USERS MANUAL
FOR
DUNE EROSION MODEL:
EDUNE

By:

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DISCLAIMER

This program contains no warranty of any kind, either express or implied. The author shall not be liable to you, or for claim by any other party, for any direct or indirect damages arising from any use or misuse of the EDUNE program or arising from failure of the model to perform as intended or desired.

The reason for this disclaimer is the high degree of uncertainty involved in predicting or hindcasting beach and dune erosion due to severe storms. The physical conditions that this program attempts to model are among the most chaotic and severe of any natural phenomena; therefore, results cannot be guaranteed to accurately reflect the natural environment.

In addition, no rigorous theories or conclusive empirical results form the basis for this model. The mathematical formulas and numerical algorithms used in the model are highly simplified and highly speculative. The model is based on accepted practice where possible; however, in many instances, this model extends the state-of-the-art to the point where no previous practice exists.

The algorithms contained in the model have been checked against a limited amount of field data. Results should not be accepted unless reinforced by other engineering analysis or by professional engineering judgement. Proper use of these results, especially in cases where engineering design, construction permits, or regulatory controls may be based on program output, requires appropriate factors of safety at the user's discretion.

Reasonable efforts have been made to check for errors in the numerical code and to verify that the model will work and perform as intended. The user is cautioned, however, that this computercode may not be free from defects. Likewise, this model may not realistically simulate all prototype conditions. The author agrees to make reasonable efforts to work with the user and to attempt to correct any errors that may be found in the computer code.

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INTRODUCTION

This user's manual describes the development, calibration,and application of the EDUNE numerical model for predicting the time-dependent dune erosion due to severe storm events. The EDUNE model is a revised Version of the EBEACH model. The EBEACH model was originally developed by D. L. Kriebel and R.G. Dean and was originally released by the author in 1982.

Both the EDUNE and EBEACH models predict the time-dependent evolution of existing or design beach and dune profiles for specified storm surge and storm wave conditions. These models are based on application of Dean's (1977) equilibrium beach profile theory. This theory assumes that a given beach profile will evolve toward a new equilibrium form and position in response to elevated water levels and increased breaking wave heights. The time-dependent profile response is obtained by solving the equation for conservation of sediment in finite-difference form, along with a simplified expression for cross-shore sediment transport rates. In general, the models are written in standard FORTRAN77 and are designed for desk-top application on a personal computer.

The EBEACH model has been widely accepted in the United States for predicting the erosion impact of severe storms on the open-coast. The FORTRAN source code for the EBEACH model was originally published by Kriebel (1982) while a second form was released by Kriebel (1984a, 1984b) in a series of technical design memoranda for the Florida Department of Natural Resources. A third version of the EBEACH model has been used by the U. S. Army Corps of Engineers and has been recommended by the Corps of Engineers, e.g. Birkemeier et al. (1987), to the Federal Emergency Management Agency for use in the coastal flood insurance program. A fourth version of the EBEACH model is scheduled to be published in 1989 as part of the Corps of Engineers' Automated Coastal Engineering System.

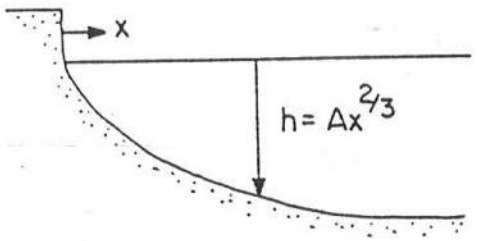
BACKGROUND

Theoretical Development

The EBEACH and EDUNE models are based on the equilibrium beach profile theory of Dean (1977, 1984). Dean analyzed several mechanisms for equilibrium profile development and concluded that observed equilibrium forms were most likely the result of uniform dissipation of wave energy per unit volume in the surf zone. Based on this assumed forcing mechanism, and the assumption of spilling breaking waves, Dean derived a power-law expression for equilibrium beach profile forms, as:

$$h = A\, x^{2/3} \tag{1}$$

where h is the water depth at a distance x seaward of the still water shoreline, while A is a scaling parameter governing the steepness of the profile, as in Figure 1. Dean also related the scaling parameter, A, to a unique value of the wave energy dissipation per unit volume, D_{eq}, which exists everywhere across the beach profile when the system is in equilibrium.



based on uniform energy dissipation per unit volume

$$A = \left[\frac{24}{5} \frac{\mathcal{D}_{eq}}{\gamma \kappa^2 g^{1/2}} \right]^{2/3}$$

both A and $\mathcal{D}_{eq}$ empirically related to sediment size.

Figure 1. Equilibrium beach profile theory of Dean (1977)

Equation 2 is similar to transport relationships used by Bakker (1968), Swart (1974), and Perlin and Dean (1983), all of which estimated the rate of offshore sediment transport in terms of the difference between actual and equilibrium profile geometries.

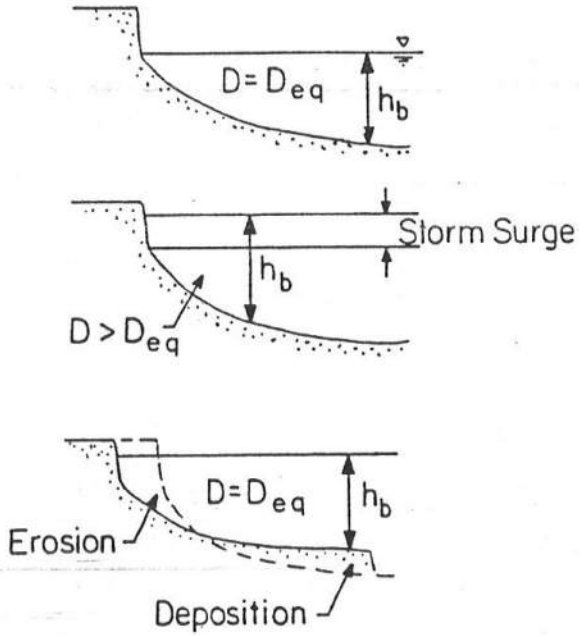


Figure 2. Profile response to equilibrium based on energy dissipation mechanism.

From dimensional analysis, the transport rate parameter, K, must vary according to some length scale; however, little progress has been made in quantifying K based on fundamental quantities. This parameter is therefore retained as the only free or adjustable parameter in the dune erosion model and, as such, it must be determined empirically through model calibration. Moore (1982) developed a numerical model based on the same governing equations and found K to be 0.001144 ft^4/lb. This value was originally adopted for use in the EBEACH model; however, the value of K is expected to vary depending on the exact numerical algorithms used in any numerical model.

In the numerical model, Equation 5 is then cast into an implicit, space-centered, finite difference form, e.g. Kriebel and Dean (1985a). By numerically integrating this equation, together with the expression for sediment transport rate in Equation 2, the change in position of elevation contours across the beach profile may be estimated over a given time step. In this case, the actual energy dissipation per unit volume, D, and the resulting sediment flux, Q_S, vary for each elevation contour depending on the water level, wave height, and profile form at the beginning of each time step. The time-dependent profile response for an arbitrary storm surge may then be simulated by simply varying water levels and wave heights at each time step for the duration of the storm event.

Verification and Acceptance of the EBEACH Model

Detailed descriptions of the original EBEACH model development are given by Kriebel (1982) and by Kriebel (1984a, 1984b), as well as by Kriebel and Dean (1984, 1985a). A reprint of the paper by Kriebel and Dean (1985a) is included in Appendix A to provide supporting documentation for this user's manual. In these publications, numerical results from the EBEACH model are shown to agree qualitatively with erosion characteristics of natural and laboratory beach profiles for a variety of water level, wave height, beach slope, and sediment characteristics.

A preliminary quantitative verification of the EBEACH model was carried out in a simulation of the average dune erosion experienced over Bay and Walton Counties in Florida during Hurricane Eloise. It was found that the model reasonably predicted the mean dune erosion experienced over the two-county shoreline, based on a comparison of predicted eroded volumes to the county-wide average eroded volumes published by Chiu (1977). Since a provision in the original EBEACH model required the dune face to erode uniformly with no change in slope and with no slope

starting in 1984. The major revisions include numerical algorithms that help eliminate numerical instabilities, that improve realism in representing the dune erosion processes, and that expand the range of pre-storm conditions to which the model may be applied.

Other revisions included in the EDUNE model have not been previously published. These include provisions for simulating pre-storm profile forms that do not conform to the standard description of a high dune that can erode with an infinite reservoir of sand. Recent revisions allow a much wider variety of pre-storm profiles, including: (1) low dunes that will be overtopped during the storm, (2) narrow dunes that will be eroded completely during the storm, and (3) dunes that are backed by seawalls that will be exposed during the storm.

The EDUNE model has also undergone more extensive calibration and verification than the EBEACH model, again as reported by Kriebel and Dean (1985b) and by Kriebel (1986). First, the model has been calibrated against a large-scale laboratory experiment of Saville (1957), as depicted in Figures 3 and 4. Based on a least-squares fit of the predicted eroded volumes to those measured by Saville, the sediment transport rate parameter, K, was found to be 0.004 to 0.005 ft^4/lb. While this value differed from that adopted from Moore (1982), it is judged more appropriate since it is based on direct calibration of the EDUNE model, rather than on Moore's calibration using a different numerical scheme.

From these calibration studies, the transport rate parameter, K, was tentatively adopted as 0.0045 ft^4/lb. As of this writing, this value is recommended for general model application. The surprising agreement between the two calibration studies was not expected, since K should vary according to sediment size or some other representative length scale; however, it does provide a reasonable basis for selecting the transport

With this algorithm, the dune face is no longer required to erode uniformly, and a near-vertical erosion scarp may be formed above a realistic wave uprush limit. Other new algorithms include routines to smooth the profile if beach slopes exceed a critical slope, to adjust the time-step according to the rate of rise of the water level, and to allow a wider range of pre-storm profile forms. These changes are described in detail in a later sections of this manual.

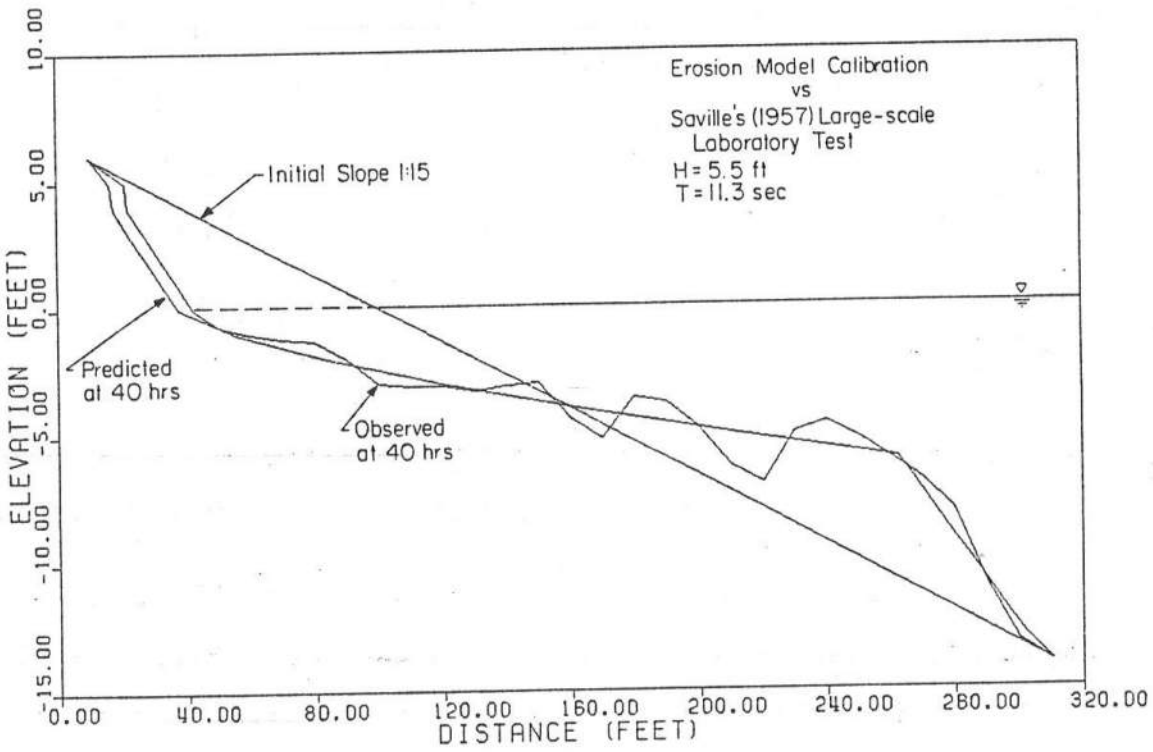


Figure 4. Comparison of final predicted profile compared to that of Saville (1957) based on model calibration.

To further evaluate the EDUNE model, 20 severely eroded profiles from the Hurricane Eloise data set were selected and used to evaluate model sensitivity and bias. This detailed simulation, also reported by Kriebel (1986) and in Appendix B, indicated that the model was capable of predicting the observed eroded volumes to within approximately 25 to 40 percent, but with little bias toward over- or under-predicting the eroded volumes,

by Birkemeier et al. (1987) and by Figure 6, however, additional factors of safety should be applied to account for the most severe erosion that may occur within a given set of beach profiles. The appropriate factor of safety should be determined by the user based on professional engineering judgement.

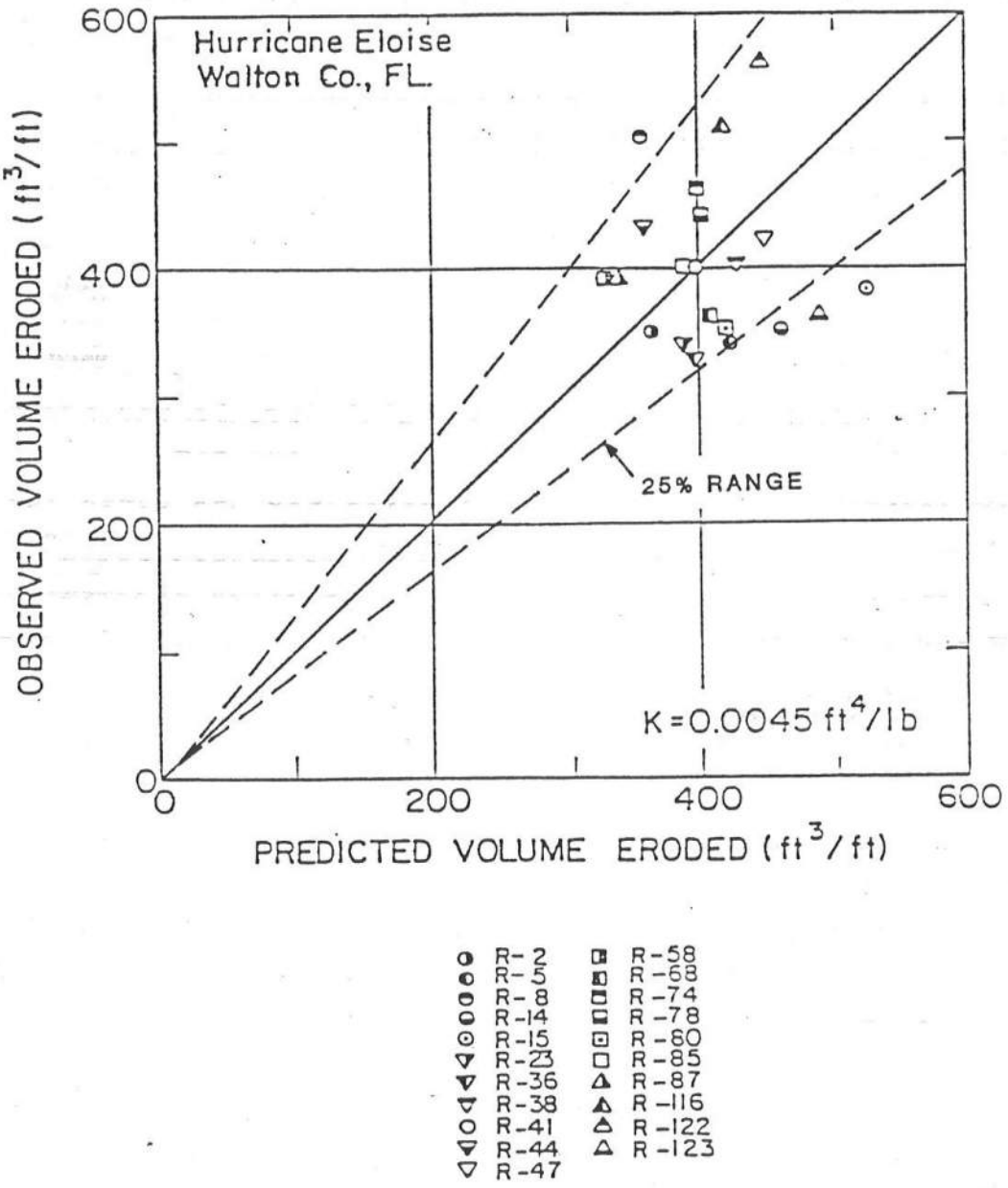


Figure 6. Comparison of predicted to measured dune erosion for 20 profiles from Hurricane Eloise data set.

PROGRAM DESCRIPTION

A flow chart for the EDUNE model is shown in Figure 7 to provide some familiarity with the routines and algorithms used in the numerical model. In this section these will be described in general terms; they are described in detail in a later section of this manual entitled "DESCRIPTION OF PROGRAM ALGORITHMS".

The EDUNE model generally contains a main DO loop which iterates over time and which contains nested DO loops to perform all erosion calculations at each time step. Before this main loop is started, however, four subroutines are called to establish the input parameters for the beach profile, the storm surge, and the wave height time-series.

Subroutine RINPUT reads the primary input data for all initial profile and hydrodynamic input conditions contained in the INPUT.DAT data file. This data is used to define the A parameter, to establish the spacing of elevation contours, and to establish several control points for defining the dune and beach profile. This information is also used to establish the maximum height of the storm surge, the surge duration, the maximum breaking wave height, and the limit of wave uprush above the still water flood level.

Subroutine PROFIL is called next to establish the initial profile form. Based on parameters passed from RINPUT, the initial profile is established in one of two ways. One option allows simplified schematic profiles, identical to those allowed in the EBEACH model, in which the profile form is defined by the location of the dune crest, the dune slope, the location of the berm crest, the beach slope, and by the A parameter offshore. The second option allows the user to read in a more exact profile description based on vertical and horizontal coordinates for the profile from the PROFIL.INP data file.

is determined according to Equation 3 and the sediment transport rate is estimated according to Equation 2. On the active beach face, a new algorithm is employed which estimates the sediment transport distribution between the still-water shoreline and the uprush limit. This algorithm is described by Kriebel and Dean (1985b) and is based on a comparison of existing beach slopes to the equilibrium beach slope to determine whether the beach face should flatten or steepen as it erodes.

Following the description of the sediment transport distribution, the sediment conservation equation is solved to determine profile response between the runup limit and the breakpoint. This solution uses the same double-sweep algorithm employed in the EBEACH model, which solves a tridiagonal matrix relating profile changes at three successive elevation contours.

At both the seaward and landward ends of the active profile, discontinuities may exist in the computed profile form. First, it is possible for the elevation contour at the breakpoint to advance seaward beyond the next contour offshore. In order to prevent this occurrence, a routine is included to redistribute sand to adjacent offshore contours until a 1:12.5 slope is attained. This limiting slope is adopted from the field observations of Vellinga (1983a). At the runup limit, a similar discontinuity may occur as the profile erodes into the dune. In this case, the contour at the runup limit may retreat landward of the next adjacent upland contour. When this occurs, successive upland contours are activated and eroded until the equilibrium dune slope is achieved, thus forming a steep erosion scarp above the runup limit. After the dune scarp is formed, a routine is employed to adjust the computed profile in cases of erosion through a narrow dune or of erosion to a fixed seawall.

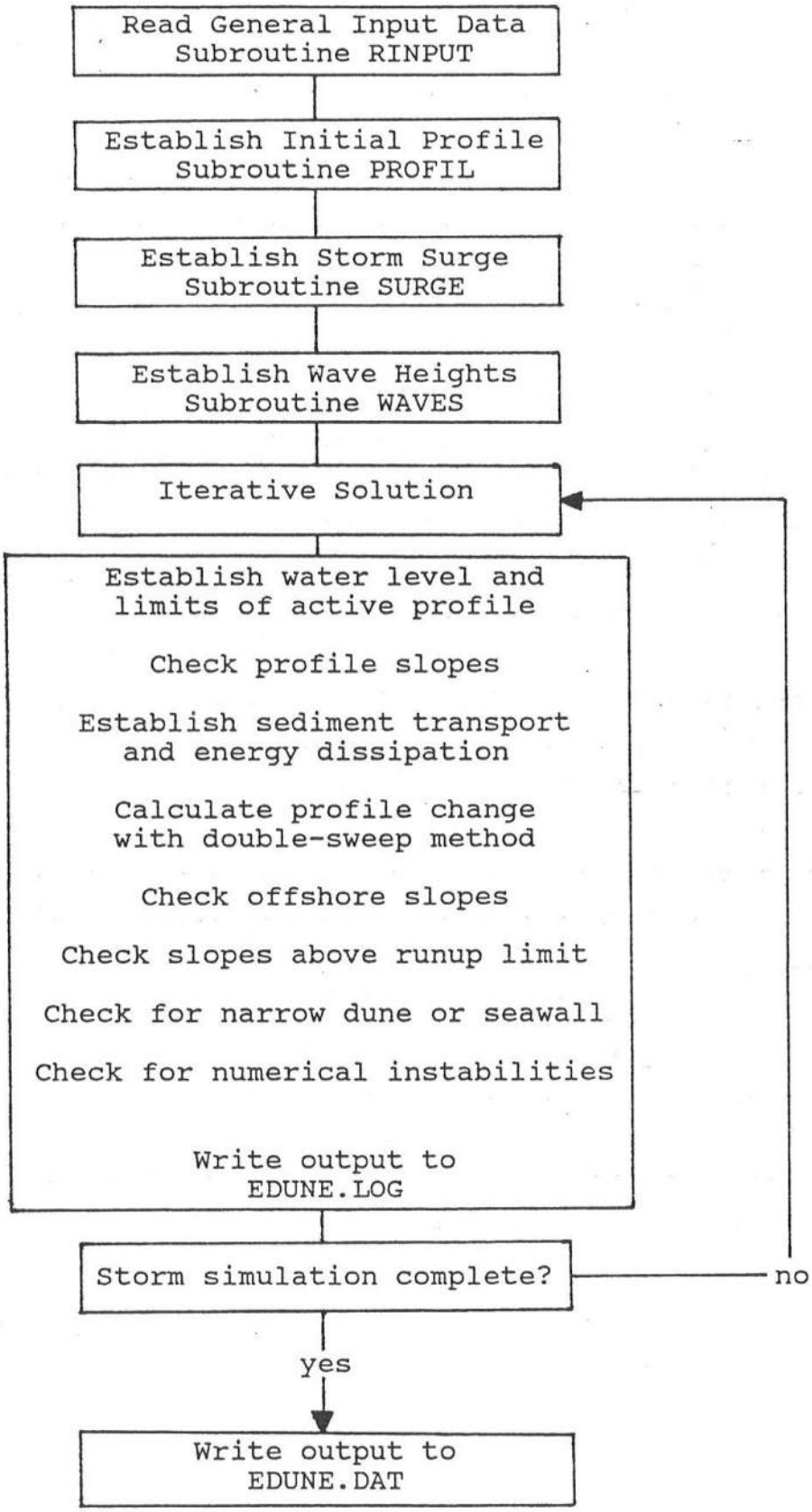


Figure 7. Flow chart for EDUNE model.

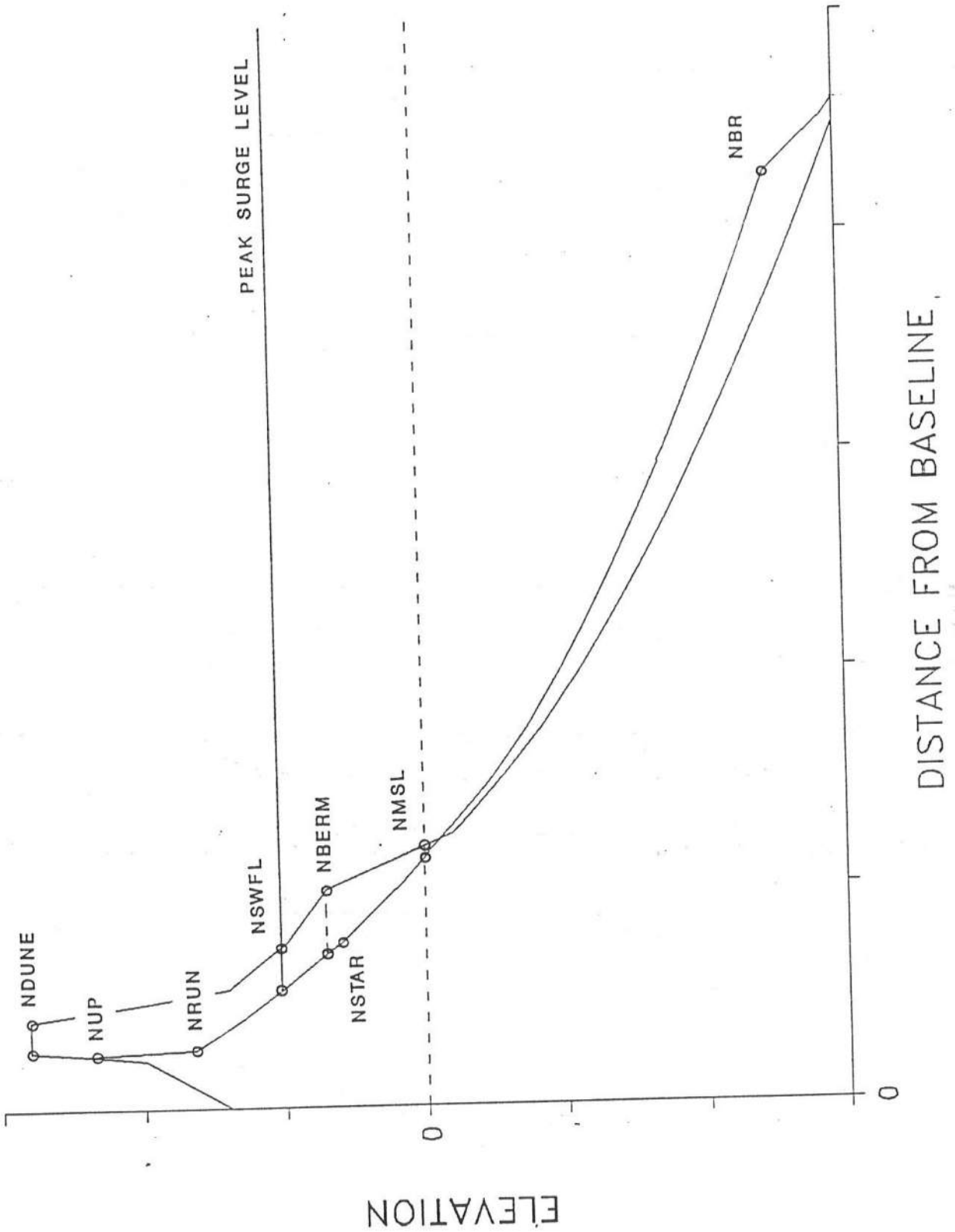


Figure 8. Definition sketch for main profile indices.

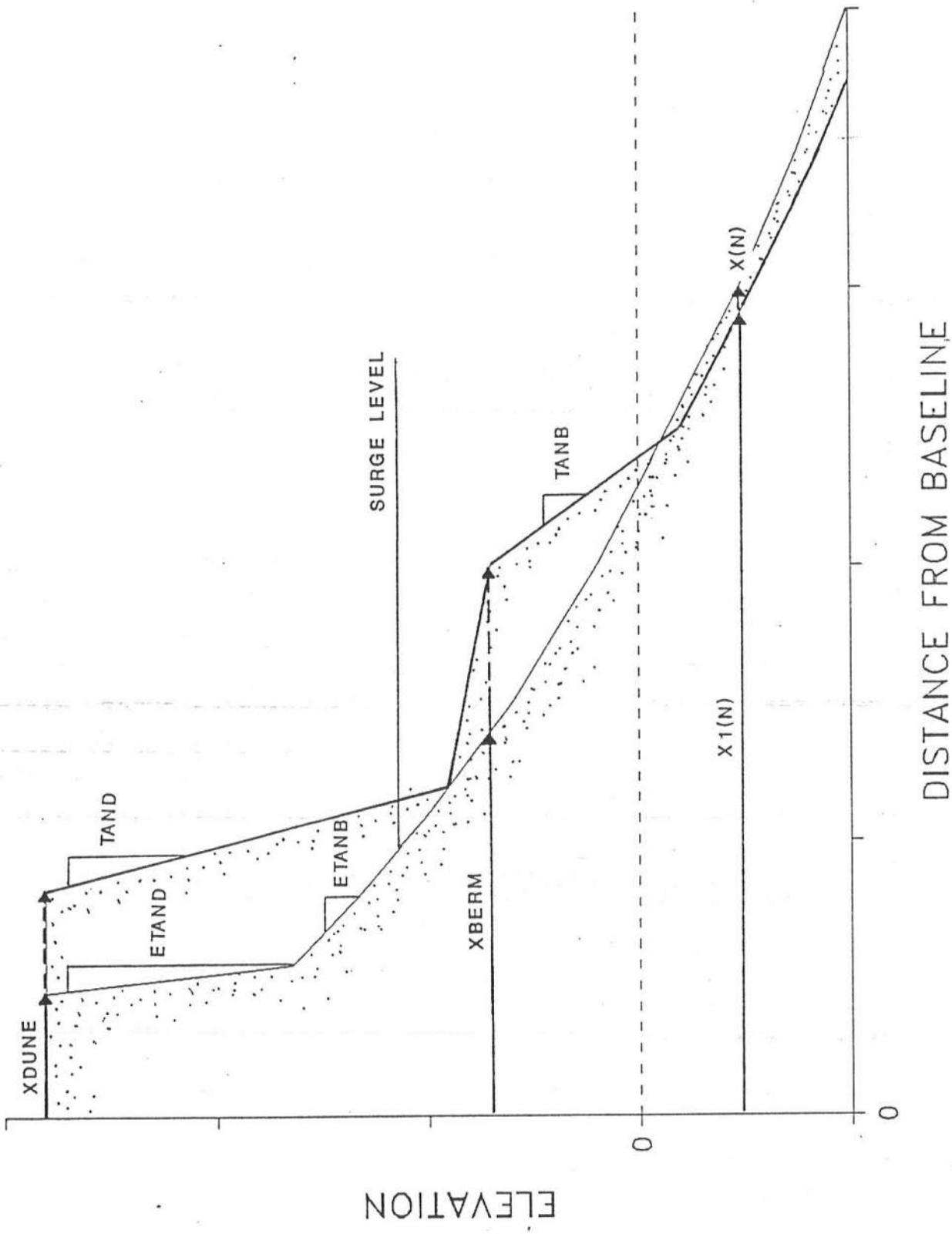


Figure 10. Definition sketch for main profile parameters based on horizontal contour locations.

DXBERM Change in position of HBERM contour from initial profile X1(NBERM) to current profile X(NBERM) in feet.

DXDUNE Change in position of HDUNE contour from initial profile X1(NDUNE) to current profile X(NDUNE) in feet.

DXMSL Change in position of mean sea level contour from initial profile X1(NMSL) to current profile X(NMSL) in feet.

DXSWFL Change in position of contour at peak still water flood level from initial profile X1(NSWFL) to current profile X(NSWFL) in feet.

E(N)
F(N) Coefficients used in recursion formula as part of double-sweep solution. Used to calculate DELX(N-1)

ETA(LT) Time-series of storm surge water levels generated in subroutine SURGE, defined as positive above mean sea level in units of feet.

ETANB Final equilibrium slope of the beach face below the runup limit. Usually obtained from local data or may be set equal to TANB.

ETAND Final equilibrium slope of the dune scarp above runup limit. May be assumed to be 1.000 based on a 1:1 slope as used in Dutch dune erosion model of Vellinga (1983a), or may be established at steeper slope based on local conditions.

H(N) Elevation of N-th contour relative to current still water level at any time step in feet. Positive when below still water level.

KD — Coefficient for calculating wave energy dissipation per unit volume. Equal to $1/4 \rho\, g^{3/2} \kappa^2$ or 55.24 $lb/ft^{5/2}$-sec.

KQ — Sediment transport rate coefficient relating sediment flux to excess energy dissipation per unit volume. Recommended value is 0.0045 ft^4/lb; however, user should re-calibrate model using local data when possible.

LO — Index for time step at which detailed output results are to be written to EDUNE.DAT

LT — Time index in main program loop, starting at LT = 1, ending at LT = LTMAX

N — Index to identify each elevation contour.

NBERM — Index of HBERM contour defining transition from backshore to beach face on initial profile. Remains fixed during simulation.

NBR — Index of breakpoint contour. Established at each time step based on breaking depth.

NDUNE — Index of HDUNE contour defining dune crest. Remains fixed during simulation.

NMAX — Index of seawardmost (deepest) elevation contour. Remains fixed during simulation.

NMSL — Index of initial mean sea level contour. Remains fixed during simulation.

NRUN — Index of contour at limit of maximum wave uprush. Established at each time step.

SELEV Peak storm surge elevation or peak still water flood level. Defined as positive above msl in units of feet.

SUMVOL(N) Cumulative or integrated volume change across profile from initial profile X1(N) to profile at end of each time step, X(N). Starts at zero offshore at NMAX, increases positively for areas of deposition, then decreases in areas of erosion. SUMVOL(1) must be zero to satisfy conservation of sand.

TANB Initial beach face slope between HBERM contour and beginning of concave $Ax^{2/3}$ profile shape. Entered as a decimal number giving vertical rise for a 1 foot horizontal distance. Example: A beach slope of 1 foot vertical to 10 feet horizontal gives TANB = 0.100.

TAND Initial dune slope between dune crest and dune toe. Entered as a decimal number giving vertical rise for a 1 foot horizontal distance. Example: A dune slope of 1 foot vertical to 4 feet horizontal gives TAND = 0.250.

TANOFF Maximum allowable slope seaward of the breakpoint. Assumed to be 0.080 based on a 1:12.5 slope in accordance with observations of Vellinga (1983a).

TANREP Maximum allowable slope in active profile, based on approximate limiting angle for wet sand under wave action. Assumed to be 0.176 based on a 10^{o} slope.

TIME Current real time at end of time step, in hours.

TOUT(LO) Time at which output results are written to EDUNE.DAT

VMAX Maximum volume eroded during storm, between initial profile and profile at time of maximum erosion above mean sea level contour. In units of ft^3/ft.

entered as non-zero value, simplified schematic beach profile is generated.

XDUNE Initial position of dune crest contour HDUNE measured seaward of baseline, in feet.

XIN(I) Initial position of specified elevation contours contained in PROFIL.INP data file. Defined as positive distance in feet seaward of baseline.

XMIN(N) Landward limit of erosion for any elevation contour in feet relative to baseline. For narrow dunes, XMIN defines the landward dune face. For seawalled profiles, XMIN defines the location of the impermeable seawall.

XMININ(I) Initial landward limit of specified elevation contours, used to define landward face of narrow dune or location of impermeable seawall. Defined as positive distance in feet seaward of baseline.

XOFF Initial position of HOFF contour seaward of baseline, in feet.

XOUT(LO,N) Position of elevation contours written to data file EDUNE.DAT at various times during the storm, including at time of maximum erosion.

XTEMP(N) Temporary array used in determination of sediment transport distribution on the beach face based on potential erosion prism and used in determination of dune scarp location.

XWALL Position of vertical seawall from baseline, in feet. Used for simplified definition of seawall location.

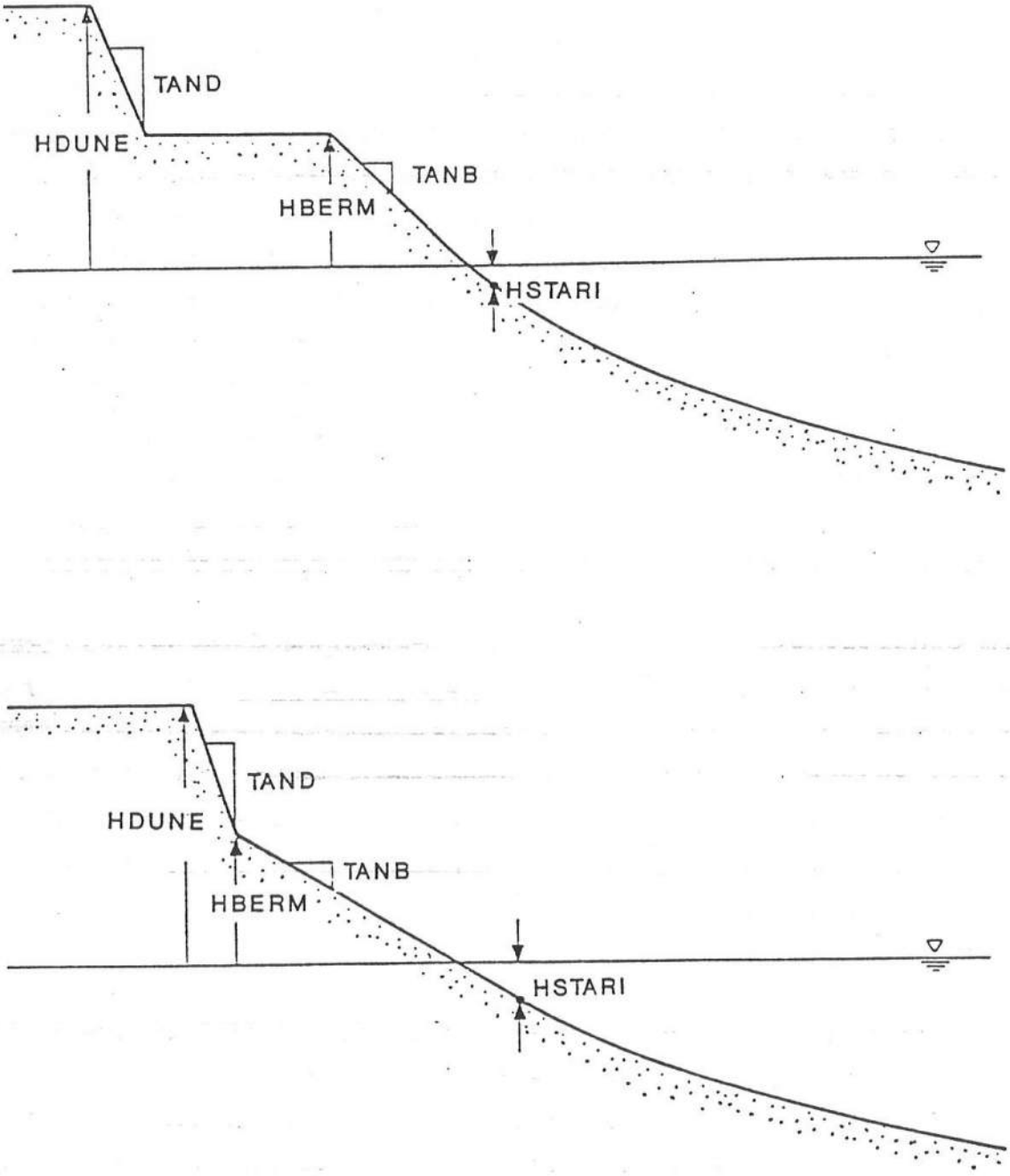


Figure 11. Idealized profile forms defined using simplified input option.

Revision 1/8/89

Cases with a wide backshore or berm, as at the top of Figure 11, are the most troublesome to simulate in the EDUNE model. As a result, special provisions have been added to model such cases more realistically. The first provision modifies the sediment transport rate if a wide berm is encountered. This routine compares slopes at successive elevation contours and, if the slope above the berm is less than one-half the slope below the berm, the sediment transport rate is set equal to zero for the contour above the berm. This allows rapid erosion below the berm and allows material eroded from the dune to be deposited above the berm, resulting in a rapid narrowing of the berm. The second provision for these wide-berm cases simply includes another check on beach slopes to ensure that, in the procedure described above, the contour above the berm does not advance seaward of the berm contour.

The user is cautioned that results for wide berm conditions, where the berm is more then about 50 to 100 feet wide, may not appear realistic due to the approximations necessary in the numerical model. In some cases, the wave runup limit may extend above the berm while the surge level is below the berm. This will result in some erosion of the dune before the berm is completely eroded. In other cases, the storm surge may rise above the berm so rapidly that the berm does not have time to fully eroded and is left "stranded" below the peak surge level. In either case, the actual mechanics of wave uprush over the wide berm should limit erosion of the dune, since substantial wave energy dissipation would occur across the berm. If results do not appear realistic, it is suggested that the input profile or storm surge characteristics be altered slightly, or that the equilibrium beach slope ETANB be varied.

B. Detailed Input

The allowable initial profile forms under the detailed input options are, with some exceptions, not limited and may closely represent the actual initial profile form. Under this option, the user must input consecutive data points to define the shape of the initial profile. The only restriction is that any elevation contour can have, at most, two X coordinates: one representing the seaward intercept, denoted XIN(I), and the other representing the landward intercept, denoted XMININ(I). Examples of this type of input are shown in Figures 13 and 14.

Starting with the dune crest, input must include the elevation of the contour, the seaward intercept of the contour, and the landward intercept of the contour. The format for this data in the PROFIL.INP data file is:

HIN(1)	XIN(1)	XMININ(1)
HIN(2)	XIN(2)	XMININ(2)
HIN(3)	XIN(3)	XMININ(3)
⋮	⋮	⋮
HIN(I)	XIN(I)	XMININ(I)

The last data point entered will be used as the transition depth (like HOFF and XOFF) beyond which the concave $Ax^{2/3}$ equilibrium profile will be generated. This point should define an elevation below mean sea level and may extend offshore as far as desired.

All elevations should again be entered to the nearest foot, or half-foot if a half-foot contour spacing is used.

For cases with a wide dune, this input option allows the user to make maximum use of field survey data to define multiple slopes on the beach and dune face. The only apparent restrictions are that elevations, HIN(I), must follow consecutively from the dune crest to offshore and that horizontal distances, XIN(I), must increase from the dune crest to offshore. In these cases, all values of XMININ(I) should be entered as 0.0.

For cases where a narrow dune exists, this input option allows both the seaward and landward dune geometries to be defined, as shown in Figure 13. The only special requirement is again that any contour defined by HIN(I), must be accompanied by values for both XIN(I) and XMININ(I). For cases with an impermeable seawall, as depicted in Figure 14, the location of the seawall is simply specified by the XMIN(I) location of each contour. Note that the seawall may be vertical or sloping.

Storm Surge Input Options

The storm surge hydrograph serves as the primary forcing mechanism in the erosion simulation. The time series for storm surge levels may be input in two ways depending on the desired level of accuracy in the simulation. The first and simplest input consists of specifying the peak surge level and duration and allowing the program to generate an approximate storm surge hydrograph with a sine-squared variation over time. The second and more detailed input consists of reading either measured or predicted storm surge from the SURGE.INP data file. These two options are elaborated below:

B. Detailed Input

The more detailed input of a storm surge time-series consists of reading water levels at uniform time increments from the input data file SURGE.INP. This option is invoked when SDUR is set equal to zero. The SURGE.INP file must contain the time increment for the digitized data, DELT, in the first line, in units of hours. Subsequent lines then contain the storm surge level, in units of feet above mean sea level, as the array WL(I). The format used in SURGE.INP is depicted in Figure 16 and is input in the form:

```
DELT
     WL(1)
     WL(2)
     WL(3)
       .
       .
     WL(I)
```

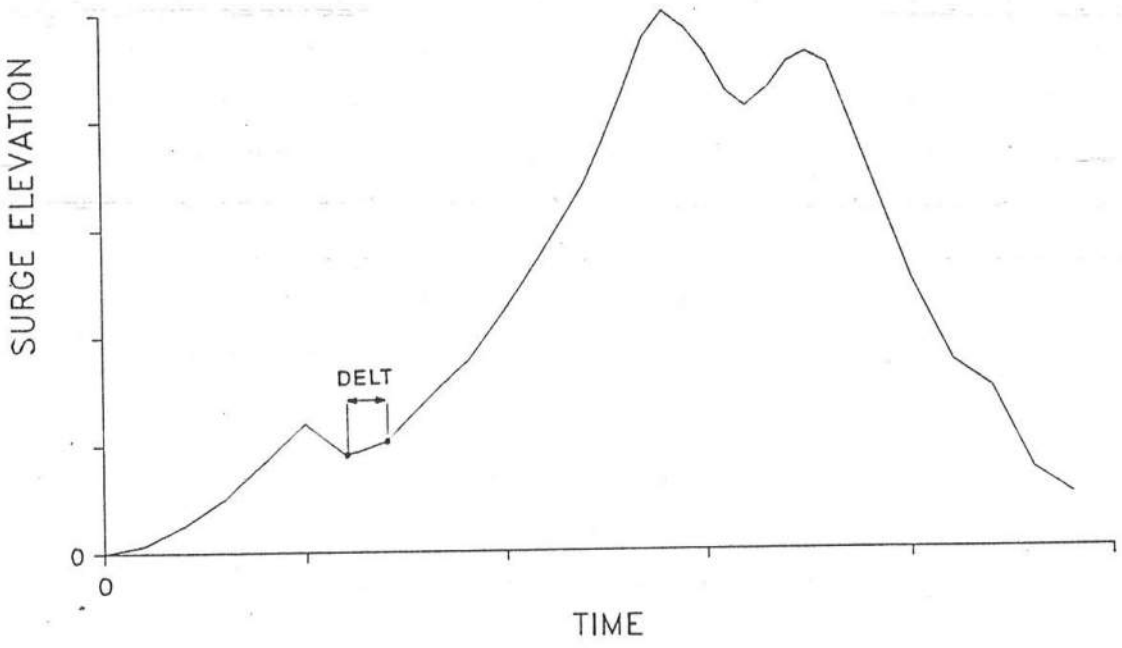


Figure 16. Digitized storm surge hydrograph in SURGE.INP

The breaking wave height therefore serves more as a boundary condition limiting the number of active elevation contours than as a driving force causing profile erosion. This is one of the major assumptions in the EBEACH and EDUNE models. As shown by Kriebel (1986), the numerical model is not overly sensitive to variations in the wave height description.

As with water level input, two options are included for input of breaking wave heights. The first and simplest method uses a constant breaking wave height, WAVEHT, throughout the duration of the storm. The second and more detailed option allows the user to input a measured or predicted time-series of breaking wave heights from the data file WAVES.INP.

A. Simplified Input

The simplest wave height input consists of the single parameter, WAVEHT, which defines a constant breaking wave height over the duration of the storm. This input is designed not only for its simplicity but also in recognition that in most cases, a measured or predicted time-series of wave heights is not available. In addition, all previous calibration studies have used a constant wave height, such that the sediment transport rate parameter K has implicitly been based on conditions of a constant wave height.

B. Detailed Input

More detailed input of breaking wave heights is available through use of the WAVES.INP data file. In this case, the file must contain the time increment for the digitized data, DELT, on the first line; this value should be the same as that used in the storm surge time series in SURGE.INP data file. Subsequent lines in the WAVES file should then contain root-mean-square breaking wave heights in units of feet, as the array WH(I). The format for WAVES.INP is:

All wave heights should represent a breaking condition in which the breaker height equals 0.78 times the local water depth. This breaking depth criterion is then similar to that used in the Dutch erosion model of Vellinga (1983a), where the offshore limit of the surf zone is taken at a depth equal to 0.76 times the significant wave height. In the present model, the breakpoint is taken at a depth of 1.28 times the root mean square wave height, or about 0.90 times the significant wave height.

Input Data File INPUT.DAT

All program input is controlled by the master data file INPUT.DAT and this file is required for all program executions. In general, the INPUT.DAT file allows the user a range of input options for the profile form, the storm surge hydrograph, the wave height time series, and other parameters, as described in previous sections. An example of the data contained in the INPUT.DAT file, and the data file format, is presented below:

```
     A
    DH
 HDUNE      XDUNE       TAND      ETAND
 HBERM      XBERM       TANB      ETANB
  HOFF       XOFF      XWALL
 SELEV      SDUR         SDT
WAVEHT
 RUNUP
```

All data contained in the INPUT.DAT file are read by the subroutine RINPUT and are passed to the main program and other subroutines by COMMON statements. To facilitate user input, variables contained in the INPUT.DAT file, and other input data files, are read with free format READ statements so that the user is not required to enter the input data using any particular format. The position of the data in the INPUT.DAT file must be maintained, however, and numerical values are required for all variables.

A second reason for the scatter in the reported A values is the sensitivity of equilibrium profile forms to the prevailing wave climate. Preliminary results of Dean (1988) indicate that the A parameter may vary according to the fall time parameter, H/wT, where H is the incident wave height, T is the incident wave period, and w is the sediment fall velocity.

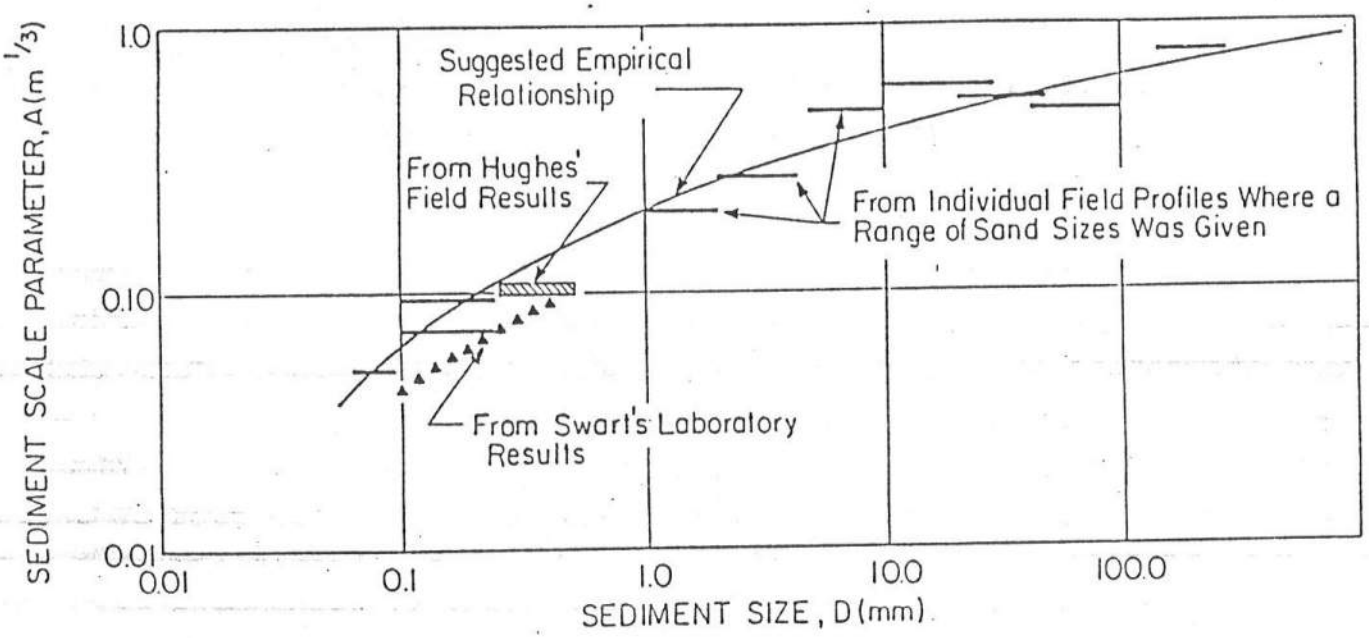


Figure 18. Suggested empirical relationship of A parameter on mean sediment grain size, after Moore (1982).

For more detailed model application, it is recommended that the user obtain the appropriate value of A based on a least-squares fit of the $Ax^{2/3}$ profile form to beach profile survey data. This procedure is outlined by Dean (1977), but the user should exercise caution in the curve-fitting procedure. Many previous results, including those given by Dean (1977), Hughes (1978), and Moore (1982), are based on a curve-fit from the shoreline out to water depths of 30 feet or more. In the author's opinion, the proper procedure is to

B. Contour spacing DH

The spacing of elevation contours may be selected by the user as either 0.5 or 1.0 feet, depending on the spatial resolution desired. Use of a contour spacing of 1.0 feet is more efficient and is recommended for most applications. If a spacing of 0.5 feet is chosen, the initial profile may be digitized with a resolution of 0.5 feet as well.

C. Dune geometry HDUNE, XDUNE, TAND, ETAND

These four parameters define the initial location of the dune crest as well as the pre-storm dune slope and the post-storm equilibrium dune slope above the runup limit.

The value of HDUNE must be included for all program runs and should be entered in feet with a **negative** sign indicating an elevation above mean sea level.

The value of XDUNE must be included only for simplified input of the initial profile. It may be set equal to zero for detailed input when the PROFIL.INP data file is used.

The value of TAND is likewise only required for simplified input and may set equal to zero for detailed input based on the PROFIL.INP data file.

The value of ETAND is always required since it is used to establish the equilibrium post-storm profile slope above the runup limit. Values of ETAND should be based on local field data and experience. This slope may be taken as 1:1 (ETAND = 1.0) to conform to the latest Federal Emergency Management Agency guidelines, based on observations of Vellinga (1983a). This slope may also be steeper, say 2:1 to 4:1; however, slopes steeper than 4:1 (ETAND=4.0) have not been tested in the model.

be milder than the existing pre-storm profile, since the pre-storm profile has typically been steepened by constructive or accretive wave conditions. If no data is available, ETANB may be set equal to TANB. This is somewhat equivalent to the simplified method used in the EBEACH model where the beach face is assumed to erode uniformly with no change in slope.

E. Control Points HOFF, XOFF, and XWALL

The coordinate point HOFF and XOFF is used only for simplified input conditions and, even then, may often be set equal to zero.

For simplified profile input, the control point defined by HOFF and XOFF may be used to specify an elevation below mean sea level at which the linear beach slope meets the concave equilibrium slope. The purpose of this parameter is to override the transition depth HSTARI and to enable the user to easily input alternate beach fill cross-sections which have may contain different berm widths or different in-place design beach slopes, as depicted in Figure 12.

For most erosion simulations with the simplified profile input, the depth HOFF is not required since the transition depth HSTARI will be used. For these cases HOFF and XOFF should be set equal to zero. Likewise, for detailed profile input from the PROFIL.INP file, HOFF and XOFF are not used and should be set equal to zero.

The control parameter XWALL is used to establish the location of a vertical seawall. This may be used with the simplified profile input option to establish the locations, XMIN(N), for all elevation contours. This option is not used with the detailed profile input.

G. Wave Height WAVEHT

The input parameter WAVEHT also serves as a primary **control parameter** governing the way in which the wave height time series is generated.

If WAVEHT is non-zero, the array WHBR(LT) is generated by simply assuming a constant wave height at each time step, equal to WAVEHT.

If WAVEHT is equal to zero, the program opens an auxiliary data file WAVES.INP and reads a digitized wave height time-series. The first line of the WAVES.INP file is read to determine the time step, DELT; subsequent lines should contain the root-mean-square wave height in units of feet, in the array WH(I). The user is cautioned that the wave height time-series must be digitized at the same rate (using the same value of DELT) as the storm surge time series in SURGE.INP.

H. Dune Scarp Location RUNUP

The parameter RUNUP is used to control the location of the dune scarp above the peak still water flood level and should be entered in units of feet as a positive quantity.

RUNUP is used as a constant value throughout the erosion simulation; therefore, it does not necessarily simulate a realistic wave runup limit at each time step. Instead, it is used to enhance the realism of post-storm profiles by allowing a dune scarp to form at an elevation above the still water flood level. The equilibrium dune slope ETAND is then established above NRUN while the profile will evolve toward the equilibrium beach slope ETANB below NRUN.

DESCRIPTION OF PROGRAM ALGORITHMS

As depicted in the flow chart in Figure 7, the EDUNE program consists of four subroutines which are called at the beginning of each program run to establish the initial profile, the storm surge hydrograph, and the wave height time-series. The main program loop then iterates over time and all erosion calculations are performed within the main program loop. In this section, specific algorithms used in the main program loop are described in order to illustrate the assumptions and approximations used in the erosion simulation.

Limits on the Active Profile

The main program loop, identified by the DO loop with the time counter LT, begins by establishing the real time in hours, TIME, corresponding to the end of the current time step of length DT, which has been redefined in units of seconds.

Subsequent nested DO loops are used to establish the forcing conditions and the physical limits of the active profile for the time step. This includes first establishing the contour elevations, H(N), relative to the storm surge level, ETA(LT), that exists for the time step. The offshore limit of the active profile is established at the breaking depth, HBR, which is taken as 1.28 times the breaking wave height, WHBR(LT). The onshore limit of the active profile is then established at the runup limit above the storm surge level, based on RUNUP.

With these depths, several indices for identifying limits of the active profile are then established. First, the seawardmost contour in the active profile, NBR, is located at the breakpoint. Next, the landwardmost contour associated with the runup limit above the still water flood level is determined as NRUN. This location can be modified if a previous iteration has resulted in

The critical limit between any two contours is based on the slope TANREP, which is defined as an approximate maximum angle for wet sand on the beach face under the destabilizing influence of wave action. As discussed by Larson (1988), the limiting slope is uncertain and probably varies with wave and sediment conditions. However, Larson's observations of large-scale wave tank experiments indicate a maximum slope of 6 to 8 degrees for both 0.22mm and 0.47mm mean grain sizes under erosive conditions. Data from the Shore Protection Manual (1984) also indicates that maximum stable beach face slopes are, at most, 10 to 11 degrees even for sand up to 0.8mm and under constructive wave conditions. Based on these observations, a limiting slope of 10^{o} is assumed and TANREP is taken as 0.176. It is assumed that although steeper slopes may exist for a short time on the beach face, wave uprush and downrush would effectively achieve the 10^{o} slope over any time step used in the numerical simulation.

Determination of Sediment Transport Rates

Once the active profile is defined and adjusted to realistic slopes, the wave energy dissipation per unit volume and the sediment transport rates must be determined across the active profile. The earlier EBEACH model determined these quantities only seaward of the depth HSTAR in what was termed a "dynamic" solution region, and then applied a linear extension of the sediment transport distribution from HSTAR to either the top of the berm or the top of the dune in what was termed a "geometric" solution region. The EDUNE model attains more realism in the simulation, first by establishing realistic runup limits, and then by defining more realistic sediment transport rates across the entire active profile from NRUN to NBR.

Between NSTAR and the runup limit NRUN, the energy dissipation levels and the sediment transport rates are defined according to the procedure outlined by Kriebel and Dean (1985b). This approach, termed the potential erosion prism method, seeks to define an approximate distribution of the sediment flux that will allow the beach face to evolve toward its equilibrium slope. In general, it is assumed that the sediment transport rate may be extrapolated from a known value at the contour NSTAR, Q_* or QS(NSTAR), to a value of zero at the runup limit. This upper limit is based on the assumption that no sand is initially activated above the maximum limit of wave uprush.

In the original EBEACH model, the sediment transport distribution was approximated by a linear extension from Q_* to zero at the upper limit of the profile, at either the top of the berm or dune, as depicted in Figure 21. This linear extension resulted in constant spatial gradients in sediment flux, dQs/dh, which in turn gave uniform retreat of the beach or dune face, dx/dt, based on continuity. As a result, the initial beach and dune slopes were maintained above the contour NSTAR, thus preventing realistic slope variations as the profile eroded.

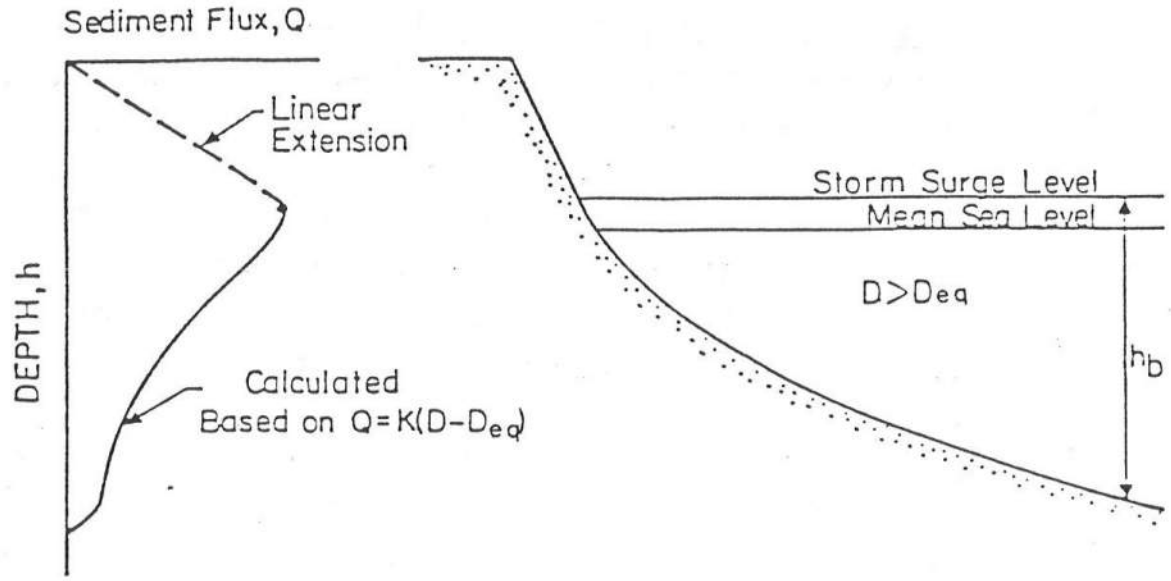


Figure 21. Method of estimating sediment transport distribution used in EBEACH model.

$$Q_n = Q_* \frac{V_{np}}{V_p}$$

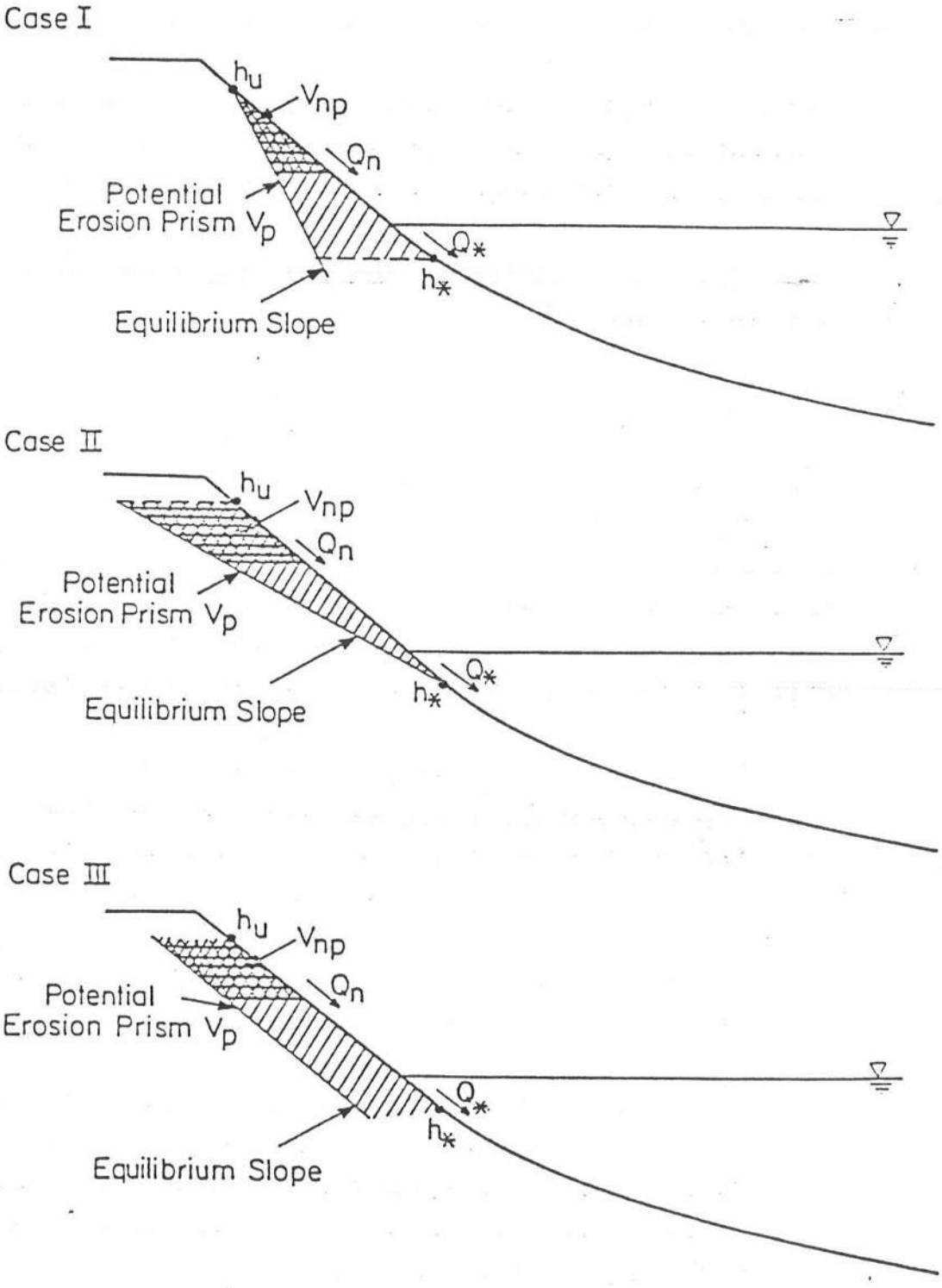


Figure 22. New method of estimating sediment transport distribution on beach face.

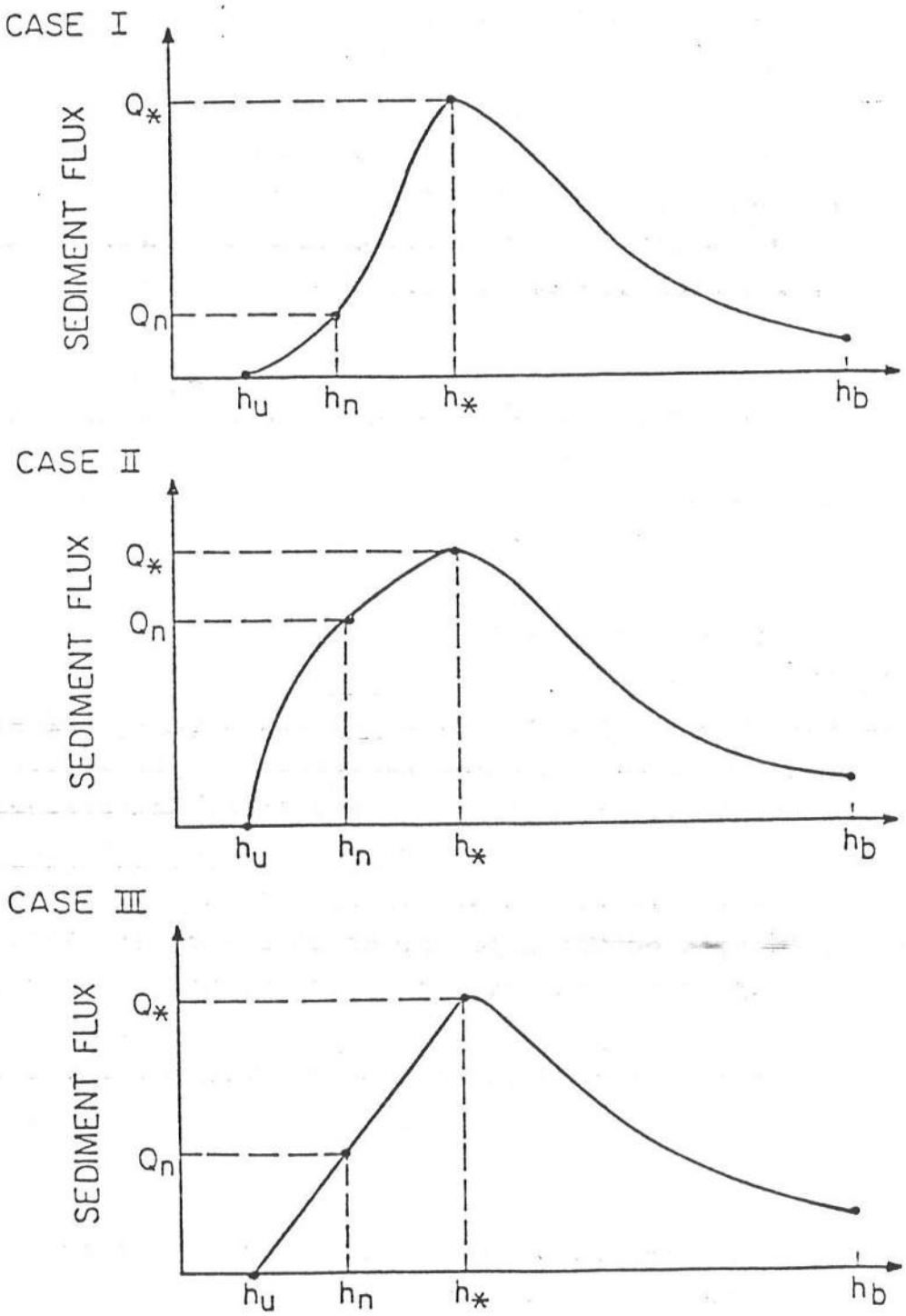


Figure 23. Examples of estimated sediment transport distributions based on potential erosion prism.

dissipation and the sediment flux into and out of elevation contours N-1, N, and N+1.

Second, a recursion formula is introduced which relates two adjacent contours as

$$DELX(N) = E(N+1)*DELX(N+1) + F(N+1)$$

and which contains two new coefficients in arrays E(N) and F(N). These are defined at contour N+1 in terms of AN, BN, CN, and ZN at the preceding elevation contour N. The coefficients E(N+1) and F(N+1) may therefore be determined in an offshore sweep across the profile, starting with a boundary condition that E(1) = 0 and that F(1) = ZN at the uppermost contour.

Third, an offshore boundary condition is applied at contour NMAX which specifies no change in the offshore contour position as DELX(NMAX) = 0. From this starting point, the recursion formula is applied in an onshore sweep to determine the change in position of each contour, DELX(N), from NMAX to NUP. Since QS and DISS are equal to zero seaward of NBR and landward of NRUN, the changes in position of these contours is identically zero.

Adjustments to Computed Profile

The completion of the double sweep solution guarantees that continuity is satisfied across the profile, such that the volume eroded from the beach face equals the volume deposited offshore. However, discontinuities may exist in the predicted profile at both the offshore and onshore limits of the active profile, specifically at contours NBR and NRUN. These possible discontinuities may then require adjustments to the computed erosion profile at each time step.

The algorithm used in the EDUNE model is based on a discrete approximation of the dune undercutting and slumping process. At each time step, the routine first checks the spacing of consecutive contours landward of NRUN. If any contour spacing is less than that defined by DH/ETAND, or if any contour has eroded landward of the next higher (onshore) contour, then the dune slope between these contours is established at the equilibrium slope ETAND. This is achieved through erosion of the landward contour and re-distribution of this eroded sand volume across the active profile.

Numerous algorithms and procedures have been evaluated for the purpose of facilitating this redistribution of sand. The most intuitive approach involved redistribution of this sand on the beach face below the dune scarp at a wet angle of repose. Numerical tests with this scheme resulted in overly steep post-storm beach slopes; however, and sand was not moved far enough offshore over each time step. Field observations of eroding dunes also show that, while dune sand initially slumps to the base of the erosion scarp, this sand is rapidly reworked by the swash and the beach face is quickly flattened up to the base of the scarp.

The routine employed in the EDUNE model is a modification of the process described above that facilitates a more rapid offshore re-distribution of sand over each time step. This routine first uses all or a portion of this eroded dune sand to "fill in" the beach face and to build the beach face to a uniform slope. Any remaining sand volume is re-distributed as a nonuniform layer across the active profile, with most of the sand remaining on the beach face but with some sand being deposited out to the breakpoint. This routine, depicted in Figure 24, is based on the assumption that any sand derived from the slumping of the dune face will remain primarily on the beach face, but that sand will move farther offshore as the beach slope steepens.

and all eroded sand is assumed to move offshore to satisfy continuity. It is then assumed that any sand volume that would have been supplied by the continued erosion of an elevation contour would, instead, be supplied by adjacent contours lower on the profile. To achieve this, the upper limit of the active profile, NUP, is then redefined as the next offshore contour that has not eroded completely. This results in a lowering and flattening of the profile once "dune blowout" is initiated.

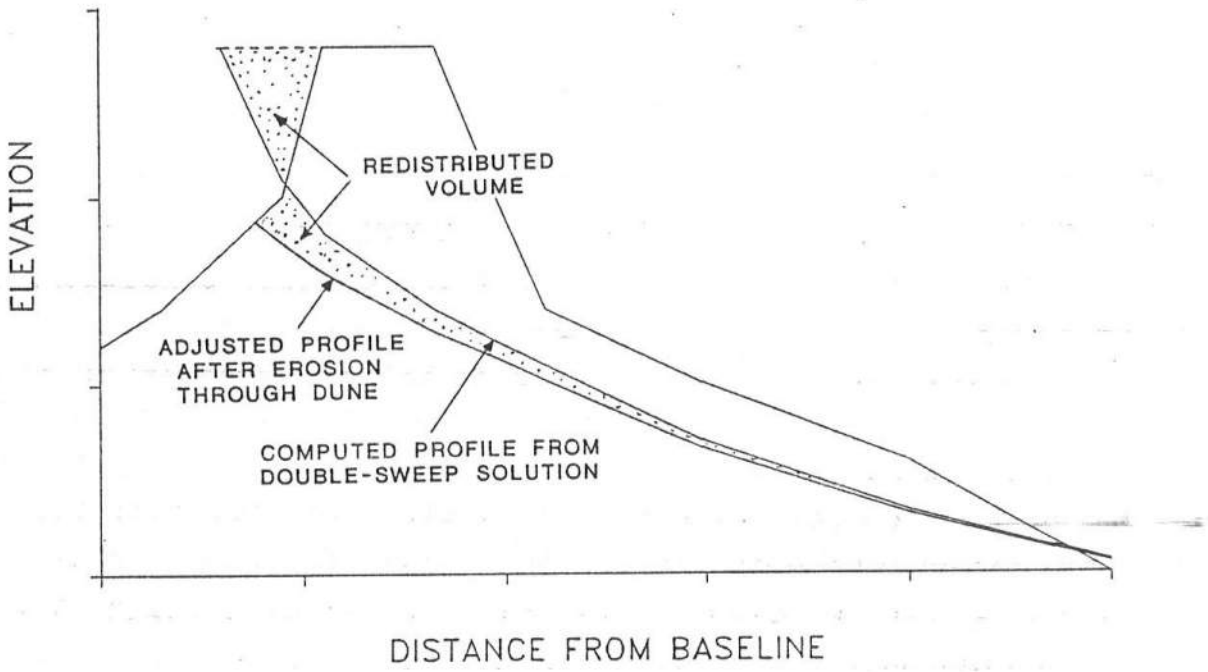


Figure 25. Example of erosion through a narrow dune.

For profiles backed by impermeable seawalls, the same algorithm may be used to limit erosion of any individual elevation contour. In this case, retreat of a contour is limited by the physical presence of the seawall at location XMIN(N) such that no sand can be supplied from areas landward of the wall. Once a contour has eroded to the wall location, any additional sand that would have eroded if the wall were not present is assumed to be supplied by adjacent contours lower on the profile.

DESCRIPTION OF PROGRAM OUTPUT

In general, three types of output are generated by the EDUNE model. At each time step, results are written directly to the screen to allow interactive monitoring of the program operations. Similar but more detailed results are also written to the data file EDUNE.LOG for hard-copy printing or plotting. Should program errors be detected that indicate numerical instabilities, these messages are also written to the screen. Finally, at the end of specified time-steps, more detailed results are written to the EDUNE.DAT file in order to record the detailed profile form at various times throughout the simulation.

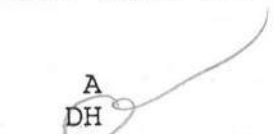
Interactive Output to Terminal

At the beginning of a program run, all information contained in the INPUT.DAT data file is printed on the screen in order to verify the initial conditions for the simulation. Following this, results at each time step are printed on the screen to enable the user to monitor program calculations.

The data printed to the screen are meant to be a summary of the overall results and include: (1) the current time, TIME, in hours, (2) the storm surge level, ETA(LT), in feet above mean sea level, (3) the wave height, WHBR(LT), in feet, (4) the total volume eroded above mean sea level, VMAX, also in ft^3/ft, and (5) the volume eroded above the peak surge level, VSWFL, in ft^3/ft. The user should monitor these results to check that the expected storm surge and wave conditions are being simulated and to ensure that erosion progresses in a logical fashion.

Output to EDUNE.LOG

At the beginning of the simulation, all information contained in the INPUT.DAT file is also written to the output file EDUNE.LOG. This data is not labelled but is in the format:



A			
DH			
HDUNE	XDUNE	TAND	ETAND
HBERM	XBERM	TANB	ETANB
HOFF	XOFF	XWALL	
SELEV	SDUR	SDT	
WAVEHT			
RUNUP			

At the end of each time step, the following data are also written on successive lines in the EDUNE.LOG file:

TIME ETA(LT) WHBR(LT) VMAX VSWFL DXDUNE DXSWFL DXBERM DXMSL

The first five parameters are identical to those written to the screen and provide a summary of the storm conditions and the volume changes, both above the still water flood level and across the eroded portion of the profile. The last four parameters are used to define the overall recession of several reference contours: (1) DXDUNE, for the contour identified as HDUNE, (2) DXSWFL, for the contour at the peak still water flood level, (3) DXBERM, for the contour identified as HBERM, and (4) DXMSL, for the mean sea level contour. In each case, the reported value is based on the difference between the computed profile position, X(N), and the initial profile position, X1(N). These are given in units of feet, with negative numbers indicating erosion and positive numbers indicating accretion. Note that in many cases, the mean sea level contour will accrete during the storm.

contour has eroded to XMIN(N), the value of XMIN(N) is displayed as the current contour location X(N).

The output times are specified to include the time at the peak storm surge level and two times before and after the peak surge level. If the simple sine-squared surge is used, the output corresponds to times at which the surge is at one-half and three-quarters of the peak surge level.

During an erosion simulation, as the storm surge elevations fall, erosion slows and eventually the profile begins to rebuild. In the numerical solution, onshore transport is initiated if the energy dissipation levels fall below the equilibrium energy dissipation DISSE. Under these circumstances, profile recovery can be observed in the numerical results as sand will be deposited on the eroded beach face. It should be emphasized, however, that no effort has been made to simulate the recovery process or to calibrate the model under these conditions. Therefore, model results should not be used except to define conditions up to the time of maximum erosion.

Plotting Results in EDUNE.DAT

The data contained in the EDUNE.DAT file may be viewed using the executable plotting program PLTDAT.EXE, contained with the EDUNE model. This plotting program contains three options that may be selected by the user, including: (1) a plot of the initial profile alone, (2) a plot of all profiles on the same graph in order to show the progression of erosion over time, and (3) a plot of the initial and final profiles, to show the maximum extent of erosion predicted by the model. In each case, the user may select to plot the entire profile, out to a depth of 30 feet, or to plot only the onshore portion of the profile above the mean sea level contour.

EXAMPLE CASES

Hurricane Eloise - Profile R-41

A detailed simulation of erosion of Profile R-41 from the Hurricane Eloise data set is presented as an example case. The input data for the simulation is contained in the following data files: (1) R41IN.DAT, which contains data for the RINPUT.DAT file, (2) R41PR.DAT, which contains data for the PROFIL.INP file, and (3) R41SU.DAT, which contains data for the SURGE.INP file. Output from the simulation is contained in two files: (1) R41.LOG, which contains the EDUNE.LOG file, and (2) R41.DAT, which contains the EDUNE.DAt output file.

To facilitate running this example case, a batch file, R41.BAT, is also included which performs the following DOS commands in order to copy the R41 data files into the appropriate files required by EDUNE:

```
COPY R41IN.DAT INPUT.DAT
COPY R41PR.DAT PROFIL.INP
COPY R41SU.DAT SURGE.INP
```

Once these files are copied, the EDUNE program may be executed.

RINPUT.DAT

Data are presented in the format:

```
      A
     DH
  HDUNE      XDUNE       TAND      ETAND
  HBERM      XBERM       TANB      ETANB
   HOFF       XOFF      XWALL
  SELEV       SDUR        SDT
 WAVEHT
  RUNUP
```

Actual values read from the SURGE.INP file are:

```
.50
     .00
     .38
     .39
     .40
     .41
     .43
     .44
     .48
     .51
     .55
     .60
     .66
    1.05
    1.68
    2.65
    4.06
    5.89
    7.80
    9.04
    8.99
    7.90
    6.67
    5.17
    4.10
    3.28
    1.62
    1.08
     .54
     .00
```

EDUNE.LOG

Output in the EDUNE.LOG file should be identical to that contained in the file R41.LOG. First the header information contained in the INPUT.DAT file is listed, then simulation results are listed in the format:

```
TIME  ETA(LT) WHBR(LT) VMAX VSWFL DXDUNE DXSWFL DXBERM DXMSL
```

The EDUNE.LOG file should contain the following data:

```
 1.840000E-001
-26.0000000    100.0000000       .0000000      2.0000000
 -5.0000000       .0000000       .0000000      6.250000E-002
   .0000000       .0000000       .0000000
   .0000000       .0000000
 12.0000000
  2.0000000
```

6.75	2.12	12.00	76.3	.0	.0	.0	-15.9	-3.5
6.88	2.37	12.00	80.0	.0	.0	.0	-17.9	-3.6
7.00	2.65	12.00	84.2	.0	.0	.0	-21.6	-3.3
7.13	2.96	12.00	88.9	.0	.0	.0	-24.1	-3.2
7.25	3.30	12.00	94.0	.0	.0	.0	-25.3	-2.9
7.38	3.67	12.00	99.6	.0	.0	.0	-26.7	-2.6
7.50	4.06	12.00	106.7	.0	.0	-.8	-28.1	-2.3
7.63	4.49	12.00	115.3	1.6	.0	-2.6	-29.5	-1.6
7.75	4.94	12.00	126.0	7.5	.0	-5.8	-29.6	-.6
7.88	5.41	12.00	137.3	15.5	.0	-9.6	-29.7	.6
8.00	5.89	12.00	148.6	24.2	.0	-13.2	-30.2	1.8
8.13	6.39	12.00	160.2	34.0	.0	-16.7	-32.1	2.9
8.25	6.88	12.00	172.3	47.2	.0	-20.8	-31.6	4.2
8.38	7.36	12.00	184.8	62.1	.0	-20.3	-31.8	5.5
8.50	7.80	12.00	197.9	77.7	.0	-20.4	-31.3	6.8
8.63	8.20	12.00	211.1	92.4	.0	-20.7	-31.2	8.1
8.75	8.54	12.00	224.6	108.1	.0	-21.1	-30.6	9.4
8.88	8.83	12.00	238.5	127.7	.0	-21.8	-30.1	10.7
9.00	9.04	12.00	252.6	144.4	.0	-22.0	-29.3	12.1
9.13	9.14	12.00	267.3	165.4	.0	-21.8	-28.7	13.4
9.25	9.16	12.00	281.5	183.2	.0	-22.2	-28.1	14.7
9.38	9.11	12.00	295.7	201.7	.0	-22.3	-27.6	15.9
9.50	8.99	12.00	306.9	206.3	.0	-24.1	-28.2	16.5
9.63	8.79	12.00	318.1	212.5	.0	-25.6	-28.8	17.1
9.75	8.53	12.00	330.2	223.3	.0	-26.0	-29.0	18.0
9.88	8.23	12.00	340.0	225.6	.0	-27.4	-30.1	18.4
10.00	7.90	12.00	349.1	227.0	.0	-28.9	-31.3	18.7
10.13	7.56	12.00	357.6	228.1	.0	-30.0	-32.7	19.0
10.25	7.20	12.00	365.5	228.5	.0	-31.0	-34.1	19.2
10.38	6.83	12.00	372.6	228.5	.0	-32.2	-35.5	19.3
10.50	6.47	12.00	379.1	228.5	.0	-32.2	-36.7	19.2
10.63	6.13	12.00	384.9	228.5	.0	-32.2	-37.7	19.1
10.75	5.80	12.00	390.1	228.5	.0	-32.2	-38.2	19.0
10.88	5.48	12.00	394.7	228.5	.0	-32.2	-38.4	18.7
11.00	5.17	12.00	398.6	228.5	.0	-32.2	-38.6	18.3
11.13	4.88	12.00	402.0	228.5	.0	-32.2	-38.7	17.9
11.25	4.61	12.00	404.8	228.5	.0	-32.2	-38.8	17.4
11.38	4.34	12.00	407.2	228.5	.0	-32.2	-38.8	16.9
11.50	4.10	12.00	409.3	228.5	.0	-32.2	-38.9	16.2
11.63	3.91	12.00	411.2	228.5	.0	-32.2	-38.9	15.6
11.75	3.73	12.00	412.8	228.5	.0	-32.2	-38.9	14.9
11.88	3.52	12.00	414.1	228.5	.0	-32.2	-38.7	14.2
12.00	3.28	12.00	414.9	228.5	.0	-32.2	-38.5	13.4
12.13	2.87	12.00	415.0	228.5	.0	-32.2	-38.1	12.5
12.25	2.43	12.00	414.3	228.5	.0	-32.2	-38.1	11.5
12.38	2.01	12.00	412.7	228.5	.0	-32.2	-38.1	10.4
12.50	1.62	12.00	410.5	228.5	.0	-32.2	-38.1	9.1
12.63	1.42	12.00	408.7	228.5	.0	-32.2	-38.1	8.2
12.75	1.28	12.00	406.9	228.5	.0	-32.2	-38.1	7.5
12.88	1.17	12.00	405.1	228.5	.0	-32.2	-38.1	7.0
13.00	1.08	12.00	403.2	228.5	.0	-32.2	-38.1	6.6

EDUNE.DAT

Output in the EDUNE.DAT file should be identical to that contained in the file R41.DAT. The format for this output is

			TOUT(1)	TOUT(2) - - -	TOUT(6)
			VOUT(1)	VOUT(2) - - -	VOUT(6)
H1(N)	XMIN(N)	X1(N)	XOUT(1,N)	XOUT(2,N) - - -	XOUT(6,N)

Results should appear as follows:

			6.9	8.1	9.3	10.4	11.6	12.1
			84.2	160.2	281.5	379.1	411.2	415.0
-26.0	96.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
-25.5	95.2	101.6	101.6	101.6	101.6	101.6	101.6	101.6
-25.0	94.4	103.2	103.2	103.2	103.2	103.2	103.2	103.2
-24.5	93.6	104.8	104.8	104.8	104.8	104.8	104.8	104.8
-24.0	92.8	106.4	106.4	106.4	106.4	106.4	106.4	106.4
-23.5	92.0	108.0	108.0	108.0	108.0	108.0	108.0	108.0
-23.0	90.3	109.6	109.6	109.6	109.6	109.6	109.6	109.6
-22.5	88.7	111.2	111.2	111.2	111.2	111.2	111.2	111.2
-22.0	87.0	112.8	112.8	112.8	112.8	112.8	112.8	112.8
-21.5	85.3	114.4	114.4	114.4	114.4	114.4	114.4	114.4
-21.0	83.7	116.0	116.0	116.0	116.0	116.0	116.0	116.0
-20.5	82.0	117.7	117.7	117.7	117.7	117.3	117.3	117.3
-20.0	80.3	119.3	119.3	119.3	119.3	117.5	117.5	117.5
-19.5	78.7	120.9	120.9	120.9	120.9	117.8	117.8	117.8
-19.0	77.0	122.5	122.5	122.5	121.2	118.0	118.0	118.0
-18.5	75.3	124.1	124.1	124.1	121.4	118.3	118.3	118.3
-18.0	73.7	125.7	125.7	125.7	121.7	118.5	118.5	118.5
-17.5	72.0	127.3	127.3	127.3	121.9	118.8	118.8	118.8
-17.0	55.0	129.0	129.0	129.0	122.2	119.0	119.0	119.0
-16.5	53.8	130.6	130.6	130.6	122.4	119.3	119.3	119.3
-16.0	52.5	132.2	132.2	132.2	122.7	119.5	119.5	119.5
-15.5	51.3	133.8	133.8	133.8	122.9	119.8	119.8	119.8
-15.0	50.0	135.4	135.4	135.4	123.2	120.0	120.0	120.0
-14.5	45.0	137.0	137.0	137.0	123.4	120.3	120.3	120.3
-14.0	40.0	138.6	138.6	138.6	123.7	120.5	120.5	120.5
-13.5	33.3	143.9	143.9	143.9	123.9	120.8	120.8	120.8
-13.0	26.7	149.3	149.3	149.3	124.2	121.0	121.0	121.0
-12.5	20.0	154.6	154.6	154.6	124.4	121.3	121.3	121.3
-12.0	13.3	159.9	159.9	156.0	124.7	121.5	121.5	121.5
-11.5	6.7	165.3	165.3	156.3	124.9	121.8	121.8	121.8
-11.0	.0	170.6	170.6	156.5	130.2	122.0	122.0	122.0
-10.5	.0	171.5	171.5	156.8	135.5	126.5	126.5	126.5
-10.0	.0	172.4	172.4	157.0	140.9	130.0	130.0	130.0
-9.5	.0	173.3	173.3	157.3	146.4	135.9	135.9	135.9
-9.0	.0	174.2	174.2	157.5	152.0	142.0	142.0	142.0
-8.5	.0	175.1	175.1	157.8	157.3	147.7	147.0	147.0
-8.0	.0	176.0	176.0	163.1	161.4	152.9	151.7	151.7
-7.5	.0	176.9	176.9	168.4	166.6	158.3	156.3	156.3
-7.0	.0	177.8	177.8	173.7	172.1	164.0	161.8	161.8
-6.5	.0	178.7	178.7	179.0	178.2	169.7	167.6	167.6

Examples of plots obtained with the PLTDAT program should be identical to those in Figures 29 and 30.

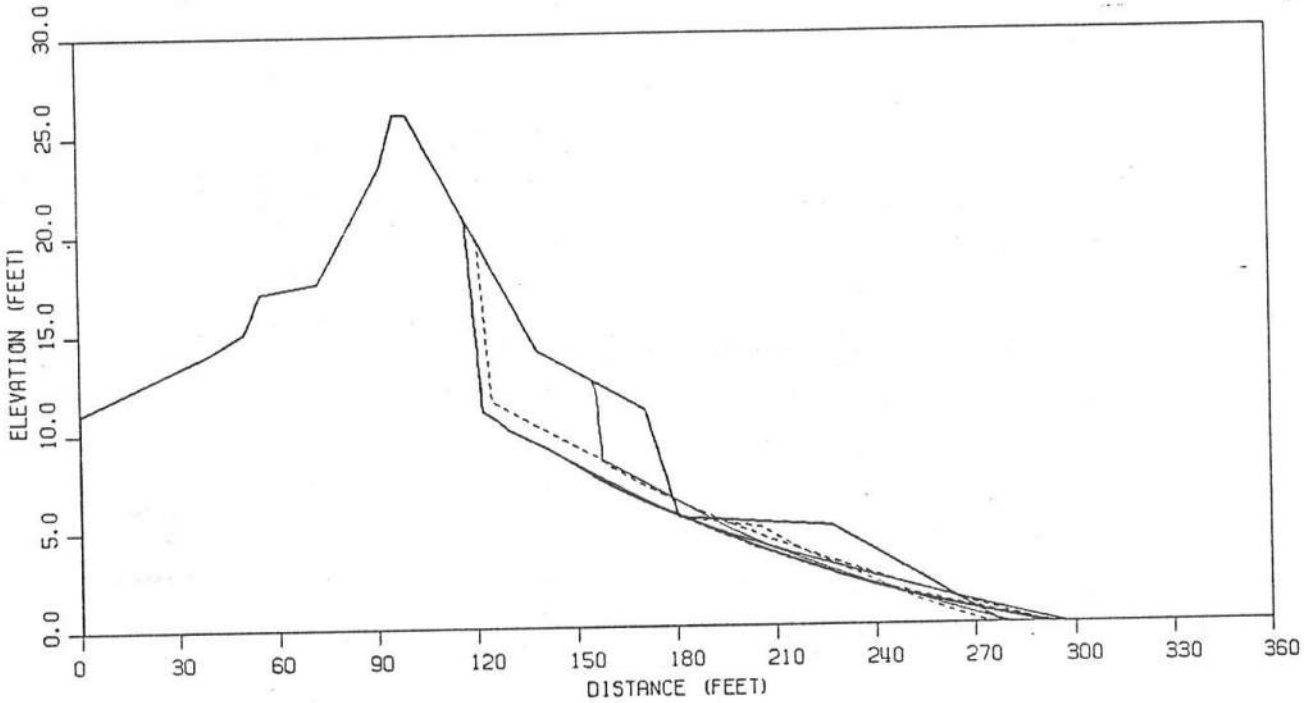


Figure 29. Results for profile evolution above mean sea level, Profile R-41.

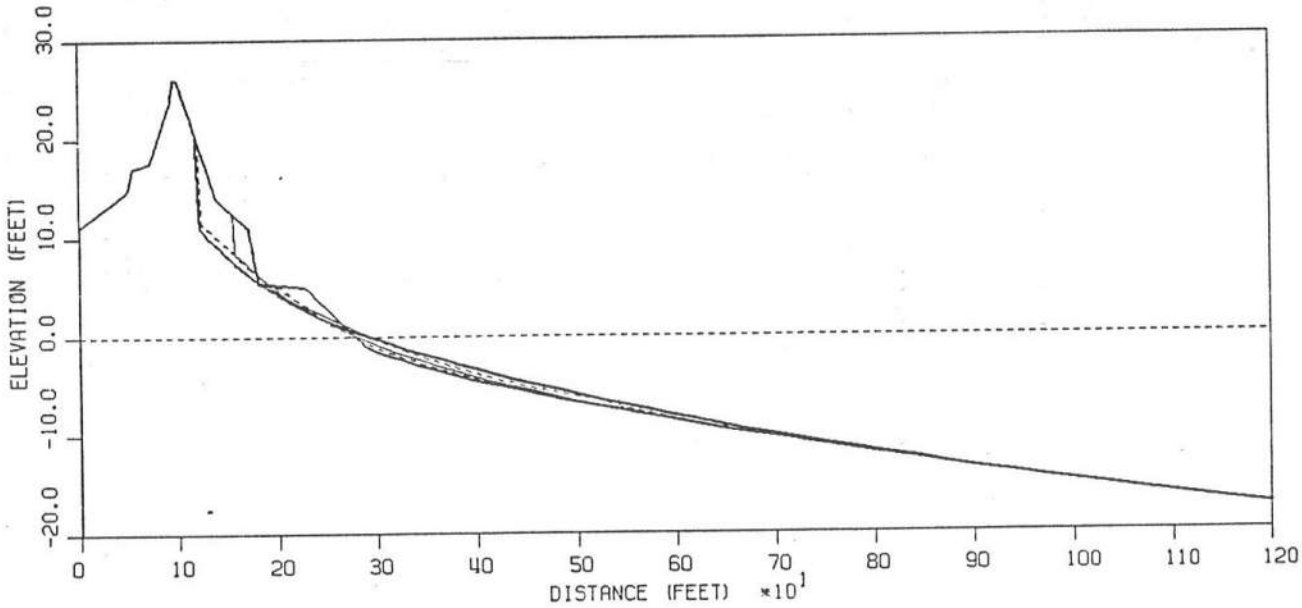


Figure 30. Results for profile evolution both onshore and offshore, Profile R-41.

EDUNE.LOG

Output in the EDUNE.LOG file will not be listed. However, examples of plotted output are shown in Figures 31 and 32.

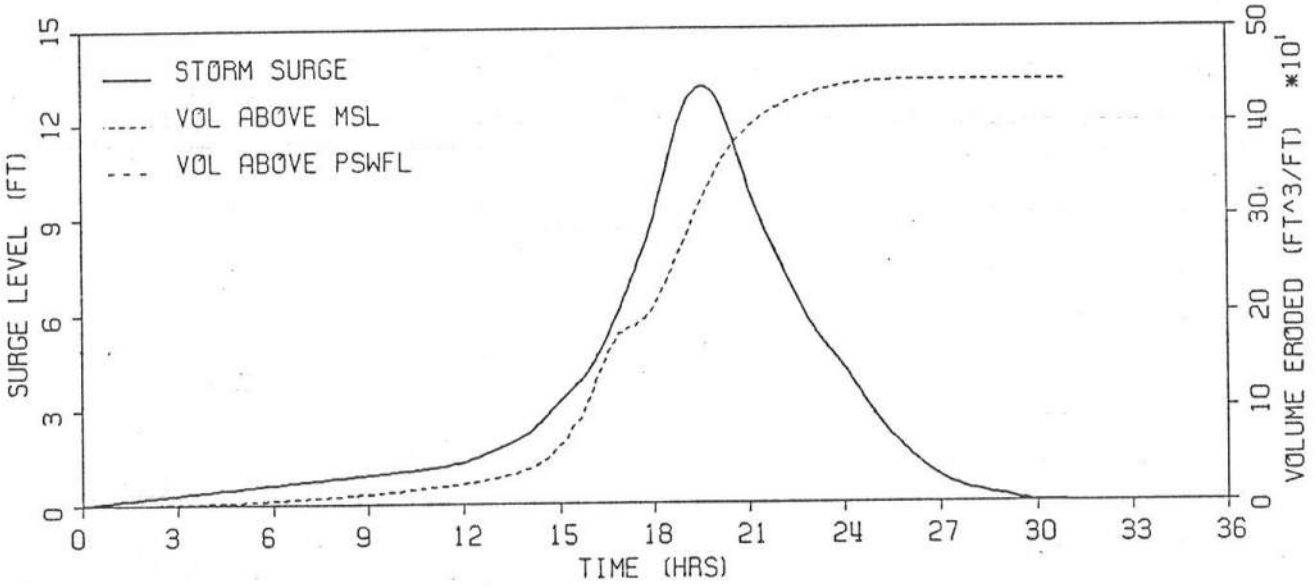


Figure 31. Example of storm surge and eroded volumes, F-9.

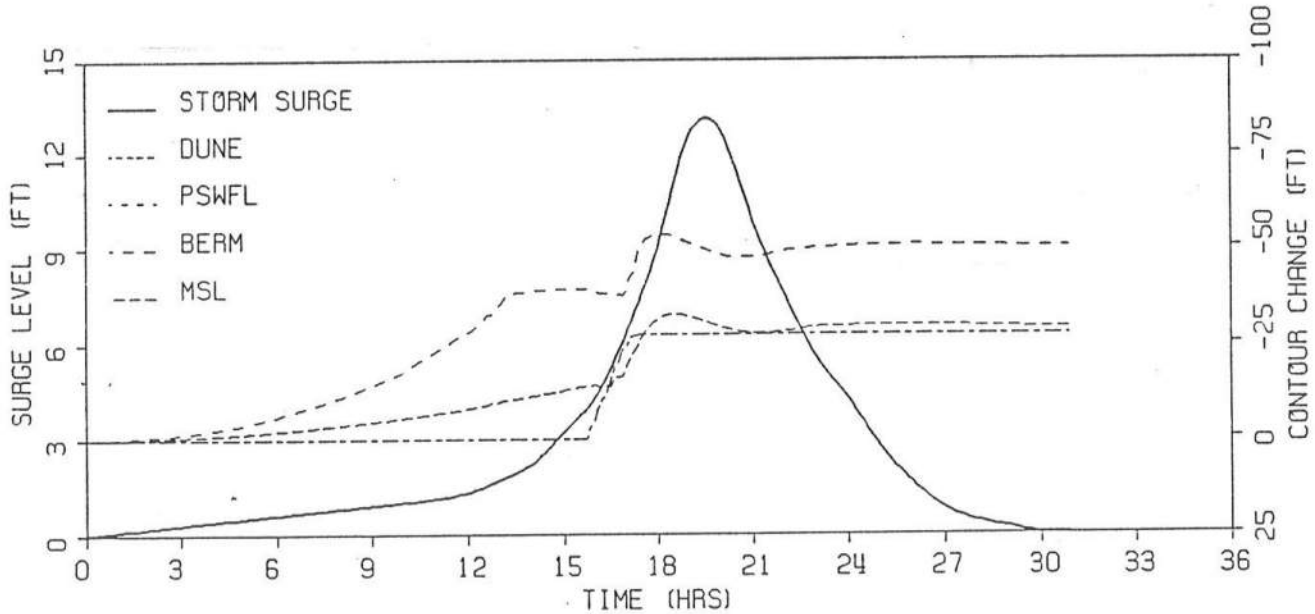


Figure 32. Example of storm surge and contour changes, F-9.

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APPENDIX A

Description of original model development and numerical algorithms for double-sweep solution, presented in reprint of the paper:

"Numerical Simulation of Time-Dependent Beach and Dune Erosion Due to Severe Storms"

Coastal Engineering, Vol. 9, Sept. 1985, pp. 221-245.