Flood Hazard Zones

FEMA Coastal Flood Hazard Analysis and Mapping Guidelines Focused Study Report

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Acronyms

ASCE	American Society of Civil Engineers
BFEs	Base Flood Elevations
CFR	Code of Federal Regulations
CRS	Community Rating System
CTP	Cooperating Technical Partner
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
G&S	*Guidelines and Specifications*
MA CZM	Massachusetts Office of Coastal Zone Management
NFIP	National Flood Insurance Program
nhc	Northwest Hydraulics Consultants
PFD	Primary Frontal Dune
SC	Study Contractor
SFHA	Special Flood Hazard Area
WHAFIS	Wave Height Analysis for Flood Insurance Studies

1 INTRODUCTION

The Flood Hazard Zone Focused Study evaluates the procedures in the current FEMA guidelines related to the establishment and mapping of coastal hazard zones. The description of each Flood Hazard Zone topic identified in Workshop 1 is listed below. In addition, each topic and needs description for Flood Hazard Zones are identified by specific coastal regions of application for Atlantic Ocean, Gulf of Mexico, Pacific Ocean, or Non-Open Coast (Sheltered Waters).

Flood Hazard Zones Topics and Priorities

Topic Number	Topic	Topic Description	Atlantic / Gulf Coast	Pacific Coast	Non-Open Coast
39	PFD	Develop better definition of landward limit of PFD (used for VE Zone limit), and gather and evaluate MA CZM and other mapping approaches.	C	I	I
17	VE Zone Limit	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	C
18	VE/AE Zone Appropriateness	Investigate the appropriateness of existing VE & AE Zone definitions for coastal areas	I	I	I
19	Combined Coastal/ Riverine	Flood risk management of combined coastal and riverine flooding hazards	A	A	A
Key: C = critical; A = available; I = important; H = helpful					

The workshop assigned each topic with a priority rating of "C" for Critical, "I" for Important, and "A" for Available, depending upon its direct impact on the FEMA coastal flood studies program, revision needs in existing *G&S*, and the expected timeline for completion and incorporation of the topic into *Appendix D* and the National Flood Insurance Program (NFIP).

The Flood Hazard Zones topics list initially included only Topics 17, 18, and 19, but was modified to include Topic 39 (previously associated with Event-Based Erosion) during Workshop 2. The topic descriptions are shown above.

1.1 FLOOD HAZARD ZONES FOCUSED STUDY GROUP

The Flood Hazard Zones Focused Study Group members are Kevin Coulton, Michael DelCharco, Darryl Hatheway (who served as the Focused Study Leader), and Chris Jones. The group worked collectively to: a) define the scope of the Focused Study and specific assignments, b) resolve any discrepancies or interpretations of the topic and needs descriptions, and c) collect related background information. The group attempted to review and apply available information on each subject to prepare this report. Each member contributed their unique insight on the subject matter, technical reports and publications, and specific report section write-ups. The collaboration of the group within the allotted Focused Study time-span is by no means comprehensive or exhaustive, but represents a considerable effort to evaluate the topics addressed in Workshop 1 (December 2003) and Workshop 2 (February 2004), and to provide recommendations that will benefit FEMA coastal flood hazard mapping guidance.

1.2 CURRENT FEMA GUIDANCE FOR FLOOD HAZARD ZONES

As part of the review of FEMA coastal flood insurance study methodologies, the Flood Hazard Zones Focused Study Group reviewed several topics from an overall matrix of specific topics. These topics (39 [formerly with Event-Based Erosion], 17, 18, and 19) addressed needs identified during the FEMA Coastal Guidelines Project Workshop 1 held by Northwest Hydraulics Consultants (nhc) in December 2003. The overall goal of the Flood Hazard Zones Focused Study was to resolve key issues related to hazard zone mapping per the current April 2003 FEMA guidelines document for coastal Flood Insurance Studies titled, "Guidelines and Specifications for Flood Hazard Mapping Partners – *Appendix D*: Guidance for Coastal Flooding Analyses and Mapping" (hereinafter referred to as the *G&S* or *Appendix D*).

Hazard zone mapping is the final product of the detailed analyses of a coastal flood study process undertaken by a Mapping Partner, performed either by the study contractor (SC), map revision requester, or Cooperating Technical Partner (CTP). The results of the coastal flood study are described in the FIS report and delineated onto a Flood Insurance Rate Map (FIRM). The FIRM depiction of the Special Flood Hazard Area (SFHA) for coastal hazards, as determined by detailed studies of storm surge flooding, storm-induced erosion, and wave effects, is generally subdivided into six different zones, including:

- VE Zones, also known as the coastal high hazard areas. They are areas subject to high velocity water including waves; they are defined by the 1% annual chance (base) flood limits (also known as the 100-year flood) and wave effects 3 feet or greater. The hazard zone is mapped with base flood elevations (BFEs) that reflect the combined influence of stillwater flood elevations, primary frontal dunes, and wave effects 3 feet or greater.

- AE Zones, also within the 100-year flood limits, are defined with BFEs that reflect the combined influence of stillwater flood elevations and wave effects less than 3 feet. The AE Zone generally extends from the landward VE zone limit to the limits of the 100-year flood from coastal sources, or until it reaches the confluence with riverine flood sources. The AE Zones also depict the SFHA due to riverine flood sources, but instead of being subdivided into separate zones of differing BFEs with possible wave effects added, they represent the flood profile determined by hydrologic and hydraulic investigations and have no wave effects.

- AO Zones, representing coastal hazard areas that are mapped with flood depths instead of base flood elevations. Depths are mapped from 1 to 3 feet, in whole-foot increments. These SFHAs generally are located in areas of sheet flow and runoff from coastal flooding where a BFE cannot be established. The AO Zone is also used in riverine flood mapping.

- AH Zones, representing coastal hazard areas associated with shallow flow or ponding, with water depths of 1 to 3 feet. These areas are usually not subdivided, and BFEs are mapped.
- X Zone (shaded), representing the coastal (or riverine) floodplain areas between the 100-year flood and 0.2% annual chance (500-year) flood. These areas are located outside the SFHA, but are depicted on the FIRM unless map scale limitations prevent detailed mapping of this area. They were formerly mapped and depicted as Zone B.
- X Zone (unshaded), representing the areas on the FIRM that are located outside the limits of the 500-year flooding. They were formerly mapped and depicted as Zone C.

Before undertaking a detailed evaluation of each topic, the Flood Hazard Zones Focus Study Group believes it is useful to examine the larger context of what hazard zones should (and should not) encompass. Starting with the NFIP definition of the FIRM, we see that the FIRM should identify hazard areas and risk premium zones (44 CFR sec. 59.1 states, *<u>"Flood Insurance Rate Map (FIRM)</u> means an official map of a community, on which the Administrator has delineated both the **special hazard areas** and the risk premium zones applicable to the community"*). A common interpretation of the FIRM is that it maps only the SFHA (SFHA is defined in 44CFR sec. 59.1 as: *the land in the flood plain within a community subject to a one percent or greater chance of flooding in any given year*) and the risk premium zones. However, the NFIP regulations clearly anticipated the mapping of other hazards on the FIRM as well – *<u>Special Hazard Area</u>* is defined in 44CFR sec. 59.1 as *an area having special flood, mudslide (i.e., mudflow), or flood-related erosion hazards.*

Thus, the Flood Hazard Zones Focus Study Group will view its charge broadly, and advise FEMA on the mapping of flood hazards in coastal areas subject to a 1% or greater chance of occurring in any given year (100-year flood), and on the mapping of other hazards associated with the coastal base flood event. Flood hazards will include standing or slowly moving water, flow velocity, wave height, wave runup, and wave overtopping. Associated hazards will include event-based erosion, overwash and sediment deposition, and flood borne or wave-cast debris.

Because a FIRM is used to regulate construction and to establish flood insurance premium rates, it makes sense to consider a wide range of coastal hazards that can damage buildings in coastal areas. It also makes sense to consider mapping- and policy-related issues (such as Primary Frontal Dune delineation) that affect the delineation of flood and associated hazards in coastal areas.

This Focused Study includes an evaluation of the following issues, but further consideration by FEMA is required prior to implementation because of policy and regulatory implications.

- Changing current coastal mapping/regulation/insurance practices in one or more aspects of the NFIP to substantially reduce damages to NFIP-compliant structures in mapped AE zones.

- Modifying the NFIP's primary frontal dune definition and V Zone delineation to better identify flood risks while maintaining dune protection and coastal construction standards.

- Revising floodplain management requirements for SFHAs included within the primary frontal dunes.

- Reviewing possible regulatory changes to redefine the criteria used to establish VE Zones. In particular, VE Zones may need to consider a variety of conditions (breaking waves, broken waves, runup, velocity, erosion, overwash) in light of recent coastal flood events that caused damage to structures on wall-type and shallow foundations located in the SFHA (Zone AE, AH, and AO) inland of the VE Zone limit.

- Reviewing possible regulatory changes to subdivide the coastal AE Zone into portions where flood conditions resemble those in VE Zones, and portions where flood conditions resemble those in riverine AE Zones.

2 CRITICAL TOPICS

Workshop 1 developed matrices listing each of the topics with specific category groupings (e.g., Flood Hazard Zones were number 17, 18, and 19), and priority classes (e.g., C, I, A). The workshop identified the highest priority topics as "Critical." As mentioned above, Topic 39 was originally assigned to Event-Based Erosion and was subsequently moved to the Flood Hazard Zones Focused Study for review and consideration. Flood Hazard Zones topics listed as Critical in one or more regions, include Topics 39 and 17. Flood Hazard Zones Topic 39 was identified as priority "C" for the Atlantic and Gulf region and only "I" for the Pacific Region and Sheltered Waters. However, all discussion for this topic will be included in this Critical topics section. In addition, Topic 17 was identified as priority "C" for all four regions - the Atlantic, Gulf, Pacific and Sheltered Waters.

2.1 TOPIC 39: LANDWARD PRIMARY FRONTAL DUNE LIMIT AND DEFINITION

2.1.1 Description of the Topic and Suggested Improvement

The December 2003 workshop identified the needs for Topic 39 as follows:

"Develop better definition of landward limit of Primary Frontal Dune (used for VE Zone limit), and gather and evaluate MA CZM and other mapping approaches."

The Focused Study group reaffirmed the importance of Topic 39 since the primary frontal dune (PFD) VE Zone (by definition) will dominate over other detailed analyses of the VE Zone limit based on wave height, wave runup, and wave overtopping. The group identified possible improvements to the existing definition within the NFIP, with the objectives of improved clarity for Mapping Partners and improved correlation between the PFD definition and hazard zone mapping (Topic 17).

The February 2004 workshop considered the topic further, and determined that a related issue also needs to be addressed – current mapping procedures result in large BFE differences at the boundary between the PFD-based VE Zone and the next landward Zone AE hazard areas or an abrupt transition into Zone X floodplain areas. These BFE and zone transition differences are a product of mapping procedures, not actual flood hazards, and should be addressed in conjunction with Topic 17.

To prepare the Flood Hazard Zones Focused Study assessment for Topic 39, the following was required:

- Review of NFIP regulations as they apply to primary frontal dune VE Zones;
- Review of existing *Appendix D* guidelines for determination of the landward limit of the primary frontal dune; and
- Assessment of current guidance on the mapping of primary frontal dune VE Zones on the FIRM.

The existing *G&S* for hazard zone mapping show various ways to map the VE Zone coastal high hazard area and BFEs due to inclusion of the primary frontal dune. In many cases, the VE Zone landward limit is defined by the definition of the primary frontal dune, rather than by analysis of water level or wave conditions. The definition of the primary frontal dune is therefore critical to hazard zone mapping on the FIRM. However, the existing definition of the primary frontal dune in NFIP regulations is qualitative, and *Appendix D* contains little direct guidance on estimation of the landward limit. A better methodology for defining the primary frontal dune and its landward limit would improve efficiency and consistency in hazard mapping.

The Focused Study Group also determined that there are other key areas of concern related to VE Zones and primary frontal dunes, which are addressed in Topic 17. The key issue for Topic 39 is the determination of the landward limit of the PFD, based on qualitative methods using the Part 59 definition.

2.1.2 Topic 39: Description of Procedures in the Existing Guidelines

Appendix D Section D.2 includes a discussion with background on recent coastal guidance updates for storm-induced erosion that also resulted in a change in the official basis for treating flood hazards near coastal sand dunes. FEMA published new rules and definitions in the May 6, 1988 *Federal Register*, pages 16269-16273 (that became effective on October 1, 1988), which included the following revised definitions in 44 CFR sec. 59.1 of the NFIP regulations:

> "*Coastal high hazard area* means an area of special flood hazard extending from offshore to the inland limit of a primary frontal dune along an open coast and any other area subject to high velocity wave action from storms or seismic sources."
>
> "*Primary frontal dune* means a continuous or nearly continuous mound or ridge of sand with relatively steep seaward and landward slopes immediately landward and adjacent to the beach and subject to erosion and overtopping from high tides and waves during major coastal storms. The inland limit of the primary frontal dune occurs at the point where there is a distinct change from a relatively steep slope to a relatively mild slope."

Figure 1, taken from the May 6, 1988 Federal Register, illustrates the Primary Frontal Dune limit described above.

44 CFR subsection 60.3(e)(7) of the NFIP regulations requires that participating communities prohibit manmade alterations of sand dunes in VE Zones which would increase potential flood damage. Thus, expansion of a VE Zone via the PFD expands the dune areas protected by 60.3(e)(7).

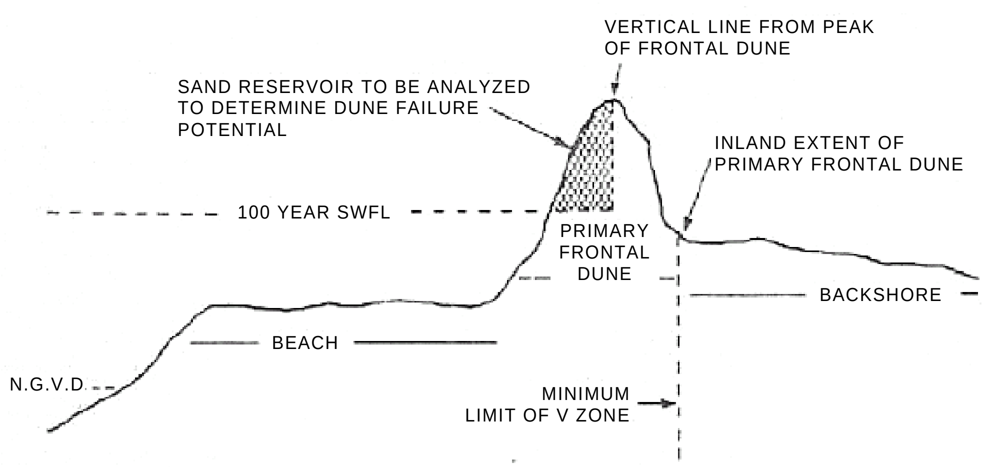

Figure 1. Primary frontal dune definition sketch
(May 6, 1988 Federal Register, p. 16271).

FEMA also included a new section in 44 CFR Part 65, requiring that the storm-induced erosion cross-sectional area of 540 square feet serve as the basic criterion to be used in evaluating whether a primary frontal dune will act as an effective barrier during the 1-percent-annual-chance flood (see Event-Based Erosion report, Topic 37).

The guidance in *Appendix D* for primary frontal dunes as it pertains to 44 CFR Parts 59, 60,and 65 described above, needs some clarification (which is addressed in some detail in Critical Topic

17 to follow). *Appendix D* Section D.2.7.2 defines the VE Zone as the area where 1) 3-foot or greater breaking wave heights could occur; 2) the eroded ground profile is 3 feet or more below the representative runup elevation; and 3) the entire primary frontal dune, by definition. However, detailed criteria for determining the landward limit of the primary frontal dune are not provided. For hazard zone purposes the definitions in 44 CFR Part 59 are the key issues to be considered by this focused study.

2.1.3 Application of Existing Guideline to Topic – History and/or Implications for the NFIP

A general description of hazard risk zones and mapping criteria for VE Zones and other hazard zones is presented in *Appendix D* section D.2.7.2, "Identification of Flood Insurance Risk Zones". Within this section is the first mention of and example for mapping the primary frontal dune, described as follows:

> "Identifying appropriate zones and elevations may require particular care for dunes, given that the entire primary frontal dune is defined as Coastal High Hazard Area. Although the analyses may have determined a dune will not completely erode and wave action should stop at the retreated dune face with only overtopping possibly propagating inland, the Mapping Partner shall designate the entire dune as Zone VE. The Mapping Partner shall assign the BFE at the dune face for the remainder of the dune.
>
> It may seem unusual to use a BFE that is lower than the ground elevation, although this is actually fairly common. Most of the BFEs for areas where the dune was assumed to be eroded are also below existing ground elevations. In these cases, it is the VE Zone designation that is most important to the NFIP, under current regulations, structures in VE Zones must be built on pilings and prohibits alterations to the dune."

The method or practical approach for identifying the landward limit of the primary frontal dune (or heel of the dune) is not discussed, nor is there any clarification provided to assist the Mapping Partner in locating the point for the VE Zone termination based on the "relatively steep to relatively mild slope" criterion from the NFIP regulations (44 CFR sec. 59.1).

However, *Appendix D* does contain several figures that demonstrate inclusion of the primary frontal dune considerations in VE Zone mapping -- see Figure 2 below, from *Appendix D,* and other figures contained within the Appendix (1) located at the end of this report. *Appendix D* does not provide a complete overview of all possible examples for primary frontal dune VE Zone hazard mapping scenarios, but does provide some general examples of hazard assessment results and the mapping of hazard zones and BFEs.

<u>Explanation of Figure 2:</u> Schematic summary for three of the four criteria used to define the landward limit to the Coastal High Hazard Area (i.e., 3-foot wave height, 3-foot runup depth, and primary frontal dune–the fourth criterion, wave overtopping, does not apply to this example).

The VE Zone limit for each of the three applicable criteria is identified, and the VE/AE boundary placed at the one furthest landward, in this example, 3-foot runup depth. Note that in the majority

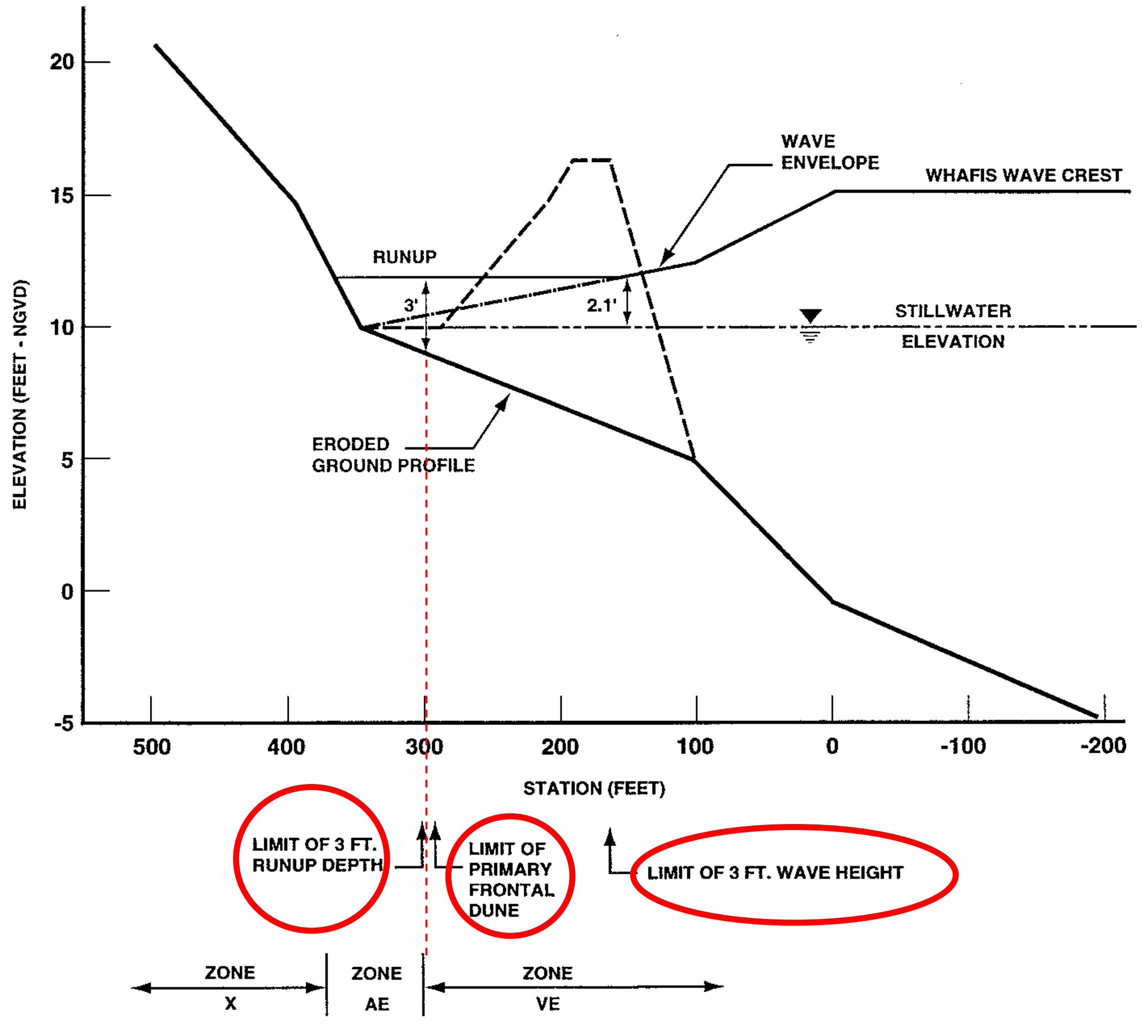

Figure 2. Possible V-Zone limits at eroded dune.

of cases with a primary frontal dune, the PFD criterion will be the most landward and will determine the VE limit.

Based on the experience of the Focused Study Group members in preparation and review of numerous coastal analyses and flood insurance studies, the definition of the primary frontal dune has a significant influence on coastal hazard mapping for the NFIP. In many areas, the definition of the primary frontal dune landward limit dominates the VE Zone mapping, yet no quantitative criteria are available for its determination.

In some cases, the PFD VE Zone shown on the FIRM is located landward of the portion of the SFHA subject to active coastal processes during the base flood (erosion, wave height, wave runup, and wave overtopping). Thus it has limited risk to coastal flooding. The landward portion of the PFD-based VE Zone in this scenario does not really represent an area of 1% risk to coastal flooding–it primarily serves as a floodplain management tool to protect dunes from alterations, and to regulate coastal construction practices and building standards. Moreover, the property owner's flood insurance premium rates are set at the maximum level, yet the property does not share a risk equivalent to that of other VE Zones within the SFHA that are mapped based on the effects of erosion and wave action.

Primary Frontal Dune Definition – Current Practice

The methodology used by Mapping Partners to define the landward heel of the primary frontal dune is presently very qualitative. The first step in mapping a VE Zone limit using the primary frontal dune criterion for mapping a VE Zone is to determine whether or not dune features meeting the regulatory definition are present in the study area according to the definition in 44 CFR Section 59.1. Note, however, that this definition is not currently provided in *Appendix D*.

If the study area includes primary frontal dunes, the next step requires detailed topographic information and/or beach and dune profiles taken from shoreline to a point landward of the dune feature. These data assist in the assessment of the point where the landward dune face transitions from a "relatively steep slope to relatively mild slope".

In a flood insurance study, the following data are desirable and the following methods typically applied:

- Topographic Mapping Basis
    - Topographic information with 1- to 2-foot contour intervals is needed to accurately determine where the slope change occurs.
    - From the topographic information, the primary frontal dune heel location will be identified and mapped based on the contour interval spacing and transitions (wide contour interval indicates mild slope and narrow contour interval spacing indicates steep slopes).
- Beach and Dune Cross Section (Profile) Basis
    - If beach and dune profiles are used instead of, or in addition to general topography, they should have sufficient vertical and horizontal resolution to capture all major slope transitions (e.g., the dune toe, peak and heel locations).
    - From beach and dune profiles, the point of the landward limit is established and then a smooth interpolation between profiles can be mapped with or without the use of topographic information (depending upon proximity of the profiles to each other and uniform nature of the primary frontal dune ridge).

- In certain situations, man-made impacts to the landward dune face may have altered the terrain (excavations for homes and appurtenant structures) and will indicate a false transition point for the primary frontal dune heel. In those scenarios, the natural dune feature and primary frontal dune heel location may be evaluated based on historic data, unaltered portions of the dune, and/or aerial photography.

It should be noted that FIRM scale limitations, and minor variations in qualitative assessments of primary frontal dune limits using topographic contours, can result in the inadvertent inclusion of the entire first row of homes located directly landward of the dune limits. Verification of mapping limits using aerial imagery and detailed beach and dune profiles can help resolve issues related to inadvertent inclusions in FIRM revisions based solely upon inclusion of the PFD VE Zone.

The methods outlined above are not documented or discussed in any of *Appendix D*. Additional guidance should be included to quantify the definition of the landward limit of the primary frontal dune where it serves as the basis for VE Zone determination. Topic 17 discusses the limitations associated with this use of the primary frontal dune definition for mapping coastal hazards in more detail.

2.1.4 Alternatives for Improvement

Based on the above review of the existing hazard zone guidance and problems with identification and mapping of landward limit of the primary frontal dune VE Zones, the following alternatives should be considered for *Appendix D* improvement:

Alternative 1- Revise the PFD definition and consider an improved definition of the slope transition, possibly as a percent of slope change in both the shore perpendicular direction and the shore parallel direction, with limited discretion on the part of Mapping Partners when they evaluate potential primary frontal dune features.

Alternative 2- The MA CZM has an integrated approach that uses high resolution aerial laser topographic data, Geographic Information Systems, and slope transition analyses to quantitatively define the primary frontal dune. The MA CZM proposed methodology provides an example of a technically defensible determination tool for a basic automated delineation of the primary frontal dune feature. There should be further review and consideration of this approach for application in coastal areas outside of MA, but the basic technical approach has merit for inclusion in the update to *Appendix D*.

2.1.5 Recommendations

The alternatives discussed above were discussed at Workshop 2 in Sacramento in February 2004, and recommendations developed based on the consensus of the Technical Working Group.

2.1.6 Related “Critical”, “Available,” and/or “Important” Topics

Related topics can be found in Focused Study Topics 17 and 18.

2.2 TOPIC 17: VE ZONE CRITERIA AND DEFINITIONS

2.2.1 Description of the Topic and Suggested Improvement

The workshop identified the needs for Flood Hazard Zones Topic 17 as follows:

"Enhance existing guidelines for defining inland limit of VE Zone including the development of a basis for better guidance for heavily overtopped areas."

The Focused Study Group determined that Topic 17 should include all coastal high hazard areas, not just “heavily overtopped areas.” The group evaluated criteria and mapping practices for all VE Zones. The group identified possible improvements to the guidelines and methodologies to best represent the projected hazards and damage potential for this unique SFHA. One goal of the study group is to provide better guidance to Mapping Partners, so that VE Zone inconsistencies are reduced.

The group subdivided Topic 17 into six issues, four associated with the existing definitions of the VE Zone coastal high hazard areas, and two new considerations, listed below as Topics 17 (a) to (f).

Topic 17 (a) – Primary Frontal Dune VE Zones

Topic 39 addressed the definition of the primary frontal dune and the delineation of its landward limit. Topic 17 addressed the mapping consequences and BFE discontinuities resulting from mapping VE Zones based on the primary frontal dune. For example, current guidance in *Appendix D*, section D.2.7.2 calls for extending the last computed wave height- or wave runup-based BFE at the dune face landward through the dune feature to the landward limit (heel) of the primary frontal dune. In cases where the landward limit of the primary frontal dune is located within a different flood source and stillwater elevation, or outside the area calculated to have a 1% annual chance of flooding, this can lead to sudden BFE changes of many feet (so-called “waterfalls”) and abrupt transitions in hazard zones. Portions of the areas within the primary frontal dune limits are mapped as VE zones, but may be outside the calculated 1% annual chance limits, and thus do not meet the regulatory definition of the SFHA.

These BFE and zone transition differences are a product of mapping procedures associated with the primary frontal dune definition, and not with analyses of water level or wave conditions. The issue is inconsistency in the delineation of VE Zones using the primary frontal dune definition relative to other SFHAs, and uncertainty of how the VE Zone was established relative to the associated risk. This issue has implications for insurance rating, building standards, and coastal land use.

Topic 17 (b) – 3-foot (or Greater) Breaking Wave Height VE Zones

One NFIP definition of the VE Zone specifies that the hazard area is subject to breaking wave heights of 3 or more feet, which according to NFIP mapping procedures, occurs where stillwater depths equal or exceed 3.85 feet (waves are depth-limited, with the wave height limited to 0.78 times the stillwater depth–see Figure 3 below). A sub-topic for this study is to examine this VE Zone limit and to assess whether the 3-foot breaking wave height provides a reasonable definition of the coastal high hazard area, and whether a different wave height should be adopted as the VE Zone limit. This topic is closely related to an alternate approach that is considered in Topic 18 (Coastal A Zone).

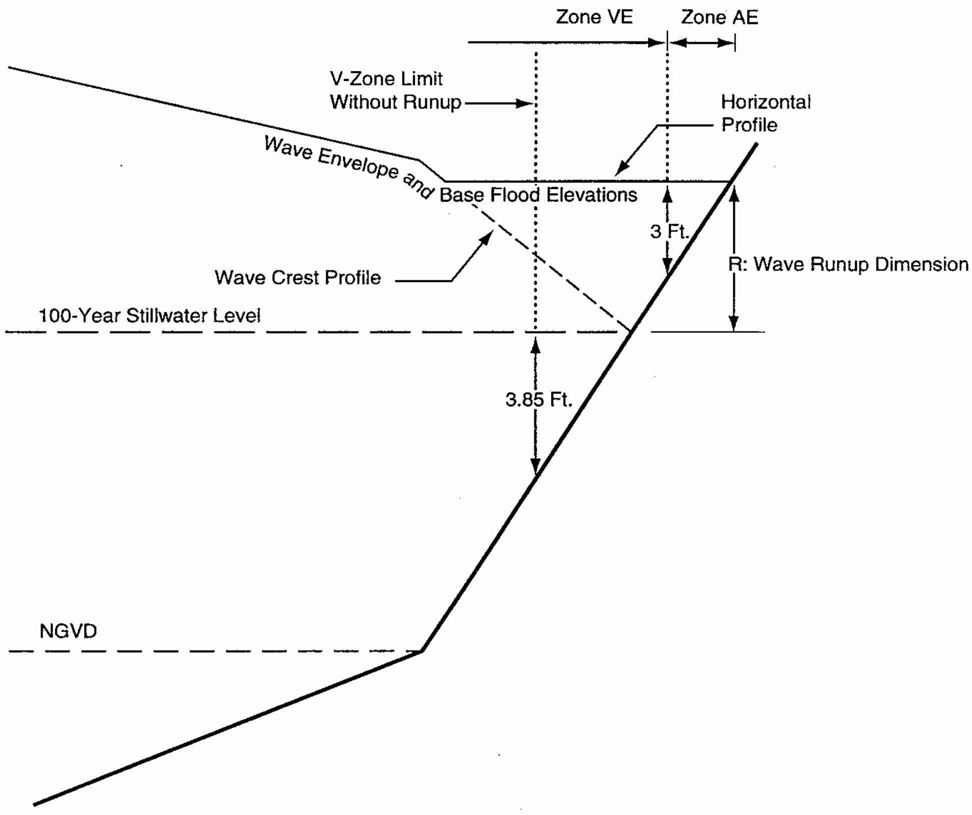

Figure 3. VE Zone limits based on wave heights and wave runup.

Topic 17 (c) – 3-foot (or Greater) Wave Runup Depth VE Zones

Another VE Zone definition specifies that the hazard area is subject to wave runup depths of 3 or more feet (see Figure 3 above). A sub-topic for this study is to examine whether the 3-foot runup depth provides a reasonable and accurate limit to the coastal high hazard area.

Topic 17 (d) – Wave Overtopping (Splash Zone) VE Zones

The *G&S* also call for the mapping of a VE Zone to account for high levels of wave overtopping, in effect via a splash zone (approximately 30 to 50 feet), that extend landward of a coastal shore protection structure, such as a seawall, bulkhead, or revetment (see Table 4 in the Runup and Overtopping Focus Study). A sub-topic for this study is to review the trigger (mean overtopping rate) and lateral extent of the VE Zone, and to consider use of another coastal high hazard zone defined in the NFIP regulations to represent this type of hazard area – the VO zone.

Topic 17 (e) –Wave-Cast Debris VE Zones

The study group identified the need for a new classification of VE Zone or use of the VO Zone criteria for coastal areas that experience damaging wave-cast debris in conjunction with wave action and/or overtopping. This new zone would identify the area as a coastal high hazard and also account for the size, quantity and velocity of the wave-cast debris unique to this zone. Evaluation of this potential coastal high hazard zone criteria and mapping standards for a VE or VO Zone with wave-cast debris is necessary since none exist presently within *Appendix D*. This issue is also related to Topic 17 (d).

Topic 17 (f) – Structural Load VE Zones

The study group identified a second potential new VE zone definition that is based on structural loads that act on buildings and structures. There are a variety of existing VE zone definitions that may or may not be consistent in terms of the magnitude and effects of structural loads they induce. A new VE zone definition could be based on the loads themselves, rather than the proxies (e.g., breaking wave height, wave runup depth, mean overtopping rate) used at present. A new VE designation such as this could help guide the evaluation of mapping results discussed in *Appendix D*, section 2.7, "Prior to mapping the flood elevations and zones, the Mapping Partner shall review results from the models and assessments from a common-sense viewpoint and compare them to available historical data." A structural load-based VE Zone criterion might aid in this review, and help resolve inconsistencies between these and other hazard zones and BFEs.

2.2.2 Description of Procedures in the Existing Guidelines

In *Appendix D*, Section D.2.7.2, "Identification of Flood Insurance Risk Zones", the *G&S* present 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 dune, and coastal flood protection structures. The general lack of guidance on primary frontal dune definition (Sub-topic 17a) was discussed in Topic 39. Procedures for determining the wave height and runup characteristics (Sub-topics 17b and 17c) are included in the existing guidelines and discussed in separate focused studies on these subjects. Procedures for delineation of splash zones (Sub-topic 17c) are also included in the guidelines. Procedures for delineation of hazards due to wave cast debris (Sub-topic 17d) and structural load-based zones (Sub-topic 17e) are not presently included.

The *G&S* do not presently provide a complete set of examples for wave transect hazard mapping that are applicable in all situations. However, the *G&S* do include several figures that serve as general examples and descriptions of mapping results (these figures have been reproduced in Appendix (1) located at the end of this Focused Study report). It should be noted that all of these transect illustrations relate to Atlantic and Gulf Coast examples.

The examples in the existing guidelines show a WHAFIS wave crest envelope. The existing versions of WHAFIS will not produce results that would govern hazard zone delineation and BFEs on the Pacific Coast. WHAFIS in its present form is not appropriate for use on the Pacific Coast given its wind speed and vegetation subroutines. Based on past experience, the WHAFIS-type analysis for wave heights will not determine significant BFEs and flood hazard zones for most of the Pacific Coast due to low storm surge levels. On the Pacific Coast, extreme wave runup and wave overtopping flooding effects typically control the BFEs, flood depths, and hazard zone mapping criteria.

2.2.3 Application of Existing Guideline to Topic – History and/or Implications for the NFIP

As determined by the Focused Study Group, the following are key areas of concern. Resolution of each issue will improve the NFIP regulation and mapping of the VE Zone coastal high hazard areas.

Topic 17 (a) – Primary Frontal Dune VE Zones

There is no current mechanism in place to allow a Mapping Partner or FIRM reviewer to distinguish the active velocity zone portion of the VE Zone SFHA from the portion of the VE Zone SFHA that is based on the landward extension to the heel of the primary frontal dune Once the VE Zone is mapped, there is no way to distinguish the rationale for and accuracy of the zone and BFE.

Moreover, there are several implications – for the NFIP, participating communities, and owners of coastal property–of the current mapping procedures:

1. The current NFIP definition of "coastal high hazard area" includes the primary frontal dune, but is ambiguous as to where primary frontal dunes are designated. That is, should the NFIP definition ("Coastal high hazard area means an area of special flood hazard extending from offshore to the inland limit of a primary frontal dune along an open coast and any other area subject to high velocity wave action from storms or seismic sources.") be interpreted to mean: (1) primary frontal dunes are designated only along an "open coast" (open coast is not defined by the NFIP), or (2) primary frontal dunes are designated along an open coast and along any "area subject to high velocity wave action

from storms or seismic sources." The difference is critical. The May 6, 1988 Federal Register notice (see Event Based Erosion report, Topic 37, Appendix A) does not clarify this point. The exact meaning of the definition should be determined; especially since the applicability of the PFD designation to sheltered water shorelines is unclear and could be problematic in many Pacific Coast study areas.

2. If not for the primary frontal dune criterion, some portions of the VE zone would typically be mapped as AE or AO Zones, or Zone X (shaded or unshaded). Owners of buildings within PFD-based VE zones that would otherwise be mapped as less hazardous zones are faced with high flood insurance premium rates that do not reflect the actual base flood risk.

3. If not for the primary frontal dune criterion, BFEs along the analysis transects would reflect the 1% flood hazard, including the effects of event based erosion. BFEs based on the primary frontal dune designation can lie several feet higher than they would if mapped as less hazardous zones.

4. A problem associated with Issue (3) is the mapping of "waterfalls". This occurs when the transition from an extended Zone VE BFE to the primary frontal dune limit merges with a much lower BFE associated with Zone AE, Likewise, the sudden transition from a VE Zone to Zone X appears unusual without clarification of the primary frontal dune mapping criteria. In these cases, the landward limit of the primary frontal dune is located at point in the profile and coastal area that is above the stillwater elevation, has no wave effects, and is outside the SFHA entirely.

5. The designation of the primary frontal dune as a VE Zone not only supports hazard-specific building standards and land use requirements, but also protects the dune from man-made impacts or physical alterations. Any changes to the primary frontal dune mapping procedures should attempt to preserve the dune protection and construction standard requirements as intended in FEMA's floodplain management ordinances.

Several questions arise from this discussion above for Topic 17(a). The group feels that the following important questions should be addressed in the subsequent effort. The items presented will be addressed in more detail as part of the recommendations for Topic 17:

- Should primary frontal dunes be identified at dune features along all coasts and wave exposures, or should they be limited to open coast areas, or should they be limited to areas that would otherwise have VE zones designated (e.g., by wave height, wave runup or wave overtopping criteria)?

- Should FEMA identify the basis for VE zone designations (e.g., 3-foot wave height, 3-foot runup depth, primary frontal dune, and wave overtopping zone)?

- Should the portion of the primary frontal dune SFHA be represented by decreasing BFEs to its landward limit? Or should FEMA continue its current procedure of extending the last and most landward-calculated VE Zone BFE (from the wave height or wave runup analyses) to the landward limit of the primary frontal dune (see Figure D-28 in Appendix 1)?

- Should FEMA consider a new VE Zone classification or identification mechanism for the mapped portion of the SFHA for primary frontal dunes? Or should FEMA continue to map the area the same way it maps other velocity hazard zones even though the primary frontal dune is outside any historically known or calculated hazards?

- How should primary frontal dune VE Zones be merged into the adjacent AE Zones or X Zones to avoid BFE waterfalls or sudden transitions?

Topic 17 (b) – 3-foot (or Greater) Breaking Wave Height VE Zones

The identification of coastal high hazard areas (areas subject to high velocity waters and wave action) dates to the inception of the NFIP. The 3-foot wave height criterion was used, and continues to be used, as a dividing line between the coastal high hazard area (VE Zone) and other portions of the SFHA.

The Galveston District of the USACE (1975) produced guidelines for identifying coastal high hazard areas, part of which included an assessment of the “critical wave” (a wave possessing sufficient energy to cause major damage on contact with conventional structures). Appendix B of the 1975 USACE study concluded that the critical wave is a 3-foot breaking wave; however, a closer reading of calculations in Appendix B shows the USACE determined breaking waves 2.1 feet high are capable of destroying conventional wood-frame walls and connections. Nevertheless, the 3-foot standard was adopted by the 1975 USACE study, in recognition of the fact that conditions in the field (slope of ground, angle of wave attack, sheltering, etc.) may not be identical to those assumed in the study.

More recent full-scale laboratory tests of breakaway wall sections determined that breaking wave heights as low as 1.5 feet consistently cause failure of traditional stud wall construction. The tests were part of a larger effort to improve breakaway wall design standards (FEMA, 1999).

Post-Hurricane Opal (1995) studies at Pensacola Beach examined building damage caused by storm surge and wave heights in mapped VE and AE Zones, and determined that damages in AE Zones were consistent with damages in VE Zones (EQE, 2000). While the purpose of the study was to test FIA depth-damage functions for VE Zones and AE Zones, it indicates that wave heights less than 3 feet caused significant structural damage to AE Zone-type construction during the 1995 hurricane.

Taken together, the three studies suggest that the 3-foot wave height definition of the VE Zone may underestimate the extent of the coastal high hazard area.

The question that arises is whether FEMA should modify its VE Zone definition to one that uses a breaking wave height less than 3 feet. The Focus Study Group believes this concept should be explored fully. Note that this issue is closely tied to Topic 18, which considers subdividing the AE zone into a seaward "Coastal A Zone" where construction would be regulated like a VE zone, and a more landward AE Zone where current construction standards would be maintained. The expanded VE Zone and the Coastal A Zone should be considered mutually exclusive options – both accomplish the same goal, but in different ways.

Topic 17 (c) – 3-foot (or Greater) Wave Runup Depth VE Zones

Wave runup based flood hazard zones were introduced in the early 1980s in New England. Prior to that point in time, wave heights were the only basis for VE Zone mapping. Present FEMA methods call for mapping a VE Zone seaward of the point where the ground elevation lays 3 or more feet below the mean runup elevation at the shoreline (see Figure 3). The origin of the 3-foot "runup depth" VE Zone criterion is unknown to the Focus Study Group, but it notes that the documentation for FEMA's first runup model states, "a criterion has been adopted which states that a runup value of less than 2 feet is incapable of causing significant damage" (Stone and Webster, 1981).

The 3-foot runup depth criterion should be evaluated under both tsunami runup and non-tsunami runup scenarios to determine if it provides an appropriate limit to the VE Zone.

The Focus Study Group also notes that there may be a consistency issue between the 3-foot wave height and 3-foot runup depth criteria, when the force of each on typical building components (piles, walls) is compared – see Topic 17 (f).

Topic 17 (d) – Wave Overtopping (Splash Zone) VE Zones

There is a need to expand the coastal study guidance on wave overtopping criteria (wave and barrier characteristics, overtopping rate, high hazard zone limit) used to delineate the VE Zone hazard areas beyond overtopped dunes and shore protection structures. The existing guidance calls for VE Zones to be 30 feet wide where the mean overtopping rate exceeds 1.0 cfs/ft (see *G&S* Table D-7 and footnote that reads, "Appropriate inland extent of velocity hazards should take into account structure width, incident wave period or wavelength, and other factors").

Three aspects of this procedure should be evaluated: 1) the threshold overtopping rate used to map Zone VE (this assessment should be part of Topic 13, see the Runup and Overtopping Focused Study report), 2) the inland extent of the VE zone (i.e., provide more specific guidance than that contained in the footnote to Table D-7), which should be evaluated by the Flood Hazard Zones group, and 3) evaluation of the VO Zone designation for use in wave overtopping hazard identification. It is possible that additional factors such as velocity of flow (similar to alluvial fans) may help to expand and better define this hazard area. The VO Zone hazard assessment and identification procedures are not currently included in the guidance of *Appendix D.*

Development of specific hazard assessment criteria for VO Zone could enhance *Appendix D* with respect to these topics, and its evaluation is recommended by the focus study group.

Another approach, derived in a recent flood insurance study in Puget Sound for Whatcom County, Washington, and approved by FEMA, involved the use of an equation that describes the attenuation of an overtopping wave on a flat backshore surface (Cox and Machemehl, 1986). From a flood hazard standpoint, the Cox equation still appears to be a reasonable, simple approach to account for inland decay of wave heights over a distance to estimate flood hazards immediately inland of a shoreline where insured structures may be located.

Topic 17 (e) –Wave-Cast Debris VE Zones

FEMA mapping procedures currently define the limits of coastal high hazard areas based on wave action and the primary frontal dune, but fail to consider the wave-cast debris issue. However, flood damages resulting from drift logs (damaging building foundations) and wave-sprayed gravel (breaking windows) has been observed inland of mapped velocity zones. It would be useful to isolate and identify areas subject to damaging wave cast debris, possibly using existing or new hazard zones, special FIRM notes and FIS descriptions of the significance of the hazard. The role of winds in driving wave-spray gravel inland should also be investigated for future use and consideration in coastal hazard assessments. This effort should be tied closely with Topic 17(d) in this focused study, which deals with wave overtopping hazards, and with Topics 13 and 14 in the Wave Runup and Overtopping Focused Study.

Topic 17 (f) – Structural Load VE Zones

Preliminary calculations determined that wave runup loads on typical building components, for a 3-foot runup depth (i.e., at the runup-based VE Zone boundary), are of lesser magnitude than the loads due to a 3-foot breaking wave (at the wave height-based VE zone boundary). In fact, the runup loads are similar to loads resulting from breaking wave heights of approximately 1.5 feet. The inconsistency could be resolved by modifying the definition of the VE Zone criteria to use a lesser breaking wave height, or by increasing the wave runup depth used to define the VE zone limit, or by defining a new VE zone limit based on hydrodynamic loads resulting from wave effects. Of the three options, the second is probably contrary to observations of actual flood damages in post-storm assessments. The first was contemplated in Topic 17 (b). The third would be a new method that could resolve inconsistencies in existing coastal high hazard mapping procedures.

2.2.4 Alternatives for Improvement

Based on the above review of the existing hazard zone guidance and problems with identification and mapping of VE Zones, the group recommended the following alternatives be considered for *Appendix D* improvement:

- Retain VE zone mapping rationale. Develop ways to display the VE zone mapping rationale (e.g., wave height, runup depth, PFD, overtopping, etc.). Alternative methods include use of a DFIRM layer, archived back-up data, explanation in the FIS report, and designation on the FIRM.

- Revised primary frontal dune mapping procedures. Consider mapping BFEs across the primary frontal dune to minimize discontinuities at the landward limit. Alternatives include use of alternate flood hazard zones in areas where the primary frontal dune dominates. These could include approximate V, D, E, VO, AO, coastal A zone (see Topic 18), or a new PFD zone.

- Revised wave height VE zone criterion. Consider mapping Zone VE using a lesser breaking wave height. Prior studies suggest something on the order of a 1.5- to 2.0-foot wave height might be appropriate. In effect, this alternative would capture some of the area presently mapped as Zone AE, and is closely related to another alternative described in Topic 18.

- Revised wave runup depth VE zone criterion. Consider mapping Zone VE with a wave runup depth other than 3.0 feet. The selection of the appropriate runup depth will depend on the flood source (tsunami, hurricane, other coastal storm) and should reflect flood hazards generally consistent with the wave height VE criterion.

- Revised wave overtopping VE/VO zone criterion. Consideration of new VE Zone definition and/or proposed refinement and utilization of the VO Zone could improve the guidance. The VO Zone is listed in the NFIP regulations, but details regarding its possible mapping and use are not included. The VO zone would be appropriate for a variety of coastal hazard zones subject to high overtopping rates and/or flow velocities, whether on the open coast or on sheltered water shorelines. The VO Zone could be considered for mapping wave runup on the foreshore slopes or sheet flow down the backshore slopes of beaches and dunes (sandy, cobble or other), low coastal ridges, and coastal structures. A simplified procedure outlined in the current *G&S* for mapping wave overtopping AO Zones (which makes a transition from 3 feet or greater depth of wave runup overtopping into a Zone AO, Depth 2 feet, and for less than 3-foot depth of wave runup overtopping a transition into a Zone AO, Depth 1 foot), is shown in Figure 4 (from Appendix D, Figure D-15). This simplified concept can be improved to better mimic the actual physical processes and flood risk, and expanded to consider more energetic flow regimes in VO zones.

- Wave-cast debris hazard delineation. One key problem to be faced is how to evaluate and identify severely overtopped areas with damaging debris loads, separately from the typical VE zone designations (e.g., 3-foot wave height, 3-foot wave runup, and primary frontal dune VE Zones). A methodology is needed and mapping guidance would have to be developed. Data from the Pacific Northwest and New England should be reviewed and potential methods should be formulated and evaluated. Alternatives include a specific zone designation for wave cast debris hazards, or development of methods to consider wave cast debris in delineation of existing or modified zones.

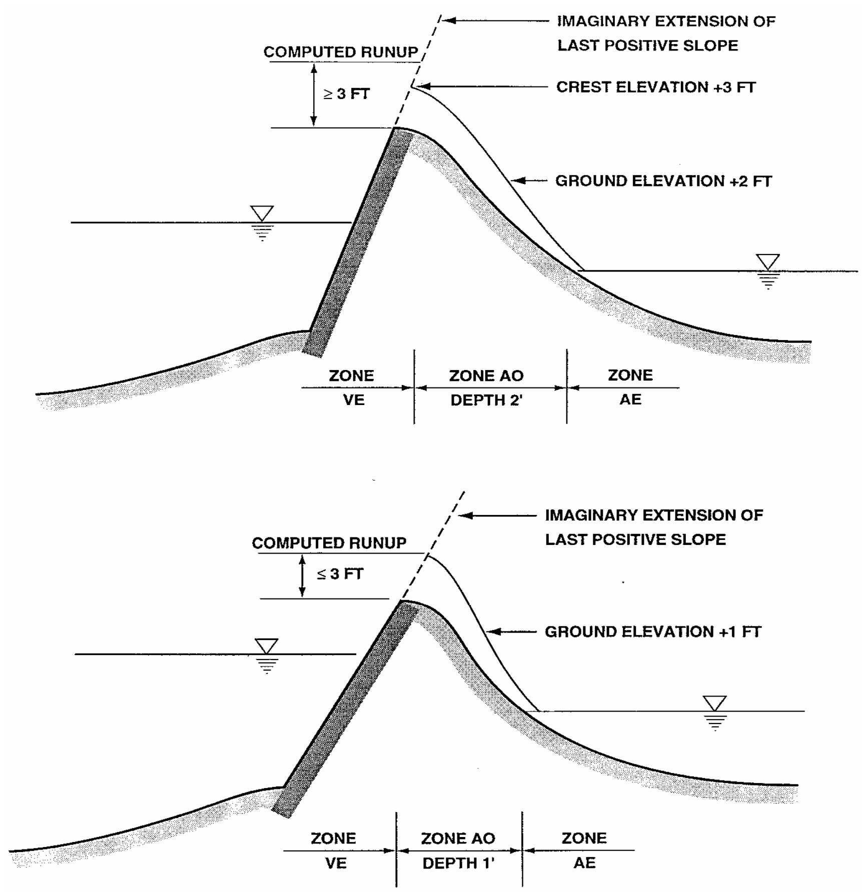

Figure 4. Simplified runoff procedures, Zone AO (FEMA, 2003).

@ Structural loading VE zone criterion. A possible new VE zone criterion, based on flood loads, should be developed and considered. Such a method should be based on field damage reports and analytical calculations of flood and wave forces acting on typical building components (e.g., piles, columns, walls). The method could be used as a check on other VE zone criteria, and as a way to resolve discrepancies between mapping resulting from those criteria.

2.2.5 Recommendations

The alternatives discussed above were discussed at Workshop 2 in Sacramento in February 2004, and recommendations developed based on the consensus of the Technical Working Group. For

Topic 17, the summary of recommendations based on the issues and alternatives presented above include:

1. Investigate and develop guidance to better map the BFE transition between PFD dominated VE Zones and landward SFHA (and Zone X) hazard zones, and test and apply these procedures in a case study;

2. Establish procedures (hazard identification and mapping) to better utilize VO Zones;

3. Establish procedures for identifying and mapping hazard zones for wave overtopping and wave-cast debris hazards; and

4. Establish improved procedures for establishing the landward limit of the PFD (also related to Topic 39 discussions above).

2.2.6 Related "Critical", "Available," and/or "Important" Topics

For Flood Hazard Zones Topic 17, related topics are Topic 39, which discussed the primary frontal dune definition, and Topics 11 to 14 in the Runup and Overtopping Focused Study. Recommendations for the Critical, Important, and Available issues of Topics 11 to 14 that might be applicable to Flood Hazard Zones Topic 17 could be related to new data sets to change hazard definitions or procedures for VE Zone mapping.

3 AVAILABLE TOPICS

Topic 19 was determined to be a priority "A" (Available) for the geographical regions of the Atlantic, Gulf, Pacific and Sheltered Waters. Available topics were considered to have information readily available for incorporation into revised guidelines. While an extensive compilation of this information (e.g., data sets, programs, procedures, etc.) is not a part of the focused study, the classification of the topic should be confirmed based on review of the available information and its potential for rapid use in study guidelines.

3.1 TOPIC 19: MAPPING FOR COMBINED COASTAL-RIVERINE PROBABILITIES

The description for Topic 19 is as follows:

"Flood risk management of combined coastal and riverine flood hazards."

As described, Topic 19 is considered to be an update to implement previous guidance and provide some clarification on its application to coastal flood studies.

3.1.1 Description of the Topic and Suggested Improvement

The current *G&S* do not provide guidance for flood level determination or mapping standards for combined coastal-riverine flood hazard areas. Past guidance is available from FEMA coastal storm surge modeling documentation prepared by Tetra Tech (FEMA, 1981) that includes specific guidance for flood level determination, but none is available for special mapping standards for this combined hazard zone. Therefore, the Topic 19 assessment reviews previous FEMA guidance for determining and mapping flood hazard areas when coastal backwater flooding combines with a riverine flood profile – referred to as the combined coastal-riverine hazard area. The combination of coastal and riverine flood hazards has often been overlooked in past coastal and riverine flood studies. These combined coastal-riverine hazard areas may occur far inland from the open coast, and are common in sheltered water areas.

To prepare the Flood Hazard Zones Focused Study assessment for Topic 19, the group performed the following tasks:

- Reviewed previous and any existing guidance for determining and mapping the area between the coastal backwater flood hazard area and riverine profile, referred to as the combined coastal-riverine hazard area.
- Reviewed previous Tetra Tech guidance in the FEMA "Coastal Flooding Handbook" from 1978 and/or FEMA "Coastal Storm Surge Model Users Manual" from 1981 related to this topic for consideration and application in future revision to the *G&S*.
- Reviewed/summarized other published methods to consider joint probability analyses of coastal-riverine flooding effects (combined or independent) to determine range of methods available.
- Identified potential case study coastal FIS examples related to combined coastal-riverine flood hazard study areas.

At this time, the following work is recommended to improve the *G&S*:

- Compile the best available prior guidance from previous FEMA publications (FEMA, 1981) to help clarify and develop new mapping standards for inclusion in *Appendix D*.
- Compile an annotated bibliography of related papers and publications in support of similar or new methods for identifying and mapping flood hazard areas of combined coastal-riverine influence using joint probability techniques.
- Identify the specific sections of *Appendix D* or other sections of the *G&S* that need to be revised or enhanced to include guidance on how to conduct the assessment and mapping of combined coastal and riverine areas.

- Perform a case study and prepare an example using a previously studied coastal area to demonstrate the improvement in guidance on combined coastal-riverine mapping (including standard notes and mapping methods).

During the recent restudy of flood hazards for Pasquotank County, NC, the Mapping Partner required guidance regarding delineation of combined coastal-riverine flooding on the FIRM and in the FIS report. The combined coastal-riverine probability and flood level determination methodology from the FEMA *Coastal Flooding Handbook* (1978) prepared by Tetra Tech were used in the effective Pasquotank County, unincorporated areas FIS report, and have also been used in other areas of North Carolina.

Further investigation may find that little or inconsistent consideration of combined coastal-riverine flooding is occurring in FEMA flood studies in other areas, and that BFEs may be underestimated as a result. For example, if the riverine and coastal flood events are assumed to be independent, the probabilities of the events can be added together to estimate the combined probability of both events. The point at which the 1% annual chance river flood elevation profile passes through the coastal 1% annual chance surge elevation is therefore 0.01 + 0.01 or 0.02, which is the 2% annual chance (50-year) flood event. This is further explained in the following insert.

> **Combined Effects: Surge Plus Riverine Runoff**
> The following example concerns the determination of the 1% stillwater flood level in a tidal location subject to flooding by both coastal and riverine mechanisms. This is the case in the lower reaches of all tidal rivers.
>
> It is assumed that the extreme levels from coastal and riverine processes are independent, or at least widely separate in time. This assumption is generally true since the storms which produce extreme rainfall and runoff may not be from the same set as the storms which produce the greatest storm surge. Furthermore, if a single storm does produce both large surge and large runoff, the runoff is usually delayed because of overland flow, causing the runoff elevation to peak long after the storm surge. Clearly, there may be particular storms for which these assumptions are not true, but even so they are not expected to be so common as to strongly influence the final statistics.
>
> Given these assumptions, the Study Contractor can determine the appropriate combined flood frequencies by a simple procedure. For a range of elevations covering all elevations of interest at a particular point, one determines the rate of occurrence of that elevation from surge alone, and the rate from riverine runoff alone. The total rate of occurrence of that level is then just the sum of the two contributing rates. This process must be repeated at intervals along the tidal river, from the mouth upstream to a point where the coastal influence in negligible.
>
> This procedure is discussed in more detail in Subsection D.4.8.2. Note that at the coast, the total elevation frequency curve is just that of the surge, since the river runoff cannot raise the ocean level. Conversely, at a distance upstream, the total elevation frequency curve approaches that of the riverine flood. Note, too, that at the intermediate point where the individual 1% profiles of the two floods cross, the crossing elevation equals the 2% (50 year) level, since it is assumed to occur twice in 100 years.

Two problems arise from the lack of guidance for this issue: 1) Inconsistent methodology and application; and 2) Inconsistent presentation of flood elevations in FIRM mapping, flood profile, and floodway data table. The current *G&S* for the issue of combined probabilities does not provide the contractor any background or technical discussion of the problem.

The notation of the combined riverine and coastal flood hazard zone is not clearly defined on the FIRM, flood profile, or the floodway data table. As a result, the FIS report (including coastal stillwater elevation tables and floodway data tables) does not match the data shown on flood profiles and depicted on the FIRM. Of course, this causes some confusion for the communities using the maps as well as subsequent restudies by Mapping Partners.

The recommended approach includes two items that the group determined are in need of clarification: the existing *G&S* needs to be modified to describe the process to combine the probability and flood levels; and the FIRM should be able to distinctly clarify hazard zones and/or flooding reaches affected by the combined probability adjustments.

3.1.2 Confirm "Availability"

Appendix D in Section 1.2.6 simply states the following regarding Topic 19:

"Describe and report adjustments to account for the combined probability of coastal and riverine flooding for each area where such an approach was taken."

The addition of text similar to that provided in previous guidance documents (specifically "Coastal Flooding Storm Surge Model, Part 1, Methodology", February 1981) would greatly improve the existing *G&S*. The referenced report provides a brief narrative presenting the technical problem and appropriate methodology to combine the probabilities and adjust the flood levels accordingly.

Further, this Focused Study recommends new guidelines be developed to clarify the appropriate documentation and description of the combined probability in the FIS text, including floodway data tables and flood profiles. This text should modify section D 1.2.6 of the current *G&S*.

A recent North Carolina mapping update for some combined coastal-riverine areas in Pasquotank County, NC, resulted in the placement of a special note and flood gutter on the FIRM at the lower and upper boundaries of the combined coastal-riverine area that coincided with the same locations on the flood profile. This provided clarification of exactly where this combined coastal-riverine flood hazard area is located along the respective reach of the river. This combined coastal-riverine hazard zone was studied and mapped for many coastal areas in North Carolina. This Focused Study recommends that FEMA consider the mapping approach applied in North Carolina as the basic method for combined coastal-riverine SFHA mapping, and adjust, as necessary, to meet FEMA's nation-wide needs.

The required methodology is confirmed to be generally available and can be incorporated into a new or updated guidelines.

3.1.3 Recommendations

The following recommendations were developed for Topic 19:

1. Review the previous guidance from 1981 for adoption into *Appendix D*; and

2. Develop mapping standards to clearly identify areas affected by combined coastal and riverine flood hazards on FIRMS, flood profiles and floodway data tables.

4 IMPORTANT TOPICS

As described above, Workshop 1 resulted in the preparation of matrices that listed each of the numbered topics with specific category groupings and specific priority classes. Topic 18 was classified as "Important" ("I"). Topic 18 was determined to be a priority "I" for the geographical regions of the Atlantic, Gulf, Pacific and Sheltered Waters.

4.1 TOPIC 18: ADEQUACY OF VE AND AE ZONE DEFINITIONS

The needs description for Flood Hazard Zones Topic 18 is as follows:

"Investigate the appropriateness of existing VE and AE Zone definitions for coastal areas."

In essence, Topic 18 asks whether VE and AE Zone mapping methods accurately distinguish and delineate two hazard zones representing different risks and BFEs, but within each of which common building standards can be applied. The Topic 17(b) discussion indicates that mapping VE Zones using the 3.0 ft wave height criterion may fail to capture all of the coastal high hazard area. Topic 18 presents an alternate approach – that of leaving the 3.0 ft VE Zone criterion intact and subdividing the AE Zone into two portions: 1) a more seaward portion of the AE Zone (exposed to direct flood and wave effects from a principle flood source) where hazards are similar in nature (but reduced in magnitude) to the VE Zone, but where VE Zone building standards are deemed to be appropriate, and 2) a more landward portion of the AE Zone where wave effects are negligible and traditional AE Zone building standards are appropriate. The more seaward portion is often referred to as the "Coastal A Zone". The paper included in Appendix 2 provides background information on the proposed Coastal A Zone designation.

4.1.1 Description of the Topic and Suggested Improvement

The Coastal A Zone concept investigated in Topic 18 has been or is being employed in several instances. For example:

1. FEMA's revised Coastal Construction Manual (FEMA, 2000) promotes use of VE Zone construction techniques in designated AE Zones subject to waves and erosion. The value of this practice was borne out in Pensacola Beach and Navarre Beach, FL, during Hurricane Opal (1995) when damages to newer pile-supported buildings in AE zones were minimal, while damages to older style construction (on shallow footings with wall-type construction) were more extensive.

2. FEMA's Community Rating System (CRS) awards points toward reduced flood insurance premiums for communities that adopt VE Zone-type construction standards in AE Zones that are subject to coastal flooding and wave effects.

3. The American Society of Civil Engineers (ASCE) national load standard for buildings, ASCE-7, differentiates between load combinations in riverine-type AE Zones and coastal-type AE Zones (the latter uses the same load combinations as in coastal VE Zones);

4. ASCE-24 (standard for flood-resistant construction) and ASCE 7-02 are being updated with a recommendation to apply similar construction practices in Coastal A Zones as in VE Zones – e.g., pile supported buildings instead of slab on grade – (both ASCE-7 and ASCE-24 will, in the next editions, likely support use of the 1.5-foot breaking wave height as the landward limit of the Coastal A Zone), as shown in Figure 5 below. The focus study group finds it preferable to pursue the Coastal A Zone concept as opposed to trying to change the VE Zone wave height criteria to the 1.5-foot breaking wave height. The VE zone delineation has been closely associated with the 3-foot wave height for over 30 years, and changing that designation would be difficult. Moreover, there may be legitimate reasons (i.e., related to flood insurance premiums, floodplain management, and land use policy) to differentiate between VE zones and the Coastal A Zone – those issues must be identified and considered carefully as work on Topic 18 goes forward.

5. The focus study group also acknowledges that adoption of the Coastal A Zone by the NFIP will probably require changes to NFIP regulations, a process which can often be time consuming and where the outcome is uncertain. Nevertheless, the identification of the Coastal A Zone – even if not linked to mandatory NFIP building regulations – is of value as a hazard identification and public outreach tool. It can also provide communities that wish to exceed minimum NFIP requirements with a consistent and defensible approach.

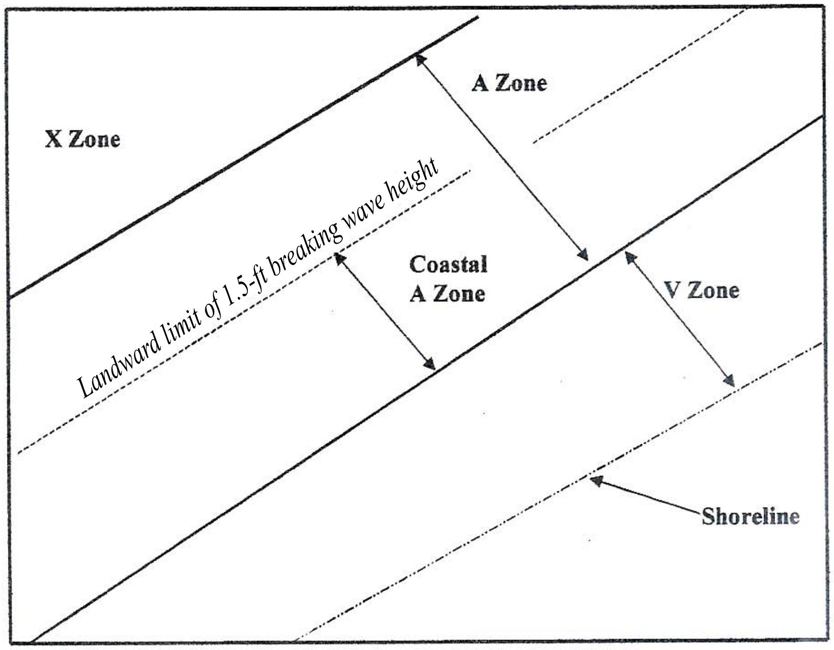

Figure 5. Proposed coastal A Zone mapping concept being considered for revisions to ASCE 24-98 and ASCE 7-02.

It is hoped that the inclusion of new guidance in Appendix D for mapping the Coastal A Zone high hazard area (as AE Zone with wave effects in the BFE) can enhance the delineation of the wave-affected floodplains.

4.1.2 Description of Potential Alternatives

The adoption of the Coastal A Zone concept is considered a priority, and may address problems associated with existing VE Zone and AE Zone delineations, and reduce storm damage outside of the designated VE Zone.

Some of the work required to support the above goals for Topic 18 would include:

- Identify Coastal A Zone Criteria: The 1.5-foot breaking wave height seems to represent a logical wave height division between the Coastal A Zone and the remainder of Zone AE. Using this as a starting point, develop criteria to address other VE zone hazards (wave runup, wave overtopping, PFD, wave-cast debris, etc.) on a consistent basis. The criteria should be developed so that they can be applied to all coasts (Atlantic, Gulf, Pacific, Great Lakes) and all wave exposures (open coasts and sheltered). This effort will also require an assessment of the NFIP regulations in 44CFR, and *Appendix D* sections, to clarify any regulatory and technical changes that must be made.

- Post-Storm Data Analysis: Perform additional analyses of post-storm hazard and damage data to refine the Coastal A Zone delineation. At present, limited data sets exist (Pensacola Beach, FL, Hurricane Opal, 1995; a soon to be completed study of Topsail Island, NC, Hurricane Fran, 1996). Additional analyses should be performed for shorelines where wave runup and overtopping dominate base flood hazards.

- Mapping Partner and Community Guidance: Prepare new FEMA Policy Memos and Technical Bulletins to help clarify the revised AE Zone (including Coastal A Zone) definitions and their application to the NFIP. These publications should include a bibliography of references and literature that would support expanded or new guidance.

- Case Study: select a community and test Coastal A Zone delineation methods. Include wave height, wave runup, wave overtopping, wave-cast debris and primary frontal dune considerations.

4.1.3 Recommendations

The following recommendations were developed for Topic 18:

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. Develop an annotated bibliography of related research and papers to support new guidance; and

4. Apply new concepts in a case study area.

5 SUMMARY

This Focused Study addresses two critical topics (39 and 17) dealing with flood hazard zone definitions and means for hazard delineation. Available topic 19 is discussed regarding mapping of combined coastal and riverine hazard zones. Adequacy and needs to define alternative hazard zones are discussed. Recommended approaches for addressing these issues are presented.

Table 1. Summary of Findings and Recommendations for Flood Hazard Zones

Topic Number	Topic	Coastal Area	Priority Class	Availability/ Adequacy	Recommended Approach	Related Topics
39	PFD	AC	C	MAJ	(1) Consider an improved and refined definition of the PFD slope transition as revision to NFIP regs, (2) provide further technical guidance in *Appendix D* to clarify the PFD mapping criteria, and (3) consider adoption of new quantitative methodologies for identification and mapping (e.g., MA CZM)	17, 18
		GC	C	MAJ		
		PC	I	PRO		
		SW	I	PRO		
17	VE Zone Limit	AC	C	MAJ	(1) Investigate and develop guidance to better map the BFE transition between PFD and landward hazard zones, and apply in a case study; (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 hazard zones; and (4) establish improved procedures for establishing the landward limit of the PFD (see Topic 39).	39, 11, 12, 13, & 14
		GC	C	MAJ		
		PC	C	MAJ		
		SW	C	MAJ		
19	Combined Coastal/ Riverine	AC	A	Y	(1) Review the previous guidance from 1981 for adoption into *Appendix D*, and (2) develop mapping standards to clearly identify this hazard zone	N/A
		GC	A	Y		
		PC	A	Y		
		SW	A	Y		
18	VE/AE Zone Appropriateness	AC	I	PRO	(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) develop an annotated bibliography of related research and papers to support new guidance; and (4) apply new concepts in a case study area.	11, 12, 13, & 14
		GC	I	PRO		
		PC	I	PRO		
		SW	I	PRO		

Key:
Coastal Area
AC = Atlantic Coast; GC = Gulf Coast; PC = Pacific Coast; SW = Sheltered Waters
Priority Class
C = critical; A = available; I = important; H = helpful
(Recommend priority italicized if focused study recommended a change in priority class)
Availability/Adequacy
"Critical" Items: MIN = needed revisions are relatively minor; MAJ = needed revisions are major
"Available" Items: Y = availability confirmed; N = data or methods are not readily available
"Important" Items: PRO = procedures or methods must be developed; DAT = new data are required; PRODAT = both new procedures and data are required

Table 2. Time Estimates for Flood Hazard Zones Topics		
Topic Number	Topic	Time (person months)
39	**Landward Primary Frontal Dune Limit and Definition**	
	Refine PFD definition in NFIP regs	0.5
	Review PFS mapping criteria	1
	Review and consider new PFD identification and mapping methods	2
	TOTAL	3.5
17	**VE Zone Criteria and Definitions**	
	Revise PFD mapping criteria	0.5
	Review Coastal A Zone mapping criteria	1
	Define VO Zone mapping & determination criteria	2
	Review alternative VE Zone wave height	0.5
	Define wave cast debris VE Zone criteria	1
	Prepare examples of new criteria	2
	TOTAL	7
19	**Mapping for Combined Coastal-Riverine Probabilities**	
	Convert 1981 and/or new additional guidance for inclusion to *Appendix D*	1.5
	Prepare FIRM mapping criteria for combined coastal-riverine SFHA	1
	TOTAL	2.5
18	**Adequacy of VE and AE Zone Definitions**	
	Define the Coastal A Zone revisions needed for NFIP regulations & mapping criteria	2.5
	Review FEMA technical bulletins needs for revised/ new VE, VO, and AE zones.	0.5
	Case study for revised/new VE, VO, and AE mapping definitions (including PFD)	1
	Annotated bibliography preparation	0.5
	TOTAL	4.5
Flood Hazard Zones Preliminary Time and Cost Estimate Totals by Topic		
39	Landward Primary Frontal Dune Limit and Definition	3.5
17	VE Zone Criteria and Definitions	7
19	Mapping for Combined Coastal-Riverine Probabilities	2.5
18	Adequacy of VE and AE Zone Definitions	4.5
	TOTAL	17.5

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APPENDIX 1

Coastal Mapping Examples taken from FEMA (2003) *Guidelines and Specifications for Flood Hazard Mapping Partners*

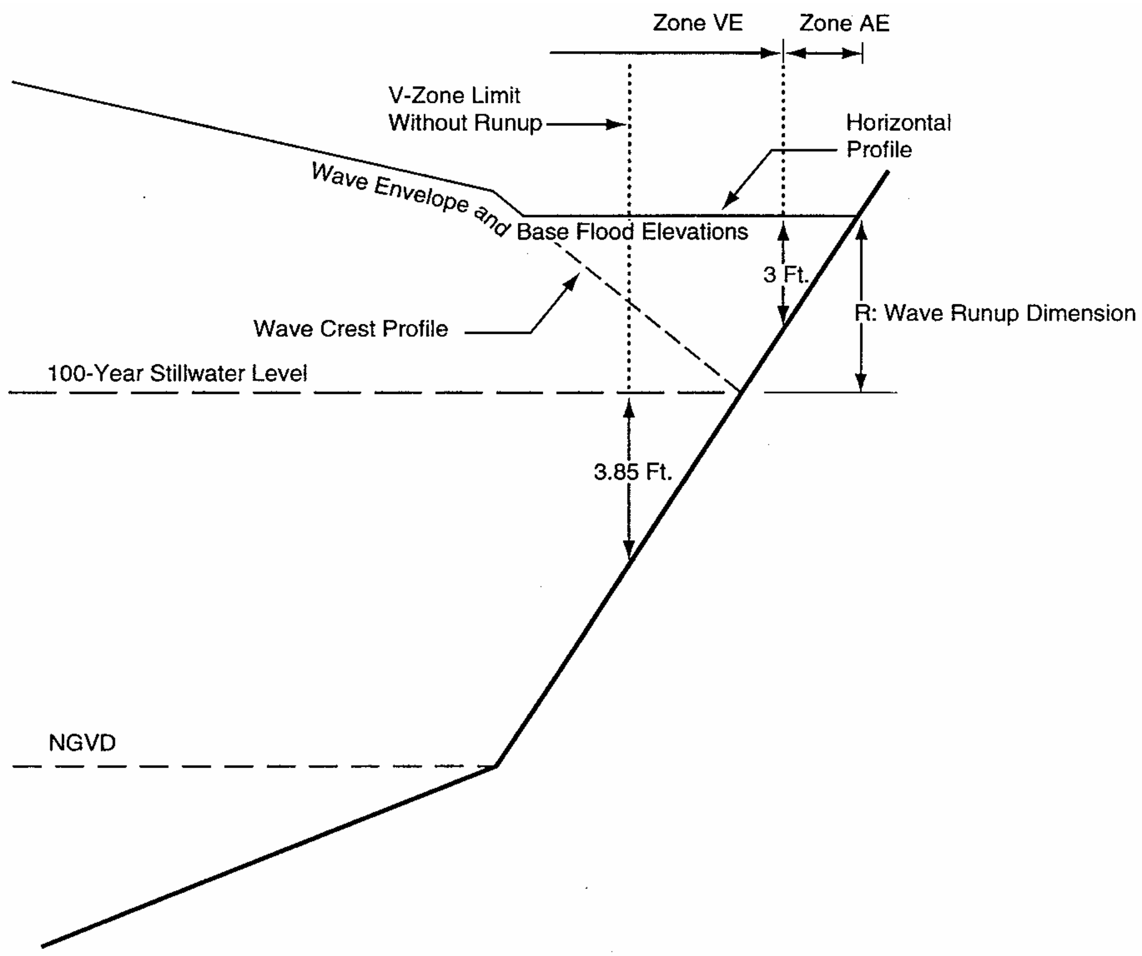

Figure D-25. Wave Envelope Resulting from Combination of Nearshore Crest Elevations and Shore Runup Elevation

<u>Explanation of Figure D-25:</u> "Shows that the wave envelope is a combination of representative wave runup elevation with the controlling wave crest profile determined by WHAFIS. The wave crest profile is plotted on the transect from the data in Part 2 of the WHAFIS output. A horizontal line is extended seaward from the wave runup elevation to its intersection with the wave crest profile to obtain the wave envelope, as shown in Figure D-25."

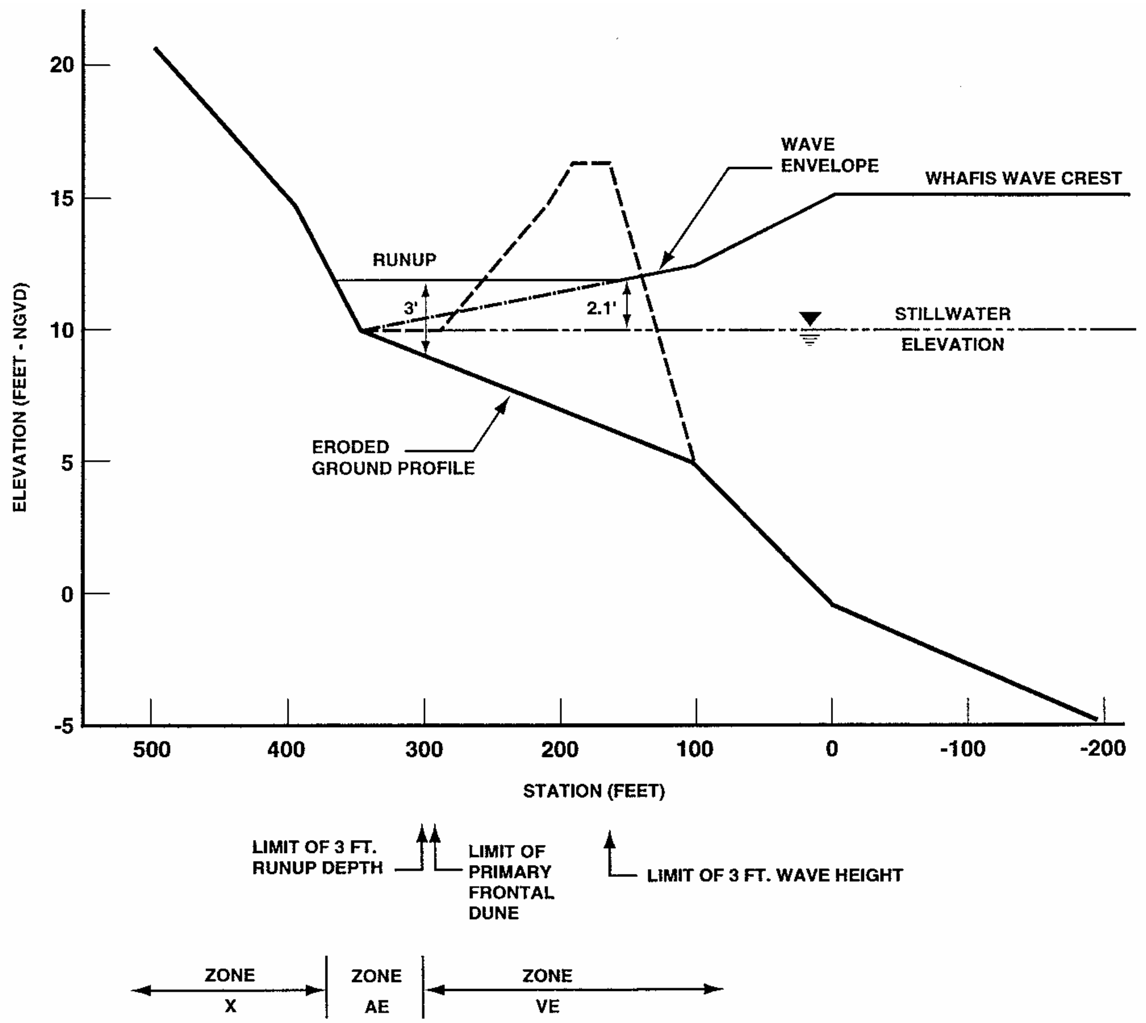

Figure D-26. Possible V-Zone Limits at Eroded Dune

Explanation of Figure D-26: "Provides a schematic summary for the three criteria potentially defining the landward limit to the Coastal High Hazard Area. The VE zone limit for each of the three criteria is identified, and the VE/AE boundary placed at the one furthest landward, as shown in Figure D-26."

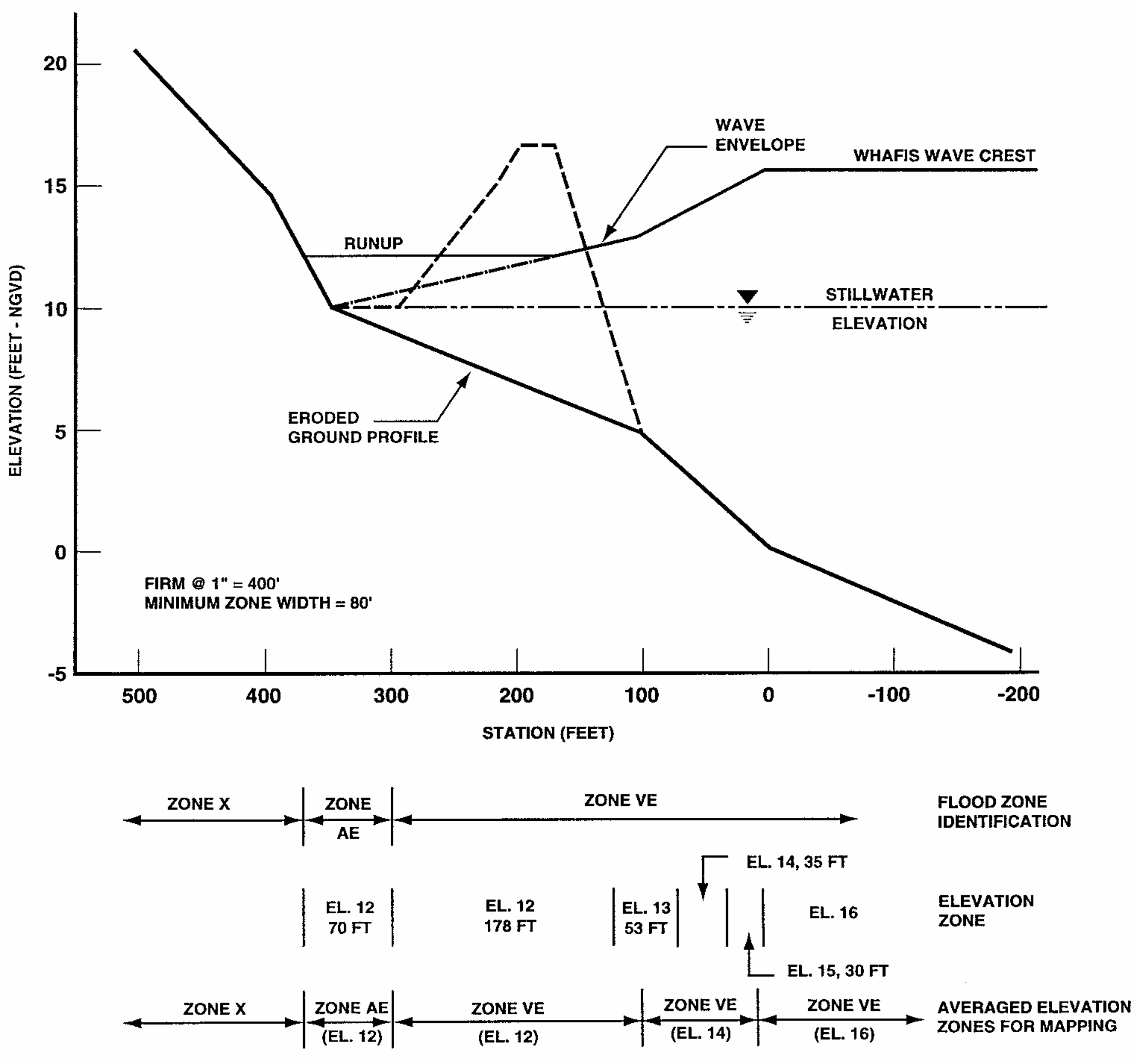

Figure D-27. Identification of Elevation Zones, Example 1: Dune Removal with Wave Runup Landward

<u>Explanation of Figure D-27:</u> "Presents an example of dune removal with appreciable runup occurring on the eroded profile. For this transect, the VE Zones with BFEs of 13, 14, and 15 feet are too narrow to be mapped, so they are averaged to a BFE of 14 feet."

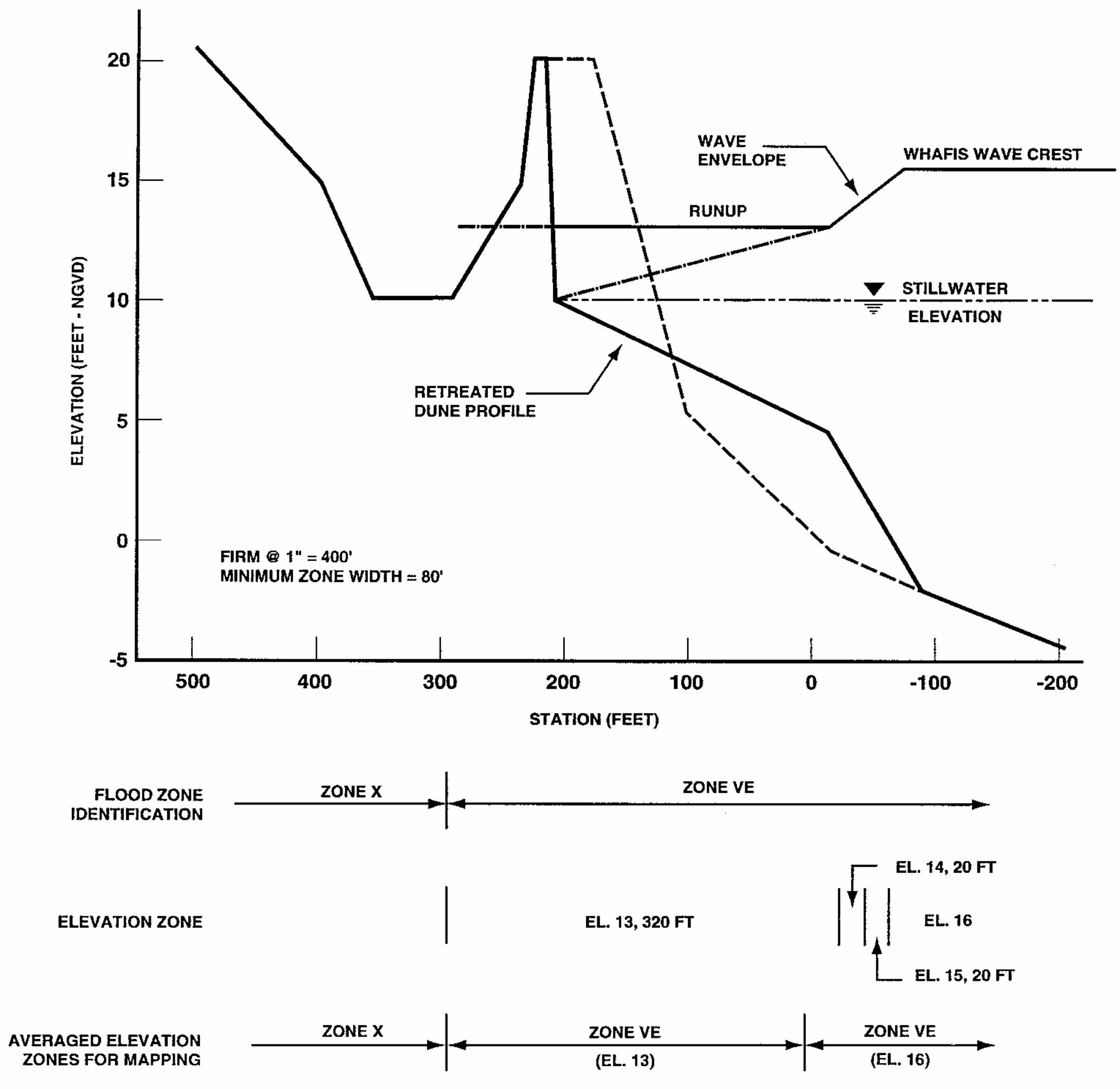

Figure D-28. Identification of Elevation Zones, Example 2: Duneface Retreat with Relatively High Remnant.

Explanation of Figure D-28: "Illustrates an example of a relatively high retreated dune face. A mean runup elevation of 13 feet is calculated for the eroded dune face. This elevation is assigned through the dune, all of which is designated as Zone VE. Because the dune remnant extends more than 7 feet above the SWEL, no flooding landward of the dune is indicated by designating the area as Zone X."

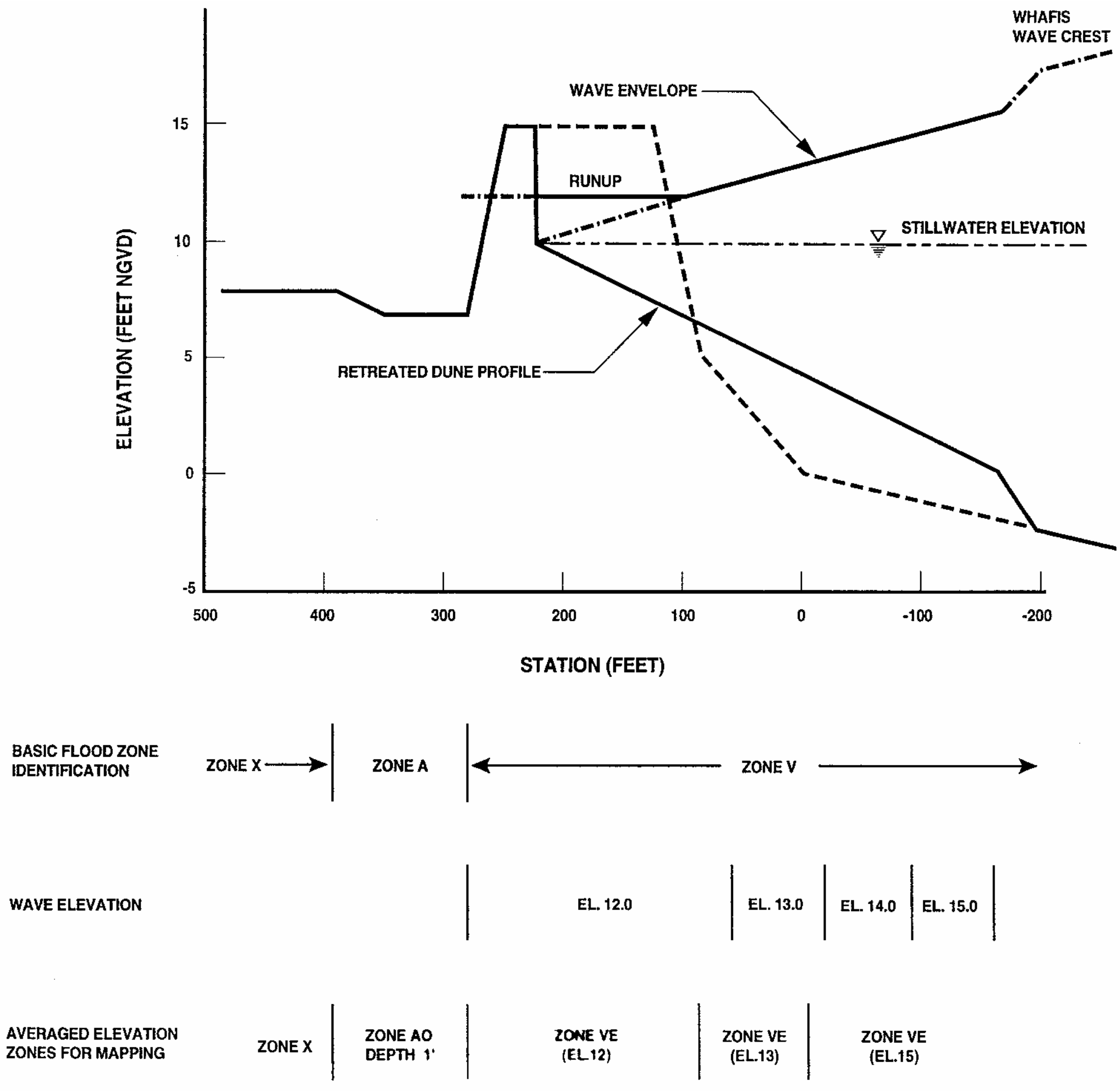

Figure D-29. Identification of Elevation Zones, Example 3: Low Retreated Dune with Wave Overtopping.

<u>Explanation of Figure D-29:</u> "Illustrates an example of a retreated dune face with a relatively small remnant having low relief. A mean runup elevation of 12 feet is calculated for the eroded profile, and this flood elevation is assigned through the dune, all of which is designated as Zone VE. The division into separate map zones is similar to the division in Figure D-28."

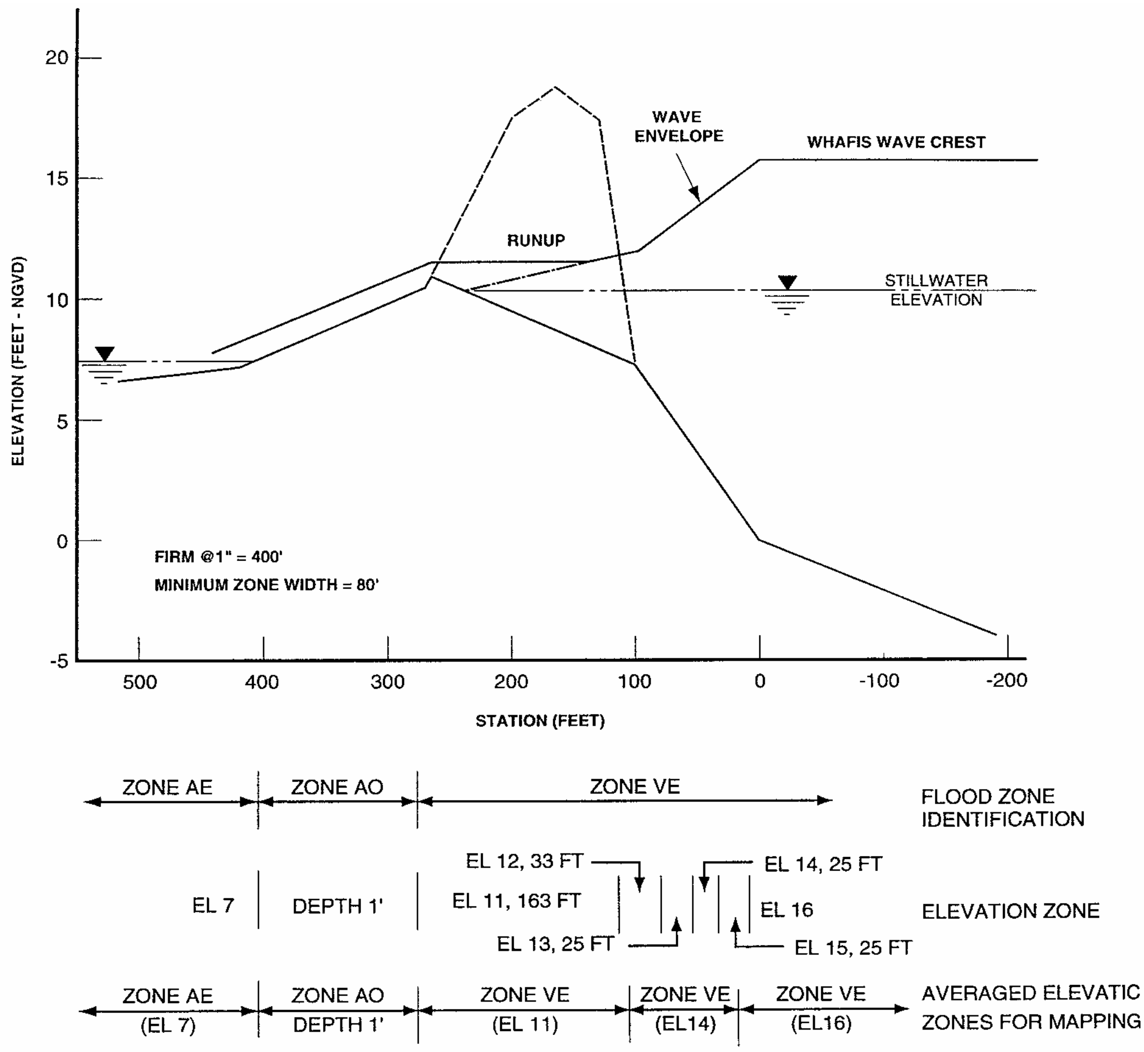

Figure D-30. Identification of Elevation Zones, Example 4: Dune Removal with Wave Runup and Runoff

Explanation of Figure D-30: "Illustrates an example of dune removal where there is some runup and overtopping of the remaining stub. As in Figure D-27, the VE zone with a runup elevation of 11 feet is extended to the dune toe and the Zone VE, elevation 16 feet, is located just landward of the shoreline."

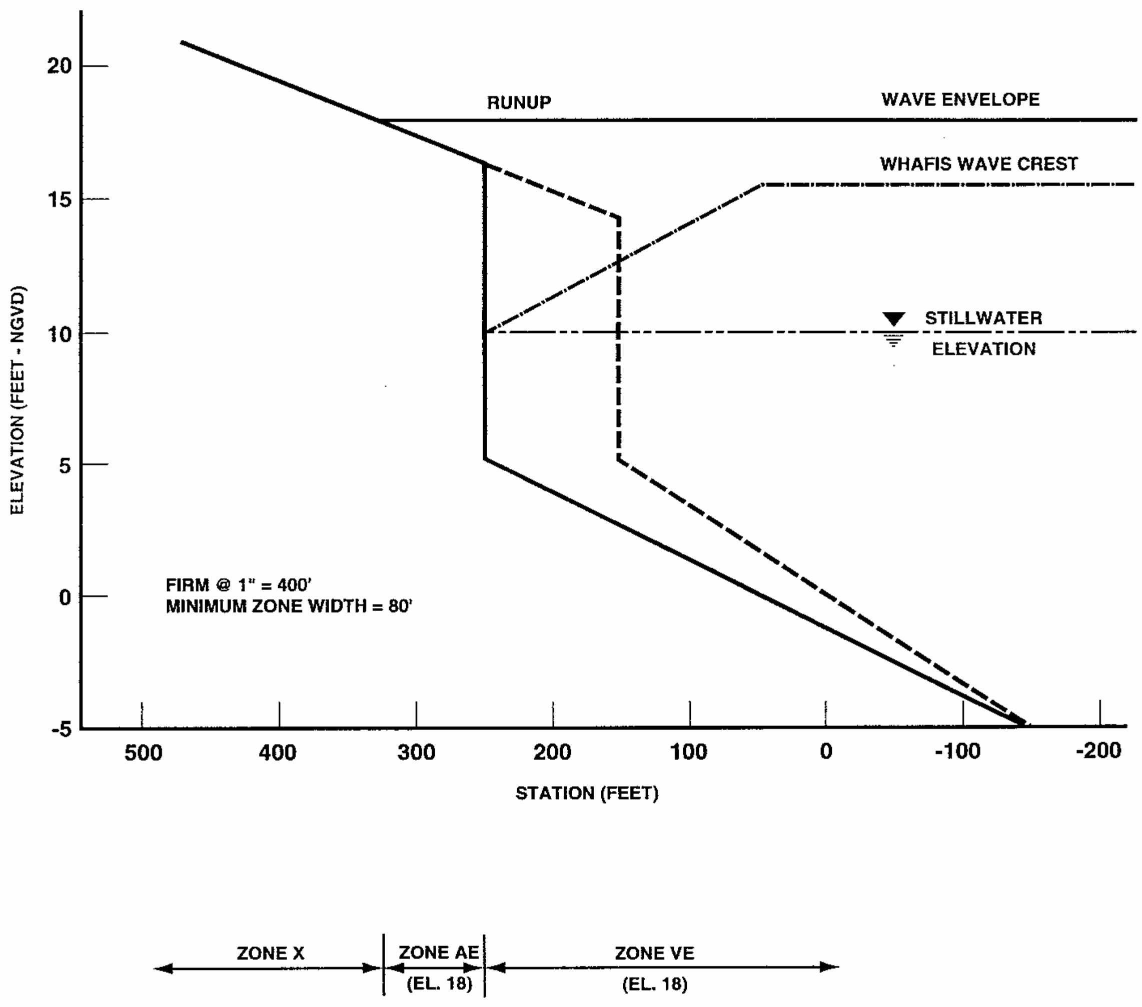

Figure D-31. Identification of Elevation Zones, Example 5: Eroded Bluff with Wave Runup

Explanation of Figure D-31: "An eroded bluff is shown in Figure D-31. The angle of the bluff face remains the same while the seaward extension from the toe is a 1 on 40 slope. The computed runup elevation slightly exceeds the bluff crest and is higher than the maximum wave crest elevation. The area is designated Zone VE, elevation 18 feet, until the difference between the runup elevation and the ground is less than 3 feet."

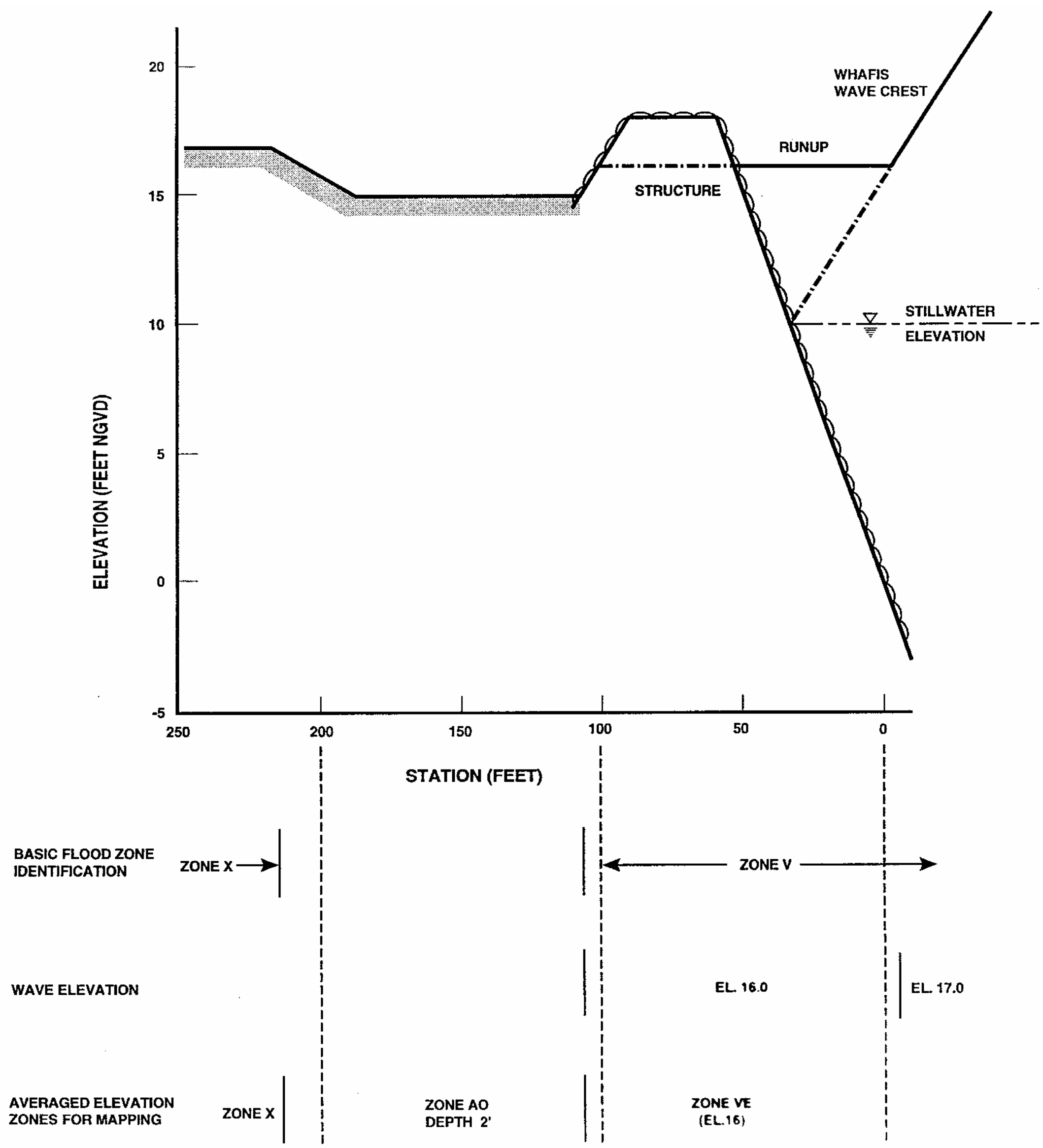

Figure D-32. Identification of Elevation Zones, Example 6: Coastal Structure with Moderate Wave Overtopping

Explanation of Figure D-32: "Figure D-32 illustrates an example of moderate structure overtopping expected for waves accompanying the 1-percent-annual-chance flood. The structure crest has sufficient freeboard above the 1-percent-annual-chance SWEL to contain a calculated mean runup of 6 feet, but extreme wave runups are likely to overtop the structure intermittently."

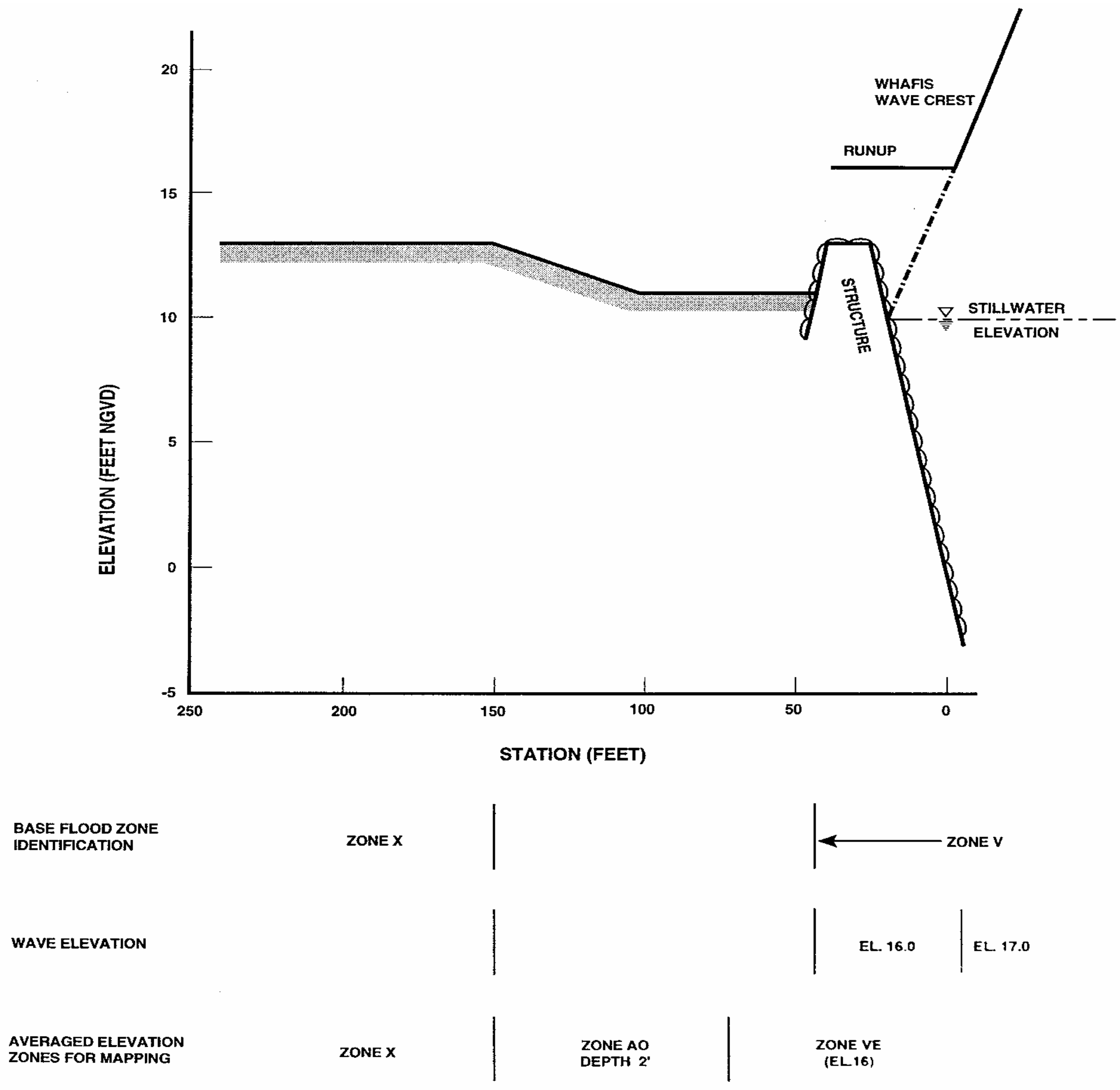

Figure D-33. Identification of Elevation Zones, Example 7: Coastal Structure with Severe Wave Overtopping

Explanation of Figure D-33: "Figure D-33 illustrates an example for a structure extending above the 1-percent-annual-chance SWEL but heavily overtopped by wave action. The calculated mean runup elevation is 5 feet above the seaward face, but that is reduced to the maximum excess runup of 3 feet in assigning a flood elevation of 16 feet for the shorefront VE zone. That zone extends through the entire structure and over an additional 30 feet landward, because likely wave impact area reaches beyond the structure during the 1-percent-annual-chance flood."

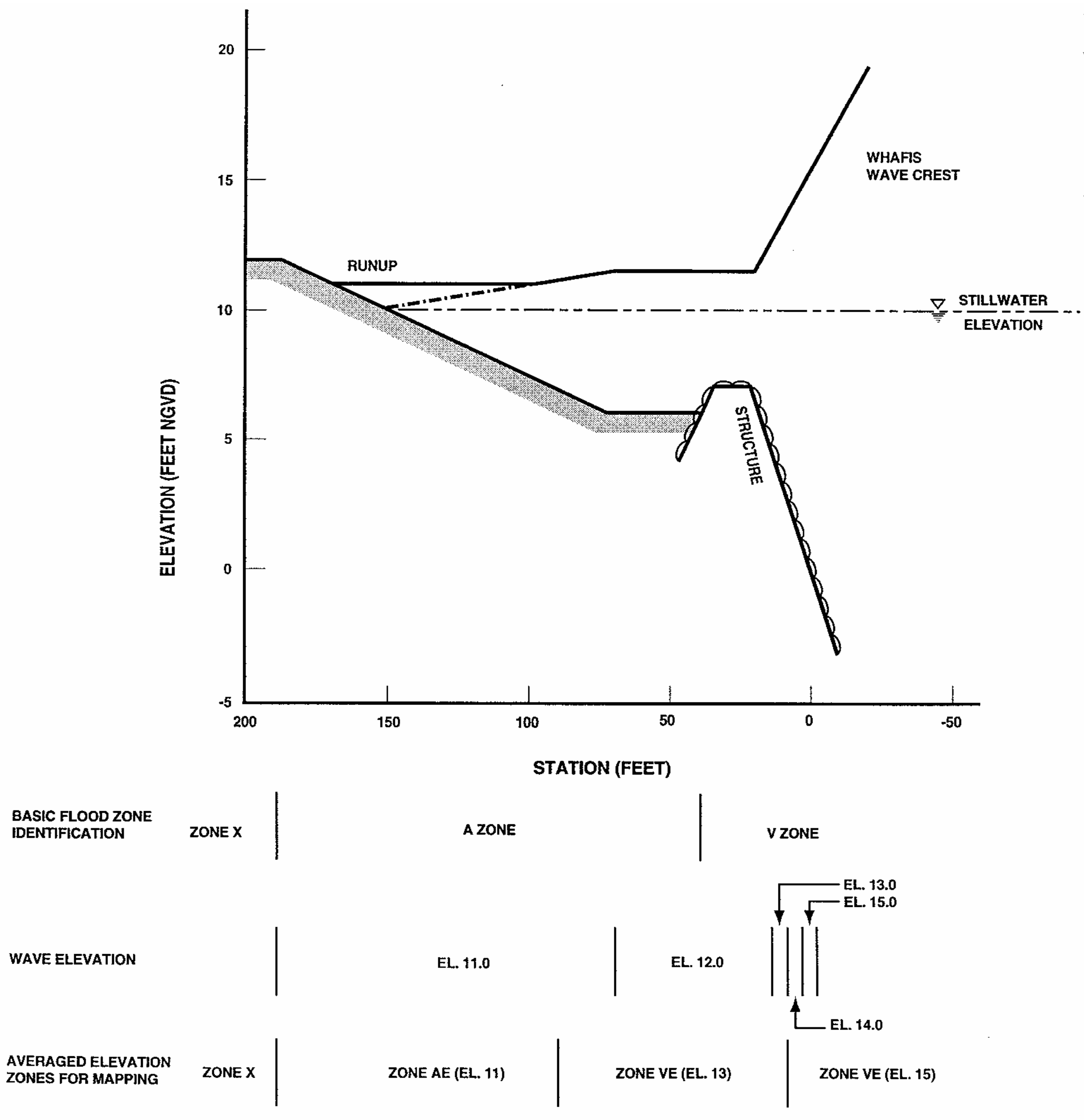

Figure D-34. Identification of Elevation Zones, Example 8: Coastal Structure with Inundation

Explanation of Figure D-34: "Figure D-34 illustrates an example of a structure covered by 3 feet of water during the 1-percent-annual-chance flood. Flood depth is not sufficient for waves 3 feet in height to propagate inland of the structure, but the V zone must extend to 30 feet landward of the structure, in view of likely wave impacts through the flood's course."

APPENDIX 2

Paper presented at the

2001 ASFPM Annual Conference, Charlotte, NC

Consideration of a New Flood Hazard Zone: the Coastal A Zone

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INTRODUCTION

Present NFIP regulations make no distinction between coastal A zones and riverine A zones -- design and construction requirements are the same for both (i.e., elevation on fill, or on solid walls with flood openings, is permissible; reference elevation is the top of the lowest floor, etc.). However, there is a growing body of evidence that design and construction requirements in coastal A zones should be more like those in V zones than those in riverine A zones. This paper will discuss four topics that support this contention: 1) the nature of flood damage, 2) damages observed following coastal flood events, 3) the origin and validity of the V zone (3' breaking wave) criteria, and 4) testing of FIA depth-damage functions following a coastal flood event.

NATURE OF FLOOD DAMAGE

The types of flood damage experienced by a building are related directly to the flood hazards and forces affecting the building -- different hazards (i.e., stillwater flooding vs. breaking waves) will result in different types of damage to the building. Table 1 provides a crude accounting of the dominant flood hazards present in riverine A zones, coastal A zones and V zones, and shows that coastal A zone flood hazards are similar to those in V zones, not riverine A zones.

Table 1. Dominant Flood Hazards Present in Different Flood Zones

Hazard	Riverine A Zone	Coastal A Zone	V Zone
Elevated water level	X	X	X
currents	X	X	X
Waves		X	X
Debris	X	X	X
Scour & Erosion		X	X

OBSERVED DAMAGES

Post-flood damage inspections in coastal V zones consistently show damage to pre-FIRM buildings supported on fill or solid wall foundations. The same inspections frequently show similar damage to post-FIRM buildings supported on fill or solid wall foundations in coastal A zones. Recent inspections following hurricanes Hugo (South Carolina, 1989), Opal (Florida, 1995) and Fran (North Carolina, 1996) have all documented wave and erosion damage to post-FIRM coastal A zone buildings constructed in compliance with A zone standards (see FEMA's Building Performance Assessment Team reports).

ORIGIN AND VALIDITY OF THE V ZONE (3-FOOT BREAKING WAVE) CRITERIA

The 3-foot breaking wave height is often used to distinguish V zones from A zones in coastal areas. Where did the 3-foot wave height standard originate? A study by the Galveston District (USACE, 1975) defined the "Critical Wave" as "a wave possessing sufficient energy to cause major damage on contact with conventional structures." Appendix B of the study concluded that the critical wave is a 3-foot breaking wave; however, a closer reading of calculations in Appendix B shows breaking waves 2.1 foot high are capable of destroying conventional wood-frame walls and connections. The 3-foot standard was adopted by the study, in recognition of the fact that conditions in the field (slope of ground, angle of wave attack, sheltering, etc.) may not be identical to those assumed in the study.

Recent full-scale laboratory tests of breakaway wall sections determined that breaking wave heights as low as 1.5- foot high consistently cause failure of traditional stud wall construction. The tests were part of a larger effort to improve breakaway wall design standards (FEMA, 1999).

TESTING FIA DEPTH-DAMAGE FUNCTIONS

The Federal Insurance Administration has developed damage functions to predict structural and contents damages due to floods. The functions relate flood damage (as a percent of structure/contents value) to flood depth, where depth is measured from a reference elevation -- top of lowest floor in A zones, bottom of lowest horizontal structural member in V zones -- to the top of the water surface (including wave height). Once the A zone and V zone damage functions are shifted to the same reference elevation, a direct comparison between the functions is possible. This comparison (see Table 2) shows there is a great difference in predicted structural damage for a given structure and water depth, depending on the flood zone designation.

Table 2. Percent Structural Damage vs. Flood Depth Using FIA A Zone and V Zone Damage Functions

Flood Depth	A Zone (2-story, no basement)	V Zone (no obstructions)
-2 ft	0 %	10 %
0 ft	0 %	15 %
2 ft	5 %	35 %
4 ft	13 %	58 %
6 ft	20 %	66.5 %

* Flood depth is measured from bottom of lowest horizontal structural member to the top of the flood surface (including wave height). The table assumes the distance between the top of floor and the bottom of lowest horizontal structural member is 2 ft for the A zone building.

Consider the case of the V/A boundary established using the 3-foot breaking wave height (i.e., where the stillwater depth is 3.8 feet and the "depth" between the ground and the wave crest elevation is 5.9 feet). If a pre-FIRM structure was built at this boundary on a slab foundation, with the top of the slab just above the ground, application of the A zone damage function to base flood conditions would predict structural damage at approximately 20% of the structure value. Application of the V zone damage function in the same case would predict approximately 66% structural damage. Consider another comparison, this one for post-FIRM construction built at the same V/A boundary. If the location was classified an A zone and the building was elevated with the top of the lowest floor at the BFE, the A zone damage function predicts 5% structural damage under base flood conditions. The same structure would suffer an estimated 35% damage with a V zone designation (bottom of lowest horizontal structural member 2 feet below BFE).

Given the importance of the zone designation and corresponding damage function in predicting coastal flood damages, testing was carried out as part of the development of the coastal flood module for HAZUS (EQE International, 2000). Predicted structural damage was compared against Hurricane Opal flood claims data for 81 residential structures (63 A zone, 18 V zone) at Pensacola Beach, FL. Predicted damages were based on ground elevations, building characteristics (value, number of stories, lowest floor elevation), estimated flood elevations during Opal, and FIA depth-damage functions. The results of the analysis are summarized in Table 3. The general conclusion is that, in this case, application of the V zone damage function to coastal A zone buildings provided a better aggregate estimate of structural damage due to Opal. Use of the A zone damage function underestimated structural damage to coastal A zone structures.

Table 3. Comparison of Predicted and Actual Structural Damage due to Hurricane Opal, Pensacola Beach, FL (81 residential structures)

Building Type and Damage Fn	Aggregate Value ($1,000)	Predicted Damage ($1,000)	Actual Damage ($1,000)	Predicted / Actual Ratio
1-story, A zone	$1,565	$490	$958	0.51
1-story, A zone	$1,360	$261	$710	0.37
V zone	$1,180	$731	$615	1.19
V Zone function applied to all	$2,925	$1,770	$1,668	1.06

Recognizing the uncertainty associated with some of the parameters used to estimate structural damage, sensitivity tests were carried out. In order for predicted damages to equal actual damages, the following adjustments would be required: increasing the A zone flood depth over 20 feet, and reducing the V zone flood depth 1.7 feet; multiplying A zone building valuations by a factor of 2.2, and multiplying V zone building valuations by a factor of 0.84. The A zone flood depth adjustment is unreasonable. The required building value adjustments would make A zone buildings more expensive than V zone buildings, contrary to actual experience. In summary, the difference between predicted and actual structure damage cannot be due to errors in flood depths or building values, but must be due to the damage function applied.

Application of the FIA damage function to buildings demolished after the storm (and presumed to have sustained > 50% actual damage) yielded similar results. The A zone damage function failed to predict > 50% damage to any of 22 demolished A zone buildings. Application of the V zone damage function to those same 22 buildings predicted > 50% damage in 18 out of 22 cases.

FINAL COMMENTS

This paper has discussed the issue of distinguishing between coastal A zones and riverine A zones. The authors believe sufficient justification exists for doing so, and this concept is finding its way into the literature [e.g., the national load standard (ASCE, 1998) and the revised Coastal Construction Manual (FEMA, 2000)]. However, on a broad scale, how should this concept be implemented? Is it best to implement mapping changes (redefine V zone delineation) or management changes (leave FIRMs as they are and apply V zone standards to coastal A zones)? Those questions have yet to be answered. More work on the subject and more discussion are required.

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