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April 6, 2015

Fay Rubin, Project Manager
Earth Systems Research Center
Eight College Road
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Durham, New Hampshire 03824

Re: Re: Summary of Additional Data Required to Support an Appeal of Preliminary Flood Insurance Rate Map (FIRM) number 33015CO432F in the Town of Rye, NH (dated March 5, 2015).

Dear Fay:

The Woods Hole Group is providing this follow-up Response to Comment document to address the conference call on March 30, 2015 in regards to the letter from FEMA requesting additional data for the Town of Rye, NH, dated March 5, 2015. Specifically, FEMA requested that we analyze 1) scour at the toe of the structure for failed structure analysis and 2) re-delineate the LiMWA.

The Woods Hole Group, Inc. analyzed Transect TR-39 (CHAMP TR-42) for both the intact and failed cases in the initial response to comment letter; however, FEMA requested that the reanalysis of the failed structure include scour. The reason that scour was twofold. First, there was no water depth at the toe of the structure and the scour equations from the Coastal Engineering Manual require water depth in order estimate the depth limited wave for scour to be calculated. Second, the document "New_Hampshire_Failed_Structures_070313.docx" in the Wave_Runup folder of the Coastal Data Backup Disk provided an explanation of why FEMA did not consider scour at the structure in question at Transect 39 (TR-42):

> *"Structures were failed for modeling purposes at transects 24, 26, 42, 58, and 59. Vertical walls were failed at a slope of 1.5 to 1 (H:V) and revetments were failed at a slope of 3 to 1 (H:V). Such approach is in line with the FEMA 2007 G&S Section D.2.9.4.5.2 and D.2.10. A preliminary scour analysis was conducted but resulting wave runup analysis provided too high wave runup elevation, not realistic for the study area. It was therefore considered to not perform scour analysis as limited information regarding the structure geometry was known."*

However, the initial reanalysis showed that wave runup reached the toe of the structure, and that scour could be possible. To do so require that scour be estimated based on engineering judgment since the existing scour equations do not adequately account for this unique situation. The 2007 FEMA Guidelines state that a conservative estimate for the maximum scour depth of a structure would be equivalent to the depth of the toe of the structure. Unfortunately, there are no as-built plans or survey data for the structure to determine the burial depth of the toe as noted in the Coastal Data Backup Disk. Another assumption states that the depth of scour can be approximated to be equal to the thickness of the armor layer of the structure. For this failed seawall case, it is assumed that the structure fails on a 1V:3H slope with stones from the seawall falling along this slope and acting as an armoring similar to that as a sloped revetment. The stones used to construct this seawall are about 1 foot in diameter, and, therefore, it is assumed that the depth of scour at the toe of the structure would be 1 foot deep so that the new toe for the failed structure would be set to 9.4 feet NAVD88. The failed structure slope of 1V:3H would start at this new structure toe depth and continue landward until it merged into the existing profile NAVD88 as shown in Figure 1.

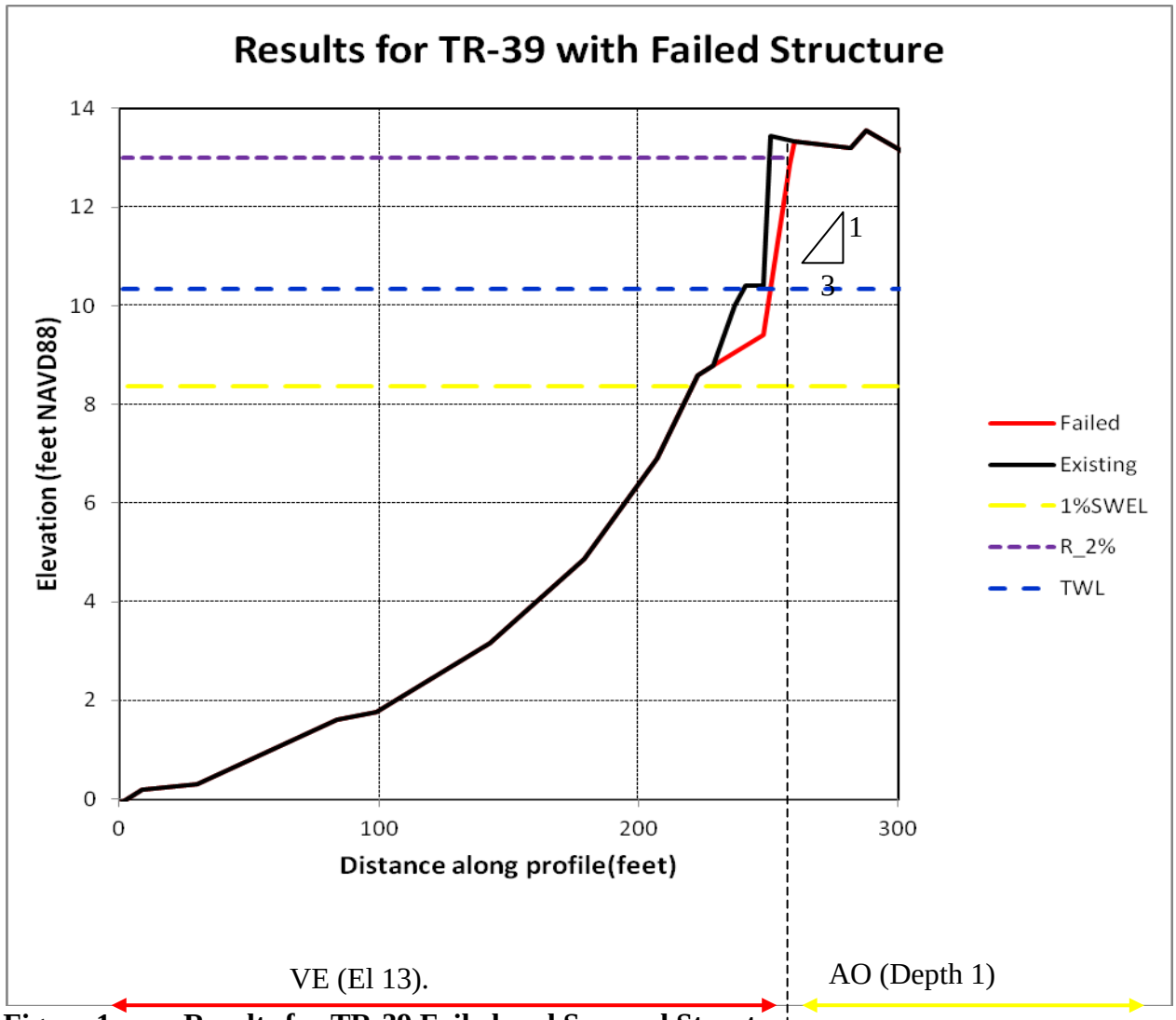

Figure 1. Results for TR-39 Failed and Scoured Structure.

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The failed structure case was then analyzed by the TAW Method and Overtopping to determine wave runup and a copy of the revised TAW Calculations are attached at the end of this document. The 2% runup value was calculated to be 2.79 feet for a resulting 2% runup elevation of 13.14 feet NAVD88. The TAW Method runup results for the failed case (VE El. 13) are more conservative than the WHAFIS results for the intact case (VE El. 12) from the initial response to comment letter, and, therefore, the runup results would be used to map the flood zones. Based upon the runup results, a VE Zone (El. 13) would be mapped to the crest of the structure and followed by an AO Zone (1 foot depth) based on runup and overtopping. The delineation of the landward extent of the AO Zone was retained from the initial PFIRM mapping since a comparison of the LIDAR contours to the new mapping results did not show enough change to warrant editing. The PFD was also removed from the TR-39 Transect Reach based upon the initial Appeal. A copy of the associated shapefiles is provided with this letter. A figure depicting the revised mapping is shown in Figure 2 below.

Additionally, Woods Hole Group reviewed the FEMA Operating Guidance document (OG-13-13) related to LiMWA delineation and determined that a LiMWA should not be mapped for this transect reach since the inland VE Zone limit is delineated using runup based on Item 4 of OG-13-13:

> "The LiMWA should not be shown on the FIRM in areas where the inland VE limit is delineated based on the Primary Frontal Dune (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. This guidance supersedes guidance in PM 50 which states it may be advantageous to continue the LiMWA across runup-dominated areas, and which states the LiMWA should be delineated immediately landward of the VE/AE Zone boundary in PFD and wave overtopping VE Zones."

However, the mapped FEMA LiMWA Shapefile is a continuous series polygons, rather than discontinuous line segments, meaning that a gap cannot be created along this Transect Reach within GIS. Therefore, LiMWA is mapped along the landward limit of the VE Zone (i.e. the VE – AO Zone boundary) as shown in Figure 2. A copy of the associated LiMWA shapefiles is provided with this letter.

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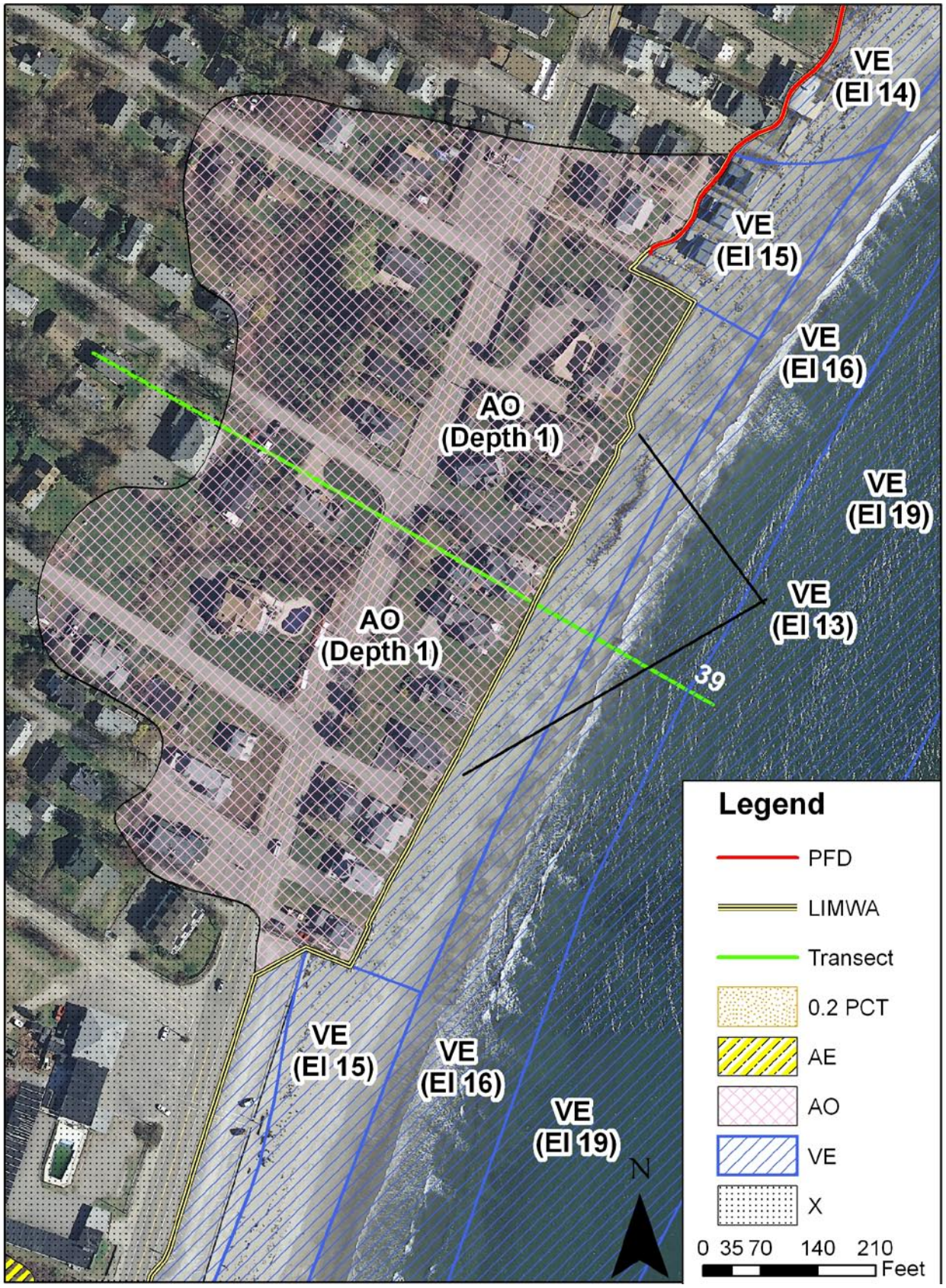

Figure 2. Revised Flood Mapping.

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If there are any questions in regards to the responses to the comments or there is need for additional data, please feel free to contact myself, Mitchell Buck, via phone (508-495-6210) or email (mbuck@whgrp.com).

Sincerely,

Mitchell Buck

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CALCULATIONS IN SUPPORT OF RUNUP

Analysis of Wave Runup on a Failed Seawall by TAW Method for Transect TR-39 (TR-42 in CHAMP) in Town of Rye, NH

The TAW method was originally formulated for manmade dikes, but has since successfully been applied by FEMA to natural shorelines that mimic a dike in function. The TAW method in this case was analyzed for the failed structure (seawall) case with scour. Note that initially this case was analyzed for a failed slope of 1V:1.5H as specified in the FEMA document "New_Hampshire_Failed_Structures_070313.docx"; however, it was found that Iribarren was not acceptable for the TAW Method and the failed slope was set to 1V:3H. It appears that FEMA had similar issues as a slope of 1V:3H was in fact used for TR-39/TR-42 for the TAW Method & Overtopping in the Overtopping Data Based in the Coastal Backup Data Disk.

Input Data and Assumptions

The following assumptions from are utilized:

- The Preliminary April 9, 2014 Preliminary FIRM Backup Data apply except where noted.
- Wave height, H_{mo}, is the deepwater wave height and is not in water of transitional depth.
- Wave period, T_p, remains constant and independent of depth for oscillatory waves
- Wave setup dynamically calculated by SWAN1D includes both the effects of static and dynamic wave setup.

The offshore wave parameters utilized by FEMA in the April 9, 2014 Preliminary FIRM Coastal Backup Data for Transect TR-39 apply to this location. Those parameters are:

- Peak Wave Period: **T_p = 11.66 seconds** (FEMA OFFSHORE STWAVE Results)
- Deepwater significant wave height: **H_0 = 25.1 feet** (FEMA OFFSHORE STWAVE Results)
- 1% Stillwater Elevation: **SWEL1% = 8.36 feet NAVD88** (FEMA Preliminary FIS)
- Wave Setup **η = 1.99** feet (WHG computed by SWAN1D)
- Acceleration due to gravity: **g = 32.17 ft/s^2**
- Structure Crest Elevation = 12.8 feet NAVD88
- Maximum Topo Crest Elevation = 13.55 feet NAVD88

STEP ONE – Determine Water Levels and Structure Configuration

The TAW method assumes that the wave that impacts the structure is the depth-limited wave at the toe of the structure; however, the total water level (SWEL1% + Wave Setup = 10.35 ft NAVD88) is below the toe of the structure in this case meaning that there is no wave impacting the structure toe. FEMA requested that we analyze scour at the toe of the wall so that the TAW method would be valid, however, the scour equations also rely on the water depth at the toe so it cannot be computed directly. Therefore, scour has to be estimated based on engineering judgment. The 2007 FEMA Guidelines state that a conservative estimate of maximum depth of scour for a structure would be equivalent to the depth of the toe of the structure. Unfortunately, there are no as-built plans or survey data for the structure to determine the burial depth of the toe. Another assumption states that the depth of scour can be

approximated to be equal to the thickness of the armor layer of the structure. For this failed seawall case, it is assumed that the structure fails on a 1V:3H slope with stones from the seawall falling along this slope so that it acts similar to a sloped revetment. The stones used to construct this seawall are about 1 foot in diameter, and, therefore, it is assumed that the depth of scour at the toe of the structure would be 1 foot deep so that the new toe for the failed structure would be set to 9.4 feet NAVD88. The failed structure slope of 1V:3H would start at this new structure toe depth and continue landward until it merged into the existing profile as seen in Figure 1 with a Structure Crest of 1. The depth at the toe is then calculated by subtracting the elevation of the scoured toe (9.4 ft NAVD88) from the total water level (10.35 feet NAVD88). Therefore, the depth, d_s, is calculated by:

→ d_s = SWEL1% + η – depth at shoal crest = 8.36 + 1.99 – 9.40 = **0.95 feet**

STEP TWO – Determine Wave Parameters

Now we need to determine the wave parameters at the failed seawall based on the offshore wave characteristics and transect data.

Check if Wave is depth limited at the structure:

- "Broken" if: $H_0 \geq 0.78*d_s$
  "Not Broken" if: $H_0 < 0.78*d_s$
  "Undetermined" if: otherwise

  → $H_0 = 0.78*d_s$ = **0.74 feet** < 25.1 feet
  Therefore, the wave that impacts the seawall is **"Broken"** and H_b will be used in place of the deepwater H_{mo}.

- Need to determine the deepwater wave length, L_0, from existing wave parameters:
  $L_0 = \frac{g * Tp^2}{2\pi}$ → Therefore, $\mathbf{L_0}$ **= 696.7 feet**

The wave type at the seawall is determined by the following criteria:

- Wave Type = "Shallow" if $d_s/L_0 < 0.2$
  "Transitional" if $0.2 \leq d_s/L_0 < 0.5$
  "Deep" if $d_s/L_0 \geq 0.5$

  → $d_s/L_0 = 0.001 < 0.2$ Therefore, the wave is a **"Shallow water wave"**

Now determine the local wave parameters at the seawall (H_{mo}, T_{m10}, and L_{mo}):

- H_{mo} = "d_s * 0.78" if wave "Broken"
  "H_{mo}" if wave "Not Broken"
  "0" otherwise

  → Wave Type is "Broken" from the first bullet therefore calculate the depth-limited wave:
  $H_{mo} = d_s * 0.78$ = **0.74 feet**.

The corresponding T_{m10} and L_{mo} are calculated as follows:

- $T_{m10} = T_p/1.1 =$ **10.6 seconds**
- $L_{mo} = \frac{g * T_{m10}^2}{2\pi}$ = **575.8 feet**

STEP THREE – Check TAW validity

The TAW method is valid is the following criteria are met:

- TAW Method is valid if:
  a. $0.5 < \zeta_{om} < 8\text{-}10$ where ζ_{om} is the Iribarren Number
  b. $1{:}1 < m < 1{:}8$ where m is the slope

→ Determine Iribarren number: $\zeta_{om} = \frac{m}{\sqrt{Hmo/Lmo}}$

Now calculate the Iribarren Number ζ_{om} based on the slope *m* of the failed seawall set to 1V:3H:

→ $\zeta_{om} = \frac{m}{\sqrt{Hmo/Lmo}} =$ **8.9**

Therefore, the **TAW Method is Valid** since $0.5 < \zeta_{om} =$ **8.9** $<$ 8-10 & $1{:}1 < m =$ **1:3** $<$ 1:8-10

STEP FOUR – Calculate Runup

Runup is calculated based on the TAW by the following method:

- Runup $R_{2\%} =$

$H_{mo}\,(1.77 * \gamma_r * \gamma_b * \gamma_\beta * \gamma_p * \zeta_{om})$	if $0.5 \le \gamma_b * \zeta_{om} < 1.8$
$H_{mo}\,[\,\gamma_r * \gamma_b * \gamma_\beta * \gamma_p * (4.3 - 1.6/\sqrt{\zeta om})]$	if $1.8 \le \gamma_b * \zeta_{om}$
0	Otherwise

Where γ_r, γ_b, γ_β, and γ_p are influence or reduction factors that are determined below:

- Roughness reduction factor: $\boldsymbol{\gamma_r = 1}$
  → Default 1.

- Wave Direction Factor: $\boldsymbol{\gamma_\beta = 1}$
  → The waves are normally incident, therefore this value is set to the default of 1.

- Berm Section Factor: $\boldsymbol{\gamma_b = 1}$
  → There is no berm so this value is set to the default is 1.

- Porosity Factor: $\boldsymbol{\gamma_p = 1}$
  → For an assumed default porosity of 0.5, the default is 1.

- Now determine which runup equation to use by calculating $\gamma_b * \zeta_{om}$

→ $\gamma_b * \zeta_{om} = 1*3.77 = 3.77 > 1.8$, therefore use second equation:

$R_{2\%} = H_{mo}\ [\ \gamma_r * \gamma_b * \gamma_\beta * \gamma_p * (4.3 - 1.6/\sqrt{\xi_{om}})]$ **= 2.79 feet**

- Now calculate the runup elevation by summing the runup and SWEL1%:

  → $Z_{2\%} = R_{2\%}$ + SWEL1% = **13.14 feet NAVD88**

In order to determine the new Base Flood Zone Elevation (BFE), the Runup Elevation must be rounded to the nearest foot. Therefore the new **BFE is 13 feet NAVD88.**

STEP FIVE – Check for Overtopping

Lastly, determine whether overtopping is occurring and, if so, the severity of the overtopping.

- Is the 2% runup elevation exceeding the barrier crest?
  $Z_{2\%}$ = 13.4 ft > failed structure crest =12.8 ft but $Z_{2\%}$ is same elevation as topo crest at 13.4 feet.

  → Yes, overtopping of the structure is occurring. The runup Depth is 13.4 – 12.8 = 0.6 feet over failed structure crest (but is below the topo crest) which falls in the range 0.1 – 1.5 feet that indicates that it is an AO Zone with a Depth of 1 foot based upon the 2007 FEMA Guidelines Section D.2.8.1.7.

- The mean overtopping rate is then calculated by the Coastal Engineering Manual (CEM) using the following formula (Eqn. IV-5-25) for overtopping by Van der Meer and Jansen (1995):

  $$Q_{mean} = 0.2\sqrt{gH_s^3}\ exp\left[-2.6\ \frac{Re}{H_s}\ \frac{1}{\gamma_r\gamma_\beta\gamma_b\ \gamma_p}\right]$$

  where R_e is the crest elevation above the TWL = 12.80 ft – 10.36 ft = 2.44 ft
  $H_s = H_{mo}$ = 0.74 feet
  $\gamma_r = \gamma_b = \gamma_B = \gamma_p = 1$

  → Q_{mean}= **0.0013 cfs/ft**

→ Based on Table D.2.8-6 of FEMA Guidelines this Q_{mean} of 0.00013 cfs/ft equates to an AO Zone with a 1 foot depth which reinforces the first bullet. Therefore, the final designation is a VE Zone with a BFE of 13 ft to the crest of the failed structure, followed by an AO Zone with a depth 1 foot moving landward until it reaches the 10 foot contour based upon the revised TWL of 10.35 feet.