1 EXECUTIVE SUMMARY

1.1 PURPOSE OF STUDY

The Federal Emergency Management Agency (FEMA) is responsible for preparing Federal Insurance Rate Maps (FIRMs) that delineate hazard zones and Base Flood Elevations in coastal areas of the United States. These areas are among the most densely populated and economically important areas in the nation. Coastal areas are subject to a variety of natural processes that result in significant hazards to public safety and property along the nation's coastlines, including extreme conditions of storm surge flooding, waves, erosion, rainfall, and wind. The purpose of this study is to evaluate existing FEMA procedures for delineating coastal flood hazard areas in three major coastal regions of the United States (Atlantic, Gulf, and Pacific) and to develop recommended new guidelines and procedures in one of these areas (Pacific).

This project was authorized cooperatively by FEMA Headquarters, FEMA Region IX, and FEMA Region X in October 2003. The project is managed by Les Sakumoto, Project Officer for FEMA Region IX. Northwest Hydraulic Consultants, Inc. is the lead consultant and manager of the Technical Working Group. This Phase 1 Summary Report provides a brief background on the project approach; describes the process for evaluating existing guidelines; and summarizes the recommendations for the Pacific, Atlantic, and Gulf Coasts. Appendices to this report include information on the Technical Working Group, key references, and Focused Studies on 11 categories of technical topics.

1.2 PROJECT CONTEXT AND GOAL

Approximately 50 percent of the population of the United States resides on or near the coast (less than 50 miles from the coastline). More than 3,000 communities are located in this 12,000-mile-long coastal zone, which is covered by approximately 7,400 existing FIRM panels. Much of this inventory of coastal FIRMs is more than 20 years old. Faced with maintenance of the present inventory and creation of new FIRM panels, FEMA began an ambitious plan for Map Modernization in 1997. Congress approved a FY 2003 budget that included a significant increase for funding the Map Modernization Plan, and FEMA has placed a high priority on coastal flood hazard mapping.

In considering the needs of Map Modernization in coastal areas, FEMA recognized the need for a comprehensive review of procedures that will be used to identify coastal flood hazards. This review is needed to consider advances in coastal flood hazard assessment and mapping that might be accomplished based on the current state-of-the-art in scientific understanding of coastal processes, new technology and numerical modeling techniques, improved and expanded data, and modern mapping techniques.

The goal of this project is to incorporate recent advances in the sciences and in coastal engineering into a recommended approach for improved coastal flood hazard mapping, based on an understanding of local and regional coastal processes.

1.3 DESCRIPTION OF NEEDS BY GEOGRAPHIC REGION

Guidelines and Specifications for Flood Hazard Partners Appendix D: Guidance for Coastal Flooding Analyses and Mapping (*G&S*) for the Atlantic Coast, Gulf Coast, and Great Lakes have been assembled from elements developed over the course of many years; however, no comprehensive assessment has been done to evaluate their effectiveness in hazard mapping for the Atlantic and Gulf Coasts. During this time, the Pacific Coast was recognized as a special case because of differences in coastal processes (e.g., tsunamis, El Niño) and geomorphic characteristics, but no FEMA guidance was established specifically for this coast.

1.3.1 Pacific Coast

The present *G&S* do not address the Pacific Coast as noted in Section D.4, "No FEMA guidance documents have been published for Pacific Ocean coastal flood studies. Guidance is to be developed based on existing methodologies recommend by FEMA coastal states for coastal analyses in the Pacific Ocean." The existing guidelines focus on storm types and coastal processes that are relevant to the open coast settings of the Atlantic and Gulf Coasts. The Pacific Coast is subject to storm types, wave conditions, and coastal processes that differ from those in other coastal regions of the country. Therefore, much of the existing guidance is not directly transferable to the analysis of Pacific Coast coastal flood hazards. An assessment of the existing guidance is needed to determine which portions may be transferred or modified for use on the Pacific Coast and what new procedures are needed. In general, the FIRMs for the Pacific Coast of the United States are more than 20 years old. These maps require comprehensive updating to adequately define hazard zones in some of the most densely populated and fastest growing areas of the United States.

1.3.2 Atlantic and Gulf Coasts

The procedures in the existing guidelines can benefit from a comprehensive review considering more recent experience and new technology. Modified or new procedures may be needed to incorporate experience from previous studies and appeals, information on actual damages, and post-storm verification data. In addition, the basis of existing procedures should be reviewed with an improved understanding of ocean and coastal processes from recent research and data. The existing procedures include little guidance on analysis of storm meteorology, storm surge, or wave setup. The existing guidance also may need expansion to address flood hazards in coastal areas not directly exposed to ocean swell and storm seas (e.g., bays and estuaries, referred to as Sheltered Waters in this report)

1.3.3 Other Areas

The review and update of the guidelines are intended to facilitate consistent and accurate mapping of coastal flood hazards in the Map Modernization Plan. Because of the unique coastal processes in Alaska, Hawaii, the Great Lakes, Caribbean islands, and Pacific islands, the project focuses on guidelines for the oceanic coastlines of the conterminous United States. It is anticipated that many of the identified procedures will be transferable to these other areas but that additional work will be required to address unique physical characteristics and processes in each of these regions.

1.4 PROJECT APPROACH AND SCHEDULE

The project approach includes two key elements to ensure that the project can be completed rapidly and effectively: (1) assembling a team of technical experts (Technical Working Group, or TWG) with experience in various coastal processes and their effects in different geographic regions of the country and (2) conducting the project in two phases—Phase 1 to evaluate the existing guidelines for all three coasts and Phase 2 to develop proposed new draft guidelines for the Pacific Coast.

The TWG is comprised of coastal experts from private industry, academic and research institutions, federal agencies (National Oceanic and Atmospheric Administration, U.S. Army Corps of Engineers, and U.S. Geological Survey), Flood Insurance Study (FIS) contractors, map coordination contractors, and FEMA Headquarters and regional engineers. The TWG includes members from all three coastal regions of the United States and from Europe. This group was organized to implement a collaborative approach to identify the needs and priorities for improved coastal flood hazard mapping procedures, consider potential alternatives, and develop recommendations.

The phased approach to the project allows updated, modified, and new procedures to be developed first for the Pacific Coast, where none are currently specified. Some of these procedures will be applicable with slight modification to study elements for the Atlantic and Gulf Coasts or to specific areas on these coasts. This approach provides an efficient use of new *G&S* developed for the Pacific Coast.

A thorough evaluation of the guidelines must be completed on a schedule that allows coastal mapping to proceed according to the Map Modernization Plan. Needed guideline improvements must be prioritized to maintain this schedule. Phase 1 was initiated in October 2003, and a final report is scheduled for June 2004.

During Phase 2, a draft set of *G&S* for the Pacific Coast will be produced, along with associated backup information and reports. The draft guidelines are scheduled for delivery to FEMA in September 2004. A final draft set of Pacific Coast guidelines is anticipated in October 2004. This schedule will allow coastal flood insurance studies to proceed with new draft guidance in fiscal year (FY) 2004/2005. This schedule requires an intensive work effort to complete a comprehensive review of existing procedures, make necessary modifications to existing procedures, develop new methods, and prepare *G&S*. This effort involves approximately 20 organizations and active participation of more than 50 individuals.

1.5 PHASE 1 TASKS

The approach for the assessment phase of the project (Phase 1) was to examine all technical areas of the coastal flood hazard mapping process. Initial tasks focused on a review of the existing guidelines and the needs and priorities for their improvement. Under these tasks, coastal experts from the TWG reviewed existing guideline methodologies for the ocean and coastal processes analyzed in flood insurance studies (e.g., storm meteorology, storm surge, wave setup, wave transformation, wave runup, and overtopping) and evaluated their applicability for each coastline. Case studies were prepared to demonstrate application of guideline methodologies in previous coastal flood insurance studies on each coast, and representative studies were prepared to demonstrate application of guideline procedures to particular coastal processes.

An international literature search was conducted to identify sources of information on existing and evolving coastal engineering practices and to identify pertinent scientific research that may be useful in developing new guidelines. The international experience of several TWG members was used during this task to provide the project with information, techniques, and practices from around the world.

The initial tasks described above served as the basis for reporting and discussion at Workshop 1, held in Sacramento, California, on December 2–4, 2003. The workshop was attended by 38 members of the TWG from across the country. The workshop agenda included:

- review of existing guidelines and practices;
- technical presentations on the state of the science in coastal processes;
- workshop sessions to identify needs, priorities, and potential guideline improvements by coastal geographic areas and coastal processes; and
- summary sessions to list and prioritize needed guideline improvements.

The primary result of Workshop 1 was a list of 53 technical topics for consideration in updating the guidelines. Each item also included an initial assessment of the time and data required to develop improved procedures. This assessment resulted in categorizing each topic as "Critical," "Important," "Available," or "Helpful." "Critical" and "Important" topics were considered the highest priorities for development of new or improved procedures, and were subdivided into topics that could likely be addressed in the 6-month time frame of the project ("Critical") and those that would require longer term development by FEMA ("Important"). "Available" topics were considered areas where existing data or methodologies were readily available for updating or creating guidelines. "Helpful" topics were considered valuable but lower priority. These priority classes were assigned by the TWG for each topic on the Atlantic and Gulf Coasts, Pacific Coast, and in Sheltered Waters (Non-Open Coast).

The results of Workshop 1 were used to formulate Focused Studies that organized the 53 technical topics into 11 categories according to coastal processes and coastal flood hazard mapping procedures. Each of these 11 categories became the subject of a Focused Study:

1) Storm Meteorology
2) Stillwater Elevations
3) Storm Wave Characteristics
4) Wave Transformation
5) Wave Setup
6) Wave Runup and Overtopping
7) Event-Based Erosion
8) Coastal Structures
9) Tsunami
10) Sheltered Waters
11) Hazard Zones

These Focused Studies are included in the Appendices to this report.

The focused studies were conducted by groups of individuals from the TWG, each coordinated by a Focused Study leader. This organization allowed the 11 Focused Studies to be completed simultaneously

and rapidly. Preliminary drafts of the Focused Studies were presented at Workshop 2 on February 23–26, 2004, and subsequently were refined by the study groups.

The Focused Studies contain recommendations on the approach for updating the guidelines on three coasts (Pacific, Atlantic, Gulf). These recommendations include further studies and guideline development work that vary in complexity, level of effort, and time requirements. The level of effort required to complete the recommendations for "Critical" and "Available" items identified in Workshop 2 significantly exceeded the available time and budget for Phase 2 (Pacific Coast guidelines). Therefore, in March, the project team engaged in a significant effort to develop options for limiting the scope and cost of Phase 2 work while retaining the most important topics and a balance among the 11 technical categories. The selected option defers some recommendations for future development in the National Flood Insurance Program (NFIP) but maintains the target of producing reliable guidelines for coastal studies on the Pacific Coast in FY 2004/2005.

1.6 SUMMARY OF PHASE 1 FINDINGS

A complete list of topics and recommendations developed by the TWG during Workshops 1 and 2 is provided in Table 2 and the Focus Studies in the Appendices. The following are a few of the key findings from the Phase 1 activities:

- Procedures are needed to compute the 1% annual chance flood elevation where 1% stillwater levels do not necessarily coincide with 1% wave conditions (e.g., the Pacific Coast and sheltered waters along all three coasts).
- Procedures to better represent wave setup are needed on all coasts
- Procedures should be developed to use regional databases and wave transformation models to develop wave spectra at the surf zone.
- Methods are needed to evaluate the amount of wave dissipation due to propagation over muddy or flat nearshore areas.
- Procedures to quantify the effects of wave setup and event-based erosion in a variety of geomorphic settings are needed.
- On the Atlantic Coast, a review of the 540 square-foot erosion criterion is needed considering new data; on the Pacific Coast, a similar geometric method is needed based on Pacific Coast data.
- A probabilistic method for tsunami hazard assessment and methods for combining tsunami hazards with other coastal hazards are needed.
- Updates and amplification of existing guidelines for wave runup and overtopping and associated hazard zones are needed. Improved methodology for wave overwash is needed.
- Some coastal processes, such as surge, wave transformation, and tsunamis, are best analyzed at a regional scale rather than in flood studies of individual communities.
- Sheltered waters (non-open coast areas) require specialized guidance because of their unique hydrodynamic and geomorphic characteristics compared to the open coast. For example, new

methods for calculating fetch-limited wind waves should be evaluated and incorporated in guidelines, to the extent appropriate.

1.7 RECOMMENDED APPROACH FOR PHASE 2

Recommended approaches to address these and other needs are included in Sections 4 and 5 of this report. A portion of these recommendations will be implemented in Phase 2 to prepare guidelines for the Pacific Coast. The guidelines developed in Phase 2 will be designed to address the following general requirements:

- consideration of geomorphic settings and their relationship to required analysis, including clear distinction between the open coast and sheltered water settings;
- development of alternative procedures for defining the 1% percent annual chance flood elevation where 1% stillwater and 1% wave conditions do not necessarily coincide, and consistency in their application to multiple analyses in a coastal study; and
- identification of analyses that may best be accomplished at regional scale (e.g., tsunami analysis, wave transformation), and the appropriate input to local analyses and hazard mapping.

Phase 2 includes limited case studies in the following areas to develop and test new procedures and to develop simple models designed specifically for use in FEMA flood insurance studies:

- Storm Meteorology – testing to develop procedures for 1% flood elevation determination based on wave and water level combinations in open coast and sheltered waters settings
- Stillwater Elevations – testing for procedures to extract surge data from tide gage data; development of a simplified surge model for the Pacific Coast
- Wave Characteristics – case study to develop wind field and other input data specifications and methods for application of spectral models
- Wave Transformation – testing of wave transformation models
- Wave Setup – testing of Boussinesq models; development and testing of new setup model
- Runup and Overtopping – runup model testing combined with 1% flood elevation testing in Storm Meteorology
- Event-Based Erosion – testing of geometric models and procedures

A case study is also recommended by the TWG to develop a probabilistic methodology that considers both near-field and far-field sources of tsunamis. This case study will be accomplished outside the scope of the current project because of the highly specialized nature of the required analyses. This case study is expected to be accomplished through interagency cooperation among FEMA, the National Oceanic and Atmospheric Administration, and the U.S. Geological Survey, with assistance from private consultants and research institutions, such as the University of Southern California.

Some "Critical" and "Important" topics were identified for the Pacific Coast that will not be addressed in Phase 2 because of limited time and resources. The Focused Studies provide background on these topics, and Section 4 of this report provides a brief summary that can be used for planning of future guidance development by FEMA.

No additional work will be performed for the Atlantic and Gulf Coasts in this project. Section 5 of this report provides a brief summary of recommendations that can be used for planning future guidance development by FEMA. In addition, some Pacific Coast guidelines to be developed in Phase 2 may be applicable to analyses on the Atlantic and Gulf Coasts with little or no modification. The applicability of Pacific Coast guidelines in specific technical categories is identified in Section 5. The Focused Studies also provide reference information that may be useful to study contractors as a supplement to the existing guidelines.

The project approach has relied heavily on the collaboration of Technical Working Group members to meet a compressed schedule. This collaboration and interaction is a significant successful work product of the project, and is gratefully acknowledged.

EXECUTIVE SUMMARY
PHASE 1 SUMMARY REPORT

2 INTRODUCTION

This section describes the project and its role in the FEMA Map Modernization Plan. It describes the need for a comprehensive review and update of coastal flood hazard analyses and mapping and provides a brief description of the overall project approach.

2.1 PROJECT DESCRIPTION

2.1.1 Overview – Map Modernization Plan and Coastal Flood Hazards

Federal law mandates FEMA to compile and update flood hazard maps for more than 19,000 communities nationwide. Because flood hazard conditions change over time due to natural and human-induced changes, FEMA has an ongoing program to update flood maps for floodprone communities. Over time, the needs for flood map updates have increased while federal funding to accomplish this has been limited. Therefore, a significant portion of the present flood map inventory is out of date, while newer communities may not have been mapped yet. To reverse this trend, FEMA prepared a Map Modernization Plan with the goal to upgrade the 100,000-panel national flood map inventory which includes both riverine and coastal areas. To accomplish this goal Congress approved a FY 2003 budget that included a significant increase for funding the Map Modernization Plan. FEMA plans to meet the Map Modernization goals by:

- Developing up-to-date flood hazard data for all floodprone areas, including coastlines nationwide, to support sound floodplain management and prudent flood insurance decisions;
- Providing the maps and data in digital format to improve the efficiency and precision with which mapping program customers can use this information;
- Fully integrating FEMA's community and state partners into the mapping process to build on local knowledge and efforts;
- Improving processes to make it faster to create and update the maps; and
- Improving customer services to speed processing of flood map orders and raise public awareness of flood hazards.

Approximately 50% of the population of the United States lives within 50 miles of the coast. There are more than 3,000 communities along 12,000 miles of coastline, and approximately 7,400 Flood Insurance Rate Map (FIRM) panels covering these coastal communities. Therefore, performance of coastal flood insurance studies and preparing updates to coastal flood hazard mapping are key elements in meeting Map Modernization goals for a large portion of the nation's population. The coastal flood insurance studies and updates to FEMA's new digital mapping format (DFIRM) require application of consistent, scientifically based analysis and mapping procedures. In considering the needs of Map Modernization in coastal areas, FEMA recognized the need for a comprehensive review of procedures that will be used to assess coastal flood hazards. This review is needed to consider advances in coastal flood hazard mapping that can be accomplished based on the current state-of-the-art in scientific understanding of coastal processes, new technology and numerical modeling techniques, improved and expanded data, and modern mapping techniques.

Existing procedures for coastal flood hazard analysis and mapping are described in Appendix D of *Guidelines and Specifications for Flood Hazard Mapping Partners* (FEMA, 2003). This project includes a comprehensive review of these procedures (referred to as guidelines or *G&S* in this report), resulting in a recommended approach for updates to Appendix D. The existing guidelines were written for the Atlantic Coast, Gulf Coast, and Great Lakes areas of the United States. There are currently no guidelines specifically for the Pacific Coast. The project, therefore, also includes preparation of new guidelines for the Pacific Coast.

2.1.2 Pacific Coast – Description of Needs

In general, the FIRMs for the Pacific Coast of the United States are more than 20 years old. These maps require comprehensive updating to adequately define hazard zones in some of the most densely populated and fastest growing areas of the United States. The existing guidelines focus on storm types and coastal processes that are relevant to the open coast settings of the Atlantic and Gulf Coasts. The Pacific Coast is subject to different storm types, wave conditions, and coastal processes than other coastal regions of the country. Therefore, much of the existing guidance is not directly transferable to the analysis of Pacific Coast flood hazards.

2.1.3 Atlantic and Gulf Coasts – Description of Needs

On the Atlantic and Gulf Coasts, the existing guidelines were developed over an extended period of time, and applied in flood insurance studies in a variety of geomorphic settings. The procedures included in the existing guidelines can benefit from a comprehensive review with more recent experience and new technology. Modified or new procedures may be needed to incorporate experience from previous studies and appeals, information on actual damages, post-storm flood hazard verification data, and new knowledge and technology. In addition, there is a need to review the existing guidelines and their basis in physical processes. An improved understanding of these ocean and coastal processes, based on recent research and data, may allow the analysis procedures in the guidelines to be linked more directly and accurately to these processes. Most recent coastal flood insurance studies have focused on updating the mapping based on analysis of local wave effects at the shoreline. The existing procedures provide little guidance on analysis of storm meteorology, storm surge, or wave setup. New and expanded guidance or regional analyses may be needed to update these areas. The existing guidance may also need expansion to address flood hazards in protected coastal areas (e.g., sheltered bays and estuaries).

2.1.4 Purpose Statement and Project Authorization

FEMA is responsible for preparing Federal Insurance Rate Maps (FIRMs) that delineate hazard zones in coastal areas of the United States. These areas are among the most densely populated and economically important areas of the nation. Coastal areas are subject to a variety of natural processes that result in significant hazards to public safety and property, including conditions of extreme rainfall, wind, waves, surge, and erosion. The purpose of this project is to evaluate existing FEMA procedures for delineation of coastal flood hazard areas in three major coastal regions of the United States (Atlantic, Gulf, and Pacific), and to develop recommended new guidelines and procedures in one of these areas (Pacific).

This project was authorized cooperatively by FEMA Headquarters, FEMA Region IX, and FEMA Region X in October 2003. The project is managed by Les Sakumoto, Project Officer for FEMA Region IX. Northwest Hydraulic Consultants, Inc. is the lead consultant and manager of the Technical Working Group.

2.1.5 Phase 1 Summary Report

This report was prepared to summarize the first phase of the project. The report provides a brief background on the project approach, describes the process pursued by the TWG to complete the evaluation of existing guidelines and recommend an approach to update them, and summarizes the recommendations for the Pacific, Atlantic, and Gulf Coasts. Appendices to this report include information on the TWG, Key References, and Focused Studies on 11 categories of technical topics.

2.2 PROJECT APPROACH

2.2.1 Scope – Pacific, Atlantic, Gulf Coasts

The scope of the project includes the three major coastlines (Atlantic, Gulf, and Pacific) of the conterminous United States. The evaluation of existing guidelines and development of procedures is expected to also have applicability in Alaska, Hawaii, and other Pacific and Caribbean islands. However, these areas are subject to unique coastal processes that cannot be adequately addressed in the timeframe of the project. Future development of procedures specific to these areas will be required, drawing on project results for the Pacific Coast.

The project approach includes two key elements to ensure that the project can be completed rapidly and effectively:

1) Assembling a team of technical experts with experience in various coastal processes and their effects in different geographic regions of the country; and
2) Conducting the project in two phases to first evaluate the existing guidelines for all three coasts, and then develop proposed new draft guidelines for the Pacific Coast.

2.2.2 Technical Working Group – A Collaborative Approach

The process of evaluating and developing guidelines for coastal flood hazard delineation requires a combination of high technical knowledge, practical experience, and familiarity with FEMA regulations and procedures. Few individuals or organizations possess the capabilities to address the range of technical challenges associated with the diverse processes affecting the three major coastal regions. Yet a comprehensive set of guidelines is highly desirable to ensure consistency in hazard mapping and flood insurance administration.

The project approach therefore relies on collaboration among a team of technical experts and experienced floodplain management professionals from across the country. This team of experts is referred to as the Technical Working Group (TWG), and includes members from: FEMA Headquarters and FEMA Regions I, II, III, IV, VI, IX, and X; National Oceanic and Atmospheric Administration (NOAA), U.S. Geological Survey (USGS), and the U.S. Army Corps of Engineers (USACE); FEMA FIS contractors; coastal engineering and scientific experts from consulting organizations, universities, and institutes; international experts; and floodplain management professionals. The TWG provides a forum for building consensus on the technical issues, provides high-level review of existing guidelines and new procedures, and also provides a connection to a pool of additional technical resources through various organizations.

2.2.3 Phased Approach

A phased approach was adopted for the project. The first phase of the work included:

- Reviewing existing procedures and identifying needs as they pertain to the Pacific, Atlantic, and Gulf Coasts;
- Prioritizing issues and identifying additional studies required;
- Conducting Focused Studies to address specific hazard analysis and delineation issues;
- Preparing recommendations to FEMA for: (1) updating guidelines for the Atlantic and Gulf Coasts, and (2) producing guidelines applicable to the Pacific Coast.

This report and the attached appendices are the primary deliverables for Phase 1.

In the second phase, the TWG will focus on procedures specifically needed to assess coastal flooding processes on the Pacific Coast, while identifying procedures that may also be applicable in other regions. For this phase, TWG members will draw upon technical resources available from within their organizations to:

- Perform technical studies to improve existing or develop new assessment and mapping procedures specifically for the Pacific Coast; and
- Produce new coastal flood hazard mapping draft Guidelines and Specifications for the Pacific Coast.

The primary deliverable from Phase 2 will be a set of draft Guidelines and Specifications for Coastal Flood Hazard Mapping on the Pacific Coast. Detailed guidelines development or modification for the Atlantic and Gulf Coasts are not included in this project. However, it is anticipated that much of the work done during the Phase 1 assessment of existing guidelines and during the Phase 2 development of the Pacific Coast guidelines will be informative during the development of flood insurance studies on the Atlantic and Gulf coasts.

The phased approach ensures consistency in the technical basis for updating and developing new guidelines across all three regions, and allows new procedures that are developed for the Pacific Coast to potentially be applied in updates for other areas. The results of this project will assist FEMA to prepare updates of guidelines for the Atlantic and Gulf Coasts, if undertaken in the future. Figure 1 illustrates the key steps and flow of work in each phase.

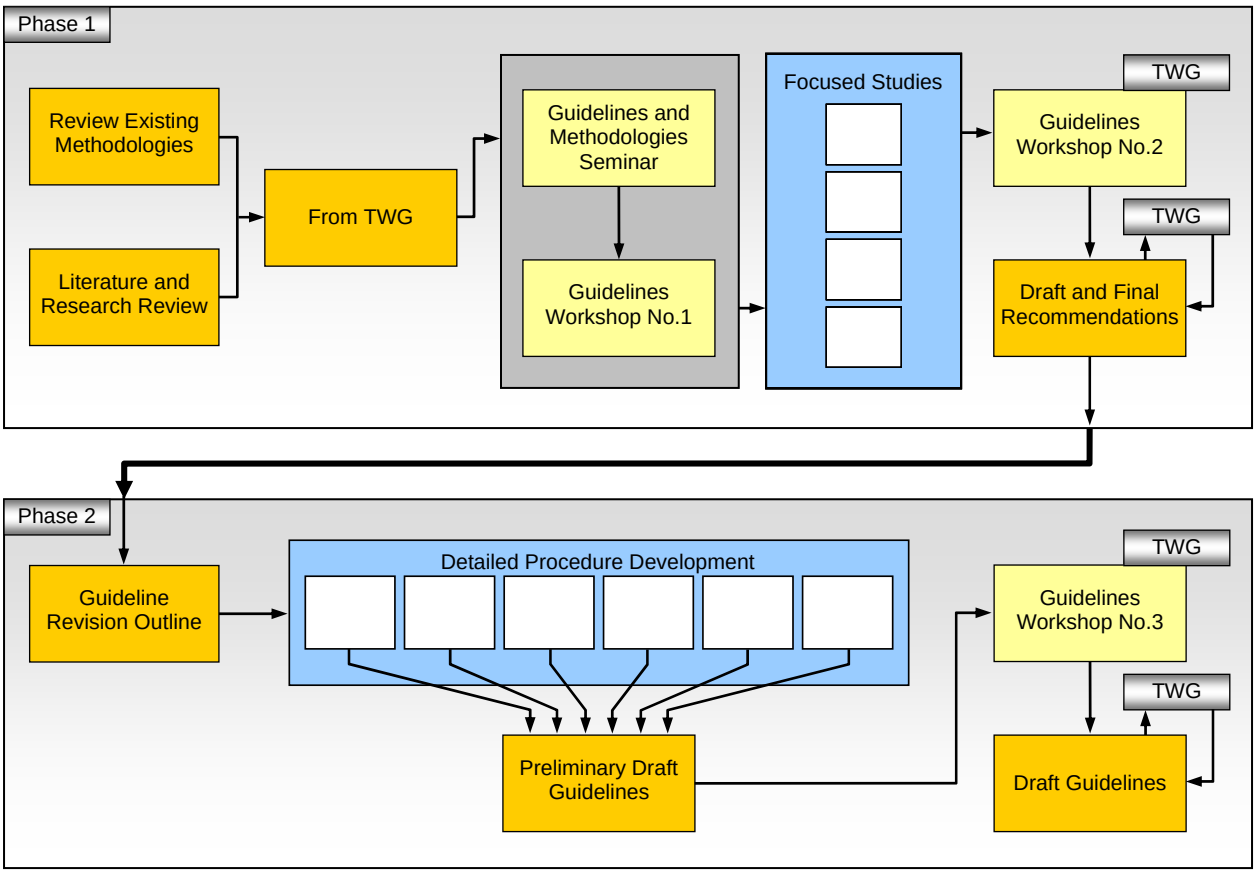

Figure 1. Project Approach

2.2.4 Objectives and Project Schedule

The objectives of the project are tied to the needs of Map Modernization – a comprehensive review of existing guidelines is needed, as well as development of technical procedures and methodologies to improve the efficiency and reliability of coastal flood hazard mapping. Coastal flood hazard mapping combines the analysis of a series of complex physical processes with FEMA mapping standards for the National Flood Insurance Program (NFIP). A review of all subjects that influence coastal flood hazard zone delineations is therefore an extremely broad and ambitious task.

At the same time, the evaluation and preparation of the guidelines must respect the schedule for Map Modernization and the need to conduct coastal flood insurance studies in FY 2004/2005. For these reasons, the objectives of the project are to make significant improvements in coastal FIS guidance by October 2004. This necessarily results in prioritization of needed improvements to ensure that they can be accomplished within this ambitious schedule.

Figure 2 shows the schedule for the project, including key milestones for Phase 1 and Phase 2.

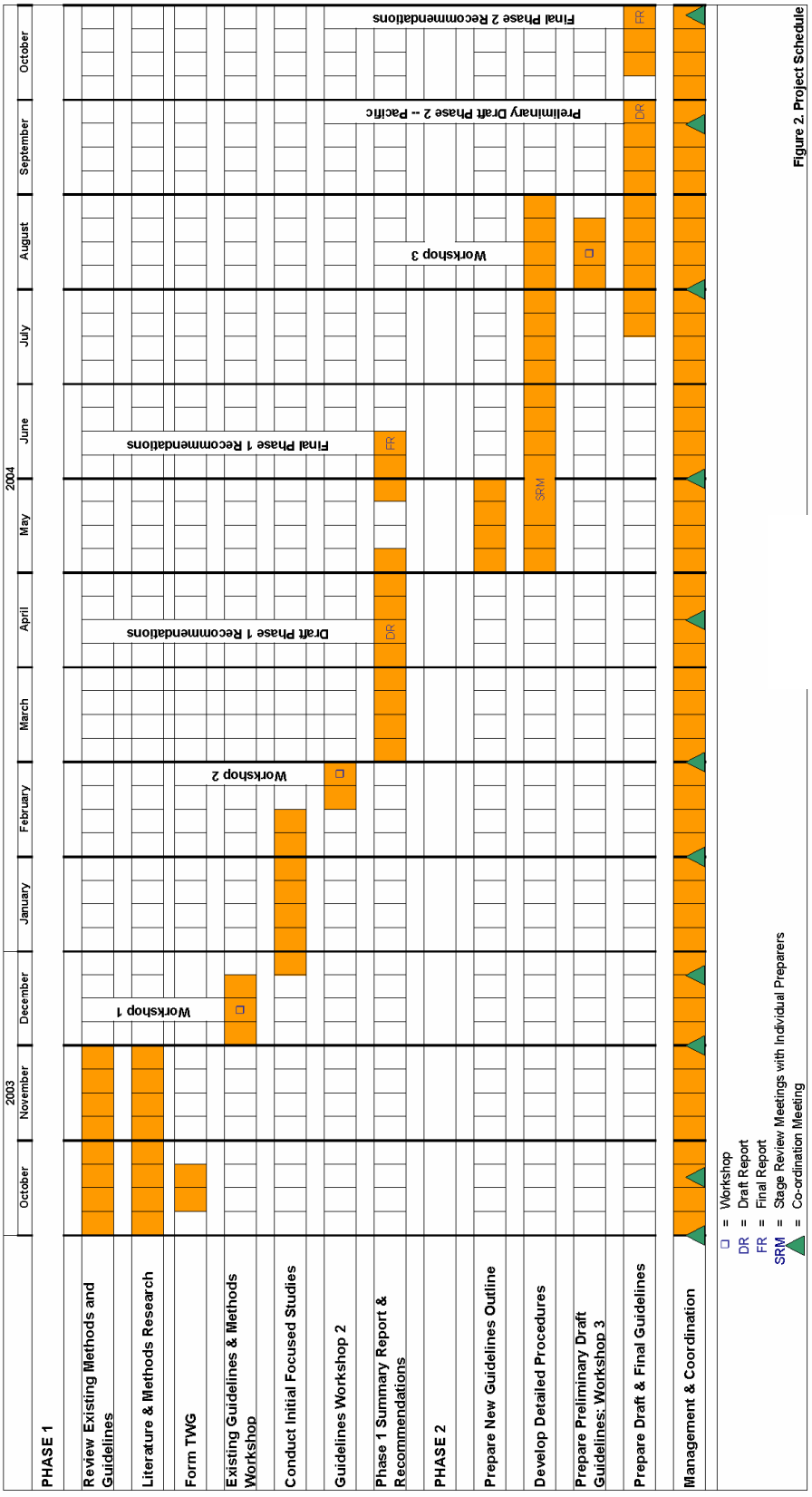

Figure 2. Project Schedule

FIGURE 2 PROJECT SCHEDULE

3 PHASE 1

The purpose of Phase 1 is to establish guidance for updating the *G&S* based on the recommendations from a diverse group of scientists, coastal engineers, and floodplain managers. This section describes the activities of the TWG which evaluated technical issues for coastal flood hazard analyses and mapping and developed priorities for addressing these issues. This information will be used for developing the Phase II scope of this project, which is the development of *G&S* for the Pacific Coast.

3.1 FORMATION OF TECHNICAL WORKING GROUP (TWG)

The TWG was formed early in the project, primarily by considering the range of physical processes and analyses that comprise coastal flood hazard analysis for FEMA, and identifying key resources to address these subjects. Expertise was required in a broad range of coastal processes, and experience was required in application of FEMA procedures. The TWG is comprised of about 40 individuals that provide this range of expertise and experience, drawing from sources at:

- FEMA Headquarters and FEMA Regions I, II ,III, IV, VI, IX, and X
- NOAA Pacific Marine Environmental Laboratory
- USACE
- USGS
- FEMA Map Coordination Contractors and National Service Provider
- FEMA FIS Contractors in California, Oregon, Washington, Florida, North Carolina, Mississippi, and Massachusetts
- University of Florida, University of California, University of Southern California, and Oregon State University, and Scripps Institute of Oceanography
- Coastal Experts from Denmark and England

The TWG continues to grow as new technical requirements and resources are identified. Preliminary scoping for Phase 2 efforts expands the TWG with additional members from the United States, as well as coastal engineering expertise from Australia, Japan, and New Zealand.

3.2 INITIAL STUDIES

The initial tasks for the project included a review of the existing *G&S* and a literature and practice search. These tasks included an initial assessment of the existing guidelines, organized in a set of 11 technical categories. The 11 categories were selected to represent ocean processes, coastal processes, and mapping procedures that are considered in coastal flood insurance studies. They can be placed in an order that generally coincides with a progression in the coastal study analysis from the open ocean toward the coastline, the effects of the processes at the coastline, and the delineation of flood hazard zones. These categories include:

1) Storm Meteorology
2) Stillwater

3) Storm Wave Characteristics
4) Wave Transformation
5) Wave Setup
6) Wave Runup and Overtopping
7) Event-Based Erosion
8) Coastal Structures
9) Tsunami
10) Sheltered Waters
11) Hazard Zones

These categories have been used through the course of Phase 1 to organize discussion and technical topics, prepare detailed studies, and formulate recommendations. These 11 categories were defined to break down the determination of coastal flood hazard mapping into a number of smaller, more tractable physical processes. The ordering corresponds to the issues as they would be considered in a typical mapping analysis starting from the offshore forcing conditions and moving shoreward. Storm Wave Meteorology defines the wind and wave conditions offshore. Stillwater determines the water depth and Storm Wave Characteristics define the character of the waves. Wave Transformation brings the offshore waves to the nearshore and Wave Setup is the increase in the mean water level due to the presence of the waves. Wave Runup and Overtopping can then be determined from the wave and water level information (and beach profile information). Event-Based Erosion is the adjustment of the beach and shoreline to large events. Tsunami is a Pacific Coast mechanism that may have a significant influence on flood zone mapping. Sheltered Waters relate the above processes to semi-enclosed bodies of water. Hazard Zone provides guidance for the application of the above analyses to the determination of coastal flood hazard maps.

The initial assessment of the existing guidelines was supplemented by a set of case studies and representative studies. Case studies were compiled for specific sites on the Atlantic, Gulf, and Pacific Coasts. These case studies were used to illustrate the application of existing guidelines and practices to problems in coastal flood hazard analysis. The representative studies were used to focus on specific processes or application of specific procedures. The literature search compiled a list of national and international references, and specific references were made available to the TWG.

These materials were provided to TWG members and were the subject of presentations at Workshop 1, held in Sacramento on 2-4 December 2003 (Workshop 1 Binder, nhc 2003). This workshop focused on the needs and priorities for updating the existing guidelines on the Atlantic and Gulf Coasts and for preparing new guidelines for the Pacific Coast. The workshop included plenary sessions for presentations on the existing guidelines, case studies, representative studies, and selected technical topics (e.g., storm surge modeling, wave setup implications, current programs and information on regional wave transformation modeling, recent research on coastal erosion, and state-of-the-art efforts in tsunami modeling and research). Smaller working sessions were organized by geography (Atlantic/Gulf and Pacific Coasts) and by categories of technical topics.

3.2.1 Workshop I Prioritization

Table 1 summarizes the topics that were compiled over the course of the three-day workshop, including an initial assessment of priorities. These priorities were categorized considering the project schedule, which allowed approximately six months for development of new guidelines for the Pacific Coast.

Priorities for the Atlantic and Gulf Coasts and Non-Open coasts were also developed using the same categories. Based on this practical consideration, topics were characterized as follows:

- *Critical* – topics that were considered important to improve coastal flood hazard analysis and mapping for the NFIP, that required significant effort to analyze or develop, but could be developed or resolved in six months or less.
- *Important* – topics that were considered important to improve coastal flood hazard analysis and mapping for the NFIP, that required significant effort to analyze or develop, and are likely to require more than six months to be developed or resolved.
- *Available* – topics that could be improved with relatively available data or procedures in less than six months.
- *Helpful* – topics that would be helpful to the NFIP, but were considered less significant or lower priority.

A total of 53 topics were discussed at Workshop 1. As listed in Table 1 significant recommendations from Workshop 1 included the need to:

- Evaluate alternative methodologies for determination of 1% annual chance flood elevations where 1% stillwater elevations do not necessarily coincide with 1% wave conditions, especially for the Pacific Coast and in some sheltered waters
- Consider the use of regional databases and wave transformation models to develop wave spectra at the surf zone
- Develop improved methods for analysis of wave transformation over dissipative bottoms
- Develop a procedure to quantify the effects of wave setup in a variety of geomorphic settings
- Consider updates and application of simple geometric models (e.g., existing “540” criterion) for storm event erosion, as well as potentially feasible of process-based methods and models for estimating erosion
- Consider updates and amplification of existing guidelines for wave runup and overtopping, and for analysis of coastal structures
- Consider the feasibility of frequency-based estimates for tsunami effects, and their combination with other coastal processes and hazards
- Develop procedures for sheltered waters (non-open coasts), considering the unique processes and combinations of processes in these areas in contrast to open coast

3.3 WORKSHOP 1 LIST OF TOPICS

Table 1
Workshop 1 List of Topics

ID	Category	Topic Description	Atlantic / Gulf	Pacific	Non-Open Coast
1	Wave Characteristics	Definitions of wave types using contemporary terminology (so that everyone is using the same nomenclature): standardize the terms	A	A	
3	Wave Characteristics	Conversion from Shore Protection Manual to Coastal Engineering Manual	A	A	
4	Wave Characteristics	Open coast/deep water waves, swell exposure: Use hind-cast databases, select based on evaluation	A	C	
5	Wave Characteristics	Local seas: use nearshore representation of wind waves rather than offshore wave hindcast	A	C	
6	Sheltered Waters	Write guidelines for sheltered water methods	H	C	C
7	Wave Transformation	Evaluate regional models for California		C	
8	Wave Transformation	Assess need for regional models (beyond CA); outline methodologies to use	H	C	
9	Wave Transformation	Propagation over dissipative bottoms/friction (flat, shallow, slopes); evaluate Suhayda methods, etc., and write guidelines	C	H	C
10	Wave Transformation	Overland wave propagation: review and evaluate new methods to better represent vegetation effects, treatment of elevated pile supported buildings (WHAFIS issue)	I	H	H
11	Runup, Setup, Overtopping	Review programs, methods, and field data for run-up and over-topping; provide explicit guidance on where models should be applied	H	A	A
12	Runup, Setup, Overtopping	Review appropriateness of the mean v. higher values for run-up, set-up, and overtopping	H	C	C
13	Runup, Setup, Overtopping	Develop improved guidance on mapping and determining overtopping volumes		A	A
14	Runup, Setup, Overtopping	Review available methods and develop guidance for wavecast debris	H	I	I
15	Runup, Setup, Overtopping	Tsunamis: Address use of National Tsunami Hazard Mitigation Program products and approaches in the NFIP	H	C	C
16	Runup, Setup, Overtopping	Tsunamis: Develop method to predict 100-year tsunami events	H	I	
17	Hazard Zones	Enhance existing guidelines for defining inland limit of VE-zone including the development of a basis for better guidance for heavily over-topped areas	C	C	
18	Hazard Zones	Investigate the appropriateness of existing VE and AE zone definitions for coastal areas	I	I	
19	Hazard Zones	Flood risk management of combined coastal and riverine flooding hazards	A	A	
20	Hazard Zones	Tsunami-structure-debris interaction to define hazard zones	H	I	
21	Coastal Structures	Failed Coastal Structures: Clarify guidance that when a structure is determined to fail under base flood conditions, the structure is removed, but fill/topography remains and is	A	A	A

Table 1
Workshop 1 List of Topics

ID	Category	Topic Description	Atlantic / Gulf	Pacific	Non-Open Coast
		subject to erosion, wave analyses			
22	Coastal Structures	Failed Coastal Structures: Investigate configuration of failed structures	H	H	H
23	Coastal Structures	Buried Coastal Structures: Add *G&S* language that buried structures are to be evaluated	A	A	A
24	Coastal Structures	Flood Protection Structures: Review 89-15 and other literature for tsunami failure information/guidance		A	
25	Coastal Structures	Flood Protection Structures: Review *G*&S language -- (Study Contractor not required to evaluate all structures) using 89-15	A	A	A
26	Coastal Structures	Flood Protection Structures: Review data on (and add to G&S) effects of structures on flood hazards on adjacent properties, flooding/waves behind structures via adjacent properties	H	H	H
27	Coastal Structures	Coastal Levee vs. Structure Treatment: Review *G&S* and regulations regarding treatment of coastal levees and structures; identify conflicts; clarify *G&S* that evaluations of all "structures" to be per 89-15	A	A	A
29	Event - Based Erosion	Tsunami Induced Erosion: Review methods for estimating tsunami-induced erosion and provide recommendations		I	
30	Event - Based Erosion	Geometric Erosion Assessment: Review empirical geometric techniques; review pre- and post-event data for CA, OR, WA; review OR setback methodology; develop geometric techniques for Pacific shorelines, including sea cliff, bluff, dunes, beaches		C	
31	Event - Based Erosion	Geometric Erosion Assessment: Add/revise *G&S* language regarding bluff erosion in Atlantic/Gulf areas -- better descriptions/discussions are needed	A		
32	Event - Based Erosion	Geometric Erosion Assessment: Develop geometric method for bluff erosion in Atlantic/Gulf areas	I		
33	Event - Based Erosion	Shingle/Cobble Erosion Assessment: Add *G&S* description/discussion regarding effect of cobble/shingle (including sediment mixtures/layers) on geometric erosion technique	C	C	C
34	Event - Based Erosion	Shingle/Cobble Erosion Assessment: Develop improved geometric methods which consider cobble/shingle effects	I	I	I
35	Event - Based Erosion	Guidance for Erosion Assessments in Sheltered Waters: Add *G&S* description/discussion regarding erosion assessments in Sheltered Waters			C
36	Event -Based Erosion	Guidance for Erosion Assessments in Sheltered Waters: Review data and develop geometric methods for determining eroded profile in Sheltered Waters			I
37	Event - Based Erosion	540 Criteria: Expand database from which 540 sf criterion was determined; review use of median value	I		
38	Event - Based Erosion	Physics- or Process-Based Erosion Assessment: Develop assessment procedures that consider temporal and longshore effects/variability	I	I	I
39	Event - Based Erosion	Primary Frontal Dune Definition: Develop better definition of landward limit of PFD (used for V zone limit); gather and	C	I	I

Table 1
Workshop 1 List of Topics

ID	Category	Topic Description	Atlantic / Gulf	Pacific	Non-Open Coast
		evaluate Massachusetts CZM and other approaches			
40	Event - Based Erosion	Document Vertical Erosion Depths; maintain data and make available for use in building performance and insurance tasks (depth-damage functions)	H	H	H
41	Event - Based Erosion	Long-Term Erosion/Future Conditions: Consider revising *G&S* D.5 language and putting a warning on the FIRM; reference CCM and other reports; discuss implications of study data selection	A	A	A
42	Event - Based Erosion	Treatment of Nourished Beaches: Ensure clarity in *G&S* that references FEMA policy regarding treatment of nourished beaches	A	A	
43	Event - Based Erosion	Treatment of Nourished Beaches: No consensus on long-term technical approach for handling this issue; FEMA policy dependent	-	-	-
44	Wave SetUp	Better define and document; summarize what to consider and how to approach; data requirements	C	C	C
45	Wave SetUp	Compile example/data sets to perform tests	C	C	C
46	Wave SetUp	Develop interim method (consider Coastal Engineering Manual, Shore Protection Manual procedures)	C	C	C
47	Wave SetUp	Develop "ideal method" coupled with storm surge and waves to develop set up	I	I	I
48	Wave SetUp	Develop procedure for dynamic wave set up	I	I	I
49	Wave SetUp	Review WRUP™ (available wave run-up program)	A	A	A
50	Storm Meteorology	Test and recommend storm surge procedures (JPM, EST, Monte Carlo) and identify data sets for each region (e.g., NWS38 and HURDAT for hurricanes; nor'easters; Pacific storms)	I	I	
51	Storm Meteorology	Guidance on combined probability consideration for all processes; need to define a procedure for determining the 1% annual chance flood elevation	C	C	C
52	Stillwater	Provide guidance on non-stationary processes (for example, relative sea level change) when establishing current conditions	A	A	A
53	Stillwater	Identify reliable existing data to compare to existing FEMA flood studies to test performance of surge models	C		
54	Stillwater	Develop database for surge versus wave height - develop interim west coast model for surge (possibly ADCIRC)		C	C
55	Stillwater	Review the reliability of Pacific tide data to see if surge is embedded in the data sets for the purposes of developing surge factors for regions where there are little or no tide data; provide guidance		C	C

Key: C = critical; A = available; I = important; H = helpful

3.4 FOCUSED STUDIES

Focused Study groups were established for each of the 11 technical categories developed in Workshop 1. Each Focused Study was assigned a leader and team participants based on experience in the technical areas and in flood hazard mapping. Focused Study teams were comprised of 3 to 9 members depending on the range and complexity of topics identified and the resources needed to complete the Focused Study within the project schedule. The objectives of the Focused Studies included:

- Improved definition of the issues or topics identified at Workshop 1
- Assessment of existing guidelines and procedures related to the topic
- Description of the history and implications of the topic in the NFIP
- Consideration of alternatives and available data for improved guidance
- Recommendation of an approach for updating existing and/or preparing new guidelines
- Preliminary estimation of time required to accomplish the recommended approach

Most of the Focused Studies covered several topics, with varying levels of priority. *Critical* topics were given highest priority for development in the focused studies, followed by *Available*, *Important*, and *Helpful* topics.

The draft Focused Studies were used to guide discussions during Workshop 2, and subsequently modified to reflect those discussions. Summaries of the Focused Studies are the primary technical work products of Phase 1, and are attached as Appendix C to this report. These Focused Studies are intended to:

- Guide development of Phase 2 work on the Pacific Coast
- Serve as a technical resource for preparation of flood insurance studies, especially on the Atlantic and Gulf Coasts
- Serve as a planning tool for future development of guidance on the Atlantic, Gulf, and Pacific Coasts

3.5 WORKSHOP 2

Results from the draft Focused Studies were presented at Workshop 2. This workshop was held in Sacramento 23-26 February 2004, and was attended by 40 members of the Technical Working Group. This workshop was used as a forum for discussion of the technical topics in each category and the basis for recommendations developed by each of the Focused Study groups. Table 2 lists the topics and which Focused Study group developed recommendations. The table also identifies related topics so that inter-relationships among topics can be coordinated.

Table 2 shows the compilation of TWG recommendations from Workshop 2. These recommendations were developed with the consensus of the entire TWG. For several topics, case studies were recommended to develop and test new procedures, or to test existing methods in particular settings. The

consensus of the group was also used to confirm or adjust the priority classes for each topic, and to carefully state the topic.

Table 2 presents a summary of recommended approaches for each topic and the category under which each topic is applicable as developed at Workshop 2. Due to the number of topic, Table 2 presents a significantly condensed version of the discussions held at Workshop 2. Sections 4 and 5 and the Appendices to this report provide the detailed approaches and background. information for each topic. A key for Table 2 is listed at the end of the table.

The definitions for the Priority Classes assigned to each task by the TWG were given in Section 3.2. These definitions are repeated here for ease of reference.

- *Critical* – topics that were considered important to improve coastal flood hazard analysis and mapping for the NFIP, that required significant effort to analyze or develop, but could be developed or resolved in six months or less.
- *Important* – topics that were considered important to improve coastal flood hazard analysis and mapping for the NFIP, that required significant effort to analyze or develop, and are likely to require more than six months to be developed or resolved.
- *Available* – topics that could be improved with relatively available data or procedures in less than six months.
- *Helpful* – topics that would be helpful to the NFIP, but were considered less significant or lower priority.

Table 2
Workshop 2 Recommendations

Topic	Category	Coastal Area	Priority Class	Recommended Approach	Related Topics
50 Modeling Procedures	Storm Meteorology	AC	I	Identify and summarize data sources for storm parameters, and compare storm surge statistical methods (EST, JPM, Monte Carlo approaches may all be valuable); prepare guidelines describing the use of each alternative; revisit treatment of storm wind fields and wind stress formulation	53-55
		GC	I		
		PC			
		SW			
51 Combined Probability, Determination of 1% Annual Chance Flood Elevations	Storm Meteorology	AC	C	For each major process combination, prepare Guidelines with recommended methodology and illustrative examples. For wave plus high water perform (2 open/sheltered) case studies for Pacific sites to: (1) implement Wallingford approach; (2) use NOS tide gage data; (3) use NOAA wave buoy data. Develop practical Guidelines from study findings, with examples	All
		GC	C		
		PC	C		
		SW	C		
52 Non-Stationary Processes	Stillwater	AC	A	Identify and summarize data sources for sea level rise and land subsidence and/or uplift; provide basic guidance regarding significance of non-stationarity in flood insurance applications; include guidance on interpretation of historical data. Suggest documentation of projected map impact.	
		GC	A		
		PC	A		
		SW	A		
53 Reliable	Stillwater	AC	C	Develop overview guidance for surge modeling;	6, 44-48

Table 2
Workshop 2 Recommendations

Topic	Category	Coastal Area	Priority Class	Recommended Approach	Related Topics
Surge Data		GC	C	define procedures to assess accuracy of surge estimates; suggest regional modeling approaches for study economy	
		PC			
		SW			
54 & 55 Pacific Coast/Sheltered Waters Surge Estimates	Stillwater	AC		Identify tide gage data sources; develop procedures for surge extraction from tide gage records for FIS use (including test studies); develop simplified numerical modeling method for areas without data (1-D Pacific Surge Model)	6, 44-48
		GC			
		PC	C		
		SW	C		
4 & 5 Swell and Seas	Storm Wave Characteristics	AC	C	WIS database is recommended for use. Clarify extrapolation to 100-year; investigate appropriateness of using either 100-year significant wave height or 20-year maximum; clarify use of equivalent deepwater wave - definition (Topic 1)	8,9, 51
		GC	C		
		PC	C	1. GROW database is recommended for use in near term for swell and sea. Confirm lack of bias in GROW database. WIS can be used after completion of current revision. CDIP data can be used for model verification. 2. Develop G&S for preparation of input data for wave modification models based on GROW directional spectra. 3. Conduct a study of the available nearshore data for Southern California Bight to assess whether inclusion of the local wind will make a significant change in the high frequency part of the spectrum	8,9, 51
		SW	C	Add guidance on use of Coastal Engineering Manual (CEM); conduct a Focused Study to confirm that Shore Protection Manual (SPM) results are similar (validation for previous studies). Conduct a Focused Study and describe procedures for: (1) existing parametric model guidance; (2) enhanced parametric models; (3) spectral energy models	6, 8, 9, 51
1 Wave Definitions	Storm Wave Characteristics	AC	A	The recommended approach includes: (1) adopt the CEM "Glossary of Coastal Terminology" and International Association of Hydraulic Engineering and Research "List of Sea State Parameters" (for notations); and (2) clarify the correlation of these terms to the actual guidance and various methodologies to ensure consistency	4, 5, 50, 51
		GC	A		
		PC	A		
		SW	A		
10 WHAFIS	Wave Transformation	AC	I (*C*)	Clarify where WHAFIS, 1-D, and 2-D models are most appropriate. Update WHAFIS and tie back to CHAMP. Minor Effort – code changes for more user friendly program. Moderate Effort – more intense code changes for improvement in accuracy and graphics, add wind direction. Update *G&S* accordingly	8, 9
		GC	I (*C*)		
		PC	I (*C*)		
		AC	I	Significant Effort – improve WHAFIS to include combined effects of damping and wind action over	
		GC	I		

Table 2
Workshop 2 Recommendations

Topic	Category	Coastal Area	Priority Class	Recommended Approach	Related Topics
				each segment. Include realistic wave breaking model for setup and other processes after developed.	
		PC	H	Evaluate if changes to WHAFIS dissipation criteria are necessary (see topic 9), and incorporate in *G&S* modifications for PC	
		SW	H	Refer to AG, GC, and PC *G&S* Include in PC *G&S*	
7 CDIP CA	Wave Transformation	AC			8
		GC			
		PC	C	Develop interim *G&S* for use of CDIP regional wave models and database (California)	
		PC	I	Expansion of CDIP regional model approach to develop nearshore wave climate database in areas where it is not currently available	
		SW			
8 Overall WT	Wave Transformation	AC	H	Refer to PC *G&S* for potential use of regional models	7, 9, 10
		GC	H		
		PC	C	Write *G&S* for Wave Transformations. Tasks: 1. Conduct several Focused Studies to assist in writing the Wave Transformations G&S. 2. Use available publications to identify a range of methods. 3. Develop criteria for level of analysis. 4. Include development of guidelines for spatial coverage and wave parameters, and include use of regional models such as CDIP. 5. Research available literature to adequately define wave groups, infragravity waves, shallow water spectra, etc. for input into wave setup and runup calculations. 6. Evaluate wave transformation models using a selected data set. 7. Review available literature and guidance on the range of applicability of contemporary computer models, recommend models for inclusion on the FEMA pre-approved coastal model list, and provide guidance on their application to FEMA FISs. 8. Incorporate applicable sections of existing *G&S* for other geographical areas that cover the overland propagation and wave energy dissipation topics. (Topics 9 &10)	6, 7, 9, 10, 11, 44, 45, 47, 48, 49, 54, 55
		SW	C	Include in PC *G&S*; reference for AC and GC	
9 Dissipation	Wave Transformation	AC	C	Write *G&S* to include a section on wave energy dissipation over shallow and flat bottoms based on available information. Develop typical ranges for dissipation coefficients for a variety of bed and wave conditions to include	8, 10
		GC	C		

Table 2
Workshop 2 Recommendations

Topic	Category	Coastal Area	Priority Class	Recommended Approach	Related Topics
				in the *G&S*, based on available information. Provide guidance on calibration if available data not adequate to select coefficients.	
		GC	I	Conduct studies to develop typical ranges for dissipation coefficients for variety of bed and wave conditions to include in the *G&S*. Categorize bed and wave conditions for US coastlines. Revise *G&S* to provide dissipation coefficients on a geographic basis to the extent appropriate; revise *G&S* to adopt Suhayda (1984) method. Provide guidance on calibration of available data not adequate to select coefficients.	
		AC	I		
		PC	H (*C*)	Evaluate wave dissipation over marsh and mudflats in the Pacific using available information; provide interim guidance for calculating wave dissipation.	
		PC	H(*I*)	Conduct field data collection to characterize wave dissipation over marsh and mudflats in the Pacific; provide guidance for calculating wave dissipation.	
		SW	C	Include in PC *G&S*; reference for AC and GC	
44&45 Define, Document, Compile Data	Wave Setup	AC	C	The recommended approach for this Topic is the same for all geographic regions: Conduct a thorough examination of all available relevant literature with an emphasis on quality field data sets. These would include experiments conducted especially to investigate wave setup and especially "experiments of opportunity" in major storms including high water marks. Organize data by "settings" identified in the Phase 1 effort.	11
		GC	C		
		PC	C		
		SW	C		
46 Interim Method	Wave Setup	AC	C	Several possibilities exist. The "Interim Method" should include consideration of the following: (1) Static and dynamic setup; (2) Irregular waves (implicit in (1) above); (3) Characterization of nearshore bathymetry; (4) A valid wave breaking model; (5) Nonlinearities in S_{xx}; and (6) Wave damping where appropriate. An attempt should be made to ensure that the interim method address as many of the settings identified as possible.	1, 6, 9
		GC	C		
		PC	C		
		SW	C		
47 Develop Ideal Method - Coupled	Wave Setup	AC	I	The recommended approach for this Topic is the same for all geographic regions. The ideal method would be one in which the storm surge model also incorporates a wave generation model. The wave generation model would predict directional spectra so that the characteristics of the dynamic setup could be calculated directly. It is recommended that this topic be approached as a two phase effort with the first phase evaluating approaches and the second phase pursuing the approach identified.	9, 10, and many beyond those identified in Table 1
		GC	I		
		PC	I		
		SW	I		
48 Dynamic	Wave Setup	AC	I	This topic could be incorporated into Topic 47;	9, 10, and

Table 2
Workshop 2 Recommendations

Topic	Category	Coastal Area	Priority Class	Recommended Approach	Related Topics
Wave Setup		GC	I	however, a more realistic approach is to parallel Topic 47 with a first phase to evaluate existing methodologies that could be applied. The results of the first phase would guide the second phase, which would implement the optimal approach identified. It is anticipated that the actual procedures developed would be somewhere between a full physics-based approach which would proceed from a directional spectrum, and the approaches available from Lo and Goda which are either based on somewhat simple calculations or empirical. A probable approach would be one in which the dynamic wave setup is based on parameterized spectra determined as a function of wind fields and continental shelf width of interest.	many beyond those identified in Table 1
		PC	I		
		SW	I		
30 Geometric Techniques - PC	Event - Based Erosion	AC		1. Select and evaluate existing geometric methods and models. 2. Develop guidance for determination of a Most Likely Winter Beach Profile including areas of beach nourishment. 3. Evaluate geometric modeling procedures for sand beaches and dunes on PC and test with available data sets. 4. Recommend that FEMA expand/support the present USGS/NOAA coastal survey program for the Pacific Coast; update likely winter profiles for various geomorphic settings.	31, 32, 35, 36, 37
		GC			
		PC	C		
		SW			
31 Bluff Erosion - AC/GC/(PC)	Event - Based Erosion	AC	A	Add/revise guidance language to distinguish bluff erosion from other processes with descriptions and examples.	30, 32, 35-38, 41
		GC	(*A*)		
		PC	(*A*)		
		SW	(*A*)		
32 Geometric Method for Bluffs - AC/GC/(PC)	Event - Based Erosion	AC	I (*A*)	1. Review existing bluff erosion procedures and literature. 2. Consider development of geometric procedure for bluff erosion and cliff retreat.	12, 21, 33, 35, 38, 42
		GC	I (*A*)		
		PC	(*A*)		
		SW	(*A*)		
33 Cobble/ Shingle Effects	Event - Based Erosion	AC	C	1. Prepare new sections of *G&S* to describe differences between sand dominated beaches and gravel/cobble/shingle beaches found along the north Atlantic, Gulf, Pacific and in Sheltered Waters areas. Provide photos and profile information. 2. Gather existing literature on gravel, cobble, and shingle beaches to summarize the existing state of knowledge until specific guidelines can be developed and adopted. 3. Review literature on the design and construction of dynamic revetments and cobble berms to provide guidance on beach stability and long term development.	30, 31, 32, 34, 37
		GC	C		
		PC	C		
		SW	C		

Table 2
Workshop 2 Recommendations

Topic	Category	Coastal Area	Priority Class	Recommended Approach	Related Topics
				4. Examine other possible guidance and available beach and dune data sets for possible clarifications to the 540 SF criterion for sand-dominated beaches versus gravel/cobble/shingle beaches. 5. Discuss the limitations of applying geometric models to cobble/shingle beach and dune areas	
34 Cobble/ Shingle - Geometric Method	Event - Based Erosion	AC	I	Develop geometric procedure for cobble/shingle eroded profile.	12, 21, 33, 35, 38, 42
		GC	I		
		PC	I		
		SW	I		
35 Erosion – Sheltered Waters	Event - Based Erosion	AC	C	1. Provide definitions and discussion in *G&S* for sheltered water types of beach morphology, materials, and wave characteristics. 2. Provide interim *G&S* based primarily on historical beach profiles and field observations.	5, 6, 36, 41
		GC	C		
		PC	C		
		SW	C		

Table 2
Workshop 2 Recommendations

Topic	Category	Coastal Area	Priority Class	Recommended Approach	Related Topics
36 Geometric Method – Sheltered Waters	Event - Based Erosion	AC	I	1. Provide interim *G&S* for the AC and GC based primarily on historical applications of the 540 SF criterion on AC/GC. 2. Provide interim *G&S* for the PC based primarily on historical field observations developed on PC. 3. Perform pilot studies; refine procedures and describe methods for *G&S*. 4. Incorporate event-based models where feasible into final *G&S*. 5. Provide guidance on appropriate models for erosion in sheltered waters	5, 6, 35, 38
		GC	I		
		PC	I		
		SW	I		
37 Review 540 SF Criterion	Event - Based Erosion	AC	I	1. Expand database beyond 38 storm events for AC and GC using more recent data. 2. Re-evaluate existing data points. 3. Consider storm duration in analyses. 4. Consider variability of erosion about median at each data point. 5. Evaluate geometry of retreat and removal profiles. 6. Contingent on 1. through 5., determine whether median erosion trigger should be maintained or revised.	32, 34, 36
		GC	I		
		PC			
		SW			
38 Process-Based Approach	Event - Based Erosion	AC	I	1. Further develop and test process-based models using field data and compare with geometric models. 2. Develop method to include randomness of storm waves and tides and coincidence in Item 1. 3. Provide *G&S* for erosion assessment to coastal bluff fronted by narrow beach. 4. As an interim method continue to use the 540 SF Criterion for A/G and GL, and most likely winter beach profile or best documented winter profile for the Pacific Coast.	30, 31, 32, 35, 36
		GC	I		
		PC	I		
		SW	I		
39 PFD	Event - Based Erosion	AC	C	Covered in Hazard Zones Topics	
		GC	C	Covered in Hazard Zones Topics	
		PC	I	Covered in Hazard Zones Topics	
		SW	I	Covered in Hazard Zones Topics	
40 Vertical Erosion Depths	Event - Based Erosion	AC	H	Document depths of erosion following storm events and maintain data for depths of erosion and damages to buildings in order to better determine "depth-damage" relationships. As methods and models are coded, calculate and store vertical erosion depths along transects and grids.	30-36
		GC	H		
		PC	H		
		SW	H		
41 Long-Term Erosion	Event - Based Erosion	AC	A	1. Topic considered important to NFIP, but FEMA action on previous work is pending; therefore guidance is best developed by FEMA outside of current project. 2. Better risk communication to public - outside of *G&S*.	30, 31, 32, 35, 36
		GC	A		
		PC	A		
		SW	A		

Table 2
Workshop 2 Recommendations

Topic	Category	Coastal Area	Priority Class	Recommended Approach	Related Topics
42/43 Nourished Beaches	Event - Based Erosion	AC	A	Prepare guidance to: (1) Notify FEMA that study area includes beach nourishment project; (2) Conduct research and preliminary analysis to determine whether beach nourishment is likely to have an effect on hazard zone designations and/or BFEs; (3) Provide list of types of information that may be required to assess special cases where beach nourishment may be considered in determining hazard zones and BFEs (as an exception to existing FEMA policy).	
		GC	A		
		PC	A		
		SW			
21a Failed Structures	Coastal Structures	AC	A	Expand guidance to discuss removal of seawalls, bulkheads, revetments, coastal levees.	22, 13
		GC	A		
		PC	A		
		SW	A		
21b1 Failed Structures	Coastal Structures	AC	A	Mention in guidance: removal of the effects of groins, jetties, detached breakwaters on the shoreline.	22
		GC	A		
		PC	A		
		SW	A		
21b2 Failed Structures	Coastal Structures	AC	A	Develop specific guidance on how to remove the effects of groins, jetties, detached breakwaters on the shoreline.	22
		GC	A		
		PC	A		
		SW	A		
23 Buried Structures	Coastal Structures	AC	A	Mention in guidance: buried structures may exist, should be located and should be considered in analyses.	22
		GC	A		
		PC	A		
		SW	A		
25 Flood Protection Structures	Coastal Structures	AC	A	Mention in guidance: detailed TR-89-15 evaluation/certification of coastal structures are not required during FIS, but discuss implications (see Topic 22).	22, 26, 27
		GC	A		
		PC	A		
		SW	A		
27a Coastal Levees v. Structures	Coastal Structures	AC	A	Revise *G&S* to differentiate coastal levee requirement from those for other costal flood protection structures; identify conflicts.	
		GC	A		
		PC	A		
		SW	A		
27b Coastal Structure Evaluation Criteria	Coastal Structures	AC	H	Review, revise TR-89-15 evaluation criteria.	11
		GC	H		
		PC	H		
		SW	H		
27c Coastal Structure Treatment	Coastal Structures	AC	A	Consider requiring all structures (existing and new) to meet the same evaluation criteria.	25
		GC	A		
		PC	A		
		SW	A		
24 Structures - Tsunamis	Coastal Structures	AC		Review literature and revise guidance for coastal structure evaluation criteria in tsunami-prone areas.	22
		GC			
		PC	A		

Table 2
Workshop 2 Recommendations

Topic	Category	Coastal Area	Priority Class	Recommended Approach	Related Topics
		SW			
22 Failed Structure Configuration	Coastal Structures	AC	H	Review Coastal Engineering Manual (CEM) for treatment of failed structures; revise guidance to include modified Philip Williams & Associates Sandy Point methodology (intact and failed where performance uncertain) and CEM results	21, 24
		GC	H		
		PC	H		
		SW	H		
26a Adjacent Properties	Coastal Structures	AC	H	Review literature and develop guidance for evaluating the erosion effects of coastal structures on adjacent properties.	11, 22
		GC	H		
		PC	H		
		SW	H		
26b Adjacent Properties	Coastal Structures	AC	H	Review literature and develop guidance for evaluating the hydraulic effects of coastal structures on adjacent properties.	11, 22
		GC	H		
		PC	H		
		SW	H		
26c Adjacent Properties	Coastal Structures	AC	H	Deleted	
		GC	H		
		PC	H		
		SW	H		
26d Adjacent Properties	Coastal Structures	AC	H	Develop guidance for evaluating flooding and erosion from adjacent properties.	
		GC	H		
		PC	H		
		SW	H		
26e Minimum Length	Coastal Structures	AC	H	Deleted	11, 22
		GC	H		
		PC	H		
		SW	H		
12 Mean v. Higher Value	Runup and Overtopping	AC	H *(C)*	1. Revise guidance to include sandy beach, small dune shore type in runup analyses. 2. Review runup distributions for beaches and structures during El Niño, coastal storm and hurricane conditions; review runup damages; evaluate use of R50%, select alternative value if hazard is not properly represented. 3. Tsunami runup to be treated by procedures developed specifically for tsunami events. 4. Investigate feasibility of interim procedure for modifying the results of RUNUP 2.0.	11, 16
		GC	H *(C)*		
		PC	C		
		SW	C		
11 Methods and Models	Runup and Overtopping	AC	H *(I)*	1. Evaluate expansion of "Oregon-type" and "CDIP-type" methods as interim Pacific runup method 2. Develop test scenarios for side-by-side comparisons of existing runup methods, models (give priority to Pacific and New England scenarios). Will require establishment of probabilities 3. Perform comparisons, eliminate methods, models; identify appropriate runup methods,	4, 5, 7, 8, 12, 16, 44-49
		GC	H *(I)*		
		PC	A *(C)*		
		SW	A *(C)*		

Table 2
Workshop 2 Recommendations

Topic	Category	Coastal Area	Priority Class	Recommended Approach	Related Topics
				models by location, morphology and hydraulic conditions. Address uncertainty issues.	
49 WRUP	Runup and Overtopping	AC	A	Evaluate with other runup methods and models in Topic 11.	11
		GC	A		
		PC	A		
		SW	A		
13 Overtopping Volumes	Runup and Overtopping	AC	*(A)*	1. Evaluate existing methods and models for calculating mean overtopping rates 2. Determine appropriate procedure for calculating overtopping at structures, remnant dunes, low profile beaches, and barriers 3. Revise procedures for overtopping calculations at bluffs. 4. Review literature for data on acceptable overtopping rates, revise landward flood hazard zones. 5. Review FEMA practice to limit runup elevations to 3 feet above barrier crests.	11, 12, 14
		GC	*(A)*		
		PC	A		
		SW	A		
14 Wavecast Debris	Runup and Overtopping	AC	H	1. Review the literature and quantify the significance of coastal flood damages from drift logs and wave-sprayed stone. 2. Review past flood insurance studies that have resulted in methods for defining flood hazards from wave-cast debris, and refine methods where appropriate. 3. Incorporate into mapping zones, but don't attempt to specifically map debris (i.e., map the water that carries debris, but not debris itself).	6, 13, 18, 20, 22
		GC	H		
		PC	I		
		SW	I		
15 NTHMP	Tsunamis	AG	H	The recommended approach includes: (1) develop digital database; and (2) develop a methodology, including recurrence interval estimation, for use of NTHMP products for NFIP for tsunami hazard zone delineation. (Tasks Go With Topic 16)	16,20,29
		GC	H		
		PC	C		
		SW	C		
16 100-year Recurrence	Tsunamis	AG	H	The recommended approach is to perform a comprehensive probabilistic tsunami hazard assessment at a pilot site in California or Oregon or Washington to include: (1) recurrence interval estimate of forcing functions; (2) propagation of tsunamis from Subduction Zone; (3) inundation calculations; (4) probability distributions and integration. Use results to assess whether tsunami condition will govern hazard zone delineation.	15,20,29
		GC	H		
		P	C		
		SW	C		
20 Structure-Debris Interaction	Tsunamis	PC	I	Review TR-89-15 for recommendations for impact forces using data for overland flow depths and velocities for the numerical simulations from Item 15 and 16 for one specific locale. (Conditional on Topic 16) Linked to Topic 24.	15,16

Table 2
Workshop 2 Recommendations

Topic	Category	Coastal Area	Priority Class	Recommended Approach	Related Topics
29 Erosion	Tsunamis	SW	I	Evaluate and integrate USGS erosion data into empirical relationships for the specific locale under study. (Conditional on Topic 16)	
6a Definitions and Classification	Sheltered Waters	AC	H	1. Review previous sheltered water flood studies, compare methods, geomorphic conditions, unique flood hazards. 2. Compile a list of coastal (sheltered water) flood study definitions in *G&S* and prepare definitions for Guidelines. 3. Identify and classify Pacific sheltered water physical processes and site characteristics. 4. Review classification systems established by others and refine/adapt a system for sheltered water areas.	1, 5, 9, 10, 11-14, 15-16, 17-19, 20, 21-27, 29, 30, 35-36, 37-43, 44-48, 50-51, 52-55
		GC	H		
		PC	C		
		SW	C		
6b Historical Information	Sheltered Waters	AC	H	1. Review previous sheltered water flood studies and document methods used for validating flood study results. 2. A summary of the review may include a checklist for results validation. 3. Compare results of past flood studies to actual damage and flood observations made by community officials and residents.	9-10, 11-14, 17-19, 21-22, 24, 30-31, 35-36, 53
		GC	H		
		PC	C		
		SW	C		
6c Peer Input	All	AC	H	Deleted	All
		GC	H		
		PC	C		
		SW	C		
6d 1% Annual Chance Flood Elevations	Sheltered Waters	AC	H	1. Review the methods used in previous FEMA-accepted sheltered water flood insurance studies for possible adoption as methods to reference in the new guidelines (Topic 51). 2. Evaluate potential need for guidance on joint probability effects considering coastal watersheds. 3. Expand discussion of existing guidance on wind data acquisition and analysis and fetch-limited wave forecasting.	4,5,8-10, 12, 16, 19, 44-48, 50-51, 52-55
		GC	H		
		PC	C		
		SW	C		
6e Stillwater Elevations and Tidal Currents	Sheltered Waters	AC	H	1. Review pertinent scientific literature and resource management practices. 2. Prepare guidance for the transfer of tide gauge data to ungauged sheltered water bodies. 3. Prepare guidance for the estimation and use of tidal datums in flood insurance studies. 4. Prepare guidance for the assessment of tidal and nearshore currents and their significance to flood hazards. 5. Coordinate guideline development with Wave Setup and Stillwater Focused Study Groups	44-48, 52-55
		GC	H		
		PC	C		
		SW	C		

Table 2
Workshop 2 Recommendations

Topic	Category	Coastal Area	Priority Class	Recommended Approach	Related Topics
6f Coastal Structures	Sheltered Waters	AC	H	Covered in Topic 21a	11-14, 17-19, 21-27, 35-36
		GC	H		
		PC	C		
		SW	C		
6g Hazard Zones	Sheltered Waters	AC	H	Covered in Topic 17	13-14, 17-19, 35-36
		GC	H		
		PC	C		
		SW	C		
6h Inter-relationships	Sheltered Waters	AC	H	Identify and assess interrelationships of new PC *G&S* to other sections of existing *G&S* and other FEMA multi-hazard initiatives.	All
		GC	H		
		PC	C		
		SW	C		
17 VE Zone Limit	Hazard Zones	AC	C	1. Investigate and develop guidance to better map the BFE transition between PFD and landward hazard zone. 2. Establish procedures (hazard identification and mapping) to better utilize VO Zones. 3. Establish procedures for identifying and mapping wave overtopping and wave-cast debris hazards. 4. Establish improved procedures for establishing the landward limit of the PFD .	11, 12, 13, & 14
		GC	C		
		PC	C		
		SW	C		
18 VE/AE Zone Appropriateness	Hazard Zones	AC	I	1. Investigate and develop Coastal A Zone criteria (wave and erosion damage) and procedures for application within the NFIP. 2. Prepare technical bulletins for clarification of proposed revisions to VE Zones, AE Zones, and new VO Zones related to hazard identification and floodplain management. 3. Apply new concepts in a case study area. 4. Develop an annotated bibliography of related research and papers to support new guidance.	11, 12, 13, & 14
		GC	I		
		PC	I		
		SW	I		
19 Combined Coastal/ Riverine	Hazard Zones	AC	A	1. Review the previous guidance from 1981 for adoption into *G&S.* 2. Develop mapping standards to clearly identify this hazard zone.	
		GC	A		
		PC	A		
		SW	A		

Key:

Topic	Topic Number from Table 1 - Workshop 1 List and Subject
Category	Major Category from Table 1 - e.g., Stillwater Elevations, Wave Setup, Runup and Overtopping, etc.
Geographic Region	AG = Atlantic Coast; GC = Gulf Coast; PC = Pacific Coast; SW = Sheltered Waters
Priority Class	Priority Class from Table 1; e.g., H, A, C, I (in parentheses if Focused Study has recommended a change in priority class)
Recommended Approach	Brief Description of Recommended Approach
Related Topics	Topic Number for Related Topics

3.6 PHASE 2 SCOPING – PACIFIC COAST

A primary objective of the Focused Studies and the recommendations from Workshop 2 was to guide Phase 2 work on the Pacific Coast. Following Workshop 2, the recommended approach for the Pacific Coast was compiled and an estimate of time and budget to accomplish the recommended tasks was developed. This estimate exceeded the available time and budget for the project by 300%. Therefore, options were developed and reviewed with FEMA to prioritize tasks to be included in the Phase 2 work. FEMA made a significant adjustment to the project budget to allow a larger portion of the recommendations to be explored and implemented in Phase 2. The prioritization process attempted to retain significant work in all 11 technical categories to produce a comprehensive set of guidelines for the Pacific Coast.

The selected option includes limited case studies in several areas to develop and test new procedures, and development of simple models designed specifically for use in FEMA flood insurance studies. Model development, case studies, and testing of methods and models are included in the Phase 2 work in the following areas:

- Storm Meteorology – testing to develop procedures for 1% annual chance flood elevation determination based on wave and water level combinations in open coast and sheltered waters settings
- Stillwater Elevations – testing for procedures to extract surge data from tide gage data; development of surge model for the Pacific Coast
- Wave Characteristics – case study to develop wind field and other input data specifications and methods for application of spectral models
- Wave Transformation – testing of wave transformation models
- Wave Setup – testing of Boussinesq models; development and testing of new setup model
- Runup and Overtopping – runup model testing combined with 1% annual chance flood elevation testing in Storm Meteorology
- Event-Based Erosion – testing of geometric models and procedures

A case study is also recommended by the TWG to develop a probabilistic methodology that considers both near-field and far-field sources of tsunamis. This case study will be accomplished outside the scope of the current project due to the highly specialized nature of the required analyses. This case study is expected to be accomplished through inter-agency cooperation between FEMA, NOAA, and USGS, with assistance from private consultants and research institutions such as the University of Southern California.

In addition to the model development, case studies, and testing listed above, Phase 2 work will include evaluation of existing methods and databases as they pertain to coastal flood hazard mapping on the Pacific Coast, and preparation of guidelines in each of the 11 technical categories.

4 RECOMMENDATIONS – PACIFIC COAST

This section presents recommendations for the development of *G&S* for the Pacific Coast. The first part of this section discusses the importance of considering both open coast and sheltered waters for Pacific Coast FIS and potential alternatives for the determining the 1% annual chance flood hazard. This is followed by specific recommendations for the Pacific Coast in the 11 technical categories discussed in Section 3.

4.1 INTRODUCTION – OBJECTIVES AND NFIP CONSIDERATIONS

A primary objective for these recommendations is to guide work in Phase 2 of the project for the Pacific Coast. For the Pacific Coast, the recommendations are split into recommended Phase 2 work and recommended future development. The work shown in Phase 2 will produce a set of guidelines specifically for the Pacific Coast and facilitate new and updated coastal flood insurance studies for map modernization.

The work in Phase 2 does not include all the recommended Critical, Available, Important, and Helpful topics. The Phase 2 recommendations have been adjusted from the Workshop 2 recommendations taking into consideration available resources and budgetary constraints to maintain the project schedule. These adjustments were made to allow treatment of the full range of technical categories in the guidelines at a significant level of technical detail, considering priorities for needed improvements and relative importance among categories.

Secondary objectives for this section are therefore to recommend future work to further improve and expand the guidelines and to serve as a reference for planning future FEMA technical guidance work. The summaries in this section also provide a concise connection to the appended Focused Studies, which include additional information and references on the topics that were deferred to the future. In addition to new guidelines, these Focused Studies may be valuable references for the NFIP as coastal studies move forward on the Pacific Coast.

4.2 GUIDELINES FORMAT AND STUDY PROCESS

On the Pacific Coast, new guidelines will be developed in Phase 2 that can be incorporated by FEMA into Appendix D of the Guidelines and Specifications for Flood Hazard Mapping Partners (FEMA, 2003). This set of guidelines evolved over approximately 20 years and is specifically applicable to the Atlantic and Gulf Coasts. As part of Phase 1, the existing guidelines were reviewed by the project team to determine the potential applicability of this format to new guidelines for the Pacific Coast. Based on this review, the project team feels that the new guidelines would benefit greatly from reorganization and restructuring to address particular aspects of coastal flood hazard analysis and mapping for the Pacific Coast.

Key considerations in the development of a new format for the Pacific Coast guidelines include a few key challenges that may be unique to the Pacific Coast or that may not have been fully developed in the existing guidelines. These include the need to specifically account for potential alternative methods for determining the 1& annual chance flood elevation where 1% stillwater elevations do not necessarily coincide with 1% wave conditions. This issue is particularly important on the Pacific Coast, where this

determination is not driven by a single type of event (i.e., hurricanes). In addition, the Pacific Coast guidelines should explicitly account for major differences in physiographic settings and wave climates (e.g., open coast and sheltered waters) considering the differences in the analysie required and the importance of sheltered waters in terms of population centers. The format also should account for the potential advantages of accomplishing some portions of coastal studies at a regional scale, such as wave characteristics analysis, wave transformation, and tsunami studies. Specific recommendations based on the review of the existing guidelines are described briefly below.

The existing guidelines incorporate many references to avoid excessive length. The applicability of specific references for the Pacific Coast should be clarified, updated, and connected to specific situations in coastal flood studies. The existing General Guidance lists 32 publications as references covering a variety of subjects, including 10 references on wave height and runup analysis. The list is not categorized by geographic area, geomorphic setting, or type of analysis. A more structured system for referencing specific methods outside of the guidelines is needed.

The study documentation section (Section D1.2) in the existing guidelines is fairly general and is separated from the specific guidance for major geographic areas. It may be preferable to reorganize the Pacific Coast document to show study documentation requirements near the end or in specific technical sections with specifics on the types of information required for specific situations. The study documentation required should be more specific and clearer.

The Pacific Coast guidelines could benefit from improved flowcharts to illustrate the FIS analysis process, including key decision points. The existing section on study organization and overview includes a flowchart (Figure D-1). Some of the steps that may require computations are not represented in the flowchart (e.g., storm meteorology, stillwater elevations, ocean wave characteristics), although they are discussed later in the text. Some of these are shown as “data requirements.” Figure D-1 shows the overall process, and more detailed flowcharts are used to show specific analyses (e.g., Figure D-4 for erosion assessment), but this structure could be expanded and improved. The flowcharts have little relationship to geomorphic settings, but a table is included showing model types for specific settings. The use of geomorphic settings to characterize the types of analysis that are required and the submittal requirements based on geomorphic settings could clarify the study process and review requirements.

Some processes are not treated comprehensively in the existing guidelines, such as storm meteorology and stillwater elevations, in part because of their regional scale and the need for specialized expertise and resources outside the scope of typical coastal studies. Similarly, the Pacific Coast guidelines must address potential regional studies and their use in local studies.

Specific guidance is not included in the existing guidelines for sheltered waters or for areas subject to combined coastal and riverine flood hazards. These are common geomorphic settings on the Pacific Coast, and should be addressed more specifically.

The existing guidelines are generally organized in the order in which a study is completed, but this approach could be improved, and the relationships between types of analyses (e.g., wave setup and runup and overtopping) should be clarified. Key definitions and a glossary should be included. This may be best done in one or more locations in the document to provide definitions relevant to specific technical analyses in a convenient manner. Examples are included in the existing guidelines for hazard zone

mapping. Their use is recommended for the Pacific Coast as well, possibly organized by geomorphic setting.

The following list identifies the key recommendations for the structure and format of new Pacific Coast guidelines:

- Clarify the purpose and organization at the beginning of the document.
- Clearly illustrate the study process with a series of flowcharts, including key decision criteria, and the interrelationships between analyses.
- Define the procedures for selected alternative approaches for determining the 1% annual chance flood elevation, including the connection between different elements of the study analysis using these approaches.
- Indicate analyses that may best be accomplished at regional scale and the information to be derived and used in local studies.
- Provide guidance on procedures and data applicable to specific geomorphic settings, including a specific section on sheltered waters and guidance on combined coastal/riverine flood hazards.
- Provide definitions and key examples.
- Provide improved guidance on study documentation more directly related to the types of analyses and settings included in the study.

4.3 OPEN COAST AND SHELTERED WATER SETTINGS

"Sheltered Waters" are water bodies with shorelines that are not subjected to the direct action of undiminished ocean winds and waves. Sheltered Water areas are exposed to similar flood-causing processes as those found along open coastlines, such as high winds, wave setup, runup, and overtopping. Present FEMA *G&S* adequately cover many of the general coastal flood assessment procedures needed to complete flood hazard assessments in Sheltered Waters. However, some aspects of sheltered water flood hazards can not be addressed by the current FEMA Guidelines. For example, wind-generated waves are highly dependent on the shape and orientation of the surrounding terrain to prevailing wind directions. Wave generation and transformation in sheltered waters are usually limited by their open water fetch distance, complex bathymetry and often the presence of in-bay and shoreline coastal structures. These sheltering effects reduce wave energy and flood potential compared to open coast areas.

Other processes, including the effects of terrestrial runoff which modify local tidal and surge hydrology and relatively strong in-bay currents often combine to create tidal and hydrodynamic conditions only found in sheltered waters areas. Bays and estuaries often display significant spatial variability in tidal hydrology. For example, south San Francisco Bay often has a standing tide with nearly twice the tide range of central Bay and an elevated mean tide and high water elevation compared to the open coast. By contrast, north San Francisco Bay, which extends into the Sacramento-San Joaquin Delta area, displays a different, progressively muted tidal range that is affected significantly by local winds and river runoff. Oceanic storm surge can be modified in estuaries and it is not clear whether storm surge is uniformly additive to local tidal datums throughout an estuary, or whether storm surge is amplified or muted within

an estuary, or within a given region in a large estuary. On the Pacific Coast similar questions arise during El Niño events regarding how elevated oceanic conditions may or may not affect sheltered water tidal elevations. Wave-cast debris from extreme wave runup and overtopping can be especially problematic, owing to the proximity to sources of such materials in many estuaries. These unique sheltered water flood hazards are not adequately addressed in current FEMA Guidelines.

4.4 DEFINE THE 1% ANNUAL CHANCE FLOOD HAZARD (TWO APPROACHES)

The NFIP regulations (44 CFR 59.1) define *base flood* as "the flood having a one percent chance of being equaled or exceeded in any given year." The regulations do not define *base flood elevation*, but the meaning seems clear: the flood *elevation* with a one percent chance of being equaled or exceeded in any given year. Calculating this elevation in coastal areas may be difficult, however, because flood elevation is the net result of several processes (e.g., astronomical tide, storm surge, wave setup, infragravity motions, wave heights, event-based erosion, wave runup), some of which are independent and some of which are related.

4.4.1 Two Basic Approaches: Response (Statistical) and Event Selection (Deterministic)

The FEMA *G&S* was drafted initially with a primary focus on open coast Atlantic and Gulf of Mexico flooding, which had the result of reducing the 1% annual chance flood elevation determination to computation of a 1% annual chance stillwater elevation and concurrent wave conditions which typically depend on water depth during the event. (Hurricane and extreme northeaster storm surges are large and may inundate low-lying coastal areas. Wave heights in the inundated areas become depth limited.) The procedure for the Atlantic and Gulf Coasts can be thought of as Response or Statistical, because a large number of storms of varying characteristics are simulated and the 1% annual-chance stillwater elevation is determined from the computed response. The added wave component is also computed by Response Method because the response based waves collapse to a maximum depth limited breaking condition.

The Event Selection method was used in the Great Lakes (Dewberry & Davis, 1991), where the 1% annual chance event was considered to be the 1% annual chance stillwater elevation and the 3-year wave height (or, in the case of Lake Ontario, the half-year wave height). Modified event-based erosion, wave height, and runup procedures were developed by FEMA (2003) for use with the defined 1% event.

Specific guidance for determining the 1% annual chance flood elevation along the Pacific Coast has not been developed. However, a variety of techniques have been used over the years, including a modified event selection method for the Sandy Point (Whatcom County), Washington, Flood Insurance Study (PWA, 2002). The PWA procedure defined three distinct water level and wave condition combinations (events), each with a 1% annual probability of occurrence (Figure 1). Wave runup was calculated using each event, and the event yielding the highest runup was used as the basis for flood hazard mapping.

Other procedures employed in Pacific Coast flood mapping can be collectively referred to as a **response** or **statistical** method. In this method, many combinations of water level and wave height conditions are used as input to wave models, a wave runup-frequency relationship is constructed from the model results, and the 1% annual chance runup elevation is identified from the relationship. Unlike the event selection method, no attempt is made to identify a 1% event; instead, the response of the system dictates the 1% flood elevation.

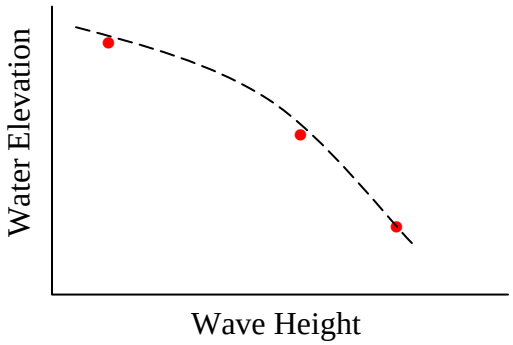

Figure 3. Multiple water level-wave height combinations (1% events).

The details of the statistical procedures may vary (e.g., joint probability, coincident time series, Monte Carlo), but each will result in an elevation-frequency distribution from which the 1% elevation is determined (Figure 4). Pacific Coast studies using the response method include the Tetra Tech Southern California Study (1982), and the Ott Water Engineers Northern California Flood Study (1984). More recent reports (1994–2002) detailing the response method have been prepared by the Hydraulic Research Station at Wallingford, and the University of Lancaster, U.K.

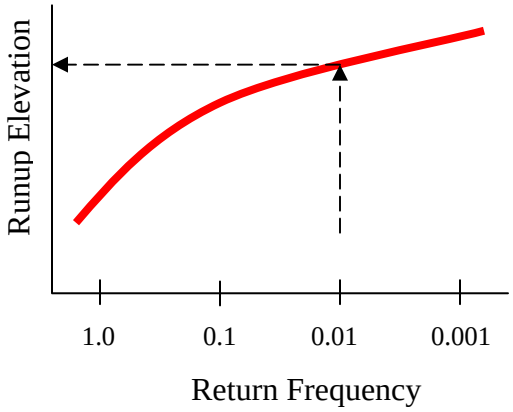

Figure 4. Runup elevation vs. return frequency.

4.4.2 Implications of Each Method for FEMA Flood Hazard Mapping

For most of the Pacific open coast and of sheltered shorelines on any coast, the event selection method may not be the most appropriate method for two reasons: (1) event specification may be difficult and is not unique (there will not necessarily be a direct correspondence between the 1% annual chance water level and wave conditions), and (2) wave runup will determine the flood elevation for most shorelines, and the maximum wave runup may not necessarily result from the highest water level or the largest waves.

Thus, the response method, although more complicated and time consuming, may yield better results for most Pacific and sheltered coasts. One disadvantage of this method is that revisions to FIRMs will be more difficult to propose and review without a clear specification of events to model. It may be possible

to overcome this difficulty (e.g., by working backward from the calculated 1% annual chance runup elevation to one or more water level-wave condition combinations), but this remains to be seen.

4.4.3 Alternatives

Three alternatives are proposed for further study and comparison:

- event selection method (with one or more selected 1% annual chance events),
- response method (using a variety of statistical procedures), and
- hybrid approach (using both methods).

Of these, the hybrid approach requires further elaboration. Such an approach could involve limited use of the response method in a study region—to gain an understanding of the dominant processes/combinations that control the 1% annual chance flood elevation—and concurrent use of the event selection method based on those 1% combinations. In effect, limited use of the response method will help to guide, "calibrate," and extend the applicability of the simpler event selection method.

4.4.4 Proposed Studies for Phase 2

Two study areas are proposed for development, testing, and comparison of the alternative methods listed above: Imperial Beach, California, and Sandy Point, Washington. The latter is a sheltered shoreline where the event selection method has been applied already, but where a 29-year time series of water levels and winds, from which waves can be hindcast, are available for use with the response method and hybrid approach. The former is an open coast shoreline where wave and water level statistics have been compiled and the response method has been applied but where the event selection and hybrid approaches can be applied.

4.5 SUMMARY BY TOPIC AREA

4.5.1 Introduction to Technical Category Summaries

The brief subsections that follow provide concise summaries of Focused Study results in the 11 technical categories for the Pacific Coast. The summaries include a brief description of the topics and key issues and a set of recommendations for the Pacific Coast. The recommendations are split into recommended Phase 2 work and recommended future development. The work shown for Phase 2 will produce a set of guidelines specifically for the Pacific Coast and facilitate new and updated coastal flood insurance studies for map modernization.

The work in Phase 2 does not include all the recommended Critical, Important, Available, or Helpful topics. Recommended future development would further improve and expand the guidelines. Future development work is not funded at this time, but these recommendations serve as a reference for planning future FEMA technical guidance work. The following summaries are the direct result of the appended Focused Studies, which include additional discussions, information, and references on the topics.

STORM METEOROLOGY

Topics and Key Issues

This category covers not only storm meteorology, but also a number of flood frequency issues. Among these are two general methods to determine the 1% annual chance level of some coastal process, characterized as the Event Selection method and the Response-Based method. These terms refer to the manner in which the 1% annual chance coastal flood level is determined. In the Event Selection method, a single 1% offshore storm or wave event is selected with the assumption that if the effects of this single event are followed all the way to the shoreline, they will approximate the true 1% runup. This is a form of the "design storm" concept in the Response-Based method, all significant events are routed from offshore to their runup limits, and only then is the 1% annual chance level determined, based on the entire set of response calculations. The same general approaches apply to processes other than runup. This question is particularly important for the Pacific Coast, where wave effects may be associated with storms at great distance from the coast instead of only with local weather conditions.

There is little guidance in the current *G&S* that is directly transferable to the Pacific Coast regarding event of response methods. For the combination of astronomical tide and storm surge, the study contractor is required to "Describe the method by which the tidal elevation data are convolved with the surge data including tidal constants and tidal records". There is no guidance regarding the combined probability of separate processes such as storm surge and rainfall runoff in a tidal river, and there are no guidelines specifically for the Pacific Coast.

The following Storm Meteorology topic was identified by the TWG:

Critical – Topic 51, Combined Probability.

Key issues are:

- The basic flooding mechanism for the Pacific Coast is the combination of waves and high water, where high water is the sum of astronomical tide, storm surge, El Niño, and the static component of wave setup. On the Pacific Coast, the critical combination of these processes is not necessarily associated with a single defined storm type, such as hurricanes is on the Atlantic and Gulf coasts.
- A key issue is whether an Event Selection or a Response-Based method should be applied. The former associates one particular offshore storm or wave event one-to-one with the coastal parameter of interest. The latter considers the effects of a range of offshore conditions, propagating each to the shore, and determining the statistics of the computed responses at the shoreline.
- Candidate methodologies are available for both Event Selection and Response-Based studies including, for example, methods used in the PWA Sandy Point Study and the Tetra Tech Southern California study, as well as the HR Wallingford JOIN-SEA method. These methods require testing before more general guidelines can be written for the Pacific Coast.
- The performance and relative merits of these approaches may differ between open coast sites and sheltered waters. Consequently, it is recommended that case studies be performed in both types of environments to investigate strengths and weaknesses of alternative methods.

- Storm surge, while small on the Pacific Coast, may be addressed by both tide gage analyses and simplified one-dimensional modeling. Appropriate frequency methods will be required to implement the latter, possibly based on Joint Probability Methods (JPM), Empirical Simulation Techniques (EST), or Monte Carlo simulations.

- Tidal rivers subject to riverine flooding are also subject to coastal flooding, which may be entirely independent, or partly correlated. Guidance should be developed to establish the manner in which these processes are integrated in the final mapping (also see Topic 19 of the Hazard Zones Focused Study).

- The astronomical tide often makes a significant contribution to the total stillwater level. Methods to determine the combination of tide and tsunamis, and tide and surge should be established.

Recommended Approach

The recommended approach to these issues includes both the development and verification of methods based partly on the findings of case studies, and the preparation of new guidelines.

Currently available methods include the JPM, EST, and Monte Carlo for storm surge statistics; numerous runup models and methods; and methods for tide and surge combination. The principal problem of the combination of waves and high water has been treated in past studies by PWA and Tetra Tech, and is the subject of the HR Wallingford JOIN-SEA method.

Recommended Approach (Critical Topics)

- Discuss and define methods to determine the 1% annual chance coastal flood level, including consideration of Event Selection and Response-Based methods.

- Document specific methods such as those used in past PWA and Tetra Tech studies, and in the HR Wallingford JOIN-SEA method.

- Perform an Open Coast case study using selected alternative approaches.

- Perform a Sheltered Water case study using selected alternative approaches.

- Based on the above, write draft guidelines on these issues appropriate for Pacific Coast studies.

- Develop guidance for frequency analysis methods for use with Pacific storm surge modeling.

- Develop appropriate methods for the combination of riverine and coastal flood estimates in tidal waters subject to both.

- Develop guidance for the combination of tsunamis and tides.

Tasks associated with Topics defined by the TWG to be *Critical* were considered for completion in Phase 2. However, time and budget constraints in Phase 2 do not allow comprehensive treatment of all the *Critical* subtopics. The table below summarizes the tasks selected for completion in Phase 2, and those deferred for future consideration by FEMA.

Table 3
Storm Meteorology Recommendations – Pacific Coast

Topic Number	Topic/Subtopic	Timing	Recommended Approach
51	General Methods to Determine 1% Coastal Levels	Phase 2	Define Event Selection and Response-Based methods for both open coast and sheltered waters
51	Define Specific Methods, Tools, and Data Guidelines for 1% Analysis	Phase 2	Document specific methods including, for example, the PWA Sandy Point approach, the HR Wallingford JOIN-SEA method, and the FEMA/Tetra Tech 1982 approach.
51	Open Coast Case Study	Phase 2	Perform a case study comparing selected methods at a specific open coast site, preferably one for which prior data is available
		Future	Perform a case study with Monte Carlo Method (Wallingford) using multiple variables. The study will take into account wave related variables of swell (height, period and direction) and sea (height) as well as the still water elevation for the open coast.
51	Sheltered Water Case Study	Phase 2	Perform a case study comparing methods at a specific sheltered water site, preferably one for which prior data is available. Monte Carlo Methods will be applied for Sheltered Water.
51	Storm Surge Modeling Frequency Analysis	Future	Test and recommend methods to associate frequency with storm surge for Pacific Coast surge modeling; recommend appropriate data sources
51	Surge/Riverine Combination	Future	Prepare recommendations for the statistical combination of surge and a riverine runoff profile, with consideration of non-independence of the processes; See also Topic 19 of the Hazard Mapping Focused Study for simple mapping suggestions
51	Tsunamis and Tide	Future	Develop guidelines for the combination of tsunamis and tide, including a worked hypothetical example

STILLWATER

Topics and Key Issues

The following Stillwater topics were identified by the TWG:

Critical – Topics 54 and 55, Surge vs. Wave Height (Pacific Coast Surge Modeling)

Available – Topic 52, Non-Stationary Processes

Key issues are:

- Storm surge estimates can be based on an analysis of tide gage data in some regions. This is especially important on the Pacific Coast where storm surge may typically be on the order of only a foot or two, compared with levels of more than 10 feet common on the Atlantic and Gulf Coasts. Consequently, tide gage analysis may be adequate for Pacific Coast stillwater determination wherever gage data are available.
- The *G&S* do not include any significant discussion of appropriate methods for tide gage analyses.
- The *G&S* provide little guidance on the considerations which must go into a storm surge modeling effort, beyond the assumptions implicit in the use of the FEMA storm surge model.
- A simplified 1-D surge model for the Pacific would be a valuable tool. A suitable prototype for such a model is the one used by the Florida Department of Environmental Protection for Florida coastal construction jurisdiction delineation. Such a model is likely to be of sufficient accuracy for estimation of the small Pacific Coast surge levels, and could be applied in areas for which tide gage data is lacking.
- The *G&S* provide little guidance on the matter of non-stationary processes, and how they might affect both the determination of stillwater levels, and the interpretation of historical data used in a FIS.
- The primary non-stationary processes of concern are the relative change of sea level (sea level rise and/or land subsidence), and localized land subsidence associated, for example, with oil and water extraction or tectonic adjustment.
- Owing to improvements in computer technology, future storm surge modeling efforts can be expanded to a regional scope, providing greater uniformity and accuracy in the surge determinations at reduced cost. While this is true for the Pacific Coast, it is particularly pertinent to the Atlantic and Gulf Coasts.

Recommended Approach

The recommended approach for addressing these issues includes both the development and verification of analytical and modeling methods (tide gage analysis and development of a 1-D surge model), as well as general revision of the *G&S* to provide greater insight for study contractors into the requirements of coastal modeling and data interpretation. Information is available for development of guidance on non-stationary processes, and for development of general storm surge modeling guidance.

Recommended Approach (Critical and Available Topics)

- Provide guidance regarding methods for determining storm surge based on tide gage data.
- Identify data sources for sea level rise, land subsidence, and tides.
- Implement a simplified 1-D storm surge model and prepare guidelines for its use.
- Write general guidelines for Pacific storm surge modeling.
- Write guidelines on how to consider non-stationary processes in a coastal FIS.

Tasks associated with Topics defined by the TWG to be *Critical* or *Available* were considered for completion in Phase 2. However, time and budget constraints in Phase 2 do not allow comprehensive treatment of all the *Critical* and *Available* topics. The table below summarizes the tasks selected for completion in Phase 2, and those deferred for future consideration by FEMA.

Table 4
Stillwater Recommendations – Pacific Coast

Topic Number	Topic/Subtopic	Timing	Recommended Approach
55	Tide Gage Analysis	Phase 2	Select and test methods to extract surge estimates from tide gage data in multiple settings.
54	Tide Gage Analysis Guidelines	Phase 2	Document procedures for tide gage frequency analysis.
54	General Considerations for Surge Modeling	Phase 2	Based on the existing literature, describe the use of surge models and the factors which require consideration in performing a study.
54	Simplified Storm Surge Model	Phase 2	Develop a 1-D (bathystrophic) surge model based on the Florida Department of Environmental Protection methodology. Although primarily for Pacific Coast applications, the model may also be useful as an auxiliary tool for the Atlantic and Gulf Coasts.
		Future	Perform testing and example studies of the 1-D surge model and provide expanded Users Manual based on test results.
52	Non-Stationary Processes	Phase 2	Write general guidelines for the consideration of non-stationary processes (for example, relative sea level rise, land subsidence), including identification of major data sources. Include guidance on interpretation of historical data. Suggest documentation of projected map impact.

STORM WAVE CHARACTERISTICS

Topics and Key Issues

The following Storm Wave Characteristics topics were identified by the TWG:

Critical – Topics 4 and 5, Swell and Seas.

Available – Topic 1, Wave Definitions.

Key issues are:

- Sources of wave data, need to be identified.
- Two candidate models, until the updated WIS is ready for use, are the Oceanweather Global Re-analysis of Ocean Waves (GROW) model and Fleet Numerical Meteorology and Oceanography Center WAVEWATCH III model.
- Low frequency swell propagation can be accurately modeled from buoy or hindcast sites outside the islands into shore in the Southern California Bight. But an approach is needed to resolve the impact of local seas on the high frequency portion of the spectrum.
- Current *G&S* refers to the Shore Protection Manual (SPM; USACE, 1984) and Automated Coastal Engineering System (ACES; USACE). Update the *G&S* to be consistent with the Coastal Engineering Manual (CEM; USACE, 2003).
- The CEM method is This is a significant deviation from the SPM. Evaluation of CEM Procedures is needed before including CEM procedure in the *G&S*.
- Include in the *G&S* other Empirical Prediction Methods such as the Composite Fetch Method.
- Spectral Energy Models (SEMs) such as SWAN, STWAVE and MIKE OSW, are available. But, SWAN and STWAVE are not included in the FEMA Approved Numerical Models List.
- Comparisons of Empirical Prediction methods and SEMs are needed to continue using Empirical Prediction Methods and for introducing SEMs.
- Definitions are needed in the *G&S* of wave types (sea, swell, and tsunami) in both the time domain and the frequency domain. Two available resources are the CEM and the "List of Sea State Parameters" published by the International Association of Hydraulic Research.
- Specific guidance is needed on how the wave related terms relate to the coastal processes associated with flood studies, methodologies, and models.

Recommended Approach

Storm Wave Characteristics topics were classified by the project team as *Critical* and *Available*. The recommended approach involves revision to the *G&S* using available references and information, and detailed investigations of wave databases and a case study. Topic 5 (Nearshore Representation of Local

Sea for Southern California Bight) is a critical topic, but it is not studied under Phase 2 to accommodate other critical topics from other Focused Studies within the limited resources. Also, this topic can be studied together with regional wave transformation modeling for the Southern California Bight.

Recommended Approach (Critical and Available Topics)

- Recommend use of GROW database for sea and swell. Study the GROW database for one location. Confirm lack of bias and validate data with measured records. Check whether the dataset properly represented extreme events.
- Develop *G&S* for preparation of input data for wave transformation models based on GROW directional spectra.
- Describe the WIS Pacific Coast Database Development and guidance for use in flood insurance studies.
- Conduct a study of the available nearshore data for Southern California Bight to assess whether inclusion of the local wind will make a significant change in the high frequency part of the spectrum.
- Based on results from the study above, adopt one of the three alternatives: 1) assuming no change in wind-induced change in the spectrum, or 2) attempt to model wind-induced changes, or 3) treat changes to the wind wave portion of the spectrum as an independent variable and use joint probability analysis techniques
- Conduct a case study to compare results using CEM procedures to results using SPM procedures for restricted fetch condition is recommended.
- Conduct a Focused Study to compare results from the SEMs and traditional Parametric Models, using restricted fetch methods. Application procedures for the SEMs would be clarified, specifically wind field definition.
- Incorporate and refine the "Glossary of Coastal Terminology" directly from the USACE CEM and from the listings of notations and parameters in the January 1986 publication from the International Association for Hydraulic Research titled, "List of Sea State Parameters."
- Provide specific guidance on use of wave related definitions for physical processes applicable to coastal flood studies

Tasks associated with Topics defined by the TWG to be *Critical* or *Available* were considered for completion in Phase 2. However, time and budget constraints in Phase 2 do not allow comprehensive treatment of all the *Critical* and *Available* topics. The table below summarizes the tasks selected for completion in Phase 2, and those deferred for future consideration by FEMA.

Table 5
Storm Wave Characteristics Recommendations – Pacific Coast

Topic Number	Topic/Subtopic	Timing	Recommended Approach
4, 5	Sea and Swell for Pacific Coast	Phase 2	Review GROW dataset for one location. Check whether the dataset represents extreme events adequately. Confirm lack of bias in the database. Develop *G&S* on use of GROW and steps for developing input data to wave transformation models. Describe the WIS database development and potential use in coastal flood insurance studies.
4, 5	Nearshore Representation of Local Sea for Southern California Bight	Future	Conduct a study of the available nearshore data for Southern California Bight to assess whether inclusion of the local wind makes a significant change in the high frequency part of the spectrum. Based on the results of the above study, adopt one of the three alternatives: a) assuming no change in wind-induced change in the spectrum, or b) attempt to model wind-induced changes, or c) treat changes to the wind wave portion of the spectrum as an independent variable and use joint probability analysis techniques
4, 5	Wave Generation in Sheltered Waters	Phase 2	Compare CEM and SPM procedures using a case study (an existing FIS site) and clarify application of CEM in FEMA studies. Perform a case study to compare SEMs and traditional parametric models using restricted fetch methods.
4, 5	Wave Generation in Sheltered Waters	Future	Develop application procedure for SEMs including wind field definition based on detailed testing.
1	Wave Definitions	Phase 2	Using the compiled glossary of terms and notations (from CHL and IAHR sources), correlate each of key terms with the coastal methodologies and application. Prepare for application for Pacific Coast Guidelines

WAVE TRANSFORMATION

Topics and Key Issues

Wave Transformations are important processes that change wave characteristics when waves propagate toward shore. These are addressed as an intermediate step between forcing processes (wave generation) and response processes (wave setup, wave runup, and overtopping) in coastal flood studies.

Wave Transformation receives input from forcing processes (wave generation) and provides output to response processes (wave setup, runup, and overtopping). Coordination with the other Focused Study categories is necessary.

The following Wave Transformation topics were identified by the TWG:

Critical – Topic 7, CDIP California; Topic 8, Overall Wave Transformations; Topic 9, Dissipation.

Helpful – Topic 10, WHAFIS.

Important – Portions of Topic 7, CDIP and Topic 9, Dissipation.

Key issues are:

- Presently, the *G&S* do not include a description of wave transformations. The methods defined in the current *G&S*, (depth limited waves) are biased toward the Atlantic and Gulf Coasts, and are inadequate for the Pacific Coast.
- Flood insurance studies for sites in the Pacific Coast Region have addressed wave transformations with different levels of complexity. The *G&S* should address the selection of methods based on the physical parameters that are encountered in the wave transformation process.
- Wave transformation analysis is required to support wave setup calculations. In particular, methods describing wave breaking and associated momentum transfer are needed.
- Contemporary wave transformation models are available and necessary for use in future studies, but are not currently recognized by FEMA.
- The Coastal Data Information Program (CDIP) currently operates a regional model that hindcasts nearshore waves along the California coast. The model transfer functions are already available to transform deepwater wave spectra to nearshore spectra, but the windwave growth is not included in this model.
- Application of the CDIP wave transformation models in central and northern California is not complete.
- Wave dissipation due to bottom effects is not routinely considered in wave transformation processes. Study contractors need guidance on when and where to apply bottom dissipation mechanisms. Some guidance is available in the current *G&S*; but primarily addresses the Atlantic and Gulf Coasts.

- Overland wave propagation is common during extreme events in the Atlantic and Gulf Coasts, and the WHAFIS 3.0 software, approved by FEMA, is typically used. Overland wave propagation can be significant in some locations in the Pacific Region, but use of WHAFIS for Pacific Coast studies will require modifications to the wind speeds specified based on Atlantic and Gulf Coast conditions.

Recommended Approach

The recommended approach focuses on development of a combination of regional and local wave transformation tools. Considerable effort is required to implement these recommendations. Adequate attention must be devoted to coordination with guidelines development for Storm Wave Characteristics, Wave Setup, and Wave Runup.

Recommended Approach (Critical Topics)

- Write *G&S* for Wave Transformations, based on a review of available literature and experience gained by the application of models and methods.
- Review available literature and guidance on the range of applicability of contemporary computer models, recommend models for inclusion on the list of "Coastal Models Accepted by FEMA for NFIP usage", and provide guidance on their application to FEMA FISs.
- Research available literature on wave groups, infra-gravity waves, and shallow water spectra for input into wave setup and runup calculations.
- Evaluate adequacy of linear wave transformation models and needs to supplement these models. Place emphasis on representation of infragravity waves.
- Use the CDIP regional wave models to create 2 sets of wave transformation coefficients in Southern California: 1) for swell waves and 2) for local wind generated waves.
- Demonstrate the CDIP model skill for predicting nearshore wave conditions during large winter storms using existing buoy data (for the southern, central, and northern California coast).
- Create database, provide user's manual, and develop Fortran and MATLAB codes to assist contractors in using the CDIP model coefficients.
- Incorporate applicable sections of existing *G&S* for other geographical areas that cover the overland propagation and wave energy dissipation topics.
- Summarize available information on wave dissipation over marsh and mudflats in the Pacific. Develop criteria to evaluate importance of wave dissipation. Evaluate if changes to WHAFIS dissipation criteria are necessary.

Recommended Approach (Important or Helpful Topics)

- Apply CDIP regional wave transformation modeling for the California Coast.
- Consider expanding regional wave modeling for Washington and Oregon coasts using CDIP or other programs (e.g., WIS).
- Evaluate any limitations due to the linearity of the transformation models.

- Research on wind wave and swell spectra combination.
- Conduct field data collection for wave dissipation on Pacific Coast
- Develop *G&S* for WHAFIS application for the Pacific Coast

Tasks associated with topics defined by the TWG to be C*ritical* were considered for completion in Phase 2. However, time and budget constraints in Phase 2 do not allow comprehensive treatment of all the C*ritical* topics. *Important* topics cannot be completed within the time frame of the project. Topics characterized as *Helpful* were also deferred for future consideration due to their lower priority. The table below summarizes the tasks selected for completion in Phase 2, and those deferred for future consideration by FEMA.

Table 6
Wave Transformation Recommendations – Pacific Coast

Topic Number	Topic/Subtopic	Timing	Recommended Approach
8	Wave Transformation with and without Regional Models	Phase 2	Write *G&S* for Wave Transformations. Tasks: 1) conduct several Focused Studies to inform the Wave Transformations *G&S;* 2) use available publications to identify a range of methods; 3) develop criteria for level of analysis; 4) include development of guidelines for spatial coverage and wave parameters, and include use of regional models such as CDIP; 5) research available literature to adequately define wave groups, infragravity waves, shallow water spectra, etc. for input into wave setup and runup calculations; 6) review available literature and guidance on the range of applicability of contemporary computer models, recommend models for inclusion on the FEMA pre-approved coastal model list, and provide guidance on their application to FEMA FISs; 7) incorporate applicable sections of existing G&S for other geographical areas that cover the overland propagation and wave energy dissipation topics. (Topics 9 &10)
		Future	Evaluate wave transformation models using a selected data set.
7	California Regional Wave Transformation Models	Phase 2	Provide CDIP Southern California validation examples and a test case for testing other WT models; Provide guidance and Users Manual on use of CDIP models and model output such as existing model coefficients.
		Future	Use CDIP model to create 2 sets of wave transformation coefficients for southern California, 1) for swell waves and 2) for local wind waves; Expand CDIP for the California Coast. Validate the models for central and northern California; Create database, provide expanded user's manual, and develop Fortran and MATLAB codes to assist contractors in using the CDIP model coefficients. Consider expanding regional wave modeling for Washington and Oregon coasts using CDIP or other programs (e.g., WIS) at the appropriate time and depending on the need, recognizing that regional wave models are more logical in densely populated areas. Individual studies may be performed in sparsely located communities (see Topic 8). Evaluate any limitations due to the linearity of the transformation models. Conduct research on wind wave and swell spectra combination.
9	Wave Energy Dissipation over Shallow Flat Bottoms	Phase 2	Evaluate wave dissipation over marsh and mudflats in the Pacific Coast from available information; Develop criteria to evaluate importance of wave dissipation in FISs; Recommend changes to methods and WHAFIS dissipation criteria to the extent feasible.
		Future	Conduct field data collection to characterize wave dissipation over marsh and mudflats and other shallow, dissipative shores in the Pacific; provide expanded guidance for calculating wave dissipation.
10	Overland Wave Propagation	Future	Evaluate if changes to WHAFIS dissipation criteria are necessary (see Topic 9), and *G&S* modifications for Pacific Coast.

WAVE SETUP

Topics and Key Issues

The following Wave Setup topics were identified by the TWG:

Critical – Topics 44 and 45, Define, Document, Compile Data; Topic 46, Interim Method.

Important – Topic 47, Develop Ideal Method-Coupled; Topic 48, Dynamic Wave Setup.

Key issues are:

- Under the action of irregular waves, wave setup consists of a static component and a dynamic component. Owing to the long waves that occur on the Pacific Coast, the latter can be quite substantial.
- The setup on the Pacific Coast can be significantly larger than the wind and barometric components during a 1% annual chance event owing, in part, to the narrow continental shelf. Thus, the dominant components will be the astronomical tide and wave setup possibly augmented by an El Niño contribution.
- Dynamic wave setup needs to be addressed. The Pacific Coast may have dynamic wave setup conditions, and the current *G&S* for the Atlantic and Gulf Coasts are based on static.
- Wave setup will require specification of directional wave spectra as input at an offshore location seaward of wave breaking.
- Wave setup is included, to some degree, in wave runup measurements and methods.
- There are two approaches for calculating wave setup: 1) The Boussinesq models which, in principle, can calculate both wave setup and wave runup, and 2) Coupling of more conventional engineering approaches.

Recommended Approach

It is recommended that methodologies be developed and *G&S* written that address the following: 1) steady and dynamic setup components, 2) irregular waves [implicit in (1) above], 3) characterization of nearshore bathymetry, 4) a valid wave breaking model, 5) nonlinear and directional characteristics of S_{xx}, and 6) wave damping where appropriate. An effort should be made to ensure that the interim method address as many of the physiographic settings applicable to the Pacific Coast as possible. A program will be developed which will calculate wave setup using, as input, the wave spectra outside the breaking zone.

Recommended Approach (Critical Topics)

- Prepare definitions applicable to Pacific Coast.
- Based on an intercomparison of Boussinesq models and comparison with data sets, determine whether this type model is appropriate for calculating wave setup and wave runup. If applicable to setup, select one of several Boussinesq models for further application.

- Develop and document an engineering based approach for wave setup modeling along open coasts and in sheltered waters based on methods and procedures available from past studies and literature and for specific types of input data (e.g., wave spectra). Note: This task would be reduced if Boussinesq models are selected.

- Compile potential data sources for testing a new Pacific Coast setup model.

- Develop breaking zone model with particular emphasis on wave setup, proof test, compare with data sets, refine, and write User's Manual. Note: The first portion of this task would be reduced if Boussinesq models are selected.

Recommended Future Development (*Important* Topics)

- Develop Ideal Methodology coupling storm surge and wave models to calculate static wave setup.

- Develop procedure for dynamic wave setup

Tasks associated with Topics defined by the TWG to be *Critical* were considered for completion in Phase 2. However, time and budget constraints in Phase 2 do not allow comprehensive treatment of all the *Critical* topics. *Important* topics cannot be completed within the time frame of the project. The table below summarizes the tasks selected for completion in Phase 2, and those deferred for future consideration by FEMA.

Table 7
Wave Setup Recommendations – Pacific Coast

Topic Number	Topic/Subtopic	Timing	Recommended Approach
44, 45	Pacific Coast Definitions	Phase 2	Develop wave setup definitions with emphasis on Pacific Coast applications.
46	Evaluate Boussinesq Models	Phase 2	Intercompare at least three Boussinesq models and compare with data.
46	Develop Engineering Based Approach	Phase 2	Couple accepted engineering models for calculating wave setup across surf zone. Include procedure for dynamic wave setup.
44, 45	Compile Data for Testing	Phase 2	Locate as much quality field data as possible for testing of developed/selected approach(es).
44, 45	Compile Data for Testing	Future	Locate and compile comprehensive national and international data sources for testing a new Pacific Coast setup model
46	Develop Breaking Zone Model	Phase 2	Evaluate candidate breaking zone models that allow specification of non planar profile.
46	Develop Draft Guidelines and Specifications	Phase 2	Incorporate findings from above into draft Guidelines and Specifications.
46	Develop Interim Method	Future	Test Model over a wide range of settings and develop and expand User's Manual based on test results.
47	Ideal Model for Static Wave Setup	Future	Couple wave generation and wave setup model, allowing specification of arbitrary tide.
48	Develop Model for Dynamic Wave Setup	Future	Develop method based on directional and nonlinear spectrum as input.

WAVE RUNUP AND OVERTOPPING

Topics and Key Issues

The following Wave Runup and Overtopping topics were identified by the TWG (Note that some of the workshop-assigned priorities and topic details were revised during the Focused Study):

Critical – Topic 12, Mean vs. higher value; Topic 11, Methods and models.

Important – Topic 14, Wavecast debris.

Available – Topic 49, WRUP™; Topic 13 Overtopping volumes.

Key issues are:

- Wave runup and overtopping will control BFEs and flood hazard zones along much of the Pacific Coast, where storm surges are low and where WHAFIS-type analyses yield low wave crest elevations. Wave runup analyses must be undertaken along those shore types analyzed for runup along the Atlantic and Gulf Coasts, plus low-profile beaches and barriers.
- Extreme runup levels tend to occur during El Niño events along the entire Pacific Coast (and possibly during hurricane events for southern California). Infragravity motions are more common and more significant on the Pacific Coast than the Atlantic or Gulf Coasts.
- Runup methodologies need to be tested against Pacific data sets that include El Niño events and infragravity waves. Wave setup may be calculated separately or included in wave runup estimates, but must be considered.
- Mapping the mean runup value may fail to adequately capture wave runup hazards.
- Mapping hazard zones with the mean overtopping rate should be sufficient, provided the thresholds for mapping hazard zones recognize the rates tolerated by buildings and structures.

Recommended Approach

The recommended approach involves a detailed evaluation and testing of available wave runup and overtopping methods and models, using Pacific Coast data sets, in conjunction with testing during other studies, particularly case studies in the Storm Meteorology Group.

Recommended Approach (Critical and Available Topics)

- Evaluation of CDIP-type and Oregon-type methods as interim methods for use until more detailed runup testing and runup calculation procedures are developed.
- Limited testing of the RUNUP 2.0 methodology in conjunction with storm meteorology, wave transformation and wave setup tasks.
- Evaluation of Pacific Coast wave runup data, including consideration of wave runup elevation distributions and associated structural damages. The $R_{50\%}$ runup value will be evaluated with regard

to its ability to capture damaging wave runups. If appropriate, an alternate $R_{x\%}$ value will be recommended and an interim procedure will be developed to adjust RUNUP 2.0 results.

- More comprehensive testing of wave runup methods and models is recommended, along with the identification of appropriate runup calculation procedures for a wide variety of shore types, profile characteristics, and incident water level and wave conditions.
- Evaluate WRUP™ and compare with other models.
- Overtopping methods and data will be evaluated to determine whether NFIP thresholds for mapping landward flood hazard zones are consistent with recent literature on "acceptable" overtopping quantities.
- Update procedures for calculating overtopping and ponding on low bluffs, with gently sloping or adverse slopes.

Recommended Approach (Important Topics)

Review and refine methods for defining flood hazards from wave-cast debris. This task will be undertaken in the hazard zone study.

Tasks associated with Topics defined by the TWG to be *Critical* or *Available* were considered for completion in Phase 2. The *Important* Topic (Topic 14, wavecast debris) will be completed with the Hazard Zone Study within the time frame of the project. Time and budget constraints in Phase 2 do not allow comprehensive treatment of all the *Critical* and *Available* topics. The table below summarizes the tasks selected for completion in Phase 2, and those deferred for future consideration by FEMA.

Table 8
Wave Runup and Overtopping Recommendations – Pacific Coast

Topic Number	Topic/Subtopic	Timing	Recommended Approach
Topic number not assigned	Runup on Beaches and Low Barriers	Phase 2	Revise guidance to call for runup analyses for sandy beach, small dune shore type
12	Evaluate Use of Mean Runup Value	Phase 2	Evaluate use of $R_{50\%}$ and select alternate $R_{x\%}$ value (probably between $R_{33\%}$ and $R_{10\%}$) if $R_{50\%}$ understates observed hazard. Develop an Interim procedure to adjust RUNUP2.0.output.
12	Evaluate Use of Mean Runup Value	Future	Review runup distributions for beaches and structures during El Niño, coastal storm and hurricane conditions; review runup damages.
11	Wave Setup Component	Phase 2	Current FEMA methodology includes the wave setup component in the calculated runup height. This procedure should be revisited for its appropriateness along the Pacific, and depending on recommended Pacific methodology (coordinate with Wave Setup study)
11	Infragravity Motions	Future	Consider effects of infragravity motions, which amplify runup and overtopping, and can be substantial along the Pacific Coast
11	Wave Setup Component	Phase 2	Current FEMA methodology includes the wave setup component in the calculated runup height. This procedure should be revisited for its appropriateness along the Pacific, and depending on recommended Pacific methodology (coordinate with Wave Setup study)
11	Conduct Comparative and Sensitivity Testing of Runup Models and Methods	Phase 2	Evaluate CDIP-type and Oregon-type methods as interim approaches. Coordinate with case studies in Storm Meteorology, Wave Transformation studies. Test runup methods and models in conjunction with other tests (use common data sets to test wave generation through stillwater level and runup).
11, 49	Conduct Comparative and Sensitivity Testing of Runup Models and Methods	Future	Identify appropriate runup methods and models by location, morphology and hydraulic conditions. Compare results using simple methods versus numerical models, deterministic (event selection) versus statistical approaches. Write Guidelines on input conditions uncertainty.
13, 14	Overtopping Rates	Phase 2	Maintain use of mean overtopping rate (cfs/ft, $m^3/m^3/s$ per m) Determine damaging overtopping rates for buildings and evaluate current FEMA hazard zone thresholds. Evaluate FEMA's guidance which limits the runup elevation to 3 feet above a barrier's crest elevation Coordinate with Hazard Zone study.
13	Overtopping Rates	Future	Overtopping at low profile beaches and barriers, dune remnants, revetments, and vertical walls should be evaluated, including consideration for calculating overtopping and ponding on low bluffs with gently sloping, flat or adverse slopes.

EVENT - BASED EROSION

Topics and Key Issues

The following Event - Based Erosion (EBE) topics were identified by the TWG:

Critical – Topic 30, Geometric Techniques; Topic 33, Cobble/Shingle Effects; Topic 35, Erosion in Sheltered Waters.

Available – Topic 31, Bluff Erosion; Topic 32, Geometric Methods for Bluff Erosion; Topic 41, Long-term Erosion; Topics 42 and 43, Nourished Beaches.

Important – Topic 34, Geometric Methods for Cobble/Shingle Beaches; Topic 36, Geometric Methods for Sheltered Waters; Topic 38, Process-Based Methods.

Helpful – Topic 40, Document vertical erosion depths.

Key issues are:

- Guidance for evaluating EBE remains unchanged since 1989 and focuses primarily on effects of extreme storms (hurricane or northeasters) along the Atlantic and Gulf Coasts, with a modified approach for the Great Lakes Coasts. Coastal erosion processes and storm characteristics found on the Pacific Coast differ dramatically from those along the Atlantic, Gulf, or Great Lakes.
- FEMA *G&S* can be improved by expanding or adding discussions on potential effects of EBE on runup and base flood elevation.
- The eroded beach profile that exists during the base event is needed in order to calculate the 1% annual chance flood elevation.
- Improved EBE *G&S* and new *G&S* need to embody the same fundamental structure that includes: 1) physiographic and geomorphic setting, 2) sediment characteristics across the active profile, 3) time histories of wave and storm tide characteristics, and 4) local or regional oceanic (El Niño) or topographic (recent tectonic adjustments) characteristics that may affect the study area. Consideration of this common structure will ensure that EBE assessments will be consistent for all applications.
- Guidance for evaluating erosion of cobble/shingle beaches is needed.
- Guidance for evaluating erosion of sandy and non-sandy bluffs and cliffs is needed.
- Guidance for evaluating erosion within sheltered water areas is needed.
- Present *G&S* provide no specific guidance on how to address beach nourishment projects.
- Present *G&S* can be improved by adding discussions of the seasonal effects of littoral as well as off-shore and on-shore sand transport and how those processes may affect beach erosion and seasonal changes in beach profiles that occur along the Pacific Coast

- Existing *G&S* can be improved by better defining "storm-induced erosion" or EBE, and different approaches for assessing beach and back beach profile changes due to erosion on all coasts of the U.S.

- Process based numerical models (1-D and 2-D, steady and unsteady) may provide improved means for assessing EBE. Evaluation of process-based models and comparison of their results with those from geometric methods is recommended

Recommended Approach

Event Based Erosion topics were classified by the project team as *Critical*, *Available*, *Important* and *Helpful*. Initially, the *G&S* should be updated using available references and information to address topics presently covered in the *G&S*. New *G&S* for the Pacific Coast will include new information and methods for assessing EBE in a variety of settings as discussed in the Focused Studies. New methods will fall into three categories and levels of effort: 1) eroded profiles based on available historical mapping and photographs, 2) profiles based on simplistic empirical methods, and 3) profiles developed from process-based (steady and unsteady) models.

Recommended Approach (Critical and Available Topics)

- Provide interim EBE *G&S* based primarily on historical beach profiles and field observations.

- Develop guidance for determining a "Most Likely Winter Beach Profile" for different settings on PC, including areas of beach nourishment.

- Evaluate and test selected geometric methods for beach and dune erosion applications along the Pacific Coast. Methods should include effects of storm duration and sediment erodibility. Document results.

- Provide discussion of bluff and cliff erosion in different settings to distinguish this type of erosion hazard from other erosion processes; provide examples, figures, and definitions.

- Develop interim approach for assessing bluff and cliff erosion in different settings based on historical profile data.

- Provide discussion of gravel, cobble, and shingle beach and dune erosion in different settings to distinguish this type of erosion hazard from other erosion processes; provide examples, figures and definitions; explain limitations of existing 540 sf Criterion for application to this type of erosion and setting.

- Develop interim approach for assessing gravel, cobble, and shingle beach and dune erosion based on historical beach profile data.

- Provide definitions and discussion of EBE found in sheltered water areas for *G&S*; provide interim *G&S* based on historical beach profiles and field observations.

- Provide language in *G&S* directing study contractors to notify FEMA if their study area includes a beach nourishment area and provide FEMA with a list of information needed to assess special cases where beach nourishment may be considered in determining hazard zones and BFEs (as an exception to existing policy).

Recommended Approach (*Important* Topics)

- Continue to develop and test geometric methods and process-based numerical models for beach and dune erosion applications along the Pacific Coast. Methods should include effects of storm duration and sediment erodibility. Document results and prepare updates for *G&S*.
- Prepare improved *G&S* for assessing bluff and cliff erosion in different settings.
- Evaluate/develop methods (geometric or process-based) for assessing gravel, cobble, and shingle beach and dune erosion.
- Long-term processes are considered important to NFIP, but FEMA action on previous work is pending. Therefore, guidance is best developed by FEMA in the Future
- Perform future pilot EBE study(s) in sheltered waters; refine interim assessment procedures; consider use of process based p-b models; prepare updated *G&S*.
- Develop suite of process based models for general coastal erosion assessments for different settings and material types, including sheltered waters.

Tasks associated with topics defined by the TWG to be *Critical* or *Available* were considered for completion in Phase 2. However, time and budget constraints in Phase 2 do not allow comprehensive treatment of all the *Critical* and *Available* topics. *Important* topics can not be completed within the time frame of the project. The *Helpful* topic was deferred for future consideration due to its lower priority. The table below summarizes the tasks selected for completion in Phase 2, and those deferred for future consideration by FEMA.

Table 9
Event Based Erosion Recommendations – Pacific Coast

Topic Number	Topic/Subtopic	Timing	Recommended Approach
30	Geometric Methods for Assessing Erosion	Phase 2	Evaluate geometric methods and models. Develop *G&S* for determining most likely Pacific winter beach profile, including beach nourishment areas. Evaluate geometric modeling procedures for sand beaches and dunes on PC and test with available data sets. At a minimum, prepare interim *G&S* methods based on historical beach profiles and field observations.
31, 32	Bluff and Cliff Erosion	Phase 2	Review available literature and reporting; provide language and descriptions to PC *G&S* to distinguish bluff and cliff erosion from other processes; provide figures and examples. Review existing bluff erosion procedures and international literature. Discuss interim approach for estimating bluff and cliff erosion based on historical profile data.
		Future	Develop geometric procedures for bluff and cliff erosion and retreat. Consider development and use of process-based numerical/statistical modeling methods for future inclusion in the NFIP program.
33, 34	Gravel, Cobble, and Shingle Beach and Dune Erosion	Phase 2	Provide discussion of gravel, cobble, and shingle beach and dune erosion in different settings to distinguish this type of erosion hazard from other erosion processes. Provide examples, figures and definitions. Discuss a simplified interim approach for cobble/shingle beaches based on historical beach profiles.
		Future	Explain limitations of existing 540 Criterion for application to this type of erosion and setting. Discuss simplified *interim approach* for assessing gravel, cobble and shingle beach and dune erosion based on historical beach profile data. Develop geometric procedures for gravel, cobble and shingle beach erosion. Consider development and use of process-based numerical/statistical modeling methods for future inclusion in the NFIP program.
35, 36	*G&S* in Sheltered Water areas	Phase 2	Provide definitions and discussion of EBE found in sheltered water areas for *G&S;* provide interim *G&S* based on historical beach profiles and field observations
		Future	Perform future pilot EBE study(s) in sheltered waters; refine interim assessment procedures; consider use of process-based models; prepare updated *G&S*
38	Physics/Process Based Methods	Phase 2	Discuss difference between simplified geometric methods and Processed-Based models.
		Future	Develop suite of Processed-Based models for general coastal erosion assessments for different settings and material types, including sheltered waters and overwash
40	Document vertical depths of erosion	Future	Document depths of erosion following storm events and maintain data for depths of erosion and damages to buildings in order to better determine "depth-damage" relationships.
41	Long-term Erosion	Future	This topic is considered important to NFIP, but FEMA action on previous work is pending. Therefore, guidance is best developed by FEMA in the future.
42, 43	Nourished Beaches	Phase 2	Provide language in *G&S* directing study contractors to notify FEMA if their study area includes a beach nourishment project and provide FEMA with a list of information needed to assess special cases where beach nourishment may be considered in determining hazard zones and

Table 9 Event Based Erosion Recommendations – Pacific Coast			
Topic Number	Topic/Subtopic	Timing	Recommended Approach
			BFEs (exception to existing FEMA policy).

COASTAL STRUCTURES

Key Topics and Issues

The following Coastal Structures topics were identified by the TWG:

Available – Topic 21, Failed Structures; Topic 23, Buried Structures; Topic 25, Flood Protection Structures; Topic 27, Coastal Levees.

Important – Topic 24, Structures-Tsunamis.

Helpful – Topic 22, Failed Structure Configuration; Topic 26, Adjacent Properties.

Key issues are:

- Coastal structures can modify flood levels, wave effects, and topography landward, seaward, and adjacent to the structures, and must be considered during the mapping of coastal flood hazards. Two scenarios are commonly encountered: 1) Structures and their effects are analyzed during Flood Insurance Studies, and 2) Structures frequently serve as the basis for revisions to FIRMs. Treatment of structures in these two cases should be consistent.
- FEMA *G&S* can be improved by expanding or adding discussions on coastal structure failure, buried structures, and the effects of structures.
- The effects of structures can be divided into two categories; effects on erosion and effects on flood conditions. Two scenarios are important for each: 1) The effects of structures on adjacent properties, and 2) The effects on property immediately landward and seaward of a structure.
- Guidance for evaluating coastal structures has been largely unchanged since publication of the USACE report CERC TR 89-15 in 1989. The evaluation criteria and guidance need to be reviewed considering more recent publications and information. Revisions may or may not be warranted.
- Guidance needs to clearly state that study contractors are not required to use CERC TR 89-15.
- Guidance on the evaluation of coastal structures in tsunami-prone areas is needed.
- FEMA *G&S* call for structure "removal" from subsequent flood hazard analyses in the event that a structure fails (i.e., does not survive the base flood event), but guidance on uncertified structure removal should be expanded and revised. More importantly, the configuration of a failed structure can affect wave runup and overtopping calculations. A method to address uncertified structures, used in a recent Pacific Coast flood study (by PWA), has been modified by the Focused Study and is recommended for use.
- Coastal structures and levees are sometimes treated differently, and those differences should be justified or eliminated. The *G&S* should address coastal levees.
- FEMA *G&S* were written primarily considering seawalls, bulkheads, revetments, and do not address the effects of other structure types (e.g., jetties, groins, breakwaters). While treatment of these other structures is needed, it is deemed a lower priority than revising the guidance related to seawalls, bulkheads, revetments, and levees.

Recommended Approach

The recommended approach involves making revisions to the *G&S* using available references and information. The effort will be modest by comparison with some of the other Focused Study topics.

Recommended Approach (Available Topics)

- Buried structures and failed structure configurations (including progressive collapse of revetments).
- Treatment of failed ("removed") structures for wave height and runup analyses.
- Investigation of structure effects on erosion and flood hazards.
- Consistency in treatment of coastal structures and coastal levees.
- Work with Tsunami Group to develop guidance for evaluating structures in tsunami-prone areas.

Recommended Approach (Helpful Topics)

- Revision/update of CERC TR 89-15 coastal structure evaluation criteria.
- Development of minimum structure characteristics necessary to receive mapping credit during Flood Insurance Studies and flood map revisions.
- Revision of guidance to consider coastal jetties, groins and breakwaters.

Tasks associated with Topics defined by the TWG to be *Available* were considered for completion in Phase 2. However, time and budget constraints in Phase 2 do not allow comprehensive treatment of all the *Available* topics. Topic 26, characterized as *Helpful*, was deferred for future consideration due to its lower priority. However Topic 22, which is also characterized as *Helpful*, was included for completion in Phase 2 because the topic has been a significant one in past FIS work in the Pacific Coast. The table below summarizes the tasks selected for completion in Phase 2, and those deferred for future consideration by FEMA.

Table 10
Coastal Structures Recommendations – Pacific Coast

Topic Number	Topic/Subtopic	Timing	Recommended Approach
21a, 21b.1, 23	Failed and Buried Structures	Phase 2	Revise guidance to better describe buried structures and failed structure configurations (including progressive failure of revetments).
22a, 22b	Wave Effects Analyses at Failed Structures	Phase 2	Using modified PWA method, write guidance for mapping runup and overtopping at uncertified (or failed) coastal structures.
25	Flood protection Structures	Phase 2	Mention in guidance, detailed TR 89-15 evaluation/certification of coastal structures are not required during FIS, but discuss implications
26a, 26b, 26d	Effects of Structures on Erosion, Flood Hazards	Phase 2	Investigate effects of structures on erosion and flood hazards; develop guidance for incorporation into flood hazard mapping.
27a	Coastal Levees and Structures	Phase 2	Identify and resolve inconsistencies in treatment of coastal levees and coastal structures
24	Tsunami-prone Structures	Future	Investigate historical data on structure failure/success during tsunamis; develop evaluation criteria for tsunami-prone structures.
27b, 27c	Structure Evaluation Criteria	Future	Review CERC TR 89-15 considering more recent data on structure stability and failure; revise structure evaluation criteria for existing and new structures.
21b.2	Jetties, Groins, Breakwaters	Future	Develop criteria/guidance for evaluating failure of other structure types, and the effects of these failures on mapped flood hazards
26e	Minimum Structure Dimensions	Future	Determine minimum structure dimensions necessary to receive mapping credit during FIS and revisions to FIRMs

TSUNAMI

Topics and Key Issues

The following Tsunami topics were identified by the TWG:

Critical – Topic 15, National Tsunami Hazard Mapping Program (NTHMP); Topic 16, 100-year recurrence.

Important – Topic 20, Structure-Debris Interaction; Topic 29, Erosion.

Key issues are:

- NOAA tsunami inundation maps presently show the maximum credible tsunami inundation limits. Since a return period was not assigned to NOAA maps, the actuarial needs of NFIP are not served by NOAA maps. Another drawback of the NOAA maps in California is that only nearfield events are considered and farfield events are not. However, NOAA maps can be a part of FEMA's multi-hazard mapping efforts.
- NOAA maps are useful, but FIS studies require consideration of 1% annual chance flood.
- Present NOAA procedures do not account for farfield events; only nearfield events are considered.
- The NTHMP has identified sources of Tsunami risks for Southern and Central California (local and distant earthquakes, and coseismic or aseismic subaerial and subaqueous slides), Northern California to Northern Washington (Cascadia Subduction Zone Earthquakes, coseismic or aseismic subaerial and subaqueous slides), Puget Sound (local earthquakes and, coseismic or aseismic subaerial and subaqueous slides and from delta failures). The issue is to determine which of these sources will contribute significantly to the 1% annual chance base flood elevation required for Flood Insurance Maps. Some of these sources may produce infrequent tsunamis with small runup elevations and may not be considered for the NFIP.
- Past FEMA Tsunami Mapping methods were developed by Houston and Garcia (1978). The limitations of their methods are: 1) only farfield events from Alaska and South America are considered and potential rupture of Cascadia Subduction Zone had not been recognized at that time; 2) the computational boundary is a vertical wall at the shoreline; and 3) faults are modeled as a simple, rapid uplift of the ocean floor. Improved methods have been developed since the 1970s and 1980s when the Houston and Garcia procedures were applied first along the Pacific Coast. FEMA needs reliable methods that will utilize state-of-the-art long wave propagation models and geophysics based probabilistic procedures to define the magnitude and probability of the forcing function for such rare events.
- FEMA needs a method that recognizes hazards from multiple tsunami sources, utilizes the knowledge available within the tsunami community in terms of source identification; geophysics based probabilistic assessments, and propagation modeling. Tsunami anomalies in tide records, where available, may be used in modeling and verification of results.

- High velocities are associated with tsunamis. Current mapping practices call for the statistical combination of tsunami runup frequency curves and storm wave runup frequency curves. A new methodology is needed to depict the hazards associated with high velocity tsunami waves propagating landward from the coastline.

- Methods for calculating debris impact loads on structures are needed. Such methods may lead to development of *G&S* for assessing the performance and survivability of coastal structures during a 1% annual chance event tsunami.

- Little is known about the physics of tsunami induced erosion. Post-tsunami observations show that tsunami induced erosion damages can be severe. Therefore, procedures for estimating likely changes in beach and back beach profiles are needed in order to determine tsunami runup elevations.

Recommended Approach

It is recommended that a Probabilistic Tsunami Hazard Assessment (PTHA) methodology be developed for NFIP purposes. The procedure will be based on an integrated, interdisciplinary, and highly focused six-month pilot study to define the tsunami hazards in a specific locale in Washington, Oregon, or California by carefully examining the NTHMP and NFIP methods and tools. The pilot study will combine recommendations from both Critical Topics 15 and 16. Topics 20 and 29 require longer-term fundamental research and are recommended for future consideration.

Recommended Approach (Critical Topics)

The recommended work will focus on Topics 15 and 16:

- Develop geologic and geophysical digital database.

- Develop a methodology suitable for NFIP tsunami hazard zone delineations, including recurrence interval estimation. The methods are likely to use existing NTHMP products and procedures.

- Conduct a six-month pilot study to develop procedures for defining tsunami hazards along the Washington, Oregon, or California coast

Recommended Approach (Important Topics)

- Estimate impact forces on typical coastal structures using overland flow depths and velocities from the numerical tsunami simulations performed above for one coastal location.

- Examine available USGS post-tsunami erosion data. Attempt to develop a simplified empirical relationship for approximating changes in beach profiles during a 1% annual chance tsunami for the specific locale under study.

Unlike the other ten work categories detailed in the Phase 1 Report, some of the tsunami research and development tasks recommended here are being considered for completion under an interagency agreement between FEMA and NOAA. This applies primarily to Topics 15 and 16. Therefore, the majority of recommended tasks associated with Topics 15 and 16 are shown below as future tasks along with Topics 20 and 29, below.

Table 11
Tsunami Recommendations – Pacific Coast

Topic Number	Topic/Subtopic	Timing	Recommended Approach
No Topic No assigned	Prepare General Procedures for Pacific Coast *G&S*	Phase 2	Prepare guidance for use of information and hazard mapping work products produced by NOAA under Topic numbers 15 and 16, below. Include these procedures in the general *G&S* for the Pacific Coast.
15	Address Use of NTHMP Program Products and Approaches	Future	Develop digital database. Develop method suitable for NFIP tsunami hazard zone delineations, including recurrence interval estimation.
16	Develop Method to Predict 100-year Tsunami Event	Future	Perform comprehensive pilot study at a selected site in California or Oregon or Washington to develop and test numerical methods for: 1) Improve recurrence interval estimating procedures for farfield and nearfield sources by increasing the coverage and quality of the historic and prehistoric tsunami records and develop probability distributions for both tsunamigenic earthquake and landslide sources. 2) Estimate the 1 percent chance tsunami 3) Test procedures for propagating tsunamis from Alaska, Chile, and Cascadia Subduction Zone to the Pacific Coast. Verify model predictions with tidal records, if available 4) Calculate runup and inundation elevations 5) Calculate combined probability distribution of tsunami runup and storm wave generated runup (if data are available).
20	Tsunami-Structure–Debris Interaction To Define Hazard Zones	Future	Estimate impact forces on typical coastal structures using overland flow depths and velocities from the numerical tsunami simulations performed above for one coastal location.
29	Review Methods of Tsunami Induced Erosion	Future	Examine available USGS post-tsunami erosion data. Attempt to develop a simplified empirical relationship for approximating changes in beach profiles during a 1% annual chance tsunami for the specific locale under study.

SHELTERED WATERS

Topics and Key Issues

The following Sheltered Waters topics were identified by the TWG:

Critical – Topic 6a, Definitions and Classification; Topic 6b, Historical Information; Topic 6d, 1% Annual Chance Flood Event; Topic 6e, Stillwater Elevations and Tidal Currents, Topic 6f, Coastal Structures (covered in 21a); Topic 6g, Hazard Zones (covered in 17); Topic 6h, Inter-Relationships.

Key issues are:

- Sheltered Waters (SW) are water bodies with shorelines that are not subjected to the direct action of undiminished ocean waves. Although similar processes contribute to flooding in sheltered water shorelines as along open coastlines, such as wave setup, runup, and overtopping, there are several aspects of sheltered water flood hazards not addressed in current *G&S*.
- Wave generation and transformation in SWs are typically limited by an open water fetch distance, complex bathymetry, and often by the presence of structures. A sheltering effect typically reduces wave energy and flood potential compared to open coast areas. However, wave runup and overtopping along SW shorelines may present additional hazards from wave-cast debris and backshore flooding.
- Wave-cast debris from extreme wave runup and overtopping can be especially problematic, owing to the proximity to fluvial sources of such materials in many estuaries.
- SW areas often have unique flood hazards, due to the effects of fluvial drainages and modified tidal and surge hydrology, and relatively strong tidal currents.
- Other unique flood-related characteristics include the complex geometry of embayments, non-coincidence of peak storm surge with peak winds, shallow water and restricted wind fetches for wave growth, and non-sandy shoreline types with special erosion and scour hazards.
- New guidelines are needed to inform and guide Mapping Partners in the preparation of coastal flood insurance studies and flood hazard maps in sheltered water areas of the coastal floodplain.

Recommended Approach

Sheltered waters topics were classified by the project team as *Critical* to the Pacific studies and applicable to all coasts. The recommended approach involves revisions to the *G&S* that will: 1) better define, provide examples, and classify SWs and associated physical processes that contribute to flooding; 2) expand existing guidance for SW areas using available references and information; 3) discuss river-tidal joint probability issues, 4) develop linkages between SW and other sections of the *G&S* and, 5) seek FEMA approval for methods used by Mapping Partners in recent Pacific Ocean sheltered water flood studies.

Recommended Approach (Critical Topics)

- Provide definitions, examples, and develop a classification method and general approach conducting SW studies versus open coast studies. This will serve as a framework and approach for Mapping Partners to follow when conducting coastal flood hazard assessments.
- Prepare general guidance for documenting and using high water marks to reconstruct historic flood conditions to validate flood study results.
- Prepare guidance specific to defining the 1% annual chance flood event, including consideration of the combined effects of riverine and tidal flooding.
- Expand guidance on wind data acquisition and analysis and on fetch-limited wave forecasting in SWs.
- Prepare guidance for estimating stillwater elevations in ungauged SWs bodies and evaluating the effects of tidal and riverine currents on wave propagation in SWs.
- Prepare guidelines that comply with other related FEMA Map Modernization objectives and multi-hazard planning initiatives.

Tasks associated with Topics defined by the TWG to be *Critical* were considered for completion in Phase 2. However, time and budget constraints in Phase 2 do not allow comprehensive treatment of all the *Critical* topics. The table below summarizes the tasks selected for completion in Phase 2, and those deferred for future consideration by FEMA.

In addition to the specific tasks listed in the table, the Sheltered Waters Phase 2 effort will involve collaboration and coordination with other study groups as indicated below:

- Work with the Storm Meteorology group to develop guidance for combined probability considerations for defining the 1% annual chance flood event in sheltered water areas (Topic 51).
- Work with the Stillwater group to develop general guidance for storm surge evaluation in sheltered waters using tide gage analysis and 1-D surge model (Topic 54 and 55).
- Work with the Wave Characteristics group to develop guidance on application of CEM and SPM methods, and to evaluate application of Spectral Energy Models and Empirical Prediction Methods in sheltered waters (Topics 4 and 5).
- Work with the Wave Transformation group to develop guidance on wave transformation (Topic 8), wave propagation over dissipative bottoms (Topic 9) and overland wave propagation (Topic 10) in SWs.
- Work with the Wave Setup group to develop guidance for defining wave setup in sheltered water settings (Topics 44, 45, 46).
- Work with the Event-Based Erosion group to develop guidance for erosion assessments in cobble/shingle materials (Topic 33) and general guidance for erosion assessments in sheltered water areas (Topic 35).

- Work with the Runup and Overtopping group to develop guidance for using mean versus higher runup heights (Topic 12) and estimating overtopping volumes for backshore hazard mapping along sheltered waters (Topic 13).
- Work with the Hazard Zones group to develop guidance for considering wave-cast debris (Topic 17) and mapping flood hazards from combined coastal-riverine flood areas (Topic 19).

Table 12
Sheltered Waters Recommendations – Pacific Coast

Topic Number	Topic/Subtopic	Timing	Recommended Approach
6a	Definitions and Classification	Phase 2	Provide definitions, examples, and develop a classification method based on SW physical processes and site characteristics that can be used during SW flood hazard studies.
6b	Flood Event Reconstruction	Phase 2	Review previous SW flood studies and document methods used for validating flood study results. Prepare general guidance for documenting and using high water marks to reconstruct historic flood conditions.
6d	Combined Tidal-Riverine 1% Annual Chance Event Assessment	Phase 2	Prepare guidance for defining the 1% annual chance flood event involving riverine and tidal flooding and expand guidance on wind data acquisition and analysis and fetch-limited wave forecasting.
6e	Stillwater Estimation	Phase 2	Prepare guidance for estimating stillwater elevations in ungauged sheltered waters bodies and evaluating the effects of tidal and riverine currents.
6h	Hazard Mitigation Coordination	Future	Prepare general guidance for Mapping Partners to coordinate the preparation of coastal studies with other hazard mitigation activities.
6h	Focused Study Coordination	Phase 2	Collaborate/coordinate with other study groups to address “Critical” sheltered waters topics found in other Focused Studies.
	PC Guidelines	Phase 2	Prepare general *G&S* section for assessing sheltered water areas on the Pacific Coast.

HAZARD ZONES

Topics and Key Issues

The following Hazard Zones topics were identified by the TWG:

Critical – Topic 17, VE Zone Limit.

Available – Topic 19, Combined Probabilities and Mapping for Areas Subject to Both Coastal and Riverine Flood Sources.

Important – Topic 18, VE/AE Zone Appropriateness; Topic 39, PFD Definition.

Key issues are:

- The existing definition of the primary frontal dune (PFD) is included in 44 CFR Section 59.1 of the NFIP regulations, and is based on "where there is a distinct change from a relatively steep slope to a relatively mild slope" in the land surface. The definition does not provide a quantitative method for defining the landward limit of the PFD, yet it has significant influence on hazard zone delineation The PFD definition and delineation also has implications for floodplain management, since dune areas within a VE Zone are protected under 44 CFR subsection 60.3(e)(7) of the NFIP regulations.
- Coastal high hazard zones are defined in 44 CFR Section 59.1 of the NFIP regulations to include the area up to the landward limit of the PFD along open coasts. In practice, this definition frequently dominates the determination of the VE Zone boundary. An improved definition or quantitative methodology is needed to improve consistency in hazard zone delineation. This issue is most applicable on the Atlantic and Gulf coasts where dunes are common, but also affects some areas of the Pacific Coast.
- The use of the PFD definition for VE Zone mapping may cause areas that are subject to significantly different levels of flood risk to be mapped in a single VE Zone. The seaward portion may be subject to inundation by active coastal processes during the base flood (erosion, wave height, wave runup, and wave overtopping), and the landward portion included solely on the basis of the PFD limit defined by topography.
- Transitions in the Base Flood Elevations (BFEs) are frequently abrupt where the PFD definition is used to establish a VE Zone limit, and the AE zone behind the PFD has a much lower computed BFE. Improved procedures are needed to accurately relate mapped BFEs to flood risk.
- The VE Zone limits are based on a breaking wave height of 3 feet or more and runup depths of 3 feet or more. The basis for these criteria is not clear, and they may underestimate areas subject to significant damage by coastal processes.
- The wave overtopping criteria presently used in VE Zone hazard mapping require expansion and review to evaluate threshold rates, extent of the mapped zones, and potential for use of VO Zones to more accurately reflect actual hazards landward of overtopped dunes, coastal ridges, and shore protection structures.

- Mapping procedures do not presently consider wave-cast debris (logs, stones, etc.), but these hazards are significant on the Pacific Coast. New procedures may be needed to identify areas subject to significant damages.

- Coastal SFHAs on the Pacific Coast are generally narrow and dominated by wave runup. Therefore, the distinction between seaward portions of AE Zones (that can be subject to severe coastal hazards) and more landward portions (that are subject to lesser flood and erosion hazards) is not deemed to be as significant an issue as on the Atlantic and Gulf Coasts. However, a nationwide review is needed to assess the feasibility of subdivision of the coastal AE Zone SFHA.

- A methodology is needed for determining and mapping flood hazard areas where coastal flooding intersects and combines with a riverine flood profile. Previous FEMA guidance should be reviewed for this purpose.

Recommended Approach

Hazard zone topics were classified by the Technical Working Group as *Critical*, *Important* and *Available*, and applicable to all coasts. The recommended approach to preparing *G&S* for the Pacific Coast has the purpose of clarifying existing guidance on coastal high hazard zones, describing FIRM hazard zone delineation using results from coastal analyses, expanding upon examples to include Pacific Coast typical conditions, and revising guidance using available references and information.

Recommended Approach (Critical and Available Topics)

- Establish improved procedures for establishing the landward limit of the PFD, and develop guidance to better map the BFE transition between PFD dominated VE Zones and landward SFHA hazard zones.

- Establish procedures (hazard identification and mapping) to better utilize VO Zones for areas subject to severe wave overtopping at dune ridges and coastal protection structures.

- Establish procedures for identifying and mapping coastal high hazard zones for wave overtopping and wave-cast debris hazards in SFHAs with historically significant damages from this unique hazard.

- Review the previous 1981 FEMA guidance and new guidance on how to conduct the assessment and mapping of combined coastal-riverine areas for adoption into the *G&S*.

Recommended Approach (Important Topics)

- Investigate and develop coastal A Zone criteria

- Prepare technical bulletins for clarification of proposed revisions to VE Zones, AE Zones, and new criteria for VO Zones related to hazard identification, mapping, and floodplain management.

- Develop new *G&S* examples of wave transect hazard mapping specifically for the expected conditions along the Pacific Coast and sheltered waters.

Tasks associated with Topics defined by the TWG to be *Critical* and *Available* were considered for completion in Phase 2. However, time and budget constraints in Phase 2 do not allow comprehensive treatment of all the *Critical* topics. *Important* topics cannot be completed within the time frame of the

project (although a limited number of mapping examples can be developed during Phase 2). The table below summarizes the tasks selected for completion in Phase 2, and those deferred for future consideration by FEMA.

Table 13
Hazard Zones Recommendations – Pacific Coast

Topic Number	Topic/Subtopic	Timing	Recommended Approach
17	Primary Frontal Dune VE Zone	Phase 2	Develop guidance to better map the BFE transition between PFD dominated VE Zones and landward SFHA hazard zones
17	Guidance on VO Zone Mapping	Phase 2	Establish procedures (hazard identification and mapping) to better utilize VO Zones for areas outside established VE Zones.
17	VE Zone Mapping Options & Criteria	Phase 2	Establish procedures for identifying and mapping wave overtopping and wave-cast debris hazard zones based on historical significance of hazard.
17, 39	VE Zone Limit and PFD Definition	Future	Establish improved procedures for establishing the landward limit of the PFD; test procedures in a case study
19	Combined Coastal-Riverine Zones	Phase 2	Review the previous 1981 FEMA or revised/new guidance on how to conduct the assessment and mapping of combined coastal-riverine areas for adoption into *G&S*.
Topic number not assigned	Hazard Zone Mapping Examples	Phase 2 and Future	Develop new hazard zone mapping examples in *G&S* specifically for the Pacific Coast.
18	Hazard Zones and Technical Bulletins	Future	Investigate and develop coastal A Zone criteria. Prepare technical bulletins for clarification of proposed revisions to VE Zones, AE Zones, and new VO Zones related to hazard identification and floodplain management. Develop an annotated bibliography of related research and apply new concepts in a case study.

4.6 SUMMARY OF TOPICS AND RECOMMENDATIONS – PACIFIC COAST

For easy reference, all of the Pacific Coast categories have been combined in one table, as follows.

Table 14
Summary of Pacific Coast Recommendations

Topic Number	Topic/Subtopic	Timing	Recommended Approach
STORM METEOROLOGY RECOMMENDATIONS – PACIFIC COAST			
51	General Methods to Determine 1% Annual Chance Coastal Levels	Phase 2	Define Event Selection and Response-Based methods for both open coast and sheltered waters
51	Define Specific Methods, Tools, and Data Guidelines for 1% Annual Chance Analysis	Phase 2	Document specific methods including, for example, the PWA Sandy Point approach, the HR Wallingford JOIN-SEA method, and the FEMA/Tetra Tech 1982 approach.
51	Open Coast Case Study	Phase 2	Perform a case study comparing selected methods at a specific open coast site, preferably one for which prior data is available
		Future	Perform a case study with Monte Carlo Method (Wallingford) using multiple variables. The study will take into account wave related variables of swell (height, period and direction) and sea (height) as well as the still water elevation for the open coast.
51	Sheltered Water Case Study	Phase 2	Perform a case study comparing methods at a specific sheltered water site, preferably one for which prior data is available. Monte Carlo Methods will be applied for Sheltered Water.
51	Storm Surge Modeling Frequency Analysis	Future	Test and recommend methods to associate frequency with storm surge for Pacific Coast surge modeling; recommend appropriate data sources
51	Surge/Riverine Combination	Future	Prepare recommendations for the statistical combination of surge and a riverine runoff profile, with consideration of non-independence of the processes; See also Topic 19 of the Hazard Mapping Focused Study for simple mapping suggestions
51	Tsunamis and Tide	Future	Develop guidelines for the combination of tsunamis and tide, including a worked hypothetical example
STILLWATER RECOMMENDATIONS – PACIFIC COAST			
55	Tide Gage Analysis	Phase 2	Select and test methods to extract surge estimates from tide gage data in multiple settings.
54	Tide Gage Analysis Guidelines	Phase 2	Document procedures for tide gage frequency analysis.
54	General Considerations for Surge Modeling	Phase 2	Based on the existing literature, describe the use of surge models and the factors which require consideration in performing a study.

54	Simplified Storm Surge Model	Phase 2	Develop a 1-D (bathystrophic) surge model based on the Florida Department of Environmental Protection methodology. Although primarily for Pacific Coast applications, the model may also be useful as an auxiliary tool for the Atlantic and Gulf coasts.
		Future	Perform testing and example studies of the 1-D surge model and provide expanded Users Manual based on test results.
52	Non-Stationary Processes	Phase 2	Write general guidelines for the consideration of non-stationary processes (for example, relative sea level rise, land subsidence), including identification of major data sources. Include guidance on interpretation of historical data. Suggest documentation of projected map impact.
STORM WAVE CHARACTERISTICS RECOMMENDATIONS – PACIFIC COAST			
4, 5	Sea and Swell for Pacific Coast	Phase 2	Review GROW dataset for one location. Check whether the dataset represents extreme events adequately. Confirm lack of bias in the database. Develop *G&S* on use of GROW and steps for developing input data to wave transformation models. Describe the WIS database development and potential use in coastal flood insurance studies.
4, 5	Nearshore Representation of Local Sea for Southern California Bight	Future	Conduct a study of the available nearshore data for Southern California Bight to assess whether inclusion of the local wind makes a significant change in the high frequency part of the spectrum. Based on the results of the above study, adopt one of the three alternatives: a) assuming no change in wind-induced change in the spectrum, or b) attempt to model wind-induced changes, or c) treat changes to the wind wave portion of the spectrum as an independent variable and use joint probability analysis techniques
4, 5	Wave Generation in Sheltered Waters	Phase 2	Compare CEM and SPM procedures using a case study (an existing FIS site) and clarify application of CEM in FEMA studies. Perform a case study to compare SEMs and traditional parametric models using restricted fetch methods.
4, 5	Wave Generation in Sheltered Waters	Future	Develop application procedure for SEMs including wind field definition based on detailed testing.
1	Wave Definitions	Phase 2	Using the compiled glossary of terms and notations (from CHL and IAHR sources), correlate each of key terms with the coastal methodologies and application. Prepare for application for Pacific Coast Guidelines
WAVE TRANSFORMATION RECOMMENDATIONS – PACIFIC COAST			
8	Wave Transformation with and without Regional Models	Phase 2	Write *G&S* for Wave Transformations. Tasks: 1) conduct several Focused Studies to inform the Wave Transformations *G&S*; 2) use available publications to identify a range of methods; 3) develop criteria for level of analysis; 4) include development of guidelines for spatial coverage and wave parameters, and include use of regional models such as CDIP; 5) research available literature to adequately define wave groups, infragravity waves, shallow water spectra, etc. for input into wave setup and runup calculations; 6) review available literature and guidance on the range of applicability of contemporary computer models, recommend models for inclusion on the FEMA pre-approved coastal model list, and provide guidance on their application to FEMA FISs; 7) incorporate applicable sections of existing *G&S* for other geographical areas that cover the overland propagation and wave energy dissipation topics. (Topics 9 &10)
		Future	Evaluate wave transformation models using a selected data set.

7	California Regional Wave Transformation Models	Phase 2	Provide CDIP Southern California validation examples and a test case for testing other WT models; Provide guidance and Users Manual on use of CDIP models and model output such as existing model coefficients.
		Future	Use CDIP model to create 2 sets of wave transformation coefficients for southern California, 1) for swell waves and 2) for local wind waves; Expand CDIP for the California Coast. Validate the models for central and northern California; Create database, provide expanded user's manual, and develop Fortran and MATLAB codes to assist contractors in using the CDIP model coefficients. Consider expanding regional wave modeling for Washington and Oregon coasts using CDIP or other programs (e.g., WIS) at the appropriate time and depending on the need, recognizing that regional wave models are more logical in densely populated areas. Individual studies may be performed in sparsely located communities (see Topic 8). Evaluate any limitations due to the linearity of the transformation models. Conduct research on wind wave and swell spectra combination.
9	Wave Energy Dissipation over Shallow Flat Bottoms	Phase 2	Evaluate wave dissipation over marsh and mudflats in the Pacific Coast from available information; Develop criteria to evaluate importance of wave dissipation in FISs; Recommend changes to methods and WHAFIS dissipation criteria to the extent feasible.
		Future	Conduct field data collection to characterize wave dissipation over marsh and mudflats and other shallow, dissipative shores in the Pacific; provide expanded guidance for calculating wave dissipation.
10	Overland Wave Propagation	Future	Evaluate if changes to WHAFIS dissipation criteria are necessary (see Topic 9), and *G&S* modifications for Pacific Coast.
WAVE SETUP RECOMMENDATIONS – PACIFIC COAST			
44, 45	Pacific Coast Definitions	Phase 2	Develop wave setup definitions with emphasis on Pacific Coast applications.
46	Evaluate Boussinesq Models	Phase 2	Intercompare at least three Boussinesq models and compare with data.
46	Develop Engineering Based Approach	Phase 2	Couple accepted engineering models for calculating wave setup across surf zone. Include procedure for dynamic wave setup.
44, 45	Compile Data for Testing	Phase 2	Locate as much quality field data as possible for testing of developed/selected approach(es).
44, 45	Compile Data for Testing	Future	Locate and compile comprehensive national and international data sources for testing a new Pacific Coast setup model
46	Develop Breaking Zone Model	Phase 2	Evaluate candidate breaking zone models that allow specification of non planar profile.
46	Develop Draft Guidelines and Specifications	Phase 2	Incorporate findings from above into draft Guidelines and Specifications.
46	Develop Interim Method	Future	Test Model over a wide range of settings and develop and expand User's Manual based on test results.

47	Ideal Model for Static Wave Setup	Future	Couple wave generation and wave setup model, allowing specification of arbitrary tide.
48	Develop Model for Dynamic Wave Setup	Future	Develop method based on directional and nonlinear spectrum as input.
WAVE RUNUP AND OVERTOPPING RECOMMENDATIONS – PACIFIC COAST			
Topic number not assigned	Runup on Beaches and Low Barriers	Phase 2	Revise guidance to call for runup analyses for sandy beach, small dune shore type
12	Evaluate Use of Mean Runup Value	Phase 2	Evaluate use of $R_{50\%}$ and select alternate $R_{x\%}$ value (probably between $R_{33\%}$ and $R_{10\%}$) if $R_{50\%}$ understates observed hazard. Develop an Interim procedure to adjust RUNUP2.0.output.
12	Evaluate Use of Mean Runup Value	Future	Review runup distributions for beaches and structures during El Niño, coastal storm, and hurricane conditions; review runup damages.
11	Wave Setup Component	Phase 2	Current FEMA methodology includes the wave setup component in the calculated runup height. This procedure should be revisited for its appropriateness along the Pacific, and depending on recommended Pacific methodology (coordinate with Wave Setup study)
11	Infragravity Motions	Future	Consider effects of infragravity motions, which amplify runup and overtopping, and can be substantial along the Pacific Coast
11	Wave Setup Component	Phase 2	Current FEMA methodology includes the wave setup component in the calculated runup height. This procedure should be revisited for its appropriateness along the Pacific, and depending on recommended Pacific methodology (coordinate with Wave Setup study)
11	Conduct Comparative and Sensitivity Testing of Runup Models and Methods	Phase 2	Evaluate CDIP-type and Oregon-type methods as interim approaches. Coordinate with case studies in Storm Meteorology, Wave Transformation studies. Test runup methods and models in conjunction with other tests (use common data sets to test wave generation through stillwater level and runup).
11, 49	Conduct Comparative and Sensitivity Testing of Runup Models and Methods	Future	Identify appropriate runup methods and models by location, morphology and hydraulic conditions. Compare results using simple methods versus numerical models, deterministic (event selection) versus statistical approaches. Write Guidelines on input conditions uncertainty.
13, 14	Overtopping Rates	Phase 2	Maintain use of mean overtopping rate (cfs/ft, m^3/ per m) Determine damaging overtopping rates for buildings and evaluate current FEMA hazard zone thresholds. Evaluate FEMA's guidance which limits the runup elevation to 3 feet above a barrier's crest elevation Coordinate with Hazard Zone study.
13	Overtopping Rates	Future	Overtopping at low profile beaches and barriers, dune remnants, revetments, and vertical walls should be evaluated, including consideration for calculating overtopping and ponding on low bluffs with gently sloping, flat or adverse slopes.
EVENT BASED EROSION RECOMMENDATIONS – PACIFIC COAST			
30	Geometric	Phase 2	Evaluate geometric methods and models. Develop *G&S* for determining most

	Methods for Assessing Erosion		likely Pacific winter beach profile, including beach nourishment areas. Evaluate geometric modeling procedures for sand beaches and dunes on PC and test with available data sets. At a minimum, prepare interim *G&S* methods based on historical beach profiles and field observations.
31, 32	Bluff and Cliff Erosion	Phase 2	Review available literature and reporting; provide language and descriptions to PC *G&S* to distinguish bluff and cliff erosion from other processes; provide figures and examples. Review existing bluff erosion procedures and international literature. Discuss interim approach for estimating bluff and cliff erosion based on historical profile data.
		Future	Develop geometric procedures for bluff and cliff erosion and retreat. Consider development and use of process-based numerical/statistical modeling methods for future inclusion in the NFIP program.
33, 34	Gravel, Cobble, and Shingle Beach and Dune Erosion	Phase 2	Provide discussion of gravel, cobble and shingle beach and dune erosion in different settings to distinguish this type of erosion hazard from other erosion processes. Provide examples, figures, and definitions. Discuss a simplified interim approach for cobble/shingle beaches based on historical beach profiles.
		Future	Explain limitations of existing 540 Criterion for application to this type of erosion and setting. Discuss simplified *interim approach* for assessing gravel, cobble, and shingle beach and dune erosion based on historical beach profile data. Develop geometric procedures for gravel, cobble, and shingle beach erosion. Consider development and use of process-based numerical/statistical modeling methods for future inclusion in the NFIP program.
35,36	*G&S* in Sheltered Water areas	Phase 2	Provide definitions and discussion of EBE found in sheltered water areas for *G&S;* provide interim *G&S* based on historical beach profiles and field observations
		Future	Perform future pilot EBE study(s) in sheltered-waters; refine interim assessment procedures; consider use of process-based models; prepare updated *G&S*
38	Physics/Process Based Methods	Phase 2	Discuss difference between simplified geometric methods and Processed Based models.
		Future	Develop suite of processed-based models for general coastal erosion assessments for different settings and material types, including sheltered waters and overwash
40	Document vertical depths of erosion	Future	Document depths of erosion following storm events and maintain data for depths of erosion and damages to buildings in order to better determine "depth-damage" relationships.
41	Long-term Erosion	Future	This topic is considered important to NFIP, but FEMA action on previous work is pending. Therefore, guidance is best developed by FEMA in the future.
42, 43	Nourished Beaches	Phase 2	Provide language in *G&S* directing study contractors to notify FEMA if their study area includes a beach nourishment project and provide FEMA with a list of information needed to assess special cases where beach nourishment may be considered in determining hazard zones and BFEs (exception to existing FEMA policy).
COASTAL STRUCTURES RECOMMENDATIONS – PACIFIC COAST			
21a, 21b.1, 23	Failed and Buried Structures	Phase 2	Revise guidance to better describe buried structures and failed structure configurations (including progressive failure of revetments).
22a, 22b	Wave Effects Analyses at	Phase 2	Using modified PWA method, write guidance for mapping runup and overtopping at uncertified (or failed) coastal structures.

	Failed Structures		
25	Flood protection Structures	Phase 2	Mention in guidance, detailed TR 89-15 evaluation/certification of coastal structures are not required during FIS, but discuss implications
26a, 26b, 26d	Effects of Structures on Erosion, Flood Hazards	Phase 2	Investigate effects of structures on erosion and flood hazards; develop guidance for incorporation into flood hazard mapping.
27a	Coastal Levees and Structures	Phase 2	Identify and resolve inconsistencies in treatment of coastal levees and coastal structures
24	Tsunami-prone Structures	Future	Investigate historical data on structure failure/success during tsunamis; develop evaluation criteria for tsunami-prone structures.
27b, 27c	Structure Evaluation Criteria	Future	Review CERC TR 89-15 considering more recent data on structure stability and failure; revise structure evaluation criteria for existing and new structures.
21b.2	Jetties, Groins, Breakwaters	Future	Develop criteria/guidance for evaluating failure of other structure types, and the effects of these failures on mapped flood hazards
26e	Minimum Structure Dimensions	Future	Determine minimum structure dimensions necessary to receive mapping credit during FIS and revisions to FIRMs
TSUNAMI RECOMMENDATIONS – PACIFIC COAST			
No Topic No assigned	Prepare General Procedures for Pacific Coast *G&S*	Phase 2	Prepare guidance for use of information and hazard mapping work products produced by NOAA under Topic numbers 15 and 16, below. Include these procedures in the general *G&S* for the Pacific Coast.
15	Address Use of NTHMP Program Products and Approaches	Future	Develop digital database. Develop method suitable for NFIP tsunami hazard zone delineations, including recurrence interval estimation.
16	Develop Method to Predict 100-Year Tsunami Event	Future	Perform comprehensive pilot study at a selected site in California, Oregon, or Washington to develop and test numerical methods for: 1) Improve recurrence interval estimating procedures for farfield and nearfield sources by increasing the coverage and quality of the historic and prehistoric tsunami records and develop probability distributions for both tsunamigenic earthquake and landslide sources. 2) Estimate the 1% annual chance tsunami 3) Test procedures for propagating tsunamis from Alaska, Chile, and Cascadia Subduction Zone to the Pacific Coast. Verify model predictions with tidal records, if available 4) Calculate runup and inundation elevations 5) Calculate combined probability distribution of tsunami runup and storm wave generated runup (if data are available).
20	Tsunami-Structure–Debris Interaction To Define Hazard Zones	Future	Estimate impact forces on typical coastal structures using overland flow depths and velocities from the numerical tsunami simulations performed above for one coastal location.
29	Review	Future	Examine available USGS post-tsunami erosion data. Attempt to develop a

	Methods of Tsunami Induced Erosion		simplified empirical relationship for approximating changes in beach profiles during a 1% annual chance tsunami for the specific locale under study.
SHELTERED WATERS RECOMMENDATIONS – PACIFIC COAST			
6a	Definitions and Classification	Phase 2	Provide definitions, examples, and develop a classification method based on SW physical processes and site characteristics that can be used during SW flood hazard studies.
6b	Flood Event Reconstruction	Phase 2	Review previous SW flood studies and document methods used for validating flood study results. Prepare general guidance for documenting and using high water marks to reconstruct historic flood conditions.
6d	Combined Tidal-Riverine 1% Annual Chance Event Assessment	Phase 2	Prepare guidance for defining the 1% annual chance flood event involving riverine and tidal flooding and expand guidance on wind data acquisition and analysis and fetch-limited wave forecasting.
6e	Stillwater Estimation	Phase 2	Prepare guidance for estimating stillwater elevations in ungauged sheltered waters bodies and evaluating the effects of tidal and riverine currents.
6h	Hazard Mitigation Coordination	Future	Prepare general guidance for Mapping Partners to coordinate the preparation of coastal studies with other hazard mitigation activities.
6h	Focused Study Coordination	Phase 2	Collaborate/coordinate with other study groups to address "Critical" sheltered waters topics found in other Focused Studies.
	PC Guidelines	Phase 2	Prepare general *G&S* section for assessing sheltered water areas on the Pacific Coast.
HAZARD ZONES RECOMMENDATIONS – PACIFIC COAST			
17	Primary Frontal Dune VE Zone	Phase 2	Develop guidance to better map the BFE transition between PFD dominated VE Zones and landward SFHA hazard zones
17	Guidance on VO Zone Mapping	Phase 2	Establish procedures (hazard identification and mapping) to better utilize VO Zones for areas outside established VE Zones.
17	VE Zone Mapping Options and Criteria	Phase 2	Establish procedures for identifying and mapping wave overtopping and wave-cast debris hazard zones based on historical significance of hazard.
17, 39	VE Zone Limit and PFD Definition	Future	Establish improved procedures for establishing the landward limit of the PFD; test procedures in a case study
19	Combined Coastal-Riverine Zones	Phase 2	Review the previous 1981 FEMA or revised/new guidance on how to conduct the assessment and mapping of combined coastal-riverine areas for adoption into *G&S*.
Topic number not assigned	Hazard Zone Mapping Examples	Phase 2 and Future	Develop new hazard zone mapping examples in *G&S* specifically for the Pacific Coast.
18	Hazard Zones and Technical Bulletins	Future	Investigate and develop coastal A Zone criteria. Prepare technical bulletins for clarification of proposed revisions to VE Zones, AE Zones, and new VO Zones related to hazard identification and floodplain management. Develop an annotated bibliography of related research and apply new concepts in a case study.

5 RECOMMENDATIONS – ATLANTIC AND GULF COASTS

5.1 INTRODUCTION – OBJECTIVES AND NFIP CONSIDERATIONS

This section of the report presents a brief discussion on the need for guidelines to address both open coast and sheltered waters settings. Specific recommendations for the Atlantic and Gulf Coasts are summarized by technical category. These summaries are very brief descriptions of the results of the Focused Studies. The reader should refer to the appendices for a more thorough treatment of the topics for the Atlantic and Gulf Coasts.

The objectives for these recommendations are to guide future development of updates to the guidelines on the Atlantic and Gulf Coasts, indicate the potential applicability of Phase 2 work on the Pacific Coast to procedures for the Atlantic and Gulf Coasts, and provide a reference for the NFIP and map modernization until the existing guidelines, procedures, and regional studies are formally updated.

5.2 OPEN COAST AND SHELTERED WATER SETTINGS

"Sheltered Waters" are water bodies with shorelines that are not subjected to the direct action of undiminished ocean winds and waves. Sheltered Water areas are exposed to similar flood-causing processes as those found along open coastlines, such as high winds, wave setup, runup and overtopping. Present FEMA *G&S* adequately cover many of the general coastal flood assessment procedures needed to complete flood hazard assessments in Sheltered Waters. However, some aspects of sheltered water flood hazards can not be addressed by the current FEMA Guidelines. For example, wind-generated waves are highly dependent on the shape and orientation of the surrounding terrain to prevailing wind directions. Wave generation and transformation in sheltered waters are usually limited by their open water fetch distance, complex bathymetry and often the presence of in-bay and shoreline coastal structures. These sheltering effects reduce wave energy and flood potential compared to open coast areas.

Other processes, including the effects of terrestrial runoff which modify local tidal and surge hydrology and relatively strong in-bay currents often combine to create tidal and hydrodynamic conditions only found in sheltered waters areas. Bays and estuaries often display significant spatial variability in tidal hydrology. For example, south San Francisco Bay often has a standing tide with nearly twice the tide range of central Bay and an elevated mean tide and high water elevation compared to the open coast. In contrast the north bay which extends into the Sacramento-San Joaquin Delta area displays a progressively muted tidal range and lower elevated mean tide resulting from combined effects of complex tidal hydraulics, residual currents, local winds and river runoff. Oceanic storm surge can be modified in estuaries and it isn't clear whether storm surge is uniformly additive to local tidal datums throughout an estuary, or whether storm surge is amplified or muted within an estuary, or within a given region within a large estuary. However, this depends on local conditions and must be evaluated with appropriate methods.

On the Atlantic coast similar questions arise during hurricane events versus local storm events regarding how storm and oceanic conditions may or may not affect sheltered water tidal elevations. Atlantic Coast sheltered waters (such as the sounds behind North Carolina's Outer Banks, Chesapeake Bay, Delaware Bay, and other smaller water bodies) may experience significant wind setup in these shallow areas followed by a sudden calming of the wind resulting in long wave seiching within the sound. Similar seiching effects are experienced in the Great Lakes. Other important flood-related characteristics include

the complex geometry of the embayments, lack of coincident peak storm surge with peak winds and waves, shallow water and restricted wind fetches for wave growth, and non-sandy shoreline types with special erosion and scour hazards. Wave-cast debris from extreme wave runup and overtopping can be especially problematic, owing to the proximity to sources of such materials in many estuaries. These sheltered water flood hazards are not adequately addressed in current FEMA Guidelines.

5.3 DEFINE THE 1% ANNUAL CHANCE FLOOD HAZARD (TWO APPROACHES)

The issues of computing the wave conditions and still water levels during a 1% annual chance event has been discussed in Section 4.3, Open Coast and Sheltered Water Settings. For the open coasts of the Atlantic and the Gulf , the *G&S* assumes that during a hurricane event the 1% annual chance wave (which becomes depth limited in shallow water) will occur simultaneously with 1% annual chance water level. In some sheltered waters along the Atlantic and Gulf Coasts, the 1% annual chance wave and 1% annual chance water level may not occur simultaneously, primarily due to hurricane track relative to the configuration of the sheltered water body. Because the hydrometeorological setting of the Atlantic and Gulf Sheltered Water is similar to the Pacific Coast in terms of statistical correlation between water levels and waves, two basic approaches for extreme event definition, the Event Selection and the Response method, described in Section 4.4 of this report will be applicable. The *G&S* does not have specific guidance detailing the 1% annual chance event issues for Sheltered Waters. Hence, the *G&S* developed for the Pacific Coast will be useful for Atlantic and Gulf Sheltered Waters.

5.4 INTRODUCTION TO TECHNICAL CATEGORY SUMMARIES

The subsections that follow provide concise summaries of Focused Study results in the 11 technical categories for the Atlantic and Gulf Coasts. The summaries include a summary of existing *G&S*, a brief description of the topics, and key issues and a set of recommendations for the Atlantic and Gulf Coasts. Phase 2 of this project does not include further work on development of guidelines for the Atlantic and Gulf Coasts. The recommendations therefore include a discussion of available methods, the potential applicability of guidelines to be developed in Phase 2 for the Pacific Coast, and recommended future development.

The following summaries are the direct result of the appended Focused Studies, which include additional discussion, information, and references on the topics. These Focused Studies provide an additional reference for the NFIP and map modernization until the existing guidelines, procedures, and regional studies are formally updated.

STORM METEOROLOGY

Overview of Existing Guidelines

This category covers not only storm meteorology, but also a number of flood frequency issues. Among these are two general methods to determine the 1% annual chance level of some coastal process, characterized as the Event Selection method and the Response-Based method. These terms refer to the manner in which the 1% annual chance coastal flood level is determined. In the Event Selection method, a single 1% annual chance offshore storm or wave event, which is followed to shore and on to its runup level, is selected with the assumption that the runup level would approximate the true 1% annual chance runup. In the Response-Based method, all significant events are routed from offshore to their runup limits, and only then is the 1% annual chance level determined, based on the entire set of response calculations. The same general approaches apply to processes other than runup.

For the Atlantic and Gulf Coasts, the question of method is less important than on the Pacific Coast, because the primary wave effects are associated with limit height breakers during local, intense hurricanes; consequently, the existing guidelines are quite limited. The Study Contractor is instructed to adopt the "controlling" wave for level mapping. There is little specific guidance on the selection of wave parameters for wave setup and runup determinations. In many places, the guidelines refer to the need to choose a parameter - deepwater wave height, for example, which is somehow "associated with" another process such as the 1% annual chance stillwater level. It is generally not clear from the guidelines how this is to be done, and the matter is left to the study contractor's judgment with the injunction that the assumptions be documented. Section D.2.2.6, for example, refers to "the meteorology of storms expected to provide approximate realizations of the 1-percent-annual-chance-flood" and suggests that such storms would be useful in "assessing wave characteristics likely associated with" that flood. Subsequently, it is suggested that "the 1-percent-annual-chance flood is likely associated with central pressure deficits having exceedance probabilities between 5 and 10 percent" with the implication that wave height and period estimated from hurricane formulas using pressures in this range would be appropriate.

Another important storm meteorology issue is the manner in which frequency is attached to storm surge calculations. The accepted approaches are all Response-Based, with a large number of storms of varying characteristics being simulated and the 1% annual chance level determined from an analysis of the computed response. An example of an Event Selection method, not commonly used in recent years, is the simulation of one particular storm (a design storm) chosen somehow to approximate 1% conditions. The basic approach discussed in the guidelines is the Joint Probability Method, which considers the total rate of occurrence of storms defined by multiple parameters with individual probabilities. The Atlantic and Gulf Coast guidelines suggest the approach originally developed by NOAA, with the required hurricane data taken from NOAA publications such as NWS 38. The newer Empirical Simulation Technique (EST) has been applied in recent studies both for the USACE and for FEMA, but is not considered in the current guidelines.

There is little additional guidance on storm meteorology in the current guidelines. The Study Contractor is required to "Describe the method by which the tidal elevation data are convoluted with the surge data including tidal constants and tidal records" for the combination of astronomic tide and storm surge. There is no guidance for the combined probability of separate processes such as storm surge and rainfall runoff in a tidal river, and there are no guidelines specifically for the Pacific Coast.

Topics and Key Issues

The following Storm Meterology topics were identified by the TWG:

Critical – Topic 51, Combined Probability.

Important – Topic 50, Modeling Procedures.

Key issues are:

- Storm surge frequency analysis can be performed using Joint Probability, Monte Carlo, or the newer EST methods. These alternatives should be compared and evaluated using a common data set and a single storm surge model.
- The adequacy of NWS 38 as a data source for new storm surge studies should be reviewed, both from the standpoint of additional years of data since its publication, and also for its use of a coast-referenced coordinate system.
- Although not as critical as on the Pacific Coast, it is important to establish what offshore wave conditions should be selected for determination of such flood-enhancing mechanisms as setup and runup.
- Astronomical tide often makes a significant contribution to the total stillwater level. The methods by which tide and surge can be combined depend on their relative magnitudes and the degree to which they may interact physically. Guidelines should be developed for techniques to perform this combination.
- The manner in which flood levels are determined in tidal zones that are subject to both riverine and coastal flooding has been neglected in the existing guidelines. Methods to determine the joint result range from simple addition of rates to complex hydrologic modeling. See also Topic 19 of the Hazard Mapping Focused Study.
- Improved observations during recent years indicate that past assumptions regarding hurricane wind fields may require improvement.
- Similarly, improved determinations of wind stress under extreme wind conditions suggest that improvement of wind stress formulations used in surge modeling may be warranted.

Recommended Approach

The recommended approach to these issues includes both the development and verification of methods, and the preparation of new and revised guidelines.

Currently Available Methods, Information, and Guidelines

Currently available Atlantic/Gulf methods include the Joint Probability, Monte Carlo, and EST methods for storm surge statistics; numerous runup models; methods for tide and surge combination summarized in the FEMA Surge Model documentation; and the Monte Carlo method adopted by the Florida Department of Environmental Protection.

Applicability of Pacific Coast Guidelines

The topics treated under Storm Meteorology have a different emphasis on the Atlantic and Gulf Coasts than on the Pacific Coast. For the Atlantic and Gulf Coasts, the primary concern is with the storm data and frequency methods used in storm surge modeling. The primary problem for the Pacific Coast is determination of the 1% annual chance flood elevation (base flood elevation) resulting from the combination of waves with tide, surge, and setup. Guidelines will be developed for the Pacific open coast based on the Event Selection Method and Response-Based Method. These methods will also be utilized to develop guidelines for determination of base flood elevation in the sheltered waters of the Pacific Coast. Sheltered waters in both the Pacific and the Atlantic and Gulf Coasts are characterized by possible non-coincidence of extreme stillwater level and extreme wave conditions. Because of this similarity, the procedures for the Pacific Coast sheltered waters, or part thereof, may be applicable to the Atlantic and Gulf Coasts. The following tasks undertaken in Phase 2 will develop procedures that may be applicable on the Atlantic and Gulf Coasts:

- Perform a sheltered water case study utilizing the Event Selection and Response-Based Methods.
- Provide guidance regarding the combination of surge and tide using convolution and FL-DEP methods. The convolution method will be applicable where surge and tide combine approximately linearly, or where one of the two processes dominates the other. The FL-DEP method does not require the assumption of linear combination and will likely apply on relatively steep open coasts.

Recommended Future Development

- Provide guidance regarding the combination of surge and tide in settings where two-dimensional surge modeling is warranted
- Develop guidance for the combined effects of riverine and coastal flooding
- Compare and evaluate storm surge frequency methods including Joint Probability Method, Monte Carlo, and Empirical Simulation Technique
- Evaluate storm parameter data sources and statistics
- Review wind field formulations for hurricanes, northeasters, and other storms
- Review wind stress formulations to reflect improved recent observations

Table 15
STORM METEOROLOGY RECOMMENDATIONS – ATLANTIC AND GULF COASTS

Topic Number	Topic/Subtopic	Recommended Approach (Future Work)
51	Tide and Surge Combination	Develop guidelines for the combination of surge and tide, including examples drawn from past studies (with consideration of FEMA surge studies, ADCIRC/EST, and the FL-DEP Monte Carlo method)
51	Surge/Riverine Combination	Prepare recommendations for the statistical combination of surge and a riverine runoff profile, with consideration of non-independence of the processes; see also Topic 19 of the Hazard Mapping Focused Study for simple mapping suggestions
50	Storm Surge Frequency Aanalysis	Apply/Compare methodologies (JPM, EST, Monte Carlo) using a common hydrodynamic model and storm data set
50	Storm parameters for surge modeling	Review and evaluate available sources of storm parameters used in storm surge modeling, including NWS 38, HURDAT, and other databases
50	Storm Wind Fields	Review best available data regarding wind fields and compare with fields used in storm surge models; recommend the most appropriate models for FIS use (tropical storms, northeasters)
50	Wind Stress Formulation	Review best available data for wind stress and compare with formulations used in storm surge models; recommend the most appropriate formulation for FIS use

STILLWATER

Overview of Existing Guidelines

For the Atlantic and Gulf Coasts, the primary difficulty with stillwater is the determination of storm surge and static wave setup, plus the contribution of astronomical tide. Existing FEMA guidelines are relatively brief–consisting primarily of checklists and requirements for data submission and documentation during a study. The material concerned with general surge modeling is contained in Section D.1.2.4, Hydrodynamic Storm Surge Model. Additional storm surge guidance is contained in Section D1.2.5, Storm Surge Model Calibration and Verification, which consists of two paragraphs on verification procedures and required backup documentation; Section D1.4.1, [Intermediate Data Submission] Before Storm Surge Model Calibration Runs, a list of eight items to be submitted for review prior to proceeding with model runs; and Section D1.4.2, Before Operational Storm Surge Runs, a checklist of seven items to be submitted for review prior to performing the main statistical simulation set of runs. There is some additional material of a general nature in Section D-2.2 dealing with Data Requirements.

The available guidelines are generally based on the use of the FEMA storm surge model, although brief mention is made of the Stone and Webster Northeaster Model and the possible stillwater elevation determination by statistical analysis of available tide gage records, provided the recorded tide gage records include 20 years or more of data. Section D.2.2 also states that "use of synthetic computer models for storm surge assessments are suggested for use and application over tide gage data, where tide gage data is limited and complex shorelines are present which cause appreciable variation in flood elevations for a community."

Topics and Key Issues

The following Stillwater topics were identified by the TWG:

Critical – Topic 53, Identify Reliable Existing Data to Compare to Existing FEMA Flood Studies to Test Performance of Surge Models.

Available – Topic 52, Provide Guidance on Non-stationary Processes [i.e., sea level change] when establishing current conditions.

Key issues are:

- Storm surge estimates can be based on an analysis of tide gage data in some regions.
- The FEMA coastal guidelines do not include any significant discussion of appropriate methods for tide gage analysis.
- The guidelines provide little guidance regarding the considerations that must be made for storm surge modeling, beyond the assumptions implicit in the use of the FEMA storm surge model.
- The availability of many new surge models and supporting tools for grid development and maintenance suggests the need for more detailed guidance regarding models and modeling practice.

- In some areas of the Atlantic and Gulf Coasts a simplified 1-D surge model would be a valuable tool. A suitable prototype for such a model is the one used by the Florida Department of Environmental Protection for Florida coastal construction jurisdictional delineations.

- The FEMA guidelines provide little guidance on the matter of non-stationary processes, and how they might affect both the determination of stillwater levels, and the interpretation of historical data used in a FIS.

- The primary non-stationary processes of concern are the relative change of sea level (sea level rise and/or land subsidence), and localized land subsidence associated, for example, with oil and water extraction or tectonic adjustment.

- Owing to improvements in computer technology, future storm surge modeling efforts can be expanded to a regional scope, providing greater uniformity and accuracy in the surge determinations, at reduced cost.

- An important question is how well FEMA coastal surge estimates will agree with experience. Model calibration in any particular study is difficult owing to uncertainties in both historical storm characteristics and levels of flooding.

- It should be possible to perform a global "calibration" through a statistical evaluation of the performance of the FEMA methodology along all major coastlines.

Recommended Approach

The recommended approach for addressing these issues includes both the development and verification of analytical and modeling methods (tide gage analysis and bathystrophic surge modeling), as well as general revision of the *G&S* to provide greater insight for Study Contractors regarding the requirements of coastal modeling and data interpretation.

Currently Available Methods, Information and Guidelines

Information is available for development of guidance on non-stationary processes, and for development of general storm surge modeling guidance.

Applicability of Pacific Coast Guidelines

The Stillwater topics are generally applicable to both the Atlantic/Gulf and Pacific Coasts. The differences are primarily matters of emphasis, not physics. In particular, storm surge is generally small on the Pacific Coast in comparison with the Atlantic/Gulf. Despite this, the work for one coast will be applicable to the other. Therefore, results from the following Phase 2 work proposed for the Pacific should provide improved guidance for the Atlantic and Gulf Coasts.

- Provide guidance regarding methods for determination of storm surge based on tide gage data.

- Write general guidelines for storm surge modeling

- Implement a simplified 1-D storm surge model with guidelines for its use

- Write guidelines for consideration of non-stationary processes in a FIS

Recommended Future Development

- Develop global methods to evaluate surge model performance
- Develop guidelines for large scale regional surge modeling

Table 16
Stillwater Recommendations – Atlantic and Gulf Coasts

Topic Number	Topic/Subtopic	Recommended Approach (Future Work)
53	General Considerations for Surge Modeling	Based on the existing literature, describe the use of surge models applicable to Atlantic and Gulf Coasts and the factors that require consideration in performing a study.
53	Surge Modeling Global Calibration	Develop statistical procedures to assess the performance of the FEMA surge models through the consideration of global experience on all coasts.
53	Regional Surge Modeling	Develop guidance for large scale regional surge modeling.

STORM WAVE CHARACTERISTICS

Overview of Existing Guidelines

Existing FEMA guidelines provide three approaches for estimating storm wave characteristics: (1) wave data from offshore wave buoys, (2) wave data from hindcasts or numerical modeling based on historical records, (3) wave data from specific calculations based on assumed storm meteorology. For the second approach the USACE Wave Information System (WIS) hindcasts are used and these are specified at some specific (average) water depth. Mapping Partners convert such wave information into an equivalent condition at some other water depth for appropriate treatment of flood effects. For the third approach, the Shore Protection Manual (SPM) and ACES V1.7 are recommended for hurricanes and extratropical storms, respectively. The current approaches are generally adequate since the "controlling" wave height (1.6 times the significant wave height) will invariably be the limiting breaking wave at the original shoreline for WHAFIS application. However, wave setup calculations are sensitive to deep water conditions for which more accurate determinations may be necessary.

Topics and Key Issues

The following Storm Wave Characteristics topics were identified by the TWG:

Critical – Topics 4 and 5, Sea and Swell for Open Atlantic/Gulf Coasts.

Available – Topic 5, Wave Generation in Sheltered Water; Topic 1, Wave Definitions.

Key issues are:

- Workshop 2 considered whether the WIS database is adequate for Atlantic and Gulf or alternative databases are necessary. The Technical Working Group determined that WIS, which was updated recently, is adequate for wave data estimation for Atlantic and Gulf Coast. Use of other available databases, such as Oceanweather's Global Re-analysis of Ocean Waves (GROW) model, is not necessary. Additionally, swell data are not important for hurricane conditions.
- Instructions are needed on the appropriate use of the WIS database–such as whether to use 100-year significant wave height or the 20-year maximum wave height in WHAFIS modeling.
- Clarification is needed on the use of equivalent deep water wave height for runup computations.
- For wave generation in sheltered waters with restricted fetch, SPM and ACES are used. The wind speed inputs into SPM or ACES are 60 mph for northeaster-dominated areas and 80 mph for hurricane-dominated areas. The appropriateness of these wind conditions should be analyzed based on more recent information.
- The Coastal Engineering Manual (CEM) has officially replaced SPM; however, CEM procedures for restricted fetch need to be evaluated before accepting the procedures for the guidelines.
- Definitions are needed in the *G&S* of waves in both the time domain and the frequency domain. Two available resources are: CEM and the International Association of Hydraulic Research publication entitled "List of Sea State Parameters".

- Specific guidance is needed on how the wave-related terms apply to the coastal processes associated with flood studies, methodologies, and models.

Recommended Approach

The recommended approach is to wait until the completion of Phase 2 work for the Pacific Coast for Topic 5 (Wave Generation in Sheltered Water) before undertaking any revision to the *G&S* for the Atlantic and Gulf Coasts. The remaining critical and available topics can be revised using available references and information. The effort will be small in comparison to the storm wave characteristics efforts for the Pacific Coast.

Currently Available Methods, Information, and Guidelines

The updated WIS database is available and recommended for use for both the Atlantic and Gulf open coasts.

Applicability of Pacific Coast Guidelines

The following Pacific Coast work on Topic 5 (Sheltered Waters) will be directly applicable to the Atlantic and Gulf coasts:

- The recommendations from the Pacific Coast case study, which will compare results using CEM procedures to results using SPM procedures for a restricted-fetch Pacific Coast site, can be adopted for the Atlantic and Gulf Coast guidelines.
- The recommendations from the case study, which will compare results from the Spectral Energy Models (SEMs) and traditional Parametric Models using restricted fetch methods, can be adopted for the Atlantic and Gulf. The study will clarify application procedures for the SEMs, specifically wind field definition.

Recommended Future Development

- The WIS database is recommended for use. Investigate the appropriateness of using either the 100-year significant wave height or the 20-year maximum wave height while modeling WHAFIS.
- Clarify use of equivalent deep water wave conditions.
- Clarify statistical methodologies for determination of the 1% annual chance event.
- Develop guidelines on sheltered water based on Pacific Coast guidelines.
- Incorporate standard wave related definitions from USACE CEM and 1986 International Association for Hydraulic Research (IAHR) publication, "List of Sea State Parameters."
- Provide specific guidance on use of wave related definitions for physical processes applicable to coastal flood studies.

Table 17
Storm Wave Characteristics Recommendations – Atlantic and Gulf Coasts

Topic Number	Topic/Subtopic	Recommended Approach (Future Work)
4,5	Sea and Swell for Open Atlantic and Gulf Coasts	Investigate the appropriateness of using either the 100-year significant wave height or the 20-year maximum wave height while modeling WHAFIS. Clarify use of equivalent deep water wave condition. Clarify extrapolation to 100-year
5	Wave Generation in Sheltered Water	Develop Guidelines on Sheltered Water based on Pacific Coast *G&S*.
1	Wave Definitions	Incorporate and refine the "Glossary of Coastal Terminology" directly from the USACE CEM. Incorporate and refine the five listings of notations and parameters in the 1986 International Association for Hydraulic Research publication, "List of Sea State Parameters." Provide specific guidance on how wave related terms in the USACE and IAHR sources relate to each other and how they should be applied relative to the following: (1) FEMA guidance for coastal flood studies, (2) physical processes that are directly associated with FEMA coastal hazard assessments and flood mapping, and (3) required coastal hazard study methodologies Prepare an application for Atlantic and Gulf Coast Guidelines

WAVE TRANSFORMATION

Overview of Existing Guidelines

Wave Transformations are addressed in of the FEMA G&S in terms of overland travel (Sections D.2.6 - 2.6.4) and application of the WHAFIS model. This treatment is one-dimensional (defined by a profile), and limited to shallow water breaking and dissipation processes. Dissipation due to propagation over shallow areas and marsh plants is included. However, wave dissipation due to muddy bottoms has not been included in WHAFIS. Wave refraction, diffraction and shoaling are not addressed, except in passing references such as on page D-70: "Where land shelter or wave refraction may result in reduced incident waves, it is appropriate to specify an initial significant wave height for the transect." The emphasis of the *G&S* is on depth-limited, shallow water propagation and dissipation, which is logical because these are important issues in the Atlantic and Gulf Coasts.

Topics and Key Issues

The following Wave Transformation topics were identified by the TWG:

Critical – Topic 9, Wave Energy Dissipation Over Shallow, Flat Bottoms.

Important – Topic 10, Overland Wave Propagation; Candidate Improvements to WHAFIS.

Helpful – Topic 8, Wave Transformation With and Without Regional Models.

Key issues are:

- Wave Transformations are important processes that change wave characteristics when propagating toward shore, generally from deep to shallow water, and are addressed as an intermediate step between forcing processes (wave generation) and response processes (wave setup, wave runup, and overtopping) in coastal flood studies.
- Wave dissipation caused by bottom effects are not routinely considered in wave transformation processes. Effects of wave energy dissipation in shallow water can result in reduced wave heights in certain shorelines. Ignoring wave dissipation may lead to overestimates of flood hazard risk for shorefront development. Study Contractors need guidance on when and where to apply bottom dissipation mechanisms. Some guidance is available in the current *G&S*.
- Overland wave propagation is common during extreme events in the Atlantic and Gulf Coasts. FEMA-approved WHAFIS 3.0 is presently applied in FISs. Potential improvements to WHAFIS have been identified (see Topic 10).
- The emphasis of the *G&S* on depth limited shallow water propagation and dissipation may be logical for the Atlantic and Gulf Coasts. However, it will be preferable to cross-reference new Pacific Coast Wave Transformation guidelines because the Atlantic and Gulf Coast methods may not be appropriate for all sites, including sheltered waters.

Recommended Approach

The recommended approach to the Wave Transformation focuses on improvement of wave dissipation and propagation modeling in Atlantic and Gulf Coast settings.

Applicability of Pacific Coast Guidelines

Pacific Coast work will be applicable to the Atlantic and Gulf for Topics 8 and 9:

- While focused on the Pacific Coast, the guidance on wave transformation will also be useful for flood studies on the Atlantic and Gulf Coasts, especially since wave transformation methods are not discussed elsewhere in the *G&S*. The wave transformation methods to be recommended are general approaches applicable to all water bodies, and hence can be used for Atlantic and Gulf Coasts, as well as sheltered waters. Guidance on the appropriate methods for a range of site conditions will also be provided.
- Guidance will also be developed for wave dissipation over shallow flats and marshes, which should complement existing guidance.

Recommended Future Development

- Write *G&S* to include a section on wave energy dissipation over shallow and flat bottoms.
- Develop typical ranges for dissipation coefficients for a variety of bed and wave conditions to be included in the *G&S*.
- Categorize bed and wave conditions for U.S. coastlines. Revise *G&S* to provide dissipation coefficients on a geographic basis; revise *G&S* to adopt the Suhayda (1984) or other appropriate method.
- Develop improvement to WHAFIS model

Table 18
Wave Transformation Recommendations – Atlantic and Gulf Coasts

Topic Number	Topic/Subtopic	Recommended Approach (Future Work)
9	Wave Energy Dissipation over Shallow Flat Bottoms	Write *G&S* to include a section on wave energy dissipation over shallow and flat bottoms; Develop typical ranges for dissipation coefficients for variety of bed and wave conditions to include in the *G&S*. Categorize bed and wave conditions for US coastlines. Revise *G&S* to provide dissipation coefficients on a geographic basis; revise *G&S* to adopt Suhayda (1984) method.
10	Overland Wave Propagation, Candidate Improvements to WHAFIS	Evaluate new methods to better represent vegetation effects, treatment of elevated pile supported buildings Minor Effort – WHAFIS code changes for more user friendly program Moderate Effort – more intense code changes for improvement in accuracy and graphics (in WHAFIS) Significant Effort - Revise WHAFIS to consider combined effects of damping and wind action over each segment.
8	Overall Wave Transformation with and	Cross reference Pacific Coast guidelines, and emulate important topics for Atlantic and Gulf Coasts.

	without Regional Models	

WAVE SETUP

Overview of Existing Guidelines

FEMA *G&S* are based on the 1984 USACE SPM. These results have been developed from laboratory tests and wave theory and are applicable for beaches of uniform slope, although some guidance is given for non-planar beach profiles. The guidance applies to the static wave setup at the shoreline, but does not address dynamic wave setup. The *G&S* mention setup across reefs, but do not provide specific guidance. The *G&S* also do not provide guidance on settings such as flooded barrier island and areas with dissipative (e.g., muddy) bottoms.

Topics and Key Issues

Table 2 lists the topics identified by the Technical Working Group for Wave Setup for the Atlantic and Gulf Coasts.

Critical – Topic 44, Better Define and Document; Topic 45, Compile Example Data and Perform Tests; Topic 46, Develop Interim Method.

Important – Topic 47, Develop Ideal Method; Topic 48, Develop Procedure for Dynamic Wave Setup.

Key issues are:

- Under the action of irregular waves, wave setup consists of a static component and a dynamic component, both of which can be substantial and are relevant to erosion and other storm-induced hazards. The dynamic component is not considered in the present guidance.
- The Atlantic and Gulf Coasts include a broad range of physiographic settings and procedures are needed for each setting.
- Considerations of inland excursion of static and dynamic setup, and wave setup variation over flooded inland areas have been a challenge in some flood studies.
- Wave setup has not been treated uniformly in previous flooding studies on the Atlantic and Gulf (A&G) Coasts. It is estimated that approximately 40% of previous studies on the A&G coasts have included wave setup in specification of the 1% annual chance storm surge. Wave setup can comprise up to approximately 50% of the total 1% surge elevation in locations with narrow continental shelves such as southeast Florida.
- Ideally, wave setup will require specification of directional wave spectra as input at an offshore location seaward of wave breaking.
- Wave setup is included, to some degree, in wave runup measurements and methods. It will be necessary to separate these terms to avoid double counting of setup.
- There are two approaches for calculating wave setup: (1) The Boussinesq models which, in principle, can calculate both wave setup and wave runup, and (2) Coupling of more conventional engineering-based models.

Recommended Approach

The recommended approach is generally similar to that for the Pacific Coast with the exception of specification of the input wave characteristics. Because the wind-induced setup plays a more dominant role on the Atlantic and Gulf Coasts, it is necessary to utilize a model that incorporates a wind field. This same wind field could be used to generate waves. The method and *G&S* should include the same elements as for the Pacific Coast. Interaction with other Focused Study groups will be essential throughout the effort.

Currently Available Methods, Information and Guidelines

The general technology includes theory, a great deal of laboratory data, but very little quality field data– are available. Challenges include selecting the most appropriate approach (Boussinesq or engineering-based models). Current guidance is based on a depth-limited wave at the shoreline. Current guidance, which is based on SPM procedures, should be retained until new methods are developed.

Applicability of Pacific Coast Guidelines

It is estimated that 60% of the work accomplished for the Pacific Coast will be applicable to Atlantic and Gulf Coasts. As noted, the principal difference will be in the specification of the wave characteristics upon which the setup will be based. In particular, the items that will be directly applicable are:

- Intercomparison of Boussinesq models and comparison with data sets. Select Boussinesq or engineering-based approach.
- Develop and document engineering-based approach for wave setup modeling along open coasts and in sheltered waters. With the exception of wave input, this item will be identical.
- Compile potential data sources for testing.
- Develop breaking zone model with particular emphasis on wave setup, proof test, compare with data sets, refine, and write draft User's Manual.

Recommended Future Development

The Atlantic and Gulf Coasts will benefit by the methods developed for the Pacific Coast and overall insights gained in Phase 2 on related coastal processes such as wave runup. However, additional work on Topics 44, 45, and 46 will be required to formulate guidance for Atlantic and Gulf Coast physiographic settings.

For the ideal method, which would couple storm surge and wave setup in a single methodology, the following additional tasks need to be undertaken:

- Develop "Ideal Methodology" coupling storm surge and waves to calculate static wave setup
- Develop modeling procedure for dynamic wave setup based on wave spectra

Table 19
Wave Setup Recommendations – Atlantic and Gulf Coasts

Topic Number	Topic/Subtopic	Recommended Approach (Future Work)
44	A&G Coast Definitions	Develop wave setup definitions with emphasis on A&G coast applications.
45	Compile Data for Testing	Locate as much quality field data as possible for testing of developed/selected approach(es).
46	Develop Engineering Based Approach	Couple accepted engineering models for calculating wave setup across surf zone. Include procedure for dynamic wave setup.
46	Evaluate Boussinesq Models	Intercompare at least three Boussinesq models and compare with data.
46	Develop Breaking Zone Model	Evaluate candidate breaking zone models that allow specification of non-planar profile
47	Ideal Model for Static Wave Setup	Couple wave generation and wave setup model, allowing specification of arbitrary tide.
48	Develop Model for Dynamic Wave Setup	Develop method based on directional and nonlinear spectrum as input.

WAVE RUNUP AND OVERTOPPING

Overview of Existing Guidelines

Existing Guidance in Section D.2 calls for the use of the FEMA RUNUP 2.0 model, except for the case of vertical/near-vertical barriers, where SPM methods are recommended. Section D.2 overtopping methods are based on Owen (1980) and Goda (1985).

Topics and Key Issues

The following Wave Runup and Overtopping topics were identified by the TWG:

Critical – Topic 12, Use of Mean vs. Higher Values for Runup and Overtopping.

Available – Topic 13, Overtopping Volumes; Topic 49, WRUP™.

Important – Topic 11, Review Methods and Models.

Helpful – Topic 14, Wavecast Debris.

Key issues are:

- Runup tends not to control BFEs along the Atlantic and Gulf Coasts, except in New England and in bluff areas (wave height and primary frontal dune criteria tend to control VE zone designations and BFEs in low-lying and dune-backed areas).
- Many effective Flood Insurance Studies were completed using the FEMA early runup model, RUNUP 1.0. Substantial differences between the results of RUNUP 1.0 and 2.0 can exist, but the magnitude and significance of these differences is currently unknown (few comparative studies have been performed).

Recommended Approach

The recommended approach involves: 1) comparing RUNUP 1.0 and 2.0 results; 2) evaluating the use of $R_{50\%;}$ 3) adjusting RUNUP 2.0 results, where appropriate; 4) testing runup methods and models (first priority is New England); and 5) evaluating overtopping and revising hazard zones.

Currently Available Methods, Information and Guidelines

Updated runup and overtopping methods, models and data exist.

Applicability of Pacific Coast Guidelines

Much of the Pacific Coast Phase 2 work will be applicable to the Atlantic and Gulf Coasts. However, many tasks need to be repeated for the specific physiographic and hydrodynamic settings of the Atlantic and Gulf Coasts. The applicable Phase 2 tasks are:

- The evaluation of the R50% value on the Pacific Coast might also be applicable to Atlantic and Gulf Coasts, but only approximate consistency between the coasts is expected. The relative importance of

infragravity motions and dynamic wave setup on different coasts will preclude transferring Pacific Rx% results (and adjustments to RUNUP 2.0) without additional testing on the Atlantic and Gulf.

- Overtopping calculations, threshold rates, and mapping methods are expected to generally transfer to the Atlantic and Gulf Coasts.
- RUNUP 2.0 has been used extensively along the Atlantic and Gulf Coasts already, and any updated guidance developed from the Pacific Coast work should serve to improve guidance in Section D.2.

Recommended Future Development

- Perform detailed comparisons of wave runup and mapping using RUNUP 1.0 and 2.0. Determine whether to adjust prior studies using RUNUP 1.0 or to restudy using RUNUP 2.0 (or other methods).
- Analyze Atlantic and Gulf runup distributions, and compare with Pacific results for transfer of appropriate Rx% level and any adjustments to RUNUP 2.0 results.
- Conduct more comprehensive testing of wave runup methods and models, and identify appropriate runup calculation procedures for a wide variety of shore types, profile characteristics, and incident water level and wave conditions (same as Pacific).
- Update procedures for calculating overtopping and ponding on low bluffs, with gently sloping or adverse slopes (same as Pacific).

Table 20
Wave Runup and Overtopping Recommendations – Atlantic and Gulf Coasts

Topic Number	Topic/Subtopic	Recommended Approach (Future Work)
No Topic number assigned.	Revise Guidance to Reflect Current FEMA Practice	Revise guidance to describe use of ACES for runup and overtopping calculations (ACES is based on more recent procedures than SPM or RUNUP 2.0). Revise guidance to clarify use of *equivalent* deepwater wave conditions with RUNUP 2.0
12	RUNUP 1.0 vs. 2.0	Perform detailed comparisons of wave runup using RUNUP 1.0 and 2.0. Determine whether to adjust prior RUNUP 1.0 studies or to restudy using RUNUP 2.0 (or other methods).
12	Evaluate Use of Mean Runup Value	Review runup distributions and damages for Atlantic/Gulf beaches and structures, compare against Pacific. Evaluate use of $R_{50\%}$ and select alternate $R_{x\%}$ value (probably between $R_{33\%}$ and $R_{10\%}$) if $R_{50\%}$ understates observed hazard.
No topic number assigned.	Wave Setup Component	Treatment of wave setup component (in FEMA's current wave runup procedure) to be coordinated with Wave Setup study.
11, 49	Conduct Comparative and Sensitivity Testing of Runup Models and Methods	Compare results using simple methods versus numerical models, deterministic (event selection) versus statistical approaches. Test runup methods and models – priority to be given to testing in New England region. Identify appropriate runup methods and models by location, morphology and hydraulic conditions
13, 14	Guidance for Overtopping and Wave Cost Debris	Maintain use of mean overtopping rate (cfs/ft, m^3/ per m) Evaluate recent data and methods Apply Pacific results relative to damaging overtopping rates and FEMA hazard zone thresholds Evaluate wave-cast debris coincidence with overtopping Coordinate with Hazard Zone study

EVENT BASED EROSION

Overview of Existing Guidelines

FEMA guidelines (Appendix D) have not been updated since 1989 and focus primarily on the effects of extreme hurricanes and northeasters. They do not provide specific guidance for assessing event-based erosion (storm-induced erosion) in sheltered waters, or non-sandy beach and coastal dune areas; and provide only a simplified empirically based geometric relationship (the 540 Criterion) for erosion assessments along the Atlantic and Gulf open coasts. Existing event-based erosion (EBE) procedures do not account for beach materials with different erodibilities, for storms with different durations, or for dune overwash processes.

Topics and Key Issues

Table 2 lists the topics identified as necessary to improve current guidelines and/or develop new guidelines related to event-based erosion.

Critical – Topic 33, Add Discussions to *G&S* Regarding Limitations of Geometric Methods for Cobble/Shingle Beaches; Topic 35, Add Discussions to *G&S* Regarding Erosion Assessments in Sheltered Water Areas.

Available – Topic 31, Add Discussions to *G&S* Regarding Bluff Erosion; Topic 32, Develop Geometric Method for Bluff Erosion; Topic 41, Discuss Long-term Erosion/Future Conditions; Topics 42 and 43, Treatment of Nourished Beaches.

Important – Topic 34, Develop Geometric Methods for Cobble/Shingle Beaches; Topic 36, Review Data and Develop Geometric Methods for Sheltered Water Areas; Topic 37, Expand Database and Re-evaluate Aspects of 540 Criterion; Topic 38, Assess and Develop Process-Based Methods.

Helpful – Topic 39, "Primary Frontal Dune Definition," was moved to the Hazard Zones Focused Study; Topic 40 Documentation of Observed Vertical Erosion Depths for "Depth-Damage" Assessments).

Key issues are:

- Guidance for evaluating EBE remains unchanged since 1989 and focuses primarily on effects of extreme storms (hurricane or northeasters) along the Atlantic and Gulf Ccoasts, with a modified approach for the Great Lakes Coasts.
- Beach material properties, coastal erosion processes, and storm characteristics found along the north Atlantic Coast may differ significantly from those along the south Atlantic, Gulf, or Great Lakes.
- The main erosion related factors affecting beach profiles are: (1) the forcing processes that include the duration and time histories of the wave characteristics, water levels, and runup; and (2) the response elements that include the physiographic setting and the beach and dune/bluff characteristics, including material erodibility.

- Refinement to Atlantic and Gulf Coast *G&S* and new *G&S* should have the same fundamental structure as the Pacific Coast *G&S* to be developed that includes: (1) physiographic and geomorphic setting, (2) sediment characteristics across the active profile, (3) the effects of time histories of storm wave and tide characteristics, and (4) local or regional oceanic or topographic characteristics that may affect the study area. Consideration of this common structure will ensure that event-based erosion assessments will be consistent for all applications.

- The eroded beach profile that exists during the base event is needed to calculate the 1% annual chance flood elevation. Present guidelines do not specifically account for event duration, different beach materials, or dune overwash processes.

- Existing *G&S* can be improved by better defining "storm induced erosion" or event-based erosion and discussing different approaches for assessing beach and back beach profile changes caused by erosion on all coasts of the United States.

- Process-based numerical models (1-D and 2-D, steady and unsteady) may provide improved means for assessing event-based erosion in the future. Reliable numerical procedures are not presently available for general applications in Flood Insurance Studies.

- Guidance for evaluating erosion of cobble/shingle beaches is needed.

- Guidance for evaluating erosion of sandy and non-sandy bluffs and cliffs is needed.

- Guidance for evaluating erosion within sheltered water areas is needed.

- Present *G&S* provide no specific guidance on how to address beach nourishment projects.

- The 540 Criterion is based on limited data from which the erosion-frequency relationship and median value trigger for dune removal were developed. Those data and criteria may need updating.

Recommended Approach

Initially, the *G&S* should be updated using more current and available reference materials and information to address topics presently covered in the *G&S*. Future *G&S* for the Atlantic and Gulf Coasts should be expanded to include new information and improved alternative methods discussed or referenced in the Focused Studies. New methods being developed for the Pacific Coast may provide additional insight and useful information in the following three categories and levels of effort: (1) developing eroded profiles based on available historical mapping, LIDAR data, and photographs, (2) profiles based on simplistic empirical methods (other than the 540 Criterion), and (3) discussions of future methods to develop profiles using process-based (steady and unsteady) models.

Currently Available Methods, Information, and Guidelines

More recent information (than is provided in the present *G&S*) on Event Based Erosion processes and evaluation procedures are available. See appended Event-Based Erosion Focused Study for discussions of sheltered water areas, cobble/shingle beach processes, insights on process-base modeling methods, and discussions on erosion processes for different physiographic settings.

Applicability of Pacific Coast Guidelines

Approaches and insights adopted from Pacific Coast Phase 2 work on the following topics may be helpful to the Atlantic and Gulf Coasts:

- Simplified geometric models (their basis and limitations).
- Interim approach for assessing bluff and cliff erosion
- Interim approach for assessing gravel, cobble and shingle beach and dune erosion
- Interim methods for erosion assessments in sheltered water areas
- Guidance on information needed to assess special cases of beach nourishment (as an exception to existing FEMA policy).

Recommended Future Development

- Provide discussion of gravel, cobble, and shingle beaches, and dune erosion in different settings to distinguish this type of erosion hazard from other erosion processes; provide examples, figures and definitions; explain limitations of existing 540 Criterion for application to this type of erosion and beach material characteristics
- Develop new methods and *G&S* for sheltered water areas
- Describe bluff and cliff erosion; explain limitations of existing 540 Criterion for application to this type of erosion process; develop methods for assessing bluff and cliff erosion in different coastal settings
- Evaluate whether nourished beaches affect hazard zone delineations and BFEs
- Develop methods (geometric or process-based) for assessing gravel, cobble, and shingle beach and dune erosion
- Expand data sets and review erosion-frequency relationship and median value trigger for dune removal upon which the 540 Criterion is based
- Develop suite of process-based models for general coastal erosion assessments in different settings, including dune overwash processes

Table 21
Event Based Erosion Recommendations – Atlantic and Gulf Coasts

Topic Number	Topic/Subtopic	Recommended Approach (Future work)
33, 34	Gravel, cobble, and shingle beach and dune erosion	Review available literature and reporting; improved *G&S* language and descriptions for Atlantic and Gulf coasts to distinguish gravel, cobble and shingle beach and dune erosion from other processes; provide figures and examples. (1) Perform case studies to test and develop new geometric methods for cobble beaches, (2) Test process based methods, (3) Develop new *G&S*.
35, 36	*G&S* in Sheltered Water areas	Improve *G&S* with definitions and discussion of characteristics of sheltered water areas and the types of morphology, material types and wave characteristics unique to sheltered water areas. Recommend interim G&S based on historical beach profiles and field observations. (1) Conduct pilot studies, (2) Test process-based methods, (3) Develop new *G&S* for sheltered water areas
31, 32	Bluff and Cliff Erosion	Review available literature and reporting; improve *G&S* language and descriptions for Atlantic and Gulf Coasts to distinguish bluff and cliff erosion from other processes; provide figures and examples. (1) Review existing bluff erosion procedures and international literature, (2) Develop geometric procedures for bluff and cliff erosion and retreat, (3) Consider development and use of process-based numerical/statistical modeling methods for future inclusion in the NFIP program.
41	Long - Term Erosion	This topic is considered important to NFIP, but FEMA action on previous work is pending. Therefore, guidance is best developed by FEMA in the future.
42, 43	Nourished Beaches	Recommend modifying *G&S* to direct Study Contractors to follow a procedure to notify FEMA that the study area includes beach nourishment project. Provide FEMA with a list of information needed to assess special cases where beach nourishment may be considered in determining hazard zones and BFEs (exception to existing FEMA policy). Conduct research and case studies to determine whether beach nourishment is likely to have an effect on hazard zone designations of BFEs.
37	Clarify Applicability and Limitations of 540 Criterion	Clarify limitations of 540 Criterion regarding its application to different types of coastal settings and material types. Discuss limitations of geometric methods versus process-based methods. For the 540 Criterion: (1) Expand data base, (2) Define erosion area-frequency relationship, (3) Review use of median value trigger for dune removal.
38	Physics and Process-Based Methods	Describe differences and advantages between "geometric" and "process-based" EBE methods. Interim methods: continue to use 540 Criterion for Atlantic and Gulf Coasts where applicable; use most documented post-storm beach and dune profiles for areas where 540 is not applicable. (1) Further develop and test process-based models; (2) Develop method to include randomness of storm wave heights and tides and their coincident occurrence; (3) Develop and test process-based methods and prepare *G&S* for process-based erosion assessment of (a) coastal bluffs fronted by narrow beaches and (b) sandy and non-sandy beaches and dunes, including dune overwash.
40	Document Vertical Depths of Erosion	Document depths of erosion following storm events and maintain data for depths of erosion and damages to buildings in order to better determine "depth-damage" relationships.

COASTAL STRUCTURES

Overview of Existing Guidelines

Existing Guidance in Section D.2 calls for the evaluation of structures to determine whether they will survive the 1% annual chanceflood event; the guidance references CERC TR 89-15 for evaluation criteria, but states study contractors should consider available documentation and performance information (i.e., use engineering judgment) as well.

Topics and Key Issues

The following Coastal Structures topics were identified by the TWG:

Available – Topic 25, Review *G&S* language regarding 89-15; add new procedure for flood hazard modeling in the presence of coastal structures; Topic 21, Clarify guidance for dealing with failed structures during base flood; Topic 23, Add *G&S* language that buried structures are to be evaluated; Topic 27, Review and clarify *G&S* and regulations regarding treatment of coastal levees and structures; Topic 24, Review 89-15 and other literature for tsunami failure information and guidance – of some importance on South Atlantic and Gulf Coasts.

Helpful – Topic 22, Investigate configuration of failed structures; Topic 26, Review data on, and add to *G&S*, effects of structures on flood hazards on adjacent properties, flooding/waves behind structures via adjacent properties; and a portion of Topic 27, Review and revise TR-89-15 evaluation criteria.

Key issues are:

- Coastal structures can modify flood levels, wave effects, and topography, both landward of, seaward of, and adjacent to the structures, and must be considered during the mapping of coastal flood hazards. Two scenarios are commonly encountered: structures and their effects are analyzed during Flood Insurance Studies; and structures frequently serve as the basis for revisions to FIRMs.
- FEMA *G&S* can be improved by expanding or adding discussions on coastal structure failure, buried structures, and the effects of structures.
- The effects of structures can be divided into two categories: effects on erosion and effects on flood conditions. Two scenarios are important for each: (1) the effects of structures on adjacent properties; and (2) the effects on property immediately landward (and seaward) of a structure.
- Guidance for evaluating coastal structures has been largely unchanged since publication of the USACE report CERC TR 89-15 in 1989. The evaluation criteria need to be reviewed considering more recent information. Revisions may or may not be warranted.
- Guidance needs to clearly state that study contractors are not required to use CERC TR 89-15.
- Guidance on the evaluation of coastal structures in tsunami-prone areas is needed.

- FEMA *G&S* call for structure "removal" from subsequent flood hazard analyses in the event that a structure fails (i.e., does not survive the base flood event), but guidance on uncertified structure removal should be expanded and revised. More importantly, the configuration of a failed structure can affect wave runup and overtopping calculations. A method to address uncertified structures, used in a recent Pacific Coast flood study (by PWA), has been modified by the Focus Study and is recommended for use.

- Coastal structures and levees are sometimes treated differently, and those differences should be justified or eliminated. The *G&S* should address coastal levees.

- FEMA *G&S* were written primarily considering seawalls, bulkheads, revetments, and do not address the effects of other structures types (e.g., jetties, groins, breakwaters). While treatment of these other structures is needed, it is deemed a lower priority than revising the guidance related to seawalls, bulkheads, revetments and levees.

Recommended Approach

The recommended approach is to revise the *G&S* using available references and information. The effort will be modest by comparison with some of the other Focus Study topics.

Currently Available Methods, Information and Guidelines

Updated information on coastal structure evaluation and criteria are available. See Coastal Structures Focused Study report.

Applicability of Pacific Coast Guidelines

Pacific coast work will be directly applicable to the Atlantic and Gulf coasts on five topics:

- Buried structures and failed structure configurations (including progressive collapse of revetments).

- Treatment of failed ("removed") structures for wave height and runup analyses.

- Investigation of structure effects on erosion and flood hazards.

- Consistency in treatment of coastal structures and coastal levees.

- Evaluating structures in tsunami-prone areas.

Recommended Future Development

- Revise/update CERC TR 89-15 coastal structure evaluation criteria.

- In addition to the current structural criteria, develop minimum structure dimensions (e.g., length, return wall length) necessary to receive mapping credit during Flood Insurance Studies and flood map revisions.

- Revise guidance to consider jetties, groins and breakwaters.

Table 22
Coastal Structures Recommendations – Atlantic and Gulf Coasts

Topic Number	Topic/Subtopic	Recommended Approach (Future work)
26	Jetties, Groins, Breakwaters	Develop criteria/guidance for evaluating failure of other structure types, and the effects of these failures on mapped flood hazards
26	Minimum Structure Dimensions	Determine minimum structure dimensions necessary to receive mapping credit during FIS and revisions to FIRMs
27	Structure Evaluation Criteria	Review CERC TR 89-15 considering more recent data on structure stability and failure; revise structure evaluation criteria.

SHELTERED WATERS

Overview of Existing Guidelines

Appendix D.1 through D.2 of the existing *G&S* are generally written to provide guidance for coastal flood studies along the open coasts of the Atlantic Ocean and Gulf of Mexico. Several references to sheltered water areas are made in these *G&S*, but detailed guidance is not provided. *G&S* for the Great Lakes regions are provided in Appendix D.3, but may not be applicable for general application to smaller shelter water areas with limited fetch.

Topics and Key Issues

The following Sheltered Waters topics were identified by the TWG:

Critical – Topic 6a, Definitions and classifications; Topic 6b, Prepare guidance for developing validation data from historic events; Topic 6d, Define 1% annual chance flood event in SW; Topic 6e, Guidance for estimating Stillwater elevations; Topic 6h, Coordinate/integrate SW guidelines with other Focused Studies and other Map Mod objectives.

Key issues are:

- The existing *G&S* are generally written to provide guidance for coastal flood studies along the open coasts of the Atlantic Ocean and Gulf of Mexico. Several references to sheltered water areas are made in these guidelines, but detailed guidance is not provided.
- Sheltered waters are water bodies with shorelines that are not subjected to the direct action of undiminished ocean waves. Although similar processes contribute to flooding along sheltered water shorelines as along open coastlines, such as wave setup, runup and overtopping, there are several aspects of sheltered water flood hazards not addressed in the current *G&S*. Additional guidance is needed.
- Wave generation and transformation in SW are typically limited by an open water fetch distance, complex bathymetry and often the presence of structures. A sheltering effect typically reduces wave energy and flood potential compared to open coast areas; however, wave runup and overtopping along SW shorelines may present additional hazards from wave-cast debris and backshore flooding.
- Wave-cast debris from extreme wave runup and overtopping can be especially problematic, owing to the proximity to fluvial sources of such materials in many estuaries.
- SW areas often have unique flood hazards due to the effects of fluvial drainages, modified tidal and surge hydrology, and relatively strong tidal currents.
- Other unique flood-related characteristics include the complex geometry of the embayments, non-coincidence of peak storm surge with peak winds, shallow water and restricted wind fetches for wave growth, and non-sandy shoreline types with special erosion and scour hazards.
- Appendix D.2.2.7 states the “analysis of restricted fetches” in “sheltered coastal sites” is addressed in the existing guidelines and the ACES software is referred to; however, more specific guidance is needed on how to apply this software to fetch-limited conditions.

- Appendix D.2.5.5 addresses wave runup and overtopping on shoreline barriers where overtopping flows discharge across landward-dipping or level backshore slopes to a "bay, river, or backwater". These situations are prevalent in SW areas. Additional guidance is needed.

- Appendix D.1.2.4 states "Methods by which barriers, inlets and rivers have been treated" are required in documentation of the hydrodynamic storm surge model. However, no guidance is provided for methods to consider modeling for sheltered waters.

- New guidelines are needed to inform and guide Mapping Partners in the preparation of coastal flood insurance studies and flood hazard maps in sheltered water areas of the coastal floodplain.

Recommended Approach

The recommended approach is identical to that for the Pacific Coast. A separate section on Sheltered Waters is recommended for the Pacific Coast *G&S* as well as the Atlantic and Gulf Coast Guidelines to direct Mapping Partners to pertinent guidance found elsewhere in the *G&S* and readily available literature. This section will also provide specific new information and guidance for assessing flood hazards in Sheltered Waters.

Currently Available Methods, Information and Guidelines

- Many FEMA-approved coastal flood insurance studies have been completed in sheltered waters located along the Atlantic and Gulf Coasts.

- The USACE has published a guide for local officials for use in planning shoreline erosion management and mitigation projects in sheltered waters.

- Other information describing the physical setting, physical processes and coastal flood hazards in sheltered waters along the Atlantic and Gulf Coasts is available on the Internet and through other public sources. See appended Focused Study on Sheltered Waters for discussions of key coastal flooding assessment topics, known procedures, and recommended sources of information.

Applicability of Pacific Coast Guidelines

Work completed for the Pacific Coast will be applicable to the Atlantic and Gulf Coasts on three topics:

- Provide general definitions, examples, and develop a classification method and general approach for conducting sheltered water studies versus open coast studies. This will serve as a framework and generalized approach for Mapping Partners to follow when conducting coastal flood hazard assessments.

- Prepare general guidance for documenting and using high water marks to reconstruct historic flood conditions to validate flood study results.

- Prepare guidelines that comply with other related FEMA Map Modernization objectives and multi-hazard planning initiatives.

The Phase 2 Sheltered Waters work for the Pacific Coast *G&S* will involve collaboration and coordination with other Focused Study groups on related sheltered water "Critical" topics listed in the

summary table for the Atlantic and Gulf Coasts. Technical references, some data, and general procedures should be applicable to Atlantic and Gulf Sheltered Water areas.

Recommended Future Development

The characteristics and physics of wave runup and overtopping are fundamentally the same on the Atlantic and Gulf Coasts as they are on the Pacific Coast. However, the physical setting, the magnitude, seasonal frequency, and direction of regional storm systems that lead to high stillwater elevations and wave action that combine to generate flood hazards can be very different on the coasts. Several of these coastal differences should be addressed in the remaining two sheltered water topics:

- Prepare guidance specific to defining the 1% annual chance flood event involving dependent and independent joint probability occurrences of riverine and tidal flooding in sheltered water areas and expand guidance on wind data acquisition and analysis and fetch-limited wave forecasting in sheltered waters.
- Prepare guidance for estimating stillwater elevations in ungaged sheltered waters bodies and evaluating the effects of tidal and riverine currents on wave propagation in sheltered waters.

Table 23
Sheltered Waters Recommendations – Atlantic and Gulf Coasts

Topic Number	Topic/Subtopic	Recommended Approach (Future work)
6a	Definitions and Classification	Provide definitions, examples, and develop a classification method for sheltered water studies.
6b	Flood Event Reconstruction	Prepare general guidance for documenting and using high water marks to reconstruct historic flood conditions.
6d	Combined Tidal-riverine 1% Annual Chance Event Assessment	Prepare guidance specific to defining the 1% annual chance flood event involving riverine and tidal flooding and expand guidance on wind data acquisition and analysis and fetch-limited wave forecasting.
6e	Stillwater Estimation	Prepare guidance for estimating stillwater elevations in ungaged sheltered water bodies and evaluating the effects of tidal and riverine currents.
6h	Hazard Mitigation Coordination	Prepare general guidance for Mapping Partners to coordinate the preparation of coastal studies with other hazard mitigation activities.
6h	Focused Study Coordination	Collaborate/coordinate with other Focused Study groups to address sheltered waters Critical topics found in other Focused Studies.

HAZARD ZONES

Overview of Existing Guidelines

FEMA *G&S* (Section D2.7) contains requirements for depicting the results of the hazard analyses on the FIRMs. In Section D.2.7.2, "Identification of Flood Insurance Risk Zones," is an overview of the various hazard zone mapping criteria for zones VE, AE, AO, AH, and X, considering the combined effects of storm-induced erosion, wave height, wave runup, wave overtopping, primary frontal dunes, and coastal flood protection structures. The *G&S* also includes a series of examples that represent common flood hazard zone mapping scenarios based on transects.

Topics and Key Issues

The following Hazard Zones topics were identified by the TWG:

Critical – Topic 39, Definition of the primary frontal dune; Topic 17, Several sub-topics related to delineation of VE Zone limits, including BFE transitions, use of VO Zones, wave overtopping, wave-cast debris hazards, and use of the primary frontal dune definition.

Available – Topic 19, Determination of combined probabilities and mapping for areas subject to both coastal and riverine flood sources).

Important – Topic 18, Several sub-topics related to the appropriateness of existing VE and AE Zones.

Key issues are:

- The definition of primary frontal dune (PFD) is "where there is a distinct change from a relatively steep slope to a relatively mild slope" in 44 CFR 59.1. The definition does not provide a quantitative method for establishing the landward limit of the PFD, yet it has significant influence on hazard zone delineation (see below). The PFD definition and delineation also has implications for floodplain management because dune areas within a VE Zone are protected under 44 CFR 60.3(e)(7).
- Coastal high hazard zones are defined in 44 CFR 59.1 to include the area up to the landward limit of the PFD along open coasts. In practice, this definition frequently dominates the determination of the VE Zone boundary. An improved definition or quantitative methodology is needed to improve consistency in hazard zone delineation.
- The use of the PFD definition for VE Zone mapping may cause areas that are subject to significantly different levels of flood risk to be mapped in a single VE Zone. The seaward portion may be subject to inundation by active coastal processes during the base flood (erosion, wave height, wave runup, and wave overtopping). The landward portion may be subject to a lower level of risk, but is included solely on the basis of the PFD limit defined by topography.
- Transitions in the BFEs are frequently abrupt where the PFD definition is used to establish a VE Zone limit, and the AE Zone behind the PFD has a much lower computed BFE. Improved

procedures are needed to accurately relate mapped BFEs to flood risk. Alternative procedures for mapping the transition in BFEs or alternative flood hazard zone delineations may be advisable.

- The wave overtopping criteria presently used in VE Zone hazard mapping require expansion and review to evaluate threshold rates, the extent of the mapped zones, and the potential for use of VO Zones to more accurately reflect actual hazards landward of overtopped dunes, coastal ridges, and shore protection structures. This is particularly applicable to the Northeast Atlantic Coast, where flood hazard zones may be dominated by wave runup and overtopping, and wave-cast debris is a significant hazard.

- Coastal Special Flood Hazard Areas (SFHAs) on the Atlantic and Gulf Coasts may be quite broad with many subdivided hazard zones and BFEs. These areas are subject to significant overland wave propagation (primarily in Mid- to South-Atlantic and entire Gulf Coast). A review is needed to determine the feasibility of subdivision of the coastal AE Zone SFHA into two portions: (1) a seaward portion exposed to direct flood and wave effects from a principal flood source, to be regulated as a Coastal A Zone (similar to VE Zone regulations): and (2) a more landward portion of the AE Zone where wave effects are reduced and VE Zone regulations are not needed.

- A methodology is needed for determining and mapping flood hazard areas where coastal flooding intersects and combines with a riverine flood profile. Previous FEMA guidance should be reviewed for this condition.

Recommended Approach

The overall recommended approach is identical to that for the Pacific Coast – revise the *G&S* using available references and information. There may be some limited use and application of primary frontal dune VE Zone identification and mapping criteria on the Pacific Coast.

Currently Available Information, Methods, and Guidelines

- The Massachusetts Coastal Zone Management (MA CZM) division has developed an improved methodology for automating the identification and mapping of the landward limits of the primary frontal dune VE Zone. This method is available and could be reviewed for potential use in other coastal areas.

- Existing guidance on Coastal A Zones are not available, but other published material helps to establish the need and possible regulatory enforcement options of the Coastal A Zone.

Applicability of Pacific Coast Guidelines

The four main items for Phase 2 work on the Pacific Coast (see recommended approaches in the Hazard Zones Focused Study) are also applicable to the Atlantic and Gulf Coasts. The following items could be based largely on Phase 2 work for the Pacific Coast, with revisions to extend their applicability to the Atlantic and Gulf coasts:

- Establish improved procedures for establishing the landward limit of the PFD, and develop guidance to better map the BFE transition between PFD-dominated VE Zones and landward SFHA hazard zones.

- Establish procedures (hazard identification and mapping) to better utilize VO Zones for severe wave overtopping areas where VE Zones have limited use and application.
- Establish procedures for identifying and mapping hazard zones for wave overtopping and wave-cast debris hazards, primarily a concern in the Northeast Atlantic region.
- Review the 1982 FEMA (Tetra Tech) or revised/new guidance on how to conduct the technical assessment and mapping of combined coastal-riverine areas for adoption into the *G&S* .

Recommended Future Development

- Provide further technical guidance in the *G&S* to clarify the PFD mapping criteria.
- Consider adoption of new quantitative methodologies for identification and mapping (e.g., MA CZM).
- Prepare technical bulletins for clarification of proposed revisions to VE Zones, AE Zones, and new criteria for VO Zones.
- Investigate and develop Coastal A Zone criteria (wave and erosion damage).
- Develop new Coastal A Zone guidance and apply new concepts in a case study area.

Table 24
Hazard Zones Recommendations – Atlantic and Gulf Coasts

Topic Number	Topic/Subtopic	Recommended Approach (Future Work)
39	Primary Frontal Dune VE Zone	Prepare an improved and refined definition of the PFD slope transition as revision to NFIP regulations, and provide further technical guidance in *G&S* to clarify the PFD mapping criteria through a case study (e.g., Lewes, DE) Consider adoption of quantitative methodologies and procedure for identification and mapping of the PFD landward limit (heel) slope criteria (e.g., MA CZM use of LIDAR and GIS automated methods)
18	Coastal A Zone Hazard Zone	Investigate and develop Coastal A Zone criteria (wave and erosion damage) and procedures for application within the NFIP; Develop an annotated bibliography of related research and papers to support new guidance for Coastal A Zones; Apply new concepts in a case study area.
18	Hazard Zone Technical Bulletins	Prepare technical bulletins for clarification of proposed revisions to VE Zones, AE Zones, and new VO Zones related to hazard identification, Special Flood Hazard Mapping and floodplain management.
19	Combined Coastal-Riverine Zones	Develop mapping standards to clearly identify this hazard zone. Develop alternate methods for identification of hazard zone.

5.5 SUMMARY OF RECOMMENDATIONS – ATLANTIC AND GULF COASTS

For ease of reference, all of the topics and all of the categories have been combined in the following table.

Table 25
SUMMARY OF ATLANTIC AND GULF COAST RECOMMENDATIONS

Topic Number	Topic/Subtopic	Recommended Approach (Future Work)
STORM METEOROLOGY RECOMMENDATIONS – ATLANTIC AND GULF COASTS		
51	Tide and Surge Combination	Develop guidelines for the combination of surge and tide, including examples drawn from past studies (with consideration of FEMA surge studies, ADCIRC/EST, and the FL-DEP Monte Carlo method)
51	Surge/Riverine Combination	Prepare recommendations for the statistical combination of surge and a riverine runoff profile, with consideration of non-independence of the processes; see also Topic 19 of the Hazard Mapping Focused Study for simple mapping suggestions
50	Storm Surge Frequency Analysis	Apply/Compare methodologies (JPM, EST, Monte Carlo) using a common hydrodynamic model and storm data set
50	Storm Parameters for Surge Modeling	Review and evaluate available sources of storm parameters used in storm surge modeling, including NWS 38, HURDAT, and other databases
50	Storm Wind Fields	Review best available data regarding wind fields and compare with fields used in storm surge models; recommend the most appropriate models for FIS use (tropical storms, northeasters)
50	Wind Stress Formulation	Review best available data for wind stress and compare with formulations used in storm surge models; recommend the most appropriate formulation for FIS use
STILLWATER RECOMMENDATIONS – ATLANTIC AND GULF COASTS		
53	General Considerations for Surge Modeling	Based on the existing literature, describe the use of surge models applicable to Atlantic and Gulf Coasts and the factors that require consideration in performing a study.
53	Surge Modeling Global Calibration	Develop statistical procedures to assess the performance of the FEMA surge models through the consideration of global experience on all coasts.
53	Regional Surge Modeling	Develop guidance for large scale regional surge modeling.
STORM WAVE CHARACTERISTICS RECOMMENDATIONS – ATLANTIC AND GULF COASTS		
4, 5	Sea and Swell for Open Atlantic and Gulf Coasts	Investigate the appropriateness of using either the 100-year significant wave height or the 20-year maximum wave height while modeling WHAFIS. Clarify use of equivalent deep water wave condition. Clarify extrapolation to 100-year
5	Wave Generation in Sheltered Water	Develop Guidelines on Sheltered Water based on Pacific Coast *G&S*.
1	Wave Definitions	Incorporate and refine the "Glossary of Coastal Terminology" directly from the USACE CEM. Incorporate and refine the five listings of notations and parameters in the 1986 International Association for Hydraulic Research publication, "List of Sea State Parameters." Provide specific guidance on how wave related terms in the USACE and IAHR sources relate to each other and how they should be applied relative to the following: (1) FEMA guidance for coastal flood studies, (2) physical processes

		that are directly associated with FEMA coastal hazard assessments and flood mapping, and (3) required coastal hazard study methodologies Prepare an application for Atlantic and Gulf Coast Guidelines
WAVE TRANSFORMATION RECOMMENDATIONS – ATLANTIC AND GULF COASTS		
9	Wave Energy Dissipation over Shallow Flat Bottoms	Write *G&S* to include a section on wave energy dissipation over shallow and flat bottoms; Develop typical ranges for dissipation coefficients for variety of bed and wave conditions to include in the *G&S*. Categorize bed and wave conditions for US coastlines. Revise *G&S* to provide dissipation coefficients on a geographic basis; revise *G&S* to adopt Suhayda (1984) method.
10	Overland Wave Propagation, Candidate Improvements to WHAFIS	Evaluate new methods to better represent vegetation effects, treatment of elevated pile supported buildings Minor Effort – WHAFIS code changes for more user friendly program Moderate Effort – more intense code changes for improvement in accuracy and graphics (in WHAFIS) Significant Effort - Revise WHAFIS to consider combined effects of damping and wind action over each segment.
8	Overall Wave Transformation with and without Regional Models	Cross reference Pacific Coast guidelines, and emulate important topics for Atlantic and Gulf Coasts.
WAVE SETUP RECOMMENDATIONS – ATLANTIC AND GULF COASTS		
44	A&G Coast Definitions	Develop wave setup definitions with emphasis on A&G Coast applications.
45	Compile Data for Testing	Locate as much quality field data as possible for testing of developed/selected approach(es).
46	Develop Engineering Based Approach	Couple accepted engineering models for calculating wave setup across surf zone. Include procedure for dynamic wave setup.
46	Evaluate Boussinesq Models	Intercompare at least three Boussinesq models and compare with data.
46	Develop Breaking Zone Model	Evaluate candidate breaking zone models that allow specification of non-planar profile
47	Ideal Model for Static Wave Setup	Couple wave generation and wave setup model, allowing specification of arbitrary tide.
48	Develop Model for Dynamic Wave Setup	Develop method based on directional and nonlinear spectrum as input.
WAVE RUNUP AND OVERTOPPING RECOMMENDATIONS – ATLANTIC AND GULF COASTS		
No Topic number assigned.	Revise Guidance to Reflect Current FEMA Practice	Revise guidance to describe use of ACES for runup and overtopping calculations (ACES is based on more recent procedures than SPM or RUNUP 2.0). Revise guidance to clarify use of *equivalent* deepwater wave conditions with RUNUP 2.0
12	RUNUP 1.0 vs. 2.0	Perform detailed comparisons of wave runup using RUNUP 1.0 and 2.0. Determine whether to adjust prior RUNUP 1.0 studies or to restudy using RUNUP 2.0 (or other methods).

12	Evaluate Use of Mean Runup Value	Review runup distributions and damages for Atlantic/Gulf beaches and structures, compare against Pacific. Evaluate use of $R_{50\%}$ and select alternate $R_{x\%}$ value (probably between $R_{33\%}$ and $R_{10\%}$) if $R_{50\%}$ understates observed hazard.
No topic number assigned.	Wave Setup Component	Treatment of wave setup component (in FEMA's current wave runup procedure) to be coordinated with Wave Setup study.
11, 49	Conduct Comparative and Sensitivity Testing of Runup Models and Methods	Compare results using simple methods versus numerical models, deterministic (event selection) versus statistical approaches. Test runup methods and models – priority to be given to testing in New England region. Identify appropriate runup methods and models by location, morphology and hydraulic conditions
13, 14	Guidance for Overtopping and Wave Cost Debris	Maintain use of mean overtopping rate (cfs/ft, m^3/ per m) Evaluate recent data and methods Apply Pacific results relative to damaging overtopping rates and FEMA hazard zone thresholds Evaluate wave-cast debris coincidence with overtopping Coordinate with Hazard Zone study
EVENT BASED EROSION RECOMMENDATIONS – ATLANTIC AND GULF COASTS		
33, 34	Gravel, Cobble and Shingle Beach & Dune Erosion	Review available literature and reporting; improved *G&S* language and descriptions for Atlantic and Gulf Coasts to distinguish gravel, cobble, and shingle beach and dune erosion from other processes; provide figures, and examples. (1) Perform case studies to test and develop new geometric methods for cobble beaches, (2) Test process based methods, (3) Develop new *G&S*.
35, 36	*G&S* in Sheltered Water Areas	Improve *G&S* with definitions and discussion of characteristics of sheltered water areas and the types of morphology, material types and wave characteristics unique to sheltered water areas. Recommend interim *G&S* based on historical beach profiles and field observations. (1) Conduct pilot studies, (2) Test process-based methods, (3) Develop new *G&S* for sheltered water areas
31, 32	Bluff and cliff erosion	Review available literature and reporting; improve *G&S* language and descriptions for Atlantic and Gulf Coasts to distinguish bluff & cliff erosion from other processes; provide figures and examples. (1) Review existing bluff erosion procedures and international literature, (2) Develop geometric procedures for bluff and cliff erosion and retreat, (3) Consider development and use of process-based numerical/statistical modeling methods for future inclusion in the NFIP program.
41	Long-term erosion	This topic is considered important to NFIP, but FEMA action on previous work is pending. Therefore, guidance is best developed by FEMA in the future.
42, 43	Nourished Beaches	Recommend modifying *G&S* to direct Study Contractors to follow a procedure to notify FEMA that the study area includes beach nourishment project. Provide FEMA with a list of information needed to assess special cases where beach nourishment may be considered in determining hazard zones and BFEs (exception to existing FEMA policy). Conduct research and case studies to determine whether beach nourishment is likely to have an effect on hazard zone designations of BFEs.

37	Clarify Applicability and Limitations of 540 Criterion	Clarify limitations of 540 Criterion regarding its application to different types of coastal settings and material types. Discuss limitations of geometric methods versus process-based methods. For the 540 Criterion: (1) Expand data base, (2) Define erosion area-frequency relationship, (3) Review use of median value trigger for dune removal.
38	Physics and Process Based Methods	Describe differences and advantages between "geometric" and "process-based" EBE methods. Interim methods: continue to use 540 Criterion for Atlantic and Gulf Coasts where applicable; use most documented post-storm beach and dune profiles for areas where 540 is not applicable. (1) Further develop and test process-based models; (2) Develop method to include randomness of storm wave heights and tides and their coincident occurrence; (3) Develop and test Process-Based methods and prepare *G&S* for Process-Based erosion assessment of (a) coastal bluffs fronted by narrow beaches and (b) sandy and non-sandy beaches and dunes, including dune overwash.
40	Document Vertical Depths of Erosion	Document depths of erosion following storm events and maintain data for depths of erosion and damages to buildings in order to better determine "depth-damage" relationships.
COASTAL STRUCTURES RECOMMENDATIONS – ATLANTIC AND GULF COASTS		
26	Jetties, Groins, Breakwaters	Develop criteria/guidance for evaluating failure of other structure types, and the effects of these failures on mapped flood hazards
26	Minimum Structure Dimensions	Determine minimum structure dimensions necessary to receive mapping credit during FIS and revisions to FIRMs
27	Structure Evaluation Criteria	Review CERC TR 89-15 considering more recent data on structure stability and failure; revise structure evaluation criteria.
SHELTERED WATERS RECOMMENDATIONS – ATLANTIC AND GULF COASTS		
6a	Definitions and Classification	Provide definitions, examples, and develop a classification method for sheltered water studies.
6b	Flood Event Reconstruction	Prepare general guidance for documenting and using high water marks to reconstruct historic flood conditions.
6d	Combined Tidal-Riverine 1% Annual Chance Event Assessment	Prepare guidance specific to defining the 1% annual chance flood event involving riverine and tidal flooding and expand guidance on wind data acquisition and analysis and fetch-limited wave forecasting.
6e	Stillwater Estimation	Prepare guidance for estimating stillwater elevations in ungaged sheltered water bodies and evaluating the effects of tidal and riverine currents.
6h	Hazard Mitigation Coordination	Prepare general guidance for Mapping Partners to coordinate the preparation of coastal studies with other hazard mitigation activities.
6h	Focused Study Coordination	Collaborate/coordinate with other Focused Study groups to address sheltered waters Critical topics found in other Focused Studies.
HAZARD ZONES RECOMMENDATIONS – ATLANTIC AND GULF COASTS		
39	Primary Frontal Dune VE Zone	Prepare an improved and refined definition of the PFD slope transition as revision to NFIP regulations, and provide further technical guidance in *G&S* to clarify the PFD mapping criteria through a case study (e.g., Lewes, DE) Consider adoption of quantitative methodologies and procedure for identification and mapping of the PFD landward limit (heel) slope criteria (e.g., MA CZM use of LIDAR and GIS automated methods)

18	Coastal A Zone Hazard Zone	Investigate and develop Coastal A Zone criteria (wave and erosion damage) and procedures for application within the NFIP; Develop an annotated bibliography of related research and papers to support new guidance for Coastal A Zones; Apply new concepts in a case study area.
18	Hazard Zone Technical Bulletins	Prepare technical bulletins for clarification of proposed revisions to VE Zones, AE Zones, and new VO Zones related to hazard identification, Special Flood Hazard Mapping and floodplain management.
19	Combined Coastal-Riverine Zones	Develop mapping standards to clearly identify this hazard zone. Develop alternate methods for identification of hazard zone.

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