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A SIMPLE AND PRACTICAL COMPUTERIZED PARAMETRIC WAVE/SWELL FORECAST MODEL

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1. INTRODUCTION

This technical memorandum describes a simple computerized wave/swell forecast model designed to provide useful "quick look" guidance for forecast offices which have marine responsibility or occasionally may need to forecast wind and wave conditions over water. The enclosed program (Appendix D) is a computerized ensemble of wave/swell research results which have been performed in the past (see Bretschneider, 1970, and the Army Corps of Engineers, 1984). The National Meteorological Center ocean wave forecast models are much more sophisticated than the one described here. However, wave forecasts are very sensitive to wind speed input (wave height is proportional to the square of the wind speed); hence in areas where model wind analyses and/or forecasts are poor, the forecaster may be able to input better estimates of current or future wind conditions, thus improving upon wave/swell forecasts in a specific area of interest. Remember, this is a simple parametric wave model. Results should be used as marine forecast guidance, ***not*** used as the marine forecast!

2. BACKGROUND INFORMATION

Information on the meteorology and oceanography of ocean wave/swell forecasting is extensive, but beyond the purpose of this memorandum. Detailed background information about characteristics, behavior, relationships, methods, and models of waves and wave/swell forecasting can be obtained in the first two of three Cooperative Program for Operational Meteorology, Education, and Training (COMET) Marine Meteorology Computer Based Learning (CBL) modules which will be available soon.[1] The user is referred to this training material as an excellent prerequisite for properly using this parametric wave forecast model.

3. SIMPLE PARAMETRIC WAVE MODEL

A parametric wave model is simply a computer version of a series of nomograms and equations which could be obtained from various charts and equations without this program. However, this program provides quicker computations, and the forecaster is able to vary parameters in an effort to converge upon an idealistically "perfect" wave/swell forecast. Parametric wave models do not integrate the wave equations through time, and this one does not supply the wave energy spectrum. Rather, the parametric wave model is based on large numbers of wave measurements for various wind speeds, fetch lengths, and wind durations. From these measurements wave growth lines are identified. For example, from measurements it is known that deep water wave-significant wave heights of 5 ft will develop with periods of about 5 sec for wind speeds of 14 kt, assuming the wind blows indefinitely over a very long distance. The parametric wave model

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[1]Information about how to obtain COMET CBL modules can be obtained by writing: Director, COMET, University Corporation for Atmospheric Research, P.O. Box 3000, Boulder, CO, 80307-3000.

can be thought of as computerized look-up tables of wave statistical behavior. The tables can give more than one solution depending upon wind input parameters. Hence, the parametric model provides you with the correct wave solution based on past wave observations. No specific wave growth computations are performed other than looking for a correct pre-computed wave growth. Wave height and period forecast equations along with swell decay equations are based upon nomograms generated by Bretschneider (1970). You might think of this parametric model as a statistical best-fit model tuned to many wave and swell observations. Significant wave height (H1/3) and wave period are primary forecast outputs. Significant wave height is approximately the wave height a trained marine observer would report when taking a subjective marine wave observation. Buoy wave measurements and NMC wave models also provide significant wave heights which have become a wave measurement and forecast standard. Statistically determined wave heights (Bretschneider, 1964) computed along with significant wave height are:

<H>	: The mean of all wave heights in a wave sample
H1/10	: The mean of the highest one-tenth of all waves in a wave sample
H1/100	: The mean of the highest one-hundredth of all waves in a wave sample
Hmax	: The maximum single wave height likely within a large wave sample

Wave period (seconds) is typically the wave period associated with waves with significant wave height. In addition, the user may compute wave/swell heights at some angle (less than 45 deg) away from the center line of the wind generation region. A final computation option allows the user to estimate breaking wave type (based on wave period and shallow water bottom slope) and breaking wave height (based on Weggel, 1972). Breaking wave height is based only on wave shoaling. Wave refraction is not included in this program. In addition, all computations, other than breaking wave heights, assume ***deep water waves***. Waves generated over and propagating for long distances over shallow water will deviate from results provided in this program. A range of wave heights is computed and displayed based upon an input wind error estimate. For example, if you anticipate a wind of 40 kt, but are certain of this speed only to within plus or minus 5 kt, then the program provides you with significant wave heights computed for 35 kt and 45 kt in addition to the 40-kt wind speed. This provides the user with wave height ranges associated with his/her estimate of wind uncertainty.

Decay swell significant height and decay swell period are computed based on wave characteristics at the front edge of the fetch generation (Bretschneider, 1973). Swell decay then takes place over a prescribed (input) decay distance. Swell travel time is provided based upon group velocity of swell with significant period. Consequently, within the entire swell spectrum, long (short) period wave/swell in a fetch generation area will arrive sooner (later). Travel time is swell period-dependent and is controlled by swell group velocity in deep water.

Throughout the program, geographical inputs may be in the form of latitude/longitude points, from which the program computes great circle distances (Bowditch, 1984), or in the form of distance without coordinates.

Wave Forecast Program inputs (units) are as follows:

Wind Speed (knots)

Wind Duration (hours)

Fetch length (nautical miles)

Fetch width (nautical miles)

Decay distance (nautical miles)

Latitude/Longitude (degrees)

Wave height computations for angles off the fetch centerline (degrees)

Bottom or beach slope (non-dimensional value of depth change per horizontal distance change, [note this ratio must have the same units e.g. ft/ft or m/m, etc.])

Southern Hemisphere latitudes are input as negative numbers.
Longitudes west of the international dateline (180W) are input as negative numbers.

Program outputs (units) are as follows:

Wave/Swell Heights (feet)

Wave/Swell Period (seconds)

Swell Travel Time (hours)

Distances (nautical miles)

Wind speeds (knots).

Note that if you fail to include any one of the requested input parameters, wave/swell forecasts are impossible!

3. SCHEMATIC OF INPUT PARAMETERS

Fig. 1 depicts a schematic of necessary input parameters obtainable from a surface weather map. Note this diagram represents a snap-shot of an instantaneous wave fetch generation area with most of the necessary information. Repeated inputs for a moving fetch are obtained in the same manner but for a different snapshot in time. The program allows you to continue to build upon wave growth for moving fetches, by changing fetches, wind speeds and wind durations. This is accomplished by answering "yes" to the question which asks if you would like to build upon existing waves. Subsequent inputs are identical to initial inputs.

4. RUNNING THE MODEL

This simple model is written to run in QBASIC. To run the model, you must obtain a disk copy of the parametric wave forecast model from National Weather Service Southern Region Headquarters, Scientific Services Division.[2] Put the wave model disk in Drive "A." Proceed to the QBASIC directory. Open the file entitled "a:wave2.bas." Then proceed to run the program from QBASIC.

5. WAVE/SWELL FORECAST EXAMPLES

A simple example of a wave height forecast at the front edge of a fetch area is outlined below. A storm is located off the northern California coast. The fetch area extends from near the coast (40N, 124W) westward to 40N, 135W. Fetch width is 600 nm, 300 nm either side of 40N. Mean wind speeds in this fetch generation area are 40 kt ($\pm$5 kt). The fetch remains stationary for 36 hr. Questions we may ask about this scenario are as follows:

> What is the deep water significant wave height and period at the fetch front after 36 hr?
>
> What are the statistical significant wave height characteristics at the fetch front after 36 hr?
>
> What is the breaking wave height and breaking wave type at a beach with a bottom slope of 1 ft depth change per 20 ft (0.05) after 36 hr?

User input, program output, and program answers appear in Appendix A.

An example of swell generated in the Southern Hemisphere which will impact the Southern California coastal zone is outlined below. The fetch generation area is defined as the front edge of the fetch at 35S, 165W, the back edge of the fetch at 50S, 172W, and a fetch width of 500 nm. Mean wind speed in the fetch is 50 kt (+- 8 kt). The final destination is 34N, 119W. Wind duration is 48 hr, and the fetch is nearly stationary. Keep in mind that in real-life scenarios, swell great circle tracks must intersect, or nearly intersect, the final destination.

> What is the deep water decay significant wave height and period at the final destination?
>
> What is the swell travel time to the final destination?
>
> What is the significant swell height 25 deg off the fetch center line at a distance equal to the final destination?

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[2]NOAA/NWS, Southern Region Headquarters, Scientific Services Division, 819 Taylor Street, Room 10A26, Fort Worth, TX, 76102.

What is the breaking swell type and height at a beach with a bottom slope of (0.05), assuming swell is directly at the beach, and bottom slope is homogeneous?

User input, program output, and program answers appear in Appendix B.

A final example of a moving fetch area with changing wind speed is outlined below. For 20 hr a cyclone moves east at 6 m per sec. The wave generating fetch area is 600 nm in length and contains sustained winds of 35 kt. The cyclone becomes stationary, intensifies and develops winds of 45 kt over the next 12 hr. Find the following:

What is the deep water significant wave height and period at the fetch front at the end of the 32 hr?

What are the statistical significant wave height characteristics at the final fetch front?

In this scenario, the fetch moves 240 nm in 20 hr; therefore, the initial fetch front remains under 35-kt winds for 20 hr; however, the fetch length for this specific location is not 600 nm for the entire 20 hr. Rather, it is reduced to about 360 nm at 20 hr, since the entire fetch has moved east of the initial fetch front. However, growing waves are also moving east. Waves at a stationary fetch front would have a height of 19.8 ft and period of 9.2 sec; hence, they would be moving at a speed of approximately 10 m per sec [wave speed in meters per second is approximately equal to 1.56 x wave period (seconds)]. Wave group velocity would be about 5 m per second. Hence, wave energy moves roughtly at the same speed as the fetch generation area and remains under the 35-kt winds for approximately the 20-hr duration. These same waves are then acted upon by 45-kt winds for 12 additional hr; and in this case the fetch remains stationary. Consequently, we can approximate wave building and growth by choosing the growing or building wave option and input to fetch wind speeds; namely, a 600-nm fetch of 35 kt for 20 hr followed by 45 kt for 12 hr.

User input, program output, and program answers appear in Appendix C.

6. CONCLUSIONS

This brief technical memorandum provides general information on how to use a simple parametric wave/swell forecast model. Accuracy of this simple model is critically dependent upon how accurate the input variables are. The purpose of this program is to provide field forecasters with any water forecast responsibility a quick and useful wave/swell forecast guidance aid. This is ***not*** intended to replace existing NMC wave model products, but rather should complement those products and can be used to cross-check NMC wave model validity and performance in your area of marine forecast responsibility.

Detailed information on the understanding of ocean wave/swell processes and forecasting can be obtained in the COMET CBL modules on "Marine Meteorology." The user is urged to examine this information source for a solid background on ocean waves and swells and forecasting both of them. In addition, information in Chapter 3 of the National Weather Service

Marine Forecaster Guide and Reference Manual[3] provides much useful information and definitions which may be used as reference material on wave/swell forecasting.

User feedback is an excellent way to improve upon techniques. We welcome your comments and suggestions to improve upon this first attempt at a simple wave/swell forecast aid.

Happy wave forecasting!

References

Army Corps of Engineers, 1984: Shore Protection Manual, Vol. 2. Coastal Engineering Research Center, Waterways Exp. Station, Corps of Engineers, Vicksburg, MS.

Bowditch, N., 1984: *American Practical Navigator, Vol. I.* Defense Mapping Agency Hydrographic/Topographic Center. Pub. No. 9.

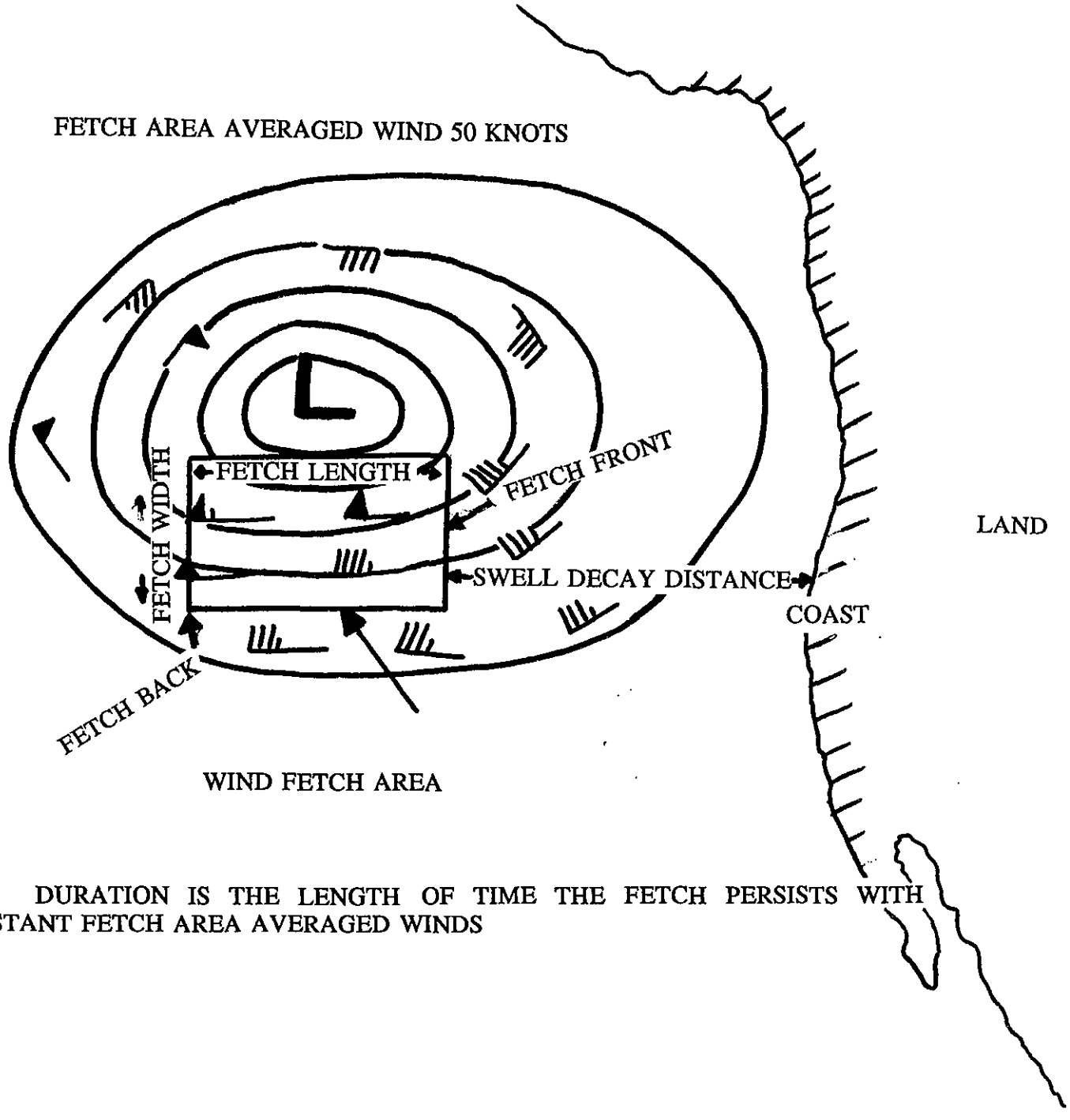
Weggel, J. R., 1972: Maximum Breaker Height. *Journal of the Waterways*, Harbors and Coastal Engineering Division, Vol. 98, WW4, Nov. 1972.

Bretschneider, C. L. 1970: Forecasting relations for wave generation. Look Lab/Hawaii, 1, No. 3, University of Hawaii, U.S.A., Aug. 1970.

Bretschneider, C. L., 1973: Prediction of waves and currents. Look Lab/Hawaii, 3, No. 1, University of Hawaii, U.S.A., Jan. 1973.

Bretschneider, C. L., 1964: Wave generation by wind, deep and shallow water. Estuary and Coastal Hydrodynamics, Engineering Societies Monograph. McGraw Hill, U.S.A., pp. 133-196.

[3]Available from NOAA, National Weather Service, Southern Region Headquarters, Marine Focal Point, 819 Taylor Street, Room 10A26, Fort Worth, TX 76102.



DURATION IS THE LENGTH OF TIME THE FETCH PERSISTS WITH CONSTANT FETCH AREA AVERAGED WINDS

Figure 1

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APPENDIX A

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THIS PROGRAM IS A PARAMETRIC WAVE/SWELL FORECAST MODEL BASED
PRIMARILY ON PAST RESEARCH AND DEVELOPMENT BY C. BRETSCHNEIDER.
ALTHOUGH THERE ARE MANY PARAMETRIC MODELS, MY OPERATIONAL EXPERIENCE
INDICATES THAT THIS ONE PERFORMS AS GOOD OR BETTER THAN MOST OTHERS.
BREAKING WAVE TYPE AND HEIGHT EQUATIONS HAVE BEEN ADAPTED FROM
THE ARMY CORPS OF ENGINEERS.
NOTE THAT SHALLOW WATER WAVE GROWTH AND BEHAVIOR MAY DIFFER FROM
WHAT THE FOLLOWING DEEP WATER WAVE EQUATIONS PROVIDE
GREAT CIRCLE EQUATIONS HAVE BEEN ADAPTED FROM BOWDITCH
-------------------------------------------------------------
-------------------------------------------------------------
THIS IS A *SIMPLE* PARAMETRIC WAVE/SWELL FORECAST MODEL
OUTPUT ACCURACY IS VERY SENSITIVE TO INPUT PARAMETER ACCURACY
SO BE CAREFUL INPUTTING VALUES
HAPPY WAVE FORECASTING, STEVEN W. LYONS!
-------------------------------------------------------------
INPUT '-333' AT ANY INPUT OPPORTUNITY TO TERMINATE THE PROGRAM
-------------------------------------------------------------
DO YOU WISH TO COMPUTE WAVES (enter 0) OR SWELLS (enter 1)?
? 0
-------------------------------------------------------------
ENTER THE FETCH AREA AVERAGE 10 METER WIND SPEED IN KNOTS
-------------------------------------------------------------
? 40
-------------------------------------------------------------
ENTER YOUR WIND UNCERTAINTY IN KNOTS (e.g. +- 10 KNOTS = 10) WITHIN FETCH
-------------------------------------------------------------
? 5
-------------------------------------------------------------
WOULD YOU LIKE TO ENTER A FETCH DISTANCE (ENTER 1) OR LAT/LONG OF FETCH AREA (EN
TER 0)?
-------------------------------------------------------------
? 0
ENTER THE LATITUDE AT THE FRONT CENTER OF THE FETCH
IF LATITUDE IS IN SOUTHERN HEMISPHERE VALUE IS NEGATIVE (e.g. 30.5S = -30.5)
-------------------------------------------------------------
? 40
-----------------------------------------------
ENTER THE LONGITUDE AT THE FRONT CENTER OF THE FETCH
IF LONGITUDE IS WEST OF 180 LONGITUDE IS NEGATIVE (e.g. 175E = -175)
-------------------------------------------------------------
? 124
-------------------------------------------------------------
ENTER THE LATITUDE AT THE BACK CENTER OF THE FETCH
IF LATITUDE IS IN SOUTHERN HEMISPHERE VALUE IS NEGATIVE (e.g. 30.5s = =30.5)
-------------------------------------------------------------
? 40
-------------------------------------------------------------
ENTER THE LONGITUDE AT THE BACK CENTER OF THE FETCH
IF LONGITUDE IS WEST OF 180 LONGITUDE IS NEGATIVE (e.g. 175e = -175)
-------------------------------------------------------------
? 135
-----------------------------------------------
DO YOU WISH TO INCLUDE A WIND DURATION LIMIT? YES=1, NO=0
-----------------------------------------------
? 1
-----------------------------------------------
ENTER THE WIND DURATION (IN HOURS) OVER THE FETCH
-----------------------------------------------
? 36
```

```
------------------------------------------------------------
WIND SPEED KNOTS                                    : 40 (KNOTS)
CALCULATED GREAT CIRCLE FETCH LENGTH                : 505 (NAUTICAL MILES)
EFFECTIVE FETCH (POSSIBLY MODIFIED BY DURATION)     : 505 (NAUTICAL MILES)
------------------------------------------------------------
**** WAVE GROWTH IS FETCH LENGTH LIMITED FOR INPUT WIND SPEED ****
------------------------------------------------------------
SIGNIFICANT WAVE HEIGHT IS Hs or H1/3               :    27.1 FT
SIGNIFICANT WAVE PERIOD IS Ps                       :    11.4 SEC
SIGNIFICANT WAVE HEIGHT FOR UNLIMITED DURATION IS   :    27.1 FT
MEAN WAVE HEIGHT IS   <H>                           :    16.9 FT
HIGHEST ONE-TENTH OF WAVES IS  H1/10                :    35.2 FT
MAX WAVE HEIGHT FOR A LARGE WAVE SAMPLE IS Hmax     :    54.2 FT

SIGNIFICANT WAVE HEIGHT RANGE FOR WIND SPEED UNCERTAINTY OF +- 5 KNOTS IS
 21.8 FT  TO   32.5 FT
------------------------------------------------------------
WOULD YOU LIKE TO CONTINUE THIS COMPUTATION BUILDING WITH NEW WAVE PARAMETERS
WHICH CONTINUE THE WIND DURATION IN TIME? ENTER 1=YES, 0=NO
? 0
DO YOU WANT TO COMPUTE APPROXIMATE BREAKING WAVE HEIGHTS? YES=1,NO=0
------------------------------------------------------------
? 1
------------------------------------------
NOTE THIS IS A CRUDE APPROXIMATION ONLY
FOR WAVE AND SWELL APPROACHING A COAST.
NO WAVE REFRACTION IS INCLUDED!
ONLY BOTTOM FRICTION, PERCOLATION AND SHOALING (WHICH IS WAVE PERIOD DEPENDENT)
ARE INCLUDED
------------------------------------------------------------
ENTER COASTAL BEACH SLOPE (WHERE WATER DEPTH/WAVELENGTH<=0.5)
SLOPE IS THE RATIO OF WATER DEPTH CHANGE TO LATERAL DISTANCE CHANGE
------------------------------------------------------------
? .05
BREAKING WAVE TYPE SHOULD BE SPILLING
------------------------------------------------------------------------
APPROXIMATE SIGNIFICANT WAVE HEIGHT AT BREAKING=         39.2 FT
APPROXIMATE SIGNIFICANT WAVE PERIOD AT BREAKING=         11 SEC
NOTE SIGNIFICANT WAVE PERIOD IS UNMODIFIED BY COASTAL PROCESSES
```

APPENDIX B

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------------------------------------------------------------------------
DO YOU WISH TO MAKE ANOTHER COMPUTATION? YES=1, NO=0
------------------------------------------------
? 1
DO YOU WISH TO COMPUTE WAVES (enter 0) OR SWELLS (enter 1)?
? 1
------------------------------------------------------------
ENTER THE FETCH AREA AVERAGE 10 METER WIND SPEED IN KNOTS
------------------------------------------------------------
? 50
------------------------------------------------------------
ENTER YOUR WIND UNCERTAINTY IN KNOTS (e.g. +- 10 KNOTS = 10) WITHIN FETCH
------------------------------------------------------------
? 8
------------------------------------------------------------
WOULD YOU LIKE TO ENTER A FETCH DISTANCE (ENTER 1) OR LAT/LONG OF FETCH AREA (EN
TER 0)?
------------------------------------------------------------
? 0
ENTER THE LATITUDE AT THE FRONT CENTER OF THE FETCH
IF LATITUDE IS IN SOUTHERN HEMISPHERE VALUE IS NEGATIVE (e.g. 30.5S = -30.5)
------------------------------------------------------------
? -35
------------------------------------------------
ENTER THE LONGITUDE AT THE FRONT CENTER OF THE FETCH
IF LONGITUDE IS WEST OF 180 LONGITUDE IS NEGATIVE (e.g. 175E = -175)
------------------------------------------------------------
? 165
------------------------------------------------------------
ENTER THE LATITUDE AT THE BACK CENTER OF THE FETCH
IF LATITUDE IS IN SOUTHERN HEMISPHERE VALUE IS NEGATIVE (e.g. 30.5s = =30.5)
------------------------------------------------------------
? -50
------------------------------------------------------------
ENTER THE LONGITUDE AT THE BACK CENTER OF THE FETCH
IF LONGITUDE IS WEST OF 180 LONGITUDE IS NEGATIVE (e.g. 175e = -175)
------------------------------------------------------------
? 172
------------------------------------------------------
DO YOU WISH TO INCLUDE A WIND DURATION LIMIT? YES=1, NO=0
------------------------------------------------------
? 1
------------------------------------------
ENTER THE WIND DURATION (IN HOURS) OVER THE FETCH
------------------------------------------
? 48
```

```
------------------------------------------------------------
WIND SPEED KNOTS                                    : 50 (KNOTS)
CALCULATED GREAT CIRCLE FETCH LENGTH                : 950 (NAUTICAL MILES)
EFFECTIVE FETCH (POSSIBLY MODIFIED BY DURATION)     : 847 (NAUTICAL MILES)
------------------------------------------------------------
**** WAVE GROWTH IS DURATION LIMITED BY  48  HOUR DURATION ****
------------------------------------------------------------
SIGNIFICANT WAVE HEIGHT IS Hs or H1/3               :    43 FT
SIGNIFICANT WAVE PERIOD IS Ps                       :    14.4 SEC
SIGNIFICANT WAVE HEIGHT FOR UNLIMITED DURATION IS   :    43.9 FT
MEAN WAVE HEIGHT IS   <H>                           :    26.9 FT
HIGHEST ONE-TENTH OF WAVES IS  H1/10                :    55.9 FT
MAX WAVE HEIGHT FOR A LARGE WAVE SAMPLE IS Hmax     :    85.9 FT

SIGNIFICANT WAVE HEIGHT RANGE FOR WIND SPEED UNCERTAINTY OF +- 8 KNOTS IS
 31.4 FT  TO   54.2 FT
------------------------------------------------------------
WOULD YOU LIKE TO CONTINUE THIS COMPUTATION BUILDING WITH NEW WAVE PARAMETERS
WHICH CONTINUE THE WIND DURATION IN TIME? ENTER 1=YES, 0=NO
? 0
IF YOU WISH TO PROVIDE A DECAY DISTANCE ENTER 1
IF YOU WISH A GREAT CIRCLE DECAY DISTANCE BE CALCULATED FROM
LATITUDE/LONGITUDE POINTS ENTER 0
------------------------------------------------------------
? 0
ENTER THE LATITUDE OF FINAL DESTINATION
IF LATITUDE IS IN SOUTHERN HEMISPHERE THEN LATITUDE IS NEGATIVE (e.g. 10S = -10)

------------------------------------------------------------
? 34
------------------------------------------------------------------------
ENTER THE LONGITUDE OF FINAL DESTINATION
IF LONGITUDE IS WEST OF 180 THEN LONGITUDE IS NEGATIVE (e.g. 175E = -175)
------------------------------------------------------------
? 119
------------------------------------------------
ENTER THE OBSERVED FETCH WIDTH IN NAUTICAL MILES
------------------------------------------------
? 500
------------------------------------------------------------
DECAY DISTANCE IS =                                 : 4879 NAUTICAL MILES
DECAY SWELL SIGNIFICANT HEIGHT IS APPROXIMATELY=    : 6 FT
DECAY SWELL SIGNIFICANT PERIOD IS APPROXIMATELY=    : 21 SEC
SIGNIFICANT SWELL TRAVEL TIME TO FINAL DESTINATION=: 150 HRS
------------------------------------------------------------
LONGER PERIOD SWELL FORRUNNERS WILL ARRIVE EARLIER
SHORTER PERIOD SWELL WILL ARRIVE LATER
------------------------------------------------------------
```

```
DO YOU WANT TO CALCULATE SWELL SIGNIFICANT HEIGHT AT AN ANGLE OFF
THE CENTER LINE GREAT CIRCLE TRACK? YES=1,NO=0
-----------------------------------------------------------------
? 1
-----------------------------------------------------------------
INPUT THE ANGLE OFF FETCH CENTER FOR YOUR AREA OF INTEREST
(ANGLE IN DEGREES MUST NOT EXCEED 45)
-----------------------------------------------------------------
? 25
-----------------------------------------------------------------------
APPROXIMATE DECAY SWELL SIGNIFICANT HEIGHT AT 25 DEGREES AWAY
FROM THE CENTER LINE DIRECTION OF THE FETCH= 5 FT
-----------------------------------------------------------------------
DO YOU WANT TO COMPUTE APPROXIMATE BREAKING WAVE HEIGHTS? YES=1,NO=0
-----------------------------------------------------------------------
? 1
-----------------------------------
NOTE THIS IS A CRUDE APPROXIMATION ONLY
FOR WAVE AND SWELL APPROACHING A COAST.
NO WAVE REFRACTION IS INCLUDED!
ONLY BOTTOM FRICTION, PERCOLATION AND SHOALING (WHICH IS WAVE PERIOD DEPENDENT)
ARE INCLUDED
-----------------------------------------------------------------
ENTER COASTAL BEACH SLOPE (WHERE WATER DEPTH/WAVELENGTH<=0.5)
SLOPE IS THE RATIO OF WATER DEPTH CHANGE TO LATERAL DISTANCE CHANGE
-----------------------------------------------------------------
? .05
BREAKING WAVE TYPE SHOULD BE PLUNGING
-------------------------------------------------------------------------------
APPROXIMATE SIGNIFICANT WAVE HEIGHT AT BREAKING=          11.5 FT
APPROXIMATE SIGNIFICANT WAVE PERIOD AT BREAKING=          21 SEC
NOTE SIGNIFICANT WAVE PERIOD IS UNMODIFIED BY COASTAL PROCESSES
-------------------------------------------------------------------------------
DO YOU WISH TO MAKE ANOTHER COMPUTATION? YES=1, NO=0
---------------------------------------------------
```

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APPENDIX C

```
------------------------------------------------------------
DO YOU WISH TO COMPUTE WAVES (enter 0) OR SWELLS (enter 1)?
? 0
------------------------------------------------------------
ENTER THE FETCH AREA AVERAGE 10 METER WIND SPEED IN KNOTS
------------------------------------------------------------
? 35
------------------------------------------------------------
ENTER YOUR WIND UNCERTAINTY IN KNOTS (e.g. +- 10 KNOTS = 10) WITHIN FETCH
------------------------------------------------------------
? 5
------------------------------------------------------------
WOULD YOU LIKE TO ENTER A FETCH DISTANCE (ENTER 1) OR LAT/LONG OF FETCH AREA (EN
TER 0)?
------------------------------------------------------------
? 1
------------------------------------------------------------
ENTER YOUR FETCH DISTANCE IN NAUTICAL MILES (VALUE MUST BE POSITIVE)
------------------------------------------------------------
? 600
------------------------------------------------------
DO YOU WISH TO INCLUDE A WIND DURATION LIMIT? YES=1, NO=0
------------------------------------------------------
? 1


------------------------------------------------
ENTER THE WIND DURATION (IN HOURS) OVER THE FETCH
------------------------------------------------
? 20
------------------------------------------------------------
WIND SPEED KNOTS                                  : 35 (KNOTS)
CALCULATED GREAT CIRCLE FETCH LENGTH              : 600 (NAUTICAL MILES)
EFFECTIVE FETCH (POSSIBLY MODIFIED BY DURATION)   : 245 (NAUTICAL MILES)
------------------------------------------------------------
**** WAVE GROWTH IS DURATION LIMITED BY  20  HOUR DURATION ****
------------------------------------------------------------
SIGNIFICANT WAVE HEIGHT IS Hs or H1/3             :    18.6 FT
SIGNIFICANT WAVE PERIOD IS Ps                     :    9.2 SEC
SIGNIFICANT WAVE HEIGHT FOR UNLIMITED DURATION IS :    22.4 FT
MEAN WAVE HEIGHT IS   <H>                         :    11.6 FT
HIGHEST ONE-TENTH OF WAVES IS  H1/10              :    24.2 FT
MAX WAVE HEIGHT FOR A LARGE WAVE SAMPLE IS Hmax   :    37.2 FT

SIGNIFICANT WAVE HEIGHT RANGE FOR WIND SPEED UNCERTAINTY OF +- 5 KNOTS IS
 14.4 FT  TO   22.5 FT
------------------------------------------------------------
```

```
WOULD YOU LIKE TO CONTINUE THIS COMPUTATION BUILDING WITH NEW WAVE PARAMETERS
WHICH CONTINUE THE WIND DURATION IN TIME? ENTER 1=YES, 0=NO
? 1
 YOU ARE ADDING ADDITIONAL WIND DURATION WITH NEW WIND SPEED AND
FETCH AREA TO EXISTING WAVES, THE FOLLOWING INPUT REQUESTS THAT NEW
INPUT. DO NOT RE-INPUT OLD FETCH AREAS, THE PROGRAM BUILDS ADDITIONAL
WAVES FROM WAVES WHICH ARE ALREADY DEVELOPED.  KEEP IN MIND THAT
IDEALLY THE NEW FETCH SHOULD OVERLAP WAVES ALREADY GENERATED
DO YOU WISH TO COMPUTE WAVES (enter 0) OR SWELLS (enter 1)?
? 0
------------------------------------------------------------
ENTER THE FETCH AREA AVERAGE 10 METER WIND SPEED IN KNOTS
------------------------------------------------------------
? 45
------------------------------------------------------------
ENTER YOUR WIND UNCERTAINTY IN KNOTS (e.g. +- 10 KNOTS = 10) WITHIN FETCH
------------------------------------------------------------
? 5


ENTER THE FETCH AREA AVERAGE 10 METER WIND SPEED IN KNOTS
------------------------------------------------------------
? 45
------------------------------------------------------------
ENTER YOUR WIND UNCERTAINTY IN KNOTS (e.g. +- 10 KNOTS = 10) WITHIN FETCH
------------------------------------------------------------
? 5
------------------------------------------------------------
WOULD YOU LIKE TO ENTER A FETCH DISTANCE (ENTER 1) OR LAT/LONG OF FETCH AREA (EN
TER 0)?
------------------------------------------------------------
? 1
------------------------------------------------------------
ENTER YOUR FETCH DISTANCE IN NAUTICAL MILES (VALUE MUST BE POSITIVE)
------------------------------------------------------------
? 600
------------------------------------------------------
DO YOU WISH TO INCLUDE A WIND DURATION LIMIT? YES=1, NO=0
------------------------------------------------------
? 1
```

```
------------------------------------------------
ENTER THE WIND DURATION (IN HOURS) OVER THE FETCH
------------------------------------------------
? 12
------------------------------------------------------------
WIND SPEED KNOTS                                  : 45 (KNOTS)
CALCULATED GREAT CIRCLE FETCH LENGTH              : 600 (NAUTICAL MILES)
EFFECTIVE FETCH (POSSIBLY MODIFIED BY DURATION)   : 446 (NAUTICAL MILES)
------------------------------------------------------------
**** WAVE GROWTH IS DURATION LIMITED BY  28.62169 HOUR DURATION ****
------------------------------------------------------------
SIGNIFICANT WAVE HEIGHT IS Hs or H1/3             :    31.5 FT
SIGNIFICANT WAVE PERIOD IS Ps                     :    12.1 SEC
SIGNIFICANT WAVE HEIGHT FOR UNLIMITED DURATION IS :    33.9 FT
MEAN WAVE HEIGHT IS   <H>                         :    19.7 FT
HIGHEST ONE-TENTH OF WAVES IS  H1/10              :    41 FT
MAX WAVE HEIGHT FOR A LARGE WAVE SAMPLE IS Hmax   :    63.1 FT

SIGNIFICANT WAVE HEIGHT RANGE FOR WIND SPEED UNCERTAINTY OF +- 5 KNOTS IS
 21.6 FT  TO   31.3 FT
------------------------------------------------------------
WOULD YOU LIKE TO CONTINUE THIS COMPUTATION BUILDING WITH NEW WAVE PARAMETERS
WHICH CONTINUE THE WIND DURATION IN TIME? ENTER 1=YES, 0=NO
?
```

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APPENDIX D

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  PRINT "-----------------------------------------------------------------"
  PRINT "THIS PROGRAM IS A PARAMETRIC WAVE/SWELL FORECAST MODEL BASED"
  PRINT "PRIMARILY ON PAST RESEARCH AND DEVELOPMENT BY C. BRETSCHNEIDER."
  PRINT "ALTHOUGH THERE ARE MANY PARAMETRIC MODELS, MY OPERATIONAL EXPERIENCE"
  PRINT "INDICATES THAT THIS ONE PERFORMS AS GOOD OR BETTER THAN MOST OTHERS."
  PRINT "BREAKING WAVE TYPE AND HEIGHT EQUATIONS HAVE BEEN ADAPTED FROM"
  PRINT "THE ARMY CORPS OF ENGINEERS."
  PRINT "NOTE THAT SHALLOW WATER WAVE GROWTH AND BEHAVIOR MAY DIFFER FROM"
  PRINT "WHAT THE FOLLOWING DEEP WATER WAVE EQUATIONS PROVIDE"
  PRINT "GREAT CIRCLE EQUATIONS HAVE BEEN ADAPTED FROM BOWDITCH"
  PRINT "-----------------------------------------------------------------"
  REM CONSTANTS-----------------------------------------------------------
  PI = 3.1415
  RAD = 3440.18
  REM ---------------------------------------------------------------------
  PRINT "-----------------------------------------------------------------"
  PRINT "THIS IS A *SIMPLE* PARAMETRIC WAVE/SWELL FORECAST MODEL"
  PRINT "OUTPUT ACCURACY IS VERY SENSITIVE TO INPUT PARAMETER ACCURACY"
  PRINT "SO BE CAREFUL INPUTTING VALUES"
  PRINT "HAPPY WAVE FORECASTING, STEVEN W. LYONS!"
  PRINT "-----------------------------------------------------------------"
  PRINT "INPUT '-333' AT ANY INPUT OPPORTUNITY TO TERMINATE THE PROGRAM"
  PRINT "-----------------------------------------------------------------"
  GOTO 1
333 PRINT " YOU ARE ADDING ADDITIONAL WIND DURATION WITH NEW WIND SPEED AND"
  PRINT "FETCH AREA TO EXISTING WAVES, THE FOLLOWING INPUT REQUESTS THAT NEW"
  PRINT "INPUT. DO NOT RE-INPUT OLD FETCH AREAS, THE PROGRAM BUILDS ADDITIONAL"
  PRINT "WAVES FROM WAVES WHICH ARE ALREADY DEVELOPED.  KEEP IN MIND THAT"
  PRINT "IDEALLY THE NEW FETCH SHOULD OVERLAP WAVES ALREADY GENERATED"
  H0 = H
  W0 = W
  L0 = L
  FET0 = FET
1 PRINT "DO YOU WISH TO COMPUTE WAVES (enter 0) OR SWELLS (enter 1)?"
  INPUT TYP
  IF TYP = -333 THEN GOTO 50
  IF TYP > 1 OR TYP < 0 THEN GOTO 1
  PRINT "-----------------------------------------------------------------"
112 PRINT "ENTER THE FETCH AREA AVERAGE 10 METER WIND SPEED IN KNOTS"
  PRINT "-----------------------------------------------------------------"
  INPUT W
  IF W = -333 THEN GOTO 50
  IF W > 150 THEN PRINT "VALUE NOT REALISTIC, TRY AGAIN!"
  IF W > 150 THEN GOTO 112
  PRINT "-----------------------------------------------------------------"
  PRINT "ENTER YOUR WIND UNCERTAINTY IN KNOTS (e.g. +- 10 KNOTS = 10) WITHIN FET
CH"
```

```
  PRINT "-----------------------------------------------------------------"
  INPUT VAR
  IF VAR = -333 THEN GOTO 50
  PRINT "-----------------------------------------------------------------"
  PRINT "WOULD YOU LIKE TO ENTER A FETCH DISTANCE (ENTER 1) OR LAT/LONG OF FETCH
 AREA (ENTER 0)?"
  PRINT "-----------------------------------------------------------------"
  INPUT IFT
  IF IFT = -333 THEN GOTO 50
  IF IFT = 0 THEN GOTO 222
  PRINT "-----------------------------------------------------------------"
321  PRINT "ENTER YOUR FETCH DISTANCE IN NAUTICAL MILES (VALUE MUST BE POSITIVE)
"
  PRINT "-----------------------------------------------------------------"
  INPUT FET
  IF FET <= 0 THEN PRINT "UNACCEPTABLE INPUT, TRY AGAIN"
  IF FET <= 0 THEN GOTO 321
  GOTO 223
  PRINT "-----------------------------------------------------------------"
222 PRINT "ENTER THE LATITUDE AT THE FRONT CENTER OF THE FETCH"
  PRINT "IF LATITUDE IS IN SOUTHERN HEMISPHERE VALUE IS NEGATIVE (e.g. 30.5S = -
30.5)"
  PRINT "-----------------------------------------------------------------"
  INPUT LAF
  IF LAF = -333 THEN GOTO 50
  PRINT "-----------------------------------------------------"
  PRINT "ENTER THE LONGITUDE AT THE FRONT CENTER OF THE FETCH"
  PRINT "IF LONGITUDE IS WEST OF 180 LONGITUDE IS NEGATIVE (e.g. 175E = -175)"
  PRINT "-----------------------------------------------------------------"
  INPUT LONF
  IF LONF = -333 THEN GOTO 50
  PRINT "-----------------------------------------------------------------"
  PRINT "ENTER THE LATITUDE AT THE BACK CENTER OF THE FETCH"
  PRINT "IF LATITUDE IS IN SOUTHERN HEMISPHERE VALUE IS NEGATIVE (e.g. 30.5s = -
30.5)"
  PRINT "-----------------------------------------------------------------"
  INPUT LAB
  IF LAB = -333 THEN GOTO 50
  PRINT "-----------------------------------------------------------------"
  PRINT "ENTER THE LONGITUDE AT THE BACK CENTER OF THE FETCH"
  PRINT "IF LONGITUDE IS WEST OF 180 LONGITUDE IS NEGATIVE (e.g. 175e = -175)"
  PRINT "-----------------------------------------------------------------"
  INPUT LOB
  REM CALCULATE GREAT CIRCLE DISTANCES-----------------------------
  IF LOB = -333 THEN GOTO 50
  LAD = (LAF - LAB)
  LOD = (LONF - LOB)
  IF LOD = 0 THEN FUNK = 0
  IF LOD = 0 THEN GOTO 33
  FUNK = ABS(LAD / LOD)
33 DD = ATN(FUNK / 57.292)
  DD = DD * 57.298
  IF LOD <= 0 AND LAD <= 0 THEN DD = DD + 270
  IF LOD <= 0 AND LAD > 0 THEN DD = 270 - DD
  IF LOD > 0 AND LAD < 0 THEN DD = 180 - DD
  ARC = SQR(LAD ^ 2 + LOD ^ 2)
  FET = (ARC / 57.296) * RAD
  ALOD = ABS(LOD / 57.296)
  ALAD = ABS(LAD / 57.296)
  RLAF = (LAF / 57.296)
  RLAB = (LAB / 57.296)
```

```
  G1 = .5 * (1 - COS(ALOD))
  G2 = COS(RLAF) * COS(RLAB)
  G3 = .5 * (1 - COS(ALAD))
  G4 = G1 * G2 + G3
  G5 = 2 * G4
  G6 = (1 - G5)
  G7 = ATN(G6 / SQR(-G6 * G6 + 1))
  GC = (G7) * (360 / (2 * 3.14159))
  GC = (90 - GC) * 60
  FET = GC
  FFET = FET
  GOTO 224
223  FFET = FET
224  PRINT "------------------------------------------------------------"
  PRINT "DO YOU WISH TO INCLUDE A WIND DURATION LIMIT? YES=1, NO=0"
  PRINT "------------------------------------------------------------"
  INPUT Z
  IF Z = -333 THEN GOTO 50
  IF Z = 0 THEN GOTO 20
  PRINT "------------------------------------------------"
  PRINT "ENTER THE WIND DURATION (IN HOURS) OVER THE FETCH"
  PRINT "------------------------------------------------"
  INPUT L
  IF L = -333 THEN GOTO 50
  IF ICON = 1 THEN GOTO 777
  REM  SIGNIFICANT WAVE HEIGHT EQUATIONS----------------------------------------
---------
  H = (100 * (L - 6) + 410) / (20.5 - 9.4 * (LOG(W - 10) / LOG(10)))
  HM = (100 * (L - 6) + 410) / (20.5 - 9.4 * (LOG((W - VAR) - 10) / LOG(10)))
  HP = (100 * (L - 6) + 410) / (20.5 - 9.4 * (LOG((W + VAR) - 10) / LOG(10)))
  IF ICON = 0 THEN GOTO 888
777 REM CALCULATE THE EFFECTIVE DURATION OF WIND SPEED OF NEW FETCH WITH OLD PA.
AMETERS
  HA = (100 * (L - 6) + 410) / (20.5 - 9.4 * (LOG(W - 10) / LOG(10)))
  IF W = W0 THEN H = HA + H0
  IF W = W0 THEN GOTO 888
  LN = (H0 * (20.5 - 9.4 * (LOG(W - 10) / LOG(10))) + 190) / 100
  LLL = L + LN
  H = (100 * (LLL - 6) + 410) / (20.5 - 9.4 * (LOG(W - 10) / LOG(10)))
888 REM SKIPPED ADDITIONAL FETCH GENERATION AREAS
  IQ = 0
  FULL = FET
  IF H >= FET THEN GOTO 20
  IF H < FET THEN IQ = 1
  IF H < FET THEN FET = H
  IF HM >= FET THEN FETM = FET
  IF HM < FET THEN FETM = HM
  IF HP >= FET THEN FETP = FET
  IF HP < FET THEN FETP = HP
  GOTO 22
20 FETM = FET
   FETP = FET
   FULL = FET
```

```
   REM CONSTANTS FOR WAVE PERIOD EQUATIONS------------------------
22 G = 68634.6
  A = .007
  B = .0085
  C = .04
  I = .067
  U = W * 1.6889
  REM CALCULATE SIGNIFICANT WAVE PERIOD
  QQ = (G * FULL) / (W ^ 2)
  Q = (G * FET) / (W ^ 2)
  QM = (G * FETM) / ((W - VAR) ^ 2)
  QP = (G * FETP) / ((W + VAR) ^ 2)
  XM = B * SQR(QM)
  XP = B * SQR(QP)
  XF = B * SQR(QQ)
  X = B * SQR(Q)
  TM = A * ((W - VAR) * 1.6889) ^ 2 * (EXP(XM) - EXP(-XM)) / (EXP(XM) + EXP(-XM)
)
  T = A * U ^ 2 * (EXP(X) - EXP(-X)) / (EXP(X) + EXP(-X))
  TP = A * ((W + VAR) * 1.6889) ^ 2 * (EXP(XP) - EXP(-XP)) / (EXP(XP) + EXP(-XP)
)
  TT = A * U ^ 2 * (EXP(XF) - EXP(-XF)) / (EXP(XF) + EXP(-XF))
  X = I * (Q ^ .25)
  RANP = TP - T
  RANM = T - TM
  P = 2 * PI * C * U * (EXP(X) - EXP(-X)) / (EXP(X) + EXP(-X))
  PD = P
  REM PRINT OUT RESULTS FOR SIGNIFICANT WAVES
  PRINT "-------------------------------------------------------------"
  PRINT "WIND SPEED KNOTS                                    :"; CINT(W); "(KNO"
S)"
REM  PRINT "FETCH DIRECTION FROM                               :"; CINT(DD); "(
DEGREES)"
  PRINT "CALCULATED GREAT CIRCLE FETCH LENGTH                  :"; INT(FFET); "(NA
UTICAL MILES)"
  PRINT "EFFECTIVE FETCH (POSSIBLY MODIFIED BY DURATION)       :"; INT(FET); "(NA"
TICAL MILES)"
  PRINT "-------------------------------------------------------------"
  IF ICON = 1 THEN GOTO 500
  IF IQ = 1 THEN PRINT "**** WAVE GROWTH IS DURATION LIMITED BY "; L; " HOUR DUR
ATION ****"
  IF IQ = 0 THEN PRINT "**** WAVE GROWTH IS FETCH LENGTH LIMITED FOR INPUT WIND
SPEED ****"
  GOTO 444
500 IF IQ = 1 THEN PRINT "**** WAVE GROWTH IS DURATION LIMITED BY "; LLL; "HOUR
DURATION ****"
  IF IQ = 0 THEN PRINT "**** WAVE GROWTH IS FETCH LENGTH LIMITED FOR INPUT WIND
SPEED ****"
444  PRINT "-------------------------------------------------------------"
```

```
  REM CALCULATE ADDITIONAL WAVE STATISTICS FROM SIGNIFICANT WAVE VALUES-------
  PRINT "SIGNIFICANT WAVE HEIGHT IS Hs or H1/3                :", CINT(T * 10) /
10; "FT"
  PRINT "SIGNIFICANT WAVE PERIOD IS Ps                        :", CINT(P * 10) /
10; "SEC"
  PRINT "SIGNIFICANT WAVE HEIGHT FOR UNLIMITED DURATION IS    :", CINT(TT * 10) /
 10; "FT"
  PRINT "MEAN WAVE HEIGHT IS    <H>                           :", CINT((T / 1.6)
* 10) / 10; "FT"
  PRINT "HIGHEST ONE-TENTH OF WAVES IS  H1/10                 :", CINT(T * 1.3 *
10) / 10; "FT"
  PRINT "MAX WAVE HEIGHT FOR A LARGE WAVE SAMPLE IS Hmax      :", CINT(T * 2 * 10
) / 10; "FT"
  PRINT " "
  PRINT "SIGNIFICANT WAVE HEIGHT RANGE FOR WIND SPEED UNCERTAINTY OF +-"; VAR;
KNOTS IS", CINT((T - RANM) * 10) / 10; "FT  TO", CINT((RANP + T) * 10) / 10; "FT
"
  PRINT "-------------------------------------------------------------"
  PRINT "WOULD YOU LIKE TO CONTINUE THIS COMPUTATION BUILDING WITH NEW WAVE PARA
METERS"
  PRINT "WHICH CONTINUE THE WIND DURATION IN TIME? ENTER 1=YES, 0=NO"
  ICON = 0
  INPUT ICON
  IF ICON = -333 THEN GOTO 50
  IF ICON = 1 THEN GOTO 333
  IF TYP <> 1 THEN GOTO 116
  PRINT "IF YOU WISH TO PROVIDE A DECAY DISTANCE ENTER 1"
  PRINT "IF YOU WISH A GREAT CIRCLE DECAY DISTANCE BE CALCULATED FROM"
  PRINT "LATITUDE/LONGITUDE POINTS ENTER 0"
  PRINT "NOTE IF YOU ENTERED FETCH DISTANCE RATHER THAN FETCH LAT/LON POINTS"
  PRINT "YOU MUST ENTER A DECAY DISTANCE, NOT A LAT/LON OF FINAL DESTINATION"
  PRINT "-------------------------------------------------------------"
  INPUT IDIS
  IF IDIS = 0 THEN GOTO 109
  IF IDIS = -333 THEN GOTO 50
555  IF IDIS = 1 THEN PRINT "INPUT DECAY DISTANCE IN NAUTICAL MILES"
  INPUT DDECAY
  IF DDECAY = -333 THEN GOTO 50
  IF DDECAY <= 0 THEN PRINT "INVALID INPUT VALUE TRY AGAIN"
  IF DDECAY <= 0 THEN GOTO 555
  IF IDIS = 1 THEN GOTO 111
  PRINT "-------------------------------------------------------------------
----------"
109 PRINT "ENTER THE LATITUDE OF FINAL DESTINATION"
  PRINT "IF LATITUDE IS IN SOUTHERN HEMISPHERE THEN LATITUDE IS NEGATIVE (e.g. 1
0S = -10)"
  PRINT "-------------------------------------------------------------"
  INPUT FLAT
  IF FLAT = -333 THEN GOTO 50
  IF FLAT > 90 OR FLAT < -90 THEN PRINT "INPUT VALUE NOT ALLOWED REINPUT WITH A
VALUE WITIN +-90"
  IF FLAT > 90 OR FLAT < -90 THEN GOTO 109
  PRINT "-------------------------------------------------------------------
---"
110 PRINT "ENTER THE LONGITUDE OF FINAL DESTINATION"
  PRINT "IF LONGITUDE IS WEST OF 180 THEN LONGITUDE IS NEGATIVE (e.g. 175E = -17
5)"
  PRINT "-------------------------------------------------------------"
```

```
  INPUT FLON
  IF FLON = -333 THEN GOTO 50
  IF FLON > 180 OR FLON < -180 THEN PRINT "INPUT VALUE NOT ALLOWED REINPUT WITH
A VALUE  WITHIN +-180"
  IF FLON > 180 OR FLON < -180 THEN GOTO 110
  PRINT "-------------------------------------------------"
111 PRINT "ENTER THE OBSERVED FETCH WIDTH IN NAUTICAL MILES"
  PRINT "-------------------------------------------------"
  INPUT FW
  REM CALCULATE SWELL GREAT CIRCLE DECAY DISTANCE--------------------------
  IF FW = -333 THEN GOTO 50
  IF FW <= 0 THEN PRINT "VALUE MUST BE >0, TRY AGAIN!"
  IF FW <= 0 THEN GOTO 111
  IF IDIS = 1 THEN GOTO 556
  DIR = ATAN(FLAT / FLON)
  DLATF = ABS(LAF - FLAT)
  DLONF = ABS(LONF - FLON)
  DDARC = SQR(DLATF ^ 2 + DLONF ^ 2)
  DECAY = (DDARC / 57.296) * RAD
  D1 = DLONF / 57.292
  D2 = DLATF / 57.292
  RFLAT = FLAT / 57.292
  RFLATF = FLATF / 57.292
  G1 = .5 * (1 - COS(D1))
  G2 = COS(RLAF) * COS(RFLAT)
  G3 = .5 * (1 - COS(D2))
  G4 = G1 * G2 + G3
  G5 = 2 * G4
  G6 = (1 - G5)
  G7 = ATN(G6 / SQR(-G6 * G6 + 1))
  GC = G7 * (360 / (2 * 3.14159))
  GC = (90 - GC) * 60
  DECAY = GC
556  IF IDIS = 1 THEN DECAY = DDECAY
  A = (LOG(DECAY) / LOG(10)) - (1.34 + ((LOG(DECAY) / LOG(10)) - 2) * 1.34) - .1
 * EXP(-.05 * T)
  B = A + .05
  REM CALCULATE THRESHOLDS FOR SWELL HEIGHT DECAY CURVE SLOPES----------------
---
  IF DECAY <= 800 AND DECAY > 100 THEN GOTO 400
  IF DECAY <= 100 THEN GOTO 100
  IF DECAY > 800 THEN GOTO 800
400 IF FW >= 400 AND FW <= 600 THEN COR = .05 * ((FW - 400) / 200)
  IF FW > 600 AND FT <= 800 THEN COR = .04 * ((FW - 600) / 200) + .05
  IF FW > 800 THEN COR = .03 * ((FW - 800) / 200) + .09
  IF FW < 400 AND FW > 200 THEN COR = .084 * ((FW - 400) / 200)
  IF FW <= 200 AND FW > 100 THEN COR = -.084 + .084 * ((FW - 200) / 100)
  IF FW <= 100 THEN COR = -.168 - .084 * ((100 - FW) / 100)
  GOTO 2000
```

```
100 IF FW >= 400 AND FW < 600 THEN COR = ((FW - 400) / 200) * .05
  IF FW >= 600 AND FW < 800 THEN COR = .05 + ((FW - 600) / 200) * .04
  IF FW >= 800 THEN COR = .09 + ((FW - 800) / 200) * .04
  GOTO 2000
800 IF FW >= 400 AND FT <= 600 THEN COR = .05 * ((FW - 400) / 200) - .012 * ((DE
CAY - 400) / 9600)
    IF FW > 600 AND FW <= 800 THEN COR = .04 * ((FW - 600) / 200) + .05 - .015 *
 ((DECAY - 400) / 9600)
    IF FW > 800 THEN COR = .03 * ((FW - 800) / 200) + .09 - .015 * ((DECAY - 40
) / 9600)
    IF FW < 400 AND FW > 200 THEN COR = .084 * ((FW - 400) / 200) - .015 * ((DEC
AY - 400) / 9600)
    IF FW <= 200 AND FW > 100 THEN COR = -.084 + .084 * ((FW - 200) / 100) - .01
5 * ((DECAY - 400) / 9600)
    IF FW <= 100 THEN COR = -.168 - .084 * ((100 - FW) / 100) - .015 * ((DECAY
 400) / 9600)
2000 REM COMPUTE THRESHOLDS FOR SWELL PERIOD DECAY CURVE SLOPES------------
  B = B + COR
  T = B * T
  C = 1.15 + ((LOG(DECAY) / LOG(10)) - 2) * .27
  J = EXP(-.24 * P - .1 - .00001 * DECAY)
  K = C - J
  IF FW >= 400 AND FW <= 600 THEN PCOR = -.08 * ((FW - 400) / 200)
  IF FW > 600 THEN PCOR = -.08 + -.038 * ((FW - 600) / 200)
  IF FW < 400 AND FW >= 200 THEN PCOR = -.1 * ((FW - 400) / 200)
  IF FW < 200 AND FW >= 100 THEN PCOR = -.1 + (-.1 * ((FW - 200) / 100))
  IF FW < 100 THEN PCOR = -.2 * ((FW - 100) / 50)
  PD = P * (K + PCOR) - (P / 14)
  IF PD < P THEN PD = 1.01 * P
  V = 20 * (DECAY / (32 * PD - 28))
  REM PRINT OUT SWELL SIGNIFICANT HEIGHT AND PERIOD STATISTICS------------
  PRINT "-----------------------------------------------------------------"
  PRINT "DECAY DISTANCE IS =                                    :"; CINT(DECAY); "NA
UTICAL MILES"
  PRINT "DECAY SWELL SIGNIFICANT HEIGHT IS APPROXIMATELY=    :"; CINT(T); "FT"
  PRINT "DECAY SWELL SIGNIFICANT PERIOD IS APPROXIMATELY=    :"; CINT(PD); "SEC"
  PRINT "SIGNIFICANT SWELL TRAVEL TIME TO FINAL DESTINATION=:"; CINT(V); "HRS"
  PRINT "-----------------------------------------------------------------"
  PRINT "LONGER PERIOD SWELL FORRUNNERS WILL ARRIVE EARLIER"
  PRINT "SHORTER PERIOD SWELL WILL ARRIVE LATER"
  PRINT "-----------------------------------------------------------------"
  PRINT "DO YOU WANT TO CALCULATE SWELL SIGNIFICANT HEIGHT AT AN ANGLE OFF"
  PRINT "THE CENTER LINE GREAT CIRCLE TRACK? YES=1,NO=0"
  PRINT "-----------------------------------------------------------------"
  INPUT ANS
  IF ANS = -333 THEN GOTO 50
  IF ANS = 0 GOTO 116
  PRINT "-----------------------------------------------------------"
115 PRINT "INPUT THE ANGLE OFF FETCH CENTER FOR YOUR AREA OF INTEREST"
  PRINT "(ANGLE IN DEGREES MUST NOT EXCEED 45)"
  PRINT "-----------------------------------------------------------"
  INPUT ANGLE
  IF ANGLE = -333 THEN GOTO 50
  IF ANGLE >= 45 THEN PRINT "INPUT VALUE EXCEEDS 45, TRY AGAIN!"
  IF ANGLE >= 45 THEN GOTO 115
  REM CALCULATE OFF CENTER LINE FACTOR-----------------------------------
  FOFF = (COS(ANGLE / 57.292)) ^ 2
  TF = T * FOFF
```

```
  PRINT "-----------------------------------------------------------------"
45 PRINT "APPROXIMATE DECAY SWELL SIGNIFICANT HEIGHT AT"; ANGLE; "DEGREES AWAY"
  PRINT "FROM THE CENTER LINE DIRECTION OF THE FETCH="; INT(TF); "FT"
  PRINT "-----------------------------------------------------------------"
116 PRINT "DO YOU WANT TO COMPUTE APPROXIMATE BREAKING WAVE HEIGHTS? YES=1,NO=0"
46 PRINT "-----------------------------------------------------------------"
  INPUT BW
  IF BW = -333 THEN GOTO 50
  IF BW = 0 THEN GOTO 50
  PRINT "-----------------------------------------"
  PRINT "NOTE THIS IS A CRUDE APPROXIMATION ONLY"
  PRINT "FOR WAVE AND SWELL APPROACHING A COAST."
  PRINT "NO WAVE REFRACTION IS INCLUDED!"
  PRINT "ONLY BOTTOM FRICTION, PERCOLATION AND SHOALING (WHICH IS WAVE PERIOD DE
PENDENT) ARE INCLUDED"
  PRINT "-----------------------------------------------------------------"
130 PRINT "ENTER COASTAL BEACH SLOPE (WHERE WATER DEPTH/WAVELENGTH<=0.5)"
  PRINT "SLOPE IS THE RATIO OF WATER DEPTH CHANGE TO LATERAL DISTANCE CHANGE"
  PRINT "-----------------------------------------------------------------"
  INPUT SLOP
  IF SLOP = -333 THEN GOTO 50
  IF SLOP > .1 THEN PRINT "THIS SLOPE IS MORE LIKE A CLIFF! TRY AGAIN!!"
  IF SLOP > .1 GOTO 130
  REM CALCULATE BREAKING WAVE SIGNIFICANT HEIGHT/TYPE BASED ON BEACH SLOPE-----
-
  STEEP = (T / 3.1833) / (9.8 * P ^ 2)
  E = TAN(SLOP) / (SQR(2 * PI) * SQR(STEEP))
  IF E > 2 THEN PRINT "BREAKING WAVE TYPE SHOULD BE SURGING/COLLAPSING"
  IF E > .4 AND E < 2 THEN PRINT "BREAKING WAVE TYPE SHOULD BE PLUNGING"
  IF E <= .4 THEN PRINT "BREAKING WAVE TYPE SHOULD BE SPILLING"
  SRATIO = .03 / STEEP
  SRATIO = LOG(SRATIO) / 4
  IF SRATIO > 1.3 THEN SRATIO = 1.3
  IF SRATIO < 0 THEN SRATIO = 0
  FACTOR = 1 + SRATIO
  REM PRINT OUT BREAK WAVE SIGNIFICANT HEIGHT----------------------------------
  PRINT "-----------------------------------------------------------------
--------"
  PRINT "APPROXIMATE SIGNIFICANT WAVE HEIGHT AT BREAKING=", CINT(FACTOR * T * 10
) / 10; "FT"
  PRINT "APPROXIMATE SIGNIFICANT WAVE PERIOD AT BREAKING=", CINT(PD); "SEC"
  PRINT "NOTE SIGNIFICANT WAVE PERIOD IS UNMODIFIED BY COASTAL PROCESSES"
  PRINT "-----------------------------------------------------------------
--------"
50 PRINT "DO YOU WISH TO MAKE ANOTHER COMPUTATION? YES=1, NO=0"
  PRINT "-------------------------------------------------"
  INPUT ZZ
  IF ZZ = 1 THEN GOTO 1
  END
```