Section 206
Flood Plain Management Services

Study of Coastal Flooding
Charlestown, Rhode Island

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The New England Division, U.S. Army Corps of Engineers(NED) conducted this study for the Town of Charlestown, Rhode Island under the authority provided by the Corps of Engineers' Section 206 Flood Plain Management Services (FPMS) program. The study investigates the potential future effects of coastal flooding on the community, primarily addressing the economic risk to the community. The study focuses on approximating the dollar value of the potential flood damages to residential structures within the coastal 100-year flood plain and provides an assessment of the potential resulting loss to community tax revenues. The study also discusses flood damage reduction measures available to the Town of Charlestown.

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EXECUTIVE SUMMARY

The New England Division, U.S. Army Corps of Engineers(NED) conducted this study for the Town of Charlestown, Rhode Island. The study was funded under the authority provided by the Corps of Engineers' Section 206 Flood Plain Management Services (FPMS) program. The study is an investigation of the potential future effects of coastal flooding on the community. The study primarily addresses the economic risk to the community due to coastal flooding. The study focuses on approximating the dollar value of the potential flood damages to residential structures within the coastal 100-year flood plain and provides an assessment of the potential resulting loss to community tax revenues. The study also discusses flood damage reduction measures available to the Town of Charlestown.

Based upon the data available and assumptions made for this study, the economic analysis estimated that expected annual damages for Charlestown at $1,010,000. This estimate is based upon a cursory survey of houses within the coastal flood plain, stage-frequency curves developed for an adjacent community, and the conservative assumption that most structures are occupied year-round. The study, however, revealed that about 25% of houses within the 100-year coastal flood plain would be impacted during a 25-year flood event. Therefore, the community should be aware of the economic risks for more frequent storm events. To help alleviate some of the risks, the community should also be cognizant of the options available to reduce flood damages and opportunities for assistance which may be available through Federal and state programs. The community should also encourage actions by individual property owners to address flooding concerns.

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1.0 Introduction

1.1 Background

The Town of Charlestown, Rhode Island requested that the U.S. Army Corps of Engineers, New England Division (NED) conduct an investigation of the potential future effects of coastal flooding on the community. The study primarily addresses the economic risk to the community due to coastal flooding. The study focuses on approximating the dollar value of the potential flood damages to residential structures within the coastal 100-year flood plain and provides an assessment of the potential resulting loss to community tax revenues. The study also discusses flood damage reduction measures available to the Town of Charlestown.

1.2 Authority

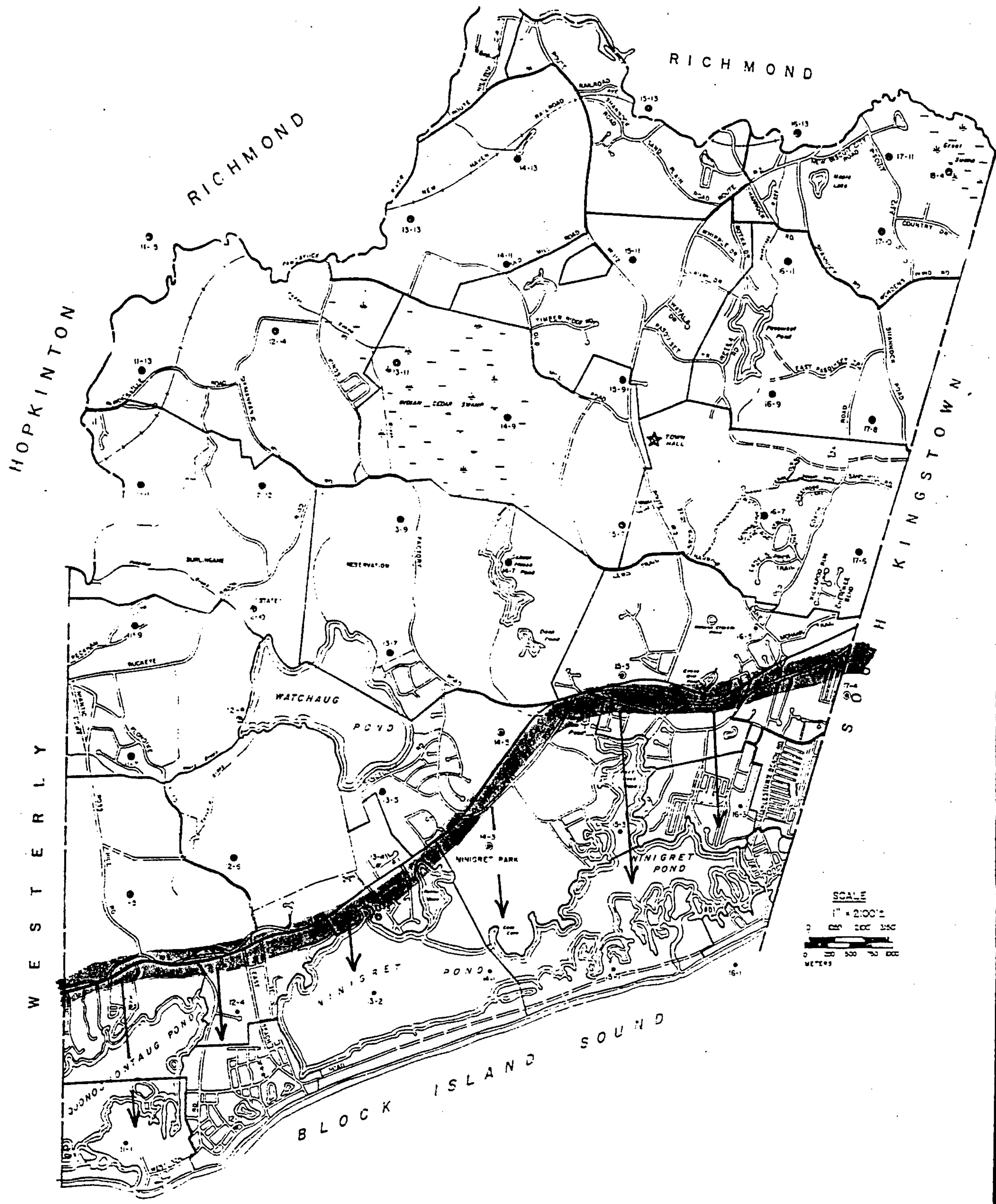
The study was conducted by the New England Division, U.S. Army Corps of Engineers, Planning Directorate for the Town of Charlestown, Rhode Island. The study was funded under the authority provided by the Corps of Engineers' Section 206 Flood Plain Management Services (FPMS) program.

1.3 Project Study Area

The study area is located in the Town of Charlestown, Washington County, Rhode Island. The study focuses on the southern portion of Charlestown; specifically, those areas located within the 100 year flood plain. The flood plain is approximated by those areas south of U.S. Route 1. (See Figure 1.0)

<u>General community description</u>

The town of Charlestown is located in the south-central portion of Washington County in southwestern Rhode Island, about 24 miles east of New London, Connecticut, and 32 miles southwest of Providence, Rhode Island. The town of South Kingston borders Charlestown to the east and the town of Westerly to the west. The towns of Richmond and Hopkinton border



Charlestown, Rhode Island
Approximate Limit of
100 Year Coastal Flood

FIGURE 1.0

Charlestown to the north and northwest, respectively. The total area contained within the corporate limits of Charlestown is 41.3 square miles, of which 36.3 square miles is comprised of land.

Rural/Historic Character

The town of Charlestown has a distinctive rural character that attracts both a permanent and seasonal population. The natural features and historic use help define the rural character of this predominantly residential community.

Many of the town's topographic features are a result of glaciation. Glacial outwash formed a 1 to 2 mile wide strip of flat land which extends north from the coast. These glacial deposits in Charlestown are known as the Charlestown recessional moraine. This glacial moraine, characterized by a ridge of steeply rolling hills running north of U.S. Route 1 parallel to the shore, divides the town's landscape into distinct areas. The flat sandy coastal area extends roughly from Route 1 south to Block Island Sound. This flat sandy area is the focus of this study. North of the moraine, however, the terrain is more gentle with a number of large wetland areas such as Cedar Swamp and several open bodies of water. Further inland the Pawcatuck River defines the town's northern boundary.

The town contains several natural resource features which help define its character. For instance, Charlestown has an unusually large amount of conservation and recreation land which demonstrates the importance of natural resources to the town. Some of the most salient natural and historic features include but are not limited to: the Ninigret and Quonochontaug Ponds, (the former Naval Air Station) Ninigret Park and Wildlife Refuge, the Old Post Road, Cross Mills, and Arnolda

Burlingame State Park, Ninigret Wildlife Refuge, Ninigret Park and East Beach comprise about 20 percent of the total land area of the town and protect wetlands, fresh and saltwater ponds, a barrier beach system, and other valuable habitats. Charlestown also contains a considerable amount of freshwater wetlands, including the Pawcatuck River.

Due to the natural resource features and topography, the town of Charlestown has developed into two distinct areas. Rather than having a central town center, the town has several small villages or settlements located at the extreme northern and southern ends of the town. Although Charlestown has these small settlements at each end, the town of Charlestown for the most part remains undeveloped except for some sparse development along the roads. Moreover, the development that has occurred tends to preserve the rural character of the community. Consequently, most development in Charlestown continues to consist of single family residential dwellings.

As previously discussed, the predominant difference between the land use in northern and southern Charlestown is attributed primarily to the land features in the two areas and the resulting historic uses. The southern portion of Charlestown has historically been more favorable for development than the northern portion because the terrain is flatter, well drained soils are present and the area encompasses the salt ponds. Therefore, this area became the location for early plantations. In addition, summer settlements developed because the area provided access to the shore. The southern Charlestown shore area continues to be a popular location for development as well as the most heavily developed area of Charlestown with many businesses supporting the residential settlements. The variety of businesses include restaurants, grocery stores, real estate offices, banks, motels and marine related businesses. The Cross Mills area also contains a post office, town library, a marina and churches. In addition, areas around the salt ponds in the southern Charlestown area continue to be developed.

Barrier Beaches of Charlestown

The coastline of Charlestown is comprised of barrier beaches. In some areas, heavy use and development of the shoreline has prevented the barrier beaches from fully recovering from past storms. For instance, the construction of permanent homes and recreational facilities may accelerate the rate of erosion for the dune systems on the beach. Homes in some cases, have continued to be built on the barrier beaches, however, many of these new homes have been specially constructed to minimize flood damage from storm waves. Nevertheless, development on the barrier beaches has continued to raise concerns over property erosion and flood damage from coastal storms.

The northern portion of Charlestown, unlike the southern portion of the town, continues to experience sparse development due to the constraints posed by the rockier and poorly draining soils and the hillier environment.

1.4 Study Objectives

The following tasks are performed in this analysis:

1. Determine approximate first floor elevations of all residential structures within the 100-year coastal flood plain. Identify the structure type of each dwelling corresponding to Corps' typical damage curves.

2. Develop stage-damage and damage-frequency curves, using existing flood stage information.

3. Determine the vulnerability of various types of residential structures to flooding for properties within the A-zone (those areas susceptible to 100-year flood stillwater) and within the V-zone (those areas within the 100-year floodplain that are also affected by wave runup). Note, however, that the same technique for the damages analysis was utilized for areas within the A-zone and V-zone. Structural damages will be calculated based on surveyed data and typical damage function data obtained for each house.

4. Utilizing the approach described above, calculate the number of residential structures within Charlestown which fall under each category and determine the corresponding loss in tax revenues to the town.

5. Qualitatively discuss other issues related to flooding and their economic impact to the town.

6. Prepare a report addressing all of the information and analysis outlined above.

2.0 Defining the Flood Risk

2.1 Historic Flood Events

Principal Flood Problems

Most flooding in Charlestown has been limited to flooding along the coastal lowlands along Block Island Sound. Riverine flooding has not been as much of a problem in the town as coastal flooding. The most severe coastal flooding occurs during hurricanes, which are tropical in nature and are characterized by low barometric pressures, wind speeds greater than or equal to 75 miles per hour, torrential rain, tremendous waves, and tidal flooding. The most significant coastal flooding experienced by Charlestown occurred from the hurricanes of September 1938 and August 1954. Both of these storms had a severe effect on the entire coastline of Charlestown. The recurrence intervals for flooding resulting from the 1938 and 1954 hurricanes were estimated at approximately 100 years and 85 years, respectively.

The 1938 and 1954 hurricanes caused extensive damage to the barrier beaches along Charlestown's coastline. The 1938 hurricane destroyed or heavily damaged several homes between and behind the three small ponds at Quonochonaug. The 1954 hurricane caused less damage. East Beach was heavily built up with summer cottages before the 1938 hurricane, but these cottages were destroyed by that hurricane. Rebuilt cottages on East Beach were again later destroyed by the 1954 hurricane. When development began again, the state condemned most of the barrier and since then has managed it as a conservation area. Similarly, the 1938 hurricane completely destroyed summer cottages on Charlestown Beach. At this time, the beach is only sparsely developed between the Charlestown Breachway and the Charlestown/South Kingston corporate limits.

Past development of the beaches has hampered the natural processes that tend to rebuild the barrier beaches. As a result of the increased beach usage, some of the inland development is subject to open wave attack from hurricanes. For instance, building structures that inhibit the movement of sand may impact the ability of the beach to provide protection against storm wave attack. Charlestown is at risk to hurricanes that may occur on an annual basis, however, the town has not suffered as extensively since the storm related damages of the 1954 hurricane. Based on a review of storm damage claims compiled by the Federal Emergency Management Agency (FEMA) since the early 1970's, the Town of Charlestown is shown to have suffered (some or moderate) storm related damages during 1978 and 1991 to 1993. Although the town of Charlestown has a policy of beach protection, current trends of increased seasonal and permanent population indicates that heavy coastline usage will continue in the future. Charlestown Beach and East Beach areas for instance, continue to be densely populated areas.

Past Studies/Related Reports

Past studies reveal that the town of Charlestown has experienced the greatest damage during major hurricane events. Property damage was greatest when storm surge and waves inundated low lying structures. Studies and experience have found that the extent of coastal flooding is determined mainly by the elevation above sea level and less by the distance inland. During a major storm event, powerful onshore winds combine with high tide and the extremely low atmospheric pressure to build up a mound of water (storm surge) that hits the coast. High water levels combined with waves raise the damaging level of the storm.

In Charlestown, a major storm surge would have significant impact upon the town. Typically, in Charlestown a major storm such as the 100-year flood event may produce a combination of storm surge and wave height up to an elevation of approximately 18 feet NGVD. These flood elevations would be experienced in the East Beach and Charlestown Beach areas. The Charlestown barrier beach system is particularly susceptible to storm surge because the barrier beach system reaches only a height of about 12 feet NGVD. Therefore, during a major storm, the storm surge would entirely overwash the barrier system. Although the barrier system helps to dissipate wave energy, waves would continue to some extent across the salt ponds, reaching a level of 16 feet NGVD.

2.2 Coastal Flooding

The previous section dealt with some of the historic flooding that has occurred in the town of Charlestown due to hurricanes and other major storms. This section will discuss in more detail what coastal flooding entails with regard to the flood insurance study (FIS), hurricane evacuation studies as well as other relevant sources of information. This section will primarily provide explanations of the analyses and the terminology used. However, before the studies are discussed, it is necessary to describe the term flood plain management.

Flood plain management has been described as a comprehensive approach to flood plain use that involves coordination and cooperation between both public entities and private owners of flood plain land in developing methods to deal with the effects of past development within the flood plain and to create for future use of the flood plain and areas adjacent to the flood plain. The goal of flood plain management is to reduce the damaging effects of flooding, preserve and enhance natural resource values, and yet provide for economic development. Flood plain management involves a complex and delicate balancing of economic development and preservation of existing flood plain resources as well as protection against potential flood related losses.

The goal of optimizing use of the flood plain is often not attained because of uncertainties and difficulties in determining the costs and benefits of flood plain uses and in quantifying flood hazard areas. Flood plain management, therefore, requires that decision makers consider the appropriate extent and type of flood plain use; determine the effects that these decisions have on adjacent areas, i.e. downstream and upstream areas; and identify, assess and select the least environmentally harmful method of effectively implementing flood plain management policy decisions.

These policy decisions, however, are not the responsibility of any one individual or government entity but a multitude of parties. Each party must take responsibility for managing the flood plain. Nevertheless, the federal government has firmly established a series of legislative acts and executive orders which provide support specifically for flood plain management. Some of these acts establish programs by which the federal government may provide planning and technical assistance to state governments, local governments and individuals in managing the flood plain.

Some of the most important federal initiatives implementing a flood plain management approach include: the National Flood Insurance Act of 1968 (as amended), the Water Resources Development Act of 1974, the Disaster Relief Act of 1974, and Executive Orders 11988 and 11990. These programs and actions tend to focus on two methods of reducing the impacts of flood losses: modifying susceptibility to flooding and modifying the impact of flooding.

Among the various program initiatives that are of particular significance to the present flood risk assessment study include the Charlestown FIS and the Rhode Island Hurricane Evacuation Study. In both cases, it is recognized that flood plain management is a difficult endeavor but an endeavor that must be performed in order to ensure that impacts from flooding are minimized and natural flood plain resources are enhanced and preserved.

A. *Flood Insurance Study (FIS)*

As noted previously, Charlestown has been and will continue to be subject to the effects of coastal flooding. In order to help alleviate the detrimental effects of coastal flooding, FEMA, under the authority provided by the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973, initiated a flood insurance study for the Town of Charlestown. FEMA recognized that the Town of Charlestown experienced severe flood hazards and that conducting an investigation under the aforementioned acts would help its administration. The purpose of this flood insurance study was to develop flood risk data for various areas of the community which would be used to develop actuarial flood insurance rates and to assist the community in developing sound flood plain management. The FIS provides guidance for the community in planning and controlling future development within the town.

In the FIS, standard hydrologic and hydraulic study methods were used to determine the flood hazard data required for the study. Flood events having special significance for flood plain management and for flood insurance rates were selected for the analysis. The flood events that were selected included the 10-, 50-, 100-, or 500-year period (recurrence interval) flood events. These flood events are commonly referred to as the 10-, 50-, 100-, and 500-year floods and have a 10, 2, 1, and 0.2 percent chance, respectively, of being equaled or exceeded during any year. Although the recurrence interval represents the long term average period floods of a specified magnitude, rare floods can occur at short intervals or even within the same year. The analysis presented in the FIS reflects flood potentials existing in the town at the time of the study.

Hydrologic analyses were carried out to establish the peak discharge-frequency and peak elevation-frequency relationships for the flooding sources studied. The analyses reported in the FIS reflect stillwater elevations due to tidal and wind setup effects. The effects of wave action were also considered in the determination of flood hazard areas. Coastal structures that are located above stillwater flood elevations may still be severely damaged by wave runup, wave-induced erosion, and wave-borne debris. Wave heights and corresponding wave crest elevations were determined using the National Academy of Sciences (NAS) methodology. The wave runup was determined using the methodology developed by Stone and Webster Engineering Corp.

Hydraulic analyses were conducted based on unobstructed flow. Hydraulic analyses, considering storm characteristics and bathymetric characteristics of the tidal flooding source studied, were carried out to provide estimates of the elevations of floods of the areas of coastline subject to significant wave attack. These areas are referred to as coastal high hazard zones. The Corps of Engineers has established the 3-foot breaking wave as the criterion for identifying the limit of coastal high hazard zones. The 3-foot wave has been determined as the minimum size wave capable of causing major damage to conventional wood frame or brick veneer structures.

A wave height analysis was also performed to determine wave heights and corresponding wave crest elevations for the areas inundated by the tidal flooding. A wave runup analysis was performed to determine the height and extent of runup beyond the limit of tidal inundation. The results of these analyses were combined into a wave envelope, which was constructed by extending the maximum wave runup elevation seaward to its intersection with the wave crest profile.

Once these analyses were complete, wave envelopes associated with the 100-year storm surge were computed. These coastal analyses required accurate topographic, land use, and land cover data. Wave heights and wave runup were then computed along transects which were located perpendicular to the average mean shoreline. The transects were located with consideration given to the physical and cultural characteristics of the land so that they would closely represent conditions in their locality. Transects were placed close together in areas of complex topography and dense development. For areas of more uniform characteristics, transects were spaced at larger intervals.

Along each transect, wave envelope elevations were computed considering the combined effects of changes in ground elevation, vegetation, and physical features. Between transects, elevations were interpolated using the topographic maps, land-use and land cover data, and engineering judgment to determine the areal extent of flooding. It was determined that wave runup was not a significant flooding factor in Charlestown.

Determination of Flood Boundaries

In order to provide a national standard for flood plain management, FEMA adopted the 100-year flood (1 percent annual chance of occurrence). The 500-year flood (0.2 percent annual chance of occurrence) was utilized to indicate additional areas of flood risk to the community. The 100-year and 500-year flood plain boundaries were delineated using the flood elevations determined at each cross section. Boundaries between cross sections were interpolated using existing topographic mapping. For tidal areas without wave action, the 100-year and 500-year flood boundaries were delineated using these same topographic maps. For the tidal areas with wave action, flood boundaries were delineated using the elevations determined at each transect; between transects, elevations were interpolated as outlined above. The 100-year flood plain was divided into whole foot increment zones based on the average wave envelope elevation in that zone.

Zone Designation for Insurance Application

For actuarial insurance rate purposes, engineering data that was developed in the hydrologic and hydraulic analyses may be transformed into flood insurance criteria. In this present study, the determination of flood insurance zones was the primary concern. The flood insurance zone designations represent a certain type of flood hazard. In this study, two primary flood insurance zones, the A-zone and V-zone were examined. A-zones or Zone A, are areas representing the 100-year flood. V-Zones or Zone V, are areas representing the 100-year coastal flooding with velocity (wave action) associated with waves of 3-foot amplitude or greater.

At the southern end of Charlestown, much of the flood plain, particularly the Charlestown beach and East Beach areas are designated as V-zone areas. Therefore, coastal structures within these areas are potentially susceptible to more severe storm damages associated with wave action. In addition, these areas are also potentially subject to wave induced coastal erosion.

B. *Present Coastal Flood Analyses*

In this study, the intent is to define the flood risk in terms of potential damages to structures within the flood plain and identify some of the alternatives that the town may pursue in order to better manage its natural resources and development. Due to limited funding, however, NED decided to utilize the results of recent hydraulic analyses conducted for the neighboring community of Westerly, Rhode Island. Stage-frequency information developed for the January 1994 Corps of Engineers Shore Protection and Flood Reduction Reconnaissance investigation for Misquamicut Beach, Westerly, Rhode Island was judged adequate for this analysis due to the close proximity of the two study areas.

C. *Hurricane Evacuation Studies*

Besides the Charlestown FIS and the Misquamicut Beach Westerly, Rhode Island Reconnaissance Investigation, the Rhode Island Hurricane Evacuation Study Technical Data Report (herein referred to as the hurricane study) provides additional support for flood plain management in the context of coastal flooding resulting from hurricanes. FEMA and NED cosponsored and conducted the hurricane study at the request of the Governor of Rhode Island.

The National Oceanic and Atmospheric Administration (NOAA) and the Rhode Island Emergency Management Agency provided assistance to NED. FEMA provided funding for the study under the Disaster Relief Act of 1974 and NED provided funding under its Flood Plain Management Services Program authorized by Section 206 of the Flood Control Act of 1960.

The purpose of the hurricane study was to provide Rhode Island Emergency Management Agency and Rhode Island coastal communities with data quantifying the major factors that are considered when making hurricane evacuation decisions. The hurricane study provides state-of-the-art information to update or revise current hurricane preparedness plans. In furtherance of the goal of supporting hurricane evacuation decision-making, the hurricane study provides information about the extent and severity of potential flooding from hurricanes, the associated vulnerable population, capacities of existing public shelters and estimated sheltering requirements, and evacuation roadway clearance times. The study developed three products: 1) the hurricane study; 2) Inundation Map atlas; and 3) Evacuation Map atlas. The Inundation atlas identifies those areas within the communities that are most vulnerable to flooding from hurricanes.(See Appendix A)

NED performed various types of analyses for the hurricane study, however, the present flood risk assessment study is mainly concerned with the hazards analysis. The purpose of the hazard analysis was to develop accurate estimates of the potential surge inundation areas resulting from hurricanes. The hurricane study utilized the 'worst case' hurricane surge estimates because the focus of the study was protection of the vulnerable population. The 'worst case' scenario was determined using the National Hurricane Center's Sea, Lake, and Overland Surges from Hurricanes (SLOSH) computer model. The SLOSH computer model calculated worst case surge inundation areas based on a composite of the critical hurricanes tracks and approach direction for all locations. The hazard analysis determined that storm surge generation in Rhode Island is significantly influenced by the hurricane's intensity category and its forward speed. The hazard analysis demonstrated that at most Rhode Island locations, surges which accompany fast moving Category 2 hurricanes can generate surge levels close to levels generated by more intense Category 3 and 4 hurricanes traveling at slower forward speeds. The hurricane study concluded that decision makers should understand that a storm's category, as well as its forward speed are both major factors in determining a storm's threat in terms of flood potential. The hurricane study recommended that FEMA and the Rhode Island Emergency Management Agency should incorporate the hurricane study results into ongoing programs of improving hurricane emergency management in Rhode Island.

2.3 Shoreline Erosion

Along with coastal flooding, policy and decision makers and natural resource managers will have to address the issue of storm induced coastal erosion. Of particular concern is the effect of recurring wave attack from hurricanes. Studies of shoreline change of the Rhode Island coastline including the town of Charlestown, have demonstrated landward movement of the high water level. (See Appendix B)

Moreover, coastal erosion is also linked to sea level rise. For instance, landward motion is an important consideration with respect to sea level rise because changes in sea level cause a change in the vertical elevation of the oceans measured with respect to a known reference point on the land. Therefore, for planning purposes the relative or local sea level provides a better indicator for trends in sea level rise. In addition, increased elevations of sea level will have a significant impact on horizontal changes in the shoreline because the coastal zone is often characterized by low flat terrain. Sea level rise remains an important consideration in planning because it causes a multitude of impacts on the coastal shoreline including erosion and coastal flooding.

3.0 Discussion of the Types of Flood Damage

General discussion

Historically, people settled along the river banks, streams, and oceans, taking advantage of the transportation, energy source, habitat and other benefits that the water bodies provided. Unfortunately, significant development of the floodplain has resulted in increasing flood damages. In response to these flood damages, the federal, state, and local governments have engaged in the construction of dams and reservoirs, levees, floodwalls, etc. in efforts to prevent or mitigate damages caused by development in the floodplain. Nevertheless, millions of acres of inland and tidal wetlands have been filled or drained, causing a loss of natural flood storage areas, a lower capacity to filter out pollutants and groundwater recharge, and a reduction or elimination of some wildlife species.

In the 1970s, however, the federal government and numerous states enacted various environmental laws and programs which began to decentralize water management and brought a broader perspective to floodplain management. Moreover, changes were made to the National Flood Insurance Program, executive orders for floodplain management and wetlands protection were issued, disaster relief was made contingent on mitigation action, and non-structural measures in federal flood control projects were required considerations. Local and state government involvement in floodplain management also increased with the appointment of National Flood Insurance Program coordinators, adoption of more state regulatory programs, increases in state budgets for floodplain management, and adoption of resource conservation legislation. Many local communities adopted floodplain management regulations to manage local coastal and wetland resources.

In the 1980s, the federal government took a greater role in coordination and providing technical assistance, while the state and local governments formulated their own locally based floodplain management strategies and also became more involved in hazard mitigation planning and implementation. The 1980s were also a period for the establishment of interagency agreements between the states and federal government for the evaluation of floodplain management options after disasters and establishing common policy on non-structural measures. For instance, the Coastal Barrier Resources Act of 1982 established a policy of nondevelopment and avoidance of high hazard areas by prohibiting new federal expenditures on certain undeveloped coastal barriers.

Yet despite these various initiatives to manage the floodplain, the coastline continues to attract people and their accompanying property and infrastructure. Accompanying this continued development of the floodplain, however, is not without its associated costs in terms of economic loss, death, loss of property, and damage or destruction of valuable natural and cultural resources.

3.1 Property Damage

Loss of property within floodplains due to flooding continues despite an increased awareness as to the value of the floodplain and the risks involved with occupancy of the floodplain. Although there is no uniform measure of flood losses, according to "Floodplain Management in the United States: An Assessment Report", flooding clearly constitutes the most pervasive and costly natural hazard facing the nation. Payments from Presidential declared disasters have indicated this trend. The National Flood Insurance Program paid about $500,000 from 1978 to 1994 for flood losses sustained to building and contents in the town of Charlestown. To some extent, homeowners of property within the floodplain (about 680 homes in Charlestown) may reduce their losses by obtaining flood insurance. Since about March 1994, in the town of Charlestown, about 84% of the properties prone to the 100-year flood event own flood insurance.

3.2 Roads and Utilities

In addition to the direct property losses from flooding, severe flooding may have detrimental effects on existing road network and utilities. Recurring flooding may undermine roads by erosion. Moreover, during a particularly severe flooding event a road may be completely inundated, thus preventing its use by emergency vehicles and evacuating residents. When floods inundate major roads, traffic and potentially commerce is affected. While interstate roads provide a major thoroughfare for commuting citizens, local or private roads often provide access for residents of a community.

For coastal communities such as Charlestown, much of the beach roads evolved historically from old cart paths and trails. These roads exemplify the historic rural roads and are characterized by narrow rights of way, minimal drainage, and a circuitous route over hills and around wetlands. These roads tend to be more susceptible to undermining during a major flood event, because many of these private rural roads are not as well developed or maintained. In Charlestown, about 55 percent of the roads are private roads and are located in the southern end of Charlestown.

3.3 Response and Recovery

Incident to any major flood event causing damages to property and loss of life, etc., the federal government, state, and local community expends funds in order to respond to an emergency and perform post emergency recovery efforts. Activities include but are not limited to: mobilization and support of emergency personnel, evacuation, shelters, restoration of access to homes, public protection and other requirements.

3.4 Natural Dune Systems

Natural dune systems provide natural defenses against erosion caused by coastal storm surge and wave action. The slopes of the foreshore form a first line of defense by dissipating the energy of the breaking waves. The berm prevents normal high water from reaching the backshore. The dune and its vegetation offer protection against storm-driven high water and provide a reservoir of sand to rebuild the beach. Therefore, proper management of this valuable resource is critical particularly after a major storm. Management of this dune system should include periodic maintenance and repair after a storm event to ensure this system can be utilized for the next major storm.

3.5 Recreation Facilities

In Charlestown as in many other coastal communities, the shoreline is highly valued for recreational use. Charlestown's tourist season produces direct and indirect revenues for the town and state. For instance, Charlestown receives revenues from beach parking fees and other recreational fees. The State also receives revenues from the ownership and operation of the Charlestown Breachway. In terms of floodplain management, however, one should realize that heavy use and development of the shoreline may accelerate the rate of erosion. Although erosion occurs due to natural shoreline processes, intensified use by human activity will increase the rate of erosion. The state of Rhode Island in cooperation with the University of Rhode Island, however, has created projected erosion shoreline change maps to amend the existing Rhode Island Coastal Resource Management Plan. Those who build permanent homes and recreational facilities should be aware that the coastline is continually being built up and worn away. Moreover, it is difficult to predict how a particular storm will effect the shoreline.

3.6 Institutional

Effects on Tax Revenue Base

Although the town's main source of revenue is generated by its residential property taxes, (in particular by seasonal homes) it does not appear that potential flood damages to residential structures along the 100-year coastal floodplain would create a dramatic long term loss of tax revenues. Charlestown relies on its residential property taxes for 73% of the town's tax revenue. The town has expressed that it is fortunate because seasonal residential structures contribute most of the town's tax revenues, yet these residences require the least amount of the town's capital expenditures on road repair and maintenance. Moreover, seasonal residences are particularly beneficial to the town's economy because they contribute property taxes to the community but do not draw as many services such as schools. Based on this information and recent site visits, it does not appear that future losses accrued by seasonal residential structures will affect the tax revenue, unless of course these structures are completely destroyed and not rebuilt. The National Flood Insurance Program (NFIP) provides that a structure experiences "substantial damage" when the costs to repair or reconstruct exceeds 50% of the market value of the structure prior to damage. A significant loss of revenue due to destruction of residential structures is unlikely because most structures within the 100-year coastal flood plain are already constructed to reduce damages due to flooding. Moreover, flooding impacts are mitigated due to the high level of flood insurance participation.

Based on shoreline change maps adopted by the Rhode Island Coastal Resources Management Council, it does not appear that predicted shoreline erosion along the coastline of Charlestown will create a short term loss of tax revenues. Shoreline erosion will only have significant effect on the town's residential property tax revenue if the structure's foundation is undermined to such an extent that rebuilding is not possible and a landowner loses more land than required by applicable zoning regulations. Although, in the short term (next 20-30 years), shoreline change may not have an effect on tax revenues, long term (approximately 100 years) shoreline change may. The aforementioned shoreline change maps indicate that the coastline along the Charlestown Beach Road vicinity will experience the greatest amount of landward movement, ranging from around three to four feet. This magnitude of shoreline change is particularly significant when combined with potential coastal flood damages to residential structures within the same area. At the present, one can not predict with certainty the extent of potential property losses, however, the town should be aware that approximately 300 structures are susceptible to this combined risk.

4.0 Flood Property Damage Analysis

4.1 Assumptions

In order to perform this investigation within the funding available under the FPMS program, several broad assumptions were made. These include:

a. The first floor elevations of all structures within the 100-year flood plain were approximated based on the best available information. This included existing mapping, town records, approximate field measurements and actual field surveys. All structures in the flood plain which have been raised were assumed to have been constructed one (1) foot above the Base Flood Elevation (BFE). The BFE is based upon the 100-year flood event.

b. The study used typical damage functions to estimate potential flood damages to individual properties.

c. No new hydraulic analyses were performed as part of this investigation. The study used the existing Flood Insurance Study (FIS) for Charlestown, Rhode Island as well as information developed as part of the January 1994 Corps' Reconnaissance investigation of Misquamicut Beach, Westerly, Rhode Island.

4.2 Methodology

Determination of First Floor Elevations

NED personnel obtained first floor elevations through a series of field visits. Data was recorded using a GPS Pathfinder data logger. Although the GPS Pathfinder used is not currently able to record accurate elevation data, the pathfinder was used to record the relative horizontal positions of the estimated spot elevations.

Data gathered during the field visits was corrected with GPS software and the information was converted into an ARC/INFO point data layer. The relative elevation point was then visually compared to existing contour information, interpolated and the corrected elevation was calculated. This procedure was performed for the 678 houses determined to be within the 100-year coastal flood plain. Best engineering judgment and field observations were used in the interpolation of the relative contour elevations and one should realize the inherent inaccuracies involved. Mapping with 5 foot contour interval were the best source of information available. More comprehensive surveying or aerial photography and aerial photo interpretation was determined to be cost prohibitive.

4.3 Economic Analysis

A flood damage analysis was performed for the 100-year flood plain areas of the coastline of the town of Charlestown, Rhode Island. The purpose of this analysis was to estimate the total recurring and expected annual flood damages for the study area as a whole. The study area includes areas to the east, west, and north of Ninigret Pond. The study area was defined by the delineation of the 100-year floodplain in the area, as shown on the Flood Insurance Rate Maps dated June 17, 1986.

The structures in the study area are nearly all residential structures, with many seasonal houses, although some of the houses appear to be year-round. Major clusters of houses in the study area are located in the area of Charlestown Beach Road, which is located to the east of Ninigret Pond, and also in the area of East Beach and West Beach Roads, which are located to the west of Ninigret Pond. In all, the study includes a total of 678 houses which are located within the 100-year floodplain of the coastline of Charlestown.

In order to estimate the recurring and expected annual flood damages for the structures in the study area, the following steps were taken. First, the first floor elevations of the dwellings in the study area were obtained as described in the previous section. Second, the structures were categorized by type of structures based on a field survey. (See Table 1.0) The following structure categories were used: 1) 1-story, small; 2) 1-story, medium; 3) 1-story, large; 4) 2-story , small; 5) 2-story, medium; 6) 2-story, large; 7) split level; and 8) cottage.

TABLE 1.0

Breakdown of Typical Structure Type

Structure Type Code	**Description of Residential Structure Category**	**Number of Houses within Coastal Floodplain of Designated Category**
1A	1-family, 1-story, small	283
1B	1-family, 1-story, medium	90
1C	1-family, 1-story, large	0
2A	1-family, 2-story, small	59
2B	1-family, 2-story, medium	180
2C	1-family, 2-story, large	17
COT	Cottage	46
SPLIT	Split Level	3
	TOTAL:	678

All of the structures in the study area are single family residential structures, so the categories used are all subsets of the single family residential structure category. Each category was further broken down into structures with basements and structures without basements. The determination of whether each structure has a basement was made through brief visual inspection during the field survey. Cottages were defined as structures obviously seasonal in nature, and smaller than the 1-story small category.

Once the structures were categorized by type, typical stage-damage functions for each type of structure were then used to estimate the flood damages that would likely occur at various flood elevations. Table 2.0 shows a breakdown of estimated first floor elevations.

TABLE 2.0
Breakdown by First Floor Elevation

First Floor Elevation	Number of Houses
6 feet	15
7 feet	29
8 feet	39
9 feet	48
10 feet	60
11 feet	88
12 feet	81
13 feet	57
14 feet	74
15 feet	55
16 feet	36
17 + feet	96
Total:	678

The typical damage functions used were developed for previous Corps of Engineers studies, updated and adjusted as was judged appropriate to represent the structures in the study area. The damage functions reflect depreciated repair and replacement costs. The damages are estimated in one foot increments from the basement up to six feet above the first floor and include estimates for structural damage, damage to contents such as rugs and furniture, damage to utilities, damage to the outside grounds, and an estimate for non-physical losses such as costs for evacuation, all of which are generally included in Corps of Engineers flood damage reduction analyses.

Stage-Damage & Frequency-Damage Curves

The stage-damage function for each structure was then combined with the elevation for each structure to determine the total stage-damage function for the study area. The total stage-damage curve was then combined with the stage-frequency curve for the study area in order to determine the flood damages that are estimated to occur in flood events of varying frequency. The stage-frequency curve used was the curve developed for the recent Corps of Engineers reconnaissance investigation for Misquamicut Beach, Westerly, Rhode

Island. The damages expected to occur at different flood events are termed the recurring losses for the study area. The recurring losses for a sample of events, along with their corresponding flood stages, the 1-, 2-, 4-, 5-, 10-, 20-, 30-, 50-, and 100-year events, are shown in Table 3.0.

TABLE 3.0
Recurring Losses
Charlestown Coastal Areas, Charlestown, Rhode Island

Probability of Occurrence	Frequency of Occurrence Stage		Recurring Losses*
100%	1 year event 3.3 feet		$0
50%	2 year event 4.2 feet		$9,000
30%	3.3 year event	5.1 feet	$84,000
20%	5 year event 5.8 feet		$338,000
10%	10 year event	7.8 feet	$2,631,000
5%	20 year event	9.3 feet	$6,160,000
4%	25 year event	9.9 feet	$8,025,000
2%	50 year event	11.5 feet	$15,037,000
1%	100-year event	11.8 feet	$16,470,000

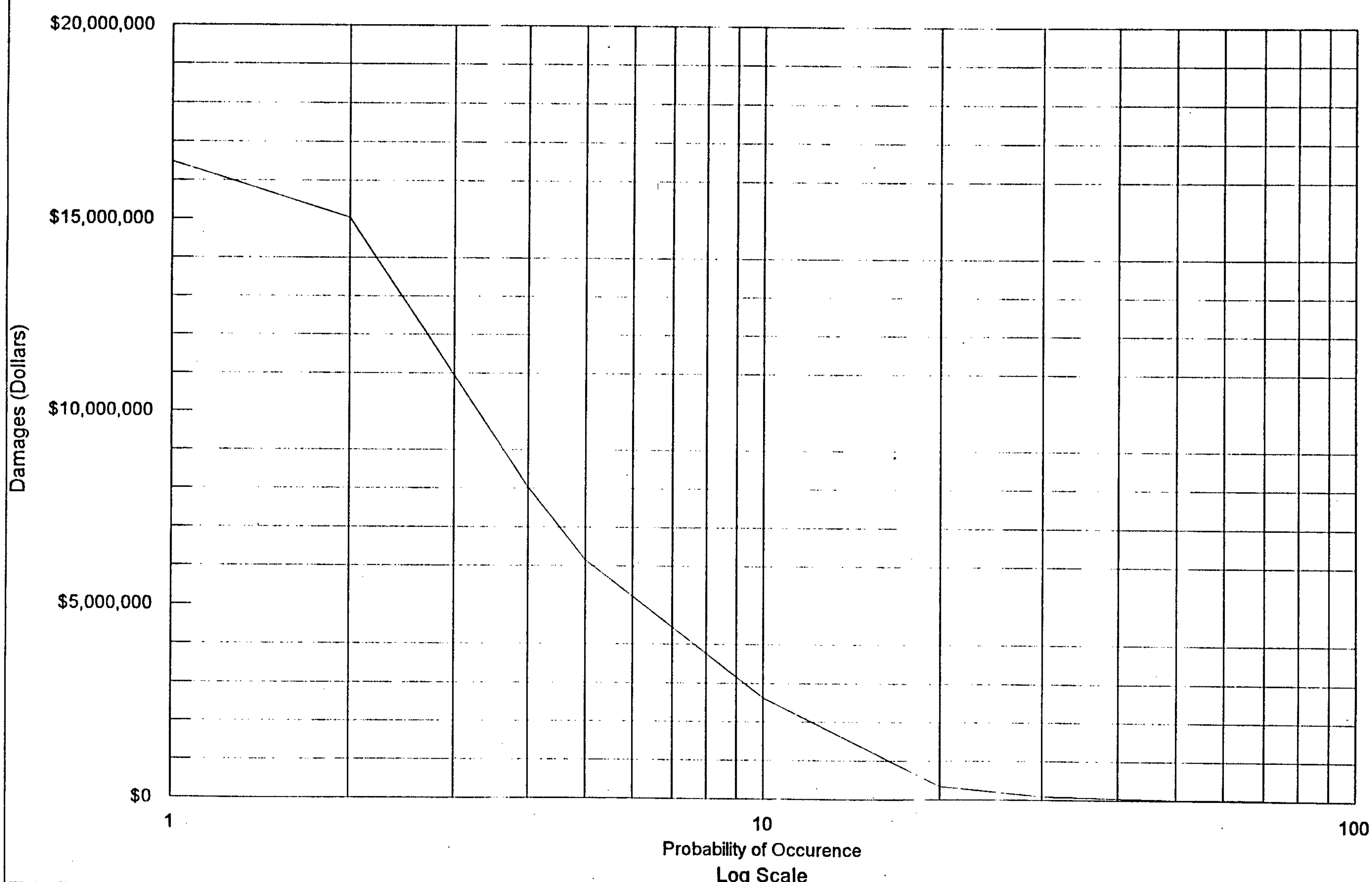
*Rounded to the nearest thousand.

Once the total stage-damage function was developed, and the recurring losses were determined, the final step was to calculate the expected annual damages for the study area. (See Figure 2.1 and Figure 2.2) The expected annual damages are calculated by multiplying the recurring loss at each elevation by the annual percent chance that the flood elevation will be reached. The resulting expected damages at each event are then added together, yielding the total annual damages that are projected to occur given each event's probability of occurrence. Using this methodology, and using the data collected as described in the above paragraphs, the expected annual damages for the study area were calculated to equal $1,010,000.

The average annual damage value of approximately 1 million dollars should only be used as an approximation of the economic risk to the area. There are several areas of uncertainty in this analysis which could affect this value. The first area of uncertainty

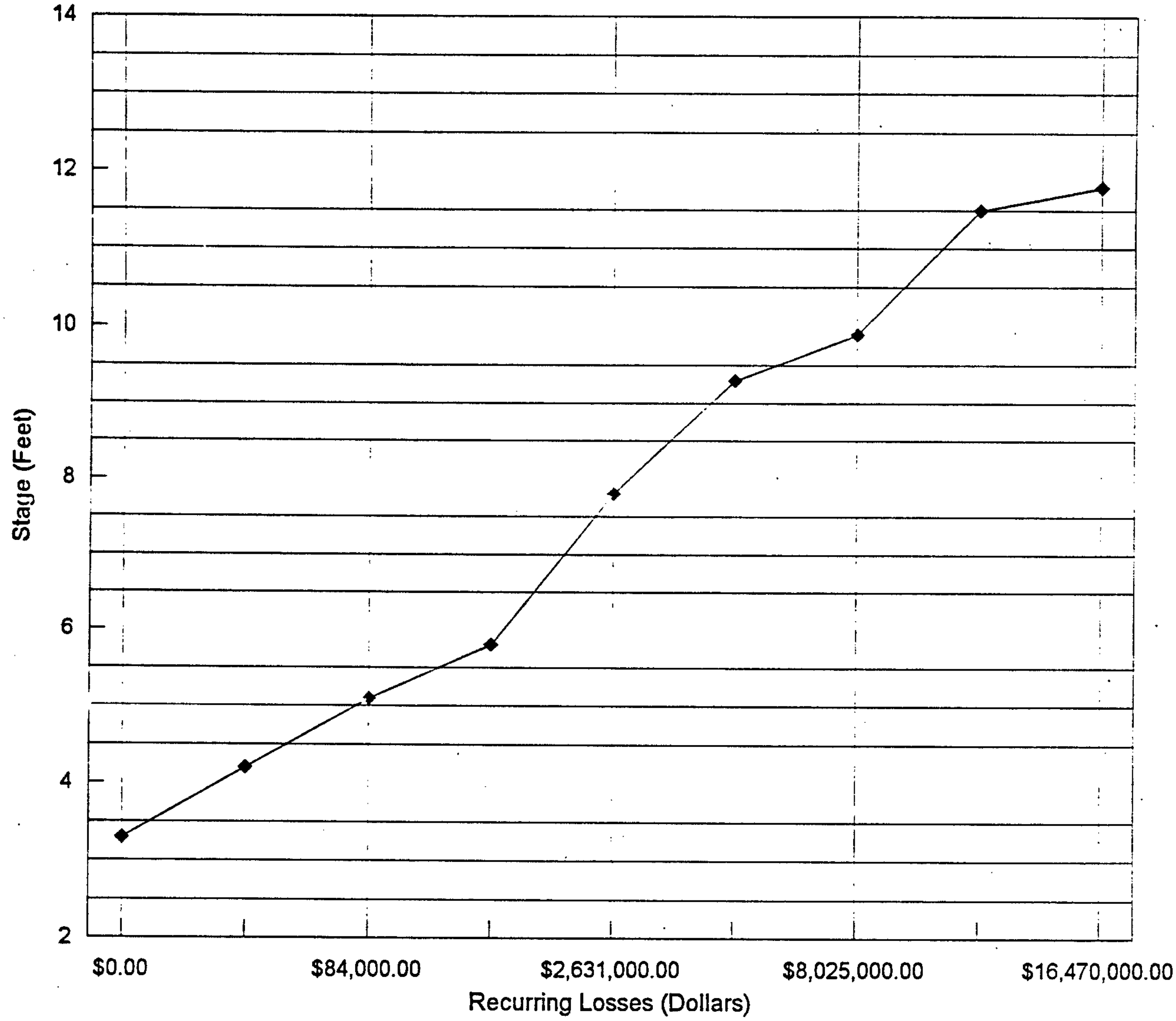
DAMAGE-FREQUENCY CURVE

FIGURE 2.1



STAGE-DAMAGE CURVE

FIGURE 2.2



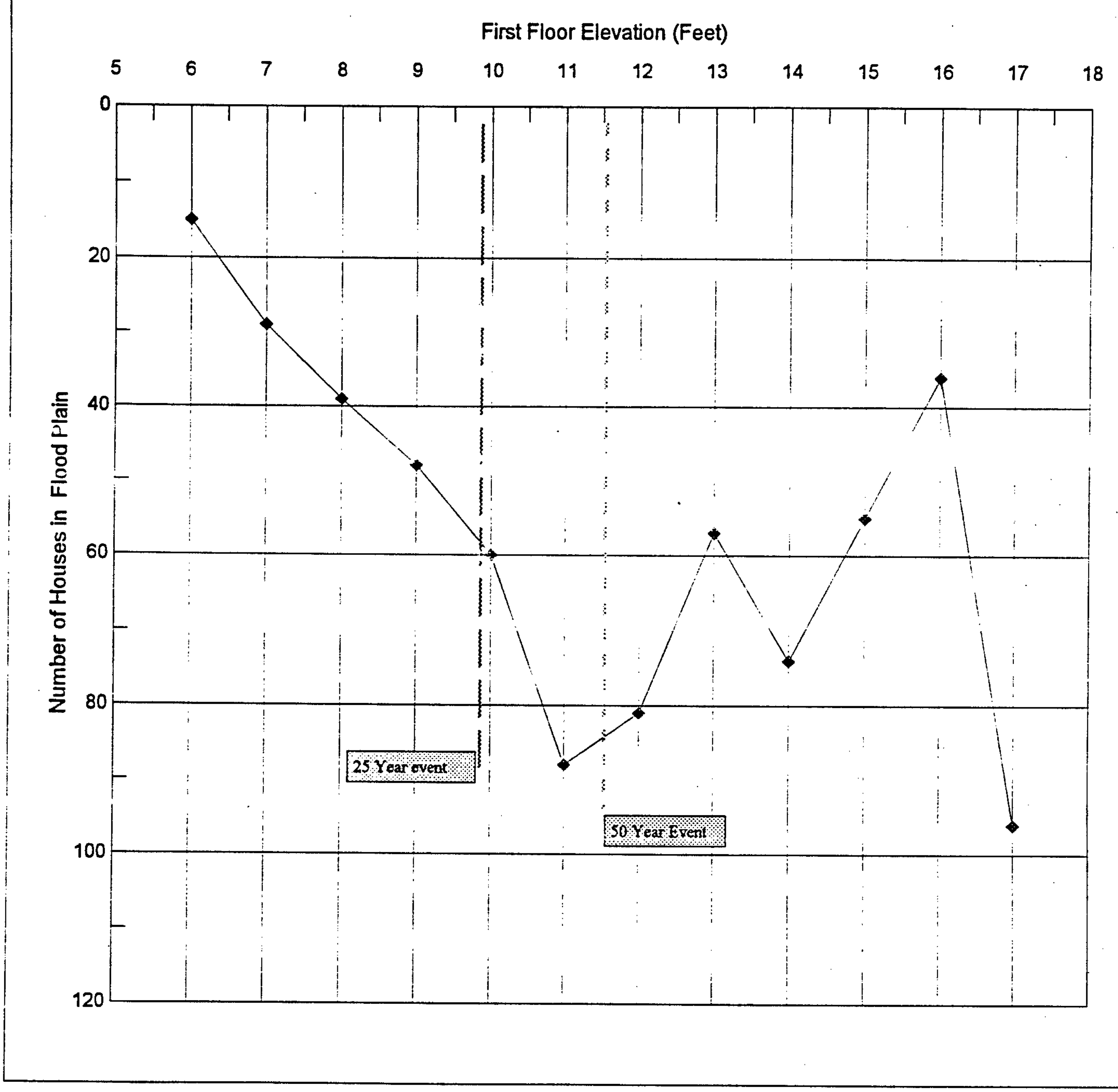
is that the first floor elevations are approximated using available mapping and were not determined through the use of onsite surveys. Performing a detailed survey of the 678 houses would have been too costly and beyond the level of funding available for this study. Errors in the first floor elevations could cause a significant difference in the value of expected annual damages. A second area of uncertainty is that it was not possible to determine, at the level of detail used for this analysis, whether each structure is occupied year-round or only seasonally. The estimated expected annual damages may be somewhat overstated if many of the houses are only seasonally occupied, since seasonally occupied houses generally would have less contents, and in some cases less valuable contents. The third area of uncertainty is that this analysis used a stage-frequency curve developed for an analysis of Misquamicut Beach in Westerly, Rhode Island, instead of a stage-frequency curve developed based on a specific hydraulic analysis of this study area. While the Westerly coastline is adjacent to the Charlestown coastline, there may be other factors, particularly in the backshore areas, which affect the applicability of the Westerly stage-frequency curve to the Charlestown study area. A fourth area of uncertainty is that the study area has not recently experienced any significant coastal storms in which actual flood damages were recorded and against which the analysis could be verified for accuracy.

A comparison between the calculated average annual damages and the actual NFIP claim payments from 1978 to 1994 show a significant discrepancy. This discrepancy may be attributed to several factors. First, development in coastal flood plains has increased dramatically during the past two decades. Second, participation in the NFIP has increased significantly from 1978 to the present. Third, the discrepancy could also be partly caused by the area not having experienced significant floods during the period between 1978 and 1994. Finally, the discrepancy could be partly caused by actual damages sustained being higher than damages reimbursable by FEMA and paid out in claims.

Despite the uncertainties mentioned above, however, the flood damage analysis provides a useful tool to assess the flood risks to the community of Charlestown. Besides the calculation of the average annual damages, Table 1.0 and Figure 3.0 demonstrate how the community is impacted by flood events of lesser magnitude but greater frequency of occurrence. For instance, about 25% of the houses within the 100-year coastal floodplain will experience flood related losses as result of the 25-year event, a flood event with four times greater probability of occurring in any year. Therefore, it is in the best interest of the community to plan for these more frequent

FIRST FLOOR ELEVATION BREAKDOWN

FIGURE 3.0



flood events as these events will create some economic impact.

Low-lying areas in Charlestown are particularly effected by the 25-year flood event. These are areas where the first floor elevation is below 9.9 feet. Shore Drive, Sea Lea Avenue and Wall Street, located in the vicinity of South Kingston are areas particularly susceptible to flooding. Meadow Lane area near Ninigret Pond is also an area impacted by the 25-year flood event. The area surrounding Ram Island, West Beach road and East Beach road are also locations prone to the 25-year flood.

5.0 Options to Reduce Flood Damages

This report has discussed the risk of flooding, the typical resultant damages from coastal flooding and the methodology for performing a flood damage analysis. The study, however, has not specifically identified the options that are available for the flood plain manager. There are many methods to reduce flood losses and protect the natural resources of the floodplain. However, the various strategies and tools differ with respect to how they work, what they cost, and the type of problem to be resolved. Successful floodplain management will often require that a combination or coordinated use of several approaches be implemented.

5.1 Overview of the Types of options available

There are three basic methods of reducing flood losses. The first two are preventive measures and the third measure may be described as remedial. The measures may be categorized as follows: 1) Structural (Modifying the flood); 2) Non-Structural (Reducing the susceptibility to flooding); and 3) Remedial (Modifying the impact of flooding on individuals and community).

Structural

Utilizing a structural option for coastal flood reduction involves the construction of structures to modify the flood such as bulkheads and concrete sea walls. Providing a structural option for reducing flood losses is probably not the most appropriate option because of the high construction costs involved. Construction of a structural flood reduction project also has several disadvantages in that: 1) planning, design and coordination requires a lengthy process; 2) structural alternatives may potentially cause detrimental effects elsewhere; 3) need for continual inspection, operation and maintenance; and 4) potential detrimental effects to the surrounding natural environment.

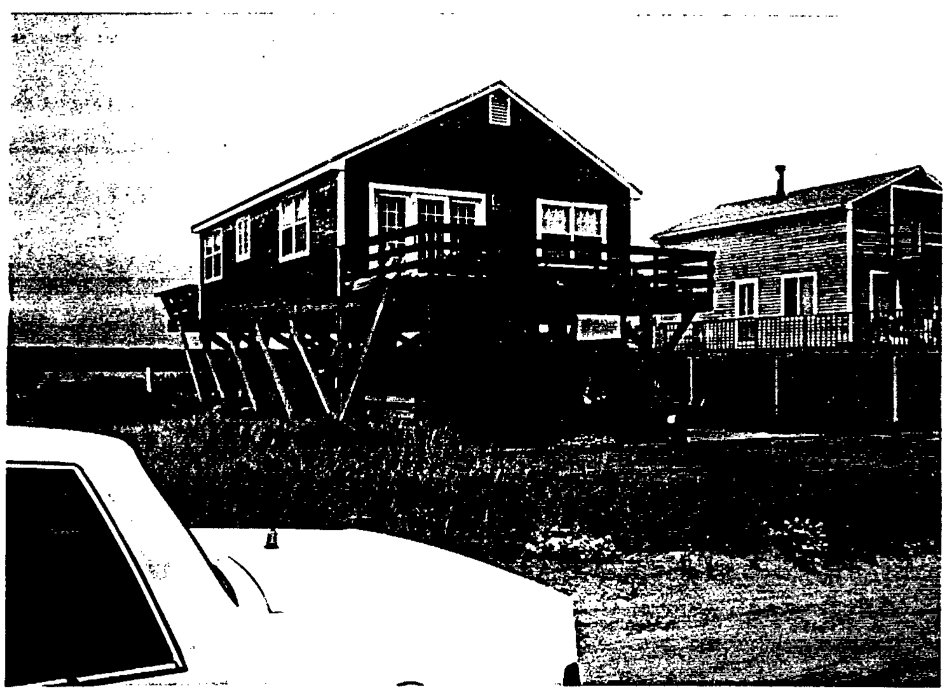
Preventive Non-Structural

The town of Charlestown should probably focus on the last two strategies in flood loss reduction, non-structural and remedial measures. To some extent the town of Charlestown has, by regulating new development, already utilized the last two methods which involve reducing the susceptibility to flooding and reducing the impacts of flooding through relief and recovery. (See Figure 4.0) Continued utilization of these two methods will help reduce the effects of flooding. However, the community is faced with some important considerations with respect to future development in the floodplain as currently the coastline area is densely populated with homes.

Nevertheless, the range of measures to reduce the susceptibility to flood damages is quite extensive. Three methods which seem appropriate to Charlestown are 1) adoption of floodplain regulations which designate flood-prone areas and restrict or limit uses dependent on the degree of flood risk; 2) limit or control development or redevelopment through various policy measures or taxation policy; 3) establish a flood warning system; 4) implement flood proofing or flood resistant construction practices.

Implementing flood plain regulations to restrict new development in flood prone areas will help reduce loss of life or excessive damage to property. Flood plain regulations will assist in protecting against the purchase and development of land in flood prone areas and reduce public costs for emergency response efforts. Moreover, flood plain regulations will help reduce the burden imposed on the federal government in terms of recovery and also for future expenditures for construction of flood control projects. A principal advantage of implementing flood plain regulations is that it provides a relatively quick and flexible means of flood plain management allowing the integration of a broad number of issues related to the economy, environment and society. Local government, however, must be aware that despite effectively preventing unwise development, flood plain regulations must be clearly drafted to comply with due process legal requirements. In addition, the community should establish a formal flood response plan.

To some extent the community has already made use of this technique of flood plain management. For instance, development on barrier beaches and dunes is regulated under Coastal Resources Management Council (CRMC) policies on coastal features. Development is not currently allowed on undeveloped barriers. Moreover, development on barriers must meet certain design criteria that minimizes the risk of flood damages. Inhabited structures are required to build above the base flood elevation and structures located below this elevation must have break away-walls. In addition, structures built in areas highly susceptible to erosion must meet certain additional setback requirements. The edge of the coastal feature (dune scarp) must be setback at least 30 times the annual erosion rate as defined in the CRMC handbook. Moreover, vehicular use on the dunes or beach is strictly enforced. Development of



Photographs of Typical Raised Structures within the Coastal Flood Hazard Area of Charlestown, Rhode Island

Charlestown Beach Area
Charlestown, Rhode Island

New England Division

US Army Corps of Engineers

FIGURE 4.0

the barrier area must also minimize damage to native vegetation.

The town of Charlestown may also implement certain taxation policies to help discourage ill-considered development of floodplain or encourage protection of property from flood damage. For instance, one might consider taxing policies whereby undeveloped land may be taxed at a lower rate than developed flood plain land at higher rates. Or, a community may encourage private efforts to reduce damages to existing properties by providing tax incentives in the form of tax credits or deductions for implementing flood proofing measures or flood aversive measures.

The town of Charlestown has already implemented the use of flood proofing measures as demonstrated by the number of houses within the 100-year flood plain that have been raised. For instance, most of the houses within the Charlestown Beach are elevated on piers. The town may also consider other flood hazard construction options such as: 1) Elevating residential slab on grade (slab elevated above the base flood elevation (BFE)); 2) Residential garage/storage area below BFE;and 3) Elevating structures on driven piles. NED, in particular, has estimated the cost to elevate houses with the crawl space type of construction for the A-zone. For this type of construction, existing foundation walls are extended with concrete creating a larger space underneath the first floor of the structure. A recent Corps study estimates that raising an existing foundation in the A-zone about 3 to 5 feet would cost approximately $30,000 to $50,000 per home. Likewise, building an entire new foundation in the A-zone would cost slightly more. This investigation has also estimated the method of elevating a residential structure on piers to be about $60,000-$80,000.

In addition to elevating structures, there are a number of other options available to the community to manage the flood plain. For instance, the community may implement a flood preparedness and response system. The warning system will enable the community to predict whether flooding will occur, when the flood will arrive and give adequate opportunity for the community to respond appropriately. Charlestown may also implement a flood preparedness plan in conjunction with the warning system. A flood preparedness plan will describe and assign responsibility to various parties and determine a course of actions to perform in the event of a flood to minimize the potential loss to life and property. These types of plans usually include evacuation, emergency flood protection, shelter for house evacuees, etc. The cost of implementing both flood warning and preparedness, however, involves costs for data collection, use of and purchase of appropriate computer equipment, communication equipment and volunteer time.

Remedial

Despite modifying the susceptibility of structures to flooding and attempts to control flooding, areas within a coastal flood plain can still experience flood losses. Thus, the primary means by which private individuals and a community such as Charlestown may reduce the financial impact of coastal flooding is through the use of flood insurance and provisions of relief from the federal government. Charlestown has to a great extent already participated in the national flood insurance program with about 84% of the flood prone properties being covered by flood insurance. Moreover, those residential structures located within the V-zone for the most part comply with FEMA regulations in regard to raising homes above the base flood elevation.

Charlestown also has implemented a regulation that requires any structure built on a barrier beach which has been damaged 50% or more of its value by storm-induced flooding, wave or wind damage may not be reconstructed. This regulation is consistent with the requirements under the NFIP. Implementing this regulation after a major storm will help eliminate unsuitable structures which have been damaged. In the case of essential structures, the regulation will ensure that these structures are rebuilt in a manner which minimizes future flood losses. Communities should take advantage of available Federal technical assistance. The key to the success of this particular method depends on Charlestown's ability to enforce these regulations.

The community of Charlestown should also be aware that the Federal government has through FEMA established a Hazards Mitigation program. Recently, new federal regulations have been published, however, at the present it is not clear how the Hazards Mitigation program will be implemented or interpreted by the states. The Mitigation assistance program will nevertheless provide financial assistance to States and communities. The granting of assistance, however, will depend on how the Director of the program interprets eligibility under the mitigation assistance program. For more information, the community should contact the State of Rhode Island and refer to the Riegle Community Development and Regulatory Improvement Act of 1994, Public Law 103-325 Title V- National Flood Insurance Reform.

6.0 Summary

This study investigated the potential future effects of coastal flooding on the community, focusing primarily on the economic risk to the community. The study revealed that although the town is susceptible to serious flooding from the 100-year coastal flood, the town's tax base would not likely be significantly affected. The study, however, revealed that the 678 houses within the 100-year coastal floodplain could experience flood-related damages. Based on the data available and assumptions made for this study, the economic analyses estimated expected annual damages for Charlestown at $1,010,000. This estimate is based upon a cursory survey of houses within the coastal flood plain, stage-frequency curves developed for an adjacent community, and the conservative assumption that most structures are occupied year-round. For this level of effort, the occupancy rate of structures as either year-round or seasonal was not determined. However, this estimate is still useful in determining the potential risks that the town could experience from coastal flooding.

More importantly, the study revealed that about 25% of houses within the 100-year coastal flood plain would be impacted during a 25-year flood event, a more frequent storm event. The community should be aware of the economic risks associated with the more frequent storms events. For instance, during a 5-year flood event, expected recurring losses are estimated at $338,000. For structures susceptible to damage in more frequent events, the town should investigate the viability of some of the flood reduction options discussed in this report. For instance, the community of Charlestown should recognize that the Federal government has established Hazards Mitigation Programs which provide financial assistance to States and communities.

The tables provided in this report describing the typical structures and the breakdown of first floor elevations may assist the town in determining the distribution of flood risk for various flood events. This information may also assist the town in developing planning policy. For instance, the town may implement taxation and redevelopment policies based upon the risk associated with each elevation above the base flood elevation.

The town may also continue to stringently enforce current policies regarding setback requirements for coastal development. In addition, the town should continue to implement flood proofing measures, particularly for those structures within the V-zone.

Flood prone residents should be made aware of the inherent risk of owning structures within the coastal flood plain. From a remedial measure standpoint, the town should prevent unsuitable structures from being rebuilt after significant storm damage has resulted.

Moreover, the town should be aware that in addition to flood related damages from the higher frequency events, the Charlestown Beach Road vicinity is susceptible to the additional long term effects from shoreline erosion. It is difficult to predict with certainty the extent of potential property losses, however, about 300 structures could potentially be impacted. The town may also experience tax revenue impacts from the long term shoreline change.

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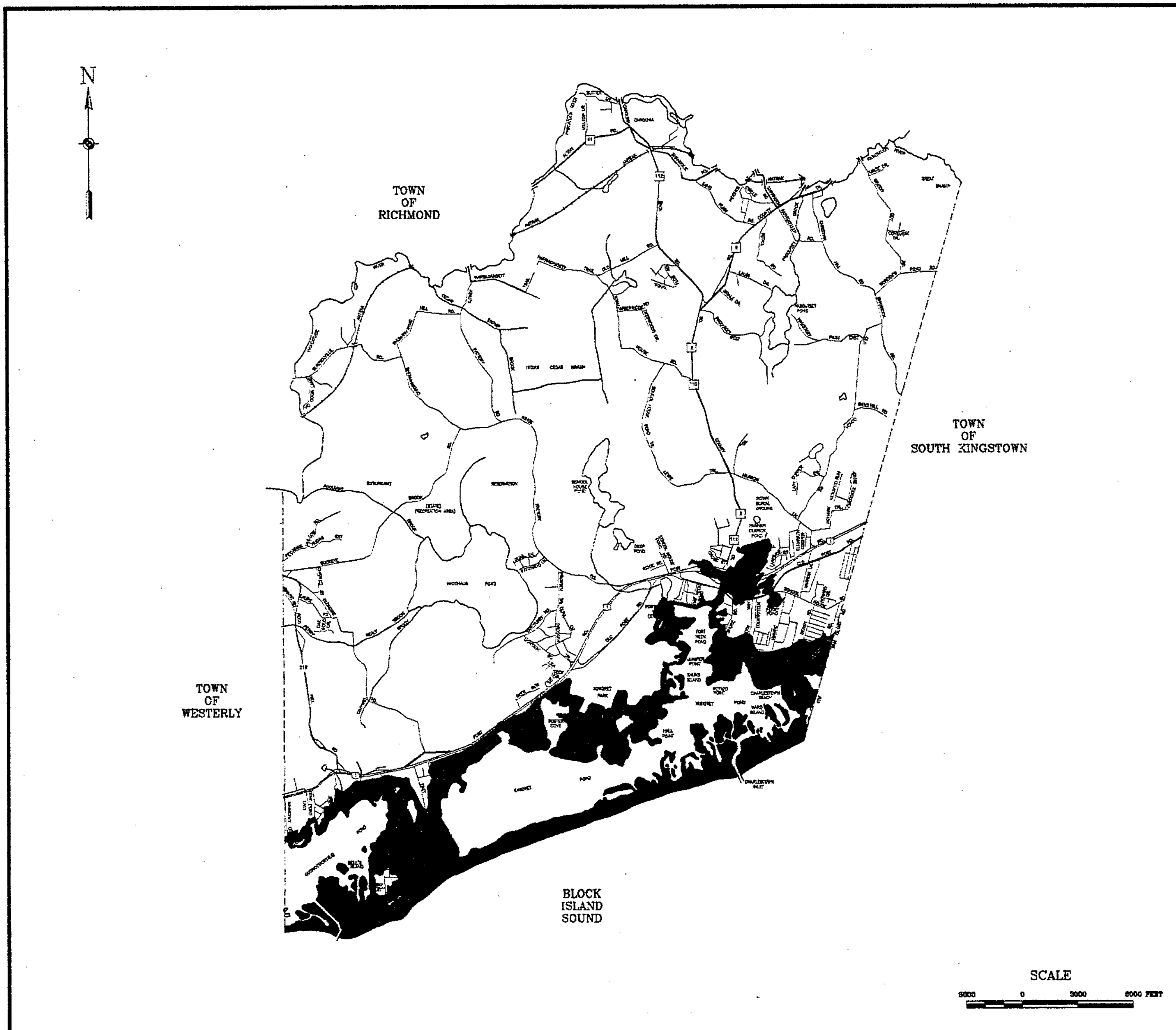
APPENDIX A:

INUNDATION MAP FROM HURRICANE EVACUATION STUDY FOR CHARLESTOWN, RHODE ISLAND



LEGEND

INUNDATION MATRIX

HURRICANE FORWARD SPEED (MPH)

HURRICANE CATEGORY	0–20	21–40	41+
1&2			
3			
4			

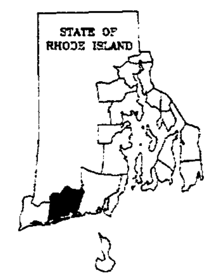
HURRICANE INUNDATION AREAS

- Inundation Area A
- Inundation Area B
- Inundation Area C

NOTES:

1. Inundation areas were derived from the National Hurricane Center's application of the SLOSH (Sea, Lake and Overland Surges from Hurricanes) model. Inundation areas reflect "WORST CASE" combinations of hurricane direction, forward speed, landfall point, and high astronomical tide.
2. Hurricane categories 1 through 4 refer to the Saffir–Simpson scale of hurricane intensity.
3. Shaded land areas represent areas with coastal flooding potential from hurricanes of the categories and forward speeds referenced by the inundation matrix shown above. Inland areas that may only be subjected to freshwater flooding are not identified.

LOCATION MAP



STATE OF RHODE ISLAND
HURRICANE EVACUATION STUDY
INUNDATION MAP

TOWN OF CHARLESTOWN
COUNTY OF WASHINGTON

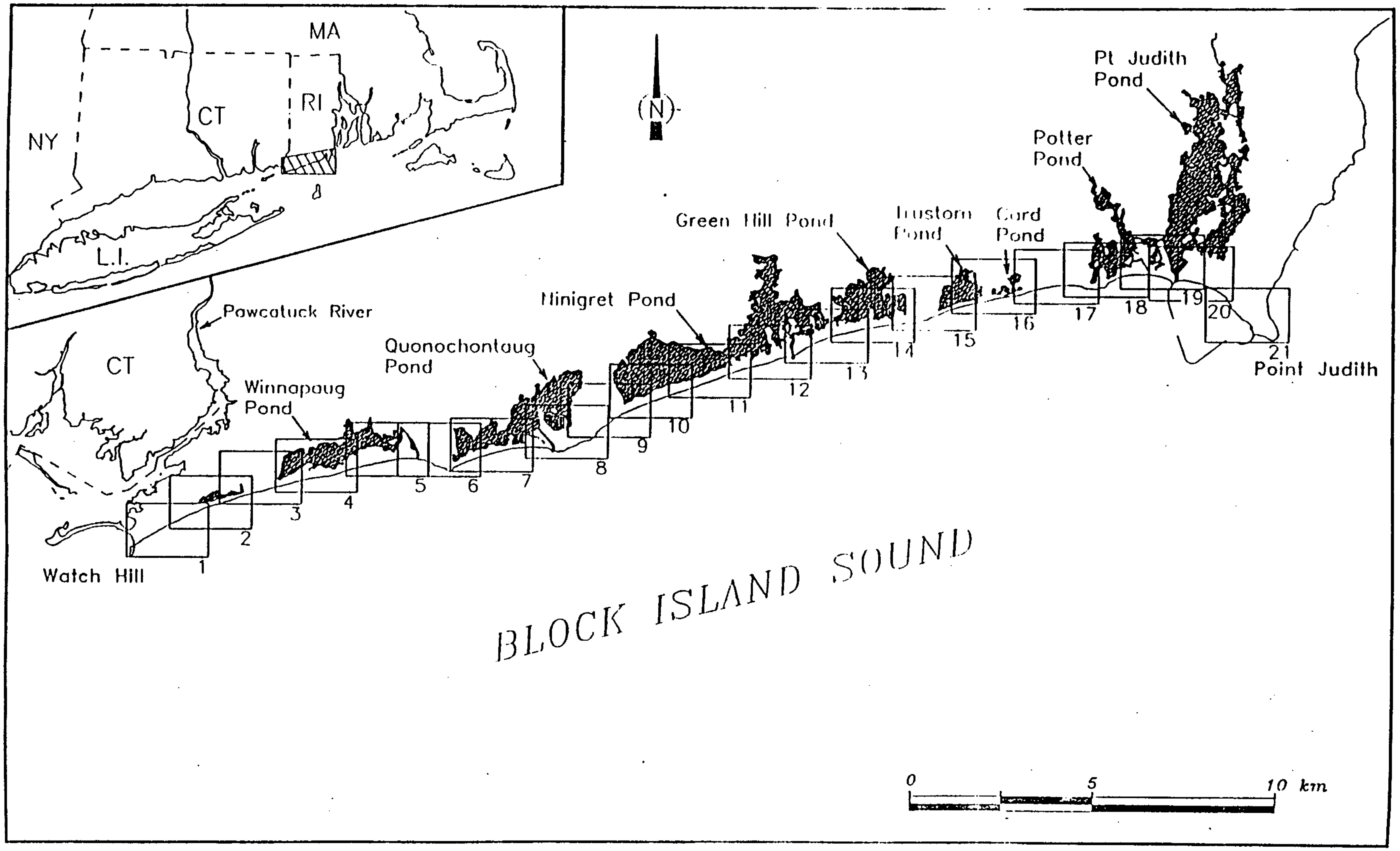
Prepared by the U.S. Army Corps of Engineers, New England Division in cooperation with the Federal Emergency Management Agency, Region I for the Rhode Island Emergency Management Agency.

PLATE I–2

APPENDIX B:

RHODE ISLAND COASTAL MANAGEMENT COUNCIL SHORELINE CHANGE MAPS FOR CHARLESTOWN, RHODE ISLAND

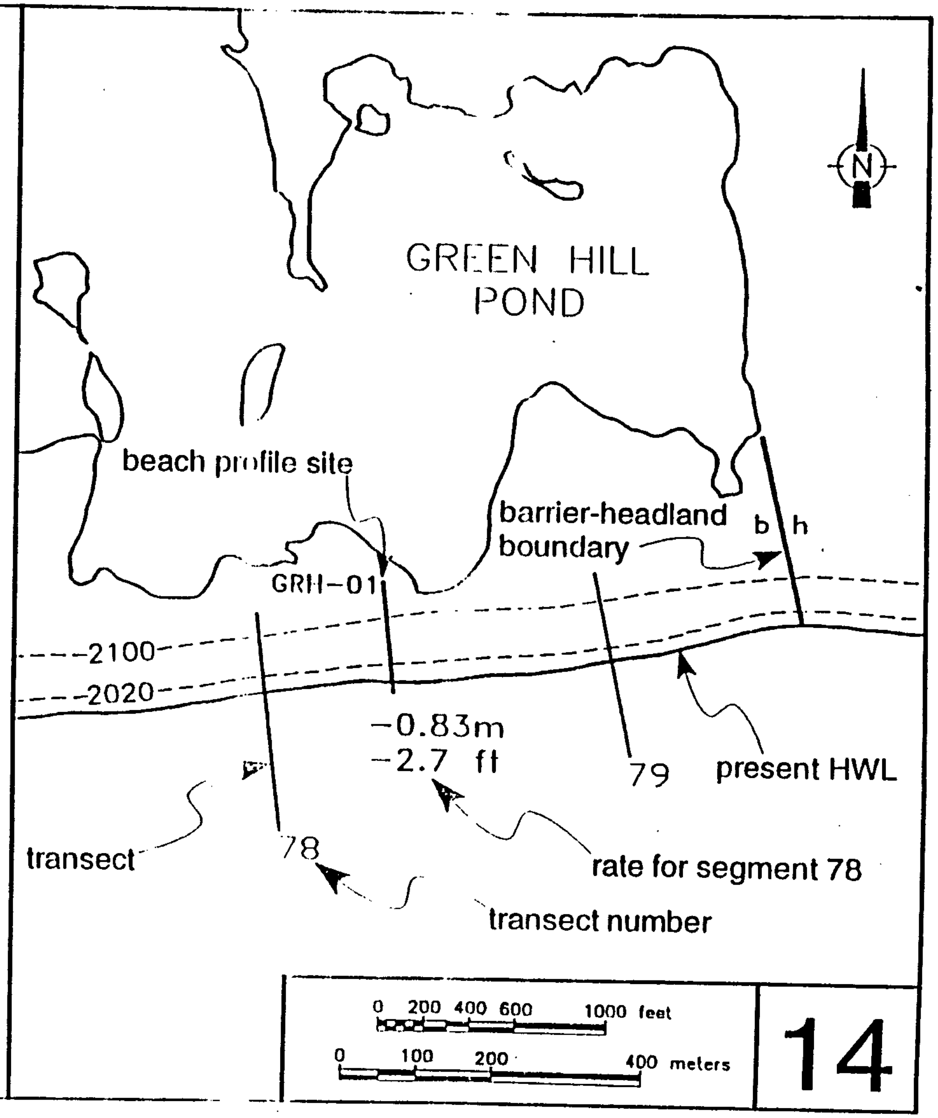
SHORELINE CHANGE MAP INDEX



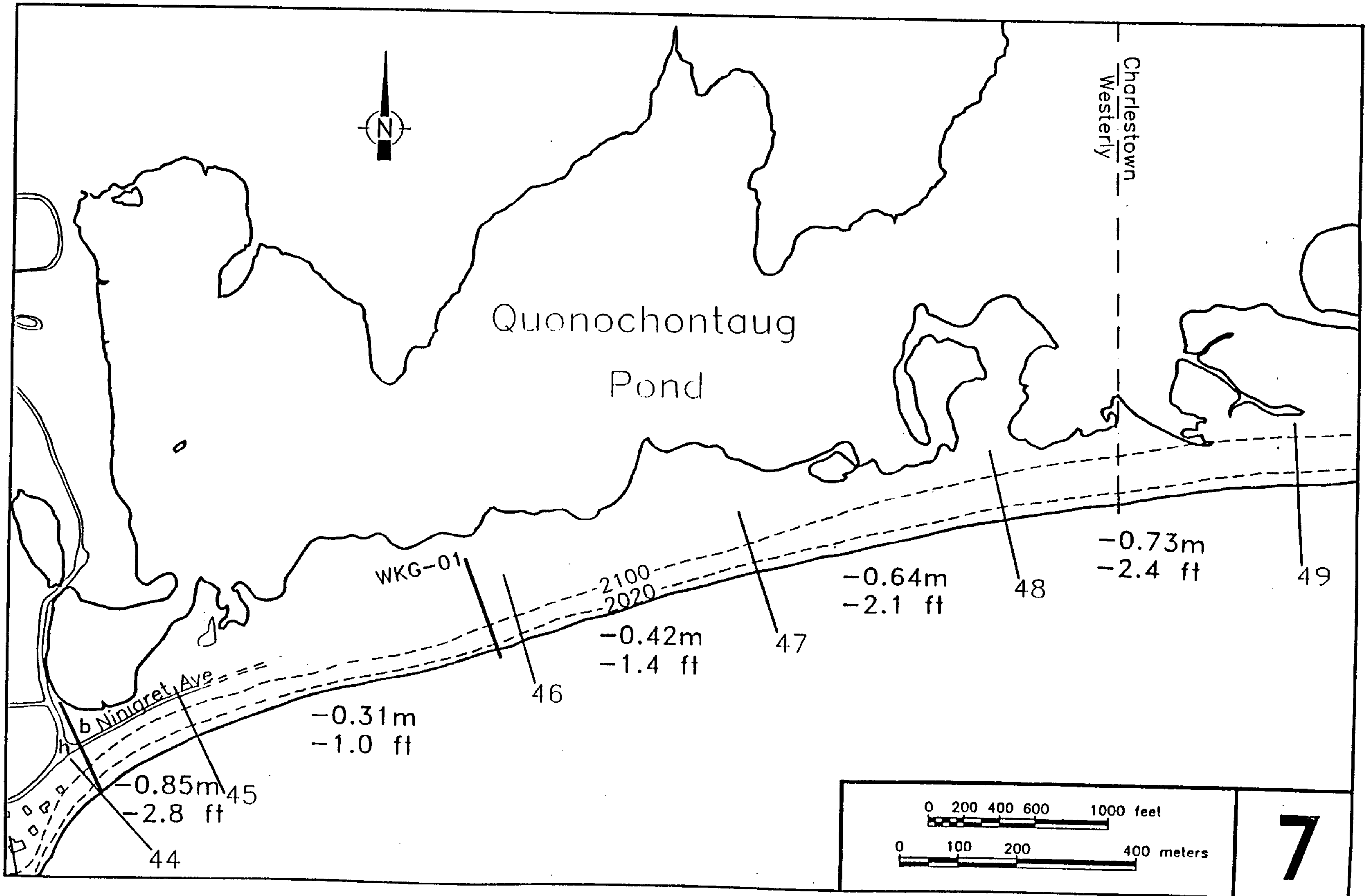
Source:
Rhode Island Coastal Resources Management Council
Shoreline Change Maps

SHORELINE CHANGE MAPS

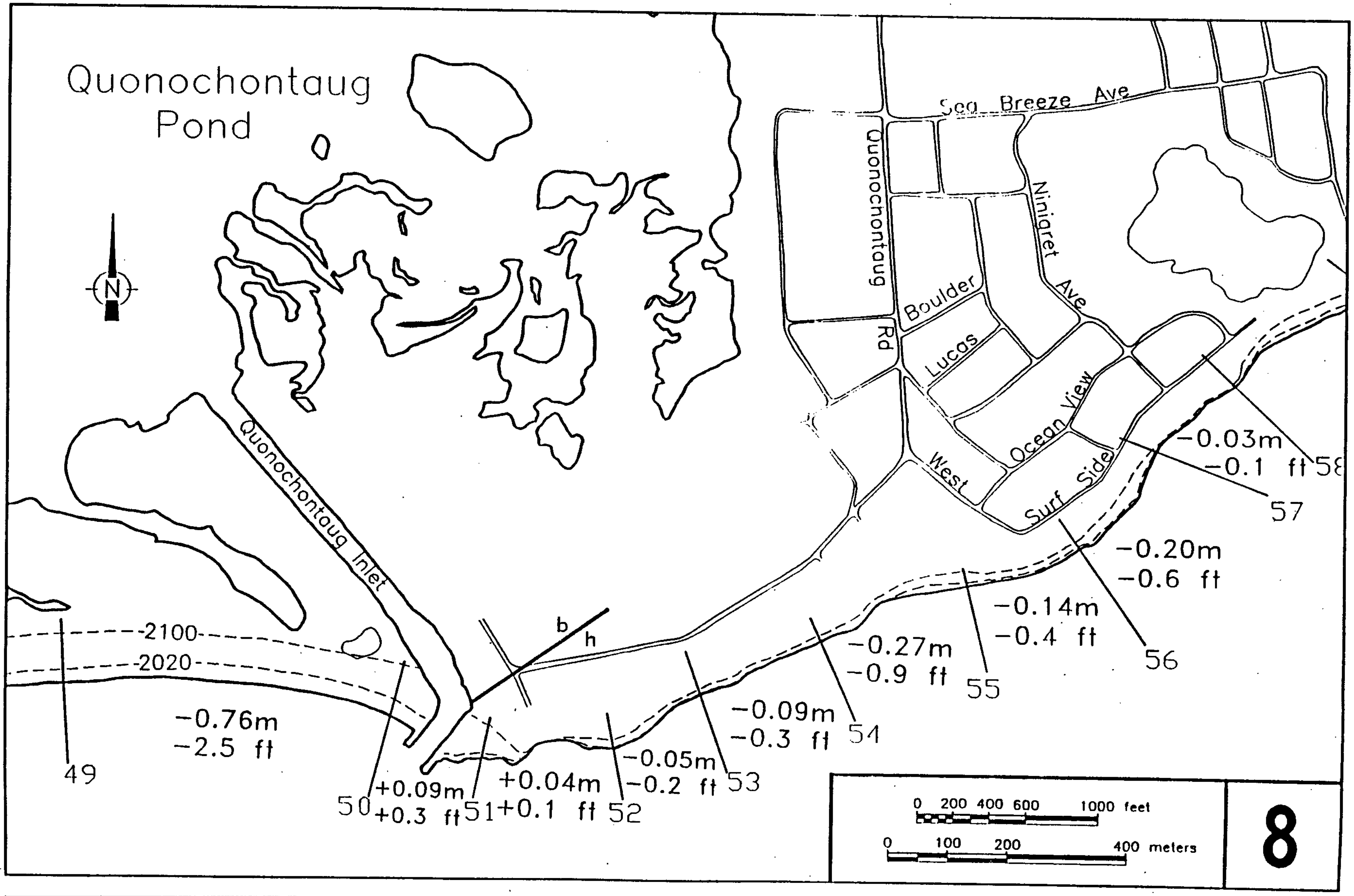
The following 21 maps show the annual rate of change in the position of the high water line (HWL) as measured from vertical aerial photographs dating back to 1939. Negative values indicate landward movement of the HWL, and positive values denote seaward displacement. Also shown are the transect lines defining the shoreline segments for which measurements were made, the locations of the long-term beach profiles, the projected HWL positions for the years 2020 and 2100, and the boundaries between barriers and headlands. Shoreline change rates for segments 15-104 are from Boothroyd et al., (1987) and rates for segments 105-113 are from Regan (1976). The maps are plotted at a scale of 1:10,000 (1cm = 100m).



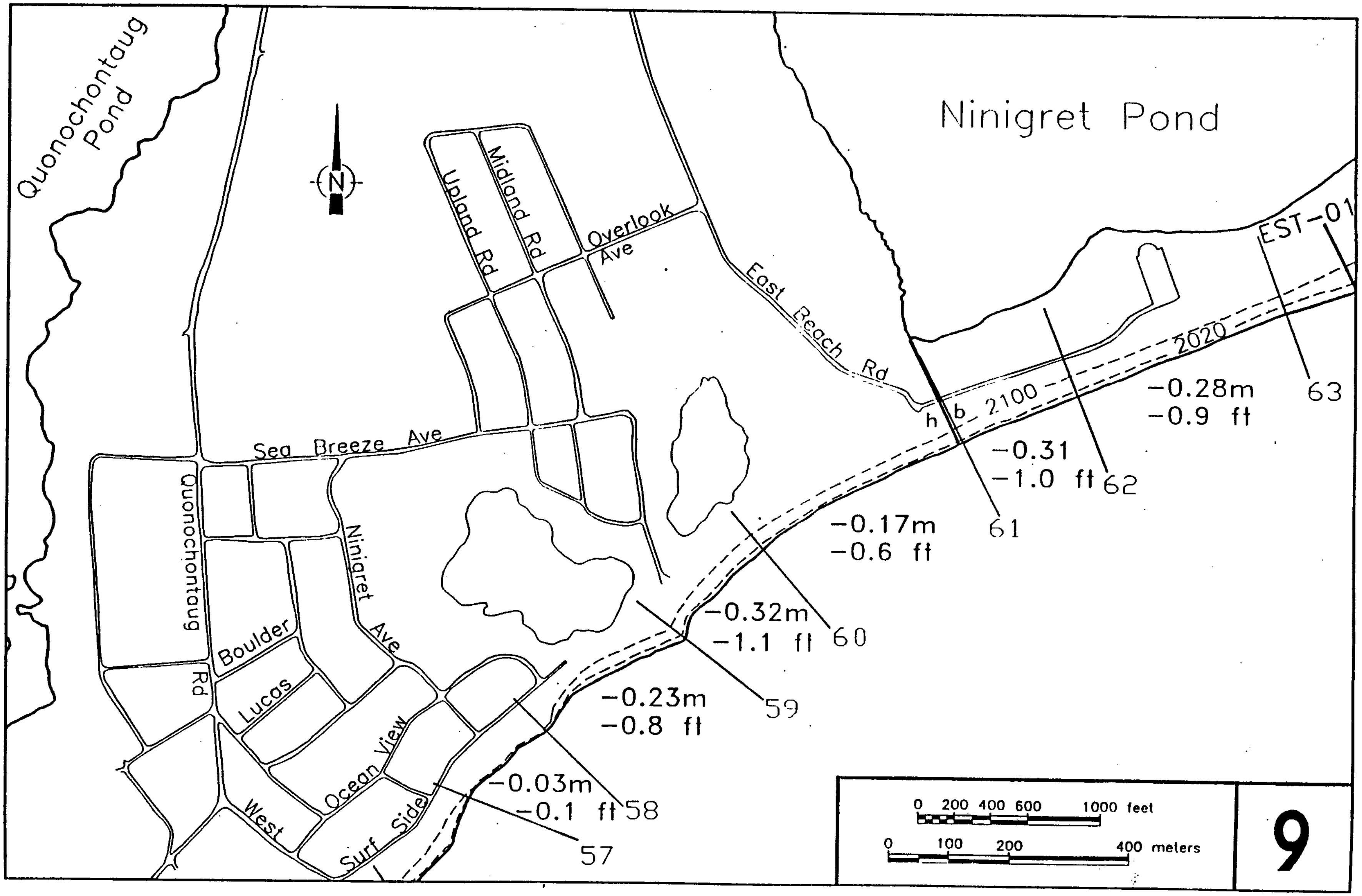
Source:
Rhode Island Coastal Resources Management Council
Shoreline Change Maps



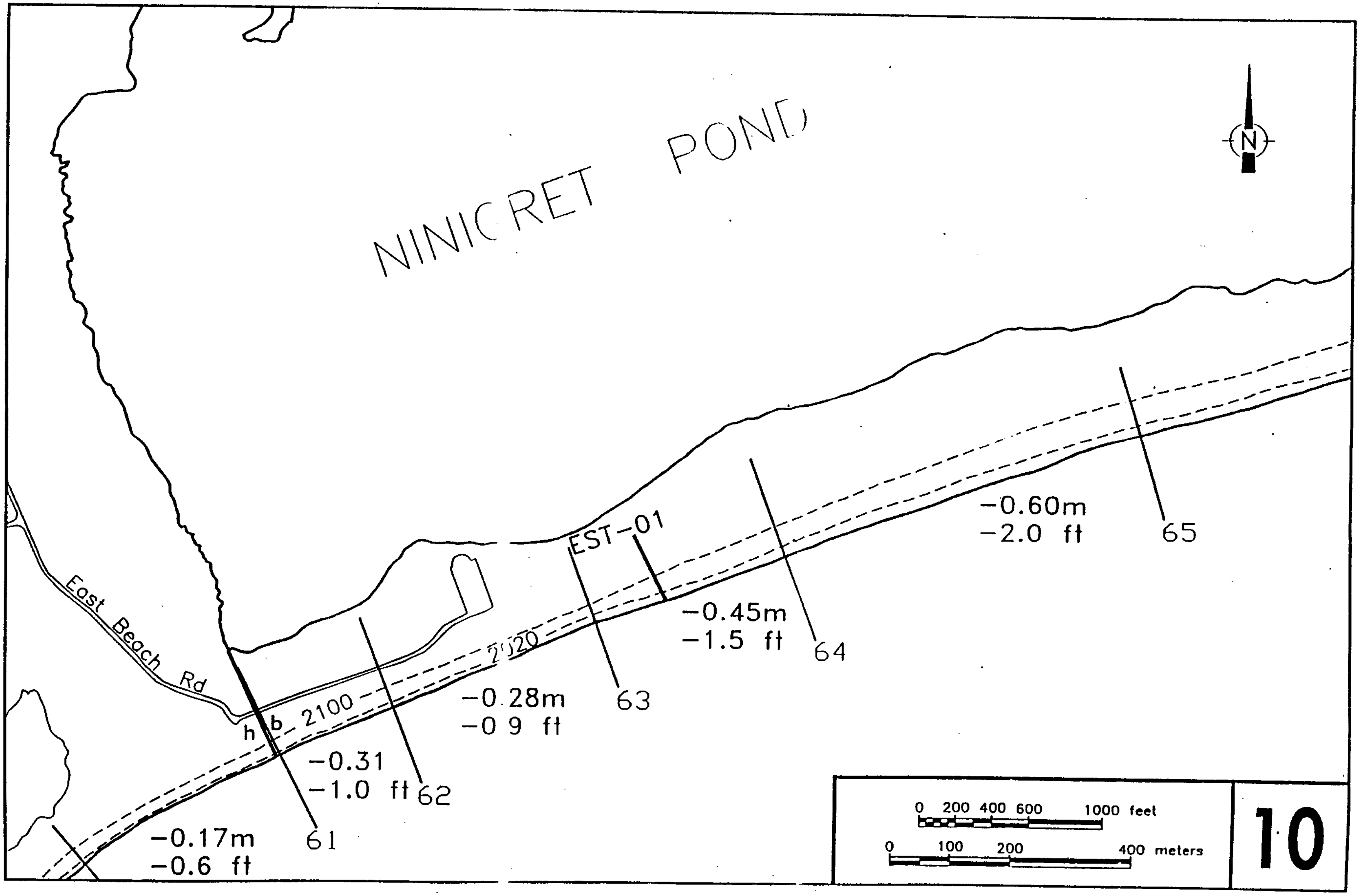
Source:
Rhode Island Coastal Resources Management Council
Shoreline Change Maps



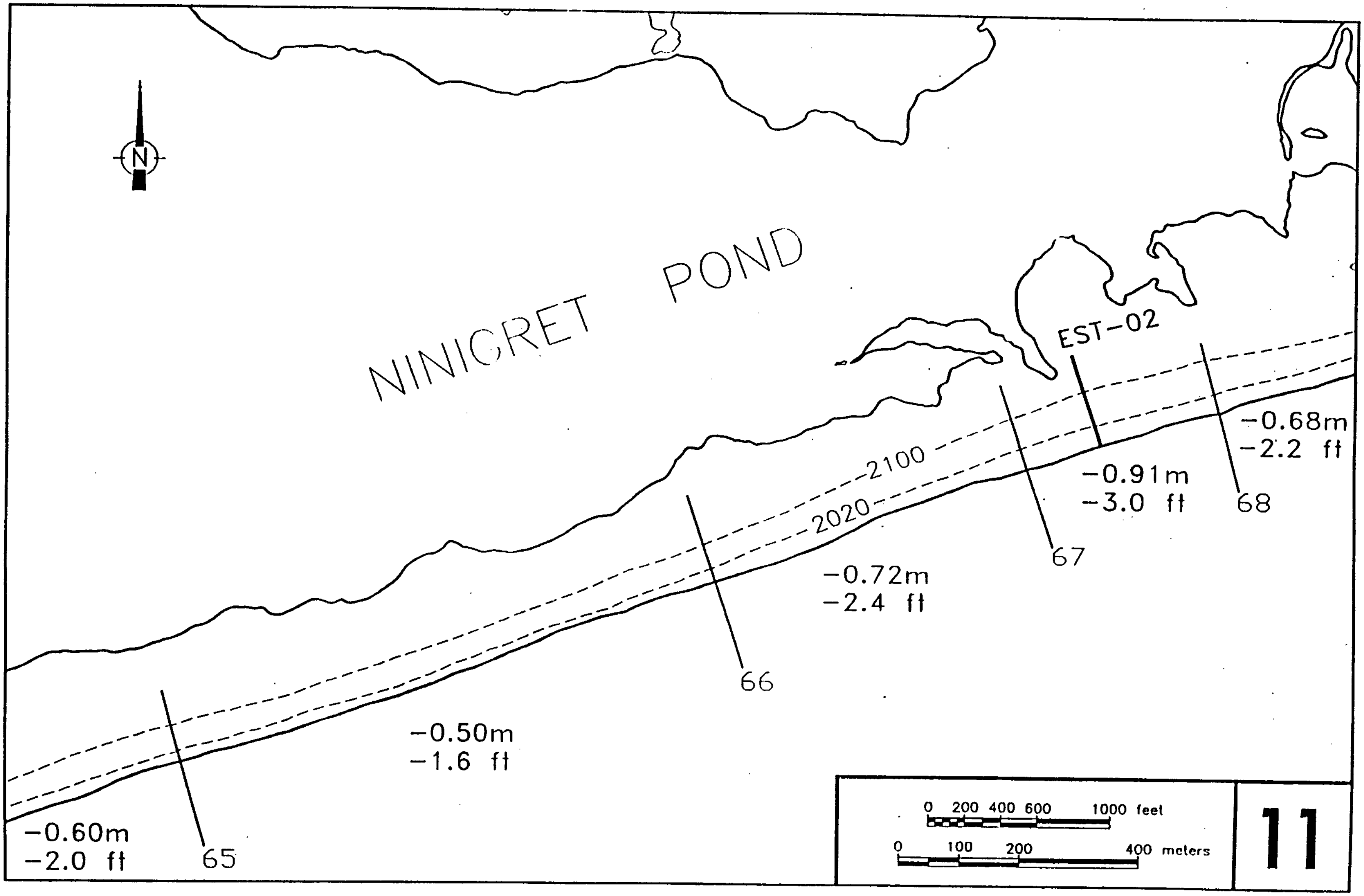
Source:
Rhode Island Coastal Resources Management Council
Shoreline Change Maps



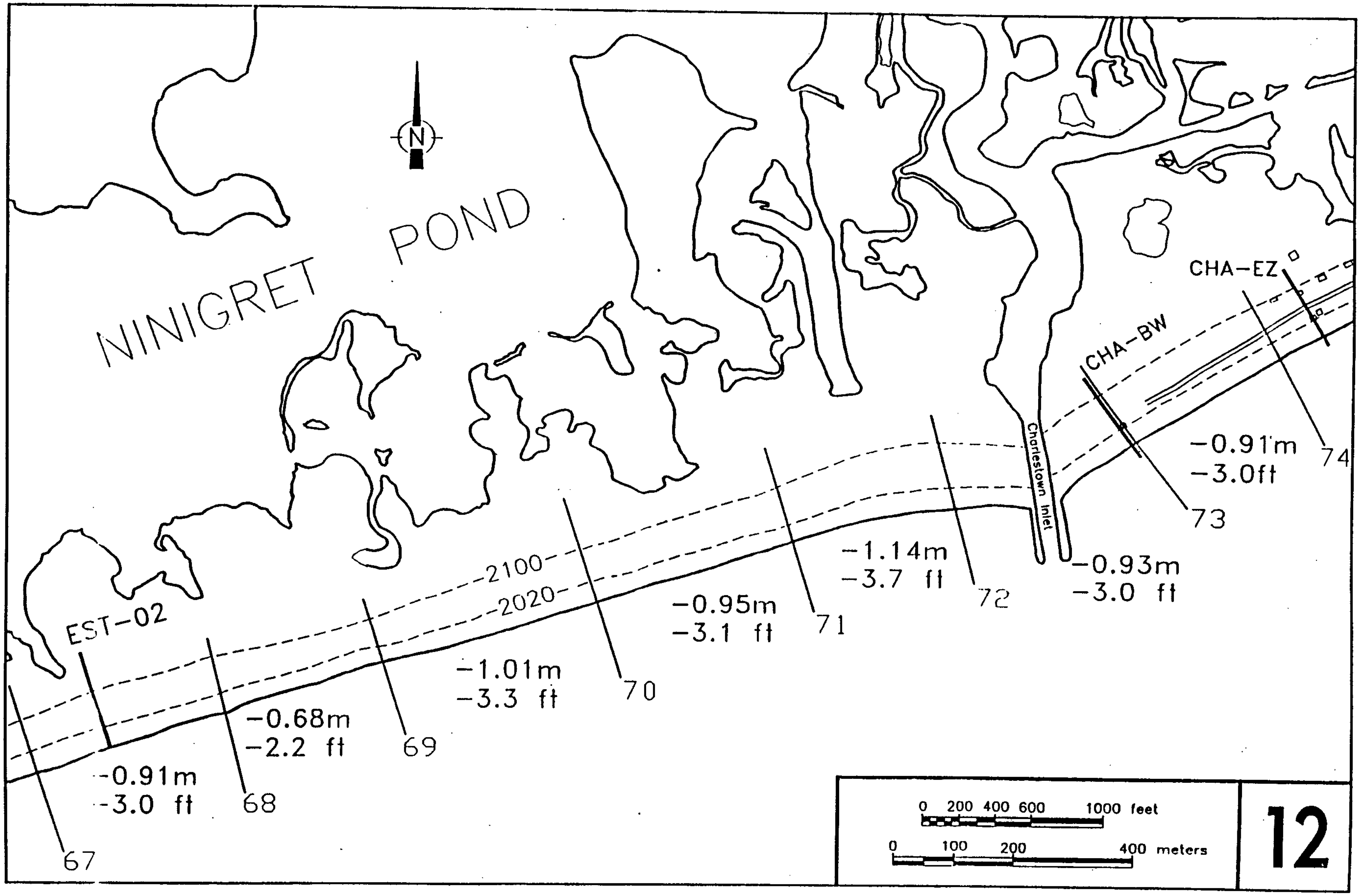
Source:
Rhode Island Coastal Resources Management Council Shoreline Change Maps



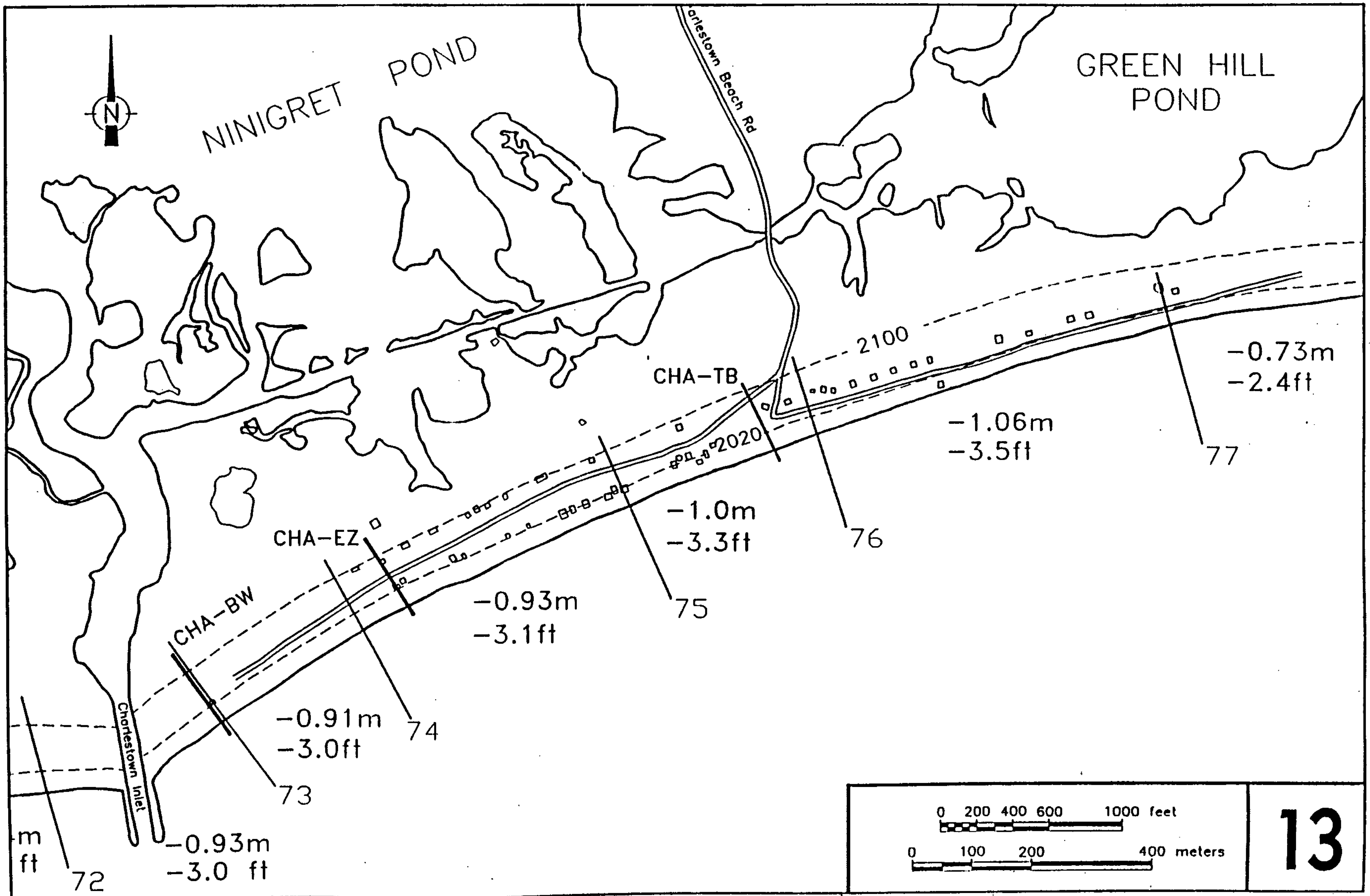
Source:
Rhode Island Coastal Resources Management Council
Shoreline Change Maps



Source:
Rhode Island Coastal Resources Management Council
Shoreline Change Maps



Source:
Rhode Island Coastal Resources Management Council
Shoreline Change Maps



Source:
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