

ULDC Analysis of the RD 17 Levee Wind Setup and Wave Runup Calculations



Purpose

The *Urban Levee Design Criteria* (ULDC) defines minimum top of levee (MTOL) requirements as the median 200-year water surface elevation (WSEL) plus the higher of (a) 3 feet, or (b) height for wind setup and wave runup. This Technical Memorandum (TM) presents the analysis used to determine the height for wind setup and wave runup along the RD17 levee system.

Study Methodology

The methodology for determining the wind setup and wave runup values for this study follow the requirements presented in the ULDC. The wind setup and wave runup calculations are based on the potential wind speed, wind direction, fetch length, and water depth along the fetch line. Guidance for developing these parameters is given in the following USACE documents:

- Coastal Engineering Manual, EM 1110-2-1100 (CEM)
- Shore Protection Manual (SPM)
- Process for the National Flood Insurance Program Levee System Evaluation, EC 1110-2-6067

Note that no guidance is given for addressing the impact of downstream river flow on the wind setup and wave runup calculation due to upstream and/or downstream winds.

Wind Speed and Duration

The ULDC defines the wind speed to be used as that which has a 50 percent non-exceedance probability in any year during a 50-year design period. This criterion yields a design wind speed with a return period of 72.6 years, or an annual probability of 0.0138. For this study, 57 years of hourly wind speed data were



analyzed from the shared National Oceanic and Atmospheric Administration (NOAA) and Western Regional Climate Center (WCRR) weather station at the Stockton Metropolitan Airport¹. Prior to use in the wind setup and wave runup calculations, the computed design wind speed was standardized to a 10-meter observation level using the CEM 1/7 rule (CEM Equation II-2-9). For fetch lengths less than 16km, the CEM recommends a factor of 1.2 to increase the wind speed for over water conditions.

The ULDC also states that the wind speed duration to be used in these calculations should be less than one-hour duration. The CEM notes that the wind duration that generates maximum wave runup is a function of the fetch length and the wind speed. When the fetch is limited, as in a river application, CEM Figure II-2-3 can be used to provide an equivalent duration for wave generation. For the fetch lengths analyzed in this study, the equivalent wind speed durations ranged from 60 to 90 minutes. To meet the requirements of the ULDC, a one-hour wind speed duration was selected for all conditions. This selection represents a conservative approach to the calculation of wind setup and wave runup.

Wind Direction and Fetch Length

The fetch is defined as the region in which the wind speed and direction are reasonably constant. In river settings, the fetch is limited by surrounding landforms. Under these circumstances, the SPM recommends determining the fetch length by extending 9 radials from the point of interest at 3-degree intervals (centered on the maximum wind direction) until they intercept the opposite shoreline. In dryland settings, the fetch is limited by the extent of the floodplain (a 200-year floodplain will be used for this study). Under these circumstances the fetch length will be determined by extending 9 radials from the point of interest at 3-degree intervals until they intercept the edge of the floodplain. The average of the 9 radial lengths represents the fetch length for a given wind direction.

Water Depth

The water depth at the toe of the levee at the design surface water elevation is used in the calculation of wave runup. The average water depth across the entire fetch length is used in the calculation of wind setup. For the purposes of this study, it is assumed that the design surface water elevation is the median 200-year still water elevation. Hydraulic modeling results² were used to determine average depths along the fetch lines.

Wind Analysis

The wind data from the Stockton Metropolitan Airport weather station is recorded as an hourly average wind speed with the prevailing wind direction in degrees. For this analysis, the wind speeds were separated into wind direction categories:

- North (337.5 to 22.5 degrees)
- Northeast (22.5 to 67.5 degrees)

¹ Period of Record from 1948 - 2014. No data was available from 1955 to 1962, but the remaining 57 years of data was available.

² 200-year Freeboard Analysis & Floodplain Mapping within RD17.Prepared for Cities of Lathrop and Manteca, May 23, 2014.



- East (67.5 to 112.5 degrees)
- Southeast (112.5 to 157.5 degrees)
- South (157.5 to 202.5 degrees)
- Southwest (202.5 to 247.5 degrees)
- West (247.5 to 292.5 degrees)
- Northwest (292.5 to 337.5 degrees)

The wind speed data was then analyzed using HEC-SSP to perform a generalized frequency analysis to determine the 72.6-year return period wind speed for each wind direction. The resulting wind speeds represent the 72.6-year return period, 60-minute wind speed at an elevation of 7.9m over land. For use in the wind setup and wave runup calculations, these wind speeds must be corrected for an elevation of 10m over water. Table 1 presents the HEC-SSP output wind speed for each wind direction category along with the necessary elevation and over water corrections. Note that for the remainder of the wind setup and wave runup analysis, the wind speeds presented in the "Corrected for Over Water Wind Speed" column will be used.

	72.6-year Return Period, 60-minute Wind Speed (mph)						
Wind Direction	Observed at Stockton Metropolitan Airport Weather Station	Corrected for 10m Elevation	Corrected for Over Water Wind Speed				
North	47	49	58				
Northeast	26	27	32				
East	34	35	42				
Southeast	47	49	58				
South	51	53	63				
Southwest	37	38	46				
West	39	40	48				
Northwest	44	46	55				

Table 1. Design wind speed for each wind direction

Fetch Length Determination

Figures 1 and 2 present the fetch lengths for each wind direction along the riverine segment of the RD17 levee. Due to the narrow corridor between the left and right banks of the San Joaquin River, the fetch lengths were minimal.

Figure 3 presents the south wind direction fetch lines that are the worst case wind scenarios for the RD 17 dryland levee. Three different analysis points were selected along the dryland levee. An additional fetch length was analyzed at the edge of the floodplain, approximately 3,000 feet east of the RD17 dryland levee. The south wind is the controlling wind for the dryland segment of the levee as it has the highest wind speeds, the longest fetch lengths, and the most direct wave angle approach.



South East Wind Direction

North Wind Direction

BEINEI

120 CANEDE CANZON

HSR

ELcuise Ave

North East Wind Direction

West Wind Direction

South Wind Direction

156

S

South West Wind Direction

Legend North Wind Direction Fetch ╉ North-East Wind Direction Fetch B South-East Wind Direction Fetch ◀ South Wind Direction Fetch South-West Wind Direction Fetch West Wind Direction Fetch RD17 Levee Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community, Esri, HERE, DeLorme, MapmyIndia, @ OpenStreetMap contributors - Other Levees 6 CITY OF LATHROP/MANTECA - 200YR PLAN FIGURE 2,000 PETERSON . BRUSTAD . INC ENGINEERING . CONSULTING Feet **RD 17 LEVEE** 1 in = 2,500 ft 2 Phone: (916) 608-2212 Fax: (916) 608-2232 WORST CASE FETCH LENGTHS 1180 Iron Point Rd., Suite 260 **DECEMBER 2, 2014** Folsom, CA 95630





In the calculation of wind setup and wave runup, a longer fetch is one of the key factors that results in a greater wind/wave value. To evaluate the worst case wind setup and wave runup values, the location along the RD17 riverine levee that would yield the longest fetch for each of the 8 wind directions was determined. Table 2 presents a summary of the worst case fetch length for each wind direction along the RD17 riverine levee. Table 3 presents a summary of the fetch lengths for the south wind direction for the RD 17 dryland levee.

The wave approach angle also impacts the calculation of wave runup – with waves that approach perpendicular to the levee generating the greatest wave runup.

Note that in the case of Profile 4 on the dryland levee, the placing of fill to create high ground is assumed in place of a dryland levee extension. Therefore, wave runup is not included as part of the analysis for Profile 4.

Note also that Table 2 presents the wind direction relative to the river flow. While there is no guidance for calculating a reduction in wind setup and wave runup, the effect of river flow on upstream wind should reduce the values of wave runup.

Wind Direction ⁽¹⁾	Worst Case Location (Approx. Levee STA)	Fetch Length (ft)	Wave Approach Angle ⁽²⁾ (degrees)	Wind Direction Relative to River Flow
		Riverine Levee		
North	518+65	3,928	5	Upstream
Northeast	631+95	2,262	22	Upstream
East	61+05	2,183	70	Downstream
Southeast	558+35	2,119	78	Downstream
South	688+25	3,110	37	Downstream
Southwest	822+25	4,928	35	Downstream
West	646+15	1,964	42	Upstream
Northwest	80+95	2,860	45	Upstream
Notes				

Table 2. Fetch Length Determination by Wind Direction for the RD17 Riverine Levee

Notes

⁽¹⁾ Wind direction represents the direction the wind is coming from (e.g. North wind direction represents wind out of the North)

⁽²⁾ Wave approach angle equals zero for wave perpendicular to the levee.



Wind Direction ⁽¹⁾	Location (Approx. Levee STA)	Fetch Length (ft)	Wave Approach Angle ⁽²⁾ (degrees)
		Dryland Levee	
South	854+10	9,658	0
South	908+60	14,573	0
South	971+60	27,139	0
South	N/A ⁽³⁾	32,442	0

Table 3. Fetch Length Determination by Wind Direction for the RD17 Dryland Levee

Notes:

⁽¹⁾ Wind direction represents the direction the wind is coming from (e.g. North wind direction represents wind out of the North) ⁽²⁾ Wave approach angle equals zero for wave perpendicular to the levee.

⁽³⁾ Analysis point is approximately 3,000 feet east of the existing RD17 dryland levee and is in an area that will be re-graded to become high ground.

Wind Setup

When wind blows over water it exerts a shear stress on the water surface. Although the wind shear stress is usually very small, its effect, when integrated over a large body of water, can result in an increase of water level at the leeward end. This effect is called wind setup. Wind setup can be estimated for small bodies of water based on Equation 15-1, USACE *Hydrologic Engineering Requirements for Reservoirs* (EM 1110-2-1420):

 $S = \frac{U^2 F}{1400d}$ Where S = wind setup (ft) U = average wind speed (mph)

F = fetch distance (miles)

d = average water depth along the fetch line (ft)

This equation is known as the Zeider Zee equation which is most appropriate for large reservoirs. For shallow water bodies, the Sibul equation below is more appropriate.

$$S = d * 2.44 * 10^{-5} * \left(\frac{F}{d}\right)^{1.66} * \left(\frac{U^2}{F * g}\right)^{\left(2.02 * \left(\frac{F}{d}\right)^{-0.0768}\right)}$$

Where S = wind setup (ft)

d = average water depth along the fetch line (ft)

F = fetch distance (ft)

U = average wind speed (ft/sec)

g = gravitational constant = 32.2 ft/sec

Recent USACE study suggested averaging the two equations when dealing with shallow impoundments (*Design Criteria Memorandum 2*, USACE/South Florida Water Management District, 2006).

The average water depth along the fetch line was estimated using the ground surface profile along the fetch line in conjunction with the HEC-RAS median 200-yr water surface elevation for the riverine segments and the FLO-2D median 200-year flood depth for dryland segment. Table 4 presents the



estimated average water depth and the calculated wind setup height for each worst case wind direction for the RD17 riverine levee. Table 5 presents the estimated average water depths and the calculated wind setup heights for the four analysis points along the RD17 dryland levee.

For average water depths greater than 16 feet, the calculated wind setup height was derived from the Zeider Zee equation only. Where average water depths were estimated to be less than 16 feet, the calculated wind setup height was taken by averaging the Zeider Zee equation and the Sibul equation.

In general, the greatest wind setup values are generated from the north and south wind directions which are the directions with the greatest wind speeds and the longest fetches.

Wind Direction	Worst Case Location (Approx. Levee STA)	Average Water Depth (ft)	Zeider Zee Wind Setup (ft)	Sibul Wind Setup (ft)	Applied Wind Setup (ft)		
Riverine Levee							
North	518+65	12	0.15	0.11	0.13		
Northeast	631+95	14	0.02	0.01	0.02		
East	61+05	8	0.07	0.05	0.06		
Southeast	558+35	15	0.07	0.06	0.06		
South	688+25	21	0.08	0.07	0.08		
Southwest	822+25	18	0.08	0.05	0.08		
West	646+15	24	0.03	0.02	0.03		
Northwest	80+95	11	0.10	0.08	0.09		

Table 4. Wind Setup Height for the RD17 Riverine Levee

Table 5. Wind Setup Height for the RD17 Dryland Levee

Wind Direction	d Direction Location (Approx. Levee STA)		Zeider Zee Wind Setup (ft)	Sibul Wind Setup (ft)	Applied Wind Setup (ft)
		Dryland L	evee		
South	854+10	12	0.43	0.25	0.34
South	908+60	11	0.75	0.41	0.58
South	971+60	9	1.62	0.84	1.23
South	N/A ⁽¹⁾	7	2.41	1.26	1.83
Notes:					

⁽¹⁾ Analysis point is approximately 3,000 feet east of the existing RD17 dryland levee and is in an area that will be re-graded to become high ground.

Wave Runup

Wave runup is defined as the vertical height above the still water level to which an incident wave will run up the bank of the levee. The wave runup depends primarily on the levee bank slope, the water depth at the levee toe, fetch length, wind speed, and wave approach angle. One method to determine wave runup determines the 2% wave runup elevation, which represents the elevation above the still water level that is exceeded by only 2% of the waves. Before the wave runup can be calculated, the wave characteristics must be determined – specifically the significant wave height and the peak wave period. These two parameters were determined using CEM Equation II-2-36:



$$\frac{g * H_{mo}}{u_f^2} = 0.0413 * \left(\frac{g * x}{u_f^2}\right)^{\frac{1}{2}} \quad \text{and} \quad \frac{g * T_p}{u_f^2} = 0.751 * \left(\frac{g * x}{u_f^2}\right)^{\frac{1}{3}}$$
Where: H_{mo} = significant wave height (ft)
T_p = peak wave period (sec)
X = fetch length (ft)
g = gravitational constant = 32.2 ft/sec
u_f = friction velocity (ft/sec)
= $(C_D * U_{10}^2)^{\frac{1}{2}}$
C_D = drag coefficient
= 0.0002 * (1.1 + 0.035 * U_{10})
U₁₀ = wind speed at 10m elevation (ft/sec)

Wave runup on a structure depends on the type of wave breaking. Wave breaker types are identified by their surf similarity parameter. With the wave characteristics defined, H_{mo} and T_p can be used to determine the surf similarity parameter per CEM Equation VI-5-2:

$$\varepsilon_p = \frac{\tan(\alpha)}{\sqrt{\frac{2\pi * H_{mo}}{g * T_p^2}}}$$

Where:

 ϵ_p = surf similarity parameter tan(α) = waterside slope of levee (assumed 1V:3H for all wind direction conditions)

After defining the wave and wave breaking characteristics, the 2% wave runup elevation can be calculated per CEM Equation VI-5-3:

$$R_{2\%} = H_{mo} * (A * \varepsilon_p + C) * \gamma_r * \gamma_b * \gamma_h * \gamma_\beta$$

Where:	R _{2%}	= 2% wave runup elevation (ft)
	A,C	= coefficients dependent on ε_p ($\varepsilon_p < 2$, A = 1.6, C = 0 and ($2 < \varepsilon_p <$
		9, A = -0.2, C = 4.5 per CEM Table VI-5-2)
	γ_r	= reduction factor for levee slope roughness (assumed $\gamma_r = 0.9$ for
		3 cm grass slopes along the riverine levee and 0.55 for 1 layer of
		rip rap along the dryland levee per CEM Table VI-5-3)
	γb	= reduction factor for influence of a berm
	$\gamma_{\rm h}$	= reduction factor for influence of shallow waves
	γβ	= reduction factor for influence of angle of incidence, β , of the
		waves on the levee
		$= 1 - 0.0022 * \beta$



Wave Runup Reduction Factors

Several factors can influence a wave as it travels along a fetch line and approaches a levee. Berms, shallow water environments, and vegetation can all serve to reduce wave runup. Reduction factors used to account for these influences are described in this section.

Wave Runup Reduction Due to Influence of a Berm

The berm reduction factor, γ_b , was determined based on CEM guidance and a reference chart from Chapter 8 of Van der Meer's analysis³ (Figure 4).

The influence of a berm can be neglected when the berm horizontal surface is positioned more than $H_s\sqrt{2}$ below the still water level. As shown in Figure 4, the influence of a berm is dependent on the relative depth (d_h/H_s) and the berm width (B/H_s). The reduction factor is limited to a value of 0.6 and reaches its minimum value if the berm is at the still water level.

The berm reduction factor did not apply to the riverine segments, but only to the dryland levee analysis (Table 6). The berm reduction factor was applied only for berms near the waterside toe of the RD17 dryland levee. Major berms such as roadways, farm field borders, and other high ground were also identified throughout the floodplain, however due to their distance from the RD17 dryland levee, these types of berms were not incorporated into the calculations of the berm reduction factors. Spreadsheets for the berm reduction factor calculations are provided in Attachment A. Note that in the case of Profile 3, there is a berm in close proximity of the dryland levee between STA 959+00 and STA 972+00 that is significant enough to apply a reduction factor.

³ Wave run-up and overtopping. Chapter 8 in: "Seawalls, dikes and revetments." Van der Meer, J.W. 1998.





Figure 4. The reduction factor γ_b for a bermed slope

*Hs and Hmo are used interchangeably for significant wave height

Wind Direction	Location (Approx. Levee STA)	Berm Reduction Factor, γb
South	854+10	-
South	908+60	-
South	971+60	0.72
South	N/A ⁽¹⁾	-
Notes:		

Table 6. Berm Reduction Factors for the RD17 Drvland Levee

⁽¹⁾ Analysis point is approximately 3,000 feet east of the existing RD17 dryland levee and is in an area that will be re-graded to become high ground.

Wave Runup Reduction Due to Influence of Shallow Waves

The shallow wave reduction factor, γ_h , was determined based on guidance outlined in Van der Meer and Janssen's analysis⁴. The following equations are applicable for a foreshore slope that does not considerably deviate from 1:100:

$$\gamma_h = 1 - 0.03 \left(4 - \frac{h_m}{H_s} \right)^2 \qquad \text{for} \qquad \frac{h_m}{H_s} < 4$$
$$\gamma_h = 1 \qquad \text{for} \qquad \frac{h_m}{H_s} \ge 4$$

⁴ Wave run-up and wave overtopping at dikes and revetments. Van der Meer, J.W. and Janssen, J.P.F.M. 1994.



Water depth at the location of the toe of the structure (h_m) is used for representing the influence of a shallow foreshore. If water depth at the location of the toe is four times greater than the significant wave height, the influence of shallow waves can be neglected.

The shallow wave reduction factor did not apply to the riverine segments, but only to sections of the dryland levee (Table 7). Spreadsheets for the shallow wave reduction factor calculations are provided in Attachment B. Note that the shallow reduction factor applies along the edge of the floodplain where water depths are less than 5 feet at the toe of the dryland levee.

Wind Direction	Location (Approx. Levee STA)	Shallow Wave Reduction Factor, γ_h
South	854+10	-
South	908+60	-
South	971+60	0.78
South	N/A ⁽¹⁾	0.52
Notes:		

Table 7. Shallow Wave Reduction Factors for the RD17 Dryland Levee

⁽¹⁾ Analysis point is approximately 3,000 feet east of the existing RD17 dryland levee and is in an area that will be re-graded to become high ground.

Wave Runup Reduction Due to Vegetation

Vegetation in the vicinity of the levee hinders wind-wave formation because it shelters the water surface from the wind. More importantly, this vegetation impedes wave travel and dissipates wave energy. These effects should result in a smaller-than-calculated wave runup on the levee and a correction factor should be applied. However, there is no theoretical guidance in the literature to account for this factor, but recent project studies in the Sacramento River watershed have made empirical corrections to account for vegetation:

- The USACE Sacramento District (Natomas General Re-Evaluation Report Wave Runup Analysis, Draft Revised May 2006) estimated vegetation correction factors based on field inspection at various points of analysis. Factors ranged from 1.0 (no vegetation) to 0.2 for areas where the vegetation on the levee was so dense that wave action will have little effect. The report presented 17 different correction factors with an average reduction factor of 0.66.
- Mead & Hunt (SAFCA Wind Setup and Wave Runup Analysis for Natomas Levee Improvement Program, May 2007) performed a visual evaluation of aerial images of the levees and classified vegetative cover into three categories none, normal, and high and assigned corresponding reduction factors of 1.0, 0.75, and 0.6.
- GEI Consultants performed field observations of wind-wave action along the Feather River and Bear River levee during a high-water event in early January 2006. The average wind speed over the water was estimated at 35 mph from the southeast and the observed wave runup was less than



1 ft. The calculated wave runup was about 2 ft, so a 0.5 correction factor was applied as part of the TRLIA Feather River Setback Levee project.

Based on these three studies and an aerial survey of vegetation cover along the presented fetch lines, an average vegetative factor of 0.67 will be used in this study.

Summary of Wave Runup Calculations with Reduction Factors

The following table provides a summary of wave runup calculations along with the reduction factors that were applied.

Wind	Location	Significant				Reduction Factor			Final 2% Wave		
Direction	(Approx. Levee STA)	Height (ft)	Α	Eр	С	γr	$\gamma_{ m B}$	γь	γ _h	γveg	Runup Height (ft)
	Riverine Levee										
North	518+65	1.12	-0.2	2.76	4.5	0.9	1.0	1.0	1.0	0.67	2.63
Northeast	631+95	0.39	1.6	1.36	0	0.9	1.0	1.0	1.0	0.67	0.48
East	61+05	0.54	1.6	1.83	0	0.9	0.8	1.0	1.0	0.67	0.80
Southeast	558+35	0.82	-0.2	2.62	4.5	0.9	0.8	1.0	1.0	0.67	1.63
South	688+25	1.11	-0.2	2.97	4.5	0.9	0.9	1.0	1.0	0.67	2.40
Southwest	822+25	0.91	1.6	2.15	0	0.9	0.9	1.0	1.0	0.67	1.73
West	646+15	0.61	1.6	2.11	0	0.9	0.9	1.0	1.0	0.67	1.13
Northwest	80+95	0.87	1.6	2.49	0	0.9	0.9	1.0	1.0	0.67	1.88
					Drylan	d Levee					
South	854+10	1.96	-0.2	4.35	4.5	0.55	1.0	1.0	1.0	0.67	2.62
0.34	908+60	2.41	-0.2	4.50	4.5	0.55	1.0	1.0	1.0	0.67	3.19
0.58	971+60	3.28	-0.2	4.74	4.5	0.55	1.0	0.7	0.8	0.67	2.41
1.23	N/A ⁽¹⁾	3.59	-0.2	4.81	4.5	0.55	1.0	1.0	0.5	0.67	N/A
⁽¹⁾ Analysis po	int is approxim	ately 3.000 fee	t east of	the RD1'	7 drvland	l levee.					

Table 8. Wave Runup Height

Conclusions

Table 9 presents the combined wind setup and wave runup calculations for each of the worst case wind direction conditions for the RD17 riverine levee. Note that the impact of wind setup and wave runup is less than 3 feet in all riverine cases. Table 10 presents the combined wind setup and wave runup calculations for the four analysis points for the RD17 dryland levee.



e	
2.63	2.8(1)
0.48	0.5 (1)
0.80	0.9
1.63	1.7
2.40	2.5
1.73	1.8
1.13	1.2 (1)
1.00	$2.0^{(1)}$
	1.75 1.13 1.88

Table 9. Combined Wind Setup and Wave Runup Heights for the RD17 Riverine Levee

⁽¹⁾ Note that these cases are for upstream traveling waves. No reduction factor has been applied to address this situation.

Table 10. Combined Wind Setup and Wave Runup Heights for the RD17 Dryland Levee

Wind Direction	Location (Approx. Levee STA)	Calculated Wind Setup (ft)	2% Wave Runup with Correction Factors (ft)	Combined Wind Setup and Wave Runup (ft)
		Dryland Levee		
South	854+10	0.34	2.62	3.0
South	908+60	0.58	3.19	3.8
South	971+60	1.23	2.41	3.6
South	N/A ⁽¹⁾	1.83	N/A	2.8(2)
Notes: ⁽¹⁾ Analysis point is app	proximately 3,000 feet eas	t of the RD17 dryland l	evee.	

⁽²⁾ A safety factor of 1 foot was added.

The analysis for the riverine levee segments showed that the design wind wave height is less than 3-feet. The minimum ULDC freeboard requirement is 3-feet which will therefore be the applied standard for the riverine levees.

The analysis for the various locations along the RD17 dryland levee calculated wind-wave height between 2.8 feet and 3.8 feet. A minimum of 3-feet of freeboard will be applied to the dryland levee, with freeboard exceeding 3-feet for areas where the wind-wave calculations governed. Figure 5 presents a profile of the required MTOL along the RD17 dryland levee alignment. The profile also extends to the edge of the floodplain where the land will be re-graded to become high ground. Spreadsheets for the dryland levee calculations are provided in Attachment C.





ATTACHMENT A

CALCULATIONS FOR BERM REDUCTION FACTOR



Is $H_{mo}\sqrt{2} > dh$:

No

DOES NOT APPLY



Significant Wave Height (H _{mo}) Calc:		$\frac{g * H_{mo}}{v^2} = 0.0413 *$	$\left(\frac{g * X}{w^2}\right)^{\frac{1}{2}}$	and	$\frac{g * T_p}{v^2} = 0.751 * \left(\frac{g * \chi}{v^2}\right)^{\frac{1}{3}}$
Assumed Fetch Length, F: Drag Coefficient, C _D : Friction Velocity, uf: Significant wave height, H _{mo} :	1.35 mi 0.00087 2.74 ft/sec 1.68 ft	$u_f^2 = 0.0413 *$ Where:		= significant wave = peak wave perior = fetch length (ft) = gravitational con = friction velocity = $(C_D * U_{10}^2)^{\frac{1}{2}}$ = drag coefficient = 0.0002 * (1.1 + = wind speed at 10	$\frac{1}{u_f^2} = 0.731 * \left(\frac{u_f^2}{u_f^2}\right)$ height (ft) d (sec) stant = 32.2 ft/sec (ft/sec) 0.035 * U ₁₀) m elevation (ft/sec)

γ _b	Cal	lcu	lat	ion
_				

d _h :	2.38 ft
$H_{mo}\sqrt{2}$:	2.38 ft
Is $H_{mo}\sqrt{2}$ > dh:	No
DOES NOT APPLY	



Van Der Meer 1998, p.9



ATTACHMENT B

CALCULATIONS FOR SHALLOW WATER REDUCTION FACTOR



h_m/H_{mo}: Is $h_m/H_{mo} < 4$: No

DOES NOT APPLY



	$\gamma_{\rm h}$ Calculation
10.69 ft	Water Depth at the toe, h _m :
6.35 ft	h _m /H _{mo} :
No	Is h _m /H _{mo} < 4:
	DOES NOT APPLY



Van Der Meer & Janssen 1994, p. 9



Van Der Meer & Janssen 1994, p. 9



ATTACHMENT C

CALCULATIONS OF WIND SETUP AND WAVE RUNUP ALONG THE RD17 DRYLAND LEVEE

WIND SETOP & WAVE KONOP INPOTS				
Primary Inputs	F1	mah		
Height at Which Observations were Taken, z_i	7.9	mpn m		
Assumed Fetch Length, F:	1.83	mi	Avg 9 radials at 3 degree intervals, pg 3-24 SP	'M (19
Average Water Depth Along Fetch Line, d:	12.08	ft	Avg depth at cell every half mile of median radial	
$\frac{1}{1}$	2.25	degrees		
Reduction Factor for Levee Slope Boughness N	0.6			
Reduction Factor for Influence of a Berm, v_h :	1.0		If no berm, $\gamma_b = 1.0$. Otherwise, see discussion on 0	CEM p
Reduction Factor for Influence of Shallow Waves, γ_h :	1.0		No shallow wave influence, γ_h = 1.0. Based on dep	oth at t
Reduction Factor for Influence of Angle of Incidence, γ_{β} :	1.000		CEM Equation VI-5-11: Short-crested waves	s
Reduction Factor for the Presence of Vegetation Along the Fetch Line, $\gamma_{\text{Veg.}}$:	0.67		See discussion on pgs. 6 & 7 in PBI TM, SBFCA's Fed	ather
Secondary/Calculated Inputs				
Design 72.9yr Wind Speed Corrected for 10m Observation Height, U ₁₀ :	52.7	mph	Wind corrected to 10m Observation Level with the	e 1/7 r
Design 72.9yr Wind Speed Corrected for Over Water:	63.3	mph	For fetch lengths less than 16km, the CEM recomm	nends
Design 72.9yr Wind Speed Corrected for Over Water: Assumed Fetch Length, F	92.8 9.658	ft/sec ft		
	5,050			
WIND SETUP CALCULATIONS				
Wind Setup (Zeider Zee Equation), S:	0.433	ft	$S = \frac{U^2 F}{1400d}$	
			Where S = wind setup (ft)	
			U = average wind speed (mph) F = fetch distance (miles)	
			d = average water depth along the fetc	h line
Wind Setup (Sibul Equation), S:	0.254	ft	$S = d * 2.44 * 10^{-5} * \left(\frac{F}{d}\right)^{1.66} * \left(\frac{U^2}{F \cdot g}\right)^{(2.02*)}$	$\left(\frac{F}{d}\right)^{-0.0}$
			Where $S = wind setup (ft)$	
			d = average water depth along the fe F = fetch distance (ft)	tch li
			g = gravitational constant = 32.2 ft/sec	ec
AVERAGE WIND SETUP, S: Wind Setup (Zeider Zee Equation) S:	0.34	ft ft	Use average wind setup for average depth less that	an 16 f
Wild Setup (Zeidel Zee Equation), 3.	-			
WAVE RUNUP CALCULATIONS				
Circlificant Mays Height (II -) Coloulation				
<u>Significant wave Height (H_{mo}) Calculation</u>	0 00087		$\frac{g_{*H_{mo}}}{g_{*}} = 0.0413 * \left(\frac{g_{*}X}{2}\right)^{\frac{1}{2}}$	a
Friction Velocity, u _f :	2.74	ft/sec	u_f^2 u_f^2 u_f^2	
Significant Wave Height, H _{mo} :	1.958	ft	Where: $H_{mo} = sig$	gnifi
		0.834744	$\begin{array}{ccc} & & & & \\ & & & \\ & & & \\ \end{array} \begin{array}{c} & & & \\ & & \\ \end{array} \begin{array}{c} & & \\ & & \\ \end{array} \end{array}$	tch l
Peak Wave Period (T.) Calculation		0.597071	g = grave	avita
Peak Wave Period, T _n :	6.05	sec	= (C	
			$C_D = dr$	ag c
			$U_{10} = 0.1$	ind s
<u>Surf Similarity (ε_p) Calculation</u>			$\tan(\alpha)$	
Waterside lovee slope angle tap g				
water side ievee slope angle, tall d.	0.44		$\qquad \qquad $	
Surf Similarity Parameter, ε_p :	0.44 4.35		$\qquad \qquad $	
Surf Similarity Parameter, ε_p :	0.44 4.35		$\frac{2\pi * H_{mo}}{g * T_p^2}$ Where: ε_p = surf si	mila
Surf Similarity Parameter, ε _p :	0.44 4.35		$\frac{z\pi * H_{mo}}{g * T_p^2}$ Where: $\varepsilon_p = \text{surf si}$ tan(α) = waters condition	imila side ns)
Surf Similarity Parameter, ε _p :	0.44 4.35		$\frac{c_p}{\sqrt{\frac{2\pi * H_{mo}}{g * T_p^2}}}$ Where: $\varepsilon_p = \text{surf si}$ $\tan(\alpha) = \text{waters}$ $\cosh(\alpha) = \frac{1}{2\pi + \frac$	imila side ms)
Surf Similarity Parameter, ε _p : 2% Wave Runup (R _{2%}) Calculation A:	-0.2		$\frac{z\pi * H_{mo}}{g * T_p^2}$ Where: $\varepsilon_p = \text{surf si}$ $\tan(\alpha) = \text{waters}$ $\operatorname{condition}$ $R_{2\%} = H_{mo} * (A * \varepsilon_p + C) * \gamma_r * \gamma_b * \gamma_b$	imila side sons)
Surf Similarity Parameter, ε _p : 2% Wave Runup (R _{2%}) Calculation A: C:	0.44 4.35 -0.2 4.5		$\frac{2\pi * H_{mo}}{g * T_p^2}$ Where: $\varepsilon_p = \text{surf si}$ $\tan(\alpha) = \text{waters}$ $\operatorname{condition}$ $R_{2\%} = H_{mo} * (A * \varepsilon_p + C) * \gamma_r * \gamma_b * \gamma_b$ Where: $R_{2\%} = 2\%$ wave	imila side (ms) $h * \gamma$ e rur
Surf Similarity Parameter, ε _p : 2% Wave Runup (R _{2%}) Calculation A: C: 2% Wave Runup, R _{2%} :	0.44 4.35 -0.2 4.5 3.91	ft	$\frac{2\pi * H_{mo}}{g * T_p^2}$ Where: $\varepsilon_p = \text{surf si}$ $\frac{2\pi * H_{mo}}{g * T_p^2}$ Where: $\varepsilon_p = \text{surf si}$ $\tan(\alpha) = \text{waters}$ $\operatorname{condition}$ $R_{2\%} = H_{mo} * (A * \varepsilon_p + C) * \gamma_r * \gamma_b * \gamma$ Where: $R_{2\%} = 2\%$ wave $A, C = \text{coefficied}$ $\operatorname{direction} c$	imila side : ons) $h * \gamma$ e rur onts o condi
Surf Similarity Parameter, ε _p : 2% Wave Runup (R _{2%}) Calculation A: C: 2% Wave Runup, R _{2%} :	0.44 4.35 -0.2 4.5 3.91 2.62	ft	$\frac{2\pi * H_{mo}}{g * T_p^2}$ Where: $\varepsilon_p = \text{surf si}$ $\frac{2\pi * H_{mo}}{g * T_p^2}$ Where: $\varepsilon_p = \text{surf si}$ $\tan(\alpha) = \text{waters}$ $\operatorname{condition}$ $R_{2\%} = H_{mo} * (A * \varepsilon_p + C) * \gamma_r * \gamma_b * \gamma$ Where: $R_{2\%} = 2\%$ wave $A, C = \text{coefficien}$ $\frac{direction c}{\gamma_r} = \text{reduction}$ 3 cm grass	imila side : ons)
Surf Similarity Parameter, ϵ_p :	0.44 4.35 -0.2 4.5 3.91 2.62	ft	$\frac{2\pi * H_{mo}}{g * T_p^2}$ Where: $\varepsilon_p = \text{surf si}$ $\frac{2\pi * H_{mo}}{g * T_p^2}$ Where: $\varepsilon_p = \text{surf si}$ $\frac{\pi}{\alpha} = \text{waters}$ $\frac{\pi}{\alpha} = H_{mo} * (A * \varepsilon_p + C) * \gamma_r * \gamma_b * \gamma_b$ Where: $R_{2\%} = 2\%$ wave A,C = coefficient direction compares $\gamma_r = \text{reduction}$	imila side : ons) e rur ents o condi n fac s slop n fac
Surf Similarity Parameter, ε _p : 2% Wave Runup (R _{2%}) Calculation Δ: C: 2% Wave Runup, R _{2%} : 2% Wave Runup, R _{2%} :	0.44 4.35 -0.2 4.5 3.91 2.62	ft	$\frac{2\pi * H_{mo}}{g * T_p^2}$ Where: $\varepsilon_p = \text{surf si}$ $\frac{2\pi * H_{mo}}{g * T_p^2}$ Where: $\varepsilon_p = \text{surf si}$ $\frac{\pi}{\tan(\alpha)} = \text{waters}$ $\frac{\pi}{\cosh(\alpha)} = H_{mo} * (A * \varepsilon_p + C) * \gamma_r * \gamma_b * \gamma_b$ Where: $R_{2\%} = 2\%$ wave A,C = coefficient direction compared of the sum	imila side : ons) e rur ents (condi s slop n fac 1) n fac
Surf Similarity Parameter, ε _p : 2% Wave Runup (R _{2%}) Calculation Δ	0.44 4.35 -0.2 4.5 3.91 2.62	ft ft	$\frac{2\pi * H_{mo}}{g * T_p^2}$ Where: $\varepsilon_p = \text{surf si}$ $\frac{2\pi * H_{mo}}{g * T_p^2}$ Where: $\varepsilon_p = \text{surf si}$ $\frac{\pi}{\alpha} = \text{waters}$ $\frac{\pi}{\alpha} = H_{mo} * (A * \varepsilon_p + C) * \gamma_r * \gamma_b * \gamma_b$ Where: $R_{2\%} = 2\%$ wave $A, C = \text{coefficient}$ $\frac{\pi}{\alpha} = \text{reduction}$ $\frac{\pi}{\beta} = \text{reduction}$ $\gamma_b = \text{reduction}$	imila side : ons) // * ? e rur ents (condi n fac s slop n fac 1) n fac ave i n fac
Surf Similarity Parameter, ε _p : 2% Wave Runup (R _{2%}) Calculation A: C: 2% Wave Runup, R _{2%} : 2% Wave Runup, R _{2%} :	0.44 4.35 -0.2 4.5 3.91 2.62	ft	$\frac{2\pi * H_{mo}}{g * T_p^2}$ Where: $\epsilon_p = \text{surf si}$ $\frac{2\pi * H_{mo}}{g * T_p^2}$ Where: $\epsilon_p = \text{surf si}$ $\frac{\pi}{1000} = \text{waters}$ $\frac{\pi}{1000} = \text{condition}$ $\frac{\pi}{1000} = H_{mo} * (A * \epsilon_p + C) * \gamma_r * \gamma_b * \gamma_b$ Where: $R_{2\%} = 2\%$ wave A,C = coefficient direction compared A,C = coefficient direction compared B,C = reduction $\gamma_r = \text{reduction}$ $\gamma_b = \text{reduction}$	imila side sons) (h * Y) e run ents of sondi n fac ave i n fac ave i n fac the lo
Surf Similarity Parameter, ε_p : 2% Wave Runup (R _{2%}) Calculation A: C: 2% Wave Runup, R _{2%} : 2% Wave Runup, R _{2%} : 2% Wave Runup, R _{2%} :	0.44 4.35 -0.2 4.5 3.91 2.62	ft ft	$ \begin{array}{c} & \sum_{p} & \sqrt{\frac{2\pi * H_{mo}}{g * T_p^2}} \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\$	imila side : (n *) e run ents c condi n fac : 1) n fac ave i n fac the le 022 :
Waterside revee slope angle, tan tr. Surf Similarity Parameter, ε_p : 2% Wave Runup ($R_{2\%}$) Calculation A: C: 2% Wave Runup, $R_{2\%}$: 2% Wave Runup, $R_{2\%}$: 2% Wave Runup, $R_{2\%}$:	0.44 4.35 -0.2 4.5 3.91 2.62	ft ft	$ \begin{array}{c} \sum_{p \in p} & \sqrt{\frac{2\pi * H_{mo}}{g * T_p^2}} \\ \hline \\ \hline \\ \hline \\ \\ \hline \\ \\ \hline \\ \\ \hline \\ \\ \\ \hline \\$	imila side : ons) //n * ? e rur ents of condi n fac : 1) n fac ave i n fac the lo 022 :
Surf Similarity Parameter, ε_p : 2% Wave Runup (R _{2%}) Calculation 2% Wave Runup (R _{2%}) Calculation A: C: 2% Wave Runup, R _{2%} : 2% Wave Runup, R _{2%} : 2% Wave Runup with Vegetative Correction, R _{2%,Veg} : 0	0.44 4.35 -0.2 4.5 3.91 2.62		$ \begin{array}{c} \sum_{p \in p} \sqrt{\frac{2\pi * H_{mo}}{g * T_p^2}} \\ \hline \\ \hline \\ \hline \\ \\ \hline \\ \\ \hline \\ \\ \hline \\ \\ \\ \hline \\ \\ \\ \\ \hline \\$	imila side : ons) //n * ? e run ents c condi n fac s slop n fac i 1) n fac ave i n fac the la 022 :
Waterstide revee slope angle, tail d. Surf Similarity Parameter, ε _p : 2% Wave Runup (R _{2%}) Calculation A: C: 2% Wave Runup, R _{2%} : 2% Wave Runup, R _{2%} : 2% Wave Runup with Vegetative Correction, R _{2%,Veg} .: OMBINED WIND SETUP & WAVE RUNUP	0.44 4.35 -0.2 4.5 3.91 2.62	Image: Control of the second secon	$ \begin{array}{c} \sum_{p \in P} & \sqrt{\frac{2\pi * H_{mo}}{g * T_p^2}} \\ \hline \\ \hline \\ \hline \\ \\ \hline \\ \\ \hline \\ \\ \hline \\ \\ \\ \hline \\ \\ \\ \\ \hline \\$	imila side : ons) //n * ? e run ents c condi n fac s slop n fac s slop n fac i 1) n fac s v i 1) n fac 222 :
Waterstde revee slope angle, tan d. Surf Similarity Parameter, ε _p : 2% Wave Runup (R _{2%}) Calculation A: C: 2% Wave Runup, R _{2%} : 2% Wave Runup, R _{2%} : 2% Wave Runup with Vegetative Correction, R _{2%,Veg} .: Output Wave Runup with Vegetative Correction, R _{2%,Veg} .: Wave Runup with Vegetative Correction, R _{2%,Veg} .: Wind Setup, S: 2% Wave Runup with Vegetative Correction. R _{2%,Veg} .:	0.44 4.35 -0.2 4.5 3.91 2.62		$ \begin{array}{c} \sum_{p \in P} & \sqrt{\frac{2\pi * H_{mo}}{g * T_p^2}} \\ \hline \\ \hline \\ \hline \\ \\ \hline \\ \\ \hline \\ \\ \\ \hline \\ \\ \\ \\ \\ \hline \\$	imila side : γ ns) e run ents c condi n fac s slop n fac (1) n fac ave i n fac the la 022 :
Waterside level sobe angle, tartit. Surf Similarity Parameter, ϵ_p : 2% Wave Runup (R _{2%}) Calculation A: C: 2% Wave Runup, R _{2%} : 2% Wave Runup, R _{2%} : 2% Wave Runup with Vegetative Correction, R _{2%,Veg} : COMBINED WIND SETUP & WAVE RUNUP Wind Setup, S: 2% Wave Runup with Vegetative Correction, R _{2%,Veg} :	0.44 4.35 -0.2 4.5 3.91 2.62		$ \begin{array}{c} & \sum_{p} & \sqrt{\frac{2\pi * H_{mo}}{g * T_p^2}} \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ &$	imila side : ons) /n * Y e run e run e run condi n fac in solop
Waterside revee slope angle, tail dt. Surf Similarity Parameter, ɛp; 2% Wave Runup (R₂‰) Calculation A: C: 2% Wave Runup, R₂‰; 2% Wave Runup, R₂‰; 2% Wave Runup with Vegetative Correction, R₂‰,veg; 2% Wave Runup with Vegetative Correction, R₂‰,veg; Wind Setup, S: 2% Wave Runup with Vegetative Correction, R₂‰,veg; COMBINED WIND SETUP & WAVE RUNUP Wind Setup, S: 2% Wave Runup with Vegetative Correction, R₂‰,veg;	0.44 4.35 -0.2 4.5 3.91 2.62 0.34 2.62 2.96		$ \begin{array}{c} & \sum_{p} & \sqrt{\frac{2\pi * H_{mo}}{g * T_p^2}} \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ &$	imila side : ons) // * ? e rur ents (condi n fac condi n fac (1) n fac ave i n fac the lo 022 :
Wate side revee stope angre, tall d. Surf Similarity Parameter, ε _p : 2% Wave Runup (R _{2%}) Calculation A: C: 2% Wave Runup, R _{2%} : 2% Wave Runup with Vegetative Correction, R _{2%,Veg} : 2% Wave Runup with Vegetative Correction, R _{2%,Veg} : Wind Setup, S: 2% Wave Runup with Vegetative Correction, R _{2%,Veg} : COMBINED WIND SETUP & WAVE RUNUP Wind Setup, S: 2% Wave Runup with Vegetative Correction, R _{2%,Veg} : COMBINED WIND SETUP & WAVE RUNUP	0.44 4.35 -0.2 4.5 3.91 2.62 0.34 2.62 2.96		$ \frac{c_p}{\sqrt{\frac{2\pi * H_{mo}}{g * T_p^2}}} $ Where: $\varepsilon_p = \text{surf si} \tan(\alpha) = \text{waters condition}$ $ \frac{c_p}{(\alpha, \beta)} = H_{mo} * (A * \varepsilon_p + C) * \gamma_r * \gamma_b * \gamma_b * \gamma_b * \gamma_b * \gamma_b * (A * \varepsilon_p + C) * \gamma_r * \gamma_b * \gamma_b * \gamma_b * (A + \varepsilon_p + C) * \gamma_r * \gamma_b * \gamma_b * \gamma_b * (A + \varepsilon_p + C) * \gamma_r * \gamma_b * \gamma_b * \gamma_b * (A + \varepsilon_p + C) * \gamma_r * \gamma_b * \gamma_b * \gamma_b * (A + \varepsilon_p + C) * \gamma_r * \gamma_b * \gamma_b * \gamma_b * (A + \varepsilon_p + C) * \gamma_r * \gamma_b * \gamma_b * \gamma_b * \gamma_b * \gamma_b * \gamma_b * (A + \varepsilon_p + C) * \gamma_r * \gamma_b * \gamma_r * \gamma_b * \gamma_b * \gamma_r * \gamma_b * \gamma_b * \gamma_b * \gamma_b * \gamma_r * \gamma_b * \gamma_b * \gamma_b * \gamma_r * \gamma_h * \gamma_r * \gamma$	imila side sons) //n * Y e rur ents condi on fac s slop n fac s slop n fac i 1) n fac ave i n fac i 222 sons u 122 sons u
Waterstide revee stope align, tall tt. Surf Similarity Parameter, ε _p : 2% Wave Runup (R _{2%}) Calculation A: C: 2% Wave Runup, R _{2%} : 2% Wave Runup with Vegetative Correction, R _{2%, Veg} .: 2% Wave Runup with Vegetative Correction, R _{2%, Veg} .: 2% Wave Runup with Vegetative Correction, R _{2%, Veg} .: 2% Wave Runup with Vegetative Correction, R _{2%, Veg} .: COMBINED WIND SETUP & WAVE RUNUP Wind Setup, S: 2% Wave Runup with Vegetative Correction, R _{2%, Veg} .: COMBINED WIND SETUP & WAVE RUNUP	0.44 4.35 -0.2 4.5 3.91 2.62 0.34 2.62 2.96		$ \begin{array}{c} & \sum_{p} & \sqrt{\frac{2\pi * H_{mo}}{g * T_{p}^{2}}} \\ \hline \\ & & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\$	imila side sons) /n * Y e rur ents condi n fac s slop n fac s slop n fac i 1) n fac ave i n fac i 1) n fac ave i n fac j 22 s

RD17 Dryland Levee Wind/Wave Analysis

Profile 1

<u>uts</u> U₂:	51	mph					WIND SET	UP &	3.0 ft					Peterson Brus Mike Rossiter,	tad, Inc. PE		
1, 2. 1, F:	1.83	mi	Avg 9 radials at 3 degree intervals, pg 3-2	 24 SPM (1984)		WAVE NON								11/21/2014			
e, d:	12.08	ft	Avg depth at cell every half mile of median r	adial													
/v): e, β:	2.25	degrees															
ors v	0.6									Table VI-5.3							
, γr. , γ _h :	1.0		If no berm, $\gamma_b = 1.0$. Otherwise, see discussion	on on CEM pg. VI-5	5-12.					Surface Roughness Red	luction Factor yr in Equation VI-	5-3, Valid for 1 <	ζ _{ορ} < 3-4				
γ _h :	1.0		No shallow wave influence, $\gamma_h = 1.0$. Based c	on depth at toe of	levee. See equati	ion and discussic	on on CEM pg. V	I-5-13		Type of Slope Surface				7	, 		
γ _β :	1.000		CEM Equation VI-5-11: Short-crested	waves	$\gamma_{\beta} = 1 - 0.002$	22 β				Smooth block revetment Grass (3 cm length)	L			1	.0 .0 .90 - 1.0		
Veg.	0.67		See discussion on pgs. 6 & 7 in PBI TM, SBFC	A's Feather River	West Levee Stren	ngthening EIP Pro	oject, Wind Setu	ip and Wave Ru	nup Analysis , January 10, 2011. (rip ra	p reduces up 2 or more layers of rock, (i	D, (H₅ /D = 1.5 - 3.0) (H₅ /D = 1.5 - 6.0)			0	.55 - 0.6 .50 - 0.55		
uts										Roughness elements on s (length parallel to waterline	smooth surface ie = ℓ, width = b, height = h)						
J ₁₀ :	52.7	mph	Wind corrected to 10m Observation Level w	/ith the 1/7 rule (C	CEM Equation II-2	2-9)	$U_{10} = U_z \left(\frac{10}{z}\right)^{\frac{1}{7}}$			Quadratic blocks, <i>e</i> = <i>b</i>							
ter:	63.3	mph	For fetch lengths less than 16km, the CEM re	ecommends a fact	tor of 1.2 to incre	ease the wind spe	eed for over wat	ter conditions (C	EM pg. II-2-36 (c))	h/b b/H₅ ar 0.88 0.12 - 0.19 0.99 0.12 - 0.24	rea coverage 1/9 1/25			0	.70 - 0.75		
ter:	92.8 9.658	ft/sec ft								0.44 0.12 - 0.24 0.88 0.12 - 0.18	1/25 1/25 1/25 (above SWL)			0	.85 - 0.95 .85 - 0.95		
.,	5,000									0.18 0.55 - 1.10	1/4			U	.75 - 0.85		
										1.00 0.12 - 0.19	1/7.5			0	.60 - 0.70		
		c.		1													
), S:	0.433	ft	$-S = \frac{U^2 F}{1400d}$		Equation 15-1,	USACE Hydrolog	ic Engineering I	Requirements fo	or Reservoirs (EM 1110-2-1420)								
			Where S = wind setup (ft)														
			U = average wind speed (mph) F = fetch distance (miles)	a fatal to an													
			d = average water depth along th	e fetch line (ft)													
				((F) =0.0768)													
), S:	0.254	ft	$-S = d * 2.44 * 10^{-5} * \left(\frac{F}{d}\right)^{1.66} * \left(\frac{U^2}{F * g}\right)^{1}$	$(2.02*(\frac{1}{d}))$	More recent st	udies show that	for shallow wat	er (< 16 ft deep)	the value from the equation above	ater Management District, 2006)							
			Where S = wind setup (ft)	the fatab line (ff													
			I = average water depth along F = fetch distance (ft) U = average wind speed (ft/sec)													
			g = gravitational constant = 32.	.2 ft/sec													
	0.24	£4															
, s: , s:	0.34	ft	Use average wind setup for average depth le	ess than 16 ft. Use	e Zeider Zee equa	tion for average	depth greater t	han 16 ft.									
ion			1				1										
cion C _D :	0.00087		$\frac{g_{*H_{mo}}}{u_c^2} = 0.0413 * \left(\frac{g_{*X}}{u_c^2}\right)^{\frac{1}{2}}$	and	<u>g</u>	$\frac{1+T_p}{\mu_c^2} = 0.75$	$1 * \left(\frac{g * X}{\mu_c^2}\right)^{\frac{1}{3}}$		CEM Equation II-2-36								
cion C _D : , u _f :	0.00087 2.74	ft/sec	$\frac{g_{*H_{mo}}}{u_{f}^{2}} = 0.0413 * \left(\frac{g_{*X}}{u_{f}^{2}}\right)^{\frac{1}{2}}$	and	<u>g</u>	$\frac{u^*T_p}{u_f^2} = 0.75$	$1 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{3}}$		CEM Equation II-2-36								
C _D : C _D : , u _f :	0.00087 2.74 1.958	ft/sec ft	$\frac{g * H_{mo}}{u_f^2} = 0.0413 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{2}}$ Where: $H_{mo} = T_p$	and = significant = peak wave	g t wave heig e period (see	$\frac{u^*T_p}{u_f^2} = 0.75$ ht (ft) c)	$1 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{3}}$		CEM Equation II-2-36								
cion C _D : , u _f : I _{mo} :	0.00087 2.74 1.958	ft/sec ft 0.834744 0.597071	$\frac{g * H_{mo}}{u_f^2} = 0.0413 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{2}}$ Where: $H_{mo} = T_p$ X	and = significant = peak wave = fetch lengt = gravitation	g t wave heig e period (see th (ft) nal constant	$\frac{u^{*T_p}}{u_f^2} = 0.75$ ht (ft) c) $x = 32.2 \text{ ft/s}$	$1 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{3}}$		CEM Equation II-2-36								
<u>ion</u> C _D : , u _f : I _{mo} :	0.00087 2.74 1.958	ft/sec ft 0.834744 0.597071	$\frac{g * H_{mo}}{u_f^2} = 0.0413 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{2}}$ Where: $H_{mo} = T_p$ X = g $u_f = u_f$	and = significant = peak wave = fetch leng = gravitation = friction ve	g t wave heig e period (see th (ft) nal constant elocity (ft/se	$\frac{u^{*T_p}}{u_f^2} = 0.75$ ht (ft) c) x = 32.2 ft/s cc)	$1 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{3}}$ ec		CEM Equation II-2-36								
<u>ion</u> C _D : , u _f : I _{mo} :	0.00087 2.74 1.958 6.05	ft/sec ft 0.834744 0.597071 sec	$\frac{g * H_{mo}}{u_f^2} = 0.0413 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{2}}$ Where: $H_{mo} = T_p$ $X = g$ u_f	and = significant = peak wave = fetch lengt = gravitation = friction ve = $(C_D * U_{10}^2)$	t wave heig e period (see th (ft) nal constant elocity (ft/se) $\frac{1}{2}$	$\frac{u^{*T_p}}{u_f^2} = 0.75$ ht (ft) c) $u = 32.2 \text{ ft/s}$ ec)	$1 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{3}}$ ec		CEM Equation II-2-36								
<u>ion</u> C _D : , u _f : I _{mo} : T _p :	0.00087 2.74 1.958 6.05	ft/sec ft 0.834744 0.597071 sec 0.100000000000000000000000000000000000	$\frac{g * H_{mo}}{u_f^2} = 0.0413 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{2}}$ Where: $H_{mo} = T_p$ $X = g$ u_f $C_D = 0$	and = significant = peak wave = fetch lengt = gravitation = friction ve = $(C_D * U_{10}^2)$ = drag coeff = 0.0002 * (t wave heig e period (see th (ft) nal constant elocity (ft/se) $\frac{1}{2}$ ficient (1.1 + 0.03	$\frac{u_f^{*T_p}}{u_f^2} = 0.75$ ht (ft) c) x = 32.2 ft/s cc) $x = 5 * U_{10}$	$1 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{3}}$ ec		CEM Equation II-2-36								
<u>ion</u> C _D : , u _f : I _{mo} : T _p :	0.00087 2.74 1.958 6.05	ft/sec ft 0.834744 0.597071 sec	$\frac{g * H_{mo}}{u_f^2} = 0.0413 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{2}}$ Where: H_{mo} = T_p = X = g u_f = C_D = U_{10} =	and = significant = peak wave = fetch leng = gravitation = friction ve = $(C_D * U_{10}^2)$ = drag coeff = 0.0002 * (= wind spee	t wave heig e period (see th (ft) nal constant elocity (ft/se) $\frac{1}{2}$ ficient (1.1 + 0.03 d at 10m elo	$\frac{u_f^{*T_p}}{u_f^2} = 0.75$ ht (ft) c) x = 32.2 ft/s c) $x = 5 * U_{10}$ evation (ft/s)	$1 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{3}}$ ec		CEM Equation II-2-36								
(ion C _D : , u _f : I _{mo} : I _{mo} : (ion T _p :	0.00087 2.74 1.958 6.05	ft/sec ft 0.834744 0.597071 sec	$\frac{g \ast H_{mo}}{u_f^2} = 0.0413 \ast \left(\frac{g \ast X}{u_f^2}\right)^{\frac{1}{2}}$ Where: H_{mo} T _p X g u _f C _D U ₁₀	and = significant = peak wave = fetch lengt = gravitation = friction ve = $(C_D * U_{10}^2)$ = drag coeff = 0.0002 * (= wind speet	t wave heig e period (see th (ft) nal constant elocity (ft/se) $\frac{1}{2}$ ficient (1.1 + 0.03 d at 10m elo	$\frac{v^*T_p}{u_f^2} = 0.75$ ht (ft) c) x = 32.2 ft/s cc) $x = 5 * U_{10}$ evation (ft/s)	$1 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{3}}$ ec		CEM Equation II-2-36								
ion C _D : , u _f : I _{mo} : Imo: ion T _p : ion ion r ion	0.00087 2.74 1.958 6.05	ft/sec ft 0.834744 0.597071 sec	$\frac{g * H_{mo}}{u_f^2} = 0.0413 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{2}}$ Where: H_{mo} T _p X g u _f C _D U ₁₀ $-\varepsilon_p = \frac{\tan(\alpha)}{\sqrt{2\pi + U_p}}$	and = significant = peak wave = fetch lengt = gravitation = friction ve = $(C_D * U_{10}^2)$ = drag coeff = 0.0002 * (= wind speet	t wave heig e period (see th (ft) nal constant elocity (ft/se) $\frac{1}{2}$ ficient (1.1 + 0.03 d at 10m elo	$\frac{v^*T_p}{u_f^2} = 0.75$ ht (ft) c) z = 32.2 ft/s cc) $z = 5 * U_{10}$ evation (ft/s)	$1 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{3}}$ ec		CEM Equation II-2-36			tan α = opp	osite/adia	cent = vertica	al/horizonta		
(ion C _D : , u _f : I _{mo} : I _{mo} : (ion T _p : (ion η α: , ε _p :	0.00087 2.74 1.958 6.05 0.44 4.35	ft/sec ft 0.834744 0.597071 sec	$\frac{g * H_{mo}}{u_f^2} = 0.0413 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{2}}$ Where: H_{mo} = T_p = X = g = u_f = C_D = U_{10} = U_{10} = $E_p = \frac{\tan(\alpha)}{\sqrt{\frac{2\pi * H_{mo}}{g * T_p^2}}}$	and = significant = peak wave = fetch leng = gravitation = friction ve = $(C_D * U_{10}^2)$ = drag coeff = 0.0002 * (= wind spee	t wave heig e period (see th (ft) nal constant elocity (ft/se) $\frac{1}{2}$ ficient (1.1 + 0.03 d at 10m elo	$\frac{v^{*T_p}}{u_f^2} = 0.75$ ht (ft) c) z = 32.2 ft/s cc) $z = 5 * U_{10}$ evation (ft/s)	$1 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{3}}$ ec		CEM Equation II-2-36			tan α = opp	oosite/adja	cent = vertica	al/horizonta		
(ion C _D : , u _f : I _{mo} : I _{mo} :	0.00087 2.74 1.958 6.05 0.44 4.35	ft/sec ft 0.834744 0.597071 sec	$\frac{g * H_{mo}}{u_f^2} = 0.0413 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{2}}$ Where: H _{mo} = T _p = X g = X u _f = C _D = U ₁₀ = U ₁₀ = U ₁₀	and = significant = peak wave = fetch leng = gravitation = friction ve = $(C_D * U_{10}^2)$ = drag coeff = 0.0002 * (= wind spee	t wave heig e period (see th (ft) nal constant elocity (ft/se $)^{\frac{1}{2}}$ ficient (1.1 + 0.03 d at 10m ele	$\frac{v^{*T_p}}{u_f^2} = 0.75$ ht (ft) c) z = 32.2 ft/s cc) $z = 5 * U_{10}$ evation (ft/s)	$1 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{3}}$ ec		CEM Equation II-2-36			tan α = opp	oosite/adja	cent = vertica	al/horizonta		
<u>cion</u> C _D : , u _f : I _{mo} : I _{mo} : C _D : I _{mo} : C _D : C	0.00087 2.74 1.958 6.05 0.44 4.35	ft/sec ft 0.834744 0.597071 sec	$\frac{g * H_{mo}}{u_f^2} = 0.0413 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{2}}$ Where: H _{mo} = T _p = X g = X u _f = C _D = U ₁₀ =	and = significant = peak wave = fetch lengt = gravitation = friction ve = $(C_D * U_{10}^2)$ = drag coeff = 0.0002 * (= wind speet	t wave heig e period (see th (ft) nal constant elocity (ft/se $)^{\frac{1}{2}}$ ficient (1.1 + 0.03 d at 10m ele	$\frac{v^{*T_p}}{u_f^2} = 0.75$ ht (ft) c) z = 32.2 ft/s cc) z = 32.2 ft/s evation (ft/s) sumed 1V:3	$1 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{3}}$ ec sec)	nd direction	CEM Equation II-2-36			tan α = opp	oosite/adja	cent = vertica	al/horizonta		
<u>cion</u> C _D : , u _f : I _{mo} : I _{mo} : I _{mo} : C _D : I _{mo} : I _{mo} : C _D : I _{mo} : C _D : I _{mo} : C _D :	0.00087 2.74 1.958 6.05 0.44 4.35	ft/sec ft 0.834744 0.597071 sec	$\frac{g * H_{mo}}{u_f^2} = 0.0413 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{2}}$ Where: H _{mo} = T _p = X g = X g = u_f = U_{10} $C_D = U_{10}$	and = significant = peak wave = fetch lengt = gravitation = friction ve = $(C_D * U_{10}^2)$ = drag coeff = 0.0002 * (= wind speet urf similarity paterside sloped ditions)	t wave heig e period (see th (ft) nal constant elocity (ft/se $)^{\frac{1}{2}}$ ficient (1.1 + 0.03 d at 10m ele parameter e of levee (as	$\frac{v^{*T_p}}{u_f^2} = 0.75$ ht (ft) c) x = 32.2 ft/s evalue (ft/s) sumed 1V:3	$1 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{3}}$ ec sec)	nd direction	CEM Equation II-2-36			tan α = opp	oosite/adja	cent = vertica	al/horizonta		
ion C _D : , u _f : I _{mo} : I _{mo} : ion T _p :	0.00087 2.74 1.958 6.05 0.44 4.35	ft/sec ft 0.834744 0.597071 sec	$\frac{g * H_{mo}}{u_f^2} = 0.0413 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{2}}$ Where: H _{mo} = T _p = X g = X g = U _f = U ₁₀ = U	and = significant = peak wave = fetch lengt = gravitation = friction ve = $(C_D * U_{10}^2)$ = drag coeff = 0.0002 * (= wind speet urf similarity paterside slope ditions) = * $\gamma_h * \gamma_R$	$\frac{g}{2}$ t wave heig e period (see th (ft) nal constant elocity (ft/se) $\frac{1}{2}$ ficient (1.1 + 0.03 d at 10m ele	$\frac{v^{*T_p}}{u_f^2} = 0.75$ ht (ft) c) z = 32.2 ft/s evalue (ft/s) sumed 1V:32	$1 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{3}}$ ec sec)	nd direction	CEM Equation II-2-36	Einding Δ 8. C:		tan α = opp	oosite/adja	cent = vertica	al/horizonta		
iion C _D : , u _f : I _{mo} : I _{mo} : iion T _p : <td>0.00087 2.74 1.958 6.05 6.05 0.44 4.35 -0.2 4.5</td> <td>ft/sec ft 0.834744 0.597071 sec </td> <td>$\frac{g*H_{mo}}{u_{f}^{2}} = 0.0413 * \left(\frac{g*X}{u_{f}^{2}}\right)^{\frac{1}{2}}$ Where: H_{mo} = T_p = X g = X g = U_f = U₁₀ = U₁₀</td> <td>and = significant = peak wave = fetch lengt = gravitation = friction ve = $(C_D * U_{10}^2)$ = drag coeff = 0.0002 * (= wind speet urf similarity paterside slope ditions) = $b * \gamma_h * \gamma_\beta$ wave runne</td> <td>$\frac{g}{2}$ t wave heig e period (see th (ft) nal constant elocity (ft/se)$\frac{1}{2}$ ficient (1.1 + 0.03 d at 10m ele parameter e of levee (as</td> <td>$\frac{v^{*T_p}}{u_f^2} = 0.75$ ht (ft) c) z = 32.2 ft/s evalue (ft/s) sumed 1V:3</td> <td>$1 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{3}}$ec sec)</td> <td>nd direction</td> <td>CEM Equation II-2-36</td> <td>Finding A & C: Τable VI-5-2</td> <td></td> <td>tan α = opp</td> <td>oosite/adja</td> <td>cent = vertica</td> <td>al/horizonta</td> <td></td> <td></td>	0.00087 2.74 1.958 6.05 6.05 0.44 4.35 -0.2 4.5	ft/sec ft 0.834744 0.597071 sec	$\frac{g*H_{mo}}{u_{f}^{2}} = 0.0413 * \left(\frac{g*X}{u_{f}^{2}}\right)^{\frac{1}{2}}$ Where: H _{mo} = T _p = X g = X g = U _f = U ₁₀	and = significant = peak wave = fetch lengt = gravitation = friction ve = $(C_D * U_{10}^2)$ = drag coeff = 0.0002 * (= wind speet urf similarity paterside slope ditions) = $b * \gamma_h * \gamma_\beta$ wave runne	$\frac{g}{2}$ t wave heig e period (see th (ft) nal constant elocity (ft/se) $\frac{1}{2}$ ficient (1.1 + 0.03 d at 10m ele parameter e of levee (as	$\frac{v^{*T_p}}{u_f^2} = 0.75$ ht (ft) c) z = 32.2 ft/s evalue (ft/s) sumed 1V:3	$1 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{3}}$ ec sec)	nd direction	CEM Equation II-2-36	Finding A & C: Τable VI-5-2		tan α = opp	oosite/adja	cent = vertica	al/horizonta		
ion C _D : , u _f : Imo:	0.00087 2.74 1.958 6.05 6.05 0.44 4.35 -0.2 4.5 3.91	ft/sec ft 0.834744 0.597071 sec	$\frac{g*H_{mo}}{u_{f}^{2}} = 0.0413 * \left(\frac{g*X}{u_{f}^{2}}\right)^{\frac{1}{2}}$ Where: H _{mo} = T _p = X g = X u _f = C _D = U ₁₀ = U ₁	and = significant = peak wave = fetch lengt = gravitation = friction ve = $(C_D * U_{10}^2)$ = drag coeff = 0.0002 * (= wind speet urf similarity paterside slope ditions) = $b * \gamma_h * \gamma_\beta$ wave runup efficients dependent	$\frac{g}{2}$ t wave heig e period (see th (ft) nal constant elocity (ft/se) $\frac{1}{2}$ ficient (1.1 + 0.03 d at 10m ele parameter e of levee (as elevation (ft) endent on ε_p (s in this stud	$\frac{v^*T_p}{u_f^2} = 0.75$ ht (ft) c) z = 32.2 ft/s evalue (ft/s) sumed 1V:3 $\varepsilon_p < 2, A = 1$	$1 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{3}}$ ec sec) H for all win	nd direction	CEM Equation II-2-36 CEM Equation II-2-36 CEM Equation VI-5-2 CEM Equation VI-5-2 CEM Equation VI-5-3 CEM Equation VI-5-3	Finding A & C: Table VI-5-2 Coefficients in Equation Irregular Waves on Smo	n VI-5-3 for Runup of Long-Cooth Impermeable Slopes	Lan α = opp	posite/adja	cent = vertica	al/horizonta		
ion C _D : , u _f : Imo: Imo: ion T _p : ion T _p : ion n α: , ε _p : ion A: C: R _{2%} :	0.00087 2.74 1.958 6.05 6.05 0.44 4.35 -0.2 4.5 3.91	ft/sec ft 0.834744 0.597071 sec	$\frac{g * H_{mo}}{u_f^2} = 0.0413 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{2}}$ Where: H_mo T _p X g u _f C _D C_D U_{10} $E_p = \frac{\tan(\alpha)}{\sqrt{\frac{2\pi * H_{mo}}{g * T_p^2}}}$ Where: $\varepsilon_p = \sup_{\text{tan}(\alpha) = w} \sup_{\text{constrained}}$ $R_{2\%} = H_{mo} * (A * \varepsilon_p + C) * \gamma_r * \gamma_r$ Where: $R_{2\%} = 2\%$ A,C = coefficient γ_r = reduce	and = significant = peak wave = fetch lengt = gravitation = friction ve = $(C_D * U_{10}^2)$ = drag coeff = 0.0002 * (= wind speet wind speet = $b^* \gamma_h * \gamma_\beta$ wave runup efficients dependent ion conditions	t wave heig e period (see th (ft) nal constant elocity (ft/se $\frac{1}{2}$ ficient (1.1 + 0.03 d at 10m ele parameter e of levee (as elevation (ft) endent on ε_p (s in this study for levee slop	$\frac{v^*T_p}{u_f^2} = 0.75$ ht (ft) c) z = 32.2 ft/s evalue (ft/s) sumed 1V:3 $\varepsilon_p < 2, A = 1$ y per CEM T be roughness lo VI 5 2	$1 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{3}}$ ec sec) H for all win .6, C = 0 for Table VI-5-2 (assumed γ_r	nd direction	CEM Equation II-2-36 CEM Equation II-2-36 Image: I	Finding A & C: Table VI-5-2 Coefficients in Equation Irregular Waves on Smo ζ R _u	n VI-5-3 for Runup of Long-Cooth Impermeable Slopes	tan α = opp	posite/adjac	cent = vertica	al/horizonta	I	
iion C _D : , u _f : Imo: iion	0.00087 2.74 1.958 6.05 6.05 0.44 4.35 -0.2 4.5 3.91 2.62	ft/sec ft 0.834744 0.597071 sec	$\frac{g * H_{mo}}{u_f^2} = 0.0413 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{2}}$ Where: H_mo T _p X g u _f C _D C_D C_D U_{10} C_D U_{10} C_D U_{10} C_D U_{10} C_D	and = significant = peak wave = fetch lengt = gravitation = friction ve = $(C_D * U_{10}^2)$ = drag coeff = 0.0002 * (= wind speet wind speet = $b^* \gamma_h * \gamma_\beta$ wave runup efficients depetion conditions action factor for for factor factor for factor facto	t wave heig e period (see th (ft) nal constant elocity (ft/se) ¹ / ₂ ficient (1.1 + 0.03 d at 10m ele parameter e of levee (as elevation (ft) endent on ε_p (s in this study for levee slop ber CEM Tab for influence	$\frac{v^*T_p}{u_f^2} = 0.75$ ht (ft) c) z = 32.2 ft/s ec) $5 * U_{10}$) evation (ft/s) sumed 1V:3 $\epsilon_p < 2, A = 1$ y per CEM T be roughness ble VI-5-3) of a berm (a	$1 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{3}}$ ec sec) H for all win .6, C = 0 for Table VI-5-2 (assumed γ_r ssumed non-	r all wind r all wind r = 0.9 for 	CEM Equation II-2-36 CEM Equation II-2-36 Image: I	Finding A & C: Table VI-5-2 Coefficients in Equation Irregular Waves on Smo ζ R _u R _{u2 percent}	n VI-5-3 for Runup of Long-Cooth Impermeable Slopes $\frac{\zeta-\text{Limits}}{\zeta_p \leq 2.5}$	Lan α = opp	posite/adjac	cent = vertica	al/horizonta	I Ru 5	
iion C _D : , u _f : I _{mo} : I _{mo} : iion , T _p :	0.00087 2.74 1.958 6.05 0.44 4.35 -0.2 4.5 3.91 2.62	ft/sec ft 0.834744 0.597071 sec sec 1	$\frac{g * H_{mo}}{u_f^2} = 0.0413 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{2}}$ Where: H_mo T _p X g u _f C _D C_D U_{10} $E_p = \frac{\tan(\alpha)}{\sqrt{\frac{2\pi * H_{mo}}{g * T_p^2}}}$ Where: $\varepsilon_p = \sup_{\substack{x \\ tan(\alpha) = w \\ con}}$ $R_{2\%} = H_{mo} * (A * \varepsilon_p + C) * \gamma_r * \gamma_r$ Where: $R_{2\%} = 2\%$ A,C = coef direct γ_r = redu βcm γ_b = redu fetch, γ_h = redu	and = significant = peak wave = fetch lengt = gravitation = friction ve = $(C_D * U_{10}^2)$ = drag coeff = 0.0002 * (= wind speet wind speet = $b^* \gamma_h * \gamma_\beta$ wave runup efficients depetion conditions action factor f grass slopes plation factor f $\gamma_b = 1$) action factor f	t wave heig e period (see th (ft) nal constant elocity (ft/se) ¹ / ₂ ficient (1.1 + 0.03 d at 10m ele parameter e of levee (as elevation (ft) endent on ε_p (s in this study for levee slop ber CEM Tab for influence	$\frac{v^*T_p}{u_f^2} = 0.75$ ht (ft) c) z = 32.2 ft/s ec) $5 * U_{10}$) evation (ft/s) sumed 1V:3 $\epsilon_p < 2, A = 1$ y per CEM T be roughness ble VI-5-3) of a berm (a of shallow w	$1 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{3}}$ ec sec) H for all win .6, C = 0 for Table VI-5-2 (assumed γ_r ssumed non- vaves (assumed assumed as a state of the second assumed as a state of the second as	r all wind r all wind r = 0.9 for -bermed ned no	CEM Equation II-2-36 CEM Equation II-2-36 Image: I	Finding A & C: Table VI-5-2 Coefficients in Equation Irregular Waves on Smo ζ R _u R _{u2 percent} ζop R	n VI-5-3 for Runup of Long-Cooth Impermeable Slopes $\frac{\zeta-Limits}{\zeta_{\rho} \leq 2.5}$ $\frac{2.5 < \zeta_{\rho} < 9}{\zeta_{\rho} \leq 2.0}$	Lan α = opp	A 1.6 -0.2 1.35	cent = vertica	σ_{Ru}	I I <t< td=""><td></td></t<>	
iion C _D : , u _f : Imo: iion	0.00087 2.74 1.958 6.05 0.44 4.35 -0.2 4.5 3.91 2.62	ft/sec ft 0.834744 0.597071 sec sec 1	$\frac{g * H_{mo}}{u_f^2} = 0.0413 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{2}}$ Where: H_mo = T_p = X g = U_f = U_f = U_{10} $-\varepsilon_p = \frac{\tan(\alpha)}{\sqrt{\frac{2\pi * H_{mo}}{g * T_p^2}}}$ Where: $\varepsilon_p = \sup_{\alpha \in \alpha} (\alpha) = \sup_{\alpha \in \alpha} (\alpha)$ $R_{2\%} = H_{mo} * (A * \varepsilon_p + C) * \gamma_r * \gamma_r$ Where: $R_{2\%} = 2\%$ A, C = coef direct $\gamma_r = \operatorname{redu}_{\beta} (\beta + C)$ Where: $R_{2\%} = 2\%$ A, C = coef direct $\gamma_r = \operatorname{redu}_{\beta} (\beta + C)$	and = significant = peak wave = fetch lengt = gravitation = friction ve = $(C_D * U_{10}^2)$ = drag coeff = 0.0002 * (= wind speet wind speet = $b^* \gamma_h * \gamma_\beta$ wave runup efficients depetion conditions b * $\gamma_h * \gamma_\beta$ wave runup efficients depetion factor f grass slopes plaction factor f $\gamma_b = 1$) action factor for for wave influence of the second sec	t wave heig e period (see th (ft) nal constant elocity (ft/se) ¹ / ₂ ficient (1.1 + 0.03 d at 10m ele d at 10m ele elevation (ft) endent on ε_p (as for levee slop ber CEM Tab for influence ence, $\gamma_h = 1$) for influence	$\frac{v^*T_p}{u_f^2} = 0.75$ ht (ft) c) z = 32.2 ft/s evation (ft/s) evation (ft/s) $\epsilon_p < 2, A = 1$ y per CEM T be roughness le VI-5-3) of a berm (a of shallow w of angle of i	1 * $\left(\frac{g*X}{u_f^2}\right)^{\frac{1}{3}}$ ec sec) H for all win .6, C = 0 for Table VI-5-2 (assumed γ_r ssumed non- vaves (assum ncidence, β ,	nd direction r all wind r all wind r = 0.9 for -bermed of the	CEM Equation II-2-36 CEM Equation II-2-36 Image: I	Finding A & C: Table VI-5-2 Coefficients in Equation Irregular Waves on Smo ζ R _u R _{u2 percent} ζ _{op} R _{us}	n VI-5-3 for Runup of Long-Cooth Impermeable Slopes ξ -Limits $\xi_{p} \leq 2.5$ $2.5 < \xi_{p} < 9$ $\xi_{p} \leq 2.0$ $2.0 < \xi_{p} < 9$	Lan α = opp	A 1.6 -0.2 1.35 -0.15	cent = vertica	σ_{Ru}	Ru 5	
ion C _D : , u _f : I _{mo} :	0.00087 2.74 1.958 6.05 0.44 4.35 -0.2 4.5 3.91 2.62	ft/sec ft 0.834744 0.597071 sec sec 1 1 sec 1	$\frac{g * H_{mo}}{u_f^2} = 0.0413 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{2}}$ Where: H_mo = T_p = X = g = U_f = U_10 = U_{10} $-\varepsilon_p = \frac{\tan(\alpha)}{\sqrt{\frac{2\pi * H_{mo}}{g * T_p^2}}}$ Where: $\varepsilon_p = \sup_{x \in \alpha \in \beta \\ x \in \beta $	and = significant = peak wave = fetch lengt = gravitation = friction ve = $(C_D * U_{10}^2)$ = drag coeff = 0.0002 * (= wind speet wind speet = $b^* \gamma_h * \gamma_\beta$ wave runup efficients depetion conditions to conditions b * $\gamma_h * \gamma_\beta$ wave runup efficients depetion conditions action factor f grass slopes plaction factor f $\gamma_b = 1$) action factor f www influence of the source of the sou	t wave heig e period (see th (ft) nal constant elocity (ft/se) ¹ / ₂ ficient (1.1 + 0.03 d at 10m ele d at 10m ele elevation (ft) endent on ε_p (as for levee slop ber CEM Tab for influence ence, $\gamma_h = 1$) for influence	$\frac{v^*T_p}{u_f^2} = 0.75$ ht (ft) c) z = 32.2 ft/s evation (ft/s) evation (ft/s) $\epsilon_p < 2, A = 1$ y per CEM T be roughness le VI-5-3) of a berm (a of shallow w of angle of i	1 * $\left(\frac{g*X}{u_f^2}\right)^{\frac{1}{3}}$ ec sec) H for all win .6, C = 0 for Table VI-5-2 (assumed γ_r ssumed non- vaves (assum ncidence, β ,	nd direction r all wind r all wind r = 0.9 for -bermed of the	CEM Equation II-2-36 CEM Equation II-2-36 Image: I	Finding A & C: Table VI-5-2 Coefficients in Equation Irregular Waves on Smo ζ R _u R _{u2 percent} ζ _{op} R _{us}	n VI-5-3 for Runup of Long-Cooth Impermeable Slopes ξ -Limits $\xi_{p} \leq 2.5$ $2.5 < \xi_{p} < 9$ $\xi_{p} \leq 2.0$ $2.0 < \xi_{p} < 9$	Lan α = opp	A 1.6 -0.2 1.35 -0.15	cent = vertica	σ_{Ru}	Ru 5 0	
ion C _D : , u _f : I _{mo} : I _{mo} : I T _p : C C C C C C C C C C C C C	0.00087 2.74 1.958 6.05 0.44 4.35 -0.2 4.5 3.91 2.62	ft/sec ft 0.834744 0.597071 sec	$\frac{g * H_{mo}}{u_f^2} = 0.0413 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{2}}$ Where: H_mo = T_p = X g = U_f = C_D = U_{10} $- \varepsilon_p = \frac{\tan(\alpha)}{\sqrt{\frac{2\pi * H_{mo}}{g * T_p^2}}}$ Where: $\varepsilon_p = \sup_{tan(\alpha) = w} \tan(\alpha) = w$ $- \varepsilon_p = H_{mo} * (A * \varepsilon_p + C) * \gamma_r * \gamma_r$ Where: $R_{2\%} = 2\%$ $A, C = \operatorname{coer}_{direct}$ $\gamma_r = \operatorname{redu}_{3 \operatorname{cm}}$ $\gamma_b = \operatorname{redu}_{5 \operatorname{hallo}}$ $\gamma_\beta = \operatorname{redu}_{5 \operatorname{hallo}}$ $\gamma_\beta = \operatorname{redu}_{5 \operatorname{hallo}}$	and = significant = peak wave = fetch leng = gravitation = friction ve = $(C_D * U_{10}^2)$ = drag coeff = 0.0002 * (= wind spee wind spee b * $\gamma_h * \gamma_\beta$ wave runup efficients dependent in conditions b * $\gamma_h * \gamma_\beta$ wave runup efficients dependent in conditions action factor for grass slopes production factor for y b = 1) action factor for wave influence 0.0022 * β	t wave heig e period (see th (ft) nal constant elocity (ft/se) ¹ / ₂ ficient (1.1 + 0.03 d at 10m ele at 10m ele elevation (ft) endent on ε_p (as for levee slop ber CEM Tab for influence for influence ence, $\gamma_h = 1$) for influence	$\frac{v^*T_p}{u_f^2} = 0.75$ ht (ft) c) z = 32.2 ft/s evation (ft/s) sumed 1V:3 $\epsilon_p < 2, A = 1$ y per CEM T be roughness le VI-5-3) of a berm (a of shallow w of angle of i	$1 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{3}}$ ec sec) H for all win .6, C = 0 for Table VI-5-2 (assumed γ_r ssumed non- vaves (assum ncidence, β ,	nd direction r all wind r all wind r = 0.9 for -bermed of the	CEM Equation II-2-36 CEM Equation II-2-36 I <	Finding A & C: Table VI-5-2 Coefficients in Equation Irregular Waves on Smo ξR_u $R_{u2 percent}$ ζ_{op} R_{us}	n VI-5-3 for Runup of Long-Cooth Impermeable Slopes ξ -Limits $\xi_{p} \leq 2.5$ $2.5 < \xi_{p} < 9$ $\xi_{p} \leq 2.0$ $2.0 < \xi_{p} < 9$	Lan α = opp	A 1.6 -0.2 1.35 -0.15	cent = vertica	σ_{Ru}	I I I	
ion C _D : , u _f : I _{mo} : I _{mo} : I I _{mo} : C ₁ C ₂ C ₁ C ₁ C ₂ C ₁ C ₁ C ₂ C ₁ C ₁	0.00087 2.74 1.958 6.05 0.44 4.35 -0.2 4.5 3.91 2.62	ft/sec ft 0.834744 0.597071 sec	$\frac{g * H_{mo}}{u_f^2} = 0.0413 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{2}}$ Where: H_mo T _p X g u _f C _D U ₁₀ $\frac{e_p}{\sqrt{\frac{2\pi * H_{mo}}{g * T_p^2}}}$ Where: $\varepsilon_p = \sup_{tan(\alpha)} = \sup_{tan(\alpha) = w} \sum_{con} \sum_{tan(\alpha) = w} \sum_{ta$	and = significant = peak wave = fetch leng = gravitation = friction ve = $(C_D * U_{10}^2)$ = drag coeff = 0.0002 * (= wind spee wind spee = $\frac{1}{2}$ wave runup efficients dependent of the second b * $\gamma_h * \gamma_\beta$ wave runup efficients dependent of the second for the second f	t wave heig e period (see th (ft) nal constant elocity (ft/se) ¹ / ₂ ficient (1.1 + 0.03 d at 10m ele parameter e of levee (as elevation (ft) endent on ε_p (is in this study for levee slop ber CEM Tab for influence for influence ence, $\gamma_h = 1$) for influence	$\frac{i*T_p}{u_f^2} = 0.75$ ht (ft) c) z = 32.2 ft/s evation (ft/s) sumed 1V:3 $\epsilon_p < 2, A = 1$ y per CEM T be roughness le VI-5-3) of a berm (a of shallow w of angle of i	$1 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{3}}$ ec sec) H for all win Cable VI-5-2 (assumed γ_r ssumed non- vaves (assum ncidence, β ,	nd direction r all wind r = 0.9 for - -bermed ned no of the	CEM Equation II-2-36 CEM Equation II-2-36 Image: I	Finding A & C: Table VI-5-2 Coefficients in Equation Irregular Waves on Smo ξR_u $R_{u2 percent$ Cop R_{us}	n VI-5-3 for Runup of Long-Cooth Impermeable Slopes ξ -Limits $\xi_p \leq 2.5$ $2.5 < \xi_p < 9$ $\xi_p \leq 2.0$ $2.0 < \xi_p < 9$	Lan α = opp	A 1.6 -0.2 1.35 -0.15	cent = vertica	σ_{Ru}	I I I	
ion C _D : , u _f : I _{mo} : ion T _p : ion n α: ε _p : ion A: C: k ₂ %: //eg.:	0.00087 2.74 1.958 6.05 0.44 4.35 -0.2 4.5 3.91 2.62	ft/sec ft 0.834744 0.597071 sec	$\frac{g * H_{mo}}{u_f^2} = 0.0413 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{2}}$ Where: H_mo T _p X g u _f C _D U ₁₀ $\frac{e_p}{\sqrt{\frac{2\pi * H_{mo}}{g * T_p^2}}}$ Where: $\varepsilon_p = \varepsilon_p$ Co U ₁₀ $\frac{e_p}{\sqrt{\frac{2\pi * H_{mo}}{g * T_p^2}}}$ Where: $\varepsilon_p = \varepsilon_p$ Con Co Co Co Co Co Co Co Co Co Co	and = significant = peak wave = fetch leng = gravitation = friction ve = $(C_D * U_{10}^2)$ = drag coeff = 0.0002 * (= wind spee wind spee = $b^* \gamma_h * \gamma_\beta$ wave runup efficients depe ion condition action factor f grass slopes p action factor f y _b = 1) action factor f w wave influe action factor f w wave influe action factor f y _b = 1) action factor f w wave influe action factor f action fa	t wave heig e period (see th (ft) nal constant elocity (ft/see) ¹ / ₂ ficient (1.1 + 0.03 d at 10m ele parameter e of levee (as elevation (ft) endent on ε_p (is in this study for levee slop ber CEM Tab for influence for influence ence, $\gamma_h = 1$) for influence	$\frac{v^*T_p}{u_f^2} = 0.75$ ht (ft) c) z = 32.2 ft/s evation (ft/s) sumed 1V:33 $\epsilon_p < 2, A = 1$ y per CEM T be roughness le VI-5-3) of a berm (a of shallow w of angle of i	$1 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{3}}$ ec sec) H for all win .6, C = 0 for Table VI-5-2 (assumed vr ssumed non- vaves (assun ncidence, β ,	r all wind r all wind r = 0.9 for -bermed of the	CEM Equation II-2-36 CEM Equation II-2-36 I <	Finding A & C: Table VI-5-2 Coefficients in Equation Irregular Waves on Smo ξR_u $R_{u2 percent$ Cop R_{us}	n VI-5-3 for Runup of Long-Cooth Impermeable Slopes ξ -Limits $\xi_p \leq 2.5$ $2.5 < \xi_p < 9$ $\xi_p \leq 2.0$ $2.0 < \xi_p < 9$	Lan α = opp	A 1.6 -0.2 1.35 -0.15	cent = vertica	σ_{Ru}	Ru 5 0 1 <t< td=""><td></td></t<>	
ion C _D : , u _f : I _{mo} : ion T _p : ion n α: ε _p : ion A: C: k ₂ %: //eg.: //eg.:	0.00087 2.74 1.958 6.05 0.44 4.35 -0.2 4.5 3.91 2.62	ft/sec ft 0.834744 0.597071 sec sec 1 1 sec 1	$\frac{g * H_{mo}}{u_f^2} = 0.0413 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{2}}$ Where: H_{mo} Tp X g Uf CD U10 $\epsilon_p = \frac{\tan(\alpha)}{\sqrt{\frac{2\pi * H_{mo}}{g * T_p^2}}}$ Where: $\epsilon_p = \sin(\alpha)$ $R_{2\%} = H_{mo} * (A * \epsilon_p + C) * \gamma_r * \gamma_r$ Where: $R_{2\%} = 2\%$ A,C = coer direct γ_r = redu 3 cm γ_b = redu β γ_{β} = redu β γ_{β} = redu β γ_{β} = redu γ_{β}	and = significant = peak wave = fetch leng = gravitation = friction ve = $(C_D * U_{10}^2)$ = drag coeff = 0.0002 * (= wind spee wind spee = $b^* \gamma_h * \gamma_\beta$ wave runup efficients depe ion condition action factor f grass slopes p action factor f $\gamma_b = 1$) action factor f w wave influe action factor f w wave influe action factor f $\gamma_b = 1$) action factor f w wave influe action factor f action factor f w wave influe action factor f action factor f actio	t wave heig e period (see th (ft) nal constant elocity (ft/see) ¹ / ₂ ficient (1.1 + 0.03 d at 10m ele parameter e of levee (as elevation (ft) endent on ε_p (is in this study for levee slop ber CEM Tab for influence for influence ence, $\gamma_h = 1$) for influence	$\frac{*T_p}{u_f^2} = 0.75$ ht (ft) c) z = 32.2 ft/s ec) $55 * U_{10}$) evation (ft/s) sumed 1V:3 $\epsilon_p < 2, A = 1$ y per CEM T be roughness le VI-5-3) of a berm (a of shallow w of angle of i	$1 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{3}}$ ec sec) H for all win .6, C = 0 for Table VI-5-2 (assumed vr ssumed non- vaves (assun ncidence, β,	nd direction r all wind r a	CEM Equation II-2-36 CEM Equation II-2-36 I <	$= \frac{1}{\alpha}$	n VI-5-3 for Runup of Long-Cooth Impermeable Slopes ξ -Limits $\xi_p \leq 2.5$ $2.5 < \xi_p < 9$ $\xi_p \leq 2.0$ $2.0 < \xi_p < 9$	Lan α = opp	A 1.6 -0.2 1.35 -0.15	cent = vertica	al/horizonta	Ru 5 0 1 <t< td=""><td></td></t<>	
iion C _D : , u _f : imo:	0.00087 2.74 1.958 6.05 0.44 4.35 -0.2 4.5 3.91 2.62	image: sec image: sec 0.834744 image: sec sec image: sec image: sec image: sec	$\frac{g * H_{mo}}{u_f^2} = 0.0413 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{2}}$ Where: H_mo Tp X g Uf CD U10 $\frac{g * H_{mo}}{V_f} = \frac{T_p}{V_f}$ $\frac{g * T_p^2}{V_f}$ Where: $\varepsilon_p = \frac{tan(\alpha)}{\sqrt{\frac{2\pi * H_{mo}}{g * T_p^2}}}$ Where: $\varepsilon_p = suttan(\alpha) = w$ con R_2% = H_mo * $(A * \varepsilon_p + C) * \gamma_r * \gamma_r$ Where: $R_{2\%} = 2\%$ A,C = coest direct $\gamma_r = redutaton Standard Standard \gamma_b = redutaton Standard Standard Standard Standard \gamma_b = redutaton Standard Standard Standard Standard \gamma_b = redutaton Standard St$	and = significant = peak wave = fetch leng = gravitation = friction ve = $(C_D * U_{10}^2)$ = drag coeff = 0.0002 * (= wind spee b * $\gamma_h * \gamma_\beta$ wave runup efficients depe ion conditions b * $\gamma_h * \gamma_\beta$ wave runup efficients depe ion conditions action factor f grass slopes p action factor f b wave influence 0.0022 * β	t wave heig e period (see th (ft) nal constant elocity (ft/see) ¹ / ₂ ficient (1.1 + 0.03 d at 10m ele parameter e of levee (as elevation (ft) endent on ε_p (is in this study for levee slop ber CEM Tab for influence for influence ence, $\gamma_h = 1$) for influence	$\frac{*T_p}{u_f^2} = 0.75$ ht (ft) c) z = 32.2 ft/s ec) z = 32.2 ft/s ec) z = 32.2 ft/s ec) z = 32.2 ft/s z =	$1 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{3}}$ ec sec) H for all win .6, C = 0 for Table VI-5-2 (assumed vr ssumed non- vaves (assun ncidence, β,	nd direction	CEM Equation II-2-36 CEM Equation II-2-36 I <	$= \frac{ }{ } = \frac{ }{ $	n VI-5-3 for Runup of Long-Cooth Impermeable Slopes ξ -Limits $\xi_p \leq 2.5$ $2.5 < \xi_p < 9$ $\xi_p \leq 2.0$ $2.0 < \xi_p < 9$	Lan α = opp	A 1.6 -0.2 1.35 -0.15	cent = vertica	al/horizonta		
iion C _D : , u _f : imo:	0.00087 2.74 1.958 6.05 0.44 4.35 -0.2 4.5 3.91 2.62 0.34 2.62	Image: sec Image: sec Sec Image: sec Image: sec Image: s	$\frac{g*H_{mo}}{u_{f}^{2}} = 0.0413 * \left(\frac{g*x}{u_{f}^{2}}\right)^{\frac{1}{2}}$ Where: H_mo T _p X g U _f C _D U ₁₀ $\frac{e_{p}}{\sqrt{\frac{2\pi * H_{mo}}{g*T_{p}^{2}}}}$ Where: ε_{p} = su tan(α) = w con $R_{2\%} = H_{mo} * (A * \varepsilon_{p} + C) * \gamma_{r} * \gamma_{r}$ Where: $R_{2\%} = 2\%$ A,C = coet direct γ_{r} = redu 3 cm γ_{b} = redu y_{b} = redu y_{b} = redu y_{c} = 1 - 1	and = significant = peak wave = fetch leng = gravitation = friction ve = $(C_D * U_{10}^2)$ = drag coeff = 0.0002 * (= wind speed wind speed = $h^2 \gamma_h * \gamma_\beta$ wave runup efficients dependent of the second b * $\gamma_h * \gamma_\beta$ wave runup efficients dependent of the second action factor for the second for the	t wave heig e period (see th (ft) nal constant elocity (ft/see) ¹ / ₂ ficient (1.1 + 0.03 d at 10m ele parameter e of levee (as elevation (ft) indent on ε_p (is in this study for levee slop ber CEM Tab for influence for influence ence, $\gamma_h = 1$) for influence	$\frac{v^*T_p}{u_f^2} = 0.75$ ht (ft) c) z = 32.2 ft/s ec) z = 32.2 ft/s ec) z = 32.2 ft/s ec) z = 32.2 ft/s z	$1 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{3}}$ ec sec) H for all win .6, C = 0 for Table VI-5-2 (assumed non- vaves (assum ncidence, β,	nd direction	CEM Equation II-2-36 CEM Equation II-2-36 I I I I I I I I I I I I I I I I I I I	$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	n VI-5-3 for Runup of Long-Cooth Impermeable Slopes ξ -Limits $\xi_{p} \leq 2.5$ $2.5 < \xi_{p} < 9$ $\xi_{p} \leq 2.0$ $2.0 < \xi_{p} < 9$	Lan α = opp	A 1.6 -0.2 1.35 -0.15	cent = vertica	al/horizonta		
iion C _D : , u _f : imo:	0.00087 2.74 1.958 6.05 6.05 0.44 4.35 0.44 4.35 3.91 2.62 0.34 2.62 0.34 2.62	i i ft/sec i ft i 0.834744 i 0.597071 i sec i sec i sec i i i sec i i i	$\frac{g*H_{mo}}{u_{f}^{2}} = 0.0413 * \left(\frac{g*x}{u_{f}^{2}}\right)^{\frac{1}{2}}$ Where: H_mo Tp X g uf CD U10 $\frac{z_{p}}{\sqrt{\frac{2\pi * H_{mo}}{g*T_{p}^{2}}}}$ Where: $\varepsilon_{p} = \frac{\tan(\alpha)}{\sqrt{\frac{2\pi * H_{mo}}{g*T_{p}^{2}}}}$ Where: $\varepsilon_{p} = s_{p}$ $\varepsilon_{p} = \frac{\tan(\alpha)}{\sqrt{\frac{2\pi * H_{mo}}{g*T_{p}^{2}}}}$ Where: $\varepsilon_{p} = s_{p}$ $\varepsilon_{p} = \frac{1}{\sqrt{\frac{2\pi * H_{mo}}{g*T_{p}^{2}}}}$ Where: $\varepsilon_{p} = c_{p}$ $\varepsilon_{p} = 1$ $\varepsilon_{p} = \frac{1}{\sqrt{\frac{2\pi * H_{mo}}{g*T_{p}^{2}}}}$ Where: $\varepsilon_{p} = 1$	and = significant = peak wave = fetch leng = gravitation = friction ve = $(C_D * U_{10}^2)$ = drag coeff = 0.0002 * (= wind spee b * $\gamma_h * \gamma_\beta$ wave runup efficients depe ion conditions b * $\gamma_h * \gamma_\beta$ wave runup efficients depe ion conditions action factor f grass slopes p action factor f b wave influence 0.0022 * β	$\frac{g}{2}$ t wave heig e period (set th (ft) nal constant elocity (ft/set) ¹ / ₂ ficient (1.1 + 0.03 d at 10m ele parameter e of levee (as elevation (ft) ndent on ε_p (is in this study for levee slop ber CEM Tab for influence for influence ence, $\gamma_h = 1$) for influence	$\frac{*T_p}{u_f^2} = 0.75$ ht (ft) c) z = 32.2 ft/s ec) $55 * U_{10}$) evation (ft/s) sumed 1V:3 $\epsilon_p < 2, A = 1$ y per CEM T be roughness le VI-5-3) of a berm (a of shallow w of angle of i	$1 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{3}}$ ec sec) H for all win .6, C = 0 for Table VI-5-2 (assumed non- vaves (assum ncidence, β,	nd direction r all wind r a	CEM Equation II-2-36CEM Equation II-2-36III	$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	n VI-5-3 for Runup of Long-Cooth Impermeable Slopes $ \frac{\xi-Limits}{\xi_{p} \leq 2.5} $ $ 2.5 < \xi_{p} < 9 $ $ \frac{\xi} - 2.5 < \xi_{p} < 9 $ $ \frac{\xi} - 2.5 < \xi_{p} < 9 $ $ \frac{\xi} - \xi_{p} < 9 $	Lan α = opp	A 1.6 -0.2 1.35 -0.15	cent = vertica	al/horizonta		
iion C _D : , u _f : Imo:	0.00087 2.74 1.958 6.05 6.05 0.2 4.35 3.91 2.62 0.2 4.5 3.91 2.62 0.2 4.5 3.91	Image: sec Image: sec Sec Image: sec Image: sec Image: s	$\frac{g*H_{mo}}{u_{f}^{2}} = 0.0413 * \left(\frac{g*x}{u_{f}^{2}}\right)^{\frac{1}{2}}$ Where: H_mo Tp X g uf CD U10 $\frac{e_{p}}{\sqrt{\frac{2\pi * H_{mo}}{g*T_{p}^{2}}}}$ Where: ε_{p} = su $\tan(\alpha) = w$ $\cos(\alpha)$ $R_{2\%} = H_{mo} * (A * \varepsilon_{p} + C) * \gamma_{r} * \gamma_{r}$ Where: $R_{2\%} = 2\%$ A,C = coet direct γ_{r} = redu 3 cm γ_{b} = redu	and = significant = peak wave = fetch lengt = gravitation = friction ve = $(C_D * U_{10}^2)$ = drag coeff = 0.0002 * (= wind speed wind speed = wind speed = $h^2 + \gamma_h * \gamma_\beta$ wave runup efficients dependent of the second b * $\gamma_h * \gamma_\beta$ wave runup efficients dependent of the second sec	t wave heig e period (see th (ft) nal constant elocity (ft/se) ¹ / ₂ ficient (1.1 + 0.03 d at 10m ele parameter e of levee (as elevation (ft) endent on ε_p (as for levee slop ber CEM Tab for influence for influence for influence	$\frac{v^*T_p}{u_f^2} = 0.75$ ht (ft) c) z = 32.2 ft/s ec) z = 32.2 ft/s ec) z = 32.2 ft/s ec) z = 32.2 ft/s ec) z = 32.2 ft/s z = 32.2 ft/	$1 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{3}}$ ec sec) H for all win .6, C = 0 for Table VI-5-2 (assumed non- vaves (assum ncidence, β,	nd direction	CEM Equation II-2-36CEM Equation II-2-36III	$= \frac{ }{ }$	n VI-5-3 for Runup of Long-Cooth Impermeable Slopes ξ -Limits $\xi_{p} \leq 2.5$ $2.5 < \xi_{p} < 9$ $\xi_{p} \leq 2.0$ $2.0 < \xi_{p} < 9$	Lan α = opp	A 1.6 -0.2 1.35 -0.15	cent = vertica	al/horizonta		
iion C _D : , u _f : Imo: iion T _p : iion T _p : iion T _p : iion T _p : iion C: Z _{2%} : Veg.: Veg.: Veg.: UP: Veg.:	0.00087 2.74 1.958 6.05 	Image: sec Image: sec Sec Image: sec Image: sec Image: s	$\frac{g*H_{mo}}{u_{f}^{2}} = 0.0413 * \left(\frac{g*x}{u_{f}^{2}}\right)^{\frac{1}{2}}$ Where: H_mo Tp X g uf CD CD U10 $\frac{z_{\pi} * H_{mo}}{\sqrt{\frac{2\pi * H_{mo}}{g * T_{p}^{2}}}}$ Where: $\varepsilon_{p} = \frac{\sin(\alpha)}{\sqrt{\frac{2\pi * H_{mo}}{g * T_{p}^{2}}}}$ Where: $R_{2\%} = 2\%$ A,C = coer direct $\gamma_{r} = \operatorname{redu}_{3 \text{ cm}}$ $\gamma_{b} = \operatorname{redu}_{3 \text{ cm}}$	and = significant = peak wave = fetch lengt = gravitation = friction ve = $(C_D * U_{10}^2)$ = drag coeff = 0.0002 * (= wind speed wind speed = wind speed = $h^2 + \gamma_h * \gamma_\beta$ wave runup efficients dependent ion conditions b * $\gamma_h * \gamma_\beta$ wave runup efficients dependent ion conditions action factor for grass slopes provide the state of the state of the second action factor for the second	t wave heig e period (see th (ft) nal constant elocity (ft/see) ¹ / ₂ Ficient (1.1 + 0.03 d at 10m ele parameter e of levee (as elevation (ft) endent on ε_p (s in this study for levee slop ber CEM Tab for influence for influence ence, $\gamma_h = 1$) for influence	$\frac{*T_p}{u_f^2} = 0.75$ ht (ft) c) z = 32.2 ft/s ec) $55 * U_{10}$) evation (ft/s) sumed 1V:3. $\varepsilon_p < 2, A = 1$ y per CEM T be roughness le VI-5-3) of a berm (a of shallow w of angle of i	$1 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{3}}$ ec sec) H for all win .6, C = 0 for Table VI-5-2 (assumed non- vaves (assum ncidence, β,	nd direction	CEM Equation II-2-36ICEM Equation II-2-36III </th <th>$\begin{array}{c c c c c c c c c c c c c c c c c c c$</th> <th>n VI-5-3 for Runup of Long-Cooth Impermeable Slopes ξ-Limits $\xi_p \leq 2.5$ $2.5 < \xi_p < 9$ $\xi_p \leq 2.0$ $2.0 < \xi_p < 9$</th> <th>Lan α = opp</th> <th>A 1.6 -0.2 1.35 -0.15 -0</th> <th>cent = vertica</th> <th>σ_{Ru}</th> <th></th> <th></th>	$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	n VI-5-3 for Runup of Long-Cooth Impermeable Slopes ξ -Limits $\xi_p \leq 2.5$ $2.5 < \xi_p < 9$ $\xi_p \leq 2.0$ $2.0 < \xi_p < 9$	Lan α = opp	A 1.6 -0.2 1.35 -0.15 -0	cent = vertica	σ_{Ru}		

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quation VI-5	-3, Valid for 1 <	: č _{op} < 3-4						
			7	r .0 .0				
			0	1.90 - 1.0 1.55 - 0.6 1.50 - 0.55				
t = h)								
).70 - 0.75).75 - 0.85).85 - 0.95).85 - 0.95				
			c).60 - 0.70				
	tan α = opp	oosite/adjad	cent = vertica	al/horizonta	al			
of Long-C Slopes mits	rested	Δ	0	<i>r</i> -	/ R			
2.5 < ξ _p < 9		1.6 -0.2	0 4.5	≈ 0.	15			
2.0 < ξ _ρ < 9		1.35 -0.15	0 3.0	≈ 0.	10			

WIND SETUP & WAVE RUNUP INPUTS

Primary Inputs		
Design 72.9yr Wind Speed, U _z : 5	1 mph	
Height at Which Observations were Taken, z: 7.9	9 m	
Assumed Fetch Length, F: 2.70	6 mi	
Average Water Depth Along Fetch Line, d: 10.5	9 ft	
Waterside Levee Slope (H/V): 2.2	5	
Angle of incidence for waves Approaching the Levee, p:	degrees	
Reduction Factors		
Reduction Factor for Levee Slope Boughness y:	6	
$\frac{1}{1}$		
$\begin{array}{c} \text{Reduction Factor for laftwares of Challen Waves and \\ \end{array}$		
Reduction Factor for influence of Shallow Waves, γ_h : 1.	0	
Reduction Factor for Influence of Angle of Incidence, γ_{β} : 1.00	0	
tor for the Presence of Vegetation Along the Fetch Line, $\gamma_{Veg.}$: 0.6	7	
Secondary/Calculated Inputs		
2.9yr Wind Speed Corrected for 10m Observation Height, U_{10} : 52.	7 mph	
Design 72.9yr Wind Speed Corrected for Over Water: 63.	3 mph	
Design 72.9yr Wind Speed Corrected for Over Water: 92.3	8 TT/SEC	
Assumed Fetch Length, F: 14,57	5 11	
ALCULATIONS		
Wind Setup (Zeider Zee Equation), S: 0.74	6 ft	
Wind Setup (Sibul Equation), S: 0.40	7 ft	
AVERAGE WIND SETUP, S: 0.5	8 ft	
Wind Setup (Zeider Zee Equation), S:	- ft	
CALCULATIONS		
Significant Wave Height (H _{mo}) Calculation		
Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : 0.0008	7	
Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : 0.0008' Friction Velocity, uc: 2.74	7 4 ft/sec	
Significant Wave Height (Hmo) Calculation Drag Coefficient, Cp: 0.0008 Friction Velocity, uf: 2.74 Significant Wave Height H 2.40	7 4 ft/sec	
Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : 0.0008 Friction Velocity, u _f : 2.74 Significant Wave Height, H _{mo} : 2.400	7 4 ft/sec 6 ft	
Significant Wave Height (Hmo) Calculation Drag Coefficient, CD: 0.0008 Friction Velocity, uf: 2.74 Significant Wave Height, Hmo: 2.40	7 4 ft/sec 6 ft 0.834744 0.733415	
Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : 0.0008 Friction Velocity, u _f : 2.74 Significant Wave Height, H _{mo} : 2.400 Peak Wave Period (T_) Calculation 1	7 4 ft/sec 6 ft 0.834744 0.733415	
Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : 0.0008 Friction Velocity, u _f : 2.74 Significant Wave Height, H _{mo} : 2.40 Peak Wave Period (T _p) Calculation 0 Peak Wave Period (T _p) Calculation 0	7 4 ft/sec 6 ft 0.834744 0.733415	
Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : 0.0008 Friction Velocity, u _f : 2.74 Significant Wave Height, H _{mo} : 2.404 Peak Wave Period (T _p) Calculation 2.404 Peak Wave Period (T _p) Calculation 6.94	7 4 ft/sec 6 ft 0.834744 0.733415 4 sec	
Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : 0.0008 Friction Velocity, u _f : 2.74 Significant Wave Height, H _{mo} : 2.40 Peak Wave Period (T _p) Calculation 1 Peak Wave Period, T _p : 6.94	7 4 ft/sec 6 ft 0.834744 0.733415 4 sec	
Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : 0.0008 Friction Velocity, u _f : 2.74 Significant Wave Height, H _{mo} : 2.40 Peak Wave Period (T _p) Calculation 1 Peak Wave Period, T _p : 6.94	7 4 ft/sec 6 ft 0.834744 0.733415 4 sec	
Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : 0.0008 Friction Velocity, u _f : 2.74 Significant Wave Height, H _{mo} : 2.404 Peak Wave Period (T _p) Calculation 2.404 Peak Wave Period (T _p) Calculation 0.0008 Peak Wave Period, T _p : 6.94	7 4 ft/sec 6 ft 0.834744 0.733415 4 sec	
Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : 0.0008 Friction Velocity, u _f : 2.74 Significant Wave Height, H _{mo} : 2.40 Peak Wave Period (T _p) Calculation 1 Peak Wave Period (T _p) Calculation 1 Significant Wave Period, T _p : 6.94 Suff Similarity (ε _n) Calculation 1	7 4 ft/sec 6 ft 0.834744 0.733415 4 sec	
Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : 0.0008 Friction Velocity, u _f : 2.7 Significant Wave Height, H _{mo} : 2.40 Peak Wave Period (T _p) Calculation 1 Peak Wave Period (T _p) Calculation 1 Significant Wave Period, T _p : 6.9 Surf Similarity (ε _p) Calculation 1 Waterside levee slope angle, tan α: 0.4	7 4 ft/sec 6 ft 0.834744 0.733415 4 sec 4 sec	
Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : 0.0008' Friction Velocity, u _f : 2.7 Significant Wave Height, H _{mo} : 2.40 Significant Wave Height, H _{mo} : 2.40 Peak Wave Period (T _p) Calculation 1 Peak Wave Period, T _p : 6.9 Surf Similarity (ε _p) Calculation 1 Waterside levee slope angle, tan α: 0.4 Surf Similarity Parameter, ε _n : 4.50	7 4 ft/sec 6 ft 0.834744 0.733415 4 sec 4 sec 4 sec 4 sec 5 ft 6 ft 7 ft	
Significant Wave Height (H_{mo}) CalculationDrag Coefficient, C_D :0.0008'Friction Velocity, u_f :2.7'Significant Wave Height, H_{mo} :2.40'Significant Wave Height, H_{mo} :2.40'Peak Wave Period (T_p) Calculation9'Peak Wave Period, T_p :6.9'Surf Similarity (ε_p) Calculation0'Waterside levee slope angle, tan α :0.4'Surf Similarity Parameter, ε_p :4.5'	7 4 ft/sec 6 ft 0.834744 0.733415 4 sec 4 sec 4 sec 4 sec	
Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : 0.0008' Friction Velocity, u _f : 2.7' Significant Wave Height, H _{mo} : 2.40' Peak Wave Period (T _p) Calculation 1 Peak Wave Period (T _p) Calculation 1 Significant Wave Period, T _p : 6.9' Surf Similarity (ε _p) Calculation 1 Waterside levee slope angle, tan α: 0.4' Surf Similarity Parameter, ε _p : 4.5'	7 4 ft/sec 6 ft 0.834744 0.733415 4 sec 4 sec 4 sec 4 sec 5 c 6 c 7 c 7 c 7 c 8 c 7 c 7 c 8 c 7 c 7 c 7 c 8 c 7 c 7 c 7 c 7 c 7 c 7 c 7 c 7	
Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : 0.0008 Friction Velocity, u _f : 2.74 Significant Wave Height, H _{mo} : 2.40 Peak Wave Period (T _p) Calculation 2.40 Peak Wave Period (T _p) Calculation 2.40 Peak Wave Period (T _p) Calculation 2.40 Wave Period (T _p) Calculation 2.40 Value	7 4 ft/sec 6 ft 0.834744 0.733415 4 sec 4 sec 4 sec 4 o	
Significant Wave Height (H_{mo}) Calculation Drag Coefficient, C_{D} : 0.0008 Friction Velocity, u_{f} : 2.74 Significant Wave Height, H_{mo} : 2.40 Peak Wave Period (T_{p}) Calculation 2.40 Peak Wave Period (T_{p}) Calculation 2.40 Significant Wave Period (T_{p}) Calculation 2.40 Surf Similarity (ϵ_{p}) Calculation 2.40 Surf Similarity Parameter, ϵ_{p} : 4.50 Surf Similarity Parameter, ϵ_{p} : 4.50	7 4 ft/sec 6 ft 0.834744 0.733415 4 sec 4 sec 4 sec 0 1 1 1 1 1 1 1 1 1 1 1 1 1	
Significant Wave Height (H _{ma}) Calculation Drag Coefficient, C _D : 0.0008 Friction Velocity, u _f : 2.74 Significant Wave Height, H _{mo} : 2.40 Significant Wave Height, H _{mo} : 2.40 Peak Wave Period (T _p) Calculation 1 Peak Wave Period (T _p) Calculation 1 Surf Similarity (ε _p) Calculation 1 Surf Similarity (ε _p) Calculation 1 Surf Similarity Parameter, ε _p : 4.51 Surf Similarity Parameter, ε _p : 4.51 Surf Similarity Calculation 1 Surf Similarity Parameter, ε _p : 4.51	7 4 ft/sec 6 ft 0.834744 0.733415 4 sec 4 sec 4 sec 1 4 sec 1 5 sec 1 1 5 sec 1 5 sec 1	
Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : 0.0008' Friction Velocity, u _f : 2.7' Significant Wave Height, H _{mo} : 2.40' Peak Wave Period (T _p) Calculation 2.40' Peak Wave Period (T _p) Calculation 6.9' Water Side levee Slope angle, tan α: 0.4' Surf Similarity Parameter, ε _p : 4.5' 2% Wave Runup (R _{2%}) Calculation A:	7 4 6 ft/sec 6 0.834744 0.733415 4 0.733415 4 0 4 0 1	
Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _p : 0.0008 Friction Velocity, u _f : 2.7 Significant Wave Height, H _{mo} : 2.40 Significant Wave Height, H _{mo} : 2.40 Peak Wave Period (T _p) Calculation 6.9 Peak Wave Period, T _p : 6.9 Surf Similarity (ε _p) Calculation 6.9 Surf Similarity (ε _p) Calculation 6.9 Surf Similarity Parameter, ε _p : 4.50 Surf Similarity Parameter, ε _p : 4.50 Surf Similarity Parameter, ε _p : 4.50 Surf Similarity Calculation 6.9 Surf Similarity Parameter, ε _p : 4.50 Surf Similarity Parameter, ε _p : 50 </td <td>7 4 ft/sec 6 ft 0.834744 0.733415 4 sec 4 sec 4 sec 4 sec 5</td> <td></td>	7 4 ft/sec 6 ft 0.834744 0.733415 4 sec 4 sec 4 sec 4 sec 5	
Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : 0.0008 Friction Velocity, u _f : 2.7 Significant Wave Height, H _{mo} : 2.40 Peak Wave Period (T _p) Calculation 2.40 Peak Wave Period (T _p) Calculation 6.9 Peak Wave Period, T _p : 6.9 Surf Similarity (ε _p) Calculation 0.4 Surf Similarity Parameter, ε _p : 4.5 Surf Similarity Parameter, ε _p : 4.5 Q% Wave Runup (R _{2%}) Calculation A: 2% Wave Runup, R _{2%} : 4.7	7 4 ft/sec 6 ft 0.834744 0.733415 4 sec 4 sec 4 sec 1 4 sec 1 4 sec 1 5 5 6 ft	
Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : 0.0008 Friction Velocity, u _f : 2.7 Significant Wave Height, H _{mo} : 2.40 Peak Wave Period (T _p) Calculation 2.40 Peak Wave Period (T _p) Calculation 6.9 Peak Wave Period, T _p : 6.9 Waterside levee slope angle, tan α: 0.4 Surf Similarity (ε _p) Calculation 4.5 Q% Wave Runup (R _{2%}) Calculation 4.5 2% Wave Runup, R _{2%} : 4.7 2% Wave Runup, R _{2%} : 4.7	7 4 ft/sec 6 ft 0.834744 0.733415 4 sec 4 sec 4 sec 4 o 5 o 6 ft 6 ft 6 ft	
Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : 0.0008 Friction Velocity, u _f : 2.7 Significant Wave Height, H _{mo} : 2.40 Peak Wave Period (T _p) Calculation 2.40 Peak Wave Period (T _p) Calculation 2.40 Peak Wave Period (T _p) Calculation 6.9 Waterside levee slope angle, tan α: 0.4 Surf Similarity (ε _p) Calculation 4.50 Waterside levee slope angle, tan α: 0.4 Surf Similarity Parameter, ε _p : 4.50 2% Wave Runup (R _{2%}) Calculation 4.50 2% Wave Runup with Vegetative Correction, R _{2%,veg} .: 3.11	7 4 6 ft/sec 6 ft 0.834744 0.733415 4 0.733415 4 9 ft	
Significant Wave Height (H _{mn}) Calculation Drag Coefficient, C _D : 0.0008 Friction Velocity, u _f : 2.7 Significant Wave Height, H _{mo} : 2.40 Peak Wave Period (T _p) Calculation 2.40 Peak Wave Period (T _p) Calculation 2.40 Peak Wave Period (T _p) Calculation 4.5 Waterside levee slope angle, tan α: 0.4 Surf Similarity Parameter, ε _p : 4.5 2% Wave Runup (R _{2%}) Calculation 4.5 2% Wave Runup, R _{2%} : 4.7 2% Wave Runup with Vegetative Correction, R _{2%, Veg} : 3.14	7 4 ft/sec 6 ft 0.834744 0.733415 4 0.733415 4 sec 4 sec 4 sec 5 ft 6 ft 9 ft	
Significant Wave Height (H _{mn}) Calculation Drag Coefficient, C _D : 0.0008 Friction Velocity, u _f : 2.7 Significant Wave Height, H _{mo} : 2.40 Peak Wave Period (T _p) Calculation 2.40 Peak Wave Period (T _p) Calculation 6.9 Vare Surf Similarity (ε _p) Calculation 0.4 Surf Similarity (ε _p) Calculation 0.4 Surf Similarity Parameter, ε _p : 4.5 2% Wave Runup (R _{2%}) Calculation 2 2% Wave Runup, R _{2%} : 4.7 2% Wave Runup with Vegetative Correction, R _{2%, Veg} .: 3.11	7 4 7 4 10.834744 0.733415 4 0.733415 4 9 ft	
Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : 0.0008 Friction Velocity, u _f : 2.7 Significant Wave Height, H _{mo} : 2.40 Peak Wave Period (T _p) Calculation 2.40 Peak Wave Period (T _p) Calculation 6.9 Peak Wave Period, T _p : 6.9 Waterside levee slope angle, tan α: 0.4 Surf Similarity (ε _p) Calculation 0.4 Surf Similarity Parameter, ε _p : 4.5 2% Wave Runup (R _{2%}) Calculation 2 2% Wave Runup, R _{2%} : 4.7 2% Wave Runup, R _{2%} : 3.1 2% Wave Runup with Vegetative Correction, R _{2%,Veg} : 3.1	7 4 7 4 1 0.834744 0.733415 4 0.733415 4 0.733415 4 0 1	
Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _p : 0.0008 Friction Velocity, u _f : 2.7 Significant Wave Height, H _{mo} : 2.40 Peak Wave Period (T _p) Calculation 2.40 Peak Wave Period (T _p) Calculation 6.9 Peak Wave Period, T _p : 6.9 Waterside levee slope angle, tan α: 0.4 Surf Similarity (ε _p) Calculation 0.4 Surf Similarity Parameter, ε _p : 4.5 2% Wave Runup (R _{2%}) Calculation 2 2% Wave Runup, R _{2%} : 4.7 2% Wave Runup with Vegetative Correction, R _{2%, Veg} : 3.1 2% Wave Runup with Vegetative Correction, R _{2%, Veg} : 3.1	7 4 ft/sec 6 ft 0.834744 0.733415 4 sec 4 sec 4 sec 4 sec 5 sec 6 ft 9 ft 9 ft	
Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : 0.0008 Friction Velocity, u _f : 2.7 Significant Wave Height, H _{mo} : 2.40 Peak Wave Period (T _p) Calculation 1 Peak Wave Period (T _p) Calculation 1 Surf Similarity (E _p) Calculation 1 Waterside levee slope angle, tan α: 0.4 Surf Similarity Parameter, ε _p : 4.5 2% Wave Runup (R _{2%}) Calculation 1 2% Wave Runup, R _{2%} : 4.7 2% Wave Runup with Vegetative Correction, R _{2%,Veg} .: 3.11	7 4 7 4 7 6 7 0.834744 0.733415 4 9 1	
Significant Wave Height (H _{mm}) Calculation Drag Coefficient, C ₀ : 0.0008 Friction Velocity, u _f : 2.7 Significant Wave Height, H _{m0} : 2.40 Peak Wave Period (T _p) Calculation 2.40 Peak Wave Period (T _p) Calculation 6.9 Peak Wave Period, T _p : 6.9 Surf Similarity (ε _p) Calculation 0.4 Surf Similarity Parameter, ε _p : 4.5 Surf Similarity Parameter, ε _p : 4.5 2% Wave Runup (R _{2%}) Calculation 2 2% Wave Runup, R _{2%} : 4.7 2% Wave Runup, R _{2%} : 3.1 2% Wave Runup with Vegetative Correction, R _{2%,Veg} : 3.1	7 4 ft/sec 6 ft 0.834744 0.733415 4 sec 4 sec 4 sec 4 sec 5 sec 6 ft 9 ft 9 ft 1 sec	
Significant Wave Height (H _{ma}) Calculation Drag Coefficient, C ₀ : 0.0008 Friction Velocity, u _i : 2.7 Significant Wave Height, H _{ma} : 2.40 Peak Wave Period (T _p) Calculation	7 4 7 4 7 6 7 0 0 1 <td< td=""><td></td></td<>	
Significant Wave Height (H _{ma}) Calculation Drag Coefficient, C ₀ : 0.0008 Friction Velocity, u _i : 2.7 Significant Wave Height, H _{ma} : 2.40 Peak Wave Period (T _p) Calculation	7 4 7 4 6 7 0.834744 0.733415 4 0.733415 4 9 ft 9 ft 1 <	
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Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _p : 0.0008 Friction Velocity, u _f : 2.7. Significant Wave Height, H _{mo} : 2.400 Peak Wave Period (T _p) Calculation 1 Peak Wave Period (T _p) Calculation 6.9. Peak Wave Period, T _p : 6.9. Surf Similarity (ε _p) Calculation 1 Waterside levee slope angle, tan α: 0.4. Surf Similarity Parameter, ε _p : 4.5. 2% Wave Runup (R _{2%}) Calculation 1 2% Wave Runup, R _{2%} Calculation 1 1 1 2% Wave Runup with Vegetative Correction, R _{2%,Veg} : 3.1 1 1 1 1 1 1 1	7 7 4 7 6 7 0.834744 0.733415 0 4 9 ft 0 1	
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Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : 0.0008 Friction Velocity, u _f : 2.7 Significant Wave Height, H _{mo} : 2.40 Peak Wave Period (T _p) Calculation 1 Peak Wave Period (T _p) Calculation 1 Peak Wave Period, T _p : 6.9 Surf Similarity (ε _p) Calculation 1 Waterside levee slope angle, tan α: 0.4 Surf Similarity Parameter, ε _p : 4.50 Surf Similarity Parameter, ε _p : 4.50 2% Wave Runup (R _{2%}) Calculation 1 2% Wave Runup, R _{2%} : 4.70 2% Wave Runup, R _{2%} : 3.10 2% Wave Runup with Vegetative Correction, R _{2%,Veg} : 3.11 Wind Setup, S: 0.51 2% Wave Runup with Vegetative Correction, R _{2%,Veg} : 3.11	Image: selection of the se	
Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : 0.0008 Friction Velocity, u _f : 2.7 Significant Wave Height, H _{mo} : 2.40 Peak Wave Period (T _p) Calculation 1 Peak Wave Period (T _p) Calculation 6.9 Peak Wave Period, T _p : 6.9 Surf Similarity (ε _p) Calculation 1 Waterside levee slope angle, tan α: 0.4 Surf Similarity Parameter, ε _p : 4.50 2% Wave Runup (R ₂₈₅) Calculation 1 2% Wave Runup, R ₂₈₅ : 4.7 2% Wave Runup, R ₂₈₅ : 4.7 2% Wave Runup with Vegetative Correction, R _{285,Veg} : 3.1 Suff Similarity Parameter, ε _p : 3.1 2% Wave Runup with Vegetative Correction, R _{285,Veg} : 3.1 Suff Setup, S: 0.5 2% Wave Runup with Vegetative Correction, R _{285,Veg} : 3.1	Image: sec	
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RD17 Dryland Levee Wind/Wave Analysis

Profile 2

																		Peters
						COMBINED	O WIND SET	TUP &	3.8	ft								Mike
		ot 2 dogroo in		4 SDM (1094)		WAVE RUN	NOP [FEET]:											11/21
	Avg 9 radials	ell every half n	nile of median ra	adial														+
	0.11.1.1																	
		 - 2										Table VI 5	3					
	If no berm, v _k =	= 1.0. Otherwi	se, see discussio	n on CEM ng. VI-	-5-12							Surface R	oughness Re	duction Factor yr i	n Equation VI-	5-3, Valid for 1 <	ζ _{op} < 3_4	
	No shallow way	ve influence. v	h = 1.0. Based o	n depth at toe of	levee. See eau	ation and discus	sion on CEM pg	. VI-5-13				Type of S	lope Surface					
	CEM Equation	VI-5-11: SI	nort-crested w	aves	$\gamma_{B} = 1 - 0.00$	22 β						Smooth, c Smooth bl	oncrete, aspha ock revetment	llt				
	See discussion	on pgs. 6 & 7 i	in PBI TM, SBFC/	A's Feather River	West Levee Str	rengthening EIP	Project, Wind S	etup and Wave	Runup Analysis	; , January 10, 2	l 011. (rip rap red	Grass (3 c duce 1 layer of i	m length) rock, diameter lavers of rock	D, (H₅/D = 1.5 - 3.0 (H₂/D = 1.5 - 6.0)	0)			
												Roughnes	s elements on	smooth surface				
							$(10)^{\frac{1}{2}}$	 				(length par	rallel to waterlin	$ne = \ell$, width = b, he	eight = <i>h</i>)			
	Wind corrected	d to 10m Obse	rvation Level wi	th the 1/7 rule (CEM Equation II	-2-9)	$U_{10} = U_z \left(\frac{10}{z}\right)^{7}$					Quadratic	blocks, $\ell = D$	area coverage				
	For fetch lengt	hs less than 16	5km, the CEM re	commends a fac	tor of 1.2 to inc	crease the wind s	speed for over v	water condition	is (CEM pg. II-2-3	36 (c))		0.88	0.12 - 0.19 0.12 - 0.24	1/9 1/25				
												0.44 0.88 0.18	0.12 - 0.24 0.12 - 0.18 0.55 - 1.10	1/25 1/25 (above SV 1/4	WL)			
												Ribs						
												1.00	0.12 - 0.19	1/7.5				
	$S = U^2 F$	F	I	I	Equation 15-1,	, USACE Hydrolo	gic Engineering	Requirements	for Reservoirs(EM 1110-2-142	:0)							
	14000	d																
	Where $S = w$ U = a	vind setup (ft) average wind s	speed (mph)															
	F = fe d = av	etch distance (verage water o	(miles) depth along the	fetch line (ft)														
		Ļ																
	_		(2)	$(F)^{-0.0768}$														
	S = d * 2.44	$1 * 10^{-5} * \left(\frac{F}{d}\right)$	$\Big)^{1.66} * \Big(\frac{U^2}{F \cdot g}\Big)^{\binom{2}{2}}$	$(02*(\overline{a}))$	should be aver	raged with the Si	t for shallow wa	iter (< 16 ft dee Design Criteria N	(p) the value from	m the equation	above Florida Water M	anagement Dist	rict. 2006)					
	Where S = w	vind setup (ft))										,,					-
	d = av F = fe	verage water etch distance	depth along th (ft)	e fetch line (ft))													
	U = a g = gi	average wind ravitational c	speed (ft/sec) onstant = 32.2	ft/sec														
	Use average wi	ind setup for a	verage depth le	ss than 16 ft. Us	e Zeider Zee equ	uation for average	ge depth greate	r than 16 ft.										
																		<u> </u>
																		
			1				1											
	$\frac{g * H_{mo}}{m^2} = 0$).0413 * ($\left(\frac{g * X}{x^2}\right)^{\frac{1}{2}}$	and	<u>g</u>	$\frac{q + T_p}{r^2} = 0.75$	$1 * \left(\frac{g * X}{r^2}\right)^{\frac{1}{3}}$		CEM Equat	tion II-2-36								
	u_f		u _f)			u_f	(u_f)											
	Wh	nere:	H _{mo} =	significant	wave heig	ht (ft)												
			$X^{p} = X$	fetch lengt	h (ft)	()												
			g =	gravitation	al constant	t = 32.2 ft/s	ec											
			u _f =	$(C + U^2)$	$\frac{1}{2}$	ec)												
			$C_D =$	$(C_D * O_{10})$ drag coeffi	cient													
			=	0.0002 * (1.1 + 0.03	$35 * U_{10}$)												
			$U_{10} =$	wind speed	i at 10m el	evation (ft/s	sec)	·										
									a									<u> </u>
	$\varepsilon_p = \frac{\tan \theta}{1}$	(α)							CEM Equat	tion VI-5-2	<u> </u>			€	· 	tan a - ong	ocito/adia	cont -
	$\frac{2\pi}{q}$	$\frac{*H_{mo}}{*T_n^2}$											α			tan u – opp	JUSILE/ auja	
	- \ ³	Ρ																
	Whe	ere:	$\varepsilon_p = surtian(\alpha) = wa$	f similarity p	of levee (as	sumed 1V·3	H for all wi	nd direction										
	-		cond	itions)	er ievee (as		- ioi aii wl											
\overline{R}	$R_{2\%}^{ } = H_{mo} *$	$(A * \varepsilon_p +$	$\begin{pmatrix} C \\ C \end{pmatrix} * \gamma_r * \gamma_b$	 * Y _h * Y _β	I	1	I	- -	CEM Equat	tion VI-5-3		Finding A 8	с:					
	Where	e: Ra	= 2% v	vave runup e	levation (ft)			-				Table VI-5	2	1	1	1		
		A,	C = coeff	icients deper	ident on ε_p ($\varepsilon_p < 2, A = 1$	1.6, C = 0 fo	r all wind				Coefficient Irregular W	ts in Equatio /aves on Sm	on VI-5-3 for Run looth Impermea	up of Long-0 ble Slopes	Crested		
		γr	= reduc	ction factor f	or levee slop	y per CEM 1 pe roughness	(assumed γ	$r_{\rm r} = 0.9 \text{ for } -$				ξ	Ru	Ę	-Limits		А	
		γ _h	3 cm g = reduc	rass slopes po ction factor for	er CEM Tab or influence	ole VI-5-3) of a berm (a	issumed non	-bermed					Ru2 percent	ć	ξ _p ≤ 2.5		1.6	
		10	fetch, γ	$y_b = 1$	or infl	of shall	vovas (-	nod ==				ςop	purera	2	2.5 < ζ _p < 9 ξ _p ≤ 2.0		-0.2 1.35	
_		γh	= reduc shallov	v wave influe	ence, $\gamma_h = 1$)	or snanow w	vaves (assur					-	Rus	2	2.0 < ځ, < 9		-0.15	
_		γβ	= reduc	ction factor fo on the levee	or influence	of angle of i	ncidence, β	, of the										
	1	1	= 1 - ($0.0022 * \beta$	1		1	-										
	*				•													

Peterson Brust Mike Rossiter,	rad, Inc. PE		
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WIND SETUP & WAVE RUNUP INPUTS

Primary Inputs			
Design 72.9yr Wind Speed, U _z :	51	mph	
Height at Which Observations were Taken, z:	7.9	m	
Assumed Fetch Length, F:	5.14	mi	
Average Water Depth Along Fetch Line, d: Waterside Levee Slope (H/V):	9.083	itt 📃	
Angle of Incidence for Waves Approaching the Levee, β:	0	degrees	
Reduction Factors			
Reduction Factor for Levee Slope Roughness, γ _r :	0.6		
Reduction Factor for Influence of a Berm, γ _b :	0.7		
Reduction Factor for Influence of Shallow Waves, γ _h :	0.8		
Reduction Factor for Influence of Angle of Incidence, γ_{β} :	1.000		
Reduction Factor for the Presence of Vegetation Along the Fetch Line, $\gamma_{Veg.}$:	0.67		
Secondary/Calculated Inputs			
Design 72.9yr Wind Speed Corrected for 10m Observation Height, U ₁₀ :	52.7	mph	
Design 72.9yr Wind Speed Corrected for Over Water:	63.3	mph	
Design 72.9yr Wind Speed Corrected for Over Water:	92.8	ft/sec	
Assumed Fetch Length, F:	27,139	ft	
WIND SETUP CALCULATIONS			
Wind Setup (Zeider Zee Equation), S:	1.619	ft	
	0.020	0	
Wind Setup (Sibul Equation), S:	0.838	ft	
AVERAGE WIND SETUP. S:	1.23	ft	
Wind Setup (Zeider Zee Equation), S:	-	ft	
			_
WAVE RUNUP CALCULATIONS			
WAVE RUNUP CALCULATIONS			
WAVE RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation			
WAVE RUNUP CALCULATIONS <u>Significant Wave Height (Hmo) Calculation</u> Drag Coefficient, Cp:	0.00087		
WAVE RUNUP CALCULATIONS <u>Significant Wave Height (H_{mo}) Calculation</u> Drag Coefficient, C _D : Friction Velocity, u _f :	0.00087	ft/sec	
WAVE RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : Friction Velocity, u _f : Significant Wave Height, H _{mo} :	0.00087 2.74 3.283	ft/sec ft	
WAVE RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : Friction Velocity, u _f : Significant Wave Height, H _{mo} :	0.00087 2.74 3.283	ft/sec ft 0.834744 1.000861	
WAVE RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : Friction Velocity, u _f : Significant Wave Height, H _{mo} : Peak Wave Period (T _n) Calculation	0.00087 2.74 3.283	ft/sec ft 0.834744 1.000861	
WAVE RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : Friction Velocity, u _f : Significant Wave Height, H _{mo} : Peak Wave Period (T _p) Calculation Peak Wave Period, T _p :	0.00087 2.74 3.283 8.54	ft/sec ft 0.834744 1.000861 sec	
WAVE RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : Friction Velocity, u _f : Significant Wave Height, H _{mo} : Peak Wave Period (T _p) Calculation Peak Wave Period, T _p :	0.00087 2.74 3.283 	ft/sec ft 0.834744 1.000861 sec	
WAVE RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : Friction Velocity, u _f : Significant Wave Height, H _{mo} : Peak Wave Period (T _p) Calculation Peak Wave Period, T _p :	0.00087 2.74 3.283 8.54	ft/sec ft 0.834744 1.000861 sec	
WAVE RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : Friction Velocity, u _f : Significant Wave Height, H _{mo} : Peak Wave Period (T _p) Calculation Peak Wave Period, T _p :	0.00087 2.74 3.283 	ft/sec ft 0.834744 1.000861 sec	
WAVE RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : Friction Velocity, u _f : Significant Wave Height, H _{mo} : Peak Wave Period (T _p) Calculation Peak Wave Period, T _p : Surf Similarity (s.) Calculation	0.00087 2.74 3.283 	ft/sec ft 0.834744 1.000861 sec	
WAVE RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : Friction Velocity, u _f : Significant Wave Height, H _{mo} : Peak Wave Period (T _p) Calculation Peak Wave Period, T _p : Surf Similarity (ε _p) Calculation Waterside levee slope angle tan gr	0.00087 2.74 3.283 8.54	ft/sec ft 0.834744 1.000861 sec	
WAVE RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : Friction Velocity, u _f : Significant Wave Height, H _{mo} : Peak Wave Period (T _p) Calculation Peak Wave Period, T _p : Surf Similarity (ε _p) Calculation Waterside levee slope angle, tan α: Surf Similarity Parameter, ε _n :	0.00087 2.74 3.283 8.54 0.44 4.74	ft/sec ft 0.834744 1.000861 sec 5ec	
WAVE RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _p : Friction Velocity, u _f : Significant Wave Height, H _{mo} : Peak Wave Period (T _p) Calculation Peak Wave Period (T _p) Calculation Peak Wave Period, T _p : Surf Similarity (ε _p) Calculation Waterside levee slope angle, tan α: Surf Similarity Parameter, ε _p :	0.00087 2.74 3.283 8.54 0.44 4.74	ft/sec ft 0.834744 1.000861 sec 	
WAVE RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _p : Friction Velocity, u _f : Significant Wave Height, H _{mo} : Peak Wave Period (T _p) Calculation Peak Wave Period, T _p : Surf Similarity (ε _p) Calculation Waterside levee slope angle, tan α: Surf Similarity Parameter, ε _p :	0.00087 2.74 3.283 8.54 0.44 4.74	ft/sec ft 0.834744 1.000861 sec 5ec	
WAVE RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : Friction Velocity, u _f : Significant Wave Height, H _{mo} : Peak Wave Period (T _p) Calculation Peak Wave Period, T _p : Surf Similarity (ε _p) Calculation Waterside levee slope angle, tan α: Surf Similarity Parameter, ε _p :	0.00087 2.74 3.283 8.54 0.44 4.74	ft/sec ft 0.834744 1.000861 sec 5ec	
WAVE RUNUP CALCULATIONS Significant Wave Height (H _{mn}) Calculation Drag Coefficient, C ₀ : Friction Velocity, u _f : Significant Wave Height, H _{mo} : Peak Wave Period (T _p) Calculation Peak Wave Period (T _p) Calculation Peak Wave Period, T _p : Surf Similarity (ε _p) Calculation Waterside levee slope angle, tan α: Surf Similarity Parameter, ε _p :	0.00087 2.74 3.283 8.54 0.44 4.74	ft/sec ft 0.834744 1.000861 sec 5ec	
WAVE RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C ₀ : Friction Velocity, u _f : Significant Wave Height, H _{mo} : Peak Wave Period (T _p) Calculation Peak Wave Period (T _p) Calculation Peak Wave Period, T _p : Surf Similarity (ε _p) Calculation Surf Similarity Parameter, ε _p : 2% Wave Runup (R _{2%}) Calculation	0.00087 2.74 3.283 8.54 0.44 4.74	ft/sec ft 0.834744 1.000861 sec 5ec	
WAVE RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C ₀ : Friction Velocity, u; Significant Wave Height, H _{mo} : Significant Wave Height, H _{mo} : Peak Wave Period (T _p) Calculation Peak Wave Period (T _p) Calculation Surf Similarity (ε _p) Calculation Waterside levee slope angle, tan α: Surf Similarity Parameter, ε _p : 2% Wave Runup (R _{2%}) Calculation A: Calculation	0.00087 2.74 3.283 8.54 0.44 4.74 	ft/sec ft 0.834744 1.000861 Sec	
WAVE RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C ₀ : Friction Velocity, u _i : Significant Wave Height, H _{mo} : Peak Wave Period (T _p) Calculation Peak Wave Period (T _p) Calculation Peak Wave Period, T _p : Surf Similarity (ε _p) Calculation Waterside levee slope angle, tan α: Surf Similarity Parameter, ε _p : 2% Wave Runup (R _{2%}) Calculation A: 2% Wave Runup, R _{2%} :	0.00087 2.74 3.283 8.54 0.44 4.74 0.44 4.74	ft/sec ft 0.834744 1.000861 sec 5ec 6 6 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7	
WAVE RUNUP CALCULATIONS Significant Wave Height (H _{ma}) Calculation Drag Coefficient, C ₀ : Friction Velocity, u _i : Significant Wave Height, H _{mo} : Peak Wave Period (T _p) Calculation Peak Wave Period (T _p) Calculation Peak Wave Period, T _p : Surf Similarity (ε _p) Calculation Waterside levee slope angle, tan α: Surf Similarity Parameter, ε _p : 2% Wave Runup (R _{2%}) Calculation A: C: 2% Wave Runup, R _{2%} :	0.00087 2.74 3.283 8.54 0.44 4.74 0.44 4.74	Image: sec Image: sec Image: sec I	
WAVE RUNUP CALCULATIONS Significant Wave Height (H _{ma}) Calculation Drag Coefficient, C ₀ : Friction Velocity, u _f : Significant Wave Height, H _{ma} : Drag Coefficient, C ₀ : Friction Velocity, u _f : Significant Wave Height, H _{ma} : Peak Wave Period (T _p) Calculation Peak Wave Period (T _p) Calculation Peak Wave Period, T _p : Surf Similarity (ε _p) Calculation Waterside levee slope angle, tan α: Surf Similarity Parameter, ε _p : Calculation A: 2% Wave Runup (R _{2w}) Calculation A: 2% Wave Runup, R _{2w} ; 2% Wave Runup with Vegetative Correction, R _{2w,veg} :	0.00087 2.74 3.283 8.54 0.44 4.74 0.44 4.74 0.44 4.74 2.41	i i ft/sec i ft i 0.834744 i 1.000861 i sec i sec i i i </td <td></td>	
WAVE RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C ₀ : Friction Velocity, u _f : Significant Wave Height, H _{mo} : OPERAW Wave Period (T _p) Calculation Peak Wave Period (T _p) Calculation Peak Wave Period, T _p : Surf Similarity (ɛ _p) Calculation Waterside levee slope angle, tan α: Surf Similarity Parameter, ɛ _p : Calculation Q% Wave Runup (R _{2%}) Calculation A: 2% Wave Runup, R _{2%} : 2% Wave Runup, R _{2%} :	0.00087 2.74 3.283 8.54 0.44 4.74 0.44 4.74 0.2 4.5 3.60 2.41	Image: sec Image: sec Sec Image: sec Image: sec Image: s	
WAVE RUNUP CALCULATIONS Significant Wave Height (H _{ma}) Calculation Drag Coefficient, C ₀ : Friction Velocity, u; Significant Wave Height, H _{mo} : Peak Wave Period (T _p) Calculation Peak Wave Period (T _p) Calculation Peak Wave Period, T _p : Surf Similarity (ε _p) Calculation Waterside levee slope angle, tan α: Surf Similarity Parameter, ε _p : 2% Wave Runup (R _{2m}) Calculation A: C: 2% Wave Runup, R _{2m} ; 2% Wave Runup, R _{2m} ;	0.00087 2.74 3.283 8.54 0.44 4.74 0.44 4.74 4.74 2.41	Image: sec Image: sec Sec Image: sec Image: sec Image: s	
WAVE RUNUP CALCULATIONS Significant Wave Height (H _{max}) Calculation Drag Coefficient, C ₀ : Friction Velocity, u; Significant Wave Height, H _{max} : Peak Wave Period (T _p) Calculation Peak Wave Period (T _p) Calculation Peak Wave Period, T _p : Calculation Surf Similarity (ε _p) Calculation Waterside levee slope angle, tan α: Surf Similarity Parameter, ε _p : Calculation 2% Wave Runup (R _{2%}) Calculation Calculation 2% Wave Runup, R _{2%} : 2% Wave Runup, R _{2%} : 2% Wave Runup, R _{2%} :	0.00087 2.74 3.283 8.54 0.44 4.74 0.44 4.74 0.44 4.74 2.41 2.41	ft/sec ft 0.834744 1.000861 sec 5ec 6 6 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7	
WAVE RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _p : Friction Velocity, u _i : Significant Wave Height, H _{mo} : Peak Wave Period (T _p) Calculation Peak Wave Period (T _p) Calculation Peak Wave Period, T _p : Surf Similarity (ε _p) Calculation Waterside levee slope angle, tan α: Surf Similarity Parameter, ε _p : 2% Wave Runup (R _{2%}) Calculation A: 2% Wave Runup, R _{2%} , Calculation 2% Wave Runup, R _{2%} , Veg.: 2% Wave Runup with Vegetative Correction, R _{2%, Veg.} :	0.00087 2.74 3.283 8.54 0.44 4.74 0.44 4.74 0.2 4.5 3.60 2.41	Image: sec Image: sec Sec Image: sec Image: sec Image: s	
WAVE RUNUP CALCULATIONS Significant Wave Height (H _{mm}) Calculation Drag Coefficient, C ₀ : Friction Velocity, u _i : Significant Wave Height, H _{mm} : Peak Wave Period (T _p) Calculation Peak Wave Period (T _p) Calculation Peak Wave Period, T _p : Surf Similarity (ε _p) Calculation Waterside levee slope angle, tan α: Surf Similarity Parameter, ε _p : 2% Wave Runup (R _{2w}) Calculation A: 2% Wave Runup, R _{2w}) Calculation A: 2% Wave Runup, R _{2w} : 2% Wave Runup with Vegetative Correction, R _{2w,Veg} :	0.00087 2.74 3.283 8.54 0.44 4.74 0.44 4.74 2.41 2.41	Image: sec Image: sec Sec Image: sec Image: sec Image: s	
WAVE RUNUP CALCULATIONS Significant Wave Height (H _{max}) Calculation Drag Coefficient, C ₀ : Friction Velocity, u ₁ : Significant Wave Height, H _{max} : Peak Wave Period (T _p) Calculation Peak Wave Period, T _p : Surf Similarity (ε _p) Calculation Waterside levee slope angle, tan α: Surf Similarity Parameter, ε _p : Surf Similarity Parameter, ε _p : Calculation Xure Runup (R _{2m}) Calculation Xure Runup with Vegetative Correction, R _{2m/reg} :	0.00087 2.74 3.283 8.54 0.44 4.74 0.44 4.74 2.41 2.41	Image: sec Image: sec Sec Image: sec Image: sec Image: s	
WAVE RUNUP CALCULATIONS Significant Wave Height (H _{max}) Calculation Drag Coefficient, C ₀ : Friction Velocity, u ₁ : Significant Wave Height, H _{max} : Peak Wave Period (T _p) Calculation Peak Wave Period (T _p) Calculation Peak Wave Period, T _p : Surf Similarity (ε _p) Calculation Waterside levee slope angle, tan α: Surf Similarity Parameter, ε _p : 2% Wave Runup (R _{2m}) Calculation A: C: 2% Wave Runup (R _{2m}) Calculation A: C: 2% Wave Runup (R _{2m}) Calculation A: C: 2% Wave Runup (R _{2m}) Calculation A: C: 2% Wave Runup, R _{2m} :	0.00087 2.74 3.283 8.54 0.44 4.74 0.44 4.74 0.2 4.5 3.60 2.41	Image: sec Image: sec Sec Image: sec Image: sec Image: s	
WAVE RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C ₀ : Friction Velocity, u; Significant Wave Height, H _{mo} : Peak Wave Period (T _p) Calculation Peak Wave Period (T _p) Calculation Peak Wave Period, T _p : Surf Similarity (e _p) Calculation Waterside levee slope angle, tan α : Surf Similarity Parameter, e _p : Other Similarity Parameter, e	0.00087 2.74 3.283 8.54 0.44 4.74 0.44 4.74 0.2 4.5 3.60 2.41	Image: sec Image: sec Sec Image: sec Image: sec Image: s	
WAVE RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C ₀ : Friction Velocity, u; Significant Wave Height, H _{mo} : Peak Wave Period (T _p) Calculation Peak Wave Period (T _p) Calculation Peak Wave Period, T _p : Surf Similarity (e _p) Calculation Waterside levee slope angle, tan α: Surf Similarity Parameter, e _p : Other Runup (R _{2%}) Calculation Other Runup With Vegetative Correction, R _{2%, Veg} : Other Runup With Vegetative Correction, R _{2%, Veg} ; Other Runup With Vegetative Correction, R _{2%, Veg} ; Other Runup With Vegetative Correction, R _{2%, Veg} ; Other Runup With Vegetative Correction, R	0.00087 2.74 3.283 8.54 0.44 4.74 0.44 4.74 2.41 2.41	Image: sec Image: sec Image: sec I	
WAVE RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C ₀ : Friction Velocity, u _i : Significant Wave Height, H _{mo} : Peak Wave Period (T _p) Calculation Peak Wave Period, T _p : Peak Wave Period, T _p : Surf Similarity (E _p) Calculation Waterside levee slope angle, tan a: Surf Similarity Parameter, ε _p : Combined Wave Runup (R _{2%}) Calculation A: C: 2% Wave Runup with Vegetative Correction, R _{2%,Veg} : COMBINED WIND SETUP & WAVE RUNUP Wind Setup, S: 2% Wave Runup with Vegetative Correction, R _{2%,Veg} :	0.00087 2.74 3.283 8.54 0.44 4.74 0.44 4.74 2.41	Image: sec Image: sec Sec Image: sec Image: sec Image: s	
WAVE RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C ₀ : Friction Velocity, u; Significant Wave Height, H _{mo} : OPEak Wave Period (T _p) Calculation Peak Wave Period (T _p) Calculation Peak Wave Period (T _p) Calculation Waterside levee slope angle, tan a: Surf Similarity (E _p) Calculation Waterside levee slope angle, tan a: Surf Similarity Parameter, E _p : Colspan="2">Calculation Ave Runup (R _{2xk}) Calculation Ave Runup with Vegetative Correction, R _{2xk} , veg COMBINED WIND SETUP & WAVE RUNUP Wind Setup, S: 2% Wave Runup with Vegetative Correction, R _{2xk} , veg	0.00087 2.74 3.283 8.54 0.44 4.74 0.44 4.74 0.44 4.74 2.41	Image: sec Image: sec Sec Image: sec Image: sec Image: sec Sec Image: sec Image: sec Image: sec	

RD17 Dryland Levee Wind/Wave Analysis Profile 3

COMBINED WIND SETUP & 3.6 ft WAVE RUNUP [FEET]: Avg 9 radials at 3 degree intervals, pg 3-24 SPM (1984) Avg depth at cell every half mile of median radial Table VI-5-3 CEM Table VI-5-3 ---Surface Roughness Reduction Factor γ_r in Equation VI-5-3, Valid for 1 < ζ_{op} < 3-4 If no berm, γ_b = 1.0. Otherwise, see discussion on CEM pg. VI-5-12. Type of Slope Surface No shallow wave influence, γ_h = 1.0. Based on depth at toe of levee. See equation and discussion on CEM pg. VI-5-13 Smooth, concrete, asphalt Smooth block revetment CEM Equation VI-5-11: Short-crested waves $\gamma_{\beta} = 1 - 0.0022 \beta$

 CEM Equation VI-5-11:
 Short-created waves
 $\gamma_{\beta} = 1 - 0.0022 \beta$ Grass (3 cm length)

 See discussion on pgs. 6 & 7 in PBI TM, SBFCA's Feather River West Levee Strengthening EIP Project, Wind Setup and Wave Runup Analysis , January 10, 2011. (rip rap reduce 2 or more layers of rock, (H₅ /D = 1.5 - 3.0)
 See discussion on pgs. 6 & 7 in PBI TM, SBFCA's Feather River West Levee Strengthening EIP Project, Wind Setup and Wave Runup Analysis , January 10, 2011. (rip rap reduce 2 or more layers of rock, (H₅ /D = 1.5 - 6.0)

 Roughness elements on smooth surface (length parallel to waterline = ℓ , width = b, height = h) $U_{10} = U_z \left(\frac{10}{z}\right)^2$ Quadratic blocks, *e* = *b* Wind corrected to 10m Observation Level with the 1/7 rule (CEM Equation II-2-9)
 h/b
 b/H_s

 0.88
 0.12 - 0.19

 0.88
 0.12 - 0.24

 0.44
 0.12 - 0.24

 0.88
 0.12 - 0.18

 0.18
 0.12 - 0.18

 0.18
 0.55 - 1.10
 area coverage For fetch lengths less than 16km, the CEM recommends a factor of 1.2 to increase the wind speed for over water conditions (CEM pg. II-2-36 (c)) 1/9 1/25 1/25 1/25 (above SWL) 1/4 Ribs 1.00 0.12 - 0.19 1/7.5 Equation 15-1, USACE Hydrologic Engineering Requirements for Reservoirs (EM 1110-2-1420) $-----S = -\frac{U^2 F}{1400d}$ Where S = wind setup (ft) U = average wind speed (mph) F = fetch distance (miles)d = average water depth along the fetch line (ft) $- S = d * 2.44 * 10^{-5} * \left(\frac{F}{d}\right)^{1.66} * \left(\frac{U^2}{F * g}\right)^{\left(2.02 * \left(\frac{F}{d}\right)^2\right)}$ More recent studies show that for shallow water (< 16 ft deep) the value from the equation above should be averaged with the Sibul equation (Design Criteria Memorandum 2, USACE/South Florida Water Management District, 2006) Where S = wind setup (ft) d = average water depth along the fetch line (ft) F = fetch distance (ft)_____ U = average wind speed (ft/sec) _____ g = gravitational constant = 32.2 ft/sec Use average wind setup for average depth less than 16 ft. Use Zeider Zee equation for average depth greater than 16 ft. $\frac{g * H_{mo}}{u_f^2} = 0.0413 * \left(\frac{g * X}{u_f^2}\right)^{\frac{1}{2}}$ $\frac{g * T_p}{u_f^2} = 0.751 * \left(\frac{g * X}{u_f^2}\right)^{\overline{3}}$ and CEM Equation II-2-36 Where: H_{mo} = significant wave height (ft) T_p = peak wave period (sec) _____ \vec{X} = fetch length (ft) = gravitational constant = 32.2 ft/sec _____ _____ u_f = friction velocity (ft/sec) $= (C_D * U_{10}^2)^{\frac{1}{2}}$ _____ C_D = drag coefficient $= 0.0002 * (1.1 + 0.035 * U_{10})$ _____ U_{10} = wind speed at 10m elevation (ft/sec) _____ _____ $\varepsilon_p = \frac{\tan(\alpha)}{1-1}$ CEM Equation VI-5-2 $\tan \alpha = opposite/adjace$ $\frac{2\pi * H_{mo}}{g * T_p^2}$ _____ α _____ _____ Where: ε_p = surf similarity parameter $tan(\alpha)$ = waterside slope of levee (assumed 1V:3H for all wind direction _____ conditions) $\overline{R_{2\%}} = H_{mo} * \left(A * \varepsilon_p + C\right) * \gamma_r * \gamma_b * \gamma_h * \gamma_\beta$ CEM Equation VI-5-3 Finding A & C: Table VI-5-2 $R_{2\%} = 2\%$ wave runup elevation (ft) Where: _____ Coefficients in Equation VI-5-3 for Runup of Long-Crested Irregular Waves on Smooth Impermeable Slopes A,C = coefficients dependent on ε_p ($\varepsilon_p < 2$, A = 1.6, C = 0 for all wind direction conditions in this study per CEM Table VI-5-2) = reduction factor for levee slope roughness (assumed $\gamma_r = 0.9$ for Ru ζ-Limits Α _____ γ_r 3 cm grass slopes per CEM Table VI-5-3) ξ_ρ ≤ 2.5 1.6 _____ = reduction factor for influence of a berm (assumed non-bermed $R_{u2 percent}$ γь 2.5 < *ξ_p* < 9 -0.2 fetch, $\gamma_b = 1$) 1.35 *ξ*_ρ ≤ 2.0 = reduction factor for influence of shallow waves (assumed no γh _____ Rus shallow wave influence, $\gamma_h = 1$) $2.0 < \xi_p < 9$ -0.15 _____ = reduction factor for influence of angle of incidence, β , of the γβ _____ waves on the levee $= 1 - 0.0022 * \beta$

eterson Brust	rad, Inc.		
1/21/2014	, L		
7	r		
1	.0 .0		
0	.90 - 1.0 .55 - 0.6		
U	.50 - 0.55		
0	.70 - 0.75 .75 - 0.85		
0	.85 - 0.95 .85 - 0.95 .75 - 0.85		
-			
U	.60 - 0.70		
nt · · ·			
nt = vertic	ai/norizonta	al	
C	σ _{Ru}	/ R _u	
4.5	≈ 0.	15	
0	≈ 0.	10	
3.0		I	

Drimany Inputs		
Design 72.9vr Wind Speed. U.:	51	mph
Height at Which Observations were Taken, z:	7.9	m
Assumed Fetch Length, F:	6.14	mi
Average Water Depth Along Fetch Line, d:	7.29	ft
Angle of Incidence for Waves Approaching the Levee, β:	2.25	degrees
<u>Reduction Factors</u>		
Reduction Factor for Levee Slope Roughness, γ_r :	0.6	
Reduction Factor for Influence of a Berm, γ_b :	1.0	
Reduction Factor for Influence of Shallow Waves, γ_h :	0.5	
Reduction Factor for the Presence of Veretation Along the Eatch Line χ_{β} .	1.000	
Reduction ractor for the resence of vegetation Along the retch Line, y _{Veg} .	0.07	
Secondary/Calculated Inputs		
Design 72.9yr Wind Speed Corrected for 10m Observation Height, U_{10} :	52.7	mph
Design 72.9yr Wind Speed Corrected for Over Water:	63.3	mph
Design 72.9yr Wind Speed Corrected for Over Water:	92.8	ft/sec
SETUP CALCULATIONS		
Wind Setup (Zeider Zee Equation), S:	2.413	ft
Wind Setup (Sibul Equation), S:	1.255	ft
AVERAGE WIND SETUP, S:	1.83	ft
Wind Setup (Zeider Zee Equation), S:	-	ft
Wind Setup (Zeider Zee Equation), S: RUNUP CALCULATIONS	-	ft
Wind Setup (Zeider Zee Equation), S: RUNUP CALCULATIONS Significant Wave Height (Hmo) Calculation	-	ft
Wind Setup (Zeider Zee Equation), S: RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D :	- 0.00087	ft
Wind Setup (Zeider Zee Equation), S: RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : Friction Velocity, u _f :	0.00087	ft ft/sec
Wind Setup (Zeider Zee Equation), S: RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : Friction Velocity, u _f : Significant Wave Height, H _{mo} :	- 0.00087 2.74 3.589	ft ft/sec ft
Wind Setup (Zeider Zee Equation), S: RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : Friction Velocity, u _f : Significant Wave Height, H _{mo} :	- 0.00087 2.74 3.589	ft ft/sec ft 0.834744
Wind Setup (Zeider Zee Equation), S: RUNUP CALCULATIONS Significant Wave Height (Hmo) Calculation Drag Coefficient, CD: Friction Velocity, uf: Significant Wave Height, Hmo:	- 0.00087 2.74 3.589	ft ft/sec ft 0.834744 1.094287
Wind Setup (Zeider Zee Equation), S: RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : Friction Velocity, u _f : Significant Wave Height, H _{mo} : Peak Wave Period (T _p) Calculation	- 0.00087 2.74 3.589	ft ft/sec ft 0.834744 1.094287
Wind Setup (Zeider Zee Equation), S: RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : Friction Velocity, u _f : Significant Wave Height, H _{mo} : Peak Wave Period (T _p) Calculation Peak Wave Period, T _p :	- 0.00087 2.74 3.589 9.06	ft ft/sec ft 0.834744 1.094287 sec
Wind Setup (Zeider Zee Equation), S: RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : Friction Velocity, u _f : Significant Wave Height, H _{mo} : Peak Wave Period (T _p) Calculation Peak Wave Period, T _p :	- 0.00087 2.74 3.589 9.06	ft ft/sec ft 0.834744 1.094287 sec
Wind Setup (Zeider Zee Equation), S: RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : Friction Velocity, u _f : Significant Wave Height, H _{mo} : Peak Wave Period (T _p) Calculation Peak Wave Period, T _p : Surf Similarity (ε _p) Calculation	- 0.00087 2.74 3.589 9.06	ft ft/sec ft 0.834744 1.094287 sec
Wind Setup (Zeider Zee Equation), S: RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _p : Friction Velocity, u _f : Significant Wave Height, H _{mo} : Significant Wave Height, H _{mo} : Peak Wave Period (T _p) Calculation Peak Wave Period, T _p : Significant Vave Height, T _{mo} : Significant Vave Height, H _{mo} :	- 0.00087 2.74 3.589 9.06 9.06	ft ft/sec ft 0.834744 1.094287 sec
Wind Setup (Zeider Zee Equation), S: RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _p : Friction Velocity, u _f : Significant Wave Height, H _{mo} : Peak Wave Period (T _p) Calculation Peak Wave Period, T _p : Surf Similarity (ε _p) Calculation Waterside levee slope angle, tan α: Surf Similarity Parameter, ε _p :		ft ft/sec ft 0.834744 1.094287 sec
Wind Setup (Zeider Zee Equation), S: RUNUP CALCULATIONS Significant Wave Height (H _{ma}) Calculation Drag Coefficient, C _D : Friction Velocity, u _f : Significant Wave Height, H _{mo} : Peak Wave Period (T _p) Calculation Peak Wave Period, T _p : Surf Similarity (ε _p) Calculation Waterside levee slope angle, tan α: Surf Similarity Parameter, ε _p : 2% Wave Runun (B _{max}) Calculation		ft ft/sec ft 0.834744 1.094287 sec
Wind Setup (Zeider Zee Equation), S: RUNUP CALCULATIONS Significant Wave Height (H _{ma}) Calculation Drag Coefficient, C _D : Friction Velocity, u _f : Significant Wave Height, H _{mo} : Peak Wave Period (T _p) Calculation Peak Wave Period, T _p : Surf Similarity (ε _p) Calculation Waterside levee slope angle, tan α: Surf Similarity Parameter, ε _p : 2% Wave Runup (R _{2%}) Calculation A:		ft ft/sec ft 0.834744 1.094287 sec
Wind Setup (Zeider Zee Equation), S: RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C _D : Friction Velocity, u _f : Significant Wave Height, H _{mo} : Significant Wave Height, H _{mo} : Peak Wave Period (T _p) Calculation Peak Wave Period, T _p : Surf Similarity (ε _p) Calculation Waterside levee slope angle, tan α: Surf Similarity Parameter, ε _p : Surf Similarity Parameter, ε _p : Attenside levee slope angle, tan α: Surf Similarity Calculation		ft ft/sec ft 0.834744 1.094287 sec
Wind Setup (Zeider Zee Equation), S: RUNUP CALCULATIONS Significant Wave Height (H _{ma}) Calculation Drag Coefficient, C _D : Friction Velocity, u _r : Significant Wave Height, H _{mo} : Significant Wave Height, H _{mo} : Peak Wave Period (T _p) Calculation Peak Wave Period, T _p : Surf Similarity (ε _p) Calculation Waterside levee slope angle, tan α: Surf Similarity Parameter, ε _p : 2% Wave Runup (R _{2%}) Calculation A: C: 2% Wave Runup, R _{2%} :		ft ft/sec ft 0.834744 1.094287 sec sec
Wind Setup (Zeider Zee Equation), S: RUNUP CALCULATIONS Significant Wave Height (H _{ma}) Calculation Drag Coefficient, C _p : Friction Velocity, u _i : Significant Wave Height, H _{ma} : Image: Significant Wave Height, H _{ma} : Peak Wave Period (T _p) Calculation Peak Wave Period, T _p : Image: Surf Similarity (ε _p) Calculation Waterside levee slope angle, tan α: Surf Similarity Parameter, ε _p : Image: Surf Similarity Parameter	0.2 4.5 3.63 0.00087 2.74 3.589 9.06	ft ft/sec ft 0.834744 1.094287 sec sec ft ft ft
Wind Setup (Zeider Zee Equation), S: RUNUP CALCULATIONS Significant Wave Height (H _{mo.}) Calculation Drag Coefficient, C ₀ : Friction Velocity, u _f : Significant Wave Height, H _{mo} : Significant Wave Height, H _{mo} : Peak Wave Period (T _p) Calculation Peak Wave Period, T _p : Peak Wave Period, T _p : Surf Similarity (E _p) Calculation Waterside levee slope angle, tan α : Surf Similarity Parameter, ϵ_p : Surf Similarity Parameter, ϵ_p : Q% Wave Runup (R _{2w}) Calculation A: C: 2% Wave Runup, R _{2w} : 2% Wave Runup, R _{2w} : 2% Wave Runup, R _{2w} :	0.2 4.5 3.63	ft ft/sec ft 0.834744 1.094287 sec
Wind Setup (Zeider Zee Equation), S: RUNUP CALCULATIONS Significant Wave Height (H _{max}) Calculation Drag Coefficient, Cg: Friction Velocity, u; Significant Wave Height, H _{ma} : Runup Reak Wave Period (Tg) Calculation Peak Wave Period (Tg) Calculation Peak Wave Period, Tg: Runup Surf Similarity (Eg) Calculation Waterside levee slope angle, tan α: Surf Similarity Parameter, Eg: Runup (R2gg) Calculation A: C: 2% Wave Runup (R2gg) Calculation A: C: 2% Wave Runup, R2gg: 2% Wave Runup, R2gg;	-0.2 4.5 3.63 2.43	ft ft/sec ft 0.834744 1.094287 sec
Wind Setup (Zeider Zee Equation), S: RUNUP CALCULATIONS Significant Wave Height (H _{mm}) Calculation Drag Coefficient, Cp: Friction Velocity, ur Significant Wave Height, H _{mp} : Peak Wave Period (Tp) Calculation Peak Wave Period (Tp) Calculation Peak Wave Period, Tp: Peak Wave Period, Tp: Surf Similarity (ep) Calculation Waterside levee slope angle, tan a: Surf Similarity Parameter, ep: Surf Similarity Parameter, ep: 2% Wave Runup (R2m) Calculation A: C: 2% Wave Runup, R2m; 2% Wave Runup, R2m; 2% Wave Runup with Vegetative Correction, R2m; Veg: 2% Wave Runup with Vegetative Correction, R2m; Veg:	0.2 4.5 3.63 2.43	ft ft/sec ft 0.834744 1.094287 sec
Wind Setup (Zeider Zee Equation), S: RUNUP CALCULATIONS Significant Wave Height (H _{mo}) Calculation Drag Coefficient, C ₀ : Friction Velocity, u; Significant Wave Height, H _{mo} : Significant Wave Height, H _{mo} : Peak Wave Period (T _p) Calculation Peak Wave Period, T _p : Peak Wave Period, T _p : Surf Similarity (ε _p) Calculation Waterside levee slope angle, tan α: Surf Similarity Parameter, ε _p : Surf Similarity Parameter, ε _p : C: 2% Wave Runup (R _{2%}) Calculation A: C: 2% Wave Runup, R _{2%} : 2% Wave Runup, R _{2%} : Image: Comparison of the system o		ft ft/sec ft 0.834744 1.094287 sec
Wind Setup (Zeider Zee Equation), S: RUNUP CALCULATIONS Significant Wave Height (H _{ma}) Calculation Drag Coefficient, C ₀ : Friction Velocity, u; Significant Wave Height, H _{me} : Significant Wave Height, H _{me} : Peak Wave Period (T _p) Calculation Peak Wave Period, T _p : Peak Wave Period, T _p : Surf Similarity (e _p) Calculation Waterside levee slope angle, tan α: Surf Similarity Parameter, e _p : Surf Similarity Parameter, e _p : 2% Wave Runup (R ₂₅₆) Calculation A: C: 2% Wave Runup, R ₂₅₆ : Image: Comparison of the structure of the	-0.2 4.5 3.63 -0.2 4.5 3.63 2.43	ft ft/sec ft 0.834744 1.094287 sec
Wind Setup (Zeider Zee Equation), S: RUNUP CALCULATIONS Significant Wave Height (H_ma) Calculation Drag Coefficient, Cp: Friction Velocity, ur; Significant Wave Height, H_mo; Significant Wave Height, H_mo; Peak Wave Period (T_p) Calculation Peak Wave Period (T_p) Calculation Peak Wave Period, Tp; Peak Wave Period, Tp; Surf Similarity (Ep) Calculation Waterside levee slope angle, tan α : Surf Similarity Parameter, Ep; Surf Similarity Parameter, Ep; Q% Wave Runup (R _{2%}) Calculation A: C: 2% Wave Runup, R _{2%} ; 2% Wave Runup, R _{2%} ; Inted wind Setup & WAVE RUNUP Wind Setup, S; 2% Wave Runup with Vegetative Correction, R _{2%,veg} ; Safety Factor;	-0.2 -0.2 4.5 3.63 2.43 -0.2 4.5 3.63 2.43 1.83	ft ft/sec ft/sec ft 0.834744 1.094287 sec

RD17 Dryland Levee Wind/Wave Analysis Profile 4

					COMBINE	D WIND SET	UP &	28	f+						
					WAVE RUI	NUP [FEET]:		2.0	11						
	Avg 9 radials a	at 3 degree intervals, pg 3-24	SPM (1984)												
	CEM Table VI-5	-3								>	Table VI-	5-3			
	lf no berm, γ _b =	1.0. Otherwise, see discussion	on CEM pg. VI-5	5-12.							Surface I	Roughness Red	luction Factor γ r in Equation VI-5	5-3, Valid for 1 <	ζ _{ορ} < 3-4
	No shallow way	ve influence, γ_h = 1.0. Based on	depth at toe of l	evee. See equa	tion and discussi	ion on CEM pg. V	(1-5-13				Smooth, o	concrete, asphal	t		
	CEM Equation	VI-5-11: Short-crested wa	aves	$\gamma_{\beta} = 1 - 0.00$	022 β						Smooth b Grass (3	lock revetment cm length)			
	See discussion	on pgs. 6 & 7 in PBI TM <i>, SBFCA</i>	's Feather River \	Nest Levee Stre	ngthening EIP Pr	roject, Wind Setu	o and Wave Run	up Analysis , Jan	uary 10, 2011. (rip rap reduces upru	2 or more	layers of rock, ($H_s/D = 1.5 - 3.0$ $H_s/D = 1.5 - 6.0$		
											Roughnes (length pa	ss elements on s arallel to waterlin	smooth surface e = ℓ, width = b, height = h)		
	Wind corrected	to 10m Observation Level with	n the 1/7 rule (Cl	EM Equation II-2	2-9)	$U_{10} = U_z \left(\frac{10}{z}\right)^{\frac{1}{7}}$					Quadratic	blocks, $\ell = b$			
	For fetch length	ns less than 16km, the CEM reco	ommends a facto	or of 1.2 to incre	ease the wind sp	beed for over wat	er conditions (C	CEM pg. II-2-36 (c))		h/b 0.88 0.88	<i>b/H</i> ₅ ai 0.12 - 0.19 0.12 - 0.24	rea coverage 1/9 1/25		
											0.44	0.12 - 0.24 0.12 - 0.24 0.12 - 0.18	1/25 1/25 (above SWL)		
											0.18 Ribs	0.55 - 1.10	1/4		
											1.00	0.12 - 0.19	1/7.5		
	$S = U^2 H$	2	1	Equation 15-1	, USACE Hydrolog	gic Engineering R	equirements fo	r Reservoirs (EN	11110-2-1420)						
	14000 Where S	ind sature (#)													
	where $S = w$ U = a F = fe	werage wind speed (mph)													
	d = a	verage water depth along the	fetch line (ft)												
	S = d * 2.44	$* 10^{-5} * \left(\frac{F}{d}\right)^{1.66} * \left(\frac{U^2}{F_{1.6}}\right)^{(2.5)}$	$.02*\left(\frac{F}{d}\right)^{-0.0768}$	More recent s	tudies show that	t for shallow wate	er (< 16 ft deep)) the value from	the equation ab	oove					
	Where S = w	vind setup (ft)		should be ave	raged with the Si	ibul equation (De	esign Criteria M	emorandum 2, l	JSACE/South Flo	orida Water Manage	ment Distric	rt, 2006)			
	d = av F = fe	verage water depth along the etch distance (ft)	e fetch line (ft))											
	U = a g = g	verage wind speed (ft/sec) ravitational constant = 32.2	ft/sec												
	Use average wi	nd setup for average depth less	s than 16 ft. Use	Zeider Zee equ	ation for average	e depth greater t	han 16 ft.								
·	$g * H_{mo} = 0$	$(g * X)^{\frac{1}{2}}$		Į	$g * T_p = 0.75$	$(g * X)^{\frac{1}{3}}$		05145							
	$\frac{u_f^2}{u_f^2} \equiv 0$	$0.0413 * \left(\frac{u_f^2}{u_f^2} \right)$	and	-	$\frac{u_f^2}{u_f^2} = 0.75$	$\int 1 * \left(\frac{u_f^2}{u_f^2} \right)$		CEM Equat	tion II-2-36						
	Wh	nere: H _{mo} =	significant	wave heig	ght (ft)										
		$T_p = X =$	peak wave fetch lengt	period (se h (ft)	c)										
		g =	gravitation	al constan	t = 32.2 ft/s	sec									
		u _f =	$(C_{\rm P} * H_{\rm C}^2)$	$\frac{1}{2}$											
		C _D =	drag coeffi	cient											
		$U_{10} =$	0.0002 * (wind speed	1.1 + 0.03 d at 10m el	$35 * U_{10}$) levation (ft/	/sec)									
			1		-										
	tan	(α)			1			CEM Equat	tion VI-5-2						
	$\varepsilon_p = \frac{2\pi}{2\pi}$	* H _{mo}) Ja	3		tan α = opp	oosite/adja
	\sqrt{g}	T_p^2										u			
	Whe	ere: $\varepsilon_p = sur$	f similarity p	parameter											
	1	$\tan(\alpha) = wa$ cond	itions)	or ievee (a	ssumed 1V:3	or for all will	nu urrection								
R	$_{2\%}^{1} = H_{mo} *$	$(A * \varepsilon_p + C) * \gamma_r * \gamma_b$	* $\gamma_h * \gamma_\beta$	1	I	I	-	CEM Equat	tion VI-5-3	Fir	nding A 8	k C:			
	Where	$R_{2\%} = 2\% w$	vave runup e	levation (ft)							Table VI-5	-2 ts in Equation	n VI-5-3 for Pupup of Long-(rested	
		A,C = coeff directio	icients depei on conditions	in this stud	$(\varepsilon_p < 2, A = 1)$ ly per CEM '	1.6, $C = 0$ for Table VI-5-2	r all wind 2)				Irregular V	Vaves on Smo	ooth Impermeable Slopes	resteu	
		$\gamma_r = reduc$ 3 cm gr	ction factor f rass slopes p	or levee sloj er CEM Tal	pe roughness ple VI-5-3)	s (assumed γ_1	$_{\rm r} = 0.9 {\rm for} -$			<u> </u>	ξ	R _u	ζ-Limits کے≤2.5		A
		γ_b = reduction fetch γ_b	ction factor $f_{\rm b} = 1$	or influence	of a berm (a	assumed non	-bermed					R _{u2 percent}	$z_p = 2.5$ 2.5 < ξ_p < 9		-0.2
<u> </u>		$\gamma_h = reduction reduction \gamma_h$	ction factor f	or influence	of shallow y	waves (assun	ned no			<u> </u>	Sop	Rus	$\zeta_p \leq 2.0$		1.35
		γ_{β} = reduc	tion factor f	or influence	of angle of	incidence, β,	of the			-			2.0 < ζ _p < 9	<u> </u>	-0.15
		waves of a = 1 - 0	0.0022 * β				-								
															<u> </u>
	In the case of P	rofile 4, high ground is assume	d in place of a dr	yland levee. Th	erefore, wave ru	unup is not incluc	led as part of th	e analysis for Pr	ofile 4						
	A safety factor	is considered to take into accou	unt climate chan	ge											
		·	1			4.	•	•		·			· I		-

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		11/21/2014							
<	: ڏ _{مہ} < 3.4								
	Şup - e i	7	r						
		1 1 0	.0 .0 90 - 1 0						
		0	.55 - 0.6 .50 - 0.55						
0.70 - 0.75									
	0.75 - 0.85								
		0	.60 - 0.70						
_									
ŗ	posite/adjac	cent = vertica	al/horizonta						
	1			I.					
	A	c	σ _{Ru}	/ R _u					
	A 1.6 -0.2 1.35	C 0 4.5 0	<i>σ_{Ru}</i> ≈ 0.	/ <i>R</i> _u 15					
	A 1.6 -0.2 1.35 -0.15	C 0 4.5 0 3.0	<i>σ_{Ru}</i> ≈ 0. ≈ 0.	/ <i>R</i> _u 15 10					
	A 1.6 -0.2 1.35 -0.15	C 0 4.5 0 3.0	<i>σ_{Ru}</i> ≈ 0. ≈ 0.	/ <i>R</i> _u 15 10					
	A 1.6 -0.2 1.35 -0.15	C 0 4.5 0 3.0	<i>σ_{Ru}</i> ≈ 0. ≈ 0.	/ <i>R</i> _u 15 10					
	A 1.6 -0.2 1.35 -0.15	C 0 4.5 0 3.0	<i>σ_{Ru}</i> ≈ 0. ≈ 0.	/ <i>R</i> _u 15 10					
	A 1.6 -0.2 1.35 -0.15	C 0 4.5 0 3.0	<i>σ_{Ru}</i> ~ 0. ≈ 0.	/ R _u 15 10					