Woods Hole Group 81 Technology Park Drive E. Falmouth, MA 02536 USA TELEPHONE: 508.540.8080 FAX: 508.540.1001 www.woodsholegroup.com

September 25, 2015

John Grace, CFM
Mitigation Risk Analysis Branch
FEMA Region I
99 High Street, Sixth Floor
Boston, MA 02110

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

Dear Mr. Grace,

The Woods Hole Group is providing this Response to Comment Letter to address the September 11, 2015 comment letter from FEMA and present the revised modeling and flood mapping related to the March 5, 2015 Preliminary FIRM Appeal for the Town of Rye in Rockingham Country, New Hampshire.

Included with this submittal are the following items:

- Revised Runup Analysis and FIRM remapping
- Revised CHAMP database for Transect TR-39 (FEMA Transect) and T2200 (2220 Ocean Blvd).
- Revised runup and overtopping calculations for TR-39 and the adjacent property at 2220 Ocean Blvd.
- GIS shapefiles showing the revised Flood Hazard Zone Mapping, LIMWA, and PFD.

Specific responses to the comments are as follows:

1. *In 2011 FEMA found an error in the 2007 FEMA G&S, Figure #2.8-3. Please ensure your calculations utilize the correct figure now enclosed in PM 60 or at https://www.fema.gov/media-library/assets/documents/23728.*

   Response: Runup calculations were updated using the corrected Figure #2.8-3 in the attached Calculations in Support of Runup.

2. *The wave condition used for the vertical wall was not calculated correctly. A breaking wave height was utilized for the wave runup on a vertical wall when the "equivalent" deepwater wave height is necessary.*

   Response: The runup calculations were revised to use an "equivalent" deepwater wave to the depth-limited wave height at the structure for Figure #2.8-3 based on Table C-1 of the Shore Protection Manual. More specifically, the ratio of depth at the structure to deepwater wave length, d/L_o, was used to find the relation of depth-limited wave to equivalent offshore wave, H/H'_o. Associated calculations are found in the attached analysis.

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3. *The incorrect slope was used for the failed wall condition. A slope of 1:1.5 is recommended by the 2007 FEMA G&S, not 1:3. Please see Figure 2.10-2. A failed slope of 1:3 could be applicable if justified by supporting evidence of appropriateness for specific type of material and location.*

Response: Woods Hole Group originally tried to use a failed-structure slope of 1:1.5, but found that the surf similarity (Iribarren Number), ζ_{om}, was outside the applicable range (1 – 8-10) for the TAW method applied to the depth-limited wave at the toe of the structure. In our review of the Preliminary FEMA Backup Data, we found that FEMA had also used a slope of 1:3 in their original calculations for failed structure case, which is why it was deemed appropriate for this analysis. However, the analysis has since been revised to use a failed structure slope of 1:1.5. See attached analysis and calculations for details.

4. *The elevation of the intact/failed crest of the structure is different at the two modeled locations (TR 39 and 2200 Ocean Drive). Please clarify what crest elevation is used in each case to determine the final mapped BFE.*

Response: Crest elevations for each intact and failed structure case for both transects are specified clearly in the analysis and Table 3 below. The more conservative case was used for mapping.

5. *Table 2 of your letter states a BFE of VE 14-19 based on what scenario (failed/intact) is used. However your proposed map shows a BFE of VE 13.*

Response: The WHAFIS results were incorrectly used to delineate the VE Zone at this location instead of runup. These calculations and results have since been revised meaning these original BFEs are no longer valid. The revised runup results attached below are used to delineate the VE Zone for this analysis.

6. *The LiMWA line should match the VE boundary. However, on your proposed map the LiWMA line is adjacent to the seawall.*

Response: A corrected LiMWA line is included on the attached CD.

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Revised Runup and Overtopping Analysis for Transects TR-39 and 2220 Ocean Blvd in the Town of Rye, NH

The following analysis of runup and overtopping was revised based on the September 11, 2015 comments from FEMA. Calculations for wave envelope, runup, and overtopping were revised based on the recent July 20, 2015 as-built survey drawings for Transect 2238 (TR-39) and 2220 Ocean Blvd. Figure 1 shows transect TR-39, the existing FEMA FIRM transect, and the additional transect that was struck at 2220 Ocean Blvd to use as a point of comparison.

Figure 1. Location of Transects TR-39 and 2220 Ocean Blvd.

Runup for FEMA Transect TR-39 (TR-42 in CHAMP)

Runup and overtopping was evaluated using for the existing FEMA Transect TR-39 (TR-42 in Champ database) for both the intact and failed structure cases. The total water level (TWL) of 10.35 feet NAVD88 includes both the 1%SWEL (8.36 ft NAVD88 from Preliminary FIS) and wave setup (1.99 ft computed by WHG using SWAN1D in the March 5, 2015 appeal). For the intact structure case, the elevation of the grade of the beach at the seawall (11.4 ft NAVD88) is above the TWL (10.35 ft NAVD88), and WHAFIS and Runup2.0 were used to evaluate waves and runup, respectively, since there is no water depth at the base of the structure for a wave to travel and impact the structure. Runup2.0 calculated a runup height, R2%, of 3.54 ft resulting in a runup elevation, Z2%, of 11.89 ft NAVD88 that is below the intact structure crest of 14.1 ft NAVD88. A depiction of the results for the intact structure case at TR-39 can be seen below in Figure 2 and the CHAMP database is included in the Data folder on the attached CD. As can be

seen from Figure 2, the 2% runup (red line) is the controlling process since the line is above and landward of limit of wave activity from WHAFIS (purple dashed line).

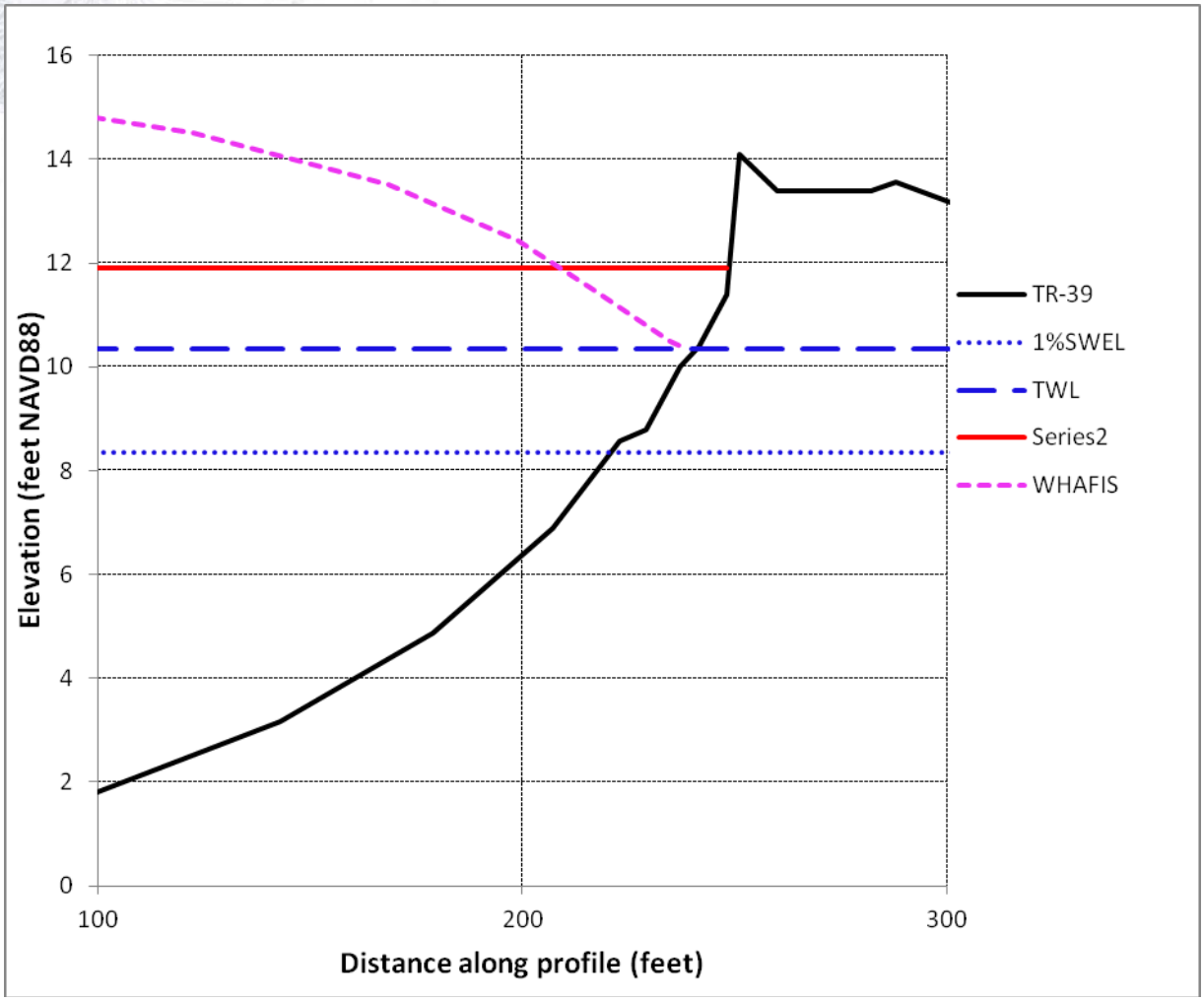

Figure 2. Revised CHAMP Results for intact structure case at TR-39 (TR-42 in CHAMP).

Next the failed structure (seawall) case for Transect TR-39 was analyzed for waves using WHAFIS and runup using the TAW method. First, the seawall was scoured to the toe of the seawall and then the seawall was failed on a 1V:1.5H slope from the scour hole until it merged with the existing ground profile landward of the original crest location; the elevation of the failed structure crest is 13.73 feet NAVD88. Then both WHAFIS and the TAW method were used to calculate the wave envelope and runup, respectively, on the failed seawall profile using the updated survey data from the July 20, 2015 as-built survey for the property. The TAW average-slope method was used because it is more applicable where small waves cause the Iribarren number to exceed the acceptable range. See the attached calculation sheet for TR-39 for details on failing the structure and the calculation of runup and overtopping. The 2% runup height, $R_{2\%}$, was 4.62 ft resulting in a runup elevation, $Z_{2\%}$, of 14.97 ft NAVD88, which is 1.24 feet above the failed structure crest of 13.73 ft NAVD88. As can be seen from Figure 3, the 2% runup (red line) is the controlling process since the line is well above and landward of limit of wave activity from WHAFIS (green purple line). Additionally, the runup elevation computed for the failed structure case (14.97 ft NAVD88) is greater than the runup for the intact structure case (11.9 ft NAVD88), indicating that the failed seawall case is the more conservative case for TR-39.

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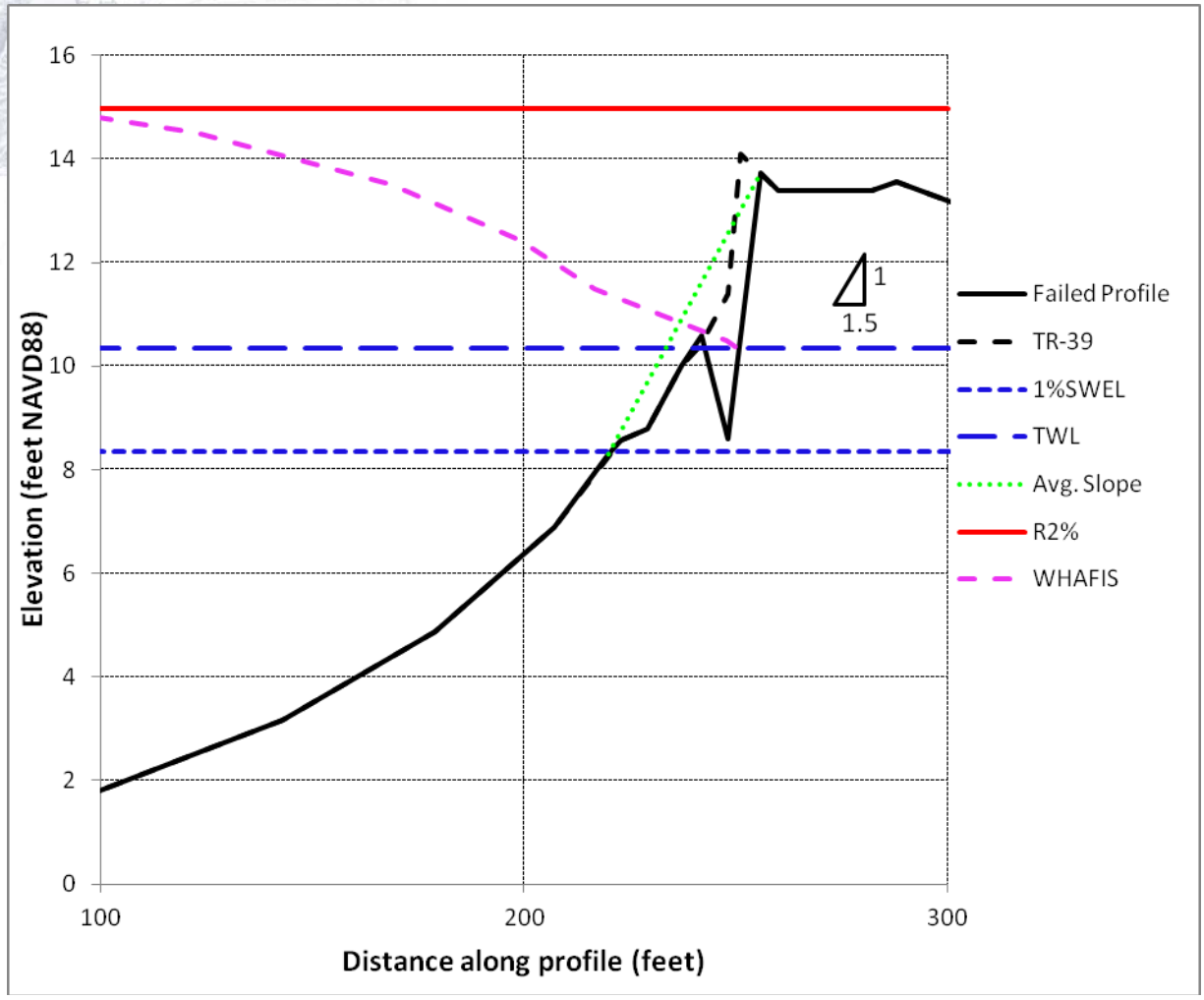

Figure 3. Runup results for failed structure case at TR-39 (TR-42F in CHAMP).

Runup for transect at 2220 Ocean Blvd

Waves, runup, and overtopping were evaluated for both an intact and failed seawall (structure) for the additional transect struck at 2220 Ocean Blvd (T2220 in CHAMP). For the case of an intact vertical seawall, the elevation of the grade of the beach (8.5 ft NAVD88) is below the TWL (10.35) meaning that there is a water depth of 1.85 ft at the base of the vertical seawall that can accommodate a depth-limited wave. The depth-limited wave height at the vertical seawall was estimated by multiplying the water depth at the seawall, d_s, of 1.85 ft by a breaker index of 0.78 resulting in a depth limited wave height, H, at the seawall of 1.44 ft. The equivalent deepwater wave, H'_o, to the depth limited wave was calculated using Table C-1 of the Shore Protection Manual (SPM) using a value of d_s/L_o of 0.0027, where Lo is the deepwater wave length of 697 feet (see attached calculation sheet). The ratio of d_s/L_o of 0.0027 equates to a ratio of H/H'_o of 1.967 resulting in an equivalent offshore wave height, H'_o, of 0.73 feet. For this case the deepwater wave is in fact smaller than the breaking wave height because the wave length is large relative to the water depth at the structure. These results for calculated the equivalent offshore wave height, H'_o, are summarized in Table 1 below.

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Table 1. Calculation of equivalent offshore wave height based on Table C-1 of the Shore Protection Manual.

	Input				Intermediate Output	
Parameter	d_s	H	L_o	d/L_o	H/H'_o	H'_o
Units	feet	feet	feet	--	--	feet
Value	1.85	1.44	697	0.0027	1.967	0.73

The equivalent deepwater wave height, H'_o, is then used to estimate runup from the updated Figure D.2.8-3 of the 2007 FEMA Guidelines. The resulting ratio of d_s/H'_0 of 1.28 is between the 1.5 and 3 curves (lines), and a value of approximately $R/H'_0 = 3.4$ was interpolated between the curves using an $H'_0/gT^2 = 0.0002$. Since the calculation of runup is derived from the depth-limited (i.e. maximum) wave height at the structure, and not the mean wave height, the resulting wave runup is directly computed to be 2.8 ft. Therefore, the resulting runup elevation, $R_{2\%}$, is 12.8 ft NAVD88 as shown in Table 2, which is below the intact structure crest of 13.8 ft NAVD88. Figure 4 depicts the wave envelope, water levels, and 2% runup for the intact structure case at 2220 Ocean Blvd.

Table 2. Calculation of runup on vertical wall using Figure D.2.8-3 of FEMA 2007 Guidelines.

	Input		Intermediate Output			Output		Crest Elev.
Parameter	d_s	H'_o	d_s/H'_0	H'_0/gT^2	R/H'_0	R_{mean}	$Z_{2\%}$	--
Units	feet	feet	--	--	--	feet	ft NAVD88	ft NAVD88
Value	1.85	0.73	2.5	0.0002	3.4	2.8	12.8	13.8

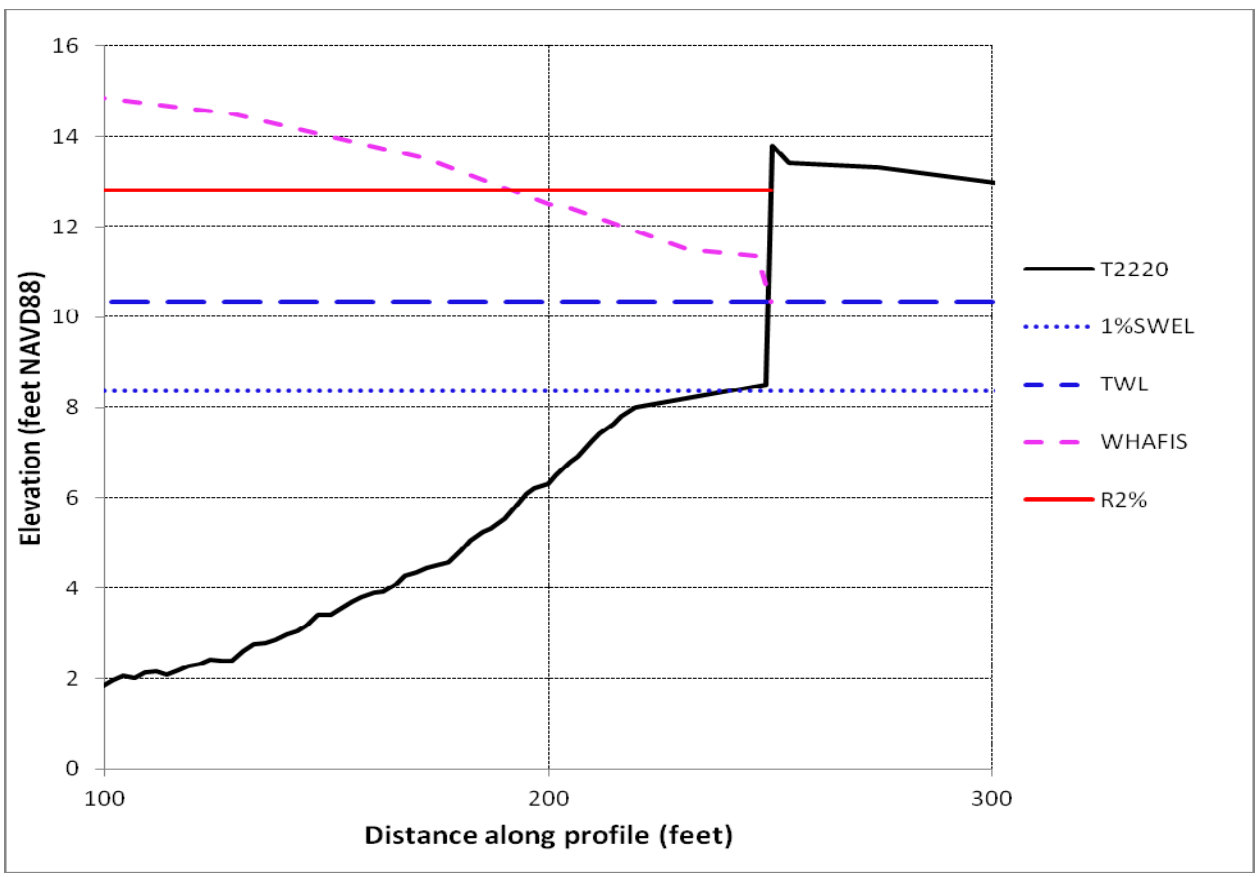

Figure 4. Revised WHAFIS and Runup Results for intact structure case at 2220 Ocean Blvd (T2220 in CHAMP).

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Next the failed structure (seawall) case for the transect at 2220 Ocean Blvd was analyzed waves, runup, and overtopping. See the attached calculation sheet for details on failing the structure and the calculations for runup and overtopping of the failed seawall (structure) case at 2220 Ocean Blvd. First, the seawall was scoured by an amount equivalent to the depth limited wave at the seawall (1.44 ft) from the intact case, and then the seawall was failed on a 1V:1.5H slope from the scour hole until it merged with the existing ground profile landward of the original crest location; the elevation of the failed structure crest is 13.40 feet NAVD88. The TAW method was used to calculate runup on the failed seawall using the updated survey data from the July 20, 2015 as-built survey for the property. The 2% runup height, $R_{2\%}$, was 5.70 ft resulting in a runup elevation, $Z_{2\%}$, of 16.05 ft NAVD88, which is 2.65 feet above the failed structure crest of 13.40 ft NAVD88. As can be seen from Figure 5, the 2% runup (red line) is the controlling process since the line is well above and landward of limit of wave activity from WHAFIS (green purple line). Additionally, the runup elevation computed for the failed structure case (16.05 ft NAVD88) is greater than the runup for the intact structure case (12.80 ft NAVD88), indicating that the failed seawall case is the more conservative case for the transect at 2220 Ocean Blvd.

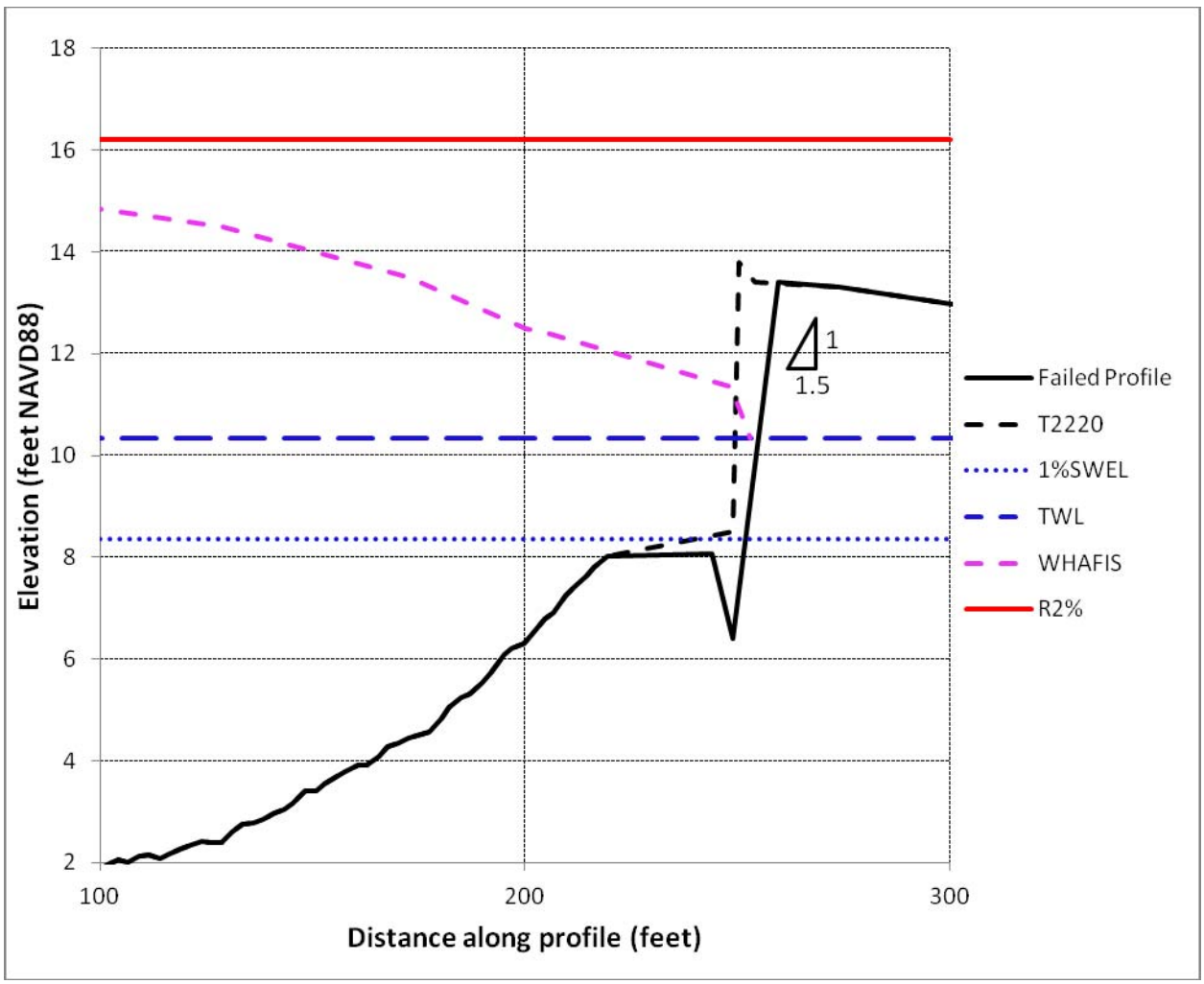

Figure 5. Revised WHAFIS and Runup Results for failed structure case at 2220 Ocean Blvd (T2220F in CHAMP).

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Summary and Revised Mapping

Table 3 presents a complete summary of the runup and overtopping results for all four (4) cases analyzed using various methods including the TAW method, Runup2.0, and updated Figure D.2.8-3. Also shown is the depth of water overtopping the structure crest. The last column indicates the resulting flood mapping results both seaward and landward of the structure crest based upon the 2007 FEMA Guidelines. The failed structure cases for the transect at 2220 Ocean Blvd produced the most conservative estimate of runup, and, therefore, was using to revise the Flood Hazard Zone mapping.

Table 3. Summary of runup and Overtopping Results for Transect Reach TR-39.

Case	Method	Crest Elev.	Runup Height	Runup Elevation	Overtopping Depth	Flood Zone Delineation	
						Seaward of Crest	Landward of Crest
Units	------	ft NAVD88	ft	ft NAVD88	ft	-----	
TR-39 Intact	Runup2.0	14.10	3.53	11.89	< 0	VE (12)	X
TR-39 Failed	TAW	13.73	4.62	14.97	1.24	VE (15)	AO (1-ft)
2220 Ocean Blvd Intact	Fig. D.2.8-3	13.80	2.50	12.80	< 0	VE(13)	X
2220 Ocean Blvd Failed	TAW	13.40	5.70	16.05	2.65	VE(16)	AO (2-ft)

Figure 6 shows the revised FIRM remapping. The revised FIRM mapping extended the VE (16) Zone from the offshore to the location of the failed seawall crest at 2220 Ocean Blvd, which is 6 ft landward of the existing intact crest. The VE-Zone was then delineated 6-ft landward of the seawall along this entire transect reach. An AO (2-ft) Zone was mapped landward of the failed structure crest and its landward extent was mapped using the NOAA 2011 LiDAR data set. The landward extent of the AO (2-ft) Zone is only slightly smaller than the preliminary FIRM because the AO Zone depth is only 1-foot less and the LIDAR contours are tightly spaced along this edge. While the BFE of the VE zone (15 ft NAVD88) is 1-foot greater than the preliminary FIRM, the VE - AO Zone boundary has been pushed seaward since the PFD has been removed as discussed in the original Appeal (please see original Appeal for documentation related to the PFD). The LiMWA delineation has also been moved to the boundary between the VE Zone boundary and AO 2-ft depth Zone. Associated GIS shapefiles including flood hazard mapping zones, PFD, and LiMWA related to the revised flood mapping are enclosed in the attached CD.

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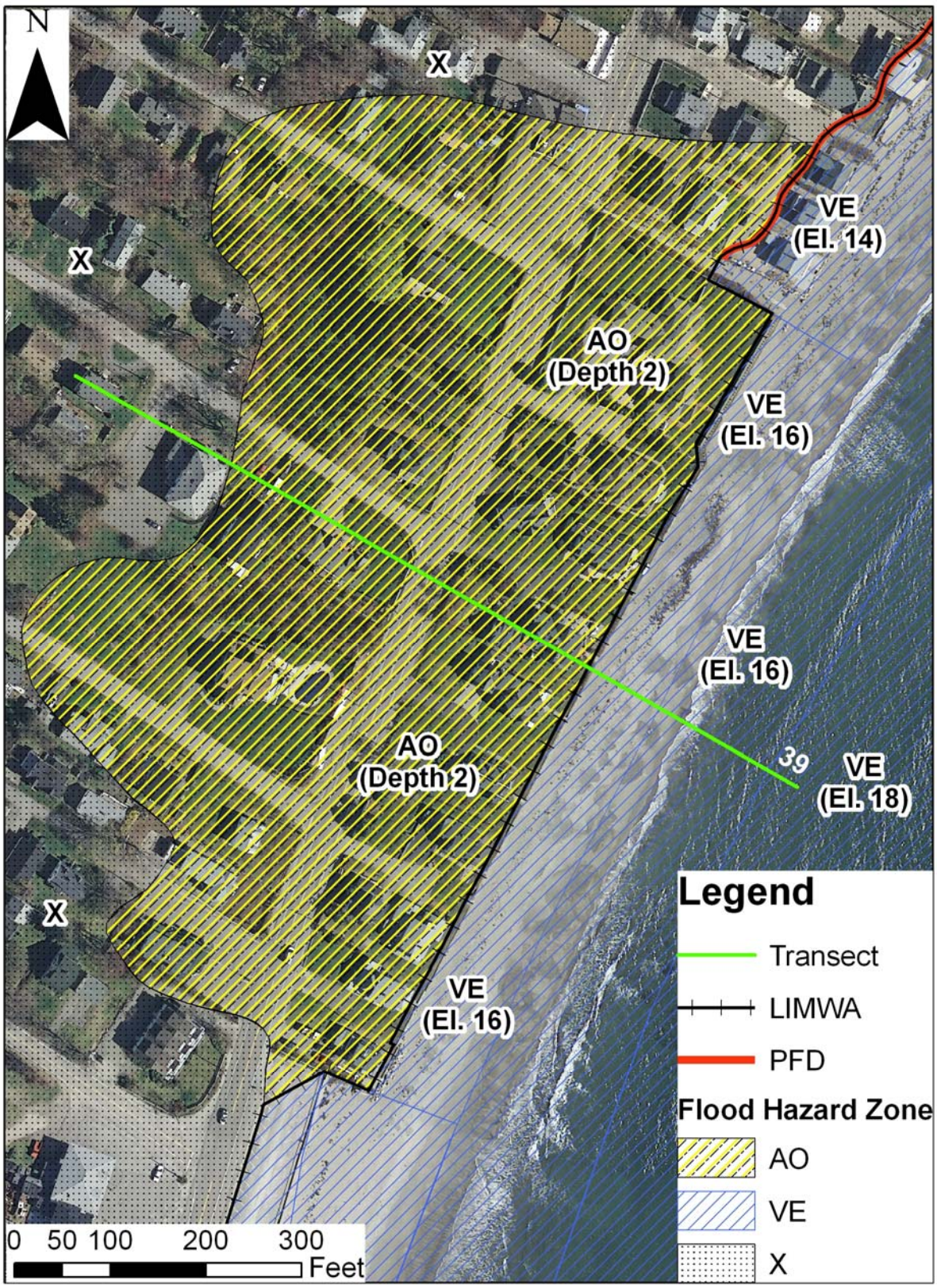

Figure 6. Revised Flood Mapping for Transect TR-39 on FEMA FIRM 33015C0432F.

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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 contact myself, Mitchell Buck, via phone (508-495-6210) or email (mbuck@whgrp.com).

Sincerely,

Mitchell Buck, P.E.
Coastal Engineer
Woods Hole Group
81 Technology Park Drive
East Falmouth, MA 02536

Enclosures: as stated

cc: Fay Rubin, UNH
Craig Musselman, Town of Rye
Marilyn Hilliard, FEMA Region 1
Jennifer Gilbert, CFM, New Hampshire Office of Energy and Planning
Edward O'Meara, Homeowner
Peter Rowell, Town of Rye
Michael Magnant, Town of Rye
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CALCULATIONS IN SUPPORT OF RUNUP

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

This worksheet uses the TAW Method to evaluate runup on a failed, scoured seawall for Transect TR-39 in the Town of Rye, NH.

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.
- Acceleration due to gravity: **g = 32.17 ft/s^2**

The offshore wave parameters utilized by FEMA in the April 9, 2014 Preliminary FIRM Coastal Backup Data and WHG Modeling Results from the March 5, 2015 Appeal for Transect TR-39 apply to this location including:

- 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)

The specifications for the seawall were taken from the July 20, 2015 As-built survey drawings including:

- Structure Crest Elevation = **14.1 – 14.2 feet NAVD88** (July 2015 Survey)
- Topo Crest Elevation = **13.4 feet NAVD88** (July 2015 Survey)
- Structure toe elevation = **8.6 – 9.3 ft NAVD88** (July 2015 Survey)
- Elevation of grade at base of wall = **11.4 ft NAVD88** (July 2015 Survey)

STEP ONE – Determine the Failed Profile and Water Levels

The failed structure (seawall) profile is determined by first estimating the depth of scour at the structure (seawall). The total water level, the sum of the SWEL% and Wave setup, for the 100-year storm is:

→ TWL = SWEL1% + Wave Setup = 8.36 + 1.99 = 10.35 ft NAVD88

Since the TWL (10.35 ft NAVD88) is below the grade of the beach at the base of the seawall (11.4 ft NAVD88), there was no depth-limited wave impacting the base of the seawall for the intact structure case. Therefore, scour cannot be computed directly using the methodologies from either the FEMA 2007 Guidelines or Coastal Engineering Manual. Therefore, scour has to be estimated based on engineering judgment. The most conservative estimate for the depth of scour would be equivalent to the

toe of the structure (the very bottom) of 8.6 ft NAVD88, for scour depth of 2.8. Note that a scour depth of 2.8 feet is a very conservative estimate for a situation where there is no water depth at the base of the structure during a large storm event. For this failed seawall case, it is assumed that the structure would first scour to 8.6 feet NAVD88 and then fail on a 1V:1.5H slope from the scour hole. The failed structure slope of 1V:1.5H would start at this new scoured toe elevation and continue landward until it merged into the existing profile landward of the original structure crest. The resulting failed structure crest is at 13.73 feet NAVD88 as seen in Figure 1. Seaward of the scoured toe, the slope of the beach was assumed to be on 1V:3H slope until it merged with the existing profile seaward of the toe.

Since the beach at the seawall has scoured to the toe below the TWL, it can now accommodate a depth-limited wave. The depth-limited breaking wave height, H_b, can be estimated using a breaker index of 0.78 based on the FEMA 2007 Guidelines. The water depth at the toe is then calculated by subtracting the elevation of the scoured toe (8.6 ft NAVD88) from the total water level (10.35 feet NAVD88). Therefore, the depth, d_s, is calculated by:

→ d_s = TWL – depth at toe = 10.35 – 8.60 = **1.75 feet**

Therefore, $H_b = 0.78*d_s$ = **1.37** ft

Profile TR-39 represents a special situation where a relatively small seawall is located at the upper end of the beach profile and landward limit of the surf zone. This limits the incoming waves to depth-limited, breaking waves at the structure toe that are much smaller than the offshore wave height. Additionally, the elevation of beach in front of the scour hole is about the same elevation as the TWL, which would limit wave activity from reaching the seawall. Section D.2.8.1.6 of the 2007 FEMA Guidelines states that for smaller waves in presence of a structure where the Iribarren number will be outside the applicable range for the TAW method applied to the structure slope, that instead the TAW average slope method should be used (verified see Step 3 below). Therefore, the representative slope used for wave run-up is the average slope in the zone between the Total Water Level (TWL) - $1.5 \bullet H_{m0}$ and the failed structure crest where the depth-limited breaking wave height, H_b, is be substituted for H_{mo}.

The average slope is now calculated between [TWL - $1.5 \bullet H_{m0}$] and the failed structure crest:

→ The location of the start of the slope is: TWL - $1.5 \bullet H_{m0}$ = 10.35 – 1.5*1.37 = **8.30** feet NAVD88 and the corresponding station is 220 ft

→ The location of the crest is station 256 ft and elevation 13.73 feet NAVD88.

→ The resulting average slope is (13.73 – 8.30)/(256 – 220) = **1V:6H**

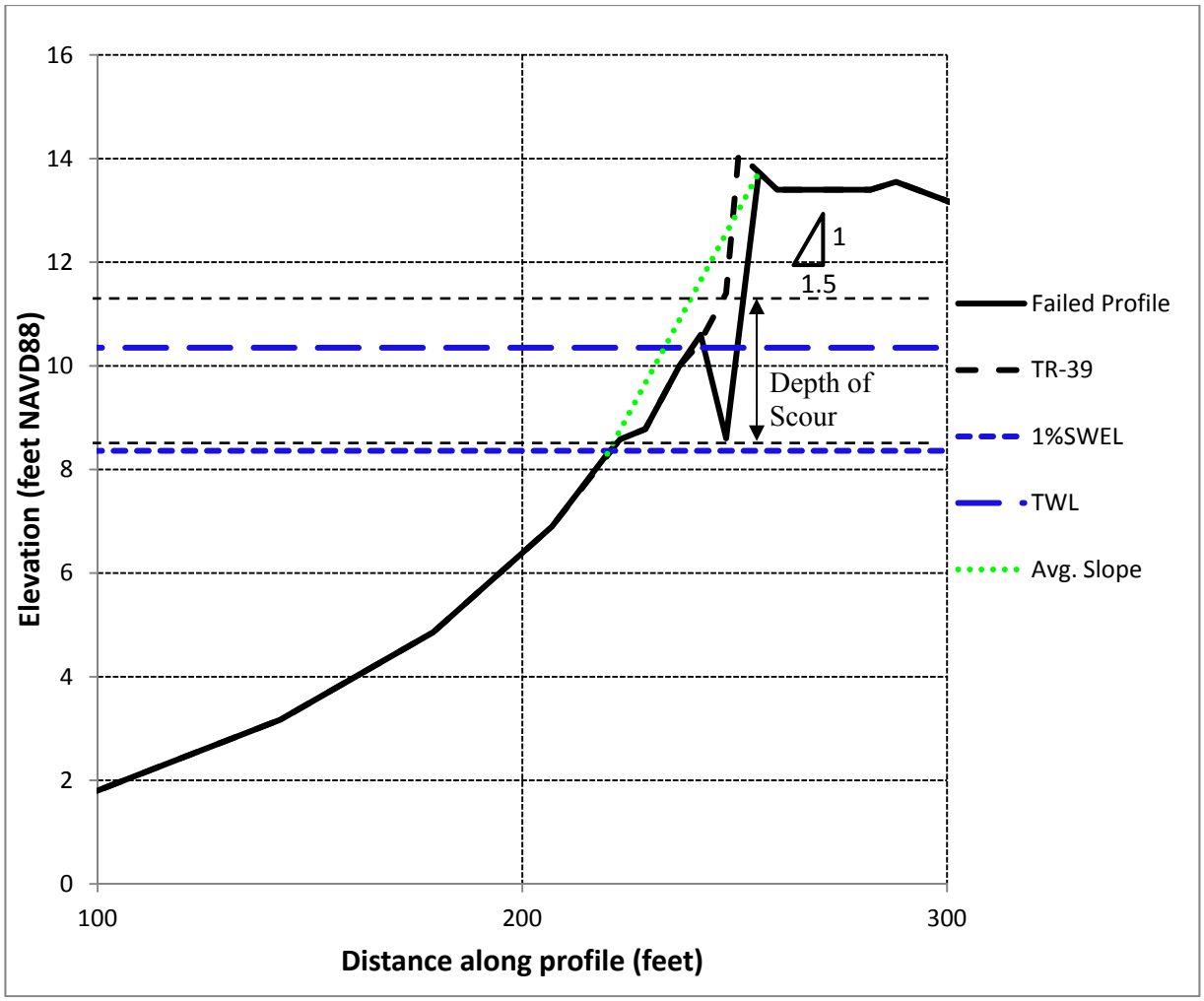

Figure 1. Intact versus failed structure profile for TR-39.

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

  → From Step One: H_b = **1.37 feet** < H_{mo} = 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 $d_s/L_0 \geq 0.5$

→ $d_s/L_0 = 0.002 < 0.2$ 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 at the structure: $H_{mo} = H_b$ = **1.37 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 average slope *m* of 1V:6H:

→ $\zeta_{om} = \frac{1/8}{\sqrt{Hmo/Lmo}}$ = **3.08**

Therefore, the TAW Method **is valid** since 0.5 < **3.08** < 8-10 and 1:1 < **1:6** < 1:8

Note, if the failed structure slope of 1V:1.5H is instead used to calculate ζ_{om} then it is out of applicable range:

→ $\zeta_{om} = \frac{1/1.5}{\sqrt{Hmo/Lmo}}$ = 1**3.67** > 10 Therefore TAW would **NOT** valid

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: $\boldsymbol{\gamma_r = 1}$

→ Typically a seawall would have a roughness reduction factor less than 1 but this is a composite "average" slope between the seawall and beach, therefore, γ_r is set to the 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: $\boldsymbol{\gamma_b = 1}$

→ The average slope method does not account for berms, therefore this value isset 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 $\gamma_b * \zeta_{om}$

→ $\gamma_b * \zeta_{om} = 3.08 > 1.8$, therefore use second equation:

$R_{2\%} = H_{mo}\,[\,\gamma_r * \gamma_b * \gamma_\beta * \gamma_p * (4.3 - 1.6/\sqrt{\xi_{om}})]$ **= 4.62 feet**

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

→ $Z_{2\%} = R_{2\%}$ + SWEL1% = **14.97 feet NAVD88**

STEP FIVE – Check for Overtopping

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

- Is the 2% runup elevation exceeding the barrier crest?

→ $Z_{2\%}$ = 14.97 ft > failed structure crest =13.73 ft

→ Yes, overtopping of the structure is occurring. The runup Depth is 14.97 – 13.7 = 1.24 feet over the structure crest which falls in the range of 0.1 to 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.

2) Analysis of Wave Runup on a Failed Seawall by TAW Method for 2220 Ocean Blvd near Transect TR-39 (TR-42 in CHAMP) in Town of Rye, NH

This worksheet uses the TAW Method to evaluate runup for the failed seawall case for 2220 Ocean Blvd in the Town of Rye, NH.

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.
- Acceleration due to gravity: **g = 32.17 ft/s^2**

The offshore wave parameters utilized by FEMA in the April 9, 2014 Preliminary FIRM Coastal Backup Data and WHG Modeling Results from the March 5, 2015 Appeal for Transect TR-39 apply to this location including:

- 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)

The specifications for the seawall were taken from the July 20, 2015 As-built survey drawings including:

- Structure Crest Elevation = **13.8 – 13.9 feet NAVD88** (July 2015 Survey)
- Topo Crest Elevation = **13.4 feet NAVD88** (July 2015 Survey)
- Structure toe elevation **6.4 – 7.1 ft NAVD88** (July 2015 Survey)
- Elevation of grade at base of wall = **8.5 – 8.6 NAVD88** (July 2015 Survey)

STEP ONE – Determine Water Levels and Failed Structure Condition

The failed structure (seawall) profile is determined by first estimating the depth of scour at the structure (seawall). The total water level, the sum of the SWEL% and Wave setup, for the 100-year storm is:

→ TWL = SWEL1% + Wave Setup = 8.36 + 1.99 = 10.35 ft NAVD88

A conservative estimate for the depth of scour is an equivalent amount to the depth limited wave at the base of the structure. The depth at the structure, d_s, is calculated by subtracting the elevation of the grade of the beach at the seawall (8.5 ft NAVD88) from the total water level (10.35 feet NAVD88) for a water depth of 1.85 feet. The depth-limited breaking wave height, H_b, can then be estimated using a breaker index of 0.78 based on the FEMA 2007 Guidelines:

$H_b = 0.78 * d_s = 0.78 * 1.85 =$ **1.44 feet**

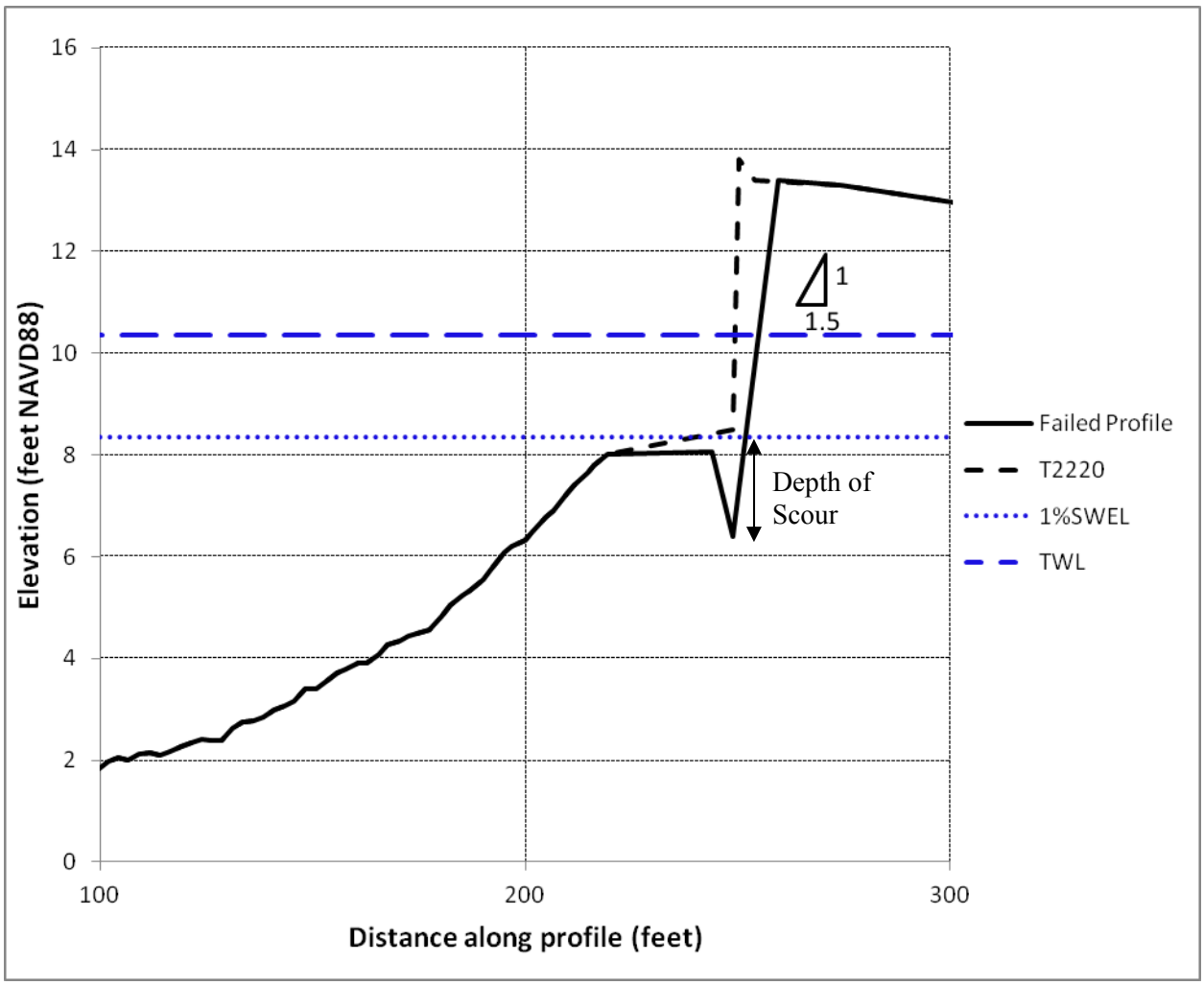

Figure 1. Intact versus failed structure profile for 2220 Ocean Blvd.

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

→ d_s = TWL – (elevation of toe - scoured depth) = 10.35 ft – (8.5 ft – 1.44 ft) = **3.29 feet**
(where scour depth = breaking wave height at structure)

$H_b = 0.78*d_s$ = **2.57** ft

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 $d_s/L_0 \geq 0.5$

  → $d_s/L_0 = 0.002 < 0.2$ 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 at the structure: $H_{mo} = H_b =$ **2.57 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 failed structure slope *m* of 1V:1.5H:

→ $\zeta_{om} = \frac{m}{\sqrt{Hmo/Lmo}} = \mathbf{9.98}$

Therefore, the TAW Method **is Valid** since $0.5 < \zeta_{om} = \mathbf{9.98} < 8\text{-}10$ & $1{:}1 < m = \mathbf{1{:}1.5} < 1{:}8$

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 $0.5 \leq \gamma_b * \zeta_{om} < 1.8$

H_{mo} [$\gamma_r * \gamma_b * \gamma_\beta * \gamma_p * (4.3 - 1.6/$ $)$] if $1.8 \leq \gamma_b * \zeta_{om}$
0 Otherwise

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

- Roughness reduction factor: $\boldsymbol{\gamma_r = 0.8}$

→ The seawall is constructed of stone filled with cement and has roughness even when it has failed. This value was taken from the original TAW Report (2002) for rock filled with cement.

- 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: $\boldsymbol{\gamma_b = 1}$

→ This profile has a berm in front of the failed seawall and it must be incorporated into the calculation of runup. From Figure 2, first calculate the depth of water over the center of the berm (d_H), berm width (B), and berm length (L_{berm}):

d_H = 2.29 ft, B = 29.5 ft, & L_{berm} = 64.0 ft

→ Now calculate **x** based on Equation D.2.8-11 of 2007 FEMA Guidelines:

$d_H/H_{mo} = 2.29/2.57 = 0.89 < 2$, therefore $X = 2*H_{mo} = 5.14$ ft

Finally, $\boldsymbol{\gamma_b} = 1 - B/[2*L_{berm}]*[\cos(\pi*d_H/x)] = \mathbf{0.73}$

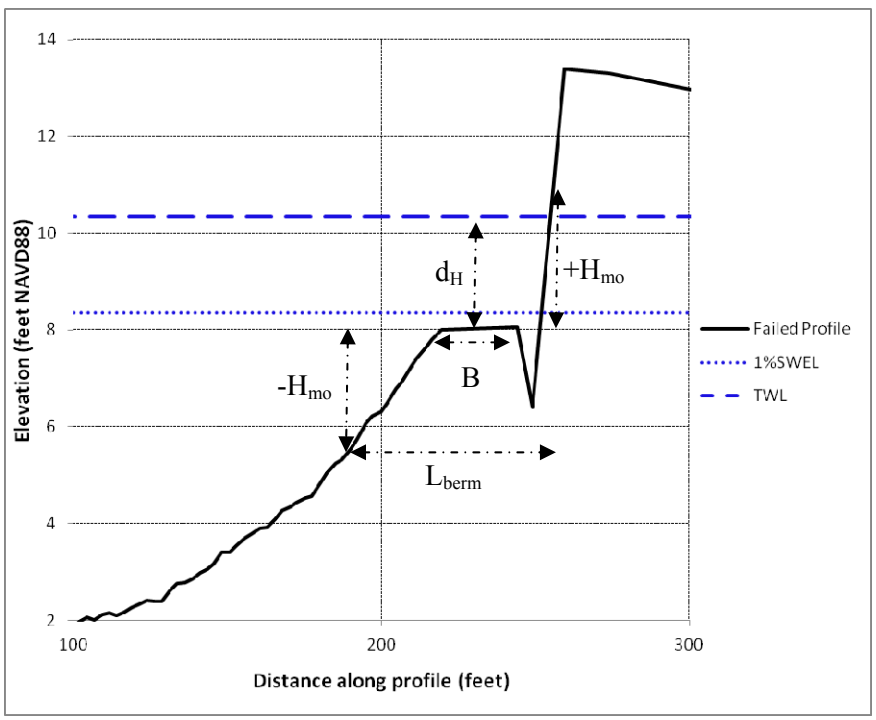

Figure 2. Berm Parameters for Wave Runup.

- 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 $\gamma_b * \zeta_{om}$

  → $\gamma_b * \zeta_{om} = 9.98 > 1.8$, therefore use second equation:

  $R_{2\%} = H_{mo} [\gamma_r * \gamma_b * \gamma_\beta * \gamma_p * (4.3 - 1.6/\sqrt{\xi_{om}})]$ **= 5.70 feet**

- Now calculate the runup elevation by summing the runup and TWL:

  → $Z_{2\%} = R_{2\%} + TWL =$ **16.05 feet NAVD88**

STEP FIVE – Check for Overtopping

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

- Is the 2% runup elevation exceeding the barrier crest?

  → $Z_{2\%} = 16.05$ ft > failed structure crest =13.4 ft

Yes, overtopping of the structure is occurring. The runup Depth is 16.05 – 13.4 = 2.65 feet over the structure crest which falls in the range of 1.5 to 2.9 feet that indicates that it is an AO Zone with a Depth of 2 foot based upon the 2007 FEMA Guidelines Section D.2.8.1.7.