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An Evaluation of Coastal Community Response to Sea Level Rise on the Delmarva Peninsula

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A thesis submitted in partial fulfillment of the requirements for the degree of Master of Urban and Regional Planning at Virginia Commonwealth University.

by

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Acknowledgement

To my wife, for her patience.

Abstract

AN EVALUATION OF COASTAL COMMUNITY RESPONSE TO SEA LEVEL RISE ON THE DELMARVA PENINSULA

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The purpose of this project is to evaluate the response of coastal community comprehensive plans to the threats posed by sea level rise. The communities evaluated are Chincoteague, VA, Ocean City, MD, and Rehoboth Beach, DE. The results of the evaluations illustrate to what extent these communities are prepared to deal with sea level rise and provide a basis for recommendations to improve plan quality. The level of community risk and the components of the individual comprehensive plans are evaluated using new models created for this project. Risk level is measured using computer disaster simulations, topographic and demographic data. The plan evaluation criteria include standard plan quality benchmarks and hazard mitigation and adaptation elements suggested by numerous agencies and resources. The plan evaluations range in quality from "poor" to "excellent". These evaluations will be used to create policy strategies and recommendations for addressing the threat of sea level rise.

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Introduction

Sea level rise poses a significant threat to coastal communities. Projections from government agencies, climate researchers and environmental groups indicate that over the next 50 to 100 years, rate of sea level rise will accelerate. In some reports, the sea level is expected to rise by 2 meters or more. Coastal communities need to prepare for this level of inundation. The purpose of this thesis is to evaluate how (or if) this is being done.

This thesis reports a study I conducted on the local plans for three coastal cities along the Delmarva Peninsula to identify and evaluate the plans' response to the threat of sea level rise. Using these communities as a basis for study, I created a mathematical formula designed to test each plan's quality. This formula evaluates quality as a function of the content, design, and process of the plan as compared with the specific risk posed to the community by sea level rise. To achieve this formula, I created two matrices.

The first matrix was designed to quantify the value of each plan's content, design, and process. This matrix is the result of studying recommendations and plan design criteria compiled from a wide variety of source material. These sources include general studies of plan design and effectiveness, as well as the U.S. Climate Change Science Program (CCSP) report on sensitivity to sea level rise in the Mid-Atlantic region (CCSP 2009). These sources serve as the basis and starting point for the majority of the matrix criteria.

A second matrix, designed to frame the potential hazard level for each community, was created using material from the fields of emergency management, risk assessment and disaster response. Additionally, Geographic Information System (GIS) modeling of each area, using different sea level rise projections, will help establish thresholds for the risk assessment criteria matrix.

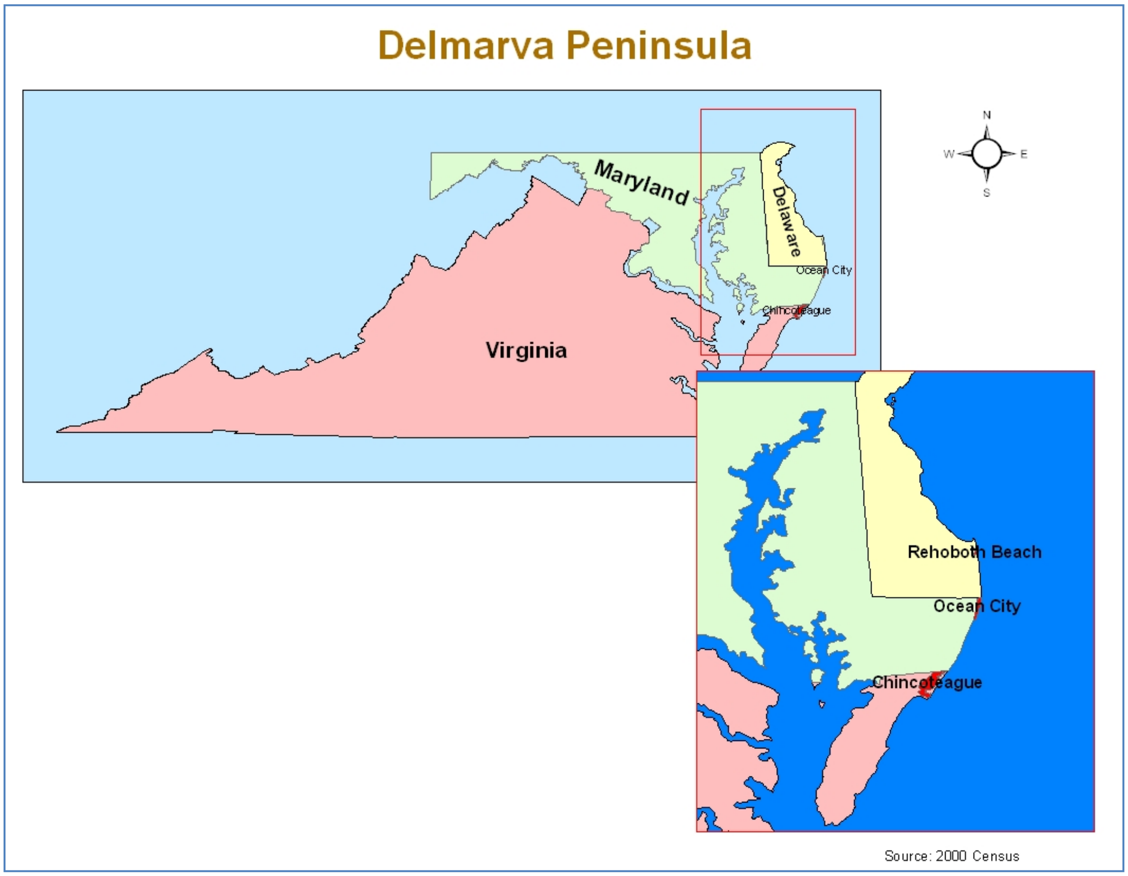
Study Area

The study area for this research is the Delmarva Peninsula (Map 1.1). The Delmarva Peninsula extends 183 miles, encompassing the entire state of Delaware, as well as portions of Maryland and Virginia. These three states give the peninsula its name (**Del-**aware, **Mar**-yland, and **V-**irgini-**a**). The Delmarva Peninsula is bounded to the east by the Delaware Bay and Atlantic Ocean and to the west by the Chesapeake Bay. The peninsula is home to over 681,000 residents (Census 2000). The three specific communities studied are Rehoboth Beach, DE, Ocean City, MD, and Chincoteague, VA.

The value of this research, a comparative analysis of Delmarva community plans to evaluate measures to adapt to and mitigate the effects of sea level rise, can be justified by two main points.

Coastal communities are vulnerable to many natural hazards, especially sea level rise.

Coastal communities face many challenges. Depending on the community's location, it may have to face hurricanes, tsunamis, pollution, coastal flooding, erosion, or other natural and man-made hazards. Some coastal communities address these challenges through their comprehensive master plan, while others may instead use special disaster plans. Both the nature and severity of challenges a community faces are related to its geographic location.



Map 1.1: Study Area

Sea level rise is determined to be one challenge that all coastal communities will face (NOAA 2009). At varying rates over the last 10,000 years, the sea level has been rising. According to the 2007 Intergovernmental Panel on Climatic Change (IPCC) assessment, between 1900 and 2000, the average global sea level rose about 0.1778m. The most conservative projections indicate the potential for an additional 0.3 - 0.6 meter rise by 2090. More dire predictions, predicated on the collapse of the Greenland and Antarctic ice shelves, foresee a rise of up 6 meters (Hansen 2007). The causes of sea level rise are primarily thermal expansion and glacial melt (Milliman, et al. 1989). The rate of sea level rise appears to be accelerating (IPCC 2007). This rise represents a growing threat to coastal communities.

As the threat posed by sea level rise worsens, it is important that community plans for mitigating and adapting to it are cataloged and assessed.

A large body of work exists that identifies the specific threats posed by sea level rise and that advises policy makers on specific adaptive and mitigating responses. Little research currently exists in evaluating current community plans for sea level rise response however. This is important because as rising sea levels begin to affect more and more communities, it would be essential for planners to have a bank of recommended practices for mitigating and adapting to the threat posed by sea level rise.

Literature Review

To frame the analysis in this research, it was necessary to investigate many aspects of the problem. First, the phenomenon of sea level rise was studied to determine the potential effects. It is imperative to identify, understand and define the threats posed by global sea level rise before assessment criteria can be established or recommendations can be made. In order to accomplish this, several questions had to be answered. These questions were: Is sea level rise occurring? If so, what are the generally accepted projections for the rate of sea level rise over the next century? Finally, what effects could sea level rise have on coastal communities?

Second, the process of risk assessment was studied. A community's response to sea level rise should result from a rational analysis of the specific vulnerability of an area. From this analysis, a community risk model can be created to serve as a starting point for plan component evaluation. Risk assessment uses a standard set of geographic and demographic criteria to construct the risk model.

Next, community techniques for addressing the effects of sea level rise were analyzed in terms of both mitigative and adaptive responses. Most current literature advises adaptive techniques to address the threats.

Finally, a review of current literature on the evaluation of plan content and accepted practices was required to ensure the validity of my proposed methodology and analysis. The development of evaluation criteria as a measure of plan quality and a mechanism to identify "best practices" is essential for creating useful recommendations for future planning. While most of the literature uses evaluation criteria for plan quality in a more general sense, the concepts can easily be applied in terms of sea level rise.

Impacts of Sea Level Rise

There is general agreement among climate researchers, oceanographers, and government agencies (Environmental Protection Agency, National Oceanic and Atmospheric Administration, National Aeronautics and Space Administration) that the sea level is rising. The ongoing process of sea level rise is generally accepted as fact. Along the east coast of the United States, there is both empirical and anecdotal evidence showing the progression of sea level rise over the last 400 years (Scott, Gayes & Collins 1995).

The projected rate of sea level rise is much more controversial. While there is solid evidence that for the last two decades, the rate of sea level rise is increasing, projections based on this increase show wildly varying results. The first threshold was established by using one of the earliest official reports acknowledging acceleration in rate of sea level rise (IPCC 1996). This report findings support a 0.6 meter to 0.8 meter rise in global sea level by 2100. The report also speculated on potential mitigating factors such as aquifer depletion and seabed expansion that could offset some of the rise. In a follow up report, a decade later, (IPCC 2007) the original findings were confirmed. The second report found that even using another decade's worth of data, the acceleration of sea level rise was consistent with the 1996 projections. Both IPCC reports used a threshold of between 0.6m and 0.8m as their expected height of sea-level rise. At this level, the IPCC predicts the main impacts to coastal communities would be a loss of land due to inundation, an increased potential for flooding and increased salinization of estuaries, groundwater and aquifers.

A second, higher sea level rise threshold was put forth in an environmental sensitivity analysis from Great Britain. This analysis projects a 2m sea level rise (Anthoff, et al. 2006). This report further projects sea level rise out over the next 500 years with an eventual zenith 10m. This faster rate of rise is based on accelerated glacial melt coupled with natural thermal expansion due to global warming. The long term consequences of this sea level rise projection include changes in settlement patterns, land values and holding capacity. These conclusions are consistent with the findings of a 1989 Royal Swedish Academy of Sciences report (Milliman, et al. 1989).

Other thresholds, such as a potential 6m rise from a critique of the earlier IPCC reports (Hansen 2007) would have consequences so catastrophic to the study areas that modeling techniques such as beach replenishment and exclusionary zoning would be moot. The cities of Chincoteague, VA (2m), Ocean City, MD (4m), and Rehoboth Beach (4.5m) would be completely submerged in this model (USGS 1976). Projections at this level assume an imminent break-up and melt of the West Antarctic Ice Shelf. Most contemporary studies dismiss these projections as alarmist. Further, despite Hansen's dire predictions, his assessment did not include any analysis of the effects of sea level rise.

Risk Assessment

Before communities can make informed choices with regard to policy and infrastructure, they must understand the scope of risk their community faces. Risk Assessment measures a community's vulnerability to a hazard. This is done by studying the demographic characteristics and geographic situation of a community to determine its capacity to anticipate, respond to, and recover from an impending hazard (Wisner, et al. 2005). Important demographic characteristics include level of poverty in a community, as well as the percentages of groups with mobility limitations. Each community's geographic situation needs to be assessed in order to specify the hazard it faces.

When assessing the risk facing a community, it is important to study the demographic characteristics of the community. From a demographic standpoint, there is little variation in terms of "at-risk" populations between types of hazards (Wisner, et al. 2005). Economic and mobility difficulties are of primary importance. The four populations within a community most at-risk are households living in poverty, those with disabilities, those under 5 years of age, and those 65 years of age or older (Clark, et al. 1998). The risk to the community increases with the percentage of community members falling within these groups.

In contrast with the generalized demographic characteristics, the risks posed by a community's geographic situation are specific to the hazard faced (Wisner, et al. 2005). For the purposes of this research, the geographic factors considered are similar to those used in assessing the risks posed by coastal flooding. A community's average elevation, the percentage of the community's land area and population within the 100 year floodplain must be determined using topographic maps, Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps and GIS (Clark, et al. 1998). Once the community's geographic situation is established from these data, GIS modeling can be used to measure the scope of the impact of the hazard on the community (Waugh 2000).

By analyzing the demographic data and geographic modeling, a Risk Assessment formula matrix can be created to measure the community's vulnerability. This formula can be modified to aid in the assessment of community responses to the hazard (Wisner et al., 2005).

Mitigation Planning

Many communities around the United States are exploring approaches for managing the challenges of sea level rise. The threat posed by sea level rise will need to be addressed through planning. There are two main planning approaches for dealing with hazards in general, mitigation and adaptation. Mitigation strategies seek to physically minimize the threat itself by using barriers, building codes and diversion techniques. Both types of approaches are necessary to deal with the threat of sea level rise.

In the simplest terms, mitigation planning for sea level rise consists of barrier construction, development restriction, and flood control/diversion. Dikes, levees, and sea walls are the only ways to physically prevent inundation. As evidenced by the Hurricane Katrina disaster, however, such barriers are not impenetrable and, if overtopped, can create basins that keep water in. Mitigation efforts such as beach nourishment, jetties, and groins can be used as physical barriers to delay or slow the progression of sea level rise (CCSP 2009). Utilizing land use controls to restrict or eliminate development in areas that are extremely vulnerable to natural disasters essentially employs planning tools to create barriers to development that avoid unnecessary risk (Burby and Dalton 1994). Unfortunately, this type of restriction does little for existing development and can expose a community to takings claims by affected property owners.

By and large, mitigation planning has been the default position with regard to both climate change and sea level rise (Denga, et al. 2003). Engineering solutions provide a physical protection and can give communities a feeling of protection by their presence alone (Turner 1994). An enforced reduction in carbon emissions is often cited as another type of mitigation response to sea level rise (Denga, et al. 2003; Turner 1994; Wheeler 2008). The analysis for this research will not include emissions control because the scope of such efforts requires action well above the community-level study being conducted.

Adaptation Planning

Mitigative approaches have their limits, in terms of both cost and effectiveness. Adaptive approaches to sea level rise can "fill the gap" left by relying solely on mitigation techniques. Adaptation seeks to minimize the effects of a threat by changing the behavior, practices and character of a community to protect lives and property from the threat (Denga, et al. 2003). Adaptive techniques can move people out of harm's way, which can reduce the impact of sea level rise by a factor of 10 (Tol 2007).

In general, adaptation strategies are much more diverse than mitigation. Where mitigation strategies generally focus on bending nature to meet human needs, adaptation strategies bend human needs in the face of nature. The necessity and mechanisms of adaptation are vital when dealing with the threat of sea level rise (Tol 2007).

One of the main benefits of adaptation planning is that the costs associated with adaptation are less than those of inaction and this becomes even more important because sea level rise is an inevitable, continuing process (Nicholls, et al. 2007). Advocates of adaptation planning fear that mitigation plans are not stringent enough in the short-term and are not being implemented quickly enough (Wheeler 2008).

Recently, the need for adaptation planning has received a great deal of attention. Some of this attention has come from analysis of existing plans. One study of the first generation of plans dealing with climate change (Wheeler 2008) found that plans at the state, metropolitan and local level generally focus on emissions mitigation and public sector mandates. This study found this to be the case even in communities considered to be "progressive." Because these plans dealt only with mitigation, the plans were labeled short-sighted since they failed to address the potential effects of climate change.

One of the main components of both mitigation and adaptation planning is risk assessment. To respond effectively to threat, in this case sea level rise, a community needs to know the specific risk to its citizens. Once the risk assessment has been done, it is the obligation of the community planners and officials to raise awareness of the potential hazards and, in the case of adaptation planning, to encourage the community to change its behavior to minimize the risks (Bettencourt, et al. 2005). While most risk assessment reports use the context of economic loss, the theory can also be applied to environmental and human losses as well. Perhaps the most important tool to use in risk assessment is accurate mapping of territory to better understand the region's vulnerabilities.

Obstacles to Planning for Sea Level Rise

As local planners begin to react to sea level rise, they confront many obstacles to planning implementation. In this paper, two of the key obstacles, political and legal, are discussed. The political obstacle results from sea level rise's link to global warming. Many political conservatives question the existence of global warming and are subsequently disinclined to make policy changes based on it or any of its associated hazards (McCright 2000). The legal obstacle has to do with property rights and takings claims. Some policies for dealing with the threat of sea level rise have provisions for acquiring private property through eminent domain and/or restricting development on private property.

There is a great deal of controversy regarding global warming. Since the earliest reports of warming began circulating, the conservative movement in the United States has consistently ridiculed and derided global warming as “hysteria” (McCright 2000). The conservative movement believes that global warming is being used to further an anti-business agenda (McCright 2000). This bitter opposition makes it difficult to implement policy that specifically deals with global warming. In a panel discussion at the 2009 Virginia Chapter of the American Planning Association conference, Delegate Joseph Bouchard of Virginia Beach described a meeting of the Agriculture, Chesapeake, and Natural Resources committee where three prominent conservative delegates told him that any bill containing the words “climate change” or “global warming” would never leave committee, regardless of content (Bouchard 2009). Because Virginia is a Dillon’s Rule state, where localities only have the powers and authority specifically given to them by the state legislature, this takes on special significance for the Virginia community in this study.

The second major obstacle to planners trying to develop policy to address sea level rise stems from a property rights issue. The issue is not whether the government has the right to take property or through regulations restrict development. "The Fifth Amendment to the Constitution says 'nor shall private property be taken for public use, without just compensation.' This is a tacit recognition of a preexisting power to take private property for public use, rather than a grant of new power" (United States v. Carmack 1946).

The extent to which planners can restrict development without having to provide compensation has been open to interpretation by the Supreme Court of the United States (SCOTUS). In Pennsylvania Coal Co. v. Mahon (1922), the SCOTUS found that "[t]he general rule at least is, that while property may be regulated to a certain extent, if regulation goes too far it will be recognized as a taking." While in Mugler v. Kansas (1887), the court found "[t]he power which the States have of prohibiting such use by individuals of their property as will be prejudicial to the health, the morals, or the safety of the public, is not—and, consistently with the existence and safety of organized society, cannot be—burdened with the condition that the State must compensate such individual owners for pecuniary losses they may sustain, by reason of their not being permitted, by a noxious use of … their property, to inflict injury upon the community."

In a decision with implications for hazard mitigation, Bowditch v. Boston (1880), the court found that in exceptional cases, such as the destruction of a particular building to prevent the spread of fire, the municipal government is not liable for a takings claim.

As the threat of sea level rise grows, political resistance to policy changes meant to deal with that threat should diminish. Slowing or impeding response to impending disasters is not a politically feasible position. Using the power of eminent domain to protect the "higher, public good," while unpopular and expensive, is a constitutionally granted power that has been upheld by the US Supreme Court.

Plan Evaluation

The success or failure of a plan has generally been measured by whether it has clearly defined goals and has been successfully adopted and implemented (Berke 1994). Initially, process and methodology were the main evaluation criteria for plan evaluation. That began to change in the late 1970s when a series of researchers began evaluating the appropriateness and efficacy of individual plan elements such as goals, objectives, and implementation plans (Fishman 1978).

When beginning to consider how to evaluate a plan. one must ask the question, "What is a good plan?" One of the earliest measures developed for plan evaluation was whether a plan sufficiently addressed the community's needs. To that end, one of the first quality evaluation models (Fishman 1978) studied comprehensive plans. This study found that the best plans integrated local policies and conditions into very specific goals. Further analysis of these plans found that specific goals, calling for specific actions, were even more effective. Another study, specifically examining emergency response plans, found that public involvement in both information gathering and decision-making led both to wider acceptance and to better plans (Wenger, et al. 1980). These are a good start, but more criteria are needed to properly assess a plan's worth.

Breaking a plan down into its component parts allows for more detailed analysis. A review of several disaster plan studies from the 1990's led to the development of an evaluation model based on three main plan components (Berke 1994; Berke and French 1994; Berke, et al. 1996). The first plan component is the "fact basis." The fact basis of a plan is evaluated by determining whether a plan adequately identifies the community's needs and catalogs local conditions. The second component measure is the "Goals" section of the plan. This is evaluated based on how a community's needs, character and values are incorporated into the goals set forth in the plan. The final component these studies evaluate is the plan's "Policies." This component incorporates the strategies, tools, and implementation sections of a plan. "Policies" are evaluated according to whether they direct the implementation of the goals in a community-appropriate way and within a community-appropriate time period.

Comparative analysis requires an objective, weighted measure. A hazard mitigation study developed measurement criteria comparing plans (Brody 2003-1). These criteria use an ordinal scale measurement to express whether a plan acknowledges or identifies the potential hazard, and whether or not it addresses the hazard.

Finally, the assessment criteria to be measured and valued need to be developed specifically for the threats posed by sea level rise. A large number of these can be drawn from a recent Environmental Protection Agency's report (CCSP 2009). This report includes a wide variety of planning tools such as beach nourishment to slow the progression of sea level rise, suggestions for new design guidelines, and special zoning requirements to minimize loss. Many of these are crucial to measure the quality of a plan's response to sea level rise.

Methodology

A community's response to sea level rise will be measured through an evaluation of the community's comprehensive plan. For this evaluation, I created a model which combines traditional plan evaluation criteria such as delineated goals, objectives and strategies, as well as the level of public involvement in the planning process with a rating system for hazard-specific plan components. To evaluate the hazard-specific components, I have created a risk assessment matrix to assess each community's vulnerability to sea level rise. This matrix will then become a function of the overall evaluation model in evaluating hazard-specific strategies for minimizing the effects of sea level rise. Because the completion of the risk assessment matrix precedes that of the evaluation model, the matrix will be described first.

Many factors, both geographic and demographic, can affect a community's vulnerability to a particular hazard. The threats posed by sea level rise are similar to those posed by coastal flooding. Because of this similarity, several of the risk assessment criteria used in this matrix come from coastal flooding literature. Other criteria are pulled from the examination of topographical maps and from the use of the Federal Emergency Management Agency's (FEMA) HAZUS-MH disaster modeling software.

FEMA's software gives the user the ability to model community impacts from three types of hazard; earthquake, hurricane and flood (both riverine and coastal). It is a self-contained risk assessment model. Using the coastal flooding model allows me to measure the scope of each community's inundation. Visually, the data are very useful to illustrate the effects of sea level on the individual communities. The use of this software package to evaluate the threat posed by sea level rise is not without its limitations, however. While sea level rise and coastal flooding are similar, there is one major difference. That key difference is time. Coastal flooding occurs more quickly but is only a temporary event, lasting days or weeks. Sea level rise is a slow progression, but the inundation of the land is measured in geological time. This difference means that some coastal flooding related damage assessments lose efficacy because there is an assumption of a return to normalcy. Property and structures deemed damaged under coastal flooding conditions would be destroyed by sea level rise. This limits the use of the FEMA package to illustration and area calculation. Because of this, I have created my own risk assessment matrix.

Risk Assessment Matrix

The Risk Assessment Matrix evaluates a community's vulnerability to sea level rise based on two types of risk, geographic and demographic. The geographic risk factors measured by this matrix are as follows (Table 3.1):

- The percentage of area and population within the 100 year floodplain. These low-lying areas will be the first to be affected by sea level rise. The greater the percentage of land and people within these areas, the greater the risk to the community.
- The number of access roads to and from an area. As sea level rise begins to affect a community, there must be enough access and egress points for supply,

commerce, or evacuation. The more restricted the access, the greater the risk to the community.

- The average elevation. The smaller the difference between the average elevation and projected sea level rise, the greater the risk to the community.
- The percentage of area and population inundated in the sea level rise models created for this project. These models were designed to show the flooding impact of sea level rise at the 0.8m and 2.0m levels using FEMA's hazard simulation software package HAZUS-MH. These models show the scope and severity of the inundation. The greater the percentage of land and people within these areas, the greater the risk to the community.

Table 3.1: Geographic Risk Matrix

Risk Assessment Matrix			
Criteria for Geographic Risk	**Scale**	**Data Source**	**Criteria Source**
Percentage of Community area within 100 year floodplain	10% of area = 1pt, 100% of area = 10pts	FEMA Flood Insurance Rate Map	Clark, et al. 1998
Percentage of Population within 100 year floodplain	10% of population = 1pt, 100% of population = 10pts	FEMA Flood Insurance Rate Map/Census	Clark, et al. 1998
Number of access roads to mainland	≥ 10 access roads = 1pt, 9 access roads = 2pts, 8 access roads = 3pts, 7 access roads = 4pts , 6 access roads = 5pts, 5 access roads = 6pts, 4 access roads = 7pts, 3 access roads = 8pts, 2 access roads = 9pts, 1 access road = 10 pts	Google Maps	Clark, et al. 1998

(Average Elevation) - (Inundation Model Height)	≥ 5 meters = 1pt, 4 - 4.99m = 2pts, 3.5 - 3.99m = 3pts, 3 – 3.49m = 4pts, 2.5 - 2.99m = 5pts, 2 – 2.49m = 6pts, 1.5 – 1.99m = 7pts, 1 – 1.49m = 8pts, 0.5 - .99m = 9pts, ≤ .49m = 10 pts	USGS Topographic Maps	Waugh, 2000
Percentage of Community area inundated by model	10% of area = 1pt, 100% of area = 10pts	HAZUS-MH-GIS	
Percentage of Population inundated by model	10% of population = 1pt, 100% of population = 10pts	HAZUS-MH-GIS	
Total possible points	**60**		

The demographic risk factors deal with the mobility of a population (Table 3.2). These factors are standard considerations when dealing with hazards (Clark et al. 1998). Mobility is an important consideration for hazard planning, despite the fact that sea level rise is an incremental threat, rather than immediate one. In the case of sea level rise, mobility does not refer to the ability to quickly evacuate to a temporary shelter. Instead, it references the population's ability to permanently relocate. The greater the percentage of the population falling within these categories, the greater the risk faced by the community. All of this data will come from the 2000 Census.

The populations with the least mobility are:

- The percentage of households at or below the federal poverty line
- The percentage of the population classified as disabled.
- The percentage of the population under the age of 5
- The percentage of the population 65 or older.

Table 3.2: Demographic Risk Matrix

Risk Assessment Matrix			
Criteria for Socio-Economic Risk	**Scale**	**Data Source**	**Criteria Source**
Percentage of Households at or below Federal Poverty line	≤ 5% = 1pt, ≤ 7.5% = 2pts, ≤ 10% = 3pts, ≤ 12.5% = 4pts, ≤ 15% = 5pts, ≤ 17.5% = 6pts, ≤ 20% = 7pts, ≤ 22.5% = 8pts, ≤ 25% = 9pts, > 25% = 10pts	2000 Census	Clark, et al. 1998
Percentage of Population Designated in Census as "Disabled"	≤ 5% = 1pt, ≤ 7.5% = 2pts, ≤ 10% = 3pts, ≤ 12.5% = 4pts, ≤ 15% = 5pts, ≤ 17.5% = 6pts, ≤ 20% = 7pts, ≤ 22.5% = 8pts, ≤ 25% = 9pts, > 25% = 10pts	2000 Census	Clark, et al. 1998
Percentage of Population under 5 years of age	≤ 5% = 1pt, ≤ 7.5% = 2pts, ≤ 10% = 3pts, ≤ 12.5% = 4pts, ≤ 15% = 5pts, ≤ 17.5% = 6pts, ≤ 20% = 7pts, ≤ 22.5% = 8pts, ≤ 25% = 9pts, > 25% = 10pts	2000 Census	Clark, et al. 1998
Percentage of Population 65 years of age or older	≤ 5% = 1pt, ≤ 7.5% = 2pts, ≤ 10% = 3pts, ≤ 12.5% = 4pts, ≤ 15% = 5pts, ≤ 17.5% = 6pts, ≤ 20% = 7pts, ≤ 22.5% = 8pts, ≤ 25% = 9pts, > 25% = 10pts	2000 Census	Clark, et al. 1998
Total possible points	**40**		
Risk Factor	**(Geographic Risk + Socio-Economic Risk)/100**		

Within the matrix, each of these criteria is given a point value based on the level of risk. For example, the criterion "percentage of a community's total area that lies within the 100 year flood plain" is given 1 point of risk for every 10% within the flood zone. The entire matrix is based on a 100 point scale. Once a score is determined, the total is converted into a risk factor to be used within the plan evaluation model. This risk factor is used to change the value of many of the evaluation criteria based on the level of risk facing the community.

Plan Evaluation Model

I have obtained the comprehensive plans from the three coastal cities in Virginia, Maryland and Delaware. To evaluate the quality of these plans, I have created a Plan Evaluation Model (Tables 3.3 – 3.6). The model appraises the plan components in four categories. These categories are General Plan Assessment, Hazard Identification, Land Use Solutions and Barrier Solutions. The Hazard Identification, Land Use Solutions and Barrier Solutions components of the plan have a direct correlation to the community's risk factor. Because of this, the components have a greater value as the risk to the community increases. The factor allows the awarding of additional points based on a greater risk to the community. The plan is evaluated on a 100 point scale. The addition of the risk factor decreases the likelihood of a perfect 100 point score. For this reason the evaluation of Excellent, Good, Fair and Poor will awarded based on the actual score divided by the maximum potential score for the community's risk level. A score of 80% or higher will be rated as an "Excellent Plan"; a score of 60% to 79.9% will be considered a "Good Plan"; a score of 50% to 59.9% will be scored as a "Fair Plan"; and a score below 50% will be considered a "Poor Plan."

The General Plan Assessment uses accepted planning quality measurements to rate the plan's adherence to accepted practices. This general evaluation makes up 10% of the plan's total score. The general assessment guidelines are laid out in Table 3.3 below.

Table 3.3: General Plan Evaluation

General Plan Assessment	Points	Effect of Risk Level on Value of Component	Criteria Source
Plan delineates goals, objectives, and implementation strategies	1	None	Fishman, 1978; Berke and French, 1994

Goals call for specific actions	1	None	Fishman, 1978; Berke and French, 1994
Goals are condition specific to community	2	None	Fishman, 1978; Berke and French, 1994
Plans show public kept informed of process	1	None	Fishman, 1978
Plans show public involvement in approval process	2	None	Wenger, et al., 1980
Plans show public involvement in information gathering and plan creation process	3	None	Wenger, et al., 1980
Total possible points	**10**		

Some of the evaluation criteria have different weight than others. There are several reasons for this. Goals tailored to the unique circumstance of the individual community are valued above generic specific goals (Fishman 1978, Berke and French 1994), regardless of the generic goal's specificity. Additionally, it has been shown (Wenger, et al. 1990) that increasing the level of public involvement in community planning results in greater success in executing the plan.

The Hazard Identification Assessment evaluates whether or not the plan identifies or acknowledges coastal hazards specific to the community. These hazards are run-off/drainage issues, storm surges, coastal flooding, climate change and sea level rise. Additionally, this section of the assessment evaluates whether the communities are using threat assessment tools to measure the potential hazards to the community. The identification of these hazards is worth a nominal score of 23 points toward the plan's overall score. These components can be given greater value as the risk facing the community rises. This relationship can result in the awarding of up to 23 additional points based on the community's risk factor for a potential total section score of 46 points.

Again, some components evaluated are given higher value than others. In the hazard identification evaluation, the identification of hazards closely related to the threat of sea level rise (coastal flooding, climate change) is more valuable than the identification of more ancillary hazards (run-off, storm surge). Because this evaluation is specific to sea level rise, the identification of it as a hazard has an even greater value. Of equal value, is a community that understands its topographic situation. Plan components calling for an elevation study and/or an inventory of the most at risk properties are highly valued. Table 3.4 illustrates these relationships.

Table 3.4: Hazard Identification Component Evaluation

Hazard Identification Criteria	Nominal Points	Effect of Risk Level on Value of Component	Criteria Source
Plan identifies run-off/drainage issues	1	Direct correlation to risk level value. Total points = (nominal points + (nominal points * risk factor))	Berke, 1994
Plan identifies threats from storm surges	1	Direct correlation to risk level value. Total points = (nominal points + (nominal points * risk factor))	Berke, 1994
Plan identifies threats from coastal flooding	3	Direct correlation to risk level value. Total points = (nominal points + (nominal points * risk factor))	Berke, 1994
Plan identifies threats from climate change	3	Direct correlation to risk level value. Total points = (nominal points + (nominal points * risk factor))	Berke, 1994
Plan identifies threats from sea level rise	5	Direct correlation to risk level value. Total points = (nominal points + (nominal points * risk factor))	Berke, 1994
Conduct a LiDAR survey of coastal areas to accurately map elevations and redraw floodplain maps as needed.	5	Direct correlation to risk level value. Total points = (nominal points + (nominal points * risk factor))	
Conduct an inventory of threatened properties to rezone, purchase or condemn as necessary.	5	Direct correlation to risk level value. Total points = (nominal points + (nominal points * risk factor))	
Total possible points	**46**		

The Land Use Solutions Assessment searches the plan to find land use components that can be used to adapt to or mitigate the effects of sea level rise. After these components are identified and classified as either adaptive or mitigative, the measures are rated using criteria from both the National Oceanographic and Atmospheric Administration (NOAA) and the Environmental Protection Agency's (EPA) Climate Change Science Program (CCSP). Such components would include regulations regarding rolling easements, shoreland and floodplain zoning, infrastructure guidelines and design requirements. Like the hazard identification criteria, these measures have a greater value in areas with a higher risk factor. This relationship can result in the awarding of up to 16 additional points based on the community's risk factor for a potential total section score of 32 points. Table 3.5 lists the criteria with their associated values.

Table 3.5: Land Use Component Evaluation

Land Use Solutions for Plan	Nominal Points	Effect of Risk Level on Value of Component	Criteria Source	Solution Approach
Establishment of a "rolling easement." The right of the jurisdiction to take public ownership of property that 'rolls' inland with the coastline as sea-level rises.	6	Direct correlation to risk level value. Total points = (nominal points + (nominal points * risk factor))	NOAA, 2007	Adaptive
Update and implement shoreland and floodplain zoning regulations to ensure that existing municipal and new private development are designed and sited to mitigate the effects of flooding and inundation.	2	Direct correlation to risk level value. Total points = (nominal points + (nominal points * risk factor))	CCSP, 2009	Mitigative
Use of new setback guidelines and transfer of development rights to encourage development in areas outside the floodplain.	2	Direct correlation to risk level value. Total points = (nominal points + (nominal points * risk factor))	CCSP, 2009	Adaptive

Require physical access to and infrastructure for coastal regions to be sited, designed and managed to minimize potential impacts from sea level rise.	3	Direct correlation to risk level value. Total points = (nominal points + (nominal points * risk factor))	CCSP, 2009	Adaptive
Design requirement for bridges and other major facilities to accommodate expected sea level rise.	3	Direct correlation to risk level value. Total points = (nominal points + (nominal points * risk factor))	CCSP, 2009	Adaptive
Total possible points	**32**			

By far, the most valuable adaptive strategy in dealing with sea level rise is the use of "rolling easement." This concept allows a government (local, state or federal) to take possession of or restrict development on property within a certain distance of the shoreline (generally defined as the high tide line). With a rolling easement, the area under this special regulation can shift as the position of the high tide line changes. This is an especially useful tool when confronted by sea level rise.

The final set of criteria that the Plan Evaluation Model seeks to identify and value are Barrier Solutions to mitigate the effects of sea level rise. Unlike other criteria, the beach nourishment barrier component actually becomes less effective as the risk factor increases. As the inundation increases and moves beyond the shoreline, beach nourishment becomes more and more a useless exercise. This component has an inverse correlation to the risk level and, at the highest possible risk factor, would become a zero value component. Since the other criteria in this section are directly correlated to the risk factor, this section could be awarded an additional 6 points for a total section score of 12. These relationships are shown in Table 3.6.

Table 3.6: Barrier Component Evaluation

Barrier Solutions for Plan	Points	Effect of Risk Level on Value of Component	Criteria Source
Require a program of beach nourishment	2	Inverse correlation between risk level and component value. Total points = (nominal points - (nominal points * risk))	CCSP, 2009
Require a program of wetlands enhancement	2	Direct correlation to risk level value. Total points = (nominal points + (nominal points * risk factor))	CCSP, 2009
Identify existing dikes at risk for overtopping at newly projected flood levels, plan for the refortification of these barriers.	2	Direct correlation to risk level value. Total points = (nominal points + (nominal points * risk factor))	CCSP, 2009
Require drainage projects to use larger gauge pipes to accommodate future sea level rise.	2	Direct correlation to risk level value. Total points = (nominal points + (nominal points * risk factor))	CCSP, 2009
Total possible points	**12**		

Without a single, widely accepted projection to base the analysis on, this assessment will be run against the community plans at two different sea level rise projections: 0.8m and 2m. Running both these projections will allow the assessment of the plan components at different thresholds with associated escalating risk values.

Finally, I will use HAZUS-MH GIS models of each area to project the impact of sea level rise on the community based on two different projected levels: 0.8m and 2m. The impact of this analysis will determine whether a community's efforts are in line with its vulnerabilities.

Study Areas

The cities I have chosen for review run the length of the Delmarva Peninsula, from Rehoboth Beach, Delaware in the north to Chincoteague Island, Virginia in the south. The study areas are three small coastal cities in Delaware, Maryland and Virginia. In addition to the criteria found in my review of the plans themselves, I found that in the

Code of Maryland Regulations, there are state regulations establishing a 100 yard critical area buffer around estuary and marine shorelines.

Assessment and Analysis

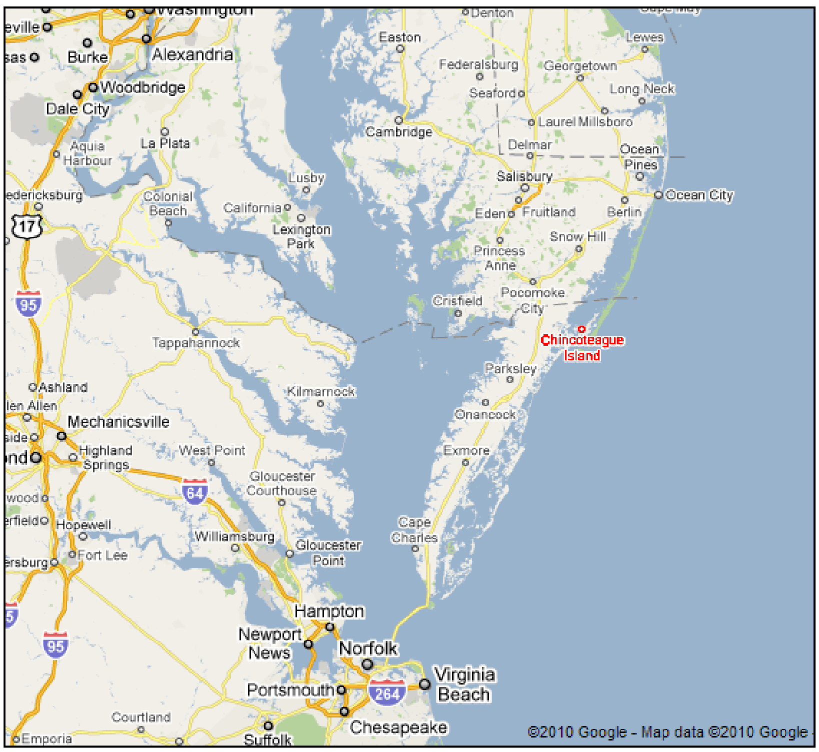
I began my analysis of the study areas with Chincoteague, VA, before moving on to Ocean City, MD, and finally Rehoboth Beach, DE. Using the Risk Assessment Matrix and Plan Evaluation Model described in the previous section, I will calculate risk faced and plan quality of each community. Additionally, in each section I will provide a brief overview of the community background, the form of local government and the organizations responsible for creating and approving the plans. In the Chincoteague section, I will illustrate more fully the mechanics of the risk assessment and plan analysis models. With the Ocean City and Rehoboth Beach sections, there will be less procedural content.

Chincoteague

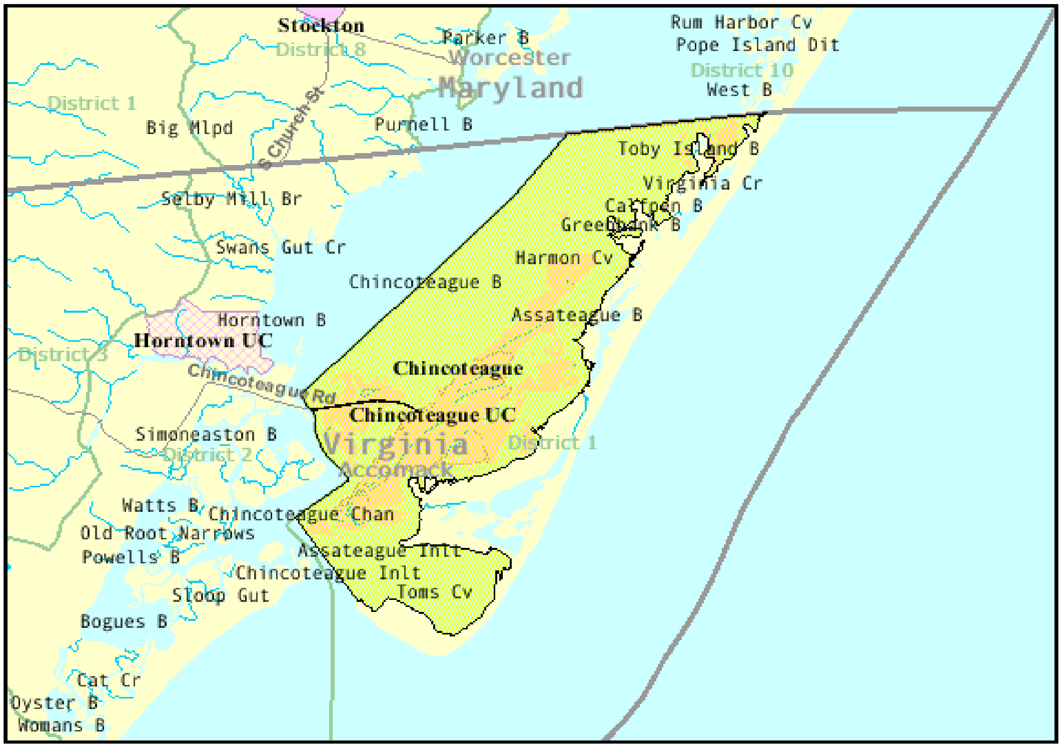
The southernmost research area is the town of Chincoteague, VA, located on a barrier island in Accomack County on Virginia's Eastern Shore (Map 4.1). Chincoteague Island is located at 37° 56' N latitude, and 75° 23' W longitude in Chincoteague Bay. The island is sheltered somewhat from storm surges in the Atlantic Ocean by another barrier island, called Assateague. Assateague Island is both a US Park Service National Seashore and a National Wildlife Refuge. To the east of Chincoteague is Wallops Island, the site of a NASA flight facility for launching unmanned rockets and a US Navy Surface Combat

Support Center. In the keynote address at the 2009 ECO-3 Conference, Louis Hinds, the Refuge Manager for the Chincoteague National Wildlife Refuge Complex, told the audience that the federal government has directed all three facilities to develop plans to deal with the impacts of sea level rise at the 1m, 1.5m and 2m levels (Hinds 2009).

The town of Chincoteague has a year-round population of 4,317 (Census 2000) and nearly 15,000 seasonal residents (Chincoteague Plan 2010). Chincoteague has a land area of approximately 9.63 sq. miles (Census 2000). This makes Chincoteague the largest research area in size and the second largest in year-round population (Map A-2).



Map 4.1: Chincoteague Location **Source: Google 2010**



Map 4.2: Chincoteague Boundary **Source: USGS 1981**

Chincoteague Community Background

Prior to colonization, the Chincoteague area was home to the Gingo-Teague Tribe. In 1608, the island was claimed for England by John Smith and colonization began. The economy of the area was primarily agriculture (food and tobacco) and fishing up until the mid 20th Century, when a children's book turned the small island into a tourist destination (Chincoteague Plan 2010).

The area's most famous residents, the "Chincoteague Ponies" began appearing in the 1700's. There is some debate over the origin of these wild ponies, but whether the ponies were the survivors of a shipwrecked Spanish Galleon or simply abandoned farm animals, they are a unique feature of the island. A yearly round-up and auction of the ponies is a fundraising activity of the Chincoteague Fire Department. In 1947, author Marguerite

Henry published "Misty of Chincoteague" based on a true story from one of the annual round ups. The book has become a classic children's story and was made into a movie in 1961. Tourism is now Chincoteague's major industry with the island attracting over 1 million visitors every year (Chincoteague Plan 2010).

Government

Chincoteague's town government is based on the council/manager model. The council is made up of six members and an at-large mayor. The town manager is appointed by the mayor and approved by council to run the day to day operations of the town. The six planning commission members are elected to 4 year terms and are charged with administrating the town plan. The most recent comprehensive plan was approved by both the planning commission and the council in January 2010. This is the plan that will be evaluated for this research paper.

Chincoteague Risk Analysis

As stated in the methodology chapter, before the assessment of the community plan can be done, it is important to use the Risk Assessment Matrix to evaluate the vulnerability of the area. The Matrix data come from three primary sources: US Census Data from 2000; the Federal Emergency Management Agency's (FEMA) Flood Insurance Rate Map (FIRM); and disaster models run using FEMA's HAZUS-MH GIS package.

The demographic data for Chincoteague were gathered from US Census data. The data show that in 2000, Chincoteague had a population of 4,317. Of that total, 21% of the population was 65 years of age or older; 20.5% of the population was disabled; 3.9% of the population was under the age of 5; finally, 12.7% of households were living below the federal poverty line. These data are entered into the Risk Assessment Matrix and return a score of 21 points out of 40 possible (Table 4.1)

Table 4.1: Chincoteague Demographic Risk

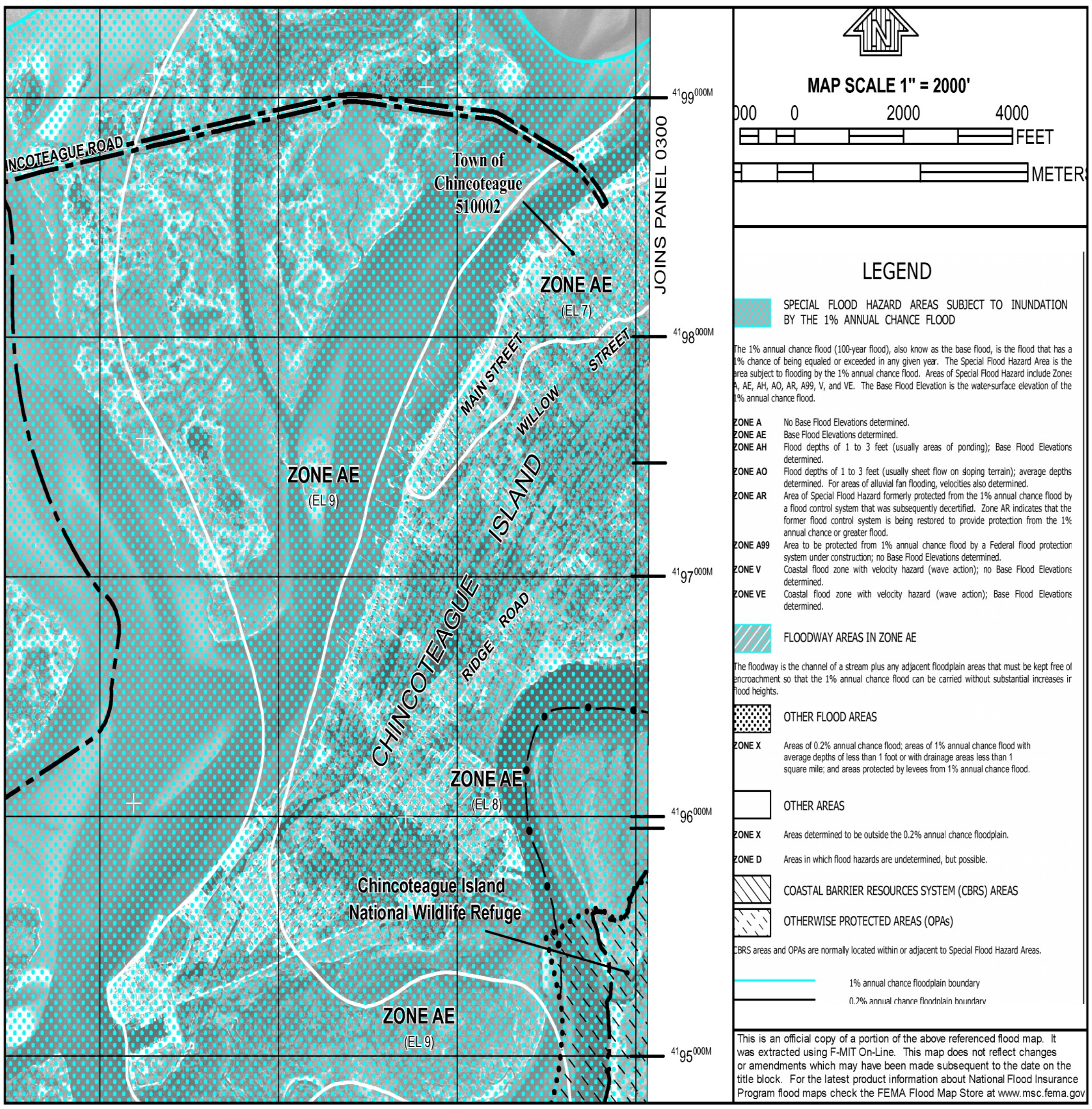
Criteria for Socio-Economic Risk	**Scale**	**Census 2000 Data**
Percentage of Households at or below Federal Poverty line	≤ 5% = 1pt, ≤ 7.5% = 2pts, ≤ 10% = 3pts, ≤ 12.5% = 4pts, ≤ 15% = 5pts, ≤ 17.5% = 6pts, ≤ 20% = 7pts, ≤ 22.5% = 8pts, ≤ 25% = 9pts, > 25% = 10pts	**4**
Percentage of Population Disabled	≤ 5% = 1pt, ≤ 7.5% = 2pts, ≤ 10% = 3pts, ≤ 12.5% = 4pts, ≤ 15% = 5pts, ≤ 17.5% = 6pts, ≤ 20% = 7pts, ≤ 22.5% = 8pts, ≤ 25% = 9pts, > 25% = 10pts	**8**
Percentage of Population under 5 years of age	≤ 5% = 1pt, ≤ 7.5% = 2pts, ≤ 10% = 3pts, ≤ 12.5% = 4pts, ≤ 15% = 5pts, ≤ 17.5% = 6pts, ≤ 20% = 7pts, ≤ 22.5% = 8pts, ≤ 25% = 9pts, > 25% = 10pts	**1**
Percentage of Population over 65 years of age	≤ 5% = 1pt, ≤ 7.5% = 2pts, ≤ 10% = 3pts, ≤ 12.5% = 4pts, ≤ 15% = 5pts, ≤ 17.5% = 6pts, ≤ 20% = 7pts, ≤ 22.5% = 8pts, ≤ 25% = 9pts, > 25% = 10pts	**8**
Total possible points	**40**	**21**

For the next set of risk criteria, the total area within the 100 year floodplain must be calculated. By using population density in conjunction with FIRM, the total percentage of the population within the floodplain can be calculated as well. In the case of Chincoteague, 100% of the town and 100% of the population lie within the 100 year floodplain. The FIRM data for Chincoteague are split across the two maps shown below (Map 4.3 and Map 4.4).

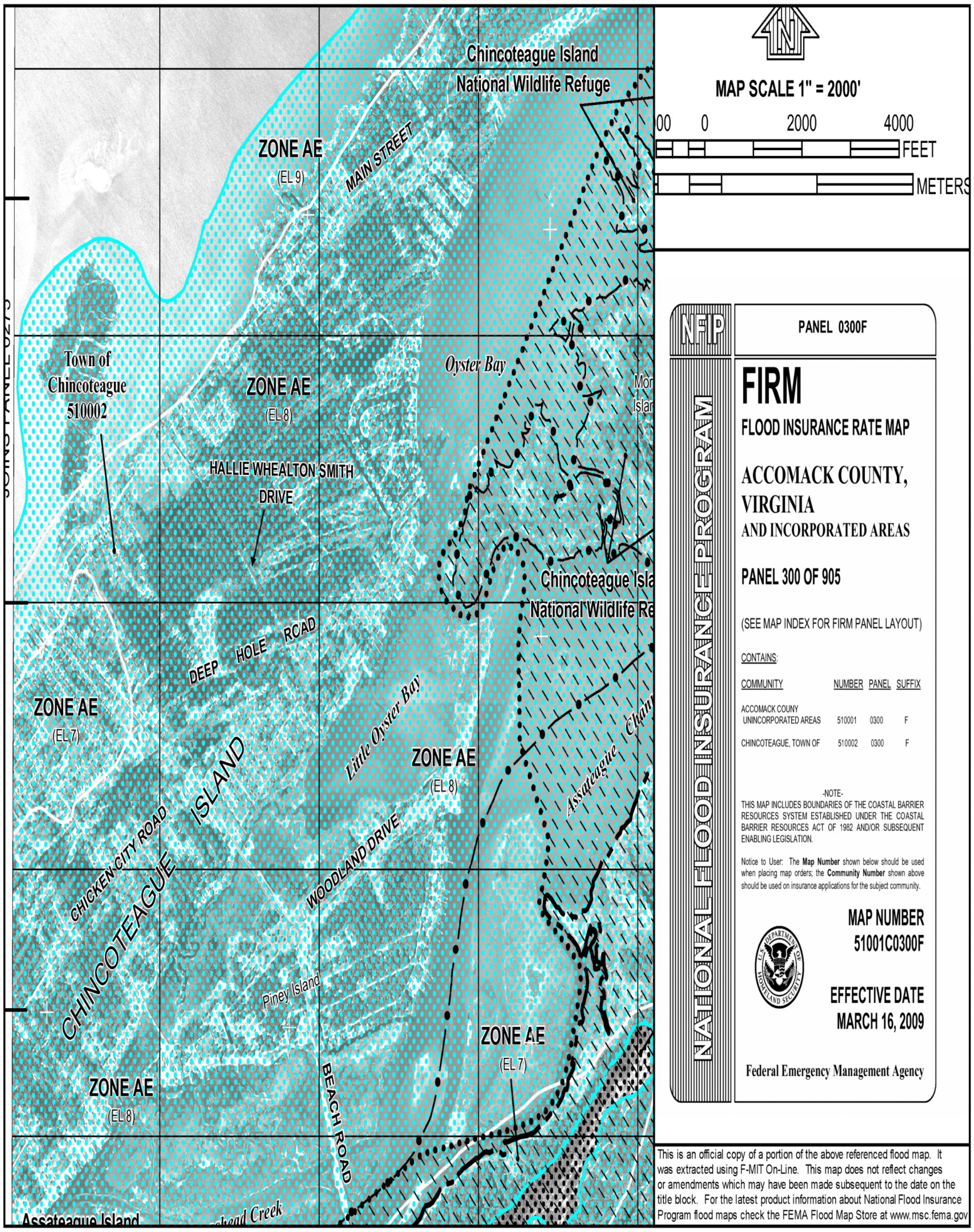
With 100% of the community within the 100 year flood inundation zone Chincoteague scores the maximum 20 out of 20 possible risk points (Table 4.2).

Table 4.2: Chincoteague Geographic Risk - Part 1

Criteria for Geographic Risk	Scale	Chincoteague
Percentage of Community area within 100 year floodplain	10% of area = 1pt, 100% of area = 10pts	**10**
Percentage of Population within 100 year floodplain	10% of population = 1pt, 100% of population = 10pts	**10**

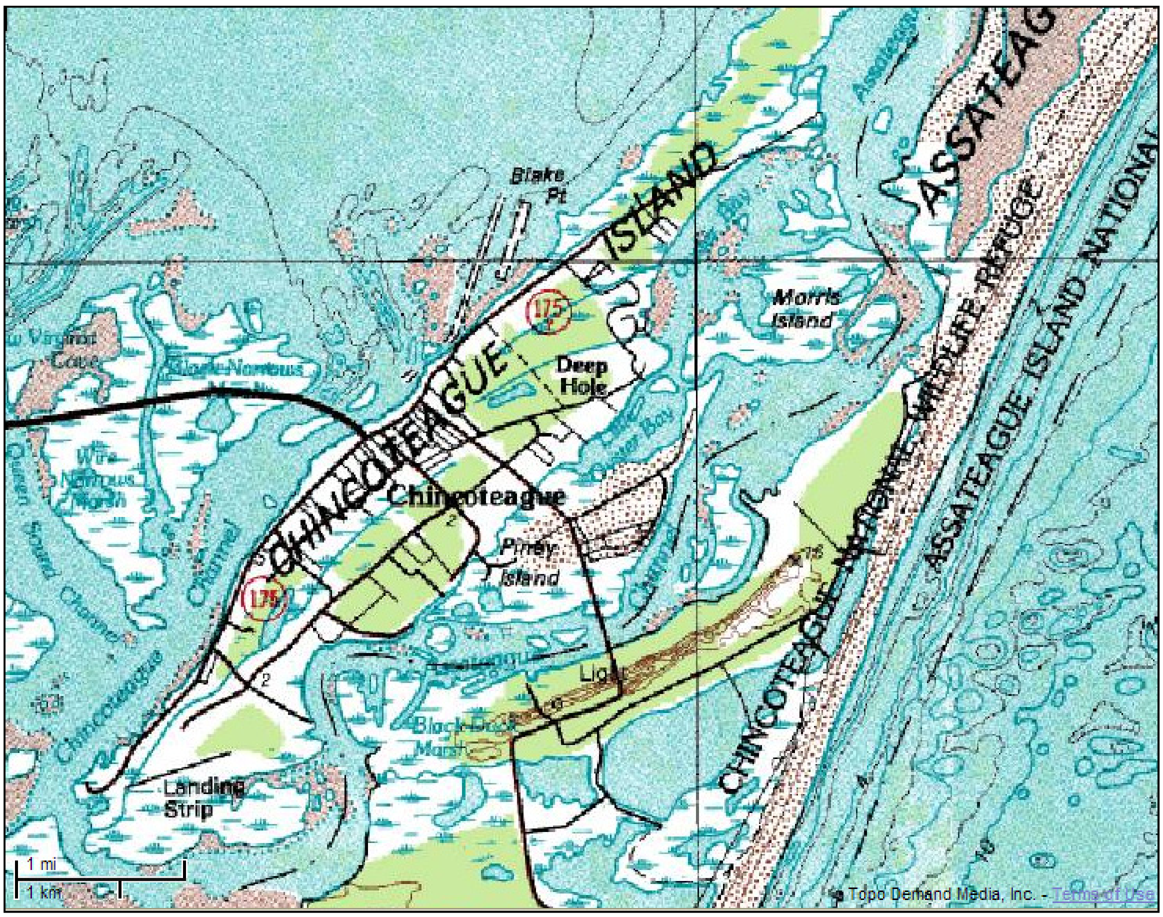


Map 4.3: Western Half of Chincoteague Island **Source: FEMA 2009**



Map 4.4: Eastern Half of Chincoteague Island **Source: FEMA 2009**

The next criterion to be examined and evaluated is topographic risk. Topographic risk is determined using United States Geographic Survey (USGS) maps to establish an area's average elevation, then subtracting the expected rise. The risk increases as the difference increases. The average elevation, based on USGS maps is 2m (Map 4.5). The highest point in Chincoteague is only 2.5m.



Map 4.5: Chincoteague Topographic Map **Source: USGS 1981**

The low-lying terrain of Chincoteague increases the risk value greatly. At the 0.8m projected rise, Chincoteague scores 8 out of 10 possible risk points. At the projected 2m rise, Chincoteague scores 10 out of 10. Adding to risk level for Chincoteague Island, and visible on the above topographic map, is the island's very limited vehicular access. There is only a single, two-lane access road connecting the mainland to Chincoteague Island. This limited access adds an additional 10 points to the risk matrix (Table 4.3).

Table 4.3: Chincoteague Geographic Risk - Part 2

Criteria for Geographic Risk	Scale	0.8m Rise	2.0m Rise
Number of access roads to mainland	≥ 10 access roads = 1pt, 9 access roads = 2pts, 8 access roads = 3pts, 7 access roads = 4pts , 6 access roads = 5pts, 5 access roads = 6pts, 4 access roads = 7pts, 3 access roads = 8pts, 2 access roads = 9pts, 1 access road = 10 pts	**10**	**10**
(Average Elevation) - (Inundation Model Height)	≥ 5 meters = 1pt, 4 - 4.99m = 2pts, 3.5 - 3.99m = 3pts, 3 – 3.49m = 4pts, 2.5 - 2.99m = 5pts, 2 – 2.49m = 6pts, 1.5 – 1.99m = 7pts, 1 – 1.49m = 8pts, 0.5 - .99m = 9pts, ≤ .49m = 10 pts	**8**	**10**

The last set of criteria results from GIS disaster modeling using FEMA's HAZUS-MH software. Using the HAZUS coastal flooding simulator and modifying the parameters to reflect the 0.8m and 2.0m rises, a grim picture emerged for the possible future of Chincoteague. Over the next few pages, several maps and images are displayed. Image 4.1 is an East to West aerial photograph of Chincoteague Island today.

Image 4.1: Chincoteague Island

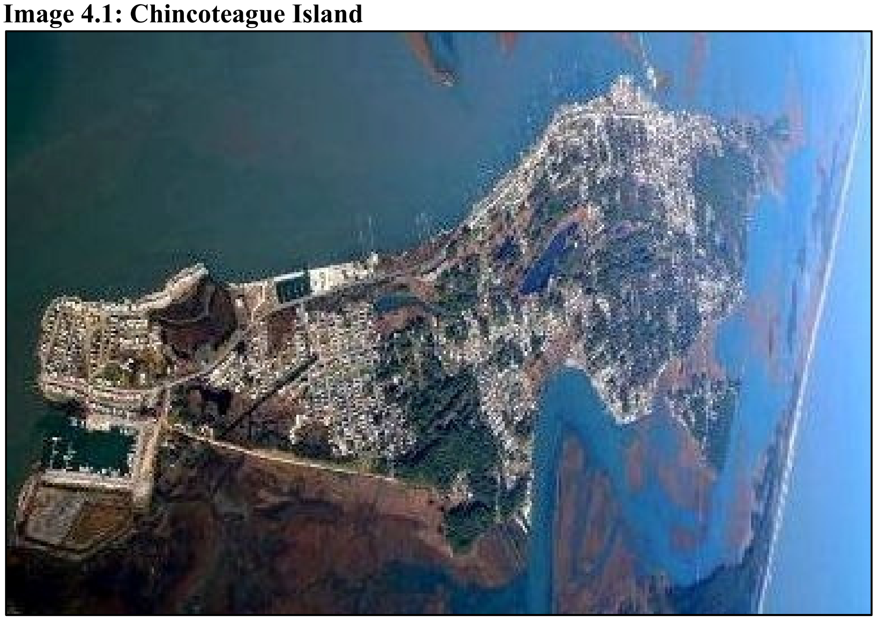
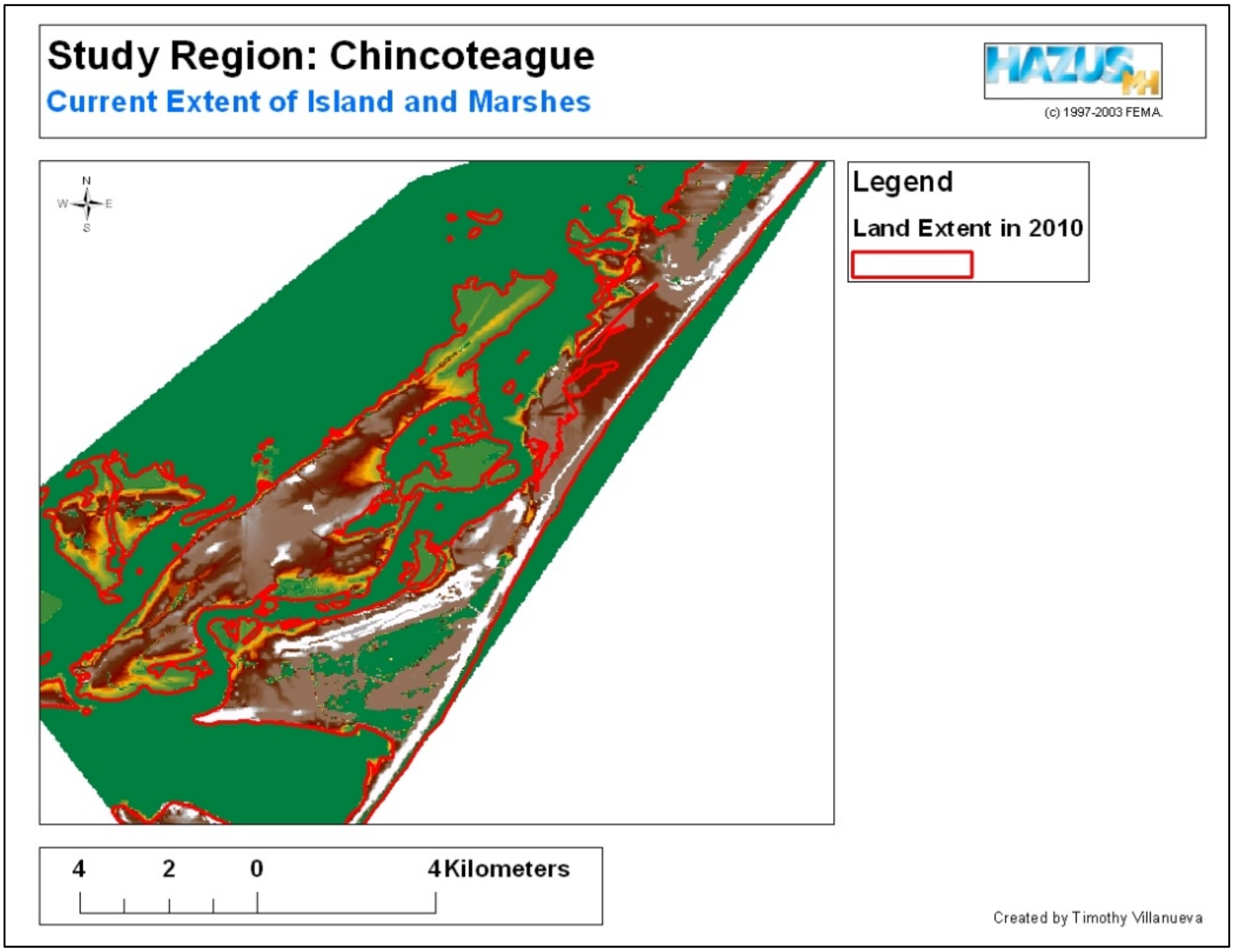


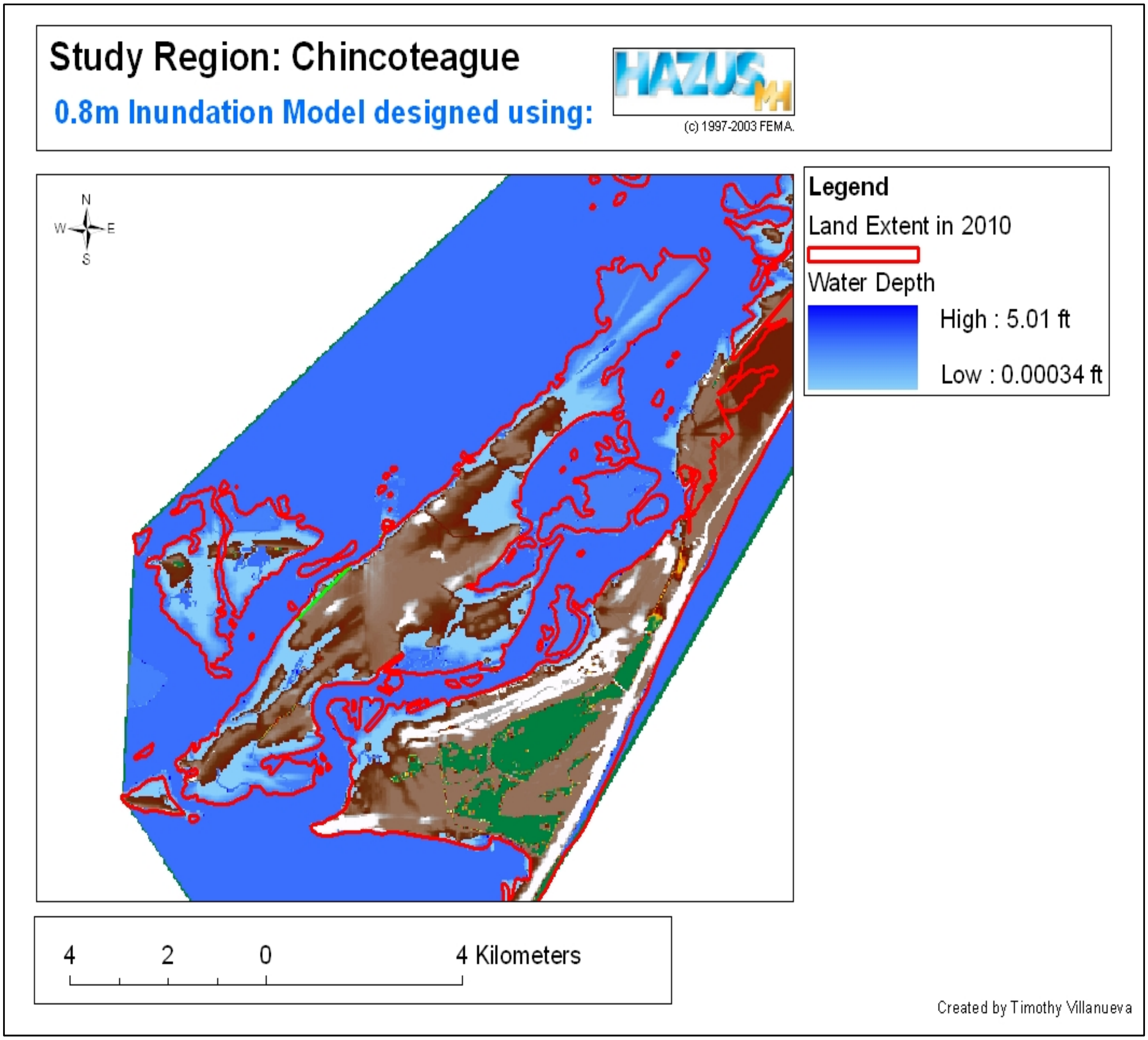
Image 4.1: Chincoteague Island **Source: HighCamera.com 2010**

Map 4.6 models the current terrain grade across Chincoteague. The dark green reflects the nearly flat surface of the surrounding water, while browns, reds and grays represent the slopes and gullies across the island proper.



Map 4.6: Chincoteague Terrain Model

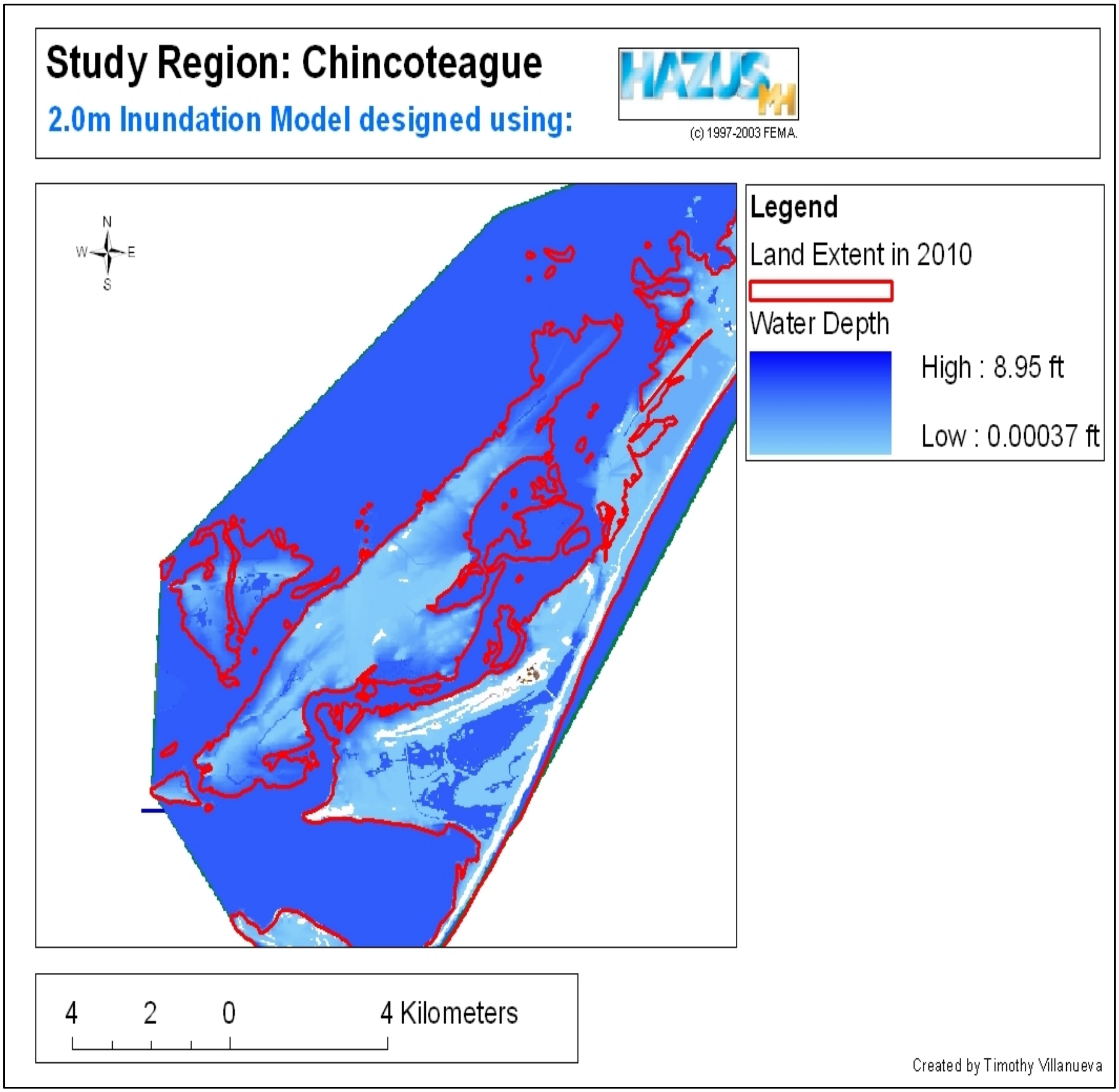
Map 4.7 reflects the inundation of Chincoteague at the 0.8m rise level. At this level, nearly 20% of the island is completely inundated and to the east, a large section has been split off from the rest of the island.



Map 4.7: Chincoteague at 0.8m Sea Level Rise

Map 4.8 shows Chincoteague at the 2.0m inundation level. Over 95% of the island is submerged in this model, the remaining land areas are too small and too widely dispersed to be habitable. At the 2m inundation level, Chincoteague is a total loss.

These models provide the final criteria for the Risk Assessment Matrix. The 0.8m rise projection produces a total risk score of 4 out of 20, while the 2.0m rise projection scores 20 out of 20 (Table 4.4).



Map 4.8: Chincoteague at 2.0m Sea Level Rise

Table 4.4: Chincoteague Geographic Risk – Part 3

Criteria for Geographic Risk	Scale	0.8m Rise	2.0m Rise
Percentage of Community area inundated according to the model	10% of area = 1pt, 100% of area = 10pts	2	10
Percentage of Population inundated according to the model	10% of population = 1pt, 100% of population = 10pts	2	10

The total risk matrix score for Chincoteague at the 0.8m is 67 out of a possible 100 points, this translates to a 0.67 factor in the plan assessment model. The matrix score for the 2.0m simulation is 81 or a 0.81 factor.

Plan Evaluation

The plan evaluation model is broken down into four sets of criteria: general plan elements, hazard identification, land use solutions, and barrier solutions. Each of these subsets is scored. The general plan elements section is evaluated independently of the Risk Assessment Matrix. The other three sections are scored based on values that are either directly or inversely dependent on the Risk Assessment Factor.

Chincoteague scores well in the evaluation of general plan elements. The plan features clearly delineated goals, objectives and strategies. The goals for Chincoteague include Land Use, Economic Development, Community Facilities and Services, Transportation, and Housing. The goals are specific in scope and in keeping with the unique character of the community. The land use goal "**Provide a quality living environment for all residents by ensuring a balanced mix of residential and commercial development, while preserving and improving natural resources and promoting the Town's image as a desirable, visually attractive, safe, and**

economically stable residential community" includes objectives to revitalize the waterfront district and to preserve wetlands and open space. Public involvement with the planning process was informative, inclusive and cooperative. The Appendix II section of the plan contains questionnaire results and comments from public meetings. **For these reasons, Chincoteague scores 10 out of 10 in the plan evaluation section (Table 4.5).**

Table 4.5: Chincoteague General Plan Evaluation

General Plan Assessment	Nominal Points	Affected by Risk Factor	Chincoteague Nominal Score	0.8m Model with Risk Factor 0.67	2.0m Model with Risk Factor 0.81
Plan delineates goals, objectives, and implementation strategies	1	N	1	1.00	1.00
Goals call for specific actions	1	N	1	1.00	1.00
Goals are condition-specific to community	2	N	2	2.00	2.00
Plans show public kept informed of process	1	N	1	1.00	1.00
Plans show public involvement in approval process	2	N	2	2.00	2.00
Plans show public involvement in information gathering and plan creation process	3	N	3	3.00	3.00
Total section points	**10**			**10.00**	**10.00**

While the general assessment of the Chincoteague plan was very favorable, the Hazard Identification Assessment was less so. The plan does identify run-off and drainage issues within the city, specifically those resulting from rainfall and storm surges. The plan also acknowledges risks posed by coastal flooding and the associated issues with standing water. Beyond those components, the plan fails to acknowledge climate change and the potential for sea level rise, except as a temporary effect of a hurricane or nor'easter. Nor does the plan call for action to confirm the island elevation through LiDAR or other scanning methods, despite the acknowledgement that the island suffers from stormwater flooding because of the low-lying topography. Further, no mention is made of evaluating the vulnerability of waterfront property or structures. Because the importance of these components grows with the risk facing the community, the plan was scored at both the 0.8m and 2.0m levels. **Out of a possible 46 points, the Chincoteague Plan received a total of 8.35 points at the 0.8m level and 9.05 points at the 2.0m level (Table 4.6).**

Table 4.6: Chincoteague Hazard Identification Evaluation

Hazard Identification Criteria	Nominal Points	Affected by Risk Factor	Chincoteague Nominal Score	0.8m Model with Risk Factor 0.67	2.0m Model with Risk Factor 0.81
Plan identifies run-off/drainage issues	1	Y	1	1.67	1.81
Plan identifies threats from storm surges	1	Y	1	1.67	1.81
Plan identifies threats from coastal flooding	3	Y	3	5.01	5.43
Plan identifies threats from climate change	3	Y	0	0.00	0.00
Plan identifies threats from sea level rise	5	Y	0	0.00	0.00
Conduct a LiDAR survey of coastal areas to accurately map elevations and redraw floodplain maps as needed.	5	Y	0	0.00	0.00
Conduct an inventory of threatened properties to rezone, purchase, or condemn as necessary.	5	Y	0	0.00	0.00
Total section points	**46**			8.35	9.05

The third area of plan evaluation examines the land use provisions of the community plan. This evaluation is to determine whether there are land use provisions in the plan designed to help the community mitigate or adapt to the effects of sea level rise. The Chincoteague plan does address floodplain zoning with an eye toward improving the FEMA flood insurance rating for the community. It specifies the need for set asides for drainage and run-off control and for new construction design and setback requirements. While the plan does satisfy those two criteria within the land use evaluation, it fails to meet any other. **Out of a possible 32 points, Chincoteague scores 6.68 points at the 0.8m risk level and 7.25 points at the 2.0m level (Table 4.7).**

Table 4.7: Chincoteague Land Use Component Evaluation

Land Use Solutions for Plan	Nominal Points	Affected by Risk Factor	Chincoteague Nominal Score	0.8m Model with Risk Factor 0.67	2.0m Model with Risk Factor 0.81
Establish a "rolling easement" that empowers the jurisdiction to take public ownership of property that 'rolls' inland with the coastline as sea-level rises.	6	Y	0	0.00	0.00
Update and implement shoreland and floodplain zoning regulations to ensure that existing municipal and new private development are designed and sited to mitigate the effects of flooding and inundation.	2	Y	2	3.34	3.62
Establish new setback guidelines and transfer of development rights to encourage development in areas outside the floodplain.	2	Y	2	3.34	3.62
Require physical access to and infrastructure for coastal regions to be sited, designed and managed to minimize potential impacts from sea level rise.	3	Y	0	0.00	0.00
Set design requirement for bridges and other major facilities to accommodate expected sea level rise.	3	Y	0	0.00	0.00
Total section points	**32**			**6.68**	**7.24**

The final section of the plan evaluation assesses any plan elements that deal with flooding/inundation mitigation through the use of barriers. These elements include beach nourishment programs, wetlands enhancement, levee construction and/or maintenance and drainage design. Chincoteague Island has no beach, so the nourishment component would not be applicable. The Chincoteague plan does call for the protection and preservation of wetlands from development encroachment. The plan lacks any mention of the use, construction and maintenance of levees or dikes.

Finally, as noted in the previous section, there is a drainage plan, but it calls for the use of open ditches and trenches rather than any sort of storm sewer or pumping station. The low cost nature of the ditch and trench system is why it was selected for the plan. Because this method depends on the water receding and then evaporating and/or percolating out through the soil, it will be largely ineffective against sea level rise. For this reason, I have only given the component half credit. **In this final section of the evaluation, Chincoteague scores 5.01 out of 12 possible points at the 0.8m risk level and 5.43 points at the 2.0m risk level (Table 4.8).**

Table 4.8: Chincoteague Barrier Component Evaluation

Barrier Solutions for Plan	Nominal Points	Affected by Risk Factor	Chincoteague Nominal Score	0.8m Model with Risk Factor 0.67	2.0m Model with Risk Factor 0.81
Require a program of beach nourishment	2 pts	Y	0	0.00	0.00
Require a program of wetlands enhancement	2 pts	Y	2	3.34	3.62
Identify existing dikes at risk for overtopping at newly projected flood levels, plan for the refortification of these barriers.	2 pts	Y	0	0.00	0.00

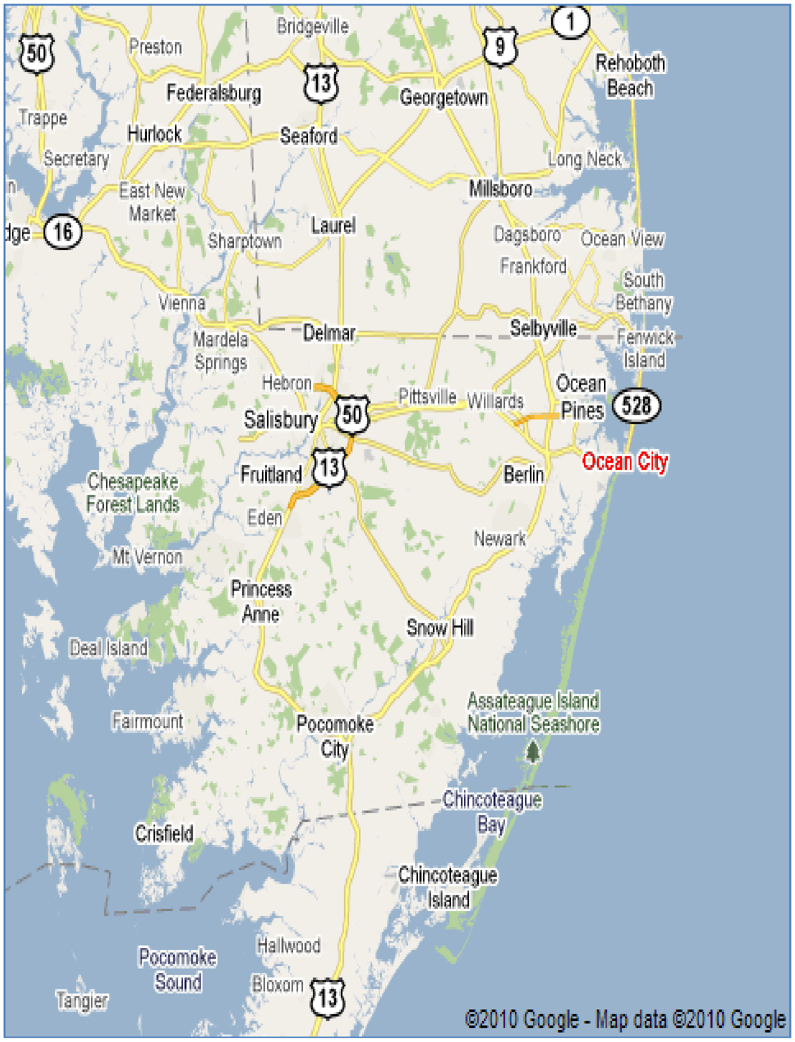
Require drainage projects to use larger gauge pipes to accommodate future sea level rise.	2 pts	Y	1	1.67	1.81
Total section points	**12**			**5.01**	**5.43**

After tallying the results from each section, a combined evaluation score is determined for each of the inundation models. **The total scores for the Chincoteague 2010 Plan are 30.04 at the 0.8m level and 31.72 at the 2.0m level. The maximum possible scores at the risk levels for Chincoteague are 85.81 at the 0.8m level and 91.83 at the 2.0m level. Using the percentage based scoring system developed for this project, both the score of 35% at the 0.8m level and 34.5% for the 2.0 inundation model rank the Chincoteague plan's response to sea level rise as "Poor."**

Ocean City

Ocean City (38° 20' N, 75° 05' W) is located on Fenwick Island, a barrier island in northeast Worcester County, MD. It is situated between the Atlantic Ocean to the east and the Assawoman and Isle of Wight Bays to the west. Directly south of Ocean City is Assateague Island National Seashore (Map 4.9). Prior to 1933, the area that is now Ocean City was the northern tip of Assateague Island. In 1933, a nor'easter storm cut an inlet between the two areas and they have remained separated ever since (Ocean City Plan 2006). As a barrier island, Ocean City is very vulnerable to the effects of sea level rise. Unlike Chincoteague, Ocean City has no buffer from the Atlantic Ocean.

Ocean City has a year-round population of 7,184 (Census 2000). Like Chincoteague, the Ocean City economy is primarily based on tourism (Ocean City Plan 2006).

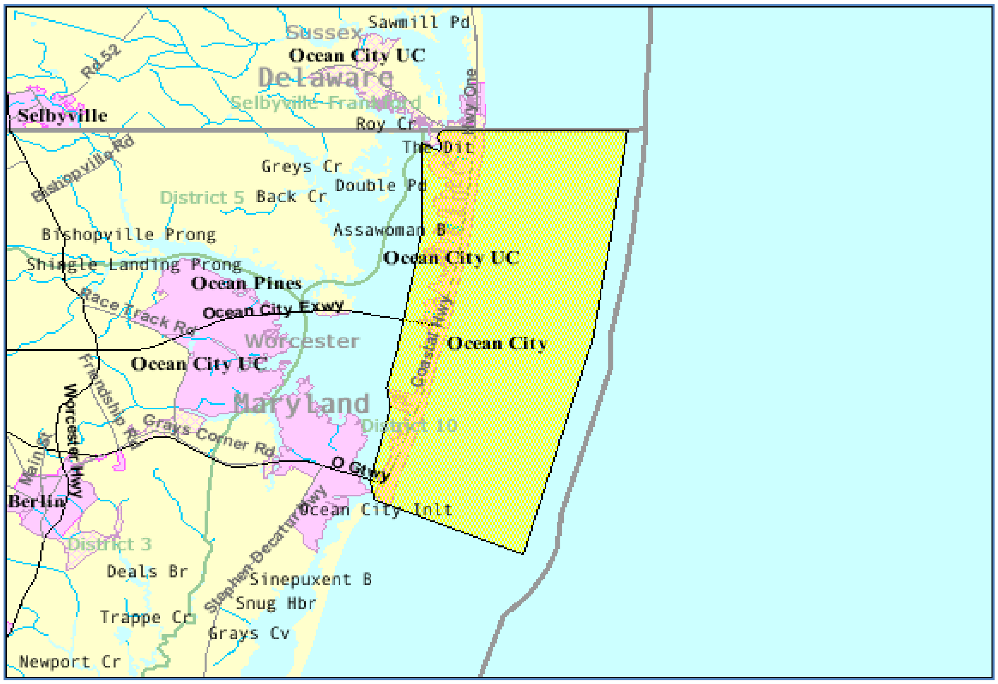


Map 4.9: Ocean City Location **Source: Google 2010**

Ocean City has a land area of approximately 4.56 sq. miles (Census 2000). This makes Ocean City the largest research area in population and second largest in land area (Map 4.10).

Ocean City Community Background

Prior to 1875, the site where Ocean City, MD now stands was pastureland shared by farmers on the mainland. In 1875, a boardwalk and the Atlantic Hotel were constructed to provide resort services.



Map 4.10: Ocean City Boundary **Source: USGS 1988**

Within 10 years of that first construction, Ocean City was a community boasting a lifesaving station, a post office, several hotels, restaurants, and attractions. The area remains a resort community to this day (Ocean City Plan 2006).

Government

Like Chincoteague's town government, Ocean City follows the council/manager model. The council is made up of seven members and an at-large mayor. The town manager is appointed by the mayor and approved by council to run the day to day operations of the town. Ocean City has a Department of Planning and Community Development and a town council appointed eight member planning commission. The most recent comprehensive plan was approved by both the planning commission and the council in April 2006. This is the plan that will be evaluated for this research paper.

Ocean City Risk Analysis

Before using the Risk Assessment Matrix to evaluate Ocean City, the standard demographic, topographic, and flood data gathering was required. The Census 2000 data for Ocean City showed a year-round population of 7,184. Of that population, 25.1% was 65 years of age or older, 22.2% was disabled, and only 2.9% of the population was under the age of 5. Additionally, 8.9% of Ocean City households live below the federal poverty line. This translates to a risk score of 22 out of 40 possible points (Table 4.9).

Table A-9: Ocean City Demographic Risk

Criteria for Socio-Economic Risk	Scale	2000 Census Data
Percentage of Households at or below Federal Poverty line	≤ 5% = 1pt, ≤ 7.5% = 2pts, ≤ 10% = 3pts, ≤ 12.5% = 4pts, ≤ 15% = 5pts, ≤ 17.5% = 6pts, ≤ 20% = 7pts, ≤ 22.5% = 8pts, ≤ 25% = 9pts, > 25% = 10pts	**3**
Percentage of Population Disabled	≤ 5% = 1pt, ≤ 7.5% = 2pts, ≤ 10% = 3pts, ≤ 12.5% = 4pts, ≤ 15% = 5pts, ≤ 17.5% = 6pts, ≤ 20% = 7pts, ≤ 22.5% = 8pts, ≤ 25% = 9pts, > 25% = 10pts	**8**
Percentage of Population under 5 years of age	≤ 5% = 1pt, ≤ 7.5% = 2pts, ≤ 10% = 3pts, ≤ 12.5% = 4pts, ≤ 15% = 5pts, ≤ 17.5% = 6pts, ≤ 20% = 7pts, ≤ 22.5% = 8pts, ≤ 25% = 9pts, > 25% = 10pts	**1**
Percentage of Population over 65 years of age	≤ 5% = 1pt, ≤ 7.5% = 2pts, ≤ 10% = 3pts, ≤ 12.5% = 4pts, ≤ 15% = 5pts, ≤ 17.5% = 6pts, ≤ 20% = 7pts, ≤ 22.5% = 8pts, ≤ 25% = 9pts, > 25% = 10pts	**10**

The FEMA flood maps for Ocean City show (Map 4.11 – Map 4.13) that over 90% of the community lies within the 100 year floodplain. These results produce a risk score of 18 out of 20 (Table 4.10).

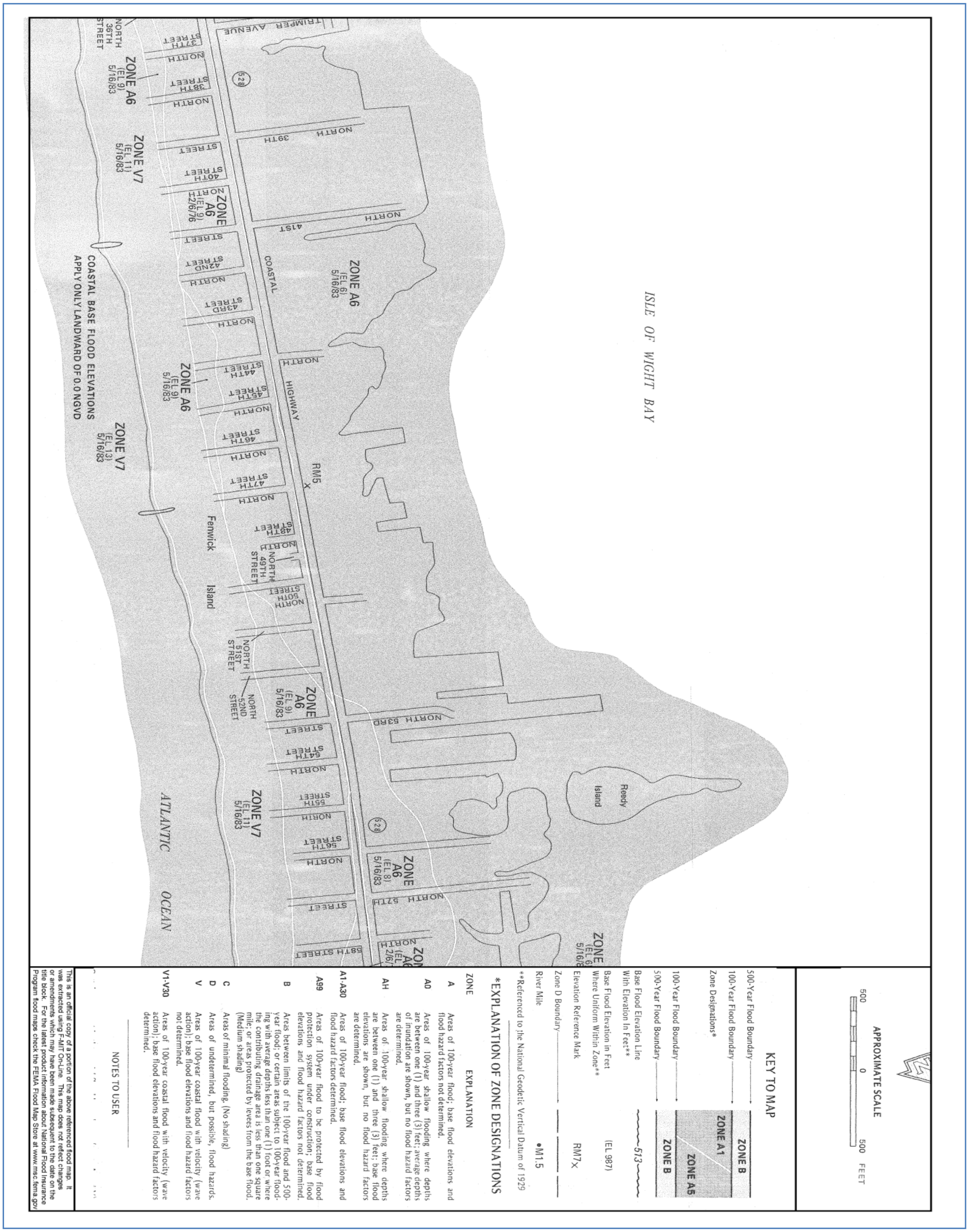
Table 4.10: Ocean City Geographic Risk - Part 1

Criteria for Geographic Risk	Scale	Ocean City
Percentage of Community area within 100 year floodplain	10% of area = 1pt, 100% of area = 10pts	9
Percentage of Population within 100 year floodplain	10% of population = 1pt, 100% of population = 10pts	9

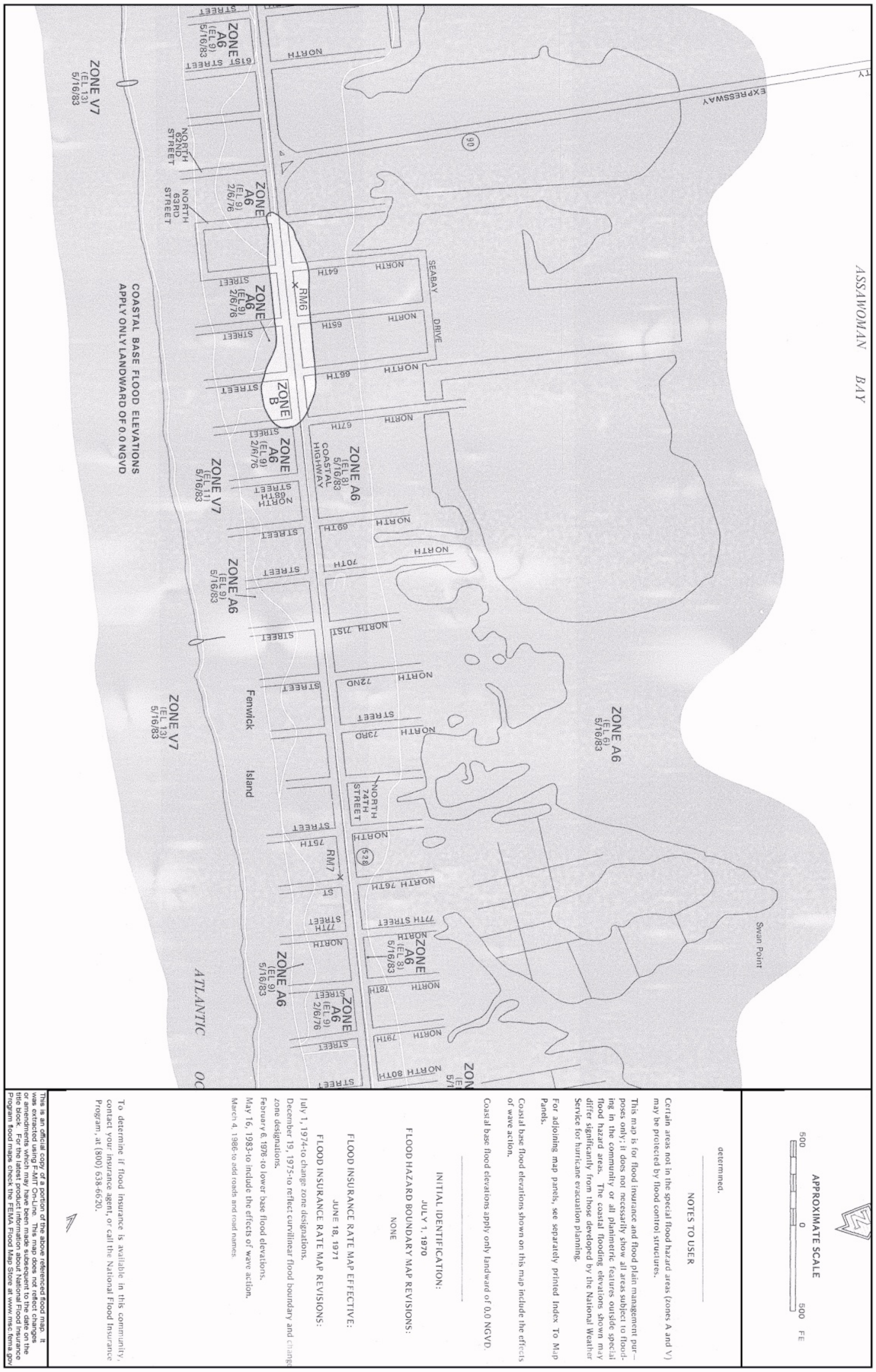
Despite the inconsistency in the map formats and styles, all the floodplain maps have the same source: FEMA's Map Service Center.

Ocean City's topographic risk is determined using United States Geographic Survey (USGS) maps to establish the average elevation, then subtracting the expected rise. Being located on a barrier island that was once part of Assateague, Ocean City might be expected to have low-lying terrain similar to that of Chincoteague. Based on USGS maps, however, the average elevation of Ocean City is 4m (Map 4.14). According to those same topographic maps, the highest point in Ocean City is 4.5m. This higher elevation reduces the area's risk significantly. At the 0.8m projected rise, the elevation/projected rise differential is 3.2m. This results in a risk score of 4 out of 10. At the 2.0m projection the differential is 2m, earning Ocean City a risk score that rises to 6 out of 10.

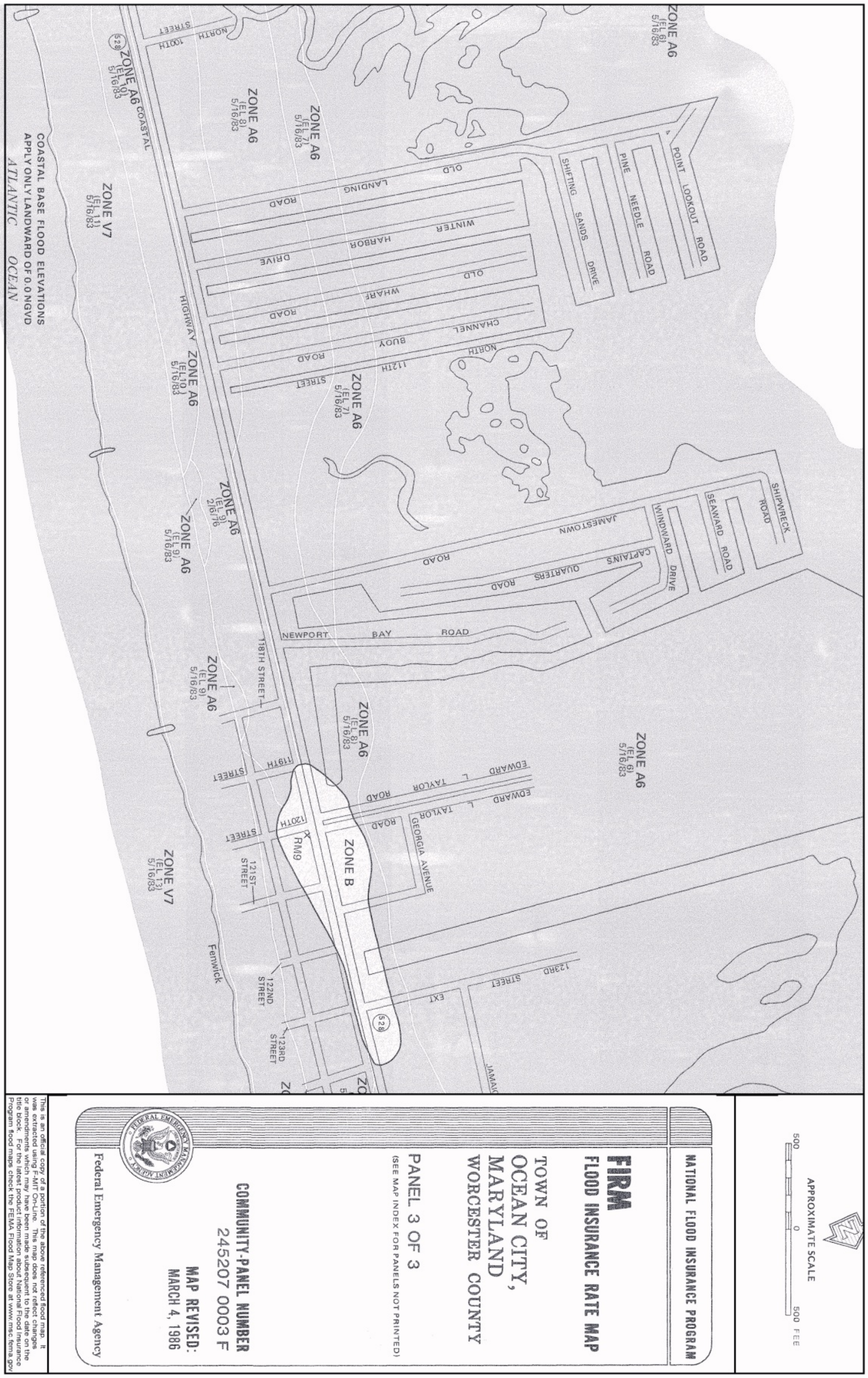
Another advantage that Ocean City has over Chincoteague Island is Ocean City's four access roads. This access level adds an additional 7 points to the risk matrix (Table 4.11).



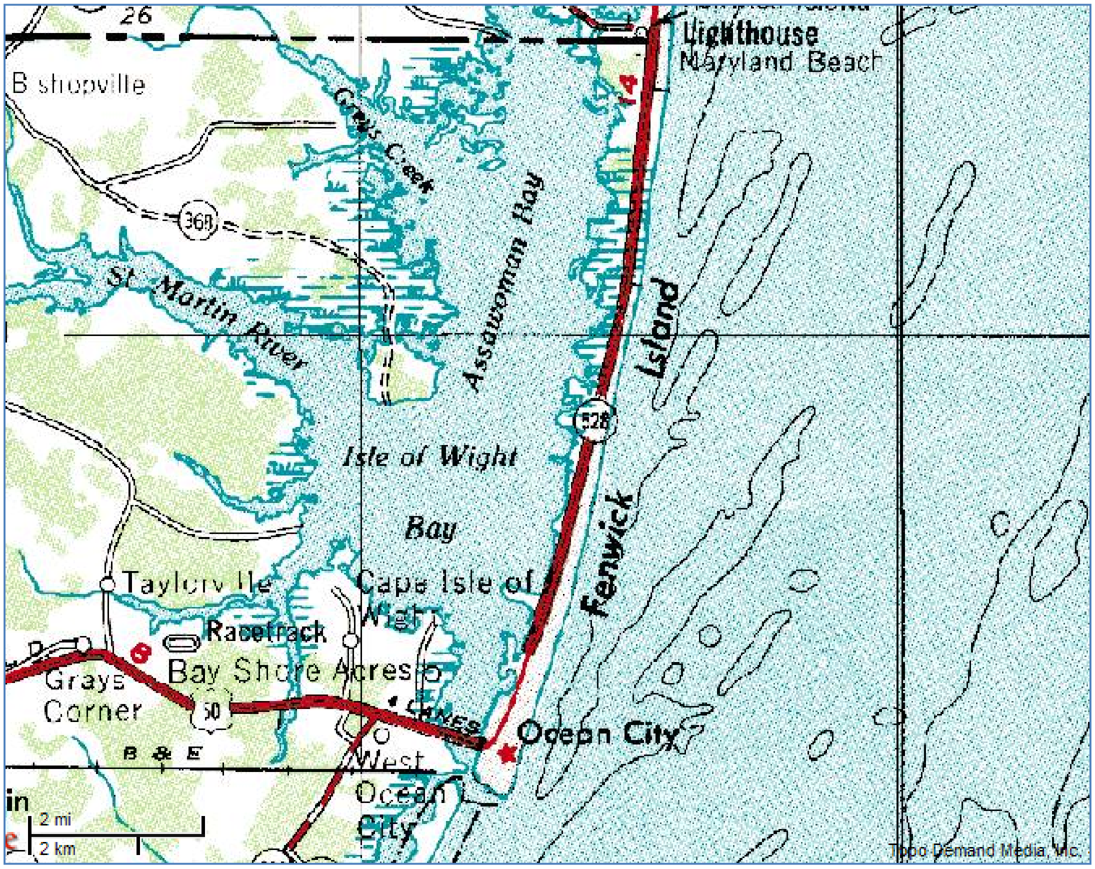
Map 4.11: South Ocean City Flood Map **Source: FEMA 1988**



Map 4.12: Central Ocean City Flood Map **Source: FEMA 1988**



Map 4.13: North Ocean City **Source: FEMA 1988**



Map 4.14: Ocean City Topographic Map **Source: USGS 1998**

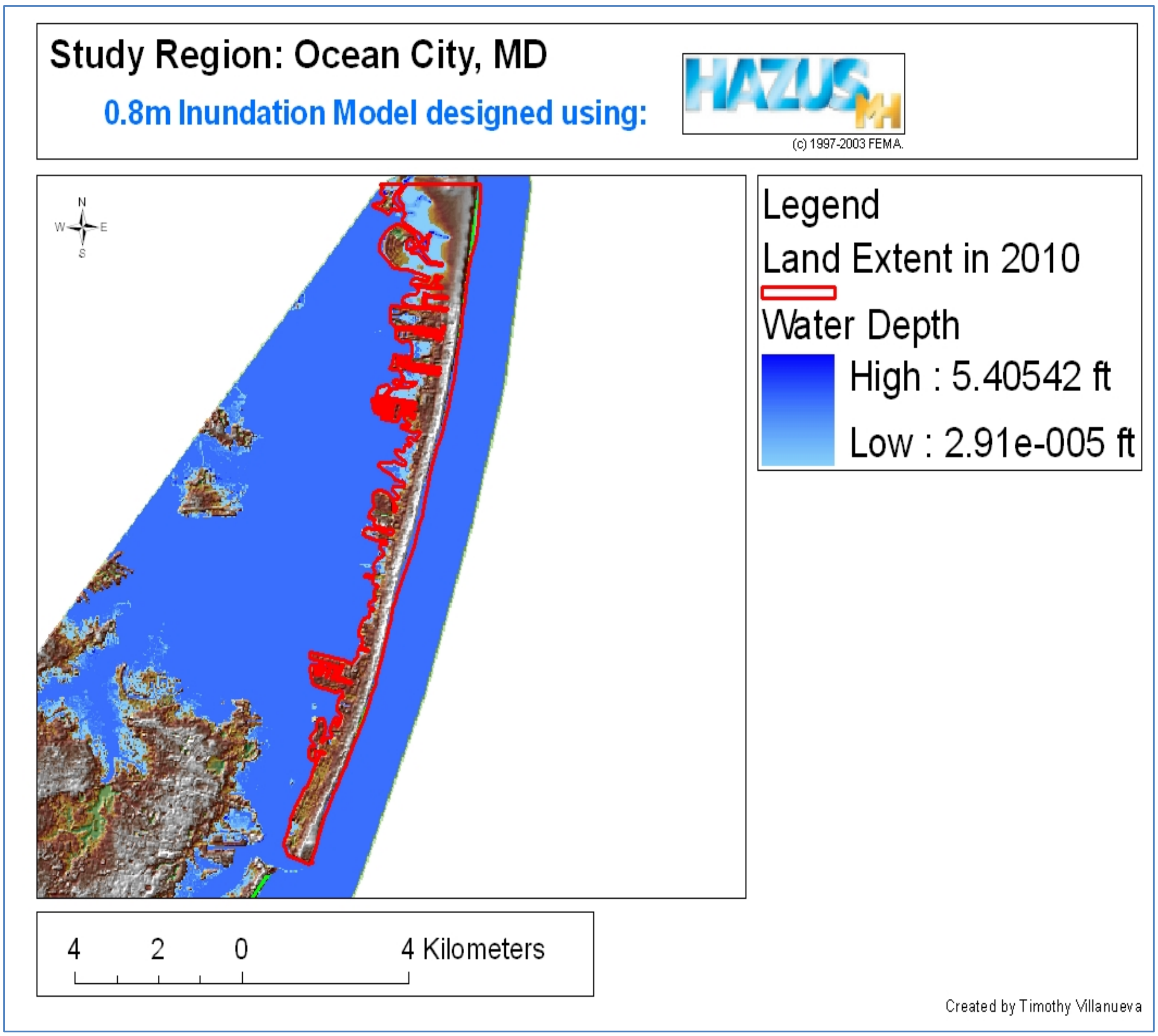
Table 4.11: Ocean City Geographic Risk - Part 2

Criteria for Geographic Risk	Scale	0.8m Rise	2.0m Rise
Number of access roads to mainland	≥ 10 access roads = 1pt, 9 access roads = 2pts, 8 access roads = 3pts, 7 access roads = 4pts , 6 access roads = 5pts, 5 access roads = 6pts, 4 access roads = 7pts, 3 access roads = 8pts, 2 access roads = 9pts, 1 access road = 10 pts	**7**	**7**
(Average Elevation) - (Inundation Model Height)	≥ 5 meters = 1pt, 4 - 4.99m = 2pts, 3.5 - 3.99m = 3pts, 3 – 3.49m = 4pts, 2.5 - 2.99m = 5pts, 2 – 2.49m = 6pts, 1.5 – 1.99m = 7pts, 1 – 1.49m = 8pts, 0.5 - .99m = 9pts, ≤ .49m = 10 pts	**4**	**6**

Using the HAZUS-MH coastal flooding simulator to reflect the 0.8m and 2.0m rises, the potential impact to Ocean City can be illustrated easily. At the 0.8m level, very little of the area is affected; only about 20% of the area is inundated and only the northern access to Fenwick Island is impeded (Map 4.15). This produces a risk score of 2 at the 0.8m level (Table 4.12).

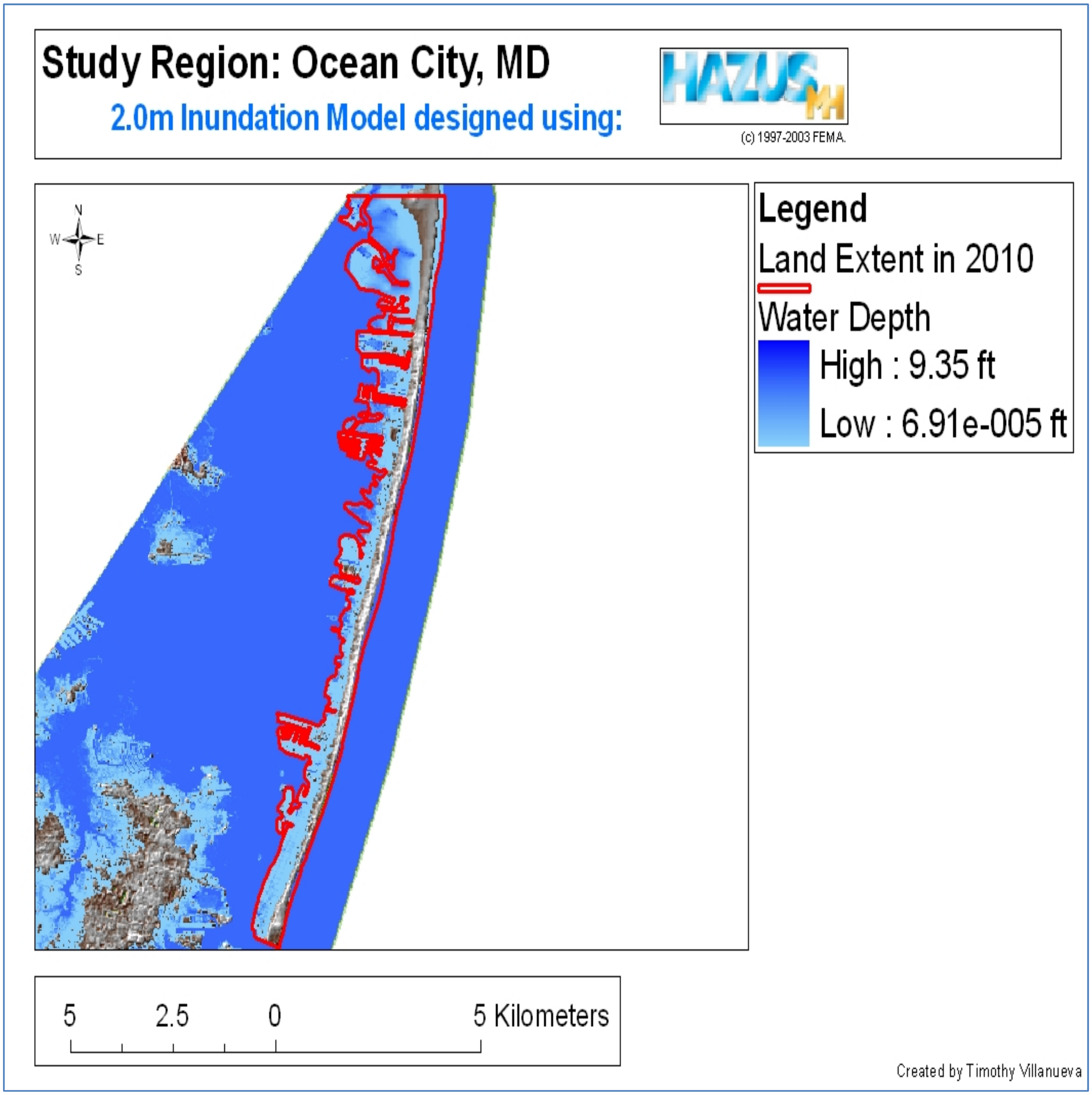
Table 4.12: Ocean City Geographic Risk - Part 3

Criteria for Geographic Risk	Scale	0.8m Rise	2.0m Rise
Percentage of Community area inundated according to the model	10% of area = 1pt, 100% of area = 10pts	2	6.5
Percentage of Population inundated according to the model	10% of population = 1pt, 100% of population = 10pts	2	6.5



Map 4.15: Ocean City at 0.8m Sea Level Rise

In the 2.0m inundation model, almost 65% of the total land area is submerged; most of the inundation occurs along the western bay coast of the island. The Atlantic coast is protected by dunes and higher elevations (Map 4.16). The risk score for the 2.0m model is 6.5 out of a possible 10 points (Table 4.12).



Map 4.16: Ocean City at 2.0m Sea Level Rise

The total risk matrix score for Ocean City at the 0.8m is 54 out of a possible 100 points; this translates to a 0.54 factor in the plan assessment model. The matrix score for the 2.0m simulation is 66 or a 0.66 factor.

Plan Evaluation

Ocean City scores well on the general plan elements evaluation section of the model. The 2006 plan features clearly delineated goals, objectives and strategies. The goals for Ocean City include Land Use; Community Character and Facilities; Economic Development; and, Services, Transportation, Housing, and Environmental Protection. The goals are specific in scope and in keeping with the unique character of the community. An example of this clear goal setting can be seen in the Land Use and Community Character goal:

> **"To foster a legible pattern of land use which accommodates variety in development type and scale appropriate to distinct neighborhoods or districts within the town and which meets the residential, commercial and cultural needs of the community."**

Included among the objectives listed to achieve this goal are the establishment of design guidelines to maintain neighborhood character and environmental regulations to minimize impact on the dunes, bays and ocean. While the public involvement with the planning process was less visible within the plan, one of the visions behind the plan and listed in the plan appendix was that "[c]itizens are active partners in the planning and implementation of community initiatives and are sensitive to their responsibilities in achieving community goals [.]" **For these reasons, Ocean City scores 10 out of 10 in the plan evaluation section (Table 4.13).**

Unlike Chincoteague, the Hazard Identification Assessment for Ocean City was also very strong. The plan identifies run-off and drainage issues within the city. It acknowledges risks posed by coastal flooding and identifies both climate change and sea level rise as potential hazards.

Table 4.13: Ocean City General Plan Evaluation

General Plan Assessment	Nominal Points	Affected by Risk Factor	Ocean City Nominal Score	0.8m Model with Risk Factor 0.54	2.0m Model with Risk Factor 0.66
Plan delineates goals, objectives, and implementation strategies	1	N	1	1.00	1.00
Goals call for specific actions	1	N	1	1.00	1.00
Goals are condition-specific to community	2	N	2	2.00	2.00
Plans show public kept informed of process	1	N	1	1.00	1.00
Plans show public involvement in approval process	2	N	2	2.00	2.00
Plans show public involvement in information gathering and plan creation process	3	N	3	3.00	3.00
Total section points	**10**			**10.00**	**10.00**

While the plan does not call for LiDAR or other scanning methods to confirm the island elevation, the planning site links to a database holding certified elevation records for all properties in Ocean City (Ocean City Government Website 2010). Because these elements are dependent on the risk factor, the plan was scored at both the 0.8m and 2.0m levels. **Out of a possible 46 points, Ocean City Plan received a total of 34.88 points at the 0.8m level and 38.18 points at the 2.0m level (Table 4.14).**

Table 4.14: Ocean City Hazard Identification Evaluation

Hazard Identification Criteria	Nominal Points	Affected by Risk Factor	Ocean City Nominal Score	0.8m Model with Risk Factor 0.54	2.0m Model with Risk Factor 0.66
Plan identifies run-off/drainage issues	1	Y	1	1.00	1.66

Plan identifies threats from storm surges	1	Y	1	1.54	1.66
Plan identifies threats from coastal flooding	3	Y	3	4.62	4.98
Plan identifies threats from climate change	3	Y	3	4.62	4.98
Plan identifies threats from sea level rise	5	Y	5	7.70	8.30
Conduct a LiDAR survey of coastal areas to accurately map elevations and redraw floodplain maps as needed.	5	Y	5	7.70	8.30
Conduct an inventory of threatened properties to rezone, purchase or condemn as necessary.	5	Y	5	7.70	8.30
Total section points	**46**			**34.88**	**38.18**

In the land use evaluation section, the Ocean City plan score is bolstered by Maryland state law. The Code of Maryland Regulations, Title: 27 Subtitle: 01 Chapter: 09 Regulation: 01 requires localities to create a 100 ft new development buffer starting from "[t]he mean high water line of tidal waters." This regulation has the effect of "rolling" the buffer as the high water moves (COMAR 1992) . In the case of sea level rise, this buffer could move significantly, depending on the topography of the area. The Ocean City plan further addresses floodplain zoning by having regulations in place which improve the FEMA flood insurance rating for the community. It specifies the need for set asides for drainage and run-off control and new construction design and setback requirements. The plan also calls for new infrastructure guidelines to accommodate threats from flooding and storm surges. The Ocean City satisfies all but one of the land use criteria. As the criteria in this section are risk dependent, the plan was scored twice. **Out of a possible 32 points, Ocean City scores 20.02 points at the 0.8m risk level and 21.58 points at the 2.0m level (Table 4.15).**

Table 4.15: Ocean City Land Use Component Evaluation

Land Use Solutions for Plan	Nominal Points	Affected by Risk Factor	Ocean City Nominal Score	0.8m Model with Risk Factor 0.54	2.0m Model with Risk Factor 0.66
Establishment of a "rolling easement." The right of the jurisdiction to take public ownership of property that 'rolls' inland with the coastline as sea-level rises.	6	Y	6	9.24	9.96
Update and implement shoreland and floodplain zoning regulations to ensure that existing municipal and new private development are designed and sited to mitigate the effects of flooding and inundation.	2	Y	2	3.08	3.32
Use of new setback guidelines and transfer of development rights to encourage development in areas outside the floodplain.	2	Y	2	3.08	3.32
Require physical access to and infrastructure for coastal regions to be sited, designed and managed to minimized potential impacts from sea level rise.	3	Y	0	0.00	0.00
Design requirement for bridges and other major facilities to accommodate expected sea level rise.	3	Y	3	4.62	4.98
Total section points	**32**			**20.02**	**21.58**

The barrier components to mitigate flooding/inundation are the final section of the Ocean City plan evaluation. The Ocean City plan calls for a beach nourishment program. Additionally, though the island is 95% built out, there is a provision in the plan for the conservation and enhancement of the remaining wetlands and natural areas. The plan also calls for the city public works department to maintain the sea wall and other flood mitigation infrastructure; there are no provisions for structural review to prevent overtopping, however. For this reason, the plan only scores one out of two possible points for barrier identification and assessment. **In the final section of the plan evaluation, Ocean City scores 7.08 out of 12 possible points at the 0.8m risk level and 7.32 points at the 2.0m risk level (Table 4.16).**

Table 4.16: Ocean City Barrier Component Evaluation

Barrier Solutions for Plan	Nominal Points	Affected by Risk Factor	Ocean City Nominal Score	0.8m Model with Risk Factor 0.54	2.0m Model with Risk Factor 0.66
Require a program of beach nourishment	2 pts	Y	2	0.92	0.68
Require a program of wetlands enhancement	2 pts	Y	2	3.08	3.32
Identify existing dikes at risk for overtopping at newly projected flood levels, plan for the refortification of these barriers.	2 pts	Y	1	1.54	1.66
Require drainage projects to use larger gauge pipes to accommodate future sea level rise.	2 pts	Y	2	3.08	3.32
Total section points	**12**			**8.62**	**8.98**

After tallying the results from each section, a combined evaluation score is determined for each of the inundation models. **The total scores for the Ocean City 2006 Plan are 73.52 at the 0.8m level and 78.74 at the 2.0m level. The maximum possible scores at the risk levels for Ocean City are 80.22 at the 0.8m level and 85.38 at the 2.0m level. Using the percentage based scoring system developed for this project, Ocean City scores a 92.3% at the 0.8m level and 92.2% at the 2.0m level. The Ocean City plan is awarded a rating of "Excellent."**

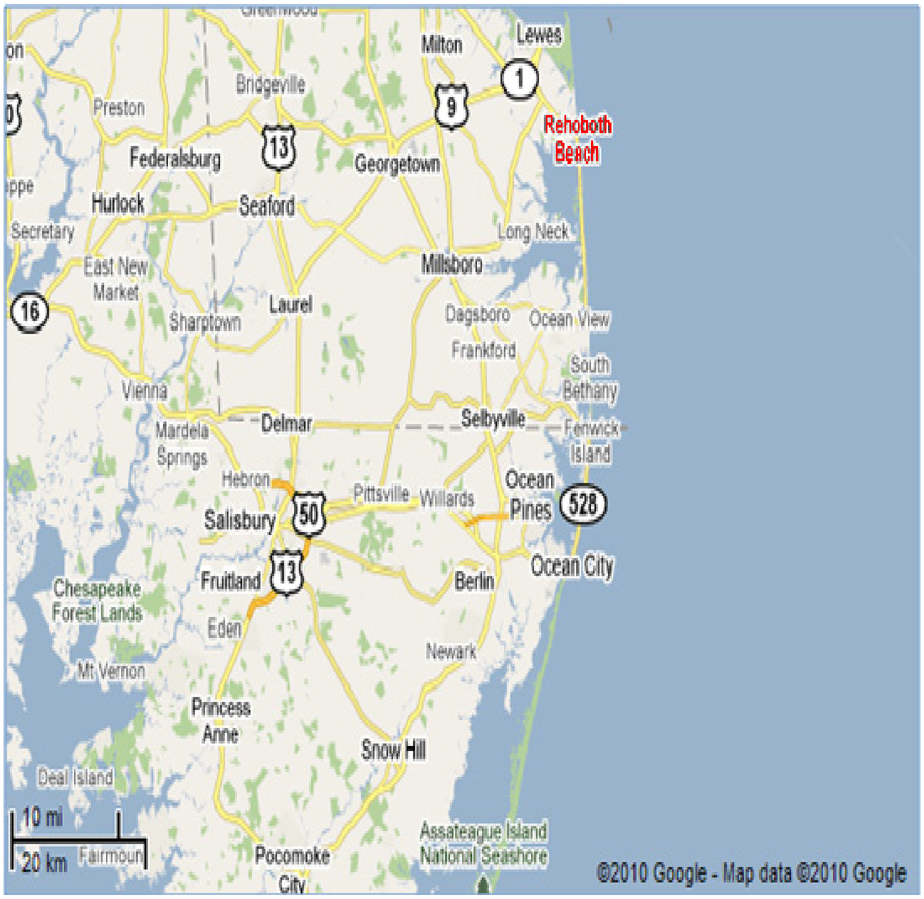
Rehoboth Beach

Rehoboth Beach (38° 43' N, 75° 04' W) is a coastal city located in eastern Sussex County, DE. It is situated on the Atlantic coast, just north of Rehoboth Bay (Map 4.17). Rehoboth Beach is bordered to the north and south by two state parks. Delaware Seashore State Park lies to the south, while Cape Henlopen State Park and the Gordon Pond Wildlife Area are just to the north. While not actually a barrier island, Rehoboth Beach is separated from the mainland by the Lewes-Rehoboth Canal connecting Delaware Bay in the north to Rehoboth Bay in the south. This man-made canal exposes western Rehoboth Beach to the effects of sea level rise.

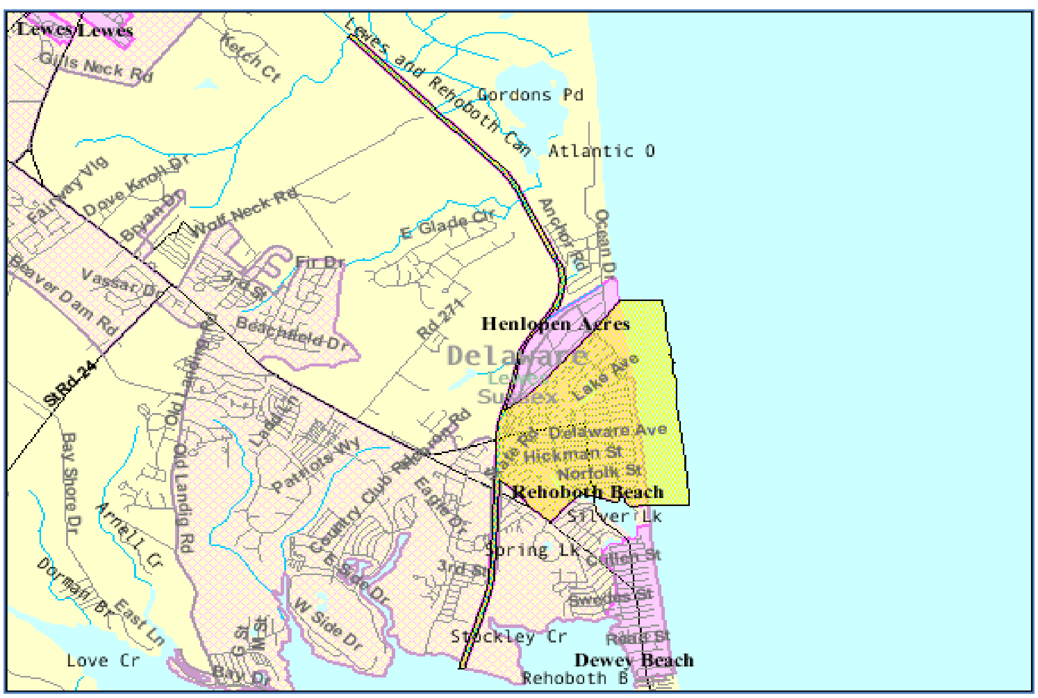
Rehoboth Beach has a year-round population of 1,488 (Census 2000). Rehoboth Beach is another resort community with an economy based on tourism (Rehoboth Beach Plan 2010). Rehoboth Beach, the smallest of the study areas in both population and physical size (Map 4.18), has a land area of only 1.18 sq. miles (Census 2000).

Rehoboth Beach Community Background

Rehoboth Beach began as a Methodist religious camp and resort in 1872. Prior to that, it had been farmland. The site became more and more popular, leading to a secularization of the camp and the establishment of a rail station. The area was incorporated in 1891.



Map 4.17: Rehoboth Beach Location **Source: Google 2010**



Map 4.18: Rehoboth Beach Boundary **Source: USGS 1991**

In the early 20th Century, the construction of the Lewes-Rehoboth Canal brought more visitors and trade to the area. While the area remains a popular resort community to this day, an influx of retirees has dramatically changed the demographic nature of the city (Rehoboth Beach Plan 2010).

Government

The government of Rehoboth Beach is very similar to the the council/manager model. Instead of a town council, Rehoboth Beach has a seven member Board of Commissioners with one member serving as Mayor. The town charter calls for a unique term structure. Members of the commission are elected every year. The two candidates with the highest vote totals receive a three year term, the candidate with the third highest vote total receives a two year term (Rehoboth Beach Charter 1963). A city manager is appointed by the commissioners to run the day to day operations of the town. The commissioners also appoint the nine-member planning commission to 3 year terms. The functions of a planning department fall under the auspices of the Department of Building and Licenses. The most recent comprehensive plan was approved by both the planning commission and the board in April 2010. This is the plan that will be evaluated for this research paper.

Rehoboth Beach Risk Analysis

As before, the risk assessment will look at the demographic risk factor, floodplain and topographic risk before running sea level rise simulations on Rehoboth Beach. The Census 2000 data for Rehoboth Beach showed a year-round population of 1,488. Of that population, an astonishing 37.5% was 65 years of age or older. This is by far the largest elderly population of any of the study areas. Additionally, 18.3% of the population identified themselves on the Census as disabled. The under 5 population of Rehoboth

Beach was only 1.4%. Rehoboth Beach has the lowest poverty rate of any of the study areas with only 5.1% of households living below the federal poverty line. This translates to a risk score of 22 out of 40 possible points (Table 4.17).

Table 4.17: Rehoboth Beach Demographic RIsk

Criteria for Socio-Economic Risk	Scale	Census 2000 Data
Percentage of Households at or below Federal Poverty line	≤ 5% = 1pt, ≤ 7.5% = 2pts, ≤ 10% = 3pts, ≤ 12.5% = 4pts, ≤ 15% = 5pts, ≤ 17.5% = 6pts, ≤ 20% = 7pts, ≤ 22.5% = 8pts, ≤ 25% = 9pts, > 25% = 10pts	2
Percentage of Population Disabled	≤ 5% = 1pt, ≤ 7.5% = 2pts, ≤ 10% = 3pts, ≤ 12.5% = 4pts, ≤ 15% = 5pts, ≤ 17.5% = 6pts, ≤ 20% = 7pts, ≤ 22.5% = 8pts, ≤ 25% = 9pts, > 25% = 10pts	7
Percentage of Population under 5 years of age	≤ 5% = 1pt, ≤ 7.5% = 2pts, ≤ 10% = 3pts, ≤ 12.5% = 4pts, ≤ 15% = 5pts, ≤ 17.5% = 6pts, ≤ 20% = 7pts, ≤ 22.5% = 8pts, ≤ 25% = 9pts, > 25% = 10pts	1
Percentage of Population over 65 years of age	≤ 5% = 1pt, ≤ 7.5% = 2pts, ≤ 10% = 3pts, ≤ 12.5% = 4pts, ≤ 15% = 5pts, ≤ 17.5% = 6pts, ≤ 20% = 7pts, ≤ 22.5% = 8pts, ≤ 25% = 9pts, > 25% = 10pts	10

Rehoboth Beach has a much smaller flood risk than either of the barrier islands. The FEMA flood insurance rate map for Rehoboth Beach shows that only 20% of the community lies within the 100 year floodplain (Map 4.19). These results produce a risk score of 4 out of 20 (Table 4.18).

Table 4.18: Rehoboth Beach Geographic Risk – Part 1

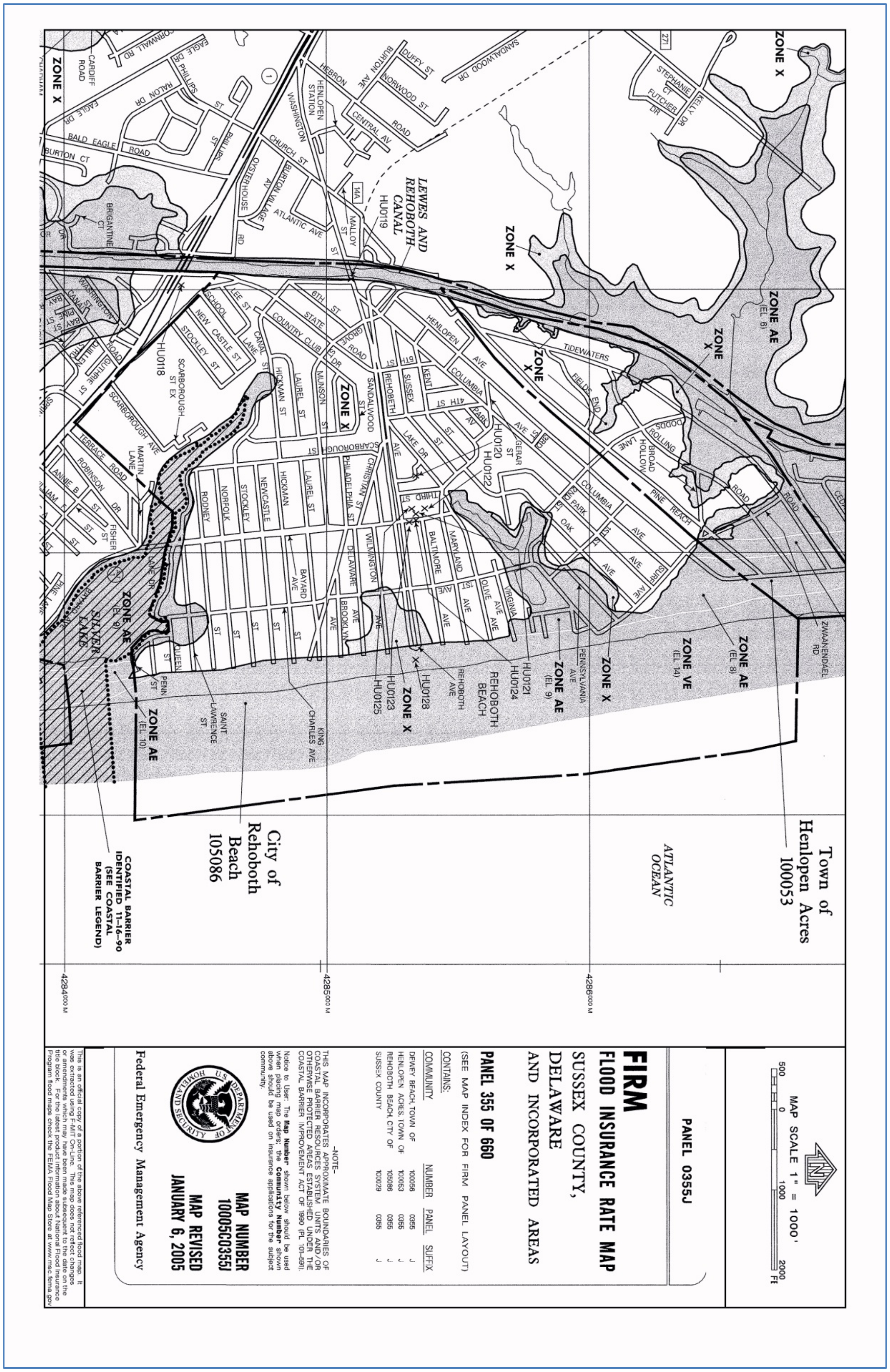
Criteria for Geographic Risk	Scale	Rehoboth Beach
Percentage of Community area within 100 year floodplain	10% of area = 1pt, 100% of area = 10pts	2
Percentage of Population within 100 year floodplain	10% of population = 1pt, 100% of population = 10pts	2

The topographic risk to Rehoboth Beach is also much less than either Chincoteague or Ocean City. The average elevation of Ocean City, based on USGS maps, is 4.5m (Map 4.20). According to those same topographic maps, the highest point in Rehoboth Beach is 11m. **At the 0.8m projected rise, the elevation/projected rise differential is 3.7m. This results in a risk score of 3 out of 10. At the 2.0m projection the differential is 2.5m, earning Rehoboth Beach a risk score of 5 (Table 4.19).**

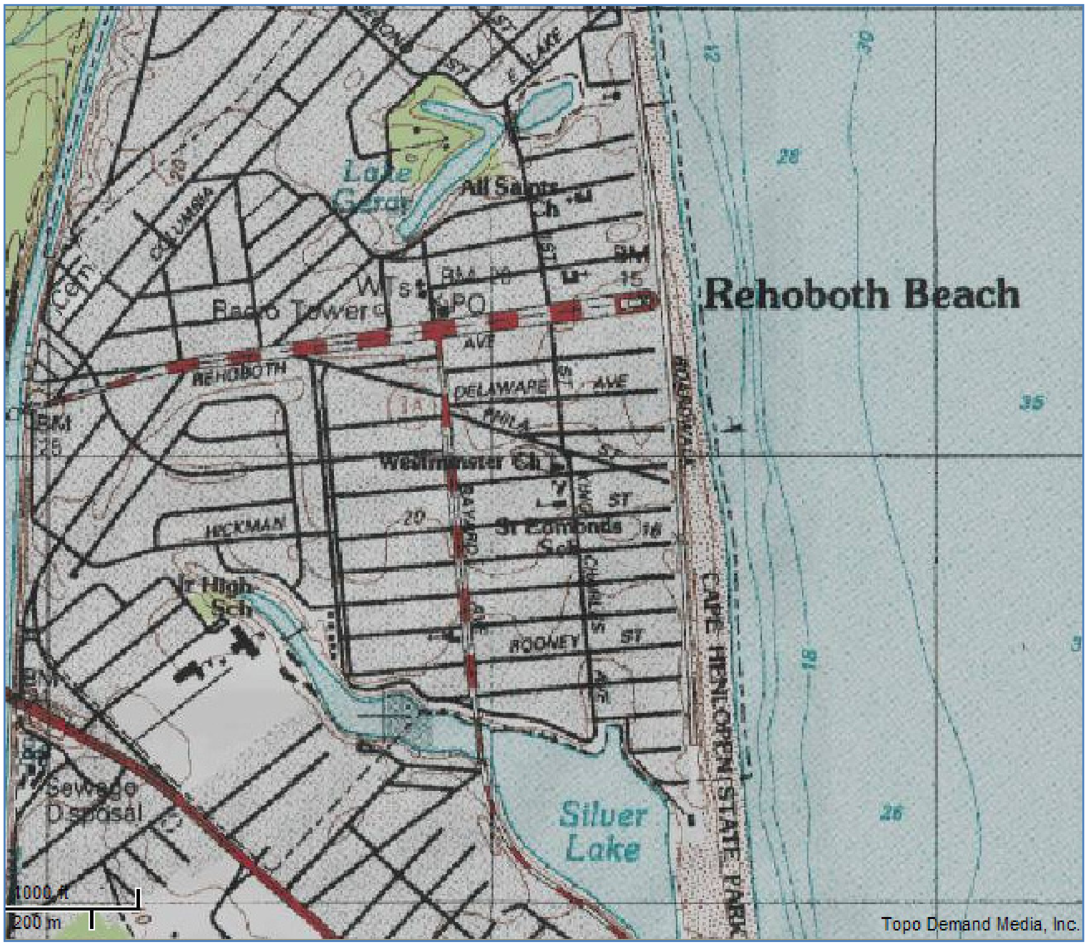
While Rehoboth Beach is part of the mainland, the Lewes-Rehoboth Canal limits access to the area. Only four canal bridges give Rehoboth Beach access to the rest of the mainland, increasing the access road risk factor to 7 out of 10 (Table 4.19).

Table 4.19: Rehoboth Beach Geographic Risk – Part 2

Criteria for Geographic Risk	Scale	0.8m Rise	2.0m Rise
Number of access roads to mainland	≥ 10 access roads = 1pt, 9 access roads = 2pts, 8 access roads = 3pts, 7 access roads = 4pts , 6 access roads = 5pts, 5 access roads = 6pts, 4 access roads = 7pts, 3 access roads = 8pts, 2 access roads = 9pts, 1 access road = 10 pts	7	7
(Average Elevation) - (Inundation Model Height)	≥ 5 meters = 1pt, 4 - 4.99m = 2pts, 3.5 - 3.99m = 3pts, 3 – 3.49m = 4pts, 2.5 - 2.99m = 5pts, 2 – 2.49m = 6pts, 1.5 – 1.99m = 7pts, 1 – 1.49m = 8pts, 0.5 - .99m = 9pts, ≤ .49m = 10 pts	3	5



Map 4.19: Rehoboth Beach Floodplain Map **Source: FEMA 2005**

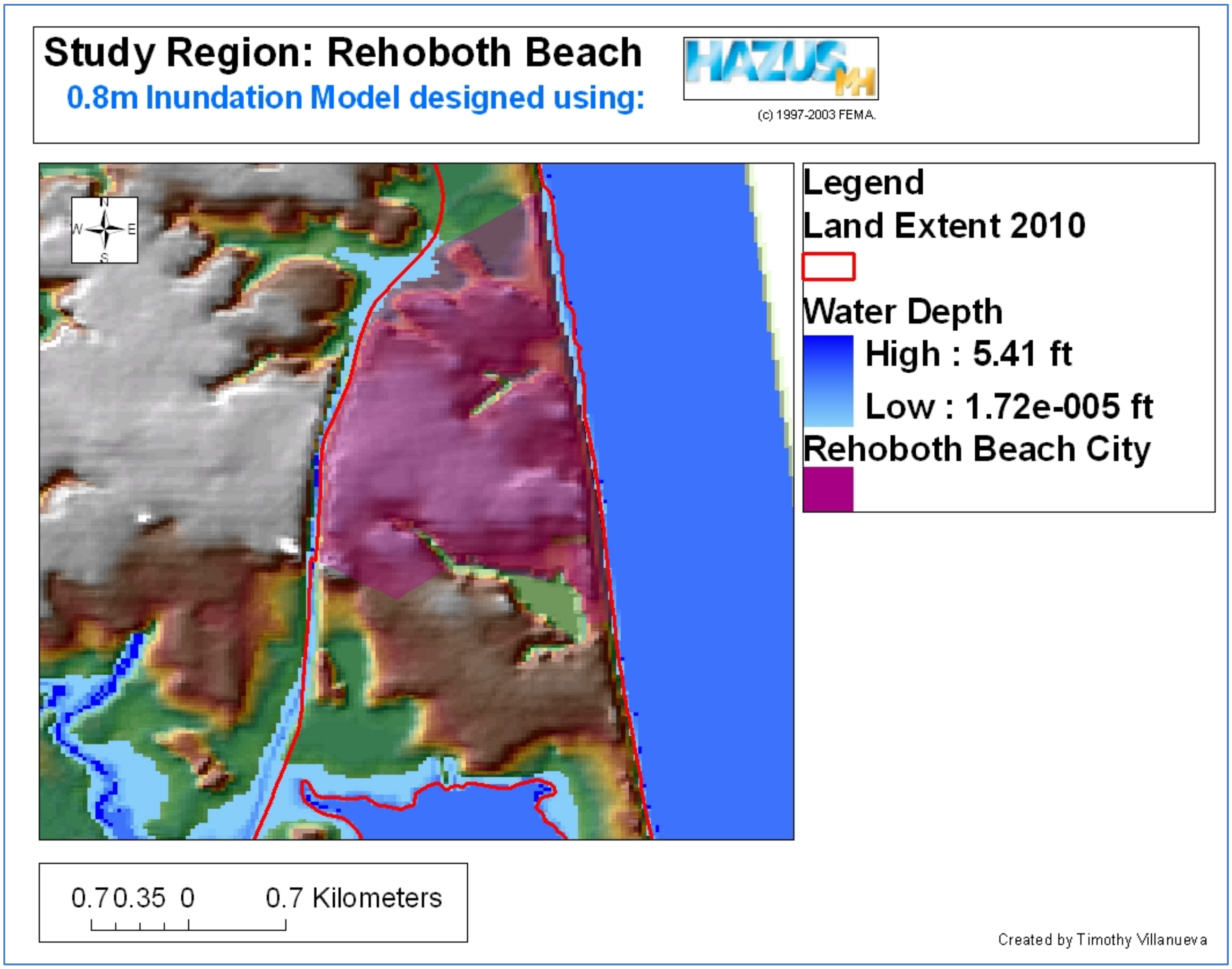


Map 4.20: Rehoboth Beach Topographic Map **Source: USGS 1991**

In the final section of the Rehoboth Beach risk assessment, I will be using the HAZUS coastal flooding simulator to display the impact of the 0.8m and 2.0m models. At the 0.8m level, less than 5% of the area is inundated; flooding is mainly along the canal (Map 4.21). This produces a risk score of 0.5 at the 0.8m level (Table 4.20).

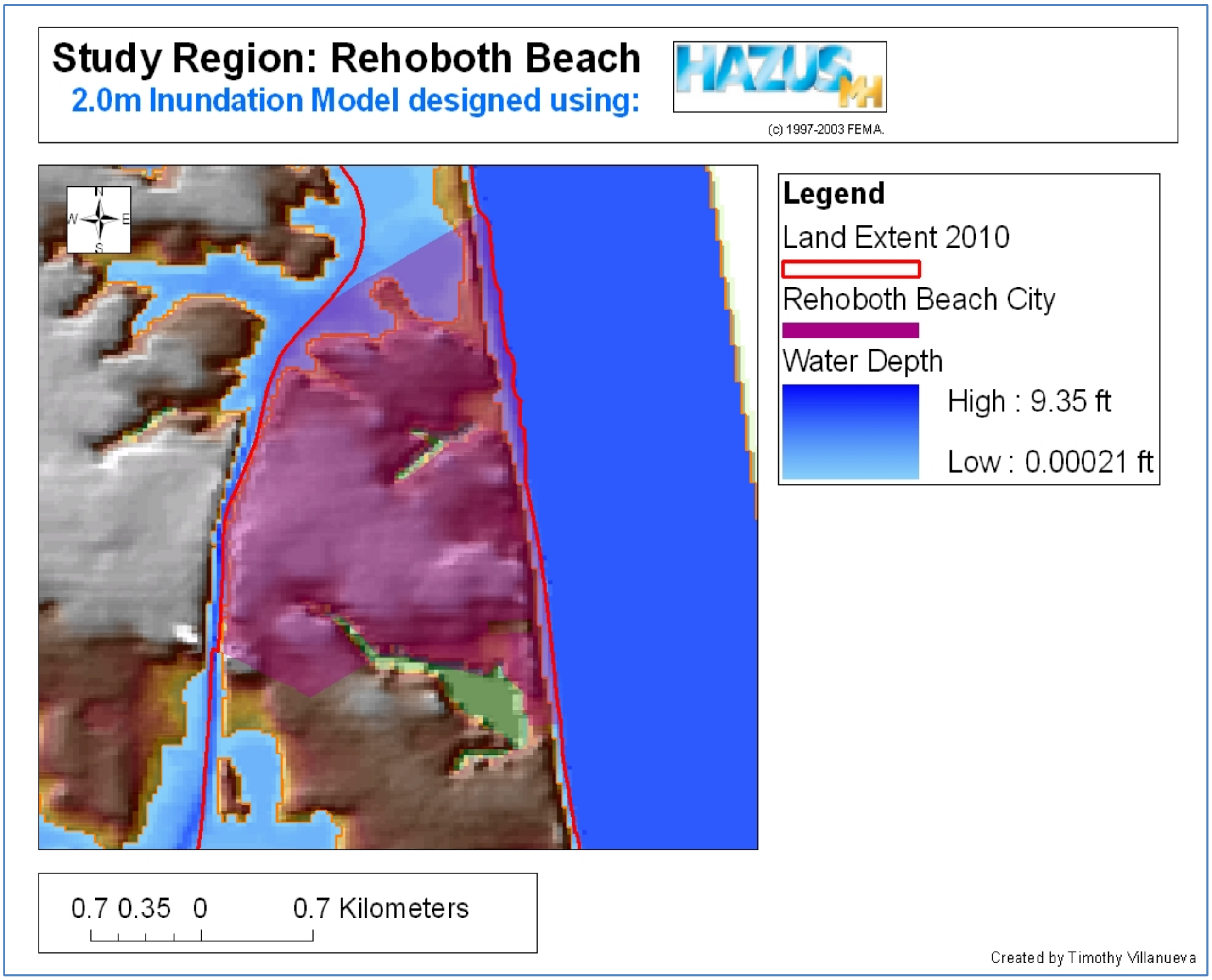
Table 4.20: Rehoboth Beach Geographic Risk – Part

Criteria for Geographic Risk	Scale	0.8m Rise	2.0m Rise
Percentage of Community area inundated according to the model	10% of area = 1pt, 100% of area = 10pts	**0.5**	**1.5**
Percentage of Population inundated according to the model	10% of population = 1pt, 100% of population = 10pts	**0.5**	**1.5**



Map 4.21: Rehoboth Beach at 0.8m Sea Level Rise

In the 2.0m inundation model, approximately 15% of the total land area in Rehoboth Beach is submerged; most of the inundation occurs along the Atlantic coast and the northern banks of the canal. The flooding shown on the map to the north and south of Rehoboth Beach primarily affects Cape Henlopen State Park and the town of Dewey Beach (Map 4.22). The risk score to Rehoboth Beach in the 2.0m inundation model is 1.5 out of a possible 10 points (Table 4.20). The total risk score for Rehoboth Beach is significantly lower than the other study areas. For the 0.8m sea level rise model, Rehoboth Beach has a risk factor of only 0.35. For the 2.0m model, the risk factor rises only to 0.39.



Map 4.22: Rehoboth Beach at 2.0m Sea Level Rise

Plan Evaluation

As was true of the other plans evaluated here, the general plan elements for Rehoboth Beach score well. The goals, objectives and strategies of the 2010 plan are clear, well defined, and tailored to the community. The Rehoboth Beach plan orders its goals differently, however, with environmental and quality of life issues taking precedence over economic development. This seems to be the result of intense citizen participation in the vision, goal setting, and approval phases of the planning. Throughout the introduction, the plan acknowledges and commends the contributions to the plan from residents, both full and part-time.

This participation led to very community-specific goals and strategies. For example, the very first set of goals seeks to protect and enhance the beaches, bays, ocean and viewsheds. These goals include:

- **Maintain physical and visual access to the ocean and other waterbodies**
- **Control the scale and use of structures along the ocean and other waterbodies**
- **Protect the natural functioning of ocean, bay, lake, and canal ecology**

The Rehoboth Plan also includes very specific strategies to achieve these goals. One of the strategies designed to achieve the visual access to the ocean goal calls for changes to the zoning ordinance to "explicitly prohibit any new building from being constructed or an existing structure renovated that would unreasonably interfere with sunlight reaching the beach." **For this work, the Rehoboth Beach plan earns all 10 points in the general plan evaluation (Table 4.20).**

Table 4.20: Rehoboth Beach General Plan Evaluation

General Plan Assessment	Nominal Points	Affected by Risk Factor	Rehoboth Beach Nominal Score	0.8m Model with Risk Factor 0.35	2.0m Model with Risk Factor 0.39
Plan delineates goals, objectives, and implementation strategies	1	N	1	1.00	1.00
Goals call for specific actions	1	N	1	1.00	1.00
Goals are condition-specific to community	2	N	2	2.00	2.00
Plans show public kept informed of process	1	N	1	1.00	1.00

Plans show public involvement in approval process	2	N	2	2.00	2.00
Plans show public involvement in information gathering and plan creation process	3	N	3	3.00	3.00
Total section points	**10**			**10.00**	**10.00**

The Hazard Identification Assessment for Rehoboth Beach did not score as well. The plan identified the risks and consequences from stormwater run-off and briefly mentioned the need for stronger building codes to minimize the effects of flooding. However, there was no mention of the threats posed by storm surges, climate change or sea level rise. Neither did the plan call for elevation studies or address efforts to determine property risk in the event of flooding or sea level rise.

These elements are dependent on the risk factor and the plan was scored at both the 0.8m and 2.0m levels. **Out of a possible 46 points, Rehoboth Beach Plan received a total of 5.4 points at the 0.8m level and 5.56 points at the 2.0m level (Table 4.21).**

Table 4.21: Rehoboth Beach Hazard Identification Evaluation

Hazard Identification Criteria	Nominal Points	Affected by Risk Factor	Rehoboth Beach Nominal Score	0.8m Model with Risk Factor 0.35	2.0m Model with Risk Factor 0.39
Plan identifies run-off/drainage issues	1	Y	1	1.35	1.39
Plan identifies threats from storm surges	1	Y	0	0.00	0.00
Plan identifies threats from coastal flooding	3	Y	3	4.05	4.17
Plan identifies threats from climate change	3	Y	0	0.00	0.00
Plan identifies threats from sea level rise	5	Y	0	0.00	0.00

Conduct a LiDAR survey of coastal areas to accurately map elevations and redraw floodplain maps as needed.	5	Y	0	0.00	0.00
Conduct an inventory of threatened properties to rezone, purchase or condemn as necessary.	5	Y	0	0.00	0.00
Total section points	**46**			**5.4**	**5.56**

In the land use evaluation section, the Rehoboth Beach plan addresses floodplain zoning with regulations designed to improve the FEMA flood insurance rating for the community. None of the other land use criteria outlined in the evaluation model is found in the Rehoboth Beach plan. **The omission of these items means that out of a possible 32 points, Rehoboth Beach scores 2.7 points at the 0.8m risk level and 2.78 points at the 2.0m level (Table 4.22).**

Table 4.22: Rehoboth Beach Land Use Component Evaluation

Land Use Solutions for Plan	Nominal Points	Affected by Risk Factor	Rehoboth Beach Nominal Score	0.8m Model with Risk Factor 0.35	2.0m Model with Risk Factor 0.39
Establishment of a “rolling easement.” The right of the jurisdiction to take public ownership of property that ‘rolls’ inland with the coastline as sea-level rises.	6	Y	0	0.00	0.00
Update and implement shoreland and floodplain zoning regulations to ensure that existing municipal and new private development are designed and sited to mitigate the effects of flooding and inundation.	2	Y	2	2.70	2.78

Use of new setback guidelines and transfer of development rights to encourage development in areas outside the floodplain.	2	Y	0	0.00	0.00
Require physical access to and infrastructure for coastal regions to be sited, designed, and managed to minimize potential impacts from sea level rise.	3	Y	0	0.00	0.00
Design requirement for bridges and other major facilities to accommodate expected sea level rise.	3	Y	0	0.00	0.00
Total section points	**32**			**2.70**	**2.78**

Finally, the barrier component to mitigate flooding/inundation section of the Rehoboth Beach plan scores well in the evaluation model. The plan calls for a beach nourishment program. Additionally, there are sections of the plan dealing with wetlands protection and support involving protection and stabilization of the sand dunes that serve as a natural levee against flooding. Because these are natural levees, there is no review for overtopping, so Rehoboth Beach only receives half credit for this goal. **In the final section of the plan evaluation, the Rehoboth Beach plan is awarded 7.08 out of 12 possible points at the 0.8m risk level and 7.32 points at the 2.0m risk level (Table 4.23).**

Table 4.23: Rehoboth Beach Barrier Component Evaluation

Barrier Solutions for Plan	**Nominal Points**	**Affected by Risk Factor**	**Rehoboth Beach Nominal Score**	**0.8m Model with Risk Factor 0.35**	**2.0m Model with Risk Factor 0.39**
Require a program of beach nourishment	2 pts	Y	2	1.30	1.22
Require a program of wetlands enhancement	2 pts	Y	2	2.70	2.78

Identify existing dikes at risk for overtopping at newly projected flood levels, plan for the refortification of these barriers.	2 pts	**Y**	**1**	**1.35**	**1.39**
Require drainage projects to use larger gauge pipes to accommodate future sea level rise.	2 pts	**Y**	**0**	**0.00**	**0.00**
Total section points	**12**			**5.35**	**5.39**

The results from each section combine for an evaluation score for each of the inundation models. The Rehoboth Beach plan had the lowest score of the three plans; this is somewhat mitigated by the fact that it also had the lowest risk factor. **The total scores for the Rehoboth Beach 2010 Plan are 23.45 at the 0.8m level and 23.73 at the 2.0m level. The maximum possible scores at the risk levels for Ocean City are 72.05 at the 0.8m level and 73.77 at the 2.0m level. Using the percentage based scoring system developed for this project, Ocean City scores a 32.5% at the 0.8m level and 32.2% at the 2.0m level. Using the scoring system developed for this project, in either inundation model, the Rehoboth Beach plan receives a rating of "Poor."**

Recommendations

In this section, I will take the results from the evaluations and recommend measures the communities could take to improve their scores. In the cases of Chincoteague and Rehoboth Beach, the recommendations will be designed to improve the plans from "Poor" to "Good." In the case of Ocean City, already rated "Excellent," I have little room to suggest improvements. Instead, I recommend that the Ocean City plan serve as a model for other coastal communities facing the threat of sea level rise.

Chincoteague

The current Chincoteague Plan was rated “Poor” in the response to sea level rise. It is therefore recommended that Chincoteague make the following addenda to its plan, especially in light of the catastrophic consequences shown in the 2.0m simulation. First, the Chincoteague plan should acknowledge the potential hazards posed by climate change and sea level rise. Next, the town needs to conduct a LiDAR survey (or other type of elevation survey) to identify the most vulnerable low-lying areas in the community.

Table 4.24: Chincoteague Recommendations

Chincoteague Recommendations	Improve From	Improve To
Acknowledge the potential hazards posed by climate change and sea level rise	Poor	Fair
Conduct Elevation Survey		
Add "Rolling Easement"	Fair	Good
Upgrade Drainage		
Inventory Property	Good	Excellent
Rezone, Condemn High Risk Property		

By following these recommendations, the plan evaluation would rise to “Fair” at both thresholds. To improve the evaluation score to “Good,” Chincoteague should follow the State of Maryland’s lead and create a “rolling easement” continuous development buffer zone along the coasts. Also, Chincoteague needs to abandon the current “open ditch” drainage system and convert to an underground, enclosed stormwater system with sufficient capacity to mitigate the effects of flooding. Adding these components would elevate the plan evaluation score from “Fair” to “Good.” To move the plan into the “Excellent” range, Chincoteague could undertake an inventory of property most endangered by sea level rise and begin a program of rezoning and/or condemnation to limit the exposure to danger.

Rehoboth Beach

Like the Chincoteague Plan, the Rehoboth Beach Plan is missing many of the components necessary to minimize the threats posed by sea level rise. Like Chincoteague, Rehoboth Beach needs a plan that acknowledges the threats from climate change and sea level rise and calls for an elevation study to move from "Poor" toward a rating of "Fair." Those changes are not enough to protect the community. For the Rehoboth Beach Plan to earn a rating of "Fair," it also needs to recognize and address the threat posed by storm surges.

Table 4.24: Rehoboth Beach Recommendations

Rehoboth Beach Recommendations	Improve	
	From	To
Acknowledge the potential hazards posed by storm surges, climate change and sea level rise	Poor	Fair
Conduct Elevation Survey		
Add "Rolling Easement"	Fair	Good
Upgrade Drainage		
Inventory Property	Good	Excellent
Rezone, Condemen High Risk Property		

Increasing the plan score to "Good" would require the addition of regulations to allow the type of rolling easement required under Maryland state law. To be rated as an "Excellent" plan, Rehoboth Beach would need to undertake a property inventory similar to the one proposed for Chincoteague as well as use zoning and incentives to discourage development on the area's floodplain.

Should sea level rise follow either model projection, Rehoboth Beach's situation is much safer than either Chincoteague or Ocean City. By being part of the mainland and being situated at a higher elevation, Rehoboth Beach is less exposed. This could account for the plan's lack of components relating to floods, storms or sea level rise.

Conclusion

The threat to coastal communities from sea level rise is severe. Action is needed at the local, state and federal level to minimize the impact of sea level rise to lives and property. In local community planning, steps can be taken to assess, mitigate and adapt to the impacts of sea level rise. This thesis was designed to create a measure for assessing the degree to which coastal communities were preparing for sea level rise while accounting for each community's unique demographic, topographic and geographic situation and risks. Future planners could then apply this model to identify areas for policy improvement and innovation.

Building on standard plan evaluation criteria, risk assessment, and hazard management approaches, I created a new model to measure community response to sea level rise. This new model used components with both a fixed value and a value dependent on the risk facing the community.

The results of running the simulations, measuring the risk, and evaluating the plans were somewhat surprising. While there was some standardization across the communities when it came to plan structure, there was little uniformity in the components dealing with hazards of any kind. All three plans dealt with run-off/drainage issues and the threat of flooding. Unfortunately, beyond that, two of the plans had little else in the way of hazard management.

Rehoboth Beach, the smallest of the communities, faces the least danger from sea level rise. However, Rehoboth Beach also has the worst plan for dealing with hazards. Rehoboth Beach, despite its coastal location, even lacked provisions managing the threats from hurricanes and storm surges. On the other extreme, Ocean City, which has a significant risk exposure to sea level rise, has the best plan for dealing with those risks.

The most significant revelation of this thesis comes from Chincoteague. This community faces the most catastrophic risk from sea level rise. While the plan does have provisions for hurricane and storm surge issues, the lack of any acknowledgement of the threat of sea level rise makes it a very "Poor" plan. Chincoteague's situation is even more surprising given the fact that the city is surrounded by two federal properties that are openly preparing contingency plans for the dangers of sea level rise.

All of this provides planners with tools and a sense of urgency for addressing the threats posed by sea level rise. But it also leaves room for further study. With possible abandonment looming in Chincoteague's future, questions are raised that are beyond the scope of this paper. Should planners plan for failure? Plans are designed to achieve a future vision for a community. What happens when this vision is dire?

Future Policy Implications

In the previous sections, the Ocean City plan and the Maryland rolling buffer regulations were held up as models for other coastal communities to successfully prepare for sea level rise, but that assessment may have been too optimistic. The models show that at the 2.0m level Chincoteague is a total loss, Ocean City is 65% submerged and even Rehoboth Beach, on the mainland, has significant damage. The threat of sea level rise exceeds a local community's ability to manage it.

Further, even the elements of Ocean City's plan may be impossible for other communities to implement due to political realities. For example, on paper, by following the recommendations, Chincoteague could devise a plan rated "Excellent." But, as previously mentioned, Virginia is a Dillon's Rule state. This means that the locality (Chincoteague) has no authority not explicitly granted it by the Virginia General Assembly. Chincoteague would need prior authorization from the state to establish the rolling buffer or regulate building codes and design requirements to account for sea level rise. Given the political climate alluded to by Delegate Bouchard of Virginia Beach, such authorization is unlikely (Bouchard 2009). These types of regulations may need to come from the federal level to become reality and to promote standardization.

Even with federal involvement, Chincoteague's situation may still become untenable. The 2.0m inundation model shows Chincoteague Island completely submerged. At that level of destruction, there are very few options and none that are inexpensive or environmentally sensitive. The proximity of the Wildlife Refuge and the corresponding sensitive areas/wetlands protection regulations, together with the specter of New Orleans following Hurricane Katrina, and the massive capital funding needed to create a system of dikes and levees, likely constitute insurmountable obstacles to such an option. Evacuation and resettlement may be the only feasible option. The Assateague Island Wildlife Refuge is already exploring relocation sites in Maryland and Delaware in the event of sea level rise in excess of 1.5m. Although Chincoteague's wild ponies reside on

Assateague Island, they are not considered an indigenous species and have been excluded from current federal relocation planning (Hinds 2009).

To lessen the emotional and economic impacts of evacuation in Chincoteague and elsewhere for as long as possible, radical new intervention techniques will be needed for the future. Because of the size of many coastal communities, most of these will require state or federal action.

These intervention techniques for dealing with relocation issues can be either active or passive. Active intervention methods would use the power of eminent domain to condemn unsafe property. After condemnation, the government could follow one of two paths. First, the government could simply evict homeowners using the state's police powers. This would likely cause conflict and be viewed negatively. A second, gentler approach would use the power of eminent domain to take ownership of all the property, but then lease it back to the community with diminishing lease tenures. Finally, the government could institute a land swap program to ensure that residents have a place to go.

Passive intervention would be to update FEMA's flood insurance rate maps to include projections for the impacts of sea level rise, while eliminating subsidies for coastal flood insurance. Then the government could simply allow collapsing property values and increasing insurance rates to make the at-risk areas an unaffordable option.

These new tools may be radical, and likely require federal intervention to be implemented, but the benefits would reach far beyond just Chincoteague. Even Ocean City, with its "Excellent" plan loses 65% of its land area in the 2.0m model. Without some sort of program beyond the state and local level, the effects of sea level rise on the coastal communities will be catastrophic.

Caveats and Future Research

Both the Risk Assessment Matrix and the Plan Evaluation Criteria were created for this paper. While the results are consistent with expectations, the models are open to the criticism that they are subjective. This criticism is especially strong in terms of the weighting of individual criteria. In retrospect, the use of Decision Support Software (DSS) with its ability to more granularly adjust the values of individual criteria would have given this research a higher level of sensitivity in assigning individual values. Alternatively, employing a research partner to conduct a blind, independent evaluation of each community's risk and plan would lessen concerns about subjectivity. Unfortunately both of these types of validation exceeded the available resources for the project.

The demographic data used is a decade out of date; unfortunately Census 2010 data was not available in time for this project. More current data could impact a community's risk factor and subsequently the evaluation score. Rerunning the models with the updated data, when it becomes available, would be a worthwhile exercise.

Future research into coastal community plan evaluation could build on the baseline established in this paper and focus on more specific plan process elements. A more focused study could be undertaken on community hazard mitigation efforts, adaptation methods, or a comparison of community planning ability vs. implementation ability. Other suggested research paths, building off this project, include the dynamics of abandoning a community site, the influence of a community's political climate its response to hazards, and the differences in hazard response between communities with tourism based economies and coastal communities with fishing, manufacturing or military based economies.

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