12-2003

Hazardous Beach-System Development in Maine and Some Outcomes of the Sand Dune Rules

Julia M. Knisel

HAZARDOUS BEACH-SYSTEM DEVELOPMENT IN MAINE AND SOME OUTCOMES OF THE SAND DUNE RULES

By

Julia M. Knisel

B.S. The Pennsylvania State University

A THESIS

Submitted in Partial Fulfillment of the

Requirements for the Degree of

Master of Science

(in Marine Policy)

The Graduate School

The University of Maine

December, 2003

Advisory Committee:

Joseph T. Kelley, Professor of Marine Geology, Advisor

Mary Kate Beard-Tisdale, Professor of Spatial Information Science and Engineering

Deirdre Mageean, Professor of Resource Economics and Policy

Daniel F. Belknap, Professor of Geology

HAZARDOUS BEACH-SYSTEM DEVELOPMENT IN MAINE AND SOME OUTCOMES OF THE SAND DUNE RULES

By Julia M. Knisel

Thesis Advisor: Dr. Joseph T. Kelley

An Abstract of the Thesis Presented
in Partial Fulfillment of the Requirements for the
Degree of Master of Science
(in Marine Policy)
December, 2003

Damages to coastal property in southwestern Maine occur primarily as a result of storms, flooding, and erosion. Maine implemented the Sand Dune Rules in 1983 to protect sand dunes and mitigate coastal property damages. Prior to this study, no indicators of the outcome of these rules were identified or evaluated to determine the effectiveness of their implementation. Assessed building values (1987), National Flood Insurance Program claims and payments (1978-1998), and sand dune permits (1984-1998) for development in Kennebunk and Saco, Maine were evaluated. A geographic information system was created to determine if (1) development on or seaward of frontal dunes or in high-velocity flood zones is at greater risk of damages than development in other beach-system areas, and (2) the setback regulations of the Sand Dune Rules have reduced the risk of damages in high-hazard areas. The indicators support the hypotheses of this study as well as the development of updated maps and an improved permit process. Managers should focus on reducing the number of buildings vulnerable to coastal hazards to mitigate the impacts on property, life, and beach systems.

ACKNOWLEDGEMENTS

Many people deserve thanks for their assistance with this thesis. First among them is my advisor Joe Kelley. Joe and Kathleen Leyden, Director of the Maine Coastal Program, funded my research. Of most importance, Joe shared his passion and expertise to prepare me for a career in coastal management. My committee members Kate Beard, Deirdre Mageean, and Dan Belknap also deserve special thanks. State and municipal officials as well as non-government professionals provided valuable data and assistance. They include Steve Dickson, Maine Geological Survey, Lou Sidell, Maine State Planning Office, Shari Goodwin, Maine Department of Environmental Protection Bureau of Land and Water Quality, City of Saco, Town of Wells, Town of Kennebunk, and Clarence Young, Sewall Company. The University of Maine Association of Graduate Students as well as the Alumni Association were generous and granted travel to professional conferences. I am also grateful to the School of Marine Sciences and the Department of Geological Sciences. Finally, I must thank my family and friends especially my parents and Allen Gontz.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1

INTRODUCTION

Purpose

The coastal zone extends from the inland limit of tidal influence to the outer continental shelf, but the influence of people is often focused near the shoreline where beaches are common. The demand for beach amenities is evident in land values that increase toward the shoreline (Yohe 1991). Development in beach systems, however, changes coastal landforms and the flow of sediment to beaches and dunes through the alteration of wind, wave, and sand transport patterns (Bush *et al.* 1996; Nordstrom 2000). Structures exposed to the short term effects of coastal processes (i.e., waves, longshore currents, and storm-induced flooding) and the long term impacts of sea-level rise and shoreline erosion place people and property at risk (Pilkey *et al.* 1989; Bush *et al.* 1996). Coastal zone management (CZM) programs have implemented policies to protect beach systems, including lives and property, from the hazards of development (Bernd-Cohen and Gordon 1999; Heinz Center 2003).

The Coastal Zone Management Act (CZMA), which was passed in 1972, defined broad national policy goals and established the federal CZM program (United States Code Congressional and Administrative News 1972; Beatley *et al.* 2002; Heinz Center 2003). As a result, the Office of Ocean and Coastal Resource Management, within the National Oceanic and Atmospheric Administration (NOAA) provides funds and technical assistance to state CZM programs (Beatley *et al.* 2002). These programs have defined goals and implemented policies to protect beach systems. Studies have supported the relevancy of these policies, but information about policy outcomes, or performance indicators, must be identified and evaluated to determine the effectiveness of the federal and state CZM programs (Hershman *et al.* 1999; Bernd-Cohen and Gordon 1999; Heinz Center 2003).

Bernd-Cohen and Gordon (1999) focused their critical evaluation of beach-system policies on ten indicators of effectiveness. Six regulatory tools, one planning measure, and three land management and acquisition provisions were studied (Bernd-Cohen and Gordon 1999). The regulatory tools included (1) setbacks, (2) construction control areas, (3) shoreline stabilization regulations, (4) permit tracking and enforcement provisions, (5) access restrictions, and (6) habitat protection.

1. *Setbacks* require that new development and redevelopment be positioned a defined distance, usually determined by the rate of shoreline erosion, landward of a critical feature.

2. *Construction control areas* limit the size, type, design, and location of permitted structures to minimize adverse impacts on beach systems. Building additions, repairs, and rebuilding are controlled.

3. *Shoreline stabilization regulations* limit the design and construction of shoreline stabilization such as seawalls and groins. The use of nonstructural alternatives places protection of beaches and dunes as a priority over protection of upland development.

4. *Permit tracking and enforcement provisions* are used to monitor permits and violations.

5. *Access restrictions* protect beach resources from pedestrian and/or vehicular traffic. Requirements for boardwalks or dune crossovers minimize adverse impacts on dunes.

6. *Habitat protection* and other controls over critical beach habitats restrict uses to protect these areas.

The first three regulatory tools often require a permit process (Bernd-Cohen and Gordon 1999). Setbacks, restrictions on the size, design, and location of structures, shoreline stabilization regulations, permit processes, access restrictions, and habitat-protection controls all protect beach systems and reduce the loss of life and property from coastal processes, sea-level rise, and shoreline erosion. Regulations proved to be the most effective tools incorporated into mitigation measures and policies (Bernd-Cohen and Gordon 1999).

Outcomes of policies that employ regulations and other tools to reduce vulnerability to coastal hazards are needed to guide future management decisions. Case studies and long-term monitoring of measurable effects that result from the implementation of policies indicate outcomes (Bernd-Cohen and Gordon 1999). Outcome or performance indicators of coastal-hazards mitigation include:

1. number of permits issued for development in beach systems;
2. number of flood insurance claims submitted by policyholders in beach systems;
3. number of structures relocated to less hazardous locations; and
4. area of beach system in state land management (Bernd-Cohen and Gordon 1999; Heinz Center 2003).

Due to data limitations as well as the expensive and time consuming nature of outcome monitoring, federal and state agencies do not routinely monitor outcomes of policy implementation (Bernd-Cohen and Gordon 1999; Hershman *et al.* 1999).

The Maine Coastal Program, which was instrumental in the development and implementation of the Sand Dune Rules (SDR), however, supported this study to identify and evaluate some outcomes of the SDR. Coastal damages that occurred during the New England Blizzard of 1978 led to the definition of development conditions in beach systems (Kelley *et al.* 1989; Cohen 2002a). Mitigation measures of the SDR were derived from the 1979 amendments to the Alteration of Coastal Wetlands Act of 1975, otherwise know as the Sand Dune Law, which became part of the Natural Resources Protection Act (NRPA) in 1987 (MRSA 1975; MRSA 1987). The Sand Dune Law encourages the protection or enhancement of coastal sand dunes. Activities within coastal sand dunes must not unreasonably:

1. interfere with existing scenic, aesthetic, recreational or navigational uses;
2. cause or increase the flooding of the alteration area or adjacent properties;
3. interfere with the natural supply or movement of sand within or to the sand dune system; or
4. increase the erosion hazard to the sand dune system (MRSA 1987).

The Sand Dune Law, however, did not specify regulations, so Maine implemented the SDR in 1983 to protect sand dunes and reduce coastal property damages often associated with storm-related flooding and erosion (DEP 1983). The SDR currently require new structures, additions, and reconstructed buildings, which were extensively damaged, to be set back behind frontal dunes and outside high-velocity flood or V zones (DEP 1993). The SDR also prohibit new shoreline stabilization and place additional controls on development in beach systems through a permit process enforced by the Maine Department of Environmental Protection (DEP). While amendments to the SDR in 1988 and 1993 broadened and clarified permit requirements, property owners still challenge the SDR to construct additions, buildings, and seawalls on the frontal dunes and beaches of Maine (DEP 1988; DEP 1993; Cohen 2002b). This is the first study to review the performance of the SDR. The purpose of this study is to identify and evaluate (1) high-hazard development in the sand beach systems of Maine and (2) some outcomes that resulted from the development regulations of the SDR.

It is hypothesized that in the sand beach systems of Maine (1) development on or seaward of frontal dunes or in high-hazard flood zones is at greatest risk of damages, and (2) the setback regulations of the SDR have reduced the risk of damages within high-hazard areas. Previous studies assessed beach-system damages using National Flood Insurance Program (NFIP) claims for building losses (Mitchell 1987; Heinz Center 2000; Esnard *et al.* 2001). This study associated NFIP claims for building losses with individual parcels, within a geographic information system (GIS), to estimate damages within beach-system environments with extensive storm-damage potential (Figure 1). DEP permit data for development within these environments was also incorporated into the GIS. Indicators used to evaluate the two hypotheses are listed below. Location refers to beach-system environment as well as the flood zone.

1a. Location of buildings.

1b. Location of NFIP claims and payments for building losses between 1978 and 1998.

2a. Type and location of DEP sand dune permits approved between 1984 and 1998.

2b. Correlation between NFIP claims and DEP sand dune permits.

Significant claims for building losses on or seaward of frontal dunes or in high-hazard flood zones would support the hypothesis that this area is at greatest risk of damages. New and redeveloped buildings as well as additions permitted in accordance with the SDR that experienced an insignificant number of losses would support the hypothesis that the setback regulations of the SDR have reduced the risk of beach-system damages in Maine.

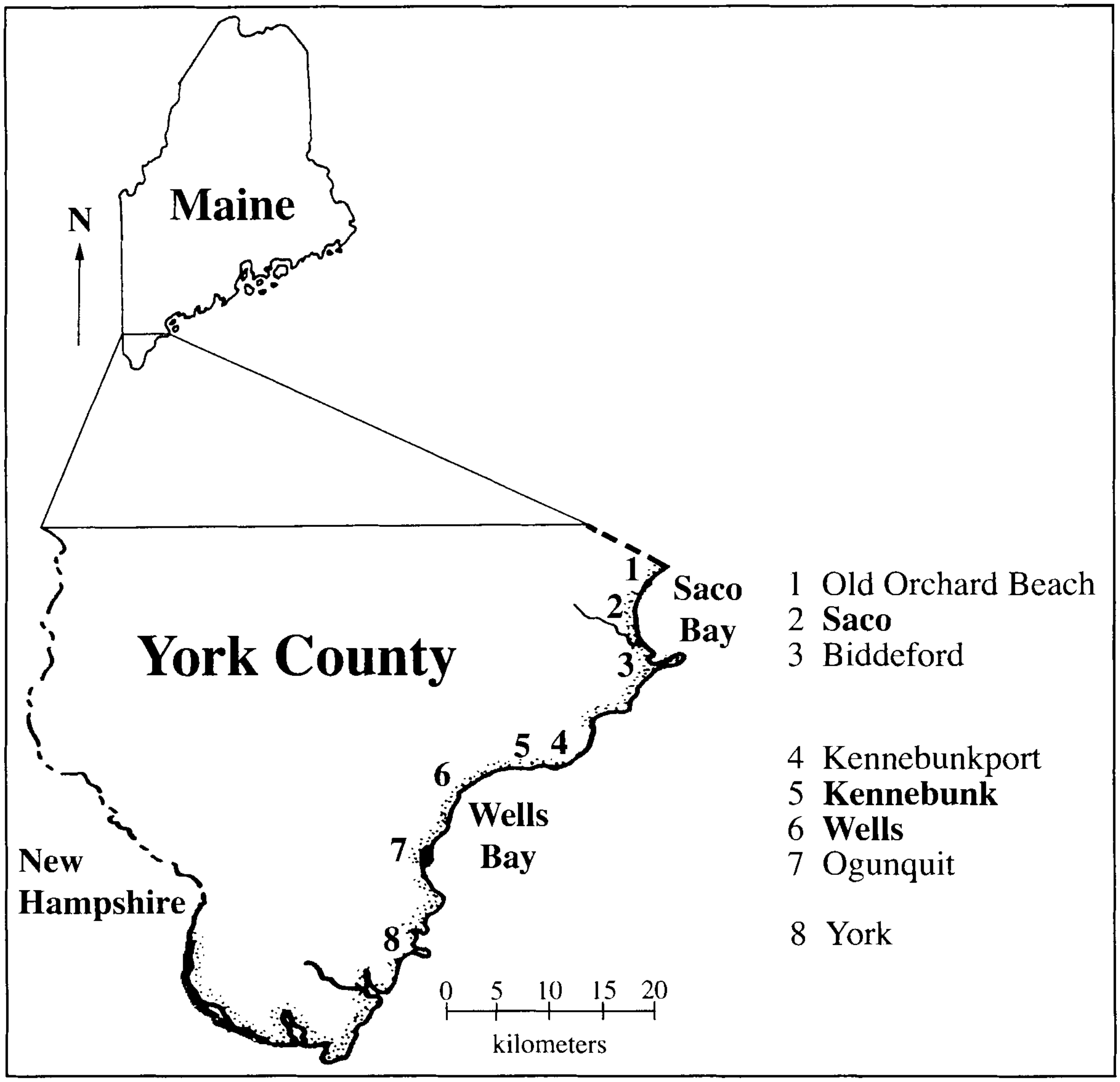


Figure 1. Location of developed beaches in York County, Maine with the potential for extensive storm damage. Beaches in Phippsburg, Hunnewell, and Scarborough also have potential for extensive storm damage, but lie to the north of York County. Categorization was based on beach orientation to northeast storm waves, density of structures, seawalls, sediment size, and sand dune height, volume and cross-sectional area (Barringer and Ten Broeck 1978). Beaches in Saco, Kennebunk, and Wells are included in this study.

Background

Coast of Maine

Maine has one of the longest shorelines in the United States. The United States Army Corps of Engineers (USACE 1971) conducted the first study of the Nation's shoreline and measured 4,023 km for Maine. NOAA (1975) later recorded two different shoreline lengths for Maine. The open ocean shoreline from New Hampshire to New Brunswick extends 370 km across the mouths of bays and sounds, while the tidal shoreline reaches 5,600 km (NOAA 1975). Only Alaska, Florida and Louisiana have longer tidal shorelines. Maine has the highest proportion of private coastal land (97%) among the 20 coastal states (NOAA 1975; Bernd-Cohen and Gordon 1999).

Coastal variability in Maine is primarily controlled by regional changes in the composition, structure, and orientation of bedrock as well as composition and abundance of Quaternary sediments (Kelley 1987). These variations subdivide the coast into four compartments: southwest (SW), south-central (SC), north-central (NC), and northeast (NE) (Figure 2A; Kelley 1987).

1. SW: rocky capes separating arcuate sand beaches that front salt marshes.
2. SC: deep, narrow estuaries among peninsulas.
3. NC: broad, deep estuaries containing numerous granitic islands.
4. NE: nearly straight with high cliffs and few estuaries.

The area of intertidal habitats (587,000 km^2 or 145,069 acres) is not distributed equally between the coastal compartments (Ward 1999). While sand beaches account for only 12,000 km^2 (2,963 acres), or 2% of this area, more than 40% of the sand beaches are located in the SW compartment (Figure 2B; Ward 1999). Sand beaches comprise the

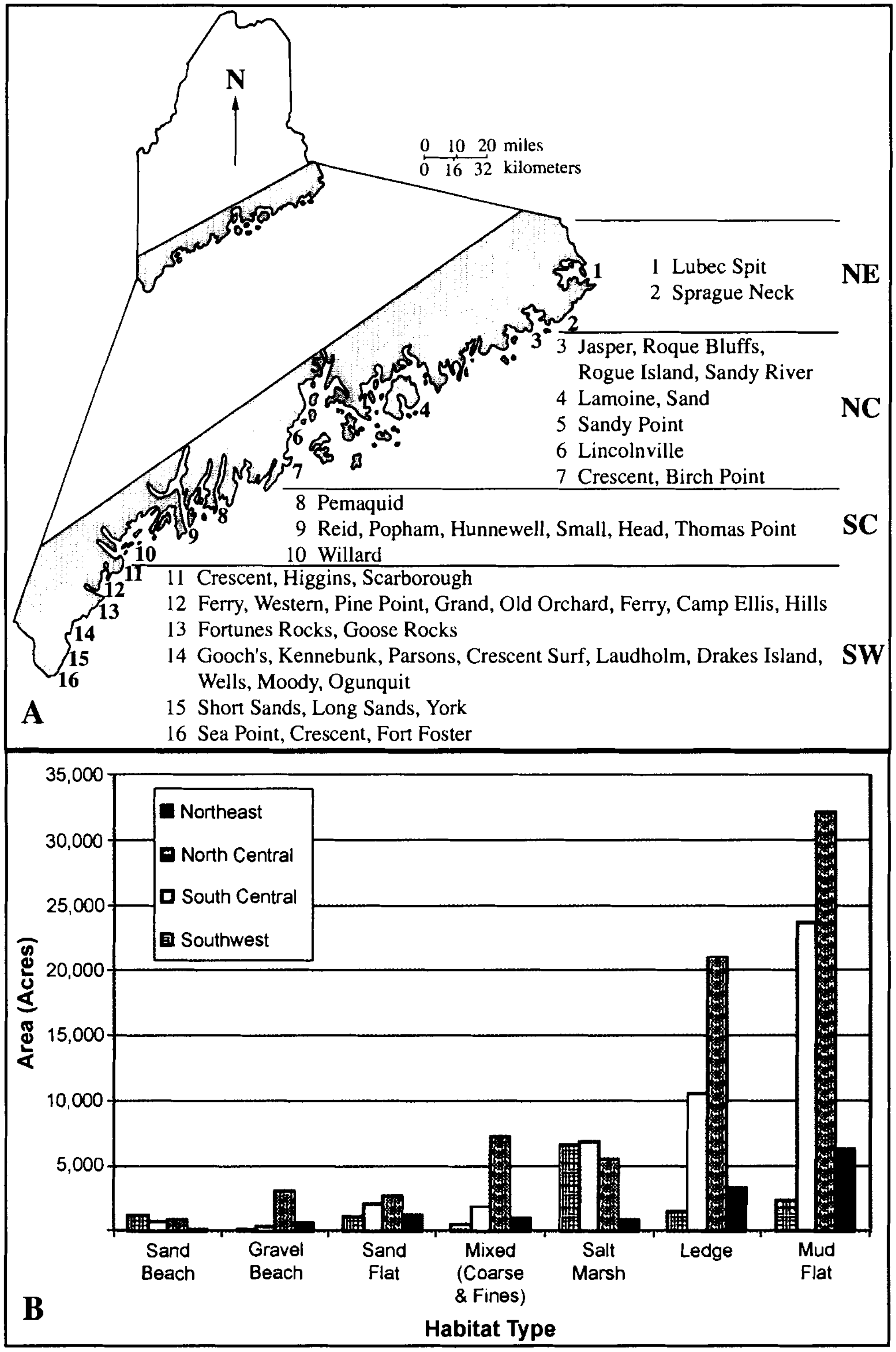


Figure 2. Location and abundance of beaches in Maine. (A) Major sand and gravel beaches grouped by coastal compartment: northeast (NE) cliffed shoreline, north-central (NC) island-bay complex, south-central (SC) indented embayments, and southwest (SW) arcuate embayments (After Barringer and Ten Broeck 1978; Kelley 1987). (B) Area of intertidal habitat by coastal compartment (After Ward 1999).

smallest portion of the intertidal geology, but serve as vital habitats and areas for residential development, recreation, and tourism in southern Maine.

Development on the sand beaches of Maine is threatened by severe although infrequent storms, as well as a 2-3 mm per year rise in sea level (Nelson 1979). With an accelerated rate of sea-level rise, sand beaches are expected to experience even greater coastal erosion and inundation (EPA 1995). The beachface and primary sand dune, or frontal dune, which provides the beach and adjacent development with a temporary line of defense against ocean wave and wind attack, are the most dynamic and erosion-prone areas within the beach system (Figure 3; Kelley *et al.* 1989; Bush *et al.* 1996). Back dunes lie landward of the frontal dune and may be stable if elevated above waves and storm-surge flooding (Kelley *et al.* 1989). Since most frontal dunes on sand beaches are developed, extensive damage to land and structures could occur with an accelerated rate of sea-level rise (> 2 mm/yr) and increase in storm frequency (EPA 1995).

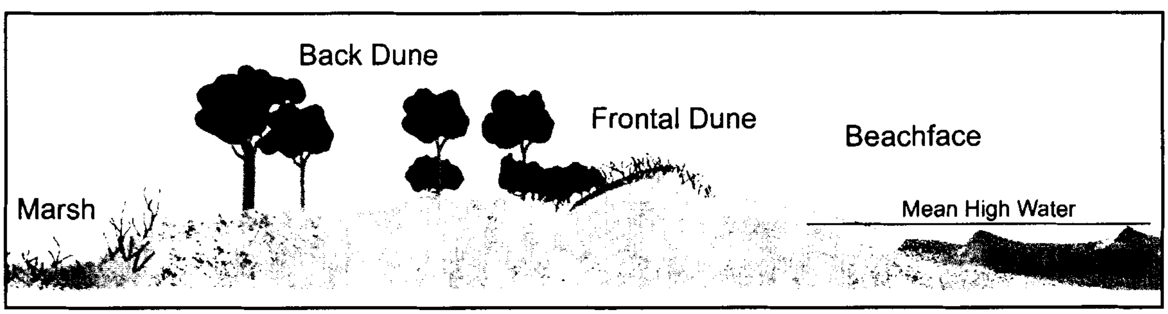


Figure 3. Cross-section of a barrier beach system with typical environments.

Coastal Development and Land Loss

Coastal counties, which are located entirely or partially within coastal watersheds, began their rapid growth in the 1960s (Culliton 1998). The 1960s experienced a population growth of 15 million coastal residents, while the non-coastal population only increased by 8 million people (Culliton 1998). Coastal counties comprise only 17% of the contiguous land area of the Unites States, but house more than 53% of the nation's population, or 139 million people (Culliton 1998). The population density of the northeast coast is more than double that of any other region (Culliton 1998). Shoreline erosion places these coastal residents at risk and challenges all levels of governments (Beatley *et al.* 2002).

The many variables that lead to coastal land loss challenge coastal managers. The primary factors include changes in sea level, coastal processes, sediment budgets, climate, and human activities (Figure 4; Pilkey *et al.* 1989; EPA 1995).

1. *Relative sea-level* changes encompass isostatic, tectonic and compactional subsidence, oceanographic changes, and world-wide sea-level changes often attributed to global climate.

2. *Coastal processes*, such as waves and currents, are intensified during hurricanes, northeasters, and other storms with strong winds.

3. Alterations in the *sediment budget* of sandy shorelines are most often caused by changes in the volume of river or bluff-derived sediment.

4. *Climate*, including temperature and precipitation, influence land loss through the decomposition of rocks, alteration of vegetation, and runoff.

5. *Human activities*, such as coastal construction projects, promote alterations and imbalances in the sediment budget, coastal processes, and relative sea level.

Coastal land loss occurs and becomes costly when development in known high hazard areas blocks natural processes such as sea-level rise. Coastal residents lose approximately $500 million per year as a result of structural damage and loss of land (Dunn *et al.* 2000). To successfully manage the coast, particularly sand beaches, regulations must recognize the events that cause land loss and incorporate responsive measures to these factors (EPA 1995). Storms are the major short-term processes that cause the loss of sand beaches in Maine (Figures 5 and 6).

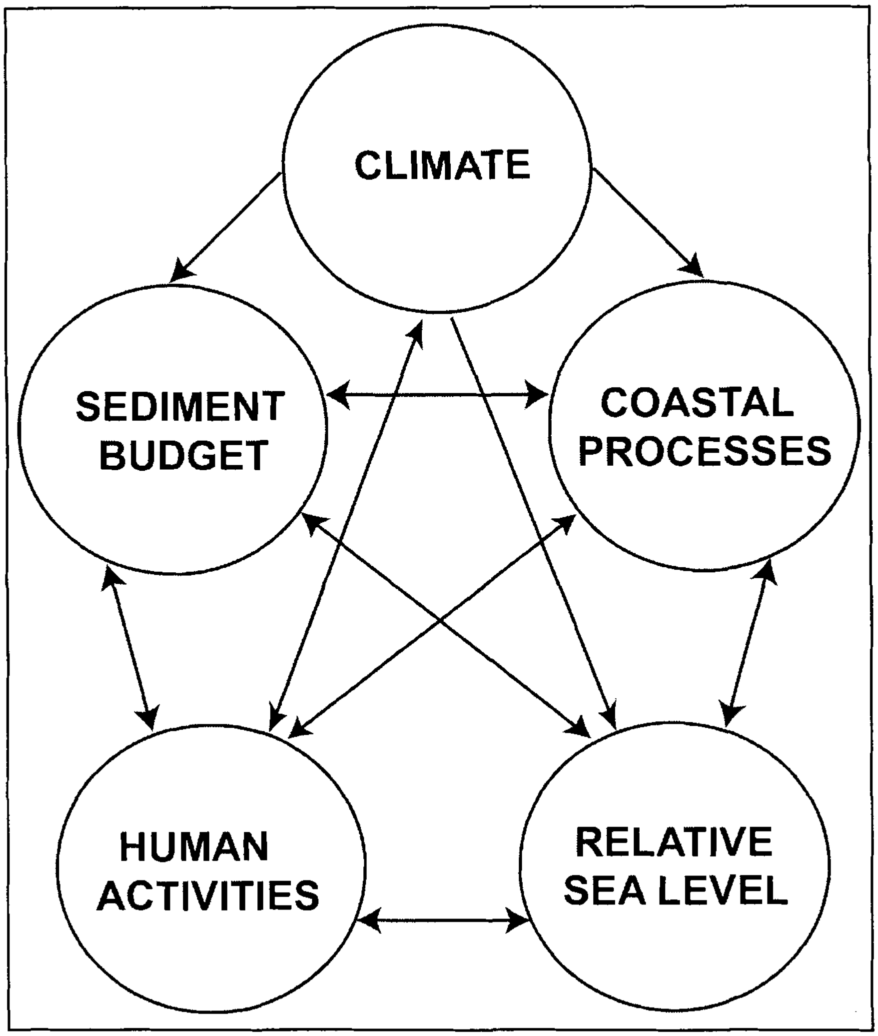


Figure 4. Interacting agents of coastal land loss (After Pilkey *et al.* 1989).

Figure 5. Shoreline erosion undermines development on the Hunnewell sand dunes in Phippsburg, Maine (Photo by J. T. Kelley).

Figure 6. Northeast storm wave attack on Camp Ellis development in Saco, Maine (Photo by S. M. Dickson).

Tropical and Extratropical Storms

Tropical and extratropical storms, hurricanes and northeasters, cause major damage along the US Atlantic coast (Coch 1993; Davis and Dolan 1993; Zhang *et al.* 2001). The concentrated, strong low-pressure systems of tropical storms usually influence relatively small lengths of shoreline (150 km) with high wind speeds (Davis and Dolan 1993; Zhang *et al.* 2001). Hurricanes form over warm tropical ocean waters and are relatively infrequent in northern New England (Coch 1993; Davis and Dolan 1993). The cold waters of the northeast have not experienced a major hurricane in over 55 years (Coch 1993). Although hurricanes can impact the Maine coast and their strong winds may cause severe property damage, they have not been major factors influencing shoreline erosion and property loss.

Extratropical storms occur more frequently than tropical storms and have large fronts along the US Atlantic coast (Zhang et al. 2001). These storms are cold-core systems (Davis and Dolan 1993). Northeasters, which are named for the direction from which their winds originate, are low-pressure systems that can stretch over 1,500 km or more of shoreline (Davis and Dolan 1993). Wind-driven shoreward transport of water and raised water-surface levels due to low air pressure produce high water surges, which can reach up to 5 m above expected tide levels on open coasts during northeasters (Davis and Dolan 1993). Wave heights of 1.5 m to 10 m create more damaging conditions when accompanied by high storm surges (Davis and Dolan 1993). Large, persistent northeasters develop surge and wave heights that cause loss of life and major damages to coastal structures in Maine (Barringer and Ten Broeck 1978; Davis and Dolan 1993; Zhang *et al.* 2001).

Extratropical storms often cause significant coastal flooding and beach erosion (Dolan and Davis 1992; Zhang *et al.* 2001; Zielinski 2002). Short-period energetic waves associated with northeasters, usually between the months of October and April, drastically reduce beach width (Figure 7A; Davis and Dolan 1993; Bertness 1999; Zhang *et al.* 2001). However, summer waves usually move sand back onshore from bars created offshore in the winter (Zhang *et al.* 2001). Physical characteristics of a coastal area, including shoreline orientation and density of structures, also affect the degree of erosion and property damage (Barringer and Ten Broeck 1978; Davis and Dolan 1993). Northeast-storm waves are major agents of beach erosion in Maine (Figure 7B; Heinze 2001; Zhang *et al.* 2001).

Severe damages to coastal land and structures due to flooding and erosion of developed beaches result from northeasters in Maine (FEMA 1983). The New England Blizzard of 1978 (February 6-7) and the Halloween Storm of 1991 (October 30–November 1) are the most severe northeasters that influenced New England since the Ash Wednesday Storm of 1962 (Davis and Dolan 1993; Fitzgerald *et al.* 1994; Zhang *et al.* 2001). The New England Blizzard brought record-breaking snowfall and hurricane-force winds that caused beach retreat and property damage in Maine (Nelson 1979; Kocin and Uccellini 1990). The Halloween Storm also resulted in erosion and considerable property damage due to heavy surf and lunar-enhanced storm surges along the coast (National Weather Service 1991; Mailhot 2000). Damages that occurred during these and other storms illustrate the need for mitigation measures in developed coastal areas.

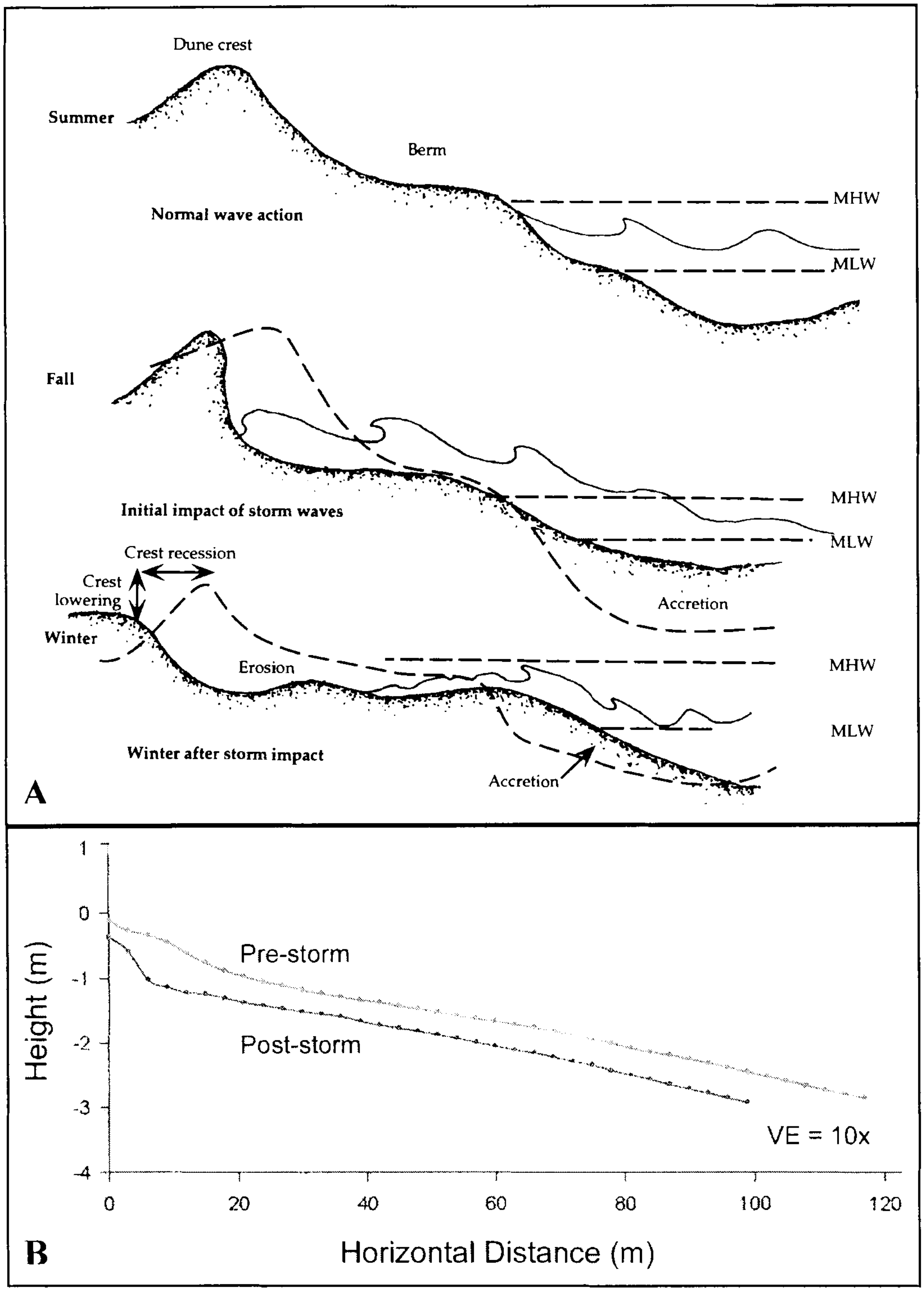


Figure 7. Beach-profile changes due to northeasters. (A) Northeast-storm waves typically erode beach sediments from the steep summer profile, which normally reflects low-energy waves. Erosion of the berm and dune creates a beach with a lower slope or dissipative profile (Bertness 1999). MHW (mean high water); MLW (mean low water). (B) Beach profile change across Goochs Beach in Kennebunk, Maine due to a northeaster on 5-6 March 2001 (after Heinze 2001). Height is not referenced to sea level.

Mitigation Measures

Many measures exist to reduce the risk of disaster along developed coasts. Regulatory tools, such as setbacks and construction controls, are used to prevent development in hazardous locations, relocate structures before severe damage occurs, and retreat once structures are destroyed. Other regulatory tools define when beach nourishment and shoreline-stabilization measures should be taken (Burby and Nelson 1991; Hanson and Lindh 1993; Appendini and Fischer 1998; Charlier and DeMeyer 1998; Nordstrom 2000). These shoreline-erosion mitigation measures require different degrees of hazard planning and result in a wide range of economic costs (Figure 8; Appendini and Fischer 1998).

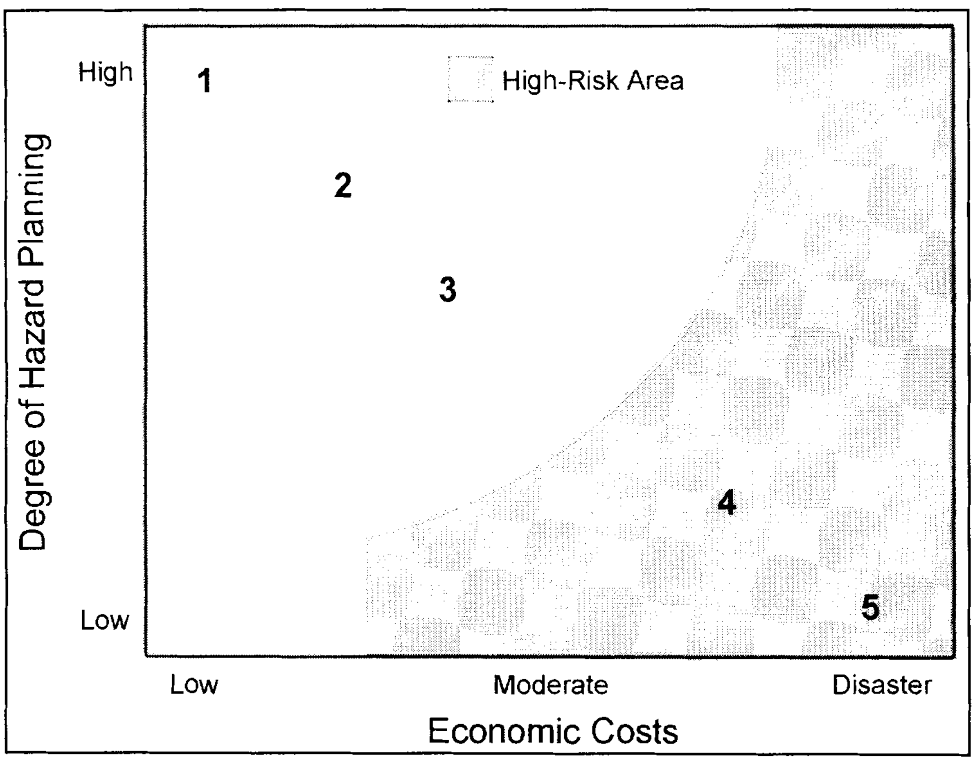


Figure 8. Risk associated with five shoreline erosion mitigation measures based on degree of hazard planning and economic costs (after Appendini and Fischer 1998). The probability of severe storm occurrence is constant. (1) Hazard avoidance; (2) relocation; (3) beach nourishment; (4) shoreline-stabilization structures; (5) do nothing.

The selection and implementation of mitigation measures depends on many characteristics of an area including physical, social, economic, political, historical, and environmental (Charlier and DeMeyer 1998).

1. *Hazard avoidance* most effectively minimizes storm disasters and economic loss, but requires the most planning (Appendini and Fischer 1998). Setbacks are used to avoid damages from major storms by permitting development only in low-risk areas. Building codes also support a policy of hazard avoidance by requiring storm-resistant structures.

2. *Relocation* of oceanfront structures involves the movement of undamaged, but threatened structures (Appendini and Fischer 1998). Relocation must be distinguished from retreat, which does not permit reconstruction of damaged structures in high-risk areas (Nordstrom 2000).

3. *Beach nourishment* increases beach width through the placement of sand. Wider beaches provide protection to property and increase the area for recreation, but require successive episodes of costly nourishment (Trembanis *et al.* 1999; Nordstrom 2000).

4. *Shoreline-stabilization structures* include seawalls, which are built parallel and adjacent to the shoreline, and groins that lie perpendicular to the shoreline. Seawalls separate the upland area from erosive waves and currents. They may contribute to the erosion and destruction of development by disrupting the natural transfer of sediment between the beach and dunes (Bush *et al.* 1996; Appendini and Fischer 1998). Groins trap sediment from longshore drift to build a protective or recreational beach at a specific site.

5. The *do-nothing* alternative has the highest potential risk. It may work as long as an extreme storm does not occur, but the cost associated with the inevitable storm is often disastrous (Appendini and Fischer 1998).

Hazard avoidance and relocation costs, as well as the economic costs of retreat, remain lower than episodes of beach nourishment, long-term maintenance of shoreline-stabilization structures, and doing nothing in most, but not all cases (Griggs 1986; Appendini and Fischer 1998; Nordstrom 2000; Parsons and Powell 2001). Hazard avoidance and relocation, which require residents and governments to restrict development and encourage new land-use patterns, are employed less often than beach nourishment and shoreline stabilization measures (Trembanis *et al.* 1999).

National Flood Insurance Program

In the mid-1960s, the use of nonstructural measures to reduce flood losses became a national priority (Committee on Coastal Erosion Zone Management *et al.* 1990). Congress created the National Flood Insurance Act and established the National Flood Insurance Program (NFIP) in 1968 as the primary federal program to reduce flood costs. When the Federal Emergency Management Agency (FEMA) was established in 1972, it acquired authority over the NFIP. FEMA developed flood zones, building requirements, and insurance coverage through the NFIP to minimize damages along rivers and in coastal areas.

Identification of the degree of flood hazards and risks forms the basis of the NFIP land-use measures and insurance rates used to influence development. Flood Insurance Rate Maps (FIRMs) include special flood-hazard areas, A and V zones, that are subject to inundation by the 100-year flood, which has a one percent chance of being equaled or exceeded in any given year (Figure 9). V zones or coastal high-hazard areas are subject to significant wave action (high-velocity waters) from storms (FEMA 1995). Models predict that one meter or greater waves break in V zones during 100-year storms (Bush *et al.* 1996; Heinz Center 2000). A breaking wave of one meter is critical in terms of causing significant structural damage (FEMA 1995). Mapping of V zones considers erosion where it affects the potential survivability of sand dunes and the height of waves during a base-flood event. Long-term erosion trends, future sea-level rise, and subsidence are not incorporated into V zones and FIRMs (Committee on Coastal Erosion Zone Management *et al.* 1990).

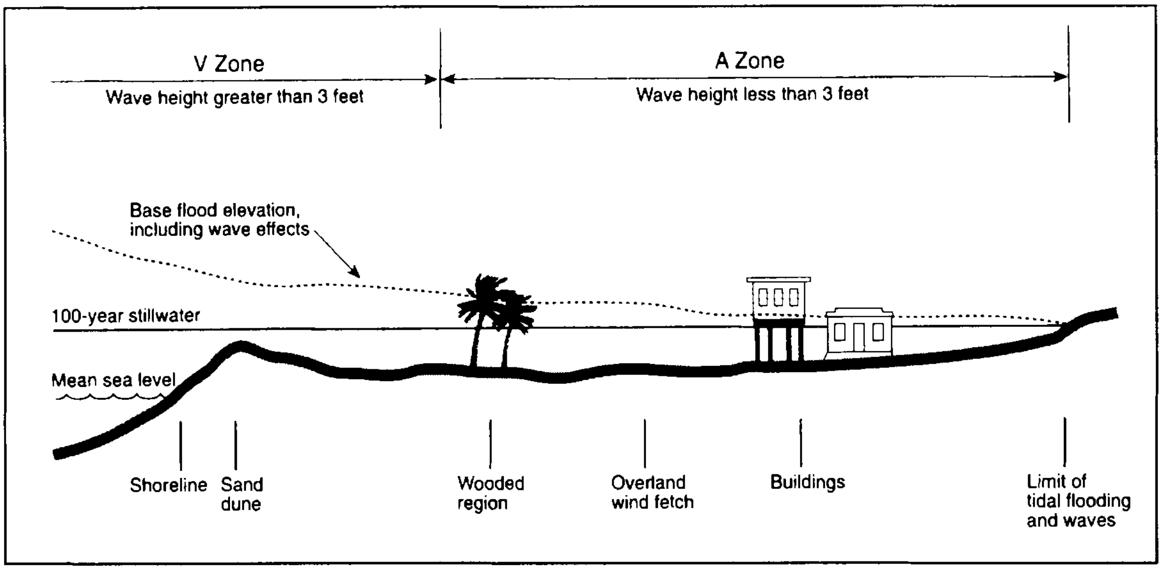


Figure 9. Special flood-hazard areas, A and V zones, within the 100-year floodplain (Bush *et al.* 1996). V zones are exposed to wind and susceptible to waves that may exceed 1 m (3 ft) in height.

FEMA allows construction of new buildings and additions in V zones as long as structures meet certain minimum standards designed to reduce future flood damage. Structural requirements of the NFIP have resulted in the construction of strengthened buildings that are raised and located as far seaward as the mean high-tide line (FEMA 2000; Heinz Center 2000). Although the density of development has increased in high flood-hazard areas, estimates indicate that damages have been lower than if the program had not been enacted (Heinz Center 2000). However, FEMA has not designated erosion hazard areas or established standards for setbacks or other management requirements for erosion-prone coasts (Committee on Coastal Erosion Zone Management *et al.* 1990). The addition of erosion-hazard areas could increase the coastal high-hazard zone by 15% (Heinz Center 2000). NFIP elevation and related requirements for buildings have reduced flood damage, but have not encouraged people to move structures away from the shore to allow for shoreline movement and reduce erosion damage (Heinz Center 2000).

Communities that institute sound floodplain management to limit future flood losses are eligible for insurance through the NFIP. Coverage for residential buildings may not exceed \$250,000 and content coverage is limited to \$100,000 (FEMA 2001). Non-residential properties may receive up to \$500,000 each for structures and contents (FEMA 2001). The NFIP does not pay for loss of land or the full value of many coastal houses, but insurance covers flood-related erosion losses (Heinz Center 2000; Committee on Coastal Erosion Zone Management *et al.* 1990).

Premiums should cover claims and reduce the dependence of citizens impacted by disasters on federal tax money (Platt 1999). However, premiums are all based on the same rate and policyholders build to the same requirements even though coastal erosion risk varies (Heinz Center 2000). Barrier-island communities receive a disproportionate amount of payments relative to their populations (Mitchell 1987). Repetitive-loss properties, which have at least two claims that exceed \$1,000 in a ten-year period, exist in many coastal areas (Esnard *et al.* 2001). The NFIP will cover only a small fraction of the expected \$500-530 million damages to coastal property each year (Dunn *et al.* 2000; Heinz Center 2000). Only half of the homeowners in high erosion-hazard areas on the Atlantic coast currently purchase flood insurance (Heinz Center 2000). As the shore erodes into areas of higher density development, the cost of erosion increases. State and local governments have undertaken regulatory programs to address flood as well as erosion hazards (Committee on Coastal Erosion Zone Management *et al.* 1990).

Sand Dune Rules

Implementation of the SDR in 1983 equipped the State of Maine to regulate private land-use decisions in sand beach systems and to prevent or reduce coastal damages from storms, flooding, and erosion (Barringer and Ten Broeck 1978; Kelley *et al.* 1989). The SDR restrict the density and location of development as well as the size of structures to prevent the creation of flood hazards and to protect the natural supply and movement of sand (DEP 1993). Major measures of the current SDR:

1. set all new structures back behind the V zone and frontal dune boundary;
2. preclude new structures that exceed 35 ft (11 m) in height or cover more than 2,500 ft^2 (760 m^2) from dune systems that will not remain stable given a sea-level rise of 3 ft (1 m) over the next 100 years;
3. prohibit reconstruction of severely damaged (more than 50% of the appraised market value) buildings unless the reconstructed buildings adhere to the current standards;
4. prohibit new or expanded seawalls; and
5. remove structures and restore sites to natural conditions if the shoreline recedes and tidal lands extend to any part of the structures (including support posts) for six months or more (DEP 1993; EPA 1995).

New structures and reconstruction of severely damaged buildings on frontal dunes or in V zones, which were designated prior to 1999, are currently prohibited (DEP 1993; MRSA 1999). While new and expanded seawalls are also prohibited by the SDR, the NRPA allows property owners to protect or strengthen their seawalls in emergency situations (DEP 1993; MRSA 1995). The SDR promote hazard avoidance and retreat from erosion and flood-hazard areas to mitigate risks to the sand dune system and structures.

The current retreat policy allows for any rate of shoreline change and applies to all buildings that are severely damaged on the frontal dune or in the V zone. If a building sustains damage to the extent of 50% or more of its appraised value, it may not be repaired or rebuilt without a permit (DEP 1993). The DEP is required to deny a permit for reconstruction unless the applicant can meet all of the requirements for new construction. This stringent regulation has prevented the reconstruction of severely damaged buildings in Maine. The SDR anticipate that buildings damaged to this extent would lie within the frontal dune or V zone, so the DEP would deny permits to repair or rebuild these buildings (EPA 1995). It is expected that there will be fewer repetitive losses and development in high-hazard areas once pre-SDR buildings have been set back.

The amended SDR recently adopted by the Board of Environmental Protection (BEP) may weaken the hazard avoidance and retreat policies. If approved by the Legislature, the amended SDR adopted on June 19, 2003 would allow new development and additions on frontal dunes, and reconstruction of destroyed buildings on frontal dunes and within V zones to be permitted by the DEP with restrictions (DEP 2003). Competing bills introduced by state representatives during the first regular session of the 121st Maine Legislature led to the compromise by the DEP. Rep. David Lemoine, D-Old Orchard Beach, with the support of a citizen group, ironically named Save Our Shores, submitted a bill to prevent the state from strengthening the ban on reconstructing severely damaged buildings (Fish 2003a; Lemoine 2003). Rep. Scott Cowger, D-Hallowell, sponsored a bill on behalf of the Maine Audubon Society to prohibit:

1. construction of new or enlargement of existing seawalls, bulkheads or similar structures on the coastal sand dune system;

2. reconstruction or replacement of buildings that are damaged by more than 50% and are located in the coastal sand dune system, if the damage was caused by wave action due to an ocean storm;

3. maintenance and repair of a structure located in the coastal sand dune system when the cost, including the value of labor and materials, is equivalent to or exceeds 50% of the structure's assessed value; and

4. construction of new buildings in the frontal dune (Fish 2003a; Cowger; 2003).

The Natural Resources Committee of the Legislature decided not to establish the SDR by law (Fish 2003b). Before amendments approved by the BEP will take effect, they will be sent to the Legislature to review, modify, and approve (Fish 2003b; Anonymous 2003).

The hazard avoidance and retreat mitigation measures of the SDR are based on flood and erosion-hazard zones. FEMA FIRMs and Coastal Sand Dune Maps prepared by the Maine Geological Survey (MGS) are used as best available information in the permit application process administered by the DEP (Figure 10; DEP 1993). FEMA prepares the FIRMs for communities that participate in the NFIP, which include all of the developed sand beaches in Maine. The MGS has mapped most of the sand dune systems in southern Maine. The Coastal Sand Dune Maps show the location of the beach, frontal dunes, back dunes, and other coastal environments (Figure 10B). Areas that have been modified by development are mapped on the basis of present beach profile, dune positions along the shore, and regional trends in dune width (DEP 1993). The Coastal Sand Dune Maps do not indicate the risk associated with the formation or migration of inlet and marsh channels, coastal structures such as seawalls and jetties, or future change due to sea-level rise (DEP 1993). While the maps do not consider sea-level rise directly, it is addressed in the permitting process. The FIRMs and Coastal Sand Dune Maps,

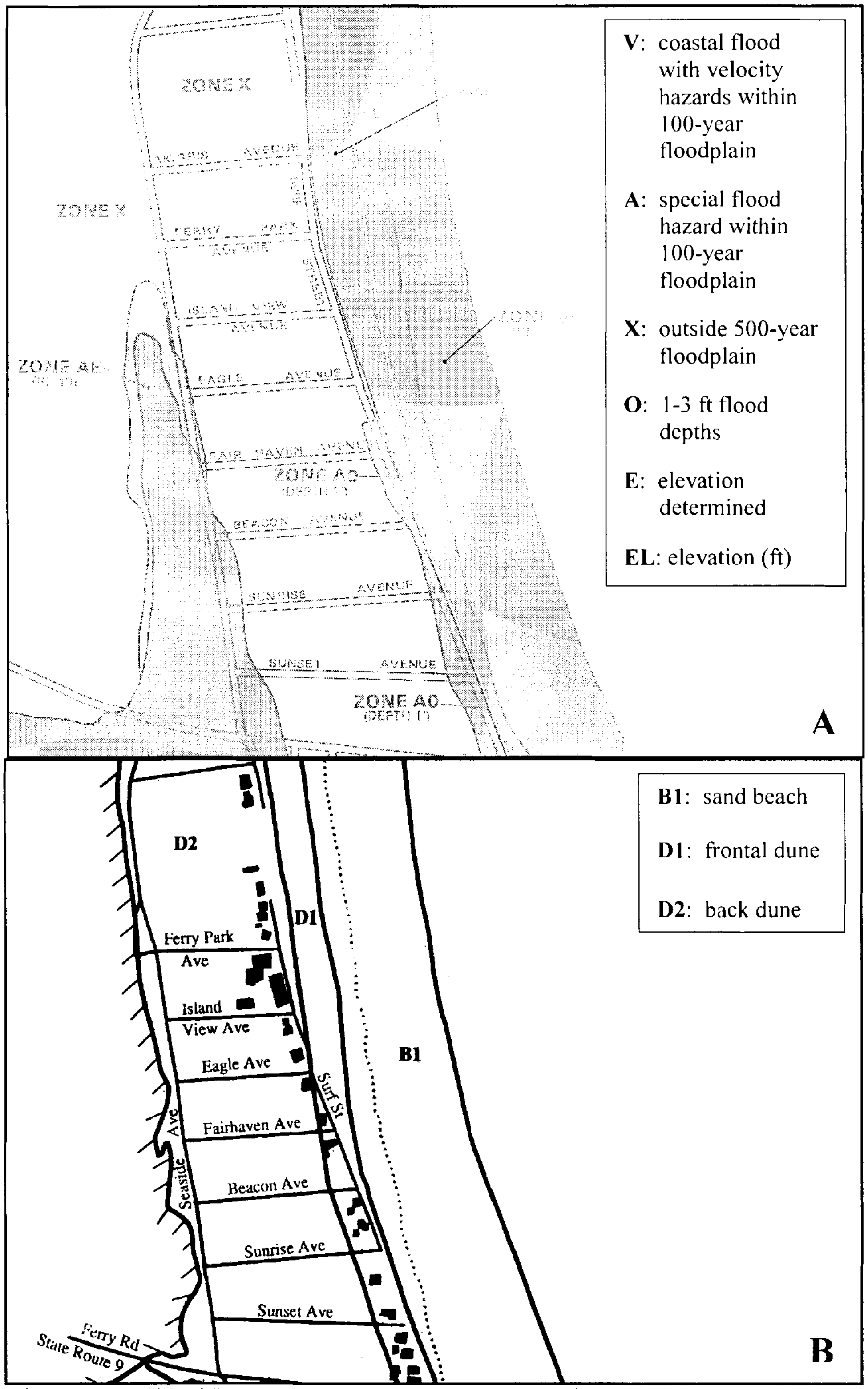


Figure 10. Flood Insurance Rate Map and Coastal Sand Dune Map examples for Camp Ellis in Saco, Maine. (A) Flood Insurance Rate Map based on the Flood Insurance Study for Saco (FEMA 1998a). (B) Coastal Sand Dune Map based on aerial photos and fieldwork by the Maine Geological Survey (Dickson 1990a).

which are essential to flood and erosion-hazard mitigation, enabled the measurement of high-hazard development and policy outcomes.

Chapter 2

STUDY SITES

Overview

The developed beaches of Kennebunk, Wells, and Saco in York County, Maine were chosen as the study sites for this project based on three criteria (Figure 1). First, these beaches lie within the southwest coastal compartment, which is characterized by arcuate embayments with an abundance of sand beaches (Figure 2; Kelley 1987; Ward 1999). More than 40% of the few sand beaches in Maine are located in this compartment (Ward 1999). Second, loss of land and buildings occurs on these beaches as a result of storms, sea-level rise, and structures such as seawalls and jetties that alter the sediment budget of the shoreline (Kelley *et al.* 1989; Kelley and Anderson 2000). The NFIP paid more than $9 million to policyholders in York County for building and content losses between 1978 and 1998 (Figure 11). Kennebunk, Wells, and Saco received 48% of the amount paid to York County (Figure 12). Third, parcel maps were available in GIS format for Kennebunk and Wells, and in AutoCAD format for Saco. These beaches were primarily chosen due to their potential for extensive storm damage, which takes into account orientation index for northeast storms as well as structures used to stabilize these shorelines, and will be discussed in the following sections (Table 1).

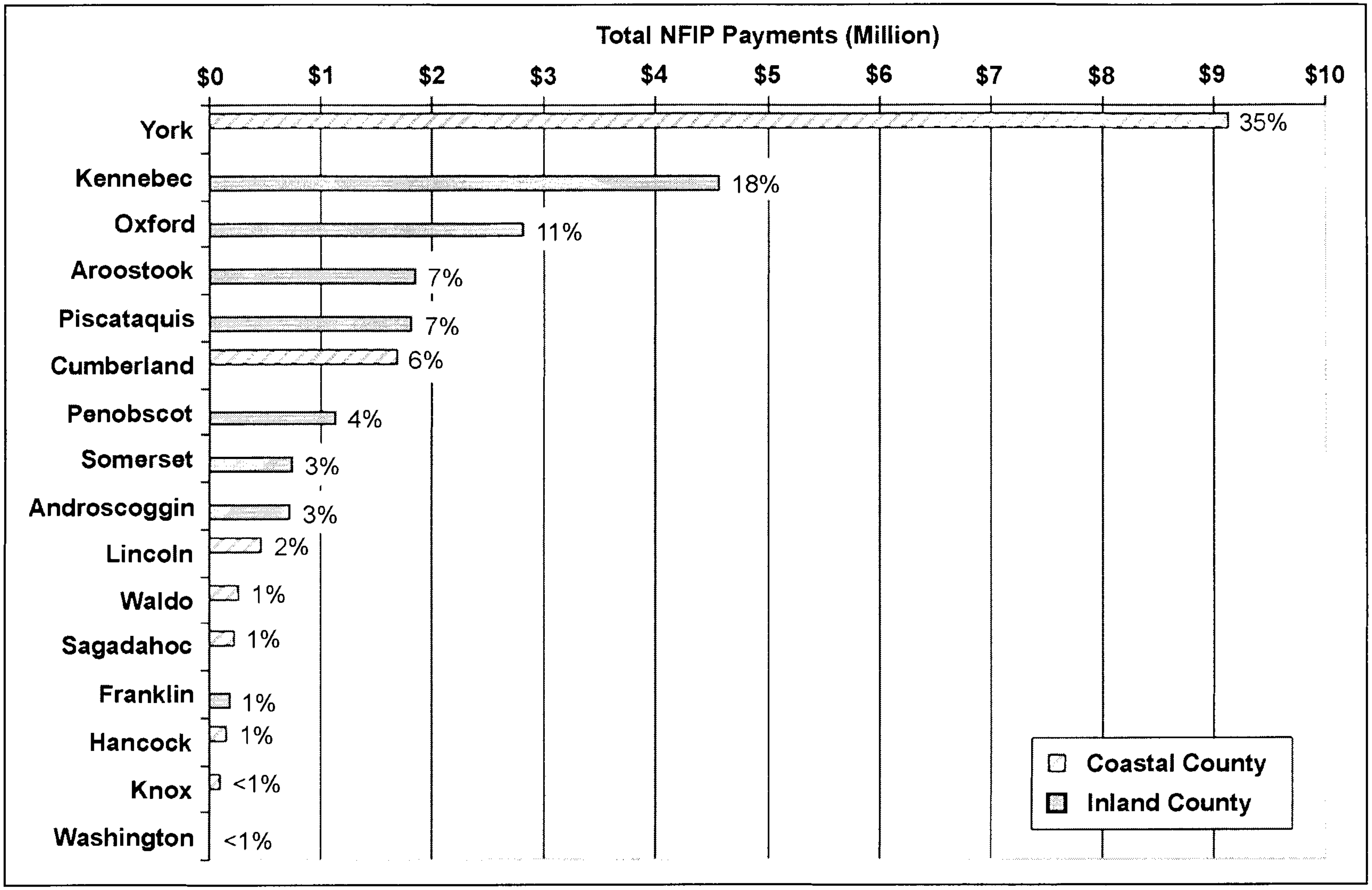


Figure 11. Policyholders in York County received the largest payment (>$9 million) from the National Flood Insurance Program for loss of buildings and contents in Maine between 1978 and 1998.

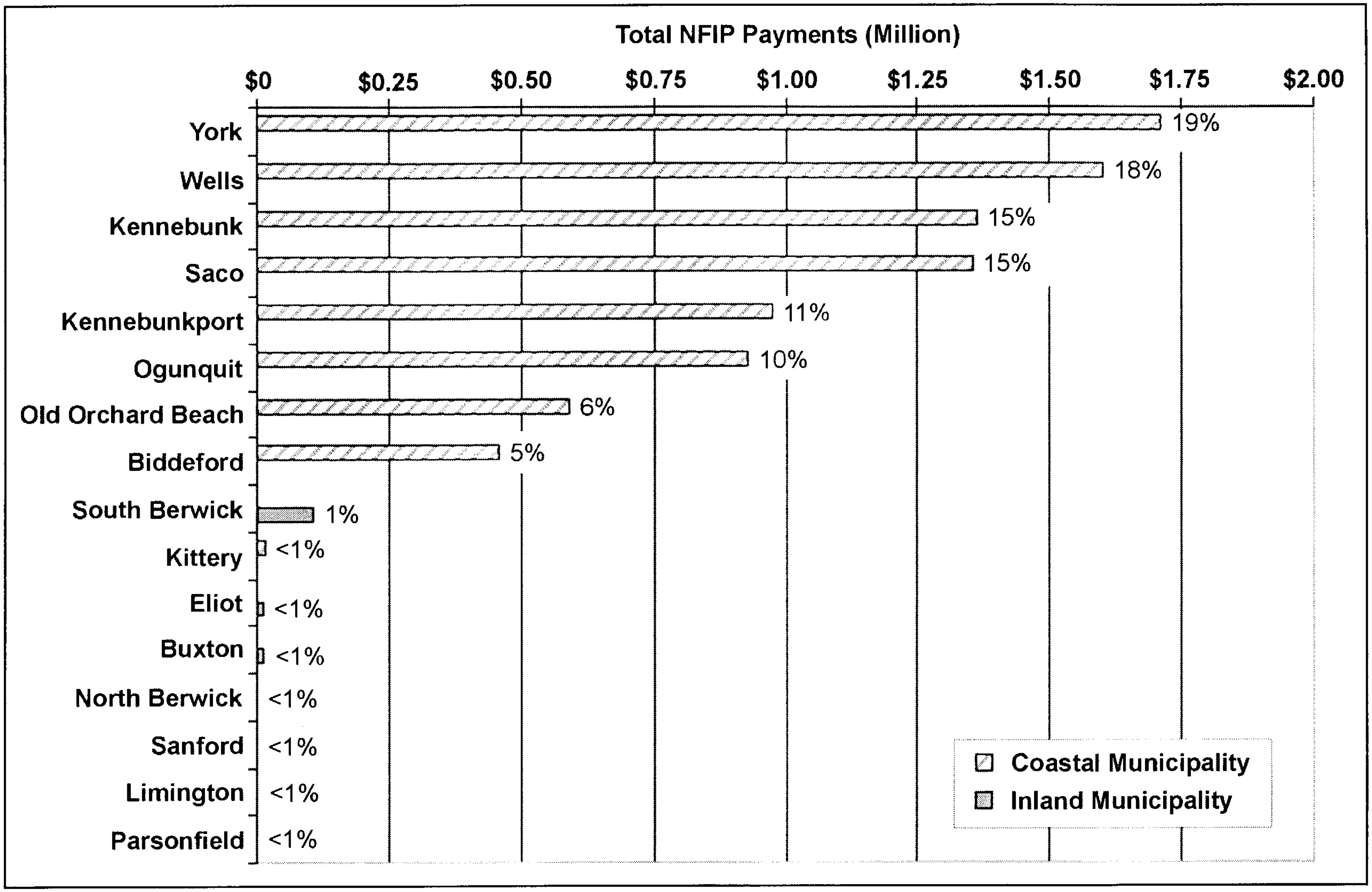


Figure 12. Policyholders in Kennebunk, Wells, and Saco received 48% of the National Flood Insurance Program payments for loss of buildings and contents in York County, Maine between 1978 and 1998.

Table 1. Major beaches in Maine with the potential for extensive storm damage (after Barringer and Ten Broeck 1978). An orientation index of 100 represents no refraction of northeast storm waves before contact with the shore. Beaches with an index of zero are oriented so that storm waves must bend 90° to arrive parallel to the shore.

Orientation Index for Northeast Storms		Beaches with High Storm Damage Potential	Municipality
Low	12	Goochs Beach Kennebunk Beach	Kennebunk
Moderate	63	Drakes Island	Wells
High	82	Wells Beach	Wells
	86	Moody Beach	Wells
	100	Kinney Shores Camp Ellis	Saco

Kennebunk, Maine

The Town of Kennebunk is a popular summer resort and yachting center with an orientation sheltered from northeast storms; however, a continuous seawall and narrow beaches result in severe storm damage (Table 1; Barringer and Ten Broeck 1978; Wells Bay Planning Committee 2002). Development is located primarily along US Route 1, Kennebunk River, Mousam River, and the coastline of Wells Bay (Figure 13; FEMA 1982). NFIP policyholders received more than $1.3 million for damages to this development between 1978 and 1998 (Figure 12). Goochs Beach and Kennebunk Beach extend 2.7 km between the Mousam River and Kennebunk River, and are developed with year-round and seasonal homes, and commercial establishments (FEMA 1982). Approximately 50 buildings are located in the frontal dunes, which lie between the seawall and marshes (Dickson 1990b; Wells Bay Planning Committee 2002). Water reaches the base of the seawall during high tide (Wells Bay Planning Committee 2002). Extensive marshes behind the narrow dunes of Goochs Beach and Kennebunk Beach

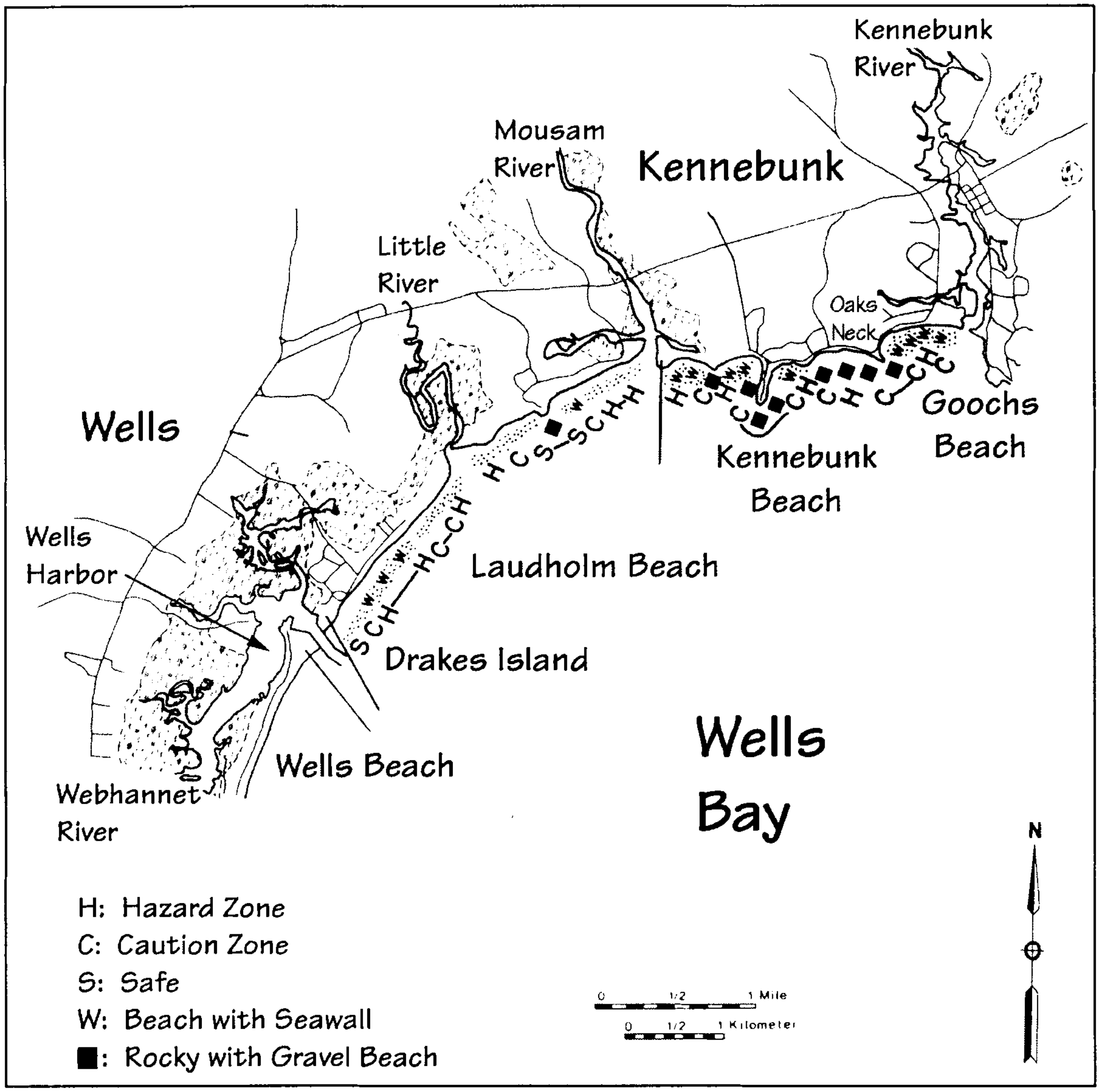


Figure 13. Goochs Beach and Kennebunk Beach located between the Mousam River and Kennebunk River in Kennebunk, Maine (after Kelley *et al.* 1989). The beaches of Wells lie to the south.

provide very limited opportunity for property owners to retreat from erosion (Wells Bay Planning Committee 2002). Most of the seawall and the road behind it have sustained substantial storm damage due to the narrow beaches (Wells Bay Planning Committee 2002).

Wells, Maine

Wells remains one of the major beach resorts in the region despite its moderate to high orientation index for northeast storms, and shoreline-stabilization structures (Table 1; Barringer and Ten Broeck 1978; FEMA 1983). Development in Wells is located primarily along Wells Bay as well as US Route 1, which parallels the coastline on the mainland (Figure 14; FEMA 1983). Loss of buildings and contents in Wells between 1978 and 1998 resulted in approximately $1.6 million in payments from the NFIP (Figure 12). Drakes Island lies to the north of Wells at the entrance of Wells Harbor, which is stabilized by two jetties and provides an anchorage for local fishermen and recreational boaters (Figure 14; FEMA 1983). Wells Beach begins at the south side of Wells Harbor and extends 3.2 km to Fishermans Cove (Figure 14). Moody Beach, which is separated from Wells Beach by Fishermans Cove and Moody Point, stretches 1.9 km before the border with the Town of Ogunquit (Figure 14). Effects of the jetties and seawalls are described below.

The USACE constructed two jetties in 1961 at the inlet between Drakes Island and Wells Beach to prevent shoaling of the Wells Harbor navigation channel (Figure 14; Kelley and Anderson 2000). As a result, 765,000 m^3 of sand were displaced (Wells Bay Planning Committee 2002). Longshore transport from both the north and south led to accretion adjacent to both jetties, which accounts for only 30% of the sand displaced

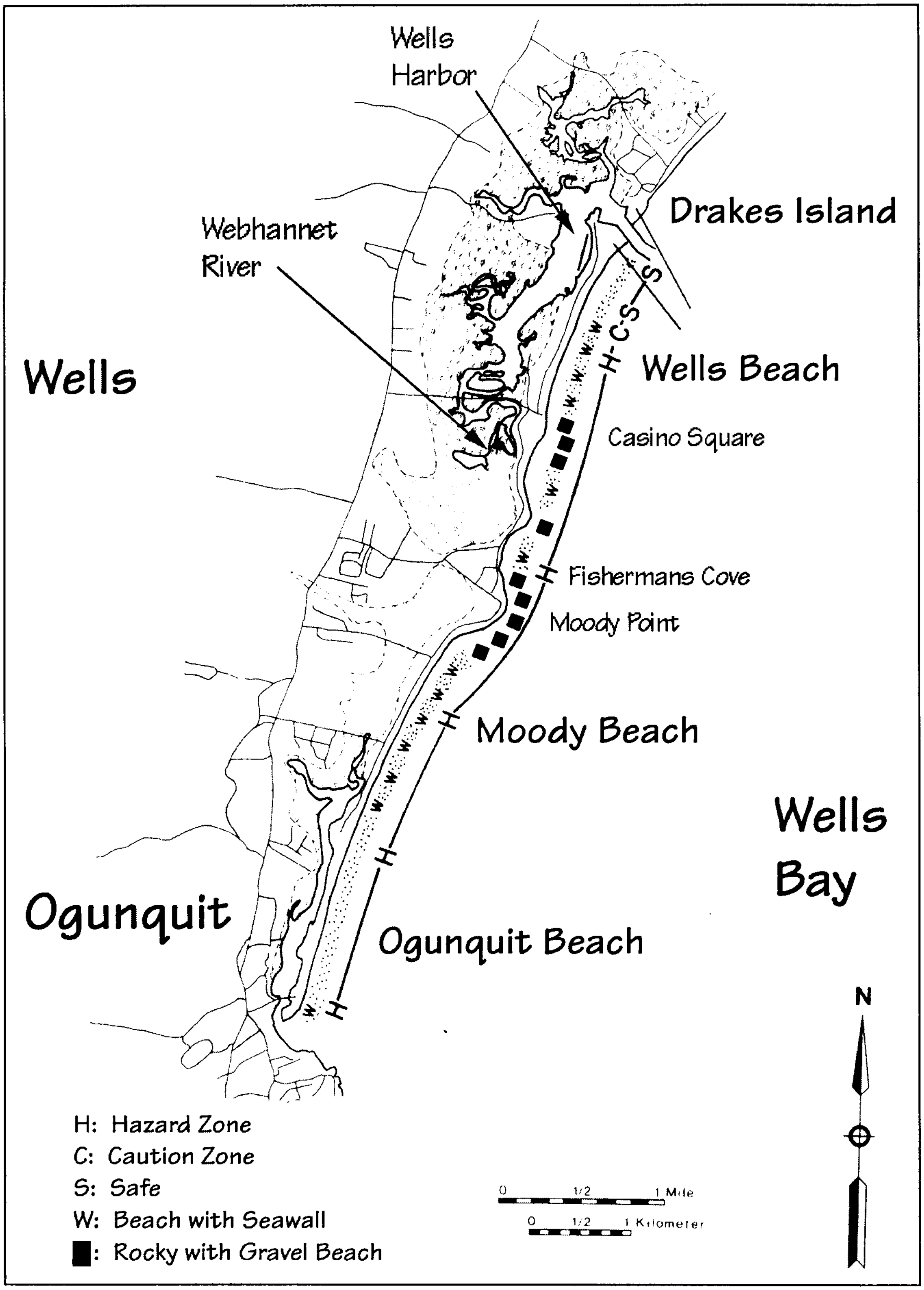


Figure 14. Drakes Island, Wells Beach, and Moody Beach located on the coast of Wells, Maine (after Kelley *et al.* 1989). Two jetties separate Drakes Island from Wells Beach at the inlet of Wells Harbor.

(Figure 15; Kelley *et al.* 1989; Wells Bay Planning Committee 2002). The remaining sand has either entered Wells Harbor or been lost from the system. Since there is limited sand offshore, except at the mouth of the Ogunquit River, both Drakes Island and Wells Beach suffer from erosion due to the jetties and change in sediment transport (Miller 1998; Kelley and Anderson 2000).

Seawalls and narrow beaches increase the risk of damages along the heavily developed, residential area from Drakes Island to Moody Beach. Thirty-six buildings exist in the frontal dunes of Drakes Island and most are associated with seawalls (Dickson 1990c; Wells Bay Planning Committee 2002). Failure of some of these seawalls led to section 480-W of the NRPA, which allows riprap to be placed at the toe of failing seawalls (MRSA 1995). Erosion in recent years left most of Drakes Island without a dry beach at high tide and particularly vulnerable to storm-wave impact until a beach nourishment project in 2000-2001 (Wells Bay Planning Committee 2002). Seawalls continuously line Wells Beach from the inlet to a rocky headland in the south that provides beach access (Wells Bay Planning Committee 2002). The frontal dunes of Wells Beach support 193 buildings (Dickson 1990d; Wells Bay Planning Committee 2002). These buildings include a relatively large motel and restaurant, but mostly residential properties (Wells Bay Planning Committee 2002). Moody Beach is densely developed with 150 buildings, all residences, built in the frontal dunes (Dickson 1990e; Wells Bay Planning Committee 2002). Seawalls front the entire stretch of developed beach, but end at the boundary between the towns of Wells and Ogunquit (Wells Bay Planning Committee 2002). These extensive seawalls have not prevented storm damage in Wells.

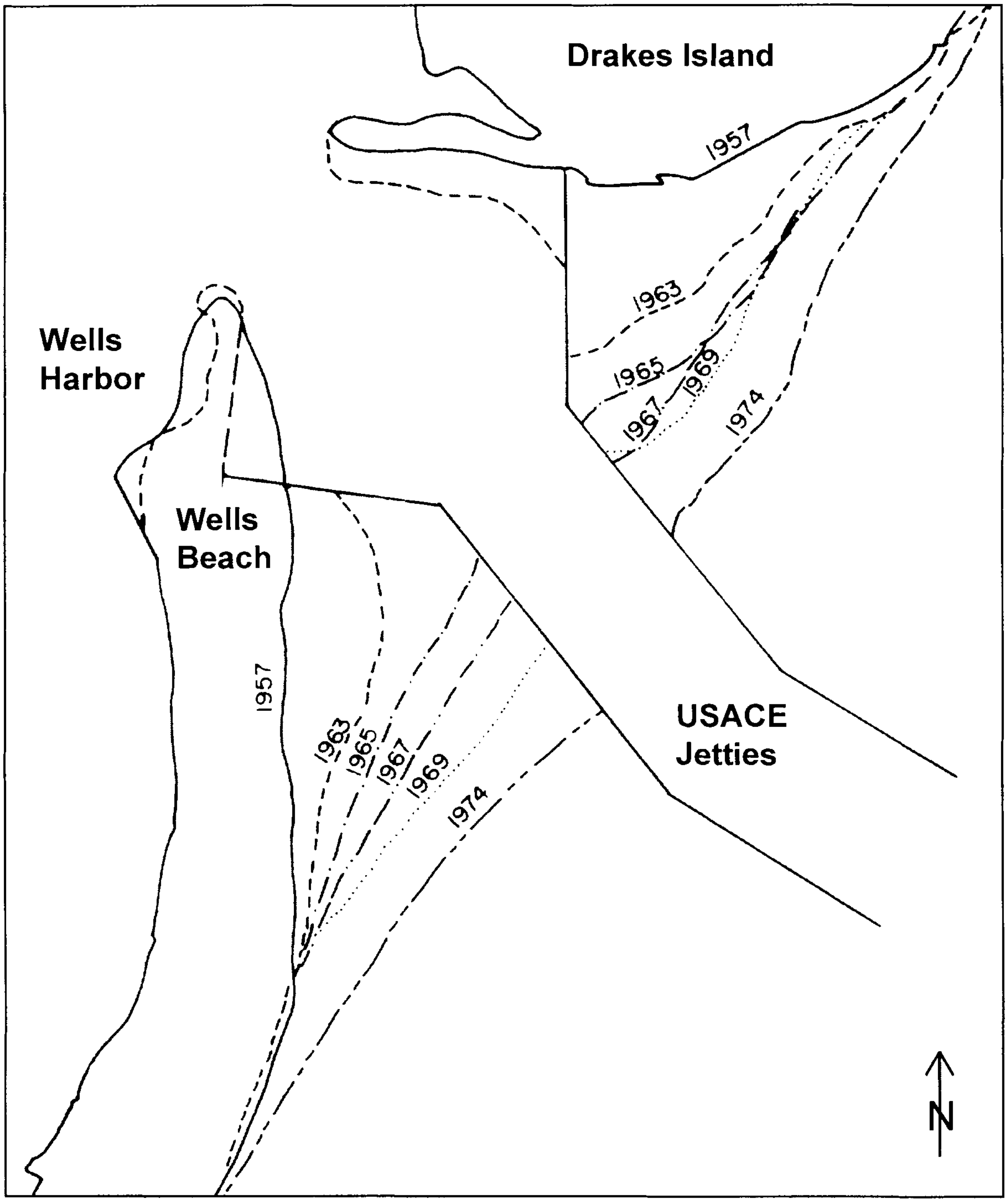


Figure 15. Accretion on Drakes Island and Wells Beach near Wells Inlet as a result of two jetties constructed by the US Army Corps of Engineers in 1961 (After Kelley *et al.* 1989).

Saco, Maine

The City of Saco comprises one of the largest industrial, commercial, and trade-centers in southwestern Maine. Its beaches are oriented directly toward northeast storm waves and a jetty has increased erosion problems (Table 1; Barringer and Ten Broeck 1978; FEMA 1998b; Saco Bay Planning Committee 2000). The sand beaches of Saco extend from Kinney Shores at the mouth of Goosefare Brook south through Ferry Beach State Park to the jetty at Camp Ellis where the Saco River enters Saco Bay (Figure 16). Kinney Shores and Camp Ellis are developed with fewer than 75 privately owned summer and year-round homes (Dickson 1990a; FEMA 1998b; Saco Bay Planning Committee 2000). Between these two beaches, development is either set back into the maritime forest or nonexistent, as in the case of the Ferry Beach State Park. Many of the small buildings in Camp Ellis were lost to storms and others precariously extend onto an eroding beach (Saco Bay Planning Committee 2000). The NFIP paid more than $1.3 million to policyholders in Saco for building and content losses between 1978 and 1998 (Figure 12). The impact of the jetty at Camp Ellis and a cost-benefit analysis of basic policy response strategies on developed shorelines are described below.

Camp Ellis lost its natural source of sand following construction of the north jetty on the mouth of the Saco River and severe erosion resulted (Kelley *et al.* 1995; Kelley and Anderson 2000; Saco Bay Planning Committee 2000). The main source of sediment for Saco Bay is the Saco River, which provides an estimated 10,000 to 16,000 m^3 of sand per year (Kelley *et al.* 1989; Barber 1995; Kelley *et al.* 1995; Kelley and Anderson 2000; Saco Bay Planning Committee 2000). The jetty disrupts the net longshore transport of river-derived sand to the north. In addition, northeast storm waves undergo minimal

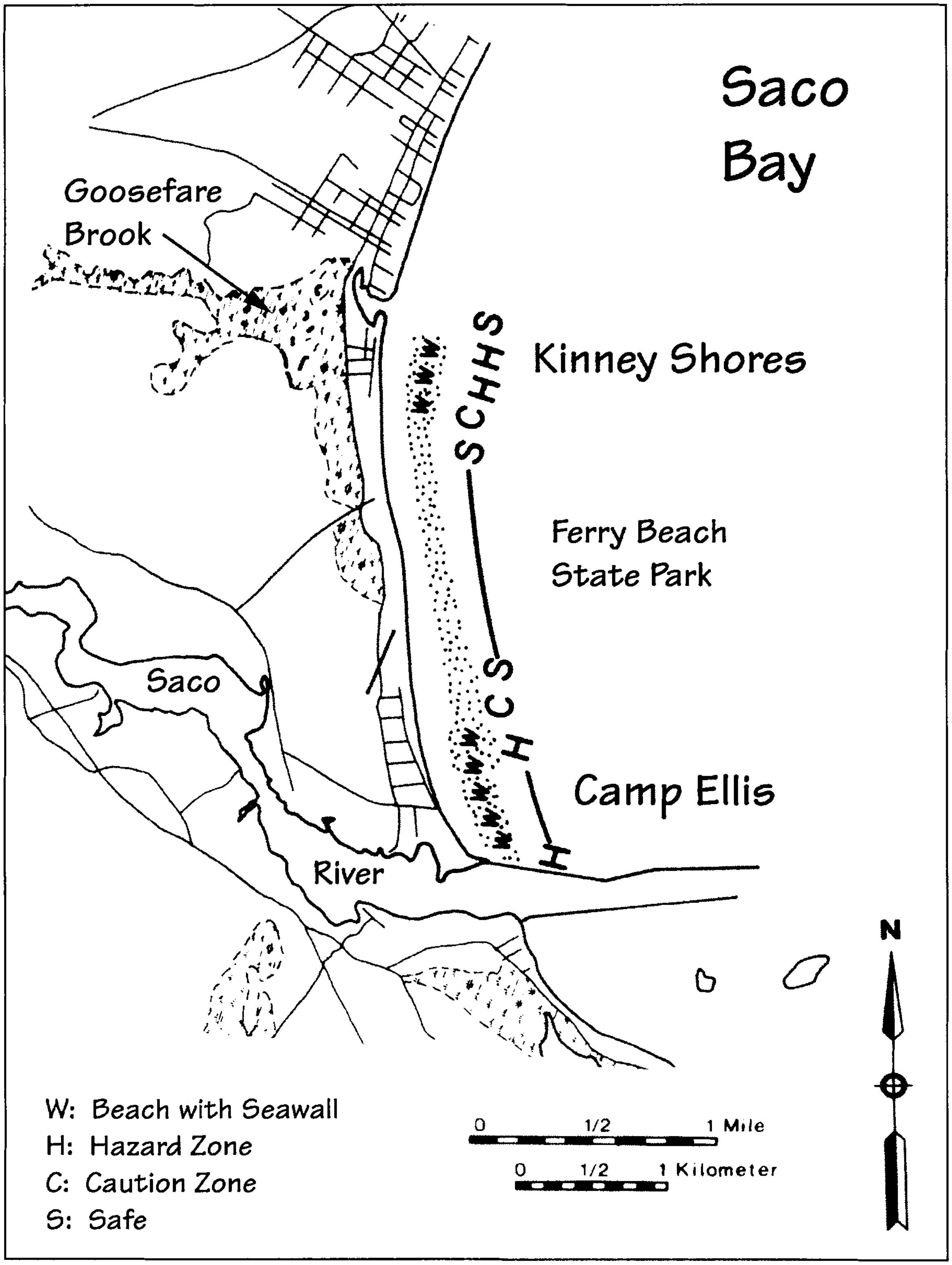


Figure 16. Kinney Shores and Camp Ellis located on the coast of Saco, Maine (after Kelley *et al.* 1989). Two jetties, 2,030 m and 1,463 m long, extend from the north and south side of the Saco River mouth.

refraction before reaching Camp Ellis and waves reflect off the jetty allegedly increasing wave heights (Table 1; Barringer and Ten Broeck 1978; USACE 1992; Pilkey and Dixon 1996; Kelley and Anderson 2000). This has led to an on-going USACE mitigation project. The Camp Ellis Beach Erosion Study Committee estimated that 33 lots eroded between 1968 and 1998 during storms (Figure 17; Saco Bay Planning Committee 2000). Repeated attempts to mitigate the impacts of severe coastal erosion have had limited success as winter storms continue to erode the beach and dunes (Saco Bay Planning Committee 2000).

The State of Maine conducted a simplified cost-benefit analysis of policy response strategies for Camp Ellis in 1995 with a 100-year study period. The four strategies evaluated included protection measures and rolling setbacks (EPA 1995).

1. The first protection strategy involved a combination of beach nourishment along sand beaches, maintenance of existing bulkheads, and construction of new bulkheads along wetlands to prevent inland migration. A substantial amount of beach nourishment was anticipated over the next century to maintain the current shoreline position and to protect the existing structures.

2. The second protection strategy differed from the first in the addition of an initial buy-out and abandonment of the structures that are most vulnerable. This compensated setback strategy would postpone beach nourishment costs and secure a volume of sand to protect the next tier of structures from the encroaching shoreline.

3. The third strategy, similar to the SDR, assumed that regulations would prohibit all new development in areas to be affected by a change in shoreline position within the next 100 years. Existing development would be subject to a rolling setback line, which would require removal of development and restoration of the site to its natural condition, as the shoreline position moved inland to affect that development.

4. The fourth strategy assumed that rolling setbacks would apply to both existing and new development. New development would be allowed on sites at risk of a change in shoreline position, but would have to be removed once the sea inundated the site.

All values and quantities used to compute the costs and benefits are listed in Appendix B. The third and fourth strategies, which incorporate rolling setbacks, were determined to be more cost-effective than the protection of structures with beach nourishment in the first two strategies (EPA 1995). The State Planning Office concluded that the present value of prohibiting new development in hazardous locations outweighs the cost of allowing the new development to occur and then removing it should the shoreline position change (EPA 1995). This simplified cost-benefit analysis supports the hazard avoidance and retreat policy. Since 1995, however, legislation has permitted property owners with failing seawalls to protect their buildings with riprap in emergency situations (MRSA 1995).

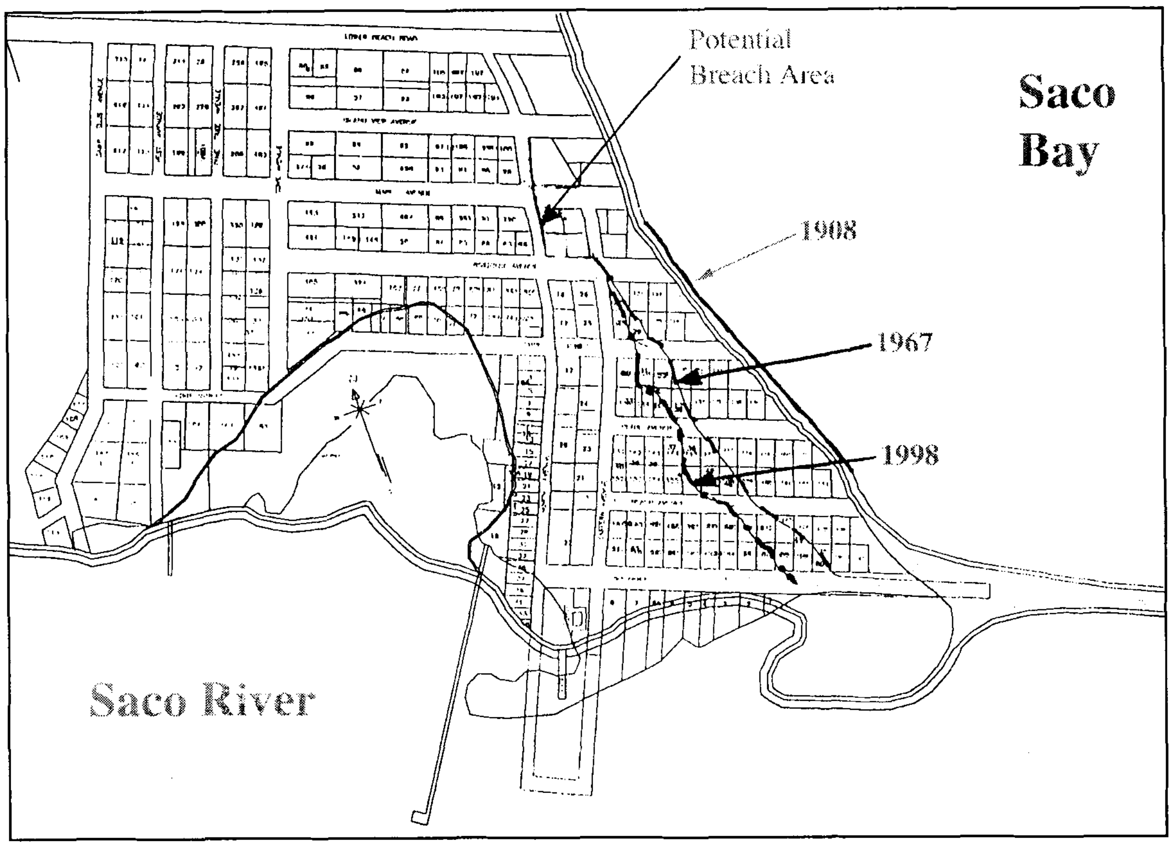


Figure 17. Erosion trend at Camp Ellis, Maine from 1908 to 1998 (Saco Bay Planning Committee 2000).

Chapter 3

DATA SOURCES AND METHODS

GIS Layers

Data Conversion

Geographic information system (GIS) vector themes were created from maps and parcel attributes to identify the beach-system environment and flood zone of claims submitted to the NFIP, as well as development permitted by the DEP. Map and lot numbers, addresses, and owner names were used to reference NFIP claims and DEP permits to individual parcels. Sand Dune Maps and generalized FIRMs delineated erosion and flood-hazard themes, respectively. Maps and parcel attributes collected for each study site, including accuracy assessments and effective dates, and methods used to convert this data into vector themes are described below.

The conversion of paper and raster maps into vector format was critical to this study. Daniels and Huxford (2001) outlined the paper-raster-vector data conversion process and primary sources of error in final vector data. The data conversion process may involve six steps.

1. Scan original paper or mylar map.
2. Identify the projection and datum used on the original map.
3. Register the raster image to the longitude and latitude projection lines on the original map.
4. Digitize features from the raster image.
5. Add attributes to the vector data file.
6. Project vector data into the desired coordinate system and datum.

Several factors may introduce error into final vector data. The primary error sources include:

1. Non-uniform shrinkage of the original map;
2. Variations in the speed of movement of the original map under the scanner;
3. Accuracy of the longitude and latitude projection lines drawn on the original map;
4. Identification of the original latitude and longitude projection lines and determination of the source datum, projection, and spheroid of the map;
5. Ability of the computer operator to accurately trace the line work on the raster image and save the data to a vector or line based file; and
6. Transformation method or program used to convert between datums, projections, and spheroid models.

The accuracy and, in one case, absence of projection lines introduced error into the vector data processed from paper and raster maps for this study. In addition, vector data obtained from various sources lacked metadata such as the datum and projection of the original maps.

Parcel Maps

The Town of Kennebunk converted its tax assessment maps from the AutoCAD drawing file format to an ArcView shapefile in 1996. The shapefile includes Goochs Beach and Kennebunk Beach. Parcel attributes, such as map, lot, owner name, land value, and building value, were associated with this shapefile. The last in-house tax assessment was completed in 1987 and adjustments for price increases were made in 1991. The parcel shapefile, without metadata, was downloaded from the website of the Town of Kennebunk (http://kennebunk.maine.org) and unzipped. The accuracy of the shapefile as well as its datum and projection were not reported.

The Town of Wells contracted Woodard and Curran, Inc. in Kennebunk to digitize and register their paper tax assessment maps. The last tax evaluation conducted by the town in the 1989/1990 fiscal year was not included in the parcel attribute table. Land and building values for Drakes Island, Wells Beach, and Moody Beach, which were updated for fiscal year 2000/2001, were photocopied in the office of the tax assessor. A parcel shapefile, without metadata, was also obtained from the Town of Wells. The accuracy, datum, and projection of the shapefile were not available.

The City of Saco contracted the James W. Sewall Company in Old Town to prepare digital parcel maps at 1:1,200 scale. AutoCAD R13 files current to April 1, 2000 for maps 1, 2, 3, 5, 6, 10, and 11 in the coastal, south section of Saco (http://www.saco maine.org/departments/assessor/maps.shtml), which cover Kinney Shores and Camp Ellis, were obtained from the City. Assessed land and building values evaluated in fiscal year 1987/1988 and current to 2000/2001 were also obtained in the form of paper copies. The seven AutoCAD files were converted to a drawing format to edit extraneous lines and join the files in Adobe Illustrator 9.0. An AutoCAD interchange file was exported. Clean and build functions of ArcInfo 8.0 were used to create a coverage from the exported file. Since the original maps lacked projection lines, a Raytheon marine global positioning system (GPS), model RN300, with 2 m accuracy and referenced to the North American Datum (NAD) of 1983, was used to locate center point coordinates of two road intersections at opposite corners of the coverage area. Based on these coordinates, Geomove, an ArcView extension, was used to project the coverage to Zone 19 of the Universal Transverse Mercator (UTM) grid. This coverage was converted into an ArcView shapefile and parcel attributes were added.

Sand Dune Maps

Coastal Sand Dune Maps were produced by the MGS in 1990 at 1:4,800 scale based on fieldwork and non-rectified aerial photographs taken in 1986. The accuracy of the maps was reported as 3.5 m (12 ft). Five maps that cover the study-site beaches in Kennebunk (Dickson 1990b), Wells (Dickson 1990c-e), and Saco (Dickson 1990a) were printed by the MGS at full scale onto mylar sheets. The James W. Sewall Company in Old Town created raster files of these mylar sheets using a large-format drum scanner. The coordinates of registration points referenced to NAD27 were converted from state plane to UTM Zone 19. These coordinates were used to register the individual raster files using the Geomove extension in ArcView. The three registered raster files for the adjacent study-site beaches in Wells did not join. The Geomove extension was used to line up the registration points, but the resultant coverage area proved to be distorted when overlayed with the parcel and flood-hazard themes. As a result, an erosion-hazard theme could not be created for Wells. Polygons of geologic environments delineated by the MGS were digitized onscreen and attribute tables were created for Kennebunk and Saco using ArcView. The MGS arbitrarily placed the shorelines offshore near the middle to low-tide position.

Sand Dune Permits

The DEP Bureau of Land and Water Quality in Augusta retains orders in their paper files that address applications for sand dune permits under the NRPA. Orders contain summary information such as applicant name, municipality, brief project description, application number, action, and date of action. This information is maintained by the DEP in an Oracle database. Site descriptions, including project locations, are included in most orders but are not stored in the database. The orders that pertain to applications for development in the sand dunes of Kennebunk and Saco between 1984 and 1998 were pulled from the paper files. Names and addresses of applicants, project locations, proposed development types, and dates of approval or denial were recorded. Since a relatively large number of orders for development in the sand dunes of Wells lacked project addresses and the registered sand dune maps for Drakes Island, Wells Beach, and Moody Beach were distorted, the town was removed from this study. When an order could not be matched with a parcel based on the applicant name and description of project location, the application filed in archives was requested. Archived applications for sand dune permits include detailed applicant and project information including map and lot numbers. Permit data was added to the parcel attribute tables for Kennebunk and Saco based on applicant names and addresses.

FIRMs

FEMA scanned hardcopy FIRMs to produce vector themes of flood risks. The vector files include V zones. Since the files were developed to overlay maps according to national standards at a scale of 1:24,000, the accuracy is limited to 12 m (40 ft). These digital files, referred to as Q3 Flood Data, as well as metadata are available from the Map Service Center of FEMA. Q3 Disk 23, which includes Maine, New Hampshire, and Vermont, was obtained from the Map Service Center (FEMA 1998c). The ArcInfo export file for York County, Maine was created in September 1998. The effective dates of the FIRMs used to create the Q3 Flood Data were July 15, 1992 for Kennebunk (FEMA 1992a) and Wells (FEMA 1992b), and March 16, 1998 for Saco (FEMA 1998a). The FIRM for Wells was updated since the creation of the Q3 Flood Data. The new effective date of the FIRM for Wells is January 16, 2003 (FEMA 2003). The lack of GIS data for the updated FIRM reinforces the decision to remove Wells from this study. The export file for York County was converted to a coverage, referenced to NAD27, and projected to UTM Zone 19 using ArcInfo. An ArcView shapefile of the V zone was then created from the coverage for the determination of flood-hazard areas in Kennebunk and Saco.

NFIP Claims

Data on NFIP claims and dollars paid to policyholders in Maine communities between 1978 and 1998 were obtained from the Floodplain Management Coordinator with the Maine State Planning Office. This claim information is legally privileged, confidential, and protected under the Privacy Act of 1974 (United States Code 1974). The Privacy Act attempts to regulate the collection, maintenance, use, and dissemination of personal information by federal executive branch agencies. The policy objective relevant to this study restricts disclosure of personally identifiable records maintained by agencies. No individual identifiers were used in this report and figures were laid out to reduce the possibility of matching the analysis of NFIP claims with other records to reconstruct individually identifiable records. Claim dates and amount paid for buildings in the beach system were added to the attribute tables of the parcel themes for Kennebunk and Saco based on local addresses of policyholders. Payments were not converted to present values. Some addresses associated with claims were incomplete or for permanent residences outside of Maine. The number of claims not associated with parcels will be presented in the next chapter.

GIS Analysis

Parcel themes that include data on NFIP claims and sand dune permits were overlayed with the erosion and flood-hazard themes in ArcView. The GeoMove extension was used to correct displacements in the x and y directions. Parcel and erosion-hazard themes were aligned with the flood-hazard theme based on distinct features. The Query Builder was used to select parcels from the study-site beaches in Kennebunk and Saco based on the indicators used to evaluate the two hypotheses for this study. Logical expressions were entered to locate parcels, with respect to the erosion and flood-hazard themes, based on (1a) building presence, (1b) NFIP claims and payments for building losses (1978-1998), (2a) approved sand dune permits (1984-1998), and (2b) claims submitted after permits were approved. Layouts were created from the results of these queries to determine if (1) development on or seaward of frontal dunes or in V zones is at greatest risk of damages, and (2) the setback policy of the SDR has reduced the risk of damages within the high-hazard areas. The small scale of the flood-hazard theme (1:24,000) limited the accuracy of this analysis to 12 m (40 ft), but the error is within the dimensions of most single lots.

Chapter 4

RESULTS

Hypothesis 1

Two indicators were used to determine whether development on or seaward of frontal dunes or in V zones is at greater risk of damages than development in more landward locations. First, the distribution of developed and undeveloped lots in the Kennebunk and Saco beach systems was observed. Of the 299 lots in the Kennebunk beach system, 17 (6%) undeveloped lots lie within or intersect the high-hazard area, which encompasses the beaches, frontal dunes, and V zone, and 18 (6%) undeveloped lots lie in other less hazardous areas for a total of 35 (12%) undeveloped lots (Figure 18). In Saco, 78 (14%) of 546 lots are undeveloped and distributed between 43 (8%) in the high-hazard area and 35 (6%) in other less hazardous areas of the beach system (Figure 19). More than 85% of the lots on the study-site beaches are developed. Of the developed lots, a greater percentage exists outside the high-hazard areas in both Kennebunk (58%) and Saco (63%; Table 2). However, average building values are greater in high-hazard areas. The significance of these trends relative to the following NFIP claims is discussed in the next chapter.

Claims submitted to the NFIP for building losses and subsequent payments were the most critical components of the analysis of this hypothesis. More than 70% of 316 claims submitted by policyholders in Kennebunk and Saco collectively were for building losses in the beach systems between 1978 and 1998 (Table 3). Payments for these claims amounted to $1.53 million. The actual sum of beach-system payments may be greater

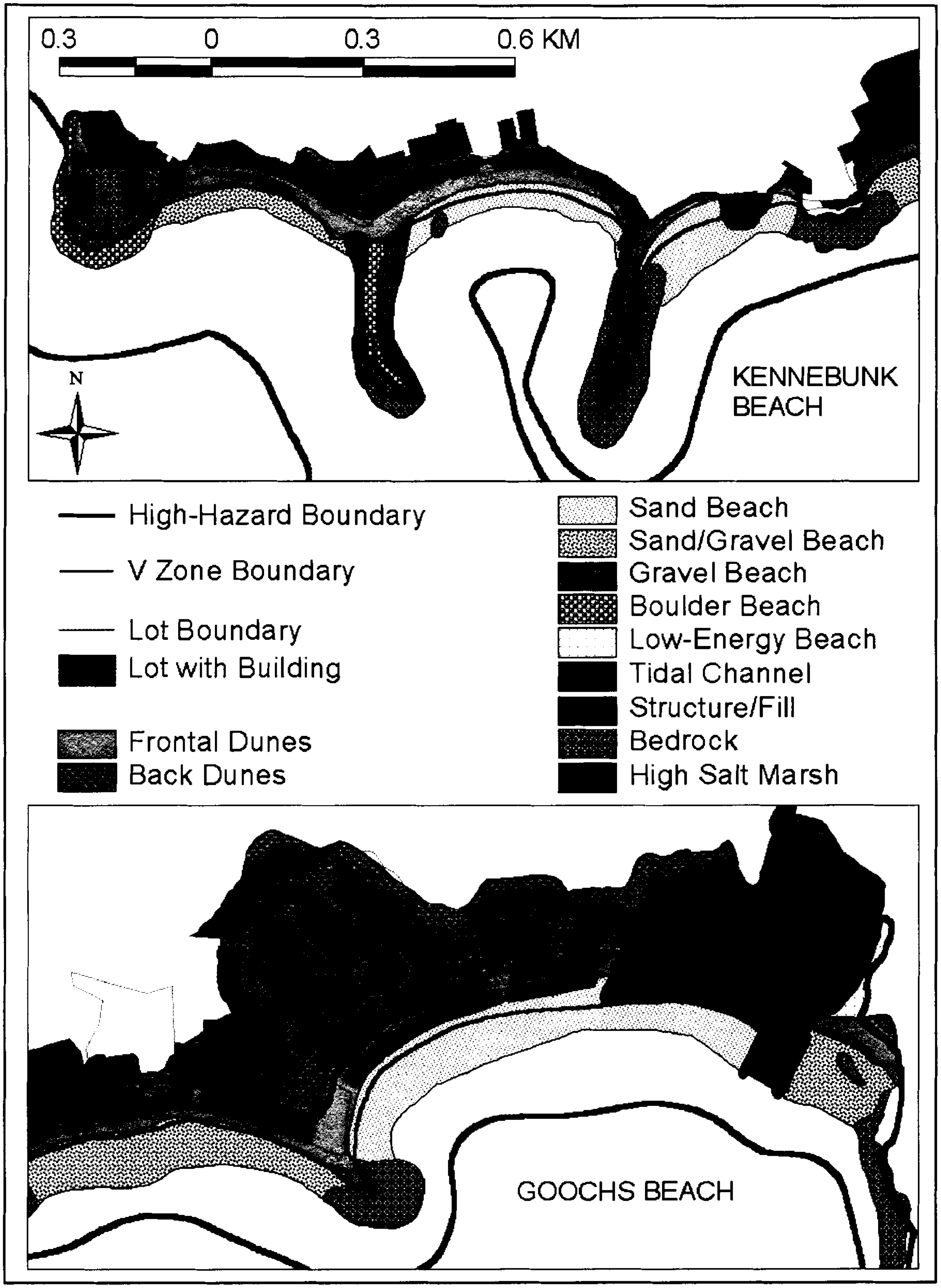


Figure 18. Developed beach-system lots in Kennebunk, Maine. Thirty-five (12%) of 299 lots in the beach system are undeveloped. The high-hazard area contains 17 (6%) lots without buildings, while other beach-system areas contain 18 (6%) undeveloped lots.

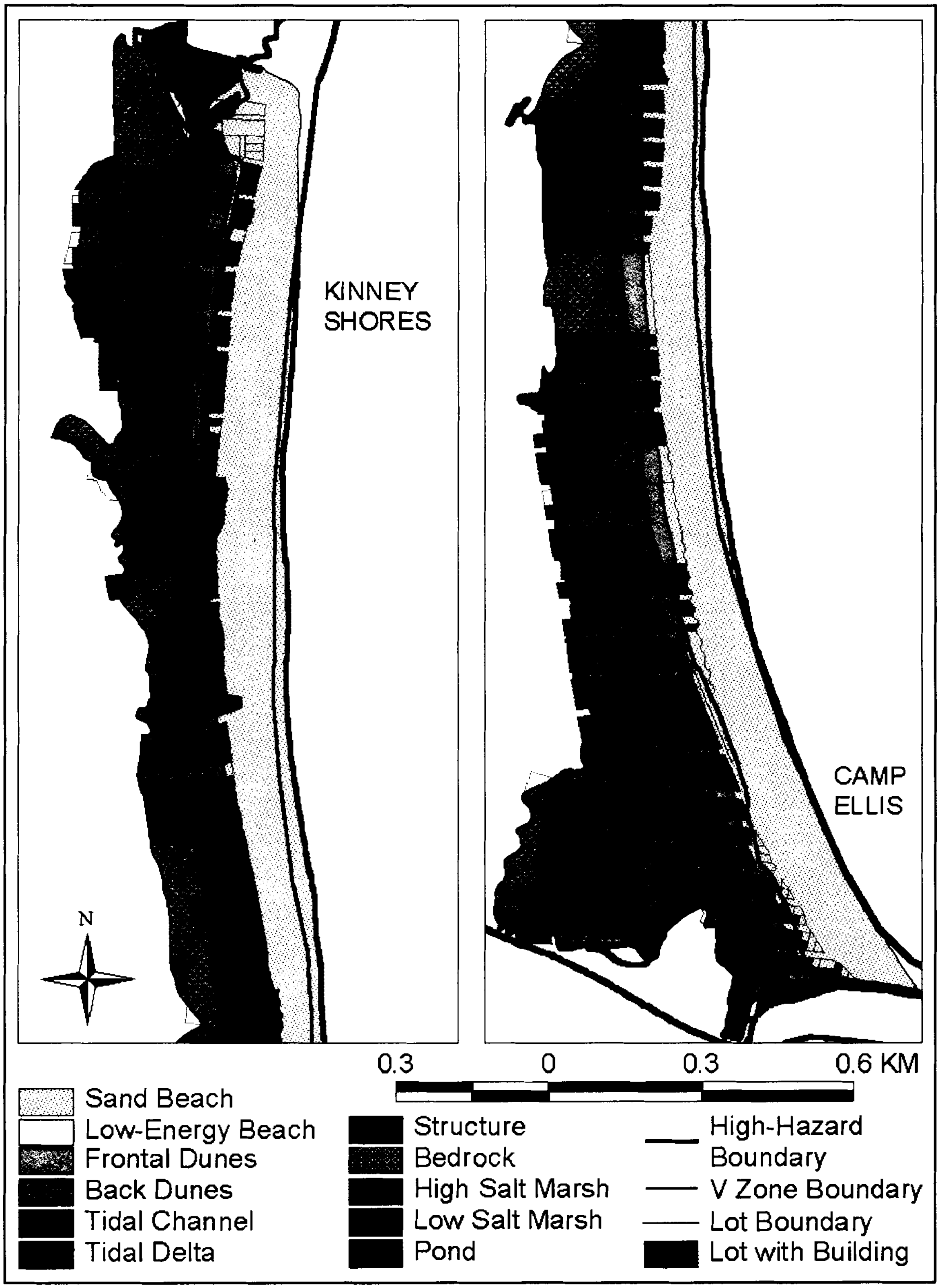


Figure 19. Developed beach-system lots in Saco, Maine. Seventy-eight (14%) of 546 lots in the beach system are undeveloped. The high-hazard area contains 43 (8%) lots without buildings, while other areas of the beach system contain 35 (6%) undeveloped lots.

Table 2. Building distribution in the developed beach systems of Kennebunk and Saco, Maine. High hazard refers to the frontal dunes, beaches, and V zone. Building values were assessed for tax purposes in 1987.

Beach System	Developed Lots		Assessed Building Value		
	Total	Percentage of Beach System	Total (Million)	Percentage of Beach System	Average
Kennebunk	**264**		**$27.0**		**$102,300**
High Hazard	111	42%	$12.1	45%	$109,000
Other	153	58%	$14.9	55%	$97,500
Saco	**468**		**$27.0**		**$57,700**
High Hazard	175	37%	$13.6	50%	$78,000
Other	293	63%	$13.4	50%	$45,600

Table 3. National Flood Insurance Program claims submitted by policyholders for building losses between 1978 and 1998 in Kennebunk and Saco, Maine. Claims with out-of-state or no address records are listed as unknown. Claims in the beach systems with complete address records, indicated in parentheses, were mapped.

Municipality	NFIP Claims		Building Payments	
	Total	Percentage of Municipality	Total	Percentage of Municipality
Kennebunk	**158**		**$1,150,000**	
Beach System	124 (96)	78% (61%)	$814,000 ($652,000)	71% (57%)
Other	15	10%	$206,000	18%
Unknown	19	12%	$127,000	11%
Saco	**158**		**$1,060,000**	
Beach System	110 (96)	70% (61%)	$717,000 ($626,000)	68% (59%)
Other	29	18%	$120,000	11%
Unknown	19	12%	$219,000	21%

due to the 19 (12%) of 158 claims in each municipality that were not associated with a specific environment. These claims were associated with out-of-state or incomplete address records. Beach-system claims with complete address records were mapped to determine the area of greatest risk within these environments. Within each developed beach system, 79 (82%) of 96 claims were submitted by policyholders for building losses mapped in high-hazard areas (Table 4; Figures 20 and 21). Recall that approximately 60% of the developed lots in the Kennebunk and Saco beach systems lie outside high-hazard areas. Payments for buildings in high-hazard areas ranged from 90% of the beach system in Kennebunk to 95% in Saco, which when combined, exceed $1.3 million (Table 4). Average assessed building values in high-hazard areas are greater than values in other beach-system areas by a factor of 1.1 in Kennebunk and 1.7 in Saco (Table 2). However, average payments for buildings in high-hazard areas exceeded those in the other beach-system areas in Kennebunk and Saco by 2.0 and 5.6, respectively, despite some repeat claims in high-hazard areas that were not paid (Table 4).

Table 4. National Flood Insurance Program claims and payments to policyholders for building losses between 1978 and 1998 mapped in the beach systems of Kennebunk and Saco, Maine. High hazard refers to the frontal dunes, beaches, and V zone.

Beach System	NFIP Claims		Building Payment			
	Total	Percentage of Beach System	Total	Percentage of Beach System	Lots	Average
Kennebunk	**96**		**$652,000**		**49**	**$13,300**
High Hazard	79	82%	$585,000	90%	40	$14,600
Other	17	18%	$67,500	10%	9	$7,500
Saco	**96**		**$783,000**		**54**	**$14,500**
High Hazard	79	82%	$741,000	95%	41	$18,100
Other	17	18%	$41,800	5%	13	$3,220

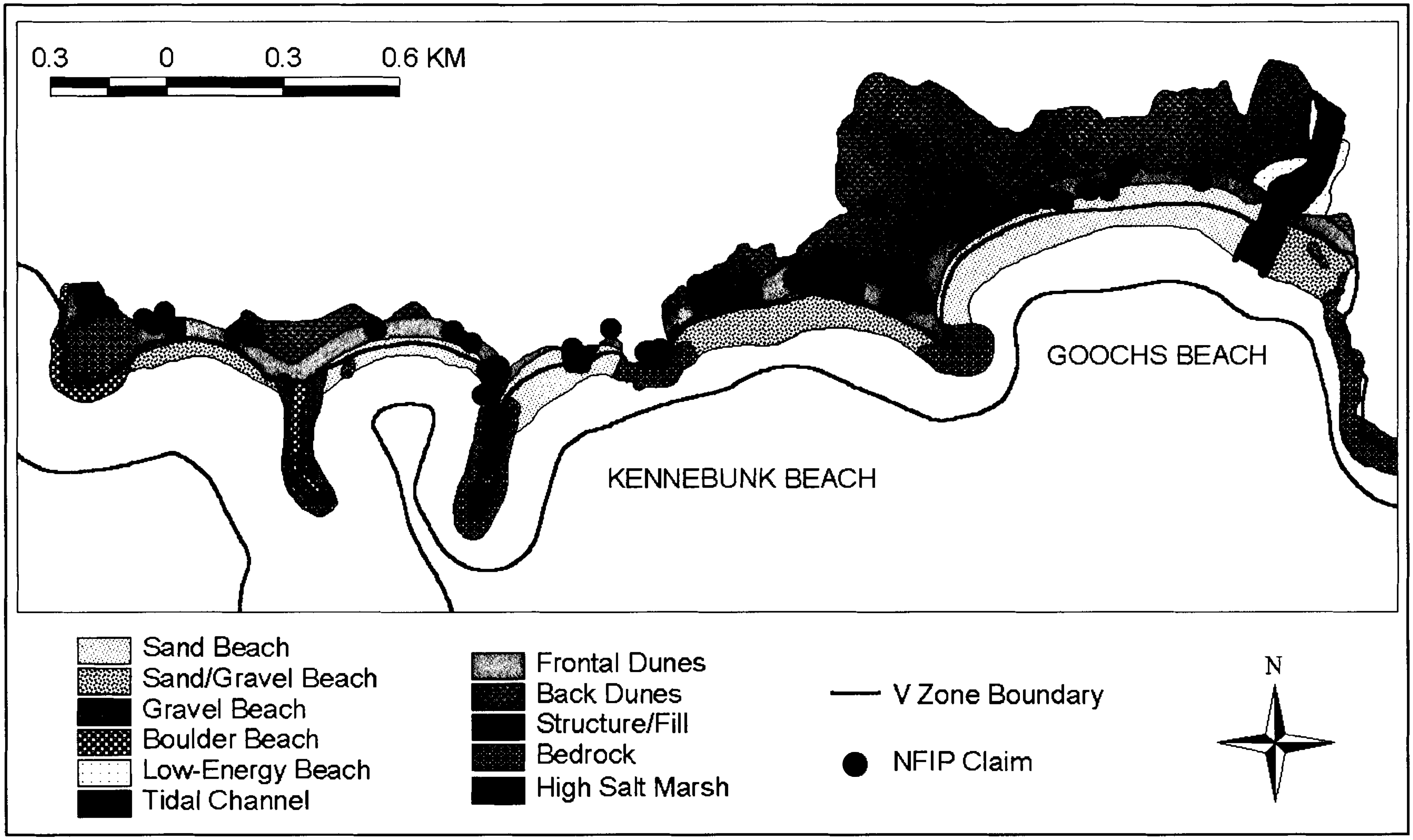


Figure 20. National Flood Insurance Program claims for building losses between 1978 and 1998 mapped in the beach system of Kennebunk, Maine. Policyholders with lots in the high-hazard area submitted 79 (82%) of 96 claims mapped in the beach system.

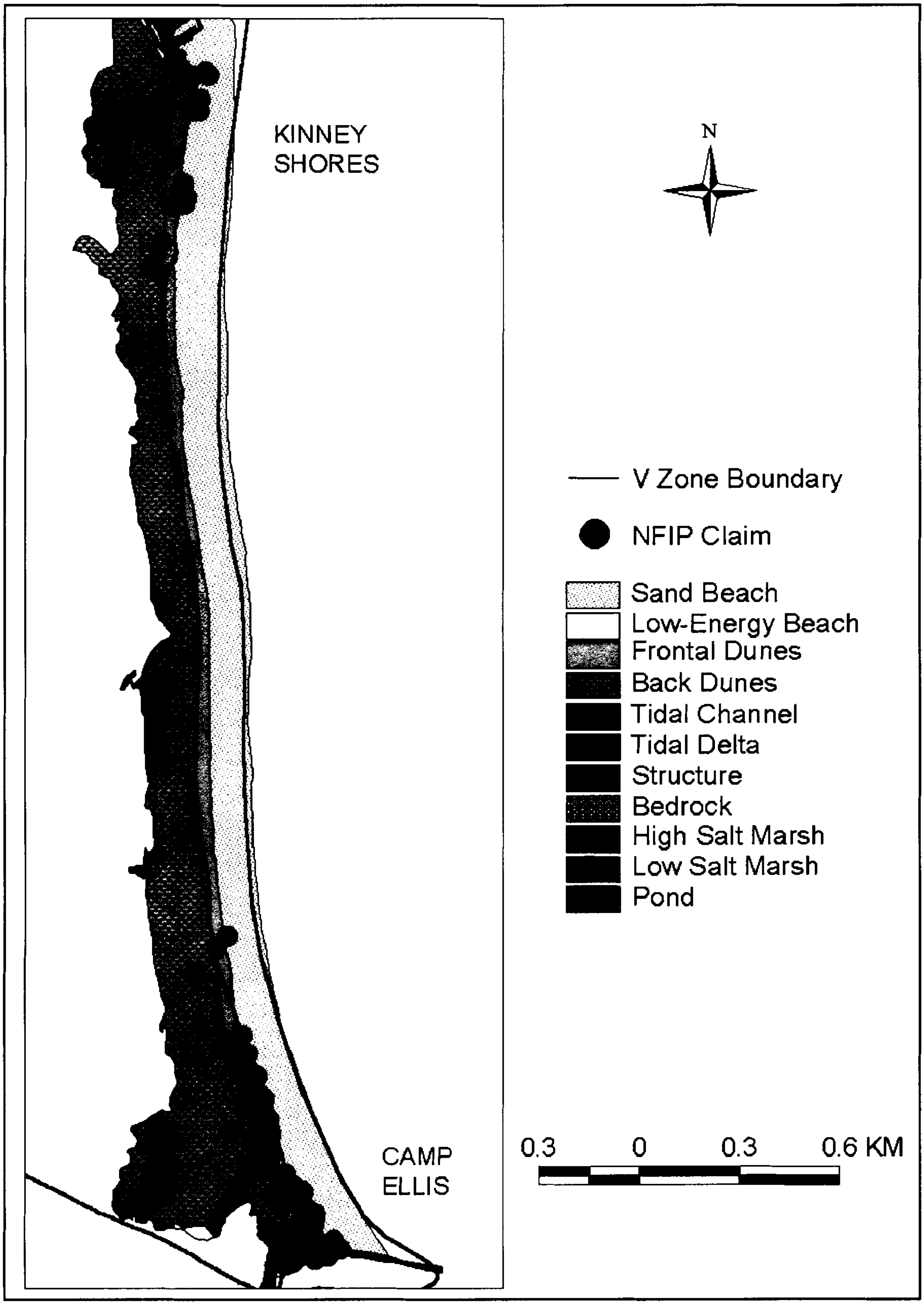


Figure 21. National Flood Insurance Program claims for building losses between 1978 and 1998 mapped in the beach system of Saco, Maine. Policyholders with lots in the high-hazard area submitted 79 (82%) of 96 claims mapped in the beach system.

Hypothesis 2

Development permitted in the beach systems of Kennebunk and Saco between 1984 and 1998 was investigated to determine if the setback policy of the SDR has reduced the risk of damages within high-hazard areas. Although 6 (50%) of 12 and 31 (30%) of 102 sand dune permits for development in Kennebunk and Saco, respectively, could not be mapped due to incomplete address records, the mapped permits demonstrate that buildings on lots that intersect high-hazard areas were constructed, added to, replaced, and relocated (Table 5). However, none of the newly constructed or replaced buildings experienced losses that were claimed. Two buildings were relocated and five additions were constructed after policyholders submitted claims to the NFIP. Only two claims were submitted after permits were approved to place fill and construct a gravel parking area.

Table 5. Development permitted between 1984 and 1998 in the beach systems of Kennebunk and Saco, Maine. Permits with complete address records were mapped. High hazard refers to the frontal dunes, beaches, and V zone.

PERMIT TYPE	KENNEBUNK			SACO		
	Total	**Mapped**	**High Hazard**	**Total**	**Mapped**	**High Hazard**
New Building	6	4	0	24	14	5
Replace Building	0	0	0	5	5	2
Relocate Building	1	1	1	3	2	2
Addition	2	1	0	41	34	10
Fill	0	0	0	5	4	2
Sand Movement	1	0	0	0	0	0
Seawall Repair	2	0	0	6	3	3
Septic System	0	0	0	4	2	0
Road/Driveway/ Parking Area	0	0	0	12	4	2
Walkway	0	0	0	1	1	0
Subdivide Lot	0	0	0	1	1	1
Total	**12**	**6**	**1**	**102**	**71**	**27**

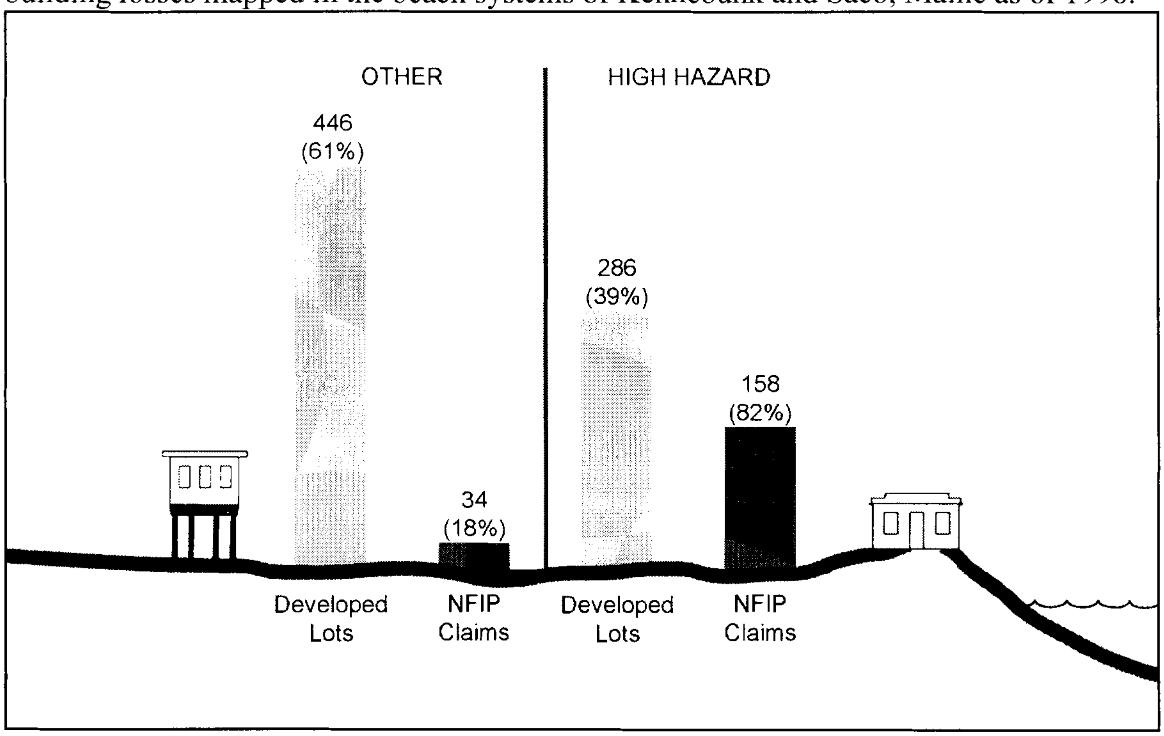
Chapter 5

DISCUSSION

The developed sand beaches in southwestern Maine are vulnerable to a variety of hazards including storms, flooding, and erosion. Maine implemented the SDR in 1983 to protect sand dunes and mitigate the loss of coastal property as well as lives. High-hazard areas within the beach systems of Maine are currently identified using NFIP FIRMs and Coastal Sand Dune Maps produced by the MGS. Development in these flood and erosion-hazard areas is subject to the regulations of the SDR. The SDR incorporate all of the regulations studied by Bernd-Cohen and Gordon (1999), which were determined to be the most effective hazard mitigation and policy tools. The purpose of this study was to determine if the high-hazard areas defined by the SDR are appropriate for the development regulations and if these regulations have been effective.

It was expected that development on or seaward of frontal dunes or in V zones is at greater risk of damages than development in other areas of beach systems. While 61% of developed lots exist outside high-hazard areas in the study-site beaches and undeveloped lots are evenly distributed, 82% of NFIP claims were submitted for building losses in high-hazard areas between 1978 and 1998 (Figure 22). Payments for these building losses exceeded 90% of the total beach-system payments. These payments reflect more than higher building values. Average assessed building values in developed high-hazard areas exceed average building values in other developed beach-system areas by a factor of 1.1 and 1.7 in Kennebunk and Saco, respectively, but payments are 2.0 to 5.6 times greater in high-hazard areas. The magnitude of payments for high-hazard buildings is a factor of 0.9 to 3.9 greater than payments for other buildings. This is an underestimate due to the greater number of repetitive-loss properties in high-hazard areas that are not eligible for payments from the NFIP. Since NFIP coverage is optional for most property owners, the number of claims is also underestimated. Unfortunately, the number of policies in force during the study period is not available. The number and value of buildings and NFIP claims served as useful indicators to support the hypothesis that the degree of risk is greater in high flood and erosion-hazard areas than other beach-system areas.

Figure 22. Level of development and National Flood Insurance Program claims for building losses mapped in the beach systems of Kennebunk and Saco, Maine as of 1998.



The setback regulations of the SDR were expected to reduce the risk of damages in high-hazard areas. Prior to implementation of the SDR, many buildings in V zones and on frontal dunes, especially in Camp Ellis, fell into the sea. Sand dune permits that were mapped reveal that new buildings and additions were constructed between 1984 and 1998 on lots that intersect high-hazard areas. None of the DEP orders for these permits reported that the lots were located in V zones or on frontal dunes, but some of the orders did not report a beach-system environment. It is possible that the new buildings and additions were constructed landward of the high-hazard area on these lots. No claims were submitted by policyholders to the NFIP for losses to these buildings as of 1998, however some of the additions were constructed after building losses occurred. Only two claims followed construction of permitted development. A gravel parking area was constructed and fill was placed on two lots prior to building losses. Buildings in high-hazard areas have appropriately been relocated after policyholders submitted claims for significant losses. Relocated buildings and claims submitted only for losses to buildings constructed prior to implementation of the SDR support the hypothesis that the setback regulations have reduced the risk of beach-system damages.

The type of development permitted since the implementation of the SDR and state of permit records indicate that the Coastal Sand Dune Maps and permit process need to be investigated. It would be beneficial to delineate updated sand dune boundaries in GIS format from recent aerial photographs, which have been geometrically rectified in at least two dimensions to remove significant distortions. The Coastal Sand Dune Maps currently in use were produced by the MGS in 1990 based on aerial photographs taken in 1986, which were not rectified. Beach-system environments, flood zones, lots, and buildings could be digitized at the same scale on the rectified images. Dissemination of this type of sand dune map would enable property owners and permit agents to easily identify the correct environment of proposed development. Permitted development could also be tracked more accurately with either map and lot numbers or GPS coordinates using the GIS database. Updated maps, permit process, database, and tracking system would facilitate future studies of policy outcomes and hazard mitigation.

In conclusion, the number of buildings vulnerable to coastal hazards must be reduced not increased. The reduction of vulnerability to hazards has been supported as a successful strategy to mitigate impacts on beach systems, property, and life. Regulations and other planning tools are often used to relocate hazardous development as well as prevent the construction of new development in hazardous areas. Maine should not allow variances to their successful regulations. Buildings destroyed in high-hazard areas should not be rebuilt and new buildings should not be constructed in these hazardous areas. In the future, more emphasis should be placed on local land-use plans to encourage the relocation of public infrastructure and private development. Finally, the public should be educated about coastal hazards and mitigation to prevent property-rights citizen groups like Save Our Shores from supporting misinformed legislative initiatives, which may ultimately lead to the destruction of property and demise of recreational beaches.

REFERENCES

Anonymous. 2003. Let State Board Make the Rules, but Dunes are Worth Protecting. *Portland Press Herald* (April 13, 2003): 4C. http://www.pressherald.com.

Appendini, C. M., and Fischer, D. W. 1998. Hazard Management Planning for Severe Storm Erosion. *Shore and Beach* 66(4): 5-8.

Barber, D. 1995. *Holocene Depositional History and Modern Sand Budget of Inner Saco Bay, Maine.* Orono, ME: Department of Geological Sciences, University of Maine. M.S. thesis. 178 pp.

Barringer, R., and Ten Broeck, C. W. 1978. *Policy Recommendations for Reducing Coastal Storm Damages.* Maine Land and Water Resources Council. 33 pp.

Beatley, T., Brower, D. J., and Schwab, A. K. 2002. *An Introduction to Coastal Zone Management.* Washington, DC: Island Press. 2nd edition. 285 pp.

Bernd-Cohen, T., and Gordon, M. 1999. State Coastal Program Effectiveness in Protecting Natural Beaches, Dunes, Bluffs, and Rocky Shores. *Coastal Management* 27: 187-217.

Bertness, M. D. 1999. *The Ecology of Atlantic Shorelines.* Sunderland, MA: Sinauer Associates. 417 pp.

Burby, R. J., and Nelson, A. C. 1991. Local Government and Public Adaptation to Sea Level Rise. *Journal of Urban Planning and Development* 117(4): 140-153.

Bush, D. M., Pilkey, O. H. Jr., and Neal, W. J. 1996. *Living by the Rules of the Sea.* Durham, NC: Duke University Press. 179 pp.

Charlier, R. H., and DeMeyer, C. P. 1998. *Coastal Erosion: Response and Management (Lecture Notes in Earth Sciences).* Germany: Springer-Verlag. 343 pp.

Coch, N. K. 1993. Hurricane Hazards Along the Northeastern Atlantic Coast of the United States. *Journal of Coastal Research* 12(Coastal Hazards Special Issue): 115-147.

Cohen, T. 2002a. DEP Proposal Would Make it Harder to Rebuild on Dunes. *Portland Press Herald* (August 14, 2002): 1A. http://www.pressherald.com.

Cohen, T. 2002b. Angry Landowners Protest Proposal to Tighten Dune Rules. *Portland Press Herald* (August 15, 2002): 1A. http://www.pressherald.com.

Committee on Coastal Erosion Zone Management, Water Science and Technology Board, Marine Board, Commission on Engineering and Technical Systems, and National Research Council. 1990. *Managing Coastal Erosion.* Washington, DC: National Academy Press. 182 pp.

Cowger, S. 2003. *An Act Concerning the Adoption of Coastal Sand Dune Rules.* 121st Maine Legislature, First Regular Session: Legislative Document 696. http://www.mainelegislature.org.

Culliton, T. J. 1998. Population: Distribution, Density and Growth. *State of the Coast Report.* Silver Springs, MD: National Oceanic and Atmospheric Administration. http://state_of_coast.noaa.gov/bulletins/html/pop_01/pop.html.

Daniels, R. C., and Huxford, R. H. 2001. An Error Assessment of Vector Data Derived from Scanned National Ocean Service Topographic Sheets. *Journal of Coastal Research* 17(3): 611-619.

Davis, R. E., and Dolan, R. 1993. Nor'easters. *American Scientist* 81: 428-439.

DEP. 1983. *Chapter 355: Coastal Sand Dune Rules.* Augusta, ME: Department of Environmental Protection, Bureau of Land and Water Quality.

DEP. 1988. *Chapter 355: Coastal Sand Dune Rules.* Augusta, ME: Department of Environmental Protection, Bureau of Land and Water Quality.

DEP. 1993. *Chapter 355: Coastal Sand Dune Rules.* Augusta, ME: Department of Environmental Protection, Bureau of Land and Water Quality. DEPLW-10. http://www.state.me.us/sos/cec/rcn/apa/06/chaps06.htm.

DEP. 2003. *Chapter 355: Coastal Sand Dune Rules.* Augusta, ME: Department of Environmental Protection, Bureau of Land and Water Quality. http://www.state.me.us/dep/blwq/rules/CH355%20June%205%20final.pdf.

Dickson, S. M. 1990a. *Coastal Sand Dune Map: Camp Ellis and Ferry Beaches, Saco, Maine.* Augusta, ME: Maine Geological Survey. Open file 90-2. 1:4,800 scale.

Dickson, S. M. 1990b. *Coastal Sand Dune Map: Kennebunk Beaches, Kennebunk, Maine.* Augusta, ME: Maine Geological Survey. Open file 90-11. 1:4,800 scale.

Dickson, S. M. 1990c. *Coastal Sand Dune Map: Drakes Island and Laudholm Beaches, Wells, Maine.* Augusta, ME: Maine Geological Survey. Open file 90-5. 1:4,800 scale.

Dickson, S. M. 1990d. *Coastal Sand Dune Map: Wells Beach, Wells, Maine.* Augusta, ME: Maine Geological Survey. Open file 90-21. 1:4,800 scale.

Dickson, S. M. 1990e. *Coastal Sand Dune Map: Moody Beach, Wells, Maine*. Augusta, ME: Maine Geological Survey. Open file 90-13. 1:4,800 scale.

Dolan, R., and Davis, R. E. 1992. An Intensity Scale for Atlantic Coast Northeast Storms. *Journal of Coastal Research* 7(1): 249-256.

Dunn, S., Friedman, R., and Baish, S. 2000. Coastal Erosion: Evaluating the Risk. *Environment* 42(7): 36-45.

EPA. 1995. *Anticipatory Planning for Sea-Level Rise Along the Coast of Maine*. EPA 230-R-95-900.

Esnard, A. M., Brower, D., and Bortz, B. 2001. Coastal Hazards and the Built Environment on Barrier Islands: A Retrospective View of Nags Head in the Late 1990s. *Coastal Management* 29: 53-72.

FEMA. 1982. *Flood Insurance Study: Town of Kennebunk, Maine*. National Flood Insurance Program. Community: Kennebunk, Twn/York Co. Map Service Center Product 230151S. http://store.msc.fema.gov/.

FEMA. 1983. *Flood Insurance Study: Town of Wells, Maine*. National Flood Insurance Program. Community: Wells, Twn/York Co. Map Service Center Product 230158S. http://store.msc.fema.gov/.

FEMA. 1992a. *Flood Insurance Rate Map: Town of Kennebunk, Maine*. National Flood Insurance Program. Community: Kennebunk, Twn/York Co. Panels 14 and 15 of 15. Map Service Center Items 2301510014D and 2301510015C. http://store.msc.fema.gov/.

FEMA. 1992b. *Flood Insurance Rate Map: Town of Wells, Maine*. National Flood Insurance Program. Community: Wells, Twn/York Co. Panels 7, 8, and 9 of 9.

FEMA. 1995. *Guidelines and Specifications for Wave Elevation Determination and V Zone Mapping*. National Flood Insurance Program. http://www.fema.gov/mit/tsd/dl_vzn.htm.

FEMA. 1998a. *Flood Insurance Rate Map: City of Saco, Maine*. National Flood Insurance Program. Community: Saco, Cty/York Co. Panels 27, 28, and 29 of 35. Map Service Center Items 2301550027C, 2301550028C, and 2301550029C. http://store.msc.fema.gov/.

FEMA. 1998b. *Flood Insurance Study: City of Saco, Maine*. National Flood Insurance Program. Community: Saco, Cty/York Co. Map Service Center Product 230155S. http://store.msc.fema.gov/.

FEMA. 1998c. *Q3 Flood Data: Disk 23 - Maine, New Hampshire, Vermont.* National Flood Insurance Program. Map Service Center Item Q3DISK23. http://store.msc.fema.gov.

FEMA. 2000. *Coastal Construction Manual.* NFIP Publication FEMA-55. http://www.fema.gov/nfip/addread.shtm.

FEMA. 2001. *Answers to Questions About the National Flood Insurance Program.* NFIP Publication FEMA-387. http://www.fema.gov/nfip/qanda.shtm.

FEMA. 2003. *Flood Insurance Rate Map: Town of Wells, Maine.* National Flood Insurance Program. Community: Wells, Twn/York Co. http://store.msc.fema.gov/.

Fish, J. 2003a. Beach Owners Ease Criticism of Dune Rules. *Portland Press Herald* (March 7, 2003): 1B. http://www.pressherald.com.

Fish, J. 2003b. Lawmakers Let BEP Set Dune Rules. *Portland Press Herald* (April 9, 2003): 1B. http://www.pressherald.com.

Fitzgerald, D. M., Van Heteren, S., and Montello, T. M. 1994. Shoreline Processes and Damage Resulting from the Halloween Eve Storm of 1991 along the North and South Shores of Massachusetts Bay, U.S.A. *Journal of Coastal Research* 10(1): 113-132.

Griggs, G. B. 1986. Reconstruction or Relocation: Viable Approaches for Structures in Areas of High Coastal Erosion. *Shore and Beach* 54: 8-16.

Hanson, H., and Lindh, G. 1993. Coastal Erosion: An Escalating Environmental Threat. *Ambio* 22(4): 188-195.

Heinz Center. 2000. *Evaluation of Erosion Hazards.* Washington, DC: H. John Heinz III Center for Science, Economics and the Environment. 205 pp. http://www.heinzctr.org.

Heinz Center. 2003. *The Coastal Zone Management Act: Developing a Framework for Identifying Performance Indicators.* Washington, DC: H. John Heinz III Center for Science, Economics and the Environment. 88 pp. http://www.heinzctr.org.

Heinze, H. W. 2001. *Anthropogenic Influences and Meteorological Effects: How They are Changing the Sand Beaches in Southern Maine.* Orono, ME: Department of Geological Sciences, University of Maine. M.S. thesis. 205 pp.

Hershman, M. J., Good, J. W., Bernd-Cohen, T., Goodwin, R. F., and Pogue, V. P. P. 1999. The Effectiveness of Coastal Zone Management in the United States. *Coastal Management* 27: 113-138.

Kelley, J. T. 1987. An Inventory of Coastal Environments and Classification of Maine's Glaciated Shoreline. *Glaciated Coasts* (Chapter 6): 151-176. Academic Press.

Kelley, J. T., and Anderson, W. A. 2000. The Maine Shore and the Army Corps: A Tale of Two Harbors, Wells and Saco, Maine. *Maine Policy Review* 20: 20-34.

Kelley, J. T., Belknap, D. F., Fitzgerald, D. M., Barber, D. C., Dickson, S. M., van Heteren, S., Fink, L. K., and Manthorp, P. A. 1995. *A Sand Budget for Saco Bay, Maine*. Augusta, ME: Maine Geological Survey. 59 pp. Open file 95-1.

Kelley, J. T., Kelley, A. R., and Pilkey, O. H. Sr. 1989. *Living with the Coast of Maine*. Durham, NC: Duke University Press. 174 pp.

Kocin, P. J., and Uccellini, L. W. 1990. Snowstorms along the Northeastern Coast of the United States: 1955 to 1985. *Meteorological Monographs* 22(44): 211-220.

Lemoine, D. 2003. *An Act to Amend the Sand Dune Laws*. 121st Maine Legislature, First Regular Session: Legislative Document 1276. http://www.mainelegislature.org.

Mailhot, M. P. 2000. *A New England Tropical Cyclone Climatology 1938-2000: Direct Hits and Near Misses II*. Westbrook, ME: EMA Storm Coordination Center. http://home.maine.rr.com/mailhot/netrop.html.

MRSA. 1975. *Alteration of Coastal Wetlands*. Title 38 (Article 5): § 417-478. http://janus.state.me.us/legis/statutes/38/title38ch3sec0.html.

MRSA. 1987. *Protection of Natural Resources*. Title 38 (Article 5-A): § 480-A *et. seq*. http://janus.state.me.us/legis/statutes/38/title38ch3sec0.html.

MRSA. 1995. *Emergency Actions to Protect Threatened Property*. Title 38 (Article 5-A): § 480-W. http://janus.state.me.us/legis/statutes/38/title38sec480-W.html.

MRSA. 1999. *Reconstruction in V-Zone*. Title 38 (Article 5-A): § 480-E(9). http://janus.state.me.us/legis/statutes/38/title38sec480-E.html.

Miller, G. T. 1998. *Deglaciation of Wells Embayment, Maine: Interpretation from Seismic and Side-Scan Sonar Data*. Orono, ME: Department of Geological Sciences, University of Maine. M.S. thesis. 231 pp.

Mitchell, J. K. 1987. A Management-Oriented, Regional Classification of Developed Coastal Barriers. *Cities on the Beach: Management Issues of Developed Coastal Barriers*. Chicago, IL: Department of Geography, University of Chicago.

NOAA. 1975. *The Coastline of the United States*. Washington, DC. NOAA/PA 71046.

National Weather Service. 1991. *The Halloween Nor'easter of 1991: East Coast of the United States: Maine to Florida and Puerto Rico*. Silver Springs, MD: NOAA. Natural Disaster Survey Report.

Nelson, B. W. 1979. *Shoreline Changes and Physiography of Maine's Sandy Coastal Beaches*. Orono, ME: Department of Geological Sciences, University of Maine. M.S. thesis. 303 pp.

Nordstrom, K. F. 2000. *Beaches and Dunes of Developed Coasts*. New York, NY: Cambridge University Press. 338 pp.

Parsons, G. R., and Powell, M. 2001. Measuring the Cost of Beach Retreat. *Coastal Management* 29: 91-103.

Pilkey, O. H., and K. L. Dixon. 1996. *The Corps and the Shore*. Washington, DC: Island Press. 272 pp.

Pilkey, O. H., Morton, R. A., Kelley, J. T., and Penland, S. 1989. Coastal Land Loss. *Short Course in Geology: Volume 2*. Washington, DC: American Geophysical Union.

Platt, R. H. 1999. *Disasters and Democracy: The Politics of Extreme Natural Events*. Washington, DC: Island Press. 339 pp.

Saco Bay Planning Committee. 2000. *Saco Bay Regional Beach Management Plan*. Sanford, ME: Southern Maine Regional Planning Commission. http://www.smrpc.maine.org/beachplan.html#anchor.

Trembanis, A. C., Pilkey, O. H., and Valverde, H. R. 1999. Comparison of Beach Nourishment along the U.S. Atlantic, Great Lakes, Gulf of Mexico, and New England Shorelines. *Coastal Management* 27: 329-340.

USACE. 1971. *National Shoreline Study*. Washington, D.C.

USACE. 1992. *Section 111 Reconnaissance Report: Camp Ellis Beach, Saco, Maine*. Waltham, MA: New England Division.

United States Code. 1974. *Records Maintained on Individuals*. Title 5: § 552A. http://www.usdoj.gov/foia/privstat.htm.

United States Code Congressional and Administrative News. 1972. *Coastal Zone Management Act of 1972*. St. Paul, MN: West Publishing Co. 90th Congress, 2nd Session, Vol. 2. 16 USC 1451.

Ward, A. E. 1999. *Maine's Coastal Wetlands: I. Types, Distribution, Rankings, Functions and Values*. Augusta, ME: Bureau of Land and Water Quality, Department of Environmental Protection. 113 pp. DEPLW1999-13.

Wells Bay Planning Committee. 2002. *Wells Bay Regional Beach Management Plan: Final Draft*. Sanford, ME: Southern Maine Regional Planning Commission. http://www.smrpc.maine.org/beachplan.html#anchor.

Yohe, G. W. 1991. The Cost of Not Holding Back the Sea-Economic Vulnerability. *Ocean and Shoreline Management* 15: 233-255.

Zhang, K., Douglas, B. C., and Leatherman, S. P. 2001. Beach Erosion Potential for Severe Nor'easters. *Journal of Coastal Research* 17(2): 309-321.

Zielinski, G. A. 2002. A Classification Scheme for Winter Storms in the Eastern and Central United States with an Emphasis on Nor'easters. *Bulletin of the American Meteorological Society* 83(1): 37-51.

Appendix A

LIST OF ACRONYMS

BEP	Board of Environmental Protection
CZM	Coastal Zone Management
CZMA	Coastal Zone Management Act
DEP	Department of Environmental Protection
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
GIS	Geographic Information System
GPS	Global Positioning System
MRSA	Maine Revised Statutes Annotated
MGS	Maine Geological Survey
NAD	North American Datum
NFIP	National Flood Insurance Program
NOAA	National Oceanic and Atmospheric Administration
NRPA	Natural Resources Protection Act
SDR	Sand Dune Rules
USACE	United States Army Corps of Engineers
UTM	Universal Transverse Mercator

Appendix B

COSTS AND BENEFITS OF POLICY RESPONSE STRATEGIES FOR CAMP ELLIS

Table 6. Price and value assumptions used to compute the total costs and benefits of policy strategies for Camp Ellis (EPA 1995).

RAW DATA: Camp Ellis Case Study (PRICE & VALUE Assumptions Used to Compute Cost Benefit Analysis)		
Replacement of roads or utilities	($/linear foot)	$200.0
Wetland mitigation	($/acre)	$30,000.0
Sand for beach nourishment (upland source)	($/cubic yard)	$7.0
Concrete block seawall construction	($/linear foot)	$755.0
Annual maintenance of seawall (estimated at 5% per year)	($/linear foot)	$37.8
Average building relocation cost	($/structure)	$78,795.0
Average cost of land to relocate	($/site)	$52,500
Average site restoration cost	($/site)	$5,000
Beach recreational value (Range from Colgan study on recreational values)		
low:	($/person-day)	$6.00
high:	($/person-day)	$50.14
Development Value ($/undeveloped unit):		
0.5 meter zone:	($/undeveloped unit)	$44,857
1.0 meter zone:	($/undeveloped unit)	$36,768
2.0 meter zone:	($/undeveloped unit)	$42,637
FY92 interest rate for federal water resources projects (as cited in the US Army Corps of Engineers, Camp Ellis Beach Reconnaissance Report)		8.5%

Table 7. Aggregate quantities used to compute costs and benefits of four policy response strategies for Camp Ellis (EPA 1995).

RAW DATA: Camp Ellis Case Study (aggregate quantities used to compute costs & benefits)			Sea Level Rise Scenarios:			
			0 cm	50 cm	100 cm	200 cm
Strategies:		**UNITS:**				
OPTION #1: **Developed Area: Reactive Protection Undeveloped Area: Reactive Protection**						
costs:	Beach Nourishment	(#cubic yds/yr)	100,000	200,000	400,000	800,000
	Maintenance of Existing Bulkhead	(# feet)	5,280	5,280	5,280	5,280
	Wetland loss	(# acres)	-	0.24	21.32	51.65
	New Bulkheads Needed	(# feet)	-	682.5	14.362.5	30,574.5
benefits:	Recreation Value	(# people/yr)	98.869	98,869	98,869	98,869
	Value of Structures	(total $'s)	-	$9,419,900	$13,979,100	$15,258,200
	Aggregate Value of Land	(total $'s)	-	$28,175,800	$41,206,000	$46,032,900
	Economic Value of Land @ Risk	(total $'s)		$14,933,174	$27,963,374	$32,790,274
OPTION #2: **Developed Area: Compensated Setbacks & Reactive Protection Undeveloped Area: Reactive Protection**						
costs:	Beach Nourishment	(#cubic yds/yr)	0	200.000-20yrs	400,000-10yrs	800,000-5yrs
	Cost of Modified Development	(total $'s)	$5,591,300	$5,591,300	$5,591,300	$5,591,300
	Maintenance of Existing Bulkhead	(S/yr)	5,280	5,280	5,280	5,280
	Wetland loss	(# acres)	-	0.24	21.32	51.65
	New Bulkheads Needed	(# feet)	-	682.5	14,362.5	30,574.5
benefits:	Recreation Value	(# people/yr)	98,869	98,869	98,869	98,869
	Value of Structures	(total $'s)	-	$8,146,314	$12,705,514	$13,984,614
	Aggregate Value of Land	(total $'s)	-	$24,366,386	$37,396,586	$42,223,486
	Economic Value of Land @ Risk	(total $'s)	-	$12,914,185	$25,944,385	$30,771,285
OPTION #3: **Developed Area: Rolling Easements Undeveloped Area: Setbacks**						
costs:	Amount of Land at Risk	(# acres)	-	71	133	260
	Aggregate Value of Land	(total $'s)	-	$28,175,800	$41,206,000	$46,032,900
	Economic Value of Land @ Risk	(total $'s)	-	$14,933,174	$27,963,374	$32,790,274
	roads at risk:	(# feet)	-	12,778	22,440	24,922
	sewer lines at risk	(# feet)	-	9,617	17,767	18,951
	water lines at risk	(# feet)	-	12,201	19,118	21,105
	Prohibited Development	(# units)	-	51	72	127
	Removal of Existing Develop.	(# structures)	-	210	334	364
	Site Restoration	(# sites)	-	210	334	364
benefits:	Cost of Reactive Protection: Opt. #1	(see above description of costs avoided under Option #1)				
OPTION #4: **Developed Area: Rolling Easements Undeveloped Area: Rolling Easements**						
costs:	Amount of Land at Risk		-	71	133	260
	Aggregate Value of Land		-	$28,175,800	$41,206,000	$46,032,900
	Economic Value of Land @ Risk		-	$14,933,174	$27,963,374	$32,790,274
	roads at risk:		-	12,778	22,440	24,922
	sewer lines at risk		-	9,617	17,767	18,951
	water lines at risk		-	12,201	19,118	21,105
	Prohibited Development		-	51	72	127
	Removal of Existing Develop.		-	210	334	364
	Site Restoration		-	261	406	491
benefits:	Cost of Reactive Protection: Opt. #1	(see above description of costs avoided under Option #1)				

Table 8. Total costs and benefits of each policy response strategy for Camp Ellis (EPA 1995).

COST BENEFIT ANALYSIS: Camp Ellis Case Study			Sea Level Rise Scenarios:			
			0 cm.	50 cm.	100 cm.	200 cm.
Strategies:		**UNITS:**				
OPTION #1: **Developed Area: Reactive Protection Undeveloped Area: Reactive Protection**						
costs:	Beach Nourishment	(total $'s)	$8,232,935	$9,199,159	$11,131,606	$14,996,501
	Maintenance of Existing Bulkhead	(total $'s)	$2,347,374	$2,347,374	$2,347,374	$2,347,374
	Subtotal Costs:	(total $'s)	$10,580,310	$115,465,33	$13,478,981	$17,343,876
	Wetland loss	(total $'s)	-	$847	$75,226	$182,242
	New Bulkheads Needed	(total $'s)	-	$67,036	$1,410,696	$3,003,052
	TOTAL COSTS:	**(total $'s)**	**$10,580,310**	**$11,614,416**	**$14,964,903**	**$20,529,170**
benefits:	Recreation Value	(total $'s)	$6,976,989	$9,976,989	$6,976,989	$6,976,989
	Value of Property Protected	(total $'s)	$2,864,247	$2,864,247	$4,932,995	$5,651,142
	TOTAL BENEFITS:	**(total $'s)**	**$9,841,236**	**$9,841,236**	**$11,909,985**	**$12,628,132**
OPTION #2: **Developed Area: Compensated Setbacks & Reactive Protection Undeveloped Area: Reactive Protection**						
costs:	Beach Nourishment	(total $'s)	$0	$1,845,764	$5,076,322	$10,253,968
	Buyout Plan	(total $'s)	$5,591,300	$5,591,300	$5,591,300	$5,591,300
	Maintenance of Existing Bulkhead	(total $'s)	$2,347,374	$2,347,374	$2,347,374$	$2,347,374
	Subtotal Costs:	(total $'s)	$9,938,674	$9,784,439	$13,014,996	$18,192,643
	Wetland loss	(total $'s)	-	$847	$75,226	$182,242
	New Bulkheads Needed	(total $'s)	-	$67,036	$1,410,696	$3,003,052
	TOTAL COSTS:	**(total $'s)**	**$7,938,674**	**$9,852,321**	**$14,500,918**	**$21,377,937**
benefits:	Recreation Value	(total $'s)	$6,976,989	$6,976,989	$6,976,989$	$6,976,989
	Value of Property Protected	(total $'s)	$2,266,418	$2,266,418	$4,335,167	$5,053,314
	TOTAL BENEFITS:	**(total $'s)**	**$9,243,407**	**$9,243,407**	**$11,312,156**	**$12,030,303**
OPTION #3: **Developed Area: Rolling Easements Undeveloped Area: Setbacks**						
costs:	Value of Land at Risk	(total $'s)	-	$1,756,341	$3,288,866	$3,856,574
	Value of Infrastructure at Risk					
	roads:	(total $'s)	-	$300,573	$527,849	$586,232
	sewers:	(total $'s)	-	$226,218	$417,927	$445,778
	water:	(total $'s)	-	$287,000	$449,706	$496,375
	Prohibited Development	(total $'s)	-	$2,287,690	$3,059,813	$5,404,829
	Removal of Existing Development	(total $'s)	-	$1,946,142	$3,095,293	$3,373,313
	Purchase of Land to Relocate	(total $'s)	-	$1,296,687	$2,062,350	$2,247,591
	Site Restoration	(total $'s)	-	$123,494	$196,414	$214,056
	TOTAL COSTS:	**(total $'s)**	**-**	**$8,224,145**	**$13,098,219**	**$16,624,750**
benefits:	**TOTAL BENEFITS=Cost of Opt #1**	**(total $'s)**	**-**	**$11,614,416**	**$14,964,903**	**$20,529,170**
OPTION #4: **Developed Area: Rolling Easements Undeveloped Area: Rolling Easements**						
costs:	Value of Land at Risk	(total $'s)	-	$1,756,341	$3,288,866	$3,856,574
	Value of Infrastructure at Risk					
	roads:	(total $'s)	-	$300,573	$527,849	$586,232
	sewers:	(total $'s)	-	$226,218	$417,927	$445,778
	water:	(total $'s)	-	$287,000	$449,706	$496,375
	Removal of New Development	(total $'s)	-	$472,635	$667,249	$1,176,953
	Removal of Existing Development	(total $'s)	-	$1,946,142	$3,095,293	$3,373,313
		(total $'s)	-	$1,611,597	$2,506,929	$3,031,778
	Site Restoration	(total $'s)	-	$153,485	$238,755	$288,741
	TOTAL COSTS:	**(total $'s)**	**-**	**$6,753,991**	**$11,192,575**	**$13,255,745**
benefits:	**TOTAL BENEFITS=Cost of Opt #1**	**(total $'s)**	**-**	**$11,614,416**	**$14,964,903**	**$20,529,170**

Table 9. Benefit to cost ratios determined for Camp Ellis (EPA 1995).

COST BENEFIT ANALYSIS: Camp Ellis Case Study	Sea Level Rise Scenarios: 0 cm	50 cm	100 cm	200 cm
Strategies:				
OPTION #1: **Developed Area: Reactive Protection Undeveloped Area: Reactive Protection**				
costs:	$10,580,310	$11,614,416	$14,964,903	$20,529,170
benefits	$9,841,236	$9,841,236	$11,909,985	$12,628,132
ratio B/C:	0.93	0.85	0.80	0.62
OPTION #2: **Developed Area: Compensated Setbacks & Reactive Protection Undeveloped Area: Reactive Protection**				
costs:	$7,938,674	$9,852,321	$14,500,918	$21,377,937
benefits	$9,243,407	$9,243,407	$11,312,156	$12,030,309
ratio B/C:	1.16	0.94	0.78	0.56
OPTION #3: **Developed Area: Rolling Easements Undeveloped Area: Setbacks**				
costs:	-	$8,224,145	$13,098,219	$16,624,750
benefits	-	$11,614,416	$14,964,903	$20,529,170
ratio B/C:	-	1.41	1.14	1.23
OPTION #4 **Developed Area: Rolling Easements Undeveloped Area: Rolling Easements**				
costs:	-	$6,753,991	$11,192,575	$13,255,745
benefits	-	$11,614,416	$14,964,903	$20,529,170
ratio B/C:	-	1.72	1.34	1.55

BIOGRAPHY OF THE AUTHOR

Julia M. Knisel was born in Somers Point, NJ on April 25, 1978. Loretta and Edward Knisel Sr. raised Julia, her twin brother, and 13-month older sister in Absecon, NJ. After graduation from Holy Spirit High School in May 1996, Julia became a freshman in Biology at The Pennsylvania State University. There she examined the physiological ecology of hydrocarbon seep mussels in the lab of Dr. Charles Fisher. Participation in the Fisher lab enabled Julia to experience the Endeavour segment of the Juan de Fuca Ridge in *Alvin*. At the end of three and a half years in State College, Julia graduated with a Bachelor of Science degree in Biology and a minor in Marine Science. Immediately after moving back to NJ in December 1999, Julia assumed the role of Atlantic City Community Coordinator with NJ Community Water Watch. She educated elementary and high school students as well as senior groups on local, state, and federal water resource problems. Julia also promoted community involvement and stewardship of water resources through water monitoring activities and cleanups. Julia left her AmeriCorps position in August 2000 and moved to ME where she entered the Marine Policy graduate program at the University of Maine under the advisement of Dr. Joseph Kelley. In May 2002, Julia was selected as a NOAA Coastal Management Fellow for 2002-2004. NOAA placed Julia with the NC Division of Coastal Management. Julia currently lives in Raleigh, NC where she is rectifying aerial photography and digitizing shorelines to delineate new inlet hazard boundaries for the management of development in these areas of environmental concern. Julia is a candidate for the Master of Science degree in Marine Policy from The University of Maine in December, 2003.