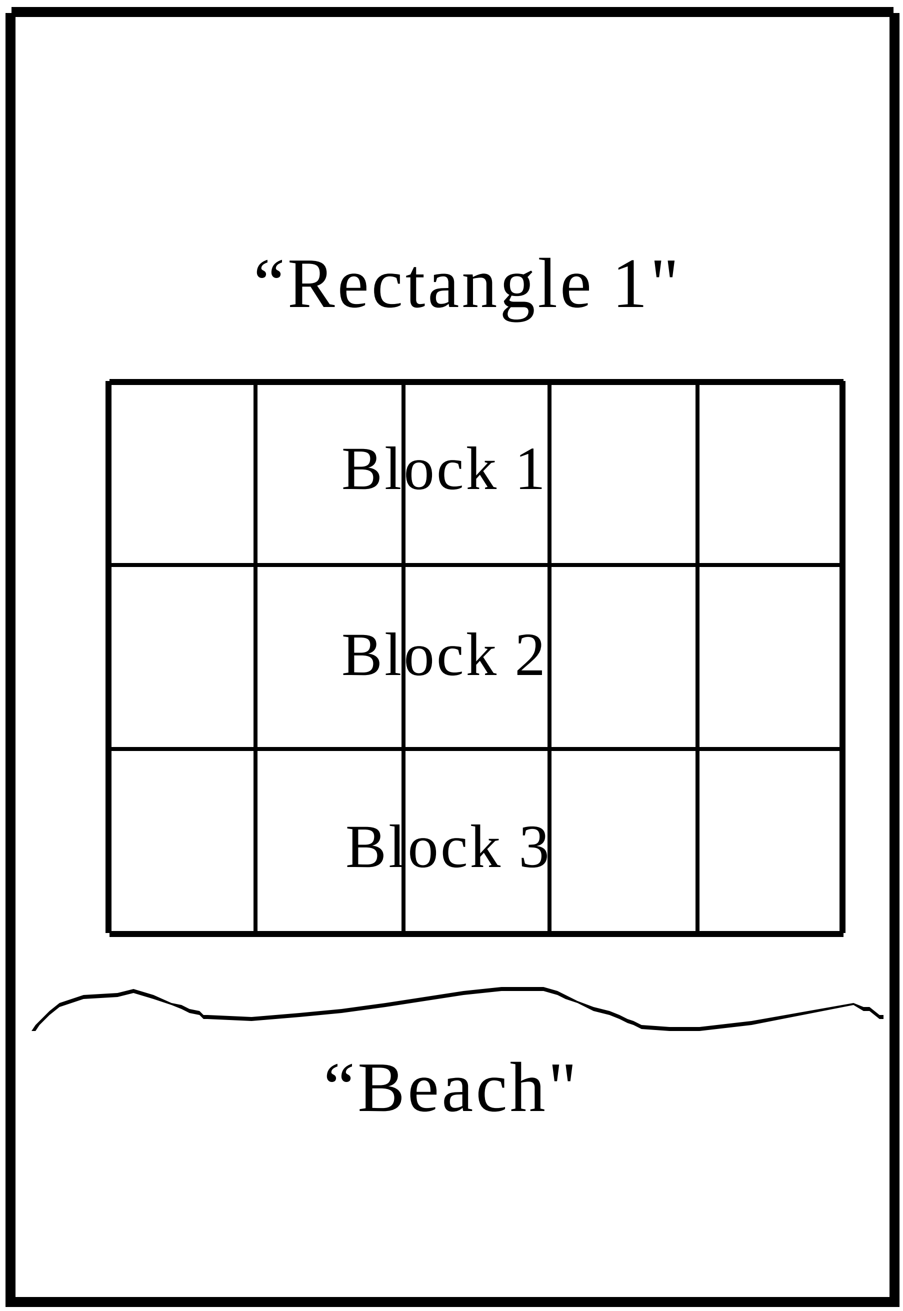

Figure 1

geographical sampling areas in that were shaped as “T’s” instead of rectangles. These “T’s” were then subdivided into blocks in the manner described above.

Step 2: Creating Development Histories for Blocks

Once the blocks were defined, information from the inventory of structures was combined with information taken from the maps to determine how development took place within each block over time. A key step in this process was to calculate the square footage of *undeveloped* as well as of developed land in each block at the time that the map was produced.

It was possible to calculate the square footage of developed land directly from the data compiled in the structures inventories, but the amount of undeveloped land within a block needed to be calculated by hand, using parcel information provided on the maps, along with the map scale.

Total undeveloped parcel square footage was also calculated for each block. Note that this variable does not measure total undeveloped land over time, but rather land that is not developed as of the time that the photographs of the beaches and the inventory of structures were taken (because data are only compiled for developed land). We can, however, use the fact that *Total Block Square Footage = Developed Square Footage + Undeveloped Square Footage* to determine how the amount of undeveloped land changed over time as more structures were constructed in each block.

The steps involved in creating a time series of development in each block are described in more detail in the Appendix. Figure 2 shows how measures of development density constructed from the data can be used to chart the course of development over time in Glynn County Rectangle # 1. The measure of development used is the *capital-to-land ratio,* which equals the ratio of total building square feet in the block to total square feet of land in the block calculated for each year between 1963 and 1997.

Figure 2 shows that there was relatively little development between 1963 and 1997 in the block farthest away from the beach (Block #1), while fairly intense development took place over this same period in the Block #3 which is closest to the beach (and the erosion hazard.). (Figure 2 also identifies the year of first participation in the NFIP by Glynn County, and the year in which the FIRM was completed. These two insurance events are shown for illustrative purposes, and not to imply any causal relationships).

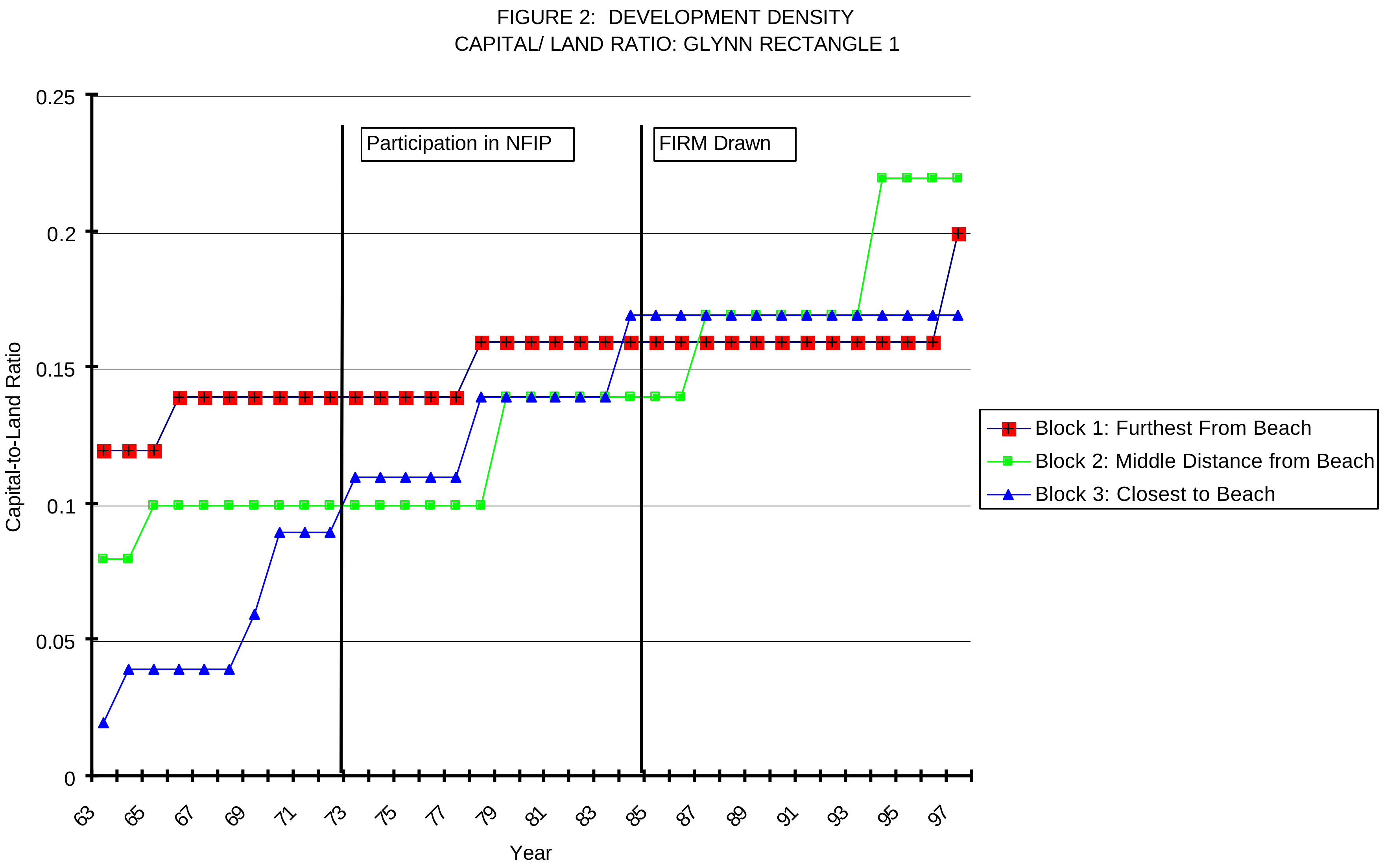
FIGURE 2: DEVELOPMENT DENSITY
CAPITAL/ LAND RATIO: GLYNN RECTANGLE 1
Participation in NFIP
FIRM Drawn
Capital-to-Land Ratio
0.25
0.2
0.15
0.1
0.05
0
63
65
67
69
71
73
75
77
79
81
83
85
87
89
91
93
95
97
Year
Block 1: Furthest From Beach
Block 2: Middle Distance from Beach
Block 3: Closest to Beach

Estimating the Effects of Insurance and Erosion from the Heinz-FEMA Survey of Structures

The statistical model attempts explain both the patterns and trends in the density of development. The unit of observation is the "block" that has just been described.

Dependent Variable

The variable to be explained is the development density in each block. Table 1 below describes the number of observations of the capital-to-land ratio that are available at each site.

Table 1: Observations on Capital-Land Ratios

Site	Communities within Site	# of Rectangles or "T's"	# of Blocks	Yrs.	# of Obs. (Yrs. X # of Blocks)
Glynn, Ga.	Jekyll Island, Sea Island, St. Simon's Island	4 (Rectangles)	14	35	490
Dare, N.C.	Avon, Duck, Kill Devil Hills, Kitty Hawk, Nags Head, Rodanthe, Southern Shores, Waves	18 (T's)	51	35	1785
Brevard, Fla	Melbourne Beach, Cocoa Beach	3(T's)	9	35	315
Lee, Fla.	Boca Grande, Sanibel, Ft. Myers Beach	11 (T's)	28	35	980
Georgetown, SC.	Garden City Beach, Litchfield Beach, Debidue	4 (T's)	12	35	420
Galveston, Tx.	Crystal Beach, Galveston, Jamaica Beach	11(T's)	33	35	1155
Santa Cruz, Ca.	Aptos, Live Oak, Capitola, Watsonville	7(T's)	17	35	595

Independent Variables

Both theoretical models of intra-community development, and the earlier empirical work of Cordes and Yezer suggest that the density of development in each block will be influenced by three different groups of variables.

Community-Level Factors

We expect that trends and patterns of development in the blocks within a community will be affected by patterns and trends in development in the community at large. We control for these effects in two ways. First, we include dummy variables for each beachfront community. Second, we include a simple time trend to control for general growth in income and employment that would tend to increase demand for recreation services in coastal communities. Third, we include variables that are intended to measure variation among communities and over time in the general "size" of the beachfront recreation industry. These variables are: the annual number of establishments in each community in the food, hotel, eating and drinking, and recreation services sectors, and total annual payroll in these sectors in each community.

Exposure to Hazards

Three variables capture the effect of differential exposure to hazards of flood and/or erosion risk. One is the average distance of each block to the current erosion reference feature. This variable is constructed by computing the distance from the erosion hazard of each parcel in the block, and then calculating the weighted average of these distances for the block using the square feet in each parcel within the block as weights. Given the annual erosion rate, we also include a measure of the projected length of time (in years) required for the process of erosion to move a block to the erosion reference feature. Lastly, we include a categorical variable that measures whether a block is in an area with high risk of flooding (V-zone).

Public Hazard Mitigation Policies

Three different variables are used to capture the effects of changes in the availability and/or terms of insurance. We include two categorical or dummy variables that describe changes in the availability and/or terms of federal flood insurance: (1) the date of initial community participation in the federal flood insurance program; and (2) the date of completion of the FIRM for the community which marked entrance of the community in to the Regular Phase of the NFIP. As may be seen in Table 2, there is a reasonable degree of variation in terms of when different communities in the analysis entered both the Emergency and the Regular Insurance Programs.

In addition to the insurance variables, we also include categorical variables to control for the effect of including a block in a CBRA area, which captures the effects of removing federal financial assistance, including flood insurance..

Lastly, we include categorical variables to reflect the presence of either federally or state-funded beach nourishment projects.

Evaluation of Erosion Hazards
Appendix D. ii.
A Statistical Model of Development

A simple statistical model of development density is presented in (1).

$$
\begin{aligned}
(1)\ K_{ijt} = {} & a_1 + a_i + \sum_{j=2}^{18} d_j\, COMMUNITY_j + b_1 TIME + b_2 TIME \bullet BEACH1 + b_3 TIME \bullet BEACH2 + b_4 EMPLOY_{jt} \\
& + b_5 BEACH1 + b_6 BEACH2 + b_7 (BEACH1 \bullet DISTANCE)_{it} + b_8 (BEACH2 \bullet DISTANCE)_{it} \\
& + b_9 VZONE + b_{10} GEOTIME_{it} + b_{11} STORM + b_{12} NFIP_{jt} + b_{13}(NFIP_{jt} \bullet DISTANCE_{it}) + b_{14} FIRM_{jt} \\
& + b_{15}(FIRM_{jt} \bullet DISTANCEsu\,bit) + b_{16} CBRA_{it} + b_{17} CBRA82_{it} + b_{18} CBRA91_{it} \\
& + b_{19} NOURISH_{jt} + b_{20}(NOURISH \bullet BEACH1) + b_{21}(NOURISH \bullet BEACH2) + v
\end{aligned}
$$

Dependent Variable

In equation (1), the dependent variable, $\mathbf{K_{ijt}}$ is the capital-to-land ratio in block i, in community j, at time t. In other words, $\mathbf{K_{ijt}}$ is the variable depicted in Figure 2 above. The coefficient a_1 is the intercept term. The coefficient a_i is a block-specific random effect that reflects attributes of each block that are not directly observed, such as the “amenity value” of the block, as well zoning or other restrictions that can affect development in the block.

Community, Time Trend, General Demand, and Location.

The coefficients d_j are a series of dummy variables for the communities in each of the five sites (see Table1). The variable **TIME** is a time trend; and the variables **TIME**x**BEACH1** And **TIME**x**BEACH2** are interactive variables to allow for different time trends in development in oceanfront blocks (**BEACH1**), middle blocks (**BEACH2**), relative to the inland blocks. The variable **EMPLOY** is the number of employees in site j engaged in providing recreation services, and measures patterns and trends in the size of the local “recreation industry” in each site. The dummy variable **BEACH1** equals 1 if the block is located in the “front row” (e.g. closest to the beach) and 0 otherwise; and **BEACH2** equals 1 if the block is located in the “middle row” and 0 otherwise. The variables **BEACH1**x**DISTANCE** and **BEACH2**x**DISTANCE** interact the beach location with the variable **DISTANCE**, which is the average distance of the block from the erosion reference feature (which varies both across blocks, and within a block over time if there is erosion).

Exposure to Hazards

The variable **VZONE** is a dummy variable that measures flood risk and equals 1 if 50% or more of a block is located in a V Zone. **GEOTIME** equals each block's average distance to the erosion reference feature divided by the erosion rate. **GEOTIME** is a measure of the degree of setback from the erosion hazard, and the greater the value of **GEOTIME** the lower the erosion risk. In cases where the erosion rate is zero, the calculated value of **GEOTIME** is infinite. To deal with these cases, we assigned a value of .01 to the erosion rate and then truncated the maximum value of **GEOTIME** to 200 years.

In addition, to explore whether people are more likely to respond to erosion risk when such risk is "evident" we include the interactive variable **(GEOTIME**x **THIRTY)**, where the variable **THIRTY** = 1 if the block is expected to converge to the erosion reference feature in 30 years, and the interactive variable **(GEOTIME**x **THIRTY/SIXTY)** where the variable **THIRTY/SIXTY** =1 if the block is expected to converge to the erosion reference feature in more than thirty years, but less than sixty years

The variable **STORM** is intended to measure whether the actual experience of a major storm has an affect on development; and is constructed as follows. First, it was determined whether a community had experienced a major storm in a given year. If it had, **STORM** was set equal to 1 in the three years following the storm.

Insurance Variables

The variables **NFIP** and **FIRM** correspond to different regimes of federal flood insurance. When it was first established in 1968, federal flood insurance was made available at subsidized rates. Subsequent changes in the program were intended to remove (or at least reduce) this subsidy. This was done administratively by requiring communities to participate in federal flood insurance in two phases. In the initial or emergency phase, a limited amount of flood insurance was provided on a subsidized basis, pending submission of a flood plain management plan, and completion of a Flood Insurance Risk Map (**FIRM**). Upon completing a FIRM, communities entered the regular phase of the flood insurance program, which provided broader coverage than the emergency program, but at premiums that were intended to correspond more closely to actuarial insurance costs. As part of the process of entry in the Regular Program, communities also promulgated building standards, such as for example, raising the height of the structure above the base flood elevation that were intended to reduce flood risk.

Thus, the variable **NFIP** is a dummy variable that equals zero in years prior to initial participation in the National Flood Insurance Program, unity during years of participation prior to completion a Flood Insurance Risk Map for the community and zero thereafter, while the variable **FIRM** is a dummy variable equal to zero in years before completion of a flood insurance map and unity in all subsequent years. The variables **NFIP**x**DISTANCE** and **FIRM**x**DISTANCE** interact the insurance dummy variables with distance from the hazard.

Variables are also included to measure the effect of the Coastal Barrier Resources Act (CBRA) enacted in 1982. Although CBRA does not prohibit privately financed development, it does prohibit new Federal financial assistance, including flood insurance within a designated Coastal Barrier Resources System

(CBRS). The scope of areas covered by CBRA was significantly increased in 1990 by passage of the Coastal Barrier Improvement Act (CBIA). Among other features, CBIA prohibited the issuance of new Federal flood insurance within "otherwise protected areas" on buildings constructed after November 16, 1991, unless the building is used in a manner consistent with the purpose which the area is protected.

Table 3: Dates of Entry into Federal Insurance Program

Sites & Communities	Entry to Emergency Program	Year of FIRM & Entry to Regular Program
Brevard County		
Cocoa Beach	1970	1972
Melbourn Beach	1970	1972
Dare County		
Avon	1971	1978
Duck	1971	1978
Kill Devil Hills	1970	1973
Kitty Hawk	1971	1978
Nags Head	1970	1973
Rodanthe	1971	1978
Southern Shores	1970	1972
Glynn County		
Jekyll Island	1974	1985
Sea Island	1974	1985
St. Simon's Island	1974	1985
Lee County		
Boca Grande	1970	1984
Ft. Myers Beach	1970	1984
Sanibel	1970	1979
Georgetown County		
Garden City Beach	1971	1984
Litchfield Beach	1971	1984
Debidue	1971	1984
Galveston County		
Crystal Beach	1971	1971
Galveston	1970	1971
Jamaica Beach	1971	1971
Santa Cruz		
Aptos	1975	1986
Capitola	1975	1984
Live Oak	1975	1984
Watsonville	1975	1984

The effects of CBRA are captured by three categorical variables. The variable **CBRA** equals 1 if any part of a block is located in an area currently designated as a CBRA area, and zero otherwise. The variable **CBRA82** captures the effect of the initial CBRA legislation, and equals one if any part of a block is located in a CBRA area and the year of the observation is between 1982 and 1991. The variable **CBRA91** is intended to capture the effect of the CBIA, which strengthened the initial CBRA legislation, and equals one if any part of a block is located in a CBRA area, and the year of observation is 1990-1997, and zero otherwise.

Beach Nourishment Variables

We also include variables, **NOURISH, BEACH1xNOURISH**, and **BEACH2xNOURISH** and **NOURISH2**, that measure both the presence and absence and the scope of Federal shore protection activities. The variable **NOURISH** is the cumulative number of shore protection and/or beach nourishment projects that had been undertaken in a community as of a given year. These data are available on-line from the "Beach Nourishment Data Base" at Duke University.

An Alternative Specification

In addition to the model described in (1), we also estimated a variant of that model described in (2).

$$(2)\quad K_{ijt} = a_1 + a_i + \sum_{j=2}^{18} d_j COMMUNITY_j + b_1 TIME + b_2 TIME \bullet BEACH1 + b_3 TIME \bullet BEACH2 + b_4 EMPLOY_{jt}$$
$$+ b_5 BEACH1 + b_6 BEACH2 + b_7 (BEACH1 \bullet DISTANCE)_{it} + b_8 (BEACH2 \bullet DISTANCE)_{it}$$
$$+ b_9 VZONE + b_{10} GEOTIME_{it} + b_{11} STORM + b_{12} NFIP_{jt} + b_{13} (NFIP_{jt} \bullet VZONE) + b_{14} FIRM_{jt}$$
$$+ b_{15} (FIRM_{jt} \bullet VZONE) + b_{16} CBRA_{it} + b_{17} CBRA82_{it} + b_{18} CBRA91_{it}$$
$$+ b_{19} NOURISH_{jt} + b_{20} (NOURISH \bullet VZONE) + v$$

The model summarized in (2) is the same as equation (1) except for the fact that the interactive variables **NFIPxDISTANCE** and **FIRM xDISTANCE** have been replaced by the interactive variables **NFIPxVZONE** and **FIRM xVZONE**. In addition the interactive variable **NOURISH xBEACH1** And **NOURISHxBEACH2** are replaced by the interactive variable **NOURISHxVZONE**.

Results

Table 6 and 7 show the results of estimating equations (1) and (2) respectively. The means of the variables are presented in Table 4; and Table 5 presents the share of the total sample of blocks located in each beachfront community.

<u>Main Findings</u>

- The coefficient of **TIME** indicates that there has been a generally upward trend in development density. In addition the negative coefficients of the interactive time dummies, **BEACH1**x**TIME** and **BEACH2**x**TIME** imply that although development density has increased in all blocks, controlling for other factors, there was a tendency for density to increase less rapidly in inland blocks. This would be consistent with a pattern of development moving outward from the shore.

- The coefficient of **EMPLOY** implies, as expected, that development density increases with increasing demand for beachfront recreation, as measured by the number of establishments providing recreation-related services.

- The coefficient of **BEACH1** is statistically significant and positive, which indicates that, controlling for other factors, location in a beachfront leads to greater development density.
  The magnitude of the coefficient for **BEACH1** implies that, all other things being equal, location in an ocean front block increases development by between one-third to one-half.

- The degree of setback from the erosion hazard, as measured by **GEOTIME** has mixed effects. In the regressions in which **GEOTIME** was interacted with the dummy variable **THIRTY**, which was set equal to one if the block was inside the 30 year EHA, increased **GEOTIME --** greater setback from the erosion hazard -- had a positive and statistically significant effect on development density *inside the 30 year EHA* (e.g. when the dummy variable **THIRTY** was equal to one); but **GEOTIME** had negative and significant effect on development density in blocks that were *outside the 30 year EHA* (e.g. when **THIRTY** equaled zero). A similar result was obtained when **GEOTIME** was allowed to interact with the dummy variable **THIRTY**, and an additional dummy variable, **SIXTY**, which was set equal to one if the block was outside the 30 year EHA but inside the 60 year EHA. In that specification of the model, the degree of setback had a positive effect development density inside the 30 year EHA, a statistically insignificant and positive effect on density in blocks outside the 30 year EHA but inside the 60 year EHA; and a negative and significant effect density in blocks outside the 60 year EHA. These results suggest that setback from the erosion reference feature (which typically is close to the shoreline) is seen as a *disamenity* when there is no imminent erosion risk (i.e. outside the 60 year EHA), but is viewed as an *amenity* in areas where the threat from erosion is seen to be more immediate (i.e. inside the 30 year EHA). Setback has a "neutral effect" on density in blocks where the setback is greater than 30 years, but less than 60 years.

- The coefficient of **VZONE** is negative and statistically significant, and implies that in the absence of insurance and other programs that reduce flood risk, development density would be roughly 20 to 30 percent less in areas that are prone to flood risks than it is in safer areas.

- Although location in a flood zone appears to discourage development, the coefficient of **STORM** indicates that major storms do not have much of an effect on development. The significant positive coefficient of **STORM** implies that development density actually increases in the three years immediately after a storm, though the quantitative magnitude of the coefficient is rather small, implying that density is roughly 7 percent higher.

- In model 1, the coefficients of the variables **NFIP**, **NFIPxDISTANCE**, **FIRM** and **FIRMxDISTANCE** imply that federal flood insurance has had the effect of increasing development density in areas close to the ocean, while decreasing it in inland areas.

    - Providing subsidized flood insurance under the Emergency Phase of the NFIP is estimated to have increased development density "at the water's edge". by roughly 40 percent. However, the negative and statistically significant coefficient of the interactive variable, **NFIPxDISTANCE**, implies that the positive effect of insurance on density declines with greater distance from the shoreline. The magnitude of the estimated coefficients of **NFIP** and **NFIPxDISTANCE** imply that the net effect of insurance is to increase density in blocks that are within 350 of the shoreline, while decreasing density in blocks beyond that distance.

    - Providing flood insurance under the Regular Program increased development at the water's edge by roughly 40 percent as well. The negative and statistically significant coefficient of the interactive variable, **FIRMxDISTANCE**, implies that the net effect of entry into the regular insurance program is to increase density in blocks that are within 350 feet of the shoreline, while decreasing density in blocks beyond that distance.

- In model 2, the coefficients of the variables **VINS** and **VFIRM** imply that Federal flood insurance has had the effect of increasing development density in areas that are prone to flood risk.

    - Providing flood insurance under the Emergency Program increased development density in V zones by roughly 18 per cent, while the Regular Insurance Program increased development density by 11 percent.

The finding that participation in the regular insurance program increased development density close to the shoreline and in V zones deserves further comment. The predicted effect of participation in the regular program is theoretically ambiguous . On one hand, better information about flood risks provided by a flood map might be expected to reduce the density of development in areas that were identified as prone to risks of flooding..

On the other hand, there are several reasons why entry into the Regular Program would have the opposite effect. Completion of a flood map prompted many communities to enact building codes intended to mitigate risks of flood damage. These regulations made it more costly to build, but if the increase in construction costs were less than the expected damages avoided by implementing such mitigation measures, stricter building codes would actually lower the net cost of locating structures in areas prone to flood risk, which would encourage more development. Moreover, although an effort was made to charge actuarial rates in the regular NFIP, it is arguable that property owners continued to benefit from subsidized insurance under the regular program, and indeed were able to insure larger amounts against loss. Administrators of the NFIP have observed that, although premiums paid to the NFIP cover losses from floods experienced over the past twenty years, it is believed that the past twenty years have been characterized by "below-average" risk of storm damage. The implication is current premiums would need to be significantly higher to cover "expected" risks from storms. Premiums charged for private insurance coverage in CBRA areas, where federal flood insurance is not available, are also higher than premiums charged under the NFIP.

- The effects of designating parts of a block as COBRA areas is captured by the coefficients of **CBRA**, **CBRA82**, and **CBRA91**. The coefficient of **CBRA** measures the effect of simply being "in" an area designated as a CBRA area, prior to the actual enactment of CBRA legislation in 1982 and 1991. in 1982 and/or 1991. As expected, this coefficient is statistically insignificant because location in a CBRA area should not matter prior to 1982 and/or 1991. In contrast, the coefficients of both **CBRA82** and **CBRA91** are statistically significant, and negative. The coefficient of **CBRA82** implies that CBRA decreased development density by roughly 40 percent during the "initial period from 1982-1991, and the coefficient of **COBRA91** implies that CBIA, which denied federal flood insurance to new construction, decreased density by almost 60 percent. The difference between the coefficients of CBRA82 and CBRA91, which is statistically significant, implies that the net impact of denying Federal flood insurance protection in CBRA areas was to lower development density by roughly 16 percent.

- The coefficient of **NOURISH** implies that the increased "frequency" of beach nourishment activities, as measured by the cumulative number of beach nourishment projects, does not have a statistically significant effect on development density, per se. The coefficients of **BCH1** x **NOURISH** in model 1, however, implies that such projects did increase development density in ocean-front blocks. Similarly, the coefficient of **NOURISH** x **VZONE** in model 2 implies that beach nourishment projects had the effect o increasing development density in V zones.

Conclusions

The results suggest that changes in the availability of insurance against flood hazards has affected the pattern, if not the level, of development in the sample of communities analyzed in this study. On balance, the results indicate that the combination of flood insurance and improved building codes increased the density of development in areas subject to "higher than average" risks of damage from coastal floods. The estimated coefficients of **GEOTIME** and **GEOTIME** x **THIRTY** further imply that while development density may respond somewhat to the presence of erosion risk, the risk must be imminent, and the magnitude of the response is fairly small.

TABLE 4: VARIABLE MEANS	
VARIABLE	**MEANS**
CAPITAL-LAND RATIO	.092
TIME (Indexed to run from 1963 = 1 to 1997 =35)	18
BEACH1xTIME	7.22
BEACH2xTIME	6.33
EMPLOY (Number employed in providing recreation services in the county or community)	6978
BEACH1 (Equal to one if block is located in the front row, and zero otherwise).	.401
BEACH2 (Equal to one if block is located in the middle row, and zero otherwise).	.352
DISTANCE (Distance to the ERF in feet).	358
GEOTIME (Number of years until block converges to the ERF)	161.8
V ZONE (Equal to one if at least 50% of the block is in a V-Zone, and zero otherwise)	.309
STORM (Equal to one in the three period after a major storm, and zero otherwise)	.089
VZONEx STORM (Interactive Variable = **VZONE X STORM**)	.042
NFIP (Equal to one during years in which community was in the Emergency Program, and zero otherwise)	.177
NFIPxDISTANCE (Interactive variable = **NFIP X DISTANCE**)	86
VZONEx DISTANCE (Interactive variable = **VZONE X NFIP**)	.042
FIRM	.575
FIRMxDISTANCE (Interactive variable = **FIRM X DISTANCE**)	178
VZONEx FIRM (Interactive variable = **VZONE X FIRM**)	.191
CBRA (Equal to one if any part of the block is in a CBRA area)	.091
CBRA82 (Equal to one if any part of the block is in a CBRA area and Year = 1982-1991, and zero otherwise)	.024
CBRA91 (Equal to one if any part of the block is in a CBRA area and Year is 1991-1997, and zero otherwise).	.018
NOURISH (Cumulative number of shore protection projects in the community in a given year).	.108
BCH1 NOURISH (Interactive variable = **NOURISH X BEACH1**)	.048

BCH2 NOURISH (Interactive variable = **NOURISH X BEACH2**)	.032

Table 5: COMMUNITY DUMMY VARIABLES	
Site and Community	Means
Brevard County	
Cocoa Beach	.0252
Melbourn Beach	.054
Dare County	
Avon	.016
Duck	.100
Kill Devil Hills	.054
Kitty Hawk	.0252
Nags Head	.076
Rodanthe	.0168
Southern Shores	.117
Glynn County	
Jekyll Island	.067
Sea Island	.0252
St. Simon's Island	.0252
Lee County	
Boca Grande	.076
Ft. Myers Beach	.084
Sanibel	.076
Georgetown County	
Garden City	.014
Litchfield	.028
Debidue	.014
Galveston County	
Crystal	.0422
Galveston	.0633
Jamaica	.0141
Santa Cruz	
Aptos	.058
Capitola	.0252
Live Oak	.0252
Watsonville	.0336

TABLE 6: STATISTICAL MODEL OF DEVELOPMENT DENSITY (Equation 1)				
Dependent Variable: Capital-Land Ratio				
	MODEL 1		MODEL 2	
INDEP.VARIABLE[1]	Coefficient	Standard Error	Coefficient	Standard Error
CONSTANT	. 1033***	.0292	.1017***	.0292
TIME	. 0041***	.00027	.0041***	.00027
BEACH1xTIME	- .0028 ***	.00028	- .0028***	.00029
BEACH2xTIME	- .0011	.00025	- .0011***	.00025
EMPLOY (Per 1000 employees)	.0034 ***	.00031	.0034***	.00031
BEACH1	.0321***	.0149	.0322***	.0149
BEACH1xDISTANCE[2]	-.0157**	.0041	- .0157***	.0041
BEACH2	.0190	.0183	.0194*	.0182
BEACH2xDISTANCE[2]	-.0050	.0037	- .0051	.0037
GEOTIME	- .00017*	.00093	- .00016*	.00009
(GEOTIMEx THIRTY)	.0009***	.0003	.0009***	.0003
(GEOTIMEx SIXTY)	N.A.	N.A.	.00004	.0001
VZONE	- .0230*	.0127	- .0230*	.0126
STORM	.0066**	.0027	.0066***	.0028
NFIP	.0375***	.0052	- .0375***	.0052
NFIPx DISTANCE[2]	- .0108**	.00129	- .0109	.00129
FIRM	.0395***	.0059	- .0395***	.0058
FIRMx DISTANCE[2]	- .0113***	.00149	- .0113***	.00149
CBRA	.0116	.0274	.0118	.0273
CBRA82	- .0369***	.0055	- .0370***	.0055
CBRA91	- .0530***	.0069	- .0531***	.0069
NOURISH	- .0081	.0058	- .0081	.0058
BCH1xNOURISH	.0129*	.0070	- .0129*	.0070
BCH2xNOURISH	.0113	.0073	.0115	.0072
R^2	.626		.620	
No. of Observations	3921		3921	

[1] Coefficients for the community dummy variables are not shown.
***** Significant at the .01 level; ** Significant at the .05 level; * Significant at the .10 level**

[2] **Distance is scaled in units of 100 feet.**

TABLE 7: STATISTICAL MODEL OF DEVELOPMENT DENSITY (Equation 2)				
Dependent Variable: Capital-Land Ratio				
	MODEL 1		MODEL 2	
INDEP.VARIABLE[1]	Coefficient	Standard Error	Coefficient	Standard Error
CONSTANT	.1107***	.0284	.1101***	.0285
TIME	.0038***	.00026	.0038***	.00026
BEACH1xTIME	- .0019***	.00025	- .0019***	.00025
BEACH2xTIME	- .0007***	.00024	- .0007***	.00024
EMPLOY (Per 1000 employees)	.0034***	.00031	.0034***	.00031
BEACH1	.0466***	.0147	.0466***	.0146
BEACH1xDISTANCE[2]	- .0133***	.0042	-.0132***	.0042
BEACH2	.0305*	.0181	.0308*	.0181
BEACH2xDISTANCE[2]	- .0048.	.0037	-.0049	.0037
GEOTIME	- .0002***	.00009	-.0002***	.00009
(GEOTIMEx THIRTY)	.0009***	.0003	.0009***	.0003
(GEOTIMEx SIXTY)	N..A.	N..A.	.000002	.0001
VZONE	- .0282**	.0130	-.0282**	.0128
STORM	.0073***	.0028	.0073***	.0027
NFIP	- .0029	.0032	-.0029	.0032
NFIPx VZONE	.0169***	.0057	.0169**	.0057
FIRM	- .0024	.0042	-.0025	.0043
FIRMx VZONE	.0099**	.0051	.0099*	.0051
CBRA	.0094	.0267	.0094	.0265
CBRA82	- .0387***	.0056	- .0387***	.0056
CBRA91	- .0531***	.0070	- .0531***	.0070
NOURISH	- .0037	.0036	- .0037	.0036
NOURISHxVZONE	.0132**	.0057	.0132**	.0057
R^2	.620		.620	
No. of Observations	3921		3921	

[1] **Coefficients for the community dummy variables are not shown.**

***** Significant at the .01 level; ** Significant at the .05 level; * Significant at the .10 level**

[2] Distance is scaled in units of 100 feet.

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APPENDIX: CREATING LONGITUDINAL DATA FOR EACH SITE

Many steps were involved in creating longitudinal panels from the original cross section data compiled in the inventory of structures. Glynn County was the first county for which complete data for the FEMA project were available. This section describes the steps used to transform these data.

Characteristics of the Original Data

The original data include observations on structures, principally residential property, with information on the year the structure was built, the square footage of the structure, the square footage of the parcel (as created on the FEMA maps), and other vital information such as the current and future (projected) distance of the property from the erosion reference line as portrayed in the maps. The data also identify whether structures are currently located in the AE, VE, or other zones and whether they will be located in such zones in the future.

The original data encompass observations for county data, presumably around 1997. FEMA maps are arranged according to grids of different beaches and beachfront property from an aerial view. The grids have current and future erosion reference lines drawn, current and future AE, VE zones demarcated, and have the beach sectioned into parcels. Some parcels contain developed land, others undeveloped. Most parcels are of roughly the same land areas. Since some observations in the data lacked complete information on pertinent variables (such as year built, square footage, etc.) and since sampling some of the area on the maps could be utilized to represent the grid in general, certain rectangles were drawn in (some of) the grids and analyzed. The rectangles were sorted into three different categories or blocks:

- block 1 is the area of the rectangle furthest from the beach
- block 3 is the beachfront, and block 2
- block 2 is the median distanced block.

(In other counties, the initial geographical unit will be a "T" as described on the Heinz Erosion Study website).

To make the data creation rather easy to manage, each rectangle in each grid affords itself its own "notebook." For example, for the first grid analyzed in Glynn County, grid 2, rectangle 1 (which is the only rectangle sampled in the grid, although more than one rectangle is possible to sample for a particular grid) has its own spreadsheet. Any data pertaining to the rectangle is extracted from the "newglynn" spreadsheet and copied to the "grid#rect#" spreadsheet as is.

Accounting for Undeveloped Land

Some of the parcels on the maps are undeveloped, although the data in the spreadsheet has observations on only developed land. Thus, in creating the longitudinal panel, special attention is paid so that when sorting the observations for the rectangle according to blocks (which have to be determined and then entered into the spreadsheet as a new variable) undeveloped land as well as developed parcels are included (a separate row for each undeveloped parcel is inserted into the spreadsheet).

Additionally, in the case of the Glynn County map, the square footage of the parcel of undeveloped land is calculated using the formula that 100 ft is equal to 1200 inches and that the legend on the maps is 1 is equal to 1000. Each undeveloped parcel is provided a code because many of these are usually present. Total undeveloped parcel square footage is also obtained for each block. Note that this variable does not represent total undeveloped land over time, but undeveloped as of the time of the photographs of the beaches and collection of data (because data is only present for developed land). Undeveloped land changes over time as more structures are built. Summations are also taken of developed building square feet and parcel square feet as of 1997 for each block. No map eyeballing is required for this as developed land has information on such.

Another variable column copied from "newglynn" that is adjusted is the column for current and projected distance from the erosion reference line. While data is present for the developed structures, those for undeveloped parcels are not. This measure is created for the undeveloped parcels by looking at the grid and measuring the distance in inches to the current and future erosion reference line and then transforming to feet. Note, that the difference between "current" and "projected" is the span of 60 years. So current distance represents the distance in feet from the erosion line and the distance of the parcel in 60 years is depicted by the projected distance (note that not all photographs were taken at the same time, and possibly not in the same year). For the present, current represents 1997 and projected refers to 2057.

Transforming Cross-Sectional Snapshots into Longitudinal Time Series

The first major step in creating the time series is the creation of dummy variables for each year. Dummies for 1963, 1964, etc. till 1997 were created. For each entry in the database, which now incorporates both developed and undeveloped land, for each year, a one is placed if development of the particular structure occurred in that year, and a zero otherwise. If the land is undeveloped in 1997 (if on the grid map the parcel looks undeveloped and no data for the parcel is provided in the "newglynn" information) then a "0" for that parcel is placed for all years. This step is automated by the use of complex "if-then" statements that say that if in the previous year for the particular parcel (recall now the database has developed and undeveloped data) a “1” is present, then for this year a “1” should be placed. In other words, if last year the parcel was developed, this year it is still developed (exception to this procedure is with 1963, which is done manually). If the year the structure was built corresponds to the year of the dummy, then again a “1” should be placed. That is, if the parcel was developed in 1964, and the dummy is for 1964, then a “1” is recorded for 1964 and following the above-mentioned for every year after 1964. If the year built is later than the particular dummy of interest or if there is no entry in the year built column for the parcel, then a “0” is recorded. For example, if the year built for a particular structure is 1976, then for all years prior to 1976, the dummies should indicate that this parcel was undeveloped till then. Further, if no year built data is available, as would be the case when a particular parcel is undeveloped, then that should be recorded as such (with “0’s”) for all years.

Longitudinal Measures of Developed and Undeveloped Land

The creation of the dummies for the years 1963 to 1997 allows the easy computation of total development in each year for each block. The “devland” series and “devbuild” series do the computations. For example, the first entry in devland 63 is for the first structure in block 1 in 1963. It multiplies the dummy for 1963 for that parcel by the parcel square feet for that entry. If the dummy recorded is “0,” this implies that the parcel was undeveloped in 1963. Once the dummy recorded is switched to “1” in 1976, then development changes to the particular parcel square ft of development. Summations are taken of all development in each year to determine how much land is developed over time. So, for example, in grid 2, block 2, it is apparent from looking at the block 2 section of the database, there was nothing developed from 1963 till 1976, but almost 100,000 square feet developed by 1997. An additional row was inserted in the database after the last parcel observation data for each block so that such calculations could be made for each block. The same was done for building square feet. In the time series database (where observations are over time over blocks which are stacked and references manually put in according to codes for county, grid, rectangle, block), which is placed directly below the chart thus far used, a column for developed land for each year for each block only requires the reference cell (to the “devland series”) to capture the total development in each year. Similarly for total building square feet developed in each year for each block. An additional column in the lower chart calculates the additional development in a particular year (for parcel square feet and building square feet respectively) by subtracting the previous year’s total development from that of the current year. Since the data for the blocks are stacked, block 2 above block 3 and block 1 above block 1, a problem arises with 1963 additional development measures, since continuing with the normal formula would subtract total development in 1997 from that of 1963 for different blocks. In order to remedy this, additional development in 1963 will be equal to the total development in 1963.

Total land area (in parcel square feet because not all parcels will be developed and have building square feet) for each block and year (unchanging over time) is the summation of the total undeveloped and developed parcel square feet for each block. As described above, undeveloped parcel square feet for each undeveloped area (as of 1997) was manually calculated and the total undeveloped parcel area for each block calculated in the top chart and that total developed parcel area was simply the summation of all developed parcel areas (as of 1997) provided. From this, total undeveloped parcel square feet is easily calculated for each year and block. Total undeveloped land in each year is simply the difference of the total land area in the block and the total development in that particular year.

Longitudinal Measures of Hazard Exposure

As a result of implementing the above procedures, data are available for each parcel (undeveloped and developed) on the current and projected distance in feet from the erosion reference line and that we know that the difference in the distance spans 60 years. In other words, the difference of the current and the projected distances provides a measure of erosion over sixty years. Dividing the difference by 60 then, will render an approximation of the degree of erosion in each year for each parcel. A column was created for erosion rates, and an average erosion rate calculated for the block. With yearly erosion data, it then becomes possible to calculate the distance from the hazard from each parcel in every year. Remember that the data provided in the "newglynn" database had the current distance from the erosion reference line for 1997 only. We can calculate the distance from the erosion reference line for each parcel in each year. This is accomplished through the "disc" series, which spans from 1963 to 1997. For a particular year the current distance for each parcel from the erosion reference line is created by adding the distance in 1997 and the difference in number of years (1997-the particular year of interest) multiplied by the erosion rate. So, the latter part of the equation will provide the total land erosion over the years. For example, say we want to know the distance from hazard for a parcel in 1992. From 1997 till 1992, there is five years of erosion taken place. Add whatever would have eroded on to the distance in 1997. Usually, you will find that the distance to the erosion reference line is greater in 1992 than in 1997.

The final step is to create the average distance of the block from the erosion reference line (remember that above we only obtained the distance for each parcel). The average distance of the entire block (undeveloped and developed) for each year was calculated by a weighted sum. That is, each parcel distance for each year was multiplied by the parcel's square feet. This was summed over the entire block. The summation was then divided by the total square feet in the block. On the computer, this is easily calculated and programmed. The "sumproduct" command is utilized to multiply square feet by distance in each year and sum over all observations for the block. To find the average distance of the developed block in each year (in parcel square feet and building square feet) from the erosion reference line was a bit more complex. Here, for each block for each year the sum of the product of the square feet of the developed block and the distances for all developed parcels are obtained and then divided by total developed block (plus "1"). Since the "devland" and "devbuild" series were already created (and captured the total development in each block in each year) this step was rendered easy. The denominator includes a "1" such that in the event that there is no development in a block in a particular year, no incomprehensible language will appear in the cell, but there will be a "0". Finally, the average distance of the undeveloped block from the erosion reference line was calculated. First, the "undev" series was created by multiplying the negative of dummy series minus "1" and the total parcel square feet (total land area undeveloped and developed). This series simply calculates the total undeveloped land for each block over time. The sum of the product of this variable with total undeveloped square feet in each block in each year divided by the total undeveloped land (plus "1") in that year will count as the average distance of the undeveloped block in each year from the erosion reference line. Note to ensure that the computer would be able to do the calculation and that it would not be forced to calculate a "0" divided by a "0," the denominator will include a "1". When there is no undeveloped land in the block, so the variable average distance of undeveloped block is nonsensical, the computer will display a "0."

Additionally, the fraction of each block (weighted by the parcel square feet) in the AE, VE, and Cobra categories was created for current and future standings. That is, dummies were created for whether a parcel was currently in the AE zone, in the VE zone, projected AE zone, projected VE zone, and whether it was included in Cobra (1 if the category applied, 0 otherwise). The individual columns then were multiplied by the parcel square feet column and then summed for each block and divided by total square feet in the block. For each block, these weighted fractions of current and projected AE and VE, and Cobra were included as variables (time invariant). An additional dummy variable was included for each block, where if any portion of the block was in Cobra (easily done with if-then statements from the variable of weighted Cobra, as described above) a "1" was assigned for that year in each block, and "0" otherwise.

Longitudinal Measures of Construction and Development Density

To determine the amount of investment in each year, the square feet of building space (developed) was divided by the total square feet in the block (developed and undeveloped). To then create a variable for investment, annual changes in the above-mentioned variable was calculated. To create an undeveloped land capacity measure, square feet of interior space over parcel square feet developed was multiplied by the square feet of undeveloped parcel area in each block each year.

Insurance and Other Risk Reduction Measures

Dummies for the availability of NFIP and Firms for each county were created ("0" before and "1" after) as well as for a dummy for the enactment of COBRA (1982).

Physical mitigation measures were incorporated into the data set if applicable using the Beach Nourishment Data base at Duke University. The time of the beach nourishment project was recorded as well as the volume (cy) of sand.

Demand for Recreation Services

Annual data on employment and number of businesses for the categories of food and eating places, amusement and recreation services, food stores, and hotel and other lodging places were obtained from the County Business Patterns series.

Evaluation of Erosion Hazards
Appendix D. ii.