PROJECT SUMMARY

PS.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. The primary work products for the study are the Final Draft Guidelines attached to this Project Summary, and a Phase 1 Summary Report (May 2004). The Final Draft Guidelines (generally referred to below as "Guidelines") provide guidance for coastal flood hazard analyses and mapping, specific to the Pacific Coast of the United States. The Phase 1 Summary Report provides background on the project approach; describes the process used for evaluating existing guidelines; and summarizes the recommendations for the Pacific, Atlantic, and Gulf Coasts. Appendices to the Phase 1 Report include information on the Technical Working Group, key references, and Focused Studies conducted on 11 categories of technical topics.

PS.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.

While 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 was needed to consider recent advances in coastal flood hazard assessment and mapping, and potential modifications to existing FEMA procedures based on state-of-the-art scientific understanding of coastal processes, new technology and numerical modeling techniques, improved and expanded data, and modern mapping techniques.

The overall 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 for the Pacific Coast of the United States, based on an understanding of local and regional coastal processes.

PS.3 DESCRIPTION OF NEEDS BY GEOGRAPHIC REGION

Guidelines 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, swell) and geomorphic characteristics, but no FEMA guidance was established specifically for this coast.

PS.3.1 Pacific Coast

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. FEMA's existing coastal flooding guidelines focus on storm types (especially hurricanes) 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 was needed to determine which portions may be transferred or modified for use on the Pacific Coast and what new procedures are needed.

PS.3.2 Atlantic and Gulf Coasts

A comprehensive review of the existing guidelines was needed in light of more recent experience and new technology. Modified or new procedures are needed to incorporate experience from previous studies and appeals, information on actual damages, and post-storm verification data. In addition, a review of the basis of existing procedures was needed in light of an improved understanding of ocean and coastal processes from recent research and new data. The existing procedures include little guidance on analysis of storm meteorology, storm surge, or wave setup. In addition, there is a need to evaluate expansion of the guidelines to address flood hazards in coastal areas not directly exposed to ocean swell and waves generated by distant weather conditions (e.g., bays and estuaries, referred to as Sheltered Waters in this document).

PS.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.

PS.4 PROJECT APPROACH AND SCHEDULE

The project approach included two key elements to ensure that the project was completed rapidly and effectively: (1) a team of technical experts (Technical Working Group, or TWG) was assembled with experience in various coastal processes and their effects in different geographic regions of the country, and (2) the project was conducted 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 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. An alphabetical listing of the Technical Working Group is provided after the Executive Summary. 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 based on consensus among coastal experts.

The project schedule was established based on FEMA's targets for the Map Modernization Plan. The project approach recognized that improvements to the Guidelines would need to be prioritized to maintain the adopted schedule. Phase 1 was initiated in October 2003, and a final draft Phase 1 Summary Report was delivered to FEMA in June 2004.

Phase 2 of the project was initiated in May 2004, and Final Draft Guidelines were delivered to FEMA in electronic format in November 2004. The Final Draft Guidelines are appended to this Project Summary in hard copy. Additional Technical Support information will be submitted to FEMA in January 2005.

Completion of the project on this schedule allows coastal flood insurance studies to proceed with new draft guidance in fiscal year (FY) 2004/2005. The schedule has required an intensive work effort to complete a comprehensive review of existing procedures, to recommend modifications to existing procedures, develop new methods, and prepare the Final Draft Guidelines. This effort involved approximately 30 organizations and active participation of more than 60 individuals.

PS.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 from 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) Wave Characteristics, (4) Wave Transformation, (5) Wave Setup, (6) Event-Based Erosion, (7) Wave Runup and Overtopping, (8) Coastal Structures, (9) Sheltered Waters, (10) Tsunamis, and (11) Hazard Zones. These focused studies are included in the Appendices to the Phase 1 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, and 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 (development of Pacific Coast guidelines). Therefore, in March 2004 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 deferred some recommendations for future development in the National Flood Insurance Program (NFIP) but maintained the target of producing reliable guidelines for coastal studies on the Pacific Coast in FY 2004/2005.

PS.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 of the Phase 1 Summary Report. 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., 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 in light of 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.

Recommended approaches to address these and other needs are included in Sections 4 and 5 of the June 2004 Phase 1 Summary Report.

PS.7 PHASE 2 – PREPARATION OF DRAFT GUIDELINES

As noted above, priorities were established by the TWG to implement a portion of the Phase 1 recommendations to prepare new guidelines for the Pacific Coast during Phase 2. The Guidelines developed in Phase 2 are 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 procedures for defining the 1% percent annual chance flood elevation as a combination of wave and water level characteristics where a single dominant storm mechanism (e.g., hurricane) can not be defined; and
- Identification of analyses that may best be accomplished at a regional scale (e.g., wave transformation, tsunamis), and the appropriate input to local analyses and hazard mapping.

Phase 2 included limited case studies to develop and test new procedures and to develop simple models designed specifically for use in FEMA flood insurance studies. The following technical areas were identified for case studies and testing:

- 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 – assess wave transformation models
- Wave Setup – testing of Boussinesq models; development and testing of a new setup model
- Runup and Overtopping – runup model testing combined with 1% flood elevation testing in Storm Meteorology; develop an analytical model for waver overtopping; and test numerical wave overtopping model
- Event-Based Erosion – testing of geometric models and procedures
- Flood Hazard Zones – development of new criteria for VE Zone mapping based on depth and velocity of flow

A separate case study was also recommended by the TWG to develop a probabilistic methodology that considers both near-field and far-field sources of tsunamis. This case study is being 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. This case study is scheduled for completion early in 2005.

The Final Draft Guidelines developed in Phase 2 provide guidance for selecting and combining specific methods to evaluate coastal flood hazards for a wide range of coastal settings and storm conditions found along the Pacific Coast of the United States. Within these Guidelines, "methods" means the individual techniques used to make specific computations. "Study methodology" is the combination of appropriate methods and data necessary to develop flood hazard zones for depiction on a Flood Insurance Rate Map (FIRM).

The Guidelines are numbered to fit into FEMA's existing guidance document for coastal flooding, Appendix D of the Guidelines and Specifications for Flood Hazard Mapping Partners (April 2003).

Section D.4.1 provides an overview of the Guidelines for the Pacific Coast, and Section D.4.2 provides guidance on study methodology. Specific methods for analysis of flood frequencies; waves and water levels; wave setup, runup, and overtopping; coastal erosion; and coastal structures are presented in Sections D.4.3 through D.4.7. Section D.4.8 provides a placeholder for future guidance on analysis of flood hazards due to tsunamis. In most cases, several methods may be applicable to a specific coastal setting. The objective of these guidelines is to provide guidance for developing an appropriate methodology based on the coastal setting and available data for a given project location. Section D.4.9 provides guidance on mapping of flood hazard zones and Base Flood Elevations, and Section D.4.10 provides guidance on study documentation. Sections D.4.11 through D.4.13 provide references, notations, and acronyms.

The following are key components of the new Pacific Coast Final Draft Guidelines:

- Guideline procedures summarize the basic steps in selecting analysis methods according to coastal setting and availability of data.
- Clear distinctions are made between "open coast" and "sheltered water" areas and how hazard assessments shall proceed in each setting.
- An approach is presented for evaluating the 1% annual chance flood, based on the concept of "system response analyses" rather than traditional "event analyses." The response approach uses measured or predicted wave conditions along with simultaneously measured or predicted water-levels to determine site specific storm response parameters, such as runup and maximum water levels at points of interest. Storm event responses in the surf zone and backshore are computed for a variety of storms, and statistically evaluated to define the 1% annual chance flood

characteristics. This method of assessing system responses in the surf zone and backshore avoids the need to consider joint probability analysis of waves and water levels.

- A statistical method is recommended for determining the 1% still water level for a tidal location subject to flooding by both coastal and riverine mechanisms.
- A section on "flood frequency analysis methods" is provided in the guidelines. For studies where long periods (greater than 30 years) of measured or hindcast data are available, the Generalized Extreme Value Distribution Method with parameters estimated by the Method of Maximum Likelihood is recommended for estimating extreme values, such as 1% annual chance total water level and stillwater level. For flood studies where long periods of measured or hindcast data are NOT available then statistical simulation methods such as the Monte Carlo Method are recommended.
- Several available wave hindcast databases are compared. The Global Reanalysis of Ocean Waves (GROW) is recommended for use in "open coast" FIS studies for the Pacific.
- A modified version of WHAFIS is described that allows for variation of wind speed and its application to the non-hurricane wind climate found along the Pacific Coast.
- Regional wave transformation modeling is recommended for areas such as the Southern California Bight where offshore islands, deep canyons and headlands require complex wave transformations.
- New procedures for computing wave setup and runup using parametric, simple numerical models, and advanced "Boussinesq" modeling procedures are provided, with guidance explaining where and when such procedures are required.
- Wave runup is recommended to be evaluated at the 2% exceedance level rather than the 50% (mean) exceedance level presently recommended in Appendix D.
- A new numerical model using the Direct Integration Method (DIM) is recommended for calculating static and dynamic (infragravity) components of wave setup for the Pacific Coast setting. Simple parameterized models are also developed based on DIM.
- The Atlantic and Gulf Coast "540 Rule" for beach and dune erosion is not recommended for the Pacific Coast. Simple "geometric models" are recommended for estimating event-based erosion of sand beaches and dunes for the Pacific Coast. The concept of the "most likely winter profile" for various coastal beach settings is introduced and procedures for estimating eroded winter profiles during 1% annual flood conditions are presented for six coastal beach settings.

- New runup and overtopping methods are recommended. A simple analytical trajectory model is developed for wave overtopping by splash. (Please note that the TWG recommends that these new methods be thoroughly tested for several settings, prior to their general application.)

- The guidelines propose to define the VE splash zone as the landward extent of the overtopping splash trajectory.

- A new criterion for VE Zone delineation referred to as the *high velocity flow zone* is proposed. This criterion is applicable to areas landward of *the wave overtopping splash zone*, where the product of flow depth times the flow velocity squared (hv^2) is greater than or equal to 200 ft ^{3}/sec^2. This new criterion may also be applicable to hazard delineation of tsunami runup in the future.

- Guidance is presented for delineating coastal flood hazard zones and Base Flood Elevations (BFEs) based on these new methods.

PS.8 Summary

These Guidelines offer insight and recommended methods to analyze complex Pacific Coast flood processes in a reasonable way. However, they require technical judgment and experience in their application, and are not a prescriptive technique that can be applied uniformly in all study areas. The Guidelines are intended to apply to a range of settings, but they cannot address all settings and conditions due to the broad variability of the Pacific Coast. They include new methods that were developed over a one-year period by the TWG assembled by FEMA. Methods were selected and developed through collaboration and consensus to be robust and reproducible, but at the release date of this document (November 2004), many of these methods have not been fully tested in FISs. Therefore, the TWG recommends that these new methods and Guidelines be thoroughly tested for a variety of settings, prior to general distribution and application throughout FEMA.

Experience and judgment in coastal engineering is required in order to apply the procedures provided in the Final Draft Guidelines. The Mapping Partner may determine that minor modifications or deviations from the Guidelines are necessary to adequately define the coastal flooding conditions and map flood hazard zones in specific areas. In these cases, documentation of these differences is required as part of the intermediate and final study submittals.

Some “Critical” and “Important” topics identified in Phase 1 for the Pacific Coast were not addressed in Phase 2 because of limited time and resources. Section 4 of the Phase 1 Summary Report provides a brief summary that can be used for planning of future guidance development by FEMA, and the Focused Studies appended to the report provide background on these topics.

No additional work on guideline development for the Atlantic and Gulf Coasts was conducted in Phase 2. Section 5 of the Phase 1 Summary Report provides a brief summary of recommendations

that can be used for planning future guidance development by FEMA. In addition, some Pacific Coast guidelines developed during Phase 2 may be applicable to analyses on the Atlantic and Gulf Coasts with little or no modification. The potential applicability of Pacific Coast guidelines in specific technical categories is identified in Section 5 of the Phase 1 Summary Report. The Focused Studies appended to the report also provide reference information that may be useful to study contractors as a supplement to the existing guidelines.

The project approach relied heavily on the collaboration of Technical Working Group members to meet a compressed schedule. It is envisioned that the next phase of guideline development for coastal flood hazards will be guided by TWG recommendations for testing, extending, and refining the procedures defined in the Final Draft Guidelines. Specialized FEMA Study Contractors and other Mapping Partners will likely be engaged in preparing test cases and examples, and in providing feedback on application to specific settings. FEMA recognizes that the Guideline is an evolving document, and will encourage refinement through various mechanisms.

PS.9 Acknowledgements

FEMA gratefully acknowledges the significant effort, collaboration, and interaction of the members of the TWG to produce this highly technical work product. Study Leaders and members of the TWG are listed below in alphabetical order.

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