7.0 MAPPING OF FLOOD ELEVATIONS AND ZONES

7.1 Review and Evaluation of Basic Results

Prior to mapping the flood elevations and zones, the results from the models and assessments should be reviewed from a common-sense viewpoint and compared to available historical data. When utilizing these models there is the potential to forget that the transects represent real shorelines of sandy beaches, rocky or cohesive bluffs, wetlands, etc., being subjected to extremely high water, waves, and winds. Familiarity and experience with the coastal area being modeled or similar areas should provide an idea of what is a "reasonable" result.

Use of the historical data is also very important in evaluating whether the results are reasonable. It would be very convenient if data from a storm closely approximating the 100-year event were available, but this is seldom the case. Although most historical flood data are for storms less intense than a 100-year event, these data will still indicate, at a minimum, what areas should be in flood zones. For instance, if a storm that produced an extreme flood below the 100-year stillwater elevation generally caused structural damage to houses 100 feet from the shoreline, a "reasonable" Zone VE width must be at least 100 feet. Similarly, houses that collected flood insurance claims for the same storm should be at least in a Zone AE, AH, or AO. If the analyses of the 100-year flood produce flood zones and elevations indicating lesser hazards than those recorded for a more common storm, the analyses should be reevaluated. One possible explanation can be that a new coastal structure acts to reduce flood hazards locally.

If there are indications that a reevaluation is needed, it should be determined whether the results of the erosion assessment are appropriate. An attempt should be made to compare the eroded profile to past effects, whether in the form of profiles, photographs, or simply descriptions. A general idea of what happened previously can be sufficient. Judgment and experience must be used to project previous storm effects to the 100-year conditions, and to ensure that the eroded profile is consistent with previous events.

The other data input to the assessments of wave effects should also be examined. This includes checking that the stillwater elevations, wave heights, wave periods, and fetch lengths were used correctly and are consistent with the historical data. Further consideration might be given to examining if the buildings or structures modeled would be destroyed by the storm or if the buildings are on pilings above the flooding.

The main point to be emphasized here 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 must be in basic agreement with past flooding patterns, and historical data must be used to evaluate these results.

7.2 Identification of Flood Hazard Zones

The flood zones and base flood elevations (BFEs) including wave heights should be identified on each transect plot before delineating zones on the work maps, because of additional wave effects along with the 1988 redefinition of Coastal High Hazard Area to include the primary frontal dune. The existing topography, the eroded transect, the combination of shore effects in the wave envelope, and other results from wave overtopping assessment are all important to the proper identification of flood hazard zones.

Specifically, the existing ground profile defines an appropriate extent of the primary frontal dune, as a ridge of sand bounded by relatively steep slopes (Section 1.2). The eroded transect for cases of duneface retreat may imply flood hazards due to wave overtopping into an area landward of WHAFIS results (Section 4.5). In addition, wave overtopping of stable shore barriers can result in flooding to areas above the mean elevation of wave runup (Section 5.7). However, the main consideration for integrated treatment of wave-controlled flood elevations is to define the wave envelope joining height and runup effects.

This 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 25. If the runup elevation is greater than the maximum wave crest elevation, the wave envelope will be a horizontal line at the runup elevation. Conversely, if the wave runup is negligible or was not modeled, the wave crest profile becomes the wave envelope.

Flood hazard zones are defined basically by the wave envelope along with the general zone descriptions in Table 13. Those results are supplemented by runup and overtopping considerations, as introduced previously. The following material outlines the process of zone identification, with specific examples presented in the next section to illustrate some usual results.

The first step in identifying the flood zones on the transect is locating the inland extent of the VE zone, also known as the VE/AE boundary. 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 26. That boundary may need to be moved further inland in the vicinity of a wave barrier where severe overtopping is indicated for the base flood, so high velocity impacts occur over a limited landward area.

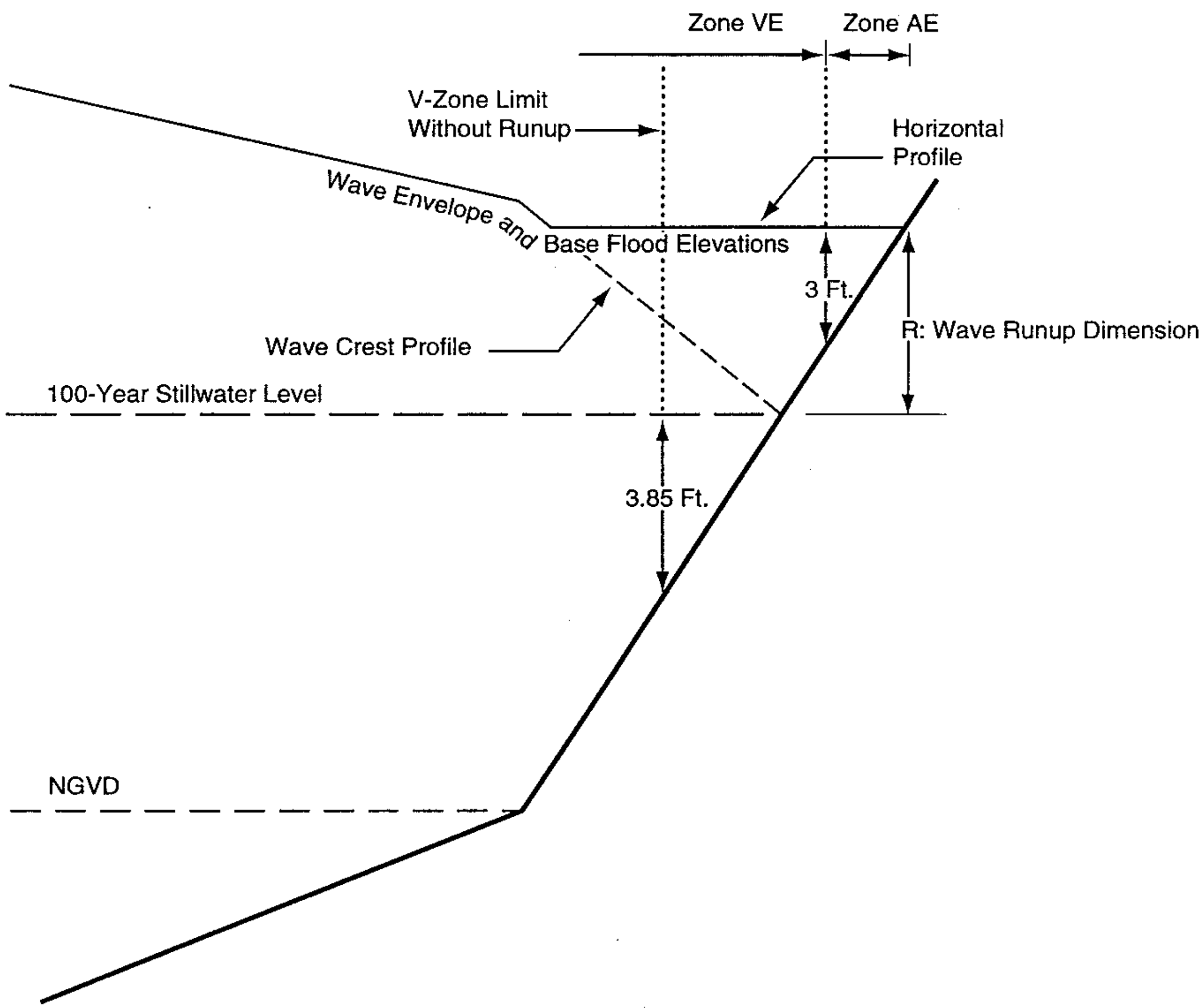

Figure 25. Wave Envelope Resulting from Combination of Nearshore Crest Elevations and Shore Runup Elevation.

Table 13. Description of Coastal Flood Zones.

Zone VE	Coastal High Hazard Areas where wave action and/or high velocity water can cause structural damage in the 100-year flood. Primarily identified by: (1) the area where 3 foot or greater wave height could occur (this is the area where the WHAFIS wave crest profile is 2.1 feet or more above the stillwater elevation), (2) the area where the eroded ground profile is 3 feet or more below the representative runup elevation, and (3) the entire primary frontal dune, by definition. Subdivided into elevation zones with BFEs assigned.
Zone AE	Areas of inundation by the 100-year flood, including wave heights less than 3 feet and runup elevations less than 3 feet above the ground. Also subdivided into elevation zones with BFEs assigned.
Zone AH	Areas of shallow flooding or ponding, with water depth equal to 3 feet or less. Usually not subdivided, but a BFE is assigned.
Zone AO	Areas of "sheet-flow" shallow flooding where overtopping water flows into another flooding source. Assigned with 1-, 2-, or 3-foot depth of flooding.
Zone X	Areas above 100-year flood inundation. On the FIRM, shaded Zone X is inundated by the 500-year flood, unshaded Zone X is above 500-year flood.

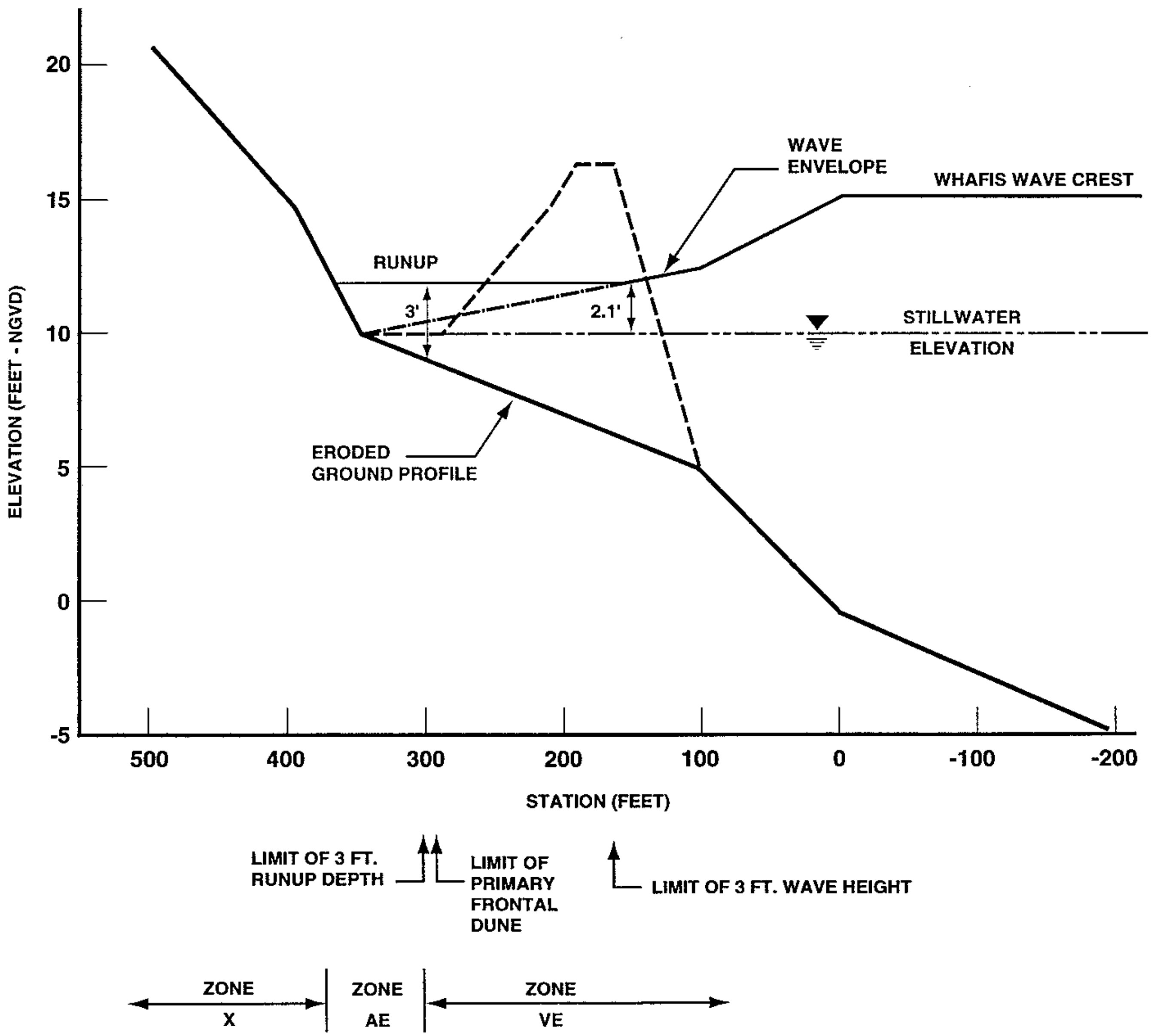

Figure 26. Possible V-Zone Limits at Eroded Dune.

The AE zone will extend from the VE/AE boundary to the inland limit of 100-year inundation, which is a ground elevation equal to the representative runup elevation, or the 100-year stillwater elevation if runup is negligible. Additional areas of shallow flooding or ponding for the 100-year event may be designated as Zone AH or Zone AO. In cases of severe wave overtopping impacts, a Zone VE may abut areas designated as Zone AH or Zone AO. All areas above the 100-year inundation are Zone X.

The AE and VE zones are then subdivided into elevation zones with whole-foot BFEs assigned according to the wave envelope. Ideally, there would be an elevation zone for every BFE in the wave envelope, but because these zones are mapped on the FIRM so that buildings or property can be located in a flood zone, a minimum width must be used for the mapped zone to provide a usable FIRM. For coastal areas, the minimum zone width is 0.2 inch on the FIRM. For identifying elevation zones on the transect, the minimum width is 0.2 times the final FIRM scale; for example, a width of 80 feet for a FIRM at 1 inch equals 400 feet, or a width of 100 feet for a FIRM at 1 inch equals 500 feet.

The horizontal runup portion of the wave envelope, if any, does not need to be subdivided; the runup elevation, rounded to the nearest whole foot, is the BFE. It is the WHAFIS wave crest profile that requires subdivision. Generally, the VE zone is subdivided first. Initially mark on the transect the location of all the elevation zone boundaries. Since whole-foot BFEs are being used, these should always be at the location of the half-foot elevation on the wave envelope.

The elevation zones that do not meet the minimum width should be combined with an adjacent zone or zones to yield an elevation zone wider than the minimum. The BFE for this combined zone is a weighted average of the combined zones. Often in subdividing VE zones, the maximum BFE zone is located just inside the mapped shoreline, and the remainder of the VE zone is then subdivided into elevation zones of the minimum width.

The AE zone, if wide enough, is subdivided in the same manner. If the total AE zone is less than the minimum width, the lowest elevation VE zone 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 to extend the AE zone slightly into the next zone seaward in order to satisfy the minimum width requirement.

Relatively low areas inland of zones assigned wave elevations may be subject to shallow flooding or ponding of flood water and designated as AH or AO Zone. Such designations can be relatively common landward of coastal structures and dunes, where wave overtopping occurs. 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 duneface with only overtopping possibly propagating inland, the entire dune is still designated as a VE zone. The BFE at the duneface is assigned 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, it requires structures to be built on pilings and prohibits alterations to the dune.

7.3 Transect Examples

Figure 26 provided a schematic summary for the three criteria potentially defining the landward limit to the Coastal High Hazard Area. The following examples depict idealized transects of typical types in order to illustrate common flood hazard zonations in a quantitative way. Coastal erosion is a dominant consideration for the first set of cases, and the second set addresses some usual effects at stable shore barriers exposed to extreme wave action.

Figure 27 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. The Zone VE, elevation 12 feet, is enlarged slightly to include some of the elevation 13-foot area so that the boundary would be located at the dune toe or 5-foot contour line, a feature easily identified on the work maps. The boundary between the Zones VE, elevation 14 feet and elevation 16 feet, is located just landward of the shoreline. The Zone AE, elevation 12 feet, in Figure 27 is only 70 feet wide, slightly less than the minimum mapping width. In this case, the work maps should be examined to determine if this zone might be wider or narrower in the contiguous area. If wider, the Zone AE should be used; if narrower, the designation extended through this area should be Zone VE, elevation 12 feet.

Figure 28 is an example of a relatively high retreated duneface. A mean runup elevation of 13 feet is calculated for the eroded duneface. This elevation is assigned through the dune, all of which is designated as a VE zone. Because the dune remnant extends more than 7 feet above stillwater elevation, no flooding landward of the dune is indicated by designating a Zone X. Note that the retreated dune profile shifts the 0.0 foot elevation shoreline 65 feet seaward. Because the work maps use the existing 0.0 foot elevation shoreline, the Zone VE, elevation 16 feet, is located just landward of the existing shoreline.

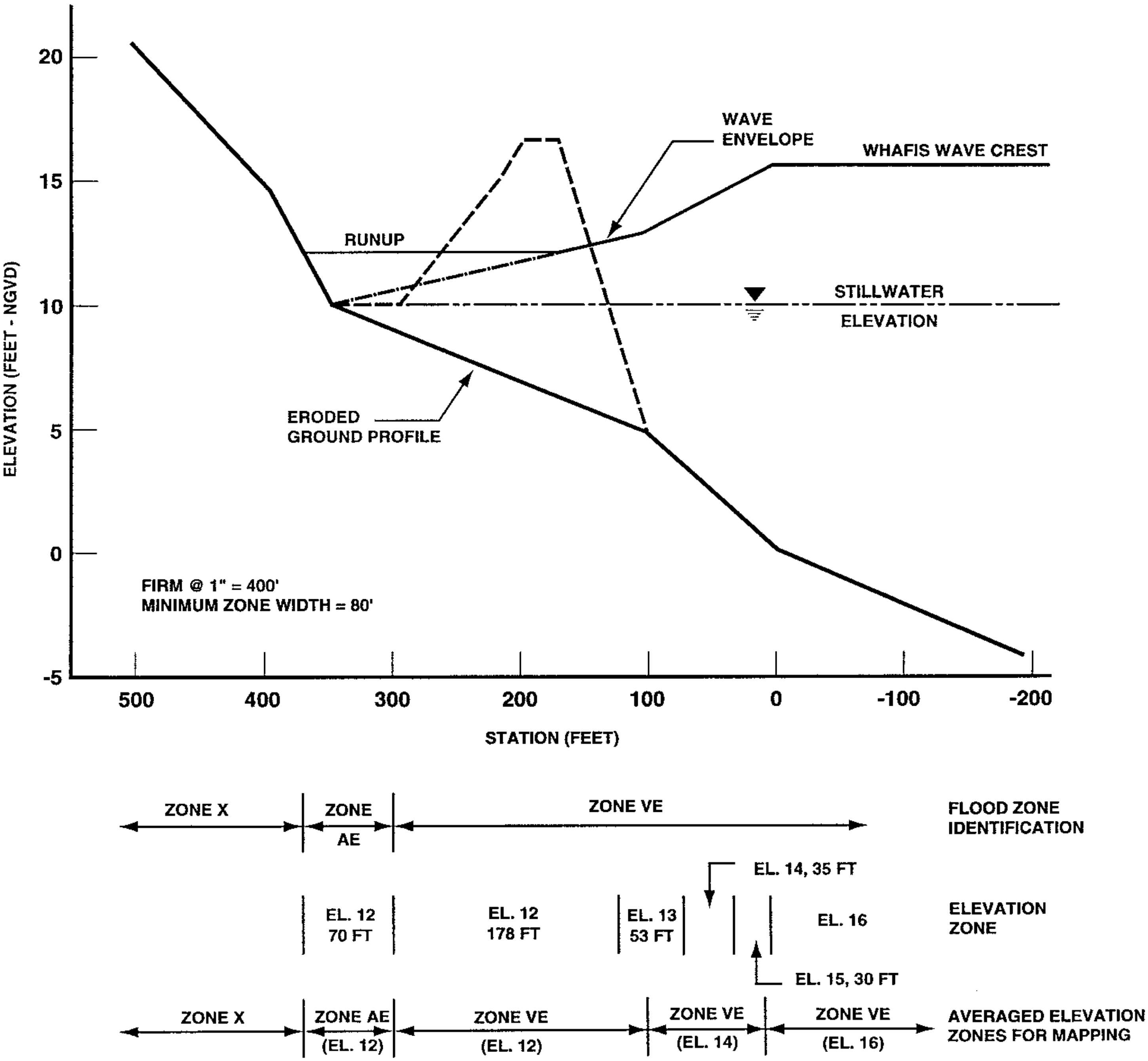

Figure 27. Identification of Flood Zones, Example 1: Dune Removal with Wave Runup Landward.

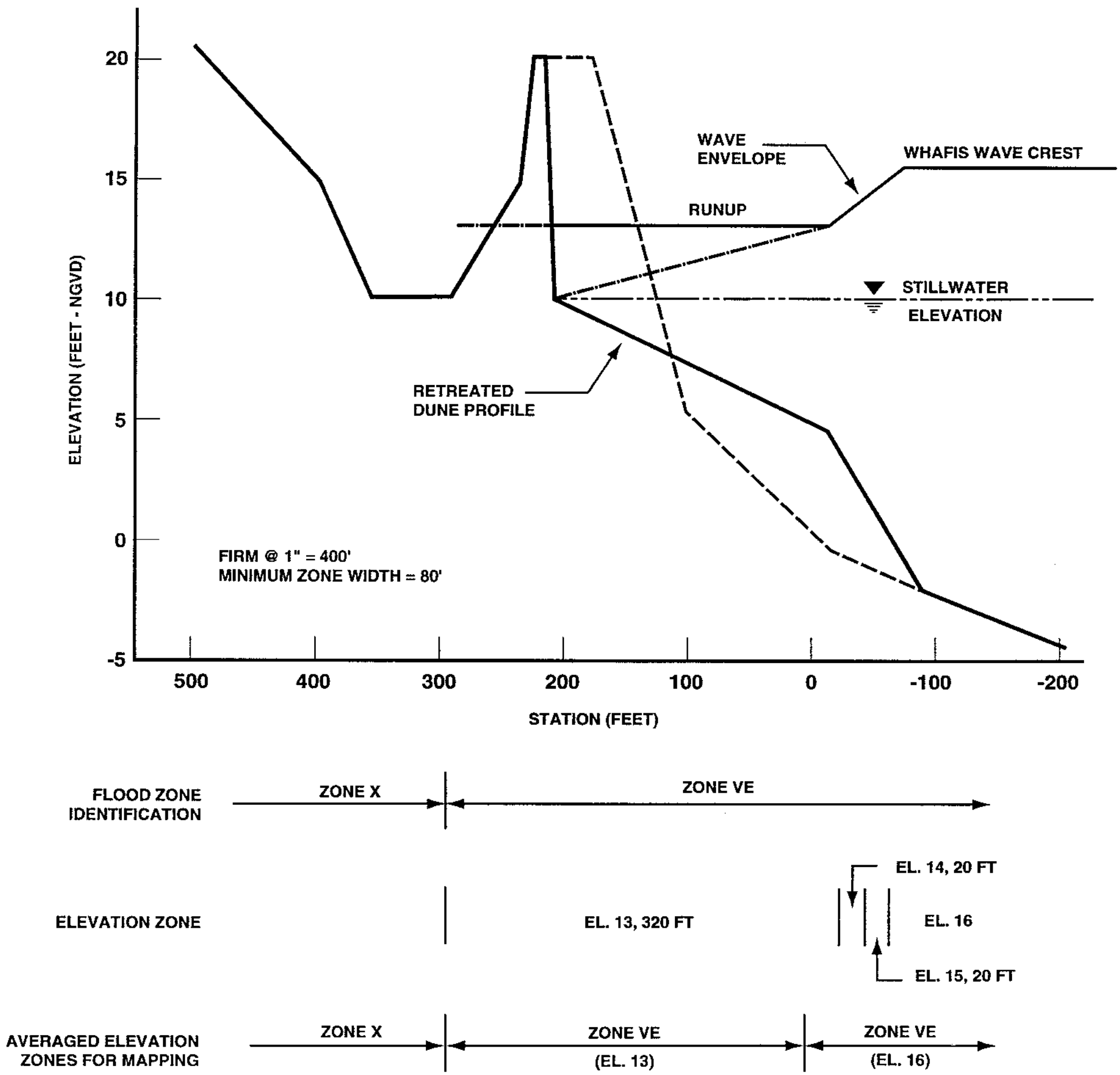

Figure 28. Identification of Flood Zones, Example 2: Duneface Retreat with Relatively High Remnant.

Figure 29 provides an example of a retreated duneface 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 a VE zone. The division into separate map zones is similar to Figure 28. Because the dune remnant extends less than 7 feet above stillwater elevation, appreciable wave overtopping is expected during the base flood. An area landward of the dune of about the minimum mapping width is designated as a Zone AO, depth 1 foot.

Figure 30 is an example of dune removal where there is some runup and overtopping of the remaining stub. As in Figure 27, the VE zone with the 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. Although elevation 14 feet is shown on Figure 30 for the intermediate VE zone, elevation 13 feet could also be used; adjacent transects should be examined and a compatible BFE selected. Also note that the boundary between the Zone AO, depth 1 foot, and the Zone AE, elevation 7 feet, is at the intersection of the stillwater elevation and ground profile.

An eroded bluff is shown in Figure 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

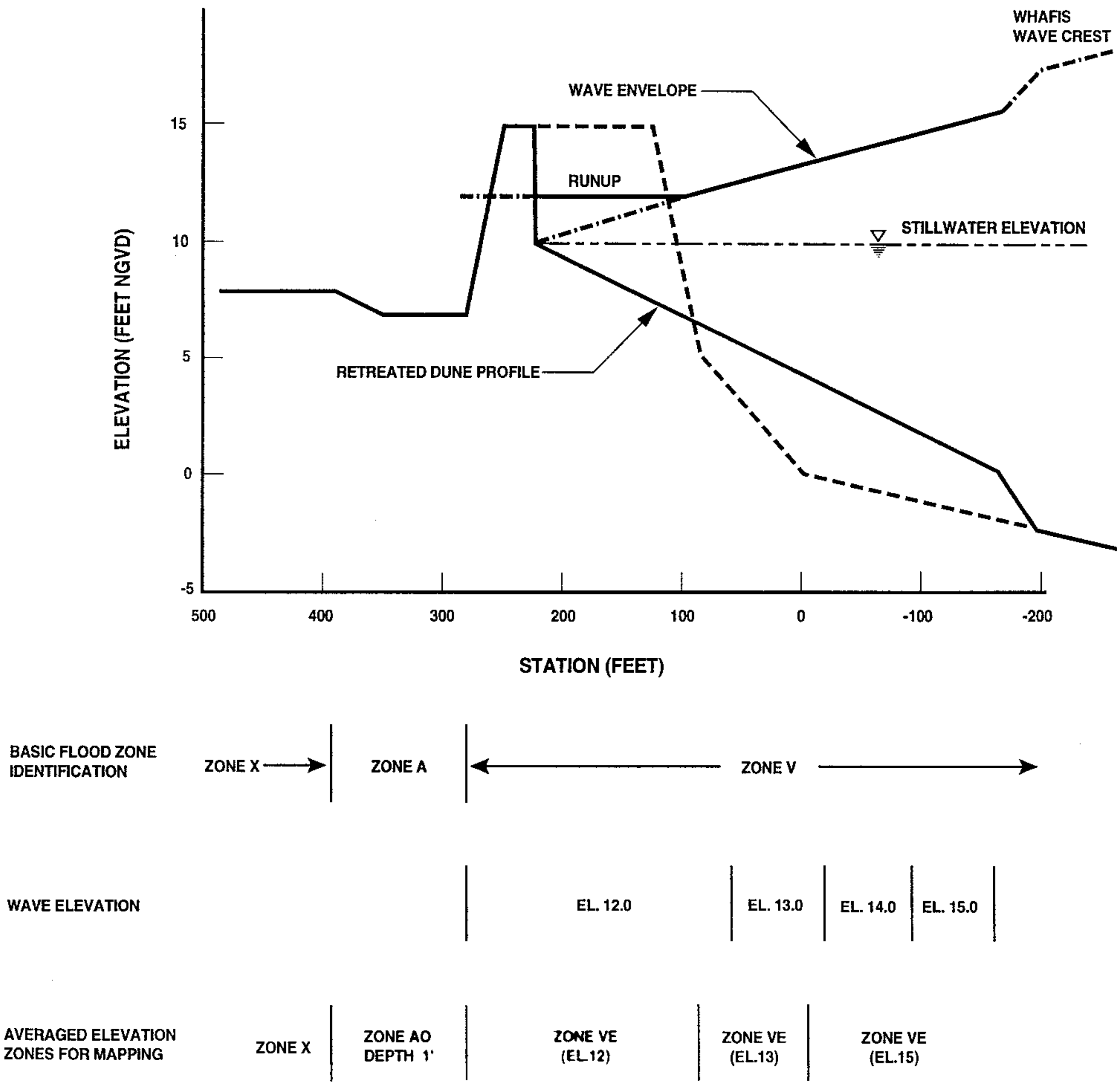

Figure 29. Identification of Elevation Zones, Example 3: Low Retreated Dune with Wave Overtopping.

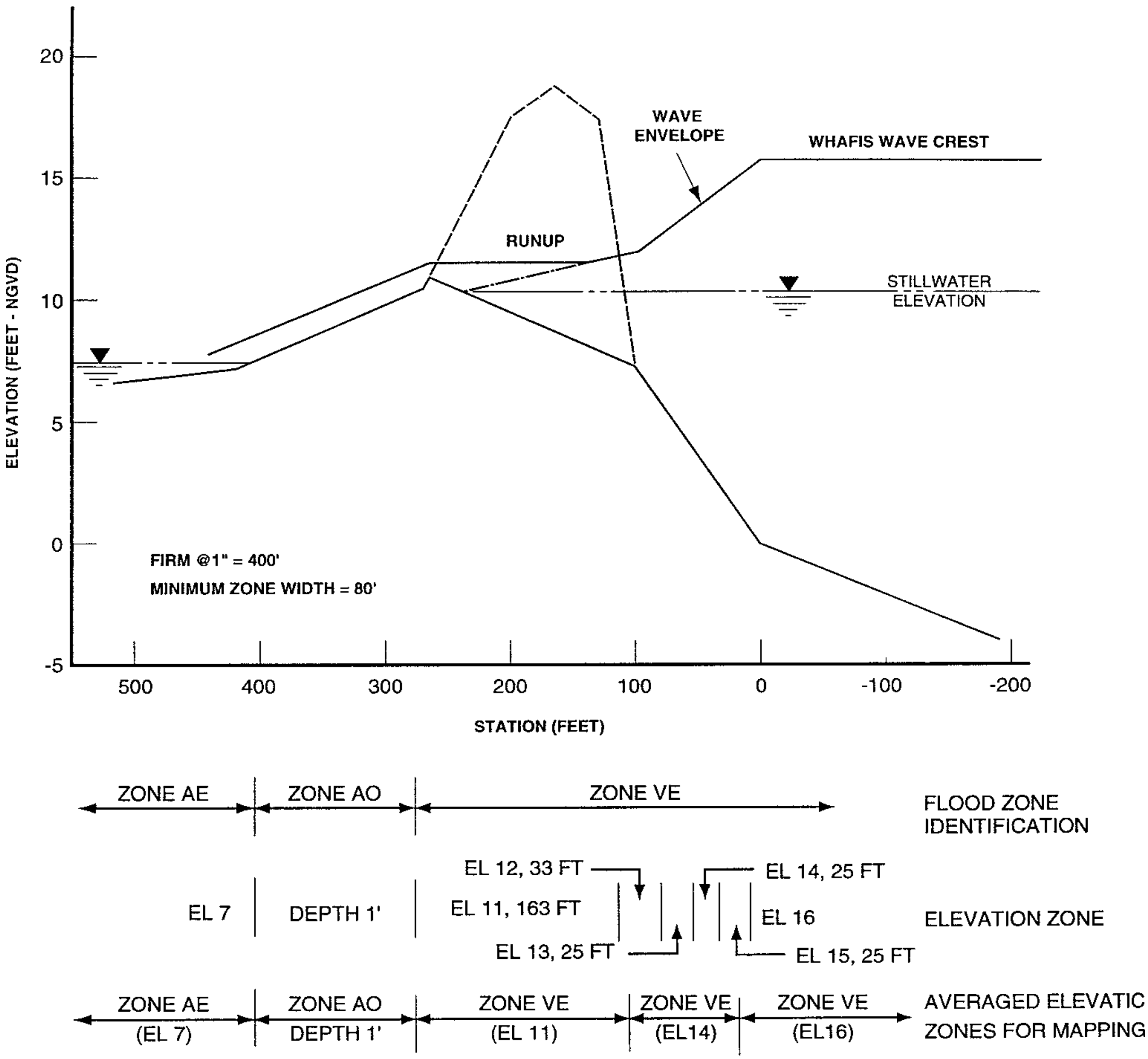

Figure 30. Identification of Elevation zones, Example 4: Dune Removal with Wave Runup and Runoff

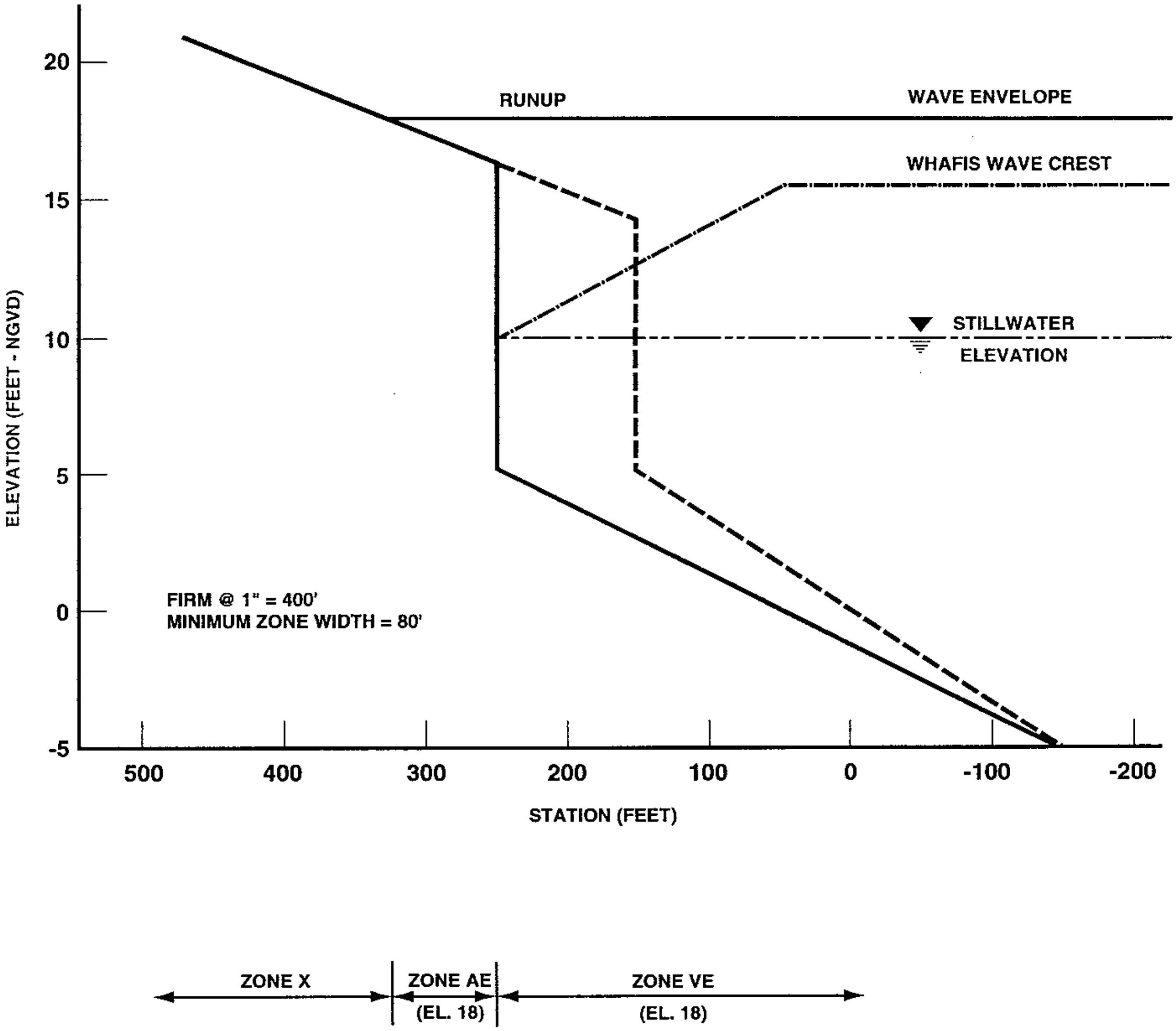

Figure 31. Identification of Flood Zones, Example 5: Eroded Bluff with Wave Runup.

between the runup elevation and the ground is less than 3 feet. In this figure, the Zone AE, elevation 18 feet, is slightly less than the minimum mapping width. As recommended for Figure 27, the neighboring area on the work map should be examined to determine if this zone should be mapped. AE zones are usually not mapped for bluffs unless computed runup exceeds the bluff crest, as shown in Figure 31. (Note that Figures 16 and 17 outline another flooding treatment of bluffs where computed runup is well above the crest).

On sandy shores, it is usual for transects to extend across barrier islands, marshes, inland water bodies, etc., such that two or more areas of VE zones can be identified. Procedures in these cases are the same with elevation averaging also very common. With a little practice, identification of the flood zones and elevations becomes fairly routine using the wave envelope and transect profile.

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. Following examples provide limited discussion of schematic effects for a few basic configurations, presuming the structures remain intact through the base flood and no appreciable shore erosion occurs.

Figure 32 presents an example with moderate structure overtopping expected for waves accompanying the base flood. The structure crest has sufficient freeboard above 100-year stillwater elevation to contain calculated mean runup of 6 feet, but extreme wave runups are likely to overtop the structure intermittently. The entire extent of shore structure is treated as a unit and designated as a VE Zone, assigned the mean runup elevation of 16 feet. Landward of the structure, an area with at least the minimum mapping width is appropriate for designation as Zone AO, depth 1 foot, with extent depending on ground profile.

Figure 33 is an example for a structure extending above 100-year stillwater elevation but heavily overtopped by wave action. 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 is judged to reach beyond the structure during the base flood. Cumulative wave overtopping yields ponding within an additional landward area 100 feet in width, designated as Zone AO, depth 2 feet.

Figure 34 provides an example with a structure covered by 3 feet of water during the base 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

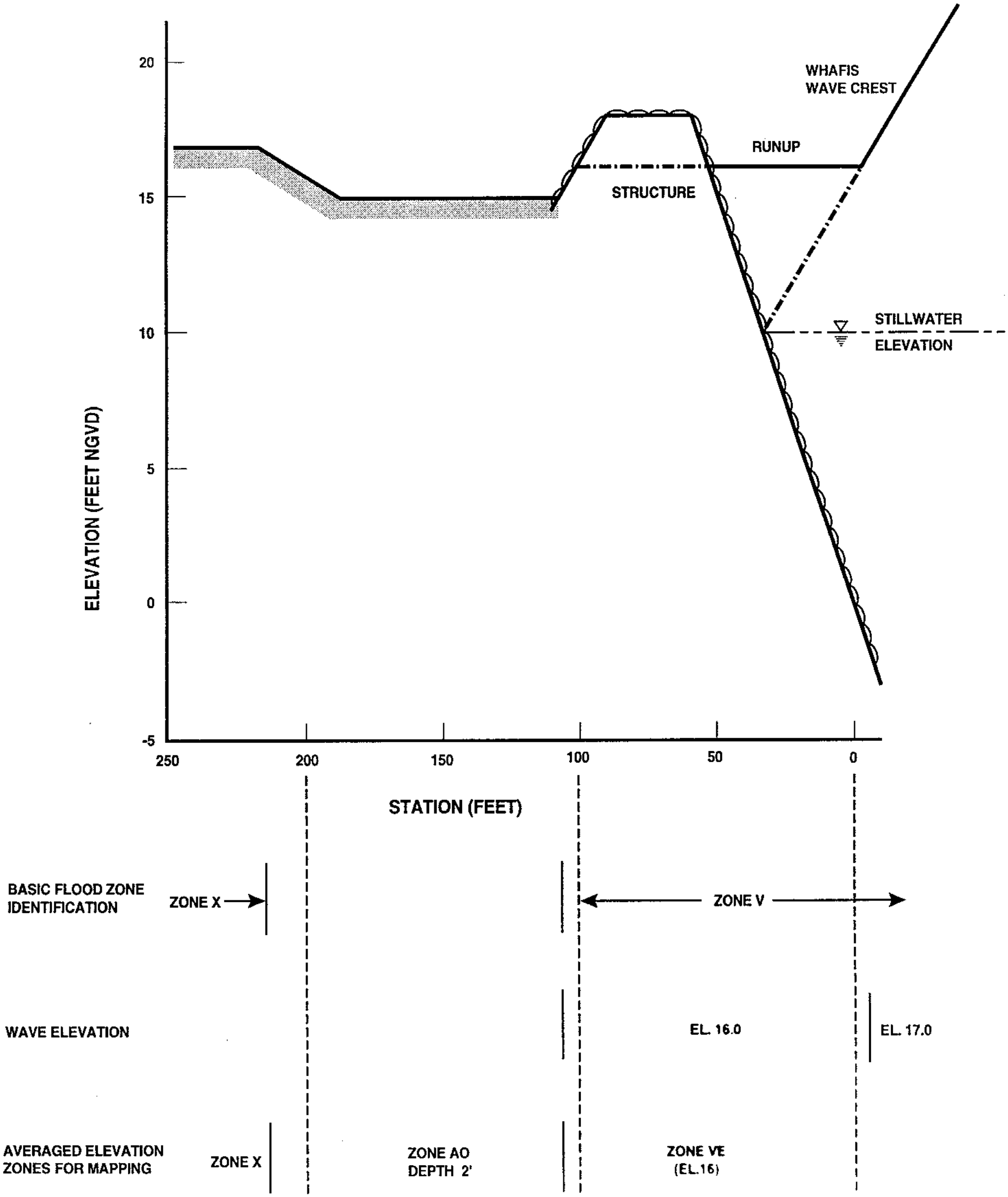

Figure 32. Identification of Elevation Zones, Example 6: Coastal Structure with Moderate Wave Overtopping.

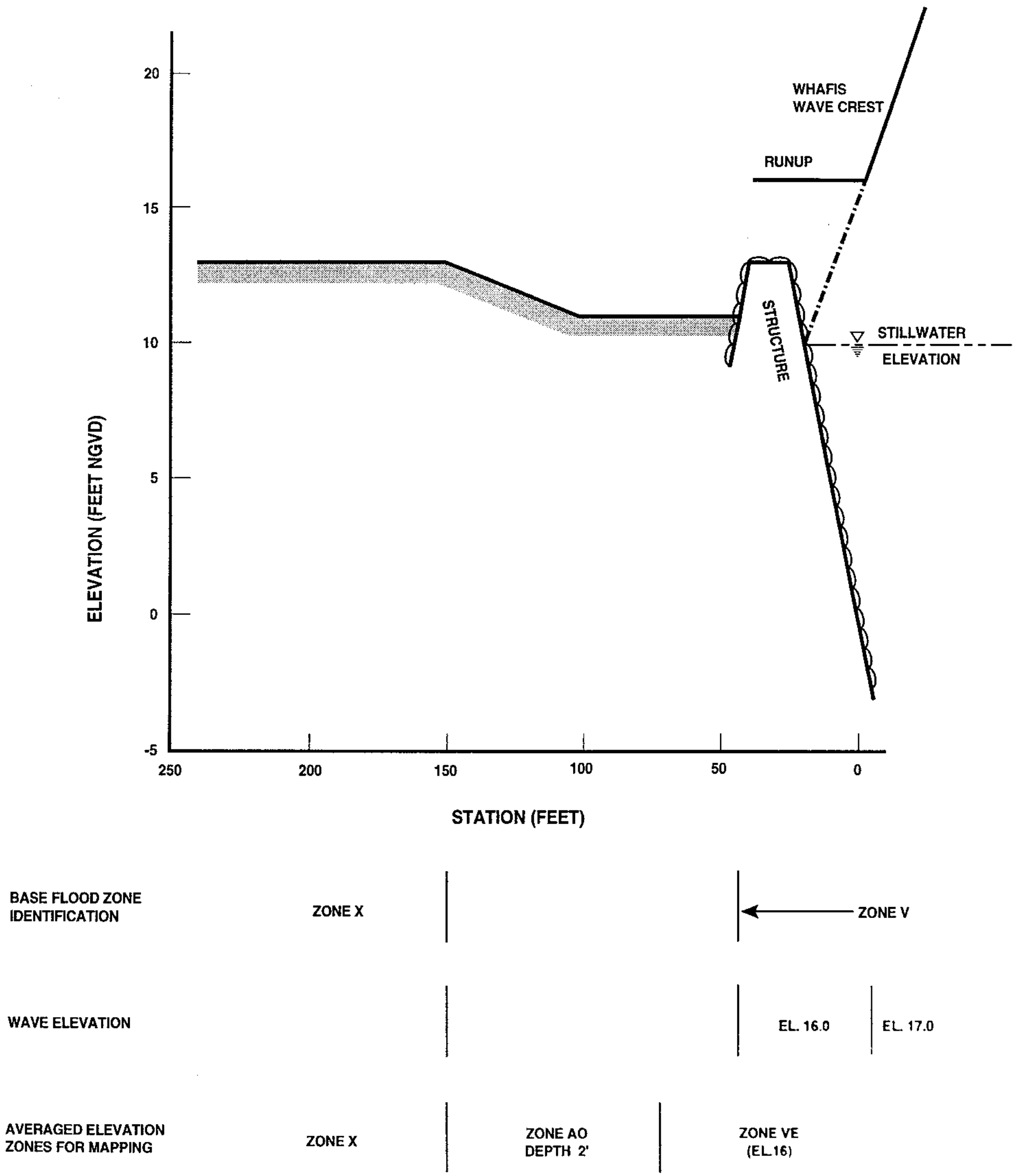

**Figure 33. Identification of Elevation Zones, Example 7:
Coastal Structure with Severe Wave Overtopping.**

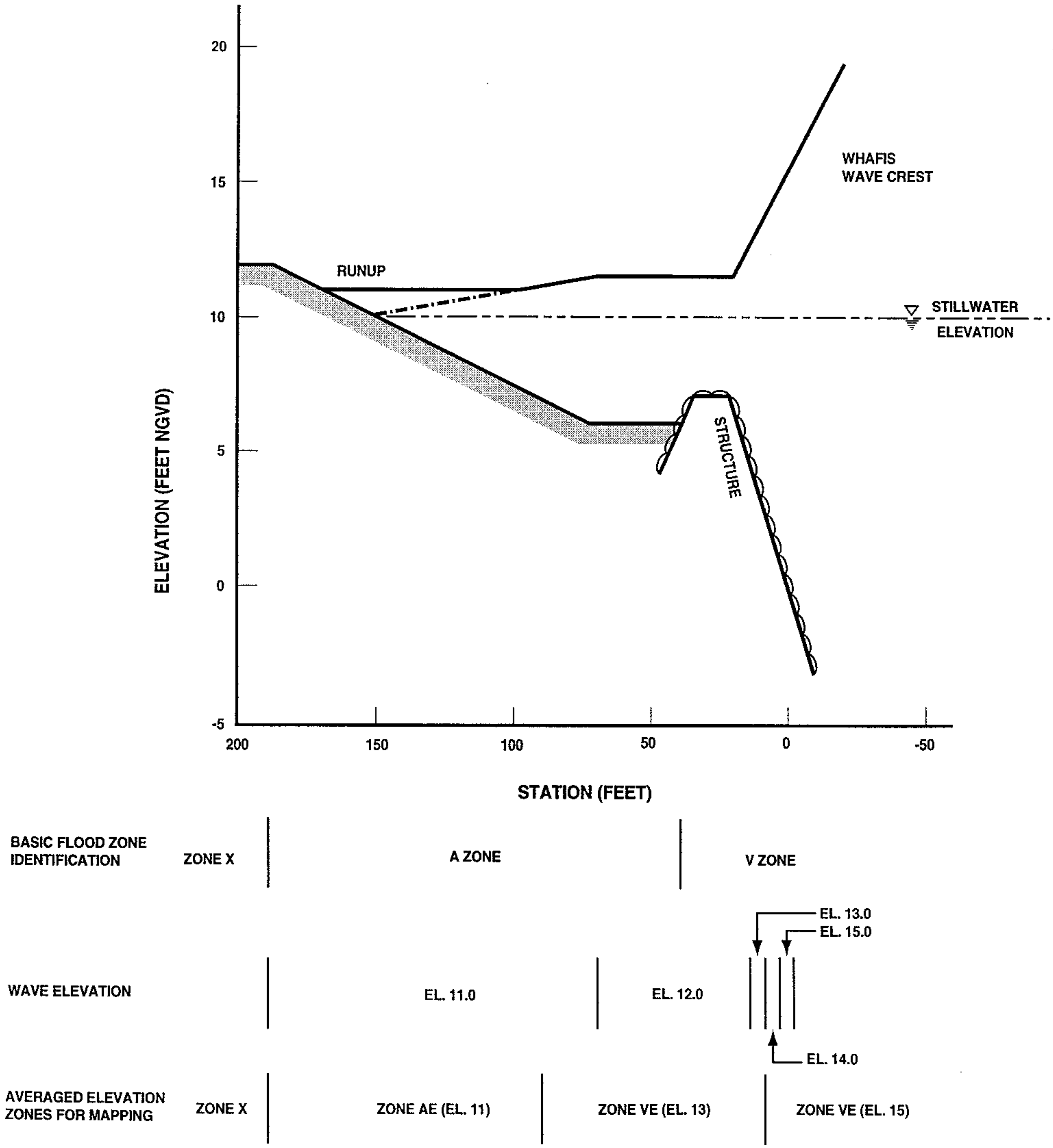

Figure 34. Identification of Elevation Zones, Example 8: Coastal Structure with Inundation.

likely wave impacts through the flood's course. The shore structure is too narrow for multiple V zones to be delineated, so there is one designation of Zone VE, elevation 13 feet. Landward of that, further wave hazards occur in the Zone AE, elevation 11 feet.

In examining Figures 32-34, it may seem surprising that relatively high structures can result in higher flood elevations, compared to an inundated structure. However, a structure with more freeboard can deflect incident wave action to greater elevations during the base flood, so the present zonations are physically appropriate. The hazard zonations landward of coastal structures generally have more importance, and those reflect the greater protection provided by higher but durable structures.

7.4 Mapping Procedures

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 extents will be negated if the results of these analyses are not properly delineated on the FIRM. The FIRM is usually produced from the work maps described in Chapter 2, so the flood zones and elevations identified on the transects need to be transferred to the work maps, and boundaries interpolated between transects. The work maps should be set up with contour lines, buildings, structures, vegetation, and transect lines clearly located. Because roads are often the only fixed physical features shown on the FIRM, it is important 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.

For each transect, the identified elevation zones are transferred from the transect to the work maps. The location of the boundaries are marked along the transect line so that boundary lines can be interpolated between transects. Care should be taken to assure that boundaries are marked at the correct location. Because of erosion assumptions, the location of the elevation 0.0 shoreline changes on the transect but not the work maps. Using the transect profile, determine the location of the zone change in relation to a physical feature such as a ground contour, the back side of a row of houses, 50 feet into a vegetated area, etc. Delineate the boundary line along this feature for the area represented by that transect.

Carefully watch the widths of the zones being delineated; if they narrow to less than 0.2 inch, they should be tapered to an end. Likewise, if the zone becomes much wider, it may be possible to break an averaged elevation zone into two mapped elevation zones.

One of the more difficult steps in delineating coastal flood zones and elevations is the transition between transect areas. Good judgment and an understanding of typical flooding patterns are the best tools for this job. Initially, locate on the work maps that area of transition: an area not exactly represented by either transect. Delineate the flood boundaries for each transect up to this area. Examine how a transition can be made across this area to connect matching zones, and still have the boundaries follow logical physical features. See if there are other transects that are similar to this area and could give an indication of flooding. Sometimes the elevation zones for the two contiguous transects are not the same; thus, some zones may have to be tapered to an end, or enlarged and divided in the transition area.

Communities with significant flooding hazards from wave runup may have one transect representing more than one area because the areas have similar shore slopes. In this case, the different areas are identified and the results of the typical transect delineated 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 boundaries. These zones should be fairly short and cover the shore segment with a slope not exactly typical of either area. The transition elevation is determined using judgment in examining runup transects with similar slopes. Transition zones should not be used if there is a very abrupt change in topography, such as the end of a structure.

Lastly, shaded Zone X's are mapped. Areas below the 500-year stillwater elevation and not covered by any other flood zone are designated Zone X and shown shaded on the FIRM. Often the maximum runup elevation is higher than the 500-year elevation; thus, there will be no shaded Zone X in that area. All other areas are designated Zone X without any shading.

Because flood elevations are rounded to the nearest whole foot, there is no reason to spend hours resolving a minor elevation difference. Also, because structures or proposed structures must be located on the FIRM, an attempt should be made whenever possible to smooth the boundary lines and to follow a fixed feature such as a road. In preparing the FIS, not only must the mapped results be technically correct, but the FIRM must be easy to use by the local insurance agent, building inspector, or permit officer.

These Guidelines have been compiled to provide guidance in the preparation of coastal FISs. The initial collection of accurate and representative data, the correct application of the models, the careful evaluation of results and comparison to historical data, and the proper delineation of flood elevations and zones will produce a FIRM that is both technically correct and directly useful. During all steps of the study, especially the mapping, the final product and its purposes should be remembered: the FIRM is used to determine flood insurance premiums and to regulate building standards.