NATIONAL ECONOMIC DEVELOPMENT

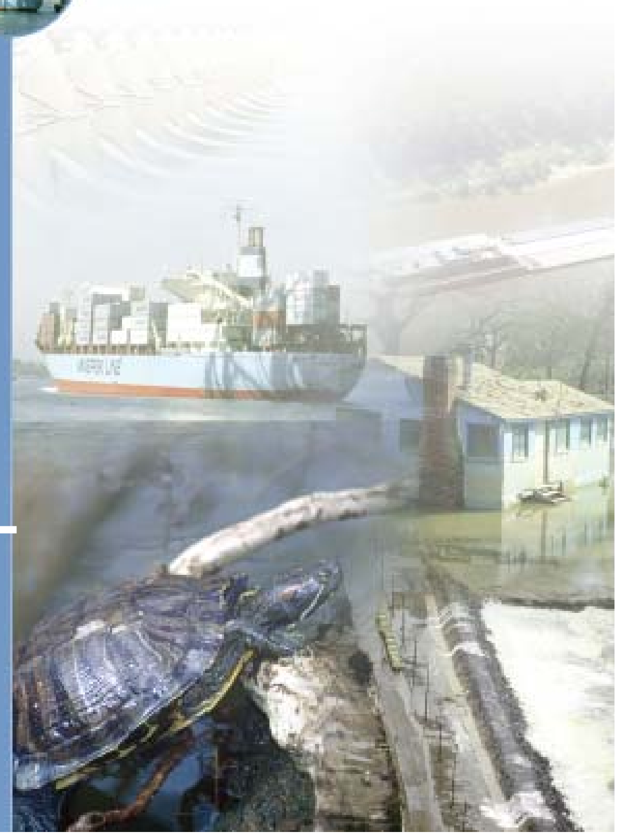
US Army Corps of Engineers®

IWR INSTITUTE FOR WATER RESOURCES

COASTAL STORM RISK MANAGEMENT

IWR Report 2011-R-09

November 2011



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INSTITUTE FOR WATER RESOURCES

U.S. ARMY ENGINEER INSTITUTE FOR WATER RESOURCES

The Institute for Water Resources (IWR) is a United States Army Corps of Engineers (USACE) Field Operating Activity. The main office is located within the Washington DC National Capital Region (NCR), in Alexandria, VA, with satellite centers in New Orleans, LA and Davis, CA. IWR was created in 1969 to analyze and anticipate changing water resources management conditions, and to develop planning methods and analytical tools to address economic, social, institutional, and environmental needs in water resources planning and policy. Since its inception, IWR has been a leader in the development of strategies and tools for planning and executing the Corps water resources planning and water management programs.

IWR strives to improve the performance of the Corps water resources program by examining water resources problems and offering practical solutions through a wide variety of technology transfer mechanisms. In addition to hosting and leading Corps participation in national forums, these include the production of white papers, reports, workshops, training courses, guidance and manuals of practice; the development of new planning, socioeconomic, and risk-informed decision-support methodologies, improved hydrologic engineering methods and software tools; and the management of national waterborne commerce statistics and other Civil Works information systems. IWR serves as the Corps expertise center for integrated water resources planning and management; hydrologic engineering; collaborative planning and environmental conflict resolution; and waterborne commerce data and marine transportation systems.

The Institute's Hydrologic Engineering Center (HEC), located in Davis, CA specializes in the development, documentation, training, and application of hydrologic engineering and hydrologic models. IWR's Navigation Data Center (NDC) and its Waterborne Commerce Statistical Center (WCSC) in New Orleans, LA, is the Corps data collection organization for waterborne commerce, vessel characteristics, port facilities, dredging information, and information on navigation locks.

Other enterprise centers at the Institute's NCR office include the International Center for Integrated Water Resources Management (ICIWRM), which is a distributed, intergovernmental center, established in partnership with several Universities and non-Government organizations; and a Collaborative Planning Center which includes a focus on both the processes associated with conflict resolution, and the integration of public participation techniques with decision support and technical modeling – Computer Assisted Dispute Resolution (CADRe). The Institute plays a prominent role within a number of the Corps Communities of Practice (CoPs), including the Economics CoP. The Corps Chief Economist is resident at the Institute, along with a critical mass of economists, sociologists and geographers specializing in water and natural resources investment decision support analysis and multi-criteria trade-off techniques.

For further information on the Institute's activities associated with the Corps Economics Community of Practice (CoP) please contact Chief Economist, Dr. David Moser, at 703-428-6289, or via-mail at: david.a.moser@usace.army.mil. The IWR contact for the Corps Planning CoP activities is Ms. Lillian Almodovar at 703-428-6021, or: lillian.almodovar@usace.army.mil.

The Director of IWR is Mr. Robert A. Pietrowsky, who can be contacted at 703-428-8015, or via e-mail at: robert.a.pietrowsky@usace.army.mil. Additional information on IWR can be found at: http://www.iwr.usace.army.mil/index.php. IWR's NCR mailing address is:

U.S. Army Institute for Water Resources
7701 Telegraph Road, 2nd Floor Casey Building, Alexandria, VA 22315-3868

OTHER NED MANUALS

All manuals are available at http://www.CorpsNEDManuals.us

10-R-4 — *Deep Draft Navigation* (February 2010). Alexandria: Institute for Water Resources. *This manual updates 91-R-13.*

09-R-3 — *Primer* (June 2009). Alexandria: U.S. Army Corps of Engineers.

09-R-2 — *Overview* (June 2009). Alexandria: Institute for Water Resources. *This manual is the update of 91-R-11.*

93-R-12 — *National Economic Development Costs* (June 1993). Alexandria: Institute for Water Resources.

93-R-2 — *Public Surveys Volume 1 – Use and Adaptation of Office of Management & Budget Approved Survey Questionnaires* (January 1993).

91-R-13 — *Deep Draft Navigation* (November 1991). *This is the original manual that was updated by IWR Report 10-R-4.*

91-R-10 — *Urban Flood Damage Vol. II: Primer for Surveying Flood Damage for Residential Structures and Contents.* Alexandria: Institute for Water Resources (October 1991).

91-R-6 — *Coastal Storm Damage and Erosion* (September 1991). Alexandria: Institute for Water Resources. *This manual replaces the outdated manual.*

91-R-7 — *Recreation Vol. IV: Evaluating Changes in the Quality of the Recreation Experience* (1991, July). Alexandria: Institute for Water Resources.

90-R-11 — *Recreation* Vol. III: *A Case Study Application of Contingent Value Method for Estimating Urban Recreation Use and Benefits* (November 1980). Alexandria: Institute for Water Resources.

88-R-2 — *Urban Flood Damage* (March 1988).

87-R-10 — *Agricultural Flood Damage* (October 1987). Alexandria: Institute for Water Resources.

86-R-4 — *Recreation Vol. I: Recreations Use and Benefit Estimation Techniques* (March 1986). Alexandria: Institute for Water Resources.

86-R-5 — *Recreation Vol. II*: *A Guide for Using the Contingent Value Methodology in Recreation Studies* (March 1986). Alexandria: Institute for Water Resources.

FOREWORD

The Corps of Engineers Planning Excellence Program is designed to build planning capability now and for the future. Economics is a vital component of the planning process and updating the National Economic Development manual series is a key element of the Planning Excellence Program.

I appreciate the efforts of the interdisciplinary team across the Corps, local sponsors and others who contributed to this manual. I am pleased to endorse its use as a tool for the Planning Community of Practice to reach out to all who are interested in our work.

Harry E. Kitch, Planning Community of Practice
Deputy, Planning Civil Works

Transparent and defensible economic analysis provides a critical piece of information for decision making. It is incumbent on the economist to inform others about sources and validity of all the data, models, and assumptions that are part of the analysis. The economist must also acknowledge the key uncertainties, their impacts on the economic analysis, and the overall confidence in the economic values presented to decision makers.

Dr. David Moser
Chief Economist
U. S. Army Corps of Engineers

ACKNOWLEDGEMENTS

The Coastal Storm Risk Management Manual is one of a series of National Economic Development (NED) Manuals. The NED Manuals are important resource documents for performing economic analysis within the Corps of Engineer's planning framework. The Manuals are part of the Planning Guidance Improvement Program. This manual has two versions: a printable digital copy and the online version, which are both available at http://www.CorpsNEDManuals.us/. If you would like to contribute to this manual, please contact Erin Rooks or the Institute for Water Resources (http://www.corpsnedmanuals.us/ContactUs.asp). We welcome your suggestions, corrections, and additions.

This manual is an update of IWR Report 91-R-6. The first version of this update was written by Chris Gehlker, Joe Mantey, and Julia Mantey and managed by Susan Durden (Institute for Water Resources-IWR). Erin Rooks (IWR) produced and co-authored the final version. Norm Starler (IWR) also did some final editing. Lillian Almodovar (IWR) has provided critical support to this effort from as the program manager for the Guidance Update Maintenance Program. Previously, Darrell Nolton (IWR) served as the Program Manager for the Planning Guidance Improvement Program and supported this manual. Information and concepts from the "Planning Core Curriculum Course 5: Hydrology and Hydraulics Considerations in Planning (2010)" were used in the writing of this manual. Editorial and production assistance was assisted by Arlene Nurthen (IWR), and by Mark Dunning under contract with CDM. Web-conversion for posting of this manual to the NED Manuals website was performed by CDM.

Dr. David Moser (IWR) and Charlie Yoe (CDM) contributed the Risk Analysis Paradigm as well as comments on the Manual. Other valuable review comments and support were provided by Dan Abecassis (Jacksonville District), Steve Cone (IWR), Steven Caparco (Southwestern Division), Steven Couch (New York District), Rick Eberts (Rock Island District), Mark Gravens (Engineer Research and Development Center-ERDC), Tom Hughes (Headquarters), Kevin Knight (IWR), Caris Moses (IWR), Joseph Lamb (Los Angeles), Ed O'Leary (New England District), Bob Selsor (Philadelphia District), Johnny Chan (New York District), Richard Ring (North Atlantic Division) and Joe Vietri (North Atlantic Division) as part of the National Planning Center Expertise for Coastal Storm Damage Reduction (PCX-CSDR, http://www.nad.usace.army.mil/pcx-accomplishments.htm).

Thank you to the many others who showed interest, and offered ideas.

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Folly Beach Shore Protection Project, South Carolina (Charleston District)

Part I – Introduction

This destruction was caused by Hurricane Ivan as it hit Gulf Shores on the Alabama coast. (Jonas N. Jordan, Savannah District)

Chapter 1: Introduction

1.1 Purpose and Objective

This manual is intended to serve as a comprehensive guide for calculating National Economic Development (NED) benefits for *Hurricane and Coastal Storm Damage Prevention Studies* described in Section IV, Appendix E of the *Planning Guidance Notebook* (PGN) (Engineer Regulation ER 1105-2-100, 2000). Users of this manual should be acquainted with this section of the PGN before applying any of the manual's instructions. The title of the manual, *Coastal Storm Risk Management*, has been changed from the original *National Economic Procedures Manual: Coastal Storm Damage and Erosion*, (IWR Report 91-R-6, 1991) to reflect a broader focus on *risk management*.

Events such as Hurricanes Katrina, Rita, Gustav and Ike have emphasized the increasing importance of managing the risks from coastal storms through risk assessment, risk communication, and risk reduction measures. Engineers, planners and economists alike have recognized that total *prevention* of damage in a natural disaster is an unrealistic goal. Furthermore, preventive measures may not consistently yield unvarying economic benefits. For this reason, the manual focuses on how to identify the NED Plan based on risk-informed decision-making process.

This manual should not be considered a *cookbook* for determining coastal storm damage risk reduction benefits and costs. The procedures found in the manual are not the sole methods by which these analyses may be performed. There are many valid ways to execute the necessary analyses because there are many uncertainties and variables. Each study can be considered unique because of the varied interactions of storms, coastal shapes, tidal fluctuations, coastal geology, offshore geometry and other factors. 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 National Planning Center Expertise for Coastal Storm Damage Reduction (http://www.nad.usace.army.mil/natplan.html, PCX-CSDR) should be the first place to start for economic and planning assistance and more recent updates. The Planning Community of Practice website will also have many of the documents listed in this manual and other recent guidance at www.CorpsPlanning.us.

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.

1.2 Application of Manual

This manual includes procedures for estimating the NED effects of Coastal Storm Risk Management projects, including reduction of damages and computing NED benefits. Many of the damaging coastal forces also act upon harbors, marshes and other wetlands, and endanger human lives. Although there has been no attempt to specifically address those areas in this manual, many of the techniques described could be applicable. The manual follows a risk-informed process and incorporates the economic and planning process from the 1983 Principles and Guidelines. A brief discussion of coastal processes and of some shoreline change models is included in the manual to emphasize the interactions and need for effective communication among economists, coastal engineers, and other planners. Additional detailed information on coastal processes and models can be found in the Coastal Engineering Manual (EM 1110-2-1100, 1998).

The procedures covered in this manual are applicable to reconnaissance reports as part of Section 905(b) reports, Continuing Authority Program (CAP) studies, pre-authorization feasibility reports, post-authorization change reports and other economic studies. The methodology described in the manual will differ only in level of detail.

The manual is primarily designed for economists responsible for preparing economic analysis of Corps Coastal Storm Risk Management projects, and presumes that they have knowledge of basic concepts of plan formulation. Other audiences for this manual include planners and project managers who must be able to understand and explain the process of benefit calculation, and determine which alternatives are promising enough to carry on to subsequent planning phases.

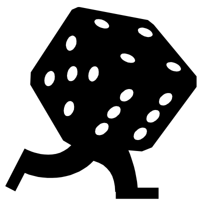
Other team members that could benefit are hydrologists, hydraulic engineers and others involved in shore protection or coastal storm damage issues. Finally, the manual can also be used to inform non-Federal sponsors of economic analysis requirements and the role of economics in decision making.

1.3 Organization of this Manual

This *Coastal Storm Risk Management Manual* (CSRM) has two parts. **Part I** (Chapters 1 through 4) provides introductory and background material on the Corps planning process and NED analysis, as well as basic information on coastal forces, and coastal damages. **Part II** (Chapters 5 through 10) describes the framework for economic analysis of coastal projects derived from a risk-informed decision-making process, Planning Guidance Notebook (PGN) steps and economic tasks, and the Six-Step Planning Process. Additionally, the manual contains an appendix that presents more detail on key terms used in coastal engineering (Appendix A-1), and in planning (Appendix A-2). Added, an acronym glossary is in Appendix B.

The manual has three icons that will help point out key features:

This icon will point out hyperlinks to other websites and documents that expand on the topic at hand.



This icon points out areas where *risks and uncertainties* are discussed.

This icon points out helpful hints on a particular topic.

Chapter 2: Corps Planning Process

Corps planning and evaluation processes and procedures are outlined by the Economic and Environmental Principles and Guidelines (P&G), Planning Guidance Notebook (PGN), Engineering Regulations (ER), Engineering Circulars (EC), Engineering Pamphlets (EP) and Engineering Memorandums (EM). These guidance materials are the foundation upon which a Coastal Storm Risk Management study is built. Nearly all of these documents can be found at www.CorpsPlanning.us.

2.1 Corps Planning and Economic Guidance

Here are some additional resources that will assist and provide guidance on planning and economic analysis. Most of these documents and links can be found at www.CorpsPlanning.us.

Economics Sub-CoP SharePoint Site (https://kme.usace.army.mil/CoPs/CivilWorksPlanning-Policy/econ/default.aspx) – Sub-Community of Practice, an interactive website for Corps access only

Principles and Guidelines (P&G, Executive Order 11747, 1983) – describes the basic requirements and the planning process that applies to all water resource projects.

Planner's Library (www.CorpsPlanning.us) – Economic Guidance Memoranda, Planning ABCs, Planning Guidance, Other Corps Guidance, Public Law, and more; one Engineer Circular to pay close attention to is EC 1165-2-211 (*Incorporating Sea-Level Change Considerations In Civil Works Programs*).

Planning Manual – provides an introduction to the 6-Step Planning Process used by the Corps

Planning Guidance Notebook (PGN, ER 1105-2-100, 2000) – principal reference for planning Corps water resource studies

NED Manual Series (www.CorpsNEDManuals.us) – this is the one-stop shop for all of the NED manuals on-line along with links to guidance documents, professional organizations, and more

Corps Risk Analysis Gateway (www.CorpsRiskAnalysisGateway.us) – this is the Corps comprehensive website for risk analysis in civil works

Institute for Water Resources (IWR, http://www.iwr.usace.army.mil/) – publications, projects, contacts and other resources to assist on economics, planning, and more

Engineer Research and Development Center (ERDC, http://www.erdc.usace.army.mil/) – water resources research and publications

2.2 Study and Legislative Authority

There are a number of legislative authorities (both general and specific) under which the Corps provides Coastal Storm Risk Management projects. Beginning with the Rivers and Harbors Act of 1930, Congress has directed the Corps to carry out programs established to protect and restore 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 designated cost sharing for the purpose of "hurricane and storm damage reduction." This introduced a new way of viewing shore protection projects which, prior to WRDA 1986, were viewed as either for "beach erosion control" or for "hurricane, tidal and lake flood protection." This specified that construction cost measures for "beach erosion control" are assigned to "hurricane and storm damage reduction" or "recreation," with cost-sharing in the same percentage as the purposes to which the costs were assigned.

Pre-authorization studies, also known as Feasibility Studies, require specific Congressional authorization. Specific study authority, by way of legislation or resolutions of appropriate Congressional committees is required.

Continuing Authorities Program (CAP)

Projects that fall under the **Continuing Authorities Program** (CAP) don't require specific Congressional authorization. They are subject to program or project limits on Federal expenditures and thus are limited in size. See the PGN (ER 1105-2-100), pages 3-1 to 3-23, for policies, procedures, and guidance affecting the Continuing Authorities Program, and the Planning Community of Practice's Planners Library for other specifics on CAP limits and planning process.

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 Public Law (PL) 79-526 authorizes emergency streambank and shoreline erosion protection for public facilities and services, up to a maximum cost of $1 million 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 $3 million. And, Section 111 of PL 90-483 authorizes mitigation of shoreline erosion damages caused by Federal navigation projects, up to a maximum of $5 million per mitigation project.

Congressionally Authorized Projects

Congressionally Authorized Projects are typically larger than CAP Projects and are pursuant to the specific authorities. Sufficiently detailed evaluation is required to support a Chief's Report with recommendations to Congress. The Office of the Assistant Secretary of the Army and the Office of Management and Budget also reviews these types of reports. These projects may provide any combination and size of coastal risk management measures such as beach renourishment or seawalls.

WRDA 2007

The **Water Resources Development Act of 2007** directed the Secretary of the Army through the Assistant Secretary of the Army for Civil Works (ASACW) to rewrite the 1983 Principles and Guidelines (P&G) to accommodate new national water resources objectives and other considerations. The WRDA 2007 directed that the new guidelines address/include:

1. The best available economic techniques, including risk and uncertainty analysis,
2. Public safety in the formulation of alternatives and recommended plans,
3. Reflect the value of projects for low-income communities and projects that use nonstructural approaches for water resources development and management,
4. The interaction of a project with other water resources projects within a region or watershed,
5. Contemporary water resources paradigms including integrated water resources management, and
6. The projects are justified by public benefits.

> As of the date of this manual's publication no new P&G guidance has been completed. Pending further developments, the guidance contained in the 1983 P&G as detailed in ER 1105-2-100 will be followed in this manual.

2.3 Federal Interest and Objective

The **Federal Interest** is the rationale for Federal participation in water resource projects. The extent of this interest is the basis for determining cost sharing and other project responsibilities. It determines how and where the government can spend taxpayer money. Verification of the Federal Interest in a project is a prerequisite to project implementation. Study reports must have a conclusive statement of why such interest does or does not exist. Criteria for determining the Federal Interest are presented in the PGN (ER 1105-2-100), Section 3-1, and includes a determination as to whether or not the water resources issue and potential solution set falls within the authorized missions of the Corps, and requires consistency with Federal policies and budgeting priorities. Federal projects must be open to public use and have reasonable public access. For coastal projects, the public ownership and use of the beach is a requirement since Federal funding is being used. This means that the project must have nearby adequate parking or public transportation to the project site and sufficient access points available to the beach area.

The **Federal Objective** is distinct from Federal Interest in that it provides investment criteria for evaluating Federal water resources projects.

> *The **Federal objective** of water and related land resources project planning is to contribute to National Economic Development consistent with protecting the Nation's environment, pursuant to national environmental statutes, applicable executive orders, and other Federal planning requirements.*
>
> *(a) Water and related land resources project plans shall be formulated to alleviate problems and take advantage of opportunities in ways that contribute to this objective.*
>
> *(b) Contributions to **National Economic Development (NED)** are increases in the net value of the national output of goods and services, expressed in monetary units. Contributions to NED are the direct net benefits that accrue in the planning area and the rest of the Nation. Contributions to NED include increases in the net value of those goods and services that are marketed, and also of those that may not be marketed.*
>
> *-Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies, 1983*

The P&G states that the single overarching objective of the Federal government is to contribute to National Economic Development (NED) consistent with protecting the Nation's environment. In the case of coastal projects, current policy specifies in ER 1105-2-100, Appendix E-24 that projects are formulated to provide hurricane and storm damage reduction and that recreation is incidental. Contributions to NED benefits in coastal areas are primarily reductions in damages to property. The NED benefit must be equal or greater than the NED costs and display a minimum 1:1 benefit cost ration. No more than 50 percent of the benefits required for justification can be attributed to recreation benefits.

The NED focuses on the efficiency gain that is produced for the Nation as a whole; not transfers from one U.S. region to another. A project may be economically attractive from a regional perspective but unwise from a national perspective. In contrast, if a study area is not large enough, problems or projects may impact other areas many miles away. This project could be highly attractive from the NED perspective, but may not look as attractive regionally to the non-Federal sponsor, community, other stakeholders and other government agencies.

NED analysis considers all NED benefits and 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 a negative impact on recreation use or adverse impacts to the shoreline outside the study area, this impact must be considered and displayed.

NED costs are the opportunity costs of diverting resources from another source to implement the project. A project is considered economically feasible if the NED benefits are greater than the NED costs. The benefit-cost ratio for such a project would then be greater than one.

The project with the highest net NED benefits, which is feasible from an engineering standpoint, environmentally sound, publicly acceptable and in compliance with Federal, state, and local regulations, is the NED Plan. Note that the plan with the highest benefit-cost ratio may not be the NED Plan. The NED Plan is required to be recommended for implementation unless an exception is granted by the Assistant Secretary of the Army for Civil Works ASA(CW). The benefits estimates developed for Coastal Storm Risk Management projects provide basic information required to identify the NED Plan.

2.4 Corps Planning and Risk Analysis

The Corps uses a **Six-Step Planning Process**, augmented with a risk analysis framework, to make responsible risk-informed decisions and select the plan with the highest net NED benefits consistent with environmental and acceptability considerations. This section presents a brief overview of the planning process, risk analysis and how the risk-informed decision process and the planning process fit together.

The Corps Six-Step Planning Process

The Corps planning process consists of the following steps:

Step 1: Identify problems and opportunities
Step 2: Inventory and forecast conditions
Step 3: Formulate alternative plans
Step 4: Evaluate alternative plans
Step 5: Compare alternative plans
Step 6: Select recommended plan

These steps are described in great detail in the Corps' Planning Manual and are consistent with the Risk Analysis framework used in this document.

Risk Analysis: Management, Assessment, and Communication

The Corps faces a wide variety of risks and no one definition of risk will suffice for all purposes. For purposes of this Manual, the following definition will be used: risk is a function of the probability (or likelihood) and consequences of uncertain future events. Risk includes the potential for gain (opportunities), and exposure to losses or adverse consequences (hazards). Adverse consequences are often thought to include, although not be limited to: loss-of-life, health effects, property damage, income losses, economic costs, and undesired ecosystem changes. In a broader context, risk also includes the commitment of current resources that may not achieve intended results (for example, actions taken to reduce flood damages without actually reducing the damages as expected). Usually, both the likelihood and the outcome are to some degree uncertain. Risk includes both the risk of loss due to some hazard and the uncertain chance of gain due to some opportunity.

Uncertainty is the result of imperfect knowledge concerning the present or future state of a system, event, situation, or (sub) population under consideration. Uncertainty leads to lack of confidence in predictions, inferences, or conclusions. Two basic kinds of uncertainty are defined for the purposes of this guidance:

(1) *Knowledge Uncertainty:* This uncertainty is attributed to a lack of knowledge on the part of the observer at the time a decision is being made that is expected to affect a future outcome. For example, there is no known distribution of values. Knowledge uncertainty is reducible in principle, although it may be costly to reduce or require significant time in advance of a decision. Knowledge uncertainty arises from incomplete understanding of a system, modeling limitations and/or limited data. Knowledge uncertainty is sometimes called epistemic, internal, functional, subjective, reducible or model form uncertainty. Knowledge uncertainty is sometimes dealt with by a) quantifying the ranges of uncertainty, b)applying factors of safety, c) adaptive management, or d) other techniques.

(2) *Natural Variability*: This uncertainty deals with inherent variability in the physical world; by assumption, this “randomness” is irreducible. In the water resources context, uncertainties related to natural variability include things such as stream flow, assumed to be a random process in time, or soil properties, assumed to be random in space. Natural variability is also sometimes referred to as external, objective, random, or stochastic uncertainty. Natural variability cannot be altered by obtaining more information, although its characterization might improve with additional knowledge. Natural variability is sometimes dealt with by statistical or probabilistic methods.

Risk analysis is a method to identify, organize, analyze, understand, communicate and manage these unknowns and risks. The proposed framework explicitly evaluates the level of risk if no action is taken and recognizes the monetary and non-monetary costs and benefits of reducing risks when making decisions. Risk analysis (see Figure 1) includes the interdependent activities of risk management, risk assessment and risk communication.

More information on risk can be found at the

Corps Risk Analysis Gateway: http://www.iwr.usace.army.mil/riskanalysis/

Figure 1. Steps of Risk Analysis

Risk management is the process of problem finding and initiating action to identify, assess, select, implement, monitor and modify over time, actions to alter and manage levels of risk, as compared to taking no action. Risk management actions include reducing the hazard, reducing exposure to the hazard, reducing vulnerability to harm, pooling the risk (for example, assurance bonds or insurance), and accepting the risk. The choice of risk management actions is made after considering the costs of each increment of risk reduction and the social acceptability of bearing any remaining risk.

Risk communication is the open, two-way exchange of information and opinion about risks and uncertainties leading to a better understanding that will facilitate risk management decisions. It is a process that begins early and continues throughout the decision making process. Risk communication ensures that those who share responsibility for decision making, including stakeholders and affected parties, understand and appreciate the process of risk assessment. In doing so, all parties can be fully engaged in, and appropriately share, the responsibility for risk management.

Risk assessment includes a variety of analytic techniques appropriate to different situations, depending upon the nature of the risk, the available data, and the needs and interests of decision makers. Risk assessment is a systematic, evidence-based approach for describing the likelihood and consequences of any action, including no action. The generic steps of a risk assessment for the Corps' Civil Works program are shown in Figure 2. Hazards are identified in the first step and analyzed in the remaining three steps.

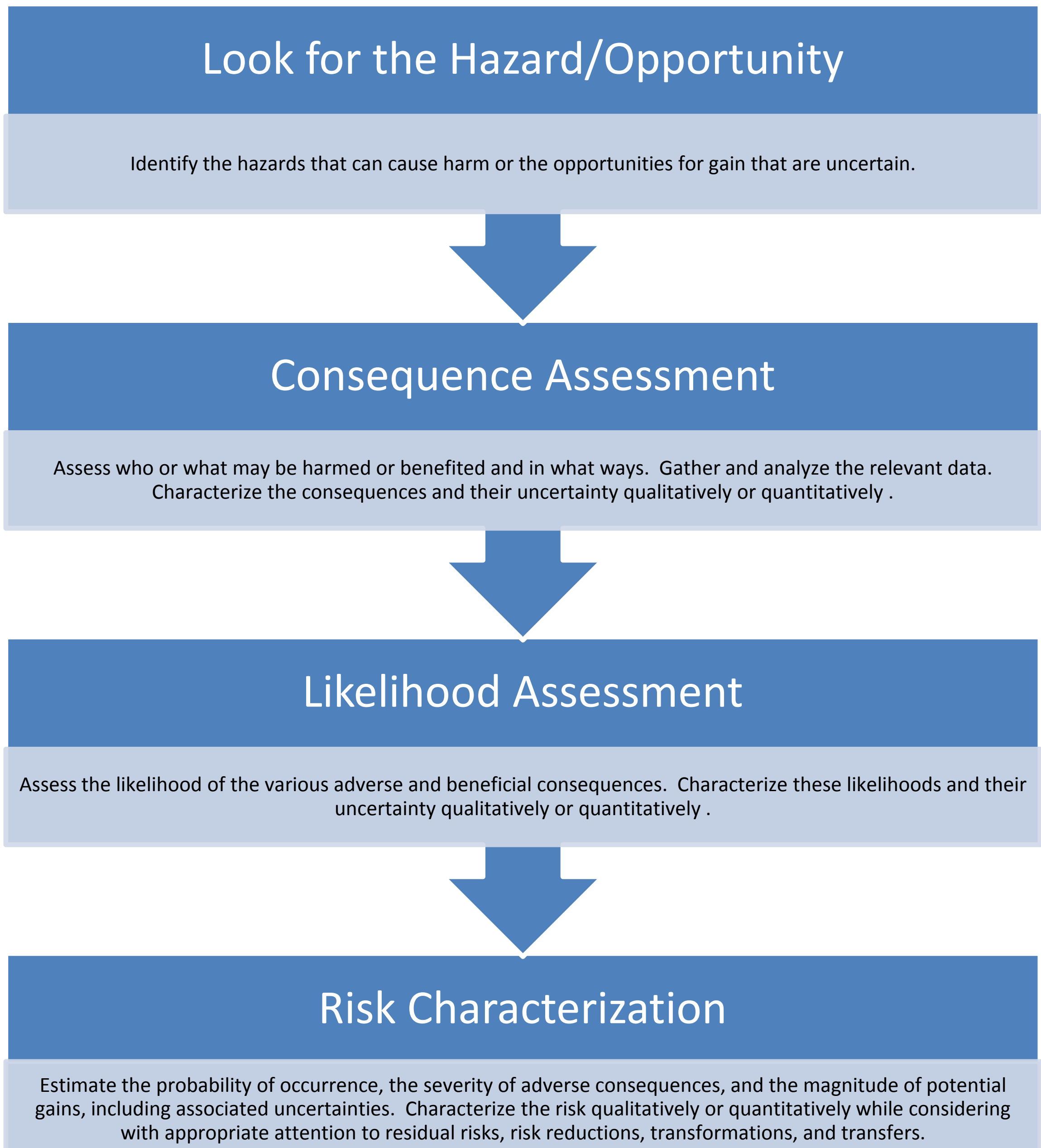


Figure 2. Steps of Risk Analysis

A five-step risk model, supported through ongoing communication and consultation, monitoring and evaluation, was proposed for use in the Corps (Figure 3). Each step in the Risk Management Decision Making (RMDM) process is briefly explained below.

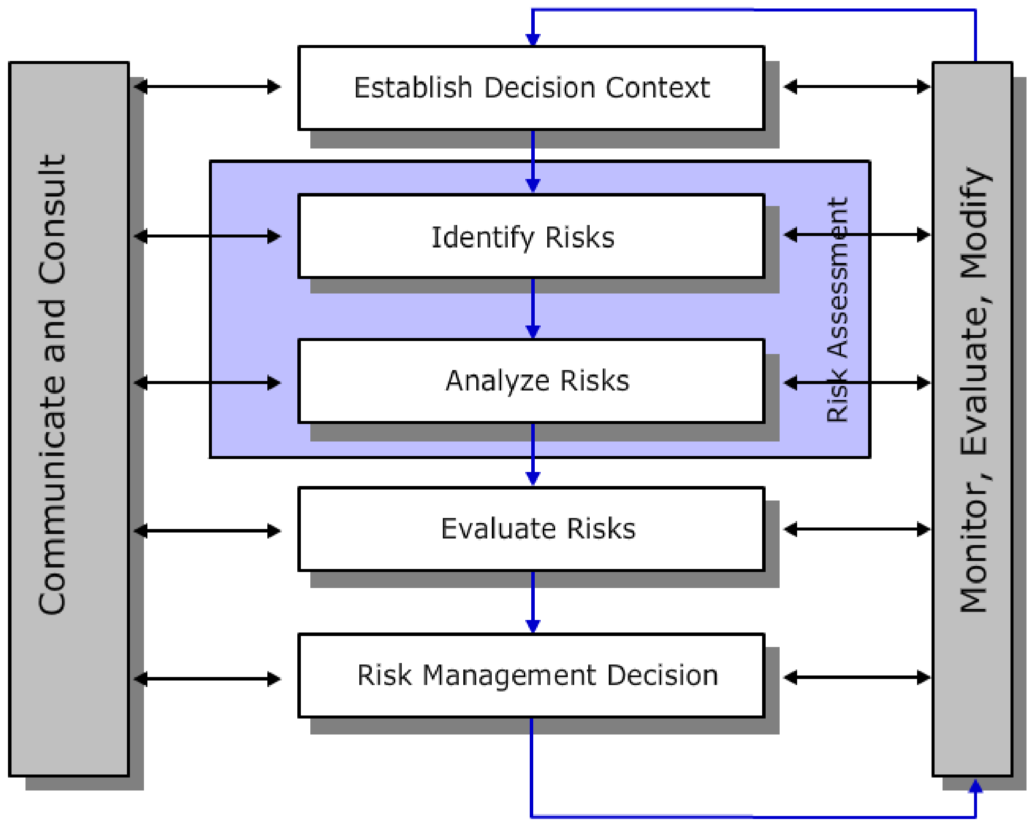


Figure 3. Corps Proposed Risk Management Decision Making (RMDM) Model

- **Step 1: Establish decision context.** The goal of this step is to define the problems being addressed, and to identify the goals, uncertainties, measurable objectives, strategies and scope of the activity being assessed. This step should identify the questions to be answered during the rest of the process and should result in a written:
    - Problem statement
    - Statement of the activity's objectives
    - List of management information questions
    - List of the decision criteria
    - List of key uncertainties

- **Step 2: Identify Risks.** In this step, the focus in on the risks relevant to the decision context. It includes asking and answering *what can go wrong* and *how can it happen* for each relevant risk variable or significant uncertainty. This means identifying but not yet quantifying the consequences (positive or negative) and likelihoods and how they will be expressed. This step should result in a narrative of significant uncertainties of concern to this risk management activity. This is the first part of a risk assessment.

- **Step 3: Analyze Risk.** Estimate the consequences and likelihoods of the risks identified in the previous step. This estimation addresses key uncertainties. The consequence and likelihood for each risk variable may be combined to produce an estimated level of risk. At the same time recognize and report decision critical uncertainties and incorporate their impact on the estimates and descriptions of risk. Alternative mitigation strategies (ways to reduce or limit risk) are analyzed in this step. This step and the preceding one together comprise the risk assessment task. This is often the principle analytical work in the risk management process. In some decision contexts a complete risk assessment may not be needed or may not be possible to complete in support of decision making. In these instances the analytical steps are modified as necessary.

- **Step 4: Evaluate Risks.** Determine if the existing risk is acceptable or if it requires management to a tolerable level. Alternatives risk management options that reduce or limit risk are evaluated and compared. This evaluation includes consideration of the risk and other decision criteria important to the decision context. Consider the cost to reduce increments of risk, who bears the risk, what risks are reduced, the risk that remains, and the risks that have been transformed or transferred to others.

- **Step 5: Risk Management Decision.** A final decision is made to accept or take a set of actions to manage the identified risks. If action is taken, a risk management strategy is developed and implemented. Desired and measurable outcomes of the management strategy are identified at this step so the success of the plan can be monitored and evaluated. Roles and responsibilities of everyone involved in managing the risk are identified. To the extent there is significant uncertainty in the analysis that could influence choice of the risk management solution, the risk management strategy will include an *adaptive management plan.* An adaptive management plan is a series of steps including identifying uncertainties at the time a decision is made and experiments that can be used to test whether the plan is meeting its objectives. The risk management plan shall include a budget and authority for adaptive management to be meaningful. Monitoring and Evaluation is part of the adaptive management plan. Monitoring and Evaluation includes:

    - collecting targeted data to assure that there is progress toward achieving the outcomes of the implemented risk management strategy
    - collecting targeted data to test hypotheses required to reduce analytical uncertainties identified in the initial planning process when an adaptive management process is needed
    - scanning the overall setting for the activity to identify hazards or changes in socioeconomic preference or conditions that may not have been recognized during the initial risk analysis process, or that may have changed in their significance. Monitoring data will be evaluated on a regular basis and the risk mitigation strategy may be modified in accordance with what is learned

Throughout the risk management process, it is critical to actively **communicate and consult** with internal and external stakeholders as appropriate. In some situations all risk analysis activities in Figure 1 will be wholly contained within the Corps' organization. In other situations, there will be varying degrees of shared responsibility for assessment, communication and choice of the risk management alternative.

The Risk Management Decision Making (RMDM) steps described can be applied in conjunction with the Corps' Six-Step Planning Process. Figure 4 presents a suggested *mind map* for integrating these processes which is further described below. Part II of this manual builds on the basic framework presented below to define the specific economic analysis tasks required for coastal storm risk management NED benefit cost evaluation.

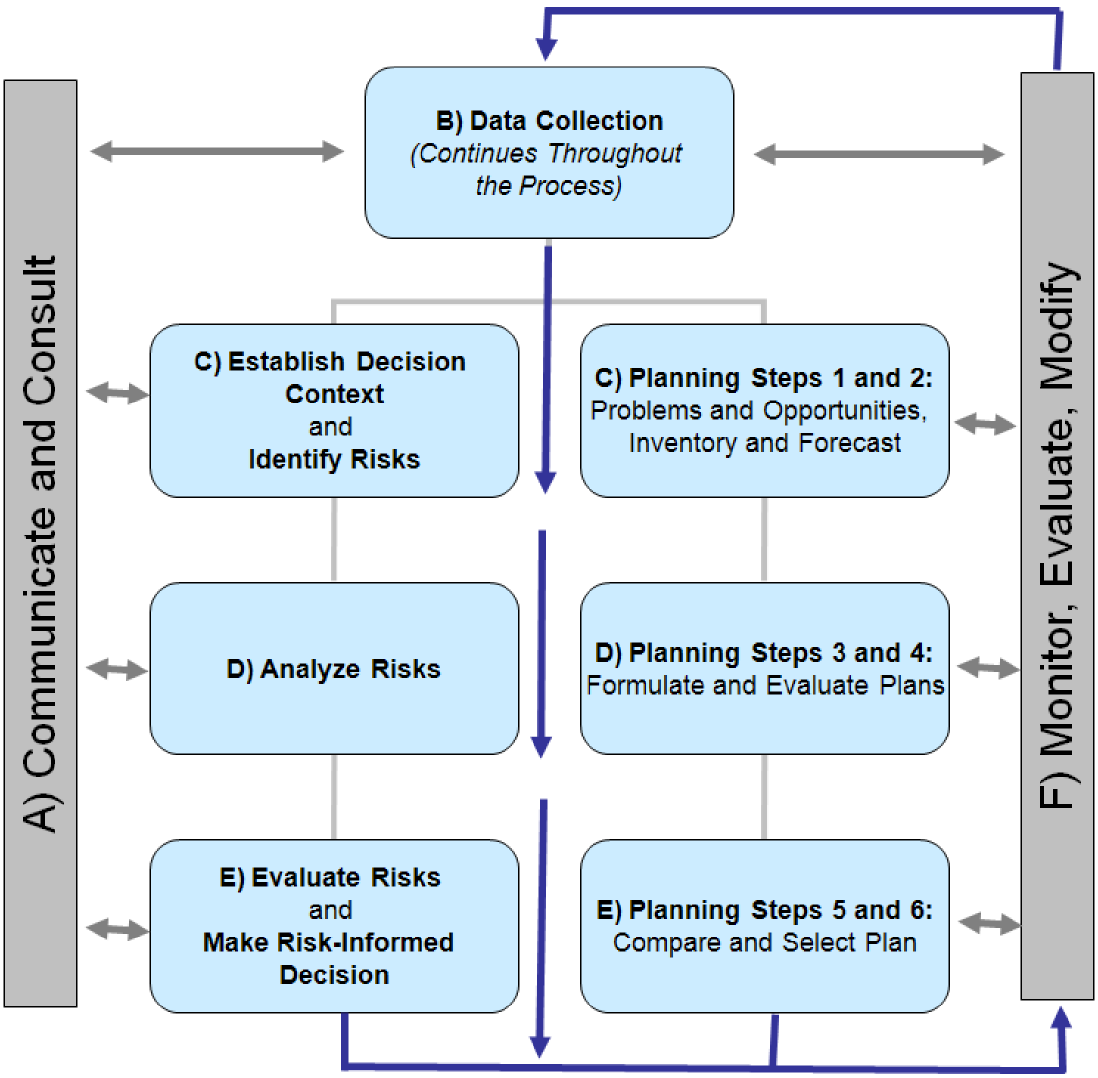


Figure 4. *Mind-Map* of Risk Management Decision Making and Six-Step Planning Processes

A. Communicate and Consult (continues throughout the process)

Active communication is an essential part of risk analysis and planning. It is important to communicate and consult with internal and external stakeholders as appropriate at each stage of the process. If there are shared risk management decisions, they should be identified, the decision participants recorded and a formal agreement documenting the shared responsibility for the decision prepared and signed by all responsible participants.

Economists and planners face several challenges in communicating and consulting with team members and project stakeholders. First, open communication and consulting means fully describing the uncertainties, challenges, and risks that the stakeholders face based on the best available information. Risks should not be overlooked or glossed over, but presented as they are. This leads to another challenge: communicating risks and risk analysis procedures in an understandable fashion. In communicating, using jargon, acronyms, and technical language is not a good idea. For example, economists often use terms such as *NED, NER, average annual equivalent benefits, or exceedance probability* to the general public. The average person has no understanding about these economic and Corps terms. To meet the requirement for clear communication it will be necessary to fully explain all concepts or choose words that match the intended audience's knowledge level.

Helpful hints for becoming a better communicator:

- Trust is the necessary condition for effective communication.
- Communication implies ***listening*** as well as transmitting.
- It is important that there are visible advocates for the use of risk analysis and management techniques at the highest organizational levels.
- Spell out all acronyms and fully describe.
- Clearly label all figures and make sure they are readable.
- Use visuals to display the story.
- Relate information to other more familiar information (e.g., using a 30-year mortgage as a basis for explaining the likelihood of experiencing a storm event of various magnitudes over time to present risk-information).
- Test the understandability of report and figures on those not familiar with the Corps or the study.

B. Data Collection (continues throughout the process)

Most data collection is likely to take place in the early stages of planning to help identify scope of problems and opportunities and to inventory and forecast conditions. However, like communication and consultation, collecting data is necessary throughout the process. **Chapter 6** discusses this topic in greater detail.

C. Establish Decision Context and Identify Risks (RMDM Steps 1 and 2; Planning Steps 1 and 2)

In a risk-informed decision making framework, this step establishes the decision context in which a risk management decision will be made. It includes identifying and defining the management problems and opportunities, the risks relevant to the decision context, inventorying and forecasting appropriate data, and establishing measurable objectives to which the risk management process is being applied. Decision-making criteria, evident uncertainties, and the questions to be answered in subsequent analytical steps are identified in this step. It includes asking and answering *what can go wrong (or right)* and *how can it happen* about the problem setting. **Chapter 7** discusses this topic in greater detail.

D. Analyze Risk (RMDM Step 3; Planning Steps 3 and 4)

Alternative plans and appropriate mitigation of adverse effects are to be formulated in a systematic manner to ensure that all reasonable alternatives are evaluated. Each alternative formulated should consider four criteria: **completeness, effectiveness, efficiency, and acceptability**. Estimate the consequences and likelihood of the risks identified in the previous step. At the same time, recognize and report decision critical knowledge of uncertainties and probabilities and incorporate them as a source of risk. The consequence and likelihood for each risk may be combined to produce an estimated level of overall risk. Alternative management strategies are analyzed in this step. The risk factors in each of the four P&G accounts should also be considered: NED, Regional Economic Development (RED), Environmental Quality (EQ), and Other Social Effects (OSE).

Steps C and D together comprise the **risk assessment task**. This is often the principle analytical step in the risk management process. In some decision contexts a complete risk assessment may not be needed or may not be possible to complete in support of decision making. In these instances the analytical steps are modified as necessary. **Chapter 8 and Chapter 9** discuss this topic in greater detail.

E. Evaluate Risks and Make Risk-Informed Decision (Planning Steps 5-6)

Risk management alternatives are evaluated and compared to identify the best NED solution. The best compatible elements of different plans may be combined, provided they are incrementally feasible and justified. The final screening process brings together economic efficiency considerations, risk, and evaluation of effects among final plans. Consider the cost to reduce increments of risk. *Who bears the risk, what risks are reduced, borne, transferred, etc?*

The NED Plan represents the decision to accept or take action to manage the identified risks. If action is taken, a risk management strategy is developed and implemented. Desired and measurable outcomes of the management strategy are identified at this step so the success of the plan can be monitored and evaluated. To the extent there is significant known analytical uncertainty, the risk management strategy could include an adaptive management plan to reduce such uncertainties over time and modify as needed the execution of the plan. **Chapter 10** discusses this topic in greater detail.

F. Monitor, Evaluate, Modify

The purpose of post-implementation monitoring is to assure that there is progress toward achieving the outcomes of the implemented risk management strategy. If there is an adaptive management process, there will be data collection targeted to reduce analytical uncertainties identified in the initial planning process, and identify hazards or changes in socioeconomic preference or conditions that may not have been recognized during the initial risk analysis process or that may have changed in their significance. In all cases, the risk mitigation strategy may be modified in accordance with what is learned.

2.5 Project Delivery Team (PDT)

No work is done in isolation. The economist must work with the PDT to be successful in accurately describing the economic analysis. Each coastal PDT is likely to have, or should consider having, a coastal engineer, cost engineer, biologist, economist, plan formulator, project manager, regulatory representative, real estate specialist, and an operations representative. However, each project and team is different and may have additional needs or special skills.

The team is important for providing plan formulation and data input for the NED evaluation process. The team also helps frame the economist's analysis and describe the four accounts (NED, Regional Economic Development, Environmental Quality, and Other Social Effects). Likewise, the economist assists the team by providing them information to help steer the study in the right direction.

The team should contact the Coastal Storm Damage Reduction Planning Center of Expertise when beginning a study for recent policy updates, and to ensure proper coordination throughout the study.

National Planning Center of Expertise for Coastal Storm Damage Reduction

The primary goal of the center is to serve as a leader in the CSDR field, including plan formulation, economics, environmental and engineering key disciplines to improve quality and timeliness of Corps coastal storm damage reduction planning studies and products. The planning center of expertise will focus primarily on plan formulation and the complex technical evaluations associated with plan formulation. The PCX-CSDR organization and operations are established consistent with other national centers and to allow for adaptive management and evolution over time as circumstances warrant.

Go to website:

http://www.nad.usace.army.mil/natplan.html

2.6 Plan Formulation

A plan formulator's role often coincides with the economist's role. Below is a brief list of a few plan formulator tasks:

- Lead planning process
- Develop the project authorization document
- Lead problem identification
- Set planning objectives
- Define existing condition
- Define future without- and with-project conditions
- Lead development of alternatives
- Conduct trade-off analysis
- Ensure cost sharing requirements are met
- Lead technical integration of PDT documents
- Facilitate review process and issue resolution

While not all tasks directly relate to economics, many of them do. Economists are essential in setting planning objectives because they will often measure the objective's success. The existing, future without- and with-project conditions are often defined through the economic analysis. When plan formulators develop alternatives, certain criteria are required to be met in formulating plans: efficiency, completeness, acceptability, and effectiveness. Economists measure effectiveness and efficiency which makes their role in plan formulation essential.

Economists often play a role in many plan formulation activities outside of NED analysis. For example, an economist may assist in cost analyses for Dredged Material Management Plans (DMMP), Operating Plans, Regional Sediment Plans, and mitigation.

2.7 Environmental Considerations

Coastal projects will usually involve analysis of one or more environmental issues such as fish and wildlife impacts particularly on endangered species. This makes the role of the environmental team member (whether biologist, ecologist, environmental scientist, or related discipline) crucial to the success of the project. Economists must understand the underlying environmental concerns on any project for several reasons:

- Environmental mitigation costs are NED project costs and will influence the level of net NED benefits.
- Economists may be asked to perform a trade-off analysis (e.g. NED vs. Environmental Quality (EQ) effects, NED Benefits vs. National Ecosystem Restoration (NER) Benefits, the Corp's term for a particular kind of EQ benefit, ecosystem improvements which are measured in non-monetary terms).
- Cost Effectiveness/Incremental Cost Analyses (CE/ICA) are required for environmental mitigation or other components and should be performed by economists.
- Environmental impact documentation often requires help from an economist on broader socioeconomic and population impacts.
- Economic outputs can often fuel debate over environmental consequences and quantifying environmental outputs.
- Collaborative planning often means that economists will have to work with stakeholders including those that have environmental and social concerns. Such collaboration includes explaining economic concepts and results.
- Consideration of significant effects from removal of sediment from borrow sites.

For these reasons, it is a good idea to work with the team biologist or environmental specialist to understand environmental issues and opportunities. The biologist also will have an understanding of the Corps Environmental Operating Principles (http://www.usace.army.mil/environment/Pages/eop.aspx), which are essential to plan formulation and consequently the economic analysis.

Environmental concerns with coastal projects can be significant and can cause long delays, project modifications, or possibly jeopardize the feasibility and acceptability of the project. The Corps' Environmental Operating Principles should guide all project analyses; the project delivery team (PDT) has the delicate role of trying to balance the environmental elements and economic development. While the project economist is working to ensure alternatives are economically justified, the economist must also understand that alternatives must be environmentally acceptable.

Environmental considerations can and will often influence the NED analysis. Coastal projects often mean disturbing aquatic ecosystems in the project footprint and surrounding areas. Endangered species can impact NED costs and timeframes used to bring all values to present value. For example, sea turtle nesting will lengthen the construction period because construction often cannot occur during this period. Sea turtles and/or other endangered species monitoring will also increase project costs which impacts the NED analysis.

The National Environmental Policy Act (NEPA) requires that each study will at a minimum require the Corps to complete an Environmental Assessment (EA). In the case of larger, more controversial studies, an Environmental Impact Statement (EIS) will be required. These NEPA analyses go beyond project economics and the natural environment to include the entire human environment which means considering other factors such as *Environmental Justice*. The law says that any Federal agency will appropriately identify and address any disproportionally high or adverse effects on minority and low-income populations. The economist may assist in describing such impacts.

However, not all environmental impacts are NED costs. For example, it is possible that adding sand to a beach would improve habitat. **The bottom line is that an economist must understand more than just economics to successfully do an analysis of a Corps Coastal Storm Risk Management project.**

2.8 Summary and Look Ahead

The Corps Coastal Storm Risk Management (CSRM) planning and evaluation processes are governed by the Principles and Guidelines, the Planning Guidance Notebook (ER 1105-2-100), as well as the emerging risk-informed decision making process. Effective CSRM projects have competent assessments of risk and uncertainties, actions to manage risks, and an effective communication process. Throughout the risk analysis process, the economist plays a crucial role on the Planning Development Team (PDT) as responsible for the analysis that determines the NED Plan. The economist must work in conjunction with other PDT members, particularly, those focusing on environmental concerns, to completely account for project costs and benefits. The next chapter describes basic coastal processes and coastal engineering principles used in CSRM studies. Its intent is not to make the economist expert in these topics but to provide sufficient information to enable effective communication with the PDT.

Chapter 3: Coastal Forces

The coasts, or shores, of the world are the margins separating the 29 percent of the earth that is land from the 71 percent that is water. By reworking and often eroding the margins of the land, the seas aid streams, subsurface water, glaciers, and the wind in wearing down the continents.

-Coastal Engineering Manual, 2002

This chapter describes the basic coastal processes and the coastal engineering principles and models used in evaluating storm and long-term erosion. Definitions for key terms and physical mechanisms can be found in Appendix A-1. This section is not intended to supplement or act as a substitute for the Coastal Engineering Manual (EM 1110-2-1100, http://chl.erdc.usace.army.mil/cem) or other technical references. The reader is encouraged to refer to that manual for more detailed explanations. The goal of this chapter is to provide sufficient information to enable economists and planners to understand the coastal processes and proposed engineering solutions.

The field of coastal engineering encompasses a variety of disciplines, a wide range of environmental conditions, and more uncertainty than that of 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 coastal processes and shoreline responses before attempting an engineering solution.

3.1 Waves

Most of the energy delivered to the shore by oceans or lakes originates from the wind acting on the water to produce waves. Wave characteristics are determined by wind direction, wind speed, wind duration, how far the wind blows over water, and how far the wave travels before reaching land.

Most waves encountered along coastlines result from the influences of distant winds. The speed of those winds, and the distance and length of time the wind blow over the water determines the size and shape of waves. These **wind waves** are commonly defined according to three variables (Figure 5):

1. Height (measurement from trough to crest)
2. Wavelength (the distance between crests)
3. Period (the time interval between the arrivals of crests at a stationary point).

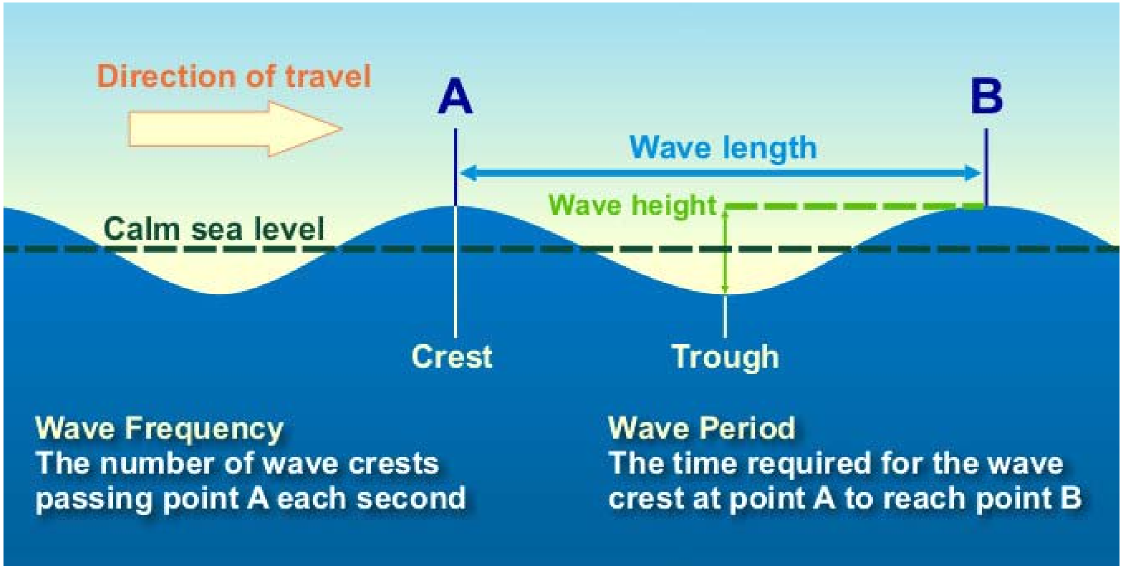


Figure 5. Anatomy of a Wind Wave (NOAA). (See JetStream MAX - An Online School for Weather: Anatomy of a Wave.)

Wave measurements for an area are expressed in terms of *significant wave height*: the average height of the highest one-third of waves in a given time period. Because this measurement is an average, the very largest waves are often significantly higher than the documented significant wave height.

There are **three types of waves**:

1. **Ripples** (also known as capillary waves): Ripples result from winds' effects on smooth waters. They die off in the absence of wind.
2. **Seas:** Seas are generated from local winds or the highly complex waves that exist within the storm area itself.
3. **Swell**: Swells are waves that have travelled out of the generation area and are typically more uniform in wave height, period, and length.

When a wave's base can no longer support its top, it will collapse. This process is known as **breaking**. Running into shallow water, meeting with an opposing wave, and attaining too great a steepness ratio (height divided by length) are all processes that can lead to wave breaking.

In the context of sediment transport affecting beaches, **breaking waves can be divided into two categories**:

1. **Constructive** waves tend to be low in height and energy, longer in wave period and wave length, and slowly, constantly move material up the beach to form berms.

2. **Deconstructive** waves are tall and toppling (steep), and high in energy. They rapidly steepen as they approach the beach, and then plunge upon arrival, scouring the beach and creating a strong backwash that pulls material away.

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 varies with the location along the coast or the distance up a river or estuary from the coast.

Figure 6. Neap and Spring Tides (http:/www.eepe.murdoch.edu.au/resources/info/Res/tidal/index.html)

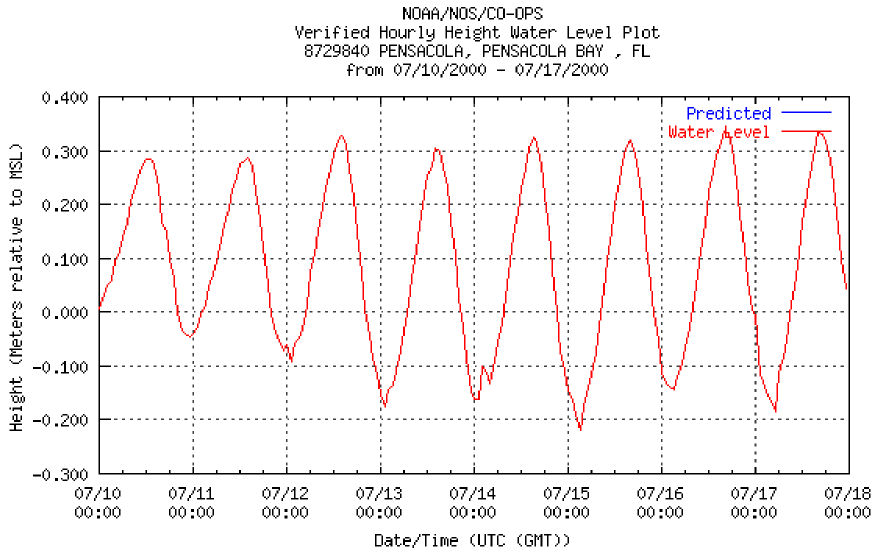


Figure 7. Diurnal Tide for Pensacola Bay, Florida

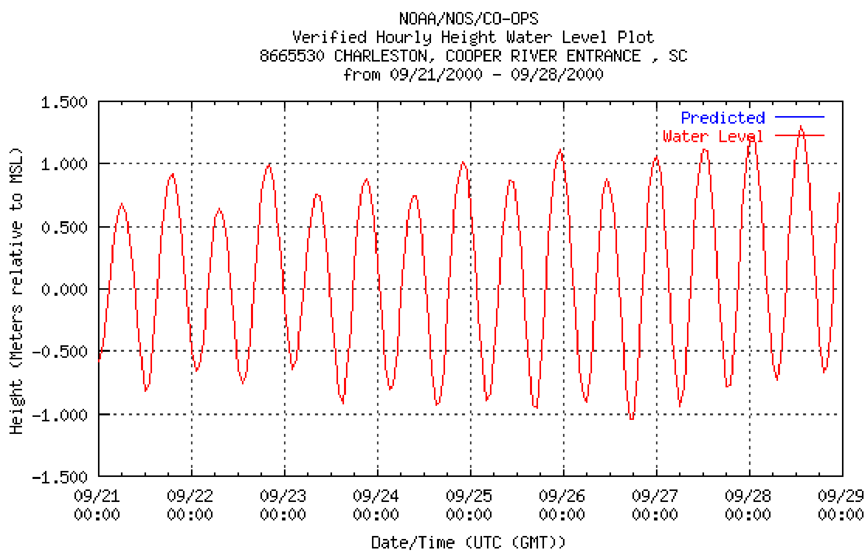
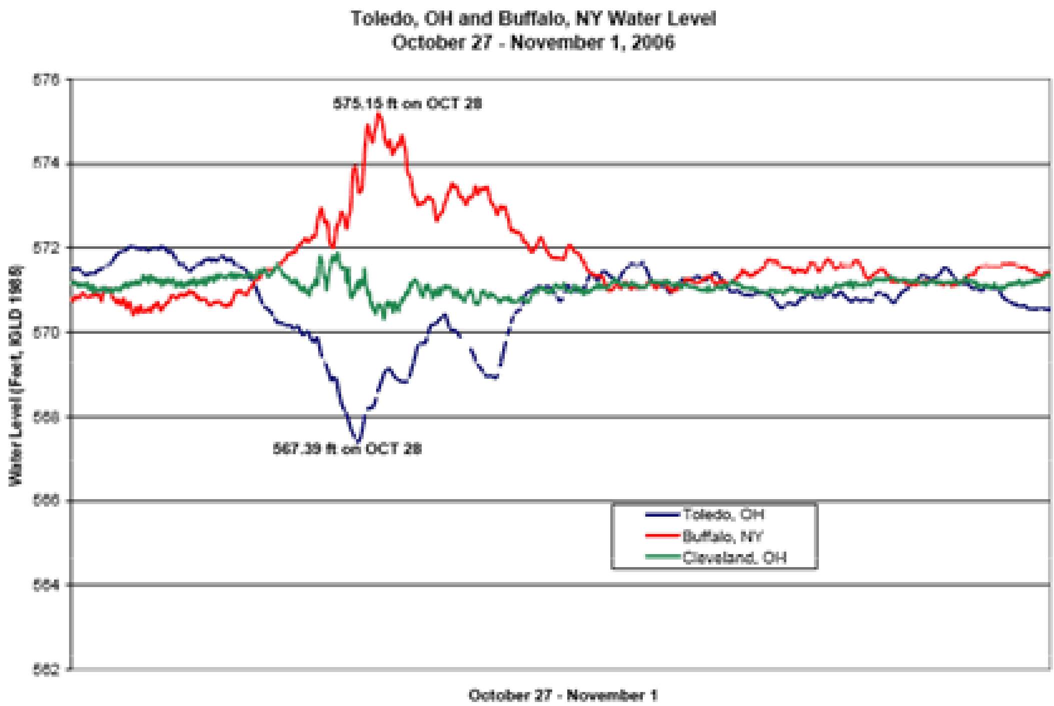


Figure 8. Semi-Diurnal Tide for Charleston, SC

Seiche

The term **seiche** (pronounced *saysh*) is used to describe a standing wave. For a seiche effect to occur, the body of water must be at least partially enclosed. In simplest terms, seiche is an effect similar to what happens to water in a bowl when the bowl is partially tipped. As the water rises on one side, it falls on the other. A common severe seiche occurs in Lake Erie; hardly surprising when one considers that the lake is 241 miles long and only 57 miles wide. (See Great Lakes Information Network, http://www.great-lakes.net/lakes/ref/eriefact.html) Prevailing winds from the west or southwest during a storm often lower the water level near Toledo, Ohio, yielding a rise in the water surface elevation around Buffalo, New York. Meanwhile, communities midway between the lake's ends, such as Cleveland, see very little seiche effect. For example, Figure 9 shows that water levels at Buffalo, NY, ranged from one to four feet greater during the period October 27 to November 1, 2006, while Toledo, OH, experienced water levels one to four feet lower than normal. Seiche occurs in harbors, bays and estuaries, and seas, as well as the Great Lakes.



Source: Detroit District

Figure 9. Differences in Water Levels on Lake Erie Caused by a Seiche, Oct – Nov 2006

3.2 Currents and Sediment

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 (or currents along the coast) can also be produced by waves breaking at an angle to the local shoreline and are important in the transport of sediment away from or toward the project site. Onshore and offshore currents create perpendicular (or cross-shore) sediment movements and longshore currents created parallel (or alongshore) sediment movements. Tidal currents are important in shallow water near tidal inlets. River discharge may also produce nearshore currents.

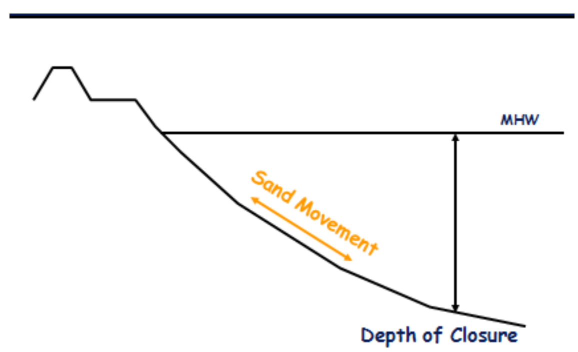


Figure 10. Cross-Shore Sediment Transport (Source: Randy Wise, NAP)

While the economist will not have primary responsibility for modeling hydrologic and hydraulic longshore processes, it is useful to have a working knowledge of the following concepts:

- The **net longshore transport rate**: the net amount of material that passes a particular point in the predominant direction in an average year.
- The **gross longshore transport rate**: the average annual total amount of material that moves past a particular point, regardless of direction.
- The **actual longshore transport rate**: the observed or measured amount of sediment water transports per unit of volume.
- The **potential transport rate**: the amount of sediment that could be transported if sufficient sediment volume were available.

The difference between potential and actual transport rates could be a result of the beach being starved of sediment. Following project completion, the former potential transport rate should become or be very close to the new actual transport rate.

The quantification of sediment transport, erosion, and deposition for a selected segment of the coast, either temporarily or permanently, is known as **sediment budget**. Sediment budget is also the balance between sediment added and sediment removed. Although the boundaries for the sediment budget are determined by the area under study, depending on the time scale of interest, the study purposes, and the implementation of a regional systems approach, separate budgets may be needed for distinct littoral cells (e.g. between inlets that separate eroding and accreting beach segments). Processes or actions that increase the quantity of sediment within the cell are called sources, while those that decrease the quantity are called sinks. The relative importance of elements in the sediment budget varies with locality and with the boundaries of the particular littoral cell.

Erosion

Beach Erosion Caused by a Storm, Assateague Island National Seashore, Maryland

There are both short-term and long-term causes of shoreline erosion. Erosion may be natural or human-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. Long-term erosion from a sea level rise due to climate change may be considered either natural or human-induced.

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. The Great Lakes are not affected by hurricanes, but they are affected by storm events. Erosion from ice movements and fluctuating lake levels are the primary causes of damage on the Great Lakes.

Why should economists care about erosion?

Erosion is the wearing down of land by wind, water, and other geological agents. Erosion is unique in that it should be dually considered as a damage-driver produced by storms and as an influential factor affecting the degree of other storm damages, structural and non-structural alternatives. Landscape changes resulting from erosion influence what effects future storms might have. In considering erosion, keep in mind that it is a continual, often gradual life-cycle process: inconspicuous, but integral to damage prevention. Also, human activities can have a tremendous influence on the degree and rate of erosion processes.

Table 1. Causes of Erosion (Revised from Source: IWR 91-R-6)		
Cause	**Short Term**	**Long Term**
Natural	Storm waves (large wave height and/or short wave period)	Sea level rise
	Storm surge	Decreased sediment supply
	Overwash	Deflation
	Flooding	Littoral transport loss
	Rip currents	Sorting of beach sediment
	Underflow	Flooding
	Ice flows (on the Great Lakes)	Rip currents
		Subsidence (compaction)
Man made	Navigation inlets	Navigation inlets
	Seawalls, groins, jetties, and other structural features	Seawalls, groins, jetties, and other structural features
		Aquifer depletion
		Dams
		Sand mining
		Dune destabilization
		Subsidence (from extracting sub-surface petrochemicals)

The subtle changes in the beach profile which occur during normal conditions may 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, high water levels and a pressure surge (storm surge) combine with steep waves which may bypass the offshore bars to break directly on the beach (Figure 11). The increased energy contained in the storm waves is spent eroding part of the beach, berm, and sometimes dune (crest recession and lowering in Figure 11, Profiles B and C), which are now exposed to wave attack by virtue of the storm surge. The eroded material is transported offshore where it is deposited to form an offshore bar. This bar may eventually grow large enough to break incoming waves, thereby dissipating some of the waves' energy over a wider surf zone. 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 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.

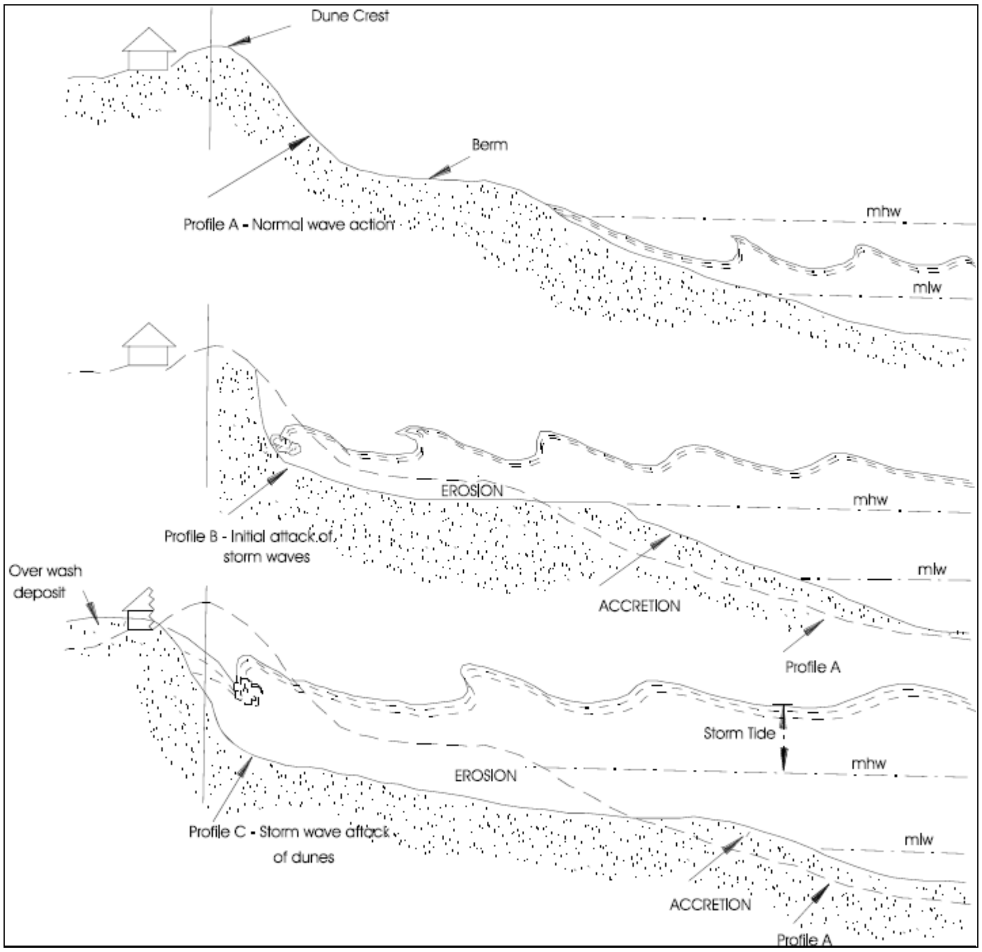


Figure 11. Schematic diagram of storm wave attack on a beach, dune, and upland structures (Source: Coastal Engineering Manual, p. V-4-2)

Dunes

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. Storm overwash and storm flooding return flow can 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 or it may close naturally.

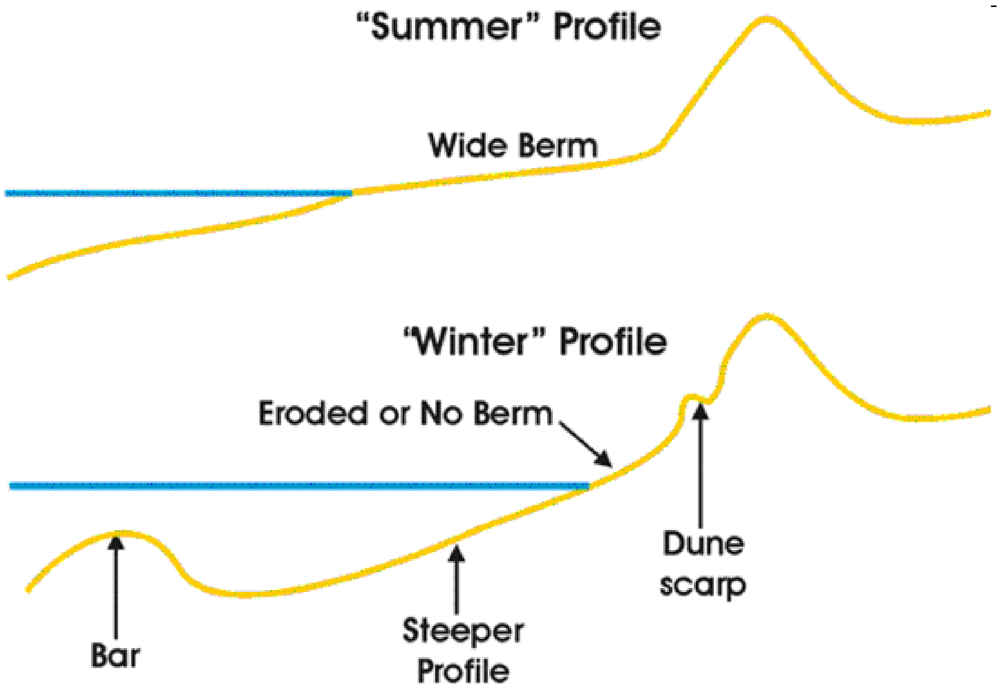


Figure 12: Examples of Summer and Winter Beach Profiles (https://www.maine.gov/doc/nrimc/mgs/explore/hazards/erosion/shape.gif)

3.3 Coastal Storms

Coastal storms and erosion along coastal or lake shores is natural. The beach is constantly changing as the tides and coastal processes shape the shore. These processes can be damaging and deadly forces for those that have chosen to make their home or living along the shores. This section describes the physical forces that are responsible for shoreline responses such as erosion, flooding, or accretion. Basic coastal processes include such forces as waves, tides, currents, storm surges, seiche, hurricanes, tsunamis and the interaction of these forces with shore features and other factors affect shoreline stability.

Storm Types from the **Coastal Engineering Manual 2008, Part V, Chapter 2**

(1) A **storm** is an atmospheric disturbance characterized by high winds that may or may not be accompanied by precipitation. Two distinctions are made in classifying storms:

(a) **tropical storm** a storm originating in the tropics (5 to 350 degrees latitude in both hemispheres);

(b) **extratropical storm** a storm resulting from a cold or warm front in the middle and high latitudes (30 to 60 degrees) (Silvester and Hsu 1993). Both storms can generate large waves and produce abnormal rises in water level in shallow water near the edge of water bodies.

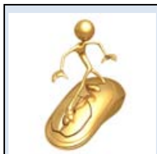
(2) A **hurricane** is a severe tropical storm with maximum sustained wind speeds of 120 km/hour (75 mph or 65 knots). These low pressure centers are known by different names geographically: hurricanes on the east coast of the Americas, **typhoons** in the western Pacific, **monsoons** in the Indian Ocean, and **tropical cyclones** in Australia (Silvester and Hsu 1993).

(3) **Extratropical storms** that occur along the northern part of the East coast of the United States, when accompanied by strong winds blowing from the northeast, are called **nor'easters**. Nearly all destructive nor'easters have occurred between November and April. Extratropical storms produce the dominant large wave conditions in the Great Lakes and generally occur between mid-October and April.

(4) **Tsunamis**, or seismic sea waves, are long-period waves generated by displacements of the seafloor by submarine earthquakes, volcanic eruptions, landslides and submarine slumps, and explosions. In the open ocean, amplitude of tsunamis is usually less than 1 m (3.3 ft) and hence may go unnoticed to passing ships. However, the wave height increases greatly as the shore is approached, resulting in potentially catastrophic flooding and damage. (Camfield 1980).

Whether they are called hurricanes, cyclones, tropical storms, northeasters (also known as nor'easters), or other names, storms and their associated winds, waves, and inundation are responsible for most destructive coastal damage and short-term erosion. It is important to note 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.

Topsail Beach, North Carolina after Hurricane Fran (Anthony Bley, Philadelphia District)



Lesser known than the Gulf Coast storm susceptibility, the Atlantic Coast is susceptible to hurricanes and devastating storms from Florida's coast to New England. In the Central Atlantic, the worst storms in terms of damages have been Nor'easters. See the *Deadliest, Costliest, and Most Intense United States Tropical Cyclones from 1851 to 2010* (NOAA, 2011).

Hurricanes[1]

Because hurricanes form around low-pressure cells in the Northern Hemisphere, their winds flow in a counter-clockwise direction. When a hurricane makes landfall, a number of major factors determine the extent of its damages, one of which is the side with which it strikes land. As a result of its counter-clockwise wind direction, a hurricane's strongest winds are those found on its right side. The storm's forward motion creates this effect. On the left side of the eye, one finds the opposite: the storm's forward motion weakens the winds' flow. When a hurricane makes landfall, communities to the right of the eye relative to the hurricane's forward motion experience higher winds than the communities to the left of the eye.

[1] This section also applies to typhoons.

Several other factors affecting a storm's damage impacts are the amount of rain, the size of the waves, magnitude of the storm surge elevation, duration of the storm, specific track of the storm with respect to local landforms, the forward speed of the storm, the central pressure deficit, radius of maximum wind speed, and the stage of the tide when the storm makes landfall. Wind speed determines a hurricane's classification within the Saffir-Simpson scale. The level of storm surge depends on wind speed ranges, slope of the continental shelf and shape of the coastline.

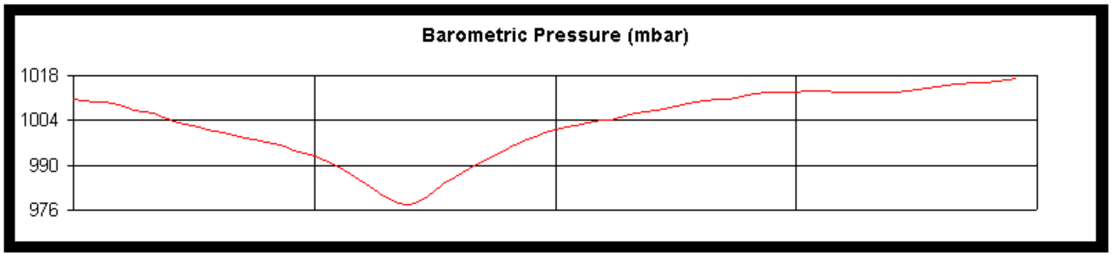


Figure 13. Hurricane Floyd Barometric Pressure, 1999 (Steven's Institute of Technology)

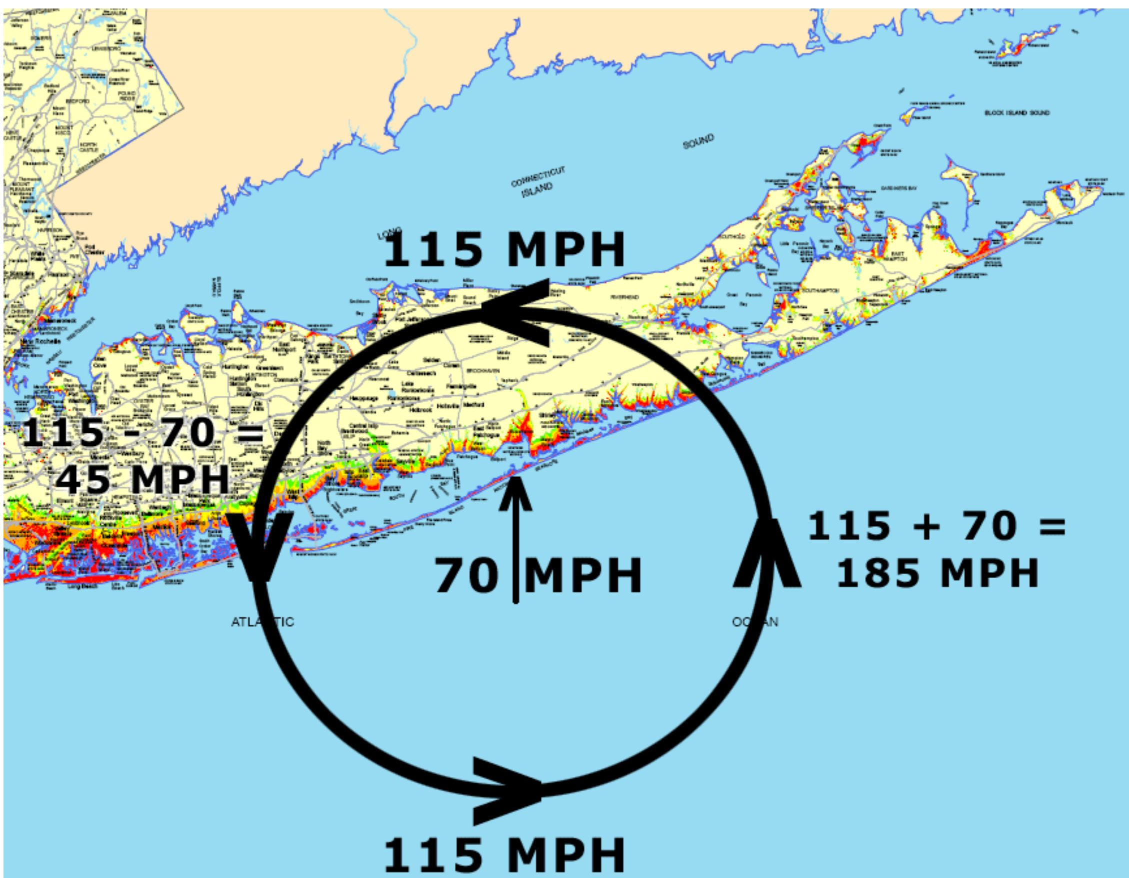


Figure 14. 1938 Hurricane, Forward Speed, and Angle of Approach (http://www2.sunysuffolk.edu/mandias/38hurricane/weather_history_38.html)

This 1938 hurricane shown in Figure 14 moved due north and accelerated in forward speed to 70 mph. In the history of hurricanes, the forward speed caused wind speeds on the eastern side of the hurricane to be extremely fast. Because hurricane winds rotate counter-clockwise and the hurricane was moving in the same direction, the forward speed added to the hurricane wind speed. Eastern Long Island and New England would later be hit with wind speeds that exceeded 180 mph. This is the fastest known forward speed of a hurricane ever recorded!

Storm Intensities

The Intergovernmental Panel on Climate Change (IPCC), in its recent report, released in 2007, noted that there has been a documented increase in hurricane intensity. The IPCC also reports a greater than 66 percent likelihood that increases in hurricane intensity will continue to be seen in the 21st century and warns of predicted increases in temperature and sea level rise. The estimated rate of sea level rise varies by region and estimation method used. The ranges of potential values in the next 100 years are from inches to feet. Obviously, any such rise in sea level will imply damage to coastal areas, and will likely affect future damage scenario predictions.

The Panel also reports that there will likely be increases in warm spells, heat waves, and heavy rainfall, increases in the areas affected by droughts, and increases in the occurrence of extreme high tides. All of the IPCC's projections are likely to hold crucial implications to the future of coastal storm reduction, as the Earth's climate continues to rapidly change and evolve.

EC 1165-2-211, *Incorporating Sea-Level Change Considerations in Civil Works Programs* (July 2009) provides guidance for incorporating the direct and indirect physical effects of projected future sea-level change in managing, planning, engineering, designing, constructing, operating, and maintaining USACE projects and systems of projects.

See the Intergovernmental Panel on Climate Change Working Group 1 Report (http://www.ipcc.ch/)

Coastal storm damage varies by area. This results from a number of factors, including the variance in topography and bathymetry across geographical regions, and differences in the weather patterns that affect them. Examples of such unique, region-specific effects are discussed below.

The Gulf Coast is especially susceptible to coastal storms, including hurricanes. As storms move over the warm waters of the Gulf, they usually increase in intensity and destructive force. Historically, it is an extremely rare event for a Category 5 hurricane to strike the US mainland. Only three Category 5 hurricanes have sustained such intensity at landfall since 1851. Hurricane Katrina in 2005 was a Category 3 when it made landfall at Louisiana and Mississippi. However, as Table 2 shows Katrina had an unusually low central-pressure. The low pressure center is what causes the hurricane to spin around the center. The storm surge along the Louisiana and Mississippi Coasts were so large because the surge was created when Hurricane Katrina was a Category 5 while still in the Gulf prior to reaching the coast and reducing its power.

Table 2. Most Intense Mainland US Hurricanes Ranked by Pressure

Rank	Hurricane	Year	Category at landfall)	Estimated Central Pressure at Landfall (Millibars)
1	Unnamed, FL (Keys)	1935	5	892
2	Camille	1969	5	909
3	Katrina	2005	3	920
4	Andrew	1992	5	922
5	Unnamed, TX (Indianola)	1886	4	925
6	Unnamed, FL (Keys)/TX	1919	4	927
7	Unnamed, FL (Lake Okeechobee)	1928	4	929
8	Donna	1960	4	930
9	Unnamed, LA (New Orleans)	1915	4	931
9	Carla	1961	4	931

Source: NOAA, *The Deadliest, Costliest, and Most Intense United States Tropical Cyclones From 1851 to 2006*, April 2007.

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, offshore bathymetric contours (sea floor relief), and the unique geometry of the landforms in the vicinity of storm landfall. Its effects are most profound when it occurs in tandem with high tide. Storm surges can be extreme. For example, Hurricane Hugo is estimated to have caused a surge of 19.8 ft at Romain Retreat, South Carolina, in 1989. Record surges include the 43-foot rise in water level that occurred in Bathurst Bay, Australia in 1899, and the 30-foot rise caused by Hurricane Katrina in Bay of St. Louis, Mississippi in 2005 (NASA http://solarsystem.nasa.gov/scitech/display.cfm?ST_ID=1350). Figure 16 shows a SLOSH (for Sea, Lake and Overland Surges from Hurricanes) model run for estimating storm surge associated with Hurricane Georges in 1998.

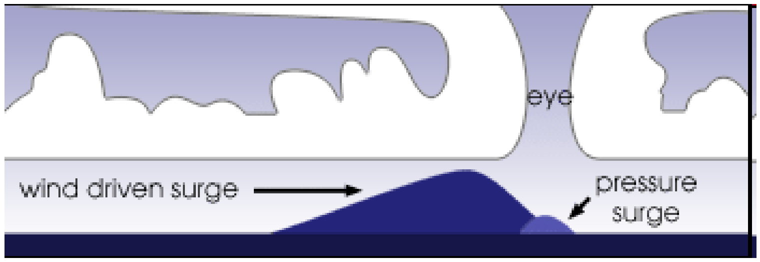


Figure 15. Storm Surge

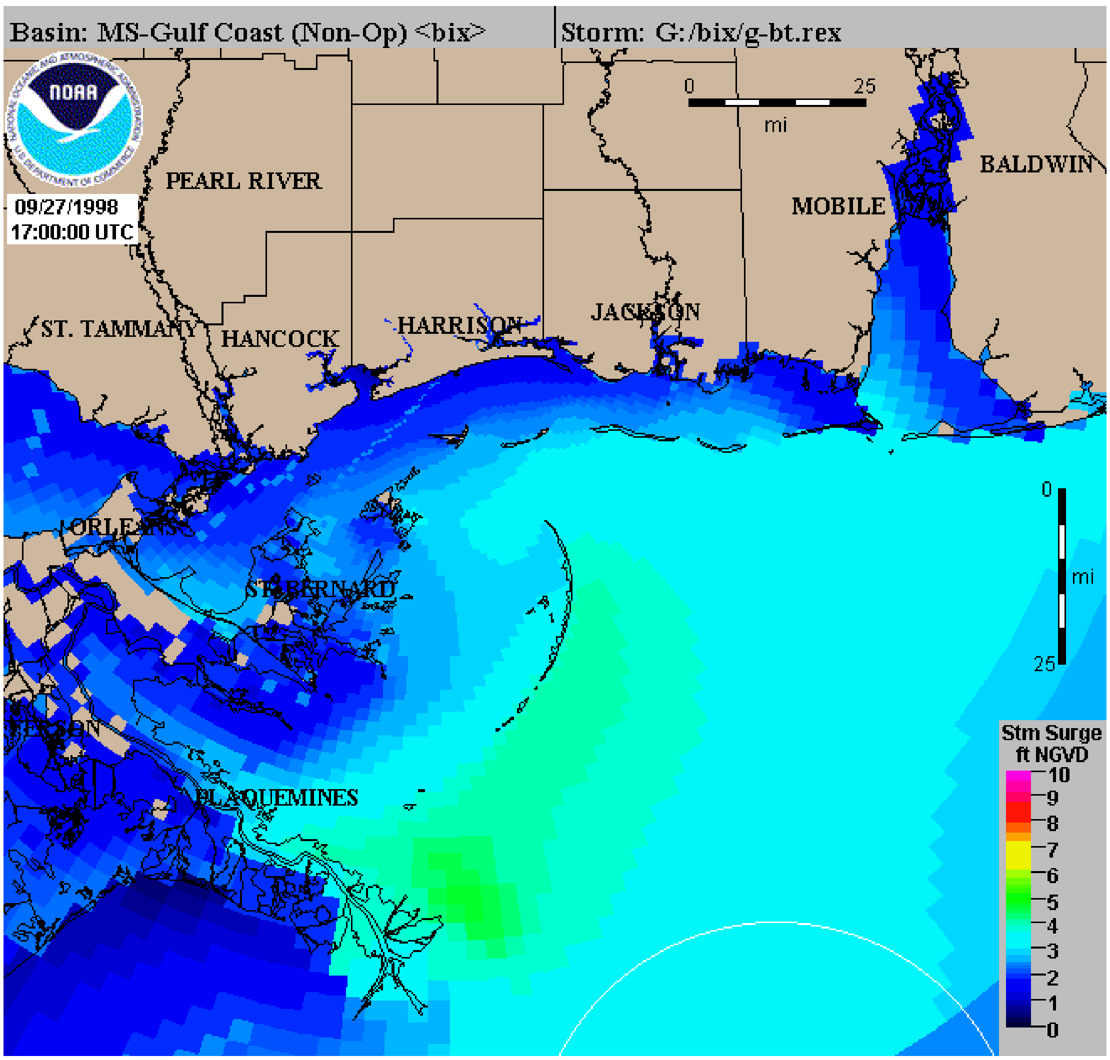


Figure 16. SLOSH Model Run of Storm Surge for Gulf Hurricane (Source: http://www.nhc.noaa.gov/HAW2/english/surge/slosh.shtml)

3.4 Coastal Storm Damages

Storm damage may occur to any structure located close enough to the water to be undermined, directly attacked by waves, or inundated by storm surge or waves. In areas with a marginal dune system, the dune may be breached or overtopped causing flooding and other damages. Also, any dune system can still be faced with lagoon side flooding. If overtopping 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 can occur 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.

Main Forces that Cause Structural Damage[2]

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. 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.

Stillwater Flooding. Water level rises cause inundation that can be treated as damage caused by stillwater. Storms can cause inundation of structures with stillwater either through overtopping of a dunes system (coastal flooding) or through flood waters coming from the bayside of a coastal island (bayside flooding). Coastal flooding implies stillwater level flooding of structures because of overtopping of a dune system or storm surge breaking through from the coastal side or lagoon side. Reduced stillwater flooding damages is a major benefit category of Corps' shore risk reduction measures. .

[2] Most Excerpts from *Coastal Storm Damage Relationships Based on Expert Opinion Elicitation (Unpublished, IWR, 2002).*

Flood "Rings" from Stillwater in New Orleans 2005 (Erin Wilson, Omaha District)

Waves

Wave action can cause significant damage to coastal structures. Conventional wisdom is that if breaking waves strike at or above a building's first floor elevation, that structure will be severely damaged. This is the rationale for the National Flood Insurance Program's (NFIP) characterization of a highly vulnerable zone (Zone V) for damage from wave action[3]. The ability to reduce wave damages is a benefit of Corps' shore risk reduction measures.

Wave Run-up. Wave run-up is the upper elevation level reached by a wave on a beach or coastal structure, relative to stillwater level (Coastal Engineering Manual, 2002). Wave run-up applies pressure on a structure in both a vertical and horizontal direction and is a function of the water depth and the square of the water velocity. These forces are measured in pounds (lbs.) per linear foot. Specific wave run-up relationships to damages and combined damages from flood and erosion is difficult to estimate; therefore, this damage factor of breaking waves attack a structure is often not explicit counted.

[3] Although FEMA demarks the V-zone as an area subject to breaking waves at least 3 feet high, recent, FEMA-sponsored tests indicate that 1.5-foot waves can break away walls. This research suggests that the V-zone might more appropriately extend to all areas subject to 1.5-foot high breaking waves.

Wave Run-Up on Monmouth Beach from Coastal Storm, New Jersey (Peter Shugert, New York District)

Erosion

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, reefs and orientation of the shoreline may lessen the effects. 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[4], does little perceptible damage but it sets the stage for downcutting of nearshore profiles and bluff recession 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- and long-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.

Erosion affects both land and structures. Erosion can be gradual or sudden. Erosion during a storm may destroy a dune, undermine shorefront structures and cause the collapse of the foundations of structures during a storm. Only sudden erosion is likely to

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

affect contents, but all erosion can impact a structure. The extent of damage will depend on the amount of storm-induced erosion at the structure and structural characteristics such as foundation and piling embedment. Damages from storm-induced erosion can be significant, regardless of the long-term erosion rate or whether natural processes rebuild the berm in the months following a storm. Often, property owners take measure to try to protect their property from erosion as the shoreline recedes and the threat of total loss increases over time.

Corps shore protection measures can provide significant reduction in damages attributable to erosion. Because erosion causes beaches to narrow over time, it is a major factor to consider in conducting a life-cycle analysis of project benefits and costs. Likewise, some beaches will gradually expand as well, which would reduce future measures to reduce risks.

Bluff and Cliff Erosion. Bluff and cliff erosion are ultimately caused by storms, precipitation, groundwater freeze-thaw cycles and other forces; however, the Corps only has authority to address erosion caused by coastal storms. This can be difficult to decipher among other erosion causes. This erosion results in the collapse of the bluff or cliff top that can occur in the short- or long-term. The preferred method for calculating this erosion is using a model such as Beach-*fx*. This model uses a Monte Carlo simulation that samples a distribution of possible episodic events over the period of analysis. The damages are not caused by direct wave attack to structures, but rather the damages occur once cumulative erosion undermines the bluffs, causing them to collapse weeks or months after the toe erosion reaches a critical depth – causing damages to property and structures atop the eroded bluff. In this way, damages are not attributable to individual storm events, or even to a particular storm season, but rather to longer-term changes that result in episodic collapse of the upper bluff.

Finally, there is beach recession caused by **littoral drift**. In this case, the frequency relationship is not a complicated function but simply an annual rate.

Erosion along Morgan Peninsula, Alabama (ERDC)

Wind Damages

High winds associated with storms can cause significant damages to structures both on the coast and much further inland. High winds and associated flying projectiles can damage doors, windows or roofs and potentially generate structural failure. Such inlet formation or dune failure also allows rainwater damage to the structure. Most of the damages from Hurricanes Andrew, Iniki, and Hugo were caused by wind and wind-related rainwater as opposed to waves, flooding, wave run-up, or erosion. Because Corps' projects do not significantly affect the wind speed of storms, wind damage is not reduced through shore risk reduction measures. However, wind speed does impact dunes, so it is still an important consideration for existing and proposed dune structures.

3.5 Summary and Look Ahead

While economists need not become experts in coastal engineering or geomorphology, it is important that they have a basic understanding of coastal forces that create the damages, the relevance to the National Economic Development (NED) analysis, and the engineering and other solutions that they will be evaluating from an NED analytical perspective. The next chapter provides an overview of NED analysis, examining NED benefits and costs, and the analytical requirements for deriving NED estimates.

Chapter 4: National Economic Development (NED) Objective

The Federal objective of water and related land resources project planning is to contribute to National Economic Development consistent with protecting the Nation's environment, pursuant to national environmental statutes, applicable executive orders, and other Federal planning requirements.

-Principles and Guidelines, 1983

4.1 NED Objective: Highest Net Benefits

National Economic Development (NED) benefits contribute to increasing the value of the national output of goods and services. The NED Objective is to maximize total net NED benefits for a project consistent with protecting the environment. NED Benefits are measured in the NED Account. The other three accounts are: (1) Environmental Quality (EQ), (2) Regional Economic Development (RED) and (3) Other Social Effects (OSE). Despite the requirement to consider the other three four accounts, the NED account is still the main factor for selecting an alternative plan. It is the primary basis for Federal investment in water resource projects and is measured in average annual equivalent terms.

Net National Economic Development (NED) Benefits

Net NED benefits are NED benefits reduced by NED costs. Economists must determine which NED benefits and costs can and should be counted towards the final net NED benefit total in average annual equivalent values. Furthermore, planners may need to identify the trade-offs between increased economic efficiency and environmental output.

See the *NED Overview* and *Economics Primer* for more information on the basis on NED analysis.

IWR Planning Suite can assist in analyzing the trade-offs between NED and other factors.

Economic justification of a project alternative requires that benefits exceed costs. While the benefit-cost ratio is a convenient device to verify justification and is often used in the

Budget Engineering Circulars (ECs), net NED benefits are the preferred measure for plan selection.

The plan with the highest benefit-cost ratio and the plan with maximum net NED benefits may not coincide. Conceptually, the most efficient use of resources is when benefits exceed costs by the maximum amount. Therefore, maximum net NED benefits are used as the primary determinant of the most efficient plan or plan scale.

All reports should include information and data sufficient to define the upper (maximum net benefit) and lower portions of the net benefits curve for a number of alternative plans. The total benefit, total cost, incremental benefit, and incremental cost curves should be shown for each alternative plan so that the relationships between total and incremental costs and benefits is evident. The most efficient plan can be determined by analysis of the relationship between costs and benefits, discounted to account for the time value of money and expressed in average annual equivalent values.

4.2 NED Benefits

NED benefits must be expressed in monetary units for benefit-cost analysis. This is true even if the value of goods and services is not derived from market transactions. The conceptual basis for determining the value of such NED benefits is willingness-to-pay (WTP) by the users of project outputs.

Benefits of coastal projects are derived mainly from reductions in damages from waves (such as storm surges), floods, and erosion. Table 3 provides a list of general NED benefits. For more detailed information, see **Chapter 9**.

Vilano Beach, Florida (Jacksonville District)

Table 3. NED Benefits of Coastal Storm Management Projects	
Benefit Category	**Benefit: Reductions in**
Reduction in Physical Damages	Structural Damage to Buildings: homes, commercial or public buildings, sheds, lumberyards, etc.
	Loss of Contents: this includes any loose items inside any structures, but could also include outside items such as lumber from a lumberyard
	Damage to Infrastructure: streets, highways, railways, sewers, bridges, power lines, boardwalks, ports, and other infrastructure.
	Agricultural Losses: crops and equipment (See the Agricultural Flood Damage NED Manual at www.corpsnedmanuals.us for more details).
	Vehicle damages: personal, public, or commercial vehicles that are not evacuated (See NED Procedures Manual: NED Costs)
	Loss of Land Value: the value of lost land
Reduction in Non-Physical Damages	Income Loss: loss of wages or profits to business over physical damages that cannot be deferred or transferred regionally. Prevention of income losses result in a contribution to NED only to the extent that the losses cannot be compensated for by postponement of an activity or transfer of the activity to other establishments. Estimates of these losses must be derived from specific independent economic data for the interests and properties affected.
	Emergency Costs: expenses from the risk of a storm and expenses from the storm itself, includes expenses for monitoring, forecasting storm problems, emergency evacuation, storm fighting efforts such as sandbagging or building closures, administrative costs of disaster relief, public clean-up costs, and increased costs for fire, police and/or military patrols.
	Public and Private Protective Measures: reduced cost in the future from a proposed project for avoiding public and private expenditures on measures to reduce damages to coastal property.
	Temporary Evacuation and Relocation: public and private expenses from relocating residents to habitable areas temporarily because of their homes are severely damaged, have sediment deposits or disruption in utility services.
	Transportation Delay Costs: public and private delay expenses from cars, rail, air or other transportation means; for example, a road could be closed for public safety reasons due to the flooding , delays and traffic rerouting that can avoided by a proposed project would be counted as NED benefits.
	Associated Agricultural Losses: crop or other losses from delays in planting or lack of access to land.
	Reduced Maintenance on Existing Structures: benefits are the extent in which maintenance costs are reduced.
	Location or Intensification Benefits: increased value from project modifications that allow for intensified activities or higher-valued developments. Ask a senior economist for more information on this.
Other NED/NER Benefits, include	Utilization of unemployed or underemployed labor in various markets: this must meet specific criteria as set by guidance to qualify.

Table 3. NED Benefits of Coastal Storm Management Projects	
Benefit Category	**Benefit: Reductions in**
but are not limited to:	National Ecosystem Restoration (NER) Benefits: these are generally not monetized but appear in the form of additional acres, habitat units, fish counts, or biodiversity indices.
	Benefits During Construction (BDC): these can be a combination of any of the above benefits that accrue prior to the base year for a long construction period.
	Recreation: economic value of adding additional recreation opportunities (See EGM, 10-03, Unit Day Values for Recreation, FY 2010) or most recently published.

4.3 NED Costs

National Economic Development (NED) costs are critical to the planning process and serve a key purpose in evaluating, comparing and selecting project alternatives. Both the financial costs (often assumed to be the construction and mitigation costs) and economic costs (including opportunity costs) throughout the project life-cycle must be considered. Analysis requires not only an economic evaluation, but also detailed engineering cost estimates for specific construction pieces as part of the NED Plan and risk consideration of the costs.

*National Economic Development (NED) costs include the opportunity costs of diverting resources for another source to implement the project. **Interest during construction** (IDC) is an example of an opportunity cost because the costs used in construction could be going to another investment with a return value that is not being earned during construction.*

See NED Procedures Manual: NED Costs at www.corpsnedmanuals.us for more information.

It is important to consider all costs related to a Coastal Storm Risk Management project, even if it appears that some are not directly linked to the project. The *NED Costs Manual* can provide more details on how to calculate costs. Below is a list of general NED costs. **Chapter 9** also provides more details.

Table 4. Project NED Costs
• **Project Costs** (construction, mitigation[5], etc.) • **Operation, Maintenance, Repair, Replacement and Rehabilitation** (OMRR&R) • **Interest During Construction** (IDC): These costs are hidden, unpaid costs that must be accounted for when determining the NED costs of a project. The cost of this waiting period is known as the *opportunity cost* and it reflects the foregone opportunity of investing the funds for other purposes. • **Associated Costs**: all costs other than those above that are required to fully implement a project for the life of the project and necessary to realize benefits.

When determining NED costs, it is important to differentiate the projected financial and economic costs from *sunk costs* – i.e., costs that have been incurred but which cannot be

[5] Mitigation may actually start prior to construction (or credited) and could also go beyond the construction period depending on the mitigation measure.

recovered. Feasibility and other study costs are considered sunk costs. In addition, improvements the sponsor will make under the without-project conditions are excluded in the analysis. For clarity, these costs are not sunk, but they are "future without-project condition costs."

4.4 Analytical Requirements

Current guidance contains some specific and general assumptions and requirements that are to be observed in NED evaluation. The manual introduces these concepts in general terms here, but more specific procedures to meet analytical requirements are addressed in **Part II** of the manual.

Systems Analysis

Coastal Storm Risk Management projects tend to provide both beneficial and adverse effects outside the immediate area of project construction. Therefore, it is important to apply a systems analysis that takes into account both the costs and benefits associated with every alternative.

> **Systems Analysis**. *Because shoreline processes are dynamic, shore protection measures may generate both beneficial and adverse impacts beyond immediate project sites. Impacts elsewhere may occur as a consequence of the design and implementation of site specific hurricane and storm damage reduction projects, and navigation projects may impact or be impacted by such projects. These impacts must be evaluated, and this requires expansion of the study area to include reaches adjacent to the project site. Generally, the adjacent reaches are bounded by natural features that interrupt or substantially limit the natural littoral processes (e.g., bays, sounds, inlets, geomorphic features, etc.).*
>
> -ER 1105-2-100, Appendix E-24, f(1)

A systems analysis looks at the inter-relationship of changes. Any structural change to the coastal area as part of a project will change the movement of sediment at placement and potentially borrow sites. The engineers on the PDT need to assess the effects in up coast and down coast littoral areas and off/on the shore. Changing the movement of sediment can impact recreation, environmental quality, and navigation—to name a few examples—outside the immediate project area. Such impacts should be measured as added costs and benefits.

Incremental Analysis, Separable Elements

Each alternative should be broken down in separable and combinable elements. Incremental analysis involves examining increments of plans or project features and determining their separable or incremental costs and benefits. Increments of plans should continue to be added and evaluated as long as the incremental benefits exceed the incremental costs. When the incremental costs exceed the incremental benefits, no further increments are supported by marginal benefits.

A *separable element* is a functional coastal planning feature or reach that can be evaluated independently of the rest of the project. Its justification is based upon its own merits. The cost and the benefit of an element should be examined to determine whether it is economically justified. It is important to try to narrow down alternatives prior to doing an incremental analysis to avoid costly, extensive, and unnecessary analyses.

Optimal plans are those plans which maximize net NED benefits.

Life-cycle Analysis

> *Storm damage reduction studies should adopt a life-cycle approach and probabilistic analysis (and display) of benefits and costs.*
>
> -ER 1105-2-100

The long periods of analysis, the limited knowledge and data available to predict natural system behaviors, and the difficulty of predicting human behavioral responses adds to the uncertainty of life-cycle analysis.

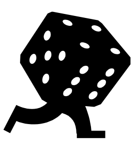
There are two basic approaches to dealing with life-cycle probabilities: a frequency-based analysis and a Monte Carlo simulation method, which is preferred.

A ***frequency-based analysis*** attempts to describe the nature of future events as a set of values or curves of magnitude vs. probability (or return period)—more extreme events are expected to have lower probabilities of occurrence. A frequency curve relating events can eventually be combined with an event-damage curve and result in a frequency-damage estimate. This was the traditional approach explained in the NED Manual for Coastal Storm Risk Management. As stated in the Coastal Manual, this approach relies on 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 at that time. For example, the probable damages associated with a 0.01 event and a 0.10 event are 0.01 and 0.1 times the damages estimated for each of these events in that year. The summation of all probable damages over the range defines expected damages for that year.

When employing the frequency-based approach, a life-cycle analysis is represented by a sequence of *snap shots* as the curves exogenously shift due to land use changes or changed hydrology. Frequency-based analysis has the advantage of being relatively easy to implement, but is less representative of complex dynamic processes. These curves are often based on limited sample historical conditions which may not be representative of future conditions.

The coastal environment requires consideration of flood, waves, and erosion combined. Erosion is typically the major cause of property damage. Generally, the erosion frequency-based framework divides the causes of property loss into two classes: storm effects and long-term shoreline erosion or accretion. Storm effects are represented by an erosion frequency relationship, and erosion effects are based on historical shoreline records, and are handled separately.

This frequency based approach has several short-comings given the dynamic nature of the coastal environment. The Life-cycle Risk Analysis, an event-based Monte Carlo simulation approach, addresses these short-comings and improves decision making. For more information on this, please see the article *"Life-cycle Risk Analysis Approach to Coastal Storm Damage Reduction Planning,"* by Moser et. al. This article explains that the life-cycle approach better captures the dynamic evolution of beach nourishment projects than the frequency approach because of the relatively infrequent historical occurrence of damaging storm events in an area. This approach provides multiple iterations of a fifty year life-cycles necessary to capture the variability of estimated damages.



An alternative and the **recommended method** that is implemented in the Coastal Storm Risk Management economic evaluation tool, **Beach-*fx***, uses ***Monte-Carlo simulation (MCS)*** of the project life-cycle (typically 50 years) by determining the coastline and structure response to a set of storms (the events driving the process). Each simulation has a set of iterations. This simulation is repeated for many different project life-cycles represented by unique random sequences of storms, and the results are averaged or discussed as a range of possibilities. An advantage of MCS is the high level of detail that can be represented, the congruence of model entities with *real-world* entities, and the capability of including a variety of dynamic responses. MCS models also lend themselves to visualization quite well. This general approach is quite common in a number of other Corps applications, such as in navigation. Disadvantages include the extensive time that may be needed to develop the simulation, potentially large data requirements, difficulty of verification and calibration, huge amounts of generated data, and the sometimes many iterations for convergence of results.

Beach-fx *automates much of this process and is a USACE certified planning model.*

4.5 Summary and Look Ahead

This chapter has presented general information about National Economic Development (NED) benefits and costs that are computed and analyzed to determine net NED benefits which are the focus of the Federal objective for Coastal Storm Risk Management (CSRM) planning. NED evaluation should employ a systems perspective, incremental analysis of separable elements, and should adopt a life-cycle approach to the quantification of benefits, costs, and uncertainties. Two general methods for accomplishing such life-cycle analyses can be employed; however, the use of Monte-Carlo simulations is recommended, and is the approach used in the Corps Beach-*fx* economic evaluation model.

Chapter 4 concludes **Part I** of this NED manual. Part I was intended to provide general contextual-level information about Corps planning processes, risk assessment, coastal processes and storm damages, and NED analysis. The manual now turns attention in **Part II** to the specifics of performing CSRM economic analysis within this framework.

Part II – The NED Analysis of Coastal Storm Risk Management (CSRM) Projects

Chapter 5: Economic Analysis of Coastal Storm Risk Management Projects

This chapter introduces the evaluation steps for conducting the economic evaluation of Coastal Storm Risk Management projects. The general logical sequence is shown in Figure 17. This figure shows the relationships of the key steps with the Corps Six-Step Planning Process and the Risk-Informed Decision Making context previously presented in **Chapter 2**. Data Collection, Communication, and Monitoring occur throughout the process. Additionally, Table 5 provides a crosswalk to help organize the process and serve as an aid in easily accessing parts of the manual.

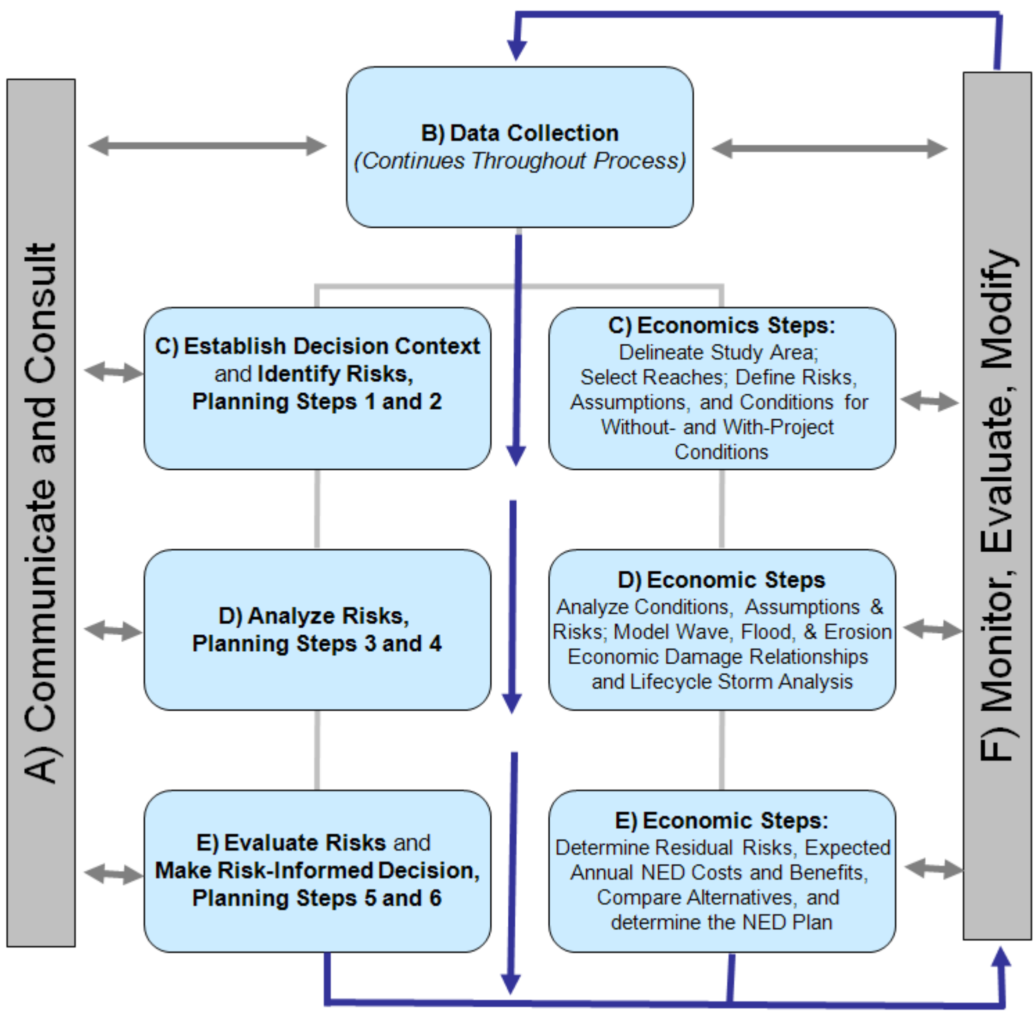


Figure 17. Risk-Informed Economic Evaluation Framework Showing Key Economic Steps

5.1 Analysis Framework

Table 5 below provides further detail on the linkage and relationship among the key components of the Corps Six-Step Planning Process, the Risk-Informed Decision Making Process, ER 1105-2-100 economic evaluation steps and the topics presented in this manual. Each section in the manual is also hyperlinked to table entries for easy access.

Table 5. Crosswalk Among Risk-Informed Steps, Corps Six-Step Planning Process Steps, Economic Evaluation Steps in ER 1105-2-100, and NED Manual Topics

Risk-Informed Step *(Data Collection, Communication and Monitoring Occur Throughout Steps)*	**Six-Step Planning Process** *(Data Collection, Communication and Monitoring Occur Throughout Steps)*	**NED Manual Economic Task Discussion (Chapter and Section)**
1. Establish decision context	1. Identify problems and opportunities	7.1 Delineate the study area Using data collection to define the study area
2. Identify risks	2. Inventory and forecast	7.2 Delineate study reaches 7.3 Describe without-project risks, uncertainties, assumptions and conditions 7.4 Period of analysis 7.5 Identify risks and uncertainties 7.6 Existing structure inventory 7.7 Forecasting future conditions 7.8 Uncertainty in forecasting with- and without-project conditions 7.9 Future structure inventory 7.10 With project conditions: description, structural and non-structural measures
3. Analyze risks	3. Formulate alternative plans	8.1 Risk=fx(probability, consequences) 8.2 Storm generation 8.3 Evaluating the damages: Flood damages Wave damages Erosion damages Other damages or potential benefits 9.1 Damage curves 9.2 How to determine the damage curve 9.3 Flooding damage curves 9.4 Wave damage curves 9.5 Erosion damage curves 9.6 Combined damage curves 9.7 Example 9.8 Calculate without-project damages
4. Evaluate risks	4. Evaluate effects of alternative plans	
5. Risk management decision	5. Compare alternative plans	10.1 Determine NED costs 10.2 Determine NED benefits 10.3 Compare alternatives
6. Risk management decision	6. Select recommended plan	10.4 Determine the NED Plan 10.5 Select recommended alternative

Although the manual lays out a general step-by-step process to perform an economic analysis of Coastal Storm Risk Management projects, it is important to remember that the process is iterative and never a simple linear sequence of steps. Below is a general description of the process as defined by each chapter.

Chapter 6 - Data Collection *(continues throughout all steps):* This chapter discusses the sources for collecting data.

Chapter 7 - Risk-Informed Decision Making: Establish Decision Context and Identify Risks *(Planning Steps 1 and 2):*

This chapter establishes the existing risk decision context and identifies what is relevant for the NED analysis. The problems and opportunities that guide the planning process can be addressed in a risk-informed context. *What could go wrong, and how could it happen?* For example, a community has experienced coastal storm erosion and structural losses despite an existing sea wall, is there a solution to reduce probability of the water exceeding the sea wall capacity thus reducing the probability of related damages, otherwise known as risk reduction? This information on problems, needs, opportunities, and risks will guide the inventory and forecasts and vice versa. The economist should delineate the study area based on the risks discovered in the floodplain analysis. Then, the economist can select reaches, based on several resources, which will be the basis for subsequent analysis, and describing the without-project condition.

Chapter 8 and Chapter 9 - Analyze Risks: Formulate and Evaluate Plans *(Planning Steps 3 and 4)***:**

The tasks identified in **Chapter 7** lead to developing the likelihood or probability and consequences of something going wrong. The without-project condition should be analyzed first and then with-project alternatives can be analyzed. Any uncertainties in this analysis should be acknowledged and managed. For example, scenario or sensitivity analyses can be used when there are unknown future conditions. The tasks described in **Chapter 8** and **Chapter 9** constitute the bulk of the risk assessment. The without- and with-project damages are calculated in this step. The with-project condition must address any residual risks and a non-structural plan must be evaluated.

> *A **scenario** is a 'particular situation, specified by a single value for each input variable' (Morgan and Henrion 1990). In the case of a capacity-exceedance scenario, specific characteristics of the exceedance are defined, the impact is estimated and qualitative and quantitative results are reported. The scenarios considered may include a **best case, worst case, and most likely case**, thus illustrating consequences for a range of conditions.*
>
> -EM 1110-2-1619 (August 1996)

Chapter 10 - Evaluate Risks and Make Risk-Informed Decision: Compare and Select Plan *(Planning Steps 5 and 6)***:**

The NED costs are the costs to implement any with-project alternative. The majority of NED benefits are the cost reductions of economic storm damages to property and belongings. Net NED benefits are the NED benefits less the NED costs. The plan with the highest net average annual equivalent NED benefits is the NED Plan. However, the plan with the highest net benefits may not be the recommended plan. Risks among alternatives should be considered for acceptability and residual risks. For example, loss-of-life implications and environmental factors among others are important to consider for comparison. Once all residual risks are described, it should be decided if these are risks that the Federal government and the community can accept. If not, then more plan formulation may become necessary. A plan, other than the NED Plan, can be recommended based on other factors and with a waiver from the Office of the Assistant Secretary of the Army for Civil Works (http://asacw.hqda.pentagon.mil/default.aspx).

To find out more about Risk Analysis, click on the following articles:

- Tools for Risk-Based Economic Analysis
- Risk Analysis Framework for Cost Estimating
- Risk-Based Analysis for Flood Damage Reduction Studies
- Applied Risk Communication Within the Corps

5.2 Evaluation Models: Beach-*fx*

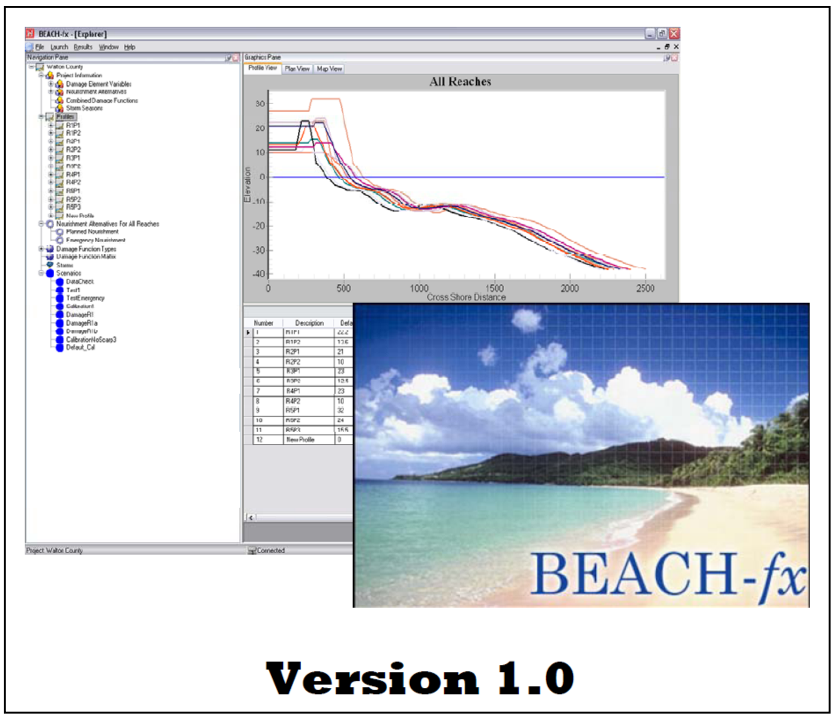
Beach-*fx* 1.0 is a Corps-certified planning model. It is designed to assist users in evaluating and analyzing the benefits and costs of storm risk management projects. The model combines coastal engineering and economics to estimate delineated study area damages and costs for project alternatives. The overall unit of analysis is the "project," a shoreline area. Beach-*fx* is a comprehensive analytical model for evaluating the physical performance and economic benefits and costs of shore risk management projects, particularly beach nourishment along sandy beaches. The model has been implemented as an event-based ***Monte Carlo life-cycle simulation tool***. Beach-*fx* uses the Monte Carlo over the period of analysis (typically 50 years) by determining the coastline and structure response to a set of storms (the events driving the process). This simulation is repeated for many different project life-cycles represented by unique random sequences of storms, and the results are averaged or discussed as a range of possibilities. It allows the user to input ranges of uncertainty on home values and other items to help describe the broader potential range of damages among various plans and scenarios.

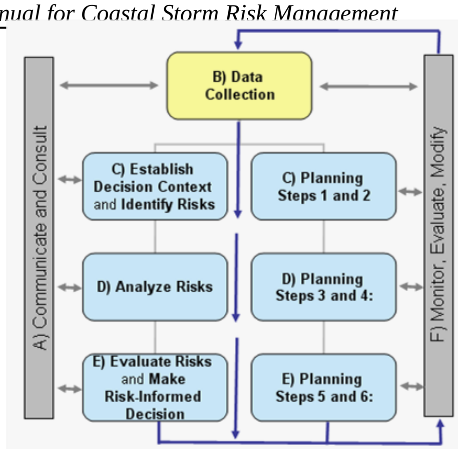
The results assist in calculating the NED benefits of a given alternative. The Beach-*fx* Model was developed through a collaborative effort between the Institute of Water

Resources (IWR) and the Coastal and Hydraulics Laboratory at the Engineering Research and Development Center (ERDC). More information can be found at the [Beach-*fx*] website where there are user guides or throughout this manual.

5.3 Summary and Look Ahead

This chapter has provided a crosswalk among the three pieces of guidance for conducting Coastal Storm Risk Management studies: ER 1105-2-100 economic evaluation steps; the Corps Six-Step Planning Process; and the Risk-Informed Decision Process and the topics describing economic tasks presented in this NED manual. The chapter has also briefly introduced the Beach-*fx* economic evaluation model. The next chapter discusses data that will be needed for a CSRM study and how to obtain it.





Chapter 6: Data Collection

ALL PLANNING STEPS

The inventory should include data appropriate to the identified problems and opportunities, as determined by scoping, and the potential for formulating and evaluating alternative plans.

-Principles and Guidelines, ER 1105-2-100, 2000

6.1 The Use of Empirical Data

Prior to starting any analysis or describing any conditions, data collection is a vital first step to understanding Coastal Storm Risk Management issues. This chapter identifies data that will likely need to be obtained in order to perform NED analyses. In general, it is preferable to collect more data in the beginning rather than be faced with not having enough of the right data at critical steps in an analysis; however, data collection is an iterative process that will take place in each step of the planning process. Communicating and consulting is encouraged to gather background about or otherwise explain the empirical data.

Sometimes there is uncertainty about the level of detail needed or the accuracy of the details, particularly for geographic, economic, and timeframe data. This is one source of uncertainty that contributes to the risk of achieving the “as planned alternative” that should be described in the economics report. In general, error should have natural variation, but this should be check for bias.

6.2 Data to be Obtained

Data to be obtained for an NED analysis may include, but is not limited to:

- Current and historical maps of coastal area
- Historical storm dates
- Historical damages in current and nominal dollars (clean-up and repair costs, etc.)
- Tides
- Wave and surge heights
- Erosion in terms of depth of recession over time or related to a specify event
- Sediment movements
- Peak stages
- Damages by category
- Existing projects in place
    - level of risk-reduction benefit
    - structural integrity
    - remaining useful life
- Operation and maintenance requirements
- Shoreline conditions
- Shoreline structure
- Population, demographics
- Land values
- Photos, current and historical
- Emergency costs
    - evacuation
    - flood fighting
    - emergency erosion control
    - miscellaneous costs that could change with various alternative plans
- Recreation activities, counts, estimates
- Structure inventory: see **Chapter 7** for more details

Please consult with your project engineer on coastal data.

6.3 Sources of Information

This section serves as toolbox of sources to find project data that will be useful in the analysis:

- **Site Visits:** Site visits are essential to collect data and develop a first-hand understanding of the coastal problem. The section below describes site visits more fully.
- **Visit the Beach Electronically**: Technology and GIS offer more options to see the beach from your computer, see the section below for more details.
- **Shared district or division data:** The local USACE District or Division office can often identify good sources of information regarding the study area. Local staff can suggest other projects, concurrent or historical, that might have similar economic issues and conditions that can serve as models for an analysis.
- **Corps National Planning Center of Expertise for Coastal Storm Damage Reduction (CENAD):** The primary goal of the Center is to serve as a leader in the CSDR field, including plan formulation, economics, environmental and engineering key disciplines to improve quality and timeliness of Corps coastal storm damage reduction planning studies and products. The planning center of expertise will focus primarily on plan formulation and the complex technical evaluations associated with plan formulation. The PCX-CSDR organization and operations are established consistent with other national centers and to allow for adaptive management and evolution over time as circumstances warrant (see website address below).
- **Team members:** Team members can often be a source for identifying and finding good information.
- **Non-Federal entities**: Local entities, such as states and counties, often publish economic and demographic information relating to their locale. County tax assessors or building permit offices may have good structure inventory data.
- **Stakeholders**: stakeholders may have local knowledge of the area, historical information and more. These can be elected officials, residents, reporters, and local government employees.
- **Other Federal Agencies:** FEMA may offer maps and emergency response information. The NOAA Coastal Services Center generally provides a wealth of information on coastal conditions and processes.

- **<u>Websites</u>:**

  - U.S. Census Bureau:
    www.census.gov
  - Bureau of Labor Statistics:
    www.bls.gov
  - FedStats:
    www.fedstats.gov
  - USDA Economic Research Service:
    www.ers.usda.gov
  - Vanderbilt University Frequently Used Sites Related to U.S. Federal Government Information:
    http://www.library.vanderbilt.edu/romans/fdtf/statistics.html
  - Corps NED Manuals Toolkit:
    http://www.iwr.usace.army.mil/ned/index.asp
  - Corps Planning Center Expertise (PCS) for Coastal Storm Damage Reduction:
    http://www.nad.usace.army.mil/natplan.html

- **<u>Printed Materials</u>**: Books, journals, newspapers, prior flood damage reports, maps.

- **<u>Primary Data Collection</u>**: While collecting primary data is always an option, this course of action is usually only feasible for small study areas. Assessor's records are the most commonly used source of secondary data. In most cases, these records should be readily available in GIS compatible files.

A Note on Coordinate Systems

There are times when you just can't get your data in a consistent format. Maybe the assessor can provide land use and value data in latitude and longitude while your profile data is in Universal Transverse Mercator (UTM). When that happens, see Professor Dutch How to Use the Spreadsheet for Converting UTM to Latitude and Longitude. The spreadsheet may has 'as is' or extract the formulas.

Site Visits

A site visit is absolutely essential to good NED analysis. Simply put, best practice coastal storms damage reduction planning cannot be done from an office. It is necessary to see, walk, know, and understand the study area and vicinity to do good planning. Ideally, the entire study team should visit the study area together. Hydrologists, economists, environmentalists, archaeologists and others all see different things when they look at the study area. It is important for team member be aware of what others see.

Familiarity with the study area, its features and use, and the development in it is indispensable to good economic analysis and planning. The project economist should be able to discuss the details of the impacted areas in a knowledgeable fashion with the planning team, as well as the people who live and work there. There is no substitute for first-hand knowledge of the study area.

The team should know the orientation of the study area, what and who are impacted by storms, and understand how the storms impact the community. The project economist should learn place names and major streets and other local landmarks, be familiar with major employers, industries and damage centers. It is preferable to walk the study area rather than to simply perform a *windshield survey*. If walking the entire study is not feasible, it is desirable to at least walk through the large damage centers. During site visits, seek out residents and business people who are knowledgeable about the area and the coastal problems and talk with them about their experiences and perceptions, and solicit their input regarding data.

Visit the Beach Electronically

While nothing substitutes for site visits technology is making it much easier to gain a better understanding of the project area using electronic maps. Here are some of the major sources of electronic maps:

CorpsMap *(corps only)*: https://corpsmap.usace.army.mil/

Google Maps: http://maps.google.com/

NASA World Wind: http://worldwind.arc.nasa.gov/[6]

Terra Server: http://terraserverusa.com/[7]

MapQuest: www.mapquest.com/

Yahoo Maps: http://maps.yahoo.com/

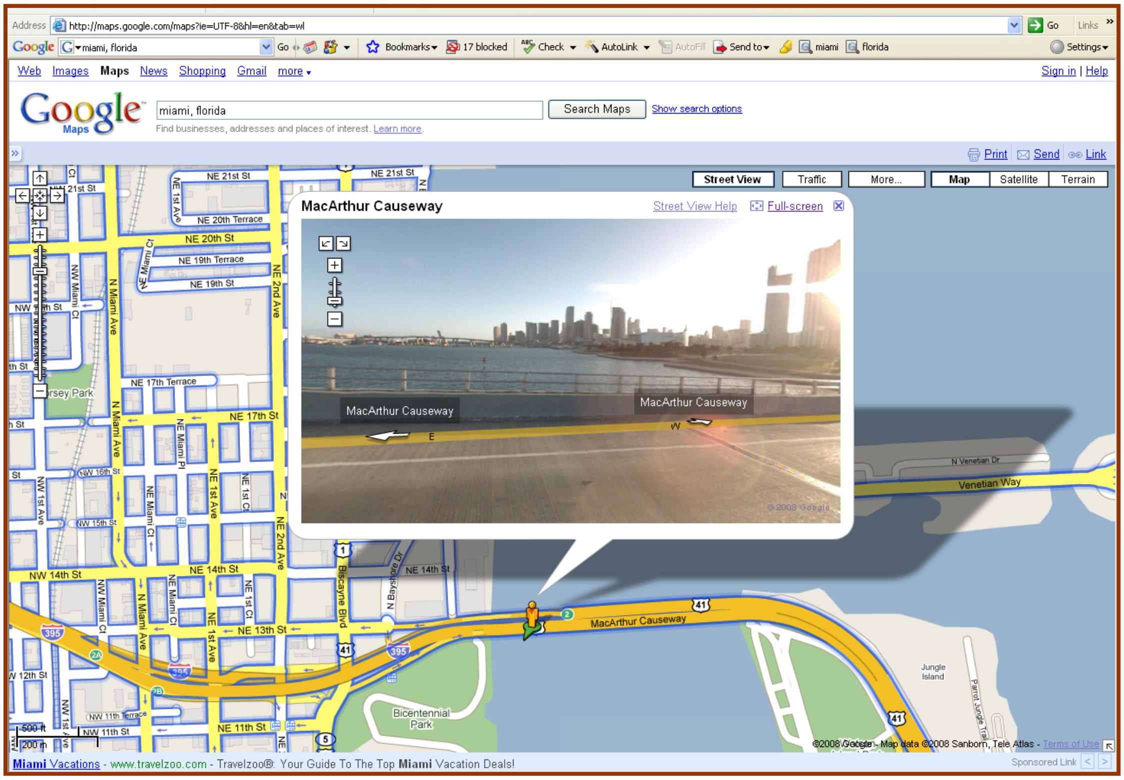
Bing Maps: http://maps.live.com/

Google Maps has developed a free *Street View* for many locations. This feature could be a helpful tool for structure inventories. The following picture shows a street view along

[6] NASA World Wind is a free and open source program sponsored by NASA that contains useful features. Currently the geospatial data that it draws upon is lower resolution in many areas than that available through the Google offerings but do check it out at.

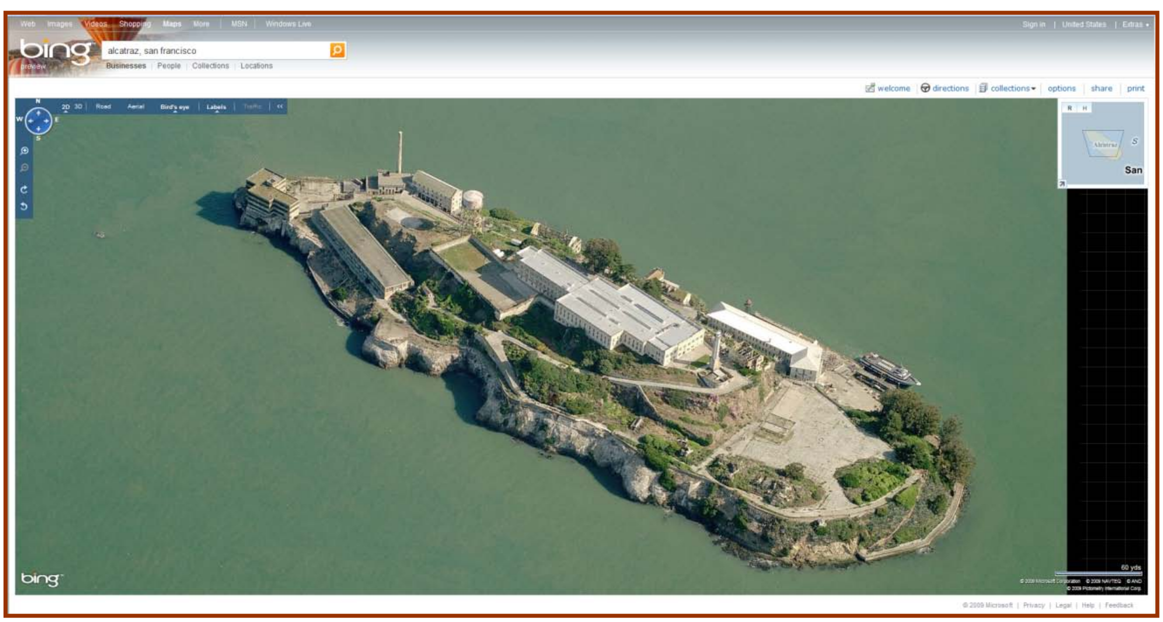
[7] TerraServer-USA (http://terraserverusa.com/) is another popular service that provides the ability to view a study area almost instantly. While the service is limited in its features, it has the advantage of not requiring the download any software.

the MacArthur Causeway in Miami, Florida. The tool allows the user to see the views in 360 degrees, zoom in and out, and walk along the roads highlighted in blue.



Street View of MacArthur Causeway, Miami, FL Using Google Map

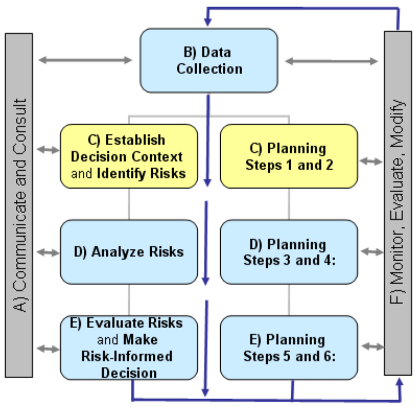
Bing Maps also offer a bird's eye view in its mapping product. The following shows a bird's eye view of Alcatraz using Bing maps.



Bird's Eye View of Alcatraz Using Bing Maps

6.4 Summary and Look Ahead

Having the right data is essential for good planning and economic analysis. Many sources of information are available on the web, and more powerful electronic tools are being developed every day. While such data are invaluable, there is no substitute for site visits to visually inspect structures and damage locales, and to engage local stakeholders about experiences, perceptions of problems, solutions, and sources of data. **Chapter 7** begins the detailed discussion of economic analysis steps focusing on delineating the study area, selecting reaches, and describing risks for the without-project condition and for with-project conditions.



Chapter 7: Establish Decision Context and Identify Risks

PLANNING STEPS 1 & 2

Identifying the problems and opportunities you face is the most important step in the planning process. Once the problems and opportunities are described, the next task is to define the objectives and constraints that will guide your efforts to solve those problems and achieve those opportunities.

The success of the entire planning process depends critically on the success of this first step. Every planning investigation, from a multimillion-dollar multiple-purpose comprehensive investigation to a several thousand-dollar preliminary study, and everything in between, should produce two sheets of paper early in the study. One of them lists problems and opportunities, the other the objectives and constraints. The first sheet says this is what is wrong here, the second says this is what you intend to do about it.

-Planning Manual, IWR 86-R-21 (1996)

Establishing the decision context means describing conditions and risks in which management decisions will be made. Planning Step 1: ***Identify Problems and Opportunities***, and Planning Step 2**:** ***Inventory and Forecast*** **both help establish the decision context.** Identifying risks should occur throughout the planning process but the area of greatest emphasis should be on defining the future without- and with-project conditions. These risks should first be qualitatively described as *what could go wrong?* and *how could it go wrong?*

The economist's main tasks in this phase of the planning process are to:

- Delineate the study area (7.1)
- Delineate study reaches (7.2)
- Describe without-project: risks, uncertainties, assumptions, and conditions (7.3 to 7.9)
- Describe with-project: risks, assumptions, and conditions (7.10 to 7.11)

7.1 Delineate Economic Study Area

> *The study area is that area affected by storms and erosion problems and by proposed alternatives. It includes areas indirectly affected by the problems and projects such as downdrift areas and navigation and other projects outside the immediate project site.*
>
> -ER 1105-2-100, Appendix E-24, f(2)(a)

Delineating the study area is important for data collection, reach delineation, and evaluating alternatives. The project study area may be defined in the study authorization language, in Reconnaissance Phase documentation and/or the Feasibility Cost Sharing Agreement. However, it should be noted that the economic study area is *not* necessarily identical to the project study area as identified in such documents. In some cases economic costs and benefits extend beyond the project study area. For example, erosion of a major road may impact traffic rerouted outside of the immediate study area: the costs and benefits of this impact must be considered if the economic analysis is to be complete. Or, a groin field (a perpendicular structure) could protect the local beach, but might change the sediment budget (http://pubs.usgs.gov/of/2003/of03-337/budget.html) elsewhere. The economic impact of induced erosion outside the area protected by a project is an NED cost that needs to be included in the overall project analysis. This is commonly known as a “system approach”. If the economic study area differs from the project study area, any differences should be described in geographic terms. If the two areas are the same, a simple summary of the description in the main report is sufficient.

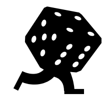
Describing the Socioeconomic Characteristics of the Study Area

Economics is a social science. The study area description should include demographic statistics. These are readily available from the U.S. Census Bureau’s American FactFinder website (http://factfinder2.census.gov/) at various levels of detail: e.g. Census block, zip code, or municipality. Regional, state, or county resources may also provide statistics, Geographic Information Systems (GIS) data, and other helpful information. Data available from census, and various state and local sites include:

- Total population, racial breakdowns, age, education, income, and employment
- Number of establishments
- Total value of sales, shipments, or receipts
- Annual payroll
- Number of employees

It is often best to present the data describing the socioeconomic characteristics of the study area compared and contrasted with the associated region so as to draw basic conclusions about the study area in relation to its region.[8]

The *American FactFinder* provides past and present statistics. Projections can normally be obtained from the state, county, and/or local government council(s). Demographic data and projections may not exactly correspond to the boundaries of the study area. In this case, it is advisable to present the available data while clearly explaining what areas they correspond with. Population projections may also need to be developed which could create an added component of uncertainty in the risk analysis. Research others' projections and query experienced economists as to how to form a defendable population projection if needed.

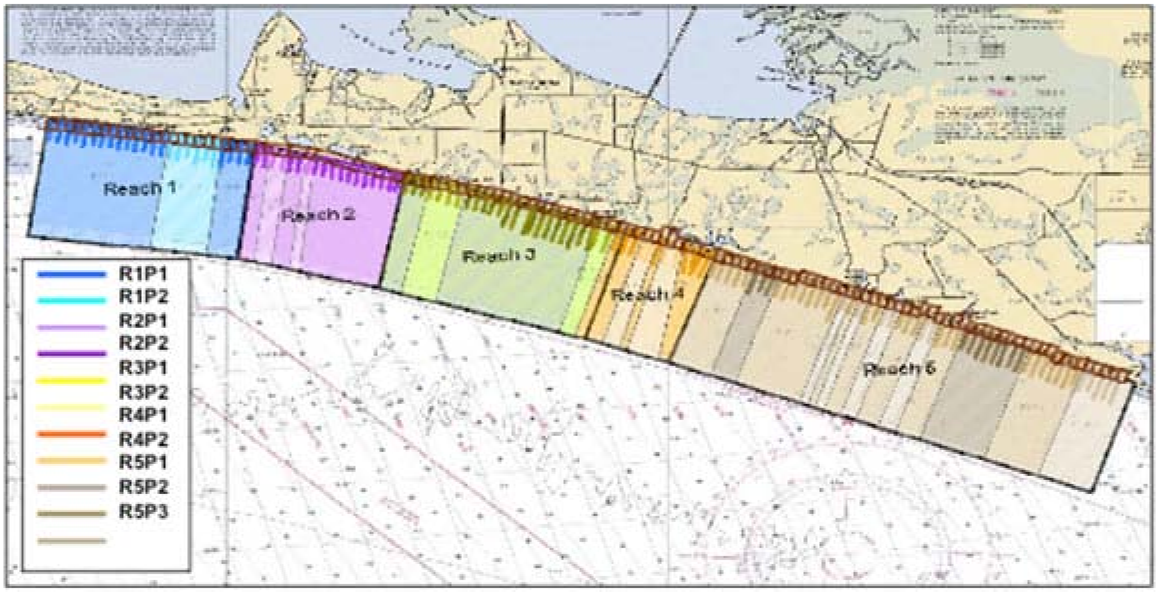


The study area description should also address land use and the local economy. The land use data considered should be consistent with the land use data obtained for the economic analysis. This is described in more detail in the next chapter.

7.2 Delineate Study Reaches

Once the economic study area has been generally determined, study reaches, can be delineated (drawn reach boundaries). A reach is a geographical section of the study area that groups together similar geographical, hydrological, political, and economic features for study purposes. All structures and features are related back to a reach identifier in most models. The delineation of economic reaches is driven by the goal of making all economic, planning, engineering, and other documentations complete, consistent, and comprehensible. Reaches are meant to identify the smallest possible breakdown of damages and benefits. The following figure shows a typical section of beach that has been divided into six reaches.

[8] The term for such an overview of socioeconomic conditions is a *Social Profile*. More detailed instructions for preparing social profiles can be found in the Corps' *Handbook on Applying "Other Social Effects" Factors in Corps of Engineers Water Resources Planning (IWR).*



Walton County, Florida coastline
(USACE, DevelopmentOfCoastalProcessesInput.pdf)

Figure 18. Reaches along Walton County, Florida, Coastline

Ideally, project planners, coastal hydrology and hydraulic (H&H) engineers and economists should collaborate in selecting reaches. The economist's role in this collaboration is to point out the factors that are important for economic analysis. For example, the downtown section of a community may have skyscrapers, beach houses or even unique historical structures. Florida beaches exemplify a continuum ranging from historical structures to skyscrapers.

It is important to designate this area as a reach and coordinate with the team to obtain data specific to that area. The other team members' role is to point out the environmental and coastal engineering features that could impact the region and thus impact the economic analysis. For example, one fairly homogenous community may have two different beach profiles. These two areas should be designated as separate reaches because the two profiles damage the structures differently. A profile is a engineering representation of the coastal shore structure as viewed from the side (a cross-cut view of the beach elevations). Another example is a homogenous community that has an endangered species nesting in one section. That section may have much higher costs for a project or be off limits altogether; therefore, it should be designated as its own reach.

Reaches come in all sizes. A reach's identifying characteristics determine its size, so the expanse of a reach is simply as large or as small as the scope of its determining traits. The trick is to choose reaches that are not so large that the information for the entire region is too general and not so small that the details of each section are overwhelming. Set the boundaries of a reach wherever any characteristic of the area changes, and make sure to use a considerable list of economic and geographic characteristics as factors in this determination. This will facilitate easy project discussions in the future: all contributors to the study team will be able to refer to identical areas—a far more efficient approach than having to painstakingly later transpose unrelated boundaries, without making any errors, if disaggregation of reaches is deemed necessary. In defining reaches, always remember a rule of thumb: **If in doubt, another reach should be the route.**

Having a large number of reaches may complicate the reporting of results. In such cases, use reasonable reach aggregation or disaggregation based on some readily identifiable characteristic. For example, use a common name such as *The Palms Condominium Complex* or *The shoreline between Crystal Pier and the harbor inlet* to aggregate or focus on a number of reaches.

> *While it is most often preferable to have common reaches across study components (i.e. engineering, H&H, economics, etc., sometimes using the same reaches for the entire team is unacceptable. The economic and other team members may have good reasons for breaking these reaches down further and creating sub-reaches within reaches or even creating entirely different reaches. If there are reasons that necessitate this approach, they should be fully documented and clearly noted.*

Factors to Consider in Selecting Reaches

Some **coastal engineering factors** to consider when delineating study reaches include:

- **Storm frequency, tide levels, erosion patterns**
    - Do these elements differ across the study area? Do certain areas consistently bear the brunt of storms, while others are left unscathed? Does erosion occur rapidly on one length of shoreline, while accretion dominates another? The division of reaches should reflect any record of regionalized variations found in the area's meteorological and geological records.
- **Beach profile**
    - Recognize that storms impact an evolving beach profile.
    - Include advanced nourishment (when present).
    - If a nourishment project is in place, it should not be assumed that the design cross-section is always in place, recognize that multiple storms could occur in a short timeframe and significantly impact the design cross-section (a cross section is a side-view of one part of the beach, See Figure 19).

- Any measure that modifies a littoral process will create new littoral cells so it might be necessary to identify any alternatives that might change current littoral conditions.
- Include treatment of post-storm recovery and dune scarping (vertical dune formations that form a small cliff).
- Consider likely future changes such as impoundments on streams updrift or downdrift of your project site.

Collaborate with project engineers to develop information on coastal processes.

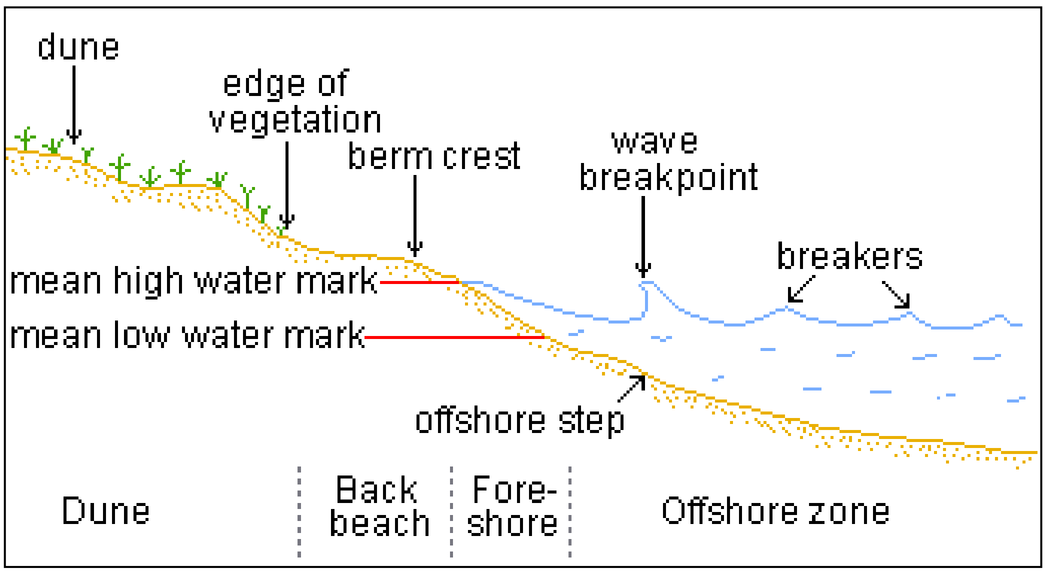


Figure 19. Typical Beach Cross-Section

Some **economic factors** to consider when delineating reaches:

- Areas of damage incurred specifically by land use
- Zones of flooding created by effects of water levels and/or wave action
- Potential changes in the types and level of management
- Breaks where there are significant changes in land use
- Political subdivisions
- Areas where changes in the types of alternatives or management areas are probable
- Demographics and population statistics
- Recreational areas
- Land Ownership (public vs. private)

Some **other factors** to consider:

- System, incremental, and life-cycle implications
- Endangered species
- Reach size
- Sediment types
- Interior drainage areas or lagoons
- Potential protection limits
- Backbay (Residual) Flooding
- Existing seawalls or other risk reduction structures
- Potential construction costs in various locations
- Roads
- Engineering Manuals

7.3 Describe Without-Project Risks, Uncertainties, Assumptions, and Conditions

The without-project condition, as its name suggests, is an assessment and forecast of the storm damage risks, assumptions, and conditions, assuming no action is taken by the Corps. If storm risk reduction measures or any other actions are imminent or likely without Corps' action, those measures and actions should be considered to be part of the without-project condition. Imminent measures and actions include those that are under construction, funded storm protection measures, development under construction, development limitations as specified under the National Flood Insurance Program, Executive Order 11988, Coastal Zone Management Plans, and any state and local regulations in effect. Since future conditions sometimes include plans which have yet to be approved or may be speculative, all assumptions about including or excluding them in the future without-project condition should be carefully explained and justified. Starting with the existing conditions and projecting outward is often a solid strategy to start the analysis for the **period of analysis**.

With- and Without-Project Conditions Defined:

(1) The <u>without-project condition</u> is the most likely condition expected to exist in the future in the absence of a proposed water resources project. Proper definition and forecast of the future without-project condition are critical to the success of the planning process. The future without-project condition constitutes the benchmark against which plans are evaluated. Forecasts of future without-project conditions shall consider all other actions, plans and programs that would be implemented in the future to address the problems and opportunities in the study area in the absence of a Corps project. Forecasts should extend from the base year (the year when the proposed project is expected to be operational) to the end of the period of analysis.

(2) The <u>with-project condition</u> is the most likely condition expected to exist in the future with the implementation of a particular water resources development project. Comparison of conditions with the project to conditions without the project will be performed to identify the beneficial and adverse effects of the proposed plans. These with and without-project comparisons provide the framework for the evaluation of alternative plans.

-Planning Guidance Notebook, ER 1105-2-100, Section 2-4 b (April 2000)

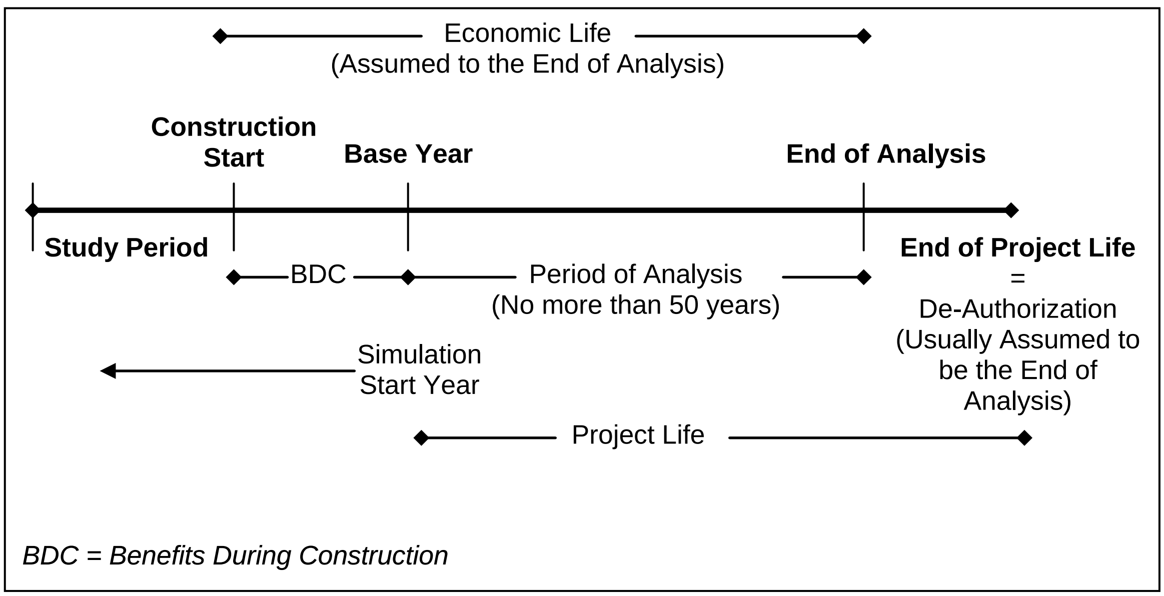
7.4 Period of Analysis

> *The period of analysis shall be the time required for implementation plus the lesser of: (1) the period of time over which any alternative plan would have significant beneficial or adverse effects, (2) a period not to exceed 50-years…*
>
> -Planning Guidance Notebook, ER 1105-2-100, Section 2-4.j (April 2000)

The **period of analysis** captures the timeframe for the with- and without-project conditions. A without-project condition needs to be developed generally to encompass the fifty years at the start of Project Year 1, also known as the base year. The base year is the year when the majority of project benefits begin accruing typically after construction is complete (see Figure 20). The base year also serves as a reference point in time to compare all alternatives. Ultimately, the NED benefits of a project are the economic value of differences between the with- and without-project conditions during the entire period of analysis and are measured in base year dollars.

The period of analysis is not the expected life of a project. The project life of an authorized Federal shore protection project continues until Congress de-authorizes it or the authorization expires (such as beach nourishment projects)

Figure 20. The Period of Analysis



Regulations interpreting the Principles & Guidelines limit the period of analysis to a maximum of 50 years. However, if one alternative provides benefits for 20 years and all other alternatives provide benefits expected to last 50 years, the period of analysis would be 50 years. The alternative providing only 20 years of benefits would have the present value of those benefits spread out over 50 years of equal annual payments. This procedure would provide an equivalent value to compare to the other alternatives.

For the Beach-*fx* Monte Carlo simulation analysis, multiple iterations over a 50-year life are necessary to capture the variability of estimated damages. Multiple iterations in the simulation allow for the inclusion of relatively infrequent occurrences of damaging storm events in an area, i.e., high consequence, low probability events. This helps demonstrate the natural variation.

7.5 Identify Risks and Uncertainties

Prior to quantifying risks and associated uncertainties, the first step is to qualitatively describe the risks and uncertainties in the without- and with-project conditions. Section 2.4 introduced the basic concepts of risk and uncertainty. This section will provide further details on risk and uncertainty and how to manage it. Briefly, risk is the likelihood and outcome of some event or action. Risk analysis has three parts: assessment, communication, and management. The 5-step proposed risk management framework breaks risk assessment into two main parts. The first part that this section discusses is risk identification. This answers the question: "*What can go wrong?"* and "*How can it happen?*" There are two types of risks to discuss: 1) Risks from a hazard or 2) Risks that arise from the uncertainty of realizing an opportunity.[9]

Qualitative Methods Toolbox:

- Narratives, graphics, and tables
- Evidence Mapping
- Screening or Ratings Operational Risk Management (Matrix)
- Develop a Generic Process
- Qualitative Assessment Models
- Multi-Criteria Decision Analysis

Identifying Coastal Storm Flooding, Waves, and Erosion Risks

In coastal storm damage evaluation, the first type of risk is that from a natural hazard: the storm. In this step, the degree of the hazard and type of consequences should be qualitatively described to establish the decision context and identify risks (Planning Steps 1 and 2) for the without-project condition followed by the with-project conditions. The next steps in the **Chapter 8** will discuss how to quantify the likelihood, consequences and uncertainties of each alternative to measure an alternative's effectiveness in reducing risks. The three main categories of hazard for coastal projects are floods, waves, and erosion. **Chapter 3** provides more information on these coastal forces that could be beneficial to describe the hazards thoroughly or provide examples of the types of

[9] Yoe, Charlie Ph. D. Presentation on "*Qualitative Risk Assessments.*" USACE, 2010.

information to be described. Table 6 presents some of the categories for damages/consequences from exposure to coastal flooding, waves, and erosion that are counted in the economic evaluation. **Chapter 4**, Table 3 introduced these damages and can provide examples of the information to be described in the evaluation.

Table 6. Risk Categories for Evaluating Damages, Losses or Other Opportunities

(a) Flood

(i) Physical Damage

1. *Urban: Structural Damage to Infrastructure, Structures, and Contents*
2. *Agricultural*
3. *Vehicles*
4. *Other*

(ii) Non-Physical Losses

1. *Income loss*
2. *Emergency costs*
3. *Public and private protective measures*
4. *Temporary evacuation and relocation*
5. *Transportation delays*
6. *Damages to associated agricultural enterprises*

(b) Wave Damages: *since these are related to water height they increase the damages associated with flood damages. They also can increase erosion damages.*

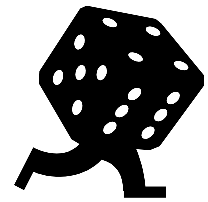
(c) Erosion Damages

1. *Urban: Structural Damage to Infrastructure, Structures,, and Contents*
2. *Loss of land value*
3. *Emergency costs*
4. *Public and private protective measures*
5. *Incidental: recreation, etc.*

(d) Other Damages or Areas of Opportunities:

1. *Reduced maintenance to existing storm damage reduction structures*
2. *Location use or intensification benefits*
3. *Risk exposure to life threatening situations*
4. *Risks to society, such as cultural and historical sites*
5. *Risks to the ecosystem*
6. *Opportunities for improvement (to consider in alternatives)*
7. *Risks from climate change*

Distinguishing Risks from Uncertainties and Variability[10]



There are two types of uncertainties that are important to keep separate. Both can contribute to not achieving a gain and the representation of a hazard. One type is knowledge uncertainty, while the second is natural variability as discussed in Chapter 2, Section 2.4. The consequences of uncertainty are that the intended result or outcome may not be achieved. This could mean the without- and with-project conditions cannot be completely and precisely described due to lack of knowledge, and the "NED plan" cannot be identified with certainty. The conditions could have worse consequences or potentially better outcomes depending on a variety of the factors that are uncertain.

Knowledge uncertainty can be identified as those parameters, models, functions, systems, empirical quantities, and decision factors that the team does not know enough about to fully describe, model, or predict with precision. Assumptions are typically made to substitute for these unknowns with *best available* or *most appropriate* values. Often, knowledge uncertainty can be reduced by spending more time and resources to learn more about the factor. Calibrating and testing models and engineering systems is one way to try to reduce this uncertainty. Treatment of knowledge uncertainty depends on the quantity and cause of the uncertainty. Examples of this include the value of homes, a location of homes, first floor elevations, content values, number of homes impacted by a costal storm, damage outcomes, project life, costs, and predicting future decisions. In many instances, knowledge uncertainty can be described by probability distributions representing the limits of knowledge. In others, such fundamentally different futures, alternative scenarios are more appropriate.

One practical approach for handling knowledge uncertainties is:

(1) Create lists of uncertain knowledge, models, and quantities

(2) Identify the ones that can be easily addressed

(3) Address them

(4) Identify the most important ones not easily addressed

(5) Develop a plan for addressing them

Natural variability cannot be reduced through greater study. Differences in outcomes will always exist because it is inherent in the system. It is common to describe variability with a probability distribution. Natural systems usually have natural variability. Hazards, such as the quantity of stream flow and intensity of storms, vary over time so that the value, such as the number of coastal storms in a year, cannot be predicted with certainty. Many types of distributions could be used to represent natural variability. The appropriate distribution is based on degree of knowledge about the system, the

[10] Yoe, Charlie Ph. D and David Moser Ph. D. Presentation on "*Uncertainty & Variability.*" USACE, 2008.

fundamental characteristics of the system or theory about the quantity represented. For instance, the number of storms in a year can be represented with a discrete Poisson distribution while the values of single family homes can be presented by a continuous normal distribution. Meaning, the value of homes can range from $0 to a large number and contain intervals such as $70,000 to $79,999.

For more information, please see EM 1110-2 -1619: Risk-Based Analysis for Flood Damage Reduction Studies.

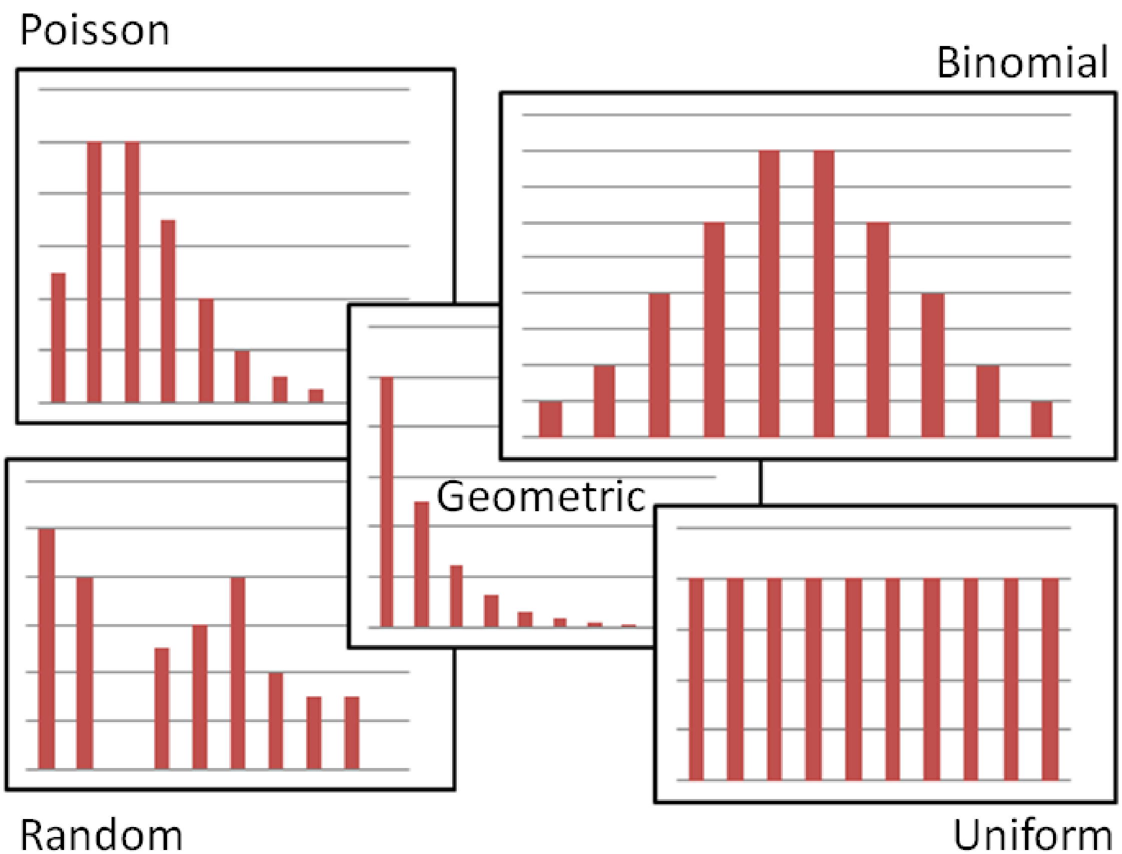


Figure 21. Discrete Distributions

In Figure 21, there are five examples of discrete probability distributions. What are examples of discrete variables? The number of storms that can occur in a year and the number of floors in a structure are such examples. The center is geometric; the upper left going clockwise is Poisson, binomial, uniform and random. These distributions contain all possible outcomes that are countable. The values are isolated points. A discrete geometric distribution (center) is formed from a series of trials. In this case, a probability mass function is used. The independent trials continue until a specific value is obtained such as throwing a dice until a 1 in shown. If the probability of the first trial is one in six, then the probability of getting a 1 in *k* trials is $(1/6)*(1-(1/6))^{\wedge(k-1)}$. A discrete Poisson distribution (upper left) is good for expressing the probability of a number of events, such as a coastal storm, occurring during a fixed interval of time. These events occur at a known average rate over many years and what happens in any one year is independent of what happens in any other year. A binomial distribution (upper right) is used for the number of successes or failures from yes/no independent trials with a known probability. A uniform distribution (lower right) is used when all possibilities are equally likely. The random distribution (lower left) is likely to be unique to each situation and they do not fit a typical distribution.

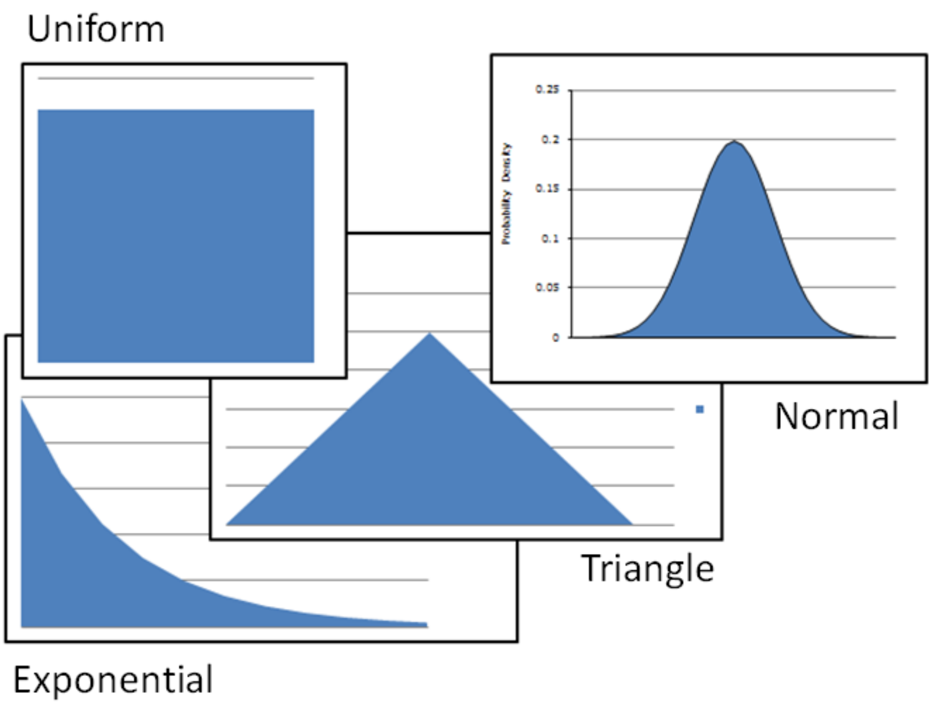


Figure 22. Continuous Distributions

Figure 22 shows some examples of continuous distributions. Starting from the upper right graphic and going clockwise, it shows normal, triangular, exponential, and uniform distributions. Normal (upper right) is a commonly used distribution to describe data. Triangular (middle) is often used to show the minimum, maximum, and most likely. An exponential curve (lower left) can be used to describe a coastal event; there are fewer larger events and a lot more smaller events. Uniform (upper left) is used when all possibility within a range equally likely.

7.6 Existing Structure Inventory

> *An inventory of affected properties, including land, is performed to estimate potential damages. The inventory is done by land use activities (i.e., residential, commercial, industrial, etc.) and includes variables such as value, use, ground elevation, distance from the water, construction materials, area, and number of stories. Areas likely to be developed in the future or where land use changes could occur are also identified.*
>
> *ER 1105-2-100, Appendix E-24, f.(2)(e)*

Typically the structure inventory is a collection of information for the structures that may be potentially impacted by flooding, waves, or erosion now or over the 50-year period of analysis. The structure inventory is fundamental to describing existing conditions, and also for developing the future without-project condition. The basic inventory also helps determine the study economic area and reaches. It is also the basis for estimating the expected annual damages to the study area.

Table 7 presents information that is typically collected in a structure inventory. Detailed instructions for carrying out a structure inventory are provided in the Flood Risk Management NED Manual. As noted previously, primary data collection is generally only feasible for small study areas. Assessor's records are the most commonly used source of secondary data. In most cases, these records should be readily available in GIS compatible files. This data could have valuable information to determine the depreciated replacement value. The assessor’s data typically has market value for a specified year rather than the depreciated replacement value. However, the depreciated replacement value must be used per Corps policy. Theoretically, a property owner would be willing to pay to avoid damages to the depreciated replacement value of his structure. The amount that he is willing to pay is an estimate of the worth of a measure that reduces the damages. .

> Assessors’ records will provide an estimate of structure and land values, but not of the value of contents. This values need to be compared to the depreciated replacement value prior to using.

Table 7.
Structure Inventory Data Requirements

- Number of structures
- Land use (residential, commercial, industrial, public, etc.)
- Minimum, maximum and most likely depreciated replacement values by structure, considering:
    - Type of structure: single family, multi-family, retail, etc.
    - Number of floors
    - Square feet
    - Foundation type: slab, pile size, etc.
    - Construction type: frame, brick, etc.
    - Basement present
    - GPS/GIS Coordinates
    - Age
- First floor elevation (min, max, most likely)
- Elevation of structure
- Ground elevation
- Minimum, maximum and most likely content values
- Geographical location from the water or bluff (Shore perpendicular distance, Shore parallel distance)
- Parcel boundary

There are a number of key points to keep in mind in assembling a structure inventory:

- The list of data inputs shown in Table 7 is much like the list of data gathered for flood damage studies. Unlike riverine flood damages, the damages from hurricanes and coastal storms are especially sensitive to the type of foundation since many structures are built in sand (at least on the east coast). This is a very important variable because the economist should use different erosion damage relationships specific to the foundation type.

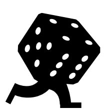
- Data on foundation type, first floor elevation and construction material are related and will typically be collected from an inventory of the study area. For very large studies, sampling may be required. Pre-approved surveys do exist and it is a good idea to check for the most up-to-date OMB approved surveys. (See also the discussion of Elevation Data in the Flood Risk Management NED Manual at www.CorpsNEDManuals.us)

- Structure damage estimates are based on the *loss of depreciated replacement value*. The easiest way of estimating depreciated replacement values is to make statistical adjustments of market values. Such adjustments are appropriate for reconnaissance studies or to obtain a general idea of values; however, they may not be accepted method for feasibility studies. In such cases, more detailed evaluation is necessary such as a survey or using *RSMeans* to estimate values.

- Knowing a structure's age or year of construction can provide a basis for estimating depreciation. However, structures are often remodeled or upgraded during the course of their existence. The effective age of a structure is more desirable to obtain, but much more difficult to estimate without an exterior and interior inspection. It is an appraiser's estimate of the physical condition based on up-keep or lack of maintenance overall.

- If structure values from the assessors' records are used, they should be checked with estimated depreciated replacement values using sources such as RSMeans, or other methods. Real estate team members may be able to provide other resources for consideration. Also, a sample of structure values can be compared to recent market sales data (from website such as http://www.trulia.com/ and others. However, often the number of recent sales is too low to provide useful results.

- First floor and ground elevations are not likely to appear in assessor's records. Ground elevations are typically gathered by team engineers and sometime these can be extracted from a GIS, LIDAR (**li**ght **d**etection **a**nd **r**anging remote sensing technology), or other databases. Margin of errors for the elevation should be recorded and discussed as part of the risk assessment.



- First floor elevations need to be measured in the field relative to the ground elevation that will eventually be used to estimate the depth of flooding. Otherwise, the depth of flooding and estimated damages will be incorrect. Someone from the study team should physically observe and record the first floor elevation of structures in the field.

Valuing Contents

While estimating the depreciated replacement value of a structure is a difficult task, it is even more difficult to estimate the value of the contents of a structure. Past experience has shown that it is reasonable to assume that the value of a structure's contents is generally related to the value of the structure itself. The content-to-structure ratio (value of contents/value of structure) is a shortcut method widely used to estimate the value of a structure's contents. Once the structure value has been estimated, the value of the contents can be deduced from the assumed ratio. Generic structure-content curves can be found in Economic Guidance Memoranda.

Bargnegat Island Shore Protection, New Jersey (Philadelphia District)

What is the Economic Value of Structural Damages?

A television is destroyed in a flood. It cost $700 when it was new 13 years ago. It was given to the floodplain occupants by their parents at no cost when it was 10 years old. The family could have sold it for $150. It would cost $500 to get a television like it today, except today's model would have features and quality the lost TV never had. Besides, the family would prefer a big screen high definition TV now. The insurance company will allow $75 for the TV. A similar TV is advertised on E-bay for $100. What value should the analyst use to estimate the loss from the flood?

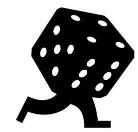
Do we take the $700 then depreciate it 13 years? Do we value it as $0 because that is what the occupants paid for it? Do we use the $500 cost to replace it or the $150 they would have accepted for it? Should we adjust the $500 replacement cost to reflect the improvements in the new TV? Is the $75 book value the loss? None of these is the answer for a flood damage estimate.

The value of the television is what a willing buyer would be willing to pay for it. So the best measure of the TV's value is the willingness to pay (WTP) for it. What would the family have been willing to pay for a 13-year old television that worked as well as this one did? Most problems of conceptualizing the dollar damage associated with a flood loss can be solved by coming back to this willingness-to-pay standard. Estimating or measuring that conceptual value can often be a problem.

Fortunately, or unfortunately, the need to grapple with this problem on a more regular basis is submerged in the use of damage curves. These curves generally rely on the input of a market value or replacement-in-kind estimate of a structure's value and an estimate of the ratio of value of the contents in the structure to the structure itself, the content-to-structure ratio. Whether the standardized curves have properly accounted for value or not is an important issue that is well beyond the scope of this manual. The only way to ascertain that is to examine or understand the construction of the damage curves.

Unique structures and floodplain activities often require a site-specific estimate of damages. In estimating damages to such structures and activities it is important to adhere to the WTP principle in estimating flood damages. Thus, replacement cost for lost assets must often be adjusted to reflect the fact that replacement of a used asset with a new one may represent betterment, and betterment is not a flood loss. For a few observations on flood damages click here Value of Flood Damage.

Accounting for Uncertainty in Estimates



Individual structure values are uncertain and this uncertainty must be accounted for in the study. A triangular distribution has been used in Beach-*fx* to fit the structure value data. It requires estimating a minimum, maximum, and most likely (mode) values for each element in the inventory. Beach-*fx* will take this information and use a Monte-Carlo, which randomly draws values from the user designated distribution, to present the range of potential values. The Monte-Carlo simulation is a preferred method for propagating uncertainty from inputs to predicted outputs of a model.

7.7 Forecasting Future Conditions

Conditions change within a 50-year period of analysis; therefore, economists develop forecasts to help predict and describe these future 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, etc. First, the without-project condition should be described in detail followed by a detailed description of the with-project condition and how it differs from the without-project condition.

Economics is a social science that anticipates rational behavior. In this case, structure and property owners along the shoreline are assumed to act rationally in protecting their property. Empirical evidence also indicates that owners protect their property (see article reference at http://cedb.asce.org/cgi/WWWdisplay.cgi?0510673 for an example, Narin and Zuzek 2005). In general, it should be assumed that individuals and communities attempt to make decisions on the basis of marginal costs and benefits. In many cases it can be expected that efforts to protect property may continue until such time that total loss of the property is imminent and further occupation or use of the property becomes unsafe.

In creating forecasts, all assumptions and limiting factors should be made explicit, fully documented and discussed among the study team. Scenario analysis can be used if uncertainties are too great.

For an excellent discussion of without-project conditions go the *Flood Risk Management NED Manual*: Without-Project Condition, which is available at www.CorpsNEDManuals.us

P & G Forecasts

*The **forecasts** of with- and without-plan conditions should use the i**nventory of existing conditions as the baseline**, and should be **based on consideration of the following (including direct, indirect, and cumulative effects)**:*

*(1) **National and regional projections** of income, employment, output, and population prepared and published by the Department of Commerce.*

*(2) Other **aggregate projections** such as exports, **land use trends** and amounts of goods and services likely to be demanded; [not all applicable in coastal]*

*(3) Expected **environmental conditions**; and*

*(4) Specific, authoritative projections for small present values using the **discount rate** established areas annually for the formulation and economic. Appropriate national and regional projections should be used as an underlying forecasting framework, and inconsistencies therewith, while permissible, should be documented and justified.*

*(c) National projections used in planning are to be based on a **full employment** economy. In this context, assumption of a full employment economy establishes a rationale for general use of market prices in estimating economic benefits and costs, but does not preclude consideration of special analyses of regions with high rates of unemployment and underemployment in calculating benefits from using unemployed and underemployed labor resources.*

*(d) National and State environmental and health **standards and regulations** should be recognized and appropriately considered in scoping the planning effort. Standards and regulations concerning water quality, air quality, public health, wetlands protection, and floodplain management should be given specific consideration in forecasting the without and with -plan condition.*

*(e) Other plans that have been adopted for the planning area and other **current planning efforts** should be considered.*

*(f) Forecasts should be made for selected years over the **period of analysis** to indicate how changes in economic and other conditions are likely to have an impact on problems and opportunities.*

-Principles and Guidelines, ER 1105-2-100, (2000)

Factors to Consider in Developing Forecasts

- Differences between the **with-** and **without-project conditions**
- **Uncertainty**: the key factors that can influence forecasts should be identified and their potential impacts on the study
- **Responses 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. 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. However, multiple scenarios may need to be considered for addressing uncertainty in this instance.
- **State Coastal Zone Management Plans** (CZMPs) or other zoning ordinances may prohibit individual protection, replacement, or repair of some damaged structures. This also includes beach and inlet management plans.
- **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.
- **Building and zoning codes** may be changed. 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.
- **Environmental Regulations** may impact future conditions. For example, California residents are only allowed to protect their property after erosion has advanced to a certain distance within their home due to environmental considerations.

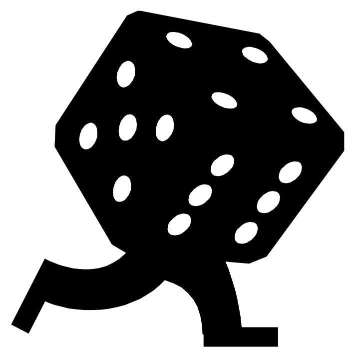
In certain situations it may be more useful to use scenarios, which relies on multiple without-project conditions.

What to Include in the Without-Project Condition:

Be careful about including measures designed to reduce damage from coastal storms in the without-project condition. It is reasonable to include measures required by local ordinance and to include private measures in future construction to the extent that they are implemented in existing buildings. Current local storm fighting, emergency response and maintenance activities may be projected into the future. It is a mistake to include any additional activities beyond these in the *no action* condition. Actions of private interests and local governments that go beyond current practice should be evaluated and presented as alternatives, regardless of the organization that might be responsible for implementing any alternative.

7.8 Uncertainty in Forecasting With- and Without Project Conditions

Forecasts are always uncertain because the parameters that drive the forecasts are unknown. The potential key components of uncertainty in defining the future with- and without-project condition for probably storm hazard include:



- Wave height above the dune
- Shoreline retreat or eroded volume
- Natural post-storm recovery
- Periodic nourishment
- Emergency nourishment
- Sea level rise
- Storm frequency and intensity
- Home rebuilding and future permits after a storm

For example, forecasted wave heights could be subject to rising sea levels or, for the Great Lakes, changes in lake levels. This could alter the economic analysis because the heights predict the damages. If periodic nourishment is scheduled with or without a project, the ability to actually conduct this activity is often affected by the availability of funds. Natural post-storm recovery is especially important when using an event-based Monte-Carlo simulation model such as Beach-*fx*. Although some of these, such as sea level rise, represent knowledge uncertainties that are so great that using a probability distribution is inappropriate. In those cases, scenario planning or scenario analysis can be used.

Scenarios represent significantly different views of the future and alternative plausible combinations of the values of the key uncertainties. This is different than a sensitivity analysis which simply asks the question of the degree of responsiveness of a value of interest to alternative values of a key inputs.

Scenario planning is one technique for understanding and describing uncertainty. The Flood Risk Management NED Manual (www.CorpsNEDManuals.us) discusses preparing a matrix showing the effect of including different measures in the future without-condition. Planning ahead and including scenario planning is recommended from the start because it is easier to remove the scenario if it is not needed versus attempting to create a scenario late in the analysis.

See the discussion of Future Conditions and Uncertainty in the Flood Risk Management NED Manual

7.9 Future Structure Inventory

Coastal development has boomed in recent years. Between 1980 and 2000, the density of development in several of the high-risk coastal areas addressed in one study increased by 60 percent. (H. John Heinz, 2000) In some places, the coastline is also moving landward as a result of ongoing erosion processes and increased sea level. The net result is a dynamic without-project condition with the threat and potential extent of damage increasing over time. The inventory should include the entire expanse of this expanding area.

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.

Ensure that your structure inventory covers the entire area that could eventually be subject to damage by the end of the study period.

Executive Order 11988 and Section 308 of WRDA 1990, Flood Plain Management specify that any structures built after July 1, 1991 that are below "the base flood "are ineligible to be counted in benefit calculations. The term "base flood shall mean that flood which has a one percent chance or greater of occurring in a given year." It would be more correct to specify an area that in a year has a one percent chance of being subjected to a flood level of equal to or greater than a given magnitude. The Corps refers to the one percent as the annual exceedance probability or the one percent annual chance floodplain.

One exception to this requirement is if the entire county is substantially located in the 1-percent-annual-chance-floodplain, then the ineligibility would apply to construction in the

10-percent-annual-chance-floodplain. Therefore, these structures should be noted in the Regional Economic Development (RED) account, but detailed data collection is unnecessary for NED purposes. However, if new homes are built above the 1-percent-annual-chance-floodplain some damage may occur and detailed data collection should be done for these structures.

Table 8 shows the actual chance of a resident being flooded. This shows that while **the “100-year” flood has a 1 percent chance of occurring in any one year, there is 39 percent chance of occurring in a 50-year period.**

Table 8. Chances of Being Flooded One or More Times in a Period of Time

Chances of Being Flooded				
Period of Time	Flood Level			
	10-yr Flood	25-yr Flood	50-yr Flood	100-yr Flood
1 year	10%	4%	2%	1%
10 years	65%	34%	18%	10%
20 years	88%	56%	33%	18%
30 years	96%	71%	45%	26%
50 years	99%	87%	64%	39%

Source: Regional Flood Control District, Clark County, Nevada

Within the study area, future development may differ from existing development. Just as Corps planners assume that the Federal government only constructs authorized projects in the future, planners should assume that future private development will conform to existing land use plans. The standards under which any development is constructed should also be assumed to conform to FEMA guidelines.

More information is also available at the discussion on Know Land Use Plans and Coordinate with Others in the Flood Risk Management NED Manual.

Consult local land use plans and use their projections for future land uses. Virtually all such plans are now readily available on the internet. For example here is a link to the Local Coastal Program Land Use Plan for Malibu, California.

There are three ways in which development can change in the future:

- Development of vacant land
- Redevelopment of current structures
- Replacement of damaged structures

Based upon studies of storm-induced erosion, wave effects, and storm surge flooding, the Flood Insurance Administration has defined three basic subdivisions to be applied to flood hazard areas when creating Flood Insurance Rate Maps. Areas within the 1-percent-annual-chance-flood zone are designated as being in either an **A-zone** or a **V-zone**, with V-zones reserved for high velocity water where erosion tends to be most likely. Areas outside the 100-year flood zone are X zones. This is important to keep in mind because it will help delineate the study area and reaches.

The zones are further subdivided as follows:

- **VE Zones**: areas, mapped according to Base Flood Elevation (**BFE**), affected by high velocity water, including waves over three feet high.
- **AE Zones**: areas, likewise mapped by BFE, affected by a combination of stillwater floods and waves less than three feet high.
- **AO Zones**: areas, mapped according to flood depth instead of BFE, affected by flooding 1 to 3 feet deep. These areas are usually those affected by sheet flow and runoff from coastal flooding,
- **AH Zones**: areas mapped with BFEs, affected by floods one to three feet deep. Flooding in AH Zones is commonly associated with shallow flow and ponding.
- **Shaded X Zones**: represent the coastal floodplain areas lying between the 100-year and 500-year flood lines.
- **Unshaded X Zones**: represent the area outside the 500-year flood line.

Older National Flood Insurance Program (NFIP) rate maps use slightly different flood zone designations. For further information, see FIA flood zones.

The flood zone dictates whether the lowest habitable finished floor—or in the case of homes in the V Zone, the bottom of the lowest horizontal member—must be placed at the *Design Flood Elevation* (DFE). The criteria mandated for the V Zone are only recommended for Coastal A Zones, which are areas landward of V Zones or an open coast. Check to see if local ordinances have adopted this recommendation and require the bottom of lowest horizontal member to be at the DFE. Local ordinances may also require freeboard. Freeboard is additional feet on levees or similar flood risk reduction structures over what is thought to be necessary to withstand the 1-percent-annual-exceedance flood.

The life-cycle approach requires consideration of future land use changes and possibly alternatives that require new standards for future construction. At the same time, using new standards could minimize or eliminate certain damages which offset the increase structure value for changes.

7.10 With-Project Conditions: Description, Structural, and Non-Structural Measures

The same process that was used to describe the without-project condition is used to describe the with-project conditions. The with-project conditions are a description of the assumptions and conditions for each alternative that is intended to reduce expected annual damages and increase National Economic Development Benefits. There are several alternatives that must be considered in the with-project analysis: the no action plan (without-project condition), a structural and a non-structural plan. A combined **non-structural** and **structural** is likely to reduce risks the most and should also be considered.

Structural Measures

Structural measures include, but are not limited to (see Appendix A-1 for additional information):

- **Beach nourishment** is the movement of sand from one location to another. Beaches have an equilibrium slope and nourishment projects generally deposit sand at a steeper slope than equilibrium. So, the initial footprint of the nourished beach should be expected to decrease, especially in the project's early years, until a new equilibrium slope is reached. Beach nourishment is sometimes very successful, and sometimes not depending on one's perspective. Miami Beach is considered a success. About 14 million cubic yards of material were placed there between 1976 and 1981. The renourishment placed only 300,000 cubic yards six years later; however, no major storms hit this area during this time. On the other hand, virtually all of the 500,000 cubic yards placed at Indialantic Beach, Florida were gone within a year after a major storm hit. While much of the beach was gone, the fact that structures likely had reduced damages from the storm could be considered a success.
- **Jetties:** structures used to stabilize channel and prevent shoaling of littoral materials to reduce wave heights and damages (within the channel).

Yaquina Bay Navigation Jetty, Oregon (Bob Heims, Portland District)

- **Breakwaters:** a structure to reduce the wave energy near the shore. These can be floating or rock piles, or something similar to dissipate wave energy. This could reduce wave heights and damages alongshore.

Presque Isle (Ken Winters, Buffalo District)

- **Channel modifications**: such as the Mississippi River - Gulf Outlet Closure to reduce storm surge damage

- **Seawalls:** to protect structures, prevent erosion and overtopping

Construction the Virginia Beach Seawall, Virginia (Norfolk District)

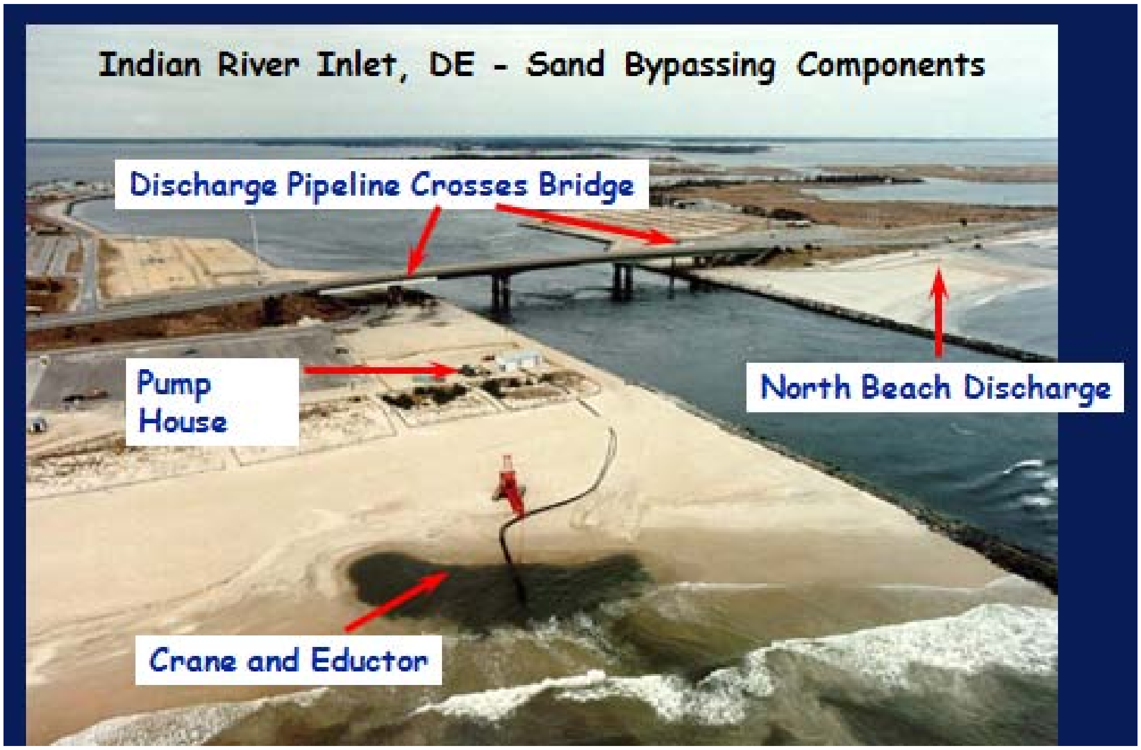
O'Shaughnessy Seawall, San Francisco, California

- **Groins:** a structure built perpendicular to the shore to stabilize shoreline position and reduce erosion under structures and reduce wave's impact to structures.

Before and After Groin Placement at Cape May Point, New Jersey

- **Bulkhead:** a structure built to retain soil and prevent erosion.

- **Sand bypass:** is a system that artificially moves sand across entrance channels.



Revetments: a stone, concrete, or other material built along the shore to prevent erosion and dissipate wave energy.

Muskegon Harbor Revetment (Detroit District)

- **Scour Aprons, Double T-Units, *Beachsave Units*** and other structures to hold sand in place.

Double T-Unit (Philadelphia District)

Scour Apron (Philadelphia District)

Placement of Beachsave Units (Philadelphia District)

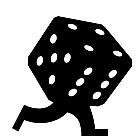
Placement of Marine Mattress (Philadelphia District)



Revetments and Other Measures (Philadelphia District)

Beach nourishment is not an exact science. Work with the rest of the PDT to estimate the uncertainty associated with this type of alternative and include it throughout the analysis. For an interesting history of the institutional environment surrounding beach nourishment, go to: http://www.csc.noaa.gov/beachnourishment/html/human/law/history.htm

Structural measures could pose risks to the environment, and will also leave residual risks for the people living and playing in these areas. Recreational boaters or swimmers may face changed conditions that could endanger their lives in addition to remaining flood risks.



Non-Structural Measures

Non-structural measures do not require a structural modification of the shoreline or adjacent waterways. They include measures that the Corps, other Federal and non-Federal agencies can undertake. These measures are typically intended to reduce the consequences from a coastal probability.

Non-structural measures include:

- **Building code improvement**
- **Land use management**
- **Construction requirements** may also be applicable and economical for without-project structures, but voluntary implementation is usually limited.
- **Land acquisition**: This is effective, but also expensive. Land acquisition should be considered in conjunction with environmental preservation or restoration in order to provide benefits in addition to reducing damages.
- **Setback requirements** impose a horizontal displacement away from the erosion and wave attack at the coastline. Many states and local municipalities require some type of setback.
- **Relocation**: this is often a difficult option to implement because residents rarely want to move, but it may be the most effective risk reduction measure.
- **Elevating Structures**
- **Storm warning systems**: their effectiveness depends on the amount of warning time. If systems are already in place, then these can be improved.
- **Individual Emergency Plans**

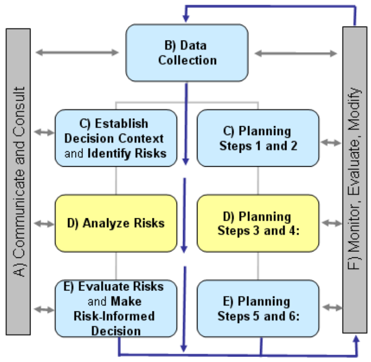
> *Alternative plans shall not be limited to those the Corps of Engineers could implement directly under current authorities. Plans that could be implemented under the authorities of other Federal agencies, State and local entities and non-government interest should also be considered.*
>
> -Planning Guidance Notebook, ER 1105-2-100, Section 2-3, c(1)(2000)

Non-structural measures also entail risks. For example, a storm warning system could fail producing catastrophic damages and loss of life. Relocating or elevating a structure could pose structural risks. Relocation of people could put them in the harm's way for a different type of disaster. There is no way to completely eliminate risk.

7.11 Summary and Look Ahead

Chapter 7 examined the many economic tasks that must be addressed in organizing the Coastal Storm Risk Management study and describing the with- and without-project condition. Key points noted include the fact that the economic study area may not coincide with the project area as described in authorizing language or other study documents since NED impacts may fall beyond project boundaries. The economist should work with the planning team to develop project reaches for the CSRM study. Economic factors such as structure type, political subdivisions, and land uses should be considered in developing project reaches. The performance of a structure inventory coupled with forecasts of development, making reasoned assumptions about future development patterns and structure composition, forms the basis of much of the determination of the without-project condition. Similarly, assumptions and forecasts are made for each project alternative *with-project condition*. These alternatives should be formulated to consider non-structural as well as structural measures, and combined plans.

Chapter 8 focuses on analyzing the probabilities and consequences of severe coastal events. The chapter is concerned with modeling wave, flood, and erosion economic damage relationships and using a life-cycle analysis to evaluate risks in plan alternatives. It also discusses knowledge uncertainties.



Chapter 8: Analyze Risks

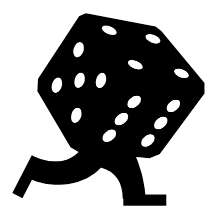
PLANNING STEPS 3 & 4

The damage-frequency relationships represent how the damage associated with a given event (i.e., storm, wave, erosion) is related to the frequency of that event (probability of occurrence). The damage relationships developed in Step 7 are combined with the frequency curves (developed by the hydraulic and hydrologic engineers) to estimate the damage-frequency relationships. Damage-frequency relationships (curves) are developed for each of the applicable damage mechanisms, i.e., long-term erosion, recession, inundation and wave attack and for each land use category. These relationships should be developed using a risk-based analytical framework.

-Planning Guidance Notebook, ER 1105-2-100 E-24, f(2)(g) (2000)

The chapter focuses on analyzing the likelihood and consequences of severe coastal events. The chapter is concerned with modeling wave, flood, and erosion economic damage relationships and using a life-cycle analysis to address Planning Steps 3 and 4: Formulate and Evaluate Plans. Risk assessment continues to be described in further details on what the likelihood and severity of consequences is in quantifiable terms.

8.1 Risk = fx (Probability, Consequences)



Risk is a measure of the probability (or likelihood) and consequences of uncertain future events. It can be described as a function of likelihood and consequences of hazard or action. The probability of a coastal storm, associated flooding, wave heights, erosion and reliability of any *protective* structures are all factors that link to the NED value. These probabilities are typically calculated by coastal engineers, based on historical information; but this could also be a joint effort among many team members as it should. In the first part of risk assessment, the economist qualitatively described the hazards/opportunities and consequences; the second part quantitatively describes the likelihood of the hazards/opportunities, the severity/magnitude of consequences, and the impact of associated uncertainties.

Knowledge uncertainties should also be described. This is known as the risk characterization.

The first step is to define the without-project conditions. Economists use the likelihood of coastal hazards and combine this with the economic consequences. The economic consequences are measured as a range of average annual equivalent damages. Economists will also assist in combining likelihood and other consequences as well; for example, loss-of-life, environmental and social impacts. Once the baseline damages are determined, all other alternatives are compared and measured to this. The NED benefits will be the reduction in the average annual equivalent damages. Other benefits for plan comparison will be the reduction in other negative impacts or increases in positive impacts.

The following sections will focus on estimating the consequences of coastal storm hazards. The parameters that drive calculations have one or both types of uncertainties which influence the risk. Increasing the amount of known information, conducting a sensitivity or scenarios analyses, using qualitative descriptions, calibrating and testing models, and using an event-based Monte-Carlo simulation or other methods can assist in managing and describing the risks, reducing knowledge and model uncertainties, and understanding variability.

At a minimum, it is recommended that a risk assessment include:

- Identification of all critical parameters and assumptions underlying the justification of each alternative
- Determination the range of conditions under which each alternative is evaluated
- The likelihood of various hazards or uncertainties
- Identification of potential consequences from the hazard or uncertainty

The risk assessment should be clearly communicated and addressed in the analysis. When in doubt, the economist should error on the side of describing more of the assumptions and uncertainties rather than less.

8.2 Storm Generation

Economists will not typically develop the storm or event frequencies for simulation; however, they should be familiar with the process.

Seasonal Variation: The frequency used for coastal storms is often divided into at least two separate frequencies: **tropical** and **extratropical**. This is especially true of the Gulf and Atlantic coasts. On the Great Lakes, separate frequencies should at least reflect winter and non-winter seasons. When sufficient historical data exists, frequencies are often calculated on a monthly basis. This is especially true for the Great Lakes where the average water surface elevation (WSE) varies by month.

Obviously, the storm generation frequency analyses are not within the purview of the economic discipline. The role of the economist is to insure that the inputs provided will meet the computational requirements of the economic analysis. Whether the economist is using simplistic models such as spreadsheets or complex tools tool such as Beach-*fx*, he or she must make sure that the storms used in the frequency analysis correspond to the storms used in modeling the storm response.

Application of Beach-Fx

In Beach-*fx* the user defines the desired storm seasons (up to 12 seasons can be defined) based on storm seasonality at the project site. Each plausible storm is assumed to take place within the season in which the original historical storm occurred. Storm seasons for different storm types (hurricanes and northeasters) can overlap such that both types of storms could take place during the same period of time. The probability of both tropical and extra-tropical storms can be defined for each season. Based on this assigned probability, a Poisson distribution is used to estimate the number of storms of each type that could occur in the season. The Poisson distribution is used because it expresses the probability of a number of events occurring in a fixed period of time assuming that the events occur with a known average rate, and are independent of the time since the last event.[11]

Table 9. Spreadsheet Showing of Storm Frequency Probabilities

Storm of	Relative Frequency	Absolute Frequency	Surge Height	Wave Height	Erosion
1948	0.021	0.002	12	8	50%
1952	0.043	0.005	7	5	30%
1993	0.085	0.009	4	3	10%
1926	0.149	0.016	4	2	0%
1963	0.170	0.019	3	1	0%
1886	0.213	0.023	3	0.5	0%
2004	0.319	0.035	2	0.5	0%
	1.00	0.110			

Table 9 is an example that shows seven historical storms for a given area and what the corresponding surge and wave height were along with the erosion rate at a give point. These storms are used as predictors of future storms to come. The relative frequency is the probability that a certain historical storm will occur as compared to the other historical storms listed. Thus, the 1926 storm is about half as likely as a 2004 storm. The absolute frequency is the probability that a storm will occur in a given year. In this example, .11 storms are expected on average in a given year; meaning, a storm won't occur every year. In Beach-fx, the Poisson is used to estimate the number in any season where the season is a fraction of a year. The number of the life-cycle is simply the summation, a random variable just like the number of storm in a season.

[11] Gravens, Mark et al. "Monte-Carlo Life-Cycle Simulation Model for Estimating Shore Protection Project Evolution and Cost Benefit Analyses." *Shore and Beach.* Vol. 75, No. 1. 2007.

A feasibility study is likely to model many more storms than seven. By simply backcasting four various levels of tide superimposed on these seven storms, the population of possible storms would increase to 28. This is because storms can have various impacts depending on the timing of the tide. For example, if the same storm hits at low tide, it will have a lesser impact than if the storm hits at high tide.

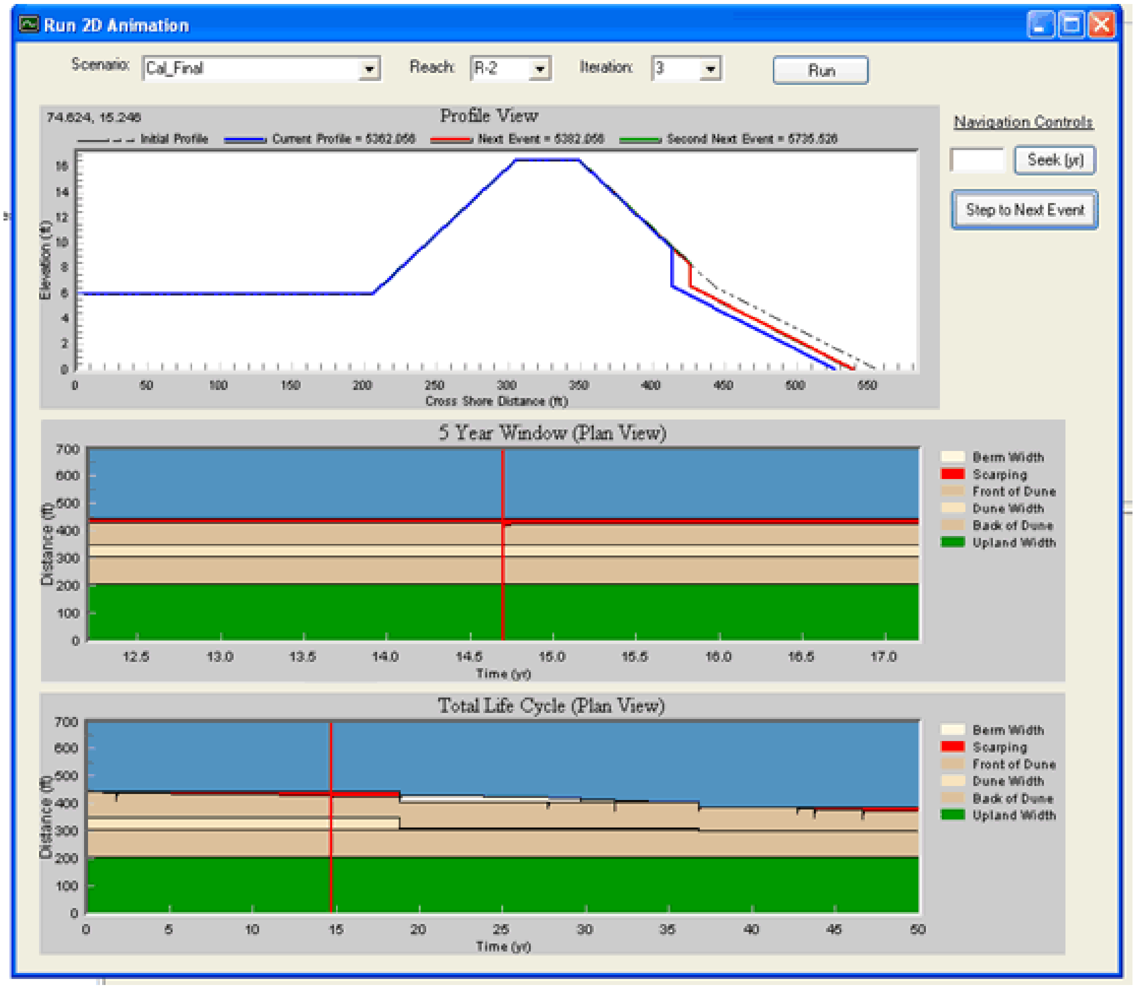


Figure 23. Beach-*fx* Plan View.

Figure 23 shows a sample plan view of a beach profile in Beach-*fx*. For further description of other output, see the Beach-*fx* manual.

8.3 Evaluating the Damages

Damages produced by flooding, waves, and erosion cause numerous types of economic damages. These damages are measured in the existing condition, and in the with- and without-project conditions. Damages are determined to be part of the benefits in the with-project condition if they are reduced from expected damages in the without-project condition.

This section describes in qualitative terms the types of damages associated with flooding, waves, and erosion that the economist should be measuring for NED evaluation of project alternatives. Additionally, economists can also have a role in measuring non-monetary factors that are important considerations in project formulation. The reader is referred to Table 6 in **Chapter 7** for a listing of the damages that are described below. The next chapter will analyze these risks in quantitative terms in order to evaluate each alternative's effectiveness in reducing risk.

Flood Damages (Consequences)

Physical Damages

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 damages 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 coastal flood reduction damages are similar to those calculated for riverine flood damages, factors such as seasonality, wind effects, and potential salt water effects must also be taken into account.

Economists estimate the depreciated replacement values of the structures and contents in the floodplain as the basis for determining damages to structures. This is why it is important to have a good structure inventory to start with. The structure inventory describes the characteristics that are used to determine the structure's value (including min, max, and most likely to address uncertainty). As discussed later, depth-damage curves are used to estimate the damages over the period of analysis. Life-cycle analysis looks at impacts on structures and contents over time. Therefore, the same structure can be damaged from multiple storms and rebuilt multiple times over the period of analysis. The structure can also be damaged while undergoing the rebuilding process; this condition can also be addressed by the Beach-*fx* model. The cumulative damage for all the years is presented as an average annual equivalent values. Historical data or surveys of current damage from recent events may be helpful in supporting estimates and/or calibrating them.

> The NED website provides sampling guidelines and techniques, which can be found at www.CorpsNEDManuals.us, Click on "You're your Damage Survey" under the Flood Risk Management Manual Table of Contents.

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

Agricultural Losses. Agricultural 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.

Procedures for calculating damage to buildings and roads are similar to the procedures for urban projects. Estimation procedures for other agricultural properties, however, 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.

Often times there is a cost for removing sediment from facilities, such as roads, culverts, and channels. 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. Therefore, it is possible to have *off-site sediment reduction benefits* are based on the costs of removing sediment from facilities between the without- and with-project conditions. 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 potential damage. However, another perspective is that some of the sediment that is removed could be re-used for beach nourishment in some cases thus reducing future placement costs and damages. The calculation of inundation or flood reduction benefits associated with sediment loads 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 run-up, salt water, and damages from sand, debris and ice.

Vehicle Losses. Vehicle depth-damage curves should not be overlooked. One estimate puts the total number of vehicles damaged in 2005 by Hurricanes Katrina and Rita at over 571,000. (Businesswire.com, *Buyer Beware! Flood Vehicles from Gulf Coast Resurfacing,* January 26, 2006.) These include new and used vehicles for sale and parked in auto dealerships. However, most damaged vehicles are privately-owned. The typical middle-income family owns between 2 and 3 vehicles, but most likely evacuates with only one of them. Estimated values should have reasonable and supportable data for the number of cars impacted, their distribution by type, their depreciated replacement value, and other pertinent information.

EGM 09-04, Generic Depth-Damage Relationships for Vehicles offers Corps planners a more targeted method for estimating the damage caused to vehicles when that category is significant for a study. Not all studies require a separate vehicle damage curve, as damages from vehicles can be included in generic *contents* curve as well. This curve is normally used in urban flood studies since rural areas will most likely have fewer vehicles. There are two methods for applying this curve, one for vehicles parked at residential locations and the other for those at non-residential locations.

Application of the vehicle depth-damage curve for vehicles parked at residential locations requires several pieces of information. The elevation of the vehicle, which is assumed to be the ground elevation at the affected property; the average number of vehicles per household in the study area, which can be found at American FactFinder (http://factfinder2.census.gov/); the approximate percentage breakdown of vehicle types (sedan, SUV, truck, etc.) found in the study area and the estimated value based on make, model, and age, found at http://usa.polk.com/ or through a sample survey; and lastly the percentage of vehicles that would actually be parked at a residence when the flood waters arrived. Estimates for this can be found in the Appendix of EGM 09-04 or sample surveys can be taken.

Application for vehicles parked in non-residential areas is similar, but more specific data must be collected. Determining the number of vehicles that are located at a business cannot be done with the residential method (American FactFinder). Data on number of vehicles and type distribution needs to be gathered from individual businesses in order to accurately assess the damage. The same generic damage curves are used for both residential and non-residential vehicles, however.

Other Structural Damages. These are any additional structural damages that are not already captured in the categories above, and may include structures such as boardwalks, pier, lifeguard structures, and other facilities that do not appear on assessor's records or do not have standard damage functions. Loss of land value could also be included depending on the circumstances.

Non-Physical Damages

Non-physical damages include emergency costs and non-recoverable income losses. This category is difficult to measure because the burden of proof is to argue that the service is unique to the damaged area. These damages should always be identified in terms of the economic resource, labor or capital that is lost during the storm.

Income Loss. Income loss is the loss of wages or net profits to businesses over and above physical storm damages. Income loss 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 or recovery activities. 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 amenities 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.

Be careful to avoid counting income transfers as income losses. It does not matter who recovers or captures an income loss. If Firm A loses $1 million and Firms B and C each earn an extra $400,000 as a result, the income loss is only $200,000.

Non-Physical Damages in New Orleans During Katrina.
Conditions for the tens of thousands of people who had sought shelter in New Orleans' superdome quickly deteriorated. Water and food supplies ran short and sanitary facilities broke down. **(BBC News)**

Emergency Costs. Emergency costs include both those expenses that result from the threat of a storm and those expenses that result from the storm itself. Emergency costs include expenses for monitoring and forecasting 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.

It may be difficult to separate out what emergency costs are attributable to what aspect of a coastal storm; for example, it is difficult to relate emergency costs directly to wave height or any such variable. Instead, it is more common to relate emergency costs to the number of residences, or perhaps total structures, affected as the independent variables. These costs should be based on historic information on past events in the study area, if available, or use data from a similar area. State and local governments, Federal agencies, and private citizens fleeing coastal storms have historically incurred significant emergency costs. When collecting emergency plans for storms note whether, and to what extent, the historic pattern is projected to change significantly in the future. Any uncertainty in the analysis can be reflected by estimating high, low, and medium emergency cost scenarios for each event.

Public and Private Protective Measures. These include costs in the future for avoiding public and private expenditures on measures to protect coastal property. This could be erosion protection or storm-proofing costs that could be incurred in construction of a new or existing development.

Temporary Evacuation and Relocation. 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. However, if the victims of storm damage have insurance coverage to help defray temporary evacuation and relocation costs, such costs cannot be attributed to the storm damage alleviation project and cannot be counted as benefits since insurance payments are offsets and both cannot be counted.

Temporary relocation includes the additional living expenses incurred by storm area residents who are forced to find a longer-term temporary housing after a storm event due to inhabitable homes. This could be caused by:

- Extended periods of inundation
- Structural damage that is too severe to live with
- Large deposits of sand and debris
- Disruption of utility services and transportation routes

In general, temporary relocation lasts longer than temporary evacuation. Only the population residing in the location where the hazard hits and at the time of the hazard can be counted in this value. This is known as the **population at risk**. The threatened population is the remaining population after evacuation.

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. Delays on bridges cause by high winds should not be counted. Bridge and road damage may cause detours for several months until repairs can be made. See the Planning Guidance Note book, ER 1105-2-100, Appendix D, Table D-4 (2000).

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 flood-related damage to access roads.

Further discussion of the types of flood damages can be found in the Flood Risk Management NED Manual at www.CorpsNEDManuals.us.

Wave Damages

The previous Coastal Storm Damage Reduction National Economic Development Manuals only addressed erosion and structural damages because established wave generation models and wave-damage curves were rudimentary. However, with advances in these areas waves are now an additional factor that should be considered independently and/or dependent of flooding and erosion as appropriate for circumstances. Damage curves are used to display the various damages caused by each factor. Waves cause essentially the same types of damages as flooding; however, the horizontal and vertical forces slamming into structures increases the damages and risks beyond the flooding. Waves also contribute to erosion. Diligence must be taken to ensure that the flooding and erosion damages do not overlap with the wave damages. Tides and storms can decrease or increase wave heights which will increase or decrease the damages above any flooding or erosion level. Beach-*fx* automatically accounts for tidal factors and its influence on the nearshore waves.

Bodie Island in Dare County, North Carolina (Wilmington District)

Storm-Induced Erosion Damages

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 (flooding and waves) and then counting it as damaged from i long-term erosion.. Most double counting can be avoided by establishing stage-damage relationships for various points 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 due to erosion, then average annual inundation damages will not be claimed for property no longer in the inventory of damageable improvements .

Urban Losses. See the flooding section for more information on the types of structures and contents damaged. Erosion will undermine the foundation of homes which could result in their collapse and other problems. Structural contents inside may or may not be able to be removed or salvaged. Therefore, the damages caused by erosion may be slightly different from flood damages. Road and other infrastructure can be impacted by erosion as well.

Loss of Land Value. It is advised that you consult with senior economists prior to undertaking this analysis. This analysis is complicated; due to land changes associated with decretion and accretion with both long-term procession erosion and storms. Traditionally, coastal engineers used historic, observed land loss in terms of recession of the shoreline. This would have been measured in feet per year using a few historic surveys, old maps or aerial photos. However, this traditional method combines both storm land loss with long term littoral process erosion, which should not be counted in NED calculations. In Beach-fx, the long term littoral erosion or accretion is calibrated using the historical sequence of storms. So at various locations, the model storm erosion can exceed the historical amounts thus implying there is background accretion being masked by the storm sequence. This background is then used to calibrate the model at each location.

According to the PGN, we use the nearshore market value to estimate the loss of private land from coastal storms. This represents the net loss assuming that the ocean front is the most valuable factor with a rent gradient declining as you move inshore. As the shoreline recedes, the extra ocean front differential value is transferred landward so the net economic loss is measured at nearshore value. It could be argued that the nearshore value underestimates the value of land loss. In practice, there are costs assumed by shoreline land owners from the risk of erosion that could result in a permanent loss of land. The Heinz institute report for FEMA (The Evaluation of Erosion Hazards, April, 2000, Enduring Environmental Solutions | The H. John Heinz III Center for Science, Economics and the Environment) suggests that the risk premium declines as you move landward; therefore, it is possible that nearshore land is more valuable than ocean front land. In other words, evaluate wisely!

These "damages" are net losses of land value due to storm erosion whether the land is occupied by structures or used for recreation. Currently, no standard damage curves for land value lost to erosion exist. This is likely due to the complexities of estimating damages from region to region. To address uncertainty, at least three sets of such model runs should be requested to estimate high, most-likely, and low erosion rates. Additionally, Engineer Regulation (ER) for *Flood Damage Reduction Measures in Urban Areas* (ER 1165-2-130) states that the value of recreation can be used to estimate the value of public lands lost to erosion. In this case, *display either the value of land lost (based on nearshore land values) or recreational losses to avoid double counting***.**

Emergency Costs. Emergency costs for erosion protection are calculated similar to flood reduction benefits. It is the reduction in emergency costs by the with-project condition.

Public and Private Protective Measures. Structures are often more severely damaged by erosion of the land under them in coastal storms than in riverine flooding situations. Responses to 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 reestablished in the same location.

Incidental Costs. There may be other miscellaneous costs associated with storms that can be identified on a case-by-case basis. Some examples are loss of the net value of production of a factory during the period when a coastal storm washed out all the access roads or increased travel costs incurred by consumers who could not reach neighborhood stores. However, while the net value of production may decrease at one factory in the study area, it may also increase at an unaffected factory outside the study area. Take special care to distinguish between NED impacts without transfers and Regional Economic Development (RED) impacts that may ignore transfers altogether.

Another example of an incidental cost from erosion is the loss of recreation due to an unsafe shoreline from erosion. This condition would reduce the amount of recreation days available to the public. Projecting recreation use is often based on the forecasted regional population growth. Defining the relevant region and identifying alternative recreation resources are important. The population forecast should be included in future conditions. Loss of public land is related to the recreation losses because the value of the land may include recreation. Therefore, it is not appropriate to display both the loss of land and recreational loss in such circumstances.

Other Risk Reduction Benefits

Note: Many of these benefits require that communities have been following any Federal guidelines if they are part of a Flood Insurance Rate Map (FIRM) Community. Failure to follow or maintain guidelines could result in benefits being ineligible or reduced.

Maintenance Costs of Existing Structures. Storm damage reduction structures in the immediate vicinity of the shore may require more frequent maintenance because of ocean spray, erosion, flooding or frequent wave attack. This can be estimated and used as a baseline for decreasing costs in the alternatives.

Location or Intensification Benefits: There could be a benefit from project modifications that allows for intensified activities or higher-valued developments. 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. For further discussion of location and intensification benefits see the Flood Risk Management Manual available at www.CorpsNEDManuls.us and go to chapter on Land Use Changes. (http://www.corpsnedmanuals.us/FloodDamageReduction/FDRID099IntensBenfts.asp)

Risk Exposure to Life Threatening Situations. Loss of life is an important consideration in describing the without-project condition. Historical storm-related deaths should be discussed as the team moves towards finding solutions to prevent life losses. Some models attempt to use population and probability statistics to predict potential deaths or the population exposed to a specific danger. For example, one model being developed by HEC and researchers from Utah State University is called LifeSim, which could assist on some coastal projects. Models and other supportable methods should be considered for use and risk and uncertainty of their estimates should be described.

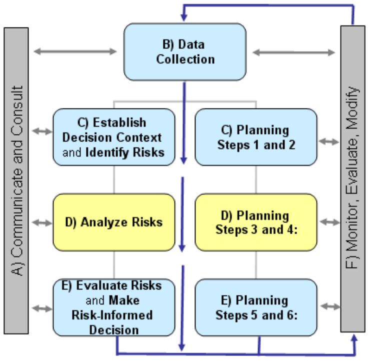
Risk to Society, Such As Cultural and Historical Sites. Many communities have important cultural and historical centers, cemeteries, or other gathering areas. When the structure inventory is being completed, the economist should note the presence of such structures and locations for the team if they come across them. The team biologist and archeologist will often describe these areas in the Environmental Assessments (EA) or Environmental Impact Statements (EIS). These structures may have higher monetary values that can be included in the structure and content damage assessment. In addition, project impacts to disadvantaged communities must be considered as part of the National Environmental Policy Act.

Risk to the Ecosystem. The existing condition may have ecological degradation that could be improved in the alternatives. The biologist will make this assessment, but it may also be something for the economist to consider in the without-project condition if the alternatives may have an ecosystem improvement component or if the project is multi-purpose.

Opportunities for Improvement. Like risk to the ecosystem above, there may be other impacted areas that could be improved. The without-project condition must first be described before alternatives can be formed and benefits assessed for such potential improvements. Although this step describes the without-project condition damages, consider including a thorough description of features that could be improved but which cannot be accounted for in an economic analysis. Examples include: recreation, shoaling impacts on nearby navigation, tidal damages, downdrift impacts, and other factors.

8.4 Summary and Look Ahead

This chapter has provided a more complete explanation of the kinds of physical and non-physical damages associated with flooding, waves, and erosion. These damages must generally be estimated on the basis of imperfect and incomplete information and so they must incorporate risk and uncertainty into the damage estimates. An example using Beach-*fx* employs random selection in a Monte-Carlo simulation process to generate a distribution of life-cycle costs associated with damages and preventive measures that can be statistically examined to quantify the uncertainty and evaluate the risk. The next chapter extends the logic of the NED evaluation process to focus on the relationship between the components of coastal storm events (flood depth, duration, wave heights, erosion) and damages incurred.



Chapter 9: Analyze Risks - Damage Curves

Planning Steps 3 & 4

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….**A risk-based analytical framework should be used to develop the damage relationships.***

- Planning Guidance Notebook, ER 1105-2-100, Appendix E-24, f.(2)(f), (2000)

9.1 Damage Curves

Damage curves portray the relationship between some damage driving coastal force (waves, erosion, etc.) and the damage caused to a specific type of structure. These curves are a simplified method to estimate damages by various forces since it would be time-consuming and almost impossible to develop specific curves for each coastal force and each individual structure. Three main types of curves are commonly used:

1) flood elevation-damage curves,
2) erosion footprint compromised-damage curves, and
3) wave height-damage curves.

Any or all of these can apply to a particular reach in the study area. Curves can be generalized or site-specific depending on the characteristics of the study area. Often, historical information is used to create these relationships.

"Estimates of losses for buildings, roads, protective works, and other features are developed at current price levels for existing development. Damage relationships are developed for each land use category. Anticipated damages from land loss due to erosion are computed as the market value of the average annual area expected to be lost. Nearshore land values are used to estimate the value of land lost" (Planning Guidance Notebook, ER 1105-2-100, Appendix E-24, 2000).

Flood and wave action damages are generally estimated as a percent of depreciated replacement value that varies with depth relative to the elevation of the first floor. Erosion damages relate to the undermining of foundation support at associated structures instead of water depth. Figures 24 through 26 show examples of categories of recently used damage curves in Beach-*fx*. Figure 24 shows a depth/damage relationship for inundation of wood frame structures with pilings expressed as the percent damage in relation to the depth of inundation above the structure's walking surface. Figure 25 illustrates an erosion damage curve where damage to the structure is expressed as a percentage of the structure's footprint that has been compromised by erosion. Figure 26 expresses damages to structures as the relationship between wave crest elevation and the elevation of bottom of the lowest horizontal member of a structure.

Warning: While these relationships have been used on several studies for similar structures, these curves are still proposals and haven't been universally approved. It is up to the analyst to choose or develop an appropriate and supportable curve for various structure types.

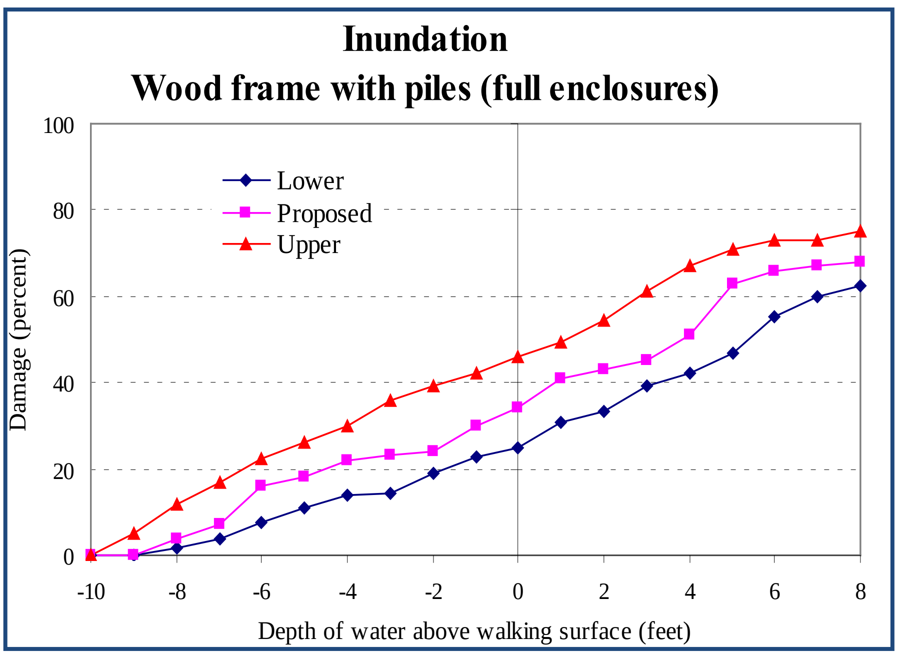


Figure 24. Flood Elevation - Damage Curve (For Example Only)

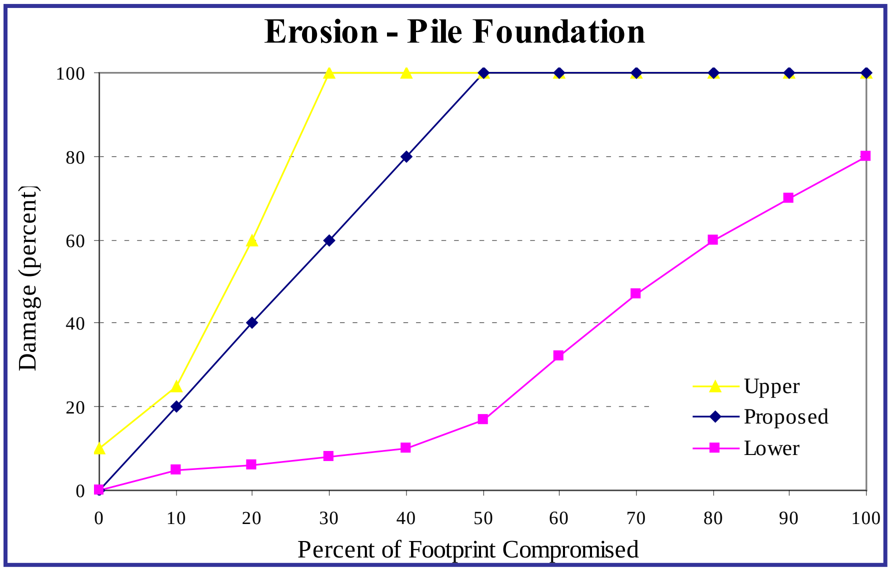
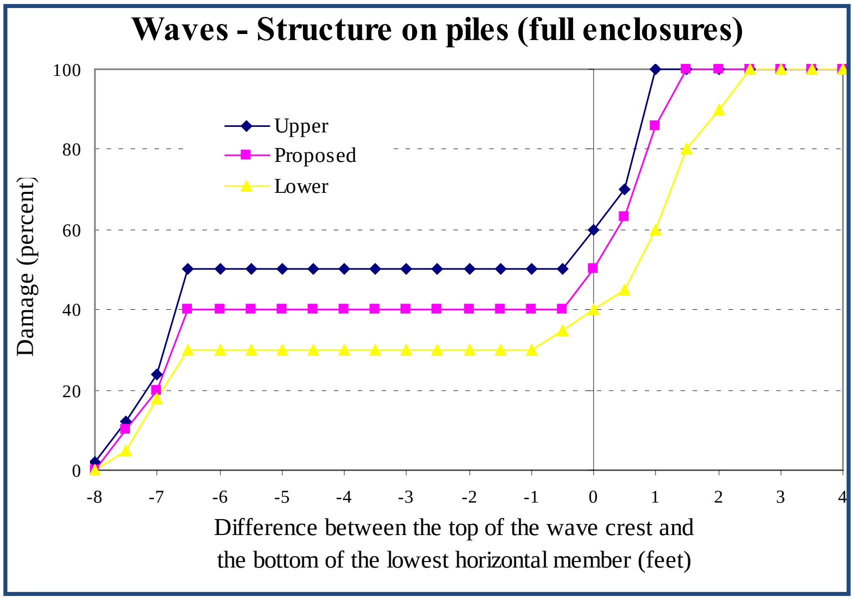


Figure 25. Erosion Footprint Compromised - Damage Curve (For Example Only)



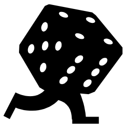


Figure 26. Wave Height – Damage Curve (For Example Only)

The sophistication of damage curves has increased, but it is still an imperfect method. However, uncertainty consideration has been added in as seen in each of the curves. These values or similar ones could be input to Beach-*fx* that employs a triangular distribution to generate the minimum, maximum, and most likely damages for a given level.[12]

[12] *This is a change from previous methods that analyzed expected annual damage each year based on a statistical probability for certain storms and independent coastal processes. The damage relationship was represented as a frequency-elevation or frequency-erosion function. This method did not consider the possibility of having similar events repeated to compound damage and structure inventory was static.*

Beach-*fx* runs a continuous simulation from year to year and captures the impact of past events on future conditions. It takes into consideration factors such as structure rebuilding time after storms and beach nourishment intervals. Therefore, two similar storms that occur at different points in time will not have equal damages.

Damages that are commonly estimated with depth-damage curves:

- **Structural**: includes all the damages to improvements that would be included in the sale of a property.
- **Contents**: losses associated with anything that is not part of the structure, from TV's to inventory and supplies. Carpets are part of a structure, but rugs are included in contents since they can be moved.
- **Vehicles**
- **Some Utilities**
- **Roads**
- Ancillary features such as boardwalks, etc.

Follow this link for a discussion of Depth-Damage Relationships in the Flood Risk Management NED Manual.

9.2 How to Determine the Damage-Curve

Finding the information to estimate appropriate damage functions is usually the most difficult part of any coastal economic study. Generalized functions exist for wave attack and foundation erosion, but are not universally approved. Ideally, actual history from previous storms in the study area can be used to estimate the damage relationships. However, even where damage data was collected from affected residents, proprietors and emergency responders in the study area, it may be difficult to separate out damages. Flooding damages can easily be confused with those from wave action or even those from wind and rain damage associated with the storm. Erosion damage is typically easier to identify.

Historical information on storm damage includes damages from inundation and high winds. Since alternatives considered in a Coastal Storm Risk Management study will not affect wind damages (e.g. damages from windblown rocks from the top of commercial buildings) the historical information used should be based on the best estimate of extra, or last-added, damages caused by aspects of the storm that no alternative may affect.

Where site-specific data is not available, data from similar areas must be used. *Similar* in this context means areas with similar construction types and storm regimes. Storm regimes tend to be similar within geographic regions, such as the North Atlantic or the Gulf Coast. Additionally, local conditions and variation can influence damage curves. Along the California coastline, for example, the effects of a storm on a south-facing beach may be very different from those found on a west-facing beach. It may be appropriate to use different damage curves for different structures along the south- or west-facing beaches.

Moreover, Table 10 below shows *hydrometeorological* variables to consider for creating damage functions. Hydrometeorology is the study of water and energy transferring the land and air (lower atmosphere). To create the most appropriate damage functions, variables that influence damage relationships for the study area should be identified and then damage relationships based on real-world conditions similar to those in the study area should be identified.

Table 10. Hydrometeorological Variables to Consider in Developing Damage Functions

Variable	Effects of Hydrometeorological Conditions
Storm Intensity	Are the storms similar to those expected in your area? Consider water height; swell size; wave height; direction relative to the coastline; and wind velocity.
Duration	Long duration storms can cause more damage than shorter, but more intense storms, especially from inundation and erosion.
Frequency	Repeated saturation can have a cumulative effect. Potential damage is greater when a large storm is preceded by several smaller storms.
Ice Effects	Mostly applies to Alaska. Ice can cause gradual erosion, but it can also protect against wave action effects during winter storms.

The amount of effort that it is appropriate to devote to the development/refinement of damage curves varies with the level of the study. Non site-specific damage functions are more acceptable in reconnaissance level studies.

9.3 Flood Damage Curves

The Corps has approved generic inundation depth-damage curves that apply to residential houses for flood damage reduction projects. There are problems, both practical and theoretical with using these curves in coastal projects. A key problem is that the generic depth-damage curves were developed from data collected from riverine floods, not from storm damage to structures that were constructed on pilings (which is often mandated for coastal buildings). However, as a practical matter the curves are available and inundation damage is likely to be the least important factor for coastal structures that are also subject to wave and erosion damage. Various damage functions are available for houses with and without basements (Economic Guidance Memorandum (EGM) 04-01 and EGM 01-03 respectively).

Applying Triangular Distributions to Damage Functions

While the Corps' generic depth-damage curves for estimating riverine flood damages allows the user to specify normal damage distributions, Beach-*fx* and other coastal models incorporating uncertainty considerations typically use triangular distributions as they are frequently developed with limited data or using expert opinion elicitation methods. To use such programs it will be necessary to *triangularize* a normal distribution in order to use depth-damage data in this form. Good practice requires testing for normality and never just assuming normality. Also at low depths a normal distribution with a reasonable standard error should predict negative damages, and at extreme depth a normal distribution will predict damages over 100 percent.

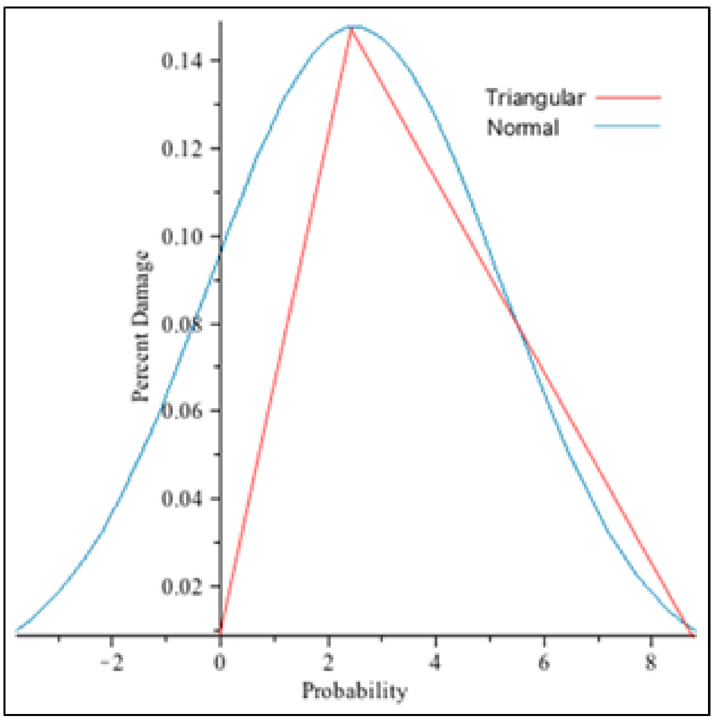


Figure 27. Triangular and Normal Distribution for Damages to Structures Without Basements at -1 Foot Depth

The first step is to plot the distribution. This can be done using a spreadsheet. Using the plot of the distribution it is easy to "*eyeball-in*" a triangular distribution. Figure 27 shows the plot of the normal distribution for single story structures without basements for a depth of -1 feet (meaning the foundation is 1 foot into the ground) . Superimposed is a triangle that fits the data without implying that damage can be a negative value. The minimum value is 0, the most likely is 2.5 percent and the maximum is 9 percent.

Factors That Can Affect Damage Functions

While existing development along the coast is mostly similar to inland development, recent and new development should be structurally different than inland development. This is because the structures are likely to be impacted differently by coastal forces and newer development is likely to have reduced damages. The National Flood Insurance Program (NFIP) now requires that new construction within at least some of the Flood Impact Areas (FIA) discussed in Section 7.10, incorporate design items intended to reduce flood damages. No such construction requirement exists for riverine floodplain development, where first floor elevation is regulated instead. These design items are listed in Table 11 below along with their effects on construction and operating costs.

Table 11. Design Items Affecting Inundation Damage Functions

Design Item	Additional Construction Cost	Required by NFIP &/or Local Building Code	Effect on Operating Costs
Pile/column foundation	High	V zone only	Lower Insurance
Joists sheathed on underside	Low	No	Lower Utility Bills
Corrosion protection	Low	Yes	Reduced maintenance
Decay protection	Medium	Yes	Reduced maintenance
Connection hardware	Low	Yes	None
Flood-resistant materials	Low	Yes	Lower Insurance
Protected utilities and mechanicals	Low	Yes	Reduced maintenance & Lower Utility Bills

Source: FEMA Technical Fact Sheet No. 6 at http://www.fema.gov/rebuild/mat/mat_fema499.shtm, (Aug 2005)

Some effort should be made in adjusting damage curves to accommodate the difference in inundation damage susceptibility between existing and future development. For example, analysis should use one set of curves for existing development and another set for future development.

Storm warning response is another variable that affects content inundation damage curves since items can be removed, elevated, and/or even looted as a function of warning time, and propensity to heed warnings.

9.4 Wave Damage Curves

Wave damage functions are similar to inundation damage curves in that they plot water surface elevation against a damage percentage. However, these curves address a number of special considerations of wave damages:

1. The relationship between wave height and surge can vary between storms even in the same reach.
2. Wave damage can start below zero stillwater elevation (see Figure 28).
3. Structural armoring is more effective against wave damage than against inundation damage, so distinguishing between them may be necessary to properly evaluate alternatives involving armoring. Specific curves may need to estimated for various alternatives. Wave run-up is not likely to be relevant behind the most seaward row of development.

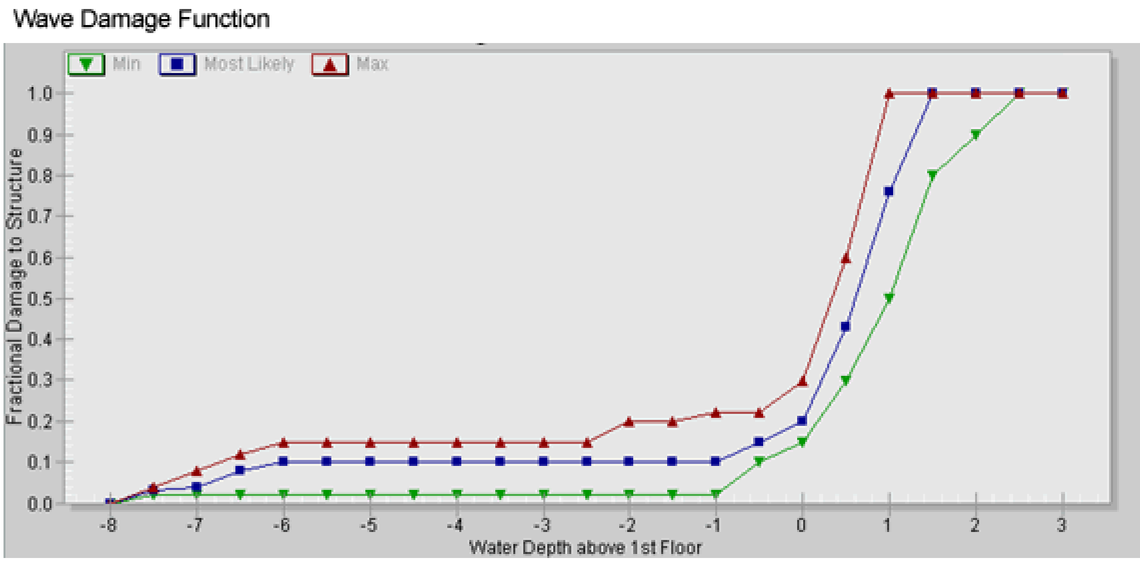


Figure 28. Wave Damage Function

Wave functions are measured as percent damage based on the height difference between the top of the wave crest and the elevation of the first floor. Waves break over and over on top of tidal elevations at similar heights, but no two waves are identical. Wave damage functions are measured at the top of unimpeded wave height based on tide plus surge plus swell. However, once the wave is impeded by a structure or the shoreline, the wave runs upward.

While there is a conceptual distinction between damage caused by wave attack and inundation damage, as a practical matter the wave damage curves in use will probably include both components. It may be necessary to designate reaches so that inundation damage curves are not applied to the same structures as combined inundation/wave damage curves since this would simply double count the inundation component. Beach-*fx* is able to combine the various functions as described in the Beach-*fx* user manual.

Do not overlook insurance adjustors as knowledgeable informants. Where the reaches of the study area subject to wave damage are small enough, wave damage may be estimated on a structure-by-structure basis using appropriate engineering models.

9.5 Erosion Damage Curves

Have you ever stood still on the beach and let the waves rush in around your feet? If so, you know how the sand washes away from behind your heels with each wave, even though the rest of the beach around you is not eroding. This kind of phenomenon occurs around pilings and is reflected in the wave-damage function for structures built on pilings. Even if structural integrity is not compromised, the pilings are left exposed and need to be covered after a storm with new sand. This phenomenon accounts for at least some of the damage at elevations well below the first flow as projected in the wave damage function shown in Figure 27.

Erosion damage functions differ from flood and wave damage curves in that they are functions of the percentage of the structure's foundation that is compromised, and they are defined for foundation types rather than structure types. A sample set of erosion curves is shown in Figure 29. Like the other damage functions, erosion functions should be identified for minimum, most likely, and maximum damage and should consider most likely conditions to facilitate uncertainty analysis.

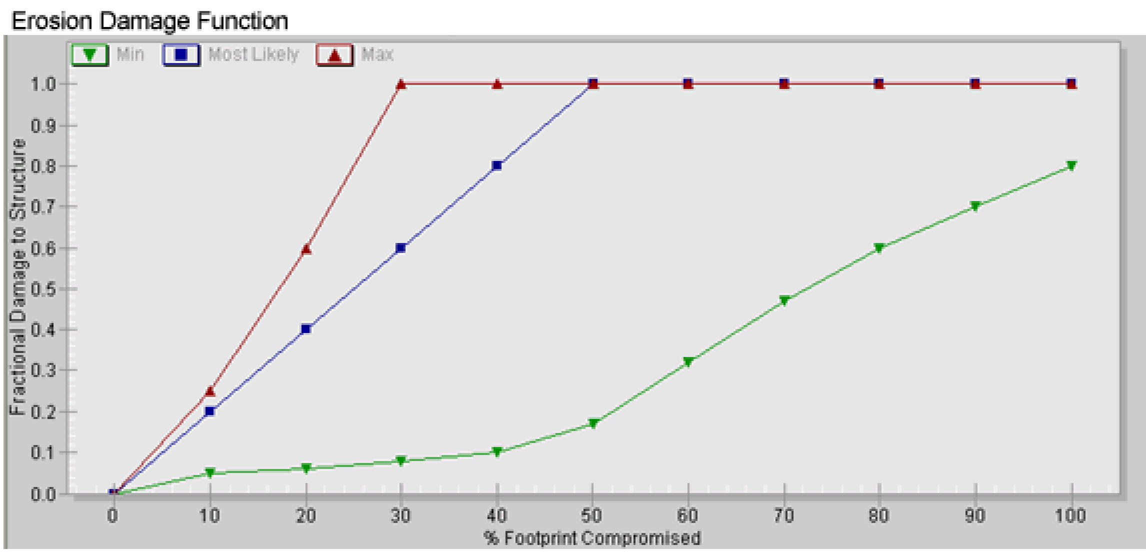


Figure 29. Erosion Damage Function

FIA rules for new development mandate erosion resistant foundations. Thus, newer and potential future structures should be evaluated with damage relationships that reflect differing susceptibility to erosion.[13] Inundation and wave damages tend to be a serious concern where the nearshore zone is gently sloping while undercutting and erosion are problems where the offshore slope is steep. The presence of wave or inundation damage in the same reach as erosion damage, and in the same project year, should raise concerns about potential double counting of damages.

9.6 Combined Damage Curves

Damageable property near the coastline is usually subject to some combination of flood, wave attack and erosion damage. It is important to eliminate the risk of double counting in such situations. Beach-*fx* already incorporates algorithms to prevent double counting. However, a standard approach, if Beach-*fx* is not used, is to develop a combined damage function and apply that to the depreciated market value of damageable items. This approach works as follows: for a given storm event determine the proportion of the property's depreciated market value that would be lost in the storm using the relevant inundation, wave attack and erosion damage functions independently. Then, subtract out the combined effects that would be double counted.

This can be expressed as an equation:

$$d = i + w + e - (i*w) - (i*e) - (w*e) + (i*w*e)$$

where:

d is the value of the combined damage factor
i is the inundation damage factor
w is the wave attack damage factor, and
e is the erosion damage factor.)

Finally, multiply ***d*** times the depreciated market value of the damageable item to compute damages to the item given the storm.

Beach-*fx* has the formula for computing the combined damage function built-in. Some other programs for estimating storm damage may also have the formula built-in.

[13] Mobile District has separate erosion curves for FIA compliant structures.

Combined Damage Equation Simplified

Astute readers will recognize that the form of the equation above is identical to that of the addition rule for computing the probability of the union of three independent events. Suppose, for example, that you roll three fair, colored dice and you want to know the probability that you will get a least one four. The probability that you will roll a four on the red die equals the probability that you will roll a four on the green die, which is the same as the probability that you will roll a four on the blue die. All of the probabilities equal 1/6, but if you simply add them up you will have over counted because you will have counted the cases where you rolled a four on two different colored dies twice. The probability of getting any of red-green, red-blue or blue-green combinations is ***1/36***. So, from the ***1/6 + 1/6 + 1/6*** probability of getting a four on any die we must subtract the ***1/36 + 1/36 + 1/36*** probability of getting a four on two or more dice. However, now we have slightly under counted because we subtracted the probably of getting a four on all three dice three times when it was initially triple-counted. So, we must add that rare probability ***(1/216)*** back in. The final computation looks like this:

$$P(\text{“4”}) = (3 * 1/6) - (3 * 1/36) + 1/216$$
$$= 91/216$$

Skeptics may draw all 216 possible cases and confirm that 91 of them have at least one four.

9.7 Calculate Without- and With-Project Damages

> *The expected annual damage is the expected value of erosion losses and storm damages in any given year. Expected annual damages are calculated by computing the area under the damage-frequency curve using a life-cycle approach. Expected annual [equivalent] damages are calculated for the with- and without-project conditions. The difference between the with- and without-project expected annual damages represents the benefit associated with the project.*
>
> -ER 1105-2-100, Appendix E-24, f.(2)(h)

The Planning Guidance Notebook (PGN), ER 1105-2-100, starts its description of this step (*Calculate Expected Annual Damages)* by defining the expected annual damage as being associated with *any given year* which implies over the life-cycle of a project or study. This statement does **NOT** refer to average annual equivalent damages associated with a particular year. The terminology used in the PGN can be confusing. **The term average annual equivalent always refers to a discounted present value amortized over the life of the project**. When the word equivalent is not used, you must judge from the context whether PGN refers to a single year or the entire project life when *expected annual* or *average annual* are used. The required method to describe values to find the NED Plan is *average annual equivalent*. This requires discounting and amortizing values for the entire period of analysis.

Table 12. Simplified Without- and With-Project Damage Calculations

Without-Project

Interest Rate 6%

Reach	Home	Storm	Year (Base 2010)	Depreciated Home 2010 Value	Flood Height	Depth-Damage Curve (3 ft.) for combined Erosion, Flood, and Waves	Total Damage	Present Value = Future Value / [(1 + $r)^{(t-s)}$]	Average Annual Equivalent Damage
1	Home 1	Storm 1	2012	$ 100,000	3 feet above floor	20% damage	$ 20,000	$18,326	$1,163
1	Home 1	Storm 2	2020	$ 100,000	2 feet above floor	10% damage	$ 10,000	$3,210	$204
Without-Project: Reach 1 Total Damage								**$ 21,536**	**$1,366**
2	Home 45	Storm 1	2012	$ 200,000	5 feet above floor	40% damage	$ 80,000	$73,305	$4,651
2	Home 45	Storm 1	2020	$ 200,000	5 feet above floor	40% damage	$ 80,000	$25,682	$1,629
2	Home 50	Storm 1	2012	$ 150,000	1 foot above floor	5% damage	$ 7,500.00	$6,872	$436
Without-Project: Reach 2 Total Damage								**$ 105,859**	**$6,716**
Without-Project Condition Total Damages								**$ 127,395**	**$8,082**

With-Project

Interest Rate 6%

Reach	Home	Storm	Year (Base 2010)	Depreciated Home 2010 Value	Flood Height	Depth-Damage Curve (3 ft.) for combined Erosion, Flood, and Waves	Total Damage	Present Value = Future Value / [(1 + $r)^{(t-s)}$]	Average Annual Equivalent Damage
1	Home 1	Storm 1	2012	$ 100,000	1 feet above floor	5% damage	$ 5,000	$4,582	$291
1	Home 1	Storm 2	2020	$ 100,000	0 feet above floor	no damage	$ -	$0	$0
With-Project: Reach 1 Total Damage								**$ 4,582**	**$291**
2	Home 45	Storm 1	2012	$ 200,000	3 feet above floor	20% damage	$ 40,000	$36,652	$2,325
2	Home 45	Storm 1	2020	$ 200,000	3 feet above floor	20% damage	$ 40,000	$12,841	$815
2	Home 50	Storm 1	2012	$ 150,000	0 feet above floor	no damage	$ -	$0	$0
With-Project: Reach 2 Total Damage								**$ 49,493**	**$3,140**
With-Project Condition Total Damages								**$ 54,075**	**$3,431**

Table 13 shows the simplified calculations for the without- and with-project conditions. The assumption in this example is that a given storm structures reduced the same storms by two feet. In reality, there are often hundreds of structures impacted across many reaches and by many storms through the project life. In this example, the total present value of the NED benefits for the with-project condition is $127,395 less $54,075. The average annual equivalent damages reduced are $4,651. However, this isn't the final NED net benefits. The NED costs must then be subtracted from these values to determine the NED plan with the highest NED benefits.

Risk and Uncertainty Considerations

Risk is different from uncertainty. Risk is the probability and likelihood of future events. Uncertainty is the lack of assurance about something. When estimating the expected annual damages, there are sources of uncertainty to consider. The three primary sources of uncertainty are knowledge, model, and natural variability. Knowledge uncertainty can be reduced by collecting further information; models can be further detailed and back tested. Natural variability cannot be eliminated, but can be described in statistical terms. Planning parameters are not known with certainty and can assume a range of values; therefore, one way to describe the parameter is through a statistical distribution. Furthermore, Monte Carlo simulation and other methods as shown in Appendix C can also help analyze value quantitatively and/or qualitatively.

Engineer Manual 1110-2-1619 explains that risk analysis combines the underlying uncertainty information so that its engineering and economic performance can be expressed in terms of probability distributions. Underlying the estimation of benefits are uncertainties associated with storm damage curves from flood erosion and waves, structure values, content values, structure types, warning times and evacuation effectiveness. The uncertainty of these variables may be due to errors in sampling measurement, estimation, and forecasting. Furthermore, these values are combined with hydrologic uncertainties that increase the uncertainty around expected annual damages. For this reason, the economist should have at least a set of minimum, maximum and most likely estimates for the average annual equivalent damages under the without-project condition. This is the baseline used to compare the with-project conditions for each alternative.

Event and Consequence/Decision Trees can assist in combining probabilities as well. Event trees, or fault trees, are one form to handle probabilities in an undesired system state. The figure below is an event tree example that shows the dependence of probabilities on earlier events. This could be done for many project aspects and adapted to coastal situations. Figure 31 shows a decision tree that has two alternatives and three outcomes. This depicts the choice between A_1 with outcome x_1 and decision A_2 with two possible outcomes (x_2 or x_3). The outcome x_2 has the probability *p* while x_3 has the probability *(1-p).*

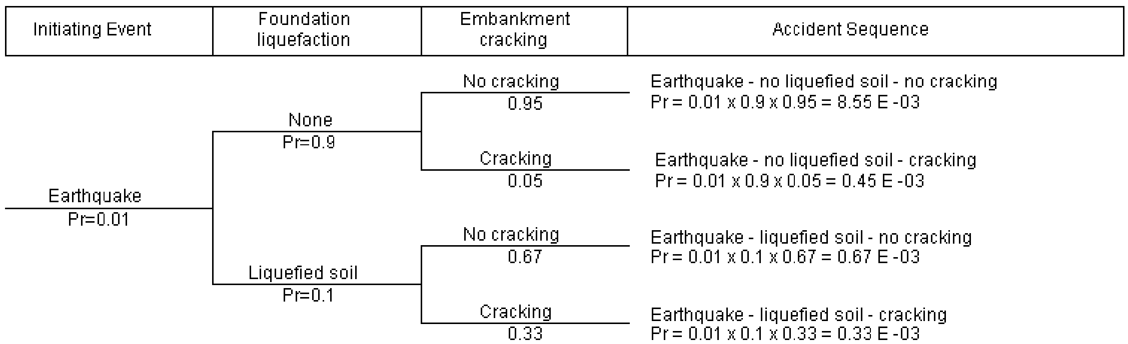


Figure 30. Event Tree[14]

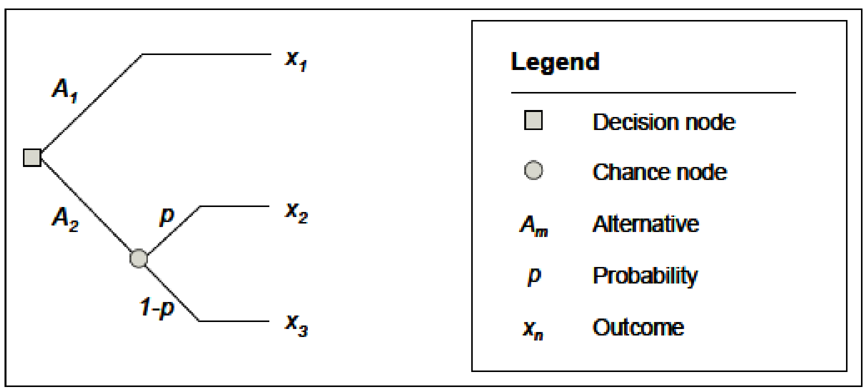


Figure 31. Decision Tree[15]

For the feasibility analysis of final alternatives life-cycle descriptions use several simulations. Each simulation has a set of iterations over the life-cycle. Beach-*fx* will provide as many simulations requested. From this set of simulations the required display of risk and economic performance can be generated. For example, the results can be displayed as either a probability density function or a cumulative density function. However, note that the distribution of simulation results will not be a nice symmetric distribution like a normal or student's t-distribution and may not be unimodal. The most important results to display are histograms of the present value of damages and residual damages for each of a few hundred life-cycle simulations.

Figure 32 displays a histogram of without project damages from an example project. Note that the distribution is quite asymmetric. In fact, it looks like a Poisson distribution, which should not be surprising in light of the fact that Beach-*fx* assumes a Poisson

[14] Patev, Robert. *Session 15a Event and Fault Trees: Risk Workshop.* 2010. Available via www.CorpsRiskAnalysisGateway.us

[15] Shultz, Martin T., Kenneth M. Mitchell, Brian K. Harper, and Todd S. Bridges, "Decision Making Under Uncertiainty," *Engineer Research and Development Center.* November 2010, p. 13. Available via www.CorpsRiskAnalysisGateway.us

distribution for storm occurrence combined with a series of triangular distributions of other variables such as replacement cost, first floor elevation, and the damage functions.

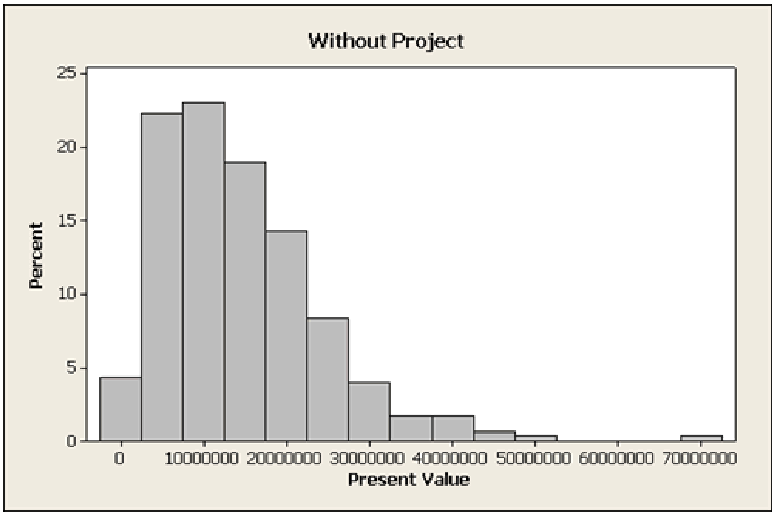


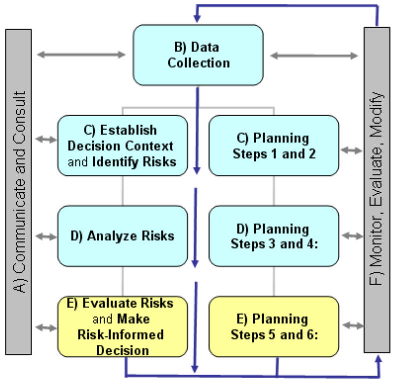
Figure 32. Without-Project Expected Damages Histogram

In general, the ability to recognize the underlying distribution from a plot of the data and then to test the data to confirm hypothesis about the underlying distribution depends on a set of skills that can be developed with practice and experience. The e-Handbook of Statistical Methods from the Department of Commerce (http://www.itl.nist.gov/div898/handbook/index.htm) is a great resource for developing relevant statistical skills rapidly and easily. There you will find:

- Galleries of statistical distributions
- Free plotting software
- And a wealth of practical advice

9.8 Summary and Look Ahead

Coastal Storm Risk Management Damage Curves portray the relationship between damage driving parameters and damages caused to coastal structures. This chapter has focused on the theoretical and practical problems associated with the development of appropriate flood, erosion, wave, and combined damage curves, and has illustrated their use in the calculation of without-project damages. Correctly and comprehensively introducing risk and uncertainty factors and life-cycle concerns into damage curves necessitates special care involving the use of triangular distributions and incorporating assumptions about future coastal structure composition. Beach-*fx* makes some of these tasks easier to accomplish. The final chapter focuses on bringing information about NED costs and NED benefits together to evaluate alternatives and to select the NED Plan.



Chapter 10: Evaluate Risks and Make Risk-Informed Decision

PLANNING STEPS 5&6

The objective of NED is to maximize increases in the net value of the ***national output*** *of goods and services. Within the Corps, this is done by comparing the difference in the value (benefits) produced by the project to the value of the resources (costs) required to produce those goods and services or construct the project.*

-Economics Primer, IWR Report 09-R-3, June 2009

10.1 Determine NED Plan

Identifying the NED Plan

National Economic Development benefits are contributions to National Economic Development that increase the value of the national output of goods and services. They are the primary basis for Federal investment in water resource projects. Net NED benefits are NED benefits reduced by NED costs. The NED Plan for a project is the plan that most reasonably maximizes net NED benefits in average annual equivalent terms.

There are several steps involved to actually determining the NED Plan. Risk analysis should be considered at each step of the process and prior to final calculations.

1. Determine NED costs and benefits over the period of analysis.
2. Discount the costs and benefits for all alternatives to a single *base year* present value. In the case of interest during construction or benefits during construction, the values would be appreciated forward to the base year.
3. Amortize the present values to find the average annual equivalent (AAE) costs and benefits.
4. Subtract the AAE costs from AAE benefits for each alternative to find the net AAE benefits.
5. Choose the plan that has the highest net AAE benefits. The NED benefits must be equal or greater than the NED costs.

6. and Up to 50 percent of the benefits required for justification (1:1 Benefit/Cost ratio) can be attributed to recreation benefits.

10.2 Determine the NED Costs

Chapter 4 discussed the theory and basics of National Economic Development costs. NED costs are found for all alternatives. There is also a NED Cost Manual at www.CorpsNEDManuals.us with more detailed information. The following are costs that need to be assessed and depreciated in the generation of a cost stream associated with each alternative over the period of analysis:

- Project costs (construction, mitigation, etc.)
- Associated costs (lands, boardwalks, recreation—no more than 50 percent of total costs, etc.)
- Operation, maintenance, repair, replacement, and rehabilitation costs (OMRR&R)
- Interest during construction (IDC)

The role of the economist in assessing these costs is to insure that the estimated costs include everything required to achieve the estimated benefits. Detailed information will be used to define and evaluate prospective project segmentation and phasing. Although costs are often presented as lump-sum items, it is useful to display disaggregation of costs applicable to particular categories when there are differences between project alternatives, segments, and/or phases. For example, costs should be broken out by reach areas (reaches are stretches of beach) to find the optimal amount beach to reduce risks.

Remember sunk costs are not counted as NED costs.

Project Costs

Project costs are the direct costs to implement a project and make it fully functional. These costs are mainly construction costs, but also include mitigation and other related costs. The major construction costs for projects are typically Federal and non-Federal. These costs are the value of the resources that must be committed in implementing each project alternative prior to the generation of project benefits. From a NED perspective, the distinction between Federal and non-Federal costs is unimportant. Federal and non-Federal costs both represent resources committed to project implementation and therefore should be reflected as NED costs. Examples of these costs include: building jetties, seawalls, or moving sand in place.

Associated Costs

Associated costs are any public, private, Federal, or non-Federal expenditures on coastal infrastructure and facilities necessary to achieve the estimated benefits for each project alternative. Associated costs are typically incurred by project users as part of an ongoing transportation or logistics process. Therefore, costs may have to be obtained from these parties or estimated by the study's cost engineer. Examples of associated costs include:

- Lands, easement, relocations, rights-of-way, and disposal sites (LERRDS)
- Parking lot construction for nearby public access points
- Boardwalks or piers, recreational structures
- Associated costs with borrow material availability over project life

Operation, Maintenance, Repair, Replacement and Rehabilitation (OMRR&R)

Operation, Maintenance, Repair, Replacement and Rehabilitation (OMRR&R) costs are the costs of all the activities required to make the project work as designed in order to realize and sustain the benefits identified during the planning phase. These costs are analyzed over the project life.

The difference between OMRR&R costs and construction costs is that the latter represent a capital investment (berm widening, dune development, groin construction, etc.) usually incurred one time when the project is implemented, whereas OMRR&R costs are incurred periodically over the project life. These costs may be incurred annually or fluctuate at some interval. OMRR&R costs are often estimated using standard engineering cost estimating techniques. The OMRR&R costs should reflect the conditions particular to the project. Unique to shore protection projects, renourishment is considered continuing construction

In accordance with Public Law 826 of 1956 (Beach Nourishment), when the Chief of Engineers determines that the most suitable and economical remedial measures would be provided by a periodic nourishment project, the Chief may consider the periodic nourishment as continuing construction for the length of time that the Chief specifies. Classifying the periodic nourishment as continuing construction establishes the Federal interest in cost sharing renourishments, usually for the economic life of the project. If the NED plan for a shore protection project includes a combination of structures and periodic nourishment, the renourishments may be considered continuing construction while future costs needed to operate, maintain, repair, rehabilitate or replace the structural components are considered operations and maintenance which is a non-Federal responsibility.

-Planning Guidance Notebook, ER 1105-2-100, Section 3-4(b)(7), (2000)

Interest During Construction Costs (IDC)

Interest during construction (IDC) costs are hidden, unpaid costs that must be accounted for when determining the NED costs of a project. The cost of this waiting period for construction is known as the *time value of money* and can be redefined as the foregone opportunity of investing the money in something else. Interest during construction costs on a $100 million project can, depending on the construction schedule, scope, and discount rate, add tens of millions of dollars to NED project costs.

Coastal projects typically require less time to construct than other Corps projects; therefore the Nation doesn't wait as long while the project is being built before the benefits can be realized. However, IDC costs still need to be computed and could be more influential in a larger and segmented project.

Interest during construction costs computation reflects that project construction costs are not incurred in one lump sum but as a flow over the construction period. IDC is often computed based on the assumption that construction expenditures are incurred at a constant rate over the construction period.

Long construction periods may also lead to benefits during construction which may offset IDC costs. For example, if one project increment is built first, it may produce benefits prior to the rest of the phases being built. These phases should be timed to maximize net benefits.

Interest during construction is computed as follows. If **B** is the project base year (the year in which construction costs end and the project begins to derive benefits), then the total cost incurred during construction, including actual expenditures and implicit interest payment, is the equivalent lump-sum expenditure in the base year, $\mathbf{C_B}$, which is computed as:

$$\mathbf{C_B = \sum_{i=1}^{t} C_i (1+r)^{t-.5}}$$

Where:

$\mathbf{C_i}$ construction expenditures in period i

r per unit interest rate; and

t number of construction periods up to the year that significant benefits start to accrue, which is the start of the period of analysis

If all costs have been correctly accounted for, a NED cost stream of the form ($\mathbf{C_B, O_1, O_2,\ldots,O_n}$) will be generated for each project alternative, where $\mathbf{C_B}$ represents the total construction costs up to the beginning of year 1 (baseline year) and the $\mathbf{O_i}$ are the O&M costs in project year 1 from year 1 (baseline year) to the end of the project life. This cost stream represents the resource costs associated with each project alternative over its life necessary to achieve the estimated benefits or traffic levels for that project alternative. Notice that the **t-.5** indicates a mid-period accounting. **Calculating IDC at mid-month is required by Corps guidance.** (PGN, Section E-63)

Cost Engineering Center of Expertise

The Cost Engineering for Civil Works and the Support for Others Program Directory of Expertise is established to maintain and/or provide the required technical expertise to perform cost engineering support, critical analysis, life cycle cost analysis, value engineering cost support, procedural/peer reviews, independent technical reviews, advisory/consultation services, risk analysis, and serve as a historic repository for cost engineering software, databases and regulations.

10.3 Determine the NED Benefits

Types of NED Benefits

Types of NED benefits include:

- Wave damage reduction
- Flood damage reduction
- Erosion reduction
- Reduced maintenance of existing structures
- Other NED/NER Benefits

Determining the NED benefits is easy once the damages caused by waves, flood, and erosion are found for the without- and with-project condition. Use the formula below:

Without-Project Damage – With-Project Damage = NED Benefits

Reduced Maintenance of Existing Structures is found very similarly and can be added to the benefits above:

Without-Project Maintenance Costs – With-Project Maintenance Costs =

NED Benefits

However, this procedure is slightly more complicated than it appears. These benefits should all be in the same present value through deprecation. Additionally, the value will need to be amortized through the period of analysis to find the average annual equivalent values prior to determining the NED Plan. This process is explained in more detail later on in Section 10.4.

Other NED Benefits

Expanding upon the simplified formula above, other NED benefits can be added to the benefits found above.

NED Benefits for Damage Reduction + Reduced Maintenance Costs (if applicable) **+ Other NED Benefits = Total NED Benefits**

Other NED benefits include, but are not limited to:

- **Recreation**: The NED benefits must be equal or greater than the NED costs and that up to 50 percent of the benefits required for justification (1:1 Benefit/Cost ratio) can be attributed to recreation benefits. Once a 1:1 ratio has been achieve with no more than 50 percent recreation benefits, then all recreation benefits can be added to the final total to find the total net benefits and determine the NED plan. The PGN allows the use of several valuation methods for recreation: travel-cost method, contingent value, and unit day value. Descriptions of these methods can be found in IWR Reports 86-R-4, 86-R-5, 90-R-11, and 91-R-7.

- **Location or land enhancement** (however, there is no Federal investment in a Corps project that is intentionally or effectively a land development project **and projects generally shou**ld not use land enhancement as a large incidental benefit).

- **Utilization of unemployed or underemployed labor** in various markets (See Appendix D of the PGN, ER 1105-2-100).

- **Benefits During Construction:** these can be a combination of any of the above benefits that accrue prior to the base year.

Loss of Land

Preventing the loss of land would seem like an easy benefit to capture; however, often this benefit cannot be claimed. Land values are important because of erosion. However, one person's beachfront property is the only thing preventing the first homeowner inland from having beachfront property. No matter how much erosion occurs, there will always be beachfront property. So, the value of losing beachfront property is limited to the value of nearby upland property. These values are also highly uncertain. A lot is rarely lost entirely and for all years. Usually, there is a combination of sudden and gradual erosion, each type causing economic loss. Each type of erosion must be counted carefully if included and evaluated for all years when determining if it is a permanent loss. *Please see* ***Chapter 8*** *for a longer discussion on this topic under Storm-Induced Erosion Damages.*

NER Benefits

National Ecosystem Restoration (NER) benefits are generally not monetized nor are they NED benefits. They appear in the form of additional acres, habitat units, fish counts, or biodiversity indices. NER benefits are listed as a separate account and are not added into NED benefits.

10.4 Compare Alternatives

Once the National Economic Development (NED) costs and NED benefits are found for each alternative, the values should be brought to a common point in time and the *average annual equivalent net benefits* are compared. **Residual risks** and non-economic factors should also be identified, compared and evaluated among alternatives. Non-economic factors include potential loss of life, environmental and other social risks. A table of effects in the project report is one way to show these.

Compute Benefit and Cost Stream over Project Life

For each alternative, the entire implementation cost including operation and maintenance for each reach must be found. This includes costs incurred by the government, sponsor and other stakeholders in order to make an alternative fully functional, but it doesn't include sunk costs. For each reach and project scale the economist should compute the difference in damages between the with- and without-project conditions for each project alternative for the project life. This will assist in incrementally justifying or not justifying scales and reaches. The economist will sum the savings for each year of the project life to obtain total benefits for each project. This will yield a benefit stream over time for each alternative of the form ($\mathbf{B_{1i}, B_{2i}, \ldots, B_{ni}}$), where n is the project life and *i* represents an index of project alternatives.

Discounting Benefits and Costs

It is possible that various alternatives may start or end their benefit or cost stream at a different times than other alternatives. To properly compare the benefit and cost streams associated with each project alternative, benefits and costs must reflect a common time standard. This is accomplished through discounting, a procedure that adjusts the value of a stream of benefits or costs to reflect the time value of money. Discounting converts a future stream of payments into an equivalent lump-sum payment at some point in time; this is typically the base year for project studies. This lump sum payment is the "net present value" or the present value of the payment stream discounted at an interest rate, reflecting the time value of money.

The present value, $\mathbf{PV_B}$, of a stream of payments ($\mathbf{P_1, P_2, \ldots P_n}$) can be calculated at mid-period as:

$$\mathbf{P_{1\text{-}.5}/(1+r)^{.5} + P_{2\text{-}.5}/(1+r)^{2\text{-}.5} + \ldots + P_n/(1+r)^n}$$

$$\mathbf{= \sum_{t=1}^{n} [P_{t\text{-}.5}/(1+r)^{t\text{-}.5}],}$$

where **r** is the discount rate, **t** is the project year, and **n** is the project life.

In other words, the total present value of the stream of benefits **equals** the sum of the following:

- The benefit value of each mid-point of the out years **divided** by one **plus**
- The interest rate for the mid-point of the year one plus the benefit value of year two divided by one **plus**
- The interest rate squared $(1+r)^2$ **plus** the pattern continues for each out year changing the benefit for that mid-year and the power to which (1+r) is raised.

The net present value (NPV) of an alternative is defined as the excess of benefits over costs discounted to reflect the time value of money. The cost stream would be found just as the benefits were and they would be subtracted from one another. Using the cost stream ($\mathbf{C_B}$**= sum of** $\mathbf{O_1, O_2, \ldots, O_n}$) and the benefit stream ($\mathbf{B_1, B_2, \ldots, B_n}$), the net present value can be computed as:

$$\mathbf{NPV = \sum_{t=1}^{n} [(B_{t\text{-}.5} - O_{t\text{-}.5})/(1+r)^\wedge{}^{t\text{-}.5}] - C_B,}$$

where **n, t,** and **r** are defined as above. The NPV is the basis for comparing the value of alternatives. The appropriate discount rate for water resources studies is determined annually based on the average yield of marketable U.S. securities having a date to maturity exceeding 15 years. It is distributed annually by the Office, Chief of Engineers and available on the web (www.hqda.army.mil/daen/). Costs are calculated in the same manner. More information on costs is available in the NED Costs manual available at www.CorpsNEDManuals.us.

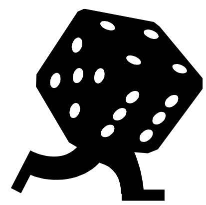
Average Annual Equivalent Benefits and Costs

Corps guidance requires the final NED benefits and costs to be in terms of *the average annual equivalent value* rather than a discounted lump sum represented by present value and net present value. Therefore, the values must be amortized. This is a discounting technique that converts a stream of unequal payments into an equivalent stream of equal payments in each time period. The average annual equivalent of a stream of payments ($\mathbf{P_1, P_2, \ldots, P_n}$) is a stream of constant payments, P, where the discounted value of both streams is equal. Average annual equivalents are primarily used as a scaling factor in discussing or presenting benefits and costs.

How to calculate the AAE

AAE Value is found by discounting the stream of benefits and costs to a common present value and multiplying each value by an amortization rate. When comparing projects, it is important to make sure that the timeframes for which the average annual equivalents are computed are the same. The amortization rate draws from the interest rate and period of analysis. The Federal discount rate for Civil Works is published each year and must be used. The period of analysis is typically 50 years. Together, the amortization rate, period of analysis, and present values is used to estimate the average annual equivalent benefits and costs, which can then be subtracted to find the net benefits.

Calculating the Residual Risks of Alternatives



No matter what alternatives or measures are taken, risk will always remain. Residual risks are the damages that would still occur with the project in place. A residual risk analysis will help assess risks further and possibly provide an opportunity for identification of measures that may be implemented for additional risk reduction. All residual risk at each increment of an alternative and with each alternative should be recognized including risk transfers to outside the immediate project area. The economic risks will have already been calculated by this point in order to find the *Average Annual Equivalent Values*. However, institutional risks, such as risks to lives, the environmental or other social factors should be discussed as well. While guidance requires the Corps to identify the NED Plan, a plan other than the NED Plan can be recommended with a waiver from the Assistant Secretary of the Army for Civil Works for other compelling reasons. **Above all else, the residual risks that a community faces must be clearly communicated.**

The economic consequences of capacity exceedance are quantified in terms of residual event and expected annual damage. Residual expected annual damage is computed with the results of economic benefit computations; it is the with-project condition EAD.

-Engineering and Design Risk-based Analysis for Flood Damage Reduction Studies, EM 110-2-1619

Application of Beach-Fx Outputs

Assuming that all information has been input correctly into Beach-*fx* and the model has been run successfully. The program has several key output files that economist should focus on to determine the storm damages. Beach-*fx* does not calculate average annual equivalent values so this step would needed for the final calculations for with- and without-project conditions.

WP_PN.prn: This is a summary ASCII output file that contains general information about the Beach-*fx* simulation as a whole (across all lifecycles simulated). In this particular file the available damage information is contained between lines 102 and 106.

WP_PN_Damage.csv: This the most detailed damage output file generated by Beach-*fx*. It contains the details of all damages estimated in the model simulation including information about the damage element and damage element attributes, information about the damage drivers, pre- and post-storm value, calculated and present value losses for combined damages, flood loss, wave loss, erosion loss, the present value factor, and the damage functions used to estimate the loss.

WP_PN_ReachYearlyDamages.csv: This file rolls-up structure and content damages by reach and year for each year of all iterations simulated. Present value and calculated losses are reported here. These values are shown disaggregated by waves, flood and erosion.

WP_PN_ReachIteration.csv: This file reports present value of the structure and content damages by reach and iteration.

WP_PN_Iteration.csv: This file reports present value total damages (structure plus content) as well as the moving average of total damages across iterations along with emergency nourishment, mobilization, and planner placement costs.

Determine NED Plan

When NED benefits and costs have been determined, brought to present value and amortized, the net annual and net total present value of NED benefits can be found. The project with the highest net present value is the NED Plan. This is calculated by simple subtraction:

Net AAE NED Benefits =

NED Average Annual Equivalent (AAE) Benefits – NED AAE Costs

Total NPV Net NED Benefits = NPV NED Benefits – NPV NED Costs

The plan with the highest net AAE NED benefit is the same plan as the one with the highest total NPV NED benefit.

As simple as this calculation is, in practice, getting to this point takes time. It also requires risk analysis in each step. The decision made to manage these risks should be recorded along with other assumptions and findings. These decisions should be based on qualitative and/or quantitative methods. **See Appendix C for a sample of Qualitative and Quantitative Methods.**

NED Incremental Justification

When a proposed project can be divided into separate benefit segments, the economic criteria for project justification requires that each project segment be either independently or conditionally justified.

In most instances, project segments will be defined based on physical and cost differences that can be observed and appear to be significant. For Coastal Storm Risk Management projects this will involve different reaches that have different structures and/or physical characteristics. Total project benefits and costs are then the sum of the benefits and costs of the individual reaches.

Each reach must be incrementally justified using the same procedures to find the AAE benefits and costs. This process is iterative and design changes are common in finding the appropriate increments.

10.5 Selection of Recommended Alternative

The selection of the recommended alternative is based on a comparison of the effects of each alternative and their relative degree of success in fulfilling project objectives. Formally, the best (NED) alternative maximizes net project benefits, where net benefits are defined to include all project impacts and acceptable levels of risk. Net benefits are computed as the difference between the present value of benefits and present value of costs for each alternative. The recommendations should be supported by a detailed assessment of the advantages and disadvantages of each alternative with a clear justification and explanation of the rationale for selection of the recommended alternative.

Economic impacts of each alternative, with associated effects of the risk analysis, will provide a basis for the critique of each alternative and selection of the best alternative.

In discussing the selection of the recommended alternative three general features of the analysis should be set forth:

- There should be a clear statement identifying the most likely scenario, that is, the assumptions and future conditions underlying the analysis that led to the selection.
- Possible phased implementation of the recommended alternative should be presented.
- Critical parameters underlying the recommended alternative must be explained. The important concept in this discussion of selecting the recommended alternative is that it should serve as a guide for reviewers. It need not fully recount the steps of the economic analysis, but it must present the important decisions and results of the economic analysis in sufficient detail to facilitate understanding by reviewers. Beach-*fx* can assist in describing many uncertainties related to these parameters such as residual alternative damages.
- The uncertainties surround the costs and benefits around key parameters should be described and analyzed appropriate to project scale. Qualitative and quantitative methods can be used to determine whether these uncertainties are significant enough to recommend one plan over another. See Appendix C for more examples.

10.6 Summary

This chapter's key concepts are:

- Benefit-cost analysis is one conceptual framework for assessing trade-offs between various project objectives and alternatives and measuring the effectiveness of various alternatives.
- Types of NED costs that need to be assessed are:
    - Project implementation (construction) costs
    - Operation and maintenance (O&M) costs
    - Interest during construction (IDC)
    - Associated costs (facilities for recreational benefits, etc.)
    - Any mitigation, monitoring or other environmental costs
    - Lands, easements, relocations, rights-or-way, disposal sites (LERRDS)

- Associated costs are any public or private Federal or non-Federal expenditures on coastal infrastructure and facilities necessary to achieve the estimated benefits for each project alternative.
- NED benefits derive from reduced coastal storm risks or other benefits such as recreation, utilization of underemployed labor, and more.
- NED benefits less NED costs equals net NED benefits. The highest net NED benefits determine the NED Plan. These values must be discounted to a present value and amortized over the project life or 50 years, whichever is most appropriate, to find the average annual equivalent benefits and costs as required by policy.
- Risk analysis is critical to the economic analysis.

References

Badger, D. D., Hansen, W. J. (1991). *Recreation*. Vol. IV: *Evaluating Changes in the Quality of the Recreation Experience.* Alexandria: Institute for Water Resources.

Davis, S. A., Hansen, W. J., Mills, A. S. (1991). *Urban Flood Damage.* Vol. II. (Updated). *Primer for Surveying Flood Damage for Residential Structures and Contents.*.Alexandria: Institute for Water Resources. Retrieved 25 June 2010, from the NED Web site: http://www.CorpsNEDManuals.us

Dunning, C. M., Moser, D. A. *Recreation*. (1986). Vol. II. *A Guide for Using the Contingent Value Methodology in Recreation Studies*. Alexandria: Institute for Water Resources.

Durden, S. E., Fredericks, J. (2009). *Economics Primer*. Alexandria: U.S. Army Corps of Engineers. Retrieved 25 June 2010, from the NED Web site: http://www.CorpsNEDManuals.us

H. John Heinz III Center for Science, Economics and the Environment, FEMA, Evaluation of Erosion Hazards, April 2000, p. 3.

Hansen, W. J. and others. (1980). *Recreation*. Vol. III. *A Case Study Application of Contingent Value Method for Estimating Urban Recreation Use and Benefits*. Alexandria: Institute for Water Resources.

Hansen, W. J., Moser, D. A., Vincent, A. K. (1986). *Recreation*. Vol. I. *Recreations Use and Benefit Estimation Techniques*. Alexandria: Institute for Water Resources.

Hansen, W. J. and others. (1987). *Agricultural Flood Damage*). Alexandria: Institute for Water Resources. Retrieved 25 June 2010, from the NED Web site: http://www.CorpsNEDManuals.us

Horn, K., Knight, K., Wilson, E. (2010). *Deep Draft Navigation*. Alexandria: Institute for Water Resources. This manual replaces 91-R-13.

Johnson, N. B. and others. (1988). *Urban Flood Damage*. (Updated). Retrieved 25 June 2010, from the NED Web site: http://www.CorpsNEDManuals.us

National Planning Center of Expertise for Coastal Storm Damage Reduction. Retrieved July 6, 2010 from http://www.nad.usace.army.mil/natplan.html, latest website is http://www.nad.usace.army.mil/pcx-accomplishments.htm

Scodari, P. (2009). *Overview*.. Alexandria: Institute for Water Resources. This manual is the update of 91-R-11.

Skaggs, L. L., McDonald F. L. (1991). *Coastal Storm Damage and Erosion* (IWR Report 91-R-6). (Updated). Retrieved June 30, 2010, from http://www.iwr.usace.army.mil/docs/iwrreports/91-R-6.pdf

U.S, Army Corps of Engineers. (2008). *Coastal Engineering Manual – Part II.* Retrieved June 30, 2010, from http://140.194.76.129/publications/eng-manuals/em1110-2-1100/PartII/PartII.htm

U.S. Army Corps of Engineers. (2000). *Planning Guidance Notebook.* Washington DC: U.S. Army Corps of Engineers.

U.S. Water Resources Council. (1983). *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* http://www.iwr.usace.army.mil/docs/iwrreports/p&g.pdf

Yoe, C. (1993). *National Economic Development Costs*. Alexandria: Institute for Water Resources. Retrieved June 30, 2010, from the NED Web site: http://www.CorpsNEDManuals.us

Yoe, C. (1993). *Use and Adaptation of Office of Management & Budget Approved Survey Questionnaires*. (1993 January). In *Public Surveys*: Vol. 1.

Appendix A: Defining Terms

A.1 Coastal Terms

See also: NOAA's Glossary of Coastal Terms at http://shoreline.noaa.gov/glossary.html

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. http://www.encora.eu/coastalwiki/Accretion

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. http://www.encora.eu/coastalwiki/Backshore

Base Flood Elevation (BFE): The elevation of the flood that has a 1 percent chance of occurring in a given year. Also known as the 1 percent annual chance flood or the 100 year flood.

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 (at different elevations)

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 areas to protect the upland from wave and current action.

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

Design flood elevation: Unless the community has designated a higher elevation, the 100-year floodplain for bridges, buildings and other important facilities, the 500-year floodplain for critical facilities, and the maximum flood that frequently occurs for all other facilities.

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.

Downdrift: Direction of longshore movement of beach materials.

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. Coastal dunes typically have a unique ecological niche with ecosystems that vary by elevation, and also protect the land against ravaging 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. Neap tides are especially weak tides. They occur when the gravitational forces of the Moon and the Sun are perpendicular to one another (with respect to the Earth). Neap tides occur during the quarter moons.

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 unite or sub-unit within a contiguous, morphologically homogenous area. The shoreline and associated upland areas are divided into reaches throughout the project unit area in which geomorphic structures, erosion conditions, or human development patterns have been determined to 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 quarry stone, usually well graded within a wide size limit, randomly placed along a structure or shore to prevent wave and current erosion.

Run-up: 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 quantification of sediment transport, erosion, and deposition for a selected segment of the coast, either temporarily or permanently. It is also the balance between sediment added and sediment removed. The algebraic difference between the sediment source and the sinks in each cell, hence, for the entire sediment budget, must equal the rate of change in sediment volume occurring within that region, accounting for possible engineering activities.

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. Spring tides are especially strong tides (they do not have anything to do with the season Spring). They occur when the earth, the sun, and the moon are in a line. Spring tides occur during the full moon and the new moon.

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.

Water Surface Elevation (WSE): The elevation of a water surface above or below an established reference level, such as (mean) sea level; the height, in relation to the National Geodetic Vertical Datum (NGVD) of 1929, or other datum, of a body of water or, for flood determination, for the specification of floods of various magnitudes and frequencies in the floodplains or coastal or riverine areas.

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.

A.2 Planning Terms

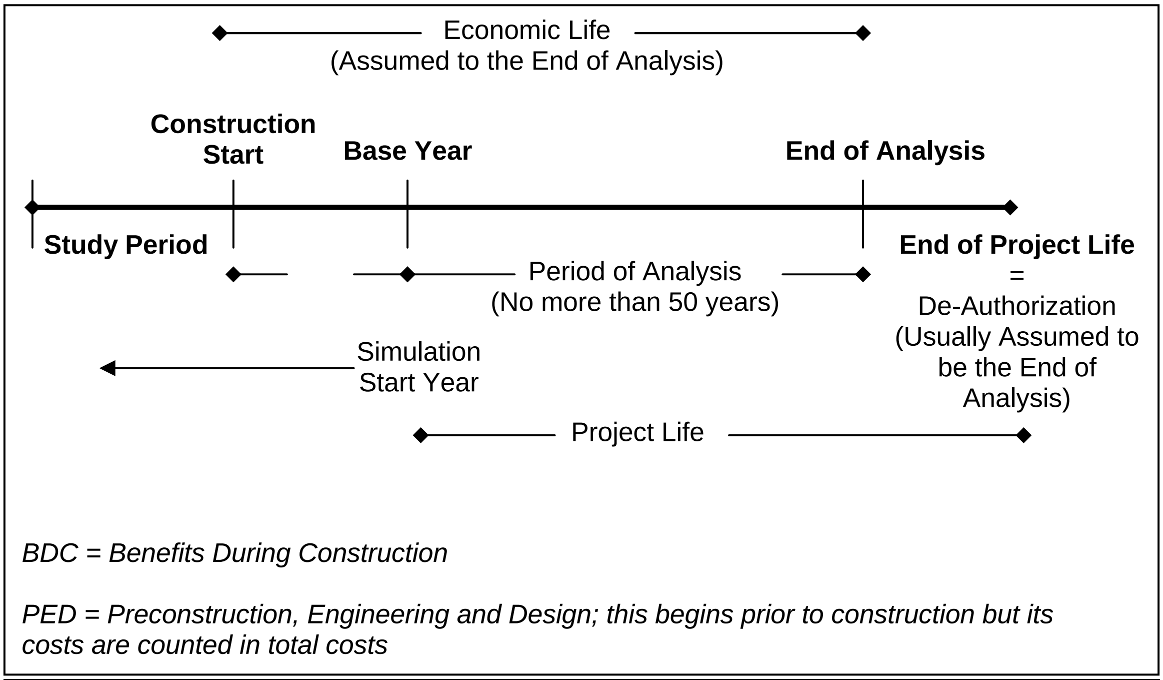


Figure A-1: Planning Life-cycle

Associated Cost: Any public or private Federal or non-Federal expenditures ancillary to the project necessary to achieve estimated benefits or traffic levels for each project alternative, such as recreational facilities for incidental recreational benefits claimed.

Average Annual Equivalent: A discounting technique that converts a stream of unequal payments into an equivalent stream of equal payments, where both streams have the same present value. This is different from average annual because average annual does not amortize the total present value, but rather it averages the value.

Baseline Condition: A scenario from which project impacts can be measured, i.e., a point of reference.

Base Year: Forecasts should extend from the base year (the year when the proposed project is expected to be operational) to the end of the period of analysis.

Benefit-Cost Analysis: An analytical method for comparing the positive (benefits) and negative (costs) impacts of an action.

Benefit-Cost Ratio (BCR): The ratio of discounted project benefits to discounted project costs. BCR's are less than one when a project's costs exceed its benefits.

Critical Parameters: Those analytical factors that are the major determinants of the level of project benefits and costs.

Discount Rate: The interest rate used to convert a flow (benefits or costs) into an equivalent stock (Present Value).

Discounting: A procedure which adjusts the value of a stream of benefits or costs to reflect the time value of money. Discounting converts a flow into an equivalent stock at some point in time. This stock is called the present value of the flow discounted at interest rate r.

Existing Condition: A description of the project setting based on present conditions; it simply describes *what is* at the time the analysis is undertaken.

Hazard: A source of potential peril or damage caused by sources extraneous to mankind associated with natural disasters such as flooding, hurricanes, and tsunamis. The source of the peril is considered a natural hazard as well as the risk of adverse consequences. The hazards affiliated with coastal storms and erosion, wave, inundation, and wind. Wind associated damages are not considered in the economic risk analysis since shore protection projects do no mitigate wind damages.

IDC: *Interest during construction* is the opportunity cost of capital incurred during construction

Incremental Analysis: A process to determine the next added segment of a project, or project scales. This analysis answers the question, *are there more benefits than costs if we add this next piece or scale to a project*? The analysis continues until costs are greater than benefits.

Incremental Benefits (Costs): The difference in benefits (costs) between two project alternatives

Internal Rate of Return (IRR): The interest rate which discounts the benefit and cost streams so that they yield a Net Present Value of zero.

Knowledge Uncertainty: This uncertainty is attributed to a lack of knowledge on the part of the observer at the time a decision is being made that is expected to affect a future outcome. For example, there is no known distribution of values. Knowledge uncertainty is reducible in principle, although it may be costly to reduce or require significant time in advance of a decision. Knowledge uncertainty arises from incomplete understanding of a system, modeling limitations and/or limited data. Knowledge uncertainty is sometimes called epistemic, internal, functional, subjective, reducible or model form uncertainty. Knowledge uncertainty is sometimes dealt with by a) quantifying the ranges of uncertainty, b)applying factors of safety, c) adaptive management, or d) other techniques.

Natural Variability: This uncertainty deals with inherent variability in the physical world; by assumption, this “randomness” is irreducible. In the water resources context, uncertainties related to natural variability include things such as stream flow, assumed to be a random process in time, or soil properties, assumed to be random in space. Natural variability is also sometimes referred to as external, objective, random, or stochastic uncertainty. Natural variability cannot be altered by obtaining more information, although its characterization might improve with additional knowledge, and is sometimes dealt with by statistical or probabilistic methods.

Most Likely Scenario: Those future conditions the analyst believes most likely to prevail.

NED Benefits: The complete benefit stream associated with implementation of a project alternative over the project life that is obtained when the project alternative is implemented.

NED Costs: The complete cost stream associated with implementation of a project alternative over the project life that is necessary to achieve the estimated benefits.

Net Present Value: The excess of inflows (benefits) over outflows (costs) discounted to reflect the time value of money.

Non-Structural Alternatives: A project alternative which does not alter the physical characteristics associated with the existing condition. Non-structural alternatives would include operational and management practices and minor structural improvements that enhance utilization of the existing project.

OBERS: Acronym for the Office of Business Economics of the U.S. Department of Commerce, the Economic Research Service of the U.S. Department of Agriculture. OBERS is the short title for projections of economic activity and population now produced by the Bureau of Economic Analysis (BEA) in Commerce. Originally they were a cooperative effort under the Water Resources Council and part of the water resources planning program.

Other Social Effects: Constituents of life that influence personal and group definitions of satisfaction, well-being, and happiness. Includes health and safety, economic vitality, social connectedness, personal and group identity, social vulnerability and resiliency, participation, and leisure and recreation opportunities.

Opportunity Cost: The cost of passing up the next best choice in a decision

Payback Period: The shortest project life yielding a net present value of zero at the current discount rate.

Phased Construction: An implementation strategy whereby the project is constructed in discrete segments with benefits and costs assigned to each individual segment.

Probability: The probability of an event is a measure of the change that the event occurs. Two measures are commonly use: the *priori* (based on a distribution of a predicted outcome, as a flip of a coin or roll of a die) and relative frequency definitions of probability based on a number of trials or empirical data. The relative frequency of an event *E* is defined as the proportion of n trials (or empirical data) which result in *E*. If the number of trials *n* is large, the proportion of trials resulting in *E* is a good estimate of the true probability that *E* will occur. Probabilities are represented by distribution functions (normal, triangular, Poisson, etc.) for either input variables or events or predicted outcomes, and are typically used to capture bounds of uncertainties in Corps water resources studies.

Project Segmentation: The practice of dividing a project alternative into discrete components which can be individually evaluated and implemented.

Risk[16]: The potential for realization of unwanted, adverse consequences; estimation of risk is usually based on the expected result of the conditional probability of the occurrence of event multiplied by the consequence of the event, given that it has occurred. The P&G describes risk situations as "…those in which the potential outcomes can be described in reasonably well-known probability distributions."

Risk and Uncertainty Assessment[17]: A detailed examination performed to understand the nature of unwanted, negative consequences; an analytical process to provide information regarding undesirable events; the process of quantification of the probabilities and expected consequences for identified risk and uncertainties. Literature commonly refers to risk analysis and risk assessment when in fact risk and uncertainty analysis is often meant.

Sensitivity Analysis: An analytical technique designed to identify those factors that are the major determinants of the level of project benefits and costs. The sensitivity analysis will assist in identifying critical study parameters and how they impact the results.

Separable Element: A functional feature that can be evaluated separately from the rest of the project.

Structural Alternatives: A project alternative which significantly alters the physical characteristics of the project area associated with the Existing Condition.

Study Year: The year in which a project is being studied, often it is the same as the existing condition; it is usually not the same as the base year.

Uncertainty: Uncertain situations are those in which the probability of potential outcomes and their results cannot be described by objectively known probability distributions, or the outcome themselves, or the result of those outcomes are indeterminate. However, Corps guidelines tends to use error and uncertainty interchangeably stemming from insufficient information, which may be unknown (i.e., unavailable in an ideal level of detail) or prohibitively expensive to collect.

***With-project* Condition**: The set of future conditions the analyst believes most likely to prevail for each project implementation over the period of analysis. These conditions may vary for each project alternative.

***Without-project* Condition**: The set of future conditions most likely to prevail in the absence of the proposed project. It does not describe conditions as they exist at the time

[16] IWR Report 92-R-1
[17] IWR Report 92-R-1

of the study, but describes the conditions that are expected to prevail over the planning horizon in the absence of a project.

Appendix B: Acronym Glossary

AAE	average annual equivalent
ASACW	Assistant Secretary of the Army for Civil Works
BFE	base flood elevation
CADRe	Computer Assisted Dispute Resolution
CAP	Continuing Authorities Program
CENAD	Corps National Planning Center of Expertise for Coastal Storm Damage Reduction
CoP	Corps Communities of Practice
CSDR	Coastal Storm Damage Reduction
CSRM	*Coastal Storm Risk Management Manual*
CZMPs	Coastal Zone Management Plans
DFE	Design Flood Elevation
DMMP	Dredged Materials Management Plans
EA	Environmental Assessment
EAD	expected annual flood damage
EC	Engineering Circulars
EIS	Environmental Impact Statement
EM	Engineering Memorandums
EP	Engineering Pamphlets
EQ	Economic Quality
ER	Engineering Regulations
ERDC	Engineering Research and Development Center
GIS	Geographic Information Systems
HEC	Hydrological Engineering Center
H&H	coastal/hydrology and hydraulics
ICIWRM	International Center for Integrated Water Resource Management
IDC	Interest During Construction
IPCC	Intergovernmental Panel on Climate Change
IWR	Institute for Water Resources
LERRDS	Lands, easement, relocations, right-of-way, and disposal sites
LiDAR	light detection and ranging remote sensing technology
NCR	National Capital Region
NDC	Navigation Data Center
NED	National Economic Development
NEPA	National Environmental Policy Act
NFIP	National Flood Insurance Program
NOAA	National Oceanic and Atmospheric Administration
O&M	Operations and Maintenance
OMRR&R	Operation, Maintenance, Repair, Replacement and Rehabilitation
OSE	Other Social Effects
PCX-CSDR	National Planning Center Expertise for Coastal Storm Damage Reduction
PDT	Project Delivery Team

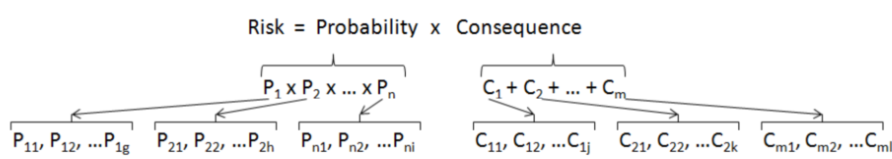
P&G	Principles and Guidelines
PGN	*Planning Guidance Notebook*
RED	Regional Economic Development
RMDM	Risk Management Decision Making
USACE	United States Army Corps of Engineers
UTM	Universal Transverse Mercator
WCSC	Waterborne Commerce Statistical Canter
WRDA	Water Resources Development Act
WSE	water surface elevation

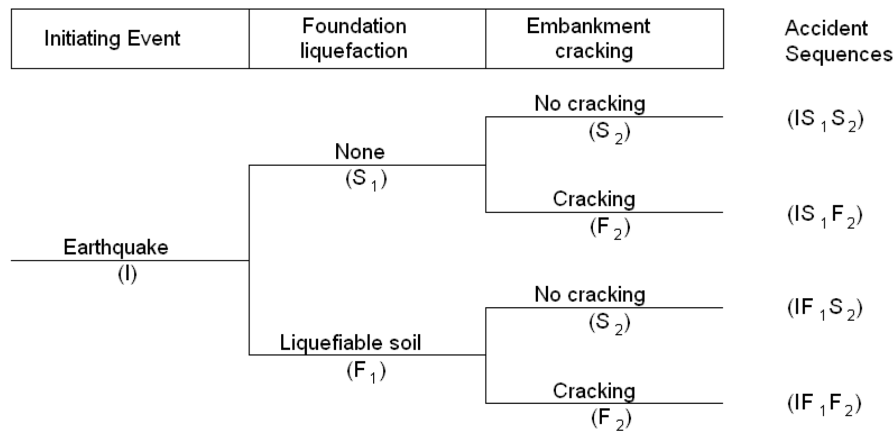
Appendix C: Qualitative and Quantitative Risk Assessment Methods

These tables were taken from a draft Institute for Water Resources Report on climate change titled "Risk Informed Decision Making for Climate Change" from May 2011, which is likely to be published in 2011 or 2012.

Qualitative Methods	Description
Increase or Decrease Risk	Identify the parts of the risk and whether the surrounding uncertainty will increase or decrease the risk with climate change. For example, wetlands establishment is based on uncertain sea level rise. The effect is a *decrease* in wetland establishment.
Evidence Mapping	Evidence maps illustrate the evidence and logic experts use to derive tentative conclusions about a potential hazard or risk in the face of great uncertainty and/or conflicting evidence. An evidence map has three core elements: evidence, pro- and con- arguments, and conclusions about the risk. The evidence map approach does so in a way that identifies the consensus/disagreement that exists and the uncertainties that remain.
Ordering: Chronological, Screening, Rating and Rankings	• *Chronological*: The sequence and timing of events sometimes reveal cause and effect relationships or they better enable us to see patterns, identify important events and see significant gaps in our understanding of cause and effect relationships. • *Screening*: One would carefully define categories, screening criteria, evidence for the criteria, and if needed, an algorithm to synthesize information to make easier decisions. For example, "structures impacted by climate change" vs. "non-impacted structures" can be categories and sorted through more easily. • *Rating*: This is an advance screening and would expand categories and criteria to provide more evidence in why certain categories are more or less important to consider. • *Ranking:* Ranking requires the same elements as a screening or rating process, but it may also include weighting the importance of the various criteria.

Quantitative Methods	Description
Statistics	Use statistics to characterize the various parameters.
Simple Probabilistic Risk Assessment	Probability X Consequence = Risk or Opportunity. The probability includes the probability of an event, exposure to the event, system response and vulnerability.
Bayes' Theorem	Bayes' Theorem builds on the notion that information can change probabilities, which is useful for updating probabilities on the basis of newly obtained information. Often one begins with an initial or prior probability that an event will occur. Then, as uncertainty is reduced or new information comes in, one will revise the probability to what is called posterior probability. This revision can be done using Bayes' theorem. Bayes' theorem is: $P(A\|B)= (P(B\|A)P(A))/(P(B))= (P(A \text{ and } B))/(P(B))$
Probability Distributions	Various models require probability distributions to represent the knowledge uncertainty and natural variability in a model's inputs. Based on the nature of the variable an appropriate distribution should be used. These can be continuous or discrete, parametric or non-parametric, (partially) bounded or unbounded.
Probabilistic Scenario Assessment	This bundle of tools combines the use of scenario structuring techniques and tools with probabilistic methods. Using probabilistic methods the potential outcomes of one or more scenarios can be characterized and evaluated.
Thresholds	Determine the point at which a decision is made or that an outcome is unacceptable and another action must be taken to keep a parameter within a certain range of tolerable risk.
Monte-Carlo Simulation	This is a process in which one samples from probability distributions for each variable input in a model and uses the sampled values to complete the model's calculations. Desired model outputs are collected. Repeated samples are taken to determine the range of potential values for each model output of interest. Analysis of the input and output distributions can reveal the significant uncertainties and their potential impacts on model outputs.

Qualitative & Quantitative Methods	Description
Enhanced Criteria Ranking	Enhanced criteria-based ranking follows eight systematic steps: 1. Criteria 2. Evidence-Based Ratings 3. All Possible Combinations of Ratings 4. Ranking 5. Evaluate Reasonableness of Ranking 6. Add Criteria 7. New Combinations of Ratings 8. New Ranking
Risk Matrix	The risk matrix is based on the probability and consequence elements of a risk. Probability is envisioned as a continuum from 0 to 1 that is broken into qualitative segments or categories such as improbable, remote, occasional, probable, and frequent (USDOD, 2000). A number of qualitative categories such as negligible, marginal, critical, and catastrophic are defined for the range of consequences as well. Estimated probabilities can also be used.
Generic Process	Break risk down into its parts and assess each part individual and categorize each piece as high, medium, low or none or another similar system to roughly categorize the total risk. 
Scenario Planning	Scenarios are narratives that describe alternative plausible futures that provide significantly different views of the future. It is used when the uncertainty driving the future can produce significantly different futures, such that a single without condition scenario is insufficient.
Multi-Criteria Decision Analysis	Multi-Criteria Decision Analysis (MCDA) is a well-established technique for making trade-offs of quantitative or qualitative information that involves the preferences of decision makers. MCDA methods are often distinguished based on the algorithm used to complete the analysis. Several methods exist such as weighted criteria or analytical hierarchy.
Event Tree	The tree begins with an initiating event and then uses a branching structure to describe a sequence of potential subsequent chance events leading to a variety of distinct endpoints or outcomes. The tree may include the quantification of probabilities and events. Below is an

	example: 
Fault Tree	A fault tree is the mirror-image of an event tree. It relies on backward logic and begins with a single end state. From there it uses a branching structure to describe a sequence of events from the end state to a variety of potential initiating events.