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COASTAL STORM DAMAGE AND EROSION

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The purpose of this manual is to provide a description of coastal storm damage erosion prevention benefit evaluation procedures based on principles included. The U.S. Water Resources Council's Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies. The report presents selected, specific procedures for the entire process of benefit estimation and is intended for use in project feasibility planning and evalution. It is intended to serve as a reference guide to questions posed by an economic analyst in conducting a coastal storm damage and erosion prevention benefit evaluation.

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NATIONAL ECONOMIC DEVELOPMENT PROCEDURES MANUAL
COASTAL STORM DAMAGE AND EROSION

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PREFACE

This manual is part of a series of comprehensive guides designed to assist in the calculation of National Economic Development Benefits. It was sponsored by Headquarters, U.S. Army Corps of Engineers (HQUSACE), as part of the Planning Methodologies Research Program. Mr. Robert Daniel, Chief of the Economic and Social Analysis Branch (CECW-PD), Mr. William Hunt, Economist (CECW-PD), and Mr. John Housley, Senior Coastal Engineer (CECW-PF) served as Technical Monitors. Mr. William J. Hansen of the Institute for Water Resources (CEWRC-IWR-R) was the study manager. Mr. L. Leigh Skaggs, also of the Institute for Water Resources (CEWRC-IWR-R), and Mr. Frank L. McDonald (CENPD-PL-EC) served as primary editors.

The manual is the product of work and review by many individuals. A first draft was prepared by a team of authors from the North Pacific Division (CENPD), including Mr. Frank McDonald, Mr. Ken Boire (CENPD-PL-EC), Mr. Steve Chesser (CENPP-PL-CH), Ms. Mona King (CENPP-PL-EE), Mr. Brent Mahan (CENPA-EN-PL), Mr. Ken Eisses (CENPA-EN-HH), Mr. Tom White (CENPD-PL-EC), and Mr. Ed Woodruff (CENPD-PL-EC). That draft was based on an annotated outline developed by a group of Corps planners, economists, and coastal engineers at an Issues Identification Workshop hosted by Jacksonville District (CESAJ) in February 1989. Workshop participants included Mr. Ken Claseman (CECW-PD), Mr. John Housley (CECW-PF), Mr. Phil Thorpe (CENAP-PL-PE), Mr. David Timpy (CENAP-PL-PP), Mr. Chris Glanz (CENCD-PL), Mr. Charles Joyce (CENED-PL), Mr. Ed

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The manual was subsequently reviewed by engineers and social scientists from several Corps Major Subordinate Commands and District Commands. Valuable comments and suggestions were received from Mr. Frank McDonald (CENPD-PL-EC), Mr. Harry Shoudy (CEBRH), Dr. C. Linwood Vincent (CEWES-CP-C), Mr. Thomas Richardson (CEWES-CD), Mr. Richard Rodakowski (CELMS-PD-U), Mr. Adrian J. Combe (CELMN-ED-HC), Mr. Ken Claseman (CESAM-PD-FE), Mr. Matthew Laws (CESAM-PM), Ms. Mona J. King (CESAM-PD), Mr. J. Thomas Jarrett (CESAW-EN-C), and Ms. Anna Zacher (CESPL-PD-CS). The final report was drafted by Mr. L. Leigh Skaggs and Mr. William J. Hansen of IWR.

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CHAPTER I

INTRODUCTION

PURPOSE AND OBJECTIVES

The purpose of this manual is to serve as a comprehensive guide for calculating National Economic Development (NED) benefits primarily for coastal and lake shore storm damage reduction and shore protection projects. This document presents selected, specific procedures for the entire process of benefit estimation. It is intended to serve as a reference guide to questions posed by the economic analyst. As a practical guide, the manual attempts to emphasize "what to look for" and "what to do," rather than "why do it." Suggestions from economists, planners, coastal engineers, and other reviewers within the U.S. Army Corps of Engineers (Corps) were incorporated.

The procedures found in this manual are not the sole methods by which analyses may be performed and regulations and guidance followed. There are many valid ways to execute the necessary analyses. There are more uncertainties and variables in coastal storm damage prevention and beach erosion control studies than with most other types of planning studies. Each study can be considered unique because of the varied interactions of storms, coastal shapes, tidal fluctuations, coastal geology, and offshore geometry. Methods should be selected according to requirements of the type of project and planning document, local conditions and needs, availability of information, funding level to perform the study, and procedures that have been successfully employed within the District or by others in the past.

The fact that a particular procedure is not referenced in this document should not be construed as disapproval of that procedure. To the contrary, a general theme woven into the comprehensive nature of this document is to encourage innovation of procedures.

This manual is based on the conceptual framework of the Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (P&G). It neither duplicates nor supersedes P&G, but rather elaborates and provides references for how the guidance of that document can be carried out. It is part of a series of NED Procedures Manuals, including the Urban Flood Damage Manual (IWR Report 88-R-2), the Agricultural Flood Damage Manual (IWR Report 87-R-10), and the Recreation Manual, Volumes I and II (IWR Reports 86-R-4 and 86-R-5). This manual often refers to other manuals in the series, and the user should be familiar with, or have access to, these reports.

SCOPE

This manual is limited to discussion of procedures for estimating the economic affects of coastal storm damage and erosion and computing NED benefits for shore protection projects. Many of the damaging forces also act upon harbors, marshes, and other wetlands. Although there has been no attempt to specifically address those areas in this manual, many of the techniques described would still be applicable.

The report covers all stages of the planning process. As such, a summary of coastal processes and discussion of some shoreline change models are included, but only to assist in communication between economists, coastal engineers, and other planners. This discussion should not be construed as an attempt to supplant other sources of coastal information, such as the well-accepted Shore Protection Manual (SPM).[1]

The procedures covered in this manual are applicable to reconnaissance reports, Continuing Authority detailed project studies, pre-authorization feasibility reports and other economic studies. The methodology used in preparing these reports will differ only in detail.

INTENDED AUDIENCE

The authors of this volume did not expect that analysts would be assigned to a coastal storm damage study without some exposure to more traditional flood control studies. It is assumed, therefore, that the reader will have some knowledge of such concepts as flood frequency, depth-damage functions, plan formulation and benefit evaluation.

The manual is primarily designed for economists and planners concerned with economic analysis of Corps coastal storm damage projects. Planners, particularly project managers, must be able to understand and explain the process of benefit calculation, and the manual provides information to help determine which alternatives are promising enough to carry on to the later planning phases. This report should also be useful to hydrologists, hydraulic engineers and anyone else involved in shore protection or coastal storm damage issues. Distribution to non-Federal sponsors is encouraged whether or not they intend to take an active part in the economic analysis.

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[1] Coastal Engineering Research Center, Shore Protection Manual. (Vicksburg, Mississippi: Waterways Experiment Station, U. S. Army Corps of Engineers, 1984).

NATIONAL ECONOMIC DEVELOPMENT (NED) BENEFITS

National Economic Development benefits are defined by P&G as increases in the economic value of the goods and services that result directly from a project. NED benefits are increases in national wealth, regardless of where in the United States they may occur. The NED measurement concept differs from regional analysis in the sense that in the NED approach, transfers from one region to another become zero unless an efficiency gain is produced for the nation as a whole. It follows that a project may be economically attractive from the regional perspective, but unwise from the NED view. In contrast, because problems or projects may impact areas many miles away, a project that is highly attractive from the NED perspective may not look as attractive from the viewpoint of the local sponsor.[2]

Because our concern is with the Federal interest, the NED analysis counts all benefits and all costs wherever they occur. Therefore, to the extent there are economic effects other than those specifically intended, they must be identified and taken into account. As an example, if shore protection has an impact on recreation use, this must be considered and displayed even if recreation is not a project purpose.

NED costs are the opportunity costs of diverting resources from another source to implement the project. Uncompensated economic losses from detrimental project effects are also economic costs. As an example, if a project indicates mitigation is needed but incremental cost analysis finds some project effects will not be fully mitigated, the unmitigated losses will be evaluated and included as an economic cost in addition to cost of the

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[2] In this case, it may be appropriate to expand the scope of the "local sponsor" either to more communities, or to a larger body, such as a county or a state agency.

mitigation plan. Conversely, if measures associated with a project have effects above those required to maintain the status quo and result in enhancement, the net gain should be counted a., a benefit. A project is considered economically feasible if the NED benefits are greater than the NED costs. The benefit cost ratio would then be greater than one.

The project with the highest net NED benefits (but not necessarily the highest benefit cost ratio), which is otherwise feasible from an engineering standpoint, environmentally sound, and publicly acceptable, is the NED plan. Specifically, the NED plan should be formulated in consideration of four criteria: completeness, the extent to which a given alternative plan provides and accounts for all necessary investments or actions to ensure the realization of the planned effects; effectiveness, the extent to which an alternative plan alleviates the specified problems and achieves the specified opportunities; efficiency, the extent to which an alternative plan is the most cost effective while protecting environmental resources; and acceptability, the compatibility of an alternative plan with existing laws, regulations, and public policies, and acceptance by the public and state and local entities.

The NED plan is formulated in detail throughout the planning process (beyond the reconnaissance phase) and is given highest priority in selecting a Corps recommended plan. Local sponsors may request a plan other than the NED plan be implemented. However, in addition to cost sharing the NED plan, any incremental costs over the NED plan would be borne by the local sponsor.

OTHER ACCOUNTS

While four accounts are described by the P&G, this manual specifically addresses only the NED account. The other three accounts (environmental quality, regional economic development, and other social effects) contribute to good planning, and are briefly described below.

ENVIRONMENTAL QUALITY

Environmental Quality (EQ) effects are very important to plan formulation. The National Environmental Policy Act of 1969 (NEPA), PL 91-90, requires that an environmental impact statement assess the significant changes in the environment that would result from an investment of Federal funds. EQ effects are assessed as to their magnitude, location, duration, reversibility, frequency, and the long-term productivity of an area's value as a resource. The objectives of environmental evaluation are to affect the formulation of plans to avoid detrimental impacts, to take advantage of opportunities for enhancement and protection of resources, and to aid in determining a mitigation plan that will offset environmentally detrimental project effects. Guidelines to environmental quality evaluation can be found in Chapter Three of P&G and Chapter Seven of Engineering Regulation (ER) 1105-2-100, 28 December 1990.

REGIONAL ECONOMIC DEVELOPMENT

Regional Economic Development (RED) benefits refer to economic gains from a project in a specific geographic area. These gains are measured by the net increases of income and employment. RED benefits include transfers or redistribution of wealth from other regions of the country as well as increases in national wealth incident to that specific region. While RED benefits not otherwise included in NED benefits cannot be used in determining the costs and benefits of the NED plan, they can be extremely helpful to the local sponsor in assessing the value and financial feasibility of the project. A detailed description of the RED account can be found in ER 1105-2-100, pages 5-20 - 5-22.

A complete evaluation of the regional economic development account should consider the net gain to regional income and employment. The value of economic activity that would not occur because of the project should be subtracted in the computation of net RED benefits.

OTHER SOCIAL EFFECTS

The Other Social Effects (OSE) account includes those impacts which are not incorporated in the other three accounts, but are still important enough to have a bearing on the decision-making process. OSE impacts are primarily impacts that can be quantified, but are not amenable to assignment of any monetary value. OSE includes changes in risks to life and health, community vitality, displacement, fiscal health, as well as the geographic and demographic distribution of income and employment impacts. The OSE account is further described in ER 1105-2-100, pages 5-22 - 5-23.

INTERRELATIONSHIP WITH OTHER MANUALS

This manual is limited to discussion of procedures for estimating the national economic effects of computing NED benefits for shore protection and storm damage reduction projects. These projects may range from small, single-purpose projects to parts of major, multi-purpose projects. Included is a discussion of some of the advantages and drawbacks of various benefit calculation methods. Much of the methodology for gathering, analyzing, and presenting basic damage information is contained in the Agricultural and Urban Flood Damage NED manuals. We have attempted to minimize duplication of that information and concentrate on areas unique to shore protection and storm damage reduction. Major areas of difference are described below.

A. CAUSE OF FLOODING - Although not a prerequisite to coastal flooding, ocean effects eroding the natural protection (e.g., dunes, beach or barrier islands) over a period of months or years may increase the susceptibility of a shoreline to flooding or increase the severity of flooding from a given storm event. The cause of coastal flooding is often related to ocean water being driven overland by the force of wind, waves, and high tides. Rainfall, however, may also have a major impact on coastal flooding when conventional drainage or storm sewer systems are blocked by storm surge. Rainwater ponds during the storm duration and releases slowly as the storm surge drops. Flood damages in riverine environments are normally caused by precipitation and snowmelt which result in high flows in channels of insufficient capacity. Natural protection (i.e., channel capacity) is usually assumed to remain relatively constant over the period of analysis.

B. FLOOD VELOCITY - In riverine flooding, velocity is determined by stream gradient, flood plain characteristics, natural storage and the volume of water. Coastal storm flood velocity is determined by wind and tidal action and can have potentially significant effects, especially where such natural or man-made features as closely-spaced buildings, beach access roads, parallel jetties, and discontinuities in shore protection structures form conduits for the passage of flood waters. In addition, high winds accompanying the coastal flood velocities often cause catastrophic property damage not directly related to flood waters or preventable by controlling flood impacts.

C. FLOOD PREDICTABILITY - In most coastal areas, erosion and storm damage records are less frequently available and less reliable than those for stream flows. Coastal storms, including hurricanes, can be very localized and arise with little warning. Hurricane warning forecasts and evacuation plans are well developed in many coastal areas, but the nature of these storms can promote uncertainties in terms of location of landfall, maximum winds, and maximum surge flood heights. Another category of coastal storms, northeasters, are typically broad in their area of influence and follow general storm tracks that, while not predictable, can be anticipated.

Flood predictability in riverine flooding is characterized by, and displayed in, frequency curves or tables. The display indicates how often a given annual peak flow or stage is exceeded. The more historical information from past floods available, the more certainty there is in the frequency analysis. Gathering and recording information on precipitation, temperature and river levels is more institutionalized than gathering and recording of coastal storm events. Coastal events may be linked to a combination of events such as local wind-driven waves, ocean swells, extremely high tides, and high river flows in adjacent coastal streams.

D. EROSION LOSSES OF A SINGLE EVENT - River bank erosion is often not storm- or flood-related. Bank erosion in meandering streams, for example, is likely to be very evident during low flow periods. Erosion can be flood-related in the sense high flows can result in saturation of materials, washouts, bank cave-ins, loss of natural protection, overtopping of armor, or avulsion (the sudden cut off of land by floods, currents, or changes in the course of a river). In river flooding it is difficult to establish a reliable link between a predicted flow or water level and consequential erosion, while water levels and storm durations are major factors in coastal erosion models. Erosion is identified with a single event against a background of a long-term series of events over time.

E. LONG-TERM EROSION LOSSES - In the riverine environment, erosion (usually bank erosion) is sometimes predicted as a function of flow, but more often is a result of repeated cycles of high and low flows over a period of years. In the coastal environment, beach profiles often shift both in and out seasonally as well as in response to storms, making annual (and seasonal) changes a "normal" situation. This long-term normal situation is an appropriate and necessary consideration in establishing the without-project condition, and against which storm-related changes must be compared.

F. DOUBLE COUNTING OF DAMAGE PREVENTED ON LANDS LOST TO EROSION - Double counting of damages is usually not a major factor for flood damage studies, but may be a major issue for storm damage or erosion prevention studies. Double counting is usually a consequence of first counting a property as damaged by a storm event and also counting it as damaged in the long-term erosion category. Most double counting can be avoided by establishing stage-damage relationships for various [illegible] in the planning period (usually 5 or 10 years as appropriate to the severity of the long-term erosion problem). If the stage-damage relationship is periodically recalculated to subtract property lost to erosion, then average annual inundation damages will not be claimed for property no longer in the inventory of damageable improvements.

G. TIDAL EFFECTS - Tides impact the flooding problem in riverine flood studies in a predictable manner since the effects are usually taken into account in backwater calculations. Tides may also be a major factor in storm damage and erosion loss studies, but tidal levels are just one parameter incorporated into coastal stage-frequency curves. Determination of frequency of water surface elevation must consider effects of wind, tide, precipitation, and any other impact, not just precipitation and runoff.

H. SALT-WATER EFFECTS - The effects of salt water are nearly always a factor with coastal storm flood damage studies, although seldom a major factor with riverine flooding.

I. EFFECTS OF SUBSIDENCE AND MARSH DETERIORATION - Natural processes or man-made events can cause land subsidence and marsh deterioration. While less significant in most inland riverine situations, the long-term effects of the decrease in land elevations or sea-level rise are very significant in low-lying coastal areas. Coastal storm damage and erosion studies will therefore treat subsidence and sea-level rise with greater significance. The results of the study should frame conclusions in a way that demonstrates sensitivity to these issues.

J. ROLE OF SIMULATIONS IN THE ANALYSIS - Monte Carlo simulation (described subsequently in this report) and other simulation techniques are convenient procedures in coastal storm damage analysis for weaving together the joint probabilities of independent causal events. They work well for problems with multiple variables which can best be described by a series of independent probability functions such as tides, high winds and other offshore storms, as well as for situations where some or all of the variables are interdependent. Traditional analysis techniques are usually adequate for most riverine flood damage studies where the stage-damage, stage-discharge, discharge-frequency, and damage-frequency curves are more easily established.

K. THE FEDERAL INTEREST - Flood damage prevention problems are clearly in the Federal interest where benefits are widespread, and have been a long standing priority of the Corps. In contrast, solutions to erosion problems are often identified as not being in the Federal interest because they are not characterized as storm-related and/or having widespread benefits. It is undoubtedly recognized that the benefits for erosion and storm damage are often interrelated; frequently long-term erosion must be halted to accomplish storm damage prevention. Nevertheless, the fact remains that the costs of constructing projects for beach erosion control must be assigned to hurricane and storm damage reduction and recreation purposes.[3] Therefore, projects which demonstrate erosion damage prevention benefits to be storm-related, and that the erosion is, to an identifiable extent, storm-caused, will likely receive higher priority.

L. IMPACT ON LAND USE AND LAND VALUE - Coastal storm damage prevention can result in an increase in usable beach area. Care must be taken to avoid double counting of beneficial effects, such as estimating benefits from both enhanced land value and increased recreational value, since both are different ways of measuring the same values. Coastal storm damage protection projects may either increase or decrease adjacent land values. Increases in land values due to a change in land use resulting from a project are evaluated as location benefits, while decreases in value are project costs. Corps projects are not formulated for land development, so it is important to distinguish the portion of benefits that are related to land development or enhancement. Widespread benefits for multiple users, derived from protection of improvements that provide for at least 50 percent of the justification of the

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[3] As specified in PL 99-662, Section 103(d). See "Appendix A, Coastal Storm Damage and Beach Erosion Control Policies and Authorities" for greater detail.

project, will be a solid basis for showing Federal interest and a Corps role.

INTERFACE WITH OTHER DISCIPLINES

Coastal storm damage and erosion studies require very close coordination between the study manager, the coastal engineer, the economist, and the environmental specialists involved in the study. Assumptions made by any of the participants may affect the other disciplines more than with any other type of study. For example, if the economist assumes that an individual owner will construct a bulkhead to protect part of his property, the bulkhead may affect the littoral transport and erosion rates updrift or downdrift, thereby potentially affecting nearby development and/or any protective measures under consideration. Similarly, the coastal engineer may determine that the bulkhead will not be effective at all, in which case the damages assumed in the without-project condition and for any proposed project will be affected. If the economist assumes a structure will be removed or relocated rather than being replaced or repaired, then long-term erosion may be affected, or it may cause the environmentalist to further assume long-term development of some significant environmental effect which would not otherwise occur.

OVERVIEW OF REMAINDER OF MANUAL

Chapter II. Chapter II gives a brief introduction to the principles of coastal engineering and shoreline responses to storms and long-term erosion. It is intended only as a source of background information for those with limited exposure to coastal storm damage prevention and shore protection studies and the relevant terminology. Those readers interested in a more detailed technical presentation should consult the Coastal Engineering Research Center's <u>Shore Protection Manual</u>.

<u>Chapter III</u>. Chapter III provides a basic outline of the types of projects and various benefit categories. Emphasis is placed on differences between storm and long-term erosion damage. Brief descriptions of alternative types of projects are provided again, only as background information, to improve communication.

<u>Chapter IV</u>. Chapter IV provides a step-by-step guide for estimating NED benefits. Eleven discrete steps are described, from delineation of the study area and establishing present and future conditions both with- and without-project to calculation of benefits. A practical methodology for conducting each step is explained, including how both the traditional evaluation procedures and simulation (Monte Carlo) methodologies can be used. An example of the methods employed in an actual storm damage reduction and beach erosion control project is presented.

<u>Chapter V</u>. Chapter V discusses the suggested minimum amount of documentation needed for various types of reports and studies.

Appendices A through C provide additional technical information on coastal storm damage and beach erosion control policies and authorities; an example of NED economic benefits analysis from an actual planning study; and an example of shoreline damage assessment using Monte Carlo simulation from another planning study.

CHAPTER II

STORM CONDITIONS AND SHORELINE RESPONSE

INTRODUCTION

This chapter describes the basic coastal processes and the coastal engineering principles and models used in evaluating storm damages and long-term erosion. The definitions and physical mechanisms are explained in relatively non-technical terms to provide some of the information necessary for non-coastal specialists to be able to work with coastal professionals to assess coastal storm damages and erosion. It is not intended to supplement or act as a substitute for the Shore Protection Manual (SPM)[1] or other technical references. The reader is encouraged to refer to that manual for more detailed explanations.

The field of coastal engineering encompasses a variety of disciplines, a wide range of environmental conditions, and more uncertainty than most hydrologic engineering. Shorelines respond dynamically to ocean tidal forces, Great Lakes water levels, wind-generated waves, and large-scale currents. Cycles of erosion and accretion may vary from hours to decades. It is important to understand both the coastal processes and the shoreline responses before attempting an engineering solution.

One goal of this chapter is to provide sufficient information to enable economists and planners to understand the engineering solutions proposed by the coastal professionals. Because of the technical nature of much of the discussion in this chapter, a short glossary is provided to standardize the

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[1] Coastal Engineering Research Center, Shore Protection Manual, (Vicksburg, Mississippi: Waterways Experiment Station, U. S. Army Corps of Engineers, 1984).

definitions of some common terms. Figure 1 provides a general illustration of some of the technical terms found in the glossary.

DEFINITIONS

Accretion – The buildup of land on a beach either due to natural forces (deposition by water or air) or in response to structures or fill.

Backshore – The part of the shore (between foreshore and dunes) acted upon by waves only during severe storms, especially when combined with exceptionally high water. The backshore is composed of berms.

Bathymetry – The measurement of the depths of water in oceans, seas, and lakes and the information derived from such measurements.

Beach – The narrow strip of shore land in immediate contact with the sea is called a beach when unconsolidated sediments, usually sand, are present.

Beach Fill – The artificial building up and/or widening of the beach by direct placement of fill material on the shore.

Berm – A nearly horizontal part of the beach formed by the deposit of material by wave action. Some beaches have no berms, others have one or several.

Breaker – A breaking wave, for example, on a shore or over a reef.

Breakwater – A structure built to block or reduce the wave energy in the lee of the structure thereby reducing the wave energy available to attack the beach or shore.

Bulkhead – A wall-like structure usually built of wood, steel, or concrete, designed primarily to retain or prevent sliding of the upland area. Bulkheads are often used in harbor and sheltered water

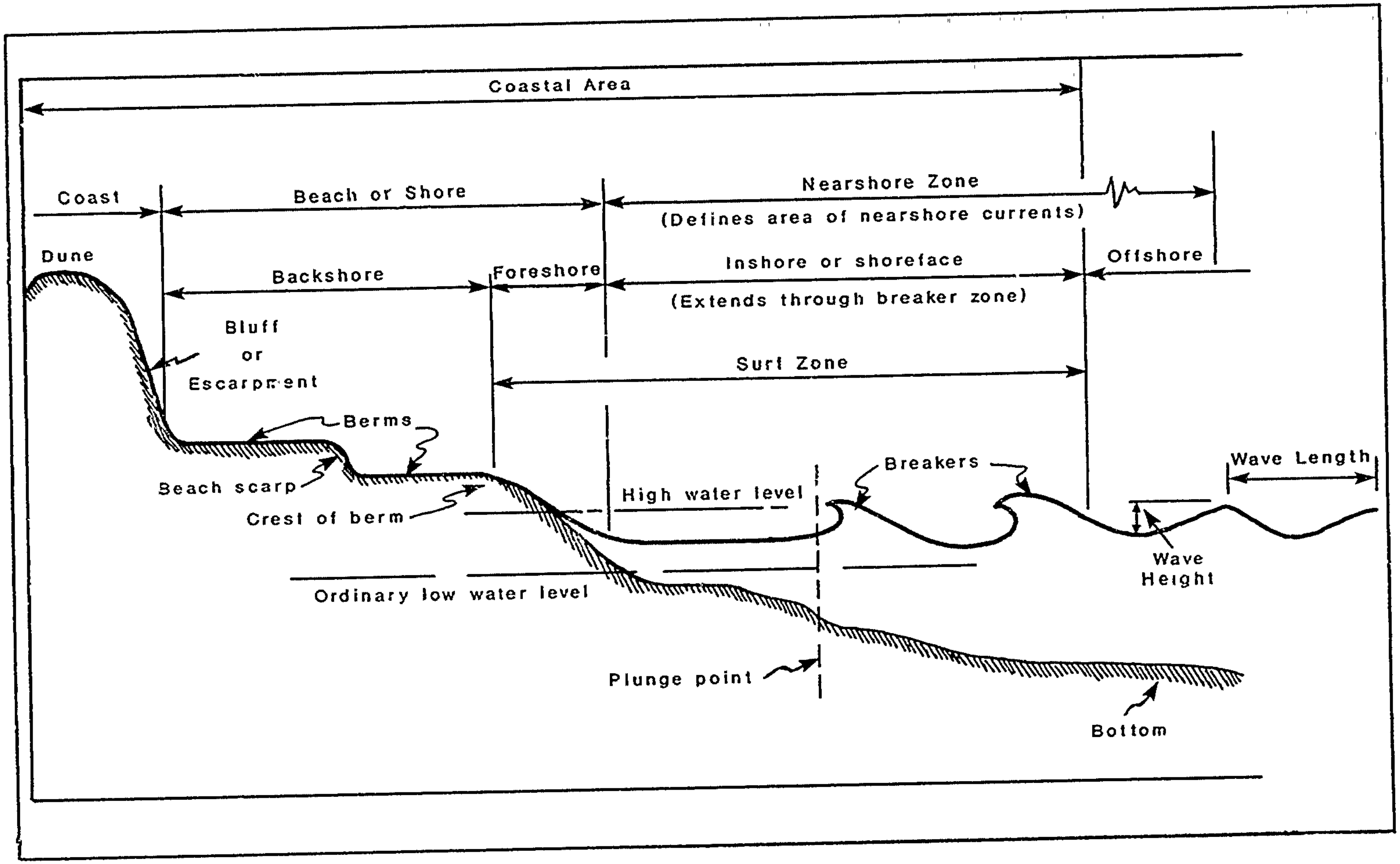

Figure 1. Coastal Area Terminology

Source: Shore Protection Manual, (Vicksburg, MS: Waterways Experiment Station, 1984).

areas to protect the upland from wave and current action.

Deflation - The removal of loose material from beach or other land surface by wind action.

Diffraction - The transmission of energy laterally along a wave crest. When waves approach a barrier, such as a breakwater, diffraction is manifested by the creation of waves in the sheltered region within the barrier's shadow.

Dune - A common feature of sandy coasts composed of wind-blown sand, generally in long ridges paralleling the shore and usually above the level of storm waves.

Erosion - The loss of beach or dune material by the action of wind, waves, and currents.

Fetch - The area in which waves are generated by a wind having a fairly constant direction and speed.

Foreshore - The part of the shore lying between the upper limit of wave wash at high tide and the ordinary low-water mark, that is ordinarily traversed by the uprush and backrush of waves as the tides rise and fall.

Groin - A structure usually built perpendicular to the shore to stabilize shoreline position and minimize erosion by trapping longshore moving sediment.

Headland - A high, steep-faced promontory extending into the sea.

Hindcast - The determination through empirical relations or numerical models of wave heights, periods, directions, and such factors as storm surge from historical weather charts or other historical records.

Inshore Zone - The zone of variable width extending from the low water line through the breaker zone.

Jetty - A structure usually built at the mouths of rivers or tidal inlets to stabilize a navigation channel and assist in maintaining project depths by preventing shoaling of littoral materials.

Littoral transport - The movement of sedimentary material due to waves and currents either parallel to the shore (longshore transport) or perpendicular to the shore (cross-shore or on-offshore transport). The sedimentary material per se is called littoral drift. The seaward limit of sediment transport defines the littoral zone.

Littoral cell - An area of the coast defined by natural headlands or features which limit littoral transport into or out of the cell.

Morphology - The shape of the shore, nearshore, and offshore surface contours.

Neap Tide - A tide occurring every two weeks having a minimum range between successive high tides and low tides.

Nearshore Zone - An indefinite zone extending seaward from the shoreline well beyond the breaker zone. It defines the area of nearshore currents.

Overwash - That portion of the wave uprush that carries over the crest of a berm or a structure.

Plunge Point - The final breaking point of the waves just before they rush up on the beach.

Reach - The primary economic analysis sub-unit. The shoreline and associated upland areas are divided into reaches throughout which geomorphic structures, erosion conditions, or human development patterns can remain relatively constant.

Recession - In this manual, the landward movement of the shoreline during a storm due to the transport of sediment, excluding the effect of post-storm accretion. Recession may also refer to the net landward movement of the shoreline over a specified period of time.

Refraction - The bending of waves by currents or underwater surface contours.

Revetment - A veneer of stone, concrete, or other material built along a bank or shore to prevent loss of land and damage to landward structures caused by wave action or currents.

Riprap - Rubble or quarrystone, usually well graded within a wide size limit, randomly placed along a structure or shore to prevent wave and current erosion.

Runup - The uprush of water along a beach or structure due to breaking waves. If this exceeds the height of the beach or structure, overtopping occurs.

Shoaling - The gradual process of a bay, inlet, or channel becoming shallower, usually caused by sediment deposition.

Shoaling coefficients - The ratio of the height of a wave in water of a given depth to its height in deep water.

Seawall - A structure similar to, but more substantial than, a revetment. It is usually constructed of pour-in-place concrete. Seawalls are generally built in areas where a high degree of protection is warranted.

Sediment budget - The process of estimating or quantifying the sediment contributions and losses within a littoral cell to determine if beach erosion or accretion should naturally occur.

Seiche - An oscillation of the surface of an enclosed or semi-enclosed body of water that varies in period from a few minutes to several hours.

Setup - Increase in water surface elevation at the shoreline independent of astronomical tides due to onshore transport of water by wave action (wave setup), or winds (wind setup).

Spring Tide - A tide occurring every two weeks having a maximum range between successive high and low tides.

Storm surge - A rise in local water level above the astronomical tide level due to a combination of wind and low atmospheric pressure during a storm or hurricane (also called storm tide).

Storm Track - The path followed by the center of low pressure of a storm.

Surf Zone - The area between the outermost breaker and the limit of wave uprush.

Surge Barrier - Structures built across the entrances of bays, lagoons, sounds, and estuaries to block the progression of storm setup or surge into these areas. These barriers generally consist of dikes with circulation and/or navigation openings which are left open during fair weather and closed when coastal storms threaten to flood the area.

Swell - Wind-generated waves that have traveled out of their generating area, usually characterized by regular, long periods and flat crests.

Tide - The periodic rise and fall of the ocean caused by the gravitational forces of the sun and the moon. The maximum height reached by water during each rising tide is called high tide or high water and the minimum level is called low tide or low water. On some coasts this occurs once a day (diurnal tide) while on other coasts this occurs twice a day (semi-diurnal tide). When one high tide is higher it is called Higher High Water (HHW) and the lowest tide is called Lower Low Water (LLW). When HHW or LLW is averaged over a 19-year period the datum is called Mean Higher High Water (MHHW) or Mean Lower Low Water (MLLW).

Tsunami - A long period ocean wave produced by an undersea earthquake or volcanic eruption, often mistakenly called a tidal wave.

Waves - Changes in the elevation of water in the ocean caused by the motion of currents and wind action. The average height of the highest one-third of the waves usually measured by observing the vertical distance between a crest and the preceding trough is called significant wave height. The wave conditions to which a shore or structure will be subjected is usually derived by combining deepwater wave statistics for height, period, and direction with computed refraction and shoaling coefficients.

Wave Height -The vertical distance between a wave crest and the preceding trough.

Wavelength - The horizontal distance between similar points on two successive waves measured perpendicular to the crest.

Wave Period - The time it takes two successive wave crests to pass a fixed point.

BASIC COASTAL PROCESSES

This section describes the physical environment that is responsible for shoreline responses such as erosion, flooding, storm damages or accretion. Much of this material is extracted from the Shore Protection Manual or other Corps publications. Basic coastal processes include such forces as waves, tides, currents, littoral transport, storm surges, seiche, hurricanes, tsunamis and the interaction of these forces with shore features and other factors affecting shore stability.

WAVES

Most of the energy delivered to the shore by the ocean originates from the wind acting on the ocean to produce waves. Wave characteristics are determined by the wind direction, wind speed, wind duration, how far the wind blows over water, and how far the wave travels before reaching land. Waves generated locally by wind action are called sea; those generated elsewhere, swell. Sea waves are generally steep (high ratio of wave height to length), while swell are usually flatter. In cases where sea and swell exist simultaneously, the sea will have shorter periods. Both can have large, damaging heights.

TIDES

Changes in water level elevations due to gravitational forces of the moon and sun occur regularly enough to predict mathematically for most points on the coast. The tide usually has two high levels and two low levels per day (semi-diurnal) or one high and one low per day (diurnal). The range from high to low tide varies with time of the month or season. Spring tides have the highest range and neap tides the lowest. Tidal range also varies with the location along the coast or the distance up a river or estuary from the coast.

CURRENTS

Currents can be generated by either winds or waves or may be part of larger ocean circulation patterns. Onshore (a direction landward from the sea) or offshore (a direction seaward from the land) winds also directly produce currents which tend to be at right angles to the wind direction. Longshore currents can also be produced by waves approaching the shore at an angle. Longshore currents are important in the transport of sediment away from or toward the project site. Tidal currents are important in shallow water near tidal inlets. River discharge may also produce nearshore currents.

LITTORAL TRANSPORT

Littoral transport, the movement of sedimentary material (i.e., littoral drift) in the littoral zone by waves and currents, has a tremendous impact on coastal morphology. The process has both a longshore and an onshore-offshore component. The former has an average net direction parallel to the shoreline, whereas the latter has an average net direction perpendicular to the shore. The quantification of sediment transportation, erosion, and deposition for a selected segment of the coast is known as a sediment budget. While the boundaries for the sediment budget are determined by the area under study, the time scale of interest, and study purposes, separate budgets may be needed for distinct littoral cells (e.g., between inlets that separate eroding and accreting beach segments).

Processes that increase the quantity of sediment within the cell are called sources, while those that decrease the quantity are called sinks. Longshore transport can function as both a source and a sink for the littoral cell. Point sources or point sinks (tidal inlets often function as the latter) add or subtract sediment across a limited part of the cell. Line sources or line sinks (an example of the latter would be wind transport landward from the beaches of a low barrier island) add or subtract sediment across an extended segment of a littoral cell. In a complete sediment budget, the difference between the sand added by all sources and the sand removed by all sinks should be zero. In the usual case, a sediment budget calculation is made to estimate an unknown erosion or deposition rate, which is the difference resulting from equating known sources and sinks.

The relative importance of elements in the sediment budget varies with locality and with the boundaries of the particular littoral cell. On many shores, the gross longshore transport rate significantly exceeds other volume rates in the sediment budget, but if the beach is approximately in equilibrium, this may not be easily noticed. The erosion of beaches and cliffs and river contributions are the principal known natural sources of beach sediment in most localities. Inlets, lagoons, and deep water in the longshore direction comprise the principal known natural sinks for beach sediment. Of potential, but usually unknown, importance as either a source or a sink is the offshore zone seaward of the beach.

STORMS

Whether they are called hurricanes, cyclones, tropical storms, northeasters, or other names, storms[2] and their associated winds, waves, and inundation are responsible for most of the destructive coastal damage and short-term erosion that occurs. It is important to note, however, that major storms, such as hurricanes, may cause massive damage and flooding with little accompanying beach erosion. Some important characteristics in assessing potential storm damage include the storm track, landfall location, storm surge elevation, storm intensity, wave height, frequency of occurrence, duration, and related meteorological factors such as wind and rainfall.

TSUNAMIS AND EARTHQUAKES

Tsunamis, sometimes mistakenly termed tidal waves, are very long-period waves generated by seismic events such as earthquakes. The waves are capable of traveling thousands of miles from the originating seismic event. Tsunamis occur rarely, but they can be very destructive to affected coastlines.

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[2] The definition of a "storm" is not absolute. According to the Shore Protection Manual, a storm is an atmospheric disturbance characterized by high winds which may or may not be accompanied by precipitation. Storms are categorized by their wind velocity and region of origin. For example, hurricanes are tropical storms having winds in excess of 73 miles per hour; northeasters are extratropical storms having strong winds (no velocity threshold, however) blowing from the northeast quadrant that occur along the Atlantic coast of the U.S.

While there is no universally-accepted set of minimum conditions that define storms, in coastal settings a storm can be defined as a period during which wave heights exceed a critical value. In this manual, a generally accepted, albeit arbitrary, distinction between storm damage events and erosion damage events is used: a one year exceedance frequency. That is, damages resulting from waves with exceedance frequencies of less than or equal to one year are characterized as erosion damages, while damages resulting from waves with exceedance frequencies of greater than one year constitute storm damages.

Additionally, earthquake events per se are destructive processes that can significantly alter the coastal landscapes where they occur.

LAKE LEVELS

Lakes have insignificant tidal variations, but are subject to seasonal and annual hydrologic changes in water level, and to water level changes caused by wind setup, barometric pressure variations, and seiche.

SHORELINE RESPONSES

The shoreline responses most often of concern are beach erosion and storm damage. Storm erosion refers to the loss of beach or dune material by waves and high water levels associated with storms, while storm damage implies physical damage (other than caused by land loss) to structures and other facilities due to any combination of winds, waves, tides, and intense rainfall. Storm damage and erosion occur along other types of shorelines, but are more critical on beaches. Beaches can be described by their material, width, slope, and by the presence of features such as bars, dunes, headlands or inlets. Beaches may be on offshore barrier islands, on the mainland, lakeshores, or along the margins of an estuary or river. The presence and type of beach is a dynamic response to the availability of sediments and the ocean forces. Under static conditions the beach can naturally absorb the ocean forces and maintain stability. If conditions change, the beach will become unstable and will erode or accrete in order to re-establish stability. For example, if sediment supply is diminished (whether caused by man-made or natural forces), or abnormal storm conditions occur, the beach erodes.

SHORELINE EROSION

There are both short-term and long-term causes of shoreline erosion. Erosion may be natural or man-induced. The most common type of short-term erosion is from storms which can produce rapid, dramatic erosion. Long-term erosion may be less noticeable, but may ultimately have more severe consequences. Table 1 lists the various causes of erosion.

TABLE 1
CAUSES OF EROSION

	SHORT-TERM	LONG-TERM
NATURAL	Storm Waves (Large Wave Height and/or Short Wave Period) Storm Surge Overwash Flooding Rip Currents Underflow Ice Flows (on the Great Lakes)	Sea Level Rise Decreased Sediment Supply Deflation Littoral Transport Loss Sorting of Beach Sediment Flooding Rip Currents Subsidence (Compaction)
MAN-MADE	Navigation Inlets Seawalls, Groins, Jetties, and Other Structural Features	Navigation Inlets Seawalls, Groins, and Other Structural Features Aquifer Depletion Damming of Rivers Sand Mining Dune Destabilization

Man-induced erosion is commonly unplanned and results from unexpected consequences of coastal or upland development. While natural channel entrances have a substantial capacity to modify sediment transport in their vicinity, artificially dredged channel entrances, structurally modified for navigational purposes, have a much greater potential for affecting the adjacent shores. Impacts vary with the characteristics of a particular entrance. Effects can extend miles from the entrance channel and are greatest where there is substantial net longshore sediment transport. Examples of significant shoreline erosion caused by structural modification of inlets and entrance channels exist at Ocean City, Maryland; St. Mary's River, Georgia; and Port Canaveral, Florida. Primary impacts have included interruption of longshore sediment transport, recession or landward migration of downdrift beaches, and loss of littoral sediments from the nearshore system. Offshore disposal of beach-quality sand dredged from inlets acts to compound the adverse impacts on adjacent shorelines. The loss of beach materials due to sand mining for construction purposes has a similar consequence.

Long-term erosion from a sea level rise due to global warming may be considered either natural or man-induced. Similarly, subsidence of land surfaces also results in beach erosion. A drop in nearshore elevation due to subsidence is equivalent to a sea level rise of the same magnitude; the beach profile is thrown out of equilibrium by the creation of a sand sink offshore, and this induces offshore sediment transport and shore recession. Examples of naturally-caused subsidence occur in the Mississippi River delta, where the weight of the accumulated sediment causes continued compaction and sinking, and in areas of seismic activity, where earthquakes can result in rapid downward displacement of the land surface. Man-induced subsidence can be caused by the mining of hydrocarbons and by water extraction for agricultural, municipal, and industrial uses. An example of subsidence due to the former exists in the Terminal Island-Long Beach region in California; an example due to the latter at the southern end of San Francisco Bay; and an example of subsidence due to both in the Houston-Galveston Bay area, Texas.

Coastal erosion may also result from man-made modifications in upstream river valleys, where the building of levees and dams for flood and debris control, water supply, and hydroelectric power can have unintended detrimental effects by cutting off supplies of sediment to the coast. This problem is particularly evident on the U.S. Pacific coast, where rivers historically have been a major source of sand for coastal beaches. Infrequent large floods are responsible for depositing large quantities of sand at river mouth deltas, and waves and currents act upon this episodic source, gradually transporting the sand along the coast.

Other sources of human-induced erosion are shoreline protective works such as groins, seawalls, and breakwaters, which are built to stabilize beaches and control erosion, but which may actually induce downdrift beach erosion. Because no new sand is created, their purpose is to redistribute sand along and across the beach profile. However, this modification of the normal littoral transport mechanism may have negative ramifications downdrift. While the use of properly engineered structures has proven successful where correctly designed, constructed, and maintained, their effects on adjacent shores must be carefully evaluated.

Beaches respond to wave action differently under normal and storm conditions. When normal conditions prevail, the wave energy is easily dissipated by the beach's natural defense mechanisms. During storm conditions, however, the increased wave energy exerted by the storm requires an extraordinary response, such as the sacrifice of large sections of beach and dune material through erosion. In time the beach may recover, but often not without a permanent loss of this littoral material.

Under normal wave conditions, the beach's first line of defense is the form of the sloping nearshore bottom. Waves break, expending some of their energy in turbulence and the transport of bottom sediment, at a depth generally defined by the breaking wave formula (a water depth equal to about

1.3 times the wave height). Most of the rest of the water's energy is spent in rushing up the beach slope between normal high and low tides (between the mean high water and mean low water levels). Above the high tide, beach sediment affected by the wind is moved shoreward into dunes. The result is a relatively stable profile (Figure 2A). If there is an increase in the incoming wave energy, the beach profile will adjust to absorb that energy, usually by the seaward transport of beach material to an area where the bottom water velocities are sufficiently reduced to cause sediment deposition. Eventually enough material is deposited to form offshore bars, which cause the incoming waves to break further seaward, dissipating their energy over a wider surf zone.

The subtle changes in the beach which occur during normal conditions may, depending on whether more sediment or beach material is removed or added, result in accretion, a stable profile, or erosion. The effects of storms, however, are often devastating in terms of shoreline erosion. During a storm event, high winds and high water levels (storm surge) combine with steep waves which may bypass the offshore bars to break directly on the beach (Figure 2B). The increased energy contained in the storm waves is spent eroding part of the beach, berm, and sometimes dune (crest recession and lowering in Figures 2C and 2D), which are now exposed to wave attack by virtue of the storm surge. The eroded material is transported farther offshore where it is deposited to form a deeper offshore bar. This bar eventually grows large enough to break incoming waves, thereby dissipating some of the waves' energy over a wider surf zone (Figure 2C). However, this offshore bar may be too deep to affect normal waves after the storm, and additional beach material is eroded to reestablish the normal offshore bar. Where there is ample sediment supply the

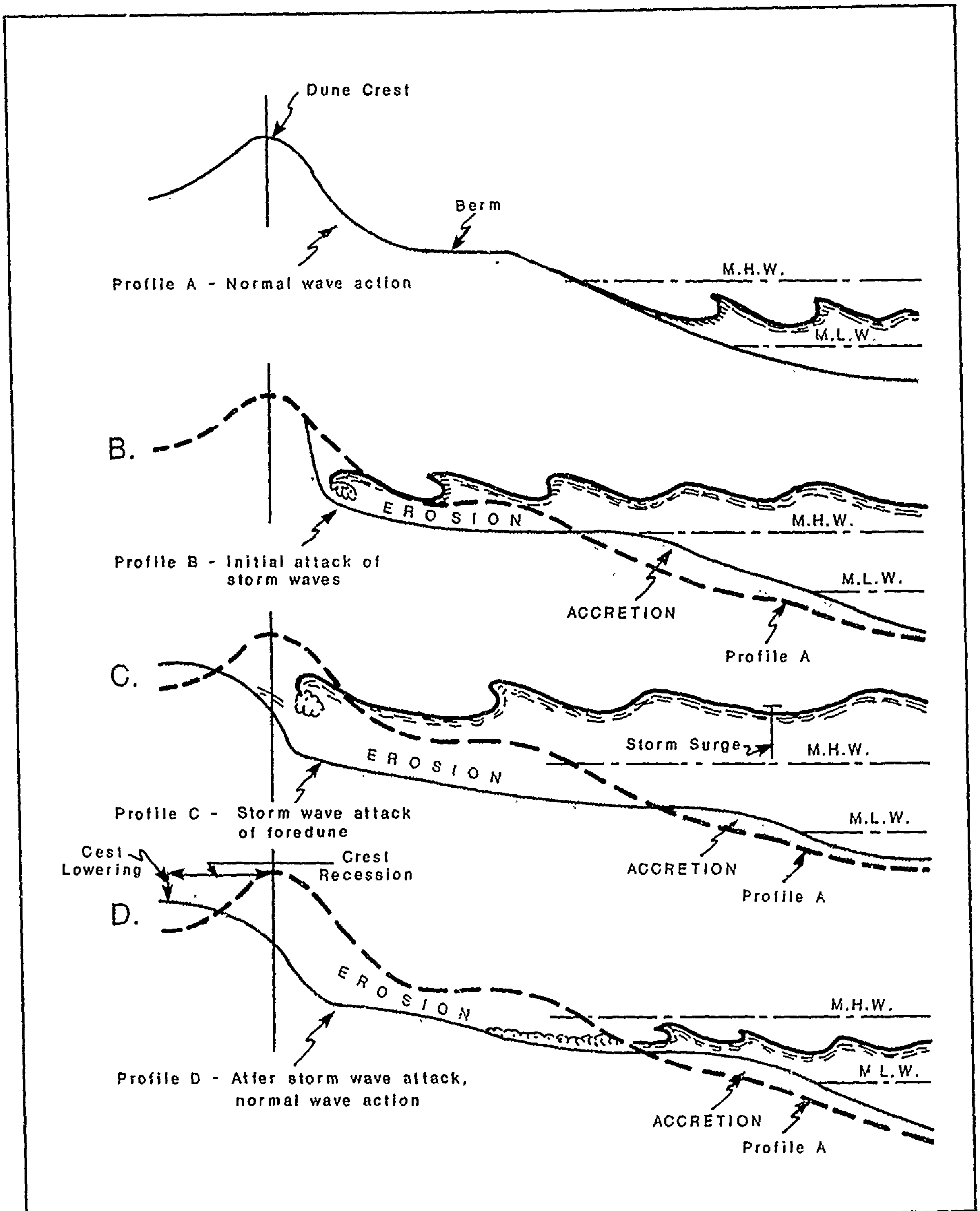

Figure 2. Schematic Diagram of Storm Wave Attack on Beach and Dune.

Source: Shore Protection Manual, (Vicksburg, MS: Waterways Experiment Station, 1984).

beach is rebuilt (accretes) during the period between storms, but if sediment supply is limited or storms are too frequent, the beach suffers a net loss of sediment.

At coastal sites having no dunes or low protective dunes, or when the storm conditions are particularly severe, the storm surge and wave action may succeed in completely overtopping the dunes causing extensive coastal flooding. When this occurs, beach and dune sediments are swept landward by the water, and in the case of barrier islands, are deposited as overwash fans on the backshore or in the lagoon. This process results in a loss of sand from the dynamic beach system. Often, storm overwash and storm flooding return flow will erode enough sand to cut a new tidal inlet through the barrier island. Depending on various factors, the new inlet may become a permanent feature of the coastline.

STORM DAMAGE

In addition to beach erosion, storm damage may occur to any structure located close enough to the water to be undermined or directly attacked by waves. In areas with an inadequate protective dune system, the dune may be breached or overtopped. If this occurs on a barrier island or spit, beach and dune sediments are carried landward and deposited on the backshore, in marshes, or in the bay. In severe instances, enough erosion occurs for a new inlet to be cut through the barrier. Inlet formation is most often caused, however, by trapped storm surge water creating a blowout from the bayside rather than erosion from the ocean side. Where low lying areas are protected by a dune system, a breach or overtopping may cause extensive flooding. In some areas with erodible formations such as sea cliffs behind the beach, loss of beach sediment may result in wave action undermining the adjacent upland causing catastrophic landslides or recession. Normal, long-term wave conditions may then rebuild a beach from the new material or, conversely, transport the sediments out of the littoral cell.

Long-term beach stability and resistance to storm damages are related to the geologic and geomorphic features of the littoral cell. On the New England and Pacific coasts, resistant headlands may minimize storm wave attack, while on other coasts, offshore rocks and reefs and orientation of the shoreline may lessen the effects of storm waves. Many parts of the Great Lakes shoreline have a clay bed overlain by varying quantities of sands, cobbles, and boulders. Erosion of the clay lakebed, when water levels are low[3], does little perceptible economic damage but it sets the stage for damages when water levels rise. On sandy coasts, the supply of sand may be the major factor contributing to beach stability. A major interruption in the littoral cell sand transport, as at a dredged tidal inlet or a naturally-occurring littoral sink, may cause serious short-term erosion which may lead to severe long-term storm damage. This vulnerability occurs if there is insufficient beach sand to rebuild the eroded beach so it can withstand storm attack. The severity of damage may vary along the shoreline depending upon the location and orientation of headlands, inlets, structures or offshore features.

FLOODING

Flooding is a common effect of coastal storms due to the superposition of tide, surge, wind, and waves, coupled with erosion of the beach and dune.

[3] Great Lakes water levels fluctuate slowly over a range of several feet with a time scale of several years.

It may occur along any section of low-lying coast. Coasts with barrier islands or beach/dune systems have some degree of protection from flooding. If storm damage or long-term erosion results in a breach of these natural protection features, more severe flooding can occur behind them. In this case, it is important to determine the height and width of protective dunes and compare them to predicted storm elevations and expected erosion. As with artificial dikes or levees, any breach in the protective dune can result in flooding the entire area behind.

COASTAL ENGINEERING CONSIDERATIONS

This section discusses the general approaches to predicting storm damage and long-term erosion. Storm erosion is primarily caused by waves and the high water levels associated with storms. Storm damage can be caused by any combination of wind, waves, water levels, and intense rainfall resulting in physical damage (other than caused by land loss) to structures and other facilities. The severity of storm erosion or damage is related to the length of time the higher energy waves occur in conjunction with elevated water levels. There are other factors which also influence the severity, including nearshore morphology, prior storm effects, and the presence or absence of erosion control structures, such as revetments or groins. Because of the complex nature of storm effects on the beach and the difficulty of collecting field data during storm events, there is no one standard storm damage or erosion analysis procedure. Rather, several storm erosion models are used throughout the Corps as the basis for evaluation. The approach used depends in large part upon the expertise of the coastal analyst and the availability of data. The primary data required for storm damages relate to storm conditions and shoreline geometry. Long-term erosion requires historic data and information on littoral transport. In all cases, the frequency of extreme storm events needs to be determined. Technical Report CERC-87-1, "Sources of Coastal Engineering Information," is a useful reference guide.[4]

STORM CONDITIONS

The most important storm conditions affecting erosion or damage at a given location are wave height, period, and direction, and the height and duration of storm surge. These variables (described below) are significant in ultimately describing erosion and storm damage frequencies. In riverine environments the discharge-elevation and discharge-frequency curves provide the basis for the elevation-frequency curve and ultimately the damage-frequency curve. In coastal settings the storm-frequency curve and the relationship of storm surge and wave heights to shoreline erosion provide the basis for erosion-frequency and storm damage-frequency curves.

Waves. Knowledge of incident wave conditions is essential for determining shoreline response. Wave conditions at the project site are frequently unknown and must be derived from either nearby measurements or from deepwater wave information.[5] Statistical analysis of available nearby wave climate data can provide mean wave height and period and direction of

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[4] Coastal Engineering Research Center, Sources of Coastal Engineering Information, Technical Report CERC-87-1, (Vicksburg, MS: Waterways Experiment Station, 1987).

[5] The Wave Information Study (WIS), an ongoing research effort performed by the Coastal Engineering Research Center, contains a database of hindcasted wave characteristics (height, period, and direction) for deepwater (ocean basin), continental shelf, and nearshore areas adjacent to all U.S. coasts.

deepwater waves approaching the shoreline. Nearshore wave height and direction can be measured directly or predicted from offshore data using a variety of numerical methods. Seasonal and long-term changes in wave climate are variable enough to require many years of data to determine the frequency of extreme waves. Hindcasting, sometimes calibrated by gauge data, is the technique most often used in frequency determination.

The project wave conditions of interest include the height, direction, and period of the largest waves, the frequency of occurrence, and the duration. Extreme wave conditions associated with the 50- or 100-year storm are also necessary and can be predicted from long-term wind records as wave hindcasts. Deepwater wave statistics are available for most of the U.S. coast. These must be mathematically transformed to account for the shoaling and refraction effects of the offshore geometry and diffraction effects of any offshore islands or structures. There are standard procedures available to do this, including computer programs such as the Automated Coastal Engineering System (ACES), Version 105, design and analysis system.

Storm Surge. Storm surge is an increase in water level above the normal astronomical tide due to a combination of wind stress, wave setup, low barometric pressure, and offshore bathymetric contours. Wind stress is the vertical rise in the still-water level of a body of water due to the friction of winds blowing over the surface of the water. Wave setup is the increase in water surface elevation at the shoreline due to onshore transport of water by wave action. An intense low atmospheric pressure condition may also cause the water surface levels to rise, while the offshore bathymetric profile impacts storm surge when a constant volume of water moving toward the shore is forced upward by shallow or constricted bottom contours, raising the water surface elevation.

The highest water levels during a storm occur when the storm surge combines with high tide, although the storm surge may persist through several tidal cycles. The normal tidal elevation is available from the predicted tide or actual measurements. Historic measurements, when available, are the best way to determine the extreme tide level and frequency of occurrence. However, if sufficient stage records are lacking, numerical analysis based on the joint probability of the random mixing of astronomical tides, northeasters, and hurricanes may be used to develop a stage-frequency curve.[6] In some cases, long-term water level change due to sea level rise, land subsidence, uplift, or a combination, can be determined from long-term records.

During most storms, low barometric pressure causes a rise in water level proportional to the magnitude of the low pressure. This may be a foot or more and can be estimated from historic water level records or calculated from empirical relations or numerical models. Storms also have high winds which can cause a rise in water level by forcing water towards the shore. This can usually be predicted using meteorological data. Wave setup increases the water surface elevation near the shoreline due to the effects of breaking waves.

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[6] Observed tide levels normally only provide information on the magnitude of the more frequent events and are therefore used to calibrate the lower end of the stage-frequency curve.

DETERMINING EXTREME STORM EVENT FREQUENCY

Hurricanes, tropical storms, northeasters or any recurring intense storms usually represent the most severe storm damage potential. These storms are usually associated with extremely large waves and/or high surge levels. Both wave height and surge level may be available from historic records. More commonly, however, they will have to be estimated based on a combination of other records. The most common procedure is to use available hindcast data to statistically derive the storm frequency relationship based upon such parameters as maximum surge height, maximum storm still water level, or meteorological characteristics. When available, long-term water level records can be used to develop an ocean stage-frequency relationship for water elevation and a surge-duration relationship. Both the height and duration of storm surge are necessary to characterize storm intensity.

SHORELINE GEOMETRY

The shoreline factors that most affect storm erosion are the size of sediments and the shape of the beach profile. The slope of the beach is directly related to the grain size of beach sediments and, therefore, in most models of shoreline change, grain size is not required if slope data are available. The offshore slope and shape of contours affect incoming waves and cause variations in severity of erosion along the shoreline. Representative beach profile surveys may be available for the area extending from the depth of offshore transport (roughly the offshore bar) to the top of the existing dune. Because of the dynamic nature of the shoreline as shown in Figure 2, beach profiles need to be surveyed at different times of the year to reflect different erosion conditions. These can be combined to give a representative profile for normal, pre-storm conditions.

LONG-TERM EROSION

A sediment budget analysis for sources of beach material, pathways of transport, and deposition of eroded material is part of the assessment of short- or long-term erosion. The goal of the littoral analysis is to determine the rate and direction of littoral transport and quantify the effect of long-term erosion. Estimates of erosion rates can be extracted from historical data such as aerial photo analysis, old maps, and surveys. One of the most widely used methods, employed by many state coastal management programs requiring setbacks for new construction, is to extrapolate trends in shoreline change from historical maps. Examination of historic data on dredging quantities may also be used in the development of the sediment budget for the area. The direction of transport is commonly inferred from historic changes in the shoreline, especially where structures or tidal inlets occur. The use of tidal inlet behavior as an indicator of the prevalent direction of sediment transport must be used with caution, however, as many inlets are known to migrate opposite to the predominate transport direction. Scour or fill at jetties or groins, indicating direction of transport, can be seen on aerial photos. Dredging quantities at inlets may give some estimate of rate of transport, although the materials dredged from ocean bar channels may be a combination of both longshore sediment transport and re-suspension of ocean bar materials. Historic bathymetric comparisons and beach profile data may be used to estimate general volume changes.

A sediment budget attempts to balance sediment input and losses in the problem area. The result shows whether there should be a net long-term erosion or accretion. Longshore transport potential can be calculated from incident directional wave statistics; when properly applied and combined with measured volume changes, these techniques provide reasonable and realistic estimates of longshore sediment transport.

RELATIONSHIP OF SHORELINE ANALYSIS TO NED BENEFITS EVALUATION

Coastal engineering analysis obviously has a major role to play in the calculation of NED benefits. Most projects involve some recommended alternatives to alleviate one or more perceived problems. The determination of benefits is based on damages prevented or erosion controlled with the project, versus the without-project conditions. The damages are associated with a zone of impact caused by elevated storm tides, high waves, high winds, and shoreline recession that occur during a severe storm, exacerbated by the effects of long-term erosion. The objective is, therefore, development of a set of relationships, using available data and models, to predict future various with- and without-project conditions. The shoreline responses, including the amount of erosion and related expected damages, would be based on the frequency of such parameters as storm surge elevations, storm duration, and wave heights. In some cases, multiple storm parameters have been combined to develop stage-frequency relationships for an area. For example, in the Sea Bright to Ocean Township, New Jersey beach erosion control project cited in Chapter IV of this manual, a range of erosion losses were developed which could be expected to occur for a given storm still water (stage) level. However, there is no one best relationship or model for all beach erosion cases. In all cases, the study team will have to exercise professional judgement. Some of the models for quantifying and predicting shoreline change are described below.

MODELS OF SHORELINE CHANGE

HISTORICAL SHORELINE CHANGE METHOD

The historical shoreline change method is based on an analysis of the long-term database of shoreline location, which must also take into account the effects of human interferences (e.g., beach nourishment, navigation channels, dredging projects, seawalls, and groins). This analysis provides an average rate of shoreline evolution as well as a distribution of the fluctuations around the trend caused by seasonal variations and episodic storm events. The existing database of shoreline locations is generally long-term and site specific.

A wide variety of information on beach erosion exists for coastal and Great Lakes shorelines. The data, however, range from highly accurate engineering surveys to fairly general comparisons of historical photographs and maps at various scales. In addition to the Corps of Engineers, the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Geological Survey (USGS) systematically collect coastal information. Further data are available from coastal states, local governments, universities, and private engineering and environmental consulting firms. Changes in shore position have been delineated using a wide range of methods, including field measurements of beach profiles, visual comparison of historic changes from photographs, and quantitative analysis of historical maps and vertical aerial photography through various photogrammetric procedures.

Extrapolation of trends based on historical shoreline change analysis must take into consideration the inherent variability in shoreline response based on differing coastal processes, sedimentary environments, and coastal exposures. Another factor is the time period of observation. The average rate of shoreline position change with respect to time may very likely differ for the same location for a 10-year versus a 20-year period because of, for example, the occurrence of extreme events (e.g., a hurricane) followed by a gradual beach rebuilding period. In general, estimates of long-term erosion rates are more accurate for longer periods of record and for higher trend rates. Furthermore, the straightforward projection of new shoreline positions based on historical change assumes that all oceanographic forces (e.g., waves, storm frequencies, sea level change) remain essentially constant. In summary, erosional trend rates can only be established accurately in those areas where long-term shoreline positions are available or where trend rates are large. Where erosion rates are calculated to be in the low range (one foot or less per year), the reliability of this measurement is probably low due to natural fluctuations in the beach width.[7]

PREDICTIVE MODELS

In recent years there has been substantial interest and much improvement in the development of calculation procedures, or models, for quantitative prediction of future shoreline changes. Such predictions are, obviously, a

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[7] National Research Council, Managing Coastal Erosion. (Washington, DC: National Academy Press, 1990).

primary input into the NED benefit analysis. As such, a brief overview of some recent modelling efforts is presented in the paragraphs below. It should be noted, however, that application and interpretation of these analytical and numerical models does require substantial effort and skill. Technical advice on these predictive models can be obtained from the Coastal Engineering Research Center (CERC) at the Corps Waterways Experiment Station.

Shoreline retreat can occur as a result of longshore sediment transport, offshore sediment transport, or both. Offshore sediment transport is primarily responsible for shoreline retreat during storms, whereas long-term retreat can be caused by either, or by a combination, of these transport components. Individual models have tended to concentrate on shore response to longshore transport. Models are generally site specific for erosion and must be verified by the history of a particular site.

Longshore models require two types of equations: 1) a transport equation relating the volumetric movement of sediment to the causative forces (e.g., waves and tides); and, 2) an equation that carries out the accounting of changes as a result of the sediment movement. Some of the earliest modeling efforts simplified the above equations for the case of longshore transport, thus allowing analytical solutions to be developed that provide considerable insight into the effects of individual parameters, such as wave height and direction. A report published by CERC[8] summarizes a number of such solutions, including the effect of constructing a groin along the shoreline, the evolution of a beach nourishment project, and sediment changes

[8] M. Larson, H. Hanson, and N. Kraus, Analytical Solutions of the One-Line Model of Shoreline Change, Technical Report CERC-87-15, (Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Center, 1987).

from the transport of sediment to the coast by a river. In addition to analytical solutions, numerical solutions have been developed that allow specification of time-varying waves and tides. These models include the GENESIS model now used by the Corps.

A primary objective in the development of cross-shore transport models is the estimation of a zone of impact caused by elevated storm tides and high waves occurring during a severe storm. Cross-shore transport models are generally based on the concept that if the prevailing waves and tides are of sufficient duration the profile will evolve to an equilibrium shape. The complexity of these models ranges from simple ones based on field and laboratory data to those that simulate profile evolution based on time-varying wave heights and storm surges as input. A report by the National Research Council, Managing Coastal Erosion,[7] provides a concise review of various cross-shore transport models, which are excerpted below.

An empirical model developed by Swart[9] is based on large-scale wave tank tests. The procedure involves numerous empirical expressions that, when programmed, make the method relatively straightforward to apply. A profile response model based on a series of wave tank tests was also developed by Vellinga[10] to evaluate the integrity of the Dutch dikes against storms. The required parameters include wave height, storm tide, and grain size. The

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[7] National Research Council, Managing Coastal Erosion, (Washington, DC: National Academy Press, 1990).

[9] D.H. Swart, "Predictive Equations Regarding Coastal Transports," in Proceedings, Fifteenth International Conference on Coastal Engineering, (New York: ASCE, 1976), pp. 1113-1132.

[10] P. Vellinga, "Predictive Computational Modelling for Beach and Dune Erosion During Storm Surges," in Proceedings of ASCE Specialty Conference Coastal Structures, (New York: ASCE, 1983), pp. 806-819.

method predicts the profile for a storm duration of five hours; procedures are presented to evaluate storms of differing durations.

A numerical model developed by Kriebel and Dean[11] allows time-varying input of storm tide and wave height and solves the equations governing cross-shore sediment transport and continuity. The cross-shore sediment transport equation is based on the profile disequilibrium caused by elevated storm tide and wave height conditions. The model was evaluated against the sediment transport caused by Hurricane Eloise for Bay County, Florida. A simplified modification of this method is currently used by the Florida Department of Natural Resources in its implementation of the Coastal Construction Control Line program.

An empirical method devised by Balsillie[12] models relationships for the average and maximum expected erosion caused by a storm based on storm tide rise time and peak storm tide. According to the National Research Council, Balsillie's approach provides encouraging correlation with numerous field data.

Finally, a model developed by Larson et al.[13] was based on extensive correlations of wave, sediment, and profile characteristics. The beach and nearshore profile is subdivided into four zones, each with different transport rate properties. The model has been applied to erosion of natural and

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[11] D.L. Kriebel and R.G. Dean, "Numerical Simulation of Time-dependent Beach and Dune Erosion," Coastal Engineering, 1987, Vol. 9, pp. 221-245.

[12] J.H. Balsillie, "Beach and Storm Erosion Due to Extreme Event Impact," Shore Beach, 1986, Vol. 54, No. 4, pp. 22-36.

[13] M. Larson, N. Kraus, and T. Sunamura, "Beach Profile Change: Morphology, Transport Rate, and Numerical Simulation," in Proceedings, Twenty-First International Conference on Coastal Engineering, (New York: ASCE, 1988), pp. 1295-1309.

seawalled profiles. It is capable of predicting single and multiple bar formations. Comparisons and evaluations have been conducted with wave tank data, field data from Duck, North Carolina, and the Kriebel and Dean model.

CHAPTER III

DESCRIPTION OF PROJECTS AND BENEFITS

AUTHORITIES

There are a number of legislative authorities (both general and specific) under which the Corps provides coastal protection projects. Beginning with the River and Harbor Act of 1930, Congress has directed the Corps to carry out programs established to maintain the shorelines of the United States, including: 1) research to determine the causes of beach erosion; 2) investigations and studies of specific beach erosion problems; and 3) construction of shore protection and beach restoration projects. The enactment of the Water Resources Development Act (WRDA) of 1986 established hurricane and storm damage reduction as project purposes. Among other changes, WRDA 1986 specified that beach erosion control costs be assigned to such "appropriate" project purposes as hurricane and storm damage reduction and recreation, with cost sharing in the same percentage as the purposes to which the costs were assigned.

Individual coastal storm damage prevention or erosion control projects may be authorized by specific Acts of Congress or granted under Sections 14, 103, and 111 of the Continuing Authorities Program. Section 14 of PL 79-526 authorizes emergency streambank and shoreline erosion protection for public facilities and services, up to a maximum cost of $500,000 per project; Section 103 of PL 87-874 authorizes Federal participation in the cost of beach erosion control for publicly owned property, up to a project maximum of $2 million; and Section 111 of PL 90-483 authorizes mitigation of shoreline erosion damages caused by Federal navigation projects, up to a maximum of $2 million per mitigation project. See ER 1105-2-100, pages 3-1 - 3-23, for policies, procedures, and guidance affecting the Continuing Authorities Program. Appendix A discusses some of the most commonly used general authorities.

OVERVIEW

There are two major types of coastline protection projects in which the Corps is authorized to participate: coastal storm damage protection and long-term erosion protection. Coastal storms can cause damages from flooding, winds, wave impacts, salt spray, and sand and debris movement. In addition, storms can cause erosion of cliffs, bluffs, marshes, beaches, and dunes, which can lead to damages to protective structures, inland buildings, infrastructure and port and marina facilities. Long-term erosion generally occurs as a result of a deficit in the supply of littoral materials due to losses in natural or man-made sinks. Over time, the coastline retreats inland and unprotected land and improvements are washed away.

TYPES OF PROJECTS

Various options exist to reduce coastal storm damage and erosion hazards to public and private buildings and infrastructure. These options can be classified as shoreline engineering works or building and land use management techniques. Shoreline engineering includes both soft structural approaches (e.g., beach nourishment) and hard structural approaches (e.g., seawalls, revetments, groins, and offshore breakwaters). Building and land use management includes building and land use restrictions (e.g., setback requirements), and relocation of existing structures from eroding shores. Combinations of both engineering and management options are used on many shorelines; however, engineering solutions tend to be employed on developed coasts, while the use of management solutions is encouraged on less developed coasts.

SHORELINE ENGINEERING

Beach Nourishment. Beach nourishment involves excavation from one site and placing large quantities of sand on an existing but retreating beach to advance the shoreline seaward. The material usually is placed on the beach at a slope steeper than the natural beach so there will be a period, of perhaps several years, during which profile equilibrium will occur. In addition, the extension of the shoreline will induce additional components of longshore sediment transport away from the original location.

According to a report from the National Research Council,[1] the additional beach benefits from a beach nourishment project depend markedly on the quality of the sand placed. The same amount of material of varying sizes results in markedly differing equilibrated beach widths. Ideally, for greatest benefit, the sand should be as coarse or coarser than the native sand. However, current knowledge about sediment transport does not include adequate information concerning the influence of grain-size distribution.

Many examples of both successful and unsuccessful beach nourishment projects exist. Successful projects include Miami Beach, Florida, where 14 million cubic yards of sand were placed over a ten-mile beach during the 1976 to 1981 period at a cost of $64 million. The first re-nourishment in 1987 placed 300,000 cubic yards, which amounts to a loss rate of less than 0.3

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[1] National Research Council, Managing Coastal Erosion, (Washington, DC: National Academy Press, 1990).

percent per year. The Indialantic Beach in Florida is regarded as an unsuccessful beach nourishment project. Approximately 500,000 cubic yards of sand were placed along two miles of beach. One year after project construction, little volume remained within the portions of the profile encompassed by wading surveys.

Groins. Groins are structures built perpendicular to the shore that may be constructed of timber, concrete, metal sheet piling, or rock (see Figure 3). They may be built singly or in a series. Groins are intended to reduce longshore sediment transport; thus, when placed on an open coast, they widen the beach on the updrift side. Groins designed with heights that match the beach profile have less potential of causing downdrift beach erosion than a high profile and/or long structure that may divert water and sediment offshore.

Groins have often been used improperly in the past, and some states have prohibited their construction. Groins used with care, however, have the potential to stabilize beach fills. A series of adjustable groins have been used in Deerfield Beach, Florida, whose upper elevations may be maintained slightly above the sand level. In this way, the structures can be adjusted to ensure that they function primarily to stabilize material in place rather than trap material in transport. A field of groins or groins placed as terminal structures might be particularly appropriate to retain material placed in a beach nourishment project. Additionally, a field of groins or a single, long terminal structure may be suitable near the end of a littoral cell, such as adjacent to a channel entrance.

Seawalls, Bulkheads, and Revetments. Properly engineered seawalls, bulkheads, and revetments protect the land behind from erosion and wave

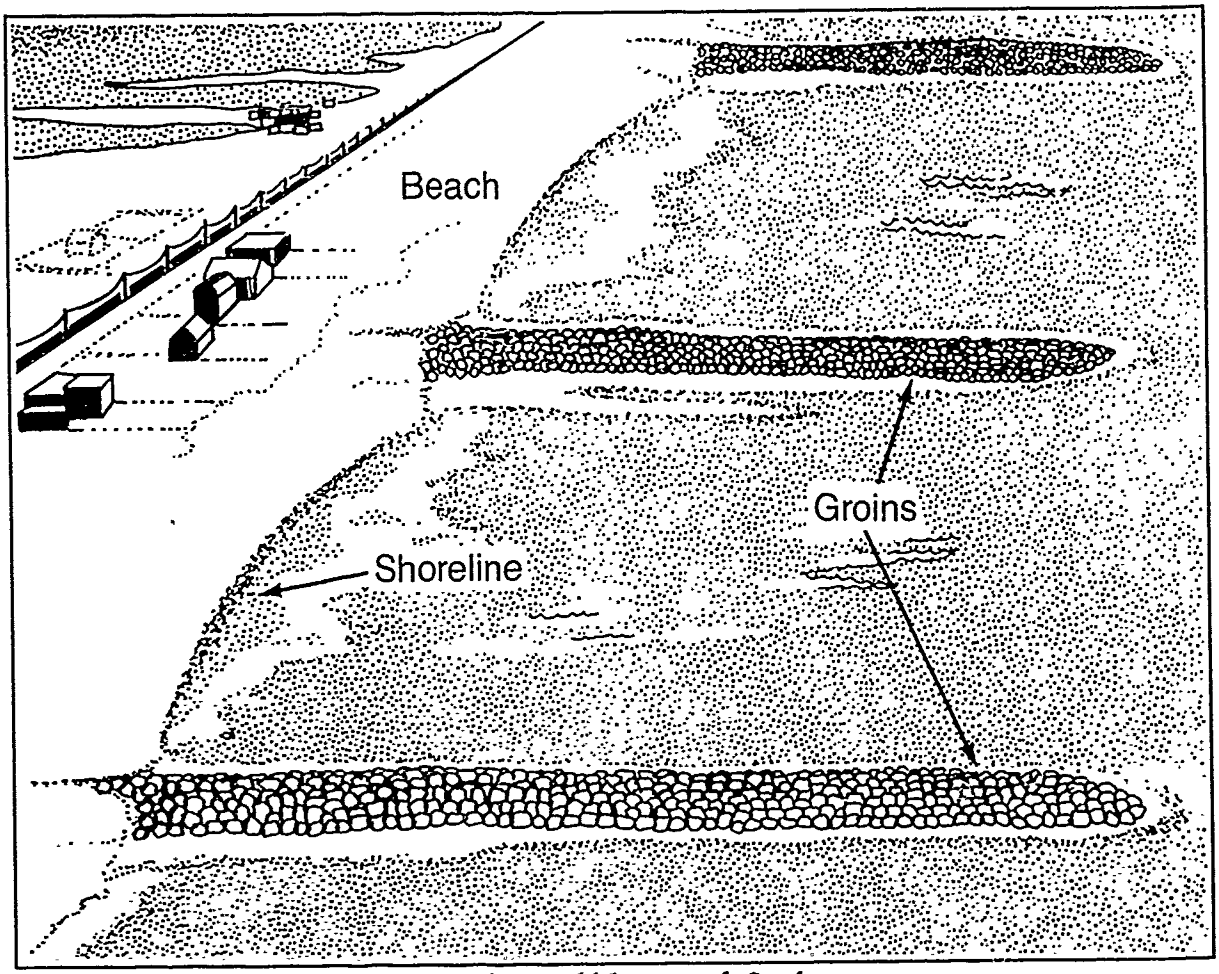

Figure 3. Rubble-mound Groins.

attack. The differences between these protective, wall-like structures are mainly matters of purpose and scale. Seawalls normally are the most massive and defend against the full force of waves. Bulkheads are generally the next largest and are designed to retain fill and resist erosion. Revetments are usually the lightest because they are designed to protect shorelines against erosion by currents or light wave action. While these structures are built on eroding shorelines, they are often blamed for additional erosion that occurs. This may happen if they are not designed and constructed properly, which can cause adverse impacts on adjacent property. The only principle that is definitely established is the one of "sediment conservation." Coastal armoring (e.g., a seawall or revetment) neither adds to nor removes sand from the sediment system but may be responsible for the redistribution of sand and can prevent sand from entering the system. Additionally, seawalls, bulkheads, and revetments are expensive and require proper maintenance.

Offshore Breakwaters. Offshore or detached breakwaters are typically constructed from rock or concrete armor units and protect the shoreline by reducing wave energy reaching it (see Figure 4). They also promote sediment deposition leeward of the structures. Most offshore breakwaters built for shore protection are segmented and detached; thus, they provide substantial protection to the shoreline without completely stopping longshore sand transport. They do not deflect and relocate currents, like breakwaters or jetties that project from the land. Unlike seawalls, revetments, and bulkheads, breakwaters aid in beach retention because they reduce wave energy. A main disadvantage is that they are more expensive to build than land-based structures.

Submerged breakwaters, also known as artificial reefs, may be composed of sunken barges or ships or any heavy objects that break up wave action. They can cost much less than breakwaters that project above the water surface because they do not have to absorb the full wave impact, but merely cause storm waves to break and spill their energy in turbulence.

Jetties are engineering structures built at the mouths of rivers or tidal inlets to help deepen or stabilize a channel. While they are thus similar in appearance to groins or breakwaters attached to the shore, their purpose is not necessarily to protect the shoreline, but rather to prevent shoaling of a channel by littoral materials and to direct and confine stream or tidal flow.

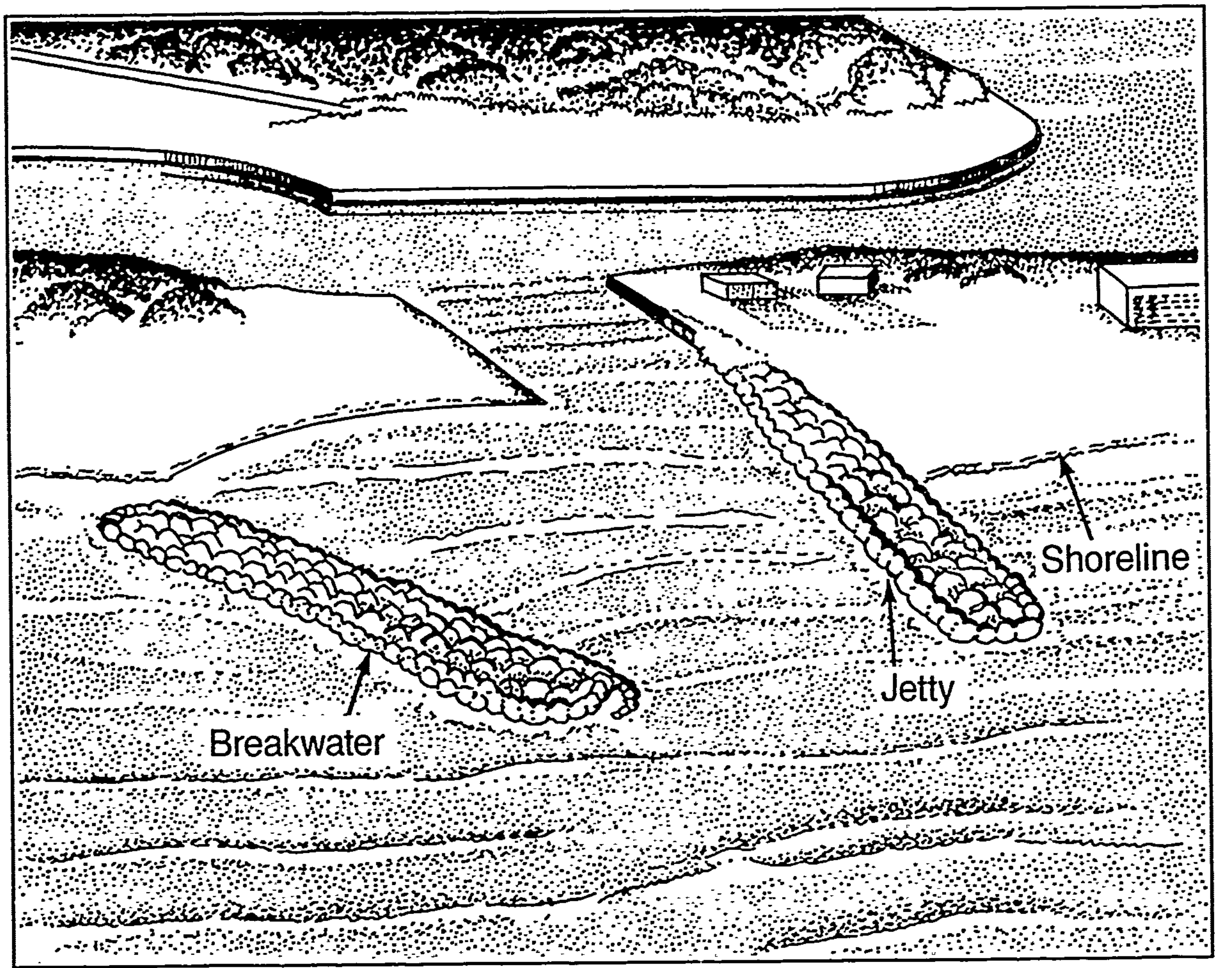

Figure 4. Detached Breakwater.

Sand Bypassing. Inlets, navigation channels, and harbor entrances all interrupt the natural flow of sediment transport along the shoreline. The interrupted flow of sand is diverted either offshore in ebb tide shoals, into bays or lagoons in flood tide shoals, or in navigation channels. They generally cause shoaling and downdrift migration of channels, which require frequent dredging in order to maintain safe navigation. As a result, erosion occurs downdrift of the interrupted coastline. Sand bypassing, by either a fixed or floating pumping system, restores the natural flow of sand to the downdrift shorelines and reduces the need for channel dredging. In Florida, the use of two fixed bypassing plants for a period of 30 years suggests the feasibility of such systems to alleviate human-induced erosion downdrift from inlet control structures. Floating dredge (temporary) bypass operations also have been used in the United States. One example is a Federal project at Channel Islands Harbor, CA, where over one million cubic yards of sand is bypassed on a biennial basis past two harbor entrances to restore eroding downdrift beaches.

Dune Building. Natural sand dunes are formed by winds blowing onshore over the beach, transporting sand landward. Grasses and sometimes bushes grow on sand dunes, creating a natural barrier against sea attack. The dunes provide a reservoir of beach sand during severe storms and thus help prevent flood and wave damage to adjacent property. In areas where substantial dunes exist, the post-storm beach width can be greater than the pre-storm width. Attempts have been made to imitate nature by promoting the formation of artificial dunes. States where large-scale dune construction has been implemented include North Carolina, Texas, Florida, New Jersey, and Maryland.

BUILDING AND LAND USE MANAGEMENT

Since the advent of the National Flood Insurance Program (NFIP) in 1968, legal and institutional ("nonstructural") measures have become important mechanisms used to reduce the vulnerability of coastal and riverine structures to flood and erosion losses. Planners have often seen engineered responses to coastal erosion as unsuitable from an economic and environmental perspective, especially when used to protect privately-owned, lower density residential development. One approach to coastal management is to influence the location, elevation, and design of new or substantially redeveloped structures through public building and land use controls.

The NFIP, in particular, has fostered the adoption of floodplain management standards by some 1200 coastal communities nationally. Like their counterparts along inland floodplains, these communities must require minimum elevation of new structures above estimated 100-year flood ("base flood") levels that include the effect of wave heights. These land development restrictions generally have been held to be constitutional.

Setback Requirements. Coastal construction standards under the NFIP have emphasized elevation rather than horizontal displacement. New buildings, on substantial pilings up to 20 feet above grade, are a familiar site in recently built communities along the Atlantic and Gulf coasts. But horizontal displacement is required under the NFIP's minimum standards, only to the extent that new buildings in high hazard zones (V-zones) must be located landward of the reach of mean high tide and must not alter dunes or mangrove stands (44 Code of Federal Regulations Section 60.3(e)). Even these requirements do not apply to coastal A-zones (e.g., bayside or other non-open ocean shorelines).

A number of coastal states have established horizontal setbacks for new construction at the individual state level. According to NOAA, there are three basic approaches states have taken: 1) natural resource protection statutes; 2) fixed setback lines, and, 3) average annual recession rate setbacks. The first category includes states, such as Massachusetts and Wisconsin, that place limitations upon development in wetlands or on dune systems. These requirements are not specifically designed to address erosion.

Fixed setback lines involve a minimum specified distance (e.g., 100 feet in Delaware) from a reference feature. Types of physical reference features include the seaward toe of primary dunes, line of vegetation, edge of eroding bluff, mean high water, or a specified elevation contour. These features may move whenever erosion occurs.

Several states use "average annual erosion rate" setbacks to mark the minimum setback for new construction. Michigan and North Carolina impose a 30-year setback on smaller structures; North Carolina also imposes a 60-year setback on larger ones.

Relocation. According to the National Research Council,[2] relocation of existing structures from eroding and/or flood-prone shorelines has long been a neglected mechanism for responding to shoreline retreat. The technical feasibility of moving small or medium-sized structures has been established. Relocation as a widespread adjustment to shore erosion is most likely to be cost effective for smaller structures, particularly one and two-story residential structures. Relocation encounters a number of institutional and economic impediments. Structures on deep lots may gain sufficient protection by relocating landward on the same lot. However, if sufficient space is not available on the same lot, an alternative site must be acquired and prepared. This increases the cost of relocation substantially. It may also incur problems of zoning; mortgage refinancing; and provision of sewer, water, and road access. The alternative site may lack the view and/or direct shoreline access that are often the reason for waterfront property ownership.

However, a structure threatened by imminent collapse essentially is valueless and poses substantial potential costs to the community in terms of lost tax revenue, deterioration related to abandonment, clearance of wreckage, casualty loss deductions from income tax liability, disaster relief payments,

[2] See Footnote 1, page 53.

and flood insurance loss payments. Relocation, therefore, may be a desirable public goal.

Construction Requirements. Damage to structures located along the shore, in some cases, can be reduced by relatively straightforward engineering and construction procedures to ensure the building's survivability during a severe storm event (e.g., the 100-year storm event). Such requirements would include elevating the lower horizontal structural members above the 100-year wave crest elevation; embedding pilings on low dunes to an adequate depth to ensure structural integrity during a 100-year storm tide and associated erosional event; and reinforcing connections between structural members to withstand anticipated 100-year wind loading. Although these construction guidelines would be required for new structures, retrofitting of existing structures may also be economically feasible.

Land Acquisition. A land acquisition program is another strategy to cope with coastal erosion and storm damage management. This is appropriate where erosion- or damage-prone areas can be acquired by government units and preserved for recreation, open space, or other appropriate public purposes. Such programs generally include specific criteria and priorities for acquisition, identify funding sources, and set timetables for action. Potential Federal funding sources include Section 1362 of the National Flood Insurance Act, the Land and Water Conservation Fund, and Section 306A of the Federal Coastal Zone Management Act. The community plans also can identify state and local resources that will be devoted to this program.

BENEFIT CATEGORIES

Since a project may protect against both storm damage and erosion, it is necessary to be able to evaluate the benefits of both types of protection, and to avoid double counting of benefits for all coastal protection projects. The remainder of this chapter discusses the potential benefit categories for storm damage prevention and erosion protection.

STORM DAMAGE ALLEVIATION BENEFIT CATEGORIES

Wave Damage Reduction Benefits. In many areas, damages caused by wave action can be the most significant coastal effect. The force of tons of water against beach front structures can be more destructive than the damage caused by erosion. This category of damage can also be the most tedious to determine, especially when damages are calculated on a structure-by-structure basis. Alternatively, a structural engineer familiar with the area may develop a matrix showing the percentage of the value of a particular structure type damaged by waves of a given magnitude.

Inundation Reduction Benefits. Many benefits from storm damage alleviation projects come from the reduction of inundation damages from coastal flooding. Inundation reduction benefits include reduction of both physical and non-physical costs. These benefits include the saving of structures and contents from flood and salt water damage, and the alleviation of clean-up costs, production losses, flood fighting expenses, evacuation costs, emergency aid, and traffic rerouting. In agricultural areas, potential benefits from inundation reduction also include the reduction of damages to crops such as inundation damages and saline effects on the soil. Inundation reduction benefits result from alleviation of a combination of the following physical and non-physical damages.

Physical Damage.

1. Urban Losses. On urbanized coasts and suburban beach communities, physical damages include structural damages to buildings; loss of contents of the buildings, including furnishings, equipment, decorations, raw materials, and processed material; and damage to streets, highways, railways, sewers, bridges, utility lines, bulkheads, seawalls, boardwalks, piers, port and marina facilities and other infrastructure. Physical damages are evaluated separately for residential, commercial, industrial, and public properties; and for transportation systems, utilities, and vehicles. Although inundation reduction damages are similar to those calculated for riverine flood damages, factors such as seasonality, wind effects, undermining potential and salt water effects must be taken into account.

2. Agricultural Losses. For flooding in agricultural areas, damages are separated into crop and non-crop losses. Crop losses are determined by calculating the net income lost as a result of flooding. Losses may result from increased production costs and/or decreased crop yields which could last for several years if salt water permeates the soil. Non-crop losses are calculated for other agricultural properties, associated agricultural enterprises, and off-site sediment damages.

Other agricultural properties include farm buildings, stored crops, movable machinery and vehicles, fixed equipment, fences, roads and railroads, drainage and irrigation ditches, livestock, pasture, seeds, pesticides, herbicides, and fertilizers. The procedures for the calculation of damage to buildings and roads are similar to the procedures for urban projects.

However, estimation procedures for other agricultural properties are unique and require specialized knowledge of inventory procedures, damage susceptibility and storm characteristics. More detailed information on the unique considerations important to the evaluation of non-crop farm losses is presented in Chapter VI of the NED Procedures Manual - Agricultural Flood Damage.

Off-site sediment reduction benefits are based on the costs of removing sediment from facilities such as roads, culverts, and channels. The increased cost of providing goods and services (such as additional treatment costs for removing sediment or other contaminants from municipal water) are also a component of pocential damage.

The calculation of inundation reduction benefits is discussed in the Urban Flood Damage and Agricultural Flood Damage NED Procedures Manuals. For coastal storm damages, inundation damage curves must be adjusted to account for wave runup, salt water, and damages from sand, debris and ice. For example, an inundation event characterized by heavy sediment load (suspended sand and/or debris) is particularly damaging to the workings of mechanical equipment and drainage systems and creates cleanup problems. Likewise, salt water's corrosive effects will have greater impact on metal structures or equipment. Even though most damage assessment procedures focus on the depth-damage relationship, the incorporation of factors like sediment load or saline content may be accomplished by "add on" percentage factors. For example, estimates of total residential damages for a given area may need to be increased by a factor of ten percent to account for the corrosive effects of salt water. Such data may be obtained from historical information on damages or individual case studies. More detail on these procedures is provided in

Chapter IV of this manual. Estimation of damages due to wave attack must always be evaluated on an individual site basis, and requires knowledge or assumptions of wave regimes.

Non-Physical Damage.

1. Income Loss. Income loss is the loss of wages or net profits to businesses over and above physical storm damages. It results from a disruption of normal activities that cannot be recouped by other businesses or from the same business at another time. Prevention of income loss can be counted as a national benefit only to the extent that such loss cannot be offset by postponement of an activity or transfer of the activity to other establishments. Agricultural crop and aquaculture losses generally result in income losses. Most business activities, except those which are unique to a given area, or which exert a major impact on the total output of a given product or industry are considered transferable to another area. Usually, tourism is not considered unique to an area, even though a given location may have sights not available anywhere else, because vacationers can and often will visit another location. To the extent the transferred business actually results in higher costs, there is a loss identified with the effect of storm damages. Higher costs can be the result of greater distances or the required use of less efficient facilities, resulting in higher unit costs. Even vacationers may be required to incur greater travel cost and/or out-of-pocket expenses for leisure time alternatives.

2. Emergency Costs. Emergency costs include both those expenses that result from the risk of a storm and those expenses that result from the storm itself. Emergency costs include expenses for monitoring and forec ting storm problems, emergency evacuation, storm fighting efforts such as sandbagging and

building closures, administrative costs of disaster relief (but not the relief itself, which is a transfer), public clean-up costs, and increased costs of police, fire and military patrol. Emergency costs should be determined by specific survey or research and should not be estimated by application of arbitrary percentages of physical damage estimates.

3. Temporary Evacuation. Temporary evacuation costs include temporary lodging and the additional costs of food, clothing and transportation offered to relieve the financial hardship experienced by storm victims during and immediately after a storm emergency. Often, temporary evacuation costs are included in emergency costs. If the victims of storm damage have insurance coverage, however, to help defray temporary evacuation and relocation costs, reductions in these costs attributed to the storm damage alleviation project cannot be counted as benefits since insurance payments are transfers.

4. Temporary Relocation. Temporary relocation includes the additional living expenses incurred by storm area residents who are forced to find temporary housing after a storm event. Homes may be made uninhabitable due to: 1) extended periods of inundation; 2) structural damage that is too severe to live with; 3) large deposits of sand and debris; and, 4) disruption of utility services and transportation routes. In general, temporary relocation lasts longer than temporary evacuation. Care must be taken to only include permanent residents (or seasonal residents when the damages occur during periods those people would normally reside in the area) in the temporary relocation benefits.

5. Transportation Delay Costs. Flooding can temporarily impede traffic by covering or destroying roads and bridges. Even the threat of flooding and concern for public safety may make it necessary to close roads and detour

traffic. Only those delays and road closures that could actually be avoided by the proposed project may be counted, as the presence of the damaging storms with or without a project may be sufficient to precipitate road closure or delays. Bridge and road damage may cause detours for several months until repairs can be made.

6. Damages to Associated Agricultural Enterprises - Associated agricultural enterprises are defined in P&G as economic activities that may be affected by changed water supply or water management conditions. An example of this type of damage is delay in spring planting on non-flooded lands because of flooding or severing of access roads.

7. Reduced maintenance of existing structures. Structures in the immediate vicinity of the shore may require more frequent maintenance because of ocean spray or frequent wave attack. Benefits can be claimed to the extent that a project would reduce the extra maintenance.

8. Other Costs of Occupying the Storm Inundation Area. Other storm inundation area occupancy costs include: 1) erosion protection/storm-proofing costs incurred in construction of new development; 2) the administrative costs of flood insurance; and, 3) modifying the use of storm inundation area property because of the flood threat.

Other Benefits. While inundation reduction benefits constitute a large portion of economic justification for storm damage projects, they do not measure the total economic gain for storm damage loss reduction. Location and intensification benefits represent increases in economic welfare because reduction in storm damage risk allows for higher economic use of the property. The following benefit categories are similar to urban flood control, and are described in more detail in the Urban Flood Damage manual: location benefits, efficiency benefits, employment benefits, advanced bridge replacement benefits, and affluence benefits.

EROSION PROTECTION BENEFIT CATEGORIES

Measures for control or prevention of beach erosion may include tangible primary benefits from physical damages prevented, emergency and business costs avoided, enhancement of property values, improvement of fish and wildlife resources, and increased recreational usage. Benefits should be measured as the difference in these values under conditions expected with and without the proposed erosion control measures.

Damages due to shore erosion include physical losses of land and beach, and associated damages to improvements such as roads, buildings and other facilities. The loss of protective structures or an increasing threat of storm damage may cause owners to defer maintenance of existing structures or construction of new (replacement) facilities with resulting depression of economic values.

Loss of Land. The area of land that would be lost in the absence of the project over the period of evaluation may be estimated on the basis of the historical rate of shore erosion in cases of long-term erosion. In instances of erosion due to coastal storms, the area that would be lost may be estimated with coastal erosion models which predict rates of erosion for storms of various frequencies. Other factors which may tend to modify the rate of the loss, such as construction of other coastal works which would change the supply of beach material to the problem area, must be taken into account.

Structural Damage Prevention. Structures are often more severely damaged by erosion of the land under them in coastal storms than in riverine looding situations. Actions taken as a result of this erosion-induced damage can include relocation of the remaining structures (if damage is not severe) or abandonment of the property. State or local coastal zoning ordinances may determine if an activity can be re-established in the same location.

Emergency Costs. Emergency costs for erosion protection benefits are similar to inundation reduction benefits. If benefits are claimed for both inundation reduction and erosion protection, care must be exercised to separate emergency costs which can be prevented by each category from those which will be realized only if both types of damage are prevented.

Reduced Maintenance Of Existing Structures. Structures in the immediate vicinity of the shore may require more frequent maintenance because of recurring incidents of erosion. Benefits can be claimed to the extent that a project would reduce the extra maintenance.

Incidental Benefits. Projects for the primary purpose of beach erosion control often result in incidental benefits to other purposes. These benefits, such as increased beach and shoreline recreational activities,[3] increased fish and wildlife habitat, reduction in shoaling at navigation projects, reduction in tidal flood damages, and incidental benefits to private property downdrift of a shore protection project, should be evaluated and credited to the beach erosion control project. While the level of effort and detail dedicated to these benefits are usually minor in comparison to other benefit categories, they should not be overlooked. For example, in some studies, downdrift effects can be substantial and need to be thoroughly investigated.

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[3] Methods of evaluating recreation benefits are illustrated in IWR Report 86-R-4, National Economic Development Procedures Manual - Recreation.

<u>Enhancement Of Property Values</u>. Location and intensification benefits attributable to an erosion control project result from increased use of land through either intensified activities or by changing to an economically higher-valued development than would occur in the absence of the project. Such benefits result because of the higher utilization made feasible by increased safety of investments in improvements. Land enhancement benefits are over and above benefits received from damage reduction.

Land already developed for its highest potential usage is assumed not to increase in real value. However, lands on which structures are being permitted to deteriorate, or on which development has been precluded simply because of vulnerability to damage arising from beach erosion, are subject to a change to a higher usage with attendant increase in value as a result of protection. A realistic appraisal should be made of the immediate project area and adjacent zones to determine which lands have been retarded from their highest potential utilization because of the prospect of erosion damage.

Location benefits should be evaluated only for lands which have a reasonable prospect of change in usage, whereas intensification benefits should be evaluated only for lands which have a reasonable prospect of remaining in the same land use but with intensified activity. Location and intensification benefits apply only to land values and not to the value of future improvements.

If a project is expected to produce location or intensification benefits, separate damage calculations must be made for the without-project and the with-project conditions. The without-project calculations would then include all damages to property (including those expected to be displaced with a project) if no Federal action is undertaken, while the with-project calculations would encompass damages to activities which would be in place with the project. The intensification/location benefits must be net of induced or residual damages to the increased development.

SYSTEMS ANALYSIS AND DOWNDRIFT IMPACTS

The term "Systems Analysis" is used to refer to an evaluation that takes into account the broad range of possible impacts induced by a Corps project on a region outside of the specific project area. In the case of coastal projects, a reduction or an increase in damages to neighboring properties or downdrift areas may result from the design and implementation of storm damage protection and navigation structures, and should be accounted for in the project analysis.

Regional "downdrift impacts" may be manifest in different ways. The use of beach nourishment as one alternative means of providing storm damage reduction may result in direct shore protection benefits downdrift of the specific project area. On the other hand, induced storm damages can result from the construction of a levee or seawall, which can cause an increase in interior ponding. A jetty built to prevent shoaling of a navigation inlet may disrupt littoral transport, and deplete a beach downdrift. Conversely, a sand by-pass operation designed to reduce shoaling of the entrance channel will also improve a downdrift beach. If dredging operations in a navigation channel result in depositing the material in deep water or upland, erosion may increase downdrift of the area, whereas using the material to replenish the downdrift beaches may improve littoral transport for many miles downdrift. Controlling erosion in one area may affect littoral transport and cause increased erosion in a downdrift area which is dependent upon sand replenishment from the project site.

Guidance for the analysis of downdrift shore protection benefits and costs induced by Corps projects is provided in EC 1105-2-191. According to the EC, "A systematic view is necessary for measuring these benefits and costs, and for deciding which combination of shoreline protection measures and navigation features are appropriate for a given region." The guidance requires that the documentation of the downdrift shore protection benefits and costs be based on a traditional approach in describing existing "with' and "without" project improvement conditions. However, the analysis should extend beyond the project site to provide a more comprehensive view of the shore including adjacent reaches bounded by natural features (e.g., bays, sounds, inlets, geomorphic features) that serve to substantially interrupt or limit the continuity of natural longshore littoral processes.

A systems analysis approach as explained in EC 1105-2-191 should describe: 1) the physical processes, including development of sediment budgets, estimates of the effects and probability of occurrence of relevant storm events, and assessments of the magnitude of average annual changes in beach area and volume; 2) the existing "without-project" coastal alterations, involving the identification of man-made alterations to the shore and their contribution to the balance of littoral processes and shoreline changes; 3) anticipated shoreline changes, including estimates of future shore nourishment and dredging activities; and, 4) the economic benefits and costs of alternative protection projects, including assessments of the extent of damageable property through storm surge and wave damage, estimates of damage reduction benefits for various project alternatives, and evaluations of all beneficial and adverse impacts for each project alternative in accordance with P&G.

In short, all effects must be measured, whether in the immediate project area or not. Therefore, it is imperative that updrift and downdrift areas be considered as part of the study area, and evaluated accordingly. After the coastal engineer has helped identify the magnitude and location of physical changes both updrift and downdrift, economic evaluation techniques employed for those areas are the same as those used for the immediate study area.

CHAPTER IV

ESTIMATING NED BENEFITS

This chapter describes the steps involved in conducting the NED benefit analysis. It is described here as an eleven-step process, which should proceed in more or less the specified sequence in order to maximize efficiency and minimize duplication of effort. Variation in the progression of steps is, of course, acceptable, and some iteration will be inevitable. However, some steps cannot be accomplished without the preceding steps already being at least partially completed, while others may be started but not fully concluded without input from the prior steps.

To more fully describe the NED benefit estimation process, examples from a recently completed coastal storm damage prevention and beach erosion control study conducted for the New Jersey coast[1] are interwoven into the following discussion. The example information is included solely for illustrative purposes. Furthermore, only portions of the study are used to highlight certain benefit estimation procedures. It is, however, based on an actual NED benefit analysis, and, as such, may serve as a useful reference for planners and economists. The reader may note that the New Jersey study did not identically follow the sequence of benefit estimation steps suggested in this manual. This discrepancy is perfectly acceptable. As suggested in Chapter I

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[1] The example information is extracted from: "Appendix D - Benefits," in Atlantic Coast of New Jersey, Sandy Hook to Barnegat Inlet Beach Erosion Control Project Section I - Sea Bright to Ocean Township, New Jersey, Technical Appendices, Volume II, General Design Memorandum. U.S. Army Engineer District New York, January, 1989. This document is reproduced as "Appendix B, An Example of NED Economic Benefits Analysis" in this manual for those readers desiring greater detail.

of this manual, analysts involved in the evaluation of coastal storm damage prevention and erosion control projects have considerable latitude in adjusting procedures to meet the needs or attributes of their particular study.

STEP ONE: DELINEATE THE STUDY AREA[2]

The study area is that area which is immediately or indirectly affected by the perceived problem[3], and thus by any resulting project. This is the geographic region that includes the storm inundation area, as well as the area that will be affected by erosion, including downdrift, over the project evaluation period. It also includes an area sufficiently inland to describe the impacts of the storm erosion events and any protective measures. For example, utility lines and roads along the beach may serve homes or businesses some distance inland, and severing of these would cause service disruptions to a wide area. The study area should encompass natural features that serve to substantially interrupt or limit the continuity of natural longshore littoral processes (e.g., bays, sounds, inlets, and the end of geomorphic features). Depending on the particular study, it may also include the nearshore areas for determination of comparable land values or for consideration of alternative development sites and/or the market area for recreation users. Figure 5 is a

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[2] The study area can also be defined and restricted by specific authorizing legislation.

[3] The first two steps frequently require many iterations. It is usually difficult to determine the study area without a definition of the problem, but it is just as difficult to fully define the problem without at least a partial definition of the study area. In many cases this effort may be facilitated by a coastal engineer's "desktop" assessment of geomorphic processes and trends, which can serve as a background for the other disciplines to use in their analysis.

EXAMPLE

In the New Jersey study, the study area is bounded by the natural features of Sandy Hook to the north and the outlet of Deal Lake to the south. It includes the most northerly 12 miles of the larger authorized project, Atlantic Coast of New Jersey, Sandy Hook to Barnegat Inlet Beach Erosion Control Project. The northern potion of the study area, including the towns of Sea Bright and the northern part of Monmouth Beach, is comprised of a barrier spit complex where the shoreline is a narrow strip of unconsolidated sand which forms a peninsula between the ocean and bay environments. The southern portion of the study area, encompassing the southern part of Monmouth Beach and the communities of Long Branch, Deal, Allenhurst, and Loch Arbour, is located on the coastal plain and is characterized by headlands meeting the sea. The entire study area is within Monmouth County. Immediately to the north of the project limit is the Sandy Hook unit of Gateway National Recreation Area, while immediately to the south is the City of Asbury Park.

The entire coastal zone within the study area is heavily developed, primarily for residential and commercial uses. Many of the residences are former summer homes converted for year-round use. In areas with substantial existing beach, high rise and townhouse development has occurred. The peninsula area is fronted by a seawall up to 20 feet in height which aids in the prevention of flooding and wave attack. Traversing the peninsula area is State Road 36 which provides the only access to Sea Bright and Sandy Hook.

STEP TWO: DEFINE THE PROBLEM

The existing storm damage and erosion problems should be carefully defined. Care must be exercised to separate problems from symptoms; if the problem should need to be redefined later in the study, it may be necessary to also redefine the without-project condition, and revise much of the rest of the analysis. Records should be consulted for instances when damaging storms have occurred in the area; the area and vertical extent of inundation and storm or wave attack should be determined; and hydrologists, coastal scientists, and engineers should gather information, for the period of record, on storms and erosion trends. Even though careful attention is paid to determination of the problem in this stage, the study team should be cognizant of the possibility that, as the study progresses, new information may reveal different causes of the symptoms.

The existing without-project condition must be properly identified since it is the basis for comparison with conditions projected with all alternative plans. Existing and anticipated without-project man-made alterations to the shore, such as seawalls, groins, sand-bypassing and recycling, dredging, breakwaters, and artificial beach nourishment should be taken into account. An evaluation should be made of the effectiveness of any existing shore protection measures, and all other relevant non-structural measures (e.g., flood warning systems) existing or expected to be implemented before construction.

The description of the existing conditions should include a history of the economic and social effects of storm damage and erosion problems in the area. Dates, storm intensities, wave heights, shoreline erosion, sediment movements, and peak stages of major storm events should be gathered. When the information is available, the economic costs and categories of damages, as well as the number of deaths and injuries, should be noted. Information on major events can be obtained from the National Weather Service, Corps emergency operations offices, and state and local emergency preparedness offices. Local and regional newspapers may be a source for documenting historical storm losses. Shoreline changes can be determined from aerial photos and maps. Sometimes historical site photos are helpful in determining structural damages. In developed areas, site survey data may be available with beach and dune positions and elevations.

A critical part of defining the existing without-project condition is a proper evaluation of the degree of protection that existing facilities can be expected to provide. The assessment involves two major considerations. The first consideration is the level of protection that existing storm and/or erosion control works actually provide. For example, if a seawall already exists, design engineers should determine how well it actually reduces overtopping and the conditions under which it would fail. Second, the protection offered by any structure is dependent on its own structural integrity. A project can only be considered effective insofar as it is structurally sound. In addition to structural integrity, the project's remaining useful life and operation and maintenance requirements should be considered. An assessment must be made of the capability and willingness of the structure's owner to adequately maintain it. This is usually rather easy for structures owned by governmental units, but may be more problematic for structures that are privately owned.

EXAMPLE

Again using the New Jersey study, the problem is described in terms of both erosion and storm damages. Investigations to ascertain the existing without-project condition indicated shrinking beach widths throughout the period of record, resulting in a majority of the shorefront property in the southern communities of the study area having no dry beach; deterioration of seawalls and groins, leaving coastal structures increasingly susceptible to storm wave damage as the beaches continue to erode; and a net northward movement of littoral drift in the study area (at an increasing rate) toward Sandy Hook. Additional research documented the history of significant coastal storms causing widespread damage throughout the study area from a combination of wave attack, storm recession, and inundation. Post-storm damage reports from severe extratropical storms in 1962 and 1984, both resulting in disaster area declarations, were updated to current dollars to provide some measure of the monetary losses from damages caused by coastal storms representative of the study area. Due to the persisting problems of shoreline erosion and attendant degradation of protective structures, associated with expected increases in coastal development, analysts expected the potential economic losses and threat to human life and safety to continue to rise.

STEP THREE: SELECT PLANNING SHORELINE REACHES

The reach is the primary economic sub-unit of analysis. The beach length and associated upland areas are divided into "reaches" or "cells" throughout which the geomorphic conditions remain practically constant, and into "sub-reaches" or "zones" where development or use changes appreciably with stage or erosion patterns.[4] The type or level of existing protection are other criteria by which reaches may be established. Frequency of storms, tide levels, wind effects on water levels, cut and fill (erosion and

[4] The coastal engineer usually refers to cells and zones, while the economist may refer to reaches and sub-reaches. Although there are technical differences, the terms are often used interchangeably.

accretion) changes, and damage data may be used for each reach; thus, data must be representative of the actual frequency of storm events and damage for that reach. A single reach may cover an entire developed area of a small community, in which case it is known as a "damage center", or it may cover only a few hundred feet of especially sensitive beach or estuary. Sub-reaches and zones may be established for the individual consideration of specific areas, particularly when a feature exists which appreciably affects inundation and/or erosion conditions.

Reaches are the primary geographic unit for planning. Plans are formulated with components that may cover a series of reaches. The hydraulic and hydrologic (H&H) effects and subsequent benefits of a project are calculated for each reach. Consequently, it is extremely important that reach selection be a joint effort by the project planner, the coastal or H&H engineer, and the economist. The hydraulic reaches and planning/economic reaches can be different; however, when possible, they should have common boundaries so that benefits can be displayed for each identified measure. When there is a doubt as to whether to begin a new reach, it is usually better to define too many reaches than too few. It is also wise to delineate and identify reaches in a manner that is consistent and acceptable to the entire study team so that all team members are referring to identical areas when they discuss a given reach. Similarly, within a given reach, a consistent numbering system for structures should be used by planners, real estate analysts, and engineers.

In defining the littoral processes, the coastal engineer, along with the rest of the study team, must look at the requirements of the local interests (and/or sponsors) and determine how far along the shoreline the problem being addressed will affect neighboring shorelines. Because reversals in littoral transport direction occur, and because different waves transport material at different rates, two components of the longshore transport rate become important. The first is the net rate; i.e., the net amount of material passing a particular point in the predominant direction in an average year. The second component is the gross rate; i.e., the total of all material moving past a given point in a year regardless of direction. Most shores consistently have a net annual longshore transport in one direction. Determining the net and gross annual amount of longshore transport is important in developing shore protection plans. Furthermore, determination of the potential transport rate may be as important as actual transport, particularly if the existing condition is sediment-starved. For instance, a large beach replenishment project may raise actual transport rates simply by providing material to the littoral system.

The littoral cell is defined by the littoral processes. A project at times may encompass one, or only a short segment, of a cell, and at other times it may involve many littoral cells. Any measure which modifies the littoral processes will affect the entire cell in which it is instituted, even if the littoral cell is many miles in length, and the project only encompasses a few hundred feet. In that case, the study area will encompass a much larger area than if the littoral cell were only the immediate project area. Study reaches could be defined as: (1) the entire area updrift from the project site; (2) the immediate project site; and, (3) the entire area downdrift from the project site; or any other logical division acceptable to the study team.

Reaches, for H&H considerations, are determined based on such elements as offshore features, beach slope, material composition, tidal influences, uniformity of the beach profile shape, and cross sections of the back-beach area. It is usually this delineation of reaches from which incremental structural and economic justification and feasibility is established. From the economists' point of view, reaches are established primarily for the purposes of plan evaluation and display. Economists use reaches to determine the smallest desired breakdown of damages and benefits. Within each reach, breakdowns will be made of damages by land use category and by zones of inundation arising from the combined effects of water levels (a function of storm-induced surge superimposed on the water levels normally caused by astronomical tides) and attendant wave action.

Shore protection management schemes often call for a combination of solutions. Solutions are based on changes, not only in hydraulic and physical considerations, but also on land use and political considerations. Reaches should be selected to help facilitate the formulation process by allowing breaks where there are significant changes in land use, changes in political subdivisions, and where there may be changes in the types of management solutions.

EXAMPLE

In the New Jersey study, economic reaches were selected at a later stage in the benefits estimation process; namely, during the inventory of existing conditions, which would correspond to Step Six in this manual. Reaches were defined to assist in determining those areas most susceptible to flooding and to identify the primary areas for sample selection for structure inventory. The initial breakdown was by municipal boundary, followed by physical characteristics. The primary physical split was between the peninsula section in the north (containing the communities of Sea Bright and Monmouth Beach) and the mainland areas to the south. These coastal segments were further divided into reaches by coastal dynamics and by the presence of such man-made structures as groins and seawalls. For example, within the municipal boundary of Long Branch, New Jersey, five reaches were selected based on whether the shore exhibited a beach without a seawall, a small beach with an upland seawall and functioning groin field, a small beach with no seawall and a functioning groin field, or a severely eroded beach with an ineffective groin field and an exposed seawall. This procedure resulted in the separation of 12 miles of coast into 14 reaches.

STEP FOUR: ESTABLISH FREQUENCY RELATIONSHIPS

A frequency is the number of times a specified phenomenon occurs in a given interval. For example, the water level may reach a height of 10 feet at a particular site 10 times in 100 years; or 20 feet or more of a beach is lost to a single storm once every 10 years. The same frequencies can also be expressed as an exceedance probability of 0.1, or an event with a 10% chance of being exceeded in any particular year. The elevation-frequency relationships (such as depicted in Figure 6) delineate the relationship between wave and water level and frequency of occurrence, while erosion-frequency relationships (which would appear very similar) delineate the relationship between periodic erosion (or accretion) and frequency of occurrence. The significant difference is that erosion may occur in one season followed by accretion in the next season; the net difference being the annual change.

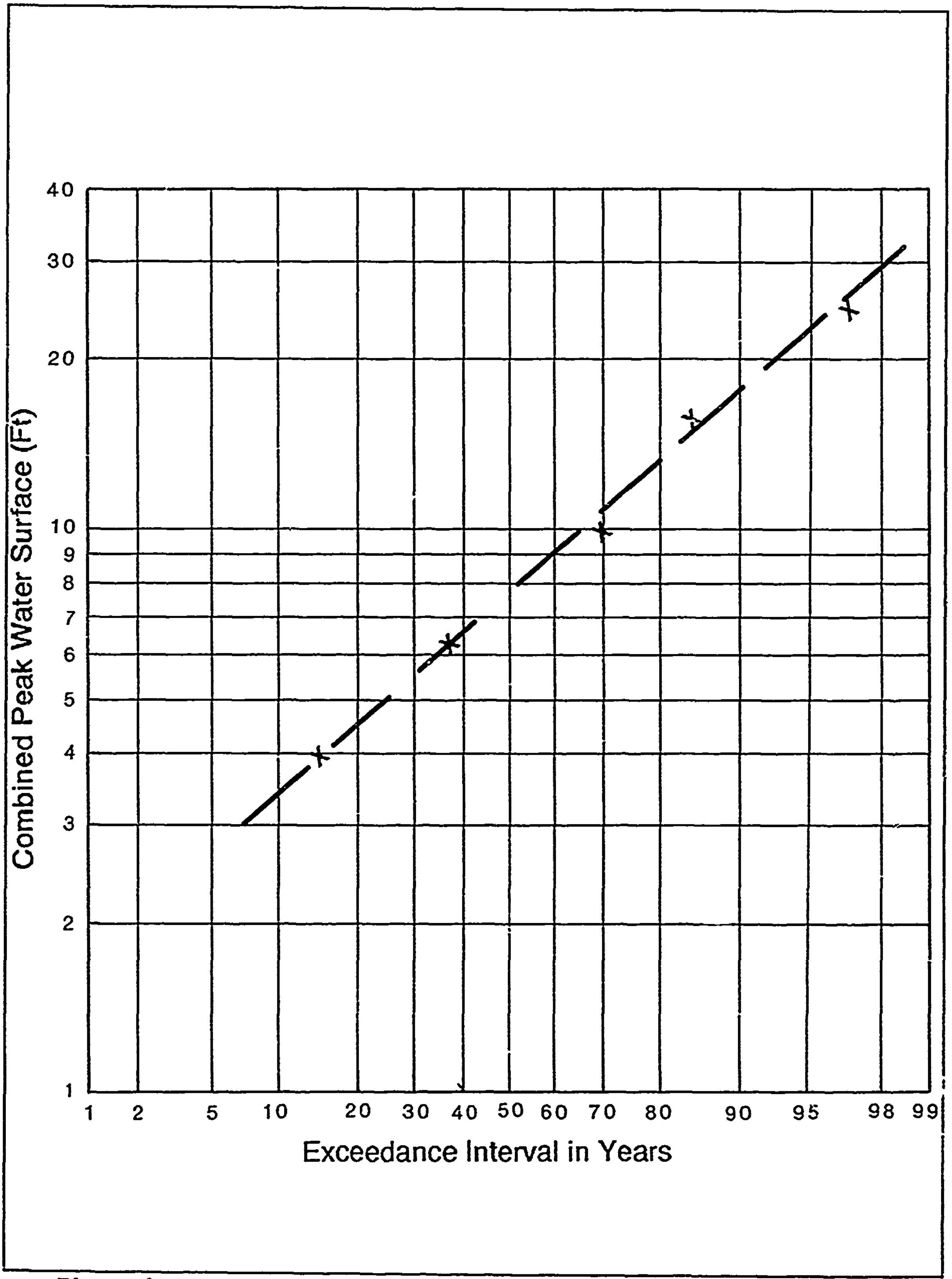

Figure 6. Combined Exceedance Frequency Curve, Wave Height and Tide.

The elevation-frequency relationships, including some consideration of the duration of inundation, are combined with elevation-damage relationships (Step Eight) to derive expected annual inundation damages. As such they are a key element in the criteria for estimating the magnitude of expected storm damage. No estimate of expected annual damages can be made without first estimating how often a particular event may occur. At the same time, the analyst must also evaluate damage caused by storm-induced erosion and other storm-induced damages.

As described in Chapter V of the NED Procedures Manual - Urban Flood Damage, in riverine environments expected annual flood damages are derived by combining the information from three basic relationships: the elevation-discharge and discharge-frequency relationships, which the hydrologic and hydraulic engineers use to compute the elevation-frequency relationship; and the elevation-damage relationship, which is determined by the economist. Similarly, in coastal storm damage studies it is necessary to determine the frequency of damage at a particular site by synthesizing information from the elevation-frequency relationship (computed by the coastal hydrologic and hydraulic engineers) with the elevation-damage relationship (estimated by the economist in Step Eight). For damages occurring due to flooding, wave attack, or wind, the determining mechanisms are wave height and water level, which are both related to tide stage. Wave height at the project during a storm may be depth-limited, in which case it would be directly related to water level. Water level in turn has tide stage as one component. Thus, the coastal engineer must typically derive the elevation-frequency relationship by combining wave height and water level, which are not highly correlated. Beach erosion and damages due to undermining are heavily dependent on storm durations or the number of smaller storms occurring in a season. As an example, the storm of record for damage to many East Coast sites is the 1962 Ash Wednesday northeaster. While the storm plotted relatively low on an elevation-frequency relationship, it persisted for several days. In general, the best techniques for evaluating erosion-frequency employ some combination of mathematical modeling, historical recession rates (where sufficient data are available), and professional judgement. A reconnaissance study which employed Monte Carlo simulation to derive the elevation-frequency and erosion-frequency relationships is provided in "Appendix C, An Example of Shoreline Damage Assessment." This example was excerpted from Appendix A of Santa Barbara County Beach Erosion and Storm Damage Reconnaissance Study.[5]

EXAMPLE

In the New Jersey study, frequency relationships were evaluated independently for each of the mechanisms responsible for structural damages: long-term erosion, inundation, recession, and wave action. This evaluation also included determination of the area subject to a particular frequency of the damaging mechanism, therefore incorporating the procedures corresponding to Step Five (described below).

The historical rate of long-term erosion was determined by coastal engineers to be three feet per year. Extrapolating this rate for the projected fifty-year life of the project, the area subject to long-term erosion was determined for the years 1990 through 2040. Based on discussions with the New Jersey Department of Environmental Protection, it was determined

[5] U.S. Army Engineer District Los Angeles, Santa Barbara County Beach Erosion and Storm Damage Reduction Reconnaissance Study. (Los Angeles: CESPL. 1990).

that ongoing maintenance efforts would protect major structures such as the seawalls and state highway paralleling the beach. Long-term erosion would therefore be arrested at the leading edge of these structures by human intervention.

Long-term shoreline change simulations were also performed for the New Jersey study by the Coastal Engineering Research Center (CERC).[6] The GENESIS shoreline contour model was utilized to simulate the longshore sand transport processes and long-term shoreline change along the project reach. The GENESIS shoreline model is a generalized system of numerical models and computer subroutines which allows simulation of long-term shoreline change under a wide variety of user specified conditions.

Inundation frequency relationships were based on stage-frequency relationships also developed by CERC. These relationships (between the maximum still water level along the study sections and the interval in time between the expected recurrence of this water level) were also used for the design of the alternative beach fill cross-sections and for berm and seawall overtopping analyses. Since historical water level variations over an extended period of time were not available for the project area, a numerical model was used. In the model, northeasters were the dominant cause of rises in the still water level at the coast for the first 25 years; after 25 years, hurricanes dominated the surge level curves. These stage-frequency relationships are described in greater detail in the aforementioned CERC study.

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[6] Detailed descriptions of the model are presented in Coastal Processes at Sea Bright to Ocean Township, New Jersey, U.S. Army Corps of Engineers, Coastal Engineering Research Center, (Vicksburg, MS: Waterways Experiment Station, 1986).

The storm recession-frequency data used for the economic analysis were also based on data developed by CERC. The stage frequency relationships (described above) were used as input for the numerical modeling of the storm-induced dune and berm erosion. This task, performed in two stages, examined dune erosion of the existing conditions and dune erosion using alternative with-project 50-, 100-, and 150-foot design fill berm widths. The numerical model used to simulate dune erosion was based on a modified Kriebel-Dean dune erosion model which is a function of a single storm surge hydrograph. For both existing and with-project conditions, 120 northeasters and 275 hurricanes were generated for model input. The storm conditions were applied in the model for existing conditions to four typical existing shore profiles (cross sections) and for with-project conditions to the various design profiles. From the numerical model, maximum recession values were determined for the various storm events. Figure 7 displays maximum recession-frequency curves developed from this analysis, including allowances for variability.

Finally, the wave attack frequency relationship in the New Jersey study was defined as the return period of the storm event which allows wave runup to destroy residential and commercial buildings within each economic reach. The wave attack line is the position in the uprush zone where the force due to the broken wave exceeds the critical force needed to destroy a structure. In the project area, the critical force necessary to destroy a typical structure was determined to be a lateral force of 1770 pounds/foot, equivalent to a breaking wave height slightly over three feet. Limits of potential wave attack were delineated in the study area as wave zones for storms with return periods of 25, 100, and 500 years. All delineations assumed complete failure of seawalls and bulkheads, but damages to buildings were not considered for storms which

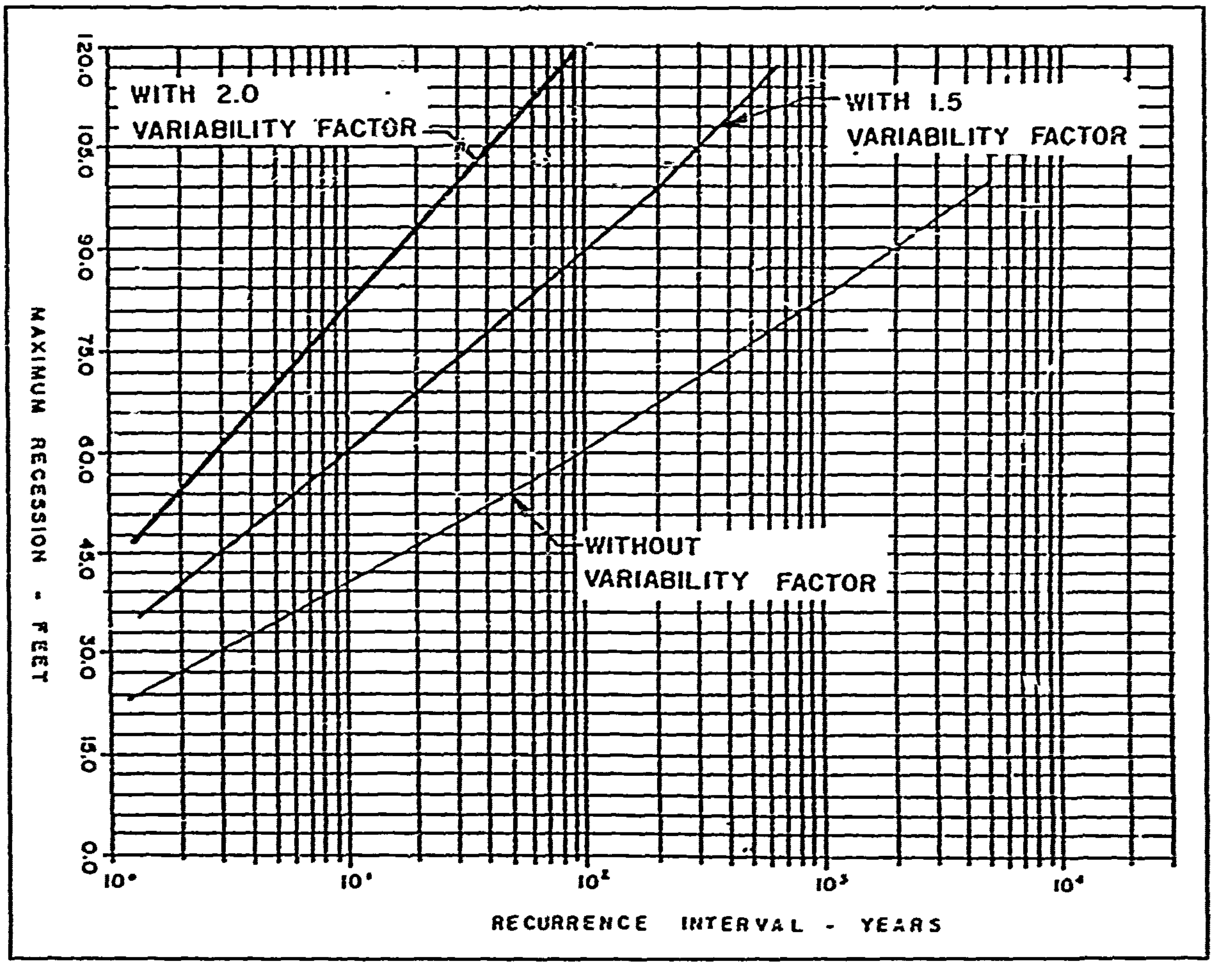

Figure 7. Maximum Recession-Frequency Curves for Combined Northeasters and Hurricanes.

Source: U.S. Army Engineer District New York, 1989.

would not cause failure of these protective structures. The wave attack limit was calculated for the existing conditions and the alternative with-project beach profiles. Specific structures subject to wave attack during the 25-year, 50-year, and 500-year storms were identified. The level of protection (in terms of storm return period in years) provided by existing beach widths and alternative with-project berm widths was determined for each economic reach.

STEP FIVE: OUTLINE AREA AFFECTED

For purposes of this manual, the area affected refers to the part of the study area most directly affected by storm damage or long-term erosion. The geographic area would be bounded by the shoreline and the immediately adjacent inland areas subject to damage. Upcoast anu downcoast boundaries would be limited by natural features such as headlands or inlets in most cases. Different coastal features in different parts of the country need to be taken into account. Sandy coasts with barrier islands, large estuaries, straight and unbroken beaches, or low-lying coastal plains would have significantly different areas affected by storm damage than rocky coasts with headlands, steep uplands or small, pocket beaches.

The affected area must be adequately described for valid comparison with project alternatives. Natural shoreline features, as well as man-made features and development, must be described. The primary purpose is to allow an accurate inventory of existing conditions, and to identify areas which may be protected by erosion/storm damage prevention measures.

The procedure for outlining the area affected is to define the physical boundaries using the wave analysis and storm surge information from the hydraulic and coastal engineering analysis. The established frequency relationships from Step Four can be used together with topographic information to determine inundation effects. The wave analysis defines the expected storm events, time or duration of occurrence, direction and type of waves, shallow water transformations and other effects. This will help to estimate wave attack damages and may also help to determine expected erosion. When combined with wave analysis and expected erosion, the shoreline geometry and topography will indicate which waterfront areas will be directly impacted by waves as well as what structures and man-made alterations will be affected. Where appropriate, the effects of existing protective measures should be taken into account.

The presence of features such as offshore islands and irregular bottom contours must be considered in determining the area affected by waves. The storm surge information, in conjunction with ground elevations, will indicate what areas would be inundated by various water levels. The inundated areas may include some or all of the shoreline in one or more littoral cells as well as parts of the adjacent floodplain some miles inland. Available floodplain information should be consulted.

EXAMPLE

In the New Jersey study, the area is described in terms of physical topography (e.g., the elevation and width of beaches, barrier islands, coastal plains, and headlands) and existing protective measures (e.g, seawalls and groins). The description of the area affected by particular frequencies of damaging mechanisms (long-term erosion, recession, inundation, and wave attack) were incorporated into Step Four (described above), the evaluation of frequency relationships.

STEP SIX: INVENTORY EXISTING CONDITIONS

An inventory is a survey of affected area properties, including land, to assist in predicting potential damage. Types of information needed to evaluate properties in the affected area include susceptibility classification (including such factors as distance from the water, the existence of natural barriers, and construction materials), value, use, ground floor area, number of stories, and elevation. This information is then used as a basic step in the computation of storm and/or erosion damages and damage reduction benefits.

The existing condition inventory should be gathered by property use activity: residential, commercial, industrial, or public. During the inventory process, the economist should note areas likely to be developed or to change use during the planning horizon (e.g., small, dilapidated homes in an area with a growing population of condominiums and tourist facilities). This will facilitate making the future development projections. Physical damage estimates should also be made for transportation facilities, public utilities, vehicles, communications equipment and other property. These estimates will have two components: any damage caused by inundation; and damage or destruction caused by recession or erosion and the failure of support facilities. The economist should refer to National Economic Development Procedures Manual - Urban Flood Damage, Chapter 5, "Step Five: Inventory of Existing Floodplain," for inventory methodology.

EXAMPLE

In the New Jersey study, the level and density of residential and commercial development and the value of residential and non-residential structures, contents, and roads and utilities in the immediate project area were described based on a structure inventory and Monmouth County tax assessments. A structural data base was generated through a survey of structures adjacent to the project area including buildings, utilities, bulkheads, seawalls, and roadways. The building data were obtained through a windshield survey of the area using topographic mapping with a scale of one inch to 200 feet with a two-foot contour interval. Information on the type of building, location, setback distance, mid-point distance, building size, number of stories, the existence of a basement, elevation, building material, and quality were collected. For utilities, roads, and structural measures the inventory data were taken from topographic mapping and primarily targeted toward physical characteristics such as size and length, in order to assign a replacement value. A key element in both aspects of the structure inventory was the front of structure setback and the mid-point setback data, used to locate each structural element relative to the water line. This was the primary mechanism used to trigger damage due to long-term erosion, storm recession, and wave attack.

The data collected were used to categorize the structure population into groups having common physical features. Data pertaining to structure usage, size, and stories assisted in the stratification of the building population. For each building, data were also gathered pertaining to its damage potential including its main floor elevation lowest opening, construction material, and proximity to the water. Replacement value was calculated for the residential and commercial structures using standard estimating guides in conjunction with size data.

STEP SEVEN: DETERMINING MOST LIKELY WITH- AND WITHOUT-PROJECT CONDITIONS

Alternative water resource management plans are formulated and evaluated on the basis of the most likely conditions expected to exist with and without implementation of each of the plans identified for analysis. The purpose of forecasting conditions expected to exist with and without each plan under consideration is to isolate the changes that are expected to occur as a result of implementation of the plan, from those that would occur if the plan were not implemented. Without-plan conditions, therefore, are the conditions expected to prevail if no Federal action is taken, while with-plan conditions are those expected to prevail with implementation of a plan.

The without-plan condition is an assessment and forecast of the storm damage or erosion problem, assuming no action is taken by the Corps to alleviate it. If storm damage prevention works or any other action are imminent or likely without Corps action, those works and actions should be considered to be part of the without-plan condition. Imminent works and actions include measures that are under construction; funded storm protection measures; development under construction; development limitations as specified under the National Flood Insurance Program, Executive Order 11988, and Coastal Zone Management Plans; and any state and local regulations in effect. Since the without-plan conditions sometimes include plans which have yet to be approved or may be speculative, all assumptions should be carefully explained and justified.

Existing development and activity can be expected to remain in place, unless facilities are in deteriorated condition, abandoned, or are to be moved or replaced. Structural assessments should be made of existing storm protection works to determine the realistic degree of protection which they provide.

Any changes in population, land use, affluence, or intensity of use expected as a result of implementation of a plan, should be included in the assessment and forecast of with-plan conditions.

The level of detail required in collecting data and forecasting future conditions depends on factors such as type of study (e.g., reconnaissance or feasibility), available time and money, sensitivity of project formulation and justification to changes in storm damage prevention benefits, and interests and concerns of the local sponsor, if applicable. Because of the compressed time frame and amount of money available for reconnaissance level reports, the amount of detail required is less than what is required for a feasibility study. The reconnaissance study should focus on without-project conditions, while the feasibility study should provide detailed formulation. In addition, a lesser level of effort in primary data collection may be appropriate when data are available for an area with similar development and economic activity and shoreline, geologic, and other features, including littoral processes. However, extreme caution should be exercised when using data from other areas, especially in planning beyond the reconnaissance study, to ensure that the areas are indeed similar.

FACTORS TO CONSIDER

Development of forecasts of future conditions requires consideration of human responses to long-term erosion and coastal storm damage.

Response to Long-Term Erosion. As long-term erosion occurs, individuals and communities will respond by taking action to protect, relocate, or abandon existing properties. In addition, action may be taken to limit future development. During the development of the forecast of future conditions, the economist must determine the most likely course of action, which will then become the basis for the analysis and forecast. It should be noted that the most likely action to be taken could change over the planning horizon; property owners may take action to protect properties initially and later to relocate or abandon the structures.

The most likely action should be based on institutional factors which may vary greatly from state to state, and the assumption of rational economic behavior (e.g., property will be protected as long as the perceived incremental cost of protection does not exceed the perceived remaining value of the property). On this basis, in many cases it can be expected that efforts to protect may continue until such time that total loss of the property is imminent and further occupation or use of the property becomes unsafe. State Coastal Zone Management Plans (CZMPs) or other zoning ordinances may prohibit such individual protection or replacement or repair of some damaged structures. All assumptions and limiting factors should be fully documented, and discussed among the study team to prevent conflicting assumptions by different team members.

Response to Storm Damage. Individuals and communities may also respond to storm damage to property in a variety of ways, including relocation, abandonment, and repair or reconstruction. In addition, building and zoning codes may be changed. As with the response to long-term erosion, the economist must determine the most likely course of action which would be taken. In general, it should be assumed that the most likely course of action will be based on rational economic behavior, whereby individuals and communities attempt to make their decisions on the basis of marginal costs and benefits. Therefore, it is assumed that property would be replaced or repaired as long as the present value of future storm damages is less than the cost of relocating the property.

DATA SOURCES

A major problem in inventorying existing, and predicting future, conditions is obtaining quality data for use in making the evaluation. Primary data sources are preferable for obtaining specific and accurate information, but using such sources is often too costly or time consuming. Secondary sources are usually less expensive, but caution should be exercised to ensure that the data are specifically applicable to the study area. Primary data include that collected firsthand by the study team through observations or surveys. Secondary data are derived from published sources, such as government reports and databases, newspapers, and technical books and periodicals. Some of the general sources for various types of information needed for storm damage analysis, in addition to information available from within Corps district offices, are summarized in Table 2.

TABLE 2 POTENTIAL DATA SOURCES BY SUBJECT	
Subject	Potential Data Sources
Land Use	A,B,C,J
Land Values	A,D,N
Coastal Geology	E,F,K,L,M,O
Historic Coast Line	A,B,E,F,H,J,K,L,M,N,O
Storm Intensity and Pattern	F,G,H,K,L,M,N
Local Littoral Processes	E,F,H,K,L,M,O

SOURCES

A - County Office of Assessment and Taxation 1/
B - County Office of Zoning and Land Use 1/
C - County or Municipal Building Departments 1/
D - County Register or Recorder of Deeds 1/
E - Geological Survey, U.S. Department of Interior
F - U.S. Army Coastal Engineering Research Center
G - National Weather Service, U.S. Department of Commerce
H - National Ocean Service, U.S. Department of Commerce
I - Coast Guard, U.S. Department of Transportation
J - Area Port Authorities
K - Local Universities
L - Sea Grant Institutions
M - Other Oceanographic Institutions
N - Newspapers 2/
O - State Geologic Survey 1/

1/ Name of the office may vary from state to state.

2/ May carry weekly compilation of real estate transactions, etc. Old copies may have descriptions and pictures of major storms.

DISTINCTION BETWEEN STORM AND LONG-TERM EROSION DAMAGE

Because Federal interest and budgetary policies on Corps participation in storm damage analysis and long-term erosion control plans may differ, it is essential that forecasts of future conditions distinguish between potential damages from storms and potential damages from long-term erosion. For storm damages, care must also be exercised to separate damages due to the storm from storm-induced erosion damages. Forecasts of future conditions should separate potential damage effects on the basis of the following definitions.

As defined in Chapter I, long-term erosion consists of the loss of land along the shoreline due to littoral transport and to wave action from storms with an exceedance frequency of up to one year.[7] Storm damage consists of the loss of land and loss or damage to associated capital improvements and other property along the shoreline due to erosion, inundation, wind, and waves from storms with an exceedance frequency of more than one year.[8]

A key factor in the analysis of long-term, wave-induced erosion is the determination of whether the loss of land is temporary (seasonal) or long-term. For the purposes of the analysis of long-term erosion, temporary loss of shoreline land should be considered to be the loss occurring annually due to a seasonal increase in the intensity of wave action, with the shoreline

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[7] Long-term erosion is determined by comparing maps, photos, and surveys, or other available historical records, that span a period of several years or decades. The cumulative shoreline changes measured from these data sources, therefore, probably include the net effects of storms with exceedance frequencies greater than one year. In order to account for long-term erosion effects and yet keep them separate from storm-related damages, the procedure used by one Corps district is to move the position of the shoreline landward over some given time increment and evaluate potential storm damages for each future shoreline position. Structures and other features overtaken by the future shoreline position during the time increment are removed from the structure inventory prior to the evaluation of future storm damage. Inherent in this analysis is the assumption that storm erosion losses are temporary; the shoreline is assumed to be completely restored to its pre-storm position following the passage of the storm.

[8] Although "normal" erosion is usually defined on a study-by-study basis, the one-year exceedance frequency demarcation between erosion wave action and storm wave action is a generally accepted, albeit arbitrary, designation. Nevertheless, shorelines can be impacted by waves with exceedance frequencies of greater than one year that are still not considered "storm waves." There can be considerable non-storm, year-to-year variation in the wave climate at a site.

being restored to its historical position annually as wave action moderates. Analysis of long-term erosion should take into account potential impacts on the rate of erosion due to natural (e.g., land slides and land subsidence or uplift) and man-made (e.g., bulkheads, seawalls, revetments, breakwaters, groins, jetties, and channels) alterations to the shoreline. Major alterations to the shoreline or offshore areas (either natural or man-made) may require the analyst to disregard all data collected prior to the alteration.

EXAMPLE

In the New Jersey study, future with-project and without-project economic conditions were estimated using the inventory of existing development conditions as a basis. Projections of future population by the New Jersey Department of Labor indicated that Monmouth County would continue to grow at a faster rate than the state average through the year 2020. Population trends in the project area communities, though varied, indicated increasing numbers of residents along the coastline. Forecast development in the project area mirrored the regional trend toward increasing townhouse and condominium units and toward more year-round housing units (as opposed to seasonal units), both in percentage of units and in numbers. Growth in the value of homeowners' contents were projected to increase at the same rate as that of per capita income for the State of New Jersey, obtained from the 1985 OBERS Regional projections produced by the Bureau of Economic Analysis. Future content values were not allowed to exceed 75 percent of associated structural values.

Future with- and without-project conditions were estimated for damages caused by long-term erosion and by storm mechanisms. Under without-project conditions, the long-term erosion problem documented in Step Two was projected to continue. Because of the loss of beach material northward due to littoral transport, and because the beach itself is the only source of that material, it was projected that the beach would continue to erode at the historical long-term erosion rate of three feet per year. The long-term erosion would result in the reduction of berm area, which acts as a natural buffer for both unprotected properties and the protective coastal structures themselves (e.g., seawalls and groins). Therefore, deterioration of the seawalls and groins was expected to continue, making them increasingly susceptible to storm wave damage and failure. Due to continuing shoreline erosion with attendant degradation of protective structures and increased coastal development, the potential economic losses were projected to rise. Under with-project conditions, the proposed project would halt long-term erosion as a result of implementing a feeder beach and an ongoing beach nourishment program.

However, under both with- or without-project scenarios, it was determined that the seawall and state highway paralleling the beach in the northern sections of the study area would be protected through the State of New Jersey's ongoing maintenance efforts. Long-term erosion would be, therefore, arrested at the leading edge of these features, although damage and/or failure from storm-induced recession or wave attack could not be prevented through seawall maintenance. Further south, structures destroyed by long-term erosion without the project were removed from the analysis for future years as it was determined they would not be reconstructed because the site was destroyed.

Recession, inundation, and wave attack damages were analyzed for future without- and with-project conditions. In the absence of the project, buildings destroyed were assumed to be rebuilt unless subject to wave or storm recession damage from storms with a recurrence interval of 1.5 years or less. In areas protected by the seawall, total rebuilding was assumed based on the perception of protection provided by the seawall. This was based on a review of existing development which presently reflects this proximity to the shoreline. For residential structures, the replaced building was considered to be elevated to meet the National Flood Insurance criteria.

Residual recession and wave attack damage under the with-project conditions were evaluated using the same methodology excluding long-term erosion since project maintenance would prevent its occurrence. Setback and midpoint distances were adjusted for the additional beach width and the seawall failure frequency was adjusted to reflect the increased level of stability provided by the project.

STEP EIGHT: DEVELOP DAMAGE RELATIONSHIPS

After the inventory and appraisal of flood-prone property, the computation or selection of damage relationships is the next important task for the economist. This section addresses the process of developing and selecting appropriate damage functions to meet the requirements of a particular situation. Damage relationships describe the expected value of structural or contents damages caused by various factors, such as depth of flooding, duration of flooding, sediment load, wave heights, amount of shoreline recession, and warning time. This section also includes a discussion of when it is necessary to compute site-specific functions and when it is possible to use generalized damage relationships.

Depth-damage relationships developed for flood control studies are based on the premise that water depth, and its relationship to structure elevation, is the most important variable in determining the expected value of damage to buildings. Similar properties, constructed, furnished, and maintained alike, and exposed to the same flood stages and forces, may be assumed to incur damages of similar magnitudes or proportion to actual values. These damage functions are often continuous in form. However, a very large percentage of coastal storm damages are related to erosion (i.e., undermining of structures) and/or wave forces rather than actual inundation of structures, and often discontinuous or stepwise damage functions are more indicative of the actual damage potential. For example, minimal damage may occur up to a determined point, followed by a large "step" in damage as part of the set of structures fail, followed by little or no additional damage, followed in turn by further structural failure and catastrophic damages, and so on. Additionally, wave uplift can be a significant source of damage for structures such as single family residences and piers built on pilings.

Undermining damage is related to structural composition of the building and foundation (e.g., concrete slab, standard foundation, piling) and depth of foundation or piling relative to composition and integrity of the surrounding soil. There is no widely accepted, quantified relationship in the United States between any of these factors and the extent of damage, so the analyst must use "best judgement" and experience in the area to make the appropriate decision. Often, a structural engineer or insurance appraiser may need to be consulted. In this step, and in the next step, the objective is to determine how much damage occurs with various types of events. Two basic approaches are discussed below.

One method of determining damage relationships is to estimate the damages that occurred during actual storm events, usually from extensive interviews with residents, business proprietors, and local officials. During the interviews, damages are also estimated for other types of events (lesser or greater frequency storms) to the extent possible. Even using extensive interviews, however, it is not always possible to separate damages from the various damaging mechanisms, particularly when inundation, waves, recession, and wind all affect the structure. Moreover, conducting interviews is a time-consuming and expensive process for most study areas. Another limitation is that previous threatening events and subsequent damaging events may be sufficiently different. For example, recent large storms may have only damaged protective features, such as dunes or barrier islands, with little damage to properties. These storms, however, have exposed properties to future damage by even smaller events. Therefore, using historic damages based on storm magnitude would underestimate the damages that might now occur.

A second approach is to use generalized inundation-damage relationships from other areas, often derived by computer-oriented analysis. This approach is described in detail in the NED Procedures Manual - Urban Flood Damage With this approach, special care must be exercised to avoid double counting (i.e., to separate erosion damages from storm damages) and to use data only from areas where the damage relationships are similar. If this approach is used for inundation damages, wave attack may need to be estimated on a structure-by-structure basis, and erosion damages will need to be evaluated separately.

The major criterion in selecting damage functions is the similarity of susceptibility relationships. Damage functions are influenced by a number of variables. Variables found to be significant in regression analysis can be used in computing reliable damage relationships. Table 3 summarizes the major hydro-meteorological, structural, and insti ıtional factors that significantly influence the amount of damage.

While most analysts involved in flood damage assessment are aware of most of these factors, it is rare that any of these factors has been isolated as part of a predictive function. It is less difficult to apply functions where the factors are reasonably close to the situation to which they are being applied. For example, damage functions computed for the New Jersey coast area may be applicable to sites along the Massachusetts coast, where storm regimes are similar, but unsuitable for use at West Coast locations, where storm regimes are very different.

TABLE 3

VARIABLES THAT INFLUENCE DAMAGE RELATIONSHIPS

VARIABLE	EFFECTS
HYDRO-METEOROLOGICAL VARIABLES	
Storm Intensity	Storm intensity is a major factor aggravating structure and content damage. High water level, wind and wave forces create greater danger of foundation collapse and forceful destruction of contents. Factors contributing to storm intensity are water height; swell size; wave height, steepness, and direction; and wind velocity.
Duration	Duration may be the most significant factor in the destruction of building fabric and lead to erosion and other damages. Continuous high water levels accentuate the effects of high waves. Continued saturation will cause wood to warp and rot, tile to buckle, and metal objects and mechanical equipment to rust. Agricultural land will sustain greater and longer term damage from sustained inundation, particularly when salt water saturates the soil. Long duration storms of a smaller magnitude may cause more damage and greater total erosion than a larger, short duration storm.
Frequency	Repeated saturations can have a cumulative effect on the deterioration of building fabric and the working of mechanical equipment. Frequent, smaller storms may result in more cumulative erosion (or prevent material from being carried onto the beach) and damage than a single large storm. When a large storm follows several smaller storms, potential damage is greater.
Ice Effects	This variable is usually a factor only on the Great Lakes. Ice can cause structural failure of many types of materials and can be particularly damaging and erosive. However, the formation of "fast ice" (solid sheets connected to the shore) can provide some degree of protection from storms.

STRUCTURAL VARIABLES	
Building Material	Steel frame and brick buildings tend to be more durable in withstanding inundation, but more susceptible to corrosion and buckling than other more flexible material such as dimensional lumber.
Inside Construction	Styrofoam and similar types of insulation are less susceptible to water damage than fiberglass and wool fiber insulation. Plaster and most types of drywall will crumble under prolonged inundation. Waterproof drywall will hold up for long periods of inundation. Paneling may be salvageable when other wall coverings are not.
Condition	Even the best building materials can collapse under stress if the construction is poor (e.g., below accepted codes) or is in deteriorated condition. Building condition should be a major determinant of depreciated replacement value.
Age	Age may not be a highly significant factor in itself, except that it may serve as an indicator of condition and building material. It would be more accurate to survey the other factors separately.
Content Location	Arrangement of contents is an important factor in determining damage relationships. These relationships could be expected to be somewhat homogenous for commercial business, particularly chain stores. Industrial property should be surveyed individually to determine how the arrangement of contents will affect the damage relationship.
INSTITUTIONAL FACTORS	
Storm Warning	Reductions in both content and structural loss can be made through emergency preparedness and evacuation activities when there is adequate warning, and resources are available to fight the storm effects. The potential for prevention of losses is somewhat less than in a riverine flooding situation due to the greater likelihood of a dangerous storm situation requiring evacuation of a wide area. Prevention of structural damage is also more difficult due to the forces of wave action. On the other hand, there is often a longer response time available because major storms such as hurricanes may be predicted days in advance so that, even though actual landfall location is uncertain, local officials have time to prepare.

GENERALIZED FUNCTIONS

Generalized damage functions are computed from either post-storm surveys or synthetic estimates. Generalized functions are sometimes as accurate as building-by-building estimates of susceptibility, but they should be field-checked whenever they are applied. Knowledge is required of the critical variables that could influence damages in the area where the generalized curves were derived, and in the area where they might be applied. This is an area where the economist and the coastal engineer must work especially close together to obtain defensible damage estimates. Please consult the NED Procedures Manual - Urban Flood Damage for more information on generalized damage functions.

DAMAGE VALUATION

Basic estimates of losses for buildings, roads, protective works, and other development features should be prepared at current price levels for the existing state of development of the problem area. For long-term erosion, historical damages may be used as a basis for estimating future losses to existing developments. Use data for as long a period as reliable records are available. All values should be adjusted to current price levels; any changes in costs of both normal and extraordinary repairs and maintenance should be noted.

Appropriate adjustments should be made in basic damage estimates to take into account: 1) any factors which would tend to modify rates of shore erosion; 2) accrued depreciation or maintenance resulting from normal wear or aging; and, 3) probable trends and nature of developments and activities in the problem area, based on the most probable economic use of the area in the absence of suitable protective measures. Local government units and planning bodies should be consulted.

Probable damage prevention benefits should be estimated for prospective development conditions that would occur in the absence of the proj... by correlating the adjusted damage estimates with expected proj... ...

Project effectiveness should be estimated on the basis of experience and knowledge of beach erosion control.

Although shore protection plans are normally designed to stabilize the shore or provide sufficient protective beach so that storm erosion will not damage on-shore installations, protection may not be feasible against occasional severe storms that cause temporary beach profile adjustments and severe recessions. Readjustment after the storm may result in recovery of temporary losses of land, but damages (especially to developed property) not prevented by the plan should be taken into account.

Damages from tidal or hurricane flooding which would not be prevented by the beach erosion control plan must be excluded from the benefit estimates. However, an adequate protective beach can ordinarily be expected to reduce flooding and damage due to wave runup or wave attack, except in the most severe storms and hurricanes. The credit taken for prevention or reduction of such damage should be based on an analysis of the level of protection which can reasonably be expected from a project.

Erosion, accretion, subsidence, uplift and littoral transport can greatly affect the susceptibility of property to future damages. A series of aerial photographs, taken in different seasons and over a period of years, should be consulted when available. The ideal situation would be to have photographs of each season for each of several years, and photographs both before and after significant events. In practice, the best available is usually only a few different years, and sometimes a series of photographs taken several weeks or months before and immediately after a very large storm.

Damages at the same stage in different floods may vary with seasonal flood characteristics. There may be seasonal differences in wind velocities, duration, debris, and natural protection (e.g., beach profiles). Estimated damages might be correlated with these seasonal factors and the probabilities of floods occurring at any particular time of the year. This seasonality situation is similar to that found with agricultural flood damage estimates as discussed in the <u>NED Procedures Manual - Agricultural Flood Damage</u> Content damage relationships may vary seasonally as well. In many areas, a significant percentage of residential units are summer or vacation homes, and these are infrequently occupied or are boarded-up for the winter. In these areas, many of the commercial units are also closed for the winter, or their inventories may vary seasonally by orders of magnitude.

EVALUATION OF COMMERCIAL LOSSES

Inventory of the study area will indicate the nature of commercial development, and the extent to which sampling procedures may be applicable or specific inspection and appraisal required. Seasonal variation can be most dramatic for commercial contents for the reasons cited above. For interviews and inspection, the questions in the set of OMB-approved questions may be used for, or adapted to, commercial properties.[9]

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[9] The approved list of questions was distributed by CEWRC-IWR to Major Subordinate Commands and District Commands in 1984 by DAEN-CWP letter; for more information, contact the Economic and Social Analysis Branch (CECW-PD), HQUSACE.

EVALUATION OF DIRECT PHYSICAL LOSSES

Actual or potential damages can be estimated by the normal methods of estimating repair or replacement costs. Where available, repair bills and company records also provide an independent source. As in other cases of direct physical damages, losses attributable to floods must be separated from repair costs that restore accrued depreciation. Shortened physical life (accelerated depreciation) of damaged items, non-recurring damages, and those preventable by good housekeeping, prudent management, or prompt action upon receipt of storm warning, should be eliminated from estimates of prospective damages.

EVALUATION OF LAND LOSS

Anticipated damages from land loss due to erosion may be computed for private lands as the market value of the average annual area expected to be lost. This should be determined from an analysis of adjacent nearshore lands of similar character for land use conditions expected in the absence of the project. According to ER 1165-2-130, other valuation methods are potentially acceptable, if it can be shown that the use of nearshore values does not provide a realistic estimate of the value of lost land. The decision to use another value must be properly explained, however.

Nearshore values are used because there will usually be "beach front" property. Erosion of the beach front property results in the property immediately behind the eroded land becoming the new beach front, usually with the higher value attributed to the previous beach front property.[10] Therefore, the value of the lost land is not that of the beach front, but that of the nearshore land. Often, this is manifest in a landward shift in shore-related uses. For example, beach front commercial property is destroyed by a storm or erosion, but is rebuilt at the "new" beach front which was previously lower quality commercial or residential property. As it is replaced by the high value "new" beach front commercial, the nearshore commercial uses shift further inland. This displacement and shifting continues until a natural, economic or institutional barrier to development is reached. It is therefore the property which is at or near this natural barrier that is "lost", rather than the beach front property until such time as all the property suitable to development is (effectively) fully developed and further erosion results in a net reduction of development. This is the purpose of the requirement to use nearshore values to compute land loss benefits. State and/or local zoning ordinances will dictate how new or replacement development may occur in the coastal area.

When market values are not available (or are unreliable or include speculative value), the value of land may be computed as the capitalized annual net income the land can produce. Anticipated damages due to storm erosion may be computed by correlating the value of historical land losses with particular storm events to develop a storm-damage curve to be used in estimating future losses.

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[10] If an area is experiencing extremely high erosion rates, however, the "new" beach front property may not be as valuable as the previous beach front property. High rates of erosion are usually accompanied by the destruction of ocean front structures. Even though the debris left as a result of the destruction may eventually be removed, the quality of the beach is normally not as good as beaches in more stable areas.

EVALUATION OF PUBLIC DAMAGES

Public property, for purposes of damage appraisal, can be considered to include all property owned by the various agencies of government or by charitable associations for the service of the public. Public property damages are principally apparent in the form of direct physical damage, or in the physical costs associated with insuring continuation of public services. The loss of public income may result if services provided on a user fee basis are interrupted. For example, the interruption of utility services such as water and electricity which are provided by a public entity would result in a net loss of public income. Besides streets, which are classified with transportation facilities and public power stations, public goods and services that may be adversely affected by storm damage and erosion include parks, recreational facilities, all public or semi-public buildings, water supply systems, sewerage systems and treatment plants, pumping stations, and fire and police protection facilities. Specific inspection and appraisal of damage potentials is required in each case.

Care must be taken to exclude losses, particularly for parks and other recreation sites which would be caused by weather (e.g., fewer visitations in winter or during especially stormy periods either with or without damage to the recreation facilities), transfers (recreationists transferring to other undamaged sites), or other seasonal factors. Degradation of the recreation experience can be counted as a damage, quantified through unit day values or the travel cost or contingent value methods.[11]

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[11] IWR Report 86-R-4, <u>NED Procedures Manual - Recreation, Volume I</u>, Chapter 3, provides information on the principles, assumptions, and appropriate use of the three recreation valuation methods (i.e., unit day, travel cost, and contingent value methods) recognized by the U.S. Water Resources Council.

Physical damages to public property can be evaluated by the restoration or relocation methods of appraisal appropriate for the problem being studied. Estimates of such damages and the costs of related emergency and normal services should be prepared in cooperation with the agency involved. The highly variable nature of other public facilities makes use of a standard form generally impractical, and appraisal computations should be adapted to each case.

It may be found that many public facilities or services overlap several reaches or cells and that damages cannot readily be assigned to specific locations. Breaks at any one or several points in water supply or sewerage systems may produce the same associated losses to all customers or taxpayers including those in other reaches or on high ground. Damage to public property such as streets, sidewalks, lighting, or water and sewer connections, for example, may duplicate part of the appraisal of specific properties served.

EVALUATION OF NON-PHYSICAL LOSSES

When researching or surveying based on historical storms, emergency costs should be separated into two categories. These costs include those incurred because of the damage (or threat of damage) which might be prevented by a Corps measure, and those incurred to protect from the high winds, rainfall, and other destructive forces which would occur even with the best possible protection. Frequently, data are only available for one significant storm. As discussed in the NED Procedures Manual - Urban Flood Damage, applying the same loss per structure to other storms based on the number of properties affected or the geographical extent of damage is usually an adequate approach. The percentage reduction in emergency costs for coastal storms is often much less than for riverine flooding situations. Only those emergency costs actually prevented may be counted, as the threat of a hurricane, for example, may precipitate emergency action regardless of the presence or absence of a Corps project.

EXAMPLE

In the New Jersey study, a sample population of buildings was selected for on-site inspection to determine damage potential. Findings from the on-site interviews conducted for the sample population were then used to develop generalized depth-damage relationships applicable to the overall population. A total of 214 site investigations, representative of two percent of the total structure population, were conducted. The inventory population was stratified according to physical characteristics (e.g., residential structures were separated into 15 categories, such as colonial, ranch, split level, bungalow, mobile home, duplex, townhouse, garden apartment, and high-rise), structure usage (e.g., various categories of commercial and industrial enterprises, offices, recreational facilities, municipal services, and others), and susceptibility to flooding for the selection of a representative sample. Care was taken to assure that each group in the stratified population was represented in the sample population. On-site inspections were conducted at the sample locations to determine damage potential for various flood depths and to determine historic damage where available. The historic damage data were used to calibrate the potential damage at each structure by providing a known reference point in the depth damage evaluation. The final population sample distribution is listed in "Appendix B, An Example of NED Economic Benefits Analysis."

Generalized damage functions were generated for physical damage, emergency costs, lost income, and residential content damage. These damage functions reflect damages per square foot of structure size, which were then applied to each structure to determine damages at one foot increments of flood stage. For non-residential structures the damage surveys evaluated the depth-damage relationship for physical losses, lost income, and emergency costs based on an assessment of the sites visited. For the residential structures, Flood Insurance Administration (FIA) curves were used to develop the physical damages based on total value of contents and structure. Lost income and emergency costs were based on interview data.

The analysis of lost income benefits was based solely on residential damage surveys, and therefore eliminated double counting business and household lost income. It also avoided transfers of economic activity, which are prevalent when the loss of income to local business firms is measured. Double counting of income loss and emergency costs was avoided by considering the evaluation of emergency costs, such as flood fighting, evacuation, and clean up, net of any income losses identified during the damage surveys. Also, an upper limit of 40 hours of income loss per household was assumed to eliminate survey responses which did not accurately distinguish between income lost due to damage to place of employment or time spent for clean up and repair.

CALCULATING BENEFITS

The steps involved in calculating benefits inc. e determination of damage-frequency relationships (Step Nine), computing expected average annual damages (Step Ten), and estimating total storm damage reduction and erosion prevention benefits (Step Eleven). For Steps Nine and Ten, two alternative computational methodologies may be used depending on the type and complexity of the erosion or storm damage situation. The first is the more traditional analytical technique similar to that used in most flood damage or shoreline change studies. The second is a simulation or Monte Carlo methodology which has been used in many other types of analytical applications with multiple independent random events.[12] The two techniques are compared in Steps Nine and Ten below.

Briefly, the traditional approach relies on the damage-frequency and erosion-frequency relationships to quantify probable damages and benefits in a given year. Damages are based on the probability of occurrence of each damaging event using the hydrologic and economic conditions that prevailed at that time. For example, the probable damages associate with a 100-year event and a 10-year event are, respectively, .01 and .1 times the damages estimated for each of these events in that year. The summation of all probable damages, over the range of events, defines expected damages for that year.

Monte Carlo, or similar simulation models, are (normally) computer-based mathematical replications of the way the real world reacts to a series of unrelated random events and situations. Unlike the standard analytical methodology which develops damages and benefits based on probabilistic

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[12] The term "Monte Carlo" is derived from the comparison of results from simulated multiple random events to the many games of chance, such as roulette or craps, popular in the casinos of Monte Carlo, Monaco.

averages, simulation techniques use the randomness associated with the variables (in this case, erosion rates or severity and duration of storms, for example) to generate a number of life cycles (called "games" in simulation terminology).

Each game represents one possible sequence of the model life. Typically, 100 or more games are played through the model (1,000 or 10,000 might be required if rare events could significantly alter the results), and relevant statistics are kept by the program to show the analyst where the greatest variability and associated risk lie within the model. From a typical model, the analyst can expect to obtain average annual damages (and/or benefits) as well as statistics about the likely distribution of the damages (i.e., the risk analysis), and, with most simulation or Monte Carlo packages, graphical displays of the results. Although such long-term trends as land subsidence are difficult to detect and can influence expected damages and benefits, Monte Carlo techniques usually assume no such trends.

Use of the Monte Carlo method has not been widespread in shore protection studies. One recent study which did employ Monte Carlo simulation in damage assessment computations, however, is the West Onslow Beach and New River Inlet, North Carolina (Topsail Beach) Hurricane Protection and Beach Erosion Control Feasibility Report.[13] The section of the feasibility report that explains the methodology for shoreline damage assessment is summarized in this manual as "Appendix D, An Example of the Use of Monte Carlo Analysis."

[13] U.S. Army Engineer District Wilmington, West Onslow Beach and New River Inlet, North Carolina (Topsail Beach) Hurricane Protection and Beach Erosion Control Feasibility Report, (Wilmington, NC: CESAW, 1990).

STEP NINE: CALCULATE DAMAGE-FREQUENCY RELATIONSHIPS

The damage-frequency relationship relates damage associated with a given event to the frequency of that event. The relationship is represented by the probability that could be associated with any level of flood damage (e.g., damages of $5 million for a given location may be exceeded once every 10 years, expressed as an exceedance probability of 0.1). As explained for riverine flood damages in the NED Procedures Manual - Urban Flood Damage, the stage-damage relationship (calculated by the economist) is combined with the stage-frequency curve (calculated by the hydraulic and hydrologic engineer) to yield the damage-frequency relationship.

In the coastal environment, however, flood damages occur as a result of a number of different, yet interrelated, causes. Structures become undermined and fall off into the ocean due to long-term erosion which occurs over a number of years, or during a single event as a result of storm recession. Structures become inundated as a result of storm surge, resulting in damage due to saturation of materials and hydrostatic pressures. Under certain conditions, wind-blown waves often add to these forces and destroy structures. Just as frequency relationships were constructed separately for various levels of long-term erosion, recession, inundation, and wave attack, damage-frequency relationships should also be calculated for each of the applicable damage mechanisms. However, because of the interdependency of these damage mechanisms it is important to avoid double-counting. This can occur when the sum of damages resulting from the individual damaging mechanisms exceeds the total damages actually incurred. The combined damage-frequency relationship should reflect the mechanism yielding the maximum damage or "critical damage" for a given return frequency. There is one damage-frequency relationship for each unique set of beach profiles, which can fluctuate from inundation to storm recession to wave attack for different frequency events. Furthermore, the analysis of cumulative damage for future years can vary as properties are removed from the damageable inventory and long-term erosion increases the landward limit of damage.

TRADITIONAL TECHNIQUE

By applying a frequency interval to each damage range, a weighted average for each of these events can be computed. For storm damage and erosion damage computations, the damage-frequency relationships may need to be computed for every five-year increment in the project life, or more often if changing erosion damage patterns warrant.

The inundation damage procedure is the same as traditional flood damage prevention procedures except the damage curves must be changed each five to ten years as the long-term erosion process adds or removes property from the damageable inventory.

MONTE CARLO TECHNIQUE

For storm damage and erosion damage computations, the damage curves should be computed for every unique erosion-damage and beach profile pattern in the same manner as the traditional approach. This does not imply that damage-frequency relationships must be developed for every foot or five feet of erosion, but rather for the points where there is a major change in the shape or magnitude of the damage relationships, such as when bulkheads are breached, the natural beach is gone, a spit is breached, or other similar major changes in profiles are noted.

The damage relationships are used by the simulation models to calculate damages from randomly generated storms. As many sets of relationships as needed to adequately describe the range of possible conditions should be generated. The model will interpolate between the curves and points on a curve to determine the actual predicted damage for a generated storm and existing beach profile. The significant difference is that a procedure is developed for the computer to select storms in a random sequence and to calculate damages as they occur for each game.

EXAMPLE

In the New Jersey study, frequency relationships were evaluated independently for each of the mechanisms responsible for structural damages: long-term erosion, inundation, recession, and wave action. These evaluations are described in Step Four above, "Establish Frequency Relationships." Likewise, damage-frequency relationships were also developed for each of the damaging mechanisms.

Based on the historical long-term erosion rate of three feet per year, the area exposed to long-term erosion was determined for ten year increments over the 50-year project life. As previously mentioned in Step Four above, no long-term erosion was considered beyond the seawalls and roadways paralleling the beach because these structures would be protected through human intervention. In determining damages, undermined structures were considered a total loss and would not be rebuilt. The value of each structure impacted by long-term erosion was removed from the evaluation when considering storm-induced damages in subsequent years.

Unlike long-term erosion which is assumed to halt at the seawalls and major access roads, storm recession occurs over a short period during the course of a major storm, thereby preventing human interruption and thus may include any structures including those protected by the seawall. In areas protected by the seawall or bulkheads, the recession is temporarily halted until frequencies significant enough to cause wall failure are reached. Once this occurs, recession takes place beyond the protective structure. The frequencies at which the seawall and bulkheads were anticipated to fail for each planning reach are presented in "Appendix B, An Example of NED Economic Benefits Analysis." The potential damage to any structure from storm recession was determined based on the structure replacement value, content value, lost income, and emergency costs as determined from sample interviews. Damage was assumed to begin when the recession distances exceeded the leading edge of the structure as defined by the setback distance with total damage occurring when recession reached the midpoint of the structure. Damage between these two points was determined using linear interpolation.

For inundation damages, generalized damage functions were generated from on-site investigations of the sample population. These functions reflected anticipated damage as a percent of building size for one foot increments of depth related to the structure's main floor. These were integrated with stage-frequency data (developed by CERC) to permit the calculation of damages due to inundation associated with a specific return period. The stage-frequency curve used for determination of ocean-related flood depths included the influence of wave setup.

Flooding could also result from the possibility of severe waves overtopping the protective seawalls and inundating the area landward of the seawall. However, overtopping rates and depths of flooding vary widely, even for storms with similar recurrence intervals due to various storm parameters. The analysis therefore developed depth-frequency curves directly from known historic flood marks, flood marks collected during damage interviews, and frequency data for the Sandy Hook gauge provided by the NOAA Tidal Records Section. The upper limit of the overtopping analysis was the frequency at which the seawall loses its structural integrity; at this point it was assumed there would be direct flooding from the ocean.

For wave attack damages resulting from direct wave impact on structures, the population subject to wave forces was defined. Analysis indicated a wave height of slightly more than three feet was necessary to cause structural failure. (This height was used primarily to depict the potential wave attack population, not to determine structural failure.) The areas subject to breaking waves of this height, or wave zones, were delineated for storms with return periods of 25, 100, and 500 years. Specific structures exposed to wave attack were identified. The actual depth necessary for structural failure was calculated for wood frame, masonry, pile-supported, and pile- and pier-supported structures. This process is described in greater detail in "Appendix B, An Example of NED Economic Benefits Analysis."

To move toward average annual damage calculations, damages for each reach were summarized by frequency-damage over the 50-year life of the project. This procedure was designed to eliminate the potential for double counting. Each one-foot stage of inundation was related to a frequency and that frequency was used to evaluate the potential damage from each damage mechanism. To prevent double counting (the sum of damages resulting from the individual damaging mechanisms will far exceed the actual damage suffered), only the maximum damage to any single structure was reported for a specific frequency. As depicted in Figure D-8 in Appendix B, the critical damage can fluctuate from inundation to storm recession to wave attack for different frequency events. For display purposes, the damage associated with the individual mechanisms are based on a percentage of their summed total corrected to restated critical damage. Furthermore, the analysis of cumulative damage by reach for future years can vary as segments of the population are removed from the data base and long-term erosion increases the landward limit of damage. To account for changing future conditions, the critical damage at each year and frequency was multiplied by the probability that the structure exists and is subject to damage at that frequency event. The probability of existence for each structure was calculated using the maximum probability of total damage from wave attack or storm recession for each year analyzed with straight line interpolation for the intervening years.

To provide a comparison to historic storm surge and damage data, the existing condition critical damage for various frequency events was aggregated into a still water ocean stage versus damage relationship. Although damage is presented in relation to stage to permit a comparison to historic storms, it should be noted that the damage associated with wave attack and recession was evaluated for the various storm frequencies and, thus, stage has merely been used as a surrogate for display purposes. The stage versus damage comparison developed using this methodology for 1985 existing conditions is presented in Table D-9 of Appendix B. Comparison of the predicted damages to the historic damage indicates concurrence with a March 1984 storm. The differences between damages reported for a 1962 storm and those predicted for 1985 appear reasonable, considering the impacts of over 20 years of shoreline erosion, intensive development, increases in real estate value, and seawall degradation.

STEP TEN: CALCULATE EXPECTED ANNUAL DAMAGES

The expected annual damage is the expected value of erosion losses and storm damages in any given year. Calculation of expected annual damages does not mean that this amount of damage will occur in any particular year, but it is rather the actuarial value of the damage risk. Over a long period of time, the average amount of damage will tend to approach that value. Expected annual damages are the most tangible measure of the severity of the existing erosion and/or storm damage problem. If there is long-term erosion, expected annual damages will increase each year.

TRADITIONAL TECHNIQUE

Erosion damage is separated from inundation damage in an attempt to avoid double counting benefits. Losses due to erosion should be calculated for each year. A family of damage curves will be needed. As erosion progresses, damage from a given event will have greater or lesser impact than its predecessor of equal intensity. The reason is that the shoreline has changed due to the prior events and hence the inventory of damageable property and damage susceptibility of the remaining property will have changed. This will result in several damage estimates for each event: damage resulting from the long-term changes in shoreline (long-term erosion), storm-related recession, storm-related inundation, and storm-related wave attack.

Expected annual damages are calculated by computing the area under the storm-related and inundation damage-frequency curves, and adding to that the effect of long-term shoreline changes. This is done mathematically by taking an integral of the function. Integration can be approximated by graphically measuring the area under the damage-frequency curve or by other non-mathematical means. Normally, a function is not computed. Several points which reasonably define the curve are computed, and any other points needed for calculations are approximated by interpolating between those points previously determined. A sample computation of this procedure is provided in the NED Procedures Manual - Urban Flood Damage. Expected values computed for frequencies in Step Nine are weighted by their exceedance probability. In most damage areas, the high frequency events usually account for the major share of the average annual damages.

MONTE CARLO TECHNIQUE

In contrast to the analytical method, this method calculates the expected annual damages by using a very large (usually 100 or more) number of trials or games, which are then averaged to produce the expected annual damages as well as other pertinent statistics.

The analyst first describes the study area in terms of property location, value, damage susceptibility, and beach profile. Storm events, erosion, and/or accretion are described in terms of frequency (how many significant events can happen in any season as well as probabilities for each level of event), and intensity. The model selects a possible event from those described by the modeler, calculates the damage (if any), logs the ending beach profile, and then proceeds to the next time period to repeat the process. As the beach profile changes, the model will calculate damages by interpolating between the appropriate damage curves.

The time period selected can be weeks or months. The modeler must describe how to distinguish between beach build-up seasons and erosion seasons. A significant advantage of this methodology is that, similar to real world conditions, events in one period determine the base condition for the next, and multiple events are possible in a given year. This situation is more realistic than having relatively static beginning conditions in every period or basing the beginning conditions on an average change over time.

EXAMPLE

In the New Jersey study, the critical damage-frequency relationships (described in Step Nine above), including adjustments for probability of structure existence, were used to compute average annual damages at ten year increments for the 50-year project life using the Hydrologic Engineering Center (HEC) computer program "Expected Annual Damages" (EAD). Average annual residential damage for physical, emergency, and lost income damage and increased residential contents damage (resulting from the affluence factor) were calculated for each reach. Total average annual flood damages (including physical, emergency, and lost income damages to structures, damages to seawalls, damages to roads and infrastructure, and public emergency costs) were also determined for all reaches in the study area. These were calculated for existing conditions as well as conditions expected during the project life (1990-2040). The methodology for estimating future conditions accounted for rebuilding of existing structures and future increases in the value of residential contents. Tables summarizing average annual residential damages (Tables D-10 and D-11) and total without project average annual damages (Table D-12) are presented in "Appendix B, An Example of NED Economic Benefits Analysis."

STEP ELEVEN: ESTIMATE STORM DAMAGE REDUCTION AND EROSION PREVENTION BENEFITS

The reduction in expected annual damage and/or long-term erosion damages that may result from implementation of a particular plan are the NED storm damage reduction and/or long-term erosion benefits. The NED benefits are used in plan formulation and evaluation. They are used to identify economically feasible alternatives, to determine the optimum scale of alternative plans, and to identify the NED plan.

The NED storm damage reduction and/or long-term erosion reduction benefit calculation is the difference between expected annual damages determined in Steps One through Ten under the without-plan conditions and the expected annual damages estimated in Steps Seven through Ten under the with-plan conditions. All benefit estimates should be made for existing conditions (those existing at the time of the study), the base year (the first year in which the project is expected to become operational), and future conditions over the period of analysis. This period, usually 50 years, is defined as the time horizon, beginning with the base year, for which project benefits and operation, maintenance, and replacement costs are considered. The discounting procedures described in "Chapter XI, Discounting Procedures" of the <u>NED Procedures Manual - Urban Flood Damage</u> should then be used to derive estimates of average annual equivalent benefits.

EXAMPLE

<u>Storm Damage Reduction Benefits</u>. In the New Jersey study, storm reduction benefits were calculated for each of the 14 economic reaches. Storm reduction benefits from the proposed plans of improvement were estimated by evaluating damages with- and without-project and under existing and future

conditions. The storm reduction benefits derived from the proposed project consisted of preventable average annual damages to buildings, roads, utilities, and other structures; reduced public emergency costs; and reduced maintenance costs.

Benefits were based on damage to existing development. Changes in future floodplain development considered in the analysis were limited to constraints on structure rebuilding and increased residential content damage due to expected increases in homeowners' affluence. Storm reduction benefits were derived from the computation of average annual flood damages resulting from the maximum damage occurring for a specific return period when considering inundation, wave attack, and storm recession. The benefit analysis conducted over the 50-year project life reflected a reduction in structure population due to long-term erosion. Damage to the seawall was based on failure of the seawall due to a combination of recession and storm attack causing displacement of the stone. Once 45 percent of the stone was displaced, the wall was considered to be effectively lost. Because the State of New Jersey already expends $5.41 to $18.98 per linear foot on annual maintenance of the seawall, reduced seawall maintenance costs upon implementation of a with-project alternative were also counted as benefits. Damage to roads and infrastructures was calculated based on storm recession undermining the facility, necessitating replacement and emergency bypassing. Breakdowns of storm damage reduction benefits to buildings, infrastructure facilities, seawalls, and reduced seawall maintenance costs for alternative plans of improvement and various berm widths are presented in Tables D-13 through D-15 in "Appendix B, An Example of NED Economic Benefits Analysis."

project limit, is a severe erosion area subject to washovers and breaching. Construction of the proposed beach fill project would eliminate this erosion and result in a reduction in beach fill maintenance cost to the National Park Service. The reduction in maintenance cost was included as a project benefit.

Other Benefits. Other benefits resulting from the proposed storm damage reduction and erosion control project, such as recreational benefits, were identified in the New Jersey study. Procedures for estimating recreation benefits are outlined in NED Procedures Manual - Recreation, Volumes I and II.

Summary of Benefits. Using the procedures summarized above, benefits associated with alternative berm widths of 50 feet, 100 feet, and 150 feet were evaluated for three plans: pure beach fill, beach fill with authorized groins, and beach fill with updated groins. Analysis indicated that a fill-only plan at a width of 100 feet provided the maximum net benefits. In order to further maximize storm protection at the least cost, the benefits associated with increasing the level of protection above the 10-foot MLW authorized berm height were evaluated. Assessment of berm caps of 0 feet, two feet, and four feet, based on the reduced probability of residual damages occurring, indicated that maximum net benefits are obtained with a two-foot berm cap.

CHAPTER V

DOCUMENTATION

PLANNING REPORTS

As noted in Chapter I, the concepts and procedures described in this manual are primarily used in implementation and other plan formulation and evaluation studies. The results and findings of such studies are usually documented in planning study reports. Basic standards for the organization, format, and content of such reports are established in ER 1105-2-100, Chapter 2, Section II. Flexibility of presentation is provided, however, for studies of varying scope, complexity, and subject matter. The main objectives of the planning reports, as presented in ER 1105-2-100, are to insure adequate presentation of study results and findings, to insure compliance with applicable statutes and policies, and to provide a sound basis for decision-makers on recommended solutions to water resources problems.

TYPES OF REPORTS

Generally, two categories of planning reports may be produced: feasibility or reevaluation reports. Feasibility reports, for which an NED storm damage and long term erosion analysis may be appropriate, include Reconnaissance Phase Reports, Feasibility Phase Reports, Legislative Phase I General Design Memoranda, and Section 903 Reports.[1] Other feasibility reports include reconnaissance, feasibility and detailed project reports

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[1] Section 903 Reports cover the 62 projects authorized for construction in the Water Resources Development Act of 1986 that are subject to Section 903(a) of that Act. The format for these reports and the list of projects to which Section 903 applies are provided in ER 1105-2-100, Appendix D, Section I.

completed under the Continuing Authority Program such as Section 103, Section 111 and Section 14 Reports. Reevaluation reports represent those resulting from preconstruction planning and engineering studies.

FEASIBILITY REPORTS

Each feasibility report documents the logic of the plan formulation process. As such, it needs to be a complete, but concise, decision-making document. On studies of broad scope and complexity, the report may include a concise summary of plan formulation, in which case detailed plan formulation may be contained in an appendix. Additional appendices may be used as necessary when the information represents an integral part of the report but their contents cannot be accommodated in the main report volume. Other technical details should be presented in supporting documentation.[2]

The feasibility report should state the study authority, the study purpose and scope, and briefly discuss prior studies, reports, and existing water projects, if applicable. A plan formulation chapter should summarize the extent of the storm damage and/or erosion problem, including the existing and future without-project conditions, problems, and opportunities that influence the evaluation. The evaluation should also address planning constraints, alternative solutions to the problem, and the rationale for selection of a recommended action or a no-project alternative.

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[2] According to ER 1105-2-100, the following supporting documentation shall be prepared and reproduced separately from the feasibility report and appendices for technical review of feasibility studies: engineering design data that supplement the plan formulation and the plan selection process; detailed economic data and any derivations from that data that support plan formulation, forecasts, or benefits; supplemental environmental material required by the applicable environmental protection statutes; any other specific subject matter of unique or complex nature necessary to support planning; and the project management plan.

A description of the recommended plan should include plan components, including mitigation; design and construction considerations; operation and maintenance considerations; plan accomplishments; and, a summary of economic, environmental, and other social effects. The benefits of the recommended plan, the NED plan (if different from the recommended plan), and any other plan carried through the planning process should be well documented. The benefits of each plan should be displayed in current dollars for existing conditions, and for conditions expected during the base year and in appropriate increments through 50 years beyond the base year (or for the duration of the project's economic life). Benefits for all years beyond the base year should be discounted by the administratively established discount rate.

Other required components of the feasibility report are an implementation plan, including institutional requirements, division of Federal responsibilities and local cooperation requirements, and the views of non-Federal sponsors and other agencies having implementation responsibilities; a summary of coordination, public views, and comments; and, the official report recommendations from the District Engineer. For greater detail on the format and content requirements of each section of the feasibility report, see ER 1105-2-100, Chapter 2.

Final feasibility reports that recommend no Federal action or plan authorization shall be organized generally in the same manner as those recommending Federal action. However, such reports may be abbreviated to the essential information needed to support the recommendation, consistent with the level of study and analysis made in arriving at the findings.

REEVALUATION REPORTS

Preconstruction planning and engineering studies which recommend post-authorization changes by Congress are considered feasibility type reports (see ER 1105-2-100, Chapter 2). They should be organized, to the extent appropriate, in the same manner as feasibility reports. More flexibility is allowed for those reevaluation studies which do not seek Congressional post-authorization approval, in which case they should be organized and detailed at a level commensurate with their findings.

SUPPORTING DOCUMENTATION

Supporting documentation, which is prepared and reproduced separately, augments the feasibility or reevaluation reports with more detailed data and analysis. It is not intended to be read alone, but rather with the main volume of the planning report. Support documentation includes engineering, design, cost, economics, and environmental material. The economics material should contain details of any forecasting analysis and of the derivation of the economic data for plan formulation. It shall also include a detailed explanation of the benefits for each plan included in the report it supplements. Specific elements to be addressed in supporting documentation, when applicable, include predicted erosion rates, structural damages by damage categories, and historic and projected storm conditions. All assumptions should be explicitly documented.

DETAIL AND DISPLAY

DETAIL

The amount of detail required in a report is a variable governed primarily by the objective of full support of the essential analyses and conclusions of the study. Clarity in the report enables reviewers to understand the rationale for the conclusions and recommendations. Since the report requires input from many different technical specialists, extensive coordination is required to insure a consistent and logical presentation. Reconnaissance level design and other technical features need only be adequate to establish general technical feasibility and an adequate, but approximate, sizing and costing of plan features.

DISPLAYS

Visual displays, such as maps, tables, graphs, and photographs, represent a very useful and often essential means of presenting a variety of information that would be too cumbersome or complex to present in textual form. Furthermore, they are indispensable in the presentation of the complex physical and economic relationships described throughout the planning report. For example, maps are necessary to illustrate the study area, existing conditions, and future with- and without-project conditions; tables are necessary for hydrologic and economic data and cost and benefit comparisons; graphs present an effective means of plotting trends in tabular data; and figures are useful in displaying alternative solutions and the logic and decision-making process that led to the study recommendations. Producing graphics is made relatively simple and inexpensive by the present availability of computer-based software.

APPENDICES

APPENDIX A

COASTAL STORM DAMAGE AND BEACH EROSION CONTROL POLICIES AND AUTHORITIES

APPENDIX A

COASTAL STORM DAMAGE AND BEACH EROSION CONTROL POLICIES AND AUTHORITIES

AUTHORITIES

Until 1930, the Federal interest in shoreline erosion problems was limited to the protection of Federal property and improvements for navigation. The following laws summarize the Corps role in shore protection as mandated by Congress.

Public Law 71-520, River and Harbor Act of 1930. This law established the Beach Erosion Board to act as a central agency to assemble data and provide engineering expertise regarding coastal protection. At the request of cities, counties, or states, the board was authorized to study effective means of preventing erosion of coastal and Great Lakes shorelines. The Federal government could share up to half the cost of each study but could not commit construction money unless Federally-owned property was involved.

Public Law 79-526, Flood Control Act of 1946. This Act authorized the Secretary of the Army to undertake emergency bank-protection measures to prevent flood damages to endangered highways, public works, and non-profit public facilities.

Public Law 79-727, 1946. This law authorized the Federal government to assist in the construction, but not the maintenance, of civil works projects to protect publicly-owned shorelines against erosion from waves and currents.

Public Law 84-71, 1955. This law authorized the Corps, in conjunction with other Federal agencies, to assemble data on the behavior and frequency of hurricanes along the U.S. Atlantic and Gulf coasts and to determine means of preventing loss of life and damages to property. This Act does not specify any cost sharing for construction of protective works.

Public Law 84-99, 1955. This legislation authorized the Corps to provide emergency protection to threatened Federally authorized and constructed hurricane and shore protection works, and to repair or restore such works damaged by wind, wave, or water action of other than an ordinary nature.

Public Law 84-826, 1956. This legislation authorized Federal participation in the protection of private property if the action was incidental to the protection of public lands or it would result in public benefits. The law also allowed Federal assistance for periodic beach nourishment on the same basis as new construction, for a period to be specified by the Chief of Engineers, when that alternative was the most suitable and economical remedial measure.

Public Law 85-500, 1958. Three hurricane flood protection projects were authorized under this Act. Local cooperation provisions were mandated: non-Federal interests were required to assume 30 percent of the total first costs, including the value of lands, easements, and rights-of-way, and to operate and maintain the projects.

Public Law 87-874, The River and Harbor Act of 1962. This sweeping legislation significantly expanded the Corps role in shoreline erosion, including authorizing the Secretary of the Army to reimburse local interests for beach erosion work already performed; making the cost of studies a Federal responsibility; increasing the Federal share of construction costs; giving authority to the ASA(CW) for planning and constructing small beach erosion control projects (Section 103 projects) within certain monetary limits without specific Congressional authorization; and introducing the multiple-purpose concept of erosion control, hurricane protection, and related purposes in shoreline studies.

Public Law 88-172, 1963. This law abolished the Beach Erosion Board and created the Coastal Engineering Research Center (CERC) within the Corps of Engineers. The review functions formerly performed by the Beach Erosion Board were transferred to the Board of Engineers for Rivers and Harbors. The Coastal Engineering Research Board was also established as an advisory group to the Chief of Engineers.

Public Law 89-72, The Federal Water Project Recreation Act of 1965. This Act required that planning of water resources projects consider opportunities for outdoor recreation and fish and wildlife enhancement. It specified that the outdoor recreation benefits that can be attributed to a project shall be taken into account in determining the overall benefits of the project. For example, the recreational use of beach fill, groins, or other protective structures shall be considered during plan formulation.

Public Law 89-298, 1965. This legislative action allowed Federal contributions toward periodic beach nourishment.

Public Law 90-483, 1968. Section 111 of this law authorized the Corps to study, plan, and implement structural and non-structural measures for the mitigation of shore damages attributable to Federal navigation works. This authority applies to both public and privately-owned shores along the coastal and Great Lakes shorelines.

Public Law 92-583, The Coastal Zone Management Act of 1972. This Act required all Federal agencies with activities directly affecting the coastal zone, or with development projects within that zone, to assure that those activities or projects are consistent with the approved state program.

Public Law 93-251, 1974. Section 27 of this law raised the cost limits for emergency bank protection projects and extended project purpose to cover construction, repair, restoration, and modification of emergency streambank and shoreline protection works. Section 55 authorized a shoreline and streambank erosion control demonstration program and approved technical and engineering assistance to non-Federal public interests for developing structural and non-structural methods of preventing damages attributable to shore and streambank erosion.

Public Law 94-587, 1976. Provisions of this legislation included authorizing the Corps to place beach-quality sand obtained from construction and maintenance of navigation inlets onto adjacent beaches if: 1) requested by the interested state government, and 2) local interests agreed to pay 100 percent of any increased costs above the cost required for alternative methods of sand disposal (e.g., open water disposal). Section 156 extended Federal participation in periodic beach nourishment up to 15 years from the initiation of construction.

Public Law 97-348, 1982. This law established the policy that coastal barrier islands are to be protected by restricting Federal expenditures which encourage development on those islands. The Act also identified undeveloped coastal barrier islands within which Federal expenditures may not be made.

Public Law 99-662, Water Resources Development Act of 1986. This legislation made several significant changes to cost sharing for shoreline protection projects. Non-Federal local sponsors were required to provide a minimum 35 percent and maximum 50 percent contribution to the cost of construction of shore protection measures. The costs were to be assigned to "appropriate" project purposes (flood control, non-structural flood control, and hurricane and storm damage reduction, recreation, and others), with cost sharing in the same percentage as the purposes to which the costs were assigned. Two exceptions were allowed. In the case of costs assigned to the prevention of losses of private lands (where the use of such lands is limited to private interests) the costs were to be non-Federal, while in the case of Federally-owned shores, all costs were to be Federal. One hundred percent of the costs of operation and maintenance of shore protection measures would be borne by non-Federal interests. Non-Federal interests would also provide all lands, easements, rights-of-way, relocations, and disposal areas (LERRD); these costs could be credited to the non-Federal share of the project cost.

The Act also extended the period of beach nourishment from 15 to 50 years. It authorized, for environmental or economic reasons, the use of non-domestic sources of fill material for beach erosion and nourishment projects if such material was not available from domestic sources. Section 933 of the Act authorized increasing to 50 percent the Federal share of the additional costs, above that required for alternative methods of disposal, for placement of material dredged during the construction and maintenance of navigation inlets onto adjacent beaches. Implementation of non-structural measures to prevent or mitigate shore damage attributable to Federal navigation projects was also authorized, with the costs of prevention or mitigation measures to be shared in the same proportion as the cost sharing provisions of the navigation project. Finally, Congressional authorization was required for all projects costing in excess of $2 million.

Public Law 100-676, Water Resources Development Act of 1988. Section 14 of this Act requires non-Federal interests to agree to participate in and comply with applicable Federal flood plain management and flood insurance programs before construction of any hurricane and storm damage reduction project.

SUMMARY OF POLICIES

Current Corps policy on shore protection is stipulated in EP 1165-2-1, Digest of Water Resources Policies and Authorities. Significant excerpts from the pamphlet are provided below.

EROSION CONTROL

Under existing shore protection laws Congress has authorized Federal participation in the cost of measures to prevent or control shore erosion, and reduce damage to upland developments caused by wind- and tidal-generated waves and currents along the nation's coasts and shores, the Great Lakes, and their associated lakes, estuaries, and bays. The shore erosion must be caused by wind and tidal generated waves; therefore, the authorization does not cover erosion at upstream locations caused by stream flows except for those actions defined as emergency measures to protect highways, public works, and non-profit public facilities. Federal participation is limited to restoration of the historic shoreline. Any extension of the shoreline beyond the historic shoreline will be at the expense of non-Federal interests.

Costs for measures for the prevention of land losses are assigned to either Federal or non-Federal interests depending upon shore ownership. Costs assigned to protection of Federally-owned lands and shores are 100 percent Federal. The cost for shore protection for lands controlled by another Federal agency (for example, military installations and National Park Service lands) will be borne by that agency. The Corps will accomplish such work on a reimbursable basis upon request. One exception is a case in which the lands in question involve only a minor, but integral, part of the overall protection frontage. In such cases, protection will be included to assure a complete overall project.

The costs to protect undeveloped private lands or developed private lands where the use of the shore is limited to private interests are allocated wholly to non-Federal interests. Costs assigned to prevention of damage to privately-owned lands that meet criteria for public use are 35 percent non-Federal. The costs are split 50/50 between Federal and non-Federal interests for those non-Federal public lands and shores used for parks and recreation or fish and wildlife purposes. Where a shore protection project encompasses more than one category of ownership and use, the non-Federal share of project costs will ordinarily be expressed as a composite percentage of total project costs derived by weighting the appropriate cost sharing percentages for the given categories by the linear feet of project shoreline within those categories. This is where the initial construction costs are reasonably uniform for the entire project; where they are not, the project shoreline will be first subdivided into segments that are relatively uniform in costs and a weighted percentage calculated from the total costs, from all segments, assigned to each category.[1]

No Federal contribution toward maintenance of a shore protection project is authorized. However, PL 84-826 allows Federal participation in periodic beach nourishment when it is found to comprise a more suitable and economical remedial measure for shore protection than retaining structures such as groins. Periodic nourishment is to be considered "construction" for funding and cost sharing purposes, and is limited to the period specified in the authorizing legislation. The Water Resources Development Act of 1986 (WRDA 86) allows extension of the authorized period to 50 years from the date of initiation of construction, if appropriate.

[1] A practical example of the cost sharing computations required for a hurricane and storm damage reduction project having mixed Federal, non-Federal, and private ownership is illustrated in ER 1165-2-130, Appendix C.

HURRICANE AND STORM DAMAGE REDUCTION

Before enactment of the WRDA 86, Federal projects to protect against hurricane and abnormal tide flooding were established case-by-case based on specific Congressional authorizations. Although such project works were usually similar to beach erosion control works, hurricane protection projects were viewed as being more like flood control projects. The 1986 Act, however, authorized Federal participation in hurricane and storm damage reduction projects and established a cost sharing formula requiring 35 percent of the construction costs to be borne by the non-Federal partner. Other than the magnitude of storms considered, there are now no real distinctions between shore protection measures for hurricane, storm-, or tidal-induced flooding and erosion.

RECREATION

Shore protection projects are to be formulated first to provide for hurricane and storm damage reduction. Although shore protection projects are usually conducive to beach and shoreline recreation activities, any enhancement of recreation associated with the project is considered incidental. Provided that the sum of storm damage reduction benefits and incidentally-generated recreation benefits (which are limited to an amount equal to or less than the storm damage reduction benefits) is sufficient for economic justification, the Corps would propose undertaking the project as a storm damage reduction project. All recreation benefits would be included in computation of the overall benefit-cost ratio. Additional beach fill beyond that needed to achieve the storm damage reduction purpose to satisfy

LAKE FLOOD PROTECTION

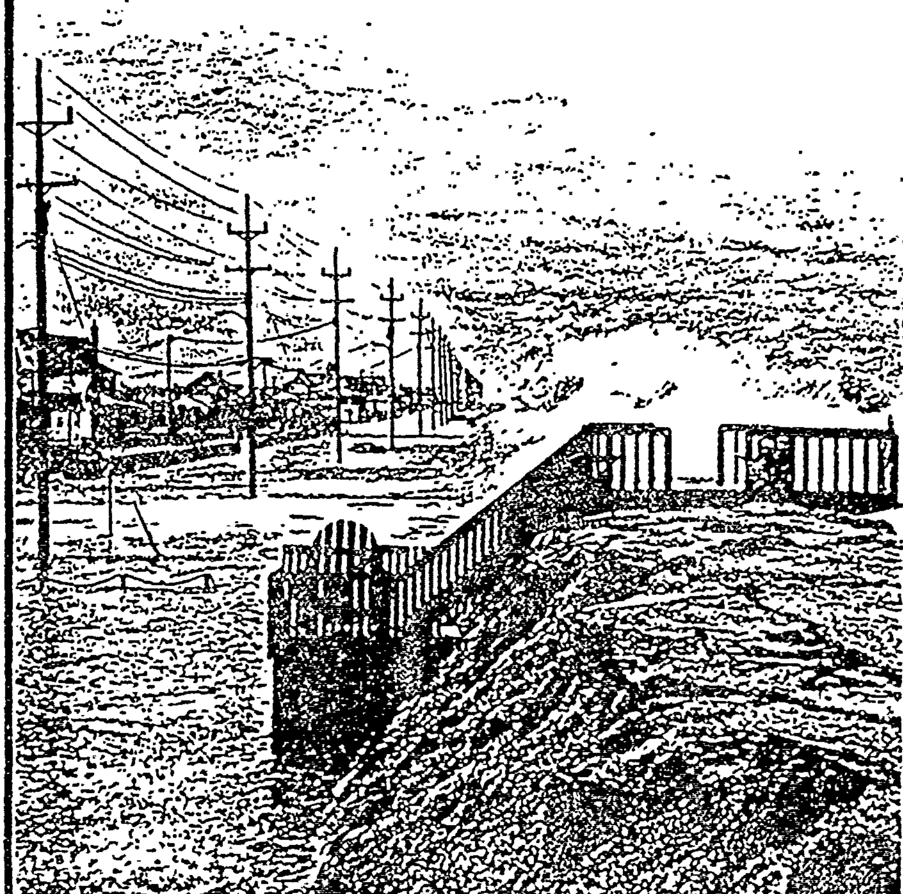
The extent of Federal interest in projects to protect against lake flooding (e.g., the Great Lakes) is not explicitly defined by legislation. Congressional authorizations for Corps construction of such projects on a case-by-case basis are helping to establish the Federal interest. The WRDA of 1986 authorized the Corps to undertake a cooperative study of shoreline protection and beach erosion control policy and related projects for the Great Lakes. This study will include recommendations for new or additional criteria for Federal participation in shoreline protection projects along the Great Lakes and connecting channels.

APPENDIX B

AN EXAMPLE OF NED ECONOMIC BENEFITS ANALYSIS

ATLANTIC COAST OF NEW JERSEY
SANDY HOOK TO BARNEGAT INLET
BEACH EROSION CONTROL PROJECT
SECTION I - SEA BRIGHT TO
OCEAN TOWNSHIP, NEW JERSEY

GENERAL DESIGN MEMORANDUM



TECHNICAL
APPENDICES

VOLUME II

January 1989

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[1]Excerpted portions included in this NED Procedures Manual are highlighted. Page numbers refer to the pages within this manual.

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GLOSSARY OF COASTAL TERMS

Accretion: Buildup of land or beach area

Berm: Nearly horizontal part of the Beach

Erosion: Erosion and Long Term Erosion refer to the wearing away of land as measured over extended periods of time. Included are the impacts of sea level rise, deficits in sediment transport and the net impacts of storms, including post-storm accretion.

Inundation: Flooding from storm surges in the ocean and Shrewsbury River including wave setup and flooding from waves overtopping the seawall. (A still water effect since it does not laterally displace structures.)

Recession: The reduction of land during a storm due to the transport of sediment. Includes the maximum area impacted by a storm before post-storm accretion. Net loss is accounted for in long-term erosion.

Runup: The rush of water up a structure or beach after the breaking of a wave.

Storm Surge: A rise in water level due to wind stress on the water surface and atmospheric pressure reduction.

Variability: The variation in recession distance along the coast.

Wave Attack: The structural failure of buildings due to the force exerted by breaking waves or wave runup.

Wave Setup: Superelevation of the water surface over normal surge elevation due to onshore mass transport of the water by wave action alone.

APPENDIX D - BENEFITS

INTRODUCTION

D1. Purpose. This Appendix evaluates the existing and future benefits which would accrue to the study area in light of current conditions and criteria. Investigations made and methodology used to evaluate the monetary value of existing and future benefits estimated to accrue as a result of implementing the proposed project are presented.

D2. Benefits were calculated for alternative plans which meet the planning objectives and constraints as described in the main text. This preliminary screening identified three plans involving the placement of beach fill as addressing the region's problems and needs within reasonable technical and cost constraints. These plans are:

1. Placement of beach fill
2. Placement of beach fill with construction of the authorized groins, and
3. Placement of beach fill with updated groins

D3. Benefit Types. Benefits to be derived from the plan of improvement are:

1. Reduction of damage associated with long-term and storm surge induced erosion including damage to roads, utilities and structures
2. Reduction of wave attack to structures
3. Reduction in inundation of structures
4. Reduced maintenance costs for seawalls
5. Reduced public emergency costs
6. Reduced maintenance costs at Sandy Hook
7. Reduction in lost land
8. Intensification
9. Increased recreation value

D4. The first five benefit categories are storm reduction benefits. Figures D-1 and D-2 provide schematic profiles displaying the location of without project damages and benefits claimed.

D5. Conditions. Estimates of monetary benefits were based on June 1988 price levels, a 50-year project life and reflect the economic condition of the flood plain as of July 1985. The base year for the proposed project is 1990. All calculations are displayed utilizing the fiscal year 1988 discount rate of 8-5/8%. Benefits at the fiscal year 1989 discount rate of 8-7/8% are presented under Economics of the Recommended Plan.

D6. Exclusions. Reduced Flood Insurance Administration costs have not been considered since the project will not provide a total 100-year level of protection, which is the criterion for determining the need for Flood Insurance. Benefits due to reduced traffic delays have also not been included since even with the project in place, low lying porti of Route 36 which is the principal north-south corridor will be sub .c to flooding from the Shrewsbury River.

DESCRIPTION OF THE STUDY AREA

D7. Location. The Sea Bright to Ocean Township study area, shown on Figure D-3, is located approximately 30 miles southeast of Newark, New Jersey, 40 miles east of Trenton, New Jersey and 65 miles northeast of Atlantic City, New Jersey. The study includes the most northerly 12 miles of the authorized project extending from just north of the Route 36 Bridge in Sea Bright southward to the outlet of Deal Lake. The area encompassed by the study includes the communities of Sea Bright, Monmouth Beach, Long Branch, Deal, Allenhurst and Loch Arbour (formerly a part of Ocean Township). The entire study area is within Monmouth County. Immediately to the north of the project limit is the Sandy Hook unit of the Gateway National Recreation Area and immediately to the south is the City of Asbury Park.

D8. Monmouth County is accessible to major population centers through a network of modern highways. The Garden State Parkway runs northward to New York State and southward to Cape May. Route 18 extends westward to New Brunswick in Middlesex County and Route 195 extends westward to the state capitol in Trenton. Direct access from these major corridors to the ocean front is provided by various state and county roads including Route 36, Route 520 and Route 71. Communities from Long Branch southward are also serviced by the shore line of New Jersey Transit which provides passenger rail access to Newark and New York City.

D9. Natural Forces. The climate in the study area is temperate with warm summers and moderate winters. The annual temperature averages approximately 53 degrees Fahrenheit (°F). On average January is the coolest month with a mean temperature of 32°F and July is the warmest month. The average annual precipitation is about 45 inches with August being the wettest month. Snowfall averages almost 25 inches annually.

D10. The mean tidal range in the project area is 4.8 feet while the spring tidal range is 5.3 feet. Waves are predominately from the southeast with an average height of 1.5 feet. These conditions may vary extremely from normal due to both extratropical northeasters and hurricanes.

D11. Natural Resources. The northern portion of the study area from Sandy Hook south to Monmouth Beach, includes the communities of Sea Bright and the northern portion of Monmouth Beach and is comprised of a barrier spit complex where the shoreline is on a narrow strip of unconsolidated sand which forms a peninsula between the ocean and bay environments. The southern portion of the study area including the southern part of Monmouth Beach, Long Branch, Deal, Allenhurst and Loch Arbour is located on the Coastal Plain and is characterized by headlands meeting the sea.

D12. The entire coastal zone within the study area is heavily developed, primarily for residential and commercial uses. Many of the residences are former summer homes converted for year round use. In areas with substantial existing beach, such as near 7 Presidents Park in North Long Branch, the recent high rise and townhouse development indicates the desirability of protected beach front property. The peninsula area is fronted by a seawall up to 20 feet in height or higher which aids in the prevention of flooding and wave attack. Traversing the peninsula area is State Road 36 which is the only major north south roadway linking the Highlands and Long Branch and provides the only access to Sea Bright and Sandy Hook.

D13. Prior to the construction of the Long Branch and Seashore Railroad, storms had repeatedly breached the barrier spit resulting in the formation of inlets that effectively joined the Shrewsbury River with the Atlantic Ocean. When first constructed in 1865 the railroad was often subject to damage due to storm induced conditions. This resulted in the first extensive erosion control measures undertaken for the area. The railroad has since been abandoned and the tracks removed, however, the seawall remains. At present the peninsula varies in width from 250 to 1500 feet at an elevation ranging from 5-10 feet above the National Geodetic Vertical Datum (NGVD).

D14. In the southern half of the study area, the existing bluffs once extended considerably seaward and have since been eroded back to their present position as a result of the combined effects of wind and waves. The bluffs immediately adjoining the ocean range in elevation from 10 to 25 NGVD, with the higher elevations located to the northern portion of the area.

D15. The severely eroded condition of project area beaches has limited their attractiveness as a recreation and development resource. Even though the average berm width is only 24 feet, over 85,000 individuals utilized the public beaches in 1985.

D16. Human Resources. Population in Monmouth County increased by 168,000 persons between 1960 and 1980. While this presents a 50% increase in 20 years, the recent trend towards smaller households has reduced the growth rate from 38% between 1960 and 1970 to 9% between 1970 and 1980. Population estimates for 1985 indicate a 5.5% increase since 1980, the fifth largest percentage increase in the state. The net population increase of 27,700 persons is the third largest in the state, ranking behind the bordering counties of Ocean and Middlesex. In general the greatest population growth has occurred in more rural western portions of the county with several exceptions including the communities of Sea Bright and Monmouth Beach. Projections of future population by the New Jersey Department of Labor, presented in Table D-1, indicate that Monmouth County will continue to grow somewhat faster than the state average and that growth in the bordering counties of Middlesex and Ocean will continue to exceed the Monmouth County rate.

D17. Population trends in the project area communities have varied widely with increasing population in the northern communities and decreasing population to the south. The total 1980 population for the six communities was 38,182 persons, a decrease of 2% from the 1970 census. Since the City of Long Branch extends farther inland than the other communities this figure does not truly represent population trends along the coastline. Excluding Long Branch the remaining five communities had a net population increase of 16%.

D18. The project area communities are generally more wealthy than the county average. With the exception of Long Branch the communities had a per capita income of between 124% and 196% of the county average. In four of the six communities growth in per capita income between 1969 and 1979 exceeded the county growth rate of 21%, but due to the large population and low growth rate in Long Branch the average increase in per capita income for all six communities is only 14.4%.

D19. Table D-2 provides a summary of population and per capita income data for Monmouth County and the individual communities in the project area.

D20. Development and Economy. The majority of land in the immediate project area contains residential development with commercial development concentrated in the centers of Sea Bright and Long Branch. Recent development in the project area mirrors the regional trend towards townhouse and condominium units, particularly in Sea Bright, Monmouth Beach and Long Branch. The co.stal area has also seen a trend towards more year round housing, both in percentage of units and in numbers. Residential development trends of communities in the study area are presented in Table D-3. Between 1970 and 1980 the number of seasonal housing units declined 21% while the total number of housing units increased by over 15%.

D21. Sea Bright, the northernmost community within the project area, is predominately residential except for the central business district adjacent to the public beach and scattered hotels, beach clubs and restaurants along Ocean Avenue.

D22. Monmouth Beach, just south of Sea Bright, is also predominately residential with occasional beach clubs and restaurants along Ocean Avenue and several marinas along the Shrewsbury River. The residential development in Monmouth Beach includes a significant number of high rise apartment buildings and townhouse complexes.

D23. The City of Long Branch includes several communities with distinct development patterns. The northern portion of the city, known as North Long Branch, is mostly residential with an increasing concentration of townhouses and condominiums. The ocean front in this area is dominated by 7 Presidents Park, a county-run public beach. Non-residential development in this area includes several restaurants and a National Guard Armory.

TABLE D-1

PROJECTIONS OF FUTURE POPULATION

MONMOUTH AND SURROUNDING COUNTIES

	Census April 1, 1970	Census April 1, 1980	Provisional Estimate* July 1, 1985	Projections to July 1 1990	1995	2000	2005	2010	2015	2020
NEW JERSEY	7,171,112	7,365,011	7,562,000	7,842,300	8,154,000	8,450,300	8,685,200	8,895,700	9,042,900	9,179,200
Middlesex County	583,813	595,893	626,700	653,600	690,600	726,600	760,800	791,800	819,900	846,000
Monmouth County	461,849	503,173	530,900	547,200	568,100	591,600	611,300	630,600	648,400	664,600
Ocean County	208,470	346,038	380,000	413,300	449,600	484,400	515,800	545,900	572,300	594,300

*The 1985 provisional state estimate is rounded to the nearest thousand persons. The 1985 county estimates and all projections are rounded to the nearest hundred persons.

SOURCE: New Jersey Department of Labor, Division of Planning and Research, Office of Demographic and Economic Analysis, October 1986.

TABLE D-2

SUMMARY OF POPULATION AND PER CAPITA INCOME TRENDS

Town	Total Population 1970	1980	% Change	Per Capita Income (1979 Dollars) 1969	1979	% Change
Sea Bright	1,339	1,812	+35.3	7,772	11,840	+52.3
Monmouth Beach	2,042	3,318	+62.5	8,976	13,471	+50.1
Long Branch	31,774	29,819	-6.2	6,727	6,970	+3.6
Deal	2,401	1,952	-18.7	13,047	16,694	+28.0
Allenhurst	1,012	912	-9.9	7,943	10,649	+34.1
Loch Arbour	395	369	-6.6	9,431	10,568	+12.1
Total/Average Project Area	38,963	38,182	-2.0	7,329	8,386	+14.4
Monmouth County	461,849	503,173	+8.9	7,054	8,539	+21.0

Town	No. of Households 1970	1980	% Change	Persons Per Household 1970	1980	% Change
Sea Bright	555	941	+69.5	2.41	1.92	-20.3
Monmouth Beach	685	1,336	+65.8	2.98	2.47	-17.1
Long Branch	10,824	11,672	+7.8	2.86	2.51	-12.2
Deal	754	650	-13.8	3.18	3.00	-5.7
Allenhurst	309	328	+6.1	3.28	2.78	-15.2
Loch Arbour	119	125	+5.0	3.32	2.95	-11.1
Total/Average Project Area	13,246	15,052	+13.6	2.88	2.50	-13.2
Monmouth County	135,230	170,130	+25.8	3.32	2.90	-12.7

TABLE D-3

STUDY AREA HOUSING TRENDS

Community	1970 Housing Units			1980 Housing Units					
	Year Round	Seasonal	Total	Year Round	% Change	Seasonal	% Change	Total	% Change
Sea Bright	674	124	798	1,009	+49.7%	127	+2.4%	1,136	+42.3%
Monmouth Beach	735	114	849	1,557	+111.8%	52	-54.4%	1,609	+89.5%
Long Branch	11,561	402	11,963	12,906	+11.6%	265	-34.1%	13,171	+10.1%
Deal	767	185	952	767	0%	166	-10.3%	933	-2.0%
Allenhurst	383	19	402	360	-6.0%	53	+78.9%	413	+2.7%
Loch Arbour	131	29	160	141	+7.6%	26	-10.3%	167	+4.4%
Total in Study Area	14,251	873	15,124	16,740	+17.5%	689	-21.1%	17,429	+15.2%
Total County	143,021	7,448	150,469	180,428	+26.2%	5,342	-28.3%	185,770	+23.5%

Source: Monmouth County Census Trends 1970-1980

D24. The center of Long Branch, once a leading resort for the wealthy, endured a long period of economic stagnation as improvements in regional transportation provided access to more southerly resorts. The current redevelopment of Long Branch is concentrated on a major hotel and convention center located adjacent to existing recreation facilities and the now vacant pier. The Long Branch pier, ravaged by fire in the spring of 1987, is likely to be redeveloped as a recreation or shopping area and should provide further stimulus to the revitalization of the adjoining commercial areas. Business activity is concentrated along the boardwalk and includes numerous arcades, restaurants and food stands.

D25. South of the Long Branch business district is the area known as West End. This area is characterized by townhouse and condominium development and a healthy retail district near the West End public beach.

D26. The area between Lake Takanassee and the Deal border is known as the Elberon section of Long Branch. This area of the coast is primarily developed with large single family residences interspersed with beach clubs.

D27. South of the City of Long Branch lies Deal Borough, a particularly stable and wealthy residential community. Notable non-residential development includes the Phillips Avenue Pavilion and the Deal Casino.

D28. The Borough of Allenhurst and Village of Loch Arbour are small communities at the southern limit of the project and are characterized by moderately expensive single family residences.

D29. The economy of Monmouth County has undergone strong growth in recent years with much of the development concentrated along major transportation routes. The majority of recent non-residential development has been for office and research facilities, probably due to the availability of comparatively inexpensive land with good access to the Northern New Jersey-New York City markets.

D30. Value of Improvements. Based on a structure inventory and damage survey, buildings and ancillary structures within the immediate project area are valued at over 500 million dollars and contain over 125 million dollars in contents. Table D-3A provides a summary of structure values. Roads and utilities adjacent to the shoreline are valued at over 14 million dollars. The 1986 Monmouth County tax assessment of value for towns in the project area is 1 billion, 280 million dollars.

DESCRIPTION OF THE PROBLEM

D31. The Erosion Problem. Erosion has seriously reduced the width of most beaches in the study area with consequent exposure of the shore to storm damage. Throughout the period of record the 12-mile study area has experienced continuous beach erosion resulting in a majority of the shorefront property in Sea Bright and Monmouth Beach having no dry beach. With the exception of sand fillets south of groins, very little beach width remains in the southern section of the study area.

TABLE D-3A
SEABRIGHT TO OCEAN TOWNSHIP
STRUCTURE VALUE TABULATION BY REACH
JUNE 1988 PRICE LEVEL
DOLLARS (IN TOUSANDS)

REACH	RESIDENTIAL STRUCTURES VALUE *	#	NON-RESIDENTIAL STRUCTURES VALUE	#	TOTALS BY REACH VALUE	#
1	$23,318	228	$10,205	145	$33,523	373
2	$22,155	176	$27,284	115	$49,439	291
3	$27,606	91	$17,613	57	$45,219	148
4	$47,418	96	$3,421	33	$50,839	129
5	$55,307	128	$6,586	39	$61,893	167
6A	$8,368	72	$9,939	53	$18,306	125
6B	$12,298	147	$18,460	95	$30,758	242
7	$55,360	73	$9,838	35	$65,198	108
8A	$70,381	52	$22,615	40	$92,996	92
8B	$16,727	86	$18,873	46	$35,601	132
9A	$20,108	69	$6,763	57	$26,872	126
9B	$5,267	19	$63	9	$5,330	28
10	$12,796	44	$1,242	21	$14,038	65
11	$15,194	69	$1,005	15	$16,198	84
TOTALS	$392,303	1350	$153,907	760	$546,210	2110

* Residential Values include: single and multifamily residences, garden apartment buildings, townhouse buildings and highrise apartments.

(Rev. March 1990)

D32. Virtually all of the protective coastal structures, including the massive seawalls and 103 groins, have deteriorated since their construction. The structures are becoming increasingly susceptible to storm wave damage as the beach continues to erode. The recreational beach areas continue to shrink as the State recreational need increases.

D33. The existence of sand fillets at the south sides of groins and the elongation of the northern end of Sandy Hook indicate a net northward movement of littoral drift in the study area. Recent erosion information indicates an increasing rate of loss of beach material northward along the study area. The actual annual net littoral drift rate was estimated to be approximately 155,000 cubic yards toward the north at Ocean Township and 493,000 cubic yards at Sea Bright. Since the beach itself is the only source of material, it is inevitable that the beach has and will continue to erode.

D34. The Storm Problem. The project area has a recorded history of damage and economic loss due to coastal storms dating back to 1889. Significant storms were recorded in 1896, 1913, 1914, 1938, 1944, 1950, 1953, 1960, 1962, 1972, 1976, 1984 and 1985. Storms such as these cause widespread damage throughout the study area from a combination of wave attack, storm recession and inundation. In addition, localized flooding due to unusually high tides cause limited damage and road closings up to 8 or 10 times a year.

D35. Documented damage reports, available for the March 1962 and March 1984 Storms, demonstrate the destructive potential of storms in the project area. Both of those extratropical storms caused major damage and resulted in disaster area declarations. Updating to June 1988, damages are estimated at 26.5 million dollars for the 1962 storm and 16.7 million dollars for the 1984 storm. Dollar figures are updated from post storm reports which reflect damages occurring at that time. Updating does not take into account the impacts of increased development, regional trends in real estate value, or continued erosion and undermining of the protective structures.

D36. Due to continuing shoreline erosion with attendant degradation of protective structures and increased coastal development, the potential economic losses and threat to human life and safety continue to rise with each passing year.

EXTENT AND SCOPE OF ALTERNATIVES

D37. The authorized project provides for Federal participation in the restoration and protection of the shore from Sea Bright to Ocean Township by artificial placement of sand to widen the beach to a minimum width of 100 feet at an elevation of 10 feet above mean low water and by the construction of 23 new groins and the extension of 14 existing groins in the Sea Bright to Ocean Township section. Based on preliminary screening as shown in Table D3A, a total of three berm widths were evaluated: 50 feet, 100 feet and 150 feet for a beach fill only plan, as well as for an updated groin plan and the authorized groin plan. After identifying the plan and berm width providing maximum net benefits the impacts of berm caps of 0 feet, 2 feet and 4 feet above the authorized berm were evaluated to ensure the maximum storm protection benefits.

TABLE D-3B
INITIAL SCREENING OF
STORM DAMAGE ALTERNATIVES
SEA BRIGHT TO OCEAN TOWNSHIP, N.J.

ALTERNATE PLAN	TECHNICAL FEASIBILITY	SOCIAL IMPACT	ANNUAL COST ($1,000)	FURTHER CONSIDERATION	REMARKS
A. No Actior	Yes	Eventual loss of beach	$0	No	No protection provided, erosion problems will continue.
B. Buy-Out Plan	Yes	Socially Unacceptable	$78,320	No	Extremely expensive, non-structural alternative.
C. Beach Restoration	Yes	Provide usable beach area and storm protection	$17,678	Yes	Considered for future development.
D. Authorized Groins	Yes	Reduced aesthetics. Increased impact at Sandy Hook.	$791	No	No protection provided, fillets provide minimal beach area. Erosion rate reduced.
E. Groins with Beach Restoration	Yes	Reduced aesthetics. Usable beach.	$18,272	Yes	Considered for future development.
F. Seawalls	Yes	Eventual loss of dry beach	$4,435	No	Continued erosion. Loss of recreational beach.
G. Seawalls with Beach Restoration	Yes	Usable beach. Excellent storm protection.	$21,811	No	Too costly.
H. Revetments	Yes	Eventual loss of beach.	$2,902	No	Continued erosion. Loss of recreational beach.

TABLE D-3B (continued)
INITIAL SCREENING OF
STORM DAMAGE ALTERNATIVES
SEA BRIGHT TO OCEAN TOWNSHIP, N.J.

ALTERNATE PLAN	TECHNICAL FEASIBILITY	SOCIAL IMPACT	ANNUAL COST ($1,000)	FURTHER CONSIDERATION	REMARKS
I. Revetments with Beach Restoration	Yes	Provide usable beach area.	$20,982	No	Too costly.
J. Breakwaters	Marginal	Could pose hazard to boaters.	$7,051	No	Minimal storm protection. Severe downdrift erosion.
K. Breakwaters with Beach Restoration	Marginal	Could pose hazard to boaters.	$23,104	No	Too costly. Marginal feasibility.
L. Perch with Beach Restoration	No	Could pose hazard to boaters.	$19,128	No	Not proven to be effective in ocean environment.

STORM DAMAGE

GENERAL

D38. Conditions. The base year for this economic evaluation is 1990. Since the project life is determined to be 50 years, damages were evaluated for the period 1990-2040 using the fiscal year 1988 interest rate of 8-5/8%. For the year 1985, the year for conditions of the study, a breakdown of damage causes is given in Table D-4. Due to the impact of long-term erosion, total damages vary in future years.

D39. Methodology and assumptions. Benefits from the proposed plans of improvement were estimated by comparing damages with and without the proposed project under existing development conditions. In calculating storm reduction benefits, the type of damage causing the maximum impact was identified at each structure for various storm frequencies. To prevent double counting only this maximum damage was included in the calculation of project benefits. Structures destroyed by long-term erosion were removed from the analysis for future years as it was determined they would not be reconstructed because the site was destroyed. For buildings destroyed by storm recession and/or wave attack, existing development patterns indicate that they would be rebuilt unless subject to wave or storm recession damage from storms with a recurrence interval of 1.5 years or less. In areas protected by the seawall, total rebuilding was considered based on perception of protection provided by the seawall. This was based on a review of existing development which presently reflects this proximity to the shore line.

TABLE D-4
BREAKDOWN OF WITHOUT PROJECT DAMAGES
EXISTING CONDITIONS

Effective Flood Stage* (NGVD)	% of Total Damage		
	Storm Recession	Wave Attack	Inundation
8	14	24	62
10	14	30	56
12	9	51	40
14	8	55	37

*Includes Wave Setup Where Applicable

For residential structures the replaced building was considered to be elevated to meet the National Flood Insurance Criteria, however, due to the impracticality of elevating the majority of low-lying commercial establishments (the center of Sea Bright) non-residential structures were considered to be replaced in kind. A review of the Flood Insurance maps for the area showed the 100-year design criteria to approximate the 25-year ocean stage determined by this investigation. Thus a 25-year level of protection was the criteria set for evaluating future losses.

Conversations with FEMA representatives indicated that this assumption is further substantiated because the structures do not lie within the high hazard 'V' zone as defined by FEMA and therefore are not required to be designed to sustain wave impacts. In addition, FIA criteria does not take into account storm recession which would further weaken foundation designs tending to lower the actual level of protection more in accord with the 25-year event. Figure D-4 provides a generalized flow chart of the analysis methodology.

D40. Inventory. To accomplish the benefit analysis the initial consideration was the development of a structural data base to assist in predicting storm damages.

D41. Survey methodology. The structural data base was generated through a survey of the structures adjacent to the project area and includes buildings, utilities, bulkheads, seawalls and roadways. The building data was obtained through a windshield survey of the area using topographic mapping with a scale of 1" = 200' with a 2-foot contour interval. Table D-5 indicates the type of physical characteristics obtained for the building inventory. For utilities, bulkheads, seawalls, etc., the inventory data was taken from the topographic mapping and is primarily targeted toward physical characteristics such as size and length in order to assign a replacement value. A key element in both aspects of the structure inventory is the front of structure setback and mid point setback data, used to locate each structural element relative to the water line. This was the primary mechanism used to trigger damage due to long-term erosion, storm recession and wave runup.

D42. The data collected was used to categorize the structure population into groups having common physical features. Data pertaining to structure usage, size and stories assisted in the stratification of the building population. For each building, data was also gathered pertaining to its damage potential including its main floor elevation lowest opening, construction material and proximity to the water. Replacement value was calculated for the residential and commercial structures using standard estimating guides in conjunction with size data.

D43. For non-building structures, such as roads, boardwalks, utility lines, seawalls, etc., a similar inventory was conducted by extracting data from the mapping. Once collected, the information was encoded for use on a computerized data base giving an overall picture of the flood plain population.

D44. Damage Survey. Following the completion of the inventory, a sample population of buildings was selected for on-site inspection to determine damage potential. Findings from the on-site interviews conducted for the sample population were then used to formulate generalized depth-damage relationships to be applied to the overall population. A total of two hundred site investigations were to be conducted. The inventory population was stratified according to physical characteristics, structure usage and susceptibility to flooding for the selection of a representative sample. Care was taken to assure that each group in the stratified population was represented in the

TABLE D-5

PHYSICAL CHARACTERISTICS OBTAINED
FOR BUILDING INVENTORY

1) Type - Residential, Commercial, etc.
2) Town
3) Zone
4) Location ID
5) Map Number
6) Structure ID
7) Set Back Distance
8) Mid Point Distance
9) Structure Size
10) Stories
11) Usage
12) Basement/Foundation
13) Ground Elevation
14) Main Floor Height
15) Low Opening
16) Number of Garage Openings
17) Exterior Material
18) Units on First Floor
19) Total Units
20) Number of Buildings
21) Quality
22) Owner Operator

sample population. On site inspections were conducted at the sample locations to determine damage potential for various flood depths and to determine historic damage where available. The historic damage data was used to calibrate the potential damage at each structure by providing a known reference point in the depth damage evaluation. The final population sample distribution is shown in Table D-6.

D45. Reach Selection. To assist in determining those areas most susceptible to flooding and thus the primary areas for sample selection, economic reaches were defined. The initial breakdown was by municipal boundary followed by physical characteristics. The primary physical split was between the peninsula section in the north and the mainland to the south. Within each section a further breakdown into reaches is indicated by coastal dynamics and man-made structures such as groins, seawalls, etc. This procedure yielded the reaches shown in Figures D-5 and D-6.

D46. Sample selection. A review of the topography of the area revealed the northern sector to be potentially the most susceptible to flooding and wave attack damage and to a lesser extent, low-lying areas near Takanassee Lake and Deal Lake. This included reaches 1 through 5 and the lake areas of reaches 8A, 8B and 11. For the remaining reaches the potential for storm damage is primarily limited to undermining from erosion or storm recession and failure from wave runup. For this reason the northern peninsula portion of the project area and properties adjacent to the lakes were the primary centers for on-site investigation. Interviews were taken outside these locals only when stratified usage types either did not exist or were unobtainable within these primary areas. For example, the Long Branch pier was unique to the study area and as such flood damage interviews pertaining to arcades could only be obtained at this location.

D47. Description of damage functions. Generalized damage functions were generated for physical damage, emergency costs, lost income and residential content damage. These damage functions reflect damages per square foot of structure size which were than applied to each structure to determine damages at 1 foot increments of flood stage. For non-residential structures the damage surveys evaluated the depth-damage relationship for physical, lost income, and emergency costs based on an assessment of the sites visited. For the residential structures, FIA curves were utilized to develop the physical damages based on total value of the Contents and Structure. Lost Income and Emergency losses were based on interview data.

D47A. The analysis of lost income benefits was based solely on residential damage surveys, and therefore eliminates double counting business and household lost income while also avoiding transfers of economic activity which are prevalent when the loss of income to local business firms is measured. Double counting of income loss and emergency costs was avoided by considering the evaluation of emergency costs, such as flood fight, evacuation and clean-up, net of any income losses identified during the damage surveys. Also, an upper limit of 40 hours of income loss per household was assumed so as to eliminate survey responses which did not accurately distinguish between income lost due to damage to place of employment or time spent for clean up and repair.

TABLE D-6

SEA BRIGHT TO OCEAN TOWNSHIP
INTERVIEW SAMPLE DISTRIBUTION

Usage	Population		Target Sample		Actual Sample		
	#	%	#	% of Target	#	% of Sample	% of Population
1. Colonial	477	22.4	31	15.5	37	17.3	7.8
2. Cape Cod	149	7.0	12	6.0	16	7.5	10.7
3. Ranch	175	8.2	10	5.0	11	5.1	6.3
4. Split Level	17	0.8	1	0.5	2	0.9	11.8
5. BiLevel	4	0.2	1	0.5	1	0.5	25.0
6. Raised Ranch	36	1.7	3	1.5	3	1.4	8.3
7. Bungalow	140	6.6	12	6.0	13	6.1	9.3
8. Custom	65	3.0	5	2.5	6	2.8	9.2
9. Mobile Home	0	0	0	0	0	0	-
10. 2-Family	61	2.9	4	2.0	5	2.3	8.2
11. Duplex	30	1.4	2	1.0	2	0.9	6.7
12. Multi-Family	41	1.9	2	1.0	2	0.9	4.9
13. Garden Apt.	67	3.1	4	2.0	5	2.3	7.5
14. High-Rise	12	0.6	2	1.0	2	0.9	16.7
15. Townhouse	76	3.6	6	3.0	8	3.7	10.5

TABLE D-6 (continued)

SEA BRIGHT TO OCEAN TOWNSHIP
INTERVIEW SAMPLE DISTRIBUTION

Usage	Population		Target Sample		Actual Sample		
	#	%	#	% of Target	#	% of Sample	% of Population
20. Arcade	9	0.4	2	1.0	2	0.9	22.2
21. Art Gallery	0	0.0	0	0	0	0	-
22. Auto Sales	2	0.1	1	0.5	1	0.5	50.0
23. Auto Service	4	0.2	1	0.5	2	0.9	50.0
24. Bank	3	0.1	1	0.5	1	0.5	33.3
25. Bar	10	0.5	2	1.0	1	0.5	10.0
26. Bath House	13	0.6	3	1.5	3	1.4	23.1
27. Church	3	0.1	1	0.5	1	0.5	33.3
28. Clothing Store	5	0.2	2	1.0	2	0.9	40.0
29. Department Store	0	0.0	0	0	0	0	-
30. Diner	29	1.4	6	3.0	6	2.8	20.7
31. Drug Store	2	0.1	1	0.5	1	0.5	50.0
32. Dry Cleaning	4	0.2	2	1.0	2	0.9	50.0
33. Food Store	10	0.5	2	1.0	2	0.9	20.0
34. Funeral Home	0	0.0	0	0	0	0	-
35. Hair Salon	3	0.1	1	0.5	1	0.5	33.3
36. Hardware	6	0.3	2	1.0	2	0.9	33.3
37. Home Furnishings	2	0.1	1	0.5	1	0.5	50.0
38. Hospital	0	0.0	0	0	0	0	-
39. Indoor Sports	4	0.2	1	0.5	1	0.5	25.0
40. Jewellers	0	0.0	0	0	0	0	-
41. Liquors	2	0.1	1	0.5	1	0.5	50.0
42. Marina	10	0.5	5	2.5	5	2.3	50.0
43. Medical Office	0	0.0	0	0	0	0	-

TABLE D-6 (continued)

SEA BRIGHT TO OCEAN TOWNSHIP
INTERVIEW SAMPLE DISTRIBUTION

Usage	Population		Target Sample		Actual Sample		
	#	%	#	% of Target	#	% of Sample	% of Population
44. Office	14	0.7	4	2.0	5	2.3	35.7
45. Office Warehouse	1	0.1	1	0.5	1	0.5	100.0
46. Outdoor Sports	2	0.1	1	0.5	1	0.5	50.0
47. Restaurant	21	1.0	7	3.5	7	3.3	33.3
48. Rooming House	33	1.5	6	3.0	7	3.3	21.2
49. Small Retail	12	0.5	5	2.5	5	2.3	41.7
50. Theaters	0	0	0	0	0	0	-
*51. Vacant	16	0.7	0	0	0	0	-
52. Cabana	83	3.9	8	4.0	8	3.7	9.6
53. Beach Club	23	1.1	7	3.5	7	3.3	30.4
54. Amusement Rides	5	0.2	1	0.5	1	0.5	20.0
71. Food and Kindred Product	1	0.1	1	0.5	1	0.5	100.0
72. Extraction	0	0.0	0	0	0	0	-
73. Textiles and Apparel	0	0.0	0	0	0	0	-
74. Lumber and Wood	2	0.1	1	0.5	1	0.5	50.0
75. Furniture and Fixtures	1	0.1	1	0.5	1	0.5	100.0
76. Paper Products	0	0.0	0	0	0	0	-
77. Printing and Publishing	1	0.1	1	0.5	1	0.5	100.0
78. Chemicals	0	0.0	0	0	0	0	-
79. Fuel Storage	0	0.0	0	0	0	0	-
80. Glass, Clay and Concrete	0	0.0	0	0	0	0	-
81. Metal Working	0	0.0	0	0	0	0	-
82. Electrical	0	0.0	0	0	0	0	-
83. Transportation Equipment	0	0.0	0	0	0	0	-
84. Warehouse	7	0.3	3	1.5	3	1.4	42.9
85. Building Contractor	1	0.1	1	0.5	1	0.5	100.0

TABLE D-6 (continued)

SEA BRIGHT TO OCEAN TOWNSHIP
INTERVIEW SAMPLE DISTRIBUTION

Usage	Population #	Population %	Target Sample #	Target Sample % of Target	Actual Sample #	Actual Sample % of Sample	% of Population
101. Sewage Treatment		0	0.0	0	0	0	0 -
102. Pump Station	4	0.2	2	1.0	2	0.9	50.0
103. Gas Substation	0	0.0	0	0	0	0	-
104. Water Treatment	0	0.0	0	0	0	0	-
105. Wells	0	0.0	0	0	0	0	-
106. Electric Substation	1	0.1	1	0.5	1	0.5	100.0
107. Miscellaneous	2	0.1	1	0.5	1	0.5	50.0
**150. Garage	293	13.7	0	0	0	0	-
**151. Tennis Court	14	0.7	0	0	0	0	-
**152. Swimming Pools	54	2.5	0	0	0	0	-
**153. Bath House (Residential)	5	0.2	0	0	0	0	-
**154. Gazebo	7	0.3	0	0	0	0	-
**156. Boat Dock (Private)	30	1.4	0	0	0	0	-
201. Fire House	3	0.1	1	0.5	1	0.5	33.3
202. Storage Garage	8	0.4	3	1.5	3	1.4	37.5
203. Municipal Building	2	0.1	1	0.5	1	0.5	50.0
204. Municipal Complex	0	0.0	0	0	0	0	0
205. Police Station	1	0.1	1	0.5	1	0.5	100.0
206. Schools	0	0.0	0	0	0	0	-
207. Rescue Squad	1	0.1	1	0.5	1	0.5	100.0
208. Library	0	0.0	0	0	0	0	-
209. Post Office	1	0.1	1	0.5	1	0.5	100.0
*210. General Storage	14	0.7	5	2.5	4	1.9	28.6
Total					214		

*Vacant Structures, No Interviews Taken
**Ancillary Structures, No Interviews Taken

D48. In a coastal environment, flood damages occur as a result of a number of different yet interrelated causes. Structures become undermined and fall off into the ocean due to long-term erosion which occurs over a number of years or during a single event as a result of storm recession. Structures become inundated as a result of storm surge resulting in damage due to saturation of materials and hydrostatic pressures. Under certain storm conditions wind blown waves often add to these forces and destroy the structure. Because of the interdependency of these damage mechanisms, it is important to avoid double counting, therefore only the mechanism yielding the maximum damage for a given return frequency has been used for the project's benefit cost-analysis. The following outlines how each damage mechanism was evaluated independently.

Long Term Erosion Damages

D49 Years and limitations. Based on the long-term erosion rate of 3 feet per year, the area subject to long-term erosion was determined for the years 1990, 2000, 2010, 2020, 2030 and 2040. Based on discussions with the New Jersey Department of Environmental Protection, Division of Coastal Resources, it was determined that ongoing maintenance efforts would protect major structures such as the Seawall and State Highway. Long Term Erosion would therefore be arrested at the leading edge of these structures through intervention by man, thus no long-term erosion was considered beyond the seawalls and roadways paralleling the beach.

D50. Methodology. In determining damage due to long-term erosion undermined structures were considered a total loss and would not be rebuilt. The value of each structure impacted by long-term erosion was removed from the evaluation when considering storm induced damages in subsequent years.

D51. The costs associated with halting long term erosion at seawalls and bulkheads are reflected in the without project seawall maintenance costs. The cost of protecting major roads exposed to long term erosion was calculated for years P0, P10, P20, P30, P40 and P50 using the following formula:

$$\text{Annual Cost} = \begin{matrix}\text{Project Annual}\\ \text{Maintenance Cost}\end{matrix} \times \frac{\text{Length of roadway impacted}}{\text{Length of Project}}$$

The calculation of these costs is presented in Table D-7.

D52. The major impact of long-term erosion is the reduction in berm area protecting structures from the impact of storm damage due to shoreline recession, wave impact and wave runup.

D53. The project as proposed will halt long-term erosion as a result of implementing the feeder beach and an ongoing maintenance program reflected in the project costs. Residual with project damages were therefore calculated without consideration for long-term erosion.

TABLE D-7

SEA BRIGHT TO OCEAN TOWNSHIP

Erosion Benefits Calculation Sheet
For Roadway Protection
Reach 6A
Interest Rate 8.625%
Maintenance Cost $ 69 /ft/Yr
Project Life 50 Years

DATE YEAR	PROJECT YEAR	LENGTH OF ROADWAY (FT)	VALUE IN YEAR	PWF	PRESENT WORTH
1990	0	0	$0	1	$0
1991	1	0	$0	0.920	$0
1992	2	0	$0	0.847	$0
1993	3	0	$0	0.780	$0
1994	4	0	$0	0.718	$0
1995	5	0	$0	0.661	$0
1996	6	0	$0	0.608	$0
1997	7	0	$0	0.560	$0
1998	8	0	$0	0.515	$0
1999	9	0	$0	0.474	$0
2000	10	0	$0	0.437	$0
2001	11	12	$828	0.402	$333
2002	12	24	$1,656	0.370	$614
2003	13	36	$2,484	0.341	$847
2004	14	48	$3,312	0.314	$1,040
2005	15	60	$4,140	0.289	$1,197
2006	16	72	$4,968	0.266	$1,322
2007	17	84	$5,796	0.245	$1,420
2008	18	96	$6,624	0.225	$1,494
2009	19	108	$7,452	0.207	$1,547
2010	20	120	$8,280	0.191	$1,583
2011	21	143	$9,867	0.175	$1,736
2012	22	166	$11,454	0.162	$1,856
2013	23	189	$13,041	0.149	$1,945
2014	24	212	$14,628	0.137	$2,008
2015	25	235	$16,215	0.126	$2,050
2016	26	258	$17,802	0.116	$2,072
2017	27	281	$19,389	0.107	$2,077
2018	28	304	$20,976	0.098	$2,069
2019	29	327	$22,563	0.090	$2,048
2020	30	350	$24,150	0.083	$2 018
2021	31	365	$25,185	0.076	$1,938
2022	32	380	$26,220	0.070	$1,857
2023	33	395	$27,255	0.065	$1,777
2024	34	410	$28,290	0.060	$1,698
2025	35	425	$29,325	0.055	$1,621
2026	36	440	$30,360	0.050	$1,545
2027	37	455	$31,395	0.046	$1,470

TABLE D-7

SEA BRIGHT TO OCEAN TOWNSHIP

Erosion Benefits Calculation Sheet
For Roadway Protection
Reach 6A
Interest Rate 8.625%
Maintenance Cost $ 69 /ft/Yr
Project Life 50 Years

DATE YEAR	PROJECT YEAR	LENGTH OF ROADWAY (FT)	VALUE IN YEAR	PWF	PRESENT WORTH
2028	38	470	$32,430	0.043	$1,398
2029	39	485	$33,465	0.039	$1,328
2030	40	500	$34,500	0.036	$1,261
2031	41	517	$35,673	0.033	$1,200
2032	42	534	$36,846	0.030	$1,141
2033	43	551	$38,019	0.028	$1,084
2034	44	568	$39,192	0.026	$1,029
2035	45	585	$40,365	0.024	$975
2036	46	602	$41,538	0.022	$924
2037	47	619	$42,711	0.020	$875
2038	48	636	$43,884	0.018	$827
2039	49	653	$45,057	0.017	$782
2040	50	670	$46,230	0.015	$739

Present Worth of Protection Costs	$56,747
X CRF 50	0.088
Actual Cost of Road Protection	$4,974

TABLE D-8

STORM RECURRENCE INTERVAL
FOR SEAWALL OR BULKHEAD FAILURE

Reach	Storm Recurrence Interval (Years) Existing Condition	10' MLW 50' Berm	10' MLW 100' Berm	10' MLW 150' Berm
1	10	50	200	1000
2	50	50	200	1000
3	50	50	200	1000
4	80	80	200	1000
5	50	50	200	1000
6B	10	50	200	1000
7	200	200	200	1000
8B	10	50	200	1000
9B	200	200	200	1000
10	5	50	200	1000

NOTE: TOTAL SEAWALL FAILURE IS ASSUMED AFTER 45% DAMAGE

D58. Methodology for evaluating storm recession damages. The potential damage to any structure was determined based on the structure replacement value, content value, lost income and emergency costs as determined from sample interviews. Damage was assumed to begin when the recession distances exceeded the leading edge of the structure as defined by the set back distance with total damage occurring when recession reached the midpoint of the structure. Damage between these two points was determined using linear interpolation.

D59. Recession damage was analyzed for existing conditions and for each decade of the project life. Analysis of future damage was based on shoreline positions adjusted for long term erosion. Based on historical trends those structures destroyed by storm induced recession were assumed to be rebuilt. This reflects the ability of the shoreline to quickly recover the majority of its loss. That portion of the shore that is not fully recovered is taken into account in the long term erosion rate. Accordingly, any structures lost to long term erosion were removed from the analysis in subsequent years due to the permanent loss of land.

D60. Residual recession damage for each plan was evaluated using the same methodology excluding long term erosion since project maintenance will prevent its occurrence. Set back and midpoint distances were adjusted for the additional beach width and the seawall failure frequency was adjusted to reflect the increased level of stability provided by each project.

Inundation Damages

D61. General. The project area is currently subject to inundation from several sources including waves overtopping the seawall and flooding in the Navesink and Shrewsbury Rivers: Presently, throttling of the storm surges through the Raritan Bay and up the Shrewsbury River cause a reduction of 2 to 4 feet in flood levels caused by the ocean. Failure of the seawall would reduce or eliminate the throttling effect and cause substantially increased flood levels along the River. The proposed project beaches, though in themselves not greatly reducing flood depths, will substantially improve the integrity of the seawall thus mitigating the direct impact of ocean stages on the back side of the peninsula.

D62. Utilizing the data from on-site investigation of the sample population, generalized damage functions were generated. The damage functions reflect the anticipated damage as a percent of building size for one foot increments of depth related to the structure's main floor. The damage functions were divided into Physical, Residential Contents, Lost Income and Emergency Costs. Employing the basic assumption that within usage stratification there is a direct correlation between structure size and damage, the potential damage for the overall population was estimated by multiplying the size of each structure by its appropriate damage function. This produces dollar damage per foot of inundation relative to each structure's main floor. When integrated with Stage Frequency data it permits the calculation of damages due to inundation associated with a specific return period.

D63. The stage-frequency curve used for determination of ocean related flood depths included the influence of wave setup. Higher water elevations associated with wave runup were not evaluated for inundation damage since these elevations are intermittent and short term by nature and the flood depths within a building rarely reflect the exterior elevations. Damages from wave runup were evaluated solely from a hydrodynamic basis and are described under wave attack damage.

D64. Wave Overtopping. In the northern section of the project area, structures are protected from direct ocean flooding by a massive seawall. The lack of beach in front of the seawall not only threatens its structural integrity, but because significant waves are able to directly impact on the wall, runup results in overtopping and subsequent flooding landward of the seawall.

D65. Since overtopping rates and depths of flooding vary widely even for storms with similar recurrence intervals due to various storm parameters, the analysis developed depth-frequency curves directly from known flood marks. The upper limit of the overtopping analysis was the frequency at which the seawall loses its structural integrity as detailed in Table D-8. At this point it was assumed that there is direct flooding from the ocean.

D66. The basic approach to determining damage due to overtopping was to develop a depth-frequency curve for each reach based on flood marks. Because there is a slight gradient from the ocean toward the Shrewsbury River, it was necessary to adjust the flood stage as the water moved landward. This scenario is schematically displayed in Figure D-7. To achieve this a constant depth-frequency was assumed based on historical flood mark data and the stage adjusted based on the gradient of the ground. The area was divided into grids with the approximate dimensions of 1000 feet parallel to the shoreline and 100 feet perpendicular to the shoreline. Within each grid, flooding at the lowest ground point was assumed to occur at depths determined from the depth-frequency curves. Damage due to overtopping was then calculated for each structure. A depth of one foot of water at the lowest point in each cell was the minimum frequency evaluated.

D67. Depth-frequency curves were developed from historic flood marks and flood marks collected during damage interviews in conjunction with frequency data for the Sandy Hook gauge provided by NOAA Tidal Records section. This methodology was proofed against photographs taken during the syzygy tides of January 1987 and found to be in concurrence.

D68. Wave Attack Damage. Oceanfront structures are subject to forces in excess of inundation as a result of direct wave impact and high energy runup. To evaluate this added potential for structural failure, it is first necessary to define the population subject to wave forces. Two separate and distinct mechanisms were utilized to define the limits of potential wave attack. The initial technique consists of transmitting a potential incoming wave landward until such point that a breaking wave of 2.3 feet could no longer be sustained. The methodology utilized for the analysis follows procedures outlined in the FEMA Manual "Ways of Estimating Wave Height in Coastal High Hazard Areas". The process takes into account energy losses associated with natural and man-made barriers as the wave is transmitted landward. The height of 2.3 feet was selected based on structural evaluations conducted along the South Shore of Long Island for a previous study in which this breaking wave height was determined to sustain enough force to cause structural failure. The wave zones were so delineated for storms with return periods of 25, 100 and 500 years. All delineations assumed complete failure of seawalls and bulkheads but damage to buildings was not considered for storms which would not cause failure of the protective structures.

D69. Subsequent analysis conducted for this investigation indicated a wave height slightly more than three feet was necessary to cause failure as described further on in this section. This means the wave zones delineated are slightly larger than necessary. The wave height necessary for failure is calculated based on the average size and orientation to the shoreline of the structures in the wave zone population and thus the difference in results. The 2.3 foot wave was used primarily to depict the potential wave attack population. It is not utilized to determine structural failure. It was deemed the results are well within the level of accuracy for the analysis.

D70. For the without project condition, limits of wave attack were reanalyzed for each 10-year time period to reflect changes due to long-term erosion. This procedure was unnecessary for the with project condition since long-term erosion will be checked by an ongoing maintenance program. Since this analysis was performed on grids of coastline rather than specific beach profiles, the impacts of recession were analyzed qualitatively based on the height and width of protective beach. Specific structures subject to wave attack during the 25-year, 100-year and 500-year storms were identified.

D71. The actual depth necessary for structural failure was calculated as described below. The purpose of segmenting the structures into the three wave zones was to avoid prematurely failing structures. Failure of individual buildings is determined based on the depth of water surrounding the structure and its potential to sustain a specific breaking wave resulting in a force capable of causing structural failure. Since the ground slopes downward away from the ocean, it is conceivable that buildings in the third or fourth row of structures will experience a greater depth of water than one closer to the ocean and under certain circumstances erroneously be assumed to fail. The reason it would be erroneous is that the frequency event being analyzed may not be capable of transmitting a wave that deep into the flood plain.

Therefore to mitigate against this potential problem, the three wave zones were delineated and structures identified in each zone. Therefore beyond the 25-year wave zone, when analyzing a less than 25-year return frequency, no matter how deep the still water is around a building, if it is located beyond the 25-year wave zone, the building was considered not to fail due to wave attack since the incoming ocean wave would be incapable of reaching the structure.

D72. The evaluation considered four structure groups. Based on data obtained from a windshield survey, there exists 310 buildings in the 1985 500-year wave zone excluding detached garages plus an additional 20 structures associated with the Long Branch Pier. Exclusive of the Long Branch Pier, which is entirely supported on piles, only slightly more than 5% of the wave zone population is elevated on either piles or piers and thus does not reflect a significant portion of the population. A single masonry garden apartment was also excluded from the analysis because, with a "footprint" of 18,000 square feet it was nearly double the next largest building, and it was oriented with its narrow side toward the water further reducing its likelihood of wave failure. Because the potential for failure is somewhat different for pile supported structures, they were evaluated as a separate category even though they represent only a small portion of the population. Thus the wave zone structures were categorized as follows for this evaluation exclusive of the Long Branch Pier.

% of Wave Zone Population	Group Name	Average Size
83%	Wood Frame Structures not elevated on piles or piers	40 x 63
11%	Masonry Structures not elevated on piles or piers	40 x 70
3%	Pile & Pier Supported Structures elevated less than or equal to 4 feet above grade	60 x 61
3%	Pile Supported Structures elevated more than 4 feet above grade	56 x 52

D73. The Long Branch Pier was excluded from the analysis because the implementation of a project would not appreciably alter its vulnerability because of its location. For wood frame structures, two beach clubs were also excluded because of their very large "footprint", the smaller of which being more than 50% greater than the next largest structure, making them outliers in the data base. Additionally, due to their size, total failure due to wave action is unrealistic. Damages to these larger structures did not assume total destruction of the building. In general, the evaluation is very conservative since it assumes all connections have been properly designed and failure will not occur as a result of joint failure or material failure. In addition, since wind loading will not be altered by project implementation, only wave forces were incorporated into the analysis. In reality, improper connections and material failure are major causes of damage, however much more detailed structural information on individual buildings would be required to make this evaluation and without such information this approach yields a conservative estimate of damages. Each group of structures therefore was only analyzed for complete failure based on overturning or lateral displacement based on the average size structure for the category. The structural analysis followed procedures presented in the Army Corps of Engineers "Shore Protection Manual" and the FEMA manual "Elevating to the Wave Crest Level" and was premised on the basis that a wave greater than 78% of the water depth will break.

D74. Pile Supported Structures - There are only 18 pile-supported structures identified within the wave zone and one pier-supported structure which was treated as pile supported. Ten of these are elevated 4 feet or less above the existing grade. The remainder range from 6 feet to eleven feet above grade with the majority being a cabana complex at 10 feet above grade. Construction varies greatly between buildings but in general the structures with the shorter support system were utilizing the piles more so as a foundation support than as a means of elevating the structure. For this group an average above-ground pile length of three feet was used. For the pile-supported structures in excess of four feet the pile was oftentimes used to elevate the structure above the flood plain. These eight structures have a pile height ranging from six to eleven feet above the ground with seven of them being ten feet or higher. Thus a height of ten feet was used for the analysis. For the longer piles, a pile diameter of twelve inches spaced ten feet on center was used. For the shorter piles an 8-inch pile was assumed with the same spacing. These values were selected based on general field observation. The analysis assumed the first two feet of sand would be unsupportive due to a combination of Liquifaction/Local Scour.

D75. No cross bracing was assumed in the analysis based on field observation of the majority of 10-foot piles and for the lower piles no cross bracing would be expected. The building code in New Jersey does not prescribe a minimum pile depth but rather sets a performance standard based on dead weight loads. This becomes dependent on soil types, existing grade elevations, etc. To simplify the analysis, the builder of a large percentage of these structures was contacted and reported using pile lengths of 30 feet. Using a pile length extending 10 feet above grade and the average ground elevation of the structures, a pile invert elevation was established at -10.3 feet NGVD, which was considered to be typical for the area. From the aforementioned conditions, it was determined that for the short piles a still water depth of 4 feet would be capable of sustaining a large enough breaking wave to cause failure and for the larger piles a water depth of 4.5 feet could cause failure.

D76. Masonry Structures - The majority of the masonry structures are built on slab. For these structures, lateral displacement exerted by the wave action will cause failure when the still water elevation is 5.1 feet above grade.

D77. Wood Frame Structures - These structures, which represent the vast majority of the population, are predominantly built on slab with some basements. For this analysis slab construction was considered. Failure was determined to occur due to lateral displacement at a still water depth of 4.2 feet. Failure of the wood frame structure occurred at a lesser depth than the masonry construction due to its smaller size and lesser unit weight.

D78. Wave Runup - In addition to structures subject to impact from a wave propagated across inundated land areas, some structures at an elevation above or beyond the limit of wave propagations are subject to equivalent forces from wave runup.

D79. The limit of wave runup impact was determined for the 10, 25, 100 and 500 year frequency events at representative beach profiles as described in Appendix A. The horizontal limits of the runup zone reported the landward limit of a force capable of causing structural failure. Since the wood frame structures represent over 80 percent of the wave zone population, the lateral force necessary to displace this category was used to set the horizontal limit of runup for each frequency analyzed for each reach. Interpolation between the analyzed frequencies was completed graphically by plotting frequency against runup up distance. The ultimate determination of damage due to runup at any particular frequency event was then determined by comparing the structures set back distance to the runup distance. If the set back equalled or was exceeded by the runup, it was assumed to fail. As in the case of breaking waves, total failure was not assumed for extremely large buildings. Wave attack for any structure was determined to be the lowest frequency event causing failure due to wave propagation or runup.

Critical Damage

D80. As previously described, structures within the study area are exposed to storm damages from a number of possible mechanisms:

- o Long Term Erosion
- o Storm Recession
- o Inundation
- o Wave Action

D81. In order to move forward to Average Annual Damage Calculations, damages for each reach were summarized by frequency-damage over the 50 year life of the project. This procedure was designed to eliminate the potential for double counting. Each one-foot stage of inundation was related to a frequency and that frequency was then utilized to evaluate the potential damage from each damage mechanism. To prevent double counting only the maximum damage to any single structure was reported for a specific frequency. As depicted in Figure D-8 the "Critical Damage" can fluctuate from inundation to Storm Recession to Wave Attack for different frequency events. Thus, the sum of damages resulting from the individual damage mechanisms will far exceed the critical damage due to double counting. For display purposes, the damage associated with the individual mechanisms are based on a percentage of their summation corrected to restated critical damage. Furthermore, the analysis of cumulative damage by reach for future years can vary as segments of the population are removed from the data base and long term erosion increases the landward limit of damage.

D82. To more accurately reflect future damages, local floodplain management and building practices were investigated to evaluate anticipated levels of protection for any structures which are rebuilt after destruction by storm recession or wave attack. It was determined that future reconstruction of any building would tolerate no greater risk of damage from wave attack or storm recession than exhibited by current building practices. Any structure which would be closer to the future waterline than current building practices was assumed to not be rebuilt. Residential structures which are rebuilt were considered protected to the 25-year event. This level of protection was arrived at by comparing the elevation criteria required by FIA to the results of the storm surge model and taking into consideration that storm recession, and in most cases wave attack are not considered by FIA. Since the majority of commercial structures in the project area which currently do not meet FIA requirements are located in the Sea Bright business district and depend on street level access by clientele drawn to the area's recreation facilities, it was determined that the physical constraints of this high density curb front development and the negative economic impacts of raising the structure would result in business owners rebuilding with no increased level of protection.

D83. In order to account for these changing future conditions, the critical damage at each year and frequency was multiplied by the probability that the structure exists and is subject to damage at that frequency event. The probability of existence for each structure was calculated using the maximum probability of total damage from wave attack or storm recession for each year analyzed with straight line interpolation for the intervening years.

D84. To provide a comparison to historic storm surge and damage data, the existing condition critical damage for various frequency events was aggregated into a still water ocean stage vs. damage relationship. Although damage is presented in relation to stage to permit a comparison to historic storms, it should be noted that the damage associated with wave attack and recession were evaluated for the various storm frequencies and thus, stage has merely been used as a surrogate for display purposes. The 1985 condition stage vs damage comparison developed utilizing this methodology is presented in Table D-9. All damages related to flooding in the Shrewsbury River have been adjusted to the corresponding still water ocean stage utilizing the combined hurricane and northeaster Stage-Frequency curves developed by CERC. Comparison of the predicted damages to the historic damage indicates concurrence with the March 1984 storm. Considering the impact of over 20 years of shoreline erosion, intensive development, the regional increase in real estate value, and seawall degradation to the point where a recurrence of the 1962 storm would result in total failure of major sections, the difference between damages reported in March 1962 and those predicted for 1985 conditions appear reasonable. In addition, the post storm reports utilized for historic damages are limited investigations which tend to underestimate the total damages.

TABLE D-9

SEA BRIGHT TO OCEAN TOWNSHIP
COMPARISON OF PREDICTED TO HISTORIC DAMAGE
JUNE 1988 PRICE LEVEL

Ocean Still Water Stage (NGVD)[1]	Predicted Damage (Millions) 1985 Conditions	Updated Historical Damage
6 ft.	$ 11.3	
6.4 ft.[2] (March 1984)	18.8	16.7[2]
7.6 ft.[3] (March 1962)	73.3	26.5[3]
8 ft.	95.7	
10 ft.	177.8	
12 ft.	252.1	

NOTES:

1. Ocean Still Water Stage not including wave setup or runup.
2. Data from "Post Storm Evaluation March 29, 1984 Northeaster." Stage is maximum recorded at Long Branch, N.J.
3. Data from "Report on Operation Five High". Stage is maximum recorded at Sandy Hook, N.J.

AVERAGE ANNUAL DAMAGES

D85. Utilizing the critical damage-frequency relationships, including adjustments for probability of existence, average annual damages were computed at 10 year increments using the HEC computer program "Expected Annual Damages" (EAD). For the structures in Reach 3, sample calculations of average annual residential damage for physical, emergency and lost income damage and increased residential contents damage (Affluence) are presented in Tables D-10 and D-11 respectively. Table D-12 summarizes the total equivalent annual flood damages for all the reaches in the study area. These damages are shown for existing conditions as well as conditions expected during the project life (1990-2040). The methodology for estimating future conditions accounts for rebuilding of existing structures and future increases in the value of residential contents.

STORM REDUCTION BENEFITS

D86. Storm reduction benefits were calculated for the 14 reaches from 1 to 11 including 6A and 6B, 8A and 8B and 9A and 9B as depicted on Figures D-5 and D-6. Storm reduction benefits from the proposed plans of improvement were estimated by evaluating damages with and without the proposed project and under existing and future conditions. The storm reduction benefits derived from the proposed project consist of:

- Preventable average annual damages to buildings, roads, utilities and other structures
- Reduced public emergency costs
- Reduced maintenance costs

D87. Benefits are based on damage to existing development. Changes in future floodplain development considered in the analysis are limited to constraints on structure rebuilding as previously described and increased residential content damage as described under affluence. Storm reduction benefits were derived from the computation of average annual flood damages resulting from the maximum damage occurring for a specific return period when considering inundation, wave attack and storm recession. The without project Average Annual Damages are displayed in Table D-12. The benefit analysis conducted over the 50-year project life reflected a reduction in structure population due to long term erosion. Tables D-13 through D-15 provide a breakdown of the Storm Damage Reduction Benefits derived from building and infrastructures into its component parts for the alternative plans of improvements and various berm widths.

TABLE D-10

REACH 3 AVERAGE ANNUAL DAMAGES
(IN THOUSANDS OF DOLLARS)

* *

** EXPECTED ANNUAL FLOOD DAMAGE **

** FOR REACH 1 = REACH 3.RES

** WITH PLAN 1 = REACH 3.RES- EXISTING CONDITIONS

** INPUT DATA YEARS = 1985 1990 2000 2010 2020 2030 2040

** PERIOD OF ANALYSIS = 50 YEARS

** DISCOUNT RATE = 8.6250 PERCENT

** DAMAGE BASE = JUNE 1988 DOLLARS

	DAMAGE CATEGORIES	STUDY YEAR 1985	BASE YEAR 1991	.... DECADE YEARS 10 2000	20 2010	30 2020	40 2030	50 2040	END OF PERIOD 2040	EQUIVALENT ANNUAL DAMAGE
1	PHYS	1310.44	[illegible]60.14	1193.50	1132.19	1080.79	1037.22	999.85	999.85	1188.57
2	EMER	115.70	111.98	107.02	102.39	98.44	95.02	92.05	92.05	106.61
3	LOIN	38.87	37.44	35.60	33.84	32.86	31.03	29.91	29.91	35.46
	TOTAL	1465.02	1409.56	1336.12	1268.42	1212.09	1163.27	1121.81	1121.81	1330.64

* *

TABLE D-11

REACH 3 AVERAGE ANNUAL DAMAGES
RESIDENTIAL CONTENTS
(IN THOUSANDS OF DOLLARS)

** EXPECTED ANNUAL FLOOD DAMAGE **

** FOR REACH 1 = REACH -3

** WITH PLAN 1 = REACH -3 EXISTING CONDITIONS

** INPUT DATA YEARS = 1985 1990 2000 2010 2020 2030 2040

** PERIOD OF ANALYSIS = 50 YEARS

** DISCOUNT RATE = 8.6250 PERCENT

** DAMAGE BASE = JUNE 1988 DOLLARS

		STUDY	BASE	DECADE YEARS					END OF	EQUIVALENT
	DAMAGE	YEAR	YEAR	10	20	30	40	50	PERIOD	ANNUAL
	CATEGORIES	1985	1991	2000	2010	2020	2030	2040	2040	DAMAGE
1	CONT	0.00	64.22	123.59	168.24	208.10	250.79	294.71	294.71	124.56
	TOTAL	0.00	64.22	123.59	168.24	208.10	250.79	294.71	294.71	124.56

TABLE D - 12
SEABRIGHT TO OCEAN TOWNSHIP
AVERAGE ANNUAL DAMAGE SUMMARY TABLE
WITHOUT PROJECT
(JUNE 1988 PRICE LEVEL) 8 5/8% INTEREST RATE

	DAMAGE IN THOUSANDS OF DOLLARS							
ECONOMIC REACH	1	2	3	4	5	6A	6B	7
WITHOUT PROJECT								
DAMAGE TO BUILDINGS								
PHYSICAL	$789.1	$4,367.3	$1,484.1	$2,973.9	$296.4	$389.6	$68.6	$1.5
EMERGENCY	$37.4	$143.6	$112.9	$123.7	$10.5	$7.7	$0.6	$0.0
LOST INCOME	$9.0	$25.4	$35.5	$40.7	$2.5	$1.1	$0.0	$0.0
BUILDINGS TOTAL (NO AFFLUENCE)	$835.5	$4,536.3	$1,632.4	$3,138.3	$309.3	$398.3	$69.2	$1.6
ADJUSTMENT FOR AFFLUENCE	$28.7	$47.0	$124.6	$188.3	$10.5	$9.6	$0.0	$0.0
BUILDINGS TOTAL (W/ AFFLUENCE)	$864.2	$4,583.2	$1,757.0	$3,326.6	$319.8	$407.9	$69.2	$1.6
DAMAGE TO SEAWALLS	$3,774.8	$0.0	$874.5	$468.0	$667.4	$0.0	$0.0	$77.0
DAMAGE TO ROADS AND INFRASTRUCTURE	$1.7	$23.3	$0.9	$4.0	$0.5	$309.3	$56.2	$3.4
PUBLIC EMERGENCY COSTS	$1.6	$0.7	$0.7	$1.0	$1.2	$0.8	$0.7	$0.0
TOTAL WITHOUT PROJECT AVERAGE ANNUAL DAMAGES (NO AFFLUENCE)	4613.6	4560.2	2508.6	3611.4	978.4	708.4	126.1	81.9
TOTAL WITHOUT PROJECT AVERAGE ANNUAL DAMAGES (W/ AFFLUENCE)	4642.3	4607.2	2633.1	3799.7	988.8	718.0	126.1	81.9

TABLE D - 12
SEABRIGHT TO OCEAN TOWNSHIP
AVERAGE ANNUAL DAMAGE SUMMARY TABLE
WITHOUT PROJECT
(JUNE 1988 PRICE LEVEL) 8 5/8% INTEREST RATE

	DAMAGE IN THOUSANDS OF DOLLARS						
ECONOMIC REACH	8A	8B	9A	9B	10	11	TOTAL
WITHOUT PROJECT							
DAMAGE TO BUILDINGS							
PHYSICAL	$1,135.0	$213.7	$481.3	$37.4	$98.0	$169.3	$12,505.1
EMERGENCY	$29.4	$5.1	$65.6	$1.0	$2.1	$3.6	$543.0
LOST INCOME	$3.5	$0.1	$10.5	$0.2	$0.2	$1.4	$130.2
BUILDINGS TOTAL (NO AFFLUENCE)	$1,168.0	$219.0	$557.4	$38.5	$100.3	$174.2	$13,178.3
ADJUSTMENT FOR AFFLUENCE	$43.6	$1.1	$98.0	$1.6	$4.4	$11.6	$568.8
BUILDINGS TOTAL (W/ AFFLUENCE)	$1,211.5	$220.1	$655.4	$40.1	$104.7	$185.8	$13,747.1
DAMAGE TO SEAWALLS	$0.0	$0.0	$0.0	$69.2	$0.0	$0.0	$5,930.9
DAMAGE TO ROADS AND INFRASTRUCTURE	$20.4	$0.0	$157.0	0.0	31.9	$186.1	$794.6
PUBLIC EMERGENCY COSTS	$0.6	$1.1	$1.4	0.2	1.1	$0.6	$11.7
TOTAL WITHOUT PROJECT AVERAGE ANNUAL DAMAGES (NO AFFLUENCE)	1188.9	220.0	715.8	107.9	133.3	360.9	19915.5
TOTAL WITHOUT PROJECT AVERAGE ANNUAL DAMAGES (W/ AFFLUENCE)	1232.5	221.1	813.8	109.5	137.7	372.5	20484.3

TABLE D - 13
SEABRIGHT TO OCEAN TOWNSHIP
STORM REDUCTION BENEFITS
SUMMARY TABLE - 50 FOOT BERM
(JUNE 1988 PRICE LEVEL) 8 5/8% INTEREST RATE

FILL ONLY PLAN

BENEFITS IN THOUSANDS OF DOLLARS

ECONOMIC REACH	1	2	3	4	5	6A	6B	7
50 FOOT PROJECT								
BENEFITS TO BUILDINGS								
PHYSICAL	$122.6	$2,196.8	$810.9	$1,952.1	$129.3	$231.8	$25.7	$0.8
EMERGENCY	$8.3	$17.3	$71.2	$86.0	$2.4	$3.0	$0.2	$0.0
LOST INCOME	$3.0	$0.0	$24.5	$32.7	$0.2	$0.1	$0.0	$0.0
BUILDING TOTAL (NO AFFLUENCE)	$133.9	$2,214.1	$906.6	$2,070.7	$132.0	$235.0	$25.9	$0.8
ADJUSTMENT FOR AFFLUENCE	$3.8	$3.7	$75.7	$173.6	$2.8	$6.5	$0.0	$0.0
BUILDING TOTAL (W/ AFFLUENCE)	$137.7	$2,217.8	$982.3	$2,244.3	$134.8	$241.4	$25.9	$0.8
REDUCED DAMAGE TO SEAWALLS	$3,013.5	$0.0	$502.6	$277.1	$383.5	$0.0	$0.0	$48.7
REDUCED DAMAGE TO ROADS AND INFRASTRUCTURE	$1.7	$22.6	$0.7	$4.0	$0.5	$233.7	$52.1	-$2.9
PUBLIC EMERGENCY COSTS	$0.3	$0.4	$0.4	$0.7	$0.5	$0.5	$0.3	$0.0
REDUCED MAINTENANCE COSTS FOR SEAWALL	$197.4	$57.3	$85.3	$22.0	$27.0	$0.0	$0.0	$0.0
TOTAL STORM REDUCTION BENEFITS (NO AFFLUENCE)	$3,346.7	$2,294.4	$1,495.6	$2,374.6	$543.4	$469.1	$78.2	$46.7
TOTAL STORM REDUCTION BENEFITS (W/ AFFLUENCE)	$3,350.5	$2,298.1	$1,571.3	$2,548.1	$546.2	$475.6	$78.2	$46.7

TABLE D - 13
SEABRIGHT TO OCEAN TOWNSHIP
STORM REDUCTION BENEFITS
SUMMARY TABLE - 50 FOOT BERM
(JUNE 1988 PRICE LEVEL) 8 5/8% INTEREST RATE

FILL ONLY PLAN

BENEFITS IN THOUSANDS OF DOLLARS

ECONOMIC REACH	8A	8B	9A	9B	10	11	TOTAL
50 FOOT PROJECT							
BENEFITS TO BUILDINGS							
PHYSICAL	$1,121.1	$213.6	$419.7	$12.5	$77.0	$14.0	$7,327.9
EMERGENCY	$29.2	$5.1	$63.5	$0.2	$1.5	$0.1	$287.9
LOST INCOME	$3.5	$0.1	$10.2	$0.0	$0.2	$0.1	$74.7
BUILDING TOTAL (NO AFFLUENCE)	$1,153.8	$218.8	$493.4	$12.8	$78.7	$14.1	$7,690.5
ADJUSTMENT FOR AFFLUENCE	$43.1	$1.1	$95.0	$1.3	$3.6	$0.9	$411.1
BUILDING TOTAL (W/ AFFLUENCE)	$1,196.9	$219.9	$588.4	$14.1	$82.2	$15.0	$8,101.5
REDUCED DAMAGE TO SEAWALLS	$0.0	$0.0	$0.0	$43.4	$0.0	$0.0	$4,268.8
REDUCED DAMAGE TO ROADS AND INFRASTRUCTURE	$17.6	$0.0	$143.2	$0.0	$24.7	$162.4	$660.3
PUBLIC EMERGENCY COSTS	$0.6	$1.1	$1.2	$0.1	$0.9	$0.0	$6.8
REDUCED MAINTENANCE COSTS FOR SEAWALL	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$389.0
TOTAL STORM REDUCTION BENEFITS (NO AFFLUENCE)	$1,172.0	$219.9	$637.7	$56.2	$104.3	$176.5	$13,015.3
TOTAL STORM REDUCTION BENEFITS (W/ AFFLUENCE)	$1,215.1	$221.0	$732.7	$57.6	$107.9	$177.4	$13,426.4

TABLE D - 13A
SEABRIGHT TO OCEAN TOWNSHIP
STORM REDUCTION BENEFITS
SUMMARY TABLE - 50 FOOT BERM
(JUNE 1988 PRICE LEVEL) 8 5/8% INTEREST RATE

BEACH FILL WITH AUTHORIZED GROINS

BENEFITS IN THOUSANDS OF DOLLARS

ECONOMIC REACH	1	2	3	4	5	6A	6B	7
50 FOOT PROJECT								
BENEFITS TO BUILDINGS								
PHYSICAL	$122.6	$2,196.8	$810.9	$1,952.1	$129.3	$231.8	$25.7	$0.8
EMERGENCY	$8.3	$17.3	$71.2	$86.0	$2.4	$3.0	$0.2	$0.0
LOST INCOME	$3.0	$0.0	$24.5	$32.7	$0.2	$0.1	$0.0	$0.0
BUILDING TOTAL (NO AFFLUENCE)	$133.9	$2,214.1	$906.6	$2,070.7	$132.0	$235.0	$25.9	$0.8
ADJUSTMENT FOR AFFLUENCE	$3.8	$3.7	$75.7	$173.6	$2.8	$6.5	$0.0	$0.0
BUILDING TOTAL (W/ AFFLUENCE)	$137.7	$2,217.8	$982.3	$2,244.3	$134.8	$241.4	$25.9	$0.8
REDUCED DAMAGE TO SEAWALLS	$3,013.5	$0.0	$502.6	$277.1	$383.5	$0.0	$0.0	$48.7
REDUCED DAMAGE TO ROADS AND INFRASTRUCTURE	$1.7	$22.6	$0.7	$4.0	$0.5	$233.7	$52.1	-$2.9
PUBLIC EMERGENCY COSTS	$0.3	$0.4	$0.4	$0.7	$0.5	$0.5	$0.3	$0.0
REDUCED MAINTENANCE COSTS FOR SEAWALL	$197.4	$57.3	$85.3	$22.0	$27.0	$0.0	$0.0	$0.0
TOTAL STORM REDUCTION BENEFITS (NO AFFLUENCE)	$3,346.7	$2,294.4	$1,495.6	$2,374.6	$543.4	$469.1	$78.2	$46.7
TOTAL STORM REDUCTION BENEFITS (W/ AFFLUENCE)	$3,350.5	$2,298.1	$1,571.3	$2,548.1	$546.2	$475.6	$78.2	$46.7

TABLE D - 13A
SEABRIGHT TO OCEAN TOWNSHIP
STORM REDUCTION BENEFITS
SUMMARY TABLE - 50 FOOT BERM
(JUNE 1988 PRICE LEVEL) 8 5/8% INTEREST RATE

BEACH FILL WITH AUTHORIZED GROINS

BENEFITS IN THOUSANDS OF DOLLARS

ECONOMIC REACH	8A	8B	9A	9B	10	11	TOTAL
50 FOOT PROJECT							
BENEFITS TO BUILDINGS							
PHYSICAL	$1,121.1	$213.6	$419.7	$12.5	$77.0	$14.0	$7,327.9
EMERGENCY	$29.2	$5.1	$63.5	$0.2	$1.5	$0.1	$287.9
LOST INCOME	$3.5	$0.1	$10.2	$0.0	$0.2	$0.1	$74.7
BUILDING TOTAL (NO AFFLUENCE)	$1,153.8	$218.8	$493.4	$12.8	$78.7	$14.1	$7,690.5
ADJUSTMENT FOR AFFLUENCE	$43.1	$1.1	$95.0	$1.3	$3.6	$0.9	$411.1
BUILDING TOTAL (W/ AFFLUENCE)	$1,196.9	$219.9	$588.4	$14.1	$82.2	$15.0	$8,101.5
REDUCED DAMAGE TO SEAWALLS	$0.0	$0.0	$0.0	$43.4	$0.0	$0.0	$4,268.8
REDUCED DAMAGE TO ROADS AND INFRASTRUCTURE	$17.6	$0.0	$143.2	$0.0	$24.7	$162.4	$660.3
PUBLIC EMERGENCY COSTS	$0.6	$1.1	$1.2	$0.1	$0.9	$0.0	$6.8
REDUCED MAINTENANCE COSTS FOR SEAWALL	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$389.0
TOTAL STORM REDUCTION BENEFITS (NO AFFLUENCE)	$1,172.0	$219.9	$637.7	$56.2	$104.3	$176.5	$13,015.3
TOTAL STORM REDUCTION BENEFITS (W/ AFFLUENCE)	$1,215.1	$221.0	$732.7	$57.6	$107.9	$177.4	$13,426.4

TABLE D - 13B
SEABRIGHT TO OCEAN TOWNSHIP
STORM REDUCTION BENEFITS
SUMMARY TABLE - 50 FOOT BERM
(JUNE 1988 PRICE LEVEL) 8 5/8% INTEREST RATE

BEACH FILL WITH UPDATED GROINS

BENEFITS IN THOUSANDS OF DOLLARS

ECONOMIC REACH	1	2	3	4	5	6A	6B	7
50 FOOT PROJECT								
BENEFITS TO BUILDINGS								
PHYSICAL	$122.6	$2,196.8	$810.9	$1,952.1	$129.3	$231.8	$25.7	$0.8
EMERGENCY	$8.3	$17.3	$71.2	$86.0	$2.4	$3.0	$0.2	$0.0
LOST INCOME	$3.0	$0.0	$24.5	$32.7	$0.2	$0.1	$0.0	$0.0
BUILDING TOTAL (NO AFFLUENCE)	$133.9	$2,214.1	$906.6	$2,070.7	$132.0	$235.0	$25.9	$0.8
ADJUSTMENT FOR AFFLUENCE	$3.8	$3.7	$75.7	$173.6	$2.8	$6.5	$0.0	$0.0
BUILDING TOTAL (W/ AFFLUENCE)	$137.7	$2,217.8	$982.3	$2,244.3	$134.8	$241.4	$25.9	$0.8
REDUCED DAMAGE TO SEAWALLS	$3,013.5	$0.0	$502.6	$277.1	$383.5	$0.0	$0.0	$48.7
REDUCED DAMAGE TO ROADS AND INFRASTRUCTURE	$1.7	$22.6	$0.7	$4.0	$0.5	$233.7	$52.1	-$2.9
PUBLIC EMERGENCY COSTS	$0.3	$0.4	$0.4	$0.7	$0.5	$0.5	$0.3	$0.0
REDUCED MAINTENANCE COSTS FOR SEAWALL	$197.4	$57.3	$85.3	$22.0	$27.0	$0.0	$0.0	$0.0
TOTAL STORM REDUCTION BENEFITS (NO AFFLUENCE)	$3,346.7	$2,294.4	$1,495.6	$2,374.6	$543.4	$469.1	$78.2	$46.7
TOTAL STORM REDUCTION BENEFITS (W/ AFFLUENCE)	$3,350.5	$2,298.1	$1,571.3	$2,548.1	$546.2	$475.6	$78.2	$46.7

TABLE D - 13B
SEABRIGHT TO OCEAN TOWNSHIP
STORM REDUCTION BENEFITS
SUMMARY TABLE - 50 FOOT BERM
(JUNE 1988 PRICE LEVEL) 8 5/8% INTEREST RATE

BEACH FILL WITH UPDATED GROINS

BENEFITS IN THOUSANDS OF DOLLARS

ECONOMIC REACH	8A	8B	9A	9B	10	11	TOTAL
50 FOOT PROJECT							
BENEFITS TO BUILDINGS							
PHYSICAL	$1,121.1	$213.6	$419.7	$12.5	$77.0	$14.0	$7,327.9
EMERGENCY	$29.2	$5.1	$63.5	$0.2	$1.5	$0.1	$287.9
LOST INCOME	$3.5	$0.1	$10.2	$0.0	$0.2	$0.1	$74.7
BUILDING TOTAL (NO AFFLUENCE)	$1,153.8	$218.8	$493.4	$12.8	$78.7	$14.1	$7,690.5
ADJUSTMENT FOR AFFLUENCE	$43.1	$1.1	$95.0	$1.3	$3.6	$0.9	$411.1
BUILDING TOTAL (W/ AFFLUENCE)	$1,196.9	$219.9	$588.4	$14.1	$82.2	$15.0	$8,101.5
REDUCED DAMAGE TO SEAWALLS	$0.0	$0.0	$0.0	$43.4	$0.0	$0.0	$4,268.8
REDUCED DAMAGE TO ROADS AND INFRASTRUCTURE	$17.6	$0.0	$143.2	$0.0	$24.7	$162.4	$660.3
PUBLIC EMERGENCY COSTS	$0.6	$1.1	$1.2	$0.1	$0.9	$0.0	$6.8
REDUCED MAINTENANCE COSTS FOR SEAWALL	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$389.0
TOTAL STORM REDUCTION BENEFITS (NO AFFLUENCE)	$1,172.0	$219.9	$637.7	$56.2	$104.3	$176.5	$13,015.3
TOTAL STORM REDUCTION BENEFITS (W/ AFFLUENCE)	$1,215.1	$221.0	$732.7	$57.6	$107.9	$177.4	$13,426.4

TABLE D - 14
SEABRIGHT TO OCEAN TOWNSHIP
STORM REDUCTION BENEFITS
SUMMARY TABLE - 100 FOOT BERM
(JUNE 1988 PRICE LEVEL) 8 5/8% INTEREST RATE

FILL ONLY PLAN

BENEFITS IN THOUSANDS OF DOLLARS

ECONOMIC REACH	1	2	3	4	5	6A	6B	7
100 FOOT PROJECT								
REDUCED DAMAGE TO BUILDINGS								
PHYSICAL	$352.9	$2,551.7	$1,112.3	$2,103.2	$220.7	$351.7	$67.4	$1.5
EMERGENCY	$15.9	$54.4	$88.1	$94.0	$6.8	$4.6	$0.5	$0.0
LOST INCOME	$4.5	$4.8	$28.2	$33.8	$1.6	$0.2	$0.0	$0.0
BUILDING TOTAL (NO AFFLUENCE)	$373.3	$2,610.9	$1,228.6	$2,231.0	$229.1	$356.5	$67.9	$1.6
ADJUSTMENT FOR AFFLUENCE	$14.2	$9.6	$87.7	$164.3	$6.9	$7.2	$0.0	$0.0
BUILDING TOTAL (W/ AFFLUENCE)	$387.5	$2,620.5	$1,316.2	$2,395.3	$236.0	$363.7	$67.9	$1.6
REDUCED DAMAGE TO SEAWALLS	$3,628.5	$0.0	$802.2	$419.1	$610.9	$0.0	$0.0	$66.4
REDUCED DAMAGE TO ROADS AND INFRASTRUCTURE	$1.7	$23.2	$0.8	$4.0	$0.5	$308.2	$55.7	$2.8
PUBLIC EMERGENCY COSTS	$0.7	$0.4	$0.5	$0.7	$0.9	$0.7	$0.7	$0.0
REDUCED MAINTENANCE COSTS FOR SEAWALL	$197.4	$57.3	$85.3	$22.0	$27.0	$0.0	$0.0	$0.0
TOTAL STORM REDUCTION BENEFITS (NO AFFLUENCE)	$4,201.6	$2,691.8	$2,117.4	$2,676.9	$868.3	$665.3	$124.3	$70.8
TOTAL STORM REDUCTION BENEFITS (W/ AFFLUENCE)	$4,215.8	$2,701.4	$2,205.1	$2,841.2	$875.3	$672.6	$124.3	$70.8

TABLE D - 14
SEABRIGHT TO OCEAN TOWNSHIP
STORM REDUCTION BENEFITS
SUMMARY TABLE - 100 FOOT BERM
(JUNE 1988 PRICE LEVEL) 8 5/8% INTEREST RATE

FILL ONLY PLAN

BENEFITS IN THOUSANDS OF DOLLARS

ECONOMIC REACH	8A	8B	9A	9B	10	11	TOTAL
100 FOOT PROJECT							
REDUCED DAMAGE TO BUILDINGS							
PHYSICAL	$1,131.5	$213.7	$478.0	36.9	77.0	$45.0	$8,743.6
EMERGENCY	$29.2	$5.1	$65.5	0.9	1.5	$0.5	$367.1
LOST INCOME	$3.5	$0.1	$10.5	0.2	0.2	$0.1	$87.6
BUILDING TOTAL (NO AFFLUENCE)	$1,164.3	$219.0	$554.0	$38.0	$78.7	$45.6	$9,198.2
ADJUSTMENT FOR AFFLUENCE	$43.4	$1.1	$97.9	$1.6	3.5	$6.0	$443.5
BUILDING TOTAL (W/ AFFLUENCE)	$1,207.7	$220.1	$651.9	$39.6	$82.2	$51.6	$9,641.7
REDUCED DAMAGE TO SEAWALLS	$0.0	$0.0	$0.0	$59.7	0.0	$0.0	$5,586.8
REDUCED DAMAGE TO ROADS AND INFRASTRUCTURE	$20.3	$0.0	$156.6	$0.0	28.3	$163.7	$765.9
PUBLIC EMERGENCY COSTS	$0.6	$1.1	$1.4	$0.2	0.9	$0.2	$8.9
REDUCED MAINTENANCE COSTS FOR SEAWALL	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$389.0
TOTAL STORM REDUCTION BENEFITS (NO AFFLUENCE)	$1,195.2	$220.0	$712.0	$97.9	$107.9	$209.4	[illegible]
TOTAL STORM REDUCTION BENEFITS (W/ AFFLUENCE)	$1,228.7	$221.1	$809.9	$99.5	$111.4	[illegible]	[illegible]

TABLE D - 14A
SEABRIGHT TO OCEAN TOWNSHIP
STORM REDUCTION BENEFITS
SUMMARY TABLE - 100 FOOT BERM
(JUNE 1988 PRICE LEVEL) 8 5/8% INTEREST RATE

BEACH FILL WITH AUTHORIZED GROINS

BENEFITS IN THOUSANDS OF DOLLARS

ECONOMIC REACH	1	2	3	4	5	6A	6B	7
100 FOOT PROJECT								
REDUCED DAMAGE TO BUILDINGS								
PHYSICAL	$352.9	$2,551.7	$1,112.3	$2,103.2	$220.7	$351.7	$67.4	$1.5
EMERGENCY	$15.9	$54.4	$88.1	$94.0	$6.8	$4.6	$0.5	$0.0
LOST INCOME	$4.5	$4.8	$28.2	$33.8	$1.6	$0.2	$0.0	$0.0
BUILDING TOTAL (NO AFFLUENCE)	$373.3	$2,610.9	$1,228.6	$2,231.0	$229.1	$356.5	$67.9	$1.6
ADJUSTMENT FOR AFFLUENCE	$14.2	$9.6	$87.7	$164.3	$6.9	$7.2	$0.0	$0.0
BUILDING TOTAL (W/ AFFLUENCE)	$387.5	$2,620.5	$1,316.2	$2,395.3	$236.0	$363.7	$67.9	$1.6
REDUCED DAMAGE TO SEAWALLS	$3,628.5	$0.0	$802.2	$419.1	$610.9	$0.0	$0.0	$66.4
REDUCED DAMAGE TO ROADS AND INFRASTRUCTURE	$1.7	$23.2	$0.8	$4.0	$0.5	$308.2	$55.7	$2.8
PUBLIC EMERGENCY COSTS	$0.7	$0.4	$0.5	$0.7	$0.9	$0.7	$0.7	$0.0
REDUCED MAINTENANCE COSTS FOR SEAWALL	$197.4	$57.3	$85.3	$22.0	$27.0	$0.0	$0.0	$0.0
TOTAL STORM REDUCTION BENEFITS (NO AFFLUENCE)	$4,201.6	$2,691.8	$2,117.4	$2,676.9	$868.3	$665.3	$124.3	$70.8
TOTAL STORM REDUCTION BENEFITS (W/ AFFLUENCE)	$4,215.8	$2,701.4	$2,205.1	$2,841.2	$875.3	$672.6	$124.3	$70.8

TABLE D - 14A
SEABRIGHT TO OCEAN TOWNSHIP
STORM REDUCTION BENEFITS
SUMMARY TABLE - 100 FOOT BERM
(JUNE 1988 PRICE LEVEL) 8 5/8% INTEREST RATE

BEACH FILL WITH AUTHORIZED GROINS

BENEFITS IN THOUSANDS OF DOLLARS

ECONOMIC REACH	8A	8B	9A	9B	10	11	TOTAL
100 FOOT PROJECT							
REDUCED DAMAGE TO BUILDINGS							
PHYSICAL	$1,131.6	$213.7	$478.0	$36.9	$77.0	$45.0	$8,743.6
EMERGENCY	$29.2	$5.1	$65.5	$0.9	$1.5	$0.5	$367.1
LOST INCOME	$3.5	$0.1	$10.5	$0.2	$0.2	$0.1	$87.6
BUILDING TOTAL (NO AFFLUENCE)	$1,164.3	$219.0	$554.0	$38.0	$78.7	$45.6	$9,198.2
ADJUSTMENT FOR AFFLUENCE	$43.4	$1.1	$97.9	$1.6	$3.5	$6.0	$443.5
BUILDING TOTAL (W/ AFFLUENCE)	$1,207.7	$220.1	$651.9	$39.6	$82.2	$51.6	$9,641.7
REDUCED DAMAGE TO SEAWALLS	$0.0	$0.0	$0.0	$59.7	$0.0	$0.0	$5,586.8
REDUCED DAMAGE TO ROADS AND INFRASTRUCTURE	$20.3	$0.0	$156.6	$0.0	$28.3	$163.7	$765.9
PUBLIC EMERGENCY COSTS	$0.6	$1.1	$1.4	$0.2	$0.9	$0.2	$8.9
REDUCED MAINTENANCE COSTS FOR SEAWALL	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$389.0
TOTAL STORM REDUCTION BENEFITS (NO AFFLUENCE)	$1,185.2	$220.0	$712.0	$97.9	$107.9	$209.4	$15,948.9
TOTAL STORM REDUCTION BENEFITS (W/ AFFLUENCE)	$1,228.7	$221.1	$809.9	$99.4	$111.4	$215.4	$16,392.4

TABLE D - 14B

SEABRIGHT TO OCEAN TOWNSHIP
STORM REDUCTION BENEFITS
SUMMARY TABLE - 100 FOOT BERM
(JUNE 1988 PRICE LEVEL) 8 5/8% INTEREST RATE

BEACH FILL WITH UPDATED GROINS

BENEFITS IN THOUSANDS OF DOLLARS

ECONOMIC REACH	1	2	3	4	5	6A	6B	7
100 FOOT PROJECT								
REDUCED DAMAGE TO BUILDINGS								
PHYSICAL	$352.9	$2,551.7	$1,112.3	$2,103.2	$220.7	$351.7	$67.4	$1.5
EMERGENCY	$15.9	$54.4	$88.1	$94.0	$6.8	$4.6	$0.5	$0.0
LOST INCOME	$4.5	$4.8	$28.2	$33.8	$1.6	$0.2	$0.0	$0.0
BUILDING TOTAL (NO AFFLUENCE)	$373.3	$2,610.9	$1,228.6	$2,231.0	$229.1	$356.5	$67.9	$1.6
ADJUSTMENT FOR AFFLUENCE	$14.2	$9.6	$87.7	$164.3	$6.9	$7.2	$0.0	$0.0
BUILDING TOTAL (W/ AFFLUENCE)	$387.5	$2,620.5	$1,316.2	$2,395.3	$236.0	$363.7	$67.9	$1.6
REDUCED DAMAGE TO SEAWALLS	$3,628.5	$0.0	$802.2	$419.1	$610.9	$0.0	$0.0	$66.4
REDUCED DAMAGE TO ROADS AND INFRASTRUCTURE	$1.7	$23.2	$0.8	$4.0	$0.5	$308.2	$55.7	$2.8
PUBLIC EMERGENCY COSTS	$0.7	$0.4	$0.5	$0.7	$0.9	$0.7	$0.7	$0.0
REDUCED MAINTENANCE COSTS FOR SEAWALL	$197.4	$57.3	$85.3	$22.0	$27.0	$0.0	$0.0	$0.0
TOTAL STORM REDUCTION BENEFITS (NO AFFLUENCE)	$4,201.6	$2,691.8	$2,117.4	$2,676.9	$868.3	$665.3	$124.3	$70.8
TOTAL STORM REDUCTION BENEFITS (W/ AFFLUENCE)	$4,215.8	$2,701.4	$2,205.1	$2,841.2	$875.3	$672.6	$124.3	$70.8

TABLE D - 14B
SEABRIGHT TO OCEAN TOWNSHIP
STORM REDUCTION BENEFITS
SUMMARY TABLE - 100 FOOT BERM
(JUNE 1988 PRICE LEVEL) 8 5/8% INTEREST RATE

BEACH FILL WITH UPDATED GROINS

BENEFITS IN THOUSANDS OF DOLLARS

ECONOMIC REACH	8A	8B	9A	9B	10	11	
100 FOOT PROJECT							
REDUCED DAMAGE TO BUILDINGS							
PHYSICAL	$1,131.6	$213.7	$478.0	$36.9	$77.0	$45.0	$8,743.6
EMERGENCY	$29.2	$5.1	$65.5	$0.9	$1.5	$0.5	$367.1
LOST INCOME	$3.5	$0.1	$10.5	$0.2	$0.2	$0.1	$87.6
BUILDING TOTAL (NO AFFLUENCE)	$1,164.3	$219.0	$554.0	$38.0	$78.7	$45.6	$9,198.2
ADJUSTMENT FOR AFFLUENCE	$43.4	$1.1	$97.9	$1.6	$3.5	$6.0	$443.5
BUILDING TOTAL (W/ AFFLUENCE)	$1,207.7	$220.1	$651.9	$39.6	$82.2	$51.6	$9,641.7
REDUCED DAMAGE TO SEAWALLS	$0.0	$0.0	$0.0	$59.7	$0.0	$0.0	$5,586.8
REDUCED DAMAGE TO ROADS AND INFRASTRUCTURE	$20.3	$0.0	$156.6	$0.0	$28.3	$163.7	$765.9
PUBLIC EMERGENCY COSTS	$0.6	$1.1	$1.4	$0.2	$0.9	$0.2	$8.9
REDUCED MAINTENANCE COSTS FOR SEAWALL	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$389.0
TOTAL STORM REDUCTION BENEFITS (NO AFFLUENCE)	$1,185.2	$220.0	$712.0	$97.9	$107.9	$209.4	$15,948.9
TOTAL STORM REDUCTION BENEFITS (W/ AFFLUENCE)	$1,228.7	$221.1	$809.9	$99.4	$111.4	$215.4	$16,392.4

TABLE D - 15

SEABRIGHT TO OCEAN TOWNSHIP
STORM REDUCTION BENEFITS
SUMMARY TABLE - 150 FOOT BERM
(JUNE 1988 PRICE LEVEL) 8 5/8% INTEREST RATE

FILL ONLY PLAN

BENEFITS IN THOUSANDS OF DOLLARS

ECONOMIC REACH	1	2	3	4	5	6A	6B	7
150 FOOT PROJECT								
REDUCED DAMAGE TO BUILDINGS								
PHYSICAL	$504.4	$2,627.9	$1,254.6	$2,228.1	$257.8	$352.2	$68.3	$1.5
EMERGENCY	$20.4	%55.7	$95.4	$100.9	$8.1	$4.7	$0.5	$0.0
LOST INCOME	$5.1	$4.9	$28.8	$34.6	$1.8	$0.2	$0.0	$0.0
BUILDING TOTAL (NO AFFLUENCE)	$529.9	$2,688.4	$1,378.8	$2,363.6	$267.7	$357.1	$68.8	$1.6
ADJUSTMENT FOR AFFLUENCE	$19.5	$10.5	$110.9	$174.7	$8.4	$7.3	$0.0	$0.0
BUILDING TOTAL (W/ AFFLUENCE)	$549.3	$2,698.9	$1,489.7	$2,538.3	$276.1	$364.4	$68.8	$1.6
REDUCED DAMAGE TO SEAWALLS	$3,774.8	$0.0	$874.5	$468.0	$667.4	$0.0	$0.0	$77.0
REDUCED DAMAGE TO ROADS AND INFRASTRUCTURE	$1.7	$23.3	$0.9	$4.0	$0.5	$309.3	$56.1	$3.4
PUBLIC EMERGENCY COSTS	$1.0	$0.4	$0.6	$0.8	$1.0	$0.7	$0.7	$0.0
REDUCED MAINTENANCE COSTS FOR SEAWALL	$197.4	$57.3	$85.3	$22.0	$27.0	$0.0	$0.0	$0.0
TOTAL STORM REDUCTION BENEFITS (NO AFFLUENCE)	$4,504.8	$2,769.4	$2,340.1	$2,858.4	$963.6	$667.1	$125.7	$81.9
TOTAL STORM REDUCTION BENEFITS (W/ AFFLUENCE)	$4,524.2	$2,779.9	$2,451.0	$3,033.1	$971.9	$674.4	$125.7	$81.9

TABLE D - 15
SEABRIGHT TO OCEAN TOWNSHIP
STORM REDUCTION BENEFITS
SUMMARY TABLE - 150 FOOT BERM
(JUNE 1988 PRICE LEVEL) 8 5/8% INTEREST RATE

FILL ONLY PLAN

BENEFITS IN THOUSANDS OF DOLLARS

ECONOMIC REACH	8A	8B	9A	9B	10	11	TOTAL
150 FOOT PROJECT							
REDUCED DAMAGE TO BUILDINGS							
PHYSICAL	$1,131.7	$213.7	$480.5	37.4	$77.0	$46.2	$9,281.4
EMERGENCY	$29.2	$5.1	$65.6	1.0	$1.5	$0.5	$388.5
LOST INCOME	$3.5	$0.1	$10.5	0.2	$0.2	$0.1	$89.9
BUILDING TOTAL (NO AFFLUENCE)	$1,164.4	$219.0	$556.6	$38.5	$78.7	$46.8	$9,759.8
ADJUSTMENT FOR AFFLUENCE	$43.4	$1.1	$98.0	$1.6	$3.6	$6.0	$484.9
BUILDING TOTAL (W/ AFFLUENCE)	$1,207.9	$220.1	$654.6	$40.1	$82.2	$52.8	$10,244.7
REDUCED DAMAGE TO SEAWALLS	$0.0	$0.0	$0.0	$69.2	$0.0	$0.0	$5,930.9
REDUCED DAMAGE TO ROADS AND INFRASTRUCTURE	$20.4	$0.0	$157.0	$0.0	$31.6	$164.3	$772.5
PUBLIC EMERGENCY COSTS	$0.6	$1.1	$1.4	$0.2	$0.9	$0.2	$9.5
REDUCED MAINTENANCE COSTS FOR SEAWALL	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$389.0
TOTAL STORM REDUCTION BENEFITS (NO AFFLUENCE)	$1,185.4	$220.0	$715.0	$107.9	$111.1	$211.2	$16,861.7
TOTAL STORM REDUCTION BENEFITS (W/ AFFLUENCE)	$1,228.8	$221.1	$813.0	$109.5	$114.7	$217.2	$17,346.6

TABLE D - 15A
SEABRIGHT TO OCEAN TOWNSHIP
STORM REDUCTION BENEFITS
SUMMARY TABLE - 150 FOOT BERM
(JUNE 1988 PRICE LEVEL) 8 5/8% INTEREST RATE

BEACH FILL WITH AUTHORIZED GROINS

BENEFITS IN THOUSANDS OF DOLLARS

ECONOMIC REACH	1	2	3	4	5	6A	6B	7
150 FOOT PROJECT								
REDUCED DAMAGE TO BUILDINGS								
PHYSICAL	$504.4	$2,627.9	$1,254.6	$2,228.1	$257.8	$352.2	$68.3	$1.5
EMERGENCY	$20.4	$55.7	$95.4	$100.9	$8.1	$4.7	$0.5	$0.0
LOST INCOME	$5.1	$4.9	$28.8	$34.6	$1.8	$0.2	$0.0	$0.0
BUILDING TOTAL (NO AFFLUENCE)	$529.9	$2,688.4	$1,378.8	$2,363.6	$267.7	$357.1	$68.8	$1.6
ADJUSTMENT FOR AFFLUENCE	$19.5	$10.5	$110.9	$174.7	$8.4	$7.3	$0.0	$0.0
BUILDING TOTAL (W/ AFFLUENCE)	$549.3	$2,698.9	$1,489.7	$2,538.3	$276.1	$364.4	$68.8	$1.6
REDUCED DAMAGE TO SEAWALLS	$3,774.8	$0.0	$874.5	$468.0	$667.4	$0.0	$0.0	$77.0
REDUCED DAMAGE TO ROADS AND INFRASTRUCTURE	$1.7	$23.3	$0.9	$4.0	$0.5	$309.3	$56.1	$3.4
PUBLIC EMERGENCY COSTS	$1.0	$0.4	$0.6	$0.8	$1.0	$0.7	$0.7	$0.0
REDUCED MAINTENANCE COSTS FOR SEAWALL	$197.4	$57.3	$85.3	$22.0	$27.0	$0.0	$0.0	$0.0
TOTAL STORM REDUCTION BENEFITS (NO AFFLUENCE)	$4,504.8	$2,769.4	$2,340.1	$2,858.4	$963.6	$667.1	$125.7	$81.9
TOTAL STORM REDUCTION BENEFITS (W/ AFFLUENCE)	$4,524.2	$2,779.9	$2,451.0	$3,033.1	$971.9	$674.4	$125.7	$81.9

TABLE D - 15A
SEABRIGHT TO OCEAN TOWNSHIP
STORM REDUCTION BENEFITS
SUMMARY TABLE - 150 FOOT BERM
(JUNE 1988 PRICE LEVEL) 8 5/8% INTEREST RATE

BEACH FILL WITH AUTHORIZED GROINS

BENEFITS IN THOUSANDS OF DOLLARS

ECONOMIC REACH	8A	8B	9A	9B	10	11	TOTAL
150 FOOT PROJECT							
REDUCED DAMAGE TO BUILDINGS							
PHYSICAL	$1,131.7	$213.7	$480.5	$37.4	$77.0	$46.2	$9,281.4
EMERGENCY	$29.2	$5.1	$65.6	$1.0	$1.5	$0.5	$388.5
LOST INCOME	$3.5	$0.1	$10.5	$0.2	$0.2	$0.1	$89.9
BUILDING TOTAL (NO AFFLUENCE)	$1,164.4	$219.0	$556.6	$38.5	$78.7	$46.8	$9,759.8
ADJUSTMENT FOR AFFLUENCE	$43.4	$1.1	$98.0	$1.6	$3.6	$6.0	$484.9
BUILDING TOTAL (W/ AFFLUENCE)	$1,207.9	$220.1	$654.6	$40.1	$82.2	$52.8	$10,244.7
REDUCED DAMAGE TO SEAWALLS	$0.0	$0.0	$0.0	$69.2	$0.0	$0.0	$5,930.9
REDUCED DAMAGE TO ROADS AND INFRASTRUCTURE	$20.4	$0.0	$157.0	$0.0	$31.6	$164.3	$772.5
PUBLIC EMERGENCY COSTS	$0.6	$1.1	$1.4	$0.2	$0.9	$0.2	$9.5
REDUCED MAINTENANCE COSTS FOR SEAWALL	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$389.0
TOTAL STORM REDUCTION BENEFITS (NO AFFLUENCE)	$1,185.4	$220.0	$715.0	$107.9	$111.1	$211.2	$16,861.7
TOTAL STORM REDUCTION BENEFITS (W/ AFFLUENCE)	$1,228.8	$221.1	$813.0	$109.5	$114.7	$217.2	$17,346.6

TABLE D - 15B
SEABRIGHT TO OCEAN TOWNSHIP
STORM REDUCTION BENEFITS
SUMMARY TABLE - 150 FOOT BERM
(JUNE 1988 PRICE LEVEL) 8 5/8% INTEREST RATE

BEACH FILL WITH UPDATED GROINS

BENEFITS IN THOUSANDS OF DOLLARS

ECONOMIC REACH	1	2	3	4	5	6A	6B	7
150 FOOT PROJECT								
REDUCED DAMAGE TO BUILDINGS								
PHYSICAL	$504.4	$2,627.9	$1,254.6	$2,228.1	$257.8	$352.2	$68.3	$1.5
EMERGENCY	$20.4	$55.7	$95.4	$100.9	$8.1	$4.7	$0.5	$0.0
LOST INCOME	$5.1	$4.9	$28.8	$34.6	$1.8	$0.2	$0.0	$0.0
BUILDING TOTAL (NO AFFLUENCE)	$529.9	$2,688.4	$1,378.8	$2,363.6	$267.7	$357.1	$68.8	$1.6
ADJUSTMENT FOR AFFLUENCE	$19.5	$10.5	$110.9	$174.7	$8.4	$7.3	$0.0	$0.0
BUILDING TOTAL (W/ AFFLUENCE)	$549.3	$2,698.9	$1,489.7	$2,538.3	$276.1	$364.4	$68.8	$1.6
REDUCED DAMAGE TO SEAWALLS	$3,774.8	$0.0	$874.5	$468.0	$667.4	$0.0	$0.0	$77.0
REDUCED DAMAGE TO ROADS AND INFRASTRUCTURE	$1.7	$23.3	$0.9	$4.0	$0.5	$309.3	$56.1	$3.4
PUBLIC EMERGENCY COSTS	$1.0	$0.4	$0.6	$0.8	$1.0	$0.7	$0.7	$0.0
REDUCED MAINTENANCE COSTS FOR SEAWALL	$197.4	$57.3	$85.3	$22.0	$27.0	$0.0	$0.0	$0.0
TOTAL STORM REDUCTION BENEFITS (NO AFFLUENCE)	$4,504.8	$2,769.4	$2,340.1	$2,858.4	$963.6	$667.1	$125.7	$81.9
TOTAL STORM REDUCTION BENEFITS (W/ AFFLUENCE)	$4,524.2	$2,779.9	$2,451.0	$3,033.1	$971.9	$674.4	$125.7	$81.9

TABLE D - 15B
SEABRIGHT TO OCEAN TOWNSHIP
STORM REDUCTION BENEFITS
SUMMARY TABLE - 150 FOOT BERM
(JUNE 1988 PRICE LEVEL) 8 5/8% INTEREST RATE

BEACH FILL WITH UPDATED GROINS

BENEFITS IN THOUSANDS OF DOLLARS

ECONOMIC REACH	8A	8B	9A	9B	10	11	TOTAL
150 FOOT PROJECT							
REDUCED DAMAGE TO BUILDINGS							
PHYSICAL	$1,131.7	$213.7	$480.5	$37.4	$77.0	$46.2	$9,281.4
EMERGENCY	$29.2	$5.1	$65.6	$1.0	$1.5	$0.5	$388.5
LOST INCOME	$3.5	$0.1	$10.5	$0.2	$0.2	$0.1	$89.9
BUILDING TOTAL (NO AFFLUENCE)	$1,164.4	$219.0	$556.6	$38.5	$78.7	$46.8	$9,759.8
ADJUSTMENT FOR AFFLUENCE	$43.4	$1.1	$98.0	$1.6	$3.6	$6.0	$484.9
BUILDING TOTAL (W/ AFFLUENCE)	$1,207.9	$220.1	$654.6	$40.1	$82.2	$52.8	$10,244.7
REDUCED DAMAGE TO SEAWALLS	$0.0	$0.0	$0.0	$69.2	$0.0	$0.0	$5,930.9
REDUCED DAMAGE TO ROADS AND INFRASTRUCTURE	$20.4	$0.0	$157.0	$0.0	$31.6	$164.3	$772.5
PUBLIC EMERGENCY COSTS	$0.6	$1.1	$1.4	$0.2	$0.9	$0.2	$9.5
REDUCED MAINTENANCE COSTS FOR SEAWALL	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$389.0
TOTAL STORM REDUCTION BENEFITS (NO AFFLUENCE)	$1,185.4	$220.0	$715.0	$107.9	$111.1	$211.2	$16,861.7
TOTAL STORM REDUCTION BENEFITS (W/ AFFLUENCE)	$1,228.8	$221.1	$813.0	$109.5	$114.7	$217.2	$17,346.6

D88. Residual damages that are not prevented by projects at the authorized berm height have also been calculated and include residual ocean flooding as well as continued flooding from the Shrewsbury River. Tables D-16 through D-18 display the Residual Damages.

D89. Affluence. Over time, the value of homeowner's possessions may be expected to increase as their personal income grows. Therefore, when estimates of damage are made, their growth in the value of damageable items must be taken into account.

D90. Growth in per capita income in the storm damage area has been projected to increase at the same rate as that of per capita income for the State of New Jersey of which the project is a part. Per capita income projections for New Jersey have been obtained from the 1985 OBERS BEA Regional Projections prepared by the U.S. Department of Commerce.

D91. Based on site specific analysis, the current value of contents susceptible to damage was estimated to be 28% of the structure value. The contents value was allowed to grow at the same rate as per capita income, with the limitation that contents value would not exceed 75% of structure value. Factors for growth in content value were calculated for each 10-year period and the residential content damage in each year analyzed was adjusted by the appropriate growth factor. Average Annual Damage was then calculated for each year and the present value of damages determined. Affluence factors are displayed in Table D-19. Application of the affluence factor increases the Existing Condition Average Annual Damages 2.5 percent.

D92. Sea Wall Damage. Damage to the seawall as indicated in Tables D-12 through D-18 was based on failure of the seawall due to a combination of recession and wave attack causing displacement of the stone. Once 45% of the stone was displaced effectively, the wall was considered to be totaled. Appendix A describes in detail the engineering analysis used to evaluate the failure. Costs associated with destruction of the seawall were based on repair costs at $36 per ton of rock plus contingencies (25%). engineering design (5%) and supervision of construction (5%). Volumes for the wall were calculated and to obtain the quantity of rock required,a void ratio of 37% was utilized, based on boring data obtained in connection with this investigation. A density of 179 lbs/cubic foot was used to obtain the required tonnage.

D93. Damage to Roads and Infrastructures. Damage was calculated based on storm recession undermining the facility necessitating replacement and emergency bypassing. For utilities and roads perpendicular to the ocean front, damage was taken based on the linear feet of recession impacting the facility . For infrastructures paralleling the ocean, damage was considered when recession reached the utility. For roads paralleling the ocean front, damage was evaluated starting at the ocean side of the roadway and linearly evaluated to 100% damage at the landward side of the roadway.

TABLE D - 16
SEABRIGHT TO OCEAN TOWNSHIP
RESIDUAL AVERAGE ANNUAL DAMAGE
SUMMARY TABLE - 50 FOOT BERM - ALL PLANS
(JUNE 1988 PRICE LEVEL) 8 5/8% INTEREST RATE

	DAMAGE IN THOUSANDS OF DOLLARS							
ECONOMIC REACH	1	2	3	4	5	6A	6B	7
50 FOOT PROJECT								
DAMAGE TO BUILDINGS								
PHYSICAL	$666.5	$2,170.5	$673.2	$1,021.9	$167.1	$157.8	$43.0	$0.7
EMERGENCY	$29.1	$126.2	$41.8	$37.7	$8.0	$4.6	$0.4	$0.0
LOST INCOME	$6.0	$25.4	$10.9	$8.0	$2.3	$0.9	$0.0	$0.0
BUILDING TOTAL (NO AFFLUENCE)	$701.6	$2,322.2	$725.8	$1,067.6	$177.4	$163.3	$43.4	$0.7
ADJUSTMENT FOR AFFLUENCE	$24.9	$43.3	$48.9	$14.7	$7.7	$3.1	$0.0	$0.0
BUILDING TOTAL (W/ AFFLUENCE)	$726.6	$2,365.4	$774.7	$1,082.3	$185.0	$166.4	$43.4	$0.7
DAMAGE TO SEAWALLS	$761.3	$0.0	$371.9	$190.9	$283.9	$0.0	$0.0	$28.3
DAMAGE TO ROADS AND INFRASTRUCTURE	$0.0	$0.6	$0.2	$0.0	$0.0	$75.7	$4.1	$6.2
PUBLIC EMERGENCY COSTS	$1.4	$0.4	$0.3	$0.4	$0.7	$0.3	$0.5	$0.0
TOTAL RESIDUAL DAMAGES (NO AFFLUENCE)	$1,464.3	$2,323.2	$1,098.3	$1,258.9	$461.9	$239.3	$47.9	$35.3
TOTAL RESIDUAL DAMAGES (W/ AFFLUENCE)	$1,489.2	$2,366.4	$1,147.1	$1,273.6	$469.6	$242.4	$47.9	$35.3

TABLE D - 16
SEABRIGHT TO OCEAN TOWNSHIP
RESIDUAL AVERAGE ANNUAL DAMAGE
SUMMARY TABLE - 50 FOOT BERM - ALL PLANS
(JUNE 1988 PRICE LEVEL) 8 5/8% INTEREST RATE

	DAMAGE IN THOUSANDS OF DOLLARS						
ECONOMIC REACH	8A	8B	9A	9B	10	11	TOTAL
50 FOOT PROJECT							
DAMAGE TO BUILDINGS							
PHYSICAL	$13.9	$0.1	$61.6	$24.8	$21.0	$155.3	$5,177.3
EMERGENCY	$0.2	$0.0	$2.1	$0.8	$0.5	$3.5	$255.1
LOST INCOME	$0.1	$0.0	$0.4	$0.2	$0.1	$1.3	$55.5
BUILDING TOTAL (NO AFFLUENCE)	$14.2	$0.1	$64.0	$25.8	$21.6	$160.1	$5,487.8
ADJUSTMENT FOR AFFLUENCE	$0.4	$0.0	$3.0	$0.3	$0.9	$10.7	$157.8
BUILDING TOTAL (W/ AFFLUENCE)	$14.6	$0.1	$67.0	$26.0	$22.4	$170.8	$5,645.6
DAMAGE TO SEAWALLS	$0.0	$0.0	$0.0	$25.8	$0.0	$0.0	$1,662.1
DAMAGE TO ROADS AND INFRASTRUCTURE	$2.8	$0.0	13.9	0.0	7.2	$23.7	$134.4
PUBLIC EMERGENCY COSTS	$0.0	$0.0	$0.2	$0.1	$0.2	$0.6	$4.9
TOTAL RESIDUAL DAMAGES (NO AFFLUENCE)	$17.0	$0.1	$78.1	$51.7	$29.0	$184.4	$7,289.2
TOTAL RESIDUAL DAMAGES (W/ AFFLUENCE)	$17.4	$0.1	$81.1	$51.9	$29.9	$195.1	$7,446.9

TABLE D - 17
SEABRIGHT TO OCEAN TOWNSHIP
RESIDUAL AVERAGE ANNUAL DAMAGE
SUMMARY TABLE - 100 FOOT BERM - ALL PLANS
(JUNE 1988 PRICE LEVEL) 8 5/8% INTEREST RATE

DAMAGE IN THOUSANDS OF DOLLARS

ECONOMIC REACH	1	2	3	4	5	6A	6B	7
100 FOOT PROJECT								
DAMAGE TO BUILDINGS								
PHYSICAL	$436.2	$1,815.6	$371.8	$870.8	$75.7	$37.9	$1.3	$0.0
EMERGENCY	$21.6	$89.1	$24.8	$29.7	$3.7	$3.0	$0.1	$0.0
LOST INCOME	$4.5	$20.6	$7.3	$6.9	$0.9	$0.9	$0.0	$0.0
BUILDING TOTAL (NO AFFLUENCE)	$462.3	$1,925.4	$403.9	$907.4	$80.2	$41.8	$1.3	$0.0
ADJUSTMENT FOR AFFLUENCE	$14.5	$37.4	$36.9	$24.0	$3.5	$2.3	$0.0	$0.0
BUILDING TOTAL (W/ AFFLUENCE)	$476.8	$1,962.7	$440.8	$931.3	$83.8	$44.1	$1.4	$0.0
DAMAGE TO SEAWALLS	$146.3	$0.0	$72.3	$48.9	$56.5	$0.0	$0.0	$10.6
DAMAGE TO ROADS AND INFRASTRUCTURE	$0.0	$0.1	$0.1	$0.0	$0.0	$1.2	$0.5	$0.5
PUBLIC EMERGENCY COSTS	$0.9	$0.3	$0.2	$0.3	$0.3	$0.1	$0.0	$0.0
TOTAL RESIDUAL DAMAGES (NO AFFLUENCE)	$609.5	$1,925.7	$476.4	$956.6	$137.0	$43.1	$1.8	$11.1
TOTAL RESIDUAL DAMAGES (W/ AFFLUENCE)	$624.0	$1,963.1	$513.3	$980.5	$140.6	$45.4	$1.8	$11.1

TABLE D - 17
SEABRIGHT TO OCEAN TOWNSHIP
RESIDUAL AVERAGE ANNUAL DAMAGE
SUMMARY TABLE - 100 FOOT BERM - ALL PLANS
(JUNE 1988 PRICE LEVEL) 8 5/8% INTEREST RATE

	DAMAGE IN THOUSANDS OF DOLLARS						
ECONOMIC REACH	8A	8B	9A	9B	10	11	TOTAL
100 FOOT PROJECT							
DAMAGE TO BUILDINGS							
PHYSICAL	$3.4	$0.0	$3.3	$0.5	$21.0	$124.3	$3,761.6
EMERGENCY	$0.2	$0.0	$0.1	$0.0	$0.5	$3.1	$175.9
LOST INCOME	$0.1	$0.0	$0.0	$0.0	$0.1	$1.3	$42.6
BUILDING TOTAL (NO AFFLUENCE)	$3.7	$0.0	$3.4	$0.5	$21.6	$128.7	$3,980.0
ADJUSTMENT FOR AFFLUENCE	$0.1	$0.0	$0.1	$0.0	$0.9	$5.5	$125.3
BUILDING TOTAL (W/ AFFLUENCE)	$3.8	$0.0	$3.5	$0.6	$22.5	$134.2	$4,105.3
DAMAGE TO SEAWALLS	$0.0	$0.0	$0.0	$9.5	$0.0	$0.0	$344.1
DAMAGE TO ROADS AND INFRASTRUCTURE	$0.0	$0.0	$0.4	0.0	3.6	$22.4	$28.7
PUBLIC EMERGENCY COSTS	$0.0	$0.0	$0.0	$0.0	$0.2	$0.5	$2.8
TOTAL RESIDUAL DAMAGES (NO AFFLUENCE)	$3.7	$0.0	$3.8	$10.0	$25.4	$151.5	$4,355.6
TOTAL RESIDUAL DAMAGES (W/ AFFLUENCE)	$3.8	$0.0	$4.0	$10.1	$26.3	$157.0	$4,480.9

TABLE D - 18
SEABRIGHT TO OCEAN TOWNSHIP
RESIDUAL AVERAGE ANNUAL DAMAGE
SUMMARY TABLE - 150 FOOT BERM - ALL PLANS
(JUNE 1988 PRICE LEVEL) 8 5/8% INTEREST RATE

	DAMAGE IN THOUSANDS OF DOLLARS							
ECONOMIC REACH	1	2	3	4	5	6A	6B	7
150 FOOT PROJECT								
DAMAGE TO BUILDINGS								
PHYSICAL	$284.7	$1,739.4	$229.5	$745.8	$38.6	$37.4	$0.3	$0.0
EMERGENCY	$17.0	$87.9	$17.5	$22.8	$2.4	$3.0	$0.1	$0.0
LOST INCOME	$3.9	$20.5	$6.7	$6.2	$0.7	$0.9	$0.0	$0.0
BUILDING TOTAL (NO AFFLUENCE)	$305.7	$1,847.8	$253.6	$774.7	$41.7	$41.2	$0.4	$0.0
ADJUSTMENT FOR AFFLUENCE	$9.2	$36.5	$13.7	$13.6	$2.1	$2.3	$0.0	$0.0
BUILDING TOTAL (W/ AFFLUENCE)	$314.9	$1,884.3	$267.3	$788.3	$43.7	$43.5	$0.4	$0.0
DAMAGE TO SEAWALLS	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
DAMAGE TO ROADS AND INFRASTRUCTURE	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
PUBLIC EMERGENCY COSTS	$0.6	$0.3	$0.1	$0.3	$0.2	$0.1	$0.0	$0.0
TOTAL RESIDUAL DAMAGES (NO AFFLUENCE)	$306.2	$1,848.1	$253.8	$775.0	$41.8	$41.3	$0.4	$0.0
TOTAL RESIDUAL DAMAGES (W/ AFFLUENCE)	$315.5	$1,884.6	$267.5	$788.6	$43.9	$43.6	$0.4	$0.0

TABLE D - 18
SEABRIGHT TO OCEAN TOWNSHIP
RESIDUAL AVERAGE ANNUAL DAMAGE
SUMMARY TABLE - 150 FOOT BERM - ALL PLANS
(JUNE 1988 PRICE LEVEL) 8 5/8% INTEREST RATE

	DAMAGE IN THOUSANDS OF DOLLARS						
ECONOMIC REACH	8A	8B	9A	9B	10	11	TOTAL
150 FOOT PROJECT							
DAMAGE TO BUILDINGS							
PHYSICAL	$3.3	$0.0	$0.8	$0.0	$21.0	$123.1	$3,223.7
EMERGENCY	$0.2	$0.0	$0.0	$0.0	$0.5	$3.1	$154.5
LOST INCOME	$0.1	$0.0	$0.0	$0.0	$0.1	$1.3	$40.3
BUILDING TOTAL (NO AFFLUENCE)	$3.5	$0.0	$0.8	$0.0	$21.6	$127.5	$3,418.5
ADJUSTMENT FOR AFFLUENCE	$0.1	$0.0	$0.0	$0.0	$0.9	$5.5	$83.9
BUILDING TOTAL (W/ AFFLUENCE)	$3.7	$0.0	$0.8	$0.0	$22.4	$133.0	$3,502.4
DAMAGE TO SEAWALLS	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
DAMAGE TO ROADS AND INFRASTRUCTURE	$0.0	$0.0	$0.0	0.0	0.3	$21.8	$22.2
PUBLIC EMERGENCY COSTS	$0.0	$0.0	$0.0	$0.0	$0.2	$0.4	$2.2
TOTAL RESIDUAL DAMAGES (NO AFFLUENCE)	$3.5	$0.0	$0.8	$0.0	$22.2	$149.7	$3,442.8
TOTAL RESIDUAL DAMAGES (W/ AFFLUENCE)	$3.7	$0.0	$0.8	$0.0	$23.0	$155.2	$3,526.7

TABLE D-19

SUMMARY OF AFFLUENCE CALCULATIONS

What is the Income Growth Rate Type?   2 = Projected Incomes

How many years to the base year?   5

Input personal income projections at present, at base year, and subsequent 10-year intervals up to Base Year + 50. There should be seven figures, each separated by a comma.

6880,7663,8662,9432,10183,11020,11926

Subperiod Growth Rates are:

2.18

1.25

0.86

0.77

0.79

0.79

What % of residential value is contents?   28%

Years After Base	Base Factor	% Contents
0	1.114	31.2
10	1.259	35.3
20	1.371	38.4
30	1.480	41.4
40	1.602	44.6
50	1.733	48.5

Growth assumed to end after 50 years.

Public Emergency Costs

D94. The costs of additional public services during storm events were analyzed using data provided by the municipalities for various storms. The towns of Deal and Loch Arbour did not report any historic costs. In order to estimate the emergency costs, it was assumed that costs would vary in relationship to damages to buildings. Data provided by Monmouth Beach indicated higher damages during the March 1984 Storm than for other storms of greater intensity. This inconsistency was apparently caused by the failure of a portion of the seawall leading to additional evacuation and public housing costs. Damage frequency curves were developed for each community. Because no recorded historic data was available for a major flood event, the curves were extrapolated using the general shape of the damage frequency curves for buildings in combination with historic data for the March 1984 Northeaster and Hurricane Gloria, September 1985.

D95. Residual emergency costs were calculated based on the ratio of residual damage to buildings vs. the without project damage to buildings.

Seawall Maintenance Costs

D96. Maintenance costs upon implementation of the various alternatives are reported as a portion of the annual project costs. Costs presently being expended by the State to maintain the existing seawall therefore become a project benefit. Historic data on maintenance costs were supplied by the State of New Jersey Department of Environmental Protection, Division of Coastal Resources for a period of record from 1963 to 1983 for the towns of Sea Bright and Monmouth Beach. The data was updated to June 1988 price levels using the consumer price index and then averaged over the reporting record. For Sea Bright the total expenditure for the 20-year period was $7,780,000 adjusted to June 1988 price levels, which yields an annual maintenance cost of $389,000. Based on a total of 20,495 linear feet, the average annual maintenance cost per linear foot of seawall in Sea Bright is estimated to be $18.98. In Monmouth Beach the 9455 lineal feet of seawall has received $1,023,000 in 1988 dollars for maintenance over the 20 year period of record, yielding an average annual maintenance cost of $5.41 per linear foot.

D97. South of Monmouth Beach there is a seawall at Long Branch and Deal. Unlike the Sea Bright and Monmouth Beach seawall both of these structures are backed by a bluff and no data was available on historical maintenance. For the purpose of benefit analysis, it was therefore assumed that no maintenance is presently performed south of Monmouth Beach.

D98. Within the two towns where maintenance is being performed, which encompasses reaches 1-5, the cost per lineal foot of seawall was utilized in conjunction with the footage of seawall to evaluate the per reach benefit. Tables D-13 through D-15 show the results of the calculation.

ERODED LAND VALUES

D99. Under the without project scenario the project area is subject to a loss of land due to long-term erosion. The value of this land represents a potential project benefit as long term erosion will be halted by the project nourishment program. The nourishment program will prevent future losses of property to long term erosion resulting in a project benefit. To quantify land loss damages the acreage subject to erosion was identified. This was accomplished by initially obtaining the ocean frontage for each reach and then applying the long-term historic erosion rate of 3 feet per year. As described earlier in the appendix, long-term erosion was assumed to be halted at the leading edge of seawalls and road system paralleling the beach, based on anticipated intervention by man. Review of shoreline development and erosion protection structures indicated that actual loss of developed land is limited to economic reaches 8A, 9A and 11. Land loss in other reaches consist primarily of beach area and recreation lands. For each town existing land values, as indicated in Table D-20, were established by gross value estimates and then applied to the potential acreage lost per year for the fifty year project life. These values are representative of nearshore land. A present worth analysis was then performed on the results. The sum of the present worth figures was amortized over the life of the project using an interest rate of 8-5/8%, yielding an average overall damage for eroded land. A detailed description of the procedures utilized in establishing the real estate appraisal is contained in Sub-Appendix D-1 "Land Appraisal Attachment". Since under with project conditions long-term erosion will be halted by annual nourishment this figure represents the average annual benefit associated with lost land. Table D-21 is a sample calculation of the analysis.

D99A. As previously noted a significant portion of the without project erosion would consist of beach area and recreation lands. This area includes four significant public recreation areas; Sea Bright public beach; Monmouth public beach; Seven Presidents County Park; and the Long Branch public beaches. The recreation output of these beaches is anticipated to decline as long term erosion eliminates the existing dry beach area. Current recreation output of these areas, summarized in Table D21A, was determined using the without project willingness to pay (WTP) as described under recreation benefits in conjunction with 1985 attendance using the following formula:

$$\text{Existing Value of Beach} = \text{\# of passes Sold at Beach} \div \text{Total Passes in Survey Area} * \text{Existing Value for Survey Area}$$

The value of lost recreation land was calculated in each year of the project life based on the percentage of usable area eroded. A present worth analysis was then performed on the results and the sum of the present worth figures was amortized over the project life resulting in annual benefits of $881,000.

REDUCED MAINTENANCE AT SANDY HOOK

D100. Immediately to the north of the project limit in the Sandy Hook unit of the Gateway National Park is a severe erosion area subject to washovers and breaching. Based on the existing conditions sediment budget analysis, the littoral drift deficit at the Sandy Hook critical zone is approximately 101,000 cubic yards annually. Construction of a beach fill only project at Sea Bright to Ocean Township will eliminate this deficit. This will result in a fill maintenance reduction cost to the National Park Service which has initiated a beach restoration program to protect the only access road and recreation support facilities.

D101. Construction of a maintenance project would be accomplished by a 27-inch pipeline dredge. The borrow area offshore of the critical zone would be utilized with an overfill factor of 1.06. The maintenance cycle would be six years. The annual cost (benefit) would be $1,702,133 annually. Table D-22 details this calculation.

D102. Fill Only Plan. Construction of a fill only erosion control plan from Sea Bright to Ocean Township will eliminate the littoral drift deficit and resulting erosion problem at Sandy Hook. Accordingly, the entire $1,702,133 would be a project benefit. This benefit is independent of berm width.

TABLE D-20

Sea Bright to Ocean Township
Value of Eroded Land Under Existing and Without Project Conditions

Location	Lineal Feet		Price per lineal foot		Gross Land Value Estimate	Price per lineal foot		Setback Distance of Land Appraisal (lineal foot)		Price per square foot
Loch Arbour	1,075	@	$5,000	=	$5,375,000	$5,000	/	250	=	$20
Deal	8,614	@	$5,000	=	$43,070,000	$5,000	/	250	=	$20
Long Branch	22,268	@	$4,500	=	$100,206,000	$4,500	/	250	=	$18

SEABRIGHT TO OCEAN TWP.
EROSION BENEFITS CALC SHEET
REACH 9A
RATE 8.625%

TABLE D-21 SAMPLE CALCULATIONSOF AVERAGE ANNUAL BENEFITS FOR LOST LAND
JUNE 1988 PRICE LEVEL
PROJECT LIFE 50 YEARS

DATE YEAR	PROJECT YEAR	LAND LOST L.F.	LAND VALUE $/SF	VALUE IN YEAR	PWF	PRESENT WORTH	CRF 50	AAD INCREMENT
1985			$20	0		$0	0.08765	
1986		1330	$20	$79,800		$0	0.08765	
1987		2660	$20	$159,600		$0	0.08765	
1988		3990	$20	$239,400		$0	0.08765	
1989		5320	$20	$319,200		$0	0.08765	
1990		6650	$20	$399,000		$0	0.08765	
1991	1	6601	$20	$396,060	0.9206	$364,612	0.08765	$31,958
1992	2	6552	$20	$393,120	0.8475	$333,170	0.08765	$29,202
1993	3	6503	$20	$390,180	0.7802	$304,422	0.08765	$26,683
1994	4	6454	$20	$387,240	0.7183	$278,138	0.08765	$24,379
1995	5	6405	$20	$384,300	0.6612	$254,110	0.08765	$22,273
1996	6	6356	$20	$381,360	0.6087	$232,143	0.08765	$20,347
1997	7	6307	$20	$378,420	0.5604	$212,063	0.08765	$18,587
1998	8	6258	$20	$375,480	0.5159	$193,708	0.08765	$16,979
1999	9	6209	$20	$372,540	0.4749	$176,931	0.08765	$15,508
2000	10	6160	$20	$369,600	0.4372	$161,597	0.08765	$14,164
2001	11	6092	$20	$365,520	0.4025	$147,124	0.08765	$12,895
2002	12	6024	$20	$361,440	0.3705	$133,930	0.08765	$11,739
2003	13	5956	$20	$357,360	0.3411	$121,904	0.08765	$10,685
2004	14	5888	$20	$353,280	0.3140	$110,944	0.08765	$9,724
2005	15	5820	$20	$349,200	0.2891	$100,955	0.08765	$8,849
2006	16	5752	$20	$345,120	0.2661	$91,853	0.08765	$8,051
2007	17	5684	$20	$341,040	0.2450	$83,560	0.08765	$7,324
2008	18	5616	$20	$336,960	0.2256	$76,005	0.08765	$6,662
2009	19	5548	$20	$332,880	0.2077	$69,123	0.08765	$6,059
2010	20	5480	$20	$328,800	0.1912	$62,854	0.08765	$5,509
2011	21	5479	$20	$328,740	0.1760	$57,853	0.08765	$5,071
2012	22	5478	$20	$328,680	0.1620	$53,250	0.08765	$4,667
2013	23	5477	$20	$328,620	0.1491	$49,013	0.08765	$4,296
2014	24	5476	$20	$328,560	0.1373	$45,113	0.08765	$3,954
2015	25	5475	$20	$328,500	0.1264	$41,523	0.08765	$3,640
2016	26	5474	$20	$328,440	0.1164	$38,219	0.08765	$3,350
2017	27	5473	$20	$328,380	0.1071	$35,178	0.08765	$3,083
2018	28	5472	$20	$328,320	0.0986	$32,379	0.08765	$2,838
2019	29	5471	$20	$328,260	0.0908	$29,803	0.08765	$2,617

SEABRIGHT TO OCEAN TWP.
EROSION BENEFITS CALC SHEET
REACH 9A
RATE 8.625%

TABLE D-21 SAMPLE CALCULATIONSOF AVERAGE ANNUAL BENEFITS FOR LOST LAND
JUNE 1988 PRICE LEVEL
PROJECT LIFE 50 YEARS

DATE YEAR	PROJECT YEAR	LAND LOST L.F.	LAND VALUE $/SF	VALUE IN YEAR	PWF	PRESENT WORTH	CRF 50	AAD INCREMENT
2020	30	5470	$20	$328,200	0.0836	$27,431	0.08765	$2,404
2021	31	5444	$20	$326,640	0.0769	$25,133	0.08765	$2,203
2022	32	5418	$20	$325,080	0.0708	$23,027	0.08765	$2,018
2023	33	5392	$20	$323,520	0.0652	$21,097	0.08765	$1,849
2024	34	5366	$20	$321,960	0.0600	$19,328	0.08765	$1,694
2025	35	5340	$20	$320,400	0.0553	$17,707	0.08765	$1,552
2026	36	5314	$20	$318,840	0.0509	$16,222	0.08765	$1,422
2027	37	5288	$20	$317,280	0.0468	$14,861	0.08765	$1,303
2028	38	5262	$20	$315,720	0.0431	$13,614	0.08765	$1,193
2029	39	5236	$20	$314,160	0.0397	$12,471	0.08765	$1,093
2030	40	5210	$20	$312,600	0.0365	$11,423	0.08765	$1,001
2031	41	5192	$20	$311,520	0.0336	$10,480	0.08765	$919
2032	42	5174	$20	$310,440	0.0310	$9,614	0.08765	$843
2033	43	5156	$20	$309,360	0.0285	$8,820	0.08765	$773
2034	44	5138	$20	$308,280	0.0262	$8,092	0.08765	$709
2035	45	5120	$20	$307,200	0.0242	$7,423	0.08765	$651
2036	46	5102	$20	$306,120	0.0222	$6,810	0.08765	$597
2037	47	5084	$20	$305,040	0.0205	$6,247	0.08765	$548
2038	48	5066	$20	$303,960	0.0189	$5,730	0.08765	$502
2039	49	5048	$20	$302,880	0.0174	$5,257	0.08765	$461
2040	50	5030	$20	$301,800	0.0160	$4,822	0.08765	$423

LONG TERM
AAD = $365,247

TABLE D-21A

Existing Recreation Output

Project Area Public Beaches

(June 1988 Price Level)

Location	Daily Passes #	Daily Passes Value	Season Passes #	Season Passes Value	Total Value
Sea Bright	29,000	$120,945	461	$15,860	$136,805
Monmouth Beach	21,000	$87,955	887	$30,510	$118,465
Seven Presidents County Park	124,000	$517,550	2,828	$97,285	$614,835
Long Branch	90,000	$374,970	1,750	$60,200	$417,170
Totals for Project Area	264,000	$1,101,420	5,926	$203,855	$1,305,276
Totals for Survey Area	2,220,000	$9,258,540	48,491	$1,668,150	$10,926,690

(Rev. March 1990)

TABLE D-22

June 1988 Price Level
Project Life 50 Years

SANDY HOOK CRITICAL ZONE
MAINTENANCE REDUCTION BENEFIT
FILL ONLY PLAN @ 8-5/8 % INTEREST

YEAR	(A) FILL VOLUME (C.Y.)	(B) FILL UNIT COST ($)	(C) MOB & DEMOB COST ($)	(D) FILL FUTURE WORTH ($)	(E) TOTAL FUTURE WORTH ($)	(F) PRESENT WORTH FACTOR	(G) PRESENT WORTH ($)
1990	710,838	7.31	1,000,000	8,287,452	8,287,452	1.00000	8,287,452
1996	710,838	7.31	1,000,000	7,292,958	7,292,958	0.60873	4,439,407
2002	710,838	7.31	1,000,000	7,292,958	7,292,958	0.37055	2,702,379
2008	710,838	7.31	1,000,000	7,292,958	7,292,958	0.22556	1,645,006
2014	710,838	7.31	1,000,000	7,292,958	7,292,958	0.13730	1,001,357
2020	710,838	7.31	1,000,000	7,292,958	7,292,958	0.08358	609,551
2026	710,838	7.31	1,000,000	7,292,958	7,292,958	0.05088	371,049
2032	710,838	7.31	1,000,000	7,292,958	7,292,958	0.03097	225,867
2038	710,838	7.31	1,000,000	7,292,958	7,292,958	0.01885	137,491

TOTAL			$19,419,558
		CAPITAL RECOVERY FACTOR	0.08765
TOTAL INITIAL FILL VOLUME (C.Y.)	710,838		
		ANNUAL COST	$1,702,133
TOTAL FIRST COST OF FILL	$8,287,452		
ANNUAL FILL COST	$1,702,000		
TOTAL ANNUAL BENEFIT	$1,702,000		

NOTE: D=((AXB)+C)X(1+CONTINGENCY)X(1+ENGINEERING&DESIGN(%)+SUPERVISION&INSPECTION(%))
25 % CONTINGENCY FOR INITIAL PROJECTS
10 % CONTINGENCY FOR MAINTENANCE PROJECTS
3.0 % E&D 4.0 % S&A

INTEREST RATE = 8.625 % CAPITAL RECOVERY FACTOR = 0.08765

D103. Authorized Groin Plan. Construction of the authorized groins is expected to reduce the loss of fill within the groin field by 15%. This would decrease the fill maintenance benefit at Sandy Hook. The annual benefit for this plan would be $1,489,678. These benefits are also independent of berm width.

D104. Updated Groin Plan. The updated groin plan was designed to reduce the littoral drift potential at the north end of the project to the existing rate of sediment movement. No significant reduction of erosion is anticipated for this erosion control plan.

INTENSIFICATION BENEFITS

D105. The plans of improvement will create intensification benefits. Intensification benefit is defined in ER1105-2-40, Section IV, pages 2.4.2(b)(2) as follows:

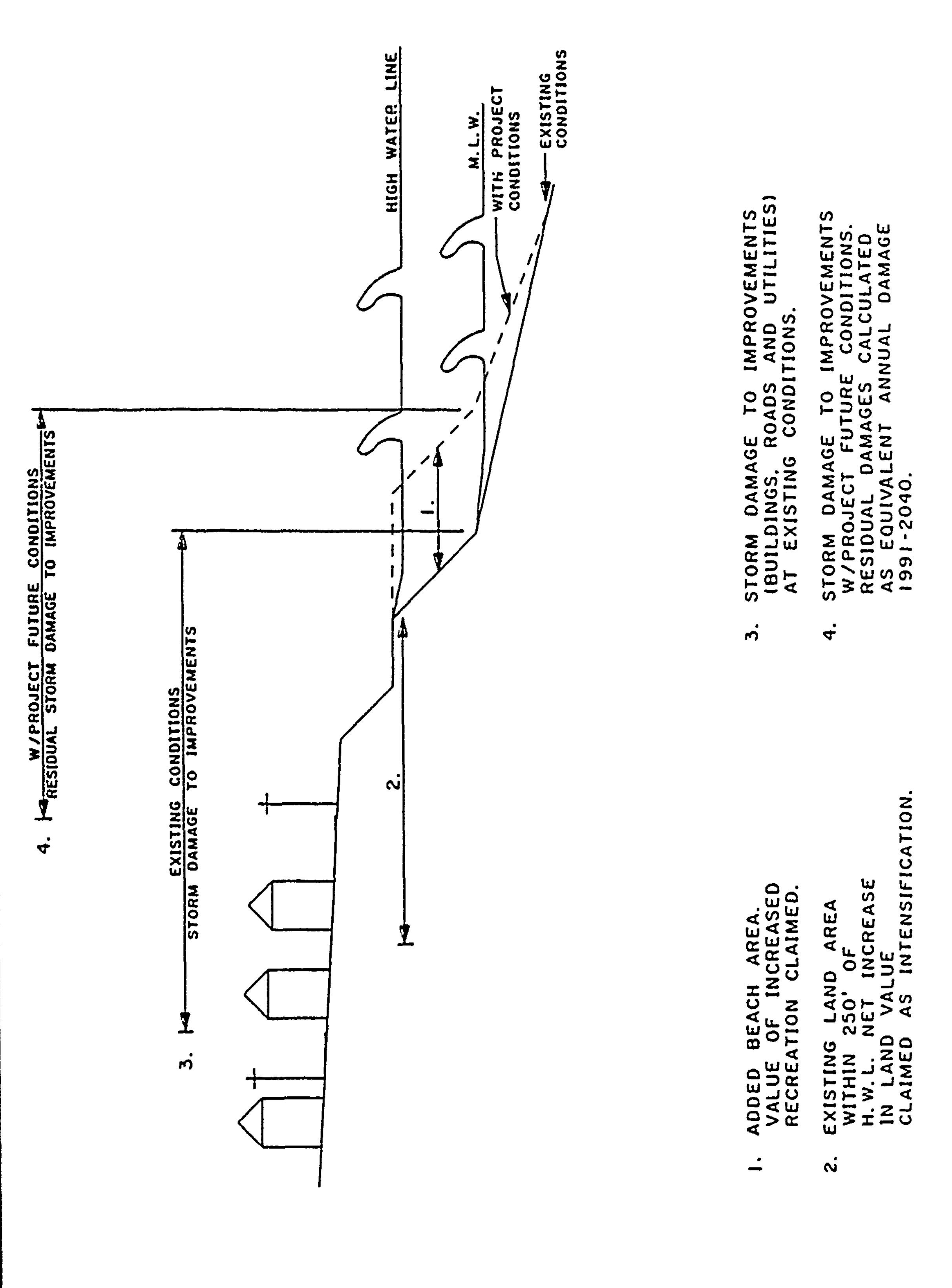
"(2) Intensification benefit. If the type of floodplain use is unchanged but the method of operation is modified because of the plan, the benefit is the increased net income generated by the floodplain activity."

Paragraph 2.4.13(b) of the same document contains instruction on calculating intensification benefits as follows:

"(b) Land use is same but more intense with project. If land use is the same but more intense, as when an activity's use of the floodplain is modified as a result of the project, base determination of the increase in income on increased land values."

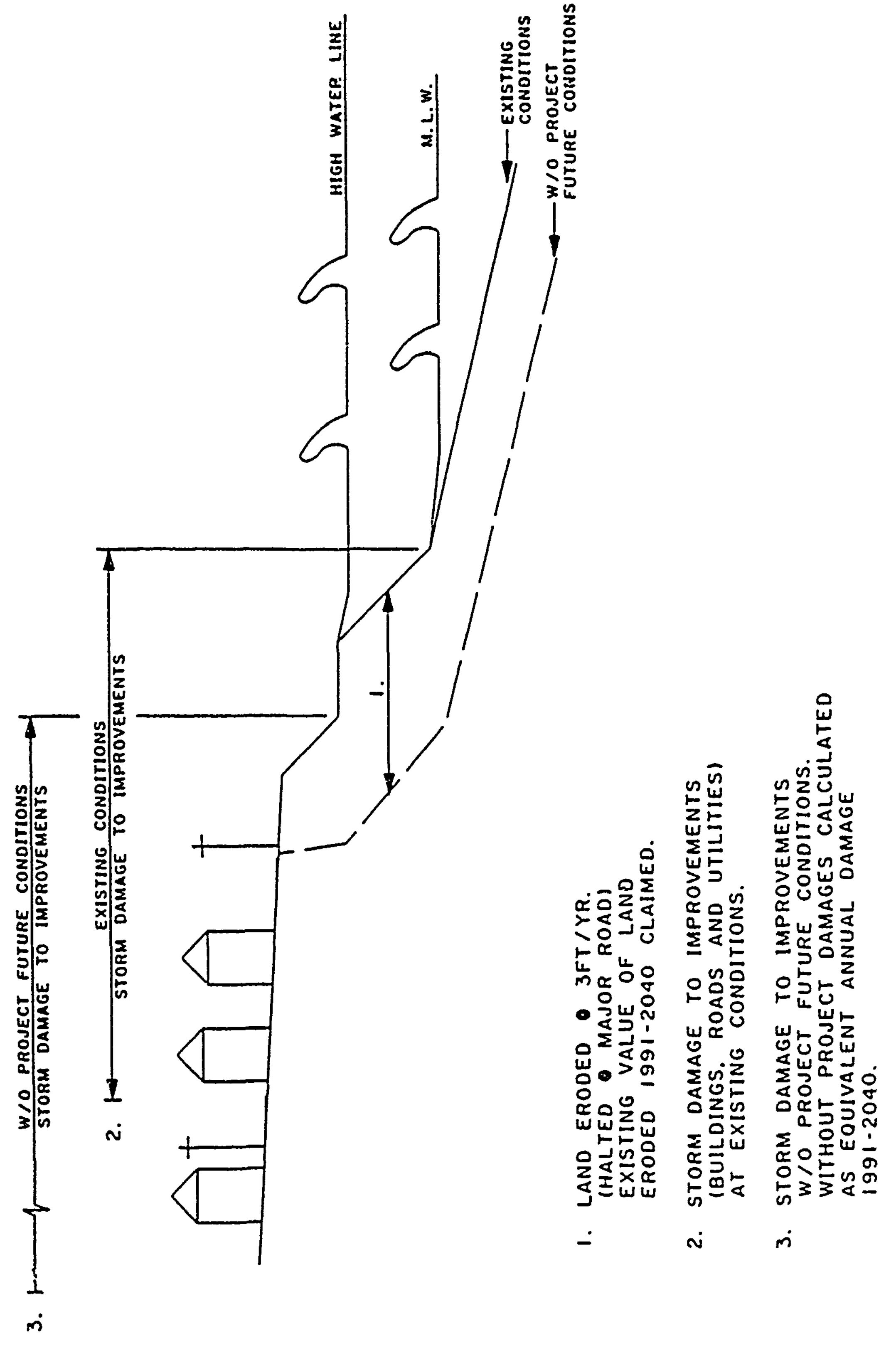
D106. Sub-Appendix D-1 "Land Appraisal Attachment" details the appraisal methodology utilized in determining the intensification benefit for the overall project. The added values of land resulting from the project is $92,650,000 which has been annualized over the 50-year project life to provide a net benefit of $8,121,000.

D107. This increased land value is driven by the storm protection erosion control accomplishments of the project. A local example of this process is the area near 7 Presidents Park in North Long Branch where a minimal protective beach has been maintained. Development has intensified from primarily older single and multi-family rental housing towards high quality townhouses and condominiums.



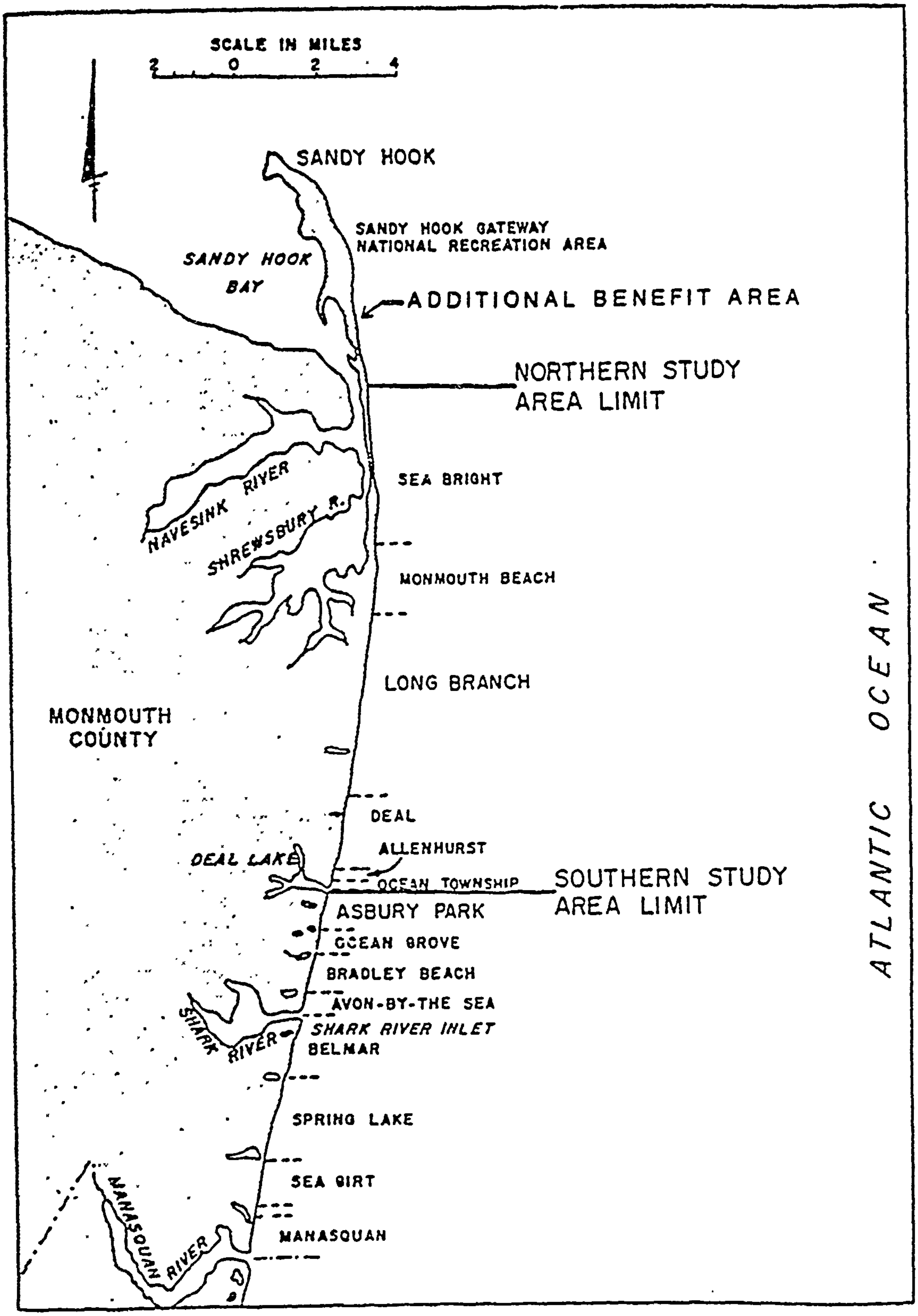
SCHEMATIC OF BENEFIT LOCATIONS

FIGURE D-1



SCHEMATIC OF DAMAGE LOCATIONS

FIGURE D-2



LOCATION OF STUDY AREA

FIGURE D3

COMBINED DAMAGE CALCULATION FLOW NET

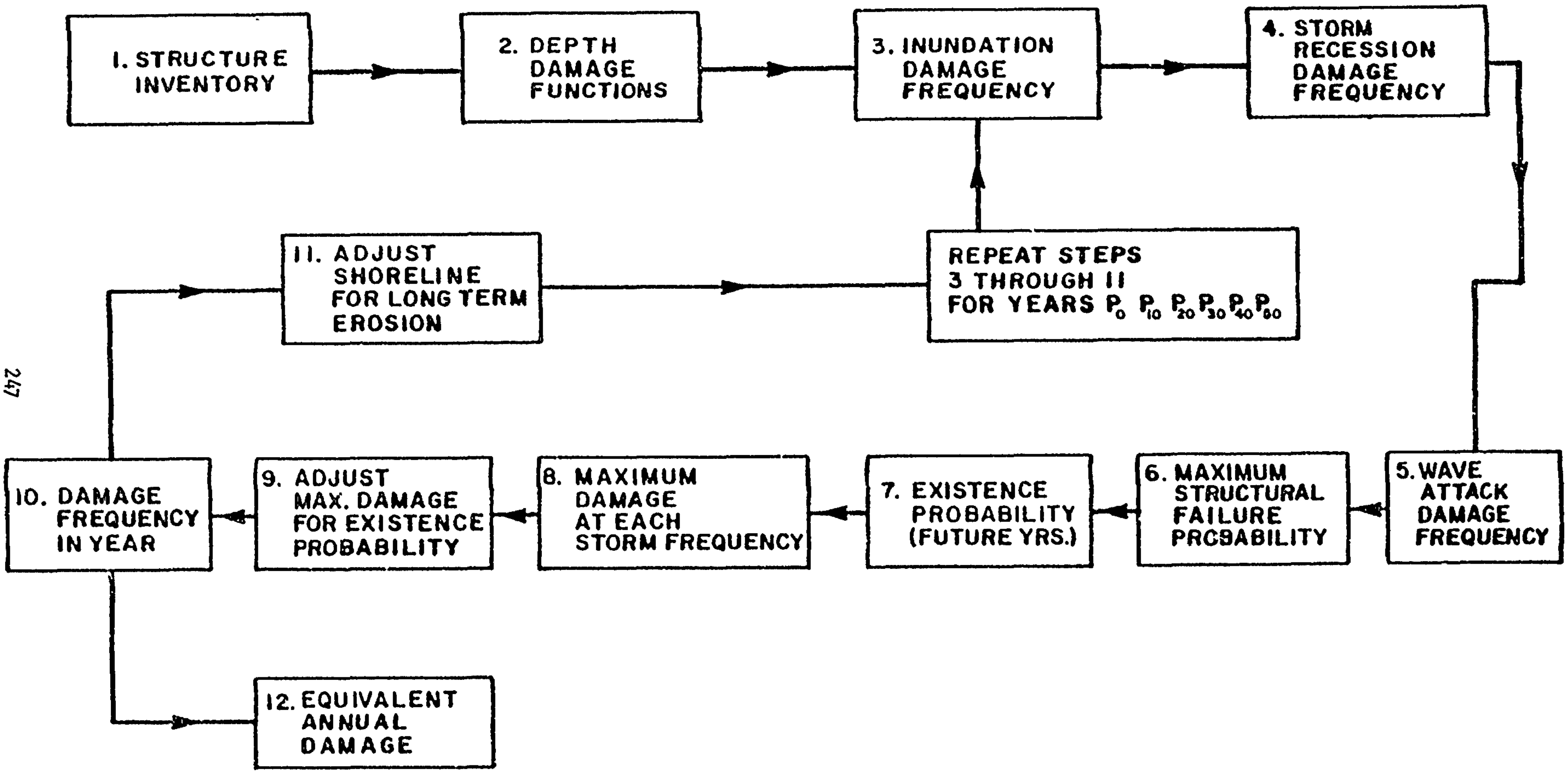
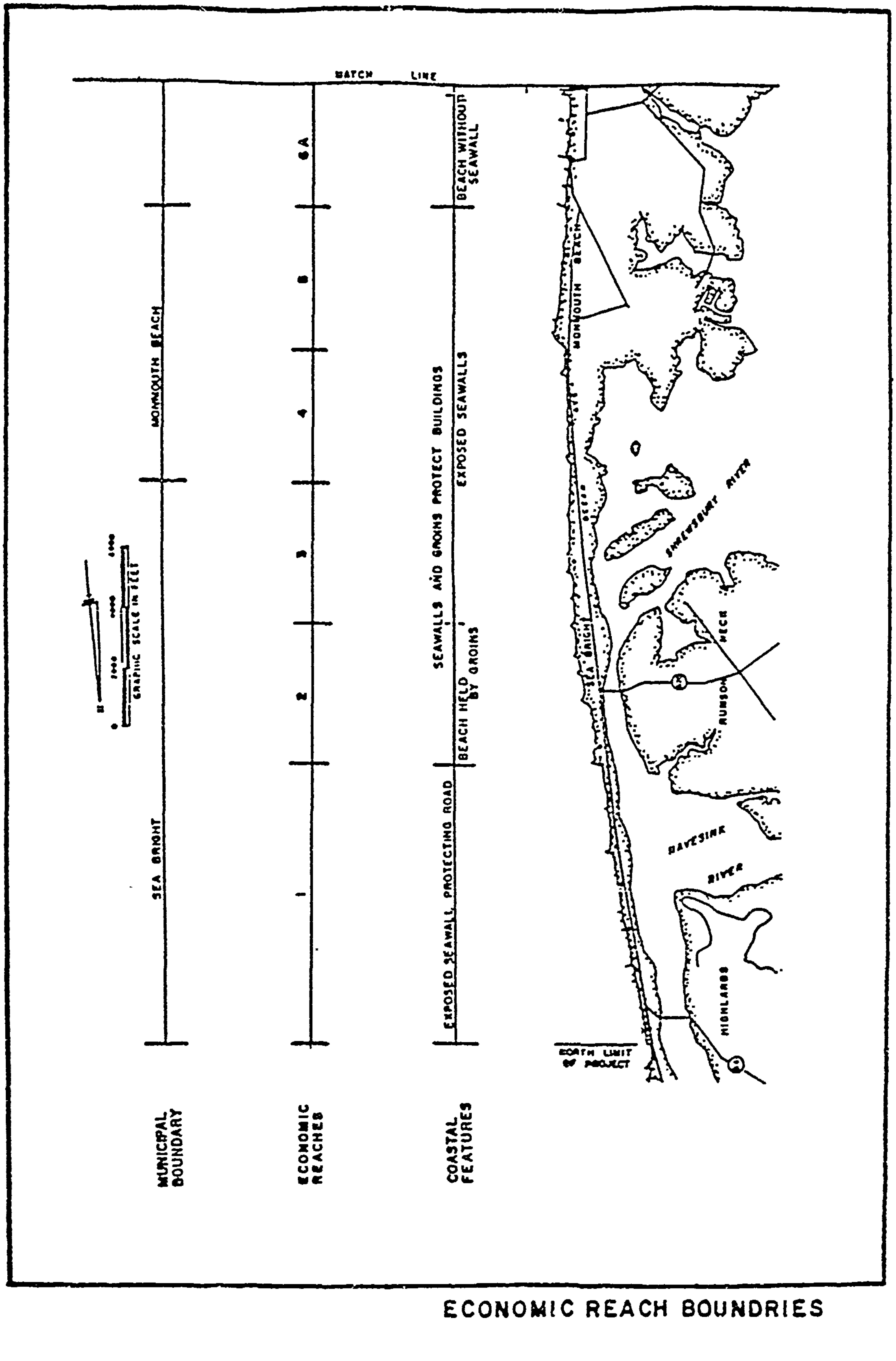
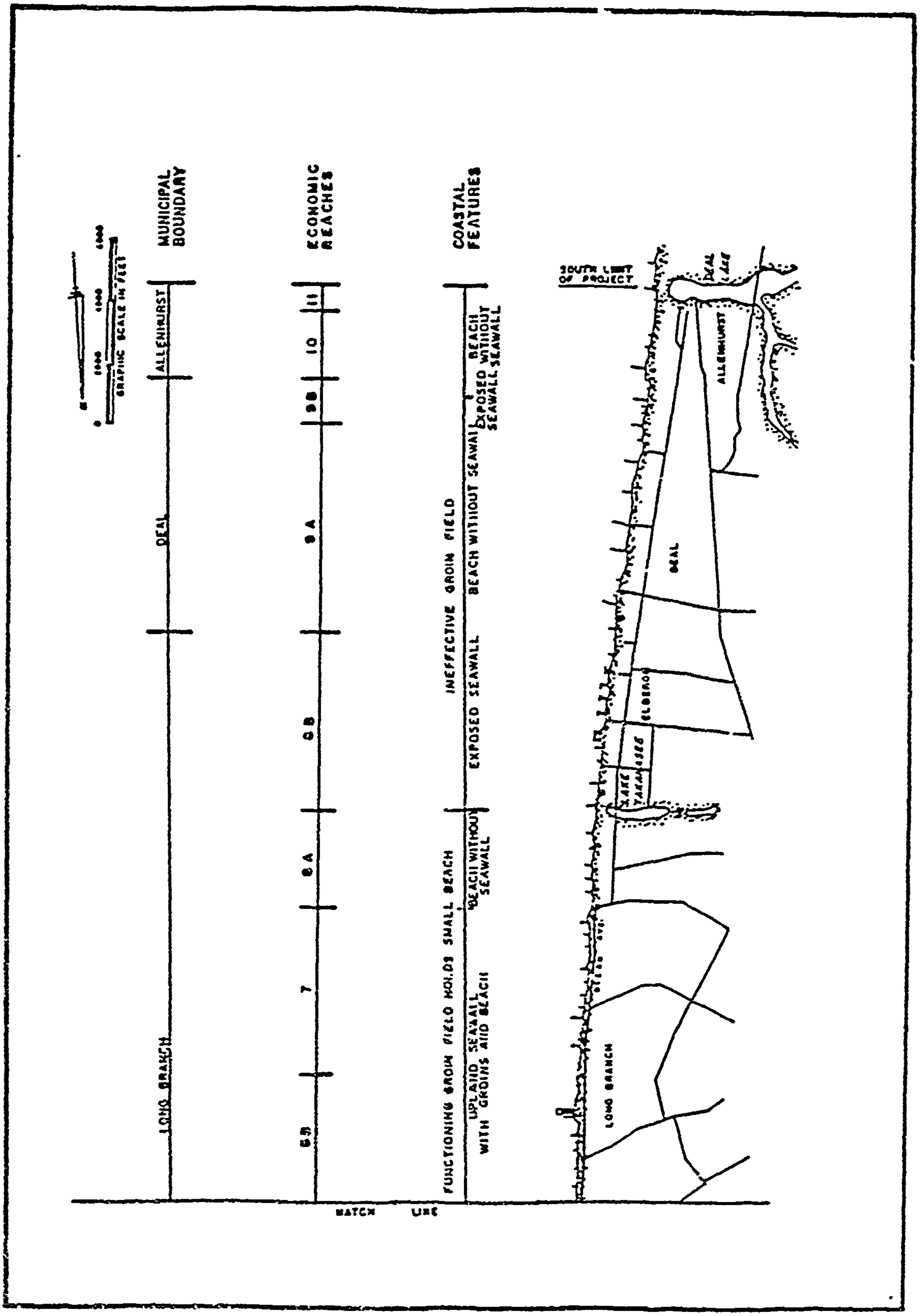


FIGURE D4



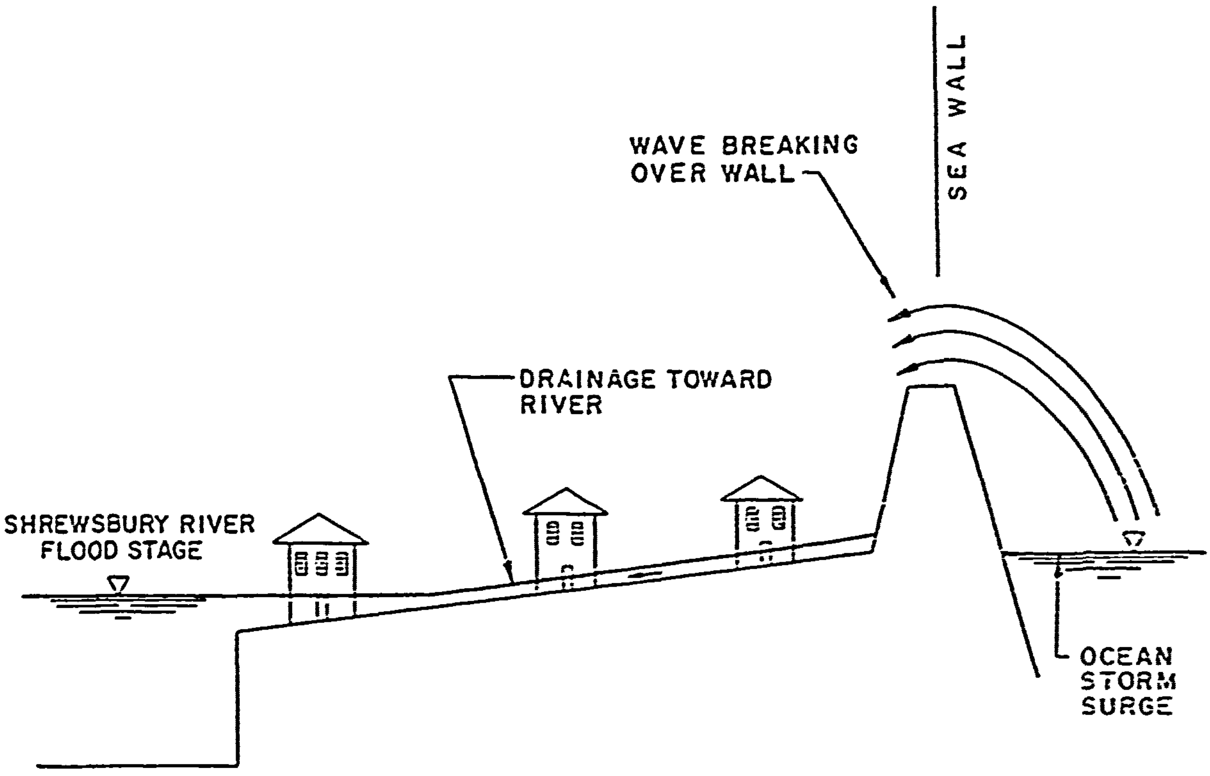
ECONOMIC REACH BOUNDRIES

FIGURE D5



ECONOMIC REACH BOUNDRIES

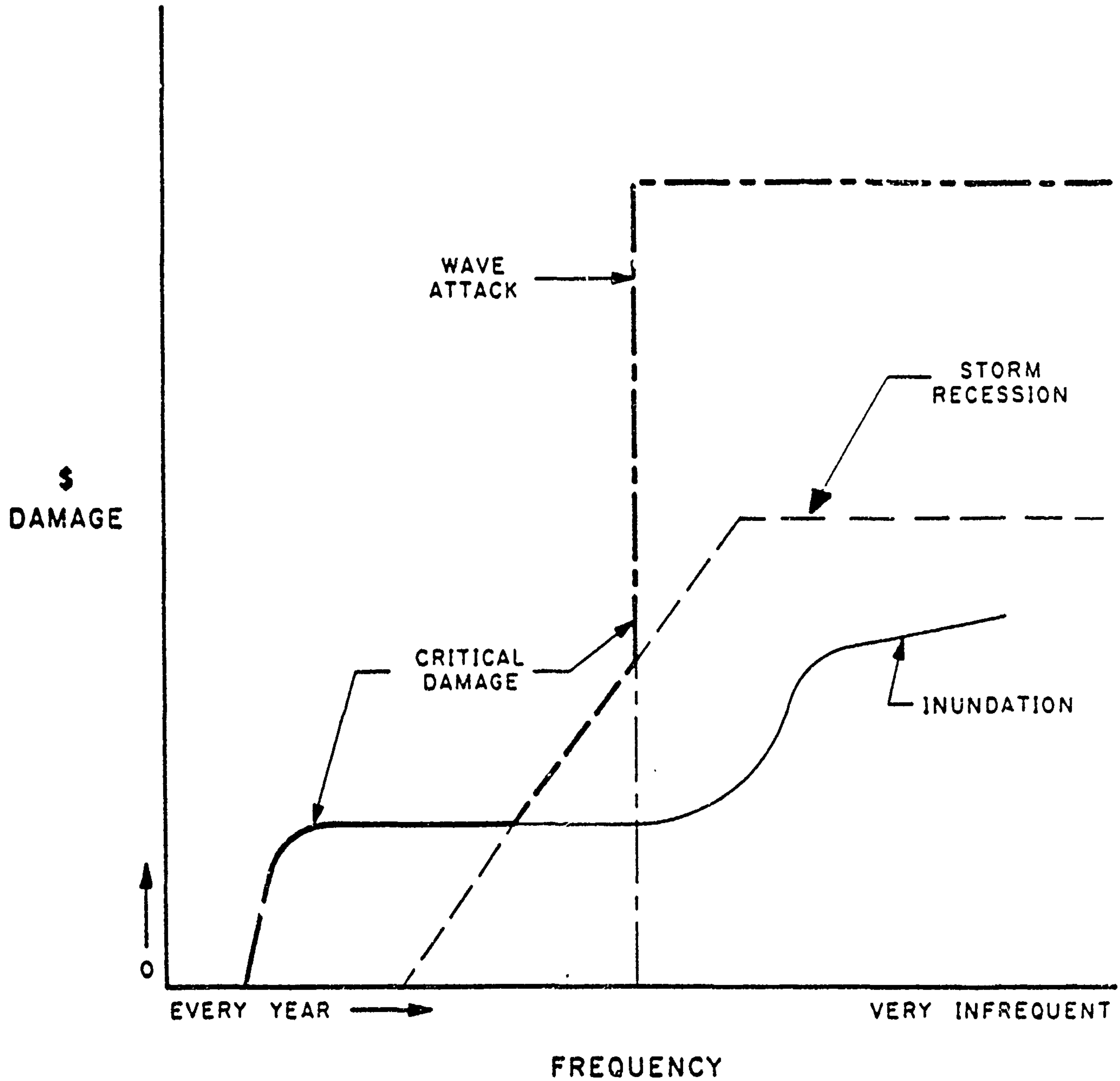
FIGURE D(



SCHEMATIC OF FLOODING
BEHIND SEA WALL

FIGURE D-7

HOUSE 'A'



SCHEMATIC OF CRITICAL DAMAGE ANALYSIS

FIGURE D-8

APPENDIX C

AN EXAMPLE OF SHORELINE DAMAGE ASSESSMENT

US Army Corps
of Engineers
Los Angeles District

SANTA BARBARA COUNTY

BEACH EROSION AND STORM DAMAGE REDUCTION

RECONNAISSANCE STUDY

AMENDED FINAL REPORT

FEBRUARY 1990

255

APPENDIX A

COASTAL PROCESSES

Part II

Methodology for Shoreline Damage Assessment

1. Introduction

The primary objective of this analysis is to predict the maximum landward extent of damage to shorefront properties by storms during extreme events for three assigned locations within Santa Barbara County: East Beach, Miramar Beach, and Carpinteria Beach. Storms under consideration for this analysis, called "design storms", are characterized by their return (or recurrence) intervals: 15, 25, 50, and 100 years.

One of the most important factors affecting the extent of wave front encroachment on shorefront property is the sea level. Various processes contribute to raising the sea level during the storm, among them the global climatic fluctuations (such as ENSO: El Nino Southern Oscillation), storm surges associated with barometric pressures, wind setup, wave setup and surf beat, and the astronomical tide. The previous FEMA study evaluating 100-year coastal flooding potentials took into consideration only some of these processes (Lee et al., 1982). In particular, the FEMA study ignored the global climatic fluctuations and further considered wind setup as insignificant in southern California. However, these factors proved to be of critical importance in the disastrous 1982-83 winter storms which occurred immediately after the FEMA methodology had been established.

In this assessment of wave front encroachment, the global climatic fluctuations and wind setup are taken into consideration. Additionally, this assessment incorporates the effect of shoreline retreat in the evaluation of horizontal excursion of the wave front - a feature which was also missing in the FEMA study. Other additional factors incorporated in this assessment are: storm duration, wave direction, and shore topography.

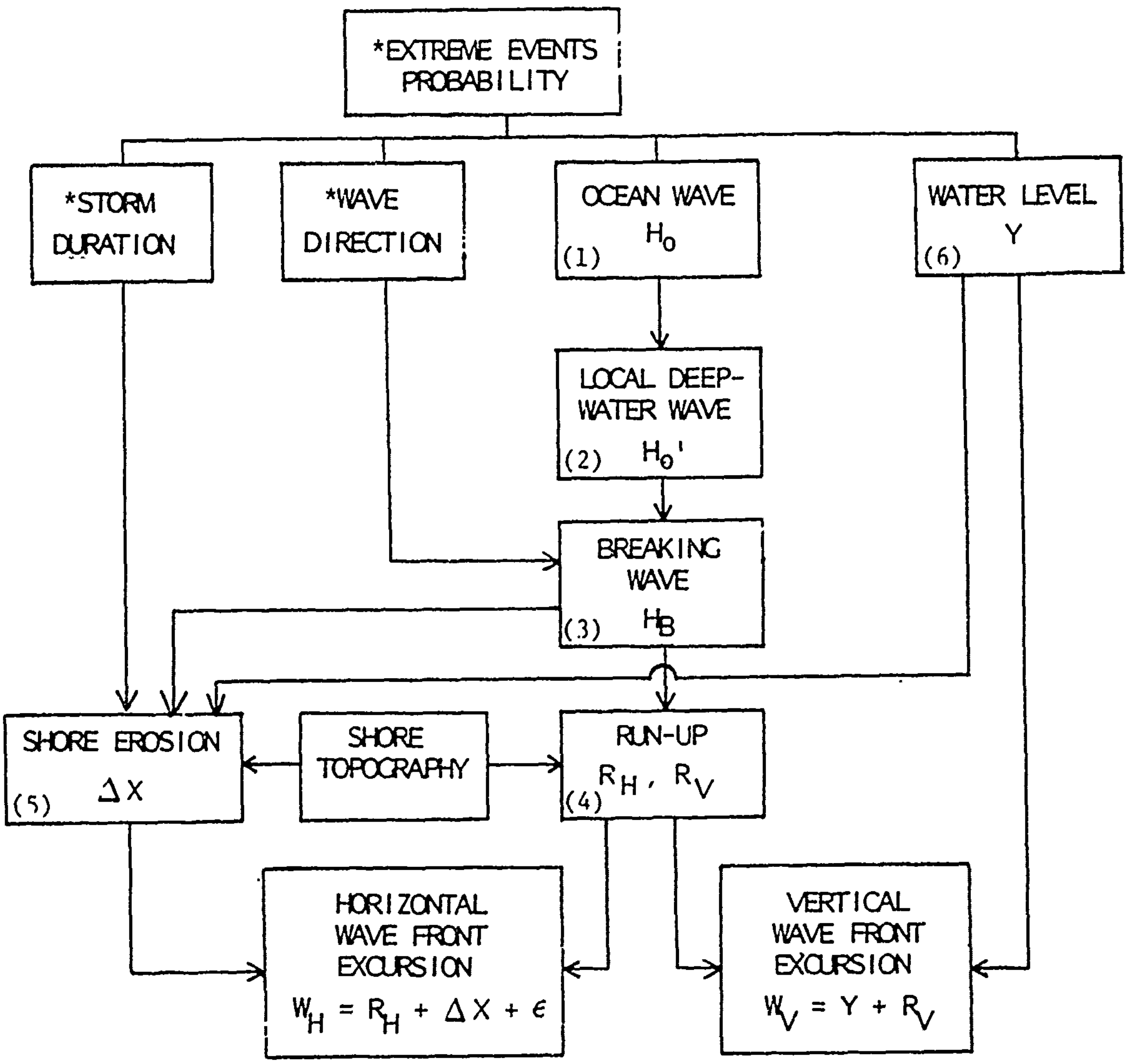
Following are two sections: the first presents a summary of the computational methodology employed to derive the landward extent of shoreline damage, and the second presents details regarding the available sources of data needed for input to the methodology, and the characteristics of the data selected for use.

2. Summary of Computational Methodology

Figure A-1 shows the flow diagram of the computations in which the wave front encroachment on the shorefront properties are computed as a function of the frequency of occurrence of design storms. The end products of these computations are the horizontal and vertical positions of the maximum wave front encroachment occurring during the design storm.

FIGURE A-1:

FLOW DIAGRAM FOR SHORELINE DAMAGE ASSESSMENT COMPUTATIONS



NOTE:

(1) WES SEAS (Sea-State Engineering Analysis System) hindcast data between 1956-1975 at 34.22 N (lat.) and 121.48 W (long.).
(2) Regression between the simultaneous hindcast data in the ocean and within Santa Barbara Channel since 1973, by Pacific Weather Analysis (1987).
(3) National Marine Consultants (1960) refraction study: "Oceanographic Study - Santa Barbara, California, 92 NMC-CE (60)".
(4) Holman, R.A., 1986: "Extreme Value Statistics for Wave Run-Up on a Natural Beach", Coastal Eng., 9 (1986), 527-544.
(5) Kriebel, D.L. (1982): "Beach and Dune Response to Hurricanes", M.S. Thesis, Univ. of Florida, Gainesville, FL, 313 p. & Appendix.
(6) Chiu, T.Y. and R. G. Dean, 1984: "Methodology on Coastal Construction Control Line Study", Department of Natural Resources, Division of Beaches and Shores, State of Florida, 169 p.
(7) NOAA Tide Gage Data at Santa Monica Pier, 1933-82.

(*) Simulated by random numbers.

The horizontal excursion, expressed W_H, is a sum of horizontal wave runup shoreward of the existing water level R_H, the net shoreline recession caused by the storm ΔX, and all other effects affecting the shoreline position, expressed as ε, including specifically the seasonal setback of the shoreline and the cumulative recession due to a continuous long-term recession (assumed in this analysis to be 0 ft/yr, and will be determined during the feasibility study.

$$W_H = R_H + \Delta X + \varepsilon \tag{1}$$

Note that the horizontal wave runup R_H is referenced to the water level occurring at the time of the storm, thus including the effect of storm surge if there is one. The vertical wave front excursion W_V is a sum of the water level at the time of the storm Y and the vertical wave runup R_V.

$$W_V = Y + R_V \tag{2}$$

A special effort was made to perform these computations with minimum of hypotheses. To simulate the statistics of ocean waves, a recent 20-year ocean wave hindcast study by Waterways Experiment Station was employed, using data for a location 34.22N (lat.) and 121.48W (long.), called SEAS (Sea-State Engineering Analysis System) Station No. 9, about 100 miles southwest of Point Conception. Although this data set does not include swell from the southern hemisphere, this deficiency is not critical to this study since it focuses on extreme wave events. Comparison of the SEAS data with other statistics available in this region shall be discussed in detail in the following section.

The procedure for deriving nearshore wave heights involves selecting design (deep-water) waves in the Pacific Ocean as given by the SEAS hindcast data and then propagating these waves to the project sites in two steps: first to deep-water locations in Santa Barbara Channel and then as far as the breaker line. The first step of this propagation process, i.e. from the Pacific Ocean into Santa Barbara Channel, is handled by comparing the simultaneous wave data for these two locations during major storms computed by Pacific Weather Analysis (1987) since 1973. In the second step, the deep-water waves in Santa Barbara Channel thus derived are refracted to the breaker line using the refraction/shoaling coefficients which have been generated in a prior study by the National Marine Consultants (1960). In the NMC study (1960), wave refraction/shoaling coefficients are available for three incident wave directions: 135 degrees, 255 degrees, and 270 degrees, at each of the project sites: East Beach, Miramar Beach, and Carpinteria Beach.

The computation of wave runup employs input from the breaking wave heights thus derived and the knowledge of shore topography. This computation is performed using Holman's (1986) study on wave runup on a natural beach which is based on extensive and reliable field data. Since the landward excursion of the wave front depends upon the horizontal erosion of the shoreline during the storm as well as the horizontal component of the wave run-up, shoreline erosion due to the storm must be determined in order to establish complete information of wave runup on the shore topography.

Computation of shoreline erosion requires input describing breaking wave heights, shore topography, and storm duration. This computation is performed using a numerical model developed by Kriebel (1982). The Kriebel model received a high rating as the best overall model of its kind in a recent review by CERC (Birkemeier et al., 1987). This model was also extensively calibrated against field data and utilized for the determination of setback lines by the State of Florida (Chiu and Dean, 1984). The water level during a design storm, which must be input into the Kriebel model, is based on the measured historical maximum annual water levels at the NOAA tide station at Santa Monica Pier between 1933 and 1982. This station has the longest tide measurements in the general vicinity, and the data from this station offers the best available approximation to the project sites since the elevations of tidal planes at this station are essentially similar to those at Santa Barbara.

Since it would be costly to carry out a simulation for the full range of variable beach topography, computations of both wave runup and shoreline erosion assume a single standard shore topography in which the beach face slope is 1V:10H, with a uniform berm height of 10 ft. This approach makes it possible to utilize the results of computations on shore erosion which have been already completed by Kriebel (1982). This hypothetical topography fits relatively well with typical beach profiles at East Beach. Since the shore topography at Miramar Beach and Carpinteria Beach departs from this standard condition, the local topography is taken into consideration when applying the results of damage assessment methodology to these sites.

There are three variables in the overall flow of computations which are probabilistic in nature. These are: extreme water levels, storm wave directions, and storm durations. In order to simulate the probabilistic nature of these variables, a random number scheme is employed in this study. The flow chart of this procedure is shown in Figure A-2. The method is essentially one of Monte Carlo simulation, in which a random number is generated to represent the combination of the extreme water level probability, storm duration, and wave direction for the design storm for each year. In this procedure, the first three digits of the random number were taken to express the exceedance probability of the year's maximum water level. The two ensuing digits represented the wave direction, and the last two the storm duration.

Damage assessment computations were performed only for extraordinary events as defined by the first three digits of the random numbers, namely the events with return intervals exceeding 15 years. For instance, if the first three digits of a random number were, say, 025, this meant that the maximum water level for this year had an exceedance probability of 0.025, corresponding to a return period of 40 years (= 1/0.025). Since this represents an extraordinary event, the subsequent steps of computation aiming at maximum storm wave front excursion were performed. If the three digits of the random number were instead 572, the maximum water level for this year represented a return period of only 1/0.572 = 1.75 years, a minor

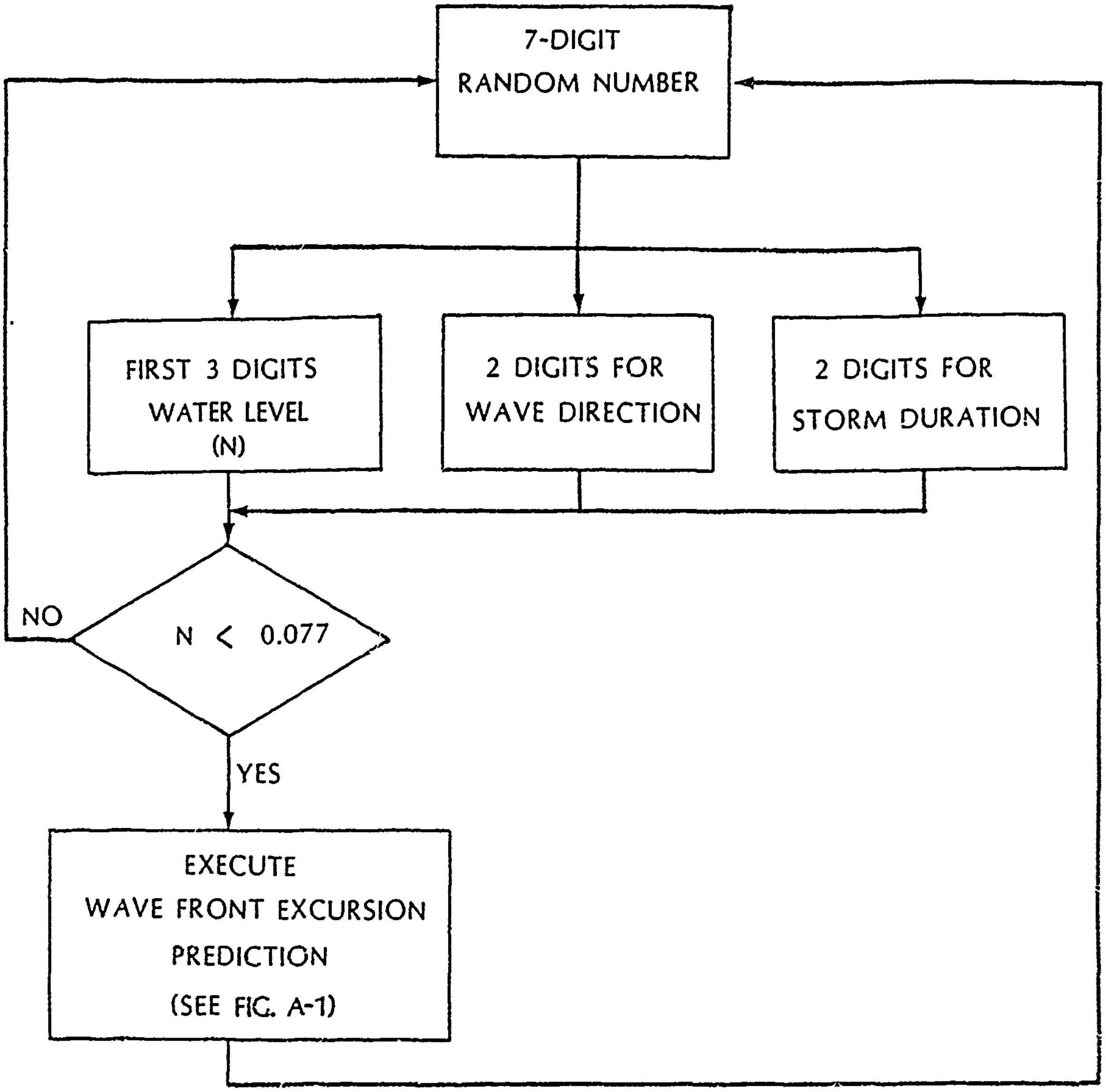


FIGURE A-2: FLOW DIAGRAM FOR MONTE CARLO PROCEDURES TAKING INTO ACCOUNT PROBABILISTIC VARIATIONS OF WATER LEVEL, WAVE DIRECTION, AND STORM DURATION storm, and the subsequent computations to derive wave front encroachment on the shorefront properties were abandoned.

The next two digits of the random number were considered to represent wave directions, 01 through 33 for SE, 34 through 66 for SW, and 67 through 00 for W. The last two digits were used to designate storm duration. Namely if these digits were 45, it meant that the storm continued for 45% of the time required to fulfill 99% of the steady state erosion.

These Monte Carlo procedures were repeated 100 times to simulate a history of extraordinary events for a continuous string of 100 years. Since the scenario of extraordinary events for any given 100-year duration will be probabilistic, a 100-year simulation was repeated a total of 10 times to take into account a range of variabilities of the 100-year history, resulting in a total simulation period of 1000 years.

It is important to recognize that the wave front encroachment distances predicted by the procedures described above define the extreme tip of the wave swash. Since the water at this point is too shallow to cause damage, an adjustment must be made to define encroachment values which could cause damages to the shorefront properties. The method for this adjustment is based on the assumption that the swash motion follows a Rayleigh distribution, and that the critical wave front value can be defined as representing an average of the one tenth highest run-up (about 76% of maximum run-up) values. From the point of view of damage assessment, the critical values of encroachment are deemed as being the farthest landward extent of total damage caused by a particular storm event.

The final products of the computational procedures presented above are summarized in Figures A-3 and A-4, which show the data points of the horizontal and vertical critical wave front encroachment distances versus their corresponding probability of occurrence for East Beach, Miramar Beach, and Carpinteria Beach. In order to identify the most conservative prediction of critical wave front encroachment, the boundary for the maximum values for different return interval storms was selected and is shown by the straight-line approximation in these figures. Table A-1 summarizes the predicted critical values for the various design storms at the respective study sites. Recalling that the methodology assumes a simplified beach topography in order to facilitate the computations, the application of these predicted values to the individual study sites must take into consideration the actual local topography.

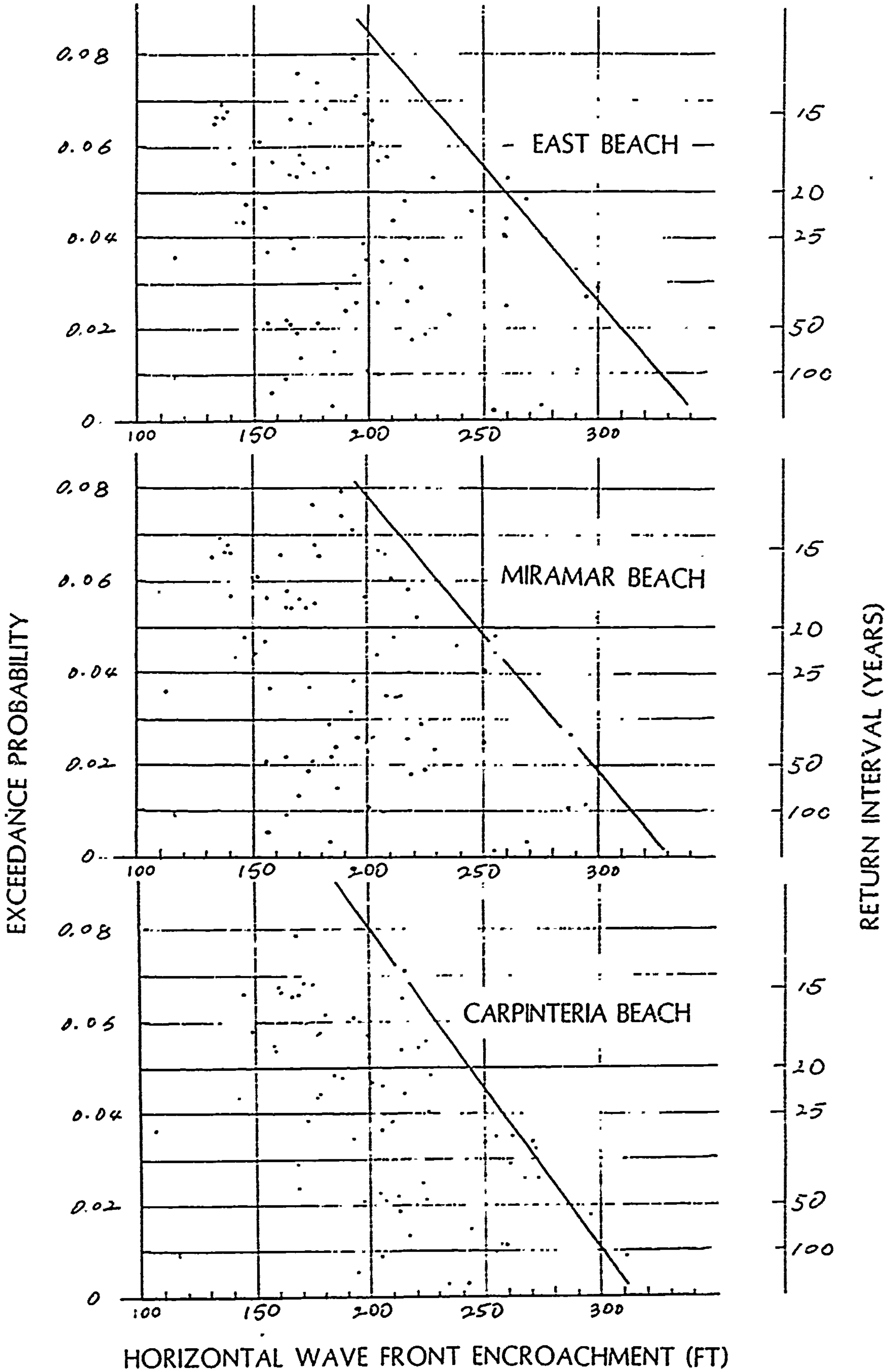


FIGURE A-3: PREDICTED MAXIMUM HORIZONTAL WAVE FRONT ENCROACHMENT

TABLE A-1

Predicted Critical Wave Front Encroachment under Design Storms

Return Interval	East Beach		Miramar B.		Carpinteria B.	
(Years)	W_H	W_V	W_H	W_V	W_H	W_V
15	230	11.7	220	11.6	216	11.4
25	275	12.3	264	12.3	255	12.2
50	310	12.9	298	12.9	286	12.9
100	325	13.3	313	13.3	300	13.2

Note: All the encroachment values are in feet referenced to the mean sea level (MSL) shoreline.

W_H= Horizontal critical wave front encroachment

W_V= Vertical critical wave front encroachment

APPENDIX D

AN EXAMPLE OF THE USE OF MONTE CARLO ANALYSIS

APPENDIX D

AN EXAMPLE OF THE USE OF MONTE CARLO ANALYSIS

The following is an example of a Monte Carlo simulation employed in the Final Feasibility Report on Hurricane Protection and Beach Erosion Control, West Onslow Beach and New River Inlet, North Carolina (Topsail Beach). Monte Carlo simulation was used in this case because without-project conditions could not be calculated in the same manner as in more typical shore protection evaluations. Only the section of the Topsail Beach report dealing with Monte Carlo simulation (i.e., the estimation of without-project average annual damages for one reach) is summarized below. For greater detail on other aspects of the study the reader should consult the final feasibility report and supporting documentation.[1]

PROBLEM SETTING

In one of the Topsail Beach study area planning reaches, a number of finger canals were located behind the shorefront on the mainland side of the barrier island. Access to the finger canals was provided through an adjacent inlet. Because the amount of land area between the shorefront and the canals was less than 200 feet, coastal engineers predicted that the land buffer would be breached by a 30-year storm (or one of a greater exceedance interval). All properties located on the finger canals would be destroyed by storms of that magnitude. If the area were breached under the without-project condition, it

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[1] U.S. Army Engineer District Wilmington, Final Feasibility Report and Environmental Impact Statement on Hurricane Protection and Be[illegible] Erosion Control, West Onslow Beach and New River Inlet, North Carolin[illegible] Topsail Beach), (Wilmington, NC: CESAW, 1990).

was reasoned that permits would not be granted to restore the area to include the finger canals to the pre-storm condition. Regulatory staff advised that a permit to fill the beach in solid (i.e., without canals) and reconstruct the homes probably would be issued, consistent with the historical precedent in other areas. This would create a development layout that would henceforth be less vulnerable to future storm damages.

However, the fact that without-project conditions were not static created a unique problem in identifying the average annual damages in the canal area. For any one year, the amount of expected annual damages would depend on whether the evaluation was done before or after a 30-year or greater storm event had occurred. The overall calculation was dependent, therefore, not only on the exceedance frequency of the 30-year or larger storm, but also on the simulated timing of such a storm during the planning horizon. For the 50-year period of analysis used for project evaluation, Wilmington District used a Monte Carlo technique to simulate when a 30-year or greater storm might occur.

APPLICATION OF MONTE CARLO SIMULATION

Monte Carlo simulation uses randomly generated numbers to simulate the occurrence of various storm events. Random numbers ranging from 1 to 1000 were used to simulate one storm occurrence per year. The probability of a 30-year or greater intensity storm occurring is 3.33 percent in a given year. In this case, this translated to 33 when multiplied by 1000, to accommodate the use of random numbers between 1 and 1000. Thus, 33 became the key number in the search for a simulated storm sufficiently large to create a blowout (i.e., breach) in the canal area.

For each "trial," random numbers were generated until a number less than or equal to 33 was found. Each number generated represented one year in the period of analysis. Thus the number of draws, or numbers generated, until a number of 33 or less was found indicated the number of years from the base year that the simulated storm would occur. The without-project damage calculation for that trial was computed in the following four-step process. (Example calculations are presented in the following section).

In the first step, the present worth of expected damages occurring prior to the blowout were calculated. Under existing canal development conditions the average annual damages that would result from storms with exceedance frequencies less than 30 years were estimated to be $327,300. These average annual damages did not include the $12.8 million loss of the entire structural and content value of the canal area that would occur with a 30-year or greater storm. For each year prior to the blowout, the $327,300 in annual damages were discounted back to the base year on the basis of the present value of an annuity of one per year.[2]

In the second step, $4.3 million in costs for refilling the breach and restoring the existing infrastructure were added to the $12.8 million in total damages resulting from loss of the entire canal area. Details on the cost of refilling the breach and restoring the infrastructure appear in the report's supporting documentation. Thus, the total damage figure for the breach was about $17.1 million. This total was brought back to present worth according

[2]To expedite their calculations, Wilmington District used average annual damage estimates from all storms with an exceedance frequency of less than 30 years for the pre-blowout condition and average annual damage estimates from all storms for the post-blowout condition (described in step 3). The more typical Monte Carlo approach would be to estimate for each year the specific damages that would result from the storm event associated with the frequency of the randomly generated number, under both pre- and post-blowout conditions; and then to determine the present worth of these storm specific, rather than average annual damage estimates.

to the number of years from the base year that the simulated storm had occurred.

In the third step the present worth of expected damages that would occur after the blowout were calculated. It was assumed that the same types and values of homes would be rebuilt on a solid land mass following the refilling of the breach. Under these post-blowout conditions, average annual damages were estimated to be $355,100, and included the <u>entire range of storm frequencies</u> in their calculation. It was the inclusion of all storm frequencies in this calculation that generated greater average annual damages than the $327,300 from the first step.

Fourth, the present value of the total damages from steps 1-3 was annualized based on an 8 7/8 percent interest rate and a 50-year project life to reflect equivalent annual damages for <u>that trial</u>.

The above process provides an estimate of the equivalent annual damages that would result from one 50-year series of simulated storm events (i.e., one game or trial in Monte Carlo vernacular). As noted in the general discussion of the Monte Carlo Technique, an overall estimate of the desired variable (in this case equivalent annual damages) is calculated by repeating the process many times and averaging the overall results. For this particular study, the process was replicated 20 times. That is, 20 sets of random numbers were generated, simulating for each trial when a blowout would occur. Steps 1-4 then were repeated 20 times to estimate the equivalent annual damages for each trial. Dividing the sum of equivalent annual damages from all of the trials by 20 (i.e., obtaining the average of the equivalent annual damages estimates for the 20 trials) resulted in estimated equivalent annual damages of $708,800 for the without-project condition in the canal area.

SAMPLE CALCULATIONS

Calculations from the first two trials of the Monte Carlo simulation are presented below to aid in the understanding of this methodology. In the first trial, the third randomly generated number was the number five. Because the random number was less than 33, this represented an event of greater intensity than a 30-year frequency storm. Since it occurred in year three, the appropriate calculations for the equivalent annual damages would follow the procedure outlined in Table D-1 below.

TABLE D-1[3]
FIRST TRIAL

		Present Value of Damages
(1)	First 3 Years $327,300 X 2.5369 (P.V. of annuity of 1/yr for 3 yrs.)	= $830,000
(2)	The Blowout $17,074,000 X .7748 (P.V.—3 yrs.)	= $13,228,900
(3)	Next 47 Years $355,100 X 11.0605 X .7748 (P.V. of Ann. of 1/yr—47 yrs.)(P.V.—3 yrs.)	= $3,043,100
(4)	Annualizing the Total	$17,102,300
	Times .090032 (I&A 8 7/8% for 50 yrs.)	X .090032
	First Trial Equivalent Annual Damages	$1,539,800

Note: Included in the parentheses are the descriptions of the discounting factors used in the analysis. All were based on an 8 7/8% interest rate. P.V. refers to present value. I&A is the capital recovery factor. For a more complete discussion of discounting procedures see Chapter XI of the Urban Flood Damage Manual.

In the second trial the number equal to or less than 33 in the random sample occurred on the twenty-seventh draw (i.e., in year 27). The equivalent annual damage calculations for this trial are presented in Table D-2 below.

[3] The damage calculations presented in Tables D-1, D-2 and D-3 and illustrated in Figure D-1 are reproduced directly from the Supporting Documentation for the West Onslow Beach and New River Inlet, North Carolina (Topsail Beach) report. The damage calculations are slightly overestimated because the damages for pre-blowout conditions are estimated to occur in t (year of blowout) time periods. Since the blowout is assumed to occur in year t, pre-blowout damages only should be included for t-1 time periods.

TABLE D-2
SECOND TRIAL

		Present Value of Damages
(1)	First 27 Years	
	$327,300 X 10.1332 (P.V. of annuity of 1/yr for 27 yrs.)	= $3,316,600
(2)	The Blowout	
	$17,074,000 X .10068 (P.V.--27 yrs.)	= $1,719,000
(3)	Next 23 Years	
	$355,100 X 9.6736 X .10068	
	(P.V. of Ann. of 1/yr--23 yrs.)(P.V.--27 yrs.)	= $345,800
(4)	Annualizing the Total	$5,381,400
	Times .090032 (I&A 8 7/8% for 50 yrs.)	X .090032
	Second Trial Equivalent Annual Damages	$484,500
(5)	Averaging the Equivalent Annual Damages	
	Total for the Two Trials ($1,539,800 + $484,500)	= $2,024,300
	Divided by Number of Trials	/2
	Equivalent Annual Damages After Two Trials	$1,012,150

Graphically, this second trial of the Monte Carlo simulation is portrayed in Figure D-1 below.

Figure D-1
Equivalent Annual Damages (Without-Project Conditions)
Second Trial, Monte Carlo Simulation

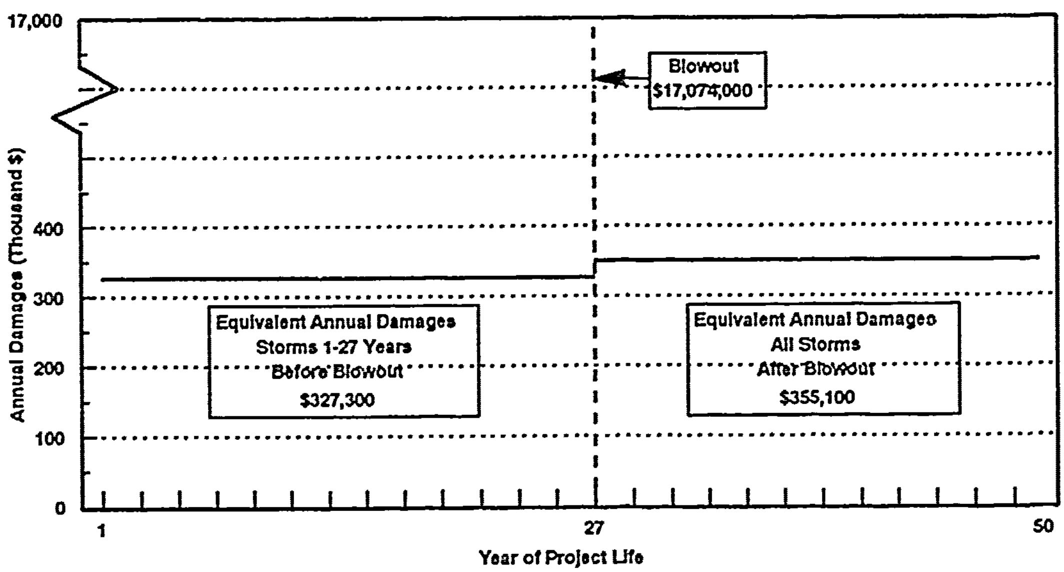

Table D-3 lists the equivalent annual damages that resulted from each of the 20 trials of the Monte Carlo simulation.

TABLE D-3
SUMMARY OF TRIALS

Trial Number	Year of Blowout	Equivalent Annual Damages
1	3	$1,539,800
2	27	484,500
3	12	891,200
4	4	1,441,000
5	N.A. (>50)	327,300
6	7	1,190,000
7	N.A. (>50)	327,300
8	30	449,000
9	19	638,100
10	6	1,266,800
11	50	348,700
12	50	348,700
13	36	400,200
14	N.A. (>50)	327,300
15	9	1,055,100
16	10	995,800
17	14	802,900
18	N.A. (>50)	327,300
19	27	484,500
20	24	530,200
		$14,175,700
		/ 20
		= $708,800

Note: N.A. (>50) indicates that none of the 50 numbers randomly generated for that trial was the number 33 or less. Thus, for that trial, a simulated blowout did not occur during the 50 year period of analysis.

In summary, this procedure was required because of the dual damageable conditions in the canal area under the without-project condition. The "composite" equivalent annual damages for this area were estimated at $708,800.

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