DEVELOPMENT OF A USERS'S MANUAL FOR GENESIS (GENERALIZED MODEL FOR SIMULATING SHORELINE CHANGE)

by

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United States Army

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The report gives two chapters of a workbook about the shoreline response numerical model GENESIS. These chapters focus on two important aspects of the simulation system: (1) error and warning messages, why they are issued and remedial measures and (2) interpretation and presentation of simulation results. The modeling system GENESIS, developed over the last decade, is now available to the Corps of Engineer Districts. The main objective of the workbook is to efficiently transfer this technology from researchers at the U.S. Army Waterways Experiment Station's (WES) Coastal Engineering Research Center (CERC) to field office personnel. For this reason, complete documentation of the numerical model is required.

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PART 8: INPUT FILES - STRUCTURE AND ERRORS

1. The first part of this chapter gives a brief discussion on the input files comprising the user interface of GENESIS. Part VI of the Technical Reference presents a more thorough description of the general structure and operation of the interface together with the preparations that must be made prior to running the modeling system. Appendix B of the Technical Reference gives blank copies of input files that may be photocopied for use in projects. It should be noted, however, that the input wave data is entered differently than the description given in the Technical Reference.

2. The second part of the chapter contains a list of error and warning messages that are presently incorporated in GENESIS. The fact that the error trapping capability is continuously being enhanced, is clearly demonstrated by the fact that some of the messages have been changed since the release of the Technical Reference.

Input and output files

3. GENESIS is operated through use of seven input data files, as illustrated in Figure 1. It should be noted that one input data file has been added as compared to the Technical Reference. Input and output file names consist of five letters with a three-letter extension. This extension, prompted by GENESIS during execution and denoted by .ext in the Figure, may be specified by the modeler, provided all necessary input files with this extension exists. GENESIS reads the input files and performs the shoreline change simulation according to the instructions and data contained in them. When the simulation is completed, the output from GENESIS is placed in three files having the same extension as the input files, as shown in Figure 1.

4. All input files must begin with four header lines, and GENESIS skips over these when the files are read. If the four header lines are not present, GENESIS will either begin reading data at an incorrect position with a possible undetected computation error, give an error message that the data file holds too few values, complain about the data input format, or give a runtime error that will be very difficult to trace, since the false data may cause a program crash at an arbitrary line of code.

5. The seven input files which GENESIS will look for when it is executed are named START.ext, SHORL.ext, SHORM.ext, WAVES.ext, SEAWL.ext, NSWAV.ext, and

DEPTH.ext, where .ext stands for the three-letter extension specified by the modeler. Of these files, START, SHORL, SHORM, and WAVES are always required, whereas SEAWL, NSWAV, and DEPTH may or may not be called by GENESIS, depending on instructions entered by the user in the START file.

START

6. The input file START.DAT contains the instructions which control the shoreline change simulation and is the principal interface between the modeler and GENESIS. The START file contains requests for information in a series of lines that are arranged in sections according to general subject. The number of lines holding values in response to a specific request is arbitrary. Unless instructed otherwise, a response (an alphanumeric character) must be given to a request. As the data is read in free format, if several values are required, they may be separated by a space or by a comma, or both. However, the line request identifier letter (A.1, B.1, C.1,...) should not be moved from column 1, as GENESIS looks for it there. Figure 23 in the Technical Reference gives an example of a START file.

SHORL

7. The input file SHORL.ext holds the position of the shoreline used by GENESIS at the start of calculation. Positions of the shoreline are given in the units selected at Line A.2 of the START file and are measured from the baseline (x-axis). A shoreline position must be given for each grid cell. It is important to note that even if only a subsection of the shoreline is used in the simulation, shoreline positions must still be given for the full range of the calculation grid (*NN* points), as GENESIS will load positions of the shoreline subsection with reference to the original, full grid. Shoreline positions may be entered in "free format," provided that exactly ten entries is placed on each line, except for the last line. Figure 24 in the Technical Reference gives an example of a SHORL file.

SHORM

8. The input file SHORM.ext holds the position of the measured shoreline that is to be reproduced in the procedure of calibrating or verifying the model. The format and rules for entering data into SHORM.ext is the same as for SHORL.ext. Figure 25 in the Technical Reference gives an example of a SHORM file.

WAVES

9. The input file WAVES.ext holds offshore wave information. If an external wave refraction model is not used (*NWD* = 0 on Line B.3 of the START file), the offshore waves drives the shoreline change simulation in GENESIS. If an external wave refraction model is used (*NWD* = 1), the shoreline change simulation in GENESIS uses nearshore wave information read from the NSWAV file as discussed below. At each wave data time step *DTW* (specified at Line B.6 of the START file) WAVES must contain a triplet of wave period, height and direction at the depth *DZ* (specified at Line B.2 of the START file).

10. The three offshore quantities of wave period, height, and direction are placed on the same line and may be entered in "free format." An example of a WAVES file with only one wave component (*NWAVES* = 1) is given in Figure 8.1 where each line corresponds to one time step. As demonstrated in the Figure, the modeler is free to write any comment after the three wave quantities. GENESIS only reads three values on each line.

Figure 8.1. Example WAVES file.

SEAWL

11. The input file SEAWL.ext holds the positions of one or more seawalls or effective seawalls with respect to the baseline and specified in the proper length units. Figure 26 in the Technical Reference gives an example of a SEAWL file. The format and rules for entering data into SEAWL.ext is the same as for SHORL.ext. Seawall positions are entered at shoreline position points, i.e., at the centers of grid cells.

DEPTH

12. The input file DEPTH.ext is read if an external wave refraction model has previously been run to provide wave data. DEPTH holds depths along the nearshore reference line from which GENESIS will continue to propagate waves using its own wave transformation routines, and the wave data held in input file WAVES will bear a one-to-one correspondence with these depths in order of grid cell number. If an external wave refraction model was not used, this file will not be read. The format and rules for entering data into DEPTH.ext is the same as for SHORL.ext.

NSWAV

13. If an external wave refraction model is used (*NWD* = 1 on Line B.3 of the START file), the input file NSWAV.ext holds nearshore wave information which drives the shoreline change simulation in GENESIS through calculation of the wave-induced longshore sand transport rate. NSWAV must contain at each time step the wave height and direction for each point on the nearshore depth reference line. The wave period is assumed to be constant alongshore, and is read from the WAVES file holding the offshore wave conditions.

14. The nearshore wave height and direction is held in "compressed format" to minimize storage space. Thus, values of individual pairs of wave height *H* and wave direction *Z* at nearshore grid points are held in a quantity *IZH* and read in the integer format 10I7. The integer *IZH* will be converted to real numbers by GENESIS. If the wave direction is negative, *IZH* should be given a negative sign. Example 1: If *ICONV* = 1 (metric units selected at Line A.2 in the START file), *H* = 2.18 m and *Z* = 10.7 deg will produce the value *IZH* = 218107. Example 2: If *ICONV* = 2 (American customary units selected), *H* = 10.1 ft and *Z* = -21.0 deg will produce the value *IZH* = -101210.

15. If an external wave transformation model is not used (*NWD* = 0 on Line B.3 of the START file) NSWAV will not be read. An example of an NSWAV file with only one wave component (*NWAVES* = 1) is given in Figure 8.2. Each data block, comprising four lines with ten values preceded by a "blank" line each represent one time step. As demonstrated by the example in the Figure, additional information may be written on the blank lines, as these are never read by GENESIS.

Figure 8.2. Example NSWAV file.

Simple configurations

16. A project may require many versions of the input files, particularly START files, since this file contains most of the information specifying project alternatives. As an example, Figure 8.3 shows a simple situation involving multiple START files. If only two alternatives are considered in the project, groins as one alternative and detached breakwaters as the other, the modeler would probably construct two START files, possibly named START.gro and START.dbw. When he or she is ready to run GENESIS for the detached breakwater alternative, the file START.dbw, together with the other input files with

extension .dbw would be used in the simulation, resulting in the corresponding output files with the same extension. Later, when the groin alternative is to be run, the modeler would specify the extension .gro to use START.gro and other .gro files as input to GENESIS. The various input files employed may be saved under their original names or renamed together with the output files to document the process of evaluating the alternatives and results.

Figure 8.3. File name extension controlling single stage simulation.

Time-Varying Structure Configurations

17. In many modeling projects structures are built, modified, or destroyed during the course of a shoreline change simulation time period. The simulation must be performed in stages in such a case. A START file with the initial configuration would run GENESIS until the time step of the change in a structure; the SHORC file (calculated shoreline) from this first stage would then be copied to a SHORL file (initial shoreline) for the next stage of the simulation, and another START file describing the new configuration would be used to continue. As an example, Figure 8.4 shows a situation involving two stages of simulations.

Figure 8.4. File name extension controlling multiple stage simulations.

18. During the first stage of simulation, the modeled beach contains only one groin. Thus, a START file, possibly called START.1gr, is constructed that contains this structure only. GENESIS is then run, using this and other input files with the same extension .1gr, resulting in three output files. At the beginning of the second stage of simulation, another groin was added to the modeled beach. This new configuration, and other conditions describing this stage, is then held in another START file, possibly called START.2gr. The calculated shoreline at the end of stage 1 will then be copied to SHORL.2gr to represent the initial shoreline for the second stage of simulation. GENESIS is run again, using these and other input files with the extension .2gr.

19. In the illustrated example, the modeler chose to divide the total simulation interval into two stages only. However, it is possible to divide the interval into any number of stages. If the construction of the second groin would cover a significant portion of time,

it might have been better to have introduced the structure with a very small length (or high permeability depending on how the construction was performed). The length of the groin could then be gradually extended (or specified as less permeable) in several stages. The number of stages is, as usual, a compromise between calculation accuracy and simulation time/effort, that the modeler has to determine from his or hers engineering experience.

20. This procedure can be chained for describing any number of modifications in structure configurations and boundary conditions. Most computer systems allow creation of a batch file to automate the chaining of calculation segments.

Error Messages

21. After all needed input files are prepared and available to be called by GENESIS, the program can be run. At the beginning of use of the model on a project, it is not uncommon and should not be unexpected to have data mismatch errors, particularly in the START file. GENESIS provides a number of error and warning messages which give the user recovery information for the more common mistakes and notification of potentially undesirable conditions encountered during a simulation. These messages are printed to screen and to the output file SETUP. Below follows error and warning messages and suggested recovery procedures.

22. One strategy that has been found useful for reducing errors is to introduce project complexity in the START file in stages, testing (running) the model for a few time steps at each stage. For example, if the project has several structures and beach fills, the START file would first be constructed with only the boundary conditions and tested. Next, perhaps only nondiffracting groins would be placed on the internal grid, if there are such structures. Then, diffracting structures would be introduced. Finally, after successful testing at each stage, the beach fills would be placed in the START file. In this way, errors can be more easily isolated.

23. An error message gives information about a "fatal" error, that is, an error detected which would stop the calculation. On the data entry level, these errors might be caused by inconsistencies in specified quantities (for example, specifying three groins but only giving positions for two) or a serious problem in the calculation (for example, running many high waves at extremely oblique incident wave angles). GENESIS is based on physical assumptions and calculation techniques which have limitations. If these limitations are

exceeded, the simulation may fail or give an erroneous result. Experience with GENESIS in a variety of projects indicates it will perform satisfactorily if prudence is taken to represent realistic wave, structure, and shoreline position conditions.

24. Messages are given in alphabetical order in bold capital letters, followed by a short explanation and suggested error-recovery procedure. For several of the errors, more than one remedial measure is suggested. It is up to the modeler to chose the appropriate alternative which should provide the best representation of the true configuration. Only those values subject to correction are reported in the error recovery procedure. In the explanatory Figures, cells of special importance are marked with their number.

25. For a more extensive discussion of the respective errors, please refer to APPENDIX C in the Technical Reference. The messages below are repetitive to avoid cross-references.

26. **ERROR. BAD BALANCE IN WAVE INPUT PARAMETERS CAUSING DLTZ TO BE NEGATIVE.** **Reason for error:** The depth of longshore sand transport is negative. This may occur if the input offshore wave data was manipulated, for example, to investigate model sensitivity, the effect of extreme conditions, or during simulation of hypothetical cases. **Remedial measure:** Change the wave height and/or period in the WAVES file to represent physically reasonable waves.

27. **ERROR. BEACH FILL IS OUTSIDE CALCULATION GRID. Reason for error:** The grid cell numbers for a beach fill, as specified on Lines I.6 and I.7 in the START file fall outside the subsection of the beach presently being modeled as specified on Line A.4. The error may also occur as a result of a mistake in entering the cell numbers, e.g. if 84 instead of 48 is entered and the total beach only consists of 50 calculation cells. **Remedial measure:** If the entire fill lies outside the subsection of beach, the error is remedied by omitting corresponding values on Lines I.4 - I.8 in the START file. If the fill is only partially outside the subsection of beach, the error is remedied by setting *IBFS* on Line I.6 equal to the grid cell number where the simulated subsection starts, if the left side of the beach fill is outside the grid, or by setting *IBFE* equal to the grid cell number where the simulated subsection ends, if the right side of the beach fill is outside the grid. Figure 8.5 illustrates the three types of illegal fill specifications and the appropriate corrections. As only a subsection, comprising $N = 8$ cells, of the total beach is included in the simulation, the total number of cells for the entire grid is denoted by *NN*.

Figure 8.5. Specification of beach fills

28. The two examples with *NN* = 20, *ISTART* = 6, and *N* = 8 in Figure 8.5 are characterized by: a. Illegal configuration; *NBF* = 3; *IBFS* = 4, 11, 16; *IBFE* = 7, 14, 18. b. Corrected configuration; *NBF* = 2; *IBFS* = 6, 11; *IBFE* = 7, 13.

29. **ERROR. BOTH SEMI-INFINITE DETACHED BREAKWATER AND A DIFFRACTING GROIN ON LEFT-HAND BOUNDARY NOT ALLOWED. Reason for error:** A detached breakwater is specified on Line G.4 in the START file to cross the left-hand boundary and, at the same time, a diffracting groin is located in cell number 1 on Line E.4 in the START file. **Remedial measure:** Do any of the three alternatives; a. Replace the diffracting groin with a non-diffracting groin, b. Extend the diffracting groin to attach to the detached breakwater, specify that the detached breakwater does not cross the left-hand boundary by setting *IDB1* = 0 on Line G.4 in the START file, and at the same time specify that the detached breakwater starts in cell number 1 on Line G.6 in the START file, or c. Move the diffracting groin so that it will no longer be inside the detached breakwater, which means that *IXDG*(1) on Line E.4 in the START file must be greater than or equal to *IXDB*(1) on Line G.6. Figure 8.6 illustrates the error and possible remedial measures.

Figure 8.6. Placement of groin and breakwater on boundary

30. The four examples in Figure 8.6 are characterized by: a. Illegal configuration; *INDG* = 0; *IDG* = 1; *IXDG* = 1; *YDG* = 50; *IDB1* = 1; *IXDB* = 3; *YDB* = 70. b. Corrected configuration; *INDG* = 1; *IXNDG* = 1; *YNDG* = 50; *IDG* = 0; *IDB1* = 1; *IXDB* = 3; *YDB* = 70. c. Corrected configuration; *INDG* = 0; *IDG* = 1; *IXDG* = 1; *YDG* = 70; *IDB1* = 0; *IXDB* = 1, 3; *YDB* = 70, 70. d. Corrected configuration; *INDG* = 0; *IDG* = 1; *IXDG* = 3; *YDG* = 50; *IDB1* = 1; *IXDB* = 3; *YDB* = 70.

31. **ERROR. BOTH SEMI-INFINITE DETACHED BREAKWATER AND A DIFFRACTING GROIN ON RIGHT-HAND BOUNDARY NOT ALLOWED. Reason for error:** A detached breakwater is specified on Line G.5 in the START file to cross the right-hand boundary and, at the same time, a diffracting groin is located in cell number *N*+1 on Line E.4 in the START file. **Remedial measure:** Do any of the three alternatives;

a. Replace the diffracting groin with a non-diffracting groin, b. Extend the diffracting groin to attach detached breakwater, specify that the detached breakwater does not cross the left-hand boundary by setting *IDBN* = 0 on Line G.5 in the START file, and at the same time specify that the detached breakwater ends in cell number *N*+1 on Line G.6 in the START file, or c. Move the diffracting groin so that it will no longer be inside the detached breakwater, which means that *IXDG(NDG)* (last diffracting groin) on Line E.4 in the START file must be smaller than or equal to *IXDB(NDBTP)* (last detached breakwater tip) on Line G.6. Figure 8.6 illustrates the corresponding error on the left-hand boundary and possible remedial measures, which are easily translated to the right-hand boundary.

32. **ERROR. DETACHED BREAKWATER CAN ONLY CONNECT TO A GROIN AT THE GROIN TIP. Reason for error:** A detached breakwater is connected to a diffracting groin other than at its tip. **Remedial measure:** Move the detached breakwater tip to the end of the groin or move either of the two structures to separate them. Figure 8.7 illustrates the error and a possible remedial measure.

Figure 8.7. Placement of connecting groin and breakwater

33. The two examples in Figure 8.7 are characterized by: a. Illegal configuration; *YDG* = 70; *YDB* = 50, 50. b. Corrected configuration; *YDG* = 70; *YDB* = 70, 50.

34. **ERROR. DETACHED BREAKWATER ENDING ON OPEN LEFT-HAND BOUNDARY NOT ALLOWED. Reason for error:** A breakwater tip is located in cell number 1 as specified on Line G.6 in the START file. **Remedial measure:** Either consider the detached breakwater as being semi-infinite by setting *IDB1* = 1 on Line G.4 in the START file or specify the first cell number to be 2 or higher, as given on Line G.6 and setting *IDB1* = 0 on Line G.4 in the START file. Figure 8.8 illustrates the error and possible remedial measures.

Figure 8.8. Specification of groin on boundary

35. The three examples in Figure 8.8 are characterized by: a. Illegal configuration; *IDB1* = 0; *IXDB* = 1, 5; b. Corrected configuration; *IDB1* = 1; *IXDB* = 5; c. Corrected configuration; *IDB1* = 0; *IXDB* = 2, 5.

36. **ERROR. DETACHED BREAKWATER ENDING ON OPEN RIGHT-HAND BOUNDARY NOT ALLOWED. Reason for error:** A breakwater tip is specified in cell number $N+1$ on Line G.6 in the START file. **Remedial measure:** Either consider the detached breakwater as being semi-infinite by setting $IDBN = 1$ on Line G.5 in the START file or specify the last cell number to be N or less as given on Line G.6 and setting $IDB1 = 0$ on Line G.4 in the START file. Figure 8.8 illustrates the corresponding error for the left-hand boundary and possible remedial measures, which are easily translated for the right-hand boundary.

37. **ERROR. DETACHED BREAKWATER TIP OUTSIDE CALCULATION GRID. Reason for error:** The grid cell numbers for a detached breakwater, as specified on Line G.6 in the START file fall outside the subsection of the beach presently being modeled as specified on Line A.4. **Remedial measure:** If only one end of the breakwater is outside the modeled subsection of beach, remove this grid cell number from Line G.6 and the corresponding distance from x-axis and depth on Lines G.7 and G.8, respectively. In addition, the detached breakwater has to be considered as being semi-infinite by setting $IDB1 = 1$ on Line G.4 or $IDBN = 1$ on Line G.5 in the START file. If the entire detached breakwater is outside the modeled subsection of beach, the corresponding transmission coefficient as specified on Line G.9 must also be removed. Figure 8.9 illustrates the three types of illegal breakwater specifications and the appropriate corrections. As only a subsection, comprising $N = 8$ cells, of the total beach is included in the simulation, the total number of cells for the entire grid is denoted by *NN.*

Figure 8.9. Specification of detached breakwaters

38. The two examples with $NN = 20$, $ISTART = 6$, and $N = 8$ in Figure 8.9 are characterized by: a. Illegal configuration; $NDB = 3$; $IDB1 = 0$; $IDBN = 0$; $IXDB = 2, 7, 11, 17, 18, 20$. b. Corrected configuration; $NDB = 2$; $IDB1 = 1$; $IDBN = 1$; $IXDB = 7, 11$.

39. **ERROR. DIFFRACTING GROIN OUTSIDE CALCULATION GRID. Reason for error:** The grid cell number for a diffracting groin, as specified on Line E.4 in the START file fall outside the subsection of the beach presently being modeled as specified

on Line A.4. **Remedial measure:** Omit the grid cell number from Line E.4 and the corresponding length and depth on Lines E.5 and E.6, respectively. In addition, the number of diffracting groins *NDG* on Line E.3 has to be corrected (decreased). If there are no more diffracting groins inside the subsection of beach, set *IDG* = 0 on Line E.1.

40. **ERROR. DIFFRACTING STRUCTURES OVERLAP. Reason for error:** Either a diffracting groin is specified on Line E.4 in the START file to be located in a cell between the two tips of a detached breakwater as specified on Line G.6, **or** two detached breakwaters overlap. **Remedial measure:** If a diffracting is placed inside of a detached breakwater, the error is remedied by any of three alternatives: a. replace the diffracting groin with a non-diffracting groin by transferring the appropriate values from Section E (Diffracting Groins and Jetties) to Section D (Non-Diffracting Groins) in the START file, b. extend the diffracting groin to attach to the detached breakwater and at the same time divide the detached breakwater into two detached breakwaters, specified on Lines G.3 and G.6 - G.8, each attaching to the tip of the groin, together constituting a T-groin, **or** c. move the diffracting groin so that it will no longer be inside the detached breakwater as specified on Line G.6 in the START file. If two detached breakwaters overlap, move one or both detached breakwaters to make the two structures end at the same cell wall, specified on Line G.6. Figure 8.10 illustrates the illegal case of two overlapping detached breakwaters and one possible correction.

Figure 8.10. Overlapping detached breakwaters

41. The two examples in Figure 8.10 are characterized by: a. Illegal configuration; *IXDB* = 3, 7, 6, 9; b. Corrected configuration; *IXDB* = 3, 6, 6, 9. Figure 8.11 illustrates the illegal case of a diffracting groin inside of a detached breakwater and the appropriate corrections.

Figure 8.11. Diffracting groin inside of detached breakwater

42. The four examples in Figure 8.11 are characterized by: a. Illegal configuration; *IXDG* = 5; *YDG* = 50; *NDB* = 1; *IXDB* = 3, 6; *YDB* = 70, 70; b. Corrected configuration; *IXNDG* = 5; *YNDG* = 50; *NDB* = 1; *IXDB* = 3, 6; *YDB* = 70, 70; c. Corrected

configuration; *IXDG* = 5; *YNDG* = 70; *NDB* = 2; *IXDB* = 3, 5, 5, 6; *YDB* = 70, 70, 70, 70; d. Corrected configuration; *IXDG* = 6; *YDG* = 50; *NDB* = 1; *IXDB* = 3, 6; *YDB* = 70, 70.

43. **ERROR. END X-COORDINATE OF SEAWALL MUST BE GREATER THAN THE START X-COORDINATE. Reason for error:** *ISWBEG* is specified to be greater than *ISWEND* on Line H.3 in the START file. **Remedial measure:** Correct the numbers on Line H.3.

44. **ERROR FOUND IN DEPIN. FILES DEPTH (AND WAVES) CONTAIN TOO FEW VALUES. Reason for error:** An external wave transformation model is used to calculate the nearshore wave conditions along the nearshore reference line, as specified on Line B.3 in the START file. The end of the DEPTH file (and later possibly the WAVES file) is prematurely encountered. **Remedial measure:** Make sure the data files contain four lines of header. If so, add more values to the DEPTH file (and possibly the WAVES file), correct (increase) the number of shoreline calculation cells per wave model element on Line B.5, correct (decrease) the value of total number of calculation cells on Line A.3, or correct the grid cell numbers where the calculation starts and/or ends on Line A.4.

45. **ERROR FOUND IN KDGODA. KD CALCULATION DID NOT CONVERGE. Reason for error:** The search procedure for the diffracted breaking wave conditions has not converged within 20 iterations. If the error persists it probably signals a significant flaw in the wave, depth, or structure configuration input data.

46. **ERROR FOUND IN SHOIN. FILE SHORM CONTAINS TOO FEW VALUES. Reason for error:** The end of the SHORM file is prematurely encountered. **Remedial measure:** Make sure the data file contains four lines of header. If so, add more values to the file, change the value of the total number of calculation cells on Line A.3, or change the grid cell numbers where the calculation starts and/or the value of the calculation cells on Line A.4.

47. **ERROR FOUND IN SHOIN. FILE SHORL CONTAINS TOO FEW VALUES. Reason for error:** The end of the SHORL file is prematurely encountered. **Remedial measure:** Make sure the data file contains four lines of header. If so, add more values to the file, change the value of the total number of calculation cells on Line A.3, or change the grid cell numbers where the calculation starts and/or the value of the calculation cells on Line A.4.

48. **ERROR FOUND IN SWLIN. FILE SEAWL CONTAINS TOO FEW VALUES. Reason for error:** The end of the SEAWL file is prematurely encountered. **Remedial measure:** Make sure the data file contains four lines of header. If so, add more values to the file, change the value of the total number of calculation cells on Line A.3, **or** change the grid cell numbers where the calculation starts and/or the value of the calculation cells on Line A.4.

49. **ERROR FOUND IN WAVIN. FILE WAVES CONTAINS TOO FEW NEARSHORE WAVE DATA POINTS. Reason for error:** An external wave transformation model is used to calculate the nearshore wave conditions along the nearshore reference line, as specified on Line B.3 in the START file. The end of the WAVES file is prematurely encountered. **Remedial measure:** Make sure the data files contain four lines of header. If so, add more values to the WAVES file, correct (increase) the number of shoreline calculation cells per wave model element on Line B.5, correct (decrease) the value of total number of calculation cells on Line A.3, **or** correct the grid cell numbers where the calculation starts and/or ends on Line A.4.

50. **ERROR. GROIN CONNECTED TO A DETACHED BREAKWATER MUST BE CLASSIFIED AS A DIFFRACTING GROIN. Reason for error:** A detached breakwater is attached to a non-diffracting groin. **Remedial measure:** Replace the non-diffracting groin with a diffracting groin by transferring the appropriate values from Section D (Non-Diffracting Groins) to Section E (Diffracting Groins and Jetties) in the START file.

51. **ERROR. GROIN NEXT TO GRID BOUNDARY. Reason for error:** A groin is placed one calculation cell away from either end of the numerical grid. **Remedial measure:** The error is remedied by any of four alternatives: a. move the groin to the end of the grid, b. move the groin at least one cell away from the end of grid, c. move the end of the grid to the location of the groin, **or** d. move the end of the grid at least one cell away from the groin. Figure 8.12 illustrates errors appearing near the left-hand boundary and possible remedial measures, which are easily translated to the right-hand boundary. As only a subsection, comprising $N = 5$ cells, of the total beach is included in the simulation, the total number of cells for the entire grid is denoted by NN.

Figure 8.12. Groin next to grid boundary

52. The five examples in Figure 8.12 are characterized by: a. Illegal configuration; *ISTART* = 3; *IX(N)DG* = 4; b. Corrected configuration; *ISTART* = 3; *IX(N)DG* = 3; c. Corrected configuration; *ISTART* = 4; *IX(N)DG* = 4; d. Corrected configuration; *ISTART* = 3; *IX(N)DG* = 5; e. Corrected configuration; *ISTART* = 1; *IX(N)DG* = 3.

53. **ERROR. GROINS MUST BE SEPARATED BY AT LEAST TWO CALCULATION CELLS. Reason for error:** Two groins are placed with only one calculation cell between them. **Remedial measure:** Move one of the groins at least one cell further away from the other groin. Figure 8.13 illustrates the error and an appropriate correction.

Figure 8.13. Groins too close together

54. The two examples in Figure 8.13 are characterized by: a. Illegal configuration; *IX(N)DG* = 4, 5; b. Corrected configuration; *IX(N)DG* = 4, 6.

55. **ERROR IN CALCULATION OF BREAKING WAVE HEIGHT. THE WAVE DID NOT BREAK. Reason for error:** The search procedure to obtain the undiffracted breaking wave conditions has not converged within 20 iterations. **Remedial measure:** Change what is probably an unphysical wave height with respect to the nearshore depth (or vice versa). If the error persists it probably signals a significant flaw in the wave, depth, or structure configuration input.

56. **ERROR. INCORRECT FORMAT FOR BEACH FILL DATES. Reason for error:** For *BFDATS* and/or *BFDATE* entered on Lines I.4 and I.5, respectively, the number of the day is greater than 31 or the number of the month is greater than 12. **Remedial measure:** Make sure each date is entered as one number in the format YYMMDD.

57. **ERROR. INCORRECT FORMAT OF SIMULATION START DATE. Reason for error:** For SIMDATS entered on Line A.6 in the START file, the number of the day is greater than 31 or the number of the month is greater than 12. **Remedial measure:** Make sure the date is entered as one number in the format YYMMDD.

58. **ERROR. SEAWALL IS OUTSIDE CALCULATION GRID. Reason for error:** The grid cell numbers for a seawall *ISWBEG* and/or *ISWEND*, as specified on Line H.3 in the START file, fall outside the subsection of the beach presently being modeled as

specified on Line A.4. **Remedial measure:** If the entire seawall lies outside the subsection of beach, the error is remedied by setting *ISW* = 0, saying there is no seawall present. If the seawall is only partially outside the subsection of beach, the error is remedied by setting *ISWBEG* on Line H.3 equal to the grid cell number where the simulated subsection starts, if the left side of the seawall is outside the grid, or by setting *ISWEND* equal to the grid cell number where the simulated subsection ends, if the right side of the seawall is outside the grid.

59. **ERROR. SIMULATION ENDING DATE MUST BE GREATER THAN THE STARTING DATE. Reason for error:** The ending date of the simulation *SIMDATE* as specified on Line A.7 in the START is earlier than the starting date of the simulation *SIMDATS* on Line A.6. **Remedial measure:** Make sure both dates are given as one number in the format YYMMDD.

60. **ERROR. SMALL GROIN OUTSIDE CALCULATION GRID. Reason for error:** The grid cell number for a non-diffracting groin, as specified on Line D.4 in the START file fall outside the subsection of the beach presently being modeled as specified on Line A.4. **Remedial measure:** Omit the grid cell number from Line D.4 and the corresponding length on Line D.5. In addition, the number of non-diffracting groins *NNDG* on Line E.3 has to be corrected (decreased). If there are no more non-diffracting groins inside the subsection of beach, set *INDG* = 0 on Line D.1.

61. **ERROR. TOO MANY BEACH FILLS. Reason for error:** The number of beach fills *NBF* on Line I.3 is greater than the maximum allowed number as specified in the PARAMETER statement in GENESIS. At present, the number is set to 50 for VAX installations and to 10 for PC versions. In the near future, it will be possible for the modeler to edit the PARAMETER statement. **Remedial measure:** Reduce *NBF* accordingly. As *NBF* is changed, corresponding changes must be introduced on Lines I.4 and I.5. The number of beach fills can be reduced by splitting up the beach in portions and then performing the simulations for one portion of the beach at a time.

62. **ERROR. TOO MANY DETACHED BREAKWATERS. Reason for error:** The number of detached breakwaters *NDB* on Line G.3 is greater than the maximum allowed number as specified in the PARAMETER statement in GENESIS. At present, the number is set to 20 for VAX installations and to 15 for PC versions. In the near future, it will be possible for the modeler to edit the PARAMETER statement. **Remedial measure:**

Reduce *NDB* accordingly. As *NDB* is changed, corresponding changes must be introduced on Lines G.4 to G.9. The number of structures can be reduced by splitting up the beach in portions and then performing the simulations for one portion of the beach at a time.

63. **ERROR. TOO MANY DIFFRACTING GROINS. Reason for error:** The number of diffracting groins *NDG* on Line E.3 is greater than the maximum allowed number as specified in the PARAMETER statement in GENESIS. At present, the number is set to 20 for VAX installations and to 15 for PC versions. In the near future, it will be possible for the modeler to edit the PARAMETER statement. **Remedial measure:** Reduce *NDG* accordingly. As *NDG* is changed, corresponding changes must be introduced on Lines E.4 to E.6. The number of structures can be reduced by splitting up the beach in portions and then performing the simulations for one portion of the beach at the time.

64. **ERROR. TOO MANY INTERMEDIATE PRINT-OUTS REQUESTED. Reason for error:** The number of requested print-outs *NOUT* on Line A.8 in the START file is greater than the maximum allowed number as specified in the PARAMETER statement in GENESIS. At present, the number is set to 30 for VAX installations and to 15 for PC versions. In the near future, it will be possible for the modeler to edit the PARAMETER statement. **Remedial measure:** Reduce *NOUT* accordingly.

65. **ERROR. TOO MANY NON-DIFFRACTING GROINS. Reason for error:** The number of non-diffracting groins *NNDG* on Line D.3 is greater than the maximum allowed number as specified in the PARAMETER statement in GENESIS. At present, the number is set to 50 for VAX installations and to 40 for PC versions. In the near future, it will be possible for the modeler to edit the PARAMETER statement. **Remedial measure:** Change *NNDG* accordingly. As *NNDG* is changed, corresponding changes must be introduced on Lines D.4 and D.5. The number of structures can be reduced by splitting up the beach in portions and then performing the simulations for one portion of the beach at a time.

66. **ERROR. TOO MANY SHORELINE CELLS. Reason for error:** The number of shoreline cells alongshore NN on Line A.3 in the START file is greater than the maximum allowed number as specified in the PARAMETER statement in GENESIS. At present, the number is set to 600 for VAX installations and to 100 for PC versions. In the

near future, it will be possible for the modeler to edit the PARAMETER statement. **Remedial measure:** Reduce *NN* accordingly.

67. **ERROR. WAVE DATA FILE STARTS LATER THAN THE SIMULATION. Reason for error:** The simulation starts later than the starting date of the wave data file as specified on Lines A.6 and B.8. **Remedial measure:** Make sure the date when the simulation starts *SIMDATS* is later than or the same as the date when the wave file starts *WDATS*. The respective dates must be given as one number in the format YYMMDD.

68. **ERROR. WRONG VALUE OF "ICONV". Reason for error:** A number other than 1 (meters) or 2 (feet) is given for the specification of input units *ICONV*. **Remedial measure:** Change *ICONV* accordingly.

Warning Messages

69. Warnings are given if a potentially undesirable condition is detected in the course of calculation. One of the more common warnings is that the stability parameter *STAB* (called R_S in the main text) has exceeded the value of 5.0 during a particular time step (see Part II). As opposed to errors, warning messages will not stop the model calculation. The messages contain information for the modeler to determine the seriousness of the problem, but it is up to the modeler to remedy the cause of the warning or decide not to.

70. **WARNING. INPUT WAVE ALREADY BROKEN. Reason for warning:** An external wave transformation is used as specified on Line B.3 in the START file. The wave height on the reference line exceeds the depth-limited wave height. **Remedial measure:** Either decrease the input wave height in the WAVES file or increase the reference depth in the DEPTH file.

71. **WARNING. SHORELINE CHANGE RESULTING FROM LONG TIME STEP IS _ IN CELL NO. _. Reason for warning:** GENESIS uses two independent algorithms for calculating the alongshore distribution of sand transport rates. These algorithms should, of course, give the same transport rate. However, for large values of the stability parameter or due to the presence of detached breakwaters, especially if they are transmissive, the two algorithms may give slightly different results. The warning is issued if, at any cell alongshore, the difference in the two calculated transport rates is greater than

0.0005 m^3/sec. At the end of the simulation, the accumulated error, in terms of shoreline change, is presented on the screen and in the SETUP file. **Remedial measure:** Decrease the stability ratio, which in turn is done by decreasing the time step *DT* on Line A.5, by increasing the grid cell size *DX* on Line A.2, **or** by decreasing the wave height, either for specific values in the WAVES file or universally on Line B.1 in the START file. The waves should only be manipulated, for example, to investigate model sensitivity, the effect of extreme conditions or in hypothetical simulations. Extremely high angles of wave incidence may also produce this error.

72. **WARNING THE STABILITY PARAMETER IS ____. Reason for error:** The value of the stability parameter R_S is greater than 5 for at least one grid point. **Remedial measure:** Either decrease the time step *DT* at Line A.5 **or** increase the grid cell size *DX* at Line A.3. Normally the time step is reduced, at the cost of longer simulations, since considerable effort is involved in developing a grid.

73. **WARNING. UNPHYSICAL DEEPWATER WAVE STEEPNESS. Reason for error:** The input offshore wave data may be manipulated, for example, to investigate model sensitivity, or the effect of extreme conditions. This message is issued if waves are specified to have a steepness H_0/L_0 exceeding 0.142. GENESIS checks that the offshore wave steepness does not exceed the value of 0.142, and, if it does, reduces the deepwater wave height to satisfy this condition. **Remedial measure:** Decrease the wave height, either for specific values in the WAVES file or universally on Line B.1 in the START file, or by increasing the input wave period in the WAVES file.

Example configurations

74. The unexperienced modeler will, when working with GENESIS the first few times, find it bit difficult to keep in mind what activities are located in cells and on cell walls, respectively. To remedy this problem, Figures 8.14 and 8.15 gives a comprehensive overview of the available coastal protection elements and how they are specified in the START file.

Figure 8.14. Specification of non-diffracting groins
and detached breakwaters.

Figure 8.15. Specification of diffracting groins, seawalls, and beach fills.

```
*********************************************
WAVES FOR ILLUSTRATIVE EXAMPLE FOR WORKBOOK.
FILE CONTAINS OFFSHORE WAVE DATA.  DT = 6 HR.
*********************************************
 2.0  1.00 -30.0  01 JAN  1987
 2.0  1.00  00.0
 2.0  1.00  00.0
 3.0  1.00 -30.0
 2.0  1.00  00.0
 2.0  1.00  00.0
 3.0  2.00  15.0
 2.0  1.00  00.0
 2.0  1.00  00.0
 3.0  2.00  15.0
 2.0  1.00  00.0
 2.0  1.00  00.0
 3.0  1.00  15.0
 2.0  1.00  00.0
 2.0  1.00  00.0
 3.0  2.00  38.0
 2.0  1.00  00.0
 2.0 . ....
```

Figure 8.1. Example WAVES file.

```
**********************************************************
WAVES FOR ILLUSTRATIVE EXAMPLE FOR WORKBOOK.
FILE CONTAINS NEARSHORE WAVE DATA.  DT = 6 HR.  DX = 15 FT.
**********************************************************
 01 JAN 1987
-114185-116203-118172-121160-123158-120155-172153-124121-102134-097119
-103122-113183-110201-127162-129167-125164-124146-154163-129199-112133
-124146-154163-129199-112133-116203-118172-121160-123158-120155-172153
-124121-102134-097119-125164-124146-154163-129199-112133-154163-129199
-112133-116203-118172-121160-123158-120155-172153

-114185-116203-118172-121160-123158-120155-172153-124121-102134-097119
-103122-113183-110201-127162-129167-125164-124146-154163-129199-112133
-124146-154163-129199-112133-116203-118172-121160-123158-120155-172153
-124121-102134-097119-125164-124146-154163-129199-112133-154163-129199
-112133-116203-118172-121160-123158-120155-172153

-114185-116203-118172-121160.......
```

Figure 8.2. Example NSWAV file.

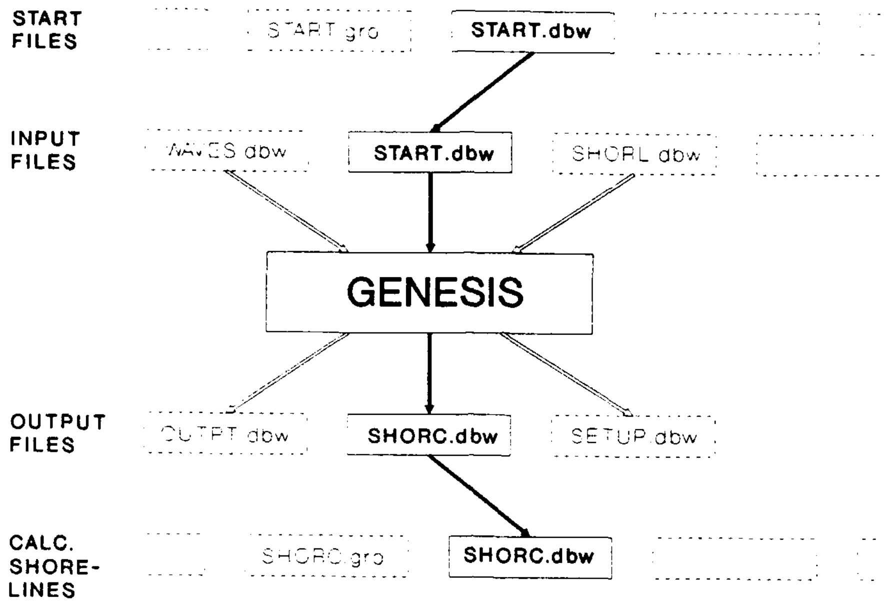


Figure 8.3. File name extension controlling single stage simulation.

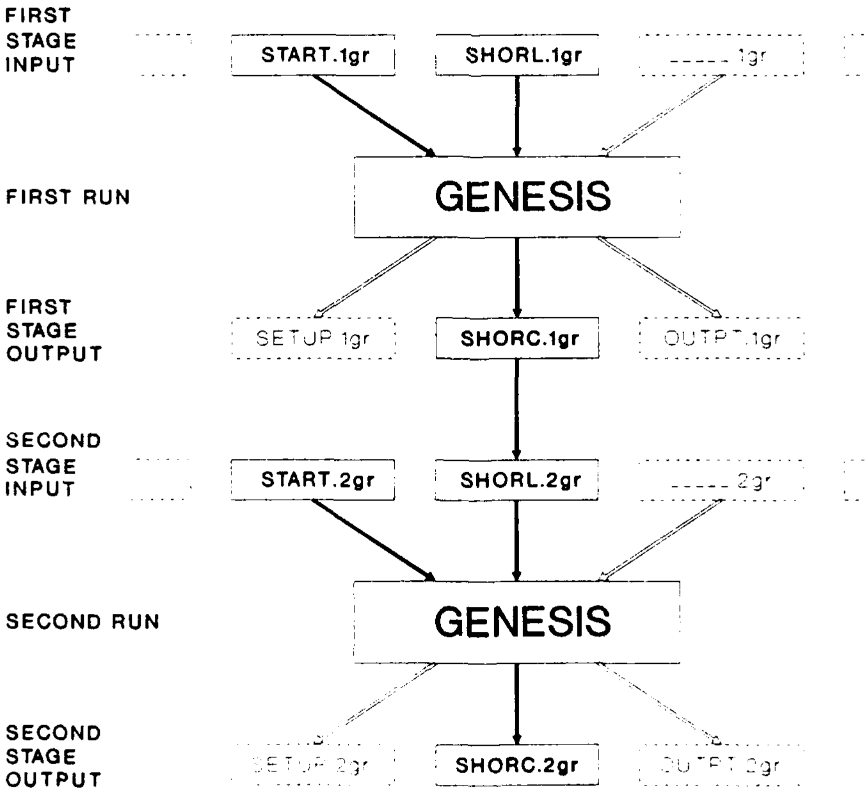
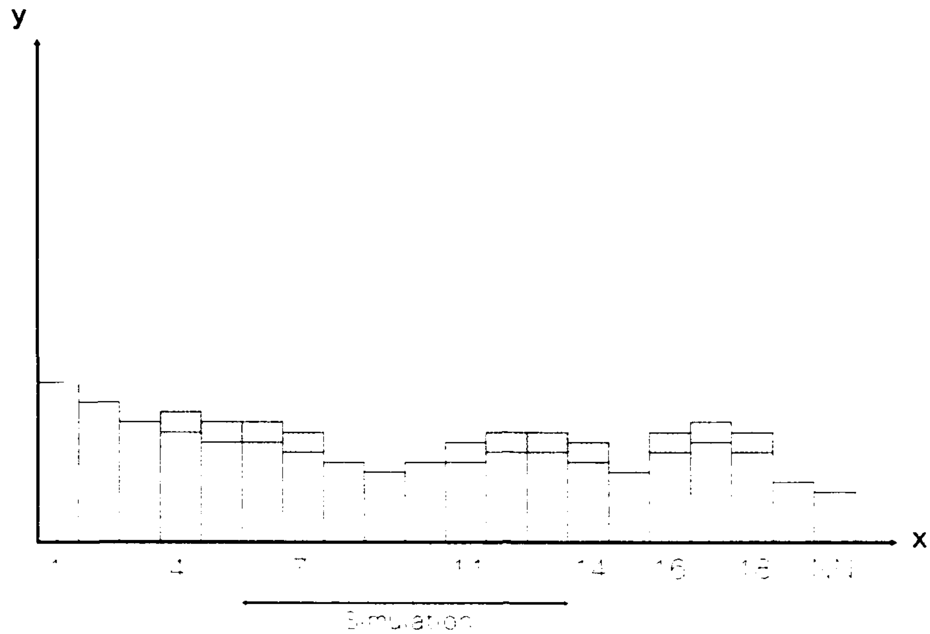
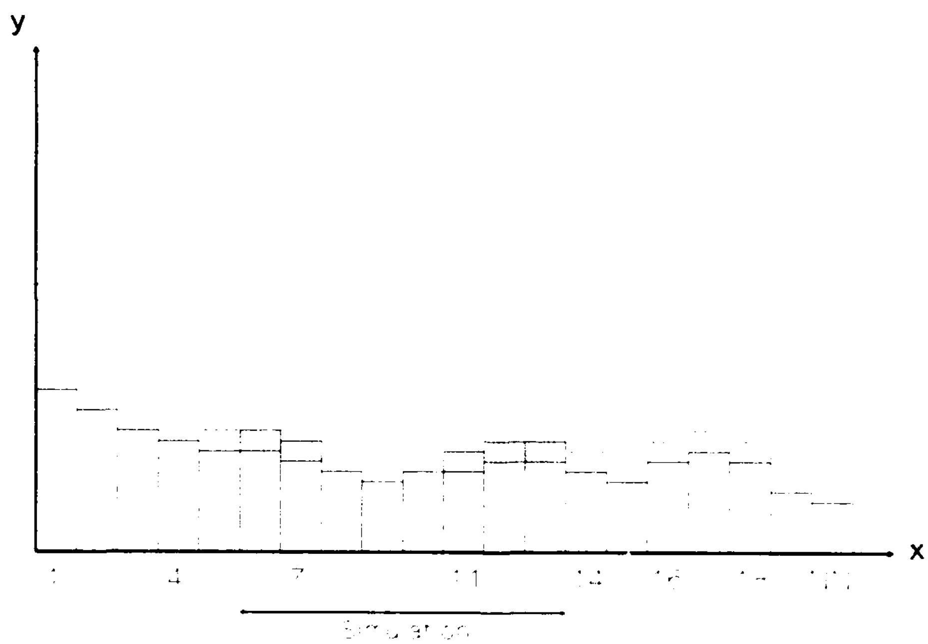


Figure 8.4. File name extension controlling multiple stage simulations.



a.



b.

Figure 8.5. Specification of beach fills

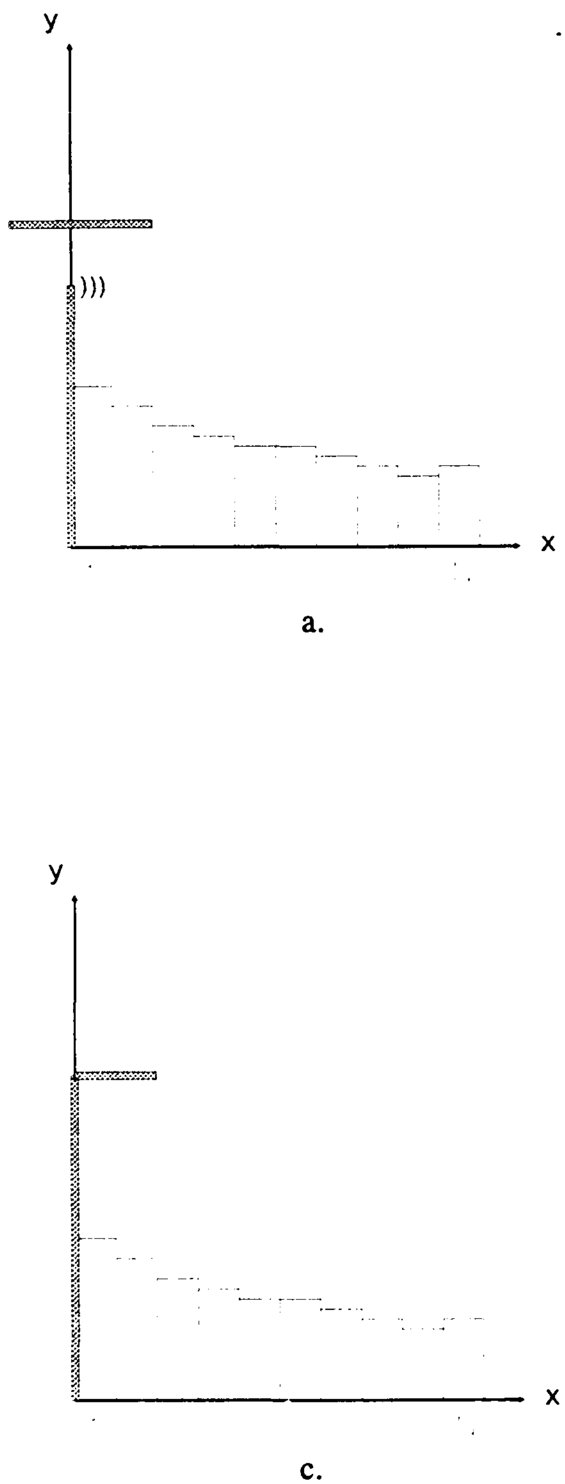
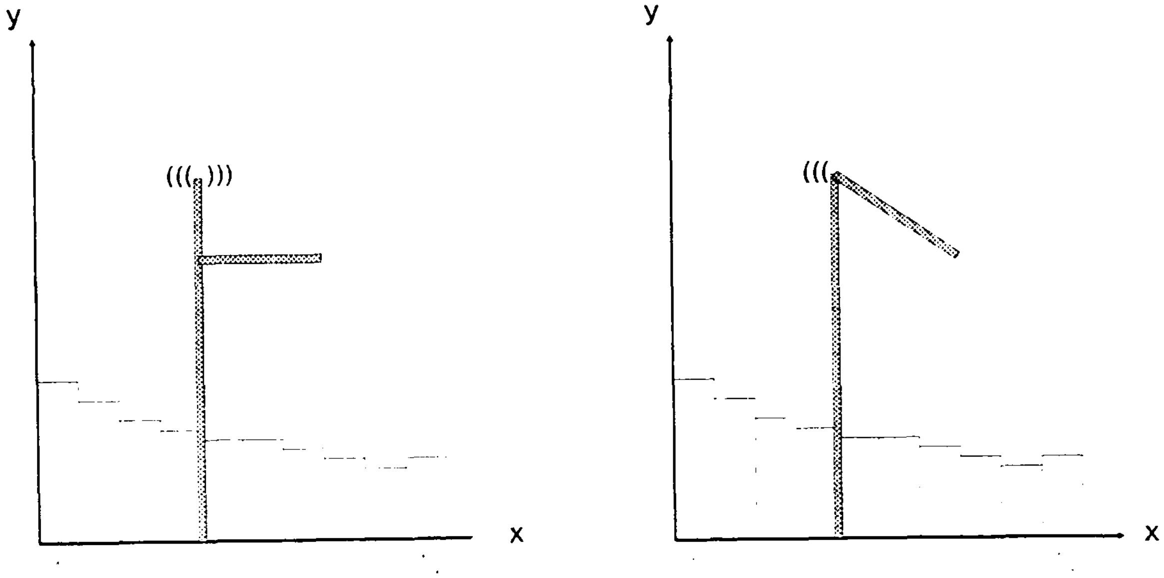
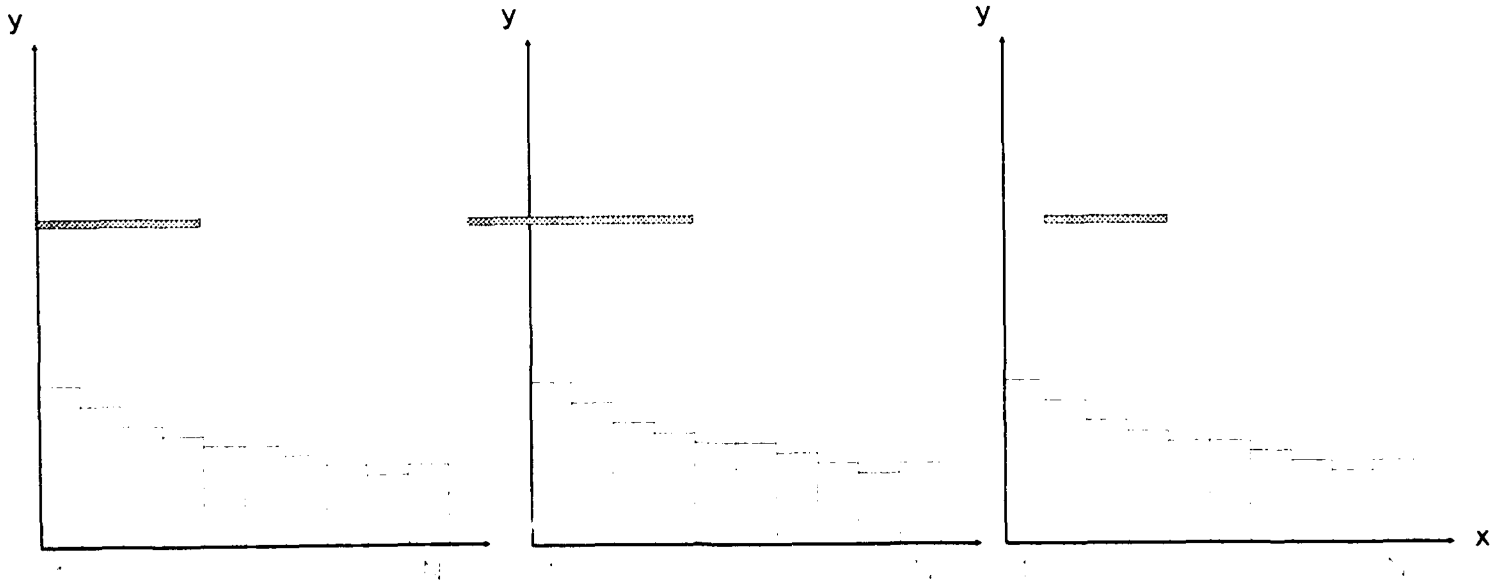


Figure 8.6. Placement of groin and breakwater on boundary



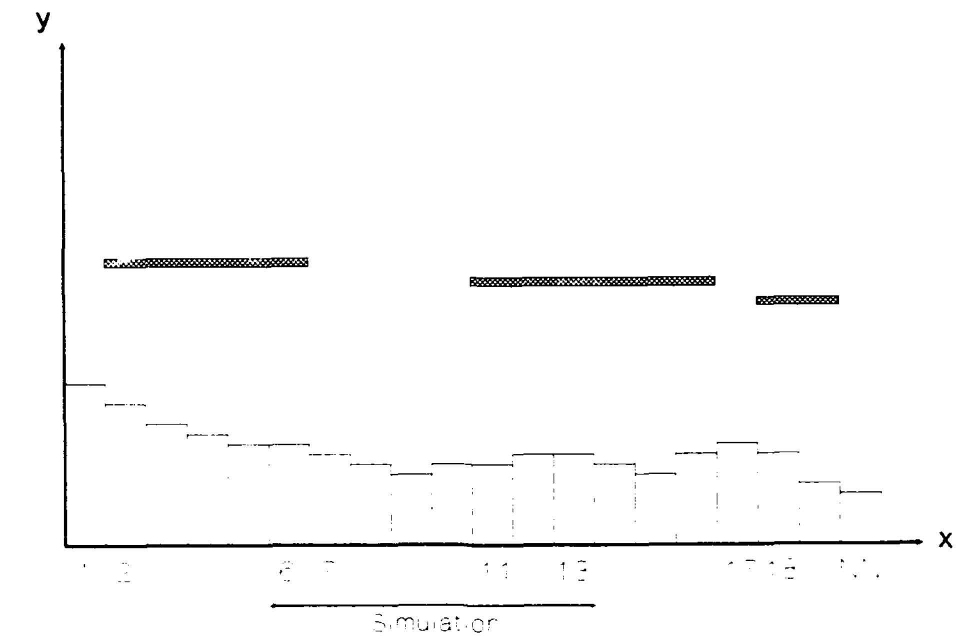
a b.

Figure 8.7. Placement of connecting groin and breakwater

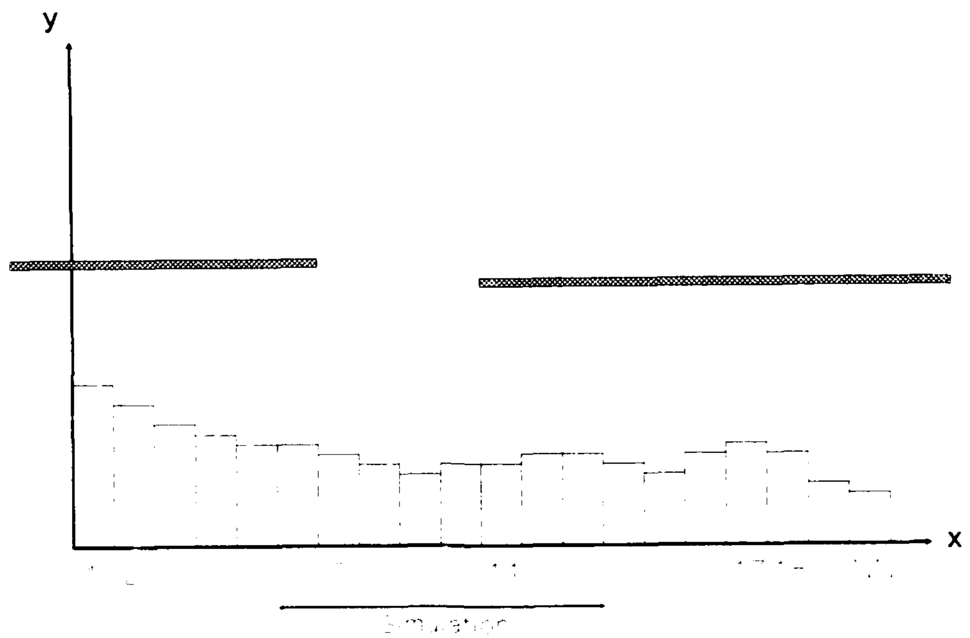


a. b. c.

Figure 8.8. Specification of groin on boundary

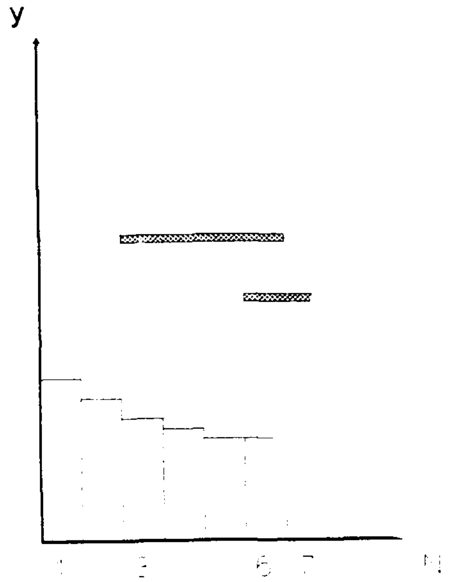


a.



b.

Figure 8.9. Specification of detached breakwaters



a.

b.

Figure 8.10. Overlapping detached breakwaters

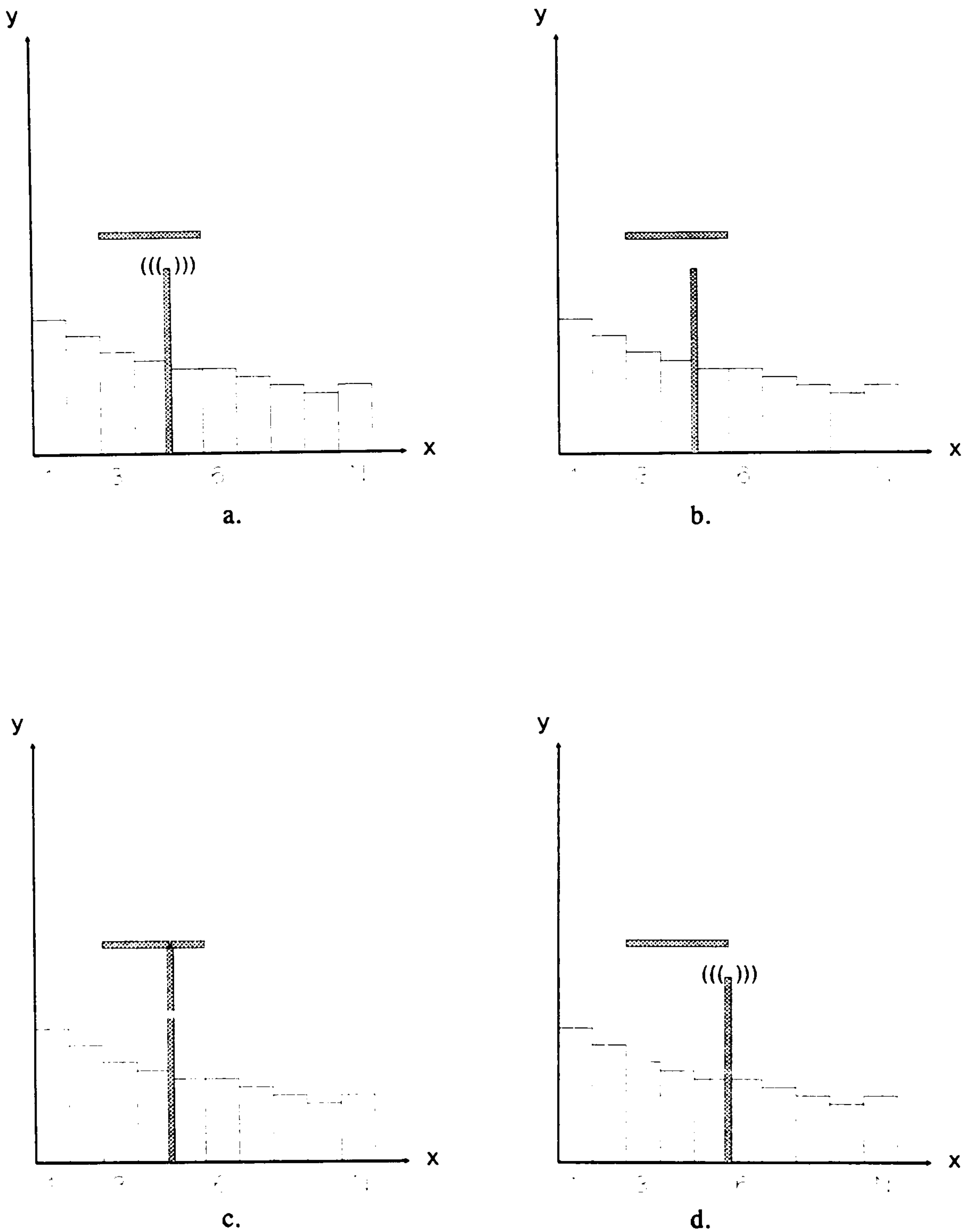


Figure 8.11. Diffracting groin inside of detached breakwater

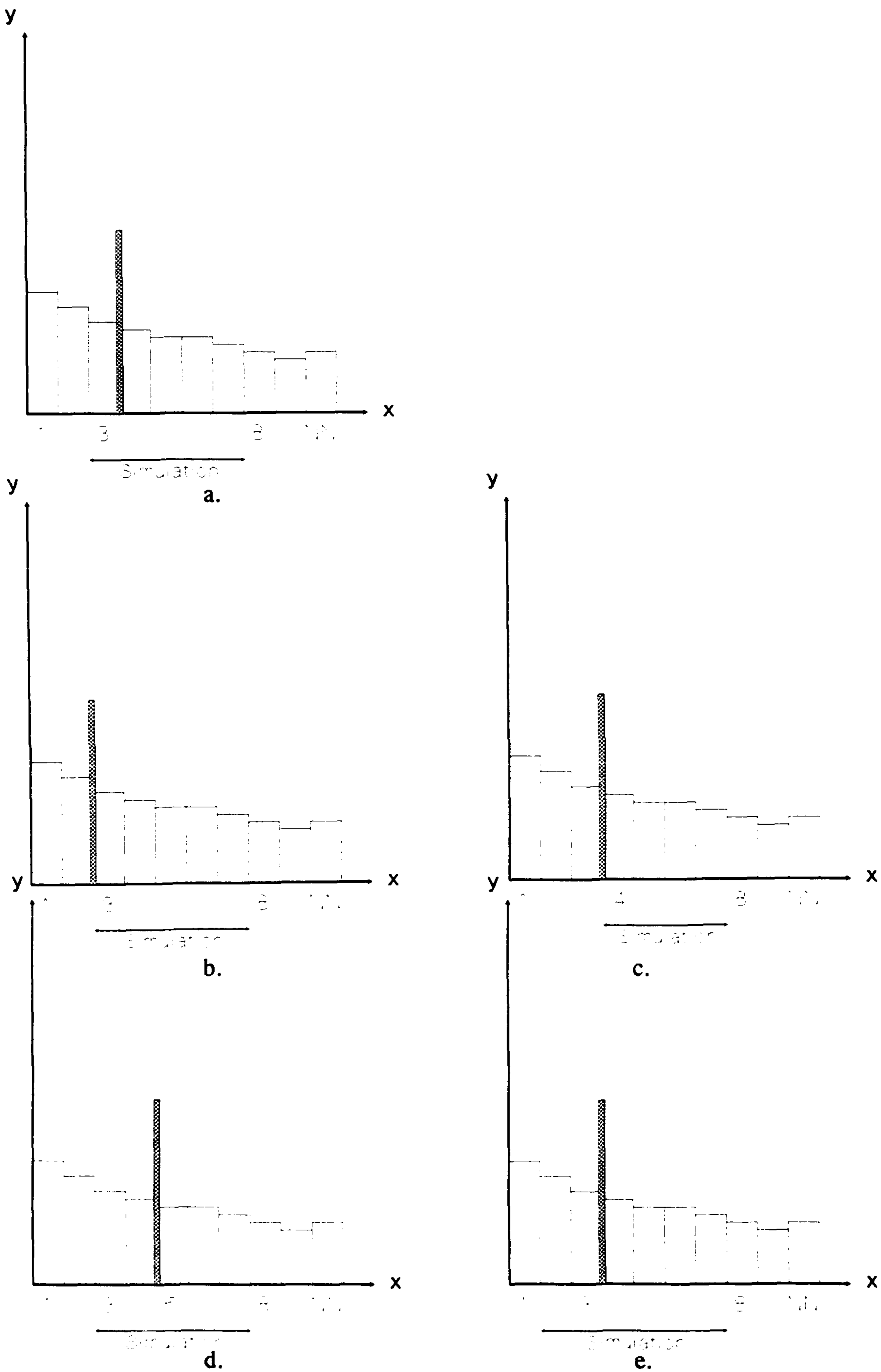
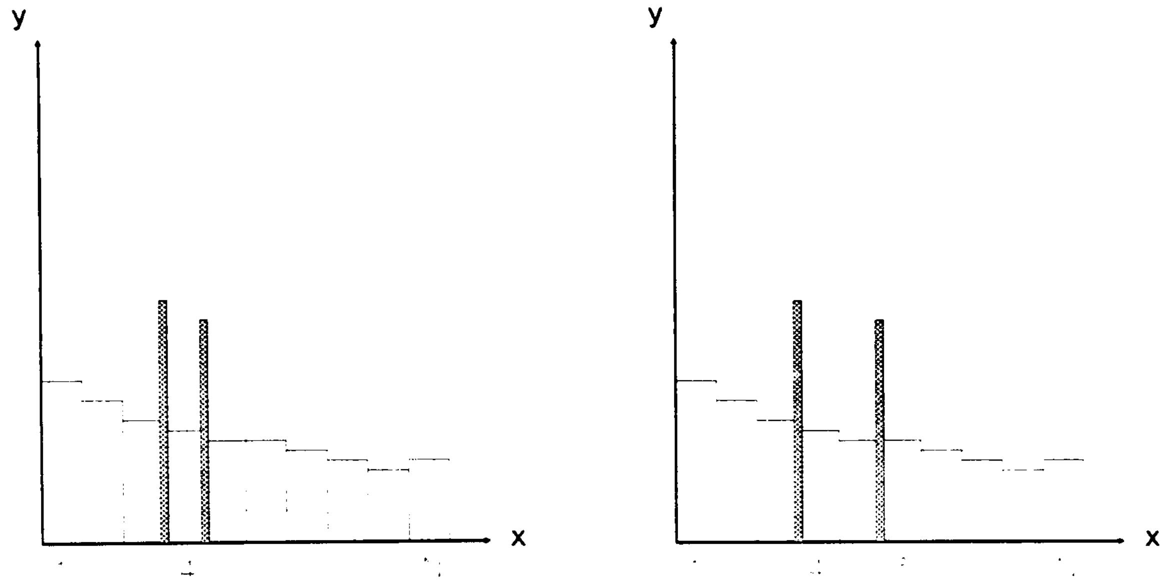


Figure 8.12. Groin next to grid boundary



a. b.

Figure 8.13. Groins too close together

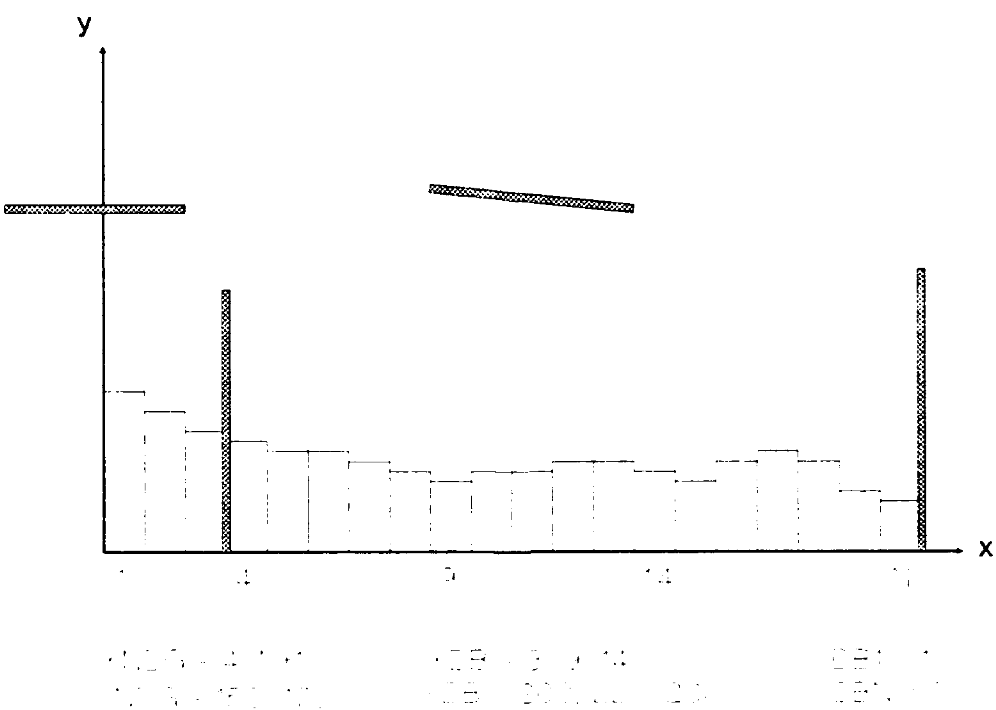


Figure 8.14. Specification of non-diffracting groins
and detached breakwaters.

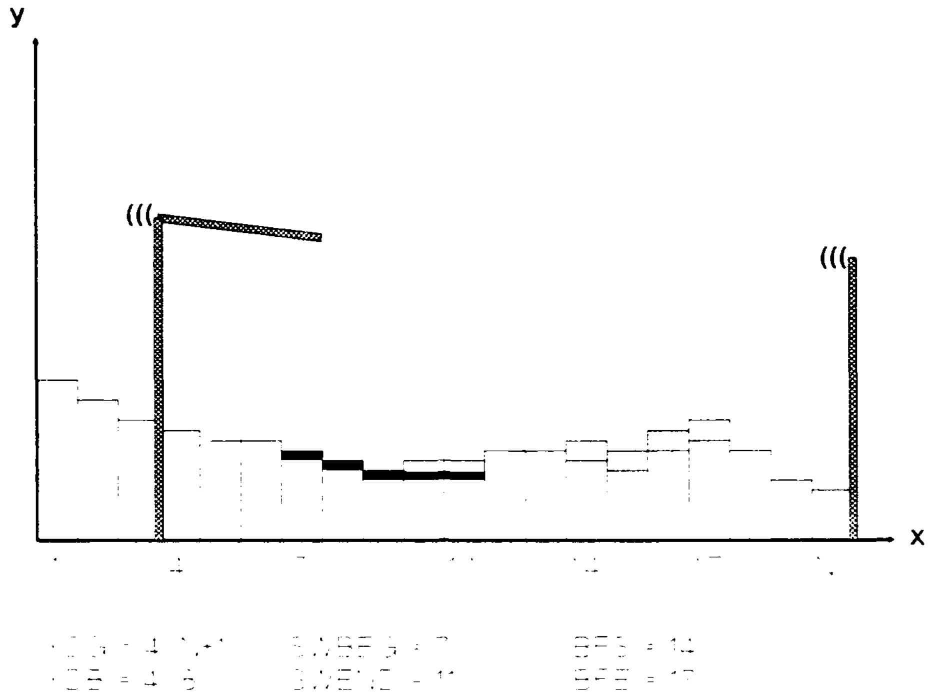


Figure 8.15. Specification of diffracting groins, seawalls, and beach fills.

PART 9: INTERPRETATION AND PRESENTATION OF GENESIS RESULTS

Evaluation of Calibration and Verification Simulation

1. As stated in the Technical Reference, model calibration refers to the procedure of determining the values of input coefficients in reproducing with the model changes in shoreline position that were measured over a certain time interval. Verification refers to the procedure of applying the model, with the same empirical coefficient values as the calibration to reproduce changes measured over a time interval different than the calibration interval. Successful verification is taken to indicate that model predictions are independent of the simulation interval. By this procedure, it is assumed that project conditions are stationary through time. Therefore, the modeler must be aware of significant changes in the physical situation that might invalidate the original verification and require new verification. Part V of the Technical Reference gives a more thorough discussion on this topic, including project evaluation, extreme events, boundary conditions, and model calibration/verification.

2. Model predictions are conveniently, although somewhat subjectively, compared by graphical means. To provide an objective measure of goodness of fit, GENESIS calculates a "Calibration/Verification Error" expressing the average absolute difference between calculated and measured shoreline positions. However, as our judgement in minimizing the discrepancy between calculated and measured shoreline positions may be influenced more strongly along some portions of the beach than along others, an average mathematically-based criterion should always be checked by visual inspection of shoreline position. For example, along a modeled reach, the major portion may be natural beach with no commercial or private property located in the vicinity of the shore, whereas small sections of the beach may hold houses and roads seriously threatened by even minor erosion. In such a case, the calibration/verification effort would, if necessary, focus on reproducing as accurate as possible shoreline changes along the sensitive portions of the beach at the expense of a good average agreement for the whole modeled reach.

3. Although the general aim of shoreline modeling is to simulate long-term change in shoreline position, information on volumetric changes can often serve as a valuable and sensitive tool in the calibration/verification procedure. In addition, the performance of beach fill operations are often evaluated in terms of volumetric changes rather than on the basis of

shoreline position. The reason is that the objective of a beach fill project usually is to obtain a certain beach area rather than a specific shape of the shoreline. A case study, as documented in Part VIII of the Technical Reference, gives an extensive discussion on the utilization of volumetric changes as a means of optimizing model setup parameters as well as modeling results.

4. In simulations involving long time periods, the wave data file may not cover the full simulation period. Instead, a shorter wave data file may be used and repeated. However, because the wave climate changes over time, the available wave data set may better represent the wave climate that existed during some periods than other periods. To some extent expected changes in wave conditions may be represented by adjusting the wave height and direction using the parameters *HCNGF, ZCNGF,* and *ZCNGA* as specified in the START file. Therefore, in some cases it may be necessary to use different values on these parameters for the verification period than used for the calibration period. In special cases, also other input parameter values may have to be altered in order to obtain good representation in GENESIS of a particular time period.

5. This case was clearly demonstrated in the case study for Lakeview Park, Lorain, Ohio, as presented in the Technical Reference. Figure 9.1 plots measured volumetric changes within the study area using the October 1977 volume as reference. Because the volumetric changes varied significantly with season, only the fall season values are displayed. For this case, only a 1-year long record of wave data was available. Also, aerial photographs showed that the conditions on the eastern boundary changed over the studied time period. Therefore, it was doubtful that the same wave conditions that resulted in a net gain of about 4,300 cu yd of sand during the calibration period would likely produce a net loss of about 300 cu yd for the verification period if all other input parameters were left unchanged.

Figure 9.1. Volume changes at Lakeview Park, Lorain, Ohio

6. Thus, the distance *YG1*, which to a large extent controls the gated boundary condition at the east boundary and specified in the START file, was specified to be different during the calibration and verification periods, respectively, as determined from measurements of shoreline position on the aerial photographs. In addition, the verification indicated

that the value of the Wave Height Change Factor *HCNGF* had to be set to 1.1, resulting in a 10 percent increase in offshore wave height, to obtain good agreement between measured and calculated volumetric change as well shoreline position. As seen from Figure 9.1 the agreement between the measured and the calculated volumetric changes was very good, as was the case for the shoreline positions as illustrated in the Technical Reference.

Variability in Coastal Processes

Problem of variability

7. Incident waves vary in space and time, and sediment particles of various sizes and shapes move along and across the shore controlled by laws which are not well known. The sediment is transported in complex three-dimensional circulation patterns of various spatial and time scales and degrees of turbulence. The beach and back-beach also exhibit different textural properties that vary alongshore, across-shore, and with time. In light of the profound variability of coastal processes, it is clear that a single answer obtained with a deterministic simulation model must be viewed as a representative result that has smoothed over a large number of unknown and highly variable conditions.

8. Similarly, in use of a deterministic model in a predictive mode, the factors responsible for beach change are not known in detail. A time series of wave height, period, and direction must be forecast for use in the prediction and can be considered as only one of many possible wave climates that might occur.

Accounting for variability

9. Since there is great variability in the nearshore system, any one prediction of shoreline change cannot be accepted as the correct answer. A simple procedure used at CERC to estimate the effect of wave variability is to compute the standard deviation of the wave height and direction in the input wave time series and then adjust values of the input waves through a range defined by these deviations. GENESIS allows adjustment of wave height and direction by user-specified amounts through the parameters *HCNGF*, *ZCNGF*, and *ZCNGA* as specified in the START file. Wave period is not normally varied, but in certain applications, such as a situation involving waves of long periods or a sea bottom with highly

irregular features, the refraction pattern will be particularly sensitive to wave period. Such an adjustment of the wave period is performed by direct manipulation of the WAVES file.

10. Another procedure uses different hindcast time series if such data are available. By varying the input wave height and direction within a physically reasonable range, a series of shoreline change predictions is made within which the actual change is expected to lie. Variation of model setup parameters is also part of the sensitivity analysis to be performed to obtain an estimate of the dependence of the calculated result on model setup and empirical parameters, as discussed in a later section.

Shoreline position

11. Plots of shoreline positions may reveal errors in the data as well as trends in shoreline change. As much as possible, the two surveys defining the respective calibration and verification intervals should be from the same season to minimize the effect of the seasonal cyclical displacement of the shoreline.

Offshore waves

12. Shoreline change is sensitive to wave direction, and this quantity is the most difficult to estimate. If information on wave direction is not available, wind direction from a nearby meteorological station, buoy, Coast Guard station, or airport may be useful, as well as consideration of possible fetches. The effects of the coastal boundary layer and daily and seasonal trends in wind speed, gustiness, and direction should be considered.

13. The wave input interval (time step), statistics of the waves, and the period to be covered must also be determined. For shoreline change model calibration and verification, either hindcast data or the actual wave record occurring over the simulation interval should be used, if available. In simulations involving long time periods and wide spatial extent, it may be impractical to handle a wave data file covering the full simulation period. Instead, a shorter wave data file can be used and repeated, a capability provided by GENESIS. The shorter record is fabricated by comparing statistics of the total available wave data set (gage or hindcast) by year, season, and month. Typical quantities which should be preserved are average significant wave height and period, maxima of these quantities, average wave

direction, and occurrence of storms. For example, a 5-year record might be composed of one year of more frequent storms (but not the extreme year as that would not be representative), a year of relatively low waves, and three years judged to be "typical."

Bathymetry and profiles

14. If a wave refraction model is used, hydrographic charts are needed to digitize the bathymetry onto the numerical grid. For users with sufficient computer hardware and related capabilities, bathymetric data for US coasts may be obtained on magnetic media from the National Oceanic and Atmospheric Administration (NOAA) and then interpolated to the grid. The nearshore information from bathymetric charts can be compared with available beach profile surveys. Profile surveys often extend to a nominal depth of 10 m (30 ft), providing information to supplement the charts. If calibration and verification simulation intervals are in the far past (for example, in the 19th century), bathymetric data from that period should be used, not the present bathymetry. This is especially pertinent if an inlet is included in the wave modeling grid, since ebb shoals can greatly change.

15. Profile data are used to estimate three quantities required to operate GENESIS: the average height of the berm, the depth of closure (seaward limit of significant sediment movement), and the average profile slope.

Sensitivity Testing

16. Sensitivity testing refers to the process of examining changes in the output of a model resulting from intentional changes in the input. If large variations in model predictions are produced by small changes in the input, calculated results will depend greatly on the quality of the verification, which is usually in some degree of doubt in practical applications. A second reason for conducting sensitivity tests concerns the natural variability existing in the nearshore system, as discussed in a previous section. No single model prediction can be expected to provide the correct answer, and a range of predictions should be made and judgment exercised to select the most probable or reasonable result. If the model is oversensitive to small changes in input values, the range of predictions will be too broad and, in essence, provide no information. Experience has shown that GENESIS is

usually insensitive to small changes in parameter values. Nevertheless, sensitivity testing should always be done.

Effect of input errors

17. The measurement of prototype wave characteristics (height, period, and direction) is a difficult task. When using such data as input to a numerical (or any other type of) model, it is therefore important to be aware of the potential uncertainties involved in the determination of these wave data, as well as the effects any errors might have on the model predictions. In this section, a simple sensitivity analysis is made, as an attempt to obtain a quantitative measure of the effects of small errors in the breaking wave height and angle.

18. The change in the calculated value of the longshore sand transport rate Q is used as the sensitivity criteria, as this is the primary variable of importance for the shoreline change. The analysis is carried out to the first order, which is accurate within 1 to 2 per cent.

$$Q = (H^2 C_g)_b \left(a_1 \sin 2\alpha_{bs} - a_2 \cos\alpha_{bs} \frac{\partial H}{\partial x}\right)_b \tag{9.1}$$

in which H = significant wave height (m), C_g = wave group speed (m/s), b = subscript denoting wave breaking condition, α_{bs} = angle of breaking waves to the local shoreline, a_1 and a_2 are nondimensional parameters, x = alongshore direction.

19. Assuming shallow water at the location of wave breaking, the wave group velocity C_{gb} can be approximated:

$$C_{gb} = C_b = \sqrt{g D_b} = \sqrt{g H_b / \gamma} \tag{9.2}$$

where γ is the proportionality constant for the wave breaking criterion, and g is the acceleration of gravity (m/s^2). This relation inserted into Equation (9.1) with $a_2 = 0$ and using α as short for α_{bs} yields:

$$Q = Q(H,\alpha) = (H^{5/2} \sin 2\alpha)_b \, a_1 \sqrt{g/\gamma} \tag{9.3}$$

20. The relative error in Q due to an error dH in the breaking wave height can be determined as, approximated to the first order in a Taylor series (omitting the subscript b for breaking):

$$\frac{Q(H \pm dH,\alpha)}{Q(H,\alpha)} = \frac{(H \pm dH)^{5/2}}{H^{5/2}} = 1 \pm \frac{5}{2}\frac{dH}{H} \tag{9.4}$$

A similar analysis for a wave angle error $d\alpha$ gives:

$$\frac{Q(H,\alpha \pm d\alpha)}{Q(H,\alpha)} = \frac{\sin(2\alpha \pm 2d\alpha)}{\sin(2\alpha)} = \frac{\sin(2\alpha) \pm 2d\alpha \; 2\cos(2\alpha)}{\sin(2\alpha)} = \\ = 1 \pm 2\frac{d\alpha}{\alpha} \tag{9.5}$$

Consequently, if the two errors appear simultaneously, the relative error in Q would be:

$$\frac{Q(H \pm dH,\alpha \pm d\alpha)}{Q(H,\alpha)} = (1 \pm \frac{5}{2}\frac{dH}{H})(1 \pm 2\frac{d\alpha}{\alpha}) = \\ = 1 \pm \frac{5}{2}\frac{dH}{H} \pm 2\frac{d\alpha}{\alpha} \pm 5\frac{dH}{H}\frac{d\alpha}{\alpha} \tag{9.6}$$

Assuming the errors dH and $d\alpha$ to be 10% each (and to have the same sign), which is considered to be a low number, the relative errors in Q would be 25%, 20%, and 50% (!) for the three respective cases. Thus, it is seen that even with small errors in the determination of breaking wave heights and angles result in significant errors in the longshore sand transport rate.

21. The rate of change of shoreline position is calculated from the relation:

$$\frac{\partial y}{\partial t} + \frac{1}{D}\frac{\partial Q}{\partial x} = 0 \qquad (9.7)$$

Viewing Equation (9.7), it is seen that deviations of the same order will appear in the shoreline change calculation. With this in mind, it is reasonable to obtain variations in the calibration parameters by a factor of 2 or more from one site application to another.

22. An illustration of the effect of changing magnitudes on wave height and direction is given in Figure 9.2. The wave climate was held constant during the respective simulations with a period of 4 sec and a total simulation time of 100 hrs. The shoreline response to an increasing obliqueness of the waves, as indicated by the thick and thin solid lines, shows a surprising linearity. The maximum shoreline advance close to the groin, as well as the accumulated volume, almost exactly doubles when the wave angle is doubled from 10 to 20 deg. This confirms the findings in Larson, Hanson, and Kraus (1987) that the sand transport relation is relatively linear with respect to wave angles if the incident breaking wave angle is less than about 30 deg.

23. Not unexpectedly, variations in the wave height, as illustrated by the thick solid, the dashed, and the dotted lines, show a much higher degree of non-linearity. A doubling of the wave height from 0.5 to 1.0 m results in an increased shoreline advance near the groin by a factor of 2.7 and an increased accumulated sand volume by a factor of about 5. An increase in wave height by 50 per cent results in a doubled shoreline advance as well as accumulated volume.

Figure 9.2. Influence of varying wave height and direction on shoreline change near a groin

24. An illustration of the effect of changing magnitudes on wave period is given in Figure 9.3. The wave climate was held constant during the respective simulations with a wave height of 1 m, normally incident wave crests, and a total simulation time of 100 hrs.

Figure 9.3. Influence of varying wave period on shoreline change behind a detached breakwater

25. As seen from the figure, an increasing wave period results in a greater salient behind the structure segment. The explanation for this is given in Figure 9.4. illustrating the associated wave height distributions inside of the detached breakwater for the three simulations in Figure 9.3. In the figure, the wave height distributions associated with wave entering on either side of the breakwater are shown separately. The longer waves shoals faster than the shorter waves, resulting in a greater breaking wave height. This means that, for longer waves, the first term in the transport Equation (K_1 - term), with a higher H-value, will transport more sand into the area behind the breakwater. Also, according to the method of Goda, Takayama, and Suzuki (1978) for calculating diffraction of random waves, the wave height for longer period waves decreases faster the that of shorter period waves. This means that, again for the longer waves, also the second term in the transport Equation (K_2 - term), with a higher $\partial H/\partial x$-value, will transport more sand into the area behind the breakwater.

Figure 9.4. Influence of varying wave period on wave height distribution near a detached breakwater

Effect of wave variability

26. Another basic property of wave time series, besides the mean value as discussed above, is the standard variation. As mentioned previously, the standard deviation is used as a measure of the wave variability, and determines the probability and magnitude of extreme events. In a forecasting situation, it is therefore of great importance to investigate the effect of changing the variability (standard deviation) on the resulting shoreline change.

27. Figure 9.5 illustrates an example showing the accumulation behind a 200 m long detached breakwater located 200 m off the initial straight shoreline. The mean values characterizing the wave climate are: $T = 4$ sec, $H = 1$ m, and $\theta = 0$ deg. The thin solid line represents a constant wave climate with $T, H,$ and θ at their mean values. In the other three simulations two of the three parameters were held constant while the third (thick solid line) as compared to that of holding two of the parameters fixed and having the third

normally distributed with standard deviations given in the figure as percentages of their respective mean values.

28. As seen from the figure, allowing the wave period T and height H to vary has very little effect on the shoreline response. As a contrast, an increased variability in the wave direction dramatically increases the accumulation behind the structure. The major reason for this is the fact that a variation of T and H normally around their respective mean value merely redistributes the incoming wave energy in time but does not to any significant extent change the total amount of longshore wave energy flux coming in. A deviation of the wave direction from normal in any direction, however, increases the longshore component of wave energy flux, which in turn causes more sand to move alongshore. Due to shadowing from the structure, more sand will be transported into than out of the shadow region behind the structure accounting for the large growth of the salient.

Figure 9.5. Influence of wave variability on shoreline change behind a detached breakwater

Effect of boundary conditions

29. As described in the Technical Reference, GENESIS allows two types of lateral boundary conditions to be implemented, a "gated" boundary and a "pinned beach" boundary. The default condition is the pinned beach; if a groin, jetty, or shore-connected breakwater is not placed on a boundary it will be treated as a pinned beach, allowing sand to freely cross it from both sides. If such a structure is placed on the boundary, the amount of sand entering or leaving the grid is determined by the distances from the shorelines on either sides of the groin to the seaward end of the groin, the beach slope near the groin, and the permeability of the groin. Needless to say, the location and specification of the lateral boundaries influence the simulated shoreline response along the whole project. The degree of influence should be analyzed through sensitivity.

30. Pinned-beach boundary. The pinned-beach boundary can used in situation where a long sandy beach is located far from the project site and has not or is not expected to change greatly in position. However, care should be taken not to place the pinned boundary too close to the project. The true interpretation of the boundary condition is "the beach does not want to move," but by placing the boundary too close the implementation of the condition

will be "the beach is not allowed to move." The independence of the result on this distance should be checked by varying the distance. An example of such an analysis is shown in Figure 9.6.

31. The figure displays three simulations of the accumulation updrift of a 200 m long jetty connected to a 100 long detached breakwater. The constant wave conditions were: $T = 4$ sec, $H = 1$ m, and $\theta = -10$ deg. Thus, the pinned beach should be placed far enough from the jetty to make the location of the simulated beach independent of the distance. More cells gives a more accurate result but cost more time/money to perform the simulations. As seen in the figure the difference in calculated shoreline positions between placing the boundary 600 or 900 m from the jetty is marginal. In contrast, placing the boundary only 300 m from the jetty is seen to hold the shoreline back significantly. Thus, placing the boundary 600 m from the jetty seems like a good compromise.

Figure 9.6. Influence of pinned-beach location on shoreline change near a groin

32. Gated boundary. The gated boundary condition offers the modeler considerable flexibility to control the rate of sand transport across a boundary. Apart from representing groins and jetties on the boundary, this boundary is used to represent often unknown transport past headlands and other portions of beaches with limited amounts of sand available. Assuming the gated boundary is implemented at cell wall 1, the amount of sand entering the grid is controlled by the distance Y_{G1} from the shoreline to the seaward end of the groin/jetty outside the grid (c.f. Figure 20 in the Technical Reference) and the permeability *PERM* of the groin. On the same boundary, the amount of sand leaving the grid is controlled by the distance from the shoreline to the seaward end of the groin/jetty inside the grid $GL - y_1$, where GL is the groin length and y_1 is the shoreline location in the first cell, the beach slope *SLOPE2* near the groin, and the permeability *PERM* of the groin.

33. Figure 9.7 displays examples illustrating the effect of varying the parameters controlling the sand transport across the gated boundary. The wave climate is represented by constant wave period $T = 4$ sec and wave height $H = 1$ m. The wave direction is normally distributed around $\theta = 0$ deg with a standard deviation of 25 deg. This means

that, along unobstructed portions of beach parallel to the x-axis, there is considerable and almost equal amounts of sand being transported in either directions.

34. The thick solid line represents a case with 50 m from the tip of the groin to the shorelines on either side of the structure. With a beach slope of 1:100, the depth at the groin tip is 0.5 m. Thus, in this case, a considerable portion of sand is expected to bypass the structure in either direction, resulting only minor shoreline change to occur near the groin, which is confirmed by the simulation.

35. By increasing y_{G1} to 200 m, virtually no sand will be transported onto the grid, while sand transport out of the grid is the same as in the previous example. This will result in a loss of sand over the gated boundary and associated erosion as illustrated by the thin solid line in the figure. A more gently sloping bottom, represented bv a dashed line in the figure, will allow more sand to bypass the tip of the structure out from the grid. The distance from the groin tip to the shoreline outside the grid is still, however, too long to allow any significant sand transport onto the grid. Thus, the erosion near the groin will increase. In the last example, shown as a dotted line, y_{G1} is reset to 50 m whereas the groin length is increased to 200 m. In this case sand may enter but not leave the grid, resulting in considerable accretion near the groin.

36. As shown by the examples, the transport onto and out from the grid may be varied independently to control the sand transport over the boundary. For the case of a short, non-diffracting groin, the gated boundary condition is expected to represent fairly well conditions in the prototype, for which case y_{G1} may be taken directly as the true distance. For long, diffracting jetties, diffraction outside the grid is not accounted for. This condition may have to be compensated for by changing the distance y_{G1} from its true value. When the gated condition is used for representing headlands or limited availability of sand, y_{G1} does not have a true correspondence in the prototype, but should be determined on the basis of resulting transport rates across the boundary. The effect of varying the groin permeability is discussed later in this Part, and will not be discussed here.

Figure 9.7. Influence of varying gated boundary parameters on shoreline change near a groin

Effect of wave sequence

37. Even if the statistical properties of the future wave climate are estimated (which is a difficult task in itself), the exact sequence of future events can not be known. Still, as shown by Le Mehaute, Wang, and Lu (1983), the calculated shoreline position is sensitive to the order of wave angle sequence, especially for open beaches not affected by diffraction structures. Therefore, when forecasting shoreline evolution for real beaches, the future shoreline configurations should not be presented individually. Instead, it is more appropriate to generate a band of shorelines, using waves with different sequences, within which the "true" shoreline can be expected to lie.

38. In order to investigate the influence of wave angle sequence on GENESIS, the shoreline evolution near a groin was analyzed. For this reason, a set of 320 wave triplets (H, T, θ) was produced. The same set was used to produce all shorelines shown in Figure 9.8. Only the relative order of the triplets was varied, thus holding the total wave energy flux constant. In all runs, the breaking wave height was held constant (1.4 m), and the breaker angle was varied. The total simulation time was 480 hr.

39. As an attempt to examine the maximum impact of resequencing, two unrealistic, ordered wave sequences were examined. In the first set, the wave angle increased linearly from -15 to 15 deg, and in the second the angle decreased linearly between the two limits. As seen, the two sets of waves result in fundamentally different shorelines. In addition, a large number of shorelines were simulated using wave sets obtained with a Monte Carlo simulation technique to resequence the original data set. Four of these are shown as thin solid lines in the figure. Shoreline change for these simulations was rather small as expected, because the angle varied randomly around its mean value ($\theta = 0$).

Figure 9.8. Influence of wave angle sequence on shoreline change near a groin.

40. The analysis can be extended to include variations in wave height. In the simulations shown in Figure 9.9, the breaking wave angle was held constant ($\theta = -15$ deg). The breaking wave height varied between 0 and 1.4 m, thus having the same average height as in the previous case. The figure shows small differences between the two extreme sequences with the wave height increasing and decreasing linearly between the two limits. This is

consistent with the observation made by Le Méhauté et al. (1983). As clearly demonstrated by the dashed line, the average situation cannot be represented by the average wave height. In this simulation the total energy flux is less than for the other curves, explaining the position of the beach well behind the others. If, instead, a constant wave height corresponding to the mean wave energy flux is used, a shoreline (dotted line) falling between the two extremes is produced. A large number of Monte Carlo simulations were also made, but since they all fell on top of the solid and dashed lines, they were not included in the figure.

41. As a conclusion, shoreline evolution is sensitive to wave angle sequence, whereas for the wave height, an energy flux weighted mean can be used, provided that the wave height is only weakly dependent on wave direction.

Figure 9.9. Influence of wave height sequence on shoreline change near a groin.

Effect of discretization in space and time

42. The size DX of the calculation cells is determined on the basis of a compromise between computer execution time, memory, usage charge, and the required spacial resolution. The time step DT is determined in a similar way. In addition, the requirement to update the waves with a certain periodicity, as well as limited information about the waves will affect the choice of DT. Typically, the value of DX is fixed early in the study, leaving only DT to be varied based on numerical and physical accuracy and computation time.

43. In addition to these considerations, for any type of numerical model, we must make sure that the calculated results are grid and time step independent. In order to investigate the sensitivity of the model output to the size of the discrete steps in space and time, a series of calculations were performed. In all cases, the stability parameter R_s was held constant and small (R_s = 0.26) in order to avoid stability problems. The calculation time in each simulation was 480 hr. Other parameters were varied according to Figure 9.10, showing only the part of the beach closest to the groin. In all runs, the breaking wave height and angle were held constant at 0.7 m and -15 deg, respectively. The run with DT = 6 hr and DX = 60 m represents typical values of DX and DT for field applications.

44. For these simulations, the differences are very small even for extremely large time steps, indicating a negligible grid and time step dependence. However, it should be

noted that for simulations involving transmissive detached breakwaters, the grid dependence could be much higher. In such cases, sensitivity analyses should always be performed before a definite determination of *DX* and *DT* is made.

Figure 9.10. Influence of grid size and time step on the calculated accumulation updrift of a groin.

Groin permeability

45. Groins typically allow sand to pass through or over them, but it is difficult to quantify sand permeability. Therefore, it is important to investigate the sensitivity of GENESIS to variations in the value of this parameter. For this reason, a series of simulations were made, illustrating the influence of groin permeability on the sand accumulation updrift of a groin exposed to 0.7-m high breaking waves with an angle of -15 deg to the x-axis for 480 hrs. The result of the simulations is displayed Figure 9.11.

Figure 9.11. Influence of groin permeability on shoreline change near a groin.

46. If the longshore sand transport would be independent of the shoreline orientation, $\partial y/\partial x$, the difference in shoreline location close to the groin would be proportional to the difference in permeability. However, as the beach is accreting near the groin, the change in shoreline orientation will have a feedback effect on the wave refraction. Due to associated changes in the wave direction and height near the groin, the sand transport rate will decrease with distance from the groin. As a result, the decrease in sand accumulation caused by the permeability is partly compensated by the reduced speed at which the sand transport rate decreases updrift of the groin. This is confirmed in Figure 9.11 were the differences between the runs are very small. If diffraction was not taken into account, the eroded shoreline downdrift of the groin would be anti-symmetric to that on the updrift side.

47. Fortunately, although a precise determination of the groin permeability is not possible to make, we can conclude that GENESIS is rather insensitive to changes in this value. At the same time, it should be noted that the effect of groin permeability in GENESIS is dependent on the representation of the groin, as a gated boundary condition. At present, the amount of sand that is allowed to pass through the groin is proportional to the transport

rate at the immediately updrift grid cell (Perlin and Dean 1978). It is expected that, as a result of ongoing research, GENESIS will undergo revision in this capability, as discussed in Gravens and Kraus (1989). Comparative calculations have shown that there are alternative representations of the groin boundary condition (Hanson and Kraus 1980) that provide greater sensitivity of shoreline position on permeability than the one presently implemented in GENESIS.

Detached breakwater transmissivity

48. In most cases, detached breakwaters designed for shore protection allow some portion of wave energy to pass through or over the structure since it is economical and often advantageous from the perspective of beach change control to build low or porous structures to allow wave energy to penetrate behind them. Wave transmissivity, referring to waves passing through as well as over a structure, is difficult to quantify. In order to describe wave transmission in the modeling system, a value of a transmission coefficient K_T must be provided for each detached breakwater. The transmission coefficient, defined as the ratio of the height of the incident waves directly shoreward of the breakwater to the height directly seaward of the breakwater, has the range $0 \leq K_T \leq 1$, for which a value of 0 implies no transmission and 1 implies complete transmission.

49. In order to investigate the sensitivity of GENESIS to variations in wave transmission, a series of simulations was made, to investigate predicted sand accumulation in the lee of a shore-parallel breakwater, as illustrated in Figure 9.12. The breakwater is 200 m long and located 250 m offshore. Incident waves with $T = 6$ sec and $H = 1.5$ m propagate with the wave crests parallel to the initially straight shoreline. The simulation time was 180 hr. As expected the seaward extent of the induced large salient decreases as wave transmission increases.

50. In comparison of Figures 9.11, illustrating the influence of groin permeability, and Figure 9.12, it is seen that shoreline response is much more sensitive to breakwater transmissivity than to groin permeability. For example, a 20 percent transmissivity reduces the maximum shoreline advance by 36 percent and the accumulated volume by 25 per cent. Due to the difficulty of determining the transmissivity for real structures, the value of the parameter is often best, at present, determined in the calibration procedure.

51. The capability to simulate wave transmission at detached breakwaters and its impact on shoreline change was tested with excellent results for Holly Beach, Louisiana, a site containing six breakwaters of different construction and transmission characteristics (Hanson, Kraus, and Nakashima 1989). This application also showed that it would not be possible to obtain good agreement between prototype measurements and model predictions if wave transmission was not taken into account.

52. Hanson and Kraus (1990) presents a generalized calibration of GENESIS regarding the shoreline response behind detached breakwaters as a function of primary parameters, including wave transmission. Their results are presented as general response criteria for distinguishing tombolo development, salient development, or no effective shoreline change.

Figure 9.12. Shoreline change as a function of transmission

Sand grain size

53. The sand grain size enters GENESIS through the equilibrium beach profile. A finer sand material results in a more gentle beach profile slope, causing waves to break further offshore. However, in areas not influenced by diffraction, the breaking wave height is unchanged. Nevertheless, the calculated transport rate will change in these areas because the average beach slope $\tan\beta$ appears in the second term in the transport equation (c.f. Equation 3), and a steeper beach acts to decrease the influence of this term.

54. Inside a wave diffraction zone, the breaking wave height and angle are sensitive to beach slope, since these quantities depend on the breaking location. The general implication is that a coarser bed material results in smaller shoreline changes. On the downdrift side of a groin, coarser sand beaches will cause the waves to break closer to shore, deeper into the shadow region. The breaking wave heights and angles will be smaller, resulting in less erosion close to the groin. In addition, the wave height gradient, $\partial H/\partial x$, will increase close to the groin, again resulting in less erosion.

55. A fundamentally different situation is displayed in Figure 9.13, showing the shoreline change behind a detached breakwater exposed to 1.4-m high breaking waves with a period of 5 sec and direction normal to the initial straight shoreline. The simulation time was 50 hr. The breakwater is 200 m long a placed 200 m from the initial shoreline. The

influence of grain size is similar to that in the groin case with a finer bed material causing the waves to break further offshore. As a result, the breaking wave heights will be smaller and the waves will be directed more into the shadow zone. Thus, both terms in the transport relation (Equation 2), through θ_{bs} and $\partial H/\partial x$, will promote sand transport into the shadow zone behind the breakwater, resulting in larger salients.

56. Although the impact of sand grain size can be determined qualitatively, a quantitative measure cannot be given. In the situation of a detached breakwater, as discussed above, the grain size effect is not only controlled by physical parameters such as wave period, length of the breakwater, and its distance from the shoreline, but also on the values of the model calibration parameters, K_1 and K_2 . For the example above, these were arbitrarily set to 0.5 and 0.3, respectively.

57. For real beaches, the choice of a representative sand grain size has to rest in part on engineering judgement. For many beaches, significant variations appear both in the alongshore and cross-shore distributions of the grain size, the latter usually being the greater. Bascom (1951) shows, on the basis of data on the US Pacific Ocean coasts, that the cross-shore sand grain size varies by a factor of about 2 in the nearshore area. For implementation into GENESIS, it recommended that measured profiles be matched with the templates in Figure 7 in the Technical Reference to determine the appropriate effective sand grain size.

Figure 9.13. Influence of sand grain size on shoreline change behind a detached breakwater.

Berm height and depth of closure

58. As seen from Equation 1, for a given alongshore sand transport gradient, the shoreline change is inversely proportional to the vertical length of the active profile $D_B + D_C$. As discussed in the Technical Reference, the depth of closure can be determined from profile surveys or estimated by reference to a maximum seasonal or annual wave height. The berm height is similarly specified by the user on the basis of berm profile measurements. For some beaches, it may be difficult to assign a representative value of the berm height. As a result, the user-specified average berm height value, will exceed the real height on some parts of the beach and be below on others. The modeler therefore needs to know the

sensitivity of the model to variations in these two parameters and how an overestimation or underestimation may change the simulated shoreline change.

59. Four runs of evenly spaced values of $1/(D_B + D_C)$ were made. The beach was exposed to 0.7-m high waves with an angle of -15 deg to the x-axis. The simulation time was 480 hr. As illustrated in Figure 9.14, the simulations show the same qualitative features as the groin permeability simulations discussed above. Again, the inter-connection between shoreline orientation and sand transport rate explains the relative small sensitivity of GENESIS to changes in the input parameters. Although the depth of closure between the first and the fourth runs was increased by a factor of four, the calculated shoreline change only decreased by about 50 percent.

Figure 9.14. Influence of berm height and depth of closure on shoreline change near a groin.

Schematic Calibration and Verification Strategies

60. Model calibration and verification should, in a strict sense, be performed only to determine the values of the calibration coefficients K_1 and K_2. All other input values should, in principle, be available and determined prior to the modeling. However, in practice, complete data sets are usually lacking. Therefore, the modeler must use his or her coastal experience as well as numerical experience with models in general and with GENESIS in particular to estimate the lacking input values. Often it is necessary to use GENESIS as a systematic tool to accomplish this. In such cases, the calibration/verification procedure may encompass determination of several input parameters.

61. Generally, only one parameter at a time should be changed in order to isolate its effect and understand its role in the overall balance with other parameters for the particular project. In addition, the strategy should be to first determine values of main parameters controlling known quantities, often the annual gross and net transport rates, or volumetric changes within the study area. In a second stage of the calibration, parameters having mainly local and more minor influence should the be determined to optimize the calibration.

62. As illustrated in the examples presented above, each input parameter has a unique influence on the calculated shoreline location. Table 9.1 gives a general description of how

a change in values of the more common input parameters is likely to affect the simulation. However, it should be noted that this is a broad guidance. Different configurations and applications will require determination of different combinations of parameters, and, in special cases, the actual change in a parameter value may produce a different result than described in Table 9.1.

63. As seen from Equations 2 and 3, the two terms in the sand transport relation, as controlled by the calibration coefficients K_1 and K_2, tend to be dominant in different modeling regions, as the first term is proportional to the magnitude of the wave height, whereas the second term is proportional to the wave height gradient alongshore. This means that the calculated shoreline is especially sensitive to the K_1-value in regions of high waves, such as on the updrift side of groins, whereas the K_2-value exerts great influence in regions with strong wave height gradients alongshore, such as in the lee of groins or detached breakwaters. Figure 9.15 shows a hypothetical example demonstrating the relative influence of K_1 and K_2 on shoreline evolution behind a detached breakwater. The K_1-term tends to flatten out the salient behind the breakwater, whereas the K_2-term tends to promote growth of the salient.

Figure 9.15. Hypothetical example illustrating the influence of the two terms in the sand transport equation. $H_b = 1$ m, $\theta_b = 0$ deg, $T = 3.5$ sec. Simulation time = 90 days.

64. The examples below illustrate possible calibration/verification strategies for applying GENESIS to different schematized configuration. However, the modeler should keep in mind, that each application is unique and may require creative application of GENESIS.

Simple Groin Configuration Example

65. A groin is located along an open beach for which the shoreline position has been surveyed three times t_1, t_2, and t_3 as displayed in Figure 9.16. The first survey was taken just prior to the construction of the groin. The groin is 150 m long, with the seaward

Table 9.1

Effect of Selected Parameters on Calculated Shoreline Position

Name	Function	Value Range (recommended)	Primary Effect
K1	Primary calibration coefficient	≥ 0 (0.1 to 1.0)	Controls magnitude of longshore sand transport rate.
K2	Secondary calibration coefficient	≥ 0 (0.5 K_1 to 1.5 K_1	Controls distribution of sand within calculation area.
ISMOOTH	Size of offshore smoothing window window	1 to N (11)	Controls time scale of shoreline response and equilibrium shape of shore.
HCNGF	Wave height change factor	≥ 0 (0.2 to 1.0)	Effects breaking wave height and location.
ZCNGA	Wave angle change amount	-180 to 180 (-30 to 30)	Effects amount and direction of sand transport.
ZCNGF	Wave angle change factor	≥ 0 (0.2 to 1.0)	Effects directional variability of waves.
IX-	Grid cell number of structure tip	1 to N+1	Effects shape and location of of shoreline change.
Y-	Distance of structure tip to x-axis	-∞ to ∞ (≥ 0)	Effects shape and location of shoreline change.
D-	Water depth at location of structure tip	> 0.01	Controls wave height and direction at diffracting tip. Effects shape and location of shoreline change.
SLOPE2	Bottom slope near groins	> 0	Controls groin bypassing. Effects shoreline change near groins.
PERM	Groin permeability	0 to 1	Controls amount of sand passing through groins. Effects shoreline change near groins.
YG-	Distance from shoreline outside grid to groin tip	≥ 0	Controls amount of sand entering the calculation area.
TRANDB	Transmission coefficient for detached breakwater	0 to 1	Controls amount of wave energy coming through detached breakwater. Affects shape of shoreline change.

end located 100 m seaward of the baseline, coinciding with the initial, approximately straight shoreline. Wave data covering an appropriate time interval are available. The task of the modeler is summarized as: a. calibrate the model, b. verify the model, and c. use the verified model to predict the shoreline location at a time t_4. As a first attempt, standard design mode values are chosen for the input parameters: DX = 50 m and DT = 6 hr. During the simulation, these values may have to be changed on the basis of warning messages issued from GENESIS. Also, checks for grid independence may be performed. Other values, e.g., effective grain size, berm height, and depth of closure, are determined from available pre-project documentation.

Figure 9.16. Measured shorelines for hypothetical groin case

66. The calibration interval is chosen to be from t_1 to t_2. Because shoreline evolution on the updrift side of a groin is usually insensitive to variations in K_2, the first step in the calibration procedure will be to determine K_1 by reproducing the shoreline change updrift the groin, as shown in Figure 9.17. While doing this, little attention is paid to the downdrift side of the groin. For this example, the best agreement was found for $K_1 = 0.5$. In the case of several groins, K_1 would be set to match the measured updrift accretion on one of the groins while exceeding it on the others. For groins experiencing excessive accretion, groin permeability should be set to decrease the accretion to obtain the best possible match. If information on annual gross and/or net transport rates is available, e.g., from dredging volumes or surveys if impound or erosion, K_1 should be set to meet these conditions.

Figure 9.17. Calibration to determine the value of K_1

67. The next step is to determine K_2 by reproducing the downdrift conditions while holding K_1 fixed, as shown in Figure 9.18. Even though good and almost identical agreement was found using $K_2 = 0.5$ as well as for $K_2 = 0.4$, the smaller value was selected. In a more realistic and complex situation, it may be necessary to repeat these two calibration steps to fine-tune the two calibration coefficient values and other parameters that may not be well known from the available data. At this stage it is also recommended that

the modeler examine the result to see if there is a reasonable balance among the input parameters.

Figure 9.18. Calibration to determine the value of K_2

68. When the modeler is satisfied with the calibration results, the model is verified by reproducing actual shoreline change from t_2 to t_3 (Figure 9.19) while holding all parameter values determined in the calibration unless some physical condition has changed that requires modification of a model setup or configuration parameter. If the available wave data time series does not cover the calibration/verification interval and, if, in addition, it is believed that the actual wave climates were different during the calibration and verification intervals, this may be partly compensated for by adjusting wave heights and angles through the use of *HCNGF, ZCNGF,* or *ZCNGA.*

Figure 9.19. Model verification of hypothetical example

69. With the model verified, it is now possible to examine future shoreline change. The first application would be use the present configuration to identify potential problems, and to perform sensitivity analyses as previously discussed. Figure 9.20 shows such a forecast from time t_3 to t_4 , including a simple wave height sensitivity test; a 10 per cent increase or decrease in the mean wave height produces relatively minor changes in the shoreline position. After more realistic sensitivity tests are done to obtain a range of shoreline predictions, the model may be used to perform a series of simulations for evaluating alternative protective plans.

Figure 9.20. Forecasting and sensitivity test

Detached Breakwater Example

70. As described in Table 1, the overall sand transport rate is mainly controlled by K_1. Also, as shown in the previous section, shoreline response updrift of groins is sensitive to changes in K_1. In contrast, shoreline change in the lee of detached breakwaters is often more sensitive to variations in K_2 than to variations in K_1. This means that in situations where the annual gross and/or net transport rate are not known and where there are no groins present, it may sometimes be difficult to determine "true" values of K_1 and, consequently, the associated value of K_2. As illustrated in Figure 9.15, the two *K*-terms tend to counteract each other behind detached breakwaters in the sense that K_1 tends to flatten the salient behind the breakwater, whereas K_2 tends to promote growth of the salient. More than one combination of values for the two *K*-terms may therefore produce reasonable results. In such cases, the selection of calibration values must again rest on the judgement of the modeler, in this case especially in terms of estimation of annual transport rates.

71. Using the case study of the three breakwaters at Lakeview Park, Lorain, Ohio, presented in the Technical Reference as an illustration (see Figure 9.21), typical steps in calibrating GENESIS in a detached breakwater project are summarized. Also, with reference to the thorough treatment of the time-consuming assembly and analysis of data presented in the Technical Reference, this part of the study is not discussed here.

Figure 9.21. Project Design, Lakeview Park

72. The grid space was set at 25 ft (7.6 m) to give 10 cells per breakwater, which were 250 ft (760 m) long. Because of this relatively small grid spacing, in the course of model calibration, the time interval was set to 0.3 hr. In summary, the calibration/verification procedure for the detached breakwater case study was performed as follows:

a. K_1 was varied to obtain historic longshore sand transport rates, estimated in previous studies.

b. K_2 and the distance *YG1* to the shoreline outside the grid to the seaward end of the western (left-hand) groin were varied to obtain the approximate magnitude of net inflow of sand to the study area from the west. At this point, all breakwaters were still considered impermeable. Therefore, all calculated salients were at least as large as the measured ones.

c. The transmission coefficients of the breakwaters were adjusted (increased) to obtain the correct (decreased) size of the salients behind the structures.

d. The longshore location of the eastern detached breakwater was translated two grid cells to the east to obtain better agreement between calculated and measured position of the easternmost salient. This was probably needed to compensate for the effects of irregular bottom bathymetry at the site on wave refraction, whereas in the model straight and parallel contours were used.

e. For the verification, the distance *YG1* was increased, as read from aerial photographs.

f. Although reasonable agreement was obtained for the verification interval, using the same 1-year long wave data set as during calibration, still better agreement was obtained by increasing the input wave height by 10 percent (*HCNGF* = 1.1).

Interpretation of Results

73. Results should always be checked for general reasonability. In this regard, an overview of regional and local coastal processes and the sediment budget calculation or first-order modeling discussed previously should be employed to judge model results. For example, is the overall trend of the calculated shoreline position correct and not just the dominant feature? Do the magnitude and direction of the calculated longshore sand transport rate agree with independent estimates? Experience gained in the verification, sensitivity analysis, and modeling of alternative plans will help uncover erroneous or misleading results. Plots of computed shoreline positions reveal obvious modeling mistakes, whereas more subtle errors of either the model or modeler may be found in the sensitivity analysis through understanding of basic dependencies of shoreline change on the wave input and boundary conditions.

74. Shoreline change is governed by nonlinear processes, many of which are represented in GENESIS. Complex beach configurations and time-dependent wave input will produce results that cannot be extrapolated from experience. However, as much as possible, experience should be called upon to evaluate the correctness of results and to comprehend the trends in shoreline change produced.

75. Finally, the user must maintain a certain distance from model results. It should be remembered that obliquely incident waves are not responsible for all longshore sand transport and shoreline change. Potential errors also enter the hindcast of the incident waves, in representing an irregular wave field by monochromatic waves, and, sometimes, through undocumented human activities and extreme wave events that have modified the beach. The probable range in variability of coastal processes must also be considered when interpreting model results.

<u>Figures</u>

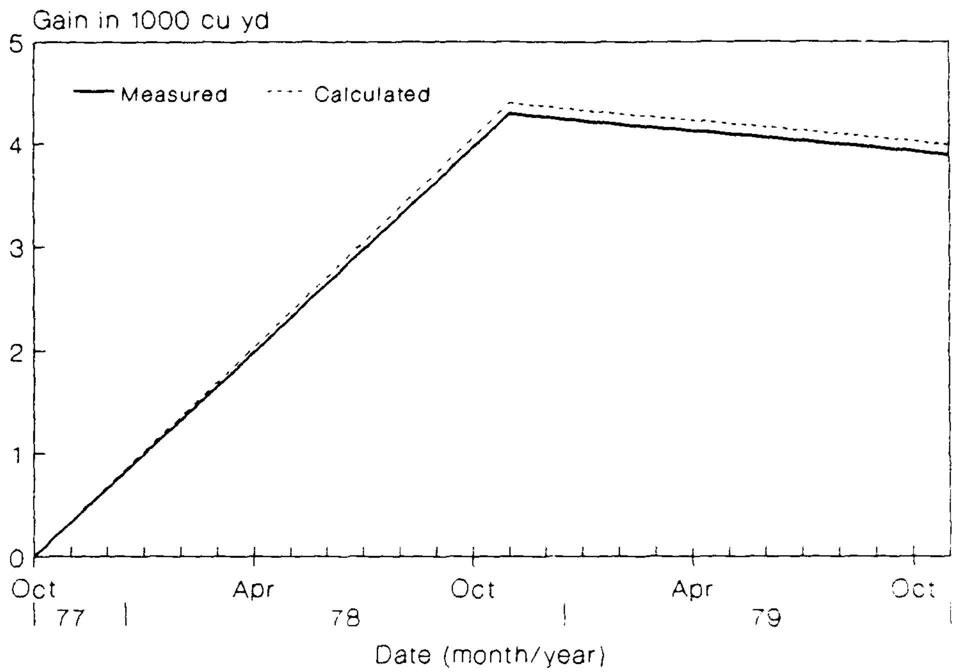


Figure 9.1. Volume changes at Lakeview Park, Lorain, Ohio

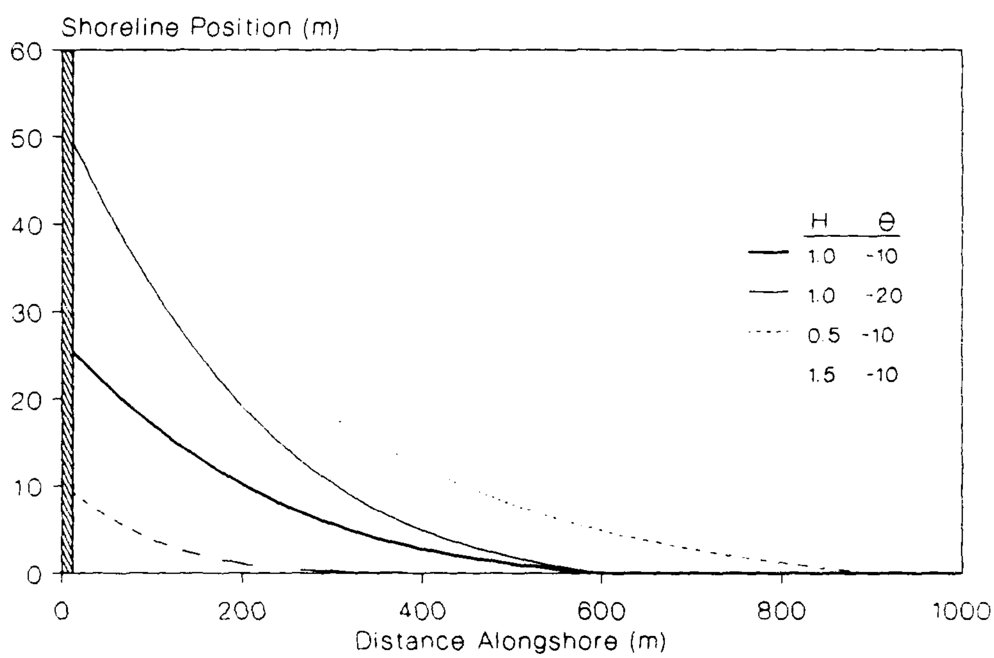


Figure 9.2. Influence of varying wave height and direction on shoreline change near a groin

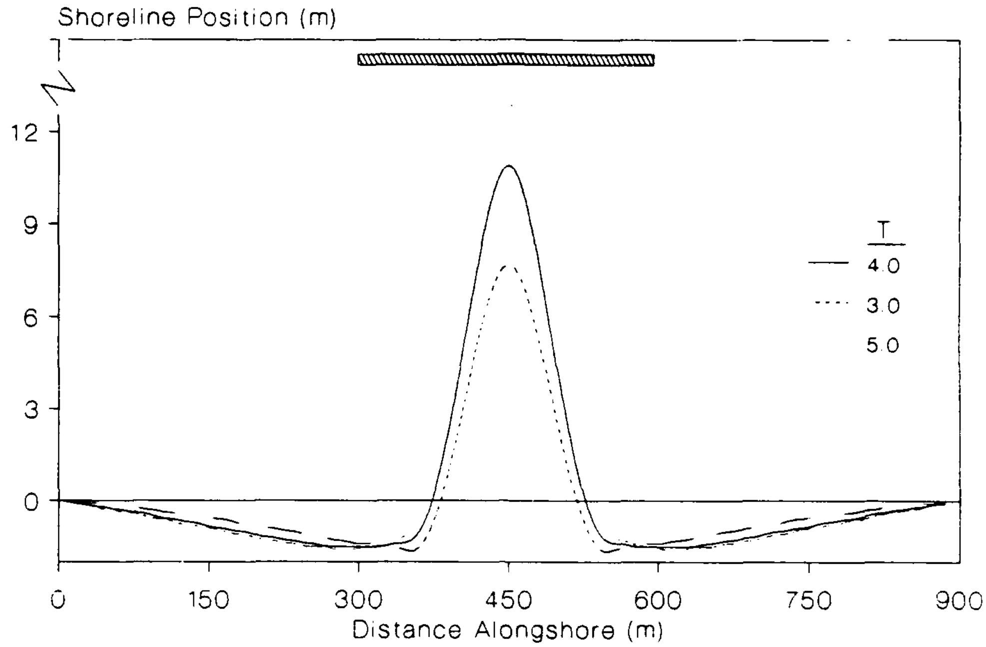


Figure 9.3. Influence of varying wave period on shoreline change behind a detached breakwater

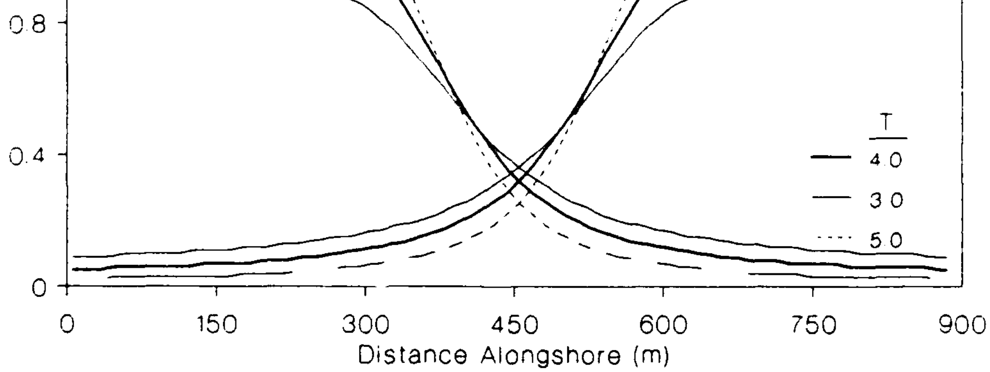


Figure 9.4. Influence of varying wave period on wave height distribution near a detached breakwater

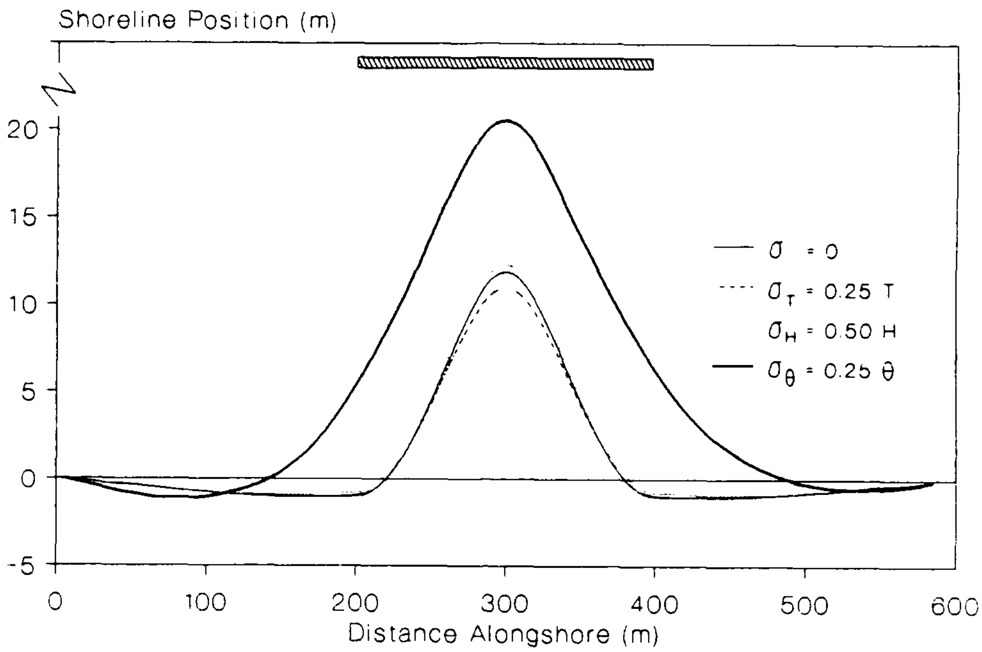


Figure 9.5. Influence of wave variability on shoreline change behind a detached breakwater

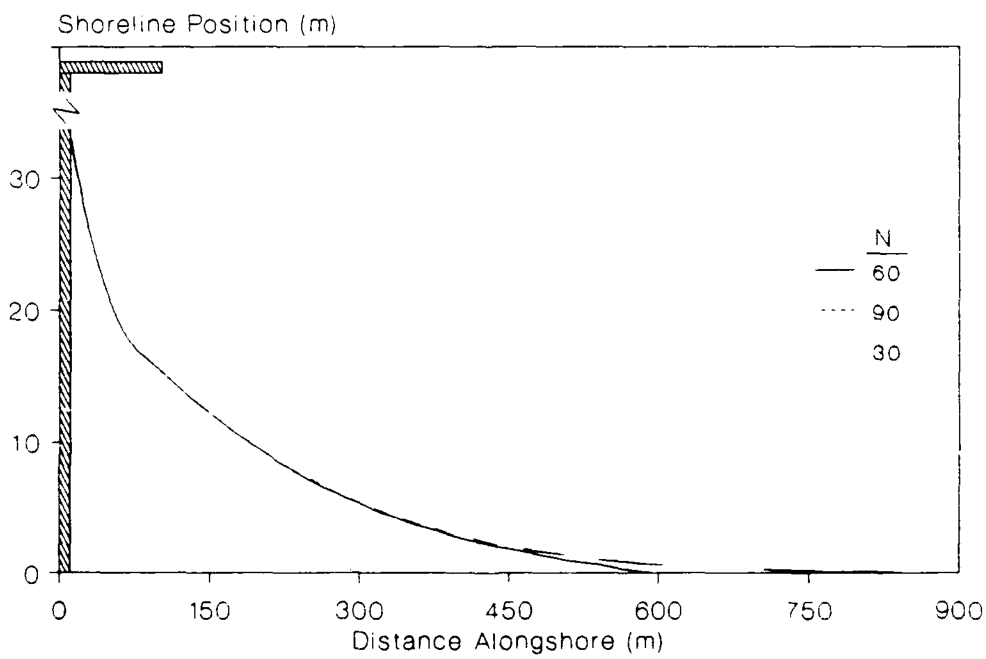


Figure 9.6. Influence of pinned-beach location on shoreline change near a groin

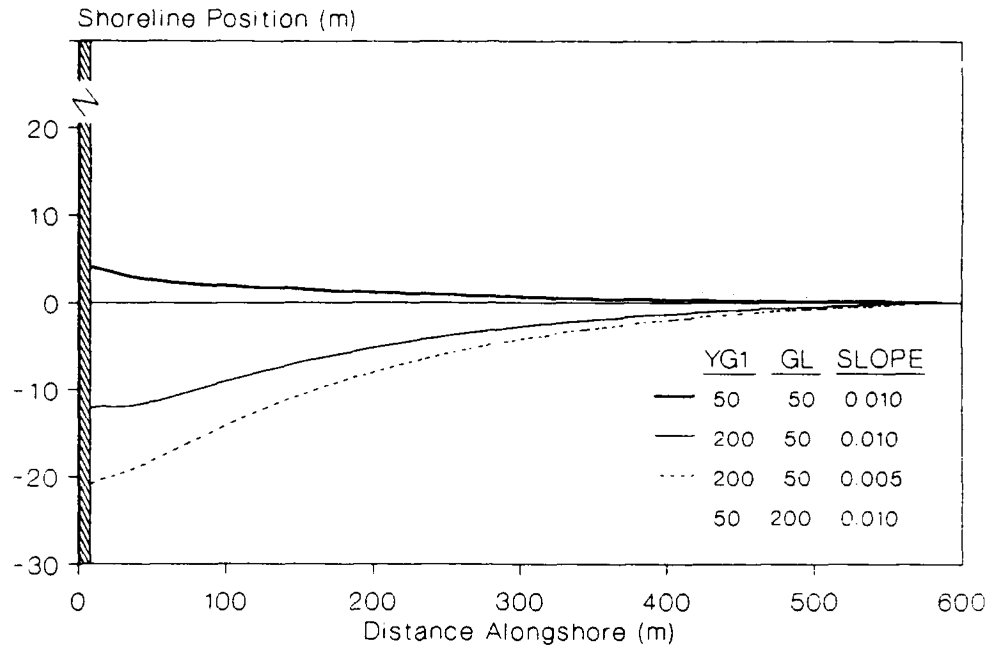


Figure 9.7. Influence of varying gated boundary parameters on shoreline change near a groin

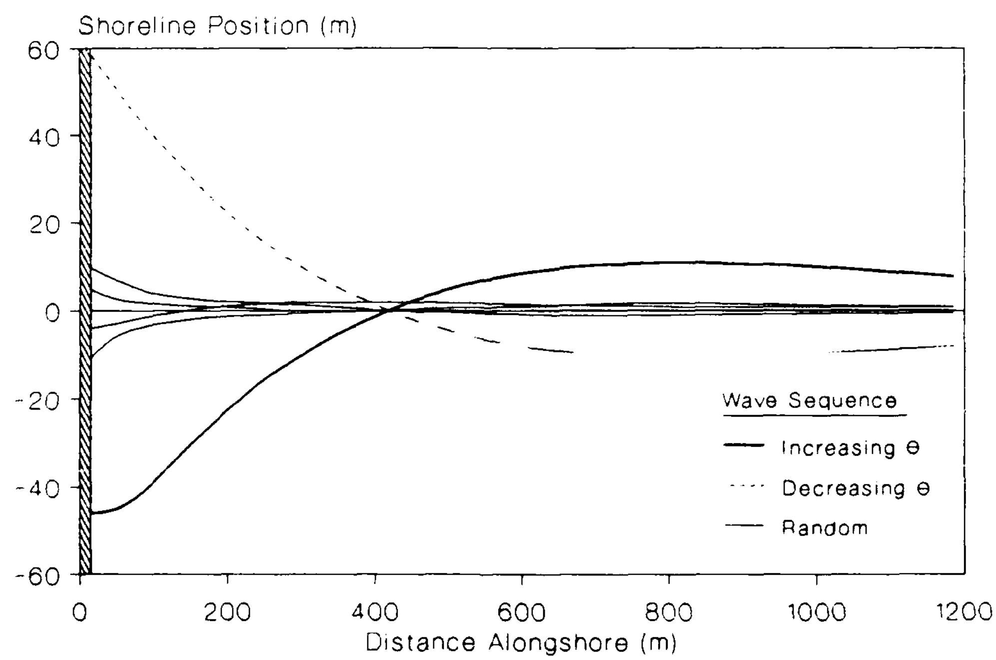


Figure 9.8. Influence of wave angle sequence on shoreline change near a groin.

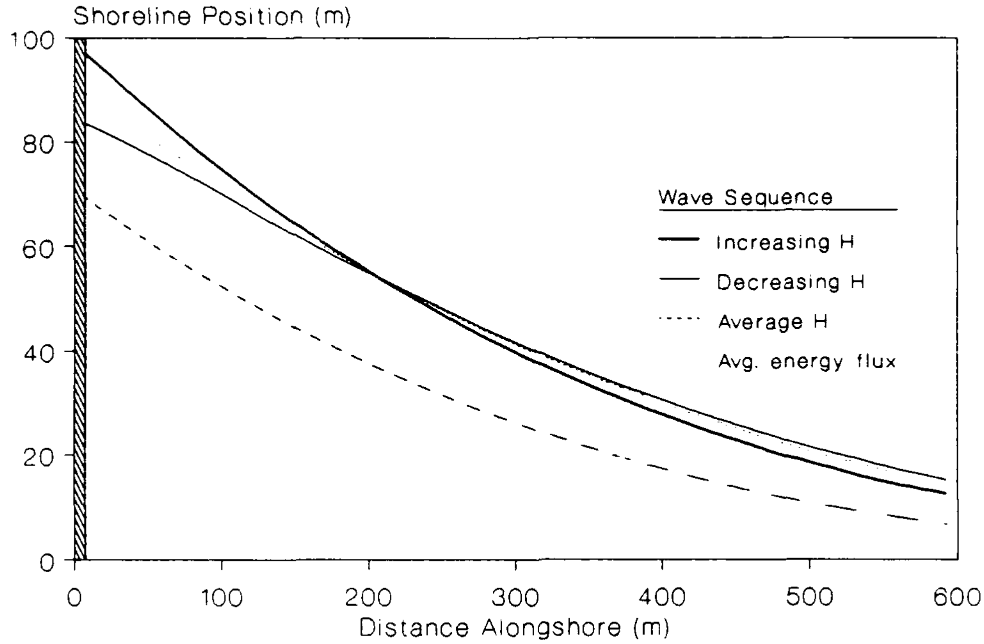


Figure 9.9. Influence of wave height sequence on shoreline change near a groin.

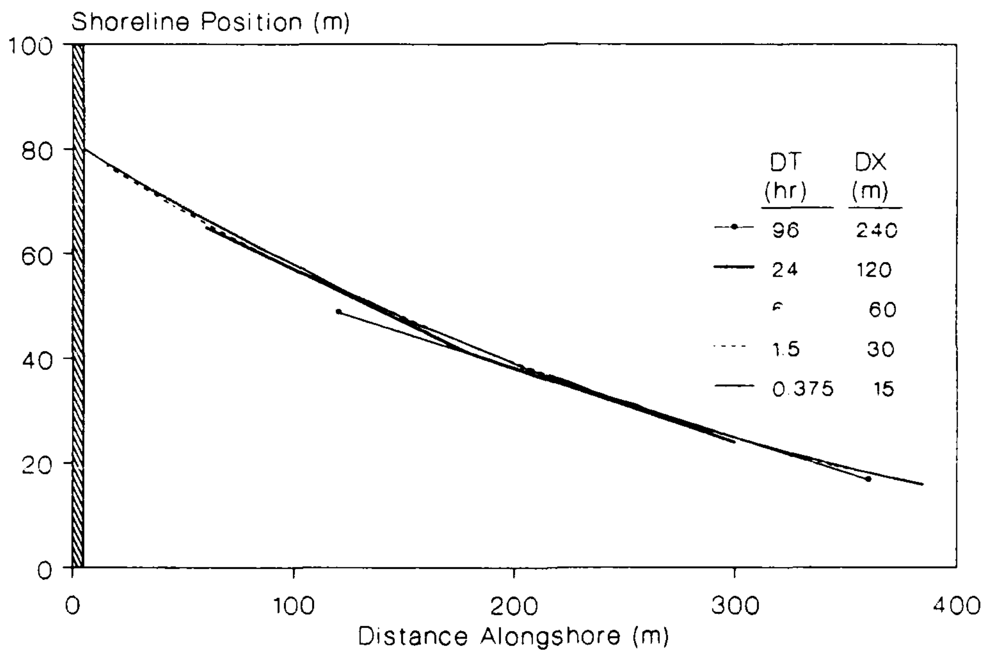


Figure 9.10. Influence of grid size and time step on the calculated accumulation updrift of a groin.

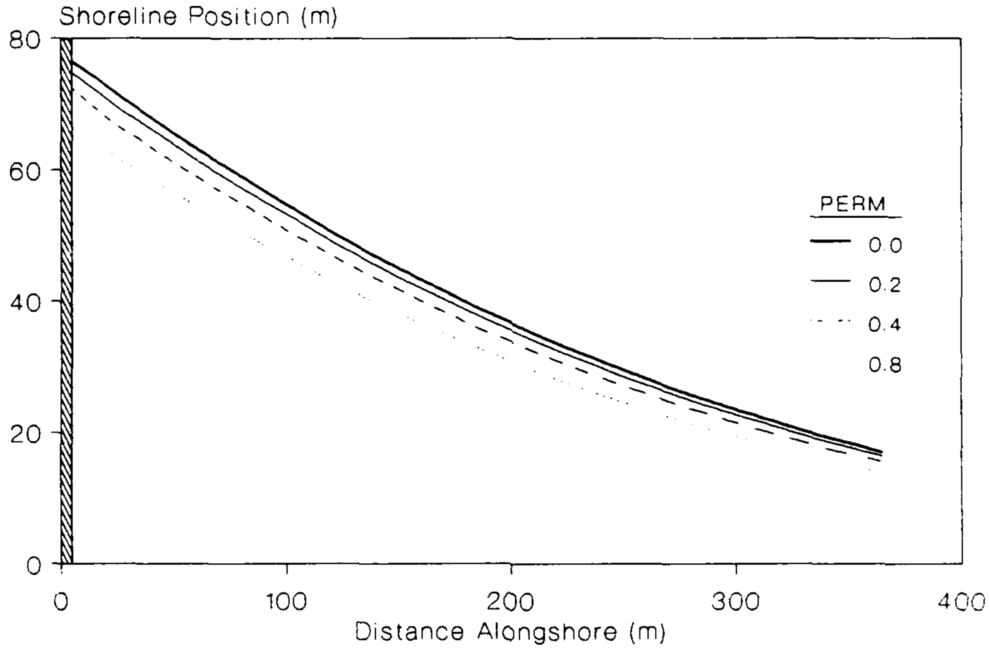


Figure 9.11. Influence of groin permeability on shoreline change near a groin.

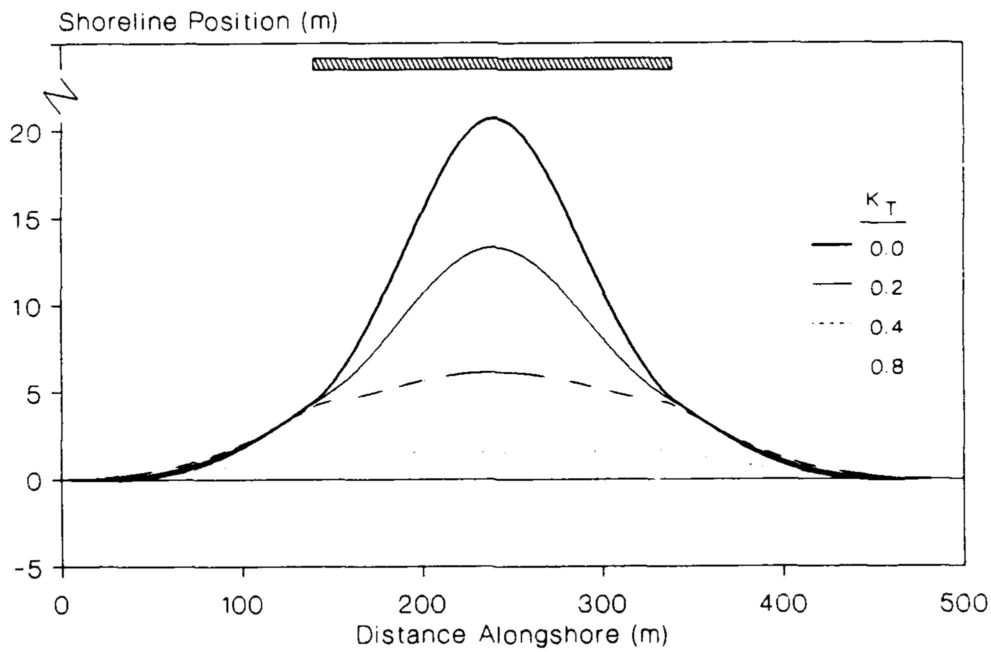


Figure 9.12. Shoreline change as a function of transmission

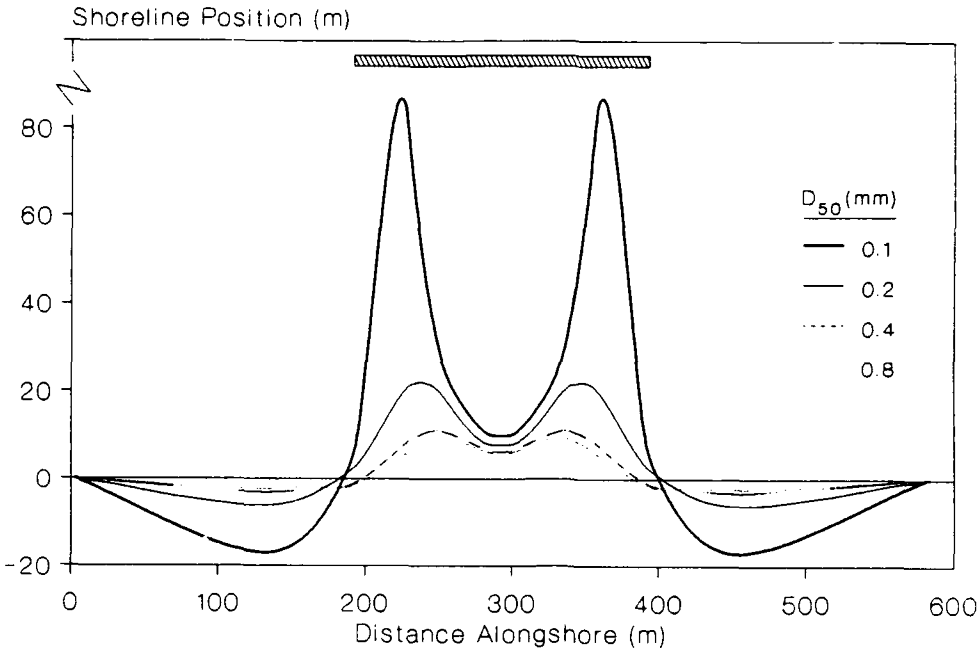


Figure 9.13. Influence of sand grain size on shoreline change behind a detached breakwater.

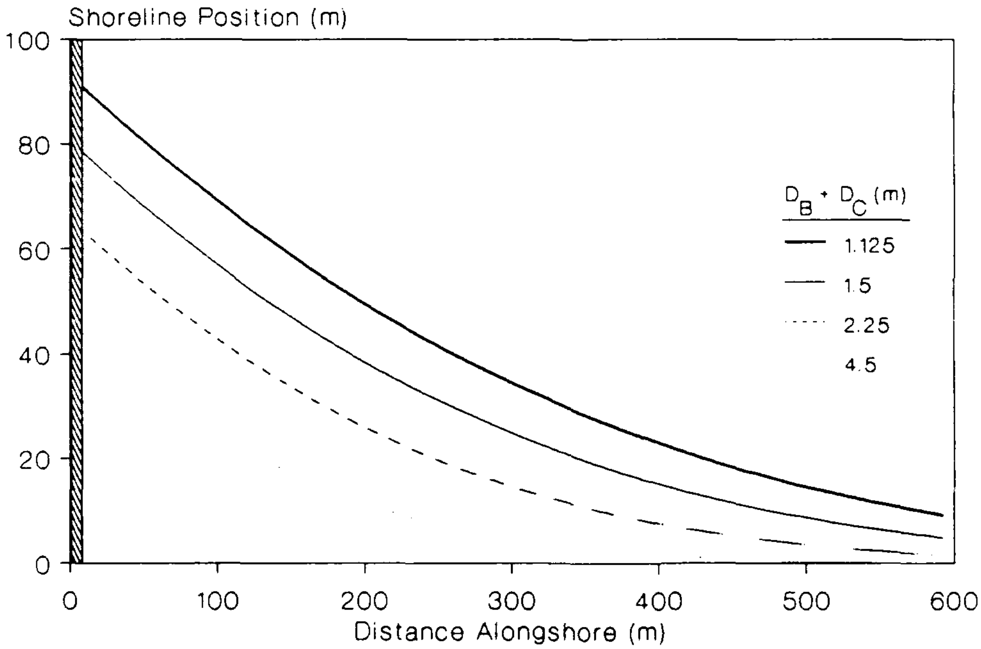


Figure 9.14. Influence of berm height and depth of closure on shoreline change near a groin.

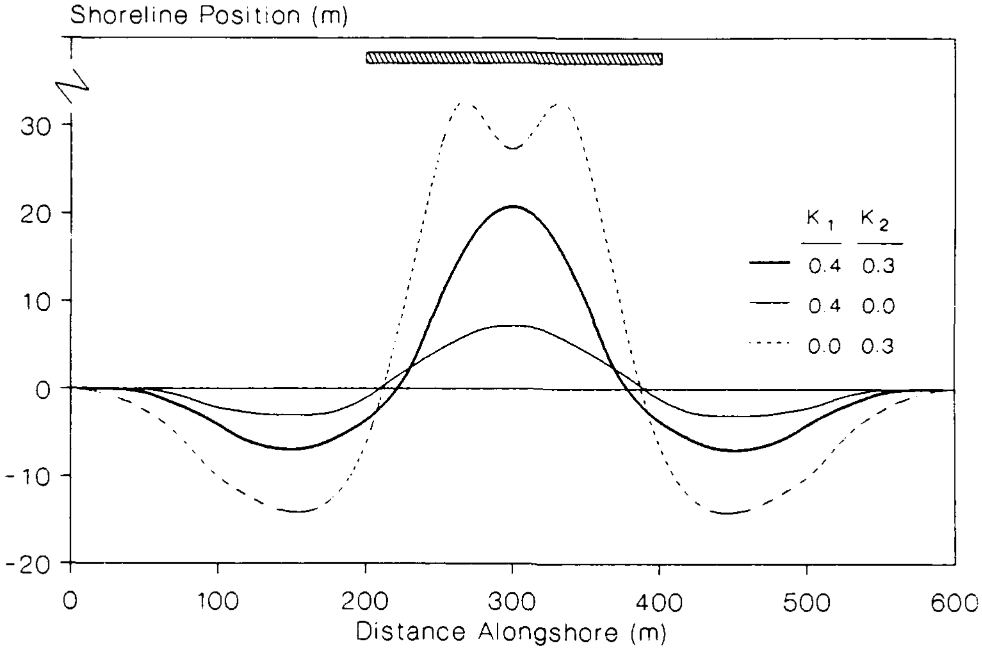


Figure 9.15. Hypothetical example illustrating the influence of the two terms in the sand transport equation. H_b = 1 m, θ_b = 0 deg, T = 3.5 sec. Simulation time = 90 days.

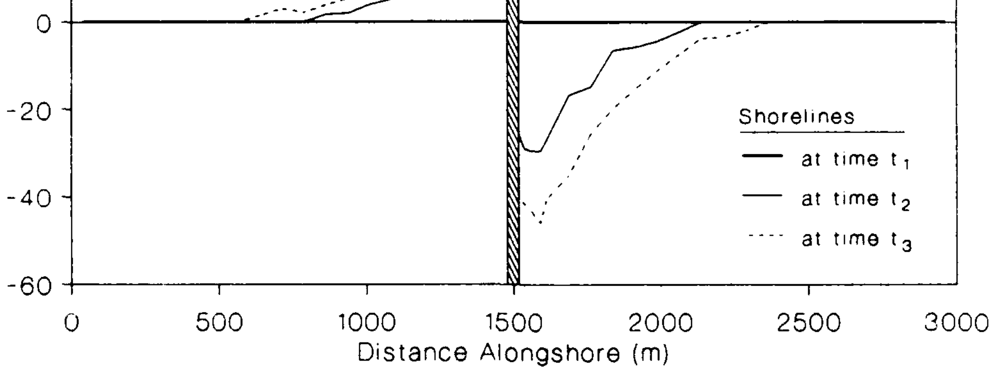


Figure 9.16. Measured shorelines for hypothetical groin case

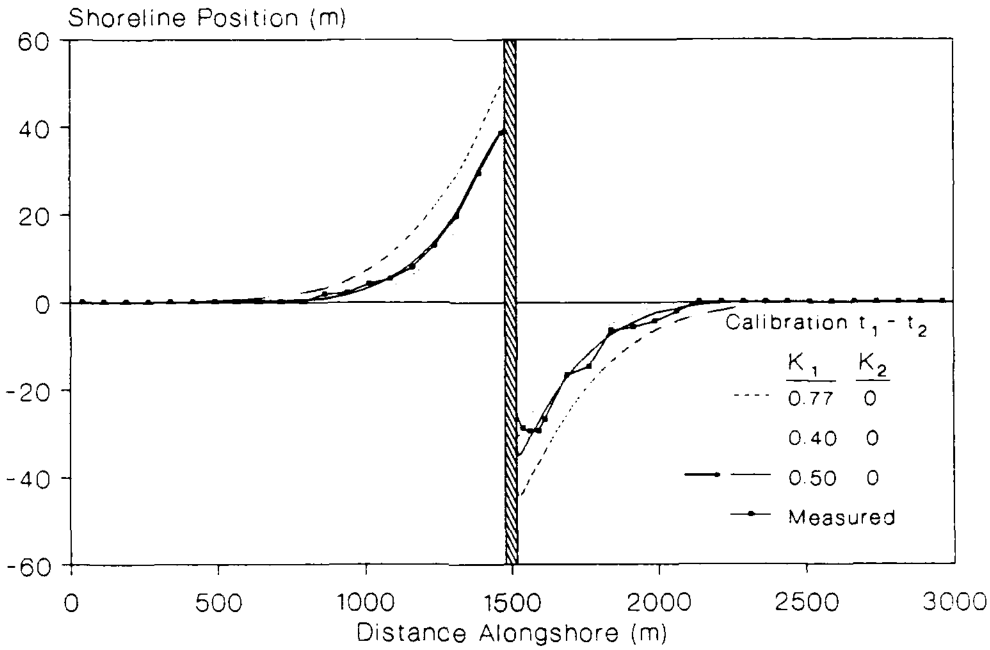


Figure 9.17. Calibration to determine the value of K_1

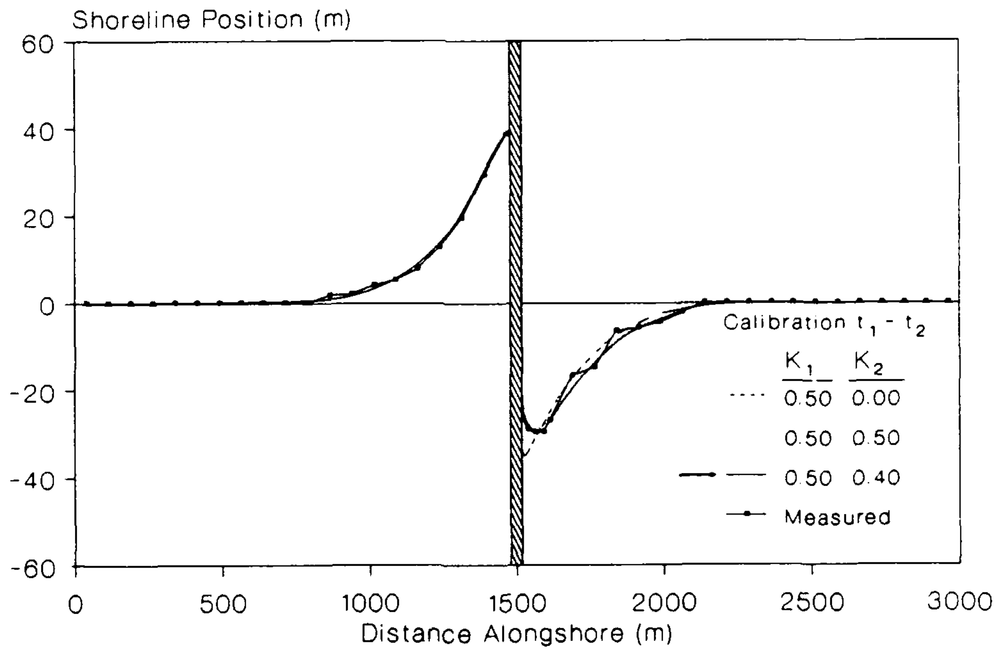


Figure 9.18. Calibration to determine the value of K_2

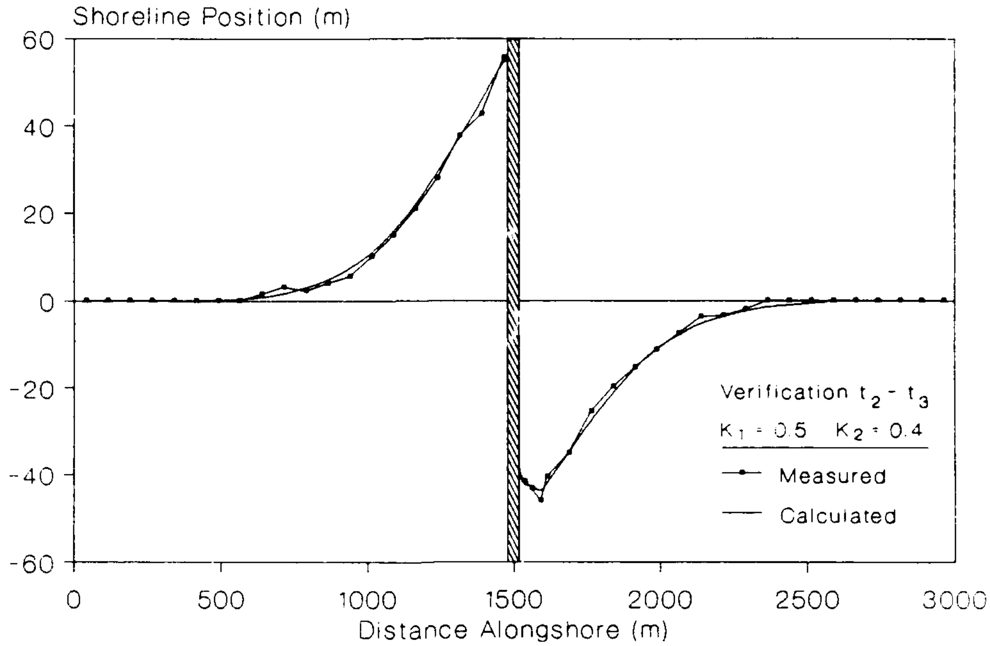


Figure 9.19. Model verification of hypothetical example

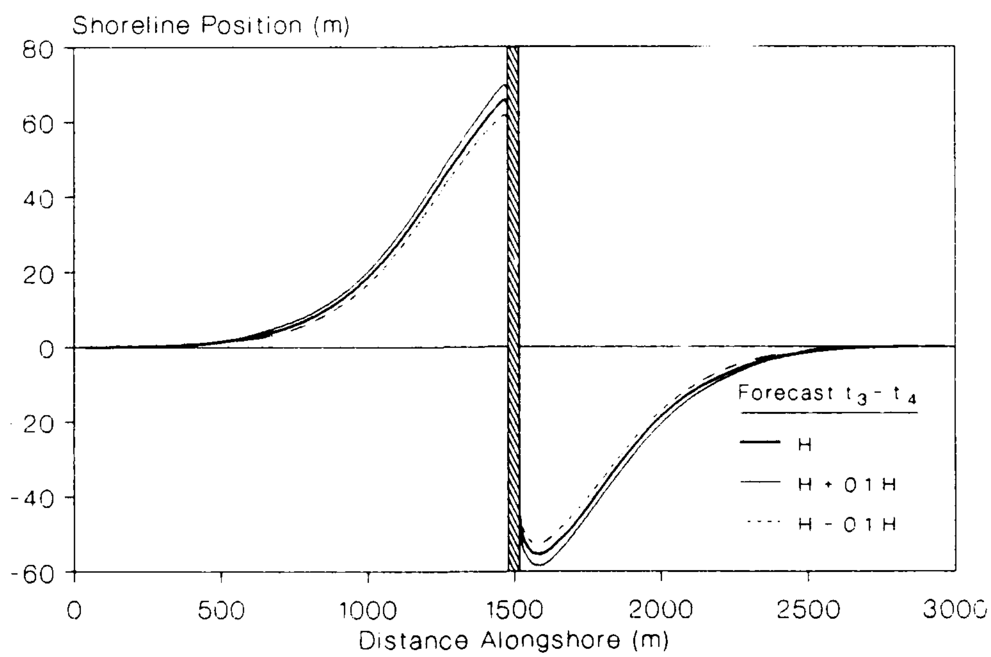


Figure 9.20. Forecasting and sensitivity test

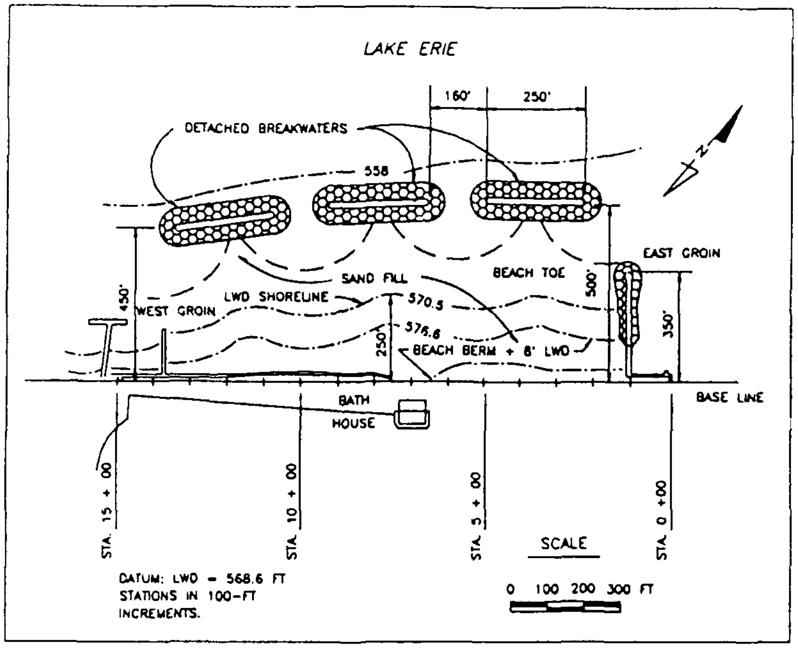


Figure 9.21. Project Design, Lakeview Park

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