Guidance for Flood Risk Analysis and Mapping

Coastal Floodplain Mapping

November 2023

FEMA

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Requirements for the FEMA Risk Mapping, Assessment, and Planning (Risk MAP) Program are specified separately by statute, regulation, or FEMA policy (primarily the Standards for Flood Risk Analysis and Mapping). This document provides guidance to support the requirements and recommends approaches for effective and efficient implementation. Alternate approaches that comply with all requirements are acceptable.

For more information, please visit the FEMA Guidelines and Standards for Flood Risk Analysis and Mapping webpage (https://www.fema.gov/guidelines-and-standards-flood-risk-analysis-and-mapping). Copies of the Standards for Flood Risk Analysis and Mapping policy, related guidance, technical references, and other information about the guidelines and standards development process are all available here. You can also search directly by document title at https://www.fema.gov/resource-document-library.

Table of Revisions

Affected Section or Subsection	Date	Description
Throughout Document	November 2023	Updated acronyms and references to other Guidance Documents

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1. Coastal Floodplain Mapping

This document provides guidance to Mapping Partners on the delineation of coastal Special Flood Hazard Areas (SFHAs) and Base Flood Elevations (BFEs). The guidance covers the Atlantic and Gulf Coast regions, Pacific Coast regions, and Great Lakes regions.

1.1. Review and Evaluation of Basic Results

Before mapping the flood elevations and SFHAs, the Mapping Partner should review results from the models and assessments from a common-sense viewpoint and compare them to available historical flood data. When using models, there is the potential to forget that transects represent real shorelines being subjected to high water, waves, and winds. Familiarity and experience with the coastal area being modeled, or with similar areas, should provide an idea of a “reasonable” result.

The main point to be emphasized is that the results should not be blindly accepted. There are many uncertainties and variables in coastal processes during an extreme flood, and many possible adjustments to methodologies for treating such an event. The validity of any model is demonstrated by its success in reproducing recorded events. Therefore, the model results should be in basic agreement with past flooding patterns, and historical data should be used to evaluate these results.

It would be very convenient if data from a storm closely approximating the 1% annual- chance flood were available, but this is seldom the case. Any single storm may impact a reach of the coast more severely in one location (close to or greater than the 1% annual-chance flooding) while the same storm may have only moderate impacts on adjacent coastal shorelines and floodplains (closer to the 10% or 20% annual-chance flooding). Although most historical flood data are for storms less intense than a 1% annual-chance flood, these data will still indicate, at a minimum, the areas that should be within a flood zone. For instance, if a storm that produced a flood below the 1% annual-chance flood elevation generally caused structural damage to houses 100 feet from the shoreline, a “reasonable” VE Zone width should be at least 100 feet in this area. Similarly, houses that collected flood insurance claims for the same storm (without building foundation or structural damages) should at least be located in an AE, AH, or AO Zone. If the analyses of the 1% annual-chance flood produce flood zones and elevations indicating lesser hazards than those recorded for a more common storm, the data should be reevaluated.

If there are indications that a reevaluation is needed, the Mapping Partner should determine whether the results of the assessment are appropriate. The Mapping Partner should attempt to compare all aspects of the coastal hazard assessment to past effects, whether in the form of data, profiles, photographs, or anecdotal descriptions. The Mapping Partner should examine other data input to the assessments for wave effects (wave setup, wave height, wave runup, and wave overtopping). This includes checking that the stillwater levels are correct and that the results of wave analyses are consistent with the historical data. The Mapping Partner should use judgment and experience to project previous storm effects onto the 1% annual-chance conditions and to ensure that the coastal assessment results are consistent with previous observed events.

2. Identification of Special Flood Hazard Areas

The Mapping Partner should identify the SFHAs and BFEs, including the wave effects along each transect, before interpolating between transects to delineate SFHAs on the work maps. The existing topography, eroded topography, coastal structure effects, combined wave analyses (wave runup, overtopping and overland propagation) are all important to the proper identification of SFHAs, and coastal study technical documentation. In areas dominated by wave runup processes, the BFE is also commonly referred to as the total water level (TWL), which is the sum of stillwater level (SWL), wave setup, and wave runup. Hazard zones that are generally mapped in coastal areas include: VE, AE, AH, AO and X. In addition, the Limit of Moderate Wave Action (LiMWA) is typically identified.

2.1. VE Zone

VE Zones are coastal high hazard areas where wave action and/or high-velocity water can cause structural damage during the 1% annual-chance flood and include the Primary Frontal Dune (PFD). VE Zones are identified using the following criteria for the 1% annual-chance flood conditions:

1. The breaking wave height zone occurs where 3-foot or greater wave heights could occur (this is the area where the wave crest profile is 2.1 feet or more above the static water elevation). (REQUIRED) For more details, see Guidance Document No. 41, Guidance for Flood Risk Analysis and Mapping: Overland Wave Propagation. Guidance Document No. 41 is accessible through the FEMA Guidelines and Standards for Flood Risk Analysis and Mapping webpage.
2. The Primary Frontal Dune (PFD) zone, as defined in 44 CFR Section 59.1 of the National Flood Insurance Program (NFIP) regulations. The entire PFD is included in the VE Zone. The inland limit of the PFD is the location where the dune profile transitions from relatively steep to relatively mild slopes. (REQUIRED) For more details, see Guidance Document No. 2, Guidance for Flood Risk Analysis and Mapping: Coastal General Study Considerations. Guidance Document No. 2 is accessible through the FEMA Guidelines and Standards for Flood Risk Analysis and Mapping webpage.
3. The wave runup zone occurs where the (eroded) ground profile is 3.0 feet or more below the TWL, and 3.0 feet of wave runup height occurs in the analysis along the profile as per Section 2.1.2 below. (REQUIRED) For more details, see Guidance Document No. 89, Guidance for Flood Risk Analysis and Mapping: Coastal Wave Runup and Overtopping. Guidance Document No. 89 is accessible through the FEMA Guidelines and Standards for Flood Risk Analysis and Mapping webpage.
4. The wave overtopping splash zone is the area landward of the crest of an overtopped barrier, in cases where the potential wave runup exceeds the barrier crest elevation by 3.0 feet or more (ΔR>3.0 feet) and exceeds 1.0 cfs/ft. (REQUIRED) See the Coastal Wave Runup and Overtopping Guidance for more details.
5. The high-velocity flow zone is landward of the overtopping splash zone (or area on a sloping beach or other shore type), where the product of depth of flow times the flood velocity squared

(hv2) is greater than or equal to 200 ft3/sec2. (OPTIONAL) See the Coastal Wave Runup and Overtopping Guidance for more details.

The actual VE Zone boundary shown on the Flood Insurance Rate Map (FIRM) is defined as the furthest inland extent of the five criteria. VE Zones are subdivided into elevation zones, and whole-foot BFEs are assigned.

The high-velocity flow zone mapping criteria was originally developed for the Pacific Coast and is based on knowledge of high-velocity flows caused by wave overtopping and overland flow in coastal areas. This criterion can be applied on beaches, and on the seaward and landward sides of coastal dunes, structures, and barriers (see Figure 2-1). Landward transitions from this VE Zone will normally be to the AO Zone, but this may vary depending upon the site and the conditions being mapped.

2.1.1. OVERTOPPING RATE CONSIDERATIONS FOR ESTABLISHING SFHAS

An interpretation of the estimated overtopping rate in terms of flood hazards is complicated by the projected duration of wave effects, the increased discharge possible under storm winds, the varying inland extent of water effects, and the specific topography and drainage landward of the barrier. Detailed guidance on overtopping rates as it might influence coastal mapping is provided in the Coastal Wave Runup and Overtopping Guidance.

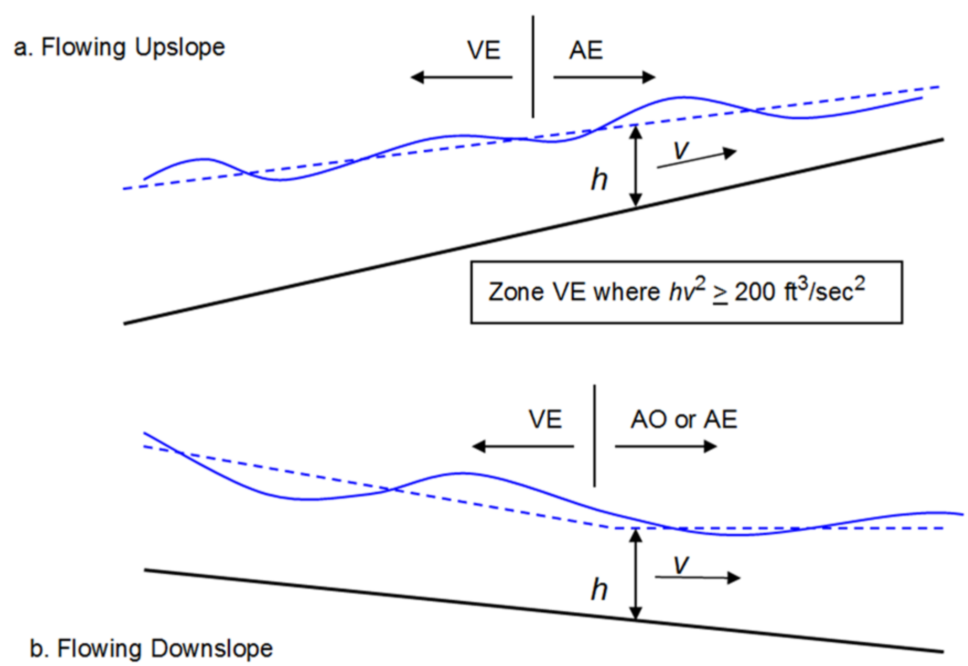

Figure 1: Example Designation of High-velocity Flow VE Zones Based on Flood Depth and Velocity

In the past there had been differing guidance on wave runup overtopping VE Zones and elevation determinations. In some areas it is standard practice to limit wave runup BFEs to 3 feet above the barrier crest when results show elevations higher than this. Additionally, a simplified runup procedure has been developed to delineate a VE Zone landward of the barrier when the potential runup is 3.0 feet or greater above the barrier crest, as shown in Figure 2.

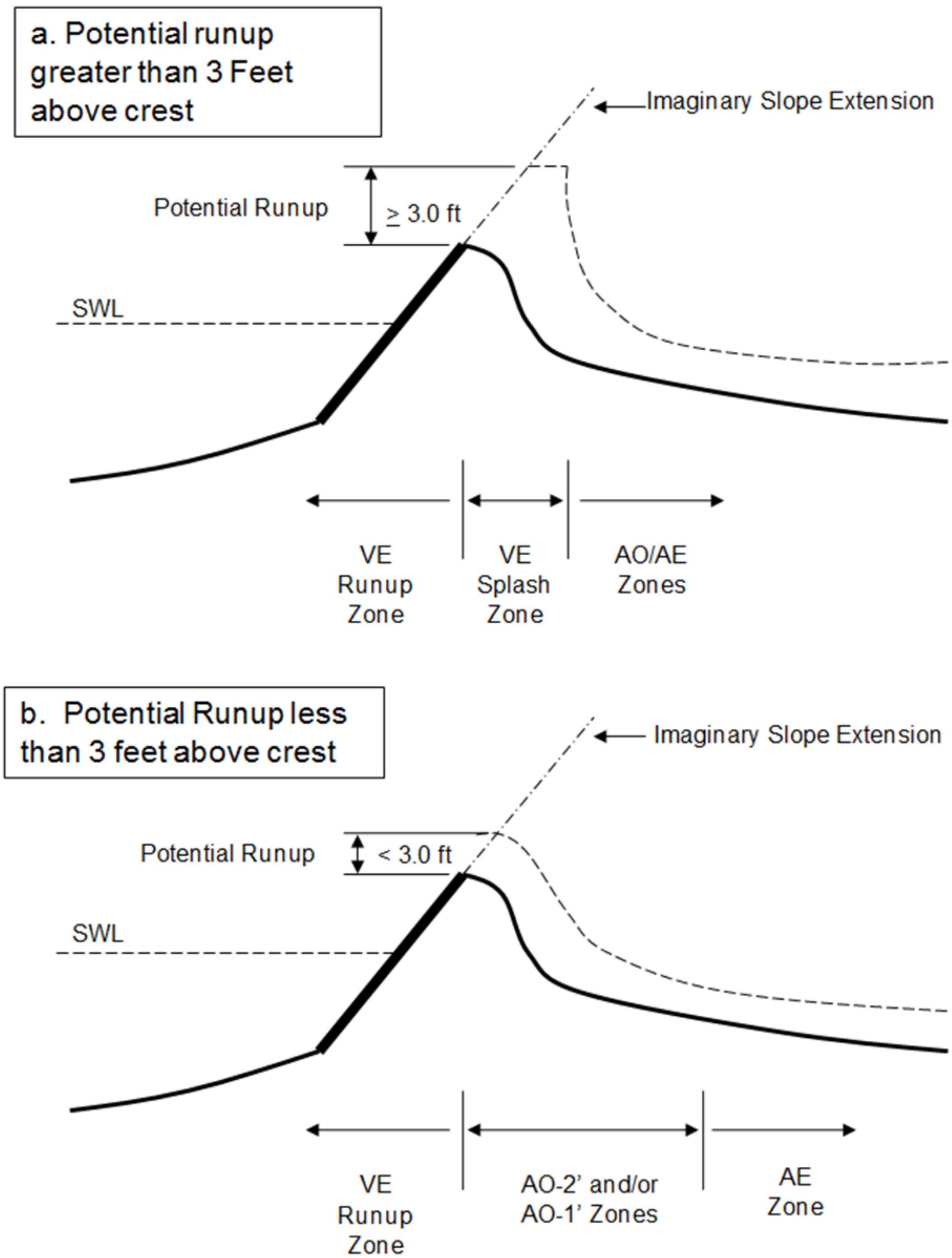

Figure 2: Simplified Mapping Procedure for Overtopped Barrier

2.1.2. VE ZONE MAPPING BASED ON WAVE RUNUP HEIGHT

For all new detailed coastal studies, the VE Zone should only be mapped for areas subject to wave runup where the 2% wave runup elevation is at least 3 feet higher than the stillwater elevation. Where runup heights are less than 3 feet, the runup zone should be mapped as AE Zone. The existing depth criterion for wave runup zones should continue to be used to determine the inland limit of VE Zone if the runup height criterion for VE Zone is met.

Previously there had been issues with implementing the wave runup criterion for VE Zone in areas with low wave energy. The current criterion states, “The wave runup zone occurs where the (eroded) ground profile is 3.0 feet or more below the 2% wave runup elevation” (Figure 3). As written, this criterion is based on depth and does not distinguish between the depth of runup and the depth of inundation.

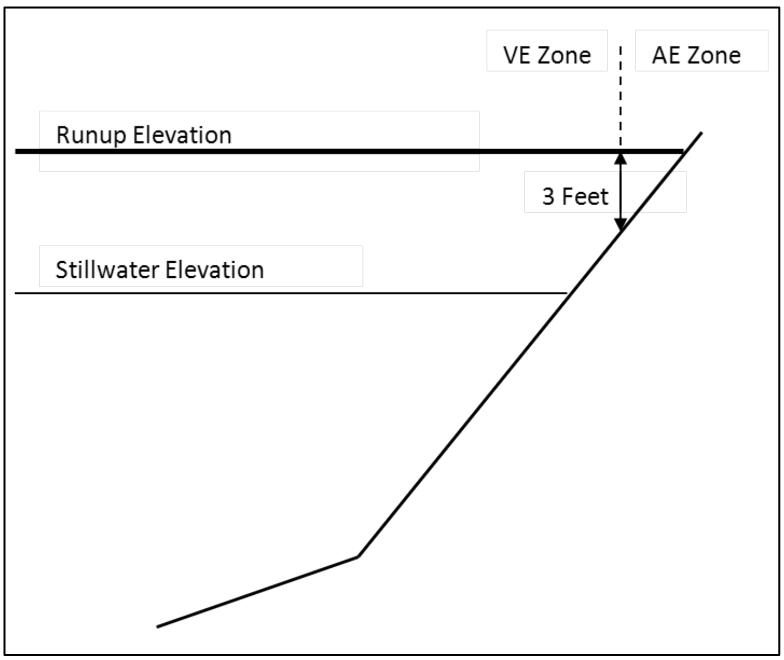

Figure 3: Mapping of wave runup as VE Zone and AE Zone, based on depth, according to current guidance

The limitation of this criterion is apparent in areas where wave runup heights (the difference between the stillwater elevation and the limit of wave runup, or the runup elevation) are relatively small. For example, an area with a wave runup height of 1 foot and a stillwater elevation of 10 feet would yield a runup elevation of 11 feet. Using the current wave runup zone criterion, the area would be mapped as VE Zone to the point where the eroded ground profile is 3 feet below the runup elevation (in the example in Figure 4, to a ground elevation of 8 feet). However, with only 1 foot of runup, a VE Zone designation is not considered appropriate since the wave hazard severity is low and 1 foot of runup is not expected to result in structural damage. Therefore, the wave runup height criterion was developed to establish a minimum runup height that warrants a VE Zone designation.

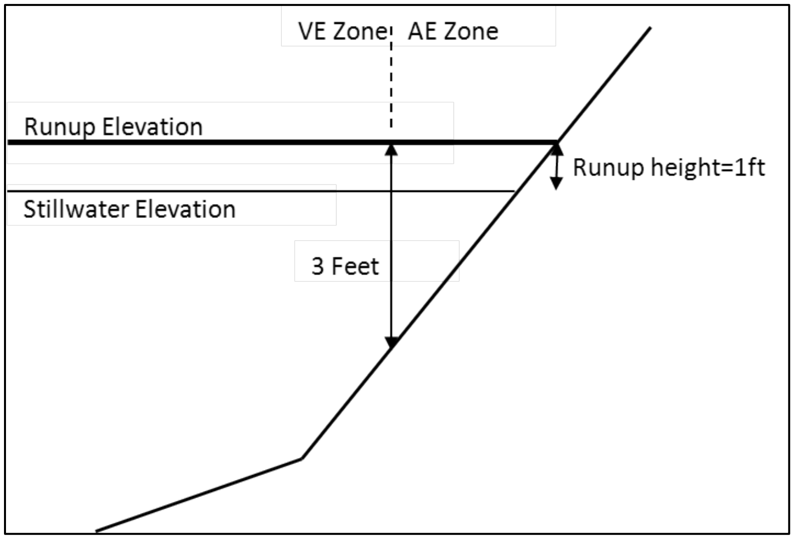

Figure 4: Current Mapping guidance results in the mapping of VE Zone, even for runup heights as small as 1 foot

In general, the energy associated with the uprush of water from a broken wave (wave runup) is less than that associated with a breaking wave. Therefore, the runup height criterion should be equal to or greater than the 3-foot overland wave propagation wave height criterion. For consistency with other VE Zone criteria, and in the absence of data supporting a larger value, 3 feet was considered a reasonable value to use as the wave runup height criterion for mapping VE Zone.

2.2. AE Zone

AE Zones are areas of inundation by the 1% annual-chance flood, including areas with wave heights less than 3.0 feet and runup elevations less than 3.0 feet above the ground. These areas are subdivided into elevation zones, and BFEs are assigned. The AE Zone will generally extend inland to the limit of the 1% annual-chance flood stillwater elevation (SWEL). New coastal studies will also typically subdivide the AE Zone by identifying the Limit of Moderate Wave Action (LiMWA). More information on the LiMWA is included in Section 6.3.

2.3. AH Zone

AH Zones are areas of shallow flooding or ponding, with average water depths between 1.0 foot and 3.0 feet. These areas are usually not subdivided, and a BFE is assigned.

2.4. AO Zone

AO Zones are areas of sheet-flow shallow flooding, or where the potential runup is less than 3.0 feet above an overtopped barrier crest ($\Delta R<3.0$ feet). The sheet flow in these areas will either flow into another flooding source (AE Zone), result in ponding (AH Zone), or deteriorate because of ground friction and energy losses to merge into the X Zone. AO areas are designated with 1-, 2-, or 3-foot depths of flooding.

2.5. X Zone

X Zones are areas above the 1% annual-chance flood level. On the FIRM, a shaded X Zone area is inundated by the 0.2% annual-chance flood, and an unshaded X Zone area is above the 0.2% annual-chance flood.

2.6. D Zone

D Zones are used for areas where there are possible but undetermined flood hazards, as no analysis of flood hazards has been conducted. D Zones may be applicable in coastal areas including across piers and wharves determined to survive a 1% annual-chance flood or behind non-accredited levees. More information on use of D Zones for piers and wharves is provided in Section 6.1.4 of Guidance Document No. 42, Guidance for Flood Risk Analysis and Mapping: Coastal Structures Guidance. D Zone mapping behind levees is explained in detail within Guidance Document No. 95, Guidance for Flood Risk Analysis and Mapping: Levees Guidance. Guidance Document No. 42 and Guidance Document No. 95 are both accessible through the FEMA Guidelines and Standards for Flood Risk Analysis and Mapping webpage.

3. Wave Envelope

The concept behind the creation of the wave envelope profile was to capture the results from all of the detailed analysis and depict their relationship to each other on the same profile. The dominant coastal processes that influence the BFEs, hazard zones, and limit of inland flooding are thus documented. The wave envelope helps to explain graphically which model results are used for the mapping.

The seaward portion of the wave envelope is a combination of the potential wave runup elevation and the controlling wave crest elevation profile. The wave crest elevation profile is plotted along a transect (from the zero (0.0 foot) map datum elevation landward) based on the results of the WHAFIS model or other methodology. A horizontal line is extended seaward from the potential wave runup elevation to its intersection with the wave crest profile to obtain the wave envelope, as shown in Figure 3-1. If the runup elevation is greater than the maximum wave crest elevation, the wave envelope will be represented as a horizontal line (extending to the elevation 0.0 location on the transect) at the runup elevation, and the BFE for mapping purposes will be based on that elevation. Conversely, if the wave runup is negligible, the wave crest elevation profile becomes the wave envelope.

The landward portion of the wave envelope (landward of the bluff edge, crest of eroded dune, or seaward edge of a coastal structure) will be a combination of an overtopping bore or splash area and sheet flow.

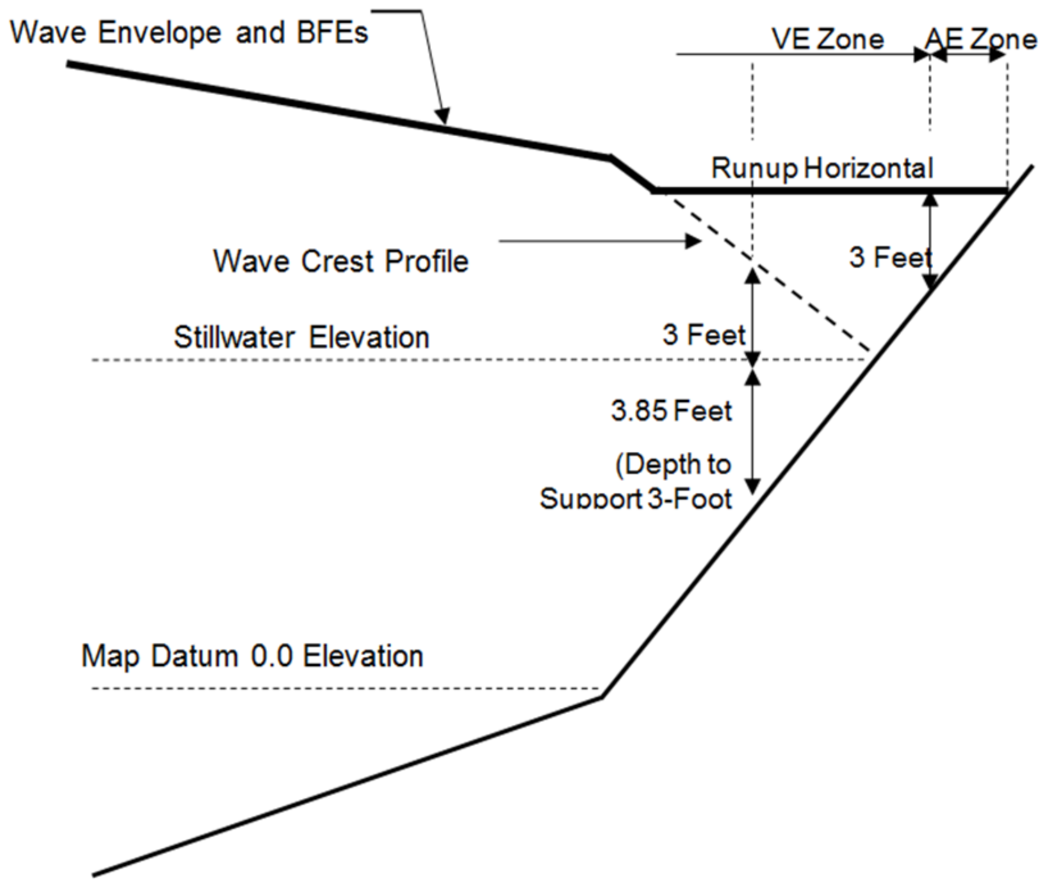

Figure 5: Seaward portion of wave envelope based on combination of nearshore crest elevations and shore runup elevation (figure not to scale)

4. Criteria for Flood Boundary and Hazard Zone Mapping

The first step in identifying the SFHAs along a transect is locating the inland extent of the VE Zone, also known as the VE/AE boundary. The mapped VE/AE Zone boundary is based on the most landward limit of the five criteria outlined above. The Mapping Partner should extend the AE Zone from the VE/AE boundary to the inland limit of 1% annual-chance inundation, which is a ground elevation equal to the potential runup elevation, or the 1% annual-chance SWEL if runup is negligible. The Mapping Partner may designate additional areas of 1% annual-chance flooding caused by wave overtopping sheet flow and shallow flooding or ponding as the AO Zone and/or the AH Zone. The Mapping Partner should label all areas above 1% annual-chance inundation as the X

Zone. The X Zone should be shaded for areas affected by the 0.2% annual-chance flood and unshaded for areas above the 0.2% annual-chance flood level.

The Mapping Partner should then subdivide the VE and AE Zone areas into elevation zones, with whole-foot BFEs assigned according to the wave envelope. Initially, the Mapping Partner should mark the location of all elevation zone boundaries on a transect. Because whole-foot BFEs are being used, these should always be mapped at the location of the half-foot elevation on the wave envelope. However, the Mapping Partner should not subdivide the horizontal runup portion of the seaward wave envelope (see Figure 3-1). The BFE should simply be the runup elevation, rounded to the nearest whole foot.

Ideally, the Mapping Partner would establish an elevation zone for every BFE in the wave envelope; however, because these zones are mapped on the FIRM so that buildings or property can be located in a SFHA, the Mapping Partner should use a minimum width for the mapped zone to provide a usable FIRM. For coastal areas, the general guidance is to have a minimum zone width of 0.2 inch on the FIRM. The mapping criteria and the ability to map all coastal BFE and hazard zone changes is dependent upon the scale of the FIRM. The minimum zone width is 0.2 times the final FIRM scale; for example, a width of 100 feet for a FIRM at a scale of 1 inch equals 500 feet. Because digital FIRM data can easily be enlarged, the map scale limitations should be reviewed by the Mapping Partner with the FEMA Project Officer and community officials.

The Mapping Partner should combine elevation zones that do not meet the minimum width requirement with an adjacent zone or zones to yield an elevation zone equal to or wider than the minimum width. The BFE for this combined zone is a weighted average of the combined zones, rounded to the nearest whole foot. When combining VE Zones, the Mapping Partner should not reduce the maximum BFE at the shoreline by averaging.

The AE Zone, if wide enough, should be subdivided in the same manner. If the total AE Zone width is less than the minimum width requirement, the VE Zone with the lowest elevation is usually assigned to that area. This situation typically occurs for steep or rapidly rising ground profiles, and it is not unreasonable to designate the entire inundated area as a VE Zone. In some cases, however, it may be appropriate for the Mapping Partner to extend the AE Zone slightly into the next zone seaward to satisfy the minimum width requirement.

Relatively low areas landward of zones subject to wave effects may be subject to shallow flooding or the ponding of floodwater; the Mapping Partner should designate these areas as AO or AH Zones. Such designations can be relatively common landward of coastal structures, bluffs, ridges, and dunes, where wave overtopping occurs.

Identifying appropriate zones and elevations may require particular care for dunes, given that the entire PFD is defined as a coastal high hazard area. Although the analyses may have determined that a dune will not completely erode and that the wave action should stop at the retreated dune face with only overtopping possibly propagating inland, the Mapping Partner should designate the entire dune as a VE Zone, as defined in the NFIP regulations. The Mapping Partner should assign the last calculated BFE at the open-coast dune face (whether VE or AE Zone) to be the dominant VE Zone BFE for the entire PFD and should extend this value to the landward limit of the PFD. It may seem unusual to use a BFE lower than the ground elevation, but this is 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 because, under current regulations, structures in VE Zones must be built on pilings and alterations to the dunes are prohibited.

Special considerations apply to mapping of piers and wharves. In addition to the magnitude of determined hazards, mapping of a pier or wharf is also dependent on the breadth of the supporting analyses. Piers or wharves without a detailed determination of survival during a 1% annual-chance flood should be wholly mapped in a Zone representative of the most hazardous conditions identified. Zone D may be applicable at piers or wharves determined to survive a 1% annual-chance flood. Additional considerations for analysis and mapping of piers and wharves are discussed in Section 6.1.4 of the Coastal Structures Guidance.

5. Transect Examples

Settings occurring along the open coastlines and sheltered waters of the Pacific Ocean, Atlantic Ocean, Gulf of Mexico, and Great Lakes regions which may include the following:

6. Sandy beach backed by a low sand berm or high sand dune formation
7. Sandy beach backed by shore protection structures
8. Cobble, gravel, shingle, or mixed grain sized beach and berms
9. Erodible coastal bluffs
10. Non-erodible coastal bluffs or cliffs
11. Tidal flats and wetlands

The examples discussed below depict idealized transects for these beach settings, where storm surge, wave heights, dune erosion, wave runup, and wave overtopping are the dominant coastal processes, to illustrate how the results of the analyses are translated into a map product. BFEs shown are arbitrary and included for illustrative purposes only.

- Example 1. Figures 6 and 7 illustrate flood hazard mapping for a non-erodible coastal bluff which is high enough to prevent overtopping during 1% annual-chance flood conditions. The area seaward of the bluff will be mapped as the VE Zone, with a BFE set at the potential runup elevation. The area landward of the bluff face will be mapped as X Zone (unshaded).

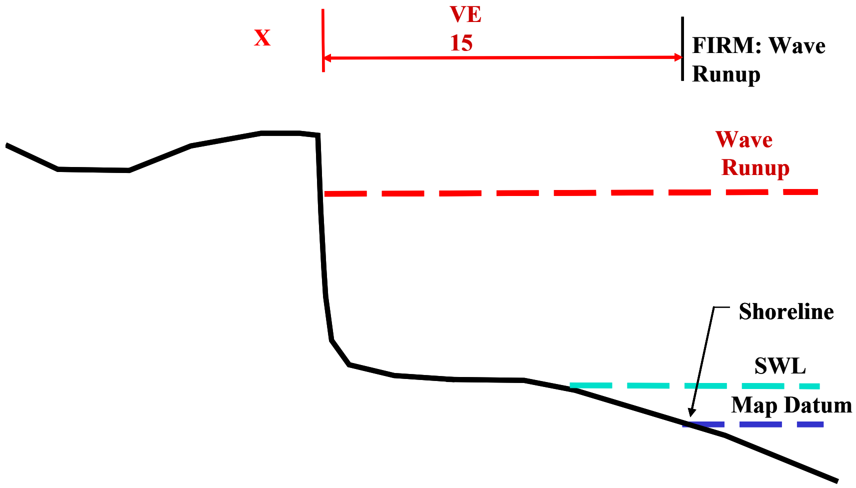

Figure 6: Non-erodible High Coastal Bluff with VE Zone Controlled by Wave Runup (No Overtopping)

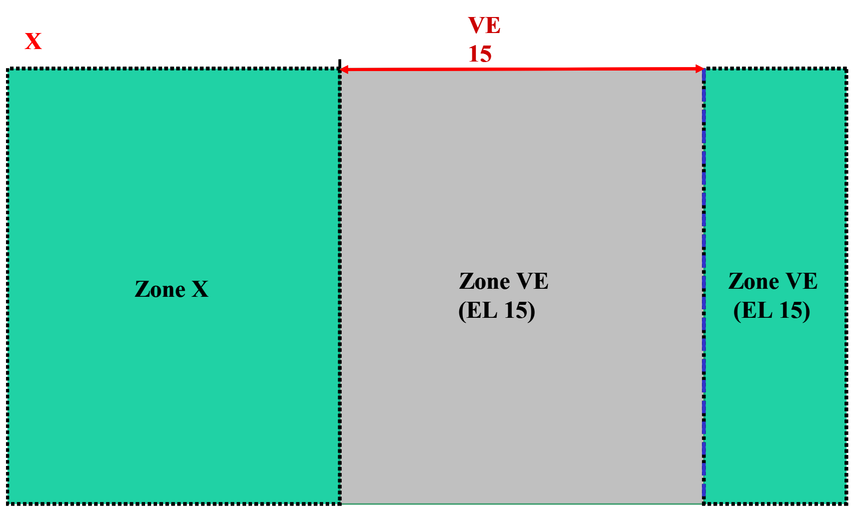

Figure 7: Plan View of Flood Hazard Zones and BFEs, Non-erodible High Coastal Bluff with VE Zone Controlled by Wave Runup (No Overtopping)

- **Example 2.** Figures 8 and 9 illustrate flood hazard mapping for an erodible coastal bluff that is not high enough to prevent overtopping and where the potential runup reaches higher than 3.0 feet above the crest. In the example shown, the eroded profile is calculated first using procedures described in Guidance Document No. 40, Guidance for Flood Risk Analysis and Mapping: Coastal Erosion, then wave runup and overtopping are mapped against the eroded profile. The area seaward of the bluff will be mapped as the VE Zone, with a BFE set at the potential runup elevation. The area immediately landward of the eroded bluff face will be mapped as VE Zone based on the calculated splash zone width. The area landward of the splash zone will be mapped as a high-velocity flow VE Zone where $hv^2 \geq 200$ ft^3/sec^2 and as AO Zone where $hv^2 < 200$ ft^3/sec^2. BFEs in the VE splash zone and VE high-velocity flow zone will be based on the calculated water surface profile decay (see the Coastal Wave Runup and Overtopping Guidance).

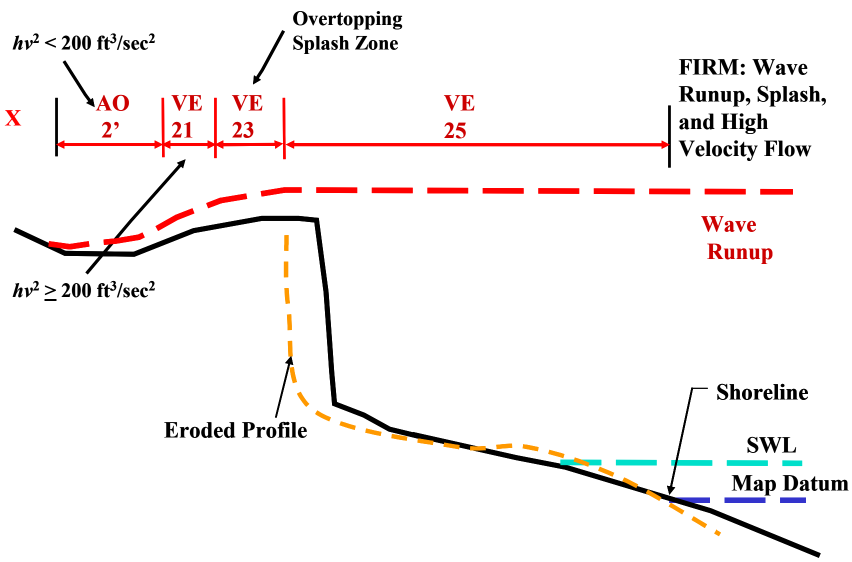

Figure 8: Erodible Low Coastal Bluff with VE Zone Controlled by Wave Runup, Overtopping Splash, and High-velocity Flow

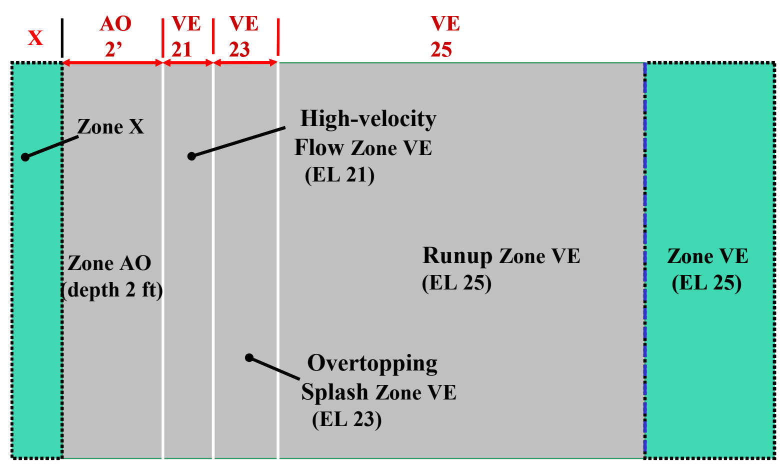

Figure 9: Erodible Low Coastal Bluff with VE Zone Controlled by Wave Runup, Overtopping Splash, and High-velocity Flow

- **Example 3.** Figures 10 and 11 illustrate flood hazard mapping for a PFD that is large enough (in cross-section) to prevent removal and high enough to prevent overtopping during 1% annual-chance flood conditions. In the example shown, the eroded profile is calculated first (see Coastal Erosion Guidance), then wave runup is mapped against the eroded profile The area seaward of the eroded dune face would, except for the PFD designation, be mapped as the AE Zone (where the runup depth < 3.0 feet) and the VE Zone (where the runup depth > 3.0 feet). The area landward of the eroded dune face would, except for the PFD designation, be mapped as X Zone. However, given the PFD designation, the area between the shoreline and the landward heel of the dune will be mapped as VE Zone; the BFE at the dune face (EL 13) will be continued landward to the PFD landward limit. Note that this is the only mapping scenario where the hazard zone (landward of the dune face) is based on coastal morphology, not on actual flood hazards during the 1% annual-chance flood. Likewise, the BFE landward of the dune face is an extension of the BFE at the dune face, not representative of the actual flood profile.

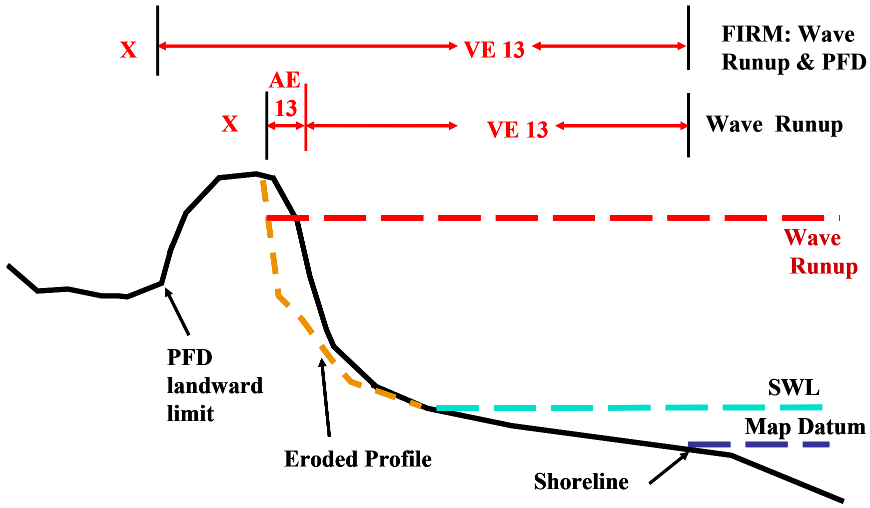

Figure 10: Sandy Beach Backed by High Sand Dune with PFD Controlling the VE Zone

If the dune in Figure 10 was not high enough to prevent overtopping and the potential runup extended more than 3.0 feet above the crest, an overtopping splash VE Zone would be indicated on the landward side of the eroded crest, and a high-velocity flow VE Zone would lie farther landward (if hv2 ≥ 200 ft3/sec2). If the high-velocity flow VE Zone terminates seaward of the PFD limit, the PFD designation would determine the VE/AE boundary. If the high-velocity flow zone extends landward of the PFD limit, the high-velocity flow VE Zone would determine the VE/AO boundary. If no high-velocity flow VE Zone exists in the example (if hv2 ≤ 200 ft3/sec2), then the VE/AO boundary would be set at the PFD limit or the overtopping splash limit, whichever is farther landward. In all cases, the BFEs landward of the eroded dune crest would be mapped at the higher of the PFD BFE, the splash zone BFE, and the high-velocity flow BFE at any given point along the transect.

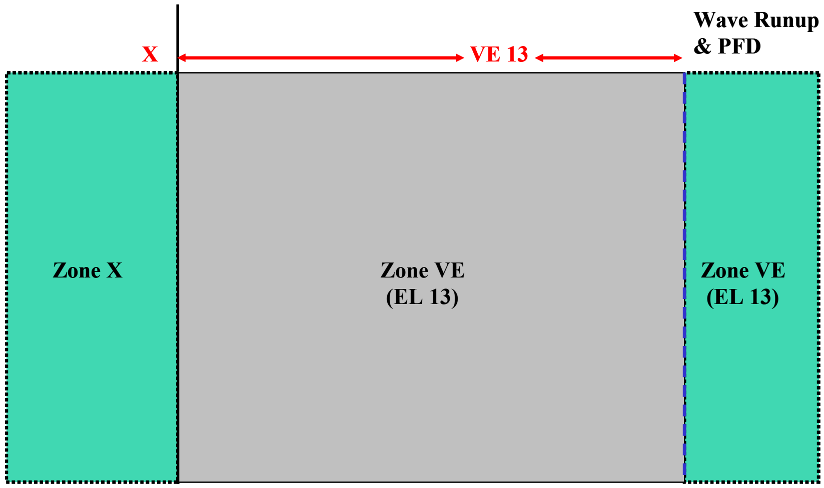

Figure 11: Sandy Beach Backed by High Sand Dune with PFD Controlling the VE Zone

- **Example 4.** Figures 12 and 13 illustrate flood hazard mapping for a low coastal dune where the dune cross-section is insufficient to prevent removal by the 1% annual-chance flood. The eroded profile is calculated and adjusted (see <u>Coastal Erosion Guidance</u>), then the resulting profile is checked for inundation, overland wave propagation, wave runup, and overtopping. In the example shown, the remnant dune crest is not inundated, so overland wave propagation is not mapped. Instead, hazard zones are mapped based on the combined effects of wave runup, overtopping splash (runup extends more than 3.0 feet above the crest in this example), high-velocity flow and PFD. The width of and BFE for the VE splash zone are calculated using the procedures described in <u>Coastal Wave Runup and Overtopping Guidance</u>. In this example, the overtopping splash zone extends farther landward than the PFD and determines the VE/AO boundary.

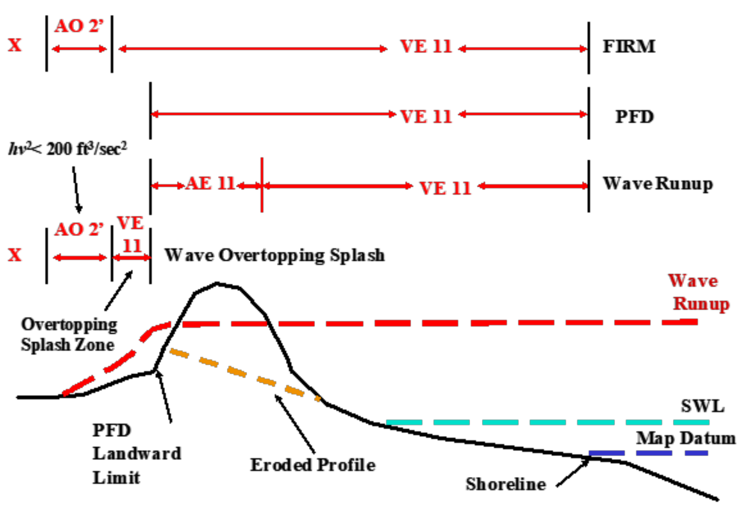

Figure 12: Sandy Beach Backed by Low Sand Dune with Overtopping Splash Controlling VE Zone

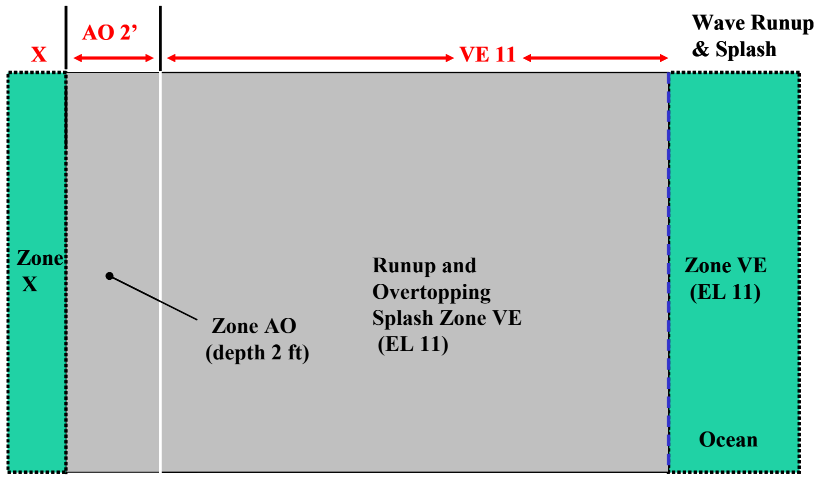

Figure 13: Sandy Beach Backed by Low Sand Dune with Overtopping Splash Controlling VE Zone

- Example 5. Figures 14 and 15 illustrate flood hazard mapping for an overtopped coastal structure that remains intact during the 1% annual-chance flood (see Coastal Structures Guidance for a discussion of structure failure and local scour considerations). In this example, the potential runup reaches an elevation greater than 3.0 feet above the crest of the structure therefore, an overtopping splash VE Zone is mapped landward of the structure; crest. (Note: If the potential runup was less than 3.0 feet above the crest, no VE overtopping splash zone would be mapped, and an AO sheet flow zone would be mapped instead.) The width of and BFE for the VE splash zone are calculated using the procedures described in Coastal Wave Runup and Overtopping Guidance. The flow velocity and water surface profile landward of the structure are used to calculate hv^2 values landward of the crest, and a high-velocity flow VE Zone is mapped where $hv^2 \geq 200$ ft^3/sec^2, while AO Zone is mapped where $hv^2 < 200$ ft^3/sec^2. Note that the same basic procedure is used for vertical and sloping structures, the principal difference being the equations used to calculate wave runup and splash distances. Thus, if this particular structure was assumed to sustain total or partial failure during the 1% annual-chance flood, a similar procedure would be applied, but with sloping structure equations rather than vertical structure equations.

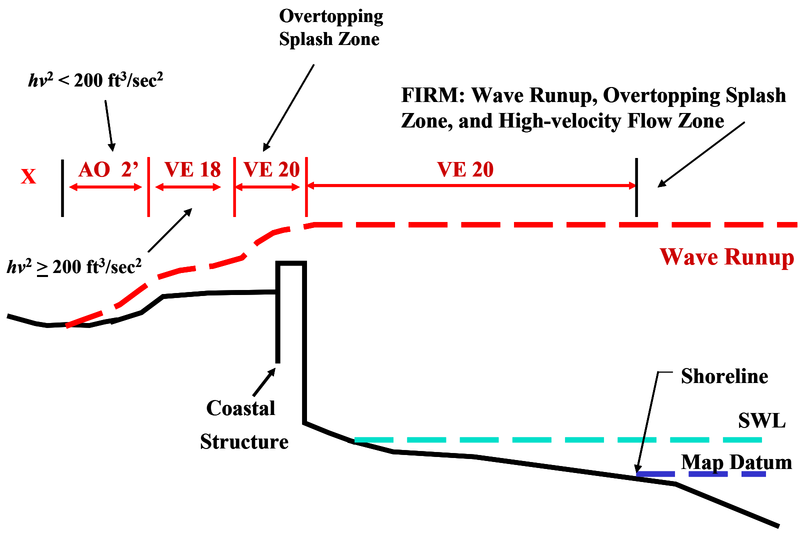

Figure 14: Sandy Beach Backed by Shore Protection Structure with VE Zone Controlled by the Splash Zone and High-velocity Flow from Wave Overtopping

With shore structures having steep slopes, runup elevations are relatively high and a wide range of wave hazards can occur, including erosion or scour near the structure. These circumstances may result in a variety of distinct and compact situations, where appreciable engineering judgment can be required for appropriate assessment of flood hazards.

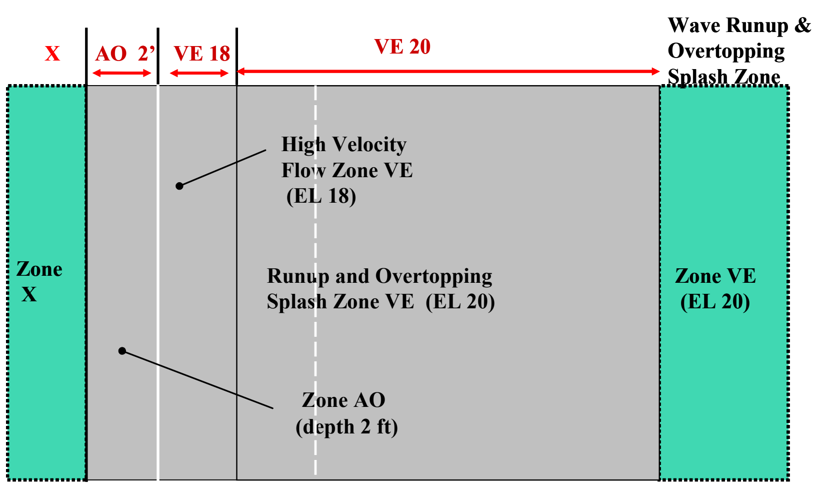

Figure 15: Sandy Beach Backed by Shore Protection Structure with VE Zone Controlled by the Splash Zone and High-velocity Flow from Wave Overtopping

- Example 6. Figures 16 and 17 illustrate flood hazard mapping for a beach profile composed of gravel, cobble, or mixed grain sizes. In this example, the profile configuration should be determined in accordance with Coastal Erosion Guidance, and the wave hazards should be modeled using the eroded profile. There will be no PFD designation for a gravel, cobble, or mixed grain size profile, so the mapped hazard zones and BFEs will reflect calculated flood hazards only.

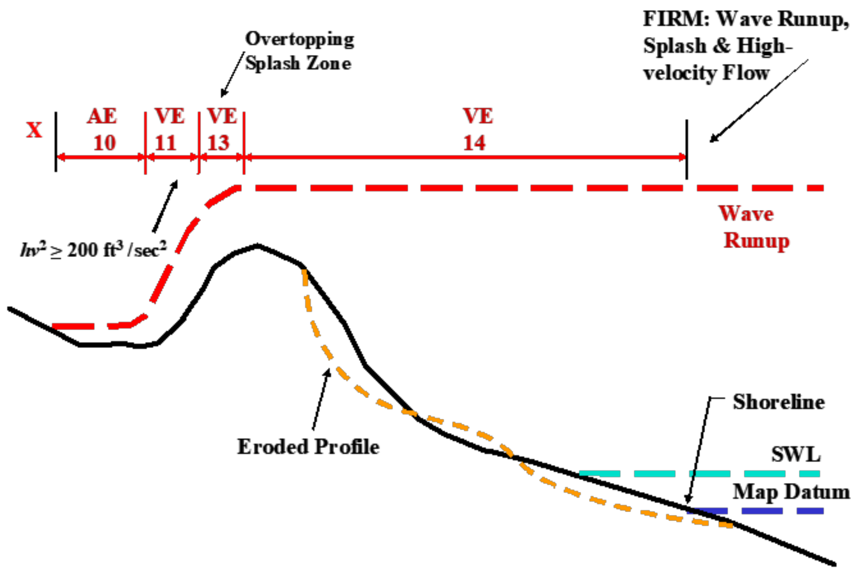

Figure 16: Cobble, Gravel, Shingle or Mixed Grain Sized Beach with VE Zone Controlled By Wave Runup, Overtopping and High Velocity Flow

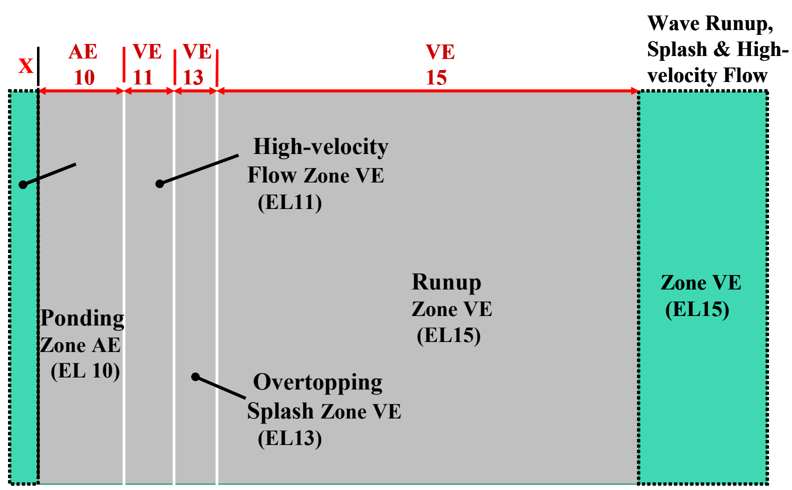

Figure 17: Cobble, Gravel, Shingle, or Mixed Grain Sized Beach with VE Zone Controlled by Wave Runup, Overtopping, and High-velocity Flow

- In this example, the potential runup is assumed to reach more than 3.0 feet above the crest, so an overtopping splash zone is mapped landward of the profile crest, with a high-velocity flow VE Zone and AE Zone to the rear. The AE Zone is mapped, instead of the AO Zones shown in Examples 2, 4, and 5, because of the overtopping ponds in the area behind the crest in this case. The mean overtopping rate calculations (see Coastal Wave Runup and Overtopping Guidance) should be used to determine the volume of water overtopping the barrier during the 1% annual-chance flood conditions, and the BFE in AE Zone shall be determined based on the overtopping volume and the local topography.

- **Example 7 (no figure).** For the case where a profile is inundated by the static water level during the 1% annual-chance flood – such as a tidal wetland, low sand beach or other flooded low-lying area – wave runup and overtopping need not be calculated and mapped. Instead, the hazard zones and BFEs shall be mapped based on the results of the WHAFIS model, (see Overland Wave Propagation Guidance), or other similar analysis, or similar analysis. The VE Zone shall be mapped where the vertical difference between the wave crest elevation and the static water level is equal to or greater than 2.1 feet; the AE Zone shall be mapped where the difference is less than 2.1 feet. BFEs shall be mapped at even-foot increments, in a stair-step fashion, following the wave crest profile.

6. Mapping Procedures

This subsection presents guidance for mapping newly studied coastal zones and remapping or redelineating coastal SFHAs. In redelineation, effective SWELs and BFEs are remapped using new or more detailed topographic data and base maps, or to implement a vertical datum conversion. Included below are guidance for reviewing the initial model results, identifying SFHAs, and depicting the results on the FIRM.

6.1. Mapping Coastal BFEs

Coastal BFEs will be shown as whole foot rounded values for new studies. There are specific exceptions that may be granted through coordination with the FEMA Project Officer and via the FEMA Guidelines and Standards Exceptions Process (e.g., Puerto Rico has BFEs mapped in meters to nearest tenth of a meter value.

6.2. Newly Studied Coastal Zones

A properly integrated delineation of the results of flooding analyses involves judgment and skill in reading topographic and land-cover maps. The time and effort put forth to determine the flood elevations and flood zone extents will be negated if the results of these analyses are not properly delineated on the FIRM. Provided below is a description of the general process by which the coastal analyses are transformed from a series of flood zones and BFEs calculated along numerous transects to a mapped product consistent with guidelines and specifications.

The preliminary FIRM is usually produced from engineering work maps based on the coastal analyses. Therefore, the Mapping Partner should transfer the flood zones and elevations identified on each transects wave profile to the work maps and interpolate boundaries between transects. To do so, the Mapping Partner should set up the work maps with contour lines, buildings, structures, vegetation, and transect lines clearly located. Because roads are often the only fixed physical features shown on the FIRM, the Mapping Partner should ensure that other features and the flood zone boundaries are properly located on the work maps in relation to the centerline of the roads as they will appear on the FIRM. The starting point (0.0 Station) for each transect should be clearly annotated on the work maps.

The Mapping Partner should transfer the identified elevation zones from the wave profile to the work maps, marking the location of the flood zone boundaries along the transect line so that boundary lines can be interpolated between transects. The Mapping Partner should ensure that boundaries are marked at the correct location. Because of erosion assumptions, the location of the 0.0-foot elevation at the shoreline can change on the transect, but the 0.0 Station, the point from which the flood zone changes from the wave profile are referenced, must remain fixed on the work map. As discussed in Section 4.0, some flood zones on the wave envelope may be too narrow to map at the current map scale. Thus, some zones must be eliminated, and elevations must be averaged. The Mapping Partner should measure the widths of the resulting flood zones carefully; zones that are too narrow to show at map scale must be tapered to an end. Likewise, if the averaged flood zone becomes much wider, it may be possible to break the averaged zone back into two (or more) separate elevation zones.

With final elevations from the wave profile plotted on the work maps and any zone averaging completed, the Mapping Partner should determine the location of each flood zone change in relation to a physical feature (e.g., ground contour, back side of a row of houses, 50 feet into a vegetated area) and delineate the boundary for the area represented by that transect along this feature. For example, if the BFE for a VE Zone decreases from 14 feet to 13 feet coincident with change from a residential area to a forest, the Mapping Partner should examine the land use data and follow the boundary of the forest to the left and right of the transect line to extend the delineation of the flood zone change.

One of the more difficult steps in delineating coastal flood zones and elevations is the transition between transects. Good judgment and an understanding of typical flooding patterns are the best tools for this job. Initially, the Mapping Partner should locate the area of transition (an area not exactly represented by either transect) on the work maps. The Mapping Partner should then delineate the floodplain boundaries for each transect up to this transition area. The Mapping Partner should examine how a transition can be made across this area to connect matching zones and still have the boundaries follow logical physical features. Other transects similar to this area could give an indication of flooding. Sometimes the elevation zones for the two contiguous transects are not the same; in such cases, the Mapping Partner may have to taper the zones to an end or enlarge the zones and subdivide them in the transition area.

With the advent of computer applications that can quickly pre- and post-process terrain, land-use, and other data to support wave analyses, coastal transects can now be generated at close alongshore spacing that approximate 2-D modeling. While the selection of the transect spacing is left to the judgment of the Mapping Partner, there is a point of diminishing returns beyond which the addition of more transects will not appreciably improve the final product. Furthermore, increasing the transect density may not fully resolve flood zone transition problems that occur coincident with physical features that end abruptly (e.g., boundaries between densely developed parcels and open space/parks; at the ends of shore protection structures). The Mapping Partner must determine the transect spacing that will be adequate to accurately model the base flood conditions and interpolate the results. The Mapping Partner should also recognize that it may not be possible to show all transects on the work maps or FIRM or include all results in the Flood Insurance Study (FIS) Report text tables or other derivative products associated with the mapping project. Care must be taken to ensure that the final work map or FIRM is consistent with the modeling completed by the Mapping Partner, and that transects shown on the final maps are, in fact, representative of these results.

In some cases, fewer transects may be adequate to characterize flood hazards in geographically separate but physically similar shoreline reaches. Areas with significant flooding hazards from wave runup may have one transect representing multiple alongshore reaches because the areas have similar shore slopes. In this case, the Mapping Partner should identify the different areas and delineate the results of the typical transect in each area.

Transition zones may be necessary between areas with high runup elevations to avoid large differences in BFEs, and to smooth the change in flood zone boundaries. These zones should be fairly short and cover the shore segment with a slope not exactly typical of either area. The Mapping Partner should determine the transition elevation using judgment in examining runup transects with similar slopes. The Mapping Partner should not use transition zones if there is a very abrupt change in topography, such as at the end of a coastal structure.

Lastly, after plotting flood zones and BFEs and interpolating results between transects, the Mapping Partner should map the X Zone areas. The Mapping Partner should show areas below the 0.2% annual-chance SWEL that are not covered by any other flood zone as X Zone (shaded) on the FIRM. Often, the maximum runup elevation associated with the base flood is higher than the 0.2% annual-chance SWEL. In such cases, the X Zone (shaded) designation will not be used in that area. All other areas are designated X Zone without shading.

Because flood elevations are rounded to the nearest whole foot, the Mapping Partner does not need to spend time resolving a minor elevation difference. Also, because coastal structures must be located on the FIRM, the Mapping Partner should attempt, whenever possible, to smooth the boundary lines and to follow a fixed feature such as a road. In preparing the FIRM, the Mapping Partner should ensure that the mapped results are technically correct and that the FIRM is easy for the community official, engineer, and surveyor to use.

6.3. Limit of Moderate Wave Action (LiMWA)

Flood hazard identification under the NFIP divides coastal flood hazard areas into two flood zones: VE Zone and AE Zone. Present NFIP regulations make no distinction between the design and construction requirements for coastal AE Zones and riverine AE Zones. However, evidence suggests that design and construction requirements in some portions of coastal AE zones should be more like VE Zone requirements. Post-storm investigations have shown that typical AE Zone construction techniques (e.g., wood frame, light gauge steel, or masonry walls on shallow footings or slabs, etc.) are subject to damage when exposed to waves less than 3-feet in height. One of the hazard identification criteria for VE Zone designation is where wave heights are estimated to be equal to or greater than 3 feet. Laboratory tests and field investigations confirm that wave heights as small as 1.5 feet can cause failure of the above-listed wall types. Other flood hazards associated with coastal waves (e.g., floating debris, high velocity flow, erosion, and scour) also damage AE Zone-type construction in these coastal areas.

The LiMWA has come to serve two purposes: 1) it indicates the location where coastal wave heights equal 1.5 feet under base flood conditions, and 2) it determines the landward limit of the CAZ as referenced in building codes and standards. Some building codes require VE Zone design and construction standards to be met in the CAZ, thus, communities use the LiMWA to determine where these building requirements apply. Despite the fact that FEMA states the LiMWA is an informational layer, building codes rely on the LiMWA for regulatory purposes.

For all new detailed coastal studies within the Atlantic Ocean, Gulf of Mexico, Great Lakes, and Pacific Ocean regions, the guidance set forth here should be utilized when mapping the LiMWA. The LiMWA should be delineated only in conjunction with a wave height VE Zone. If the wave height at a shoreline is less than 3 feet, no LiMWA should be drawn inland of that shoreline. For example, for transects that originate on the open coast and pass over land, across a water body, and then onto another land mass, multiple LiMWAs may be delineated, but only where there is a wave height VE Zone associated with a shoreline. In special situations it may be appropriate to map a LiMWA in an area where there is no VE Zone associated with the shoreline, these situations should be discussed with FEMA to establish best practice.

Only one LiMWA should be associated with each flood source and associated wave height VE Zone. In other words, if inland wave heights fluctuate above and below 1.5 feet (due to regeneration and dissipation), only one LiMWA should be drawn -- closest to the VE Zone. Special cases involving overland wave regeneration on long transects (without a secondary shoreline) should be discussed with FEMA to establish best practice for those situations.

The LiMWA should be mapped at the same time as the WHAFIS results, and where mapped, the LiMWA should be interpolated between transects and drawn in a manner consistent with the methods used to map overland wave height flood zone boundaries and gutters. Where possible, LiMWAs should not cross flood zone boundaries and gutters.

The LiMWA should not be shown on the FIRM in areas where the inland VE limit is delineated based on the PFD or wave runup and/or wave overtopping. This may result in LiMWA segments, and a discontinuous LiMWA, on the FIRM. The LiMWA should not be shifted so as to be immediately landward of the mapped VE/AE Zone boundary. Even though it may be advantageous to continue the LiMWA across runup-dominated areas, the LiMWA should not be delineated immediately landward of the VE/AE Zone boundary in PFD and wave overtopping VE Zones.

The LiMWA should not be depicted within the following zones:

- VE Zone
- Zone X (shaded or unshaded)

- AE Zone in which wave action does not exist such as an AE Zone with a BFE corresponding to the stillwater elevation

The use of Flood Risk Products to assist communities with understanding wave hazards and enforcing CAZ building standards, especially when there is a desire to provide this information in the form of polygons, is highly recommended.

6.4. Redelineation of Coastal Zones

During the project scoping phase, coastal reaches may be identified where new surge modeling and detailed wave analyses are not required. In these cases, the Mapping Partner will be responsible for remapping or redelineating the effective coastal flood hazard data onto the new FIRM. When determining how a coastal area should be redelineated, the Mapping Partner should consider the availability of new or more detailed topographic data, the base map being used for the revised FIRM (including any new shoreline position), and whether a vertical datum conversion is necessary.

Although these guidelines provide information on the most common redelineation aspects and a general approach for identifying issues, each effective coastal flood hazard dataset can pose unique problems that could, in some instances, require new modeling to resolve. For this reason, it is critical that the Mapping Partner fully investigate redelineation issues and identify the most appropriate methodology early in the scoping process, coordinating closely with the FEMA Project Officer to resolve any issues that are discovered.

Several typical redelineation scenarios, and the methods available to map the effective flood data, are presented below. Of the known redelineation concerns, shoreline retreat and datum conversions have the most significant impacts on remapping flood zone boundaries. For organizational purposes, the guidance has been subdivided based on the degree of shoreline retreat at the study site. The discussion is further subsequently subdivided to present the effects of new topographic data and/or datum conversions on the redelineation process. The Mapping Partner should review all scenarios for relevant guidance. These scenarios should not be considered all-inclusive; the guidelines will be revised and supplemented in the future, as warranted.

6.4.1. SCENARIO 1: MINIMAL TO NO SHORELINE RETREAT

In this setting, the new base map being used for the FIRM shows that the shoreline (typically the High Water Line for vector-based maps, or the wet-dry line at the time of the collection for aerial photographic base maps) has undergone minimal net landward retreat in the time elapsed because the effective FIRM was published. That is, the new shoreline still lies within the same outermost VE Zone shown on the effective FIRM (see Figure 18). (Seaward progradation of the shoreline would also fit this scenario.)

If no new topographic data are being utilized and no datum conversion from NGVD29 to NAVD88 is required, the redelineation will consist of duplicating the effective flood zone boundary locations, including the VE/AE boundary associated with the PFD (where applicable) and the 1% and 0.2% annual-chance floodplain boundaries, exactly as they are shown on the effective FIRM.

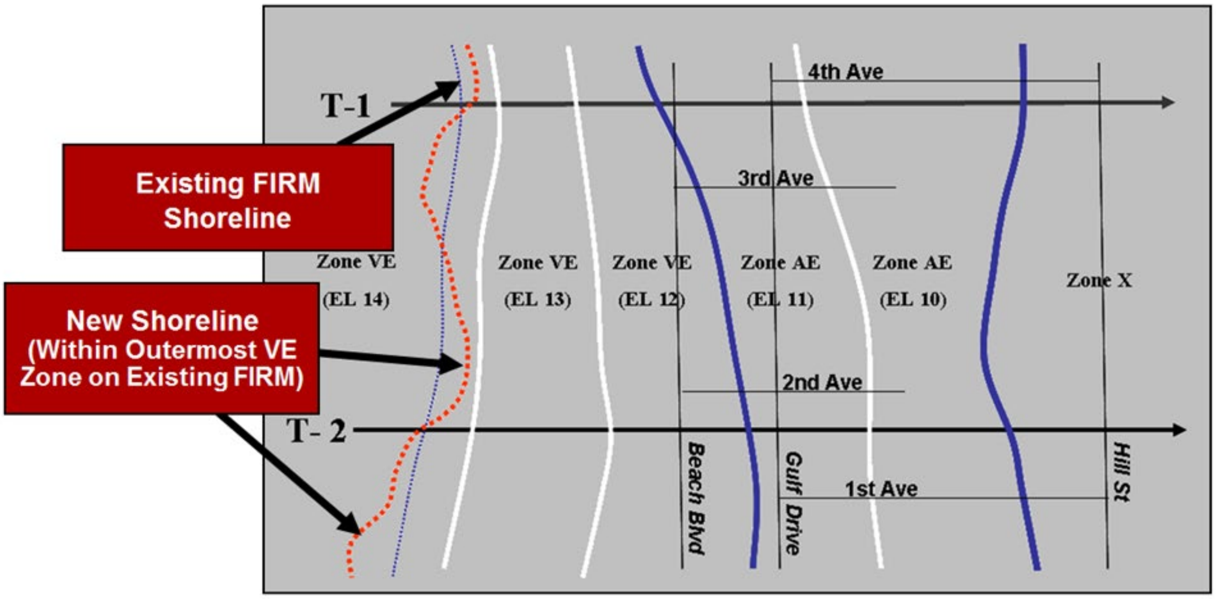

Figure 18: Work map depicting the flood zones, BFEs, and shoreline from the effective FIRM and the new shoreline position (modified from DiCamillo et al., 2005). T-1 and T-2 represent transect locations. Because the shoreline retreat is restricted to the outermost VE Zone (EL 14), it has no impact on remapping of flood zones.

If new topographic data are being used as the basis of the FIRM update, multiple flood zone boundaries can be redefined based on the new data, specifically the 1% and 0.2% annual-chance floodplain limits and any PFD-based VE/AE boundary. Prior to redelineating the limit of the 1% and 0.2% annual-chance floodplains, the Mapping Partner shall use the guidance below to review the effective FIS Report and FIRM and to determine the controlling factor for the limit of flooding in an area and determine the appropriate elevation(s) for redelineation.

Identify the final SFHA and BFE before the limit of the 1% annual-chance floodplain. Because coastal SFHAs and BFEs are frequently averaged when the zones are too narrow to be mapped, and coastal BFEs may include a wave height component, the Mapping Partner should not assume that the final whole-foot BFE immediately seaward of the limit of the 1% annual-chance floodplain is the appropriate elevation to use to redelineate the floodplain boundary. Where applicable, the Mapping Partner shall evaluate the effective modeling for areas where Zone AO is the final SFHA to determine the appropriate elevation for redelineation of the 1% annual-chance floodplain boundary. Also, in areas where Zone X is mapped immediately adjacent to the open coast, the Mapping Partner should consult the new topographic data and delineate the PFD landward heel.

The Mapping Partner shall locate the effective transect nearest to the area being redelineated and determine the 1% and 0.2% annual-chance SWELs from the “Transect Data Table” or “Transect Description Table” in the FIS Report. If the area being redelineated is along a tidally influenced stream, river, or other sheltered waters where there are no transects, the Mapping Partner shall obtain the 1% and 0.2- % annual-chance SWELs from the "Summary of Stillwater Elevations" table and/or Flood Profiles in the FIS Report. The Mapping Partner shall determine whether wave setup is included in the 1% annual-chance SWELs reported in the FIS Report and ensure that the elevation used for redelineation of the 1% annual-chance floodplain does not include wave setup.

When wave runup is the controlling factor for the limit of the 1% annual-chance floodplain, the elevation being used to map the limit will be higher than the SWEL presented in the FIS Report. The Mapping Partner shall consult the FIS Report, FIRM, aerial photography, and/or topographic data to determine areas where wave runup is the dominant hazard. In these areas, the 2% runup total water elevation should be used to redelineate the limit of the 1% annual-chance floodplain.

When redelineating the 1% and 0.2% annual-chance floodplains between transects, there will be areas where the Mapping Partner must transition from one elevation to another, such as when there are flooding sources with varying SWELs or areas with varying runup elevations. For this reason, the Mapping Partner shall determine the appropriate elevation for mapping of the 1% and 0.2% annual-chance floodplains at each transect prior to redelineation. In areas of transition between transects, the general shape of the effective boundaries should be maintained but offset to follow the new topographic data (see Figure 19).

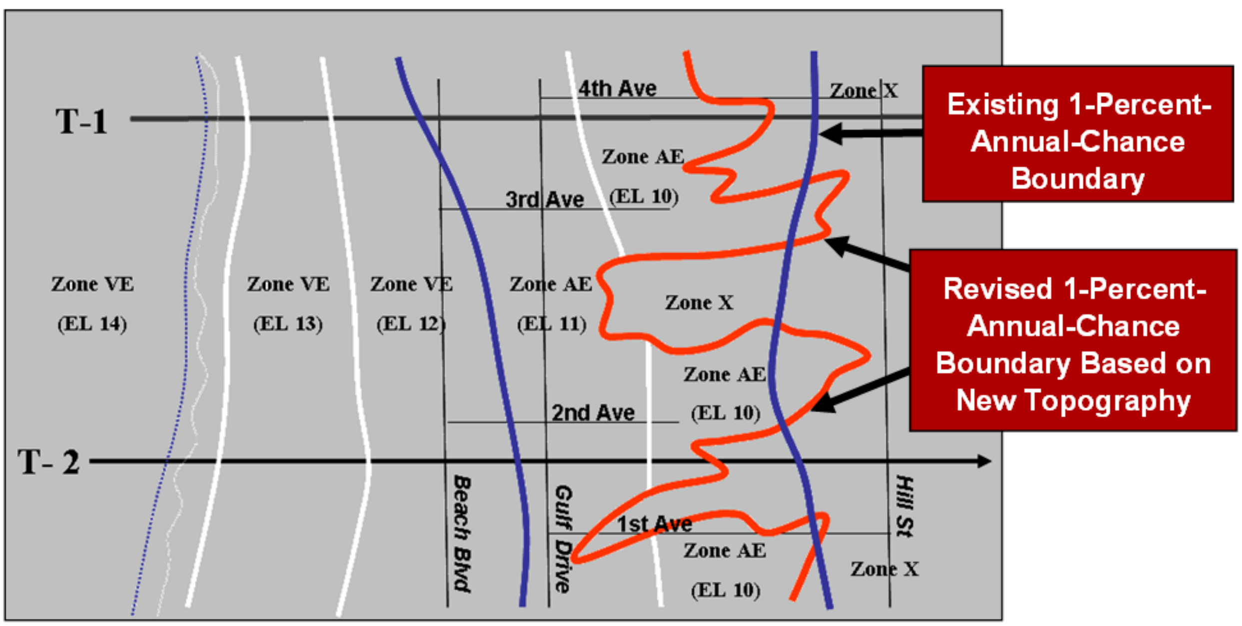

Figure 19: Work map depicting the existing 1% annual-chance floodplain boundary from the effective FIRM, and the new boundary redelineated based on the effective SWEL and new topographic data (modified from DiCamillo et al., 2005).

As shown in Figure 6-2, the redelineated limit of the 1% annual-chance floodplain may impinge upon or cross flood zone boundaries located farther seaward. Similarly, a redelineated PFD limit may intersect flood zone boundaries located landward of the effective FIRM's PFD limit. The Mapping Partner shall not revise the location of gutter lines affected by the new 1% annual-chance and PFD limits without first performing updated modeling; instead, these gutter lines should be clipped at the revised limit of flooding or PFD, as shown in Figure 19.

If no datum conversion is being performed, the Mapping Partner shall ensure that all gutter lines separating SFHAs of differing BFEs (except for the PFD-based VE/AE boundary, if redelineated) will remain in the same location and orientation as on the effective FIRM. This is true even when new topographic data are utilized in the study. While topography is a key factor in establishing the wave profile from which the coastal gutter locations are derived, it is not the only factor (see Figure 6-3).

If the study includes a datum conversion, the complexity and level of effort required by the Mapping Partner to complete the redelineation may increase significantly. That is because datum conversions may require coastal gutters separating BFEs to be moved. Recall that each BFE is a whole-foot elevation that represents flood elevations from 0.5 feet below to 0.4 feet above the BFE. With the exception of the PFD-based VE/AE boundary, the coastal gutters are located at the half-foot elevations along the wave profile. When the vertical datum conversion is applied, the horizontal location (or station) of each half-foot elevation shifts either landward or seaward on each transects wave profile (see lower panel B) on Figure 20.

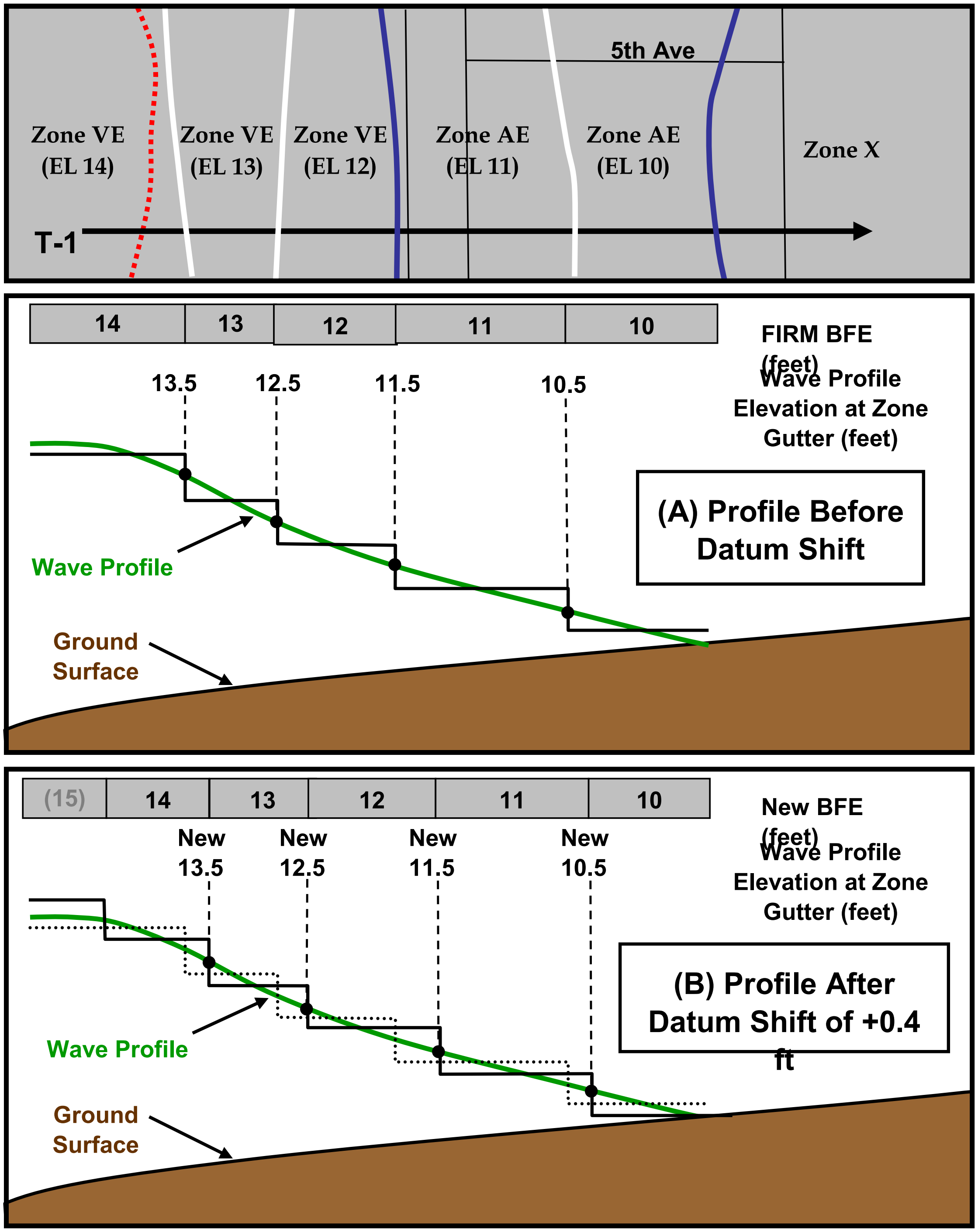

Figure 20: Comparison of gutter locations prior to a datum conversion (A) and after (B). Although Zone VE (EL 15) can be identified on the new wave profile, it lies seaward of the mapped shoreline position and thus may not need to be included on the FIRM.

Typically, a datum conversion of more than 0.1 foot can have a significant impact on gutter locations, depending on the topography. If the land is relatively steep, the impact could be minimal. If the land has a gentle slope, the impact can be much greater because the distance between half-foot elevations along the wave elevation profile can be large. If a datum conversion is around 1.0 foot, then the gutters can remain in the same location with just a change in the BFEs by 1 foot. The Mapping Partner shall determine the conversion factor, review the topography, and propose a method for redelineating coastal flood hazards in the different datum to the FEMA Project Officer. Once the Mapping Partner has determined the location of the gutters along each transect, the SFHAs and BFEs shall then be mapped as discussed in previous sections.

Redelineation of coastal gutter locations can be accomplished efficiently if the effective wave transect modeling results are available. In cases where the modeling results are not available, the Mapping Partner shall propose an approach for the datum conversion and present it to the FEMA Project Officer for approval. One option may be to construct a simplified wave profile based on the effective gutter locations, interpolating the wave height between the half-foot elevations. (see Figure 20). Application of this approach must be limited to transects where wave heights were the dominant hazard in the effective study and no PFD was mapped.

6.4.2. SCENARIO 2: MODERATE SHORELINE RETREAT

In this setting, the new base map being used for the FIRM shows that the shoreline has retreated far enough landward that one or more effective VE Zones are now located in open water. If a VE Zone gutter falls seaward of the open-coast shoreline on the new base map, the Mapping Partner shall adjust the gutter to be coincident with or just landward of the shoreline. If multiple VE Zone gutters fall seaward of the open-coast shoreline on the new base map, the intermediate zones can be completely removed. The VE Zone with the highest BFE shall be adjusted so that the gutter is coincident with or just landward of the shoreline. The Mapping Partner shall use caution to not increase the SFHA designation or BFE for any properties without modeling to justify such an increase. Incorporation of new or improved topographic data and/or a datum conversion by the Mapping Partner shall follow the guidelines provided earlier in this section.

6.4.3. SCENARIO 3: SIGNIFICANT SHORELINE RETREAT

This setting would apply in areas where the new base map indicates that the shoreline has retreated landward past the effective FIRMs VE/AE boundary (see Figure 21). Such a scenario is possible (1) on coasts subject to chronic, long-term erosion; (2) where a severe storm (or series of storms) has eroded the shoreline and beach recovery has not yet occurred; (3) adjacent to dynamic tidal inlets; or (4) downdrift of shore protection structures that impede longshore transport of sediment.

While it is not advisable to redelineate coastal flood hazards in areas where significant changes to the open-coast shoreline have occurred since the effective coastal modeling was completed, the Mapping Partner shall utilize the following guidance to ensure that the effective flood hazards are transferred to the new base map in a logical, consistent manner:

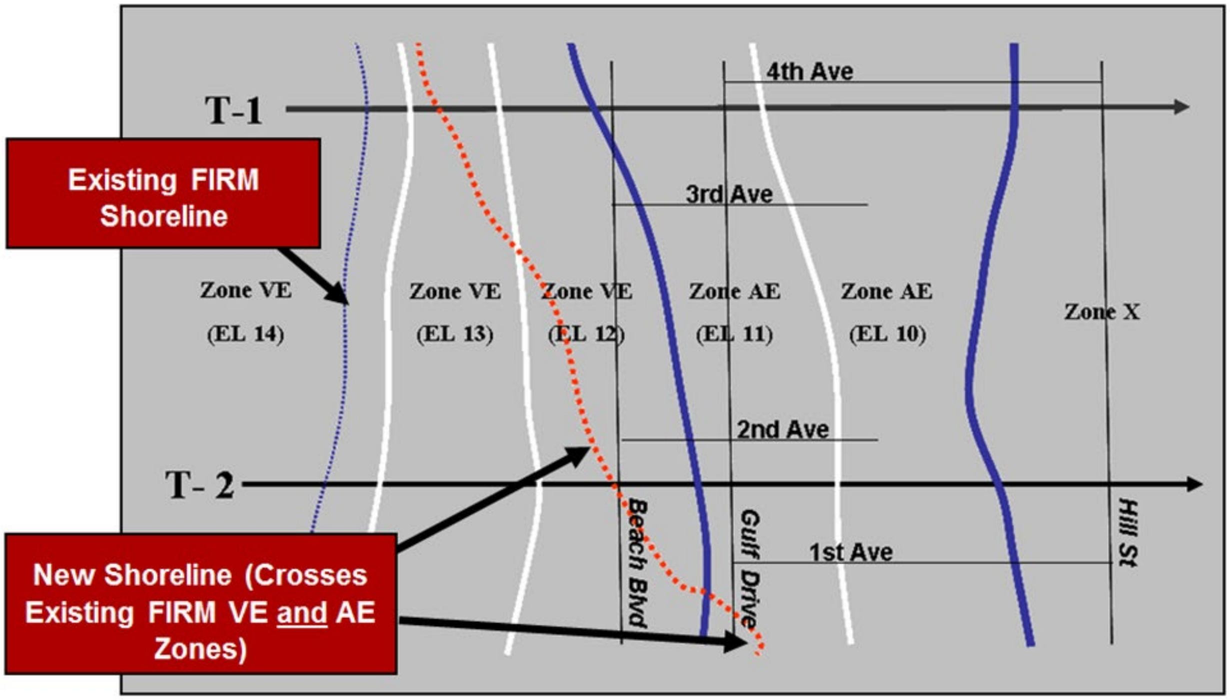

Figure 21: Work map depicting existing shoreline position from the effective FIRM and the new shoreline location (modified from DiCamillo et al., 2005). Because the shoreline retreat extends landward of the effective VE/AE boundary, reanalysis of flood hazards may be warranted (in lieu of redelineation).

If the gutter separating the VE Zone and AE Zone flood hazard areas along the open coast falls seaward of the shoreline on the new base map, the Mapping Partner shall adjust the VE/AE gutter to be just landward of the shoreline and adjust the seaward VE Zone gutter with the highest BFE to be coincident with the shoreline and remove any intermediate gutters, taking care not to increase the SFHA designation or BFE for any properties without modeling to justify such an increase. If this situation occurs with any frequency, the Mapping Partner should consider utilizing the effective shoreline rather than the shoreline from the new base map for the revised FIRM and discuss this with the FEMA Project Officer.

In areas other than the open coast where shoreline changes result in gutters located in open water, the Mapping Partner shall use best judgment in evaluating the nature of the BFE change (wave regeneration over open fetches, wave damping due to vegetation, buildings, etc.) and shift the gutters as necessary to provide a logical identification of flood hazards on the new base map. Again, the Mapping Partner should use caution to not increase the SFHA designation or BFE for any properties without modeling to justify such an increase.