# SUPPLEMENTARY RUNUP DOCUMENTATION

RUNUP 2.1

Maintenance of FEMA's RUNUP Program

August 2024

## Background Discussion:

FEMA's RUNUP program has been revised and updated for two reasons:

1. The RUNUP program needed to be re-compiled with newer FORTRAN compilers. It will enable users to execute the RUNUP program on modern operating systems and cut the dependency on Windows Vista or older for this program. The previous compiled version was created in November of 1991.
2. There is no digital version of the November 1991 RUNUP 2.0 code. The program was developed initially in FORTRAN in 1981 and updated through 1991. Only a hard copy of the code from an April 1991 document called "Investigation and Improvement of Capabilities for the FEMA Wave Runup Model" was available as a basis for code digitization and updating.

The purpose of this current effort was to create a working RUNUP executable for modern Windows operating systems and to create a digital version of the source code for future maintenance and updates if needed. The 2024 updated version will be called RUNUP 2.1 to distinguish it from the November 1991 executable version. The file name of the executable "Runup2.exe", however, will remain the same to maintain operability with other programs, such as the Coastal Hazard Analysis and Mapping Program (CHAMP).

FORTRAN source code for RUNUP 2.0 was included in the April 1991 documentation and represents all updates made to the RUNUP program between the original version in 1981 through March 1990. The hard copy of that FORTRAN code was scanned and made into a digital PDF file then converted to a text file. The hard copy included faded lines, and the digital conversion had issues interpreting the code's fonts, spaces, and characters. During the digitization effort, the code needed to be reviewed line by line to ensure the correct translation of the code. This involved deciphering the code logic, understanding the intent of the calculations, and reviewing supporting reference materials for the runup calculations to determine the correct characters for the code.

The review identified several apparent revisions that were made in the code between the printed version included in the April 1991 documentation, and the compiled version, dated November 1991. These revisions were similarly implemented during this digitization and recompilation effort. The November 1991 compiled executable is the version that has been utilized in FEMA coastal studies and revisions since its creation in 1991. The results of this update will provide the same wave runup results as the previous November 1991 program within an acceptable error tolerance of approximately 0.1 feet.

The updated version has been made compatible with modern computers. The code has been compiled using Intel Fortran Compiler Classic 2021.8.0. In addition to the above updates, this version has minor technical updates and formatting for easier readability and debugging for developers.

## What's New:

The items updated in this version of the code that were implemented to make the RUNUP program operational in modern Windows operating systems and reproduce nearly identical results as the November 1991 RUNUP 2.0 executable are provided below. Items numbered 1, 3, 7, 8, and 9 are believed to be updates to the code that occurred between the code included in April 1991 documentation and the November 1991 compiled executable.

1. Updates have been made to the slope calculations at transects where the elevation of adjacent profile points changes from negative to zero or negative to positive numbers. Logical checks have been added for the following two conditions where, if true, corrects the vertical rise calculation to obtain the correct slope output:
    a. Elevation change from negative to zero between two transects elevation input points.
    b. Elevation change from negative to positive between two transects elevation input points.

2. A new subroutine called LOGLOGR was added to perform a LOGLOG interpolation for a computed value between known values. The LOGLOGR subroutine uses real values to perform the interpolation. This subroutine was needed to avoid "division by zero" errors using integers. This subroutine is primarily called to interpolate wave runup elevations from the appropriate set of Stoa tables (curves) when one of the integer inputs gets truncated to zero.

3. The beginning and end coordinates representing the 1/50 slope line (Figure 8 in the technical document titled "Investigations and Improvements of Capabilities for the FEMA Wave Runup Model prepared by Dewberry and dated April 1991), provided in Figure 1 below, were updated to match the expected wave breaker depths. These changes were made in the DBPLOT subroutine in the code. Figure 2 shows the orginal and updated coordinates.

    Existing coordinates: (0.003, 2.6) and (0.04, 1.5)

    Updated coordinates: (0.0025, 2.8) and (0.04, 1.535)

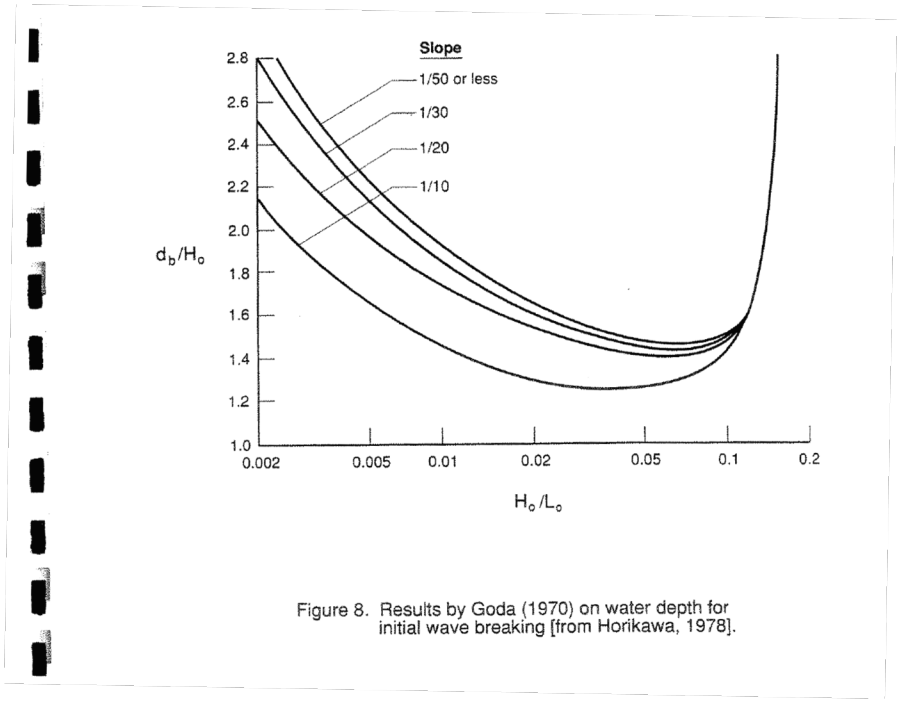



Figure 8. Results by Goda (1970) on water depth for initial wave breaking [from Horikawa, 1978].

*Figure 1: Orginal Figure 8 from April 1991 Documentation*

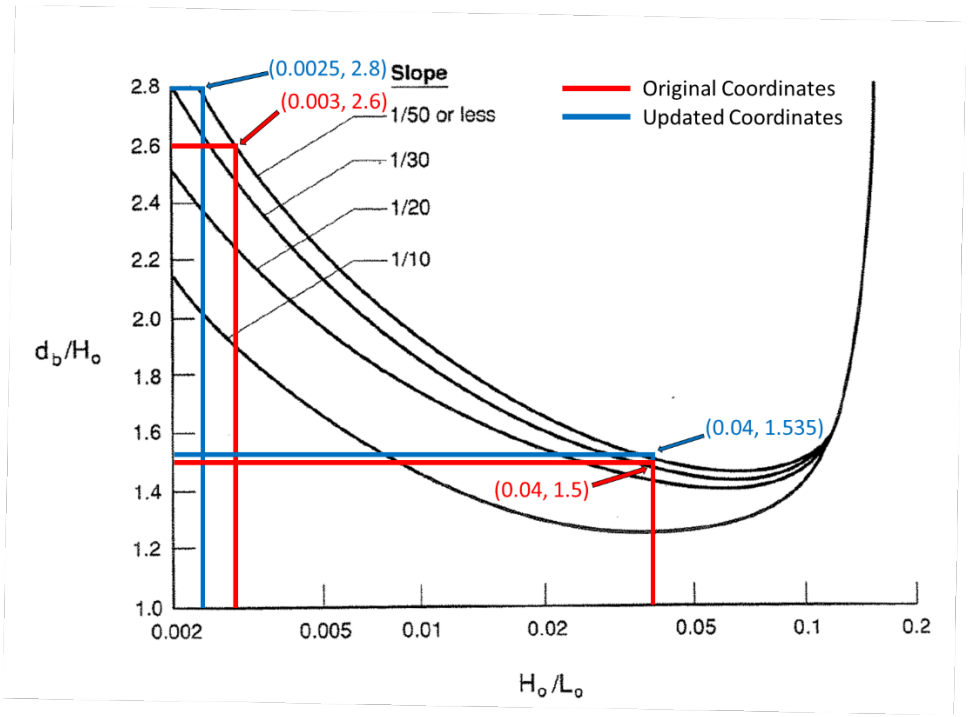



*Figure 2: Technical Document Figure 8 showing Orignal and Updated coordinates for the 1/50 Slope*

4. The value of the pointer into arrays (index of the array) for the runup lookup tables and curves was not getting passed on to the computational subroutines. The signature of the following subroutines was modified to pass the array index as a parameter.
    a. CALCS
    b. COMP
    c. CURVE
    d. SIMPLE
    e. SIMPCOMP1
    f. SIMPCOMP2
    g. SIMPCOMP3

    As an example, to call the CURVE function:
    Existing version: CALL CURVE()
    Updated version: CALL CURVE(INDEX), where "INDEX" represents the postion of a specific item within the array.

5. A new subroutine called READ_COMMAND_LINE was added to the code. This subroutine reads the command line arguments containing the input and output files for the runup executable. It allows the code to be run from command prompt or called from other programs such as CHAMP.

6. The program provides a lookup table for the parameter DS/H0, where DS is defined by the depth at the structure toe and H0 is the deep water wave height. This parameter is used by the program to determine which of the wave runup lookup tables to use. When DS/H0 values exceed the range of values in the lookup table, the November 1991 RUNUP 2.0 executable stops running and gives no error message in the output file, but would give an execution error message in the command line, referencing data being out of bounds. A new function was added to the code to maintain similar performance to the November 1991 executable. RUNUP 2.1 will stop executing when DS/H0 exceeds the values in the lookup table and will not output wave runup values. The updated program will print out the following message in the output file, "DEPTH AT STRUCTURE TOE DIVIDED BY H0 EXCEEDS LOOKUP TABLE" to alert the user that conditions have not met the program requirements. This situation will often occur when the only slope inflection point along an input profile is in deep water and input wave heights are small. Users are advised to check the applicability of the input profile and wave conditions when this error message is displayed in the output file.

7. The updated version of the RUNUP executable, RUNUP 2.1, utilizes a maximum wave steepness (H/L) limit of 0.05 and will not output wave runup values for conditions exceeding a steepness of 0.05. This is different than the assumed wave steepness limit of 0.07 utilized in the November 1991 RUNUP 2.0 executable. The source code included

in the April 1991 documentation shows the wave steepness limit to be a maximum of 0.05, but the accompanying documentation includes mention of using wave steepness values between 0.002 and 0.07 for applicability to the RUNUP 2.0 program. As part of this code update, a close inspection of source material and testing of the sensitivity of wave runup predictions to the wave steepness limit were performed.

The wave steepness is used to enter the plot shown in Figure 1 from the April 1991 documentation, to determine the wave breaking depth and later in the code to determine which segment of the profile the wave breaks on and the resultant slope for runup calculations. The code uses the log of two points bounding the negatively sloped portion of each line for interpolation. The minimum and maximum points used for interpolation correspond to the wave steepness values 0.002 and 0.04, respectively. This portion of the curves are highlighted in red in Figure 3. A wave steepness outside this range requires the code to extrapolate. The curves in Figure 3 demonstrate an inflection at a wave steepness of 0.04 to 0.05, transitioning to a positive slope. Therefore any extrapolated values for wave steepness greater than 0.04 may not match the printed curves. These observations support limiting the RUNUP program to yielding runup predictions where the wave steepness is less than 0.05 (area highlighted dark blue shading) rather than 0.07 (area highlighted by light blue shading). This limits the code to extrapolation for steepness between 0.04 and 0.05 where deviations between the extrapolated value and printed curves will be smallest.

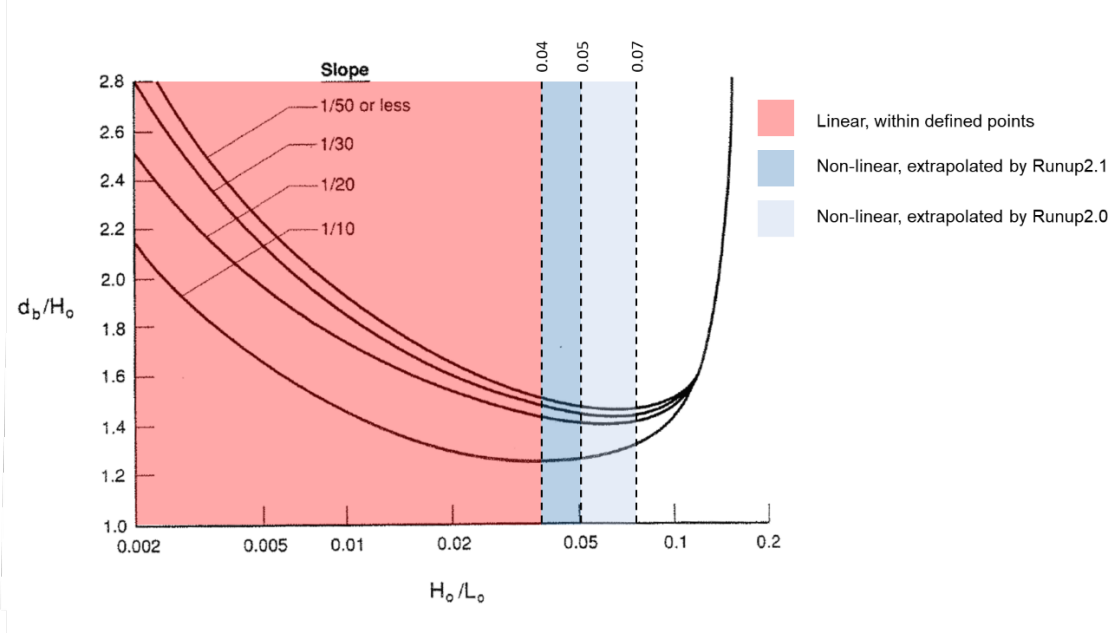



*Figure 3: Technical Document Figure 8 showing linear interpolation and extrapolation areas with key steepness values denoted by dashed lines*

Sensitivity testing was performed to compare the updated RUNUP 2.1 program with the November 1991 executable. As always, the RUNUP program calculates runup

predictions for nine combinations of wave height and period based on a single input wave height and period pairing. Using a wave steepness limit of 0.05 instead of 0.07 has the effect of triggering the steepness warning message for more wave height and period combinations than the November 1991 executable version. When this warning is triggered, the RUNUP program will not provide a runup prediction for that combination. For example, in a single RUNUP execution, the November 1991 executable may yield the warning and omit runup predictions for 2 of the 9 wave combinations and the updated RUNUP 2.1 executable may yield the warning and omit runup predictions for 4 of the wave combinations. Testing has shown that the average of runup predictions for wave combinations that do not trigger the warning yield a consistent value between the RUNUP 2.1 program and November 1991 executable within an acceptable tolerance of 0.1 feet.

It is possible that an attempted RUNUP 2.1 execution will yield only one or no wave runup values. Where this occurs, the user should consider the input wave conditions inappropriate for the RUNUP 2.1 program and review the input wave conditions or consider an alternate wave runup methodology.

8. When the “SOLUTION DOES NOT CONVERGE” warning message is printed in the output file, it was found that the updated code added an extra line in the output file. The code was revised to ensure the warning message did not add an extra line so that it would match the original program output. This maintains consistency and operability with other programs like CHAMP that import the runup output results.

9. The output text header was updated to match the header printed in the output file from the November 1991 executable and updated to print the new version number, “RUNUP 2.1”

10. The code has been formatted for easier readability and comments added where revisions were made.

The updates listed above were implemented to align the code with the November 1991 executable version that has been in regular use since 1991. Comparisons of results from the 1991 and 2024 versions indicate minor differences in some of the interim calculations including breaker depth and composite slopes; however, the predicted mean runup has been observed to match within 0.1 feet vertically.

## Command Line Usage:

RUNUP 2.1 is usually run from the command line with input and output file names provided as command line parameters, as in the following example:

Runup2.exe *inputFileName outputFileName*

Input and output file names are limited to a maximum of eight characters, consistent with previous versions. There is also a limit of 90 characters to reference the full file path of the input and output file locations.

## Installation and Setup:

The current version of the software has external dependencies to the following dynamic link libraries (dlls).

1. Libifcoremd.dll
2. Libmmd.dll
3. svml_dispmd.dll - created for the development of Intel(R) C/C++/Fortran Compiler

These are shipped along with Intel compilers that contain machine language to handle math, file access, and general FORTRAN code compilation/execution. The RUNUP executable file and these dlls should be placed in the same folder before accessing the exe. No registry edits are required. It is believed that these libraries were inherently part of the Windows operating systems in the past but are no longer available. Hence, they were not required to be provided with previous RUNUP executables. The RUNUP program will no longer run without these three dlls in the same folder as the RUNUP executable.

## How to Update the RUNUP Program for CHAMP

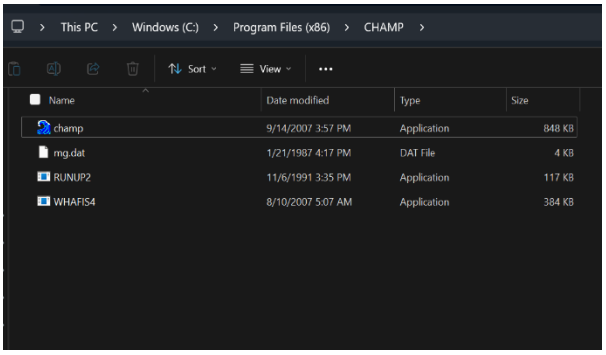
Currently, the Coastal Hazard Analysis and Mapping Program (CHAMP) will install the November 1991 version of the RUNUP executable. If CHAMP is installed on a computer with a modern Windows operating system, the RUNUP module in CHAMP will not operate correctly. To make the change, replace the Runup2.exe in the CHAMP program folder with the updated version and associated .DLL files as described by the steps below. Once the files are in the CHAMP folder, the RUNUP model from within CHAMP will operate.

1. Download the CHAMP Application from FEMA's Coastal Engineering Tools page.
2. Run the CHAMP setup.exe file to install the program
3. Download the updated RUNUP application:

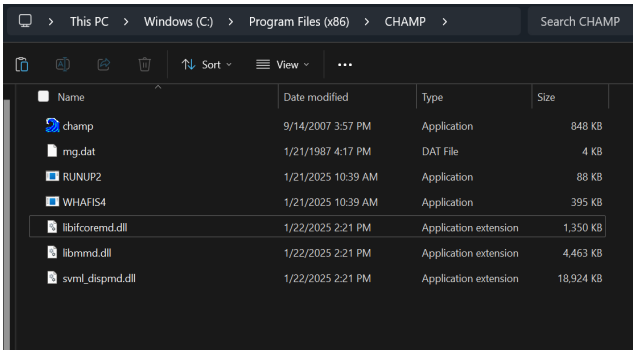
    - RUNUP Application

Clicking the link above will download a zip file to your computer. The RUNUP zip file will contain a file named “Runup2.exe” and three library files ending with the extension “.DLL” as described above.

4. On your computer, navigate to the Program Files (x86) folder. Inside the Program Files (x86) folder, you will find a folder named CHAMP, which is automatically placed there when you first install CHAMP.
5. Move the newly downloaded Runup2.exe and .DLL files to the CHAMP folder. The Runup2.exe will replace the older version but the .DLL files should not have previous versions within the folder. This can be done by selecting the new files and either dragging and dropping them into the CHAMP folder or by copying and pasting them.
    - Ensure RUNUP files are named exactly Runup2.exe and .DLL files match the naming above and pictured below.
    - This step requires administrative privileges, and may require Government Furnished Equipment (GFE) users to call the help desk for assistance and non-GFE users to contact similar organization IT resources.




The above figure shows the CHAMP folder **before** copying and pasting in the new RUNUP2.exe, WHAFIS4.exe, and DLL files.




The above figure shows the CHAMP folder **after** copying and pasting the new RUNUP2.exe, WHAFIS4.exe, and DLL files. The “date modified” column as seen above will contain updated dates, indicating the RUNUP2.exe and WHAFIS4.exe files have been replaced successfully.

6. After moving the files to the CHAMP folder, it will prompt you to replace the existing files. Click “Replace the file in destination” when prompted.