6.0 ANALYSIS OF OVERLAND WAVE DIMENSIONS

As water waves propagate near the shore and over flooded land, they can undergo marked transformations due to local winds, interaction with the bottom, and physical features such as buildings, trees, or marsh grass. Figure 21 illustrates schematic effects on the wave crest elevations and on the type of flood zone. The fundamental analysis of wave effects for an FIS is provided by a computer program (Reference 13) entitled "Wave Height Analysis for Flood Insurance Studies" (WHAFIS 3.0). This program or model calculates wave heights, wave crest elevations, flood hazard zone designations, and the location of zone boundaries along a transect.

Wave description for an FIS addresses the controlling wave height, equal to 1.6 times the significant wave height common as a representative wave description. Significant wave height is the average height of the highest one-third of waves, and controlling wave height is approximately the average height of the highest one percent of waves in storm conditions. The original basis for FIS wave treatment was the NAS methodology which accounted for varying fetch lengths, barriers to wave transmission, and the regeneration of waves over flooded land areas (Reference 4). Since the introduction of the NAS methodology there have been periodic upgrades to incorporate improved or additional wave considerations.

Technical details of the current model are fully documented in Reference 13, but a brief overview indicates the level of wave treatment in WHAFIS 3.0. A wave action conservation equation governs wave regeneration due to

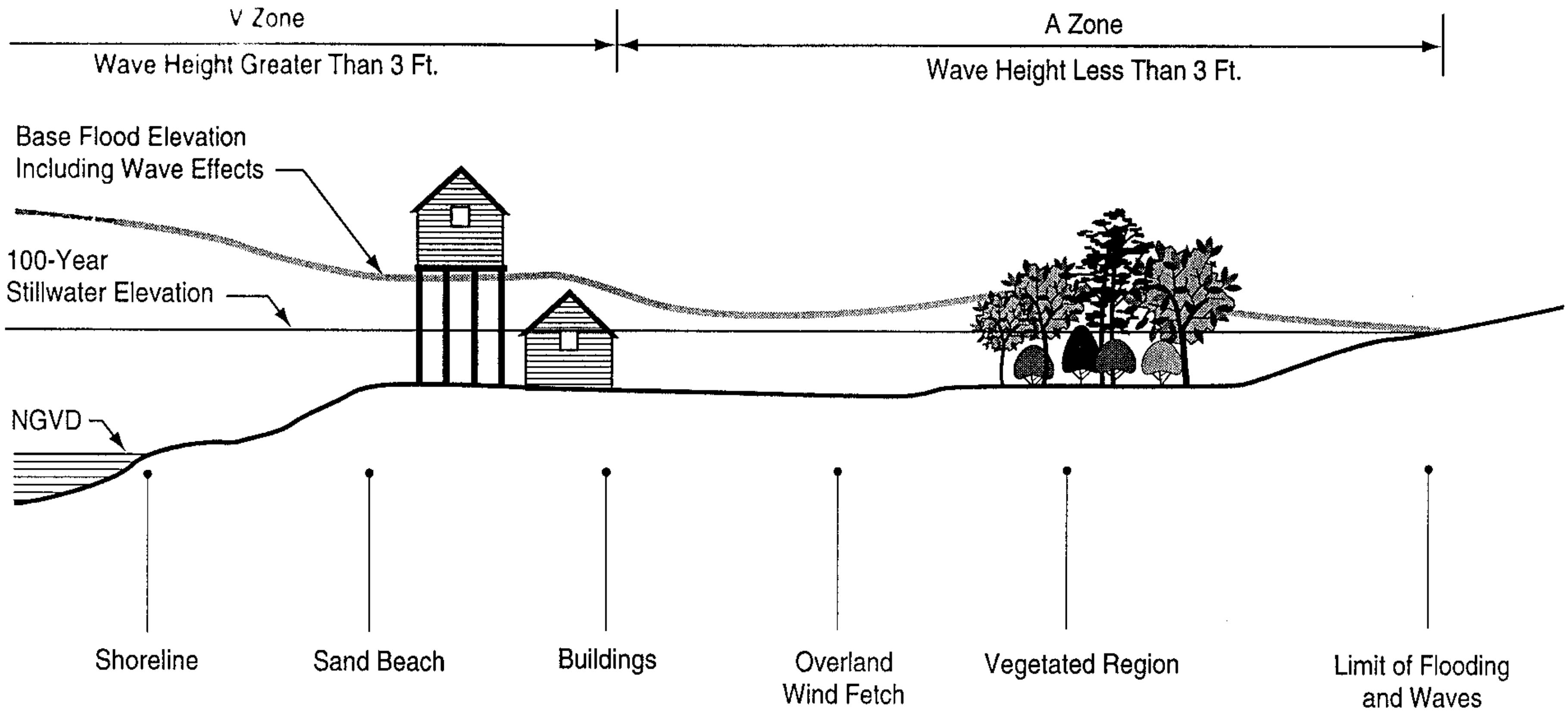

Figure 21. Schematic Wave Effects on A Transect.

wind and wave dissipation by marsh plants. This equation is supplemented by the conservation of waves equation which expresses the spatial variation of the wave period at the peak of the wave spectrum. The wave energy (equivalently, wave height) and wave period respond to changes in wind conditions, water depths, and obstructions as a wave propagates. These equations are solved as a function of distance along the transect. A predominant element in this wave treatment remains unchanged from the NAS methodology: controlling wave height is limited to 78 percent of the local mean water depth.

6.1 Use of WHAFIS 3.0 Model

This computer program usually resides on the hard-disk drive of a PC. Careful preparation and input of required site data are necessary in using WHAFIS. Like the other coastal treatments, the WHAFIS model considers the study area by representative transects. For WHAFIS, transects should be selected considering major topographic, vegetative, and cultural features. The ground profile is defined by elevations referenced to NGVD, usually begins at elevation 0.0, and proceeds landward until either the ground elevation exceeds the meanwater elevation for the base flood, or another flooding source is encountered.

Other fundamental specifications among WHAFIS input include the 100-year mean water elevation and a description of waves existing at the transect start. As the wave description, provision is made for an overwater fetch length, an initial significant wave height, or an initial period of dominant waves. In most applications, the wave period should be the input description, since that parameter is readily available from information about offshore storm waves and the period does not change during most wave transformations. WHAFIS will then compute an appropriate depth-limited wave height at the transect start. The only check necessary is to confirm that incident waves likely exceed that height and a wave condition limited by water depth occurs.

Different wave specifications can be appropriate for sites not on an open, straight coast. Where land shelter or wave refraction may result in reduced incident waves, it is appropriate to specify an initial significant wave height for the transect. Also, at sites on restricted water bodies, the overwater fetch length should be specified for likely wind direction at the flood peak. WHAFIS will then compute an appropriate incident wave condition for the transect, but note that such waves are limited and any fetch length exceeding 24 miles will yield the same results.

In preparing WHAFIS input, transects should be located on the work maps and the transect ground profile plotted from the topographic data, adjusted for erosion. Each transect should have all the input data identified on the profile plot for ease of input coding. The location, height, and extent of elongated manmade structures should also be identified and shown as part of the ground profile, after confirming the structure's stability under forces of the base flood (Chapter 3). When locating transects across barrier islands or sand spits, common practice is to continue the transect across the back bay and onto the mainland. If there is a large and/or unusually shaped embayment behind the island, it may be necessary to place additional transects just along the mainland shore. These transects may not parallel the transects from the open coast, and they may cross one another. Crossing transects should be kept to a minimum, but where it is not possible to avoid this, the transect determining greatest flood hazards should control in mapping the flood hazards.

Once representative transects are located, the local 100-year mean water levels can be defined for WHAFIS input. Reference 13 specifies that wave setup should be included in this water elevation, as a part of the appropriate mean depth controlling wave dimensions. If wave setup was not calculated separately for the site, 100-year stillwater elevation is the appropriate specification. WHAFIS also has an input field for a 10-year stillwater elevation, although it is only employed to determine flood hazard factors which are no longer used. Still, this input should be provided if it is readily available, since it could help in distinguishing between transects.

When a transect covers two or more flooding sources, an area of transition between the different stillwater elevations must be identified. This is a common situation for barrier islands with ocean elevations on one side and bay elevations on the other side. It is usually assumed that the higher ocean elevations extend inland to the highest point of the reduced ground profile. WHAFIS performs a linear interpolation within a transect segment where elevations differ at the end stations. The interpolated elevations are compared to the ground elevations and adjusted, if necessary, to be above the ground elevations. A stillwater elevation may have to be input a second time to identify areas of constant elevation and elevation transition.

The proper transect representation of some land features, particularly buildings and vegetation, merits further discussion. Buildings are specified on the transect as rows perpendicular to the transect. Since buildings are not always situated in perfect rows, judgment must be exercised to determine which buildings can be represented by a single row. The required input value for each row of buildings is the ratio of open space to total space. This is simply the sum of distances between buildings in a row, divided by the total length of that row. It should be examined whether the first row or two of buildings along the shoreline should be considered as obstructions. During a 100-year event, it is sometimes appropriate to assume that these buildings will be destroyed before the peak of the flood occurs if they are not elevated on pilings. If they are elevated, the waves should propagate under the structure with minimal reduction in height. It is useful to contact local officials to obtain typical construction methods and the lowest elevations of structures.

The WHAFIS program has two separate routines for vegetation: one for rigid vegetation that can be represented by an equivalent "stand" of equally spaced circular cylinders (Reference 5), and one for marsh vegetation that is flexible and oscillates with wave action (Reference 40). For either type, considerable care is required in selecting representative parameters and in ruling out that the vegetation will be intentionally removed or that effects would be markedly reduced during a storm through erosion, uprooting, or breakage.

For the areas of rigid vegetation located on the transect, the required input values are the drag coefficient, C_D; mean wetted height, h; mean effective diameter, D; and mean horizontal spacing, b. The value of C_D should vary between 0.35 and 1.0, with 1.0 being used in most cases of wide vegetated areas. When the vegetation is in a single stand, a value of 0.35 should be used. Representative values for h, D, and b can be obtained from stereoscopic aerial photographs or by field surveys. Various guides for terrain analysis can provide advice on estimating values from aerial photographs. Table 8 provides a useful process developed from Terrain Analysis Procedural Guide for Vegetation (Reference 41).

Table 8.

Procedures for Vegetation Analysis

Using Stereoscopic Aerial Photographs

1. Using the parallax bar or wedge, determine the height of three representative trees and compute the average height, h.

2. Locate three representative tree crowns, measure the diameters, and compute the average crown diameter, CD.

3. Determine the type of vegetation and calculate the stem diameter, D, using the following formulae:

Southern Pines	D (inches) = 5 + 0.5 CD (feet)
Eastern Hardwoods, Northern Pines and Others	D (inches) = 0.75 CD (feet)

4. Based on the scale of the aerial photographs, determine the diameter of a circle containing 0.08 hectares using Table 8a. Place the circle on the photograph, over a representative area of trees, and count the number of trees, n, in the circle. A magnifier may be needed. More than one area can be counted and an average used for n. Calculate the number of trees per hectare, N, using the following formula:

$$N = \frac{n}{0.08}$$

5. Determine the horizontal spacing between trees using the following formula:

$$b\ (feet) = (\frac{12732}{N} - \frac{D\ (inches)}{12}$$

Table 8a.

CIRCLE DIAMETERS
.08 HECTARE AREA, (1/5 ACRE)
(800 Square Meters, 8712 Square Feet)

PHOTO SCALE	.08 HECTARE CIRCLE	CIRCLE DIAMETER	
		INCHES	MILLIMETERS
1:5,000		.253	6.38
1:6,000		.211	5.32
1:7,000		.1805	4.56
1:8,000		.158	3.99
1:9,000		.140	3.55
1:10,000		.126	3.192
1:11,000		.115	2.90
1:12,000		.105	2.66
1:13,000		.092	2.46
1:14,000		.090	2.28
1:15,000		.084	2.13
1:16,000		.079	1.99
1:17,000		.074	1.88
1:18,000		.070	1.77
1:19,000		.067	1.68
1:20,000		.063	1.60
1:21,000		.060	1.52
1:22,000		.057	1.45
1:23,000		.055	1.39
1:24,000		.053	1.33
1:25,000		.051	1.28

For marsh vegetation, a more complicated specification is required for completeness, and the eight parameters used to describe dissipational properties of a specific type are explained in Table 9. However, WHAFIS incorporates considerable basic information on the eight common types of seacoast marsh plants listed in Table 10 (Reference 40). That information can be utilized either by specifying the Table 10 abbreviation, or a geographical region as indicated in Figure 22. Figure 22 shows the coastal wetland regions of the Atlantic and Gulf coasts, along with the identifying number used in WHAFIS. If the site is near a region border, the likely plant parameters can be interpolated using an input weighting factor. Although the south Texas region has insignificant amounts of marsh grass, it is included for usage in spatial interpolation.

Climate affects the geographic range of each marsh plant type, so that some plant types are not found in all regions. Table 11 lists the dominant plant type in each region, where the term dominant refers to the plant types that cover the largest amount of area in the marshes. Table 12 shows the significant plant types in each region, where the term significant refers to the plant types that occur in large enough patches (at least 10,000 square feet) to significantly affect waves. For marsh plants, simply the coastal wetland region, plant type, and area or percent of coverage may be specified. Given this information, WHAFIS will supply default values for the other marsh plant parameters appropriate to the site (see Reference 40).

Table 9. Marsh Plant Parameters

Parameter	Explanation
C_D	Effective drag coefficient. Includes effects of plant flexure and modification of the flow velocity distribution. Default value is 0.1, usually appropriate for marsh plants without strong evidence to the contrary.
F_{cov}	Fraction of coverage. A default value is calculated by the program so that each plant type in the transect is represented equally, and the sum of the coverage for the plant types is equal to 1.0.
h	Unflexed stem height (feet). The stem height does not include the flowering head of the plant, the inflorescence.
N	Number density. Expressed as plants per square foot. The relationship to the average spacing between plants, b, can be expressed as $N = 1/b^2$.
D_1	Base stem diameter (inches). Default value may be determined from stem height and regression equations built into the program.
D_2	Mid stem diameter (inches). Default value may be determined from plant type and base stem diameter.
D_3	Top stem diameter (inches), at the base of the inflorescence. Default value may be determined from plant type and base stem diameter.
CA_b	Ratio of the total frontal area of the cylindrical portion of the leaves to the frontal area of the stem below the inflorescence. Default value may be determined from the plant type.

Table 10. Abbreviations of Marsh Plant Types used in WHAFIS

SPECIES OR SUB-SPECIES	ABBREVIATION
Cladium jamaicense (saw grass)	CLAD
Distichlis spicata (salt grass)	DIST
Juncus gerardi (black grass)	JUNM
Juncus roemerianus (black needlerush)	JUNR
Spartina alterniflora (medium saltmeadow cordgrass)	SALM
Spartina alterniflora (tall saltmeadow cordgrass)	SALT
Spartina cynosuroides (big cordgrass)	SCYN
Spartina patens (saltmeadow grass)	SPAT

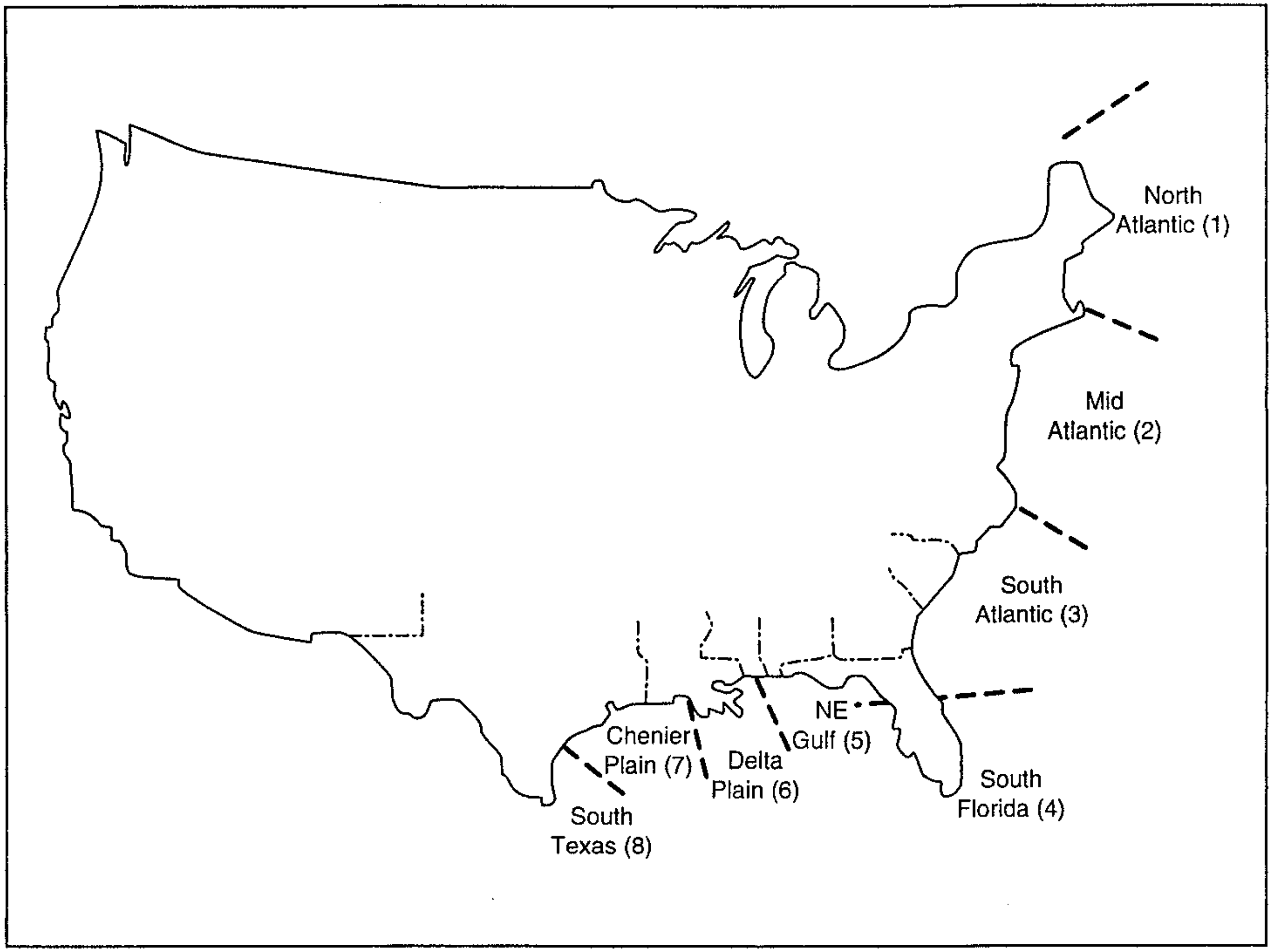

Figure 22. Coastal wetland regions of Atlantic and Gulf coasts having enough marsh grass to significantly affect wave heights. Region numbers are indicated in parentheses.

Table 11. Dominant Marsh Plant Types by Region and Habitat

Region Number	Region Name	Habitat	Dominant Species
1	North Atlantic	salt[1] brackish[2]	*S. alterniflora (medium, tall) Spartina patens
2	Mid-Atlantic	salt brackish	S. alterniflora (medium, tall) *Juncus roemerianus/S. patens
3	South Atlantic	salt brackish	*S. alterniflora (medium, tall) J. roemerianus
4	South Florida	salt brackish	S. alterniflora (medium, tall) *C. jamaicense
5	Northeastern Gulf	salt brackish	--- *J. roemerianus
6	Delta Plain	salt brackish	*S. Alterniflora (medium, tall) S. patens
7	Chenier Plain	salt brackish	S. alterniflora (medium, tall) *S. patens
8	South Texas	salt brackish	--- ---

[1]Salt concentration is greater than 20 parts per thousand (ppt)

[2]Salt concentration is between 5 and 20 ppt

*When more than one dominant plant type occurs within the region, the indicated type covers the largest geographic area (acreage).

---Indicates that there are insignificant amounts of marsh plants within the given habitat in the region.

Table 12. "Significant" Marsh Plant Types in Each Seacoast Region and Default Regional Plant Parameter Data Used in WHAFIS

Region No.	1	2	3	4	5	6	7	8
Region Name:	North Atlantic	Mid-Atlantic	South Atlantic	South Florida	Northeastern Gulf	Delta Plain	Chenier Plain	South Texas
CLAD	---	---	---	7.50(+) 0.0656 6	6.00(2) 0.0260 6	---	---	---
DIST	---	0.78(1) 0.0039 211	1.00(1) 0.038 243	1.00(+) 0.0038 248	--- ---	1.08(4) 0.0035 102	1.08(+) 0.0035 102	---
JUNM	1.23(1) 0.0042 300	1.23(+) 0.0042 300	---	---	---	---	---	---
JUNR	---	2.95(+) 0.0095 147	2.95(+) 0.0095 147	---	2.95(3) 0.0095 147	3.00(4) 0.0106 83	2.95(+) 0.0095 147	---
SALM	1.39(1) 0.0184 45	1.06(1) 0.0103 36	1.63(1) 0.0141 12	1.63(+) 0.0141 12	---	1.67(4) 0.0141 21	2.62(5) 0.0211 16	---
SALT	1.86(1) 0.0175 37	2.21(1) 0.0169 18	3.20(1) 0.0183 10	3.20(+) 0.0183 10	---	3.20(4) 0.0183 10	3.20(+) 0.0183 10	---
SCYN	---	---	8.29(+) 0.0492 6	---	---	4.00(4) 0.0267 7	---	---
SPAT	1.03(1) 0.0025 409	0.85(1) 0.0019 327	1.65(1) 0.0019 236	---	2.58(2) 0.0026 236	1.88(4) 0.0016 333	1.88(+) 0.0019 333	---

Data arranged in vertical triplets: h, stem height below inflorescence, in feet
D, base diameter, in feet
N, number density, in inverse square feet

Symbols in parentheses indicate source of data in vertical triplet:

1 = Reference 42
2 = Reference 43
3 = Reference 44
4 = Reference 45, Diameters extrapolated
5 = Reference 46, Diameters extrapolated
+ = Extrapolated Data
--- = There are insignificant amounts of this plant type in the region

Where detailed specification of marsh plants is required, some basic considerations can aid in the determination of likely types. Each marsh plant type may be associated with certain climatic conditions and certain ranges of salinity, so consultation of Figure 22 and Table 11 can be helpful. In addition, it is useful to realize that salinity levels are related to elevations above mean tide level. Figure 23 gives the salinity tolerance of marsh plants, and Figure 24 gives the preferred tidal elevation range. Care should be taken in interpreting Figure 24 because where the local tide range is less than one foot, the boundaries between species can deviate somewhat from those shown. Furthermore, in regions such as the Northeastern Gulf, where S. alterniflora does not occur in significant amounts, both Juncus species and Distichlis spicata can grow down to the mean tide level. Some plant types are usually found together, for example, tall and medium varieties of S. alterniflora. Typically, 20 to 25 percent of S. alterniflora can be characterized as tall, with the tall variety usually found adjacent to tidal creeks.

Following the identification of the marsh plant types present, the area and fraction of coverage, F_{cov}, for each plant type must be calculated. For each transect, the total area of marsh vegetation coverage is determined. The different types of vegetation within this area usually occur in patches. F_{cov} is defined for each plant type as the ratio of the patch area for that type to the total marsh area. Using the above data, a fairly good determination can be made

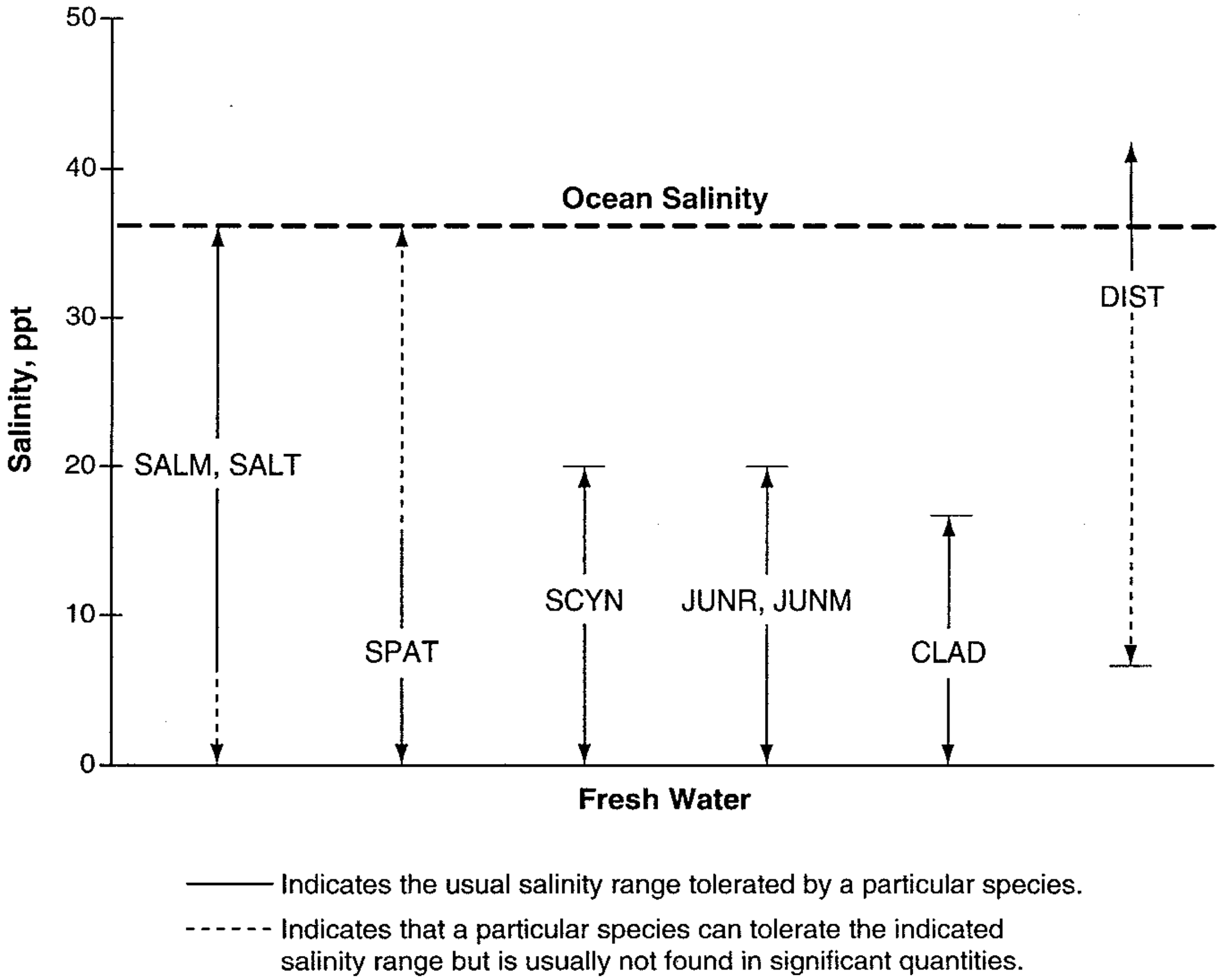

Figure 23. Salinity Tolerance of Marsh Plants, from Reference 47

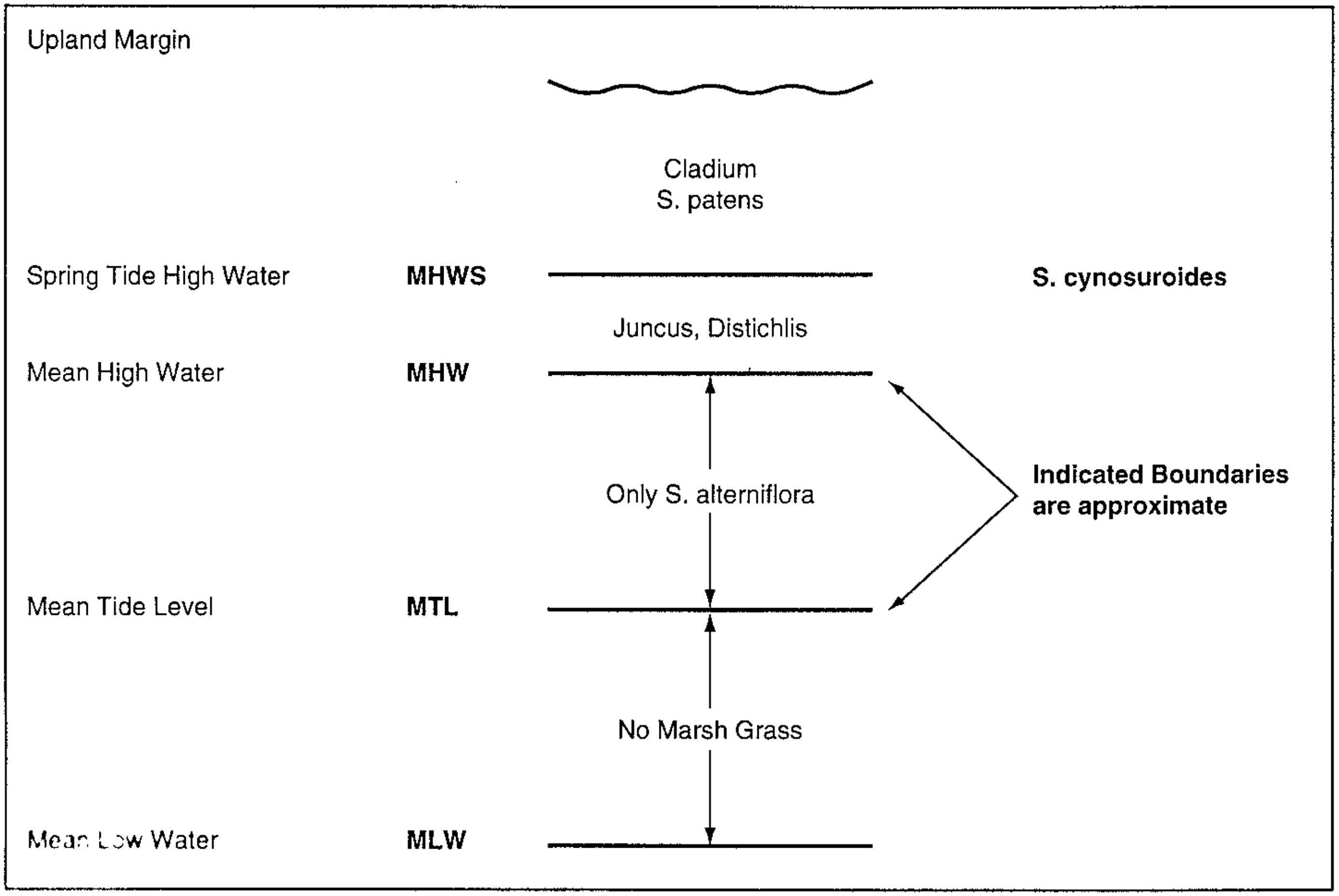

Figure 24. Tidal Control on Salt Marsh Plant Viability

of the plant types present, but an attempt should be made to confirm these plant types. Local, county, or state officials may provide some assistance, and a site visit can be very useful.

6.2 Input Coding for WHAFIS

After all the necessary input data have been identified on the transect, the transect should be divided into contiguous segments, each representing a continuous open fetch or a single obstruction. Fetches are flooded areas with no obstruction, while obstructions include dunes, manmade barriers, buildings, and vegetation. Fetches should be subdivided at points where the ground elevation abruptly changes and in the transition area of changing stillwater elevations. Obstructions should be subdivided into smaller segments at the transect's seaward edge to more accurately model the wave dissipation. Rigid vegetation should have two to three seaward segments extending 10 to 50 feet, and the first two or three rows of buildings should have a segment for each row. Marsh vegetation will be subdivided within WHAFIS so segmented input is not necessary.

The necessary data are entered via an input file created using 10 line types. Each line describes a certain type of fetch or obstruction. The IE (Initial Elevation) line describes the initial overwater fetch and the initial stillwater elevations. The IF (Inland Fetch) and OF (Overwater Fetch) lines define the end point stationing and elevation of inland and overwater fetches, respectively. Obstructions are categorized as either buildings (BU line), rigid vegetation (VE line), marsh vegetation (VH and MG lines), dunes and other natural or man-made elongated barriers (DU line), or areas where the ground elevation is greater than the 100-year stillwater elevation (AS line). The tenth line type, the ET (End of Transect) line, enters no data but indicates the end of the input data. Each line has an alphanumeric field describing the type of input for that line, followed by ten numeric fields describing the parameters.

To ensure proper modeling, all segments of each transect must be entered as either fetches or obstructions, with one input line required for each fetch or obstruction segment. The first two columns of each line identify the type of fetch or obstruction. The remaining 78 columns consist of 1 field of 6 columns followed by 9 fields of 8 columns. The numbers in any data field need to be right-justified only if no decimal point is used, and decimal points are permitted but not required. The end point of one fetch or obstruction is the beginning of the next. The first two numeric fields of each line are used to read in the stationing (measured in feet from the beginning of transect) and elevation (in feet) of the end point. The last two fields used on each line are for entering new stillwater elevations. An interpolation is performed within a transect segment starting at the closest station with an input stillwater elevation. This interpolation uses the new stillwater elevation input at the end point of the segment and the stillwater elevation input at a previous segment. If these fields are blank or zero, the stillwater elevations remain unchanged.

The input data requirements are summarized below for each line type. The Title line must be the first line, followed by the IE line, followed by any combination of the various fetch and obstruction lines. The ET line must be the last card entered for the transect. A blank line must follow to signify the end of the run. If multiple transects are being run, the Title line for the next transect will follow the blank line. All units are in feet unless otherwise specified.

<u>TITLE</u> <u>Line</u> <u>(Title)</u>

This line is required and must be the first input line.

Data Field	Columns	Contents of Data Fields
0	1-2	Blank
1-10	3-80	Title information centered about column 40

IE Line (Initial Elevations)

This line is required and must be the second input line. This line is used to begin a transect at the shoreline and compute the wave height arising through the overwater fetch.

Data Field	Columns	Contents of Data Fields
0	1-2	IE
1	3-8	Stationing of end point of initial overwater fetch in feet (zero at beginning of transect)
2	9-16	Ground elevation at end point in feet (usually zero at beginning of transect)
3	17-24	Overwater fetch length (miles), if wave condition is to be calculated. Values of 24 miles or greater yield identical results.
4	25-32	10-year stillwater elevation
5	33-40	100-year stillwater elevation
6	41-48	Initial wave height; a blank or zero causes a default to a calculated wave height
7	49-56	Initial wave period (seconds); a blank or zero causes a default to a calculated wave period. The period is usually the most convenient wave specification for open coasts.
8-10	57-80	Not used

AS Line (Above Surge)

This line is used to identify the end point of an area with ground elevation greater than the 100-year stillwater elevation (such as a high dune or other land mass). This is used when the ground surface temporarily rises above the 100-year stillwater elevation. The line immediately preceding the AS line must enter the stationing and elevation of the point at which the ground elevation first equals the 100-year stillwater elevation. Stillwater elevation on the inland side may differ from stillwater elevation on the seaward side. The ground elevation entered on the AS line must equal the stillwater elevation which applies to the inland side of the land mass. Computer calculations will be terminated if a ground elevation greater than the 100-year stillwater elevation is encountered.

Data Field	Columns	Contents of Data Fields
0	1-2	AS
1	3-8	Stationing at end point of area above 100-year stillwater elevation
2	9-16	Ground elevation at end point
3	17-24	A blank or zero indicates no change to the 10-year stillwater elevation; otherwise new 10-year stillwater elevation
4	25-32	A blank or zero indicates no change to the 100-year stillwater elevation; otherwise new 100-year stillwater elevation
5-10	33-80	Not used

BU Line (Buildings)

This line enters information needed to compute wave dissipation at each group of buildings.

Data Field	Columns	Contents of Data Fields
0	1-2	BU
1	3-8	Stationing of end point of group of buildings
2	9-16	Ground elevation at end point
3	17-24	Ratio of open space between buildings to total transverse width of developed area
4	25-32	Number of rows of buildings
5	33-40	A blank or zero indicates no change to 10-year stillwater elevation; otherwise new 10-year stillwater elevation
6	41-48	A blank or zero indicates no change to 100-year stillwater elevation; otherwise new 100-year stillwater elevation
7-10	49-80	Not used

DU Line (Dune)

This line enters information necessary to compute wave dissipation over flooded sand dunes and other natural or manmade elongated barriers (e.g., levees, seawalls).

Data Field	Columns	Contents of Data Fields
0	1-2	DU
1	3-8	Stationing at top of dune or barrier
2	9-16	Elevation at top of dune or barrier
3	17-24	A blank or zero indicates a dune or other natural barrier; any other number indicates a seawall or other manmade barrier
4	25-32	A blank or zero indicates no change to 10-year stillwater elevation; otherwise new 10-year stillwater elevation
5	33-40	A blank or zero indicates no change to 100-year stillwater elevation; otherwise new 100-year stillwater elevation
6-10	41-80	Not used

IF Line (Inland Fetch)

This line enters the parameters necessary to compute wave regeneration through somewhat sheltered fetches and over shallow inland water bodies. The IF regeneration is computed using a sustained wind speed of 60 mph.

Data Field	Columns	Contents of Data Fields
0	1-2	IF
1	3-8	Stationing at end point of fetch
2	9-16	Ground elevation at end point
3	17-24	A blank or zero indicates no change to 10-year stillwater elevation; otherwise new 10-year stillwater elevation
4	25-32	A blank or zero indicates no change to 100-year stillwater elevation; otherwise new 100-year stillwater elevation
5-10	33-80	Not used

OF Line (Overwater Fetch)

This line enters the parameters necessary to compute wave regeneration over large bodies of water (i.e., large lakes, bays) using a sustained wind speed of 80 mph. If an inland waterbody is sheltered and has a depth of ten feet or less, the IF line calling for reduced wind speed should be used.

Data Field	Columns	Contents of Data Fields
0	1-2	OF
1	3-8	Stationing at end point of fetch
2	9-16	Ground elevation at end point
3	17-24	A blank or zero indicates no change to the 10-year stillwater elevation; otherwise new 10-year stillwater elevation
4	25-32	A blank or zero indicates no change to 100-year stillwater elevation; otherwise new 100-year stillwater elevation
5-10	33-80	Not used

VE Line (Vegetation)

This line enters parameters necessary to compute wave dissipation due to rigid vegetation stands.

Data Field	Columns	Contents of Data Fields
0	1-2	VE
1	3-8	Stationing at end point of vegetation
2	9-16	Ground elevation at end point
3	17-24	Mean effective diameter of equivalent circular cylinder
4	25-32	Average actual height of vegetation
5	33-40	Average horizontal spacing between plants
6	41-48	Drag coefficient; a blank or zero causes a default to 1.0
7	49-56	A blank or zero indicates no change to 10-year stillwater elevation; otherwise new 10-year stillwater elevation
8	57-64	A blank or zero indicates no change to 100-year stillwater elevation; otherwise new 100-year stillwater elevation
9-10	65-80	Not used

VH Line (Vegetation Header for Marsh Grass)

Marsh grass is often part of a plant community that may consist of several types. The VH line is used to enter data that apply to all plant types modeled in the transect segment. To enter data for each plant type, MG lines for each plant type must follow the VH line.

Data Field	Columns	Contents of Data Fields
0	1-2	VH
1	3-8	Stationing at end point of marsh vegetation segment
2	9-16	Ground elevation at end point
3	17-24	Reg_p, number of the primary seacoast region for default plant parameters. See Figure 22.
4	25-32	Wt_p, weighting factor for the primary seacoast region.
5	33-40	Reg_s, number of secondary seacoast region. See Figure 22.
6	41-48	N_{p1}, number of plant types; range is 1 to 10, inclusive. One MG line is required for each plant type.
7	49-56	A blank or zero indicates no change to the 10-year stillwater elevation; otherwise new 10-year stillwater elevation
8	57-64	A blank or zero indicates no change to the 100-year stillwater elevation; otherwise new 100-year stillwater elevation
9	65-72	Not used
10	73-80	This field is for overriding the default method of averaging flood hazard factors in A zones; if 1 in column 80, averaging process begins or ends at end of vegetation segment; otherwise, default averaging method is used

MG Line (Marsh Grass)

This line is used to enter data for a particular plant type. The first MG line must be preceded by a VH line. For the common seacoast marsh grasses listed in Table 10, some potentially useful default values are supplied in Table 12, and program can provide additional default values (Reference 40). If a plant type not listed in the table is used, then appropriate data must be developed for Fields 2-9.

Data Field	Columns	Contents of Data Fields
0	1-2	MG
1	5-8	Marsh plant type abbreviation (see Table 10)
2	9-16	C_D, effective drag coefficient; default value is 0.1
3	17-24	F_{cov}, decimal fraction of vegetated area to be covered by this plant type; a blank or zero causes a default to be calculated so that each plant type is represented equally
4	25-32	h, mean unflexed height of stem (feet); for marsh plants, the inflorescence is not included
5	33-40	N, number of plants per square foot
6	41-48	D_1, base stem diameter (inches)
7	49-56	D_2, mid stem diameter (inches)
8	57-64	D_3, top stem diameter (inches)
9	65-72	CA_b, Ratio of the total frontal area of cylindrical part of leaves to frontal area of main stem
10	73-80	Not used

ET Line (End of Transect)

This line is required and must be the last input card because it identifies the end of input for the transect.

Data Field	Columns	Contents of Data Fields
0	1-2	ET
3-10	3-80	Not used

6.3 Error Messages

- "AS card ground elevation less than stillwater elevation, should use other type card, job dumped."

  Only use AS (above surge) line when the ground elevation is above the stillwater elevation. Can otherwise use IF, OF, BU, DU, VE, or VH.

- "Ground elevation greater than surge elevation encountered, job dumped."

  If ground elevation is above surge elevation, AS card should be used.

- "Average depth less than or equal to zero, job dumped."

  The water depth must be greater than zero or a wave height cannot be computed. Check the stillwater elevation and the ground elevation if point of job dump is not the last point along the transect profile.

- "The above card contains illegal data in the first 2 columns."

  Check input data for incorrect values or input within wrong columns. Aside from the title line, the first two columns in each line should contain the card identifiers.

- "Transmitted wave height at last fetch or obstruction = ______ which exceeds 0.5."

  The transect profile should be coded up to the inland limit where ground elevation intersects the stillwater elevation so that wave height should decrease to zero. If the scope of work ends at the corporate limits before the ground elevation meets the stillwater elevation, this message can be ignored.

- "Array dimensions exceeded. Job dumped."

  Size of the array is limited and the number of input parameters has exceeded the array. Check the number of input parameters at the location where the job dumped.

- "Invalid data in field 1 of IF card," etc.

  Check input data to make sure that data are in correct columns.

- "Wave period less than or equal to zero in subroutine fetch. Abort run."

  Either a fetch length or a wave period must be input for the program to run properly. Check input data.

- "Invalid data in field 3 or field 5 of VH card."

- "Invalid data in field 4 of VH card."

  Check input data.

- "Invalid data in field 3 of MG card."

  Check input data. The fraction of vegetated area covered by the stated plant type should be a decimal number between 0.0 and 1.0.

- "Missing MG card or incorrect data in field 6 of VH card."

  A MG card must always follow the VH card. Field 6 of the VH card pertains to the number of plant types, and one MG card is required for each plant type.

- "Invalid input data."

  Check input data for invalid characters, such as an O instead of a zero. Check to be sure that all data are in their correct columns.

- "Fcov was found to be negative for plant type = _______."

  Check input data to be sure that the decimal fraction of the vegetated area covered by the plant type is not negative.

- "Ncov is .LE. zero in Sub.Lookup when it should be .GT. zero. Abort run."

  Check input for number of plants covering the area.

- "The first card is not an IE card, this transect is aborted. Continued to next transect."

  The first card after the title line must always be an IE card. Check input data.

- "**** The surge elevation at this station (stationing ____), which is ____ card, is less than the ground elevation. The interpolation process is continued. *** Please double check the surge and ground elevations in the vicinity of this station!!!!!!"

The surge elevation should not be below the ground elevation. If the interpolated surge elevation is interpolated below the ground elevation, insert additional cards to specify surge and ground elevations and use an AS card if necessary.

- "Interpolation line cuts off more than two portions of high ground ridge. This transect is aborted, re-assign 100-year elevations at high ground stations."

When the interpolated value falls below the ground elevation, insert additional cards to better model the area and set the stillwater elevation equal to the ground elevation where appropriate. Insert AS cards as necessary.

- "**** Unreasonable high ground elevation at station ____ which is ____ card. This transect is aborted, continued to next transect. **** Double check the surge and ground elevations in the vicinity of this station. If the ground elevations are correct, either assign a higher surge elevation or use AS cards."

Add additional input data as necessary to better define the ground elevation and surge elevation in this area.

6.4 Output Description

The output of the program provides all the data necessary for plotting the BFEs and flood hazard zones along the transect. Examples are presented within Appendix A. The output is in six parts:

PART 1 - INPUT: This part is a printout showing all input data lines and the parameters assigned to each line, both manually and by default. This is followed by a more detailed printout with column headings for each input data line. When VH and MG Lines are used, a separate insert will be printed directly beneath the MG Line showing any default values supplied by the computer.

PART 2 - CONTROLLING WAVE HEIGHTS, SPECTRAL PEAK WAVE PERIOD, AND WAVE CREST ELEVATIONS: This is a listing of the calculated controlling wave heights, spectral wave peak periods, and wave crest elevations at the end point of each fetch and obstruction of the input, and at calculation points generated between the input stations.

PART 3 - LOCATION OF AREAS ABOVE 100-YEAR SURGE: This is a listing of the locations of areas where the ground elevation is greater than the 100-year stillwater (surge) elevation. Only areas identified by AS lines are listed.

PART 4 - LOCATION OF SURGE ELEVATIONS: This is a listing of the 10- and 100-year stillwater (surge) elevations and the stationing of the points where each set of stillwater elevations first becomes fully effective.

PART 5 - LOCATION OF V ZONES: This is a listing of the locations of the V/A zone boundary and locations of the V zone areas relative to these boundaries. The stationing is given for each V/A zone boundary. The locations of the V zone areas in relation to these boundaries are given as windward or leeward of the boundary.

PART 6 - NUMBERED A ZONES AND V ZONES: This is a listing of the zone data needed to delineate the flood hazard boundaries on the FIRM. The location of a flood zone boundary and the wave crest elevation at that boundary are given on the left. Between the boundary listings are the zone designations and FHFs. Under FEMA's Map Initiatives Procedure guidelines, all numbered V and A zones should be changed to VE and AE zones, respectively (elevations will not change), and the FHFs can be ignored (Reference 1). When the same zone and elevation are repeated in the listing, they should be treated as a single zone.