LITTORAL PROCESSES FM

Littoral Processes Module

User Guide

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1 About This Guide

1.1 Purpose

The main purpose of this User Guide is to enable you to use the Littoral Processes FM module for applications involving the modelling of non-cohesive sediment transport in points and littoral drift and coastline evolution along quasi-stationary coastlines using an n-line approach.

1.2 Assumed User Background

Although the Littoral Process FM module has been designed carefully with emphasis on a logical and user-friendly interface, and although the User Guide and Online Help contains modelling procedures, common sense is always needed in any practical application.

In this case, "common sense" means a background in hydraulics/hydrodynamics and sediment transport, which is sufficient for you to be able to check whether the results are reasonable or not. This User Guide is not intended as a substitute for a basic knowledge of the area in which you are working: Mathematical modelling of hydraulic/hydrodynamic and sediment drift phenomena.

It is assumed that you are familiar with the basic elements of MIKE Zero: File types and file editors, the Plot Composer, the MIKE Zero Toolbox and the Bathymetry Editor. The documentation for these can be found by the MIKE Zero Documentation Index.

1.3 General Editor Layout

The MIKE Zero setup editor consists of three separate panes.

1.3.1 Navigation tree

To the left is a navigation tree, that shows the structure of the model setup file, and is used to navigate through the separate sections of the file. By selecting an item in this tree, the corresponding editor is shown in the central pane of the setup editor.

1.3.2 Editor window

The editor for the selected section is shown in the central pane. The content of this editor is specific for the selected section, and might contain several property pages.

For sections containing spatial data - e.g. profiles, coastlines and structures - a geographic view showing the location of the relevant items will be available. The current navigation mode is selected in the bottom of this view, it can be zoomed in, zoomed out or recentered. A context menu is available from which the user can navigate to the previous and next zoom extent and to zoom to full extent.

Further options may be available in the context menu depending on the section being edited.

1.3.3 Validation window

The bottom pane of the editor shows possible validation errors, and it is dynamically updated to reflect the current status of the setup specifications.

By double-clicking on an error in this window, the editor in which this error occurs will be selected.

1.4 Online Help

The Online Help can be activated in several ways, depending on the user's requirement:

- **F1-key seeking help on a specific activated dialog:**

  To access the help associated with a specific dialog page, press the F1-key on the keyboard after opening the editor and activating the specific property page.

- **Open the Online Help system for browsing manually after a specific help page:**

  Open the Online Help system by selecting "Help Topics" in the main menu bar.

2   Introduction

The Littoral Processes FM module is an integrated modelling system that simulates non-cohesive transport in points and along quasi-stationary coastlines using an n-line approach.

The Littoral Processes module provides a powerful tool for sediment budget analysis, which is of paramount importance to all coastal morphology studies.

The Littoral Processes FM module combines a technically strong deterministic sediment transport model with a very user-friendly graphical interface. It simulates a wide range of wave and current scenarios along straight or nearly straight coastlines

For some applications it may be necessary to go into detail for the individual wave period, why the simulation of the transport for a single point provides an intra-wave period output functionality.

2.1   Short Model Description

The Littoral Process FM model contains various model types that together form a model complex that alone, or together, can be used for studies regarding non-cohesive sediment transport. A short model description of each model is given below.

2.1.1   Transport in point

This model type calculates the non-cohesive sediment transport in one or several points.

An 'intra-wave period' sediment transport model solves the vertical sediment diffusion equation on an intra-wave period grid to provide a detailed sediment transport description from combined wave and current action for all the modules in Littoral Processes FM.

The total sediment load is the sum of the bed load and suspended load, which are calculated separately. Due to the detailed calculations it is possible to output values within one wave period, however the main result from this model type is the bed load and suspended load in the two directions.

2.1.2   Littoral drift

This model type calculates the longshore transport for one or several cross-shore profiles. Important effects such as the linking of the profile to the wave propagation, the wave climate to the storm surge and the variation in sediment properties across the profile can be included. It is assumed that each cross-shore profile represent uniform conditions along a straight coast.

The model consists of two parts: a hydrodynamic model to calculate the wave propagation towards the coast and related wave driven currents and a sediment transport model to calculate the longshore transport using the detailed hydrodynamics across the profile. The calculation method for the sediment transport in a local point is similar to that of 2.1.1 Transport in point *(p. 11)*.

This sediment transport model is similar to the one for Transport in point.

The hydrodynamic model includes a description of propagation, shoaling and breaking of waves, calculation of the driving forces due to radiation stress gradients, momentum balance for the cross-shore and longshore direction giving the wave setup and the longshore current velocities. The model can be applied on complex coastal profiles with longshore bars.

The longshore sediment transport is simulated by integrating the calculated sediment transport for the grid points in the profile, each defined by by the (calculated) local hydrodynamics and sedimentological conditions. The total sediment transport usually is dominated by transport contributions from areas where wave breaking occurs.

By considering the variation on the hydrodynamic climate (e.g. the yearly wave, tide, storm surge and profile conditions), it is possible to determine the net/gross littoral climate.

The main result from the model is the hydrodynamic conditions and sediment transport across the profile as well as the integrated littoral drift rates for the individual wave event and over the simulation period.

2.1.3 Table generation

This model type generates a dedicated littoral drift transport table for using in the Coastline evolution model.

In order to reduce computation time during the simulation of coastline evolution, the transport rates are found by interpolation in pre-generated littoral drift transport tables rather than calculating the instant littoral drift for each location of the coastline.

The tables are composed by numerous littoral transport rates for an envelope of hydrodynamic conditions and generated by successive calls to the littoral transport engine. The calculation method for each of the representative events are similar to that of 2.1.2 Littoral drift *(p. 11)*.

The littoral drift transport tables can be generated using up to 8 profiles in the longshore direction.

The main result is the littoral drift transport table that consists of a number of binary files containing the sediment transport information and an ascii file, *.val, containing the overall information of the table axis. The specified wave height and wave angle correspond to the conditions at the first breaking point.

2.1.4   Coastline evolution

This model type will calculate the movements of the coastline position with respect to a straight baseline. The model is, with minor modifications, based on a one-line theory, in which the cross-shore profile is assumed to remain unchanged during erosion/accretion. Thus, the coastal morphology is solely described by the coastline position (cross-shore direction) and eventual changes of dune geometry at a given long-shore position.

The sediment transport information is derived from information in pre-generated littoral drift transport tables, described in 2.1.3 Table generation *(p. 12)*.

The coastline evolution can be calculated using up to 8 different profiles in the longshore direction, and basically four types of coastal structures can be taken into account together with sources and sinks of sediment: Groynes, jetties, off-shore breakwaters and revetments.

The main equation in the coastline evolution model is the continuity equation for sediment volumes:

$$\frac{\partial y_c}{\partial t} = -\frac{1}{h_{act}}\frac{\partial Q}{\partial x} + \frac{Q_{sou}}{h_{act}\Delta x} \tag{2.1}$$

in which *yc* is the coastline position, *t* is time, *Q* the longshore transport rates, *x* the long-shore position, *Qsou* the supply of sediment from sources, including eventual dune erosion, and *hact* is the active height of the cross-shore profile.

The main result is the distance from the baseline to the coastline, the local littoral drift rates and accumulated transport along the coastline.

2.2   Application areas

The Littoral Processes FM module provides a powerful tool for many coastal applications. Some of those are presented below:

- Impact assessment of coastal works

- Optimization of beach redevelopment schemes

- Design and evaluation of coastal protection

- Execution of morphological baseline studies

2.3   Modelling procedure

2.3.1   General

A thorough understanding of the sediment transport mechanisms and magnitude of sediment transport along a coastline is necessary to achieve the most reliable results from the model. The purpose of this chapter is to give a general checklist which you can use when Littoral Processes FM for modelling.

The work will normally consist of the tasks listed below:

- defining and limiting the subject of interest
- collecting data
- setting up the model
- calibrating and verifying the model
- running the production simulation
- presenting results

Each of these six tasks are described in the following sections. For your particular study only some of the tasks might be relevant.

2.3.2   Defining and Limiting the Subject of Interest

Identify the subject

When preparing to do a study you have to assess the following before you set up the model:

- what is the topic for the investigation ?
- what are the "important wave phenomena" ?
  The following phenomena should be taken into consideration:

    - Shoaling
    - Refraction
    - Diffraction
    - Reflection
    - Bottom dissipation
    - Wave blocking
    - Wave breaking
    - Wind generation
    - Wave spreading
    - Wave-Wave interaction
    - Wave-current interaction

    The Littoral Processes FM module can handle these phenomena with the exception of reflection, wind generation, wave-wave interaction and

wave blocking. The module considers the influence of diffraction around jetties and breakwaters internally in the calculations.

- what are the physical conditions for longshore current and longshore sediment transport ?
- what are the bathymetric conditions for the coastline of interest ?
- what structures are present on the coastline stretch of interest ?
- what are the strength of present sediment sources (and sinks) ?
- how is the history of the coastline evolution for the given site ?

Check model capabilities

Next, check if the Littoral Processes FM model is able to solve your problem. This you can do by turning to Section 2.1 Short Model Description *(p. 11)*, which gives a short description of model types and by consulting the scientific background for each modeltype.

Selecting cross-shore profiles and grid spacing

Draw up your cross-shore profiles on a sea chart showing the area of interest. The cross-shore profile should be perpendicular to the parallel depth contours. The profile is defined from deep water onto the beach. The profile should have an extension, so the wave-driven longshore currents are insignificant in the first gridpoint and the last couple of grid points always is dry.

You have to consider the grid spacing of the profile. When bars are present, the best results will occur when the single bar is described by at least five gridpoints.

Describing coastline profile and longshore grid spacing

Draw up the coastline position on a sea chart showing the area of interest. A reference baseline must be selected so structures like groynes and jetties are perpendicular to the baseline (and the beach if possible).

The position and height of dunes on the coastline may be found from a map as well as the angle between deep water contours and baseline.

The coastline alignment should have an extension so the coastline evolution in the area of interest is not influenced by the boundary conditions.

You have to consider the grid spacing of the coastline. When structures are present the best results will occur when the adjacent areas, directly influenced by the single structure, are described by at least 5 points.

2.3.3 Collecting Data

This task may take a long time if, for example, you have to initiate a monitoring programme. Alternatively, it may be carried out very quickly if you are able to use existing data immediately available. In all cases the following data should be collected:

- bathymetric data such as sea charts from local surveys or, for example, from the Hydrographic Office, UK

- sedimentological data, which should be bed samples, samples of sediment in suspension, grain curves etc.

- water level data

- wave data

- current data

- hydrodynamic calibration and validation data; these might be measured wave parameters in selected locations, eg. significant wave height, mean wave period, mean wave direction and generated longshore current.

- coastline calibration and validation data: these might historical measurements of coastline evolution, aerial photos from different periods, short term evolution scenarios or knowledge of the magnitude of the mean, annual littoral drift.

2.3.4 Setting up the Model

What does it mean

"Setting up the model" is actually another way of saying: transforming real world events and data into a format which can be understood by the numerical model. Thus generally speaking, all the data collected have to be referred to the spatial grid selected.

Bathymetry

You have to specify your coastline profile as a line series data file containing the position of the coastline. Appearance of dunes and off-shore depth contours as well as a relation to several cross-shore profiles at given positions along the coast must be defined in line series data files using the same number of grid points and grid spacing.

You have to specify the cross-shore profile as a line series data file containing the bathymetry of the cross-shore profile.

A good representation of the bathymetry is essential. The transport rates depend on the steepness of the profiles and it is important to select representative slopes and forms.

Sedimentology

The sediment characteristics along each defined cross-shore profile must be described. If the data is spatially varying the values must be defined in a line series data file using the same number of grid points and grid spacing as the cross-shore profile.

One of the more important parameters is the mean grain diameter d50.

Depending on the way of calculation either the fall velocity corresponding to d50 or the geometrical standard deviation of the sediment at the location must be specified. Generally, both items will be available from a grain sample analysis.

If uniform sediment is chosen the specified settling velocity will be used, while the geometrical standard deviation is used to determine settling velocities for non-uniform sediment.

Bottom Friction

The friction is specified as the local bed roughness across the profile.

If the data is spatially varying the values must be defined in a line series data file using the same number of grid points and grid spacing as the cross-shore profile.

Water Level

The water level describes the mean water level at deep water relative to the base level of the coastal profile. This enables the inclusion of storm surge or tidal data.

Wave Data

The wave data is specified by the spectral description of the wave field together with the wave height, wave angle and wave period given for a specific depth.

The waves must be described by either regular or irregular waves. Dependent of the choice of spectral description some parameters must be set for a description of the wave breaking.

Currents

Additional shore-parallel current, i.e. not the wave-driven longshore current, may be given by the current speed in the first grid point of the cross-shore profile.

Time series data

For the case where an input item is varying in time you have to prepare a data file containing the item value before you set up the simulation. The data file must be a time series file (dfs0). The data must cover the complete simulation period. The time step of the input data file does not, however, have to be the same as the overall time step of the simulation. A linear interpolation will be applied if the time steps differ

In case the time formulation is based on individual scenario events, the time properties of the input file should match that of the time series file containing the duration.

Sources

Sources of material may be added to the simulation of coastline evolution. In case the source value is negative, the source will act as a sink.

Structures

Several different structures may be considered in the simulation of coastline evolution:

- Groynes
- Jetties
- Revetments
- Breakwaters

The influence of these structures on the local sediment transport and coastline evolution is automatically included in the calculations.

Calculation parameters

The calculation parameters must be set according to the required accuracy of the calculations.

2.3.5 Calibrating and Verifying the Model

Purpose

Having completed all tasks listed above you are ready to do the first simulation and to start on the calibration and verification of the model.

The purpose of the calibration is to tune the model in order to reproduce known/measured conditions for a particular situation. The calibrated/tuned model is then verified by running one or more simulations for which measurements are available without changing any tuning parameters. This should ensure that simulations can be made for any situation similar to the calibra-

tion and verification situations with satisfactory results. However, you should never use simulation results, whether verified or not, without checking that they are reasonable.

Calibration and verification situations

The situations you select for calibration and verification of the model should cover the range of situations you wish to investigate in the production runs.

The main problem with e.g. coastline evolution modelling is obtaining suitable historical data. Long term data is preferable, however, if a detailed record of the wave climate is available short term coastal response to a specific event (or season) may also provide a good source of calibration/verification data.

Calibrations factors

The most important factor in the calibration is the accuracy of the data. Hence, in order to reduce the differences, you may have to change the basic model specifications listed in 2.3.4 Setting up the Model (p. 19).

Running your calibration run for the first time and comparing the simulation results to your measurements you will, in many cases, see differences between the two. The purpose of the calibration is then to tune the model so that these differences become negligible.

2.3.6 Running the Production Simulations

When you have calibrated and verified the model you can get on to the "real" work - that is, making your actual investigation. This will, in some cases, only include a few runs.

2.3.7 Presenting the results

Throughout a modelling study you are working with large amounts of data and the best way of checking them is to look at them graphically. Only in a few cases, such as when you check your bathymetry or if you want to compare simulation results to measurements in selected locations, you should look at the individual numbers. Much emphasis has therefore been placed on the capabilities for graphical presentation in MIKE Zero.

Essentially, one plot gives more information than scores of tables and, if you can present it in colours, your message will be even more easily understood. A good way of presenting the model results is through line plots of e.g. cross-shore profile and longshore sediment transport or calculated coastline position. Another output could be a line plot of accumulated amount of material along a coastline. This gives a clear indication of the positions where erosion and deposition are the most significant.

2.4 Proposed data flow analysis for coastal projects

In addition to the general checklist given in the previous section, this section contains a short description of the proposed input data and specific tasks that often will be a part of a study regarding future coastline evolution.

In general first the Littoral drift model is applied to investigate the sediment transport rates at the site. After a detailed investigation where the sediment transport rates have been calibrated, the Littoral drift table generation model is applied to create the project specific littoral drift tables followed by the application of the Coastline evolution model to simulate the coastline evolution.

2.4.1 Data requirements

The purpose of this section is to describe the data necessary to carry out a coastline evolution study.

Bathymetry

In the Littoral Processes FM module it is assumed that the coastline is quasi-uniform, i.e. the bottom contours are almost parallel to the coast. This way the hydrodynamics (longshore current and wave variation across the profile) can be calculated in one dimension (profile normal to the depth contours) as if the current profile is fully developed and no disturbances in the bathymetry is present in the longshore direction.

The cross-shore profile is described by a line series (one-dimensional grid) of the cross-shore bathymetry perpendicular to the coastline in a number of equidistant grid-points, measured from the off-shore depth. The first grid point should be at a position where the wave-generated shore-parallel currents are negligible (approx. 8-15 m water depth, depending on wave climate). The last grid point should be well up on land, so the last 2 grid points always are dry.

The coastline alignment is described by a line series (one-dimensional grid). The coastline alignment is defined by the distance from the MWL water line to a baseline, which is defined by a straight line inland with a certain origin and orientation. The active height of the profiles must be defined in each grid point and may vary along the coast. Dune properties as well as definition of off-shore contours are defined in similar way.

Sediment Properties

The sediment properties must be defined for each grid point in the cross-shore profile. To include the variation of the sediment size (usually the sediment size will become finer by increasing depth) it will be advisable to collect sediment samples at a number of positions across the profile where sediment transport is expected to take place (i.e. from the beach line out to deeper waters).

Also the availability of sand on the seabed should be investigated, as the Littoral Processes FM module calculates the sediment transport capacity (i.e. assumes that there is an unlimited source of sediment supply). If some parts of the seabed are hard rock, the conclusions of the simulation results must be modified accordingly.

Tidal data

The variation of the water level must be known as the position of the water level influences the computations of hydrodynamics and sediment transport.

Wave Climate

The main input parameters for the hydraulic computations are the wave properties: wave height, wave angle and wave period for a given (outer) depth in the profile (preferably the first grid point). From this position the program will shoal and refract the waves across the profile onto the coast and calculate the resulting longshore current across the profile. The variation across the profile of the wave height, wave angle and longshore current velocity may be defined as output.

An additional current, for instance a tidal current that is not dependent of the waves, can be included. The influence of this will be included in the calculation of the longshore current. This additional current is optional and may not be important in your case.

To calculate the annual sediment drift and apply a representative wave climate for the coastline evolution simulation, you will need to create a representative wave climate for the site, if you do not have actual wave measurements covering an entire year.

The total wave climate consists of a number of events, each described by its duration or by the time step in the input file, wave properties, water level and possible input like additional tidal currents and wind.

In case the waves have different durations a sum of 100 % correspond to a total duration of one year.

Historical Coastline Evolution

The model needs some calibration data. This could be maps of historical coastline evolution, aerial photographs of the coastline from different years or knowledge of erosion/deposition rates during a season with known wave conditions.

2.4.2   Step 1 - Processing measured data, quality assurance.

a) Overall bathymetry

Ensure that the bathymetry can be simplified to a long, quasi-uniform coastline with shore-parallel depth contours and thus valid for investigation by Littoral Processes FM.

b) Cross-shore coastal profiles

Plot all coastal profiles to investigate development of profile in time and/or change of profile characteristics along the coastline.

c) Coastline alignment

Plot all available coastlines to investigate the erosion/accretion along the coastline.

d) Sediment properties

Find the mean grain diameters to secure that the sediment will be non-cohesive material of sand size (above 0.06mm) and thus valid for investigation by Littoral Processes FM. Note that for gravel size sediment the shingle option should be chosen in the simulation.

e) Wave conditions

Plot the wave climate both step-by-step (time series plot) and by a wave rose to ensure that the wave conditions seems valid.

2.4.3   Step 2 - Calibrating littoral drift

a) Model set-up

Set-up the Littoral drift model for each relevant profile and corresponding wave climate.

b) Littoral drift for one wave event

Calculate the littoral drift using the most severe wave event. Investigate the cross-shore extension of the longshore current and the longshore sediment transport rates to validate that the cross-shore profile is sufficiently long.

c) Annual drift

Calculate the annual drift for the entire wave climate. Plot the annual drift across the profile along with the profile. Plot the 'Sediment Budget Rose' by rose plot. Evaluate if the sediment transport rates are similar to what expected.

d) Calibration

Calibrate the littoral drift model set-up by changing the bed roughness. Evaluate the influence of the coastline orientation, division of wave classes and influence of tidal water level elevation (make sensitivity analysis and plot in curves).

e) Quality assurance
Once having obtained the correct magnitude of the annual drift rates, you can progress to the stage of generating littoral drift tables for the coastline evolution simulations.

2.4.4   Step 3 - Calibrating littoral drift transport tables

a) Generate transport tables
Use the Littoral drift table generation model to make transport tables for the coastline evolution modelling. Utilize the findings from the previous investions of littoral drift to ensure that the table covers ALL possible wave conditions. The reference depth of the offshore wave climate should be corresponding to the depth at the first grid point in the cross-shore profile.

b) Check and calibrate transport tables
For simulation of coastline evolution the first major calibration factor is the net annual drift. Before beginning to calculate the coastline evolution you must ensure that the input wave climate combined with the generated littoral drift table provides the sediment transport rates you expect.

Simulate the undisturbed littoral drift along a straight coastline and check that the transport tables will give the same result as found in the previous simulations using the Littoral drift model; Simulate the coastline evolution for the entire wave climate (disable evolution), output for every duration step. Then extract a time series file from the result file and use this for comparison.

Evaluate the influence of the number of and resolution of the input events in the table.

c) Quality assurance
Once the simulation using the littoral drift model and the simulation using the coastline evolution model with a straight coastline gives the same result for the littoral drift, the tables are assumed to be representative to model all wave events. You can progress to the actual coastline model setup.

2.4.5   Step 4 - Calibrating coastline evolution

a) Model set-up
Set-up the actual coastline alignment and simulate the longshore distribution of the integrated drift (no coastline evolution). This will give a first estimate of the erosion and accretion areas along the coastline. Include coastline evolution to eventually see the evolution in time. Insert structures when needed.

b) Calibration
The final calibration can be done by altering the active depth along the coastline or by modifying the sea-wards extension of the sediment transport. The model is calibrated when the simulated coastline evolution 'fits' with the measured one.

2.4.6   Step 5 - Production runs

Once having calibrated and verified the model, you should be able to add or remove structures or sediment sources on the coastline without further calibration effort. Hence you can e.g. add new structures to the coastline model and run a 10-year wave climate to see what will happen in the future.

Having reached this stage, the model has become a powerful and reliable tool for the design and optimization of many coastal engineering projects along the coastline stretch in question. Still, the limitations of the model, e.g. regarding two- and three-dimensional effects, should always be kept in mind.

3 Examples

3.1 General

One of the best ways of learning how to use a model such as Littoral Processes FM is through practice. Therefore examples are included which you can go through yourself and which you can modify, if you like, in order to see what happens if one or other parameter is changed.

The specification files for the examples are included with the installation of MIKE Zero. A directory is provided for each example. The directory names are as follows:

- Basic Transport example:
  Examples\LITPACK\LP\BasicTransport

- Torsminde:
  Examples\LITPACK\LP\Torsminde

- Simple Structure
  Examples\LITPACK\LP\SimpleStructure

- Specifying Parameters in Local Units
  Examples\LITPACK\LP\LocalUnits

- Influence of offshore contour
  Examples\LITPACK\LP\Contour

- Update stability issues
  Examples\LITPACK\LP\Update

3.2 Basic Transport

3.2.1 Purpose of the example

This example has been chosen as a fairly simple one. The problem is to analyse the influence of different input parameters on the resulting sediment transport rate in a given point.

The bathymetry in the point is characterised by a flat bed with a water depth of 2 m. The sediment is considered to be uniform.

In this example the wave height, current speed and grain properties are varying whereas the remaining conditions are constant. The waves progress perpendicular to the currents.

3.2.2 Defining the problem

The main condition defining the problem is:

- To account for varying grain size four points are defined, each representing specific grain properties. The mean grain diameters are defined as 0.06 mm, 0.1 mm, 0.2mm and 0.4 mm, respectively, with the corresponding fall velocities 0.0025 m/s, 0.0068 m/s, 0.022 m/s and 0.049 m/s.

- The waves comes from the south with a wave period of 5s. In simulation A the wave height changes from 0.1 m to 1.0 m during the simulation. In simulation B the wave height has a constant value of 0.1 m.

- The currents flows towards east. In simulation A the current speed has a constant value of 0.1 m/s. In simulation B the current speed changes from 0.1 m/s to 1.0 m/s during the simulation.

- For detailed analysis a case with a wave height of 0.5 m, a current speed of 0.5 m/s and a mean grain diameter of 0.2 mm is applied. This is simulation C.

- Stoke' first order theory is applied

The varying conditions are described by 10 time steps with a time step interval of 3600 seconds.

3.2.3 Presenting and evaluating the results

The evaluation of the simulations are presented as follows:

- Simulation A: Varying wave height
- Simulation B: Varying current velocity
- Simulation C: Detailed analysis

Simulation A

Figure 3.1 shows the transport rate in the direction of the current displayed by bed load, suspended load and total load, respectively. It can be seen from the figure that the transport rate in the current direction increase with increasing wave height. The bed load transport increase almost linearly with increasing grain diameter, whereas the suspended load transport is the highest for small grain diameters. The total load (note the vertical scale) is more dominated by the suspended load when the grain diameter is small.
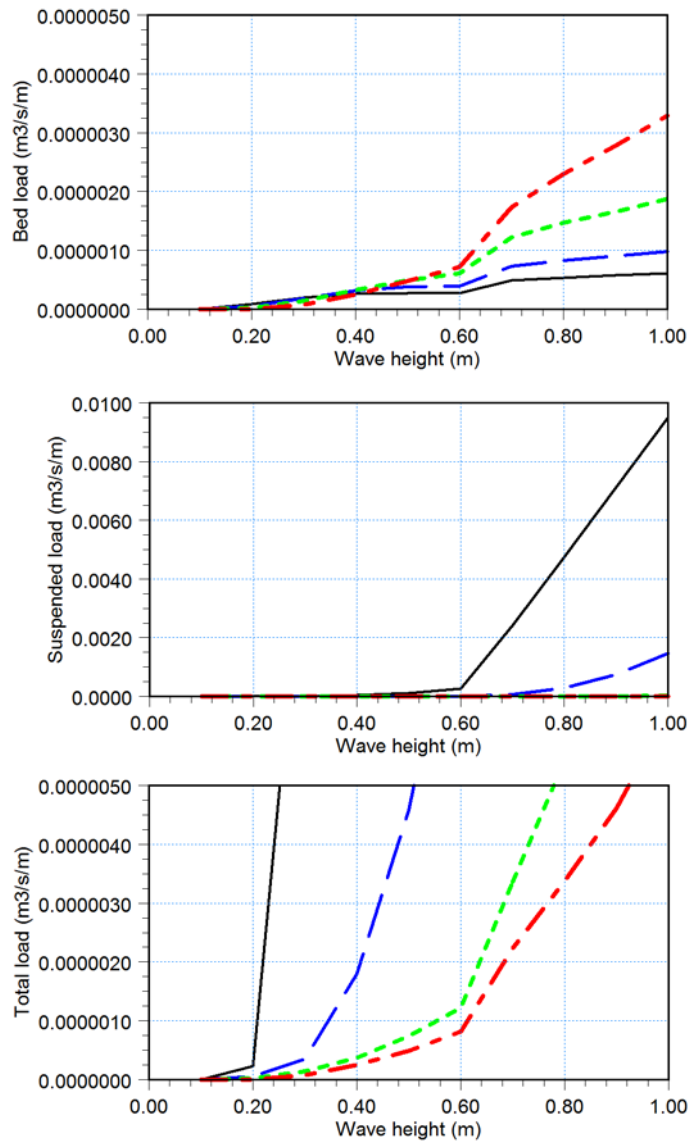
Figure 3.1   Resulting transport in current direction for varying wave height
Black solid line: d_{50} = 0.06 mm, Blue stippled line: d_{50} = 0.1 mm
Green dotted line: d_{50} = 0.2 mm, Red stippled-dot line: d_{50} = 0.4 mm

Figure 3.2 shows the resulting transport in the direction of the wave progression. It can be seen that for increasing wave height the wave breaking will become increasingly dominant and undertow will begin to effect the transport thus resulting in transport in the opposite direction of the waves.
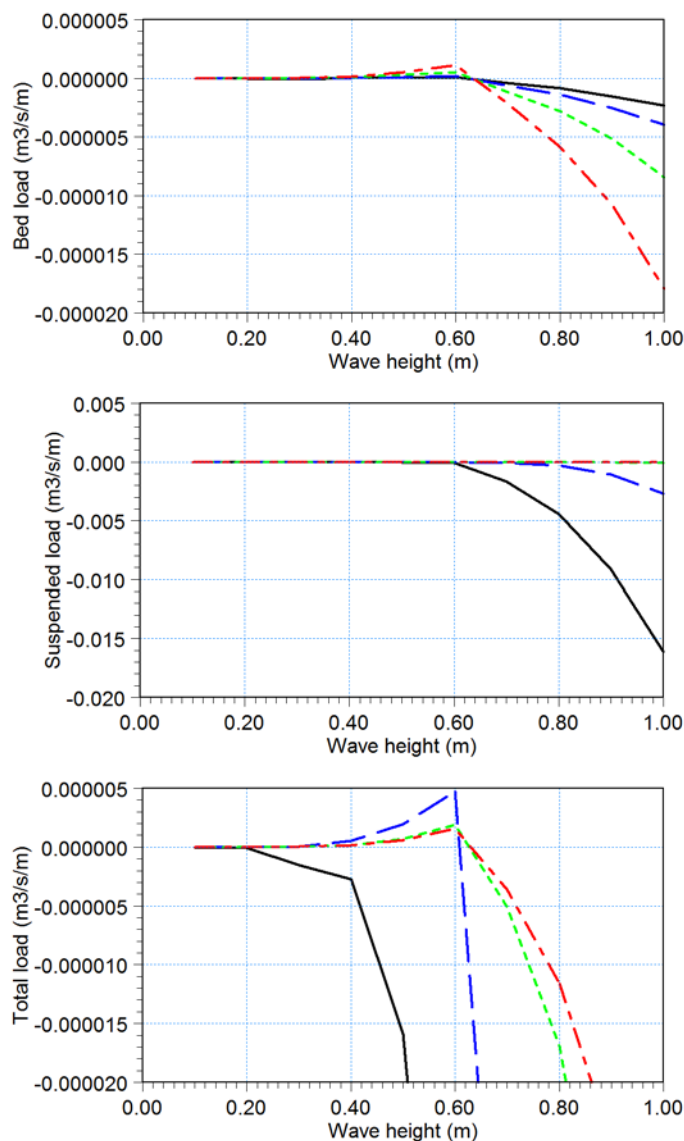
Figure 3.2   Resulting transport in wave direction for varying wave height
              Black solid line: d_{50} = 0.06 mm, Blue stippled line: d_{50} = 0.1 mm
              Green dotted line: d_{50} = 0.2 mm, Red stippled-dot line: d_{50} = 0.4 mm

Simulation B

Figure 3.3 shows the transport rate in the direction of the current. It can be seen from the figure that the transport rate in the current direction increase with increasing current speed. The bed load transport increase almost linearly with increasing grain diameter for higher velocities, whereas the suspended load transport is the highest for small grain diameters. The total load

(note the vertical scale) is more dominated by the suspended load when the grain diameter is small.
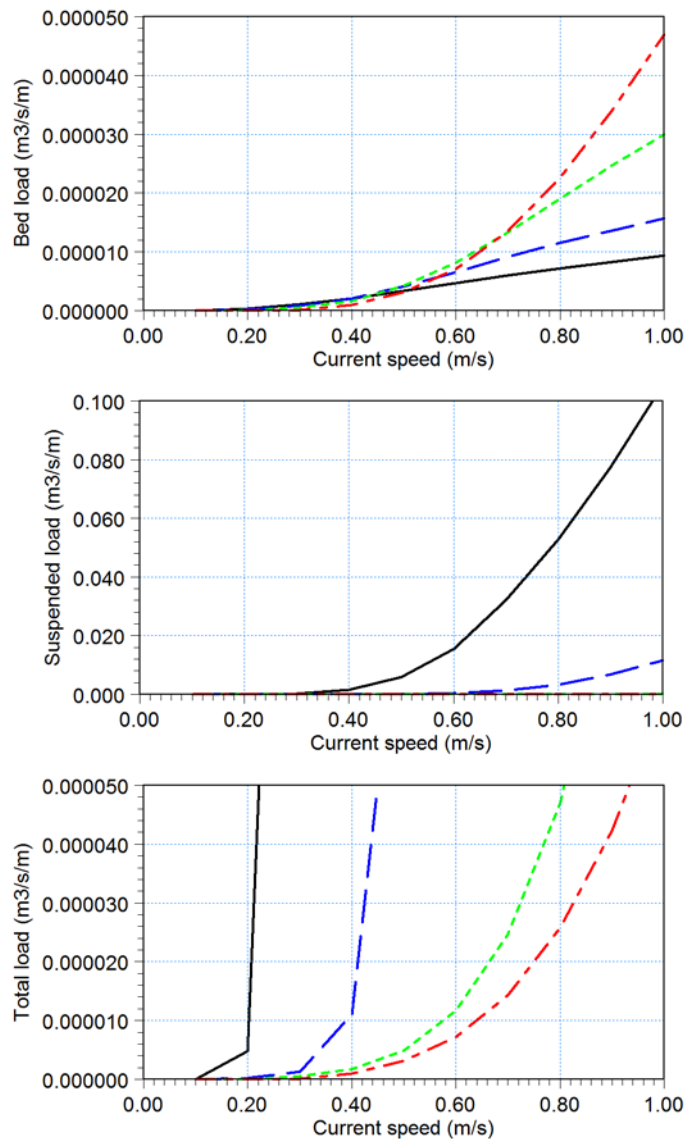

Figure 3.3   Resulting transport in current direction for varying current speed
Black solid line: d_{50} = 0.06 mm, Blue stippled line: d_{50} = 0.1 mm
Green dotted line: d_{50} = 0.2 mm, Red stippled-dot line: d_{50} = 0.4 mm

Simulation C

To review the sediment transport process in more detail the conditions near the bed during a wave period can be shown as in Figure 3.4. It can be noticed

that the presence of the wave, though perpendicular to the current, will add to the transport capacity in the current direction due to the increased amount of turbulence. For comparison the same simulation without any waves has a dimensionless bed load transport in the current direction of 0.03
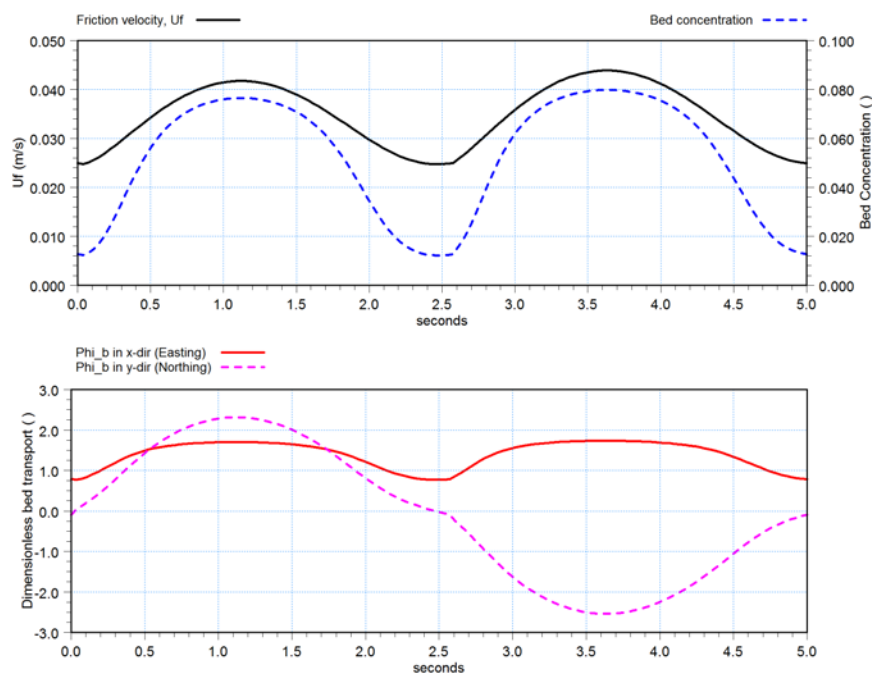

Figure 3.4   Resulting parameters during one wave period
              Upper: Friction velocity (left) and bed concentration (right)
              Lower: Dimensionless bed load in Eastern and Northern direction

3.2.4   List of data and specification files

The following data files are supplied with Littoral Processes FM:

File name: SimA.lpfm
Description: Littoral Processes FM specification file, varying waves

File name: SimB.lpfm
Description: Littoral Processes FM specification file, varying currents

File name: SimC.lpfm
Description: Littoral Processes FM specification file, single case

File name: VaryingWave.dfs0
Description: Varying wave conditions

File name: VaryingVelocity.dfs0
Description: Varying current conditions

3.3 Torsminde

3.3.1 Purpose of the example

This example has been chosen to show cases of typical use of the littoral drift calculation option during a morphological baseline study.

The site is situated at the west coast of Denmark, north of the Torsminde harbour. The overall coastline at the site is defined by quasi-uniform depth contours parallel to the coastline and the littoral drift can thus be estimated by use of the Littoral Process module.
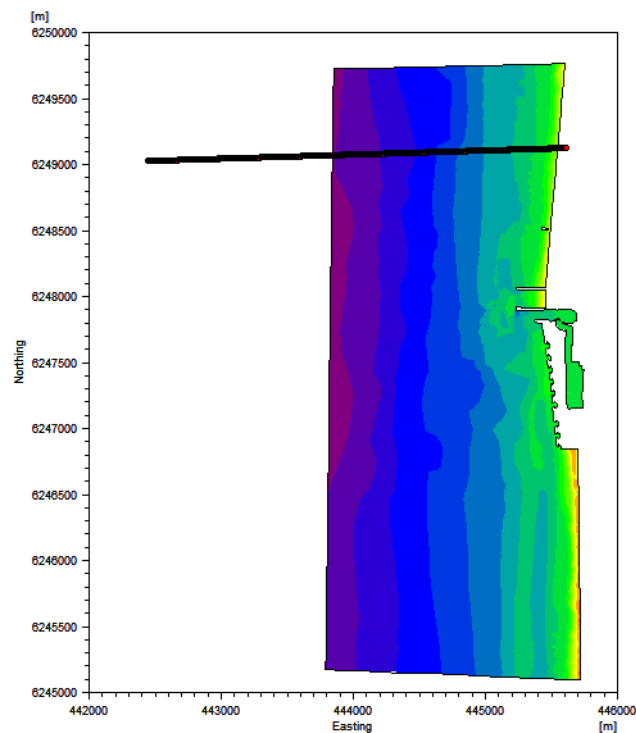

Figure 3.5   Computational domain with existing mesh
Location of default profile is indicated

The aim of this investigation is to determine the overall sediment budget and carry out various sensitivity tests related to the cross-shore bathymetry data and coastline orientation.
Furthermore a quick assessment is made as to the potential blocking of longshore transport due to the presence of a groyne.

The test conditions are:

- The cross-shore bathymetry is described by four files, representing measured conditions in 1990, 1992, 1994 and 1996, respectively.
  It can be derived from Figure 3.6 that the site has experienced erosion during this period.

- Furthermore a cross-shore bathymetry will be derived from an existing mesh file (based on bathymetry information after 1997) forming a fifth description of the cross-shore profile.

- The coast is oriented towards west

- For simplicity reasons the sediment in the profile is defined by a constant a mean grain diameter of 0.3 mm and a sediment spreading of 1.4.

- The wave conditions are described by a wave rose, describing the annual wave conditions on 20 m of water depth.

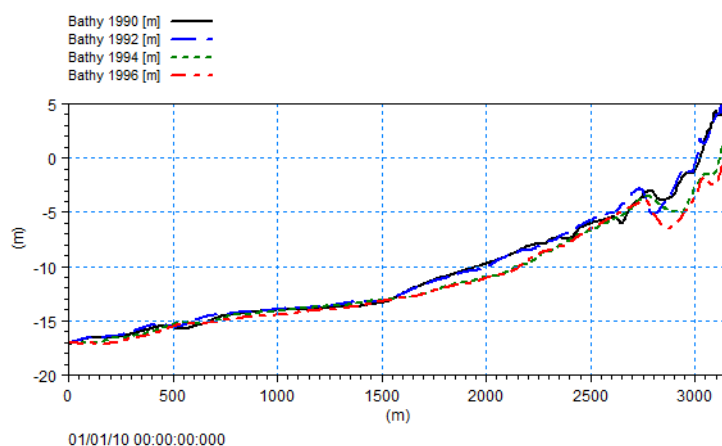- The groyne will extend 200 m from the shoreline at MWL = 0 m.

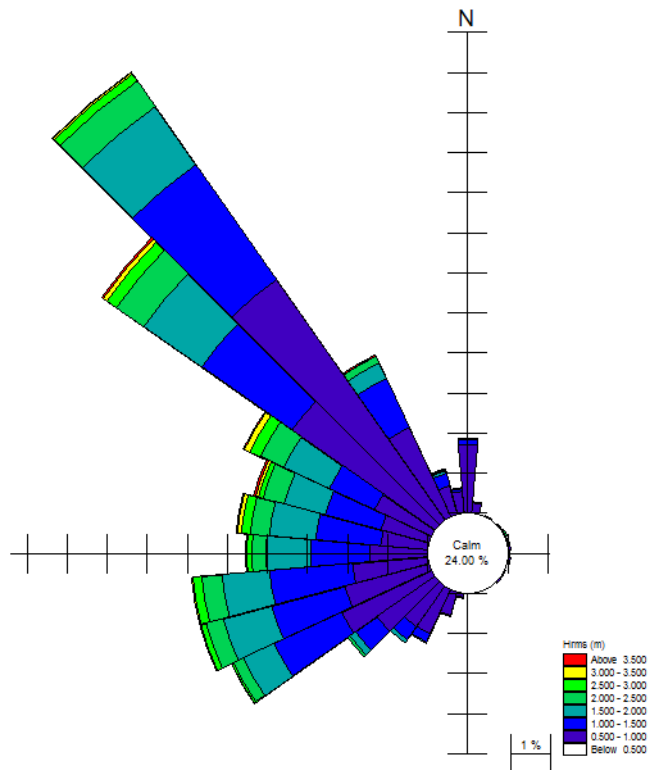Figure 3.6   Cross-shore profiles representing measurements

Figure 3.7   Annual wave conditions for offshore position (Depth = 20 m)

3.3.2   Defining the problem

The overall work flow of this investigation is as follows:

1. Evaluate resolution of cross-shore profile
    To evaluate the validity of the cross-shore profile extension the cross-shore velocity profile and littoral drift is calculated for an extreme wave event. The wave breaking in the start of the profile should not generate any significant wave-driven current and littoral drift for the profile to be considered sufficiently long.
    [Related setup file: Sim1_ExtremeEvent.lpfm]

    To evaluate the grid resolution of the cross-shore profile the longshore velocity profile is calculated for an average wave event. The surfzone should cover at least 10 grid points for the wave breaking and wave-driven current to be described in sufficiently detail.
    [Related setup file: Sim2_AverageEvent.lpfm]

2. Simulate annual drift
    The annual drift (sediment budget) for the cross-shore profile is calcu-

lated by applying the annual wave climate.
[Related setup file: Sim3_Budget_1990.lpfm]

3. Evaluate impact of different cross-shore profiles
   To evaluate the influence of using different bathymetry measurements the annual drift is calculated and compared for the four different cross-shore profiles.
   [Related setup file: Sim4_Budget_ALL.lpfm]

4. Investigate sensitivity of coastline orientation (Q-alpha)
   To evaluate the sensitivity of the profile orientation a Q-alpha curve is calculated by calculating the annual drift for different orientations.
   [Related setup file: Sim5_SensitivityAnnual.lpfm]

5. Simulate annual drift from mesh-derived profile
   Sometimes a quick estimate of the drift is needed but the only accessible bathymetry data is a mesh. The annual drift for a cross-shore profile derived from a mesh is calculated by applying the origin and the grid resolution of the cross-shore profile.
   [Related setup file: Sim6_DeriveProfileAnnual.lpfm]

6. Simulate annual drift along the coastline using mesh information
   The changes in littoral drift along the coastline is found by calculating the littoral drift in a number of mesh-derived cross-shore profiles. It is assumed that the structures near the harbour entrance do not affect the drift rates.
   [Related setup file: Sim7_DeriveAlongCoast.lpfm]

7. Evaluate blocking effect of groyne
   The amount of sediment material withheld due to the presence of a shore-perpendicular structure is assessed by integrated drift output from the model simulation of annual drift for profile 1990.
   [Related setup file: Sim3_Budget_1990.lpfm]

The main conditions for the investigations are:

- The cross-shore profiles are described by line series data files containing 635 grid steps with a grid spacing of 5 m. The orientation of the line is 89 degrees. The default cross-shore profile is the 1990 profile.

- The origin of the single derived profile is defined as (443850, 6249070). The grid spacing is 5 m and the number of grid points 335.

- The derived profiles along the coast are defined by 301 grid points with a grid spacing of 5 m. The origin and orientation of the lines are given in Table 3.1.

Table 3.1   Origin and orientation of derived profiles

Profile number	Easting	Northing	Orientation
1	444075	6249500	92
2	444000	6248700	93
3	444175	6246500	87
4	444200	6245600	90

- The wave conditions is defined by 436 representative wave events derived by combinations of measured wave height, wave direction and wave period.

- The wave simulations are carried out using the Rayleigh spectral description with 50 wave components

- The average and extreme wave event (H,T,Dir) is chosen as follows:
  Average wave event: H=1.5 m, T=4.5 s, Dir=315 deg.N
  Extreme wave event: H=5.5 m, T=6.5 s, Dir=325 deg.N

- The tip of the groyne will correspond to grid point 585 in the cross-shore profile for the year 1990.

3.3.3   Presenting and evaluating the results

The evaluation of the simulations are presented as follows:

1. Resolution of cross-shore profile
2. Annual drift
3. Blocking of longshore transport
4. Different cross-shore profiles
5. Sensitivity of coastline orientation
6. Profile derived from mesh
7. Drift along coastline

Resolution of cross-shore profile

After applying the extreme wave event (Sim1_ExtremeEvent.lpfm) Figure 3.8 shows that the wave is decreasing from the beginning of the profile thus indicating that some of the waves in the applied wave spectrum is breaking. However the generated longshore current and littoral drift is very small in the deeper waters and therefore it is concluded that the extension of the profile is sufficient to model the annual drift rates correctly.
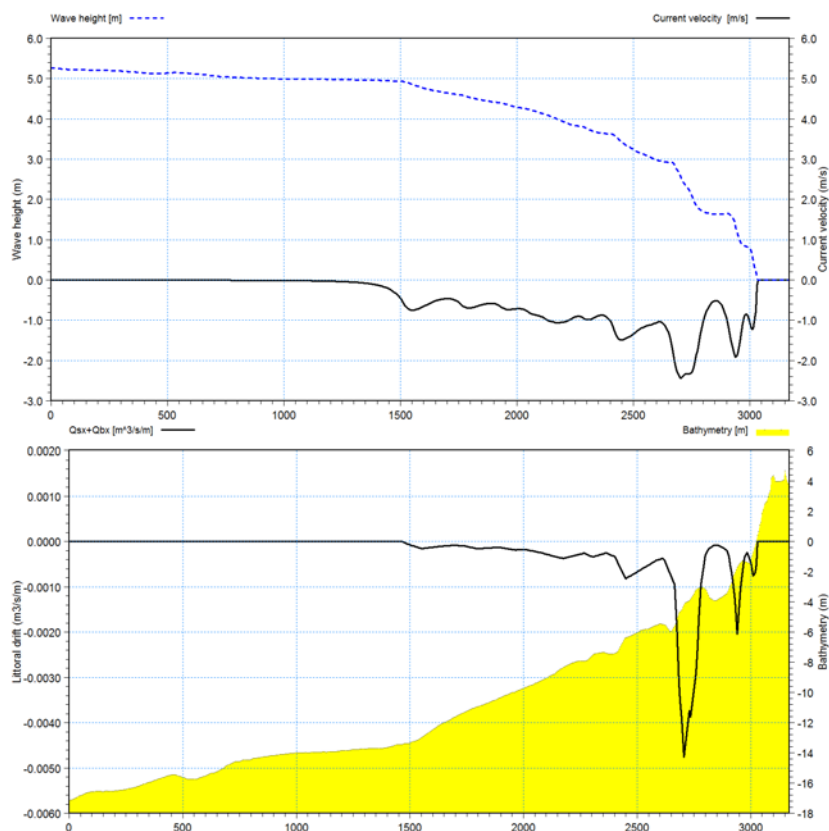
Figure 3.8   Cross-shore distribution of resulting wave height, longshore current and
              littoral drift for extreme wave event.
              Upper: wave height (left axis) and current velocity (right axis)
              Lower: littoral drift (left axis) and bathymetry (right axis)

After applying the average wave event (Sim2_AverageEvent.lpfm) Figure 3.9
shows that the cross-shore distribution of the longshore current and littoral
drift is described by smooth transitions and therefore it is concluded that the
grid resolution of the cross-shore profile is sufficient to model the annual drift
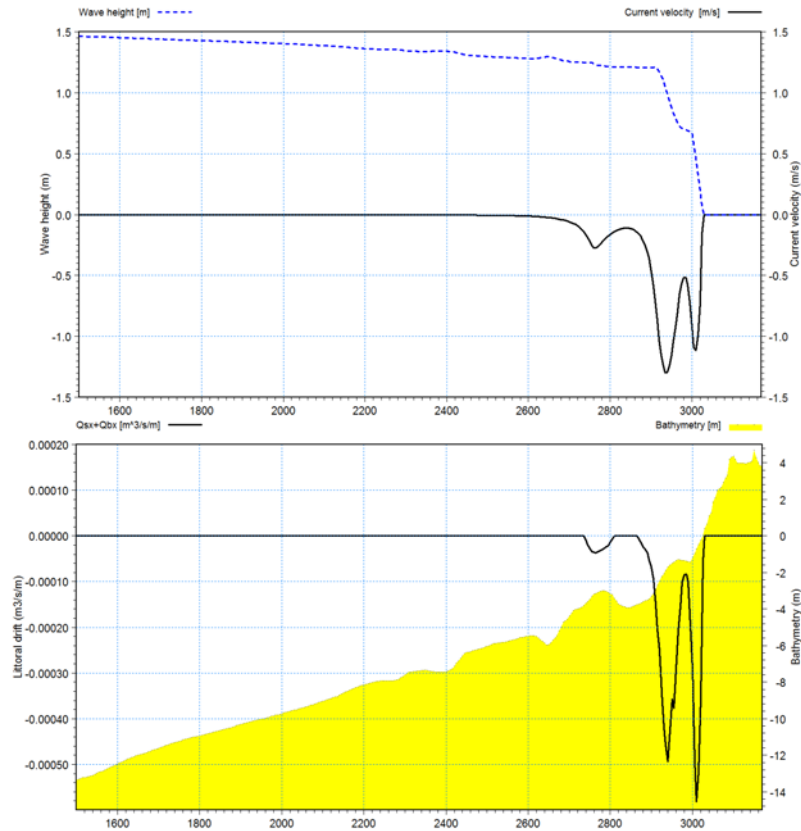rates correctly.

Figure 3.9   Cross-shore distribution of resulting wave height, longshore current and littoral drift for average wave event (detail of profile).
Upper: wave height (left axis) and current velocity (right axis)
Lower: littoral drift (left axis) and bathymetry (right axis)

Annual drift

Figure 3.10 shows the cross-shore distribution of the simulated annual drift for the default profile (Sim3_Budget_1990.lpfm). It can be noticed that the net drift is composed by two large opposite directed drift components, i.e. the gross transport rate is considerably larger than the net drift rate.

Figure 3.11 shows the gross transport by the contribution of the individual wave events in a rose plot. It can be derived from the plot that the main contribution to the annual transport origins from waves from the NW within the wave interval 1 m to 3 m.

Figure 3.10   Cross-shore distribution of net littoral drift along with the related upstream and downstream components (detail of profile)
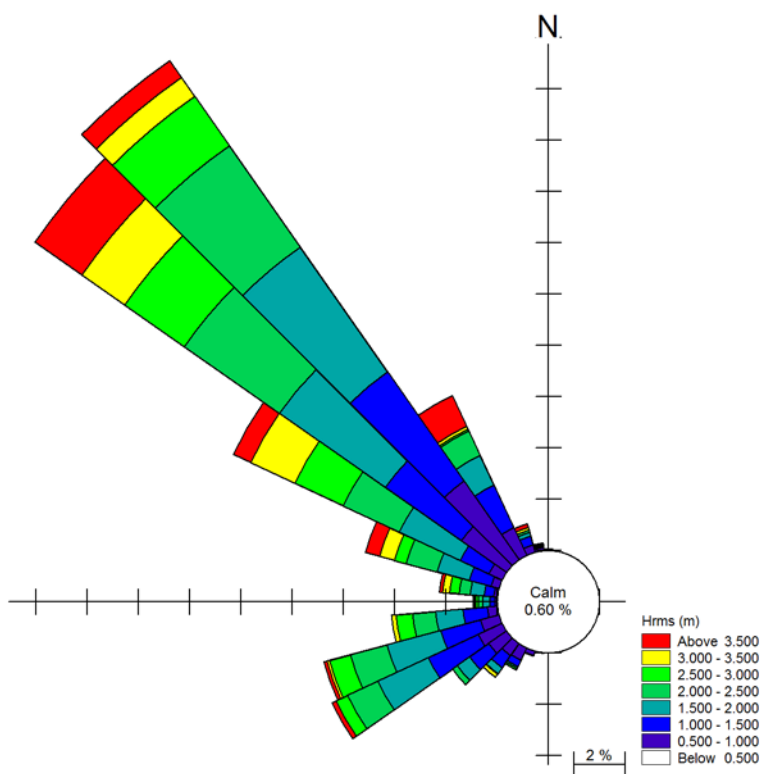

Figure 3.11   Sediment budget rose for gross annual drift using 1990 profile.

Blocking of longshore transport

Figure 3.12 shows the gross annual longshore drift as integrated from the shoreline position. The groyne extends 200 m from the shoreline position. The total amount of blocked material can be found from the curve and is found to be 300000 m³ in total.

Note that this kind of assessment is only for a quick estimate of the blocked volume as morphological changes and local coastline evolution are not considered.
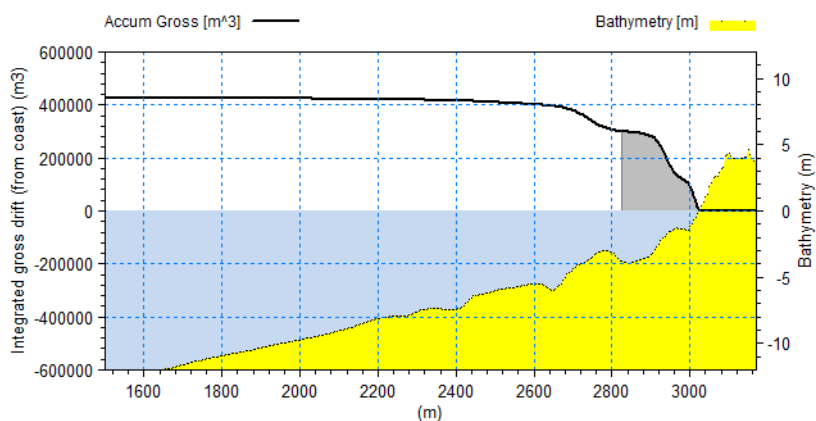

Figure 3.12   Integrated annual gross littoral drift. The shaded area indicates the part of the profile where the transport is blocked by the groyne.

Different cross-shore profiles

Table 3.2 contains the annual drift rates for the four different cross-shore profiles shown in Figure 3.6, each representing the measured profile for a specific year (Sim4_Budget_All.lpfm). It can be seen that the net drift increase in time as well as the gross drift. This indicates that the coastline is not stable but in transition which is also apparent from Figure 3.6.

Table 3.2   Resulting drift rates for four different profiles

	Net drift (m3/yr)	Gross drift (m3/yr)
Profile 1990	-212700	425000
Profile 1992	-219500	435100
Profile 1994	-225600	444300
Profile 1996	-240600	477600

Sensitivity of coastline orientation

Figure 3.13 shows the annual net drift for different coastline orientations when using the 1990 profile (Sim5_SensitivityAnnual.lpfm). It can be seen that just a minor change in the orientation will result in a significant change in the net drift.
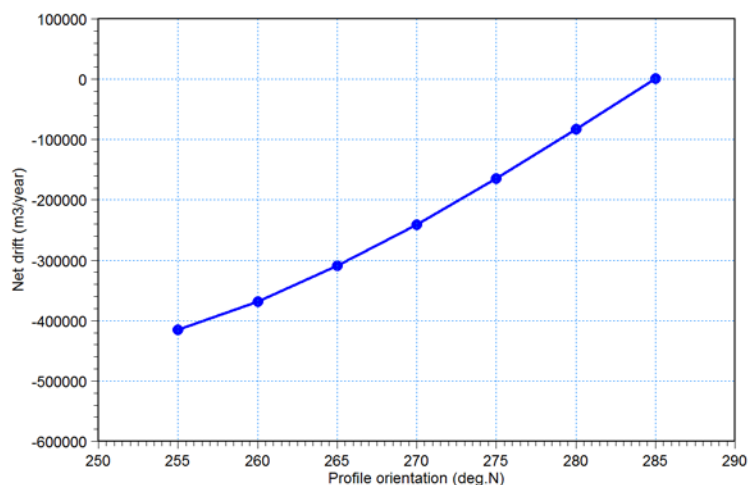

Figure 3.13   Resulting annual drift for various profile orientations

Profile derived from mesh

Figure 3.14 shows the simulated annual drift when using a cross-shore profile derived from the mesh (Sim6_DeriveProfileAnnual.lpfm). It can be seen that the cross-shore bathymetry profile is less detailed as it is based on the mesh information only (and this is usually less detailed than measurements) and it doesn't contain the bar formation which is typical in the measured cross-shore profiles. The simulated annual drift rate is found to be -310000 m³/year which is larger than the net drift rates found by the measured profiles. This is probably due to the concentration of transport in the shallow region closest to the coast.
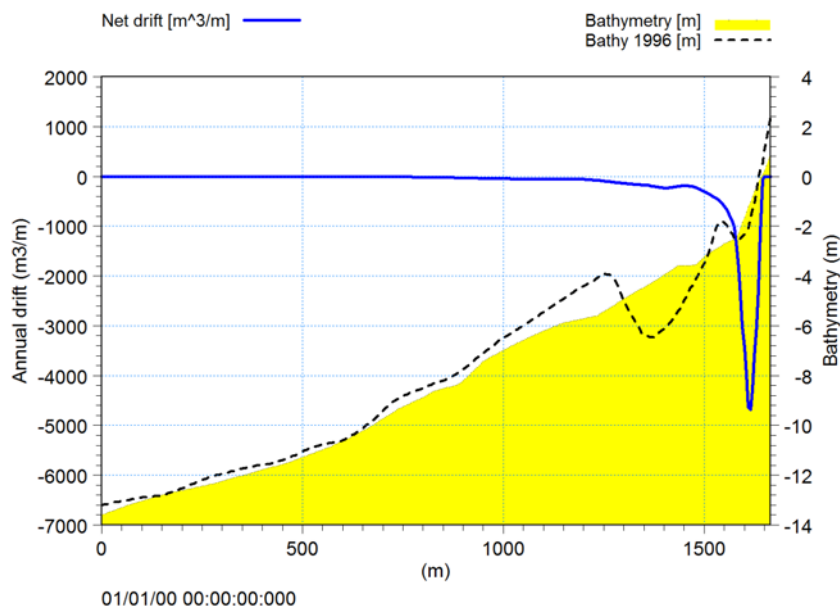
Figure 3.14   Annual littoral drift based on mesh-derived profile.
Measured profile bathymetry from 1996 added for comparison

Drift along coastline

Figure 3.15 shows the littoral drift rates for a number of mesh-derived profiles along the coastline (Sim7_DeriveAlongCoast.lpfm). The profiles are defined perpendicular to the overall depth contour lines in the surfzone.

It can be seen from the calculations that the net transport rate is almost constant north of the harbour which indicates stable conditions. South of the harbour the net littoral drift has increased. This implies that the coastline south of the harbour will erode due to the positive sediment transport gradient. The actual erosion rate will be even bigger than predicted by the difference in transport rates because the blocking effect of the upstream structure is not considered in the simulation.

Note that this kind of simulation is only for a quick overview as accuracy of the mesh that forms the basis of the cross-shore profile will influence the results as well as the estimate of the local coastline orientation.
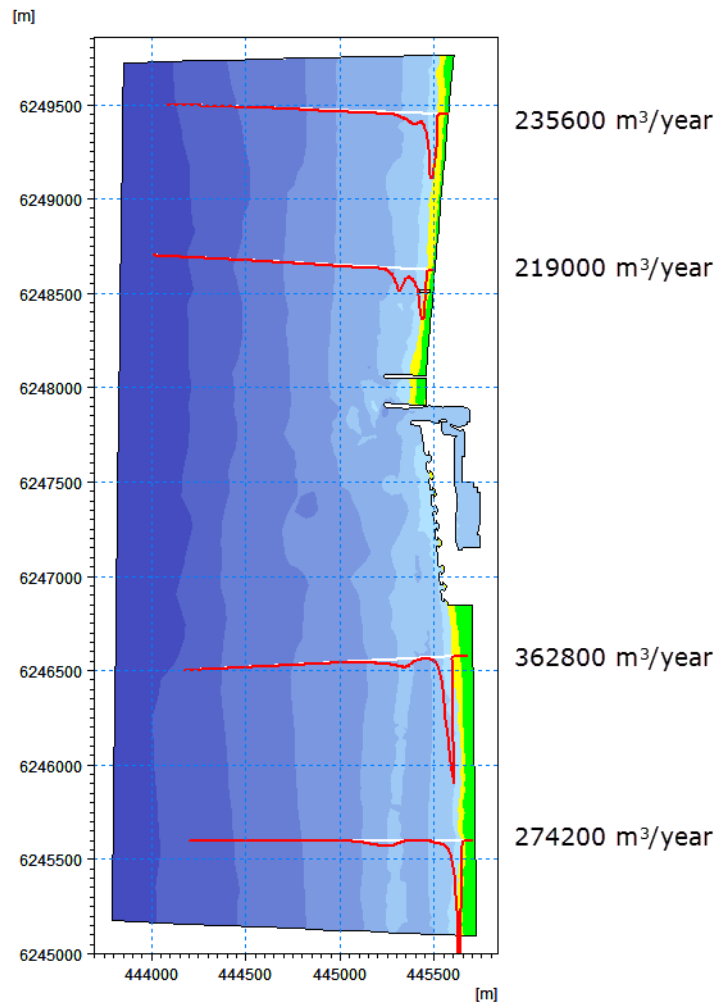
Figure 3.15   Resulting annual drift for 4 profiles derived from mesh

3.3.4   List of data and specification files

The following data files are supplied with Littoral Processes FM:

File names: Profile_199*.dfs1
Description: Cross-shore profile from measurements in 199*

File name: FineBathy.mesh
Description: Flexible mesh bathymetry

File name: OffshoreConditions.dfs0
Description: Wave conditions for depth = 20 m

File name: Sim1_ExtremeEvent.lpfm
Description: Littoral Processes FM specification file

File name: Sim2_AverageEvent.lpfm
Description: Littoral Processes FM specification file

File name: Sim3_Budget_1990.lpfm
Description: Littoral Processes FM specification file

File name: Sim4_Budget_ALL.lpfm
Description: Littoral Processes FM specification file

File name: Sim5_SensitivityAnnual.lpfm
Description: Littoral Processes FM specification file

File name: Sim6_DeriveProfileAnnual.lpfm
Description: Littoral Processes FM specification file

File name: Sim7_DeriveAlongCoast.lpfm
Description: Littoral Processes FM specification file

3.4   Simple Structure

3.4.1   Purpose of the example

This example has been chosen as a fairly simple one. The problem is to analyse the effect of a shore-perpendicular structure on longshore distribution of littoral drift and coastline evolution, given different input parameters.

The domain is characterised by a straight coastline with uniform depth contours facing towards east. The cross-shore bathymetry profile is linear with the slope 1:100, extending from -10m to +2m.
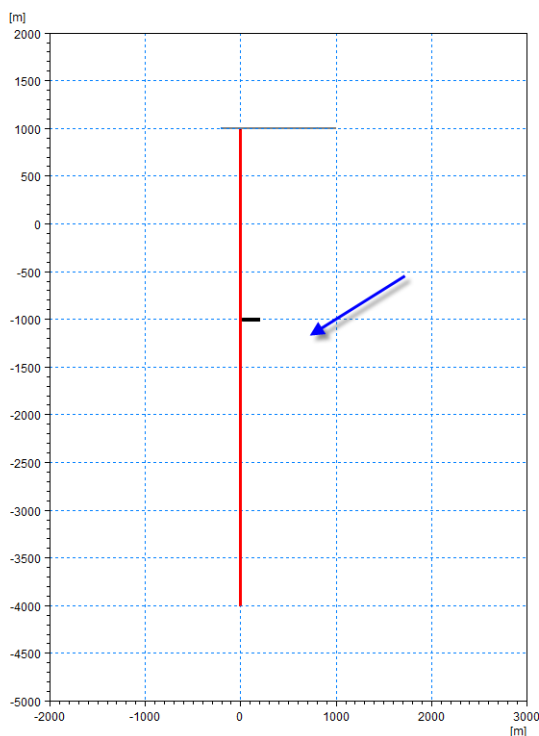
Figure 3.16   Computational domain with coastline and short groyne (reference) Extension of cross-shore profile and wave direction is indicated.

In this example the nearshore wave conditions are considered to be constant during the 30 days of simulation, whereas other parameters for structures and calculation parameters may vary.

The test conditions are:

- The coastline is straight and extends 5 km from North to South. This corresponds to a coastline orientation of 90 deg.N. The depth contours are straight and parallel to the coastline.

- The cross-shore profile bathymetry has a constant slope of 1:100 and extends from -10m to +2m with a line orientation of 270 deg.N. This corresponds a coastline orientation of 90 deg.N.

- For simplicity reasons the sediment in the cross-shore profile is defined by a constant a mean grain diameter of 0.2 mm and a sediment spreading of 1.5.

- The hydrodynamic conditions are described by constant conditions. The waves are described by the wave height 1.2 m, wave direction 60 deg.N and wave period 6s given at 10m water depth. The tidal water level and regional current have a constant value of 0 during the simulation.

- The structure is located 2 km from the start of the coastline.
  The reference structure is a short groyne with a length of 200m. For further analysis also a long groyne of 500m and a jetty of 500m are simulated.

3.4.2 Defining the problem

The overall work flow of this investigation is as follows:

1. Simulate littoral drift
   To evaluate the validity of the cross-shore profile extension the cross-shore velocity profile and littoral drift is calculated for the constant wave conditions. The cross-shore distribution of longshore sediment transport indicates the active zone for the subsequent simulations.
   [Related setup file: LittoralDrift.lpfm]

2. Generate sediment transport tables
   Before simulating the coastline evolution, sediment transport tables covering the actual conditions must be generated. The wave climate is constant so the tables is limited to reference wave heights up to 2m with the given wave period, water level and regional current.
   [Related setup file: TableGeneration.lpfm]

3. Evaluate the littoral drift along the coastline
   To evaluate the validity of the transport tables you must simulate the littoral drift along the coastline for the initial conditions and compare the value to the result of the Littoral Drift calculations. As the wave conditions are constant the value for undisturbed transport rate can be derived from the first grid step in the result file.
   [Related setup file: GroyneDrift.lpfm]

4. Evaluate effect of groyne on coastline evolution
   As a reference case the coastline evolution is simulated for 30 days using the constant wave and a groyne extending 200m from the coastline, see Figure 3.16.
   [Related setup file: Groyne.lpfm]

5. Evaluate effect of considering offshore contours in coastline evolution
   Per default the entire cross-shore profile is considered to rotate with the local shoreline orientation. This is seldom the case in reality where offshore bathymetry contours remains independent of local shoreline changes. The model setup for the reference case is modified to evaluate the effect of assuming water depths above 5 to be offshore.
   [Related setup file: Groyne_InclOffshore.lpfm]

6. Evaluate effect of reduced effect of transport tables
   Per default the entire cross-shore distribution of longshore sediment transport is considered in the coastline evolution calculations. In reality short groynes will affect only the inner transport zone. The model setup for the reference case is modified to evaluate the effect of considering a reduction of the extent of the cross-shore transport profile impacting the

coastline evolution.
[Related setup file: Groyne_ReduceTables.lpfm]

7. Evaluate choice of structure
The effect of a long structure on the coastline evolution may in reality be influenced by diffraction of the waves around the structure head. The two structures in the coastline evolution model 'groyne' and 'jetty' are defined in similar way, however the effect differs as different approaches are utilised for the two structures. The model setup for the reference case is modified to evaluate the effect of considering a groyne extending 500m compared a jetty extending 500m (i.e. well beyond the transport zone. [Related setup files: LongGroyne.lpfm, Jetty.lpfm]

The main conditions for the numerical investigations are:

- The coastline is described by a line series data file containing 501 grid steps with a grid spacing of 10m. The line orientation is 180 deg.N, corresponding to a baseline orientation of 90 deg.N. The coastline is defined by the distance 0m from the baseline.

- The cross-shore profile is described by a line series data files containing 601 grid steps with a grid spacing of 2 m. The line orientation is 270 deg.N, corresponding to a baseline orientation of 90 deg.N.

- The reference hydrodynamic conditions are constant as described previously. The wave simulations are carried out using the Rayleigh spectral description with 50 wave components.

- The transport table is resolved by 16 wave heights and 20 wave directions. The remaining parameters are the same as used in the littoral drift calculations.

3.4.3   Presenting and evaluating the results

The evaluation of the simulations are presented as follows:

1. Resolution of cross-shore profile

2. Annual drift

3. Different cross-shore profiles

4. Sensitivity of coastline orientation

5. Profile derived from mesh

6. Drift along coastline

7. Effect of structure type

Littoral drift across profile

The result from the Littoral Drift calculation (LittoralDrift.lpfm) is shown in Figure 3.17. The figure shows that the cross-shore distribution of the long-shore current and littoral drift is described by smooth transitions with nearly zero current in the deeper waters of the profile. The cross-shore extension of the longshore transport is concentrated near the shoreline. Therefore it is concluded that the extension and grid resolution of the profile is sufficient to model the wave transmission and transport rate correctly.

The results shows that the active zone for the given wave condition extend 400m from the shoreline to the -4m depth contour.
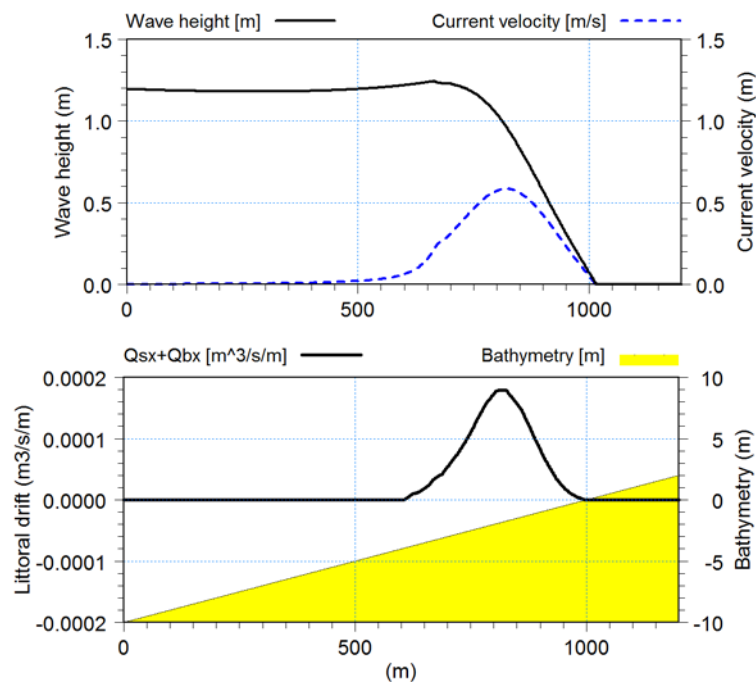

Figure 3.17   Cross-shore distribution of resulting wave height, longshore current and littoral drift for extreme wave event.
Upper: wave height (left axis) and current velocity (right axis)
Lower: littoral drift (left axis) and bathymetry (right axis)

Generate transport tables

The table generation produce an ascii file (Table.val) that describes the out-line of the transport table and three binary tables that contain table values.

Figure 3.18 shows the generated ascii file. Note the grid spacings of the table axis for wave height and incoming wave angle at the breaking line (third value in the lower two lines).

Figure 3.18   Table.val file

Littoral drift along coastline

Figure 3.19 shows the simulated initial littoral drift rate along the coastline for the reference case (a short groyne extending 200m offshore is located 2000 m from the start of the coastline).

It can be seen that the undisturbed littoral drift rate 0.0313 m^3/s (found by interpolation in the transport table) is close to that found in the littoral drift calculation (0.0310 m^3/s). The littoral drift curve shows that some of the sediment can bypass the groyne, thus maintaining a certain transport capacity at location 2000m. Downstream of the groyne the transport rate gradually increase due to the decreasing sheltering effect of the incoming wave.
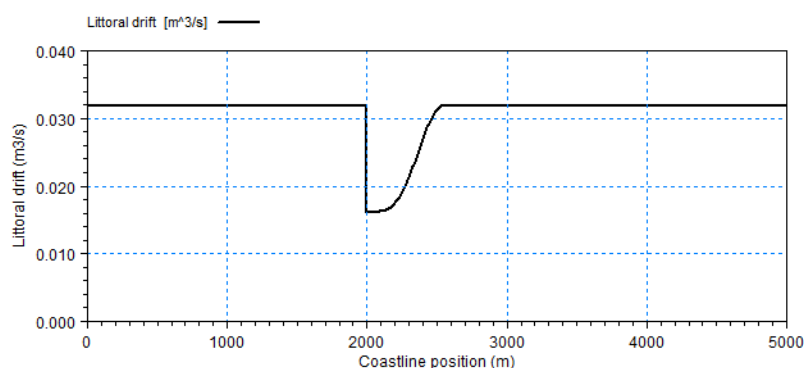

Figure 3.19   Initial littoral drift rate for reference case

Coastline evolution for reference case

Figure 3.20 shows the coastline evolution for the reference case near the groyne. As expected the coastline accrete upstream due to the blocking of sediment and erode downstream due to the continuous increase of transport capacity by distance.
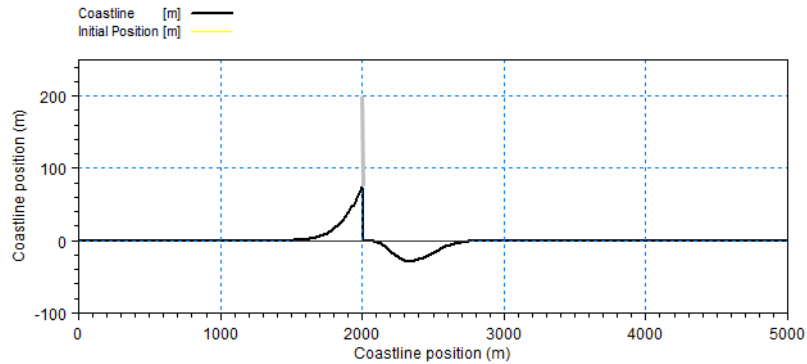
Figure 3.20   Resulting coastline evolution for short groyne after 30 days. Extension of groyne is indicated. Note distorted scale.

Effect of offshore contours

Figure 3.21 shows a detail of the simulated coastline evolution for the short groyne when considering offshore contours in the transmission of waves. When using offshore contours the effect of the changing shoreline orientation is less pronounced in incoming angles at the breaking line and thus the transport gradient along the coastline becomes smaller. This in turn decrease the evolution rate.

01/29/90 00:00:00:000
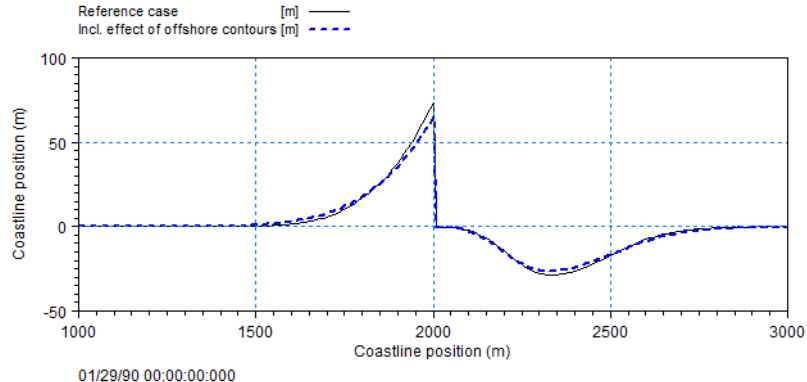
Figure 3.21   Coastline evolution near short groyne when offshore contours are considered in the wave refraction calculations. Note distorted scale. Result from reference case is shown for comparison.

Effect of reduced transport tables

Figure 3.22 shows a detail of the simulated coastline evolution for the short groyne when considering the effect of extension limited transport tables. When only considering the transport rates in the nearshore area extending to the tip of the groyne, the transport rates becomes smaller and as a result also the transport gradient. This in turn decrease the evolution rate.
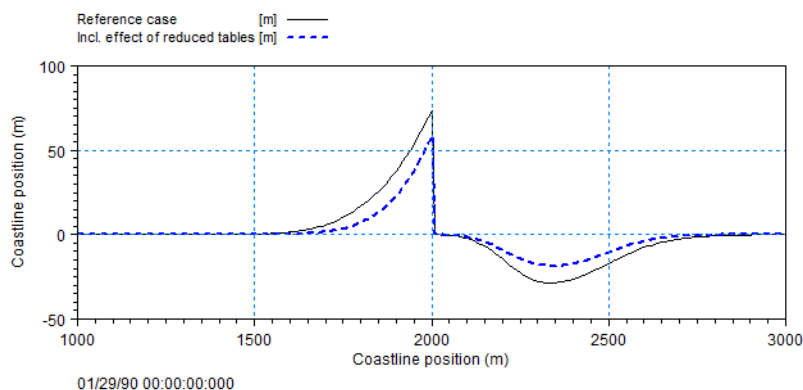
Figure 3.22 Coastline evolution for short groyne when reduced transport tables are considered in the transport calculations. Note distorted scale Result from reference case is shown for comparison.

Effect of structure type

Figure 3.23 shows the simulated initial littoral drift rate along the coastline for a long groyne and a jetty, respectively, that extend 500m offshore.

It is be seen that the littoral drift is blocked entirely by the structure. Downstream the simulated transport rates differs. The long groyne affects a longer downstream distance compared to the short groyne as the effect of the groyne is proportional to the extension of the shadow area behind the groyne. The jetty affects the transport calculation by modifying the incoming wave angles by diffraction calculations in the downstream shadow region.
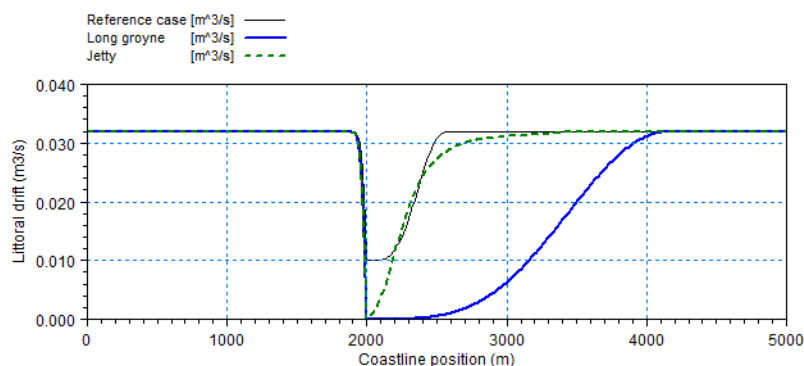
Figure 3.23 Initial littoral drift rates for long groyne and jetty. Result from reference case is shown for comparison

Figure 3.24 shows the simulated coastline evolution for the long groyne and the jetty. It can be noticed that whereas the total eroded volume is the same for the two types of structures, the affected coastline of the shoreline erosion for the jetty is concentrated in a smaller area than for the long groyne, thus resulting in a local higher erosion rates for the jetty.
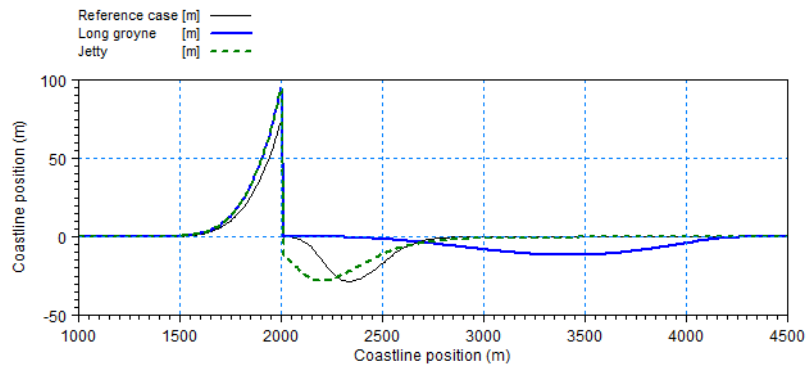
Figure 3.24   Coastline evolution for long groyne and jetty. Note distorted scale. Result from reference case is shown for comparison

3.4.4   List of data and specification files

The following data files are supplied with Littoral Processes FM:

File name: StraightCoastline_UTM32.dfs1
Description: Coastline description

File names: SimpleProfile_UTM32.dfs1
Description: Cross-shore profile

File name: LittoralDrift.lpfm
Description: Littoral Processes FM specification file

File name: TableGeneration.lpfm
Description: Littoral Processes FM specification file

File name: Groyne.lpfm
Description: Littoral Processes FM specification file

File name: Groyne_InclOffshore.lpfm
Description: Littoral Processes FM specification file

File name: Groyne_ReduceTables.lpfm
Description: Littoral Processes FM specification file

File name: LongGroyne.lpfm
Description: Littoral Processes FM specification file

File name: Jetty.lpfm
Description: Littoral Processes FM specification file

3.5 Specifying Parameters in Local Units

3.5.1 Purpose of example

This example is included in order to present the option of using local units when creating a model setup, e.g. US units. For the purpose of comparison the two setups in this example are based on setups in the previous examples.

The test conditions are:

- The local units for the editor are defined by the attached definition file EUM_Local.UBG. Wherever possible, spatial values are defined in yards, feet and inches.

- The first setup calculates the transport in a point similar to Simulation C described in 3.2 Basic Transport (p. 29).

- The second setup calculates the annual littoral drift for a derived profile similar to problem 5 described in 3.3 Torsminde (p. 35).

3.5.2 Defining the problem

First setup the MIKE Zero shell to work with local units by loading and saving the file EUM_Local.UBG using the Unit Base Group Editing utility (File→Options→Edit Unit Base Groups...), then restart MIKE Zero.

The main conditions for the simulations are shown below.

Transport in point

- The bathymetry in the point is characterised by a flat bed with a water depth of 6.562 ft.

- The waves come from the south with a wave period of 5 s and wave height 1.640 ft.

- The current flows towards east with a constant speed of 1.64 ft/s.

- The sediment properties are uniform with a mean grain diameter of 0.0079 inch and corresponding fall velocity of 0.0722 ft/s.

- Otherwise values are similar to Simulation C in the Basic Transport example.

Annual littoral drift

- The profile bathymetry is derived from the mesh along the same line as in the Torsminde example. The origin is set to (1456200 ft, 20502200 ft) with a line orientation of 88.22 deg.N. The profile is defined by 340 grid points with a grid spacing of 16.404 ft. Location is indicated in Figure 3.24.

- The wave conditions are defined by 436 representative wave events, valid for a water depth of 65.6 feet. The wave height values are given in the unit feet.

- For simplicity reasons the sediment in the profile is defined by a constant a mean grain diameter of 0.0118 inch and a sediment spreading of 1.4.

- The water temperature is specified as 49.1 degree Fahrenheit.

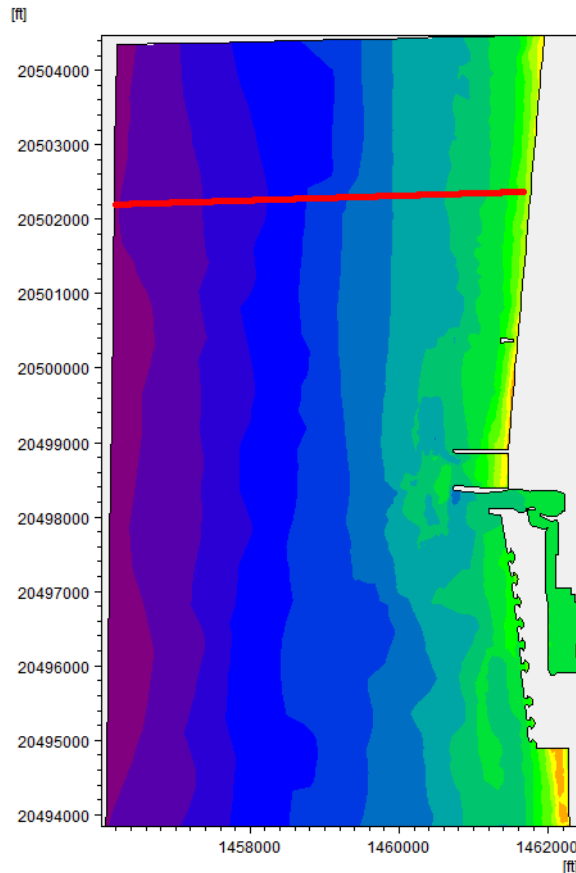- Otherwise values are similar to Problem 5 in the Torsminde example.

Figure 3.25   Location of derived profile

3.5.3   Presenting and evaluating results

The evaluation of the simulations are presented as follows:

- Transport in point
- Profile derived from mesh

Transport in point

The results obtained by using local user units are similar to the results obtained by using default units as shown in Figure 3.26. The solid curve shows the results from using default units whereas the stippled curve shows the result when using user-defined units.

As shown, the results do not depend on the choice of local user units. Note that the displayed values in the plot automatically adapts and use the local user unit for the given item type.

Figure 3.26   Comparison of resulting parameters during one wave period
Upper: Friction velocity
Lower: Dimensionless bed load in Northern direction

Annual drift

Figure 3.27 shows the simulated annual drift for a derived profile. The solid curve shows the results from using default units whereas the stippled curve shows the result when using user-defined units.

As shown, the results do not depend on the choice of local user units. Note that the displayed values in the plot automatically adapts and use the local user unit for the given item type.
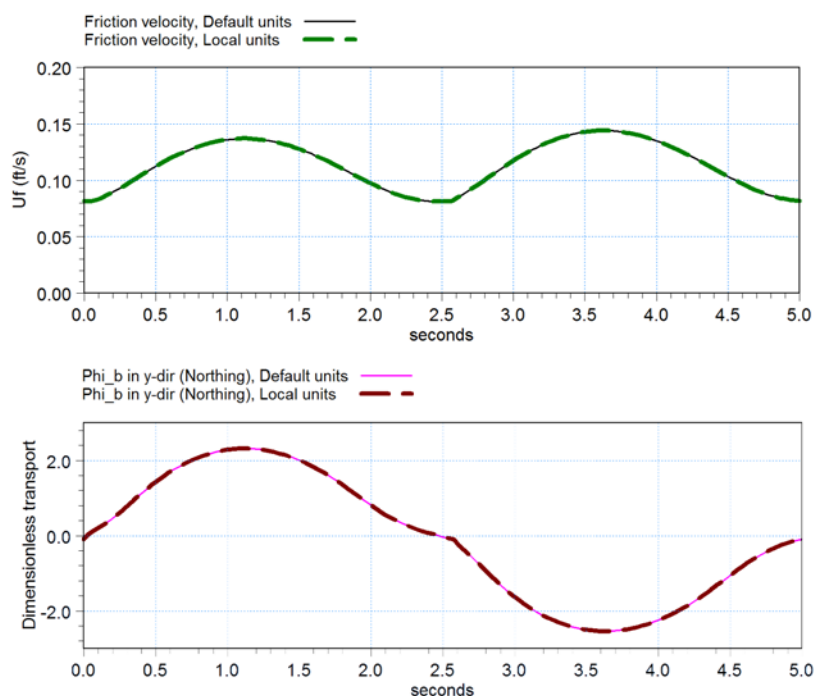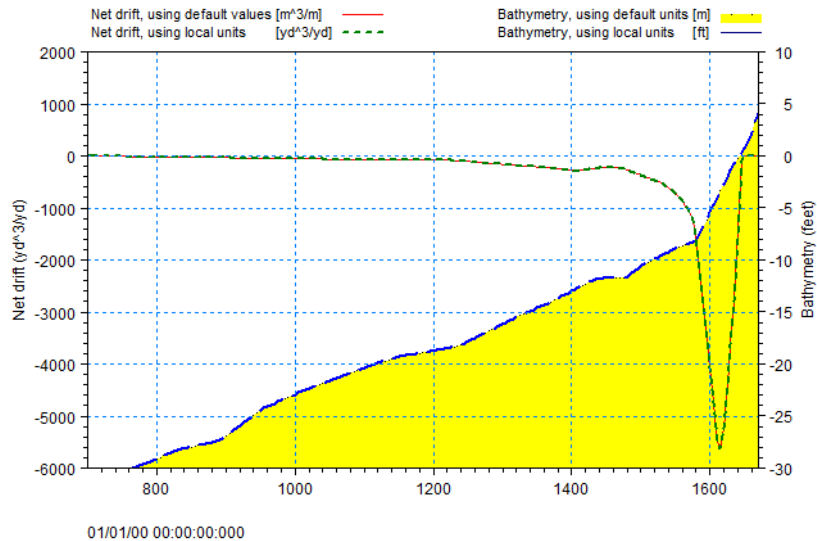
Figure 3.27   Annual littoral drift based on mesh-derived profile.

3.5.4   List of data and specification files

The following data files are supplied with Littoral Processes FM:

File name: TransportInPoint.lpfm
Description: Littoral Processes FM specification file

File name: FineBathy.mesh
Description: Flexible mesh bathymetry, defined in default units

File name: OffshoreConditions.dfs0
Description: Wave conditions for depth = 20m, defined in local units

File name: AnnualDrift.lpfm
Description: Littoral Processes FM specification file

File name: EUM_Local.UBG
Description: Local Unit Base Group definition

3.6   Influence of Offshore Contour

3.6.1   Purpose of example

Wave refraction calculations for water depths larger than the offshore depth is based on the offshore contour orientation whereas wave refraction calculations for water depths smaller than the offshore depth is carried out using the local shoreline orientation. The problem is to analyse the effect to the coastline evolution when including an offshore contour.

This example has been chosen as a fairly simple one. The domain are is characterized by the same overall attributes as in example 3.4, Simple Structure, with some variation concerning the offshore contour and incoming wave angle, as shown in Figure 3.16.

The test conditions are:

- The coastline is straight and extends 5 km from North to South. This corresponds to a coastline orientation of 90 deg.N.

- The cross-shore profile bathymetry has a constant slope of 1:100 and extends from -10m to +2m with a line orientation of 270 deg.N. This corresponds a coastline orientation of 90 deg.N.

- For simplicity reasons the sediment in the cross-shore profile is defined by a constant a mean grain diameter of 0.2 mm and a sediment spreading of 1.5.

- The hydrodynamic conditions are described by constant conditions. The waves are described by the wave height 1.2 m, wave direction 90 deg.N and wave period 6s given at 10m water depth. The tidal water level and regional current have a constant value of 0 during the simulation.

- A offshore contour is defined at 5m depth by the local distance to the baseline. The offshore contour describes an inward bending.
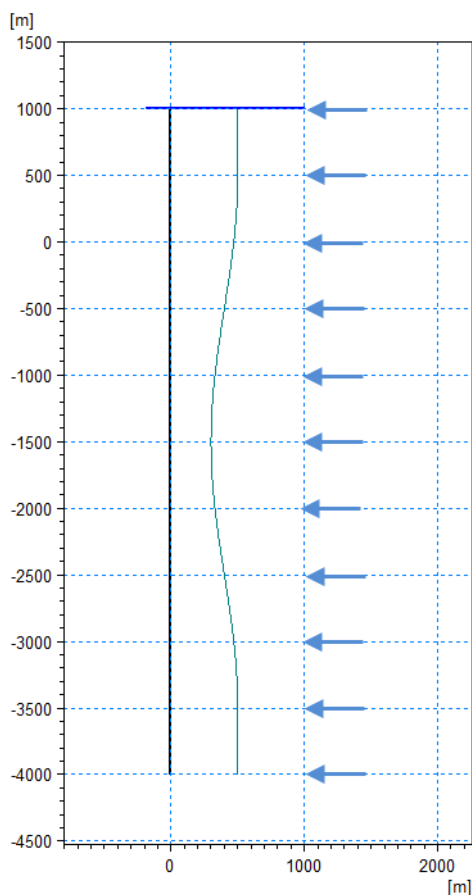
Figure 3.28   Computational domain with coastline and offshore contour
Extension of cross-shore profile and wave direction is indicated.

3.6.2   Defining the problem

The cross-shore profile is the same as in example 3.4, Simple Structure. The applied wave conditions is such that the generated transport table from here can be used directly in the present example.

To evaluate the effect of applying an offshore contour, an offshore contour characterized by a bay shape is included in the simulation.

Note that even if the offshore contour extend inwards it is assumed that the cross-shore profile is not affected.

3.6.3 Presenting and evaluating results

When simulating this setup without the offshore contour, all the incoming waves are perpendicular to the shoreline, and thus the shoreline will be stable as no longshore transport is generated.

When applying a spatially varying offshore contour, the offshore contour angle will differ from the baseline angle in some areas along the coastline. Due to the change in offshore contour angle, the waves will refract differently along the coastline and thus the sediment drift changes too. Figure 3.26 shows the initial coastline alingment together with the coastline alignment after simulating 2 years of evolution using an uniform wave climate. It can be seen that the new coastline alignment will reflect the offshore conditions, forming a bay shaped area.
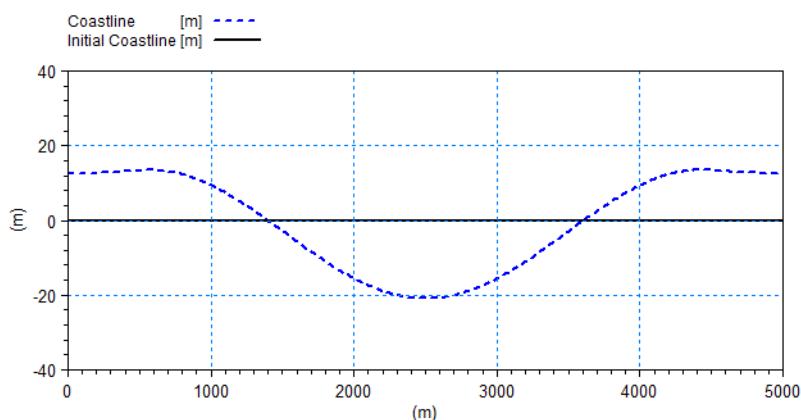
Figure 3.29   Initial and resulting coastline alignment after simulating 2 years
Note: distorted scale

A coastline evolution model always assumes the coastline gradient at the boundaries to remain the same. In this case this means the transport rate remains 0 at the boundary as the incoming wave is perpendicular to the shoreline (see Figure 3.30). The generated coastline evolution is thus quite unrealistic as the restrictions of the boundary will force the material to stay inside the model. However this emphasize the need for choosing the extension of a model domain and location of the boundary points wisely.

Figure 3.30   Integrated littoral drift rates along coastline after simulating 2 years

3.6.4   List of data and specification files

The following data files are supplied with Littoral Processes FM:

File name: StraightCoastlineWcontour_UTM32.dfs1
Description: Coastline description

File names: SimpleProfile_UTM32.dfs1
Description: Cross-shore profile

File name: Table.val (main table file)
File name: Tableqtt.1 (binary file with total transport rates)
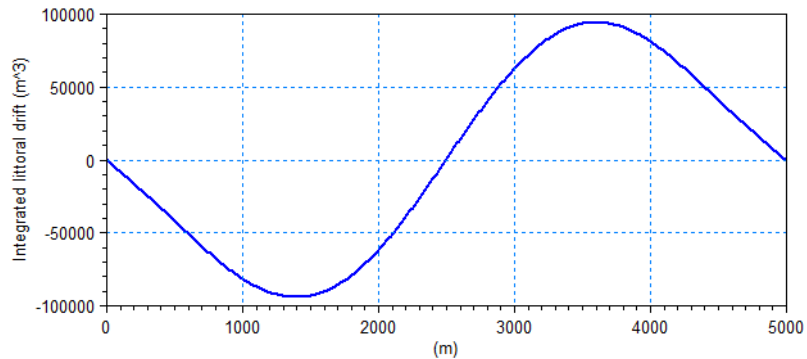File name: Tableqtd.101 (binary file with distributed transport rates)
File name: Tablenqd.101 (binary file with dstributed transport point IDs)
Description: Transport table files

File name: Contour.lpfm
Description: Littoral Processes FM specification file

3.7   Update Stability Issues

3.7.1   Purpose of example

The purpose of the present example is to show how the simulation of coastline evolution in some cases becomes unstable and what measures that can be taken to stabilised the solution.

Per default the model updates the coastline continuously using the instantaneous drift for each event. This might lead to instabilities, especially for oblique waves or wave events with long duration.

In many cases a stabilization of the Q-α curve have only little influence on the transport and the coastline evolution as the main part of the waves will approach the coastline perpendiculary. In other cases where the waves

approach the coast under a large angle the stabilization of the curve leads to an increased littoral drift, which does not reflect the natural conditions.

Using an update method that average the transport gradients can lead to a stable and fairly accurate description of the coastline evolution and littoral drift. This method can also be used for limiting the uncertainty that will appear when applying a wave climate based on statistics, i.e. with no inherent knowledge of the order of the wave events within a wave climate.

The investigation is carried out by applying a relatively small offshore breakwater on an otherwise long undisturbed coastline. This setup should ensure undisturbed conditions at the boundaries. The coastline is subjected to oblique waves, described by a wave climate generated from statistics. The expected shoreline change would be a tombolo formation behind the breakwater.

3.7.2   Defining the problem

A uniform coastline is 5000 m long and oriented 79 deg.N. A breakwater is positioned in the middle of the coastline. It is situated 200 m offshore the baseline (150 m from the initial shoreline) and the length is 250 m.
The wave climate is derived from statistical information and is described by 37 individual wave events with varying duration. A part of the waves approach the coast under an oblique angle.
The model setup and wave conditions are graphically shown in Figure 3.31.
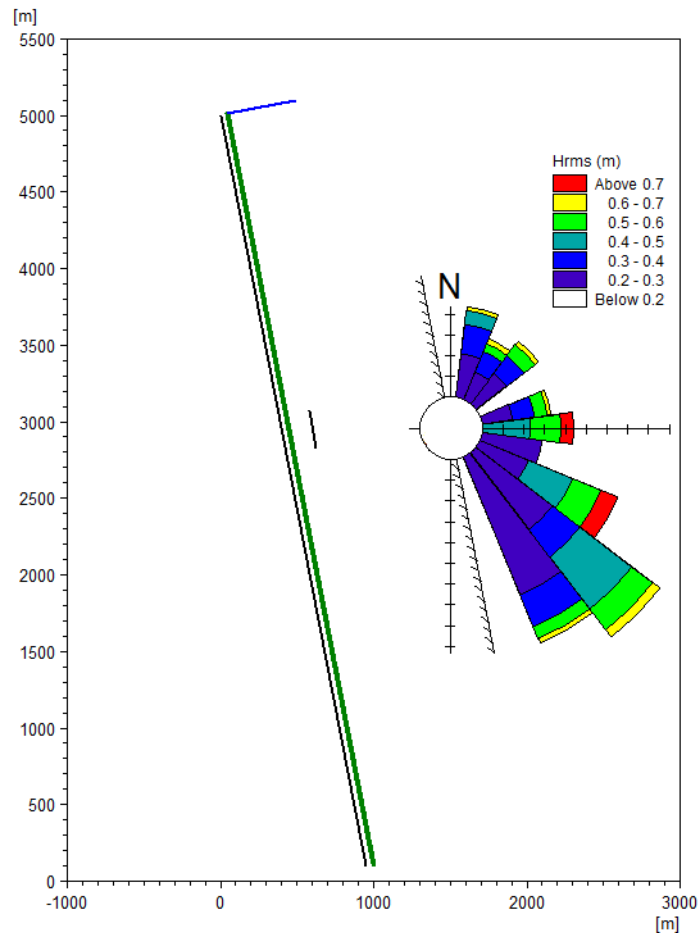
Figure 3.31   Position of breakwater and indication of wave climate

The overall work flow of this investigation is as follows:

1. Simulate littoral drift and validate cross-shore profile
   To evaluate the validity of the cross-shore profile the total littoral drift is calculated for the wave climate with 37 wave events.
   [Related setup file: LittoralDrift.lpfm]

2. Generate sediment transport tables
   Before simulating the coastline evolution, sediment transport tables covering the actual conditions must be generated.
   [Related setup file: CreateTable.lpfm]

3. Validate sediment transport tables
   To evaluate the validity of the transport tables the littoral drift along the coastline for initial conditions without the effect of a structure is simulated for the wave climate with 37 wave events and compared to the total drift rate derived previously.

[Related setup file: ControlTable.lpfm]

Now include the breakwater structure in the model setup.

4. Simulate coastline evolution using default settings
Per default the model apply continuous update without stabilizing the sediment transport curve.
[Related setup file: Evo_SimA.pfm]

5. Simulate coastline evolution using stabilized transport curve
To smoothen out instabilities in the numerical solution, it is chosen to stabilize the transport curve in the simulation.
[Related setup file: Evo_SimB.lpfm]

6. Simulate coastline evolution using update per wave event
Alternatively, instabilities can also be smoothened out by updating only after each wave event, not continuously.
[Related setup file: Evo_SimC.lpfm]

7. Simulate coastline evolution using update after all wave events
The final coastline evolution can also be derived by using the average transport from all wave events before updating.
[Related setup file: Evo_SimD.lpfm]

8. Simulate coastline evolution using repeated wave climate
As the wave climate is derived on a statistical basis, the order of the waves doesn't reflect the actual conditions. By repeating the wave climate 10 times (and reducing the duration each event accordingly) the coastline evolution is simulated using an update after each wave climate cycle (i.e. 10 times per 37 wave events).
[Related setup file: Evo_SimE.lpfm]

3.7.3 Presenting and evaluating results

The evaluation of the simulations are presented as follows:

1. Littoral drift across profile

2. Validation of littoral drift transport table

3. Coastline evolution for continuous update

4. Coastline evolution for update by wave events

5. Coastline evolution using refined wave climate

Littoral drift across profile

The result from the Littoral Drift calculation (LittoralDrift.lpfm) is shown in Figure 3.32. The figure shows that the cross-shore distribution of the integrated littoral drift is described by smooth transitions with zero transport in the

deeper waters of the profile. Therefore it is concluded that the extension and grid resolution of the profile is sufficiently detailed to model the wave transmission and transport rates correctly. The active transport zone extend about 100 m from the shoreline, why an offshore breakwater located 150 m from the shoreline can be applied.
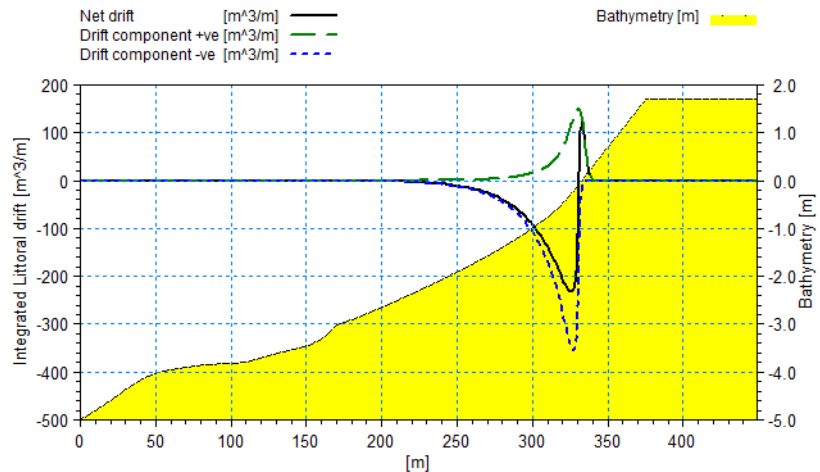

Figure 3.32   Cross-shore distribution of net littoral drift.
Solid line: net littoral drift
Dotted lines: positive and negative littoral drift components
Filled area: cross-shore profile bathymetry

Validation of littoral drift transport table

The littoral drift rates along an undisturbed coastline is calculated using the generated transport tables (CreateTable.lpfm and ControlTable.lpfm). The results by a single point at the coastline is compared with the results from the littoral drift calculation (LittoralDrift.lpfm) and shown in Figure 3.33. (Note that the results needs to be shifted one time step to match).

The figure shows that the littoral drift rates derived by interpolation in the transport table correspond well to the rates calculated directly. The interpolated integrated net drift is found to be around 6450 m^3 compared to 6670 m^3 found by direct calculation. This is below 4% difference and for this purpose it is concluded that the resolution of the transport table is sufficiently detailed to represent the transport rates correctly.
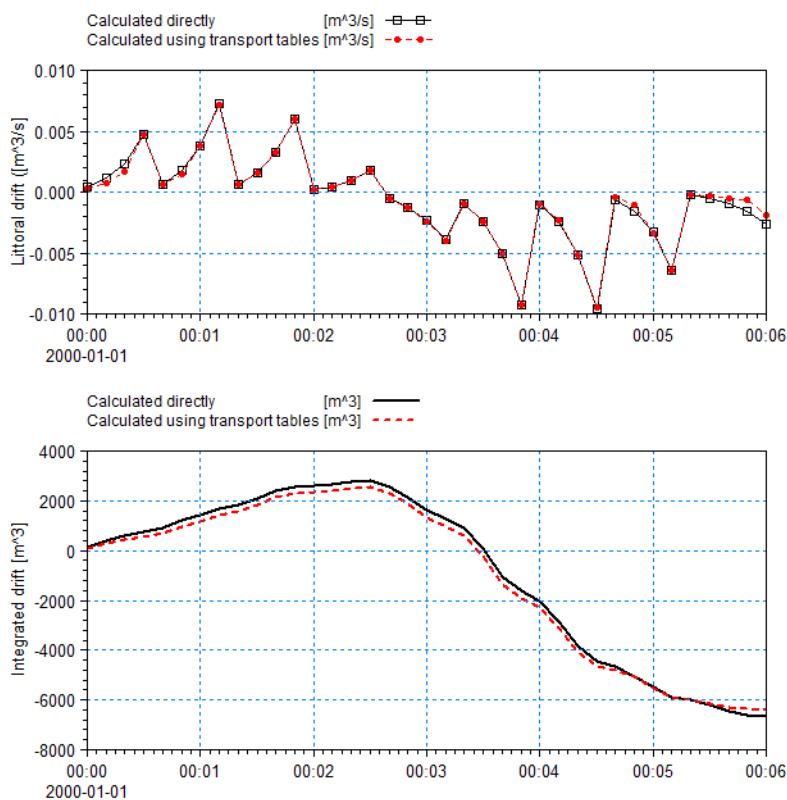
Figure 3.33   Littoral drift calculations for the 37 individual wave events in the wave
climate.
Upper: Littoral drift for each wave event
Lower: Accumulated littoral drift

Coastline evolution for continuous update

Figure 3.34 shows the calculated shoreline and integrated littoral drift for the
two cases where the coastline alignment is updated continuously during the
simulation period (Evo_SimA.lpfm and Evo_SimB.lpfm). The latter simulation
was carried out using a stabilized transport curve.
It can be seen that using the default settings, the simulation results are domi-
nated by instabilities. When using a stabilized transport curve, the resulting
coastline evolution seems much more realistic, however the stabilization pro-
cess cause the total integrated transport rates to be over-estimated. I.e. none
of these update schemes can be recommended.

Figure 3.34   Result after 2 years when using continuous update.
Solid line: original Q-α curve, Dashed line: stabilized Q-α curve
Upper: Coastline alignment (Note distorted scale)
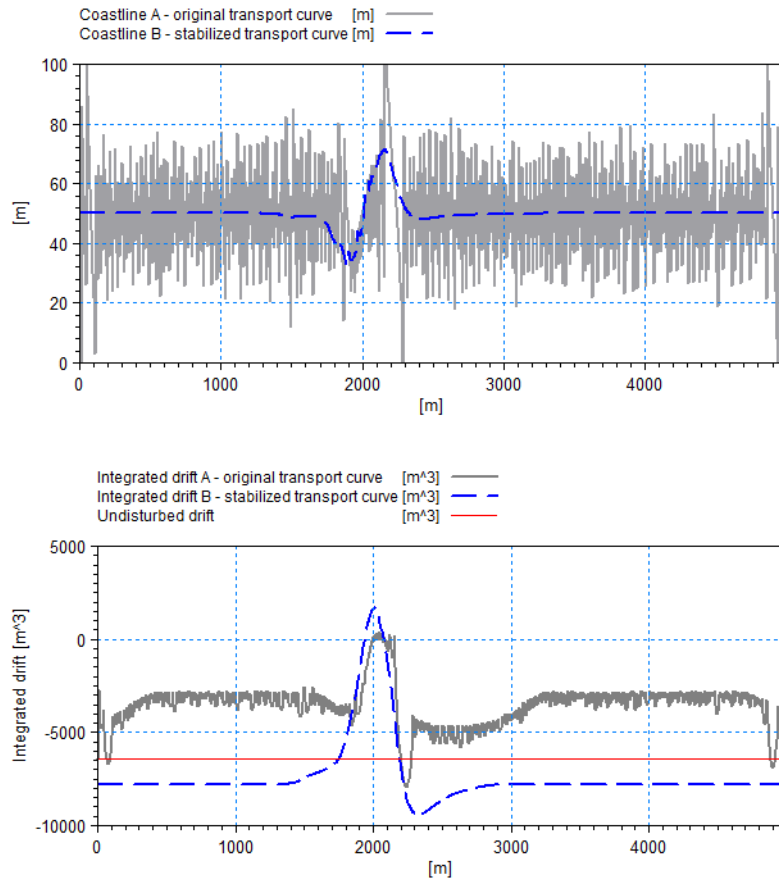Lower: Accumulated littoral drift

Coastline evolution for update by wave event

Figure 3.35 shows the calculated shoreline and integrated littoral drift for the two cases where the coastline alignment is updated after each wave event (Evo_SimC.lpfm) and after all wave events (Evo_SimD.lpfm) in the simulation period. The original transport tables are applied.

It can be seen that the coastline evolution becomes more stable when selecting to update after each event compared to the default setting. However the shoreline change is still dominated by instabilities as the effect of each wave event will have a relatively large impact on the coastline evolution due to the long duration. When choosing to apply the averaged influence from the wave climate events by updating after ALL events the resulting coastline evolution seems seems the most realistic as the destabilization effect from the oblique waves are counteracted by the effect of more perpendicular directed waves.
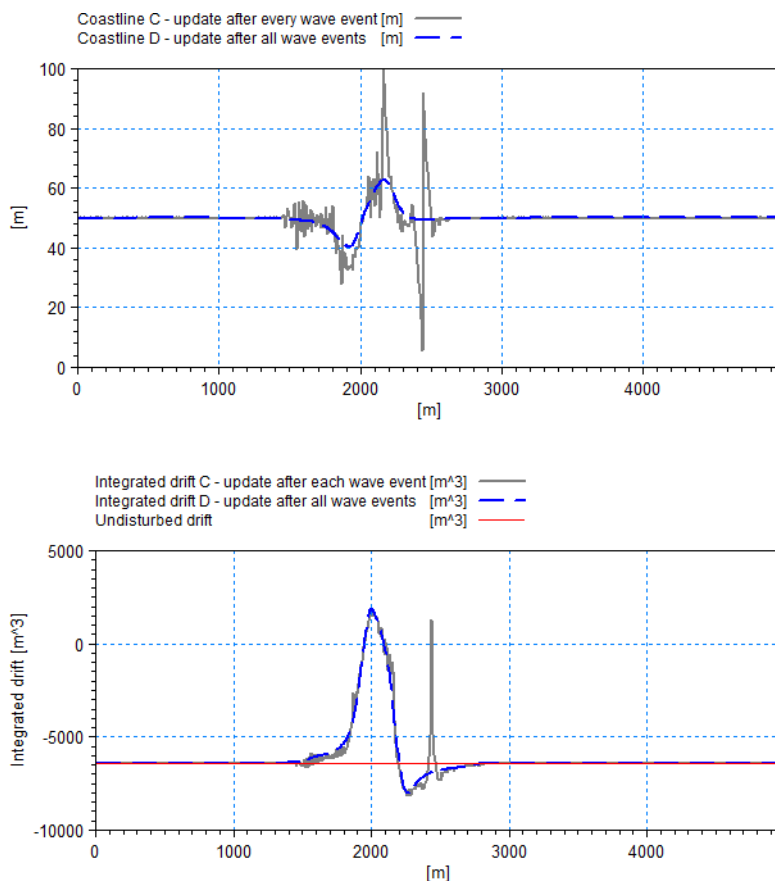
Figure 3.35   Result after 2 years when using event update
Solid line: Update per event, Dashed line: update after all events
Upper: Coastline alignment (Note distorted scale)
Lower: Accumulated littoral drift

Coastline evolution using refined wave climate

As the wave climate is based on statistics there is no correlation between the wave events and the order of the events is random. This implies that the wave climate could just as well be defined by 10 times the events, each event with a duration 10% of the original. Thus, instead of using only one wave cycle and updating once in the simulation period, it is possible to use 10 shorter wave cycles and update the coastline 10 times within the same simulation period. This will give another result which will be equally valid.

Figure 3.36 shows the calculated shoreline and integrated littoral drift for the two cases where the coastline alignment is updated after one wave cycle (Evo_SimD.lpfm) and after 10 shorter wave cycles (Evo_SimE.lpfm) in the simulation period. The original transport tables are applied.
It can be seen that by updating over more wave cycles, the coastline evolu-

tion becomes more destinct as the transport gradient in time reacts to the local shoreline orientation.
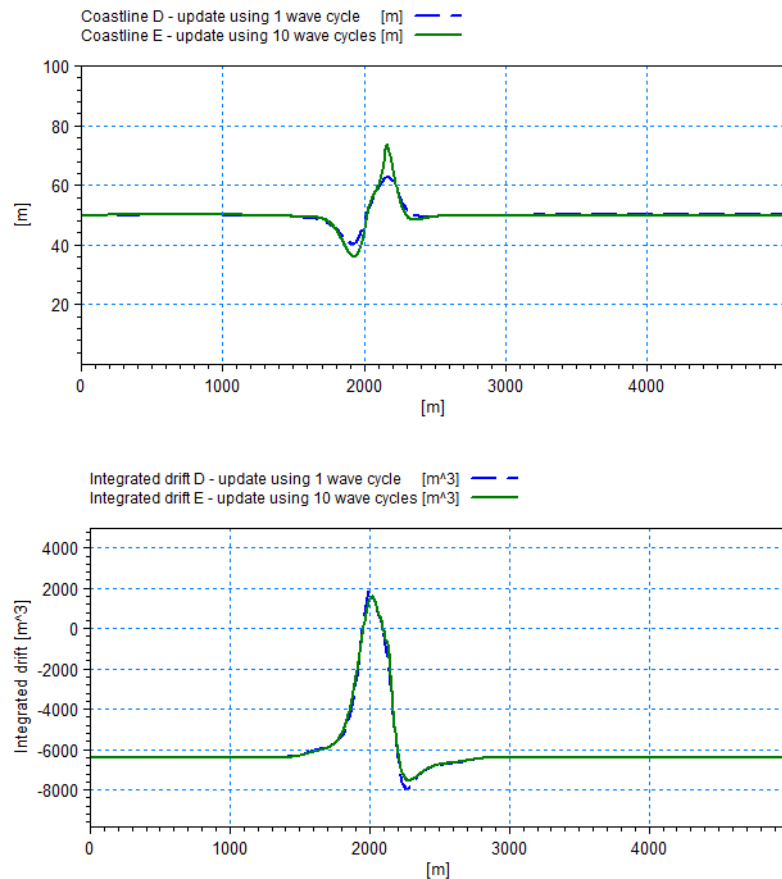
Figure 3.36   Result after 2 years when using refined wave climate
Solid line: Update by 1 wave cycle, Dashed line: update by 10 wave cycle
Upper: Coastline alignment (Note distorted scale)
Lower: Accumulated littoral drift

3.7.4   List of data and specification files

The following data files are supplied with Littoral Processes FM:

File name: Coast.dfs1
Description: Coastline description

File names: Profile.dfs1
Description: Cross-shore profile

File names: Climate.dfs0
Description: Wave climate, 37 individual wave events

File names: Climate_x10.dfs0
Description: Wave climate, 37 individual wave events repeated 10 times

File name: Littoral Drift.lpfm
Description: Littoral Processes FM specification file

File name: CreateTable.lpfm
Description: Littoral Processes FM specification file

File name: ControlTable.lpfm
Description: Littoral Processes FM specification file

File name: Evo_SimA.lpfm
Description: Littoral Processes FM specification file

File name: Evo_SimB.lpfm
Description: Littoral Processes FM specification file

File name: Evo_SimC.lpfm
Description: Littoral Processes FM specification file

File name: Evo_SimD.lpfm
Description: Littoral Processes FM specification file

File name: Evo_SimE.lpfm
Description: Littoral Processes FM specification file

4 Domain

4.1 Domain area

Providing the Littoral Processes FM module with a suitable domain helps the setup as the bathymetric description (using lines and points) can be visualised within a 2D environment.

You may specify the domain either explicitly by defining the map projection and the extension of the area, or you can specify a 2D mesh bathymetry file, by which the map projection and enclosure will define the domain area.

The geographic view in the setup dialogs will per default display the defined domain area, but you have access to zoom and pan functionality via right-click in the display.

If you have specified the domain from a 2D mesh bathymetry file you will later have the option to extract bathymetry data from the mesh bathymetry for use in the calculation.

The selected map projection defines the projection of the output. Having a different map projection in data files (e.g. the cross-shore profile) may lead to unexpected results.

The LONG/LAT map projection is only applicable for the model type "Transport in point".

4.2 Background image

It is possible to include a geo-referenced image as a background map in the geographic views showing the domain area.

Having defined an image you can activate the view of the background image in each individual geographic view in the dialogs by right-clicking the displayed area.

You cannot display both 2D bathymetry and Background image at the same time, apart from in the Domain area dialog.

5 Littoral Processes Module

The Littoral Processes module calculates non-cohesive sediment transport in points and littoral drift along quasi-uniform coastlines.

5.1 Model Definition

The Littoral process model comprises various model types, and you can choose between the following:

- Transport in point
- Littoral drift
- Table generation
- Coastline evolution

5.1.1 Transport in point

This model type calculates the transport rate in one or several individual points based on the local conditions of waves, currents and sediment properties.

Depending on the number of points and time steps in the simulation you may have one or several options for output, see Output specification *(p. 111)*.

5.1.2 Littoral drift

This model type calculates the cross-shore distribution of wave height and direction, the related wave driven currents and littoral drift for one or several individual cross-shore profiles based on wave and current conditions in a single point.

Depending on the number of profiles in the simulation you may have three or four options for output, see Output specification *(p. 111)*.

5.1.3 Table generation

This model type calculates the cross-shore distribution of littoral drift for one or several individual cross-shore profiles based on representative wave, current and water level conditions and saves the results in littoral drift transport tables necessary for the calculation of Coastline evolution.

Note: The maximum number of different cross-shore profiles in a littoral drift transport table is 8.

The model setup should be based on findings in a Littoral drift baseline study.

5.1.4 Coastline evolution

This model type calculates the coastline evolution for a coastline with one or several representative cross-shore profiles.

Prior to the coastline evolution simulation you can create the transport tables necessary for the calculation. The choice will be determined by the Table mode *(p. 94)*.

5.2 Time

You have three ways of describing the time formulation:

- Real-time
- Scenario formulation in time (for Coastline evolution only)
- Individual scenario events

5.2.1 Real-time

You have to specify the simulation start date, the overall number of time steps and the overall time step interval. The overall discrete time step specified on this page is used to determine the frequency for which output can be obtained and to synchronise the input values.

Time-varying hydrodynamic conditions are interpolated to the local time.
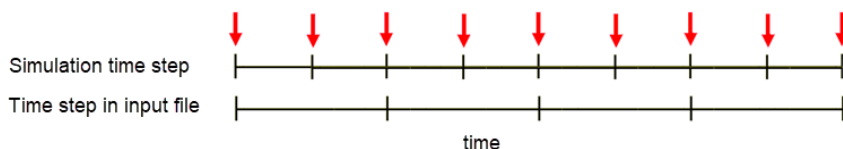
Figure 5.1   Illustration of Real-time formulation

5.2.2 Scenario formulation in time

You have to specify the simulation start date, the overall number of time steps, the overall time step interval and the Duration of the individual scenarios by a time series. You may specify the start date. The overall discrete time step specified on this page is used to determine the frequency for which output can be obtained and the duration defines the time step that is used to determine the synchronised input values.

Time-varying hydrodynamic conditions will remain constant within a duration step.

Figure 5.2   Illustration of Scenario formulation in time

Duration

The duration of an individual event is per default given in percentage of the year.

5.2.3   Individual scenario events

You have to specify the simulation start date and the Duration of the individual scenarios by a time series. This option does not relate to any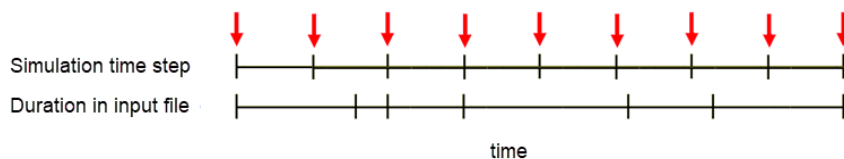 specific date as the scenario events are considered to be unrelated in time. The number of time steps in the calculation is fixed to the number of time steps in the data file.

Time varying values of water level, wave and current data will refer to this duration by the number of time step in the data file.
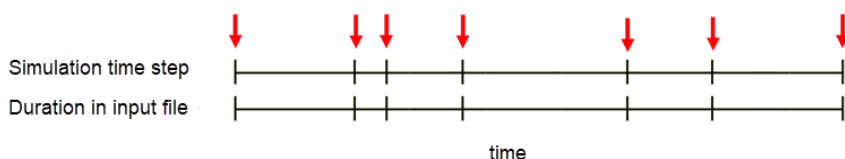
Figure 5.3   Illustration of Individual scenario events

Duration

The duration of an individual event is per default given in percentage of the year.

5.3   Bathymetry

Providing the model with a suitable bathymetry description is essential for obtaining reliable results from your model.

Depending on the Model Definition you have the option to define a Point, a Profile and a Coastline.

The position of the specified bathymetry data is shown in the graphical overview.

5.3.1 Point

You can create a new point by clicking the 'New Point' button. By selecting a point in the Point list and clicking on the 'Delete point' button you can remove this point.

You define a point by a Point name, a Location and a Bathymetry description. In case you have defined the domain area by a 2D bathymetry, you have the option to extract the bathymetry description directly from the mesh file.

It is possible to define and use several points in one simulation.

Note, however, that some output options are not available if several points are defined.

Location

You define the location of the point by the coordinates given by the map projection for the domain.

Bathymetry description

You define the bathymetry of the point by the reference water depth (a positive value) and the bed slopes in the eastern and northern direction, respectively.
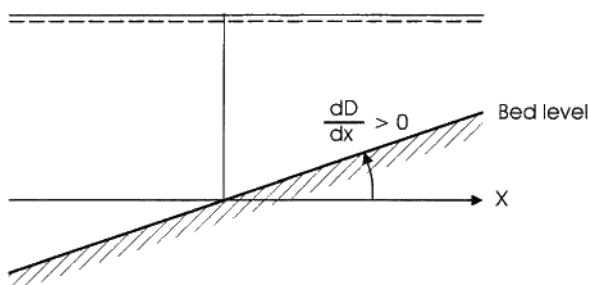

Figure 5.4   Definition of bed slope

5.3.2 Profile

You can specify a new profile by clicking the 'New profile' button. By selecting a profile in the Profile list and clicking on the 'Delete profile' button you can remove this profile.

You define a cross-shore profile by a profile name, the location and the bathymetry description along a line and the orientation of the same line. You may have two options to define the cross-shore profile:

- Specify Line series data file
- Extract Bathymetry from mesh (in case mesh file is defined)

It is possible to define and use several profiles in one simulation. In such case all profiles must have the same spatial resolution, i.e. the grid spacing and number of grid steps must be the same.

Bathymetry description

You may generate a cross-section bathymetry file by the use of the Profile Editor. A cross-section profile bathymetry describes the bed level values along a straight line with equidistant grid steps compared to a base level (often set as the mean water level, MWL). The profile origin should be positioned at a chosen off-shore water depth, and the profile extends in the direction of the shoreline along an axis, which is perpendicular to the depth contours. The last points in the cross-shore profile should reflect dry land.

This bathymetry is considered to be representative along a longer stretch of the coastline such that one can assume long and uniform depth contours in the calculation.
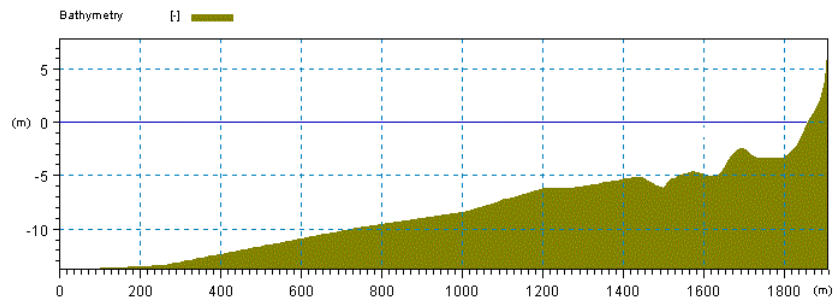
Figure 5.5   Example of cross-shore profile bathymetry

Grid spacing

It is important that the grid spacing is selected to provide adequate resolution of the bathymetry and the wave field under consideration. The grid spacing must be of an order, so the surfzone is represented by at least 10 grid points.

Line series data file

You have to specify a line series file that contains the description of a cross-section bathymetry. The line series file must contain information about the geographical position and the orientation of the line.

Per default the coastline orientation α_0 is derived from the line series file, but you have the option to modify this (see Remarks and hints *(p. 77)*).

Figure 5.6   Definition of coastline orientation α_0 and cross-shore profile alignment

The input coastline orientation for the cross-shore profile is opposite the direction of the actual line series.
The orientation at the origin refers to 'True North'.

Extract Bathymetry from mesh

You have to specify the origin of the profile line along with the line orientation. The grid resolution is defined by the grid spacing and number of grid points.

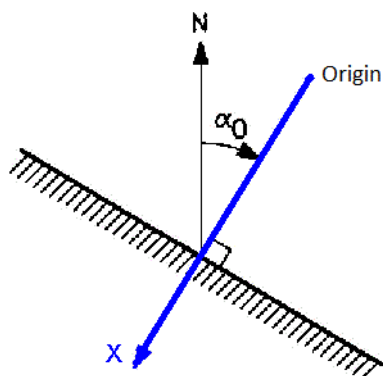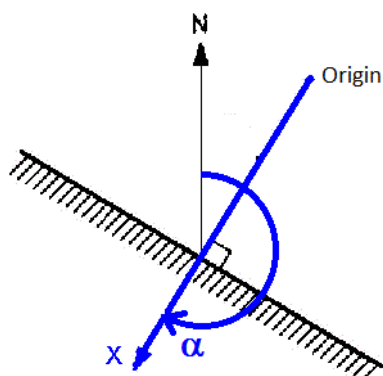Figure 5.7   Definition of line orientation *a* and cross-shore profile alignment

The line orientation for the mesh-derived cross-shore profile is opposite the direction of coastline orientation.
The orientation at the origin refers to 'True North'.

Remarks and hints

It is often used to change the coastline orientation for quick sensitivity tests (this corresponds to "turning" the wave climate). This is only possible when you define the profiles by line series data files.

Note: The Table generation model is only capable of using up to 8 different cross-shore profiles in a transport table.

5.3.3 Coastline

A coastline bathymetry is described by a combination of conditions along the coastline and conditions across the coastline. The conditions across the coastline are specified by one or a number of cross-shore profiles (see 5.3.2 Profile *(p. 74)*).

In this dialogue you have to specify the conditions in the longshore direction. You have to specify conditions for the following:

- Shoreline
- Profile location
- Offshore contour
- Dune description

The description of the coastline is defined relative to a baseline, which has to run parallel to the general orientation of the coastline in question. The line series file for the shoreline position contains information about the geographical position and the fixed orientation of the baseline (normal to the baseline). Per default the coastline orientation is derived from the line series file, but you have the option to modify this.
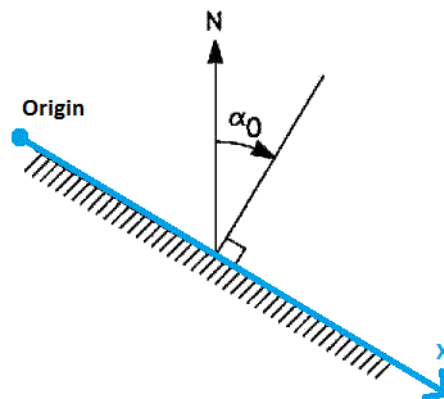
Figure 5.8   Definition of coastline orientation and baseline alignment

The orientation of the coastline is defined as 90 degrees counter-clockwise to the direction of the actual line series.
The orientation at the origin refers to the 'True North' direction.

Shoreline

You may generate a coastline data file by the use of the Profile Editor. The shoreline values describe the nearest distance from a point on the shoreline to the baseline, see Figure 5.9.

The baseline origin should be positioned such that the seawards side of the coastline extends to the left in the baseline direction.
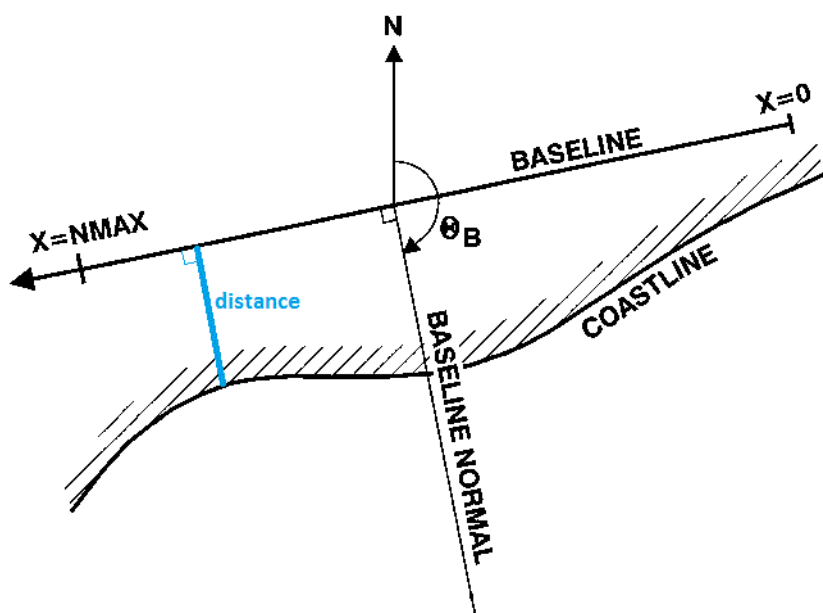
Figure 5.9   Definition of shoreline position

Profile location

You must specify the position and which cross-shore profile to use when calculating the change of wave properties from offshore to the point of wave breaking. This can be specified in two ways:

- Constant
- Specify profile location

In case the profile location is Constant, the local wave properties at the breaking point are derived using the first profile in the Profile list.

In case you specify the profile location, you have to define the profile number, as defined in the Profile list, in a dfs1 file. The file must have the same extension and grid spacing as the Shoreline data file.

Offshore contour

You must specify the influence from offshore contours. Per default the depth contours offshore the position of the first grid point in the cross-shore profile are considered to be parallel to the baseline. And per default the local depth contours (for depths within the cross-shore profile) are defined as having the same orientation as the instant shoreline (coast parallel). However, it is possible to define a local offshore contour in order to maintain a constant refraction of the waves to a certain user-defined offshore depth, independent of the local shoreline orientation.

Offshore contours can specified in three different ways:

- No off-shore contours (default settings are applied)
- Angle between baseline and offshore depth contour
- Distance from baseline to offshore contour

The data must be defined in a dfs1 file. The file must have the same extension and grid spacing as the Shoreline data file.
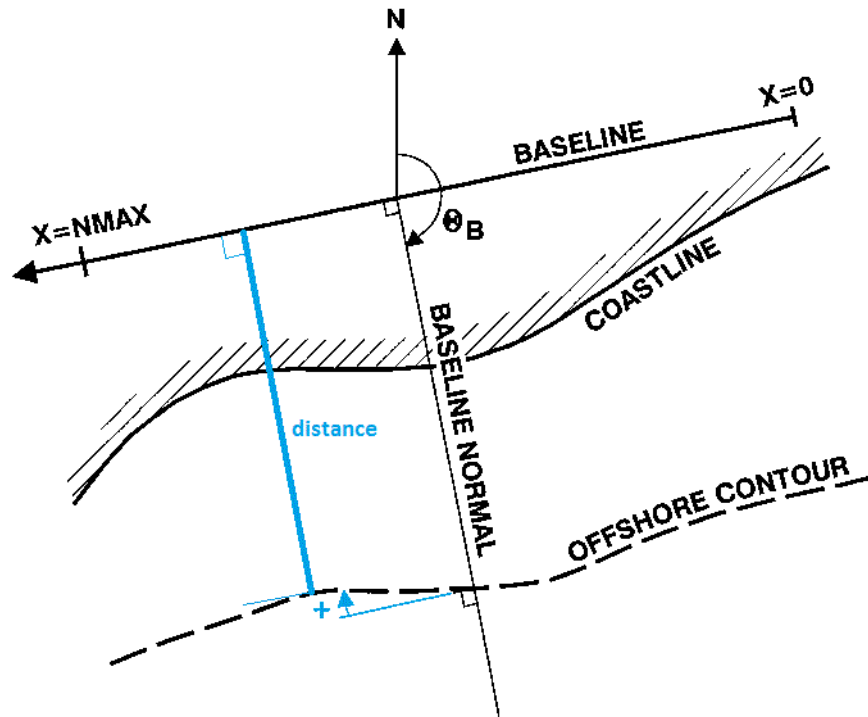
Figure 5.10   Definition of offshore contour position

Dune description

You have the option to include the influence from dunes. The sediment material from eroding dunes acts as a source of sediment during the morphological simulation.

When including dunes you have to specify the distance from the baseline to the dunes as well as the dune height along the coastline.

The data must be defined in a dfs1 file. The file must have the same extension and grid spacing as the Shoreline data file.
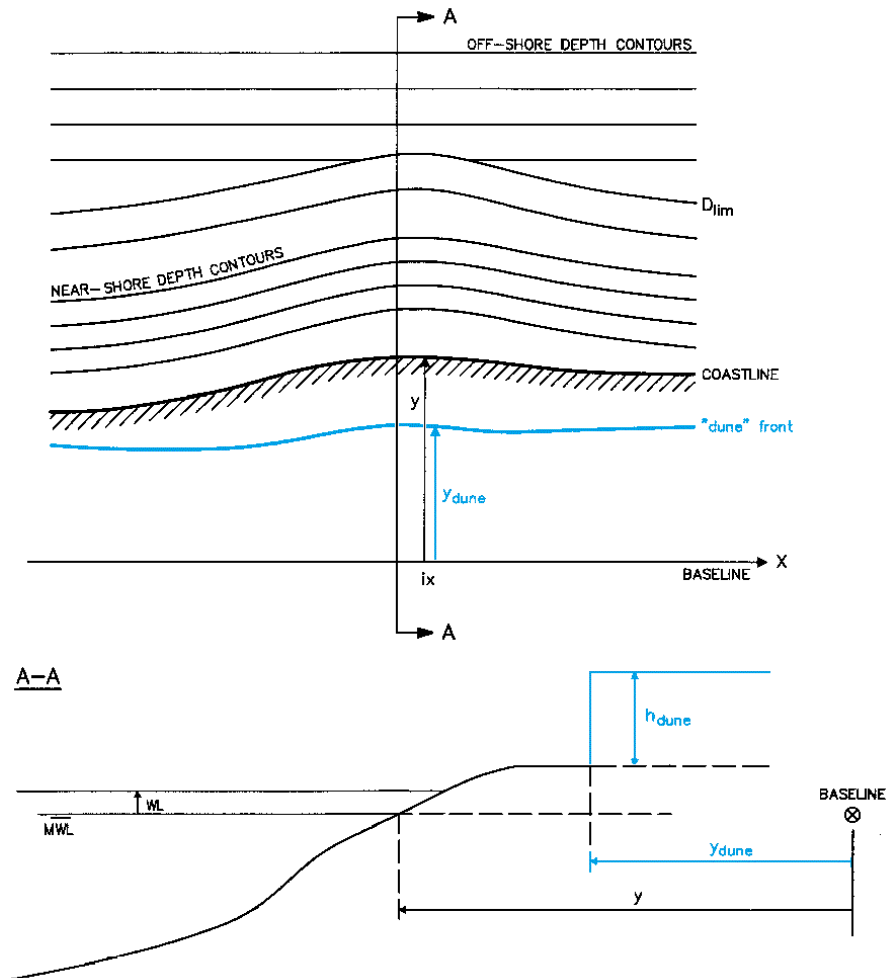
Figure 5.11   Definition of dune position and dune height

5.4   Resistance

As waves propagate into shallow water, the orbital wave velocities penetrate the water depth, and the source function due to wave-bottom interaction become important.

For each cross-shore profile, the bed friction must be specified in each grid point of the profile.

Data

The Nikuradse roughness can be specified in two ways

- Constant (in domain)

- Varying in domain

For the case with values varying in domain you have to prepare a data file containing the bottom friction. The file must be a line series file with the same grid spacing and number of grid points as the cross-shore profile.

5.5   Water level

For wave simulations in tidal areas, it is important that the correct water level is used in the simulation. This will ensure that the changes in wave and current conditions due to varying water depths resulting from the tides are properly modelled. The water level condition can be specified in two different ways

- No water level variation
- Specified water level variation

When selecting the Specified water level variation option, you must specify the water level. Otherwise the water level is assumed to be 0.

In case your calculation mode is Transport in point the value of the water level is added to the local water depth in the point. Otherwise the water level describes the mean water level at deep water relative to the base level for the cross-shore profile.

Data

The format of the water level data can be specified as

- Constant
- Varying in time, constant in domain
- Varying in time, varying in space (only for Coastline evolution)

The water level is only specified for the first grid point in the cross-shore profile. Per default the wave setup is included in the calculations for littoral drift why the water level will not be entirely horizontal across the profile.

For the case with water level varying in time but constant in domain, you have to prepare a data file containing the water level before you setup the simulation. The data file must be a time series file (dfs0). The data must cover the complete simulation period. In case the Time specification is not defined as Real-time the scenario events will be correlated according to the time step position in the data file.

For the case with water level varying in both time and along the coastline you have to prepare a data file containing the water level values along a line before you setup the simulation. The data file must be a profile series file

(dfs1). The first and last point of the line are mapped to the first and last grid point of the coastline and the intermediate values are found by linear interpolation. The data must cover the complete simulation period. In case the Time specification is not defined as Real-time the scenario events will be correlated according to the time step position in the data file.

5.6 Current

It is possible to include the effect of a current in the calculations.

In case your calculation mode is 'Transport in point', the current is the local current in the point. Otherwise this current corresponds to a regional current, e.g. tidal current. The regional current is different from the wave-driven current which will be automatically calculated during simulation.
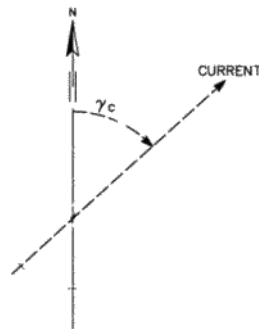
Figure 5.12   Definition of input current direction

Data

The format of the current data can be specified as

- Constant
- Varying in time, constant in domain
- Varying in time, varying in space (only for Coastline evolution)

Per default the regional current is defined by the values in the first grid point of the cross-shore profile.

For the case with current varying in time but constant in domain, you have to prepare a data file containing the current speed and the current direction before you setup the simulation. The data file must be a time series file (dfs0). The data must cover the complete simulation period. In case the Time specification is not defined as Real-time the scenario events will be correlated according to the time step position in the data file.

For the case with current varying in both time and along the coastline you have to prepare a data file containing the current speed and the current direction values along a line before you setup the simulation. The data file must be a profile series file (dfs1). The first and last point of the line are mapped to the first and last grid point of the coastline and the intermediate values are found by linear interpolation. The data must cover the complete simulation period. In case the Time specification is not defined as Real-time the scenario events will be correlated according to the time step position in the data file.

5.7 Waves

The Model Definition determines the necessary parameters for defining the properties of the waves as well as the possible ways of describing the waves. There are in total four ways to describe the waves:

- No waves
- Local wave conditions
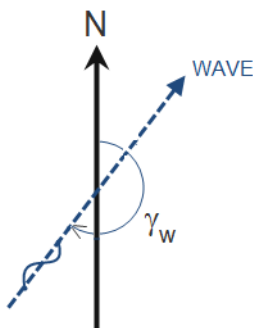- Nearshore wave conditions
- Offshore wave conditions

Figure 5.13   Definition of input wave direction

5.7.1 Parameters

Local wave conditions
For Transport in point you have to define the wave height, the wave period and the mean wave direction.

Nearshore wave conditions
You have to define the wave height, the wave period and the mean wave direction along with a reduction factor.

The conditions will be related to the first point of the cross-shore profile.

Offshore wave conditions

You have to define the wave height, the wave period and the mean wave direction along with a reduction factor.

The conditions will be related to the given reference depth and is not dependent on the cross-shore profile.

Reference Depth

The reference depth is the water depth at which the values of the offshore wave properties are defined. The reference depth is positive and measured relative to the base level for the coastal profile. It is preferable that the reference depth is larger than or equal to the deepest point in the coastal profile. The reference depth is constant during the simulation but the actual water level will be added to the reference depth in refraction calculations. The waves will be refracted from the reference depth to the first point of the profile using the local offshore contour angles.

Data

The format of the wave data can be specified as

- Constant
- Varying in time, constant in domain
- Varying in time, varying in space (only for Coastline evolution)

For the case with waves varying in time but constant in domain, you have to prepare a data file containing the wave conditions before you setup the simulation. The data file must be a time series file (dfs0). The data must cover the complete simulation period. In case the Time specification is not defined as Real-time the scenario events will be correlated according to the time step position in the data file.

For the case with waves varying in both time and along the coastline you have to prepare a data file containing the wave conditions along a line before you setup the simulation. The data file must be a profile series file (dfs1). The first and last point of the line are mapped to the first and last grid point of the coastline and the intermediate values are found by linear interpolation. The data must cover the complete simulation period. In case the Time specification is not defined as Real-time the scenario events will be correlated according to the time step position in the data file. It is only possible to use a profile series file to specify nearshore wave conditions.

Remarks and hints

The wave height is given by H_{rms}. The wave period is in general given by T_z, however for Battjes & Janssen waves the peak period T_p is given instead.

5.7.2   Spectral description

The model is applicable with the following three uni-directional wave descriptions:

- Regular waves
- Rayleigh waves
- Battjes & Janssen waves

Rayleigh waves

The waves are described as a series of regular wave trains, each characterised by the wave height and frequency of occurrence. The wave heights are Rayleigh distributed and the wave period is fixed. Each wave train is tracked across the coastal profile similar to the regular waves.

Battjes & Janssen waves

The statistical description of the wave heights is a truncated Rayleigh distribution where the upper bound is the local maximum wave height. The mean wave energy balance equation is applied to calculate the rms-value of the wave heights across the coastal/beach profile, whereas the wave period is fixed.

The use of Battjes and Janssen demands longer profiles as the wave-breaking in theory starts at deeper waters.

5.7.3   Wave breaking

Depth-induced wave breaking is the process by which waves dissipate energy when the waves are too high to be supported by the water depth, i.e. reach a limiting wave height/depth ratio.

There are four ways to describe wave breaking:

- No wave breaking
- Specified gamma (Battjes and Janssen (1978))
  Gamma parameters are specified
- Specified fraction of breaking waves (for Transport in point only)
- Functional form (Nelson (1987)) (for Littoral drift only)
  Gamma parameters are derived internally

Parameters

Alpha

The alpha controls the rate of dissipation and is a proportional factor on the wave breaking source function. The default value is 1.

Gamma (wave steepness)

This gamma value controls the wave steepness condition. The default value is 1.

In case you apply the Functional form type, this value is set internally to 0.88.

Gamma

This gamma value controls the limiting water depth condition. The default value is 0.8.

In case you apply the Functional form type the this value is derived internally by the wave steepness in the start of the profile.

Dissipation factor

The dissipation factor is a measure of the percentage of waves that are breaking. The value is between 0 (no wave breaking) and 1 (full wave breaking).

Remarks and hints

By increasing the gamma and/or alpha parameter, the dissipation can be reduced. In the calibration process it is recommended first to consider the influence of changing/varying the gamma value controlling the depth-induced wave breaking.

The default value of 1 for the gamma value controlling the dissipation due to wave steepness can in some cases give a too strong dissipation. In this case a larger value (2-5) can be used.

5.8 Sediment

The calculation requires the sediment characteristics for the given location (point/profile).

The grain size is regarded as a representative grain size for a specific grid point in the modelling area. This means that the sediment properties can vary spatially across a profile. On coasts with wave impact, coarser sediment is often found on the beach and on shallow water while finer sediment are found in deeper waters.

5.8.1 General description

The calculation of sediment transport rates are based on the assumption that there is an unlimited supply of sand available and that the concentration profile is fully developed. The calculation only considers the local conditions and as thus the transport rates in the individual grid points can be considered independently.

The core of the sediment transport calculation model (STPQ3D) solves the vertical diffusion equation on an intra-wave period grid to provide a detailed description of the non-cohesive sediment transport in combined waves and currents.

The bed load and the suspended load are calculated separately, thus enabling a detailed analysis of the sediment transport.

Sediment description

The calculation of the non-cohesive sediment transport is based on the type of material:

- Uniform sand
  The transport is calculated based on the assumption that the sediment in the bed only consists of one size of grains, specified by the mean grain diameter and the fall velocity.

- Graded sand
  The transport is calculated based on the assumption that the sediment in the bed can be described by a grain curve, specified by the mean grain diameter and a grading coefficient (sediment spreading).

- Shingle sized sediment
  The transport is calculated based on the assumption that the sediment in the bed only consists of one size of large grains, specified by the mean grain diameter. Any suspended load is not considered but effects of inertia forcings on the individual grain particle are included.

Presently it is not possible to mix the different types of sediment within one simulation.

5.8.2 Sediment properties

You have the option of specifying the type of sediment in four different ways:

- No sand transport (sediment properties superfluous)
- Uniform sand
  Mean Grain diameter and Fall velocity must be specified
- Graded sand
  Mean Grain diameter and Grading coefficient must be specified
- Shingle sized material
  Mean Grain diameter must be specified

You also have to define the relative sediment density for the material.

Mean Grain diameter

The mean grain diameter (d_{50}) must be specified for each point in the bathymetry. The grain size can be specified in two ways

- Constant
- Varying in domain (for Littoral drift only)

For the case with values varying in domain, you have to prepare a data file containing the grain size. The file must be a line series file with the same grid spacing and number of grid points as the cross-shore profile.

Fall velocity

For uniform sand you must specify the fall velocity of the material for each point in the bathymetry. The fall velocity can be specified in two ways

- Constant
- Varying in domain (for Littoral drift only)

For the case with values varying in domain, you have to prepare a data file containing the fall velocity. The file must be a line series file with the same grid spacing and number of grid points as the cross-shore profile.
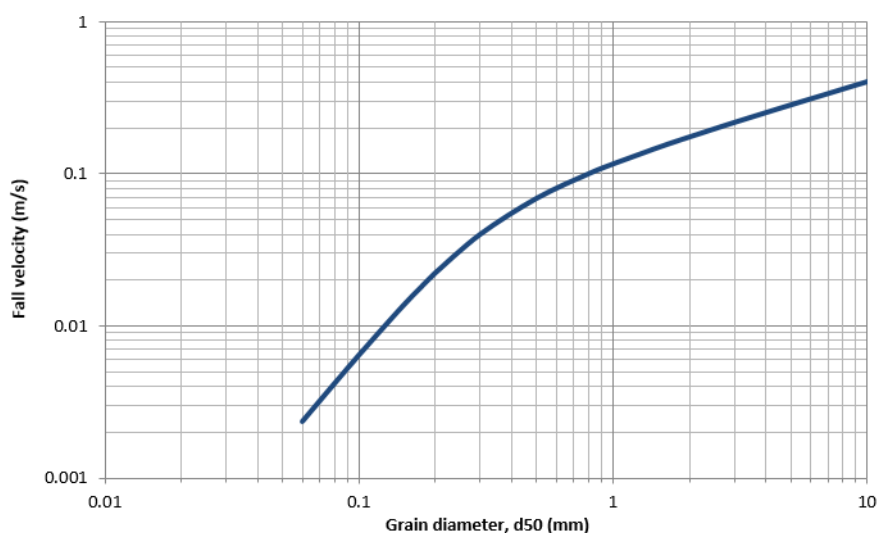

Figure 5.14   Fall velocity for uniform sediment by a water temperature of 12ºC

Grading coefficient

For graded sand, you must specify the grading coefficient of the material in each grid point of the cross-shore profile. The grading coefficient, σ_g, is specified by the shape of the grain curve:

$$\sigma_g = \sqrt{d_{84}} / \sqrt{d_{16}}$$

where d_{84} and d_{16} represent fractiles on the grain curve.

The grading coefficient can be specified in two ways

- Constant
- Varying in domain (for Littoral drift only)

For the case with values varying in domain, you have to prepare a data file containing the grading coefficient. The file must be a line series file with the same grid spacing and number of grid points as the cross-shore profile.

5.8.3 Bed parameters

Bed parameters influence the processes going on near or at the bed.

Porosity
The sediment porosity controls the Littoral drift output as sediment drift is given in volume.

The output from a Transport in point defines transport capacity which is given in solid material.

Ripples
The effect of ripples on the bed shear stresses may be included.

The four constants C1, C2, C3 and C4 are used for assessing the dimensions and the effect of wave ripples, if any. It is usually not recommended to change the default values.

Critical Shields parameter
The criterion for sediment in movement is that the critical shear stress for erosion is exceeded corresponding to the driving forces exceeding the stabilising forces. The default value is 0.045.

In case of shingle sized material, the inertia forcings may influence the dynamics and the critical Shields parameter is calculated internally based on the inertia coefficients. For sand particles, the critical shear stress for erosion is constant throughout the simulation.

Inertia coefficients
When simulating shingle sized material, the individual grains are considered to be of a size where inertia will begin to have an impact of the movement of the sediment.

You have to define the following five inertia coefficients:

1. Dynamic friction coefficient
   The dynamic friction coefficient, μ_d, is related to the dynamic friction angle for the bed sediment, $\mu_d = \tan(\phi_d)$.

2. Static friction coefficient
   The static friction coefficient, μ_s, is related to the static friction angle (angle of repose) for the sediment, $\mu_s = \tan(\phi_s)$.

3. Alpha coefficient
   The Alpha coefficient is a non-dimensional coefficient.

4. Drag coefficient
   The drag coefficient, c_d, is about 1.4 for shingle sized sediment.

5. Hydrodynamic mass coefficient
   The hydrodynamic mass coefficient, c_m, is about 0.5 for shingle.

5.8.4 Water column parameters

For graded sand, you have to specify the number of fractions you want to use in your simulation. The sediment transport rate is calculated for each grain fraction, individually, and integrated to obtain the resulting transport rate.

The program automatically calculates the grain fractions that are able of moving. For more details, please see the Scientific Documentation (LittoralProcessesFM_ScientificDoc.pdf) located in the default manuals directory.

The water temperature affects the fall velocity of the individual grain fractions.

5.8.5 Sediment calculation parameters

The sediment calculation parameters relates to theories applied in the calculation of the sediment transport.

Wave theory
The wave theory is used for calculating the orbital wave motion of the intra-wave period. You can choose between the following five theories:

- Stokes (orders 1 to 5)
- Cnoidal (orders 1 to 5)
- Vocoidal
- Isobe & Horikawa
- Doering & Bowen

Calculation parameters
The calculation parameters are used in the iterative process of calculating the fully developed concentration profile.

Bed concentration

The bed concentration may be determined by a deterministic approach or by an empirical formula.

5.9 Transport

The Coastline evolution *(p. 72)* model utilises customised sediment transport tables in order to speed up the calculations. Rather than calculating the cross-shore distribution of the sediment transport rate directly for each calculation point along the coastline, the transport rates are found by interpolation in tables.

5.9.1 General description

During the calculation of coastline evolution, the transport rates are found by interpolation in the tables rather than calculating each transport rate directly. The tables contain the transport rates for given conditions at the line of wave breaking.

The tables are generated by successive calls to the littoral drift model engine, and input includes the usual input to Littoral drift. The varying hydrodynamic parameters are specified by the minimum and the maximum value, valid for the first grid point in the profile, and the number of different values occurring in the table. The table may contain different cross-shore profiles as well.

Based on the input, the total transport rates Q_t $(I_g,wl,T,h_b,\alpha b,i)$ as well as the cross-shore distribution Q_d $(I_g,wl,T,h_b,\alpha b)$ are tabulated for an envelope of the hydrodynamic and bathymetric conditions. The maximum dimensions for the various parameters describing a table is given in Table 5.1 below.

Table 5.1   List of parameters to describe a LITLINE table

Name	Description	Max. number of values
i_g:	Slope of water surface due to regional current	9
wl:	Water level	25
T:	Wave period	25
h_b:	Wave height at breaking point	25
αb:	Incoming wave angle at breaking point	25
i:	Cross-shore profile (cross-section number)	8

The tables are specified by a Global name "*name*" which is common for all the files that combined represent one table. A transport table for coastline evolution consists of four different types of files.

Table 5.2   List of files contained in a LITLINE table

File name	Description
name.val	This file (ASCII format) contains information about the parameters related to the transport rates in the tables.
*name*qtt.*i*	This file (binary format) contains the total sediment transport rates for cross-section no. *i* along the coastline
*name*qtd.*i0j*	This file (binary format) contains the distributed sediment transport rates across the profile for cross-section no. *i* and surface slope no. *j*
*name*nqd.*i0j*	This file (binary format) contains the positions of the distributed sediment transport rates across the profile for cross-section no. *i* and surface slope no. *j*

Some combinations of I_g, wl, T, h_b and α_b cannot exist for the given bathymetric conditions. In these cases the sediment transport rate will be given a very small default value below 10^{-7} m³/s.

Breaking point

The breaking point is defined as the grid point where the wave height, *H*, first becomes 0.8 times the water depth, *D*, for a wave progressing towards the shoreline.

$$\frac{H}{D} \geq 0,8 \quad = \ wavebreaking \tag{5.1}$$

Incoming wave angle

Contrary to the common way of defining wave direction, the incoming wave angle in the sediment transport tables are related to the coastline normal, see Figure 5.15.
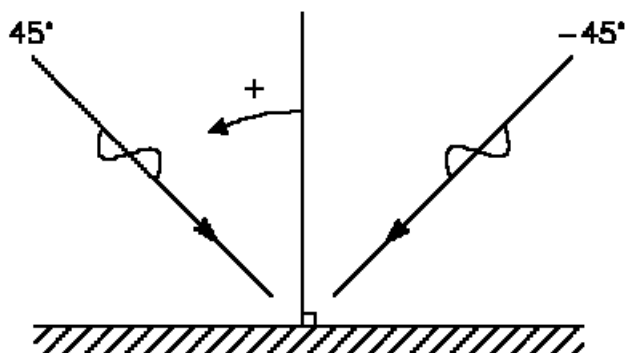
Figure 5.15   Definition of incoming wave angle in sediment transport tables

Global name

The combined transport table is defined as described in Table 5.2. Below is an example of a .val file that defines the accompanying binary transport tables.
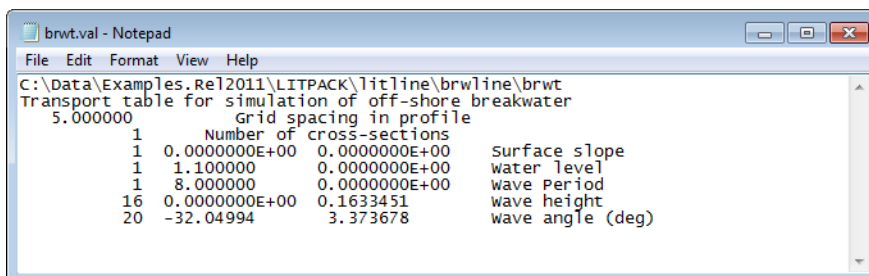

Figure 5.16   Example of definition file for global table named 'brwt'.
The limits refer to the conditions at the Breaking point

5.9.2   Table mode

You have to specify the transport table to use in the coastline evolution calculations. If you do not have a to use, you have to create the table prior to the morphological simulation. Depending on the Model Definition the type of calculation will be set to one of the two types of calculation:

- Create table
- Use table

You have to define the global name (*.val) of the transport table in either case.

Create table

NOTE: In case the table file already exists, the old transport table file will be overwritten.

Use table

It is assumed that the accompanying binary table files exist in the same directory as the specified global name (*.val) file.

The number of binary files, N, can be calculated by:

$$N = No_{prof}(1 + 2No_{slopes})$$ (5.2)

where No_{prof} is the number of profiles in the table and No_{slopes} is the number of surface slopes.

5.9.3 Table limits

The table limits reflect the validity of the transport table. The contents of the GUI depends on the choice of table mode:

- Create table
  Define limiting nearshore wave conditions and axis size

- Use table
  Review table axis for conditions at breaker line

The axis values within the table are found by linear interpolation between the minimum and the maximum limit.
The maximum number of values for a given axis is described under General description, page 92.

Create table

Here you define the limits of the input hydrodynamics.

The values entered should cover any conditions that are expected to occur in the coastline evolution calculations.

The number of values in the table defines the total number of values in the resulting transport table. Thus increasing the number of values increases the accuracy of the transport rate values in the coastline evolution simulations.

The combined effect of possible wave properties, mean water level and regional current will determine the maximum values of wave conditions at the Breaking point in the resulting transport table and the maximum value of surface slopes.

The Incoming wave angle is defined relatively to shore normal.

Use table

Here you can see the limits of the hydrodynamics contained in the transport table. The values relate to the conditions at the Breaking point.

You cannot edit the values.

The Incoming wave angle is defined relatively to shore normal.

5.9.4 Cross section

A cross-section defines a position where the transport conditions are derived from using one profile only. The contents of the GUI depends on the choice of table mode:

● Create table
● Use table

Create table

During the generation of the transport tables each defined cross-shore profile will correspond to a cross-section by a one-to-one relationship. It is not possible to edit the values.

Note: The model is only capable of handling up to 8 different profiles in a transport table. You can however use the same cross-section table more than once along the coastline when using the table.

Use table

Here you define the location and associated cross-shore profile for different cross-sections to be included in the calculation. For each defined cross-section you may choose to include or exclude it from the calculations in the coastline evolution.

The transport rates along the coast in points that are positioned in between defined cross-sections will be interpolated.

The model is only capable of handling up to 8 different profiles in a transport table. You can however use the same cross-section table more than once. It is possible to define up to 20 cross-sections along the coastline.

5.10 Structures

You may add various structures to include in the coastline evolution calculations.

The graphical overview indicates the defined location of the structures in the simulation.

Note: Structures cannot be located at a boundary point or at the point next to the last boundary point.

5.10.1 Groynes

A groyne is defined as a non-permeable structure, oriented normal to the baseline.

You can create a new groyne clicking on the 'New groyne' button.

You have to define the position and bypass length of the groyne. The position of the groyne is defined by the position of the tip. The bypass length defines the section length at the tip of the groyne where longshore bypass of sediment may occur despite the presence of the structure. The down-wave sheltering effect of groynes is calculated from an empirical formulation.

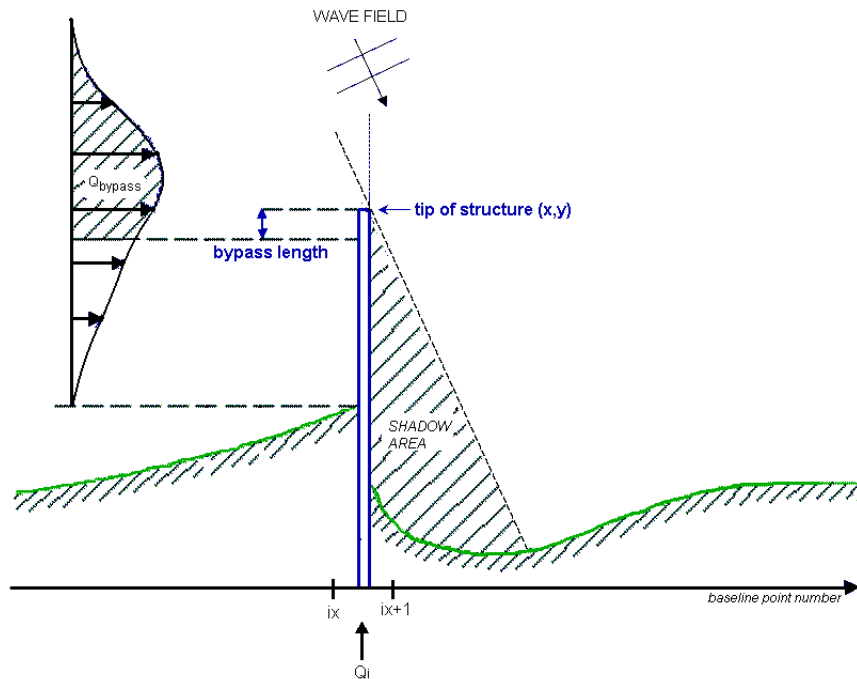A groyne may, contrary to Jetties, be positioned behind Offshore breakwaters.

Figure 5.17   Definition of groyne

It is possible to define a negative bypass length to e.g. block all transport from upstream as illustrated in Figure 5.18 below.
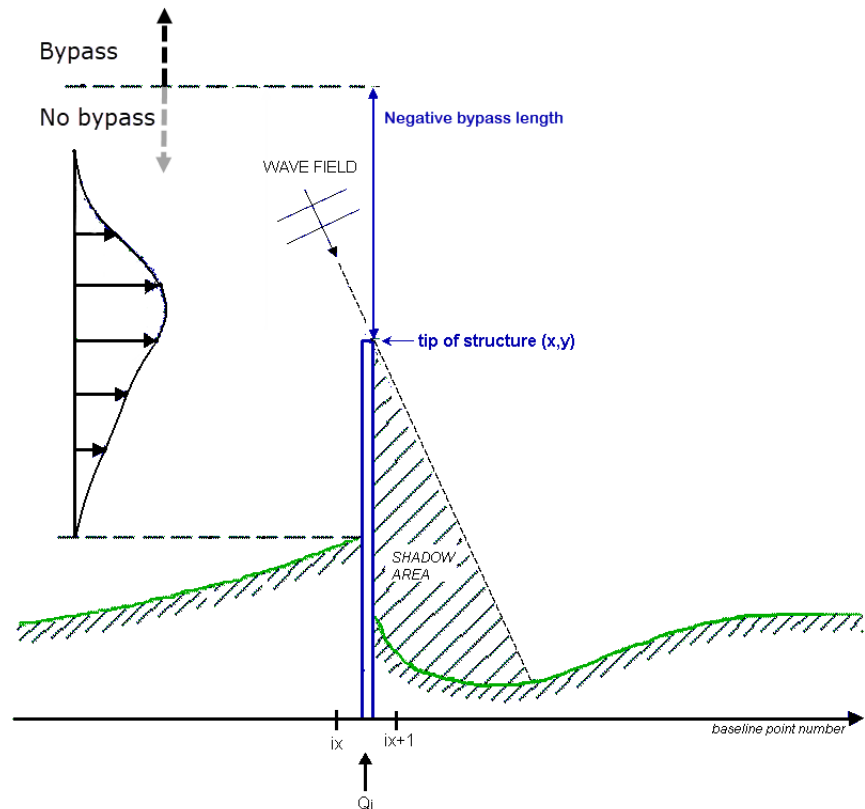
Figure 5.18   Using negative bypass length to block transport

5.10.2 Jetties

A jetty is defined as a non-permeable structure, oriented normal to the baseline.

You can create a new groyne clicking on the 'New jetty' button.

You have to define the position and the bypass length of the jetty. The position of the jetty is defined by the position of the tip. The bypass length defines the section length at the tip of the jetty where longshore bypass of sediment occurs despite the presence of the structure.

Jetties as such are usually fairly long structures, and diffraction phenomena due to jetties are included in the calculation of coastline evolution.

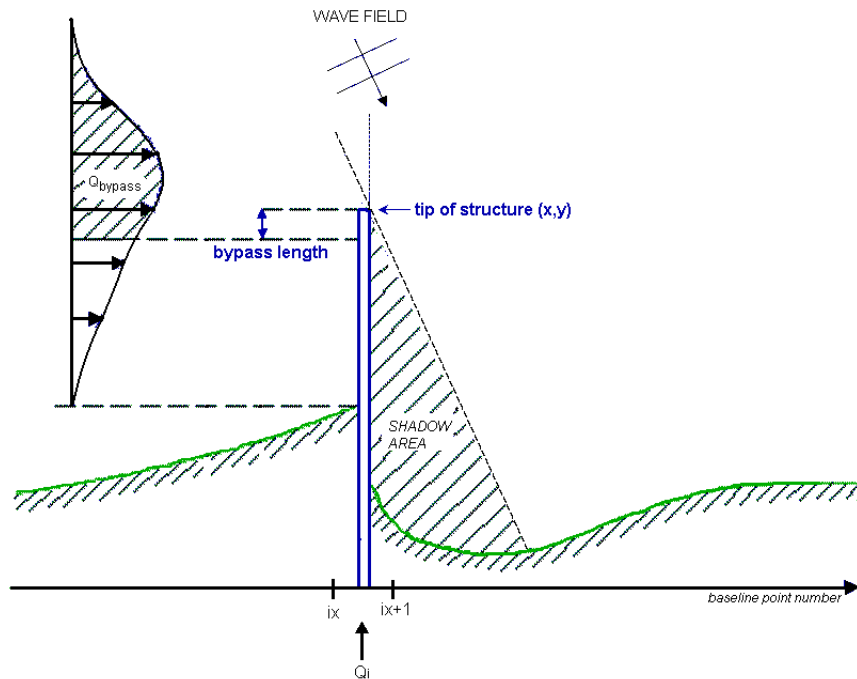Jetties cannot be positioned behind Offshore breakwaters.

Figure 5.19   Definition of jetty

5.10.3 Offshore breakwaters

An offshore breakwater is defined as a structure positioned in the water off the beach outside the breaker zone but within the profile. The breakwater is defined by the position of the start and end the point of the structure.
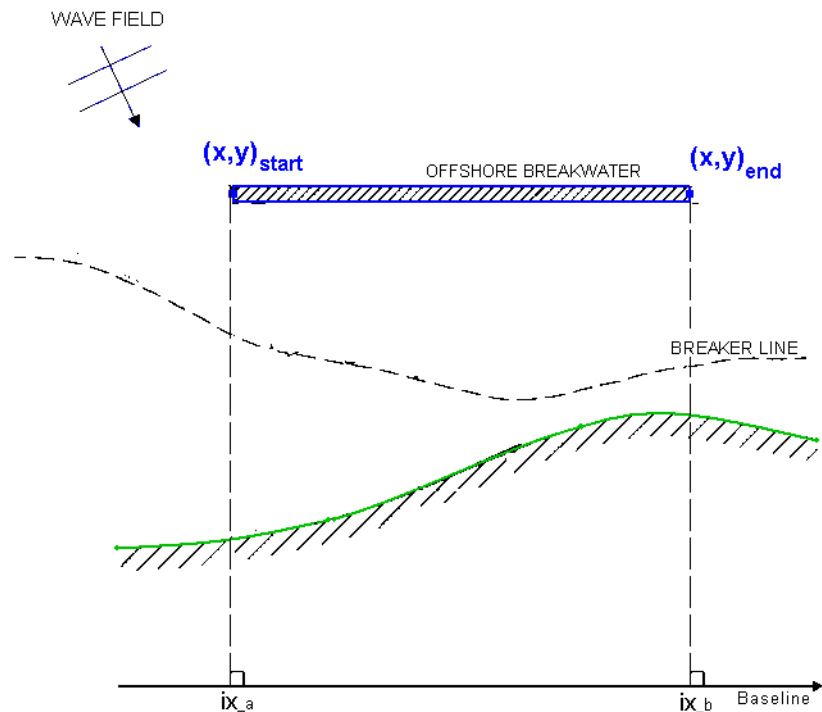
Figure 5.20   Definition of offshore breakwater

5.10.4 Revetments

A revetment is defined as a structure on (or behind) the beach line, defined by the position of two (or several) points.

The revetment acts as a seawall by preventing the coastline from eroding and retreating along the extension of the revetment. Erosion may take place in front of the revetment, resulting in an increase of the water depth at the position of the revetment.

The maximum retreat is the maximum possible distance from the end of the revetment to the point on the coastline next to it, measured normal to the baseline. It essentially corresponds to the active width of the profile. The maximum retreat is also used in calculation of the depth and the sediment transport in front of the revetment.

When the coastline is retreating next to a revetment, the end of the revetment may shelter the waves coming from certain directions. This effect on the sediment transport rate may be included or omitted.

Revetments cannot be positioned next to a boundary point.

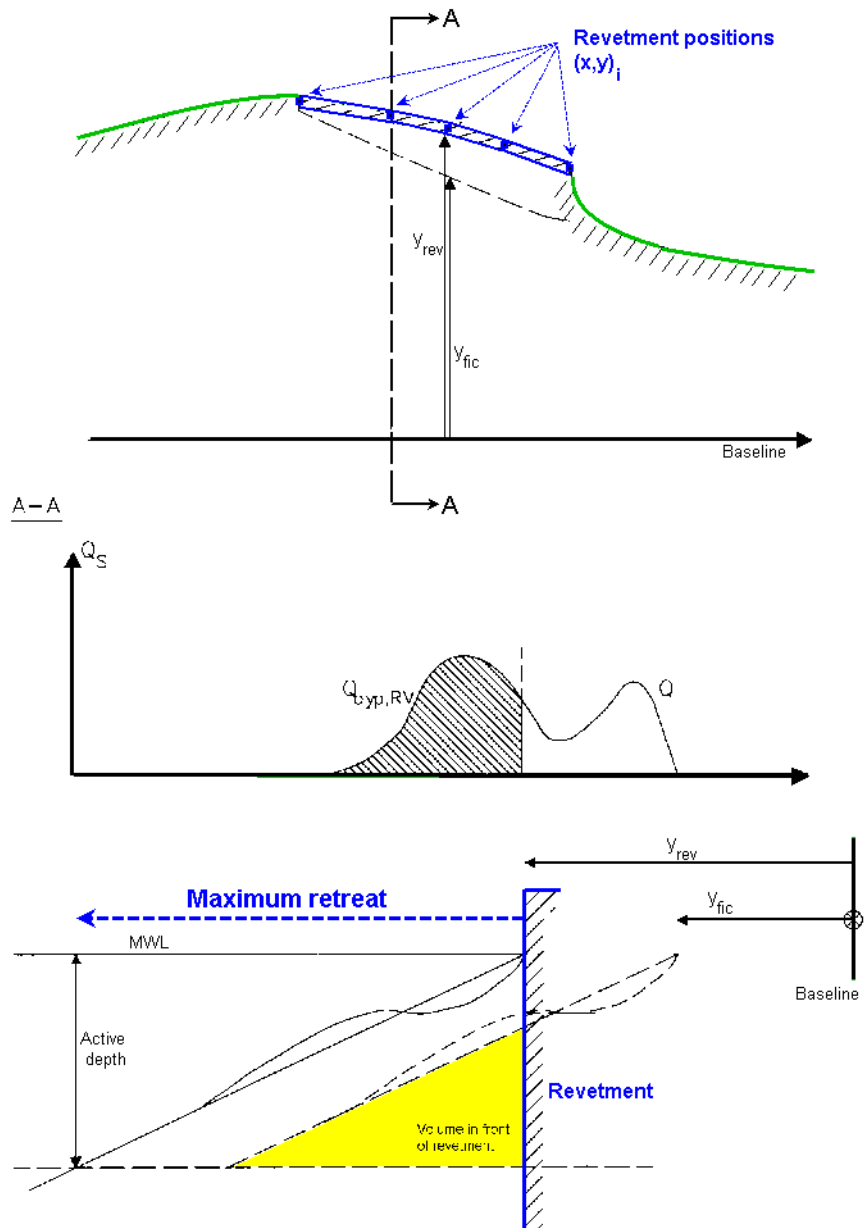A too small value of the maximum retreat may lead to fluctuation in the depth in front of the revetment.

Figure 5.21   Definition of revetment

Location

The revetment is defined by the position of two (or several) points. The points should be in succession such that the first and the last coordinate correspond to the start and end the point of the revetment in the direction of the baseline. The final description of the revetment will be found by linear interpolation between the specified points.

5.10.5 Remarks and hints

The number of structures are restricted as listed in Table 5.3 below:

Table 5.3   Maximum number of structures

Type	Maximum number
Groyne	40
Jetty	10
Offshore breakwater	10
Revement (points per revetment)	50 (100)

Choice of structure

The choice of which structure to use depends on the dominant effect the structure is expected to have on the coastline evolution.

The sheltering effect of the groyne on the down-stream wave climate and the associated reduction in transport capacity is included by reducing the "un-disturbed" transport rates in the sheltered area, whereas the sheltering effect of the jetty is calculated by diffraction.

Groynes influence the coastline evolution by blocking all or parts of the long-shore sediment drift. Thus it is apparent that groynes are to be regarded as fairly short structures where the groyne tip is within or just outside the active transport zone. It is assumed that the littoral drift downstream the groyne first will be fully in equilibrium at the distance 10 times the length of the groyne.

Jetties also block the transport but furthermore influence the coastline evolution by changing the incoming wave properties by diffraction. This in turn changes the longshore sediment transport as interpolated from tables. Thus, it is apparent that jetties are to be regarded as fairly long structures where the jetty tip is well outside the active transport zone. The influence from jetties on the downstream sediment transport rates are considered to be apparent up to a distance twice the length of the jetty.

The simulation of shore-perpendicular structures will always require some assessing of which type of structure will represent the local processes the

best. The effects of groynes and jetties can be calibrated by modifying the length and the bypass length of the structures.

Solution technique

The position of the structures are related to the nearest grid point on the baseline before calculations takes place.

You can read more about the solution technique in detail in the Scientific Documentation (LittoralProcessesFM_ScientificDoc.pdf) located in the default manuals directory.

5.11 Sources

A sediment source adds extra sediment into the system and will be included in the sediment balance for the specified location. The source may have a negative value and behave like a sink; extracting sediment from the system.

You specify a source by clicking on the 'New source' button in the List View. By selecting a source in the Source list and clicking on the 'Delete source' button you can remove this source. For each source, you can specify the name of the source and whether the source should be active or not. The specification of detailed information for each source is made subsequently. From the list view page you can go to the dialogue for specification by clicking on the 'Go to...' button.

The Geographic view display the location of the sources.

Note: Sources cannot be located at a boundary point.

5.11.1 Source specification

You can choose between two types of sources:

- Point source
- Distributed source

Depending on the source type, you have to define the location of one or two points.
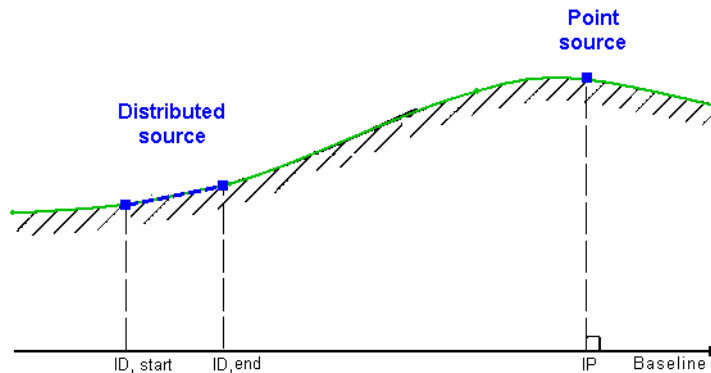
Figure 5.22   Definition of source location

You have to specify the total magnitude of the source QS (in m³/s). The format of the source data can be specified as:

- Constant.
  The source is the same for the whole simulation period

- Varying in time.
  The source may vary during the simulation period

If the magnitude of the source is positive, sediment is added to coastline and if the magnitude is negative sediment is removed from the coastline.

Data

For the case with time varying sediment source, you have to prepare a data file containing the necessary source data before you setup the simulation. The data file must be a time series file (dfs0). The data must cover the complete simulation period. In case the Time specification is not defined as Realtime, the scenario events will be correlated according to the time step position in the data file.

The value for QS are given in porous volumes (taking the porosity of the material into account).

Remarks and hints

The number of sources are restricted to 6 point sources and 6 distributed sources.

Point sources are related to a specific longshore position. In order to avoid a large discontinuity in the calculation, the source QS from a point source is distributed to the neighbouring grid points as indicated in Figure 5.23.

Point sources could typically be used to simulate discharge from a river.

Distributed sources are related to a defined stretch of the coastline. The source QS are equally distributed to the related grid points as indicated in Figure 5.23.

Distributed sources could typically be used to simulate beach nourishment or loss of sediment by on-offshore transport.
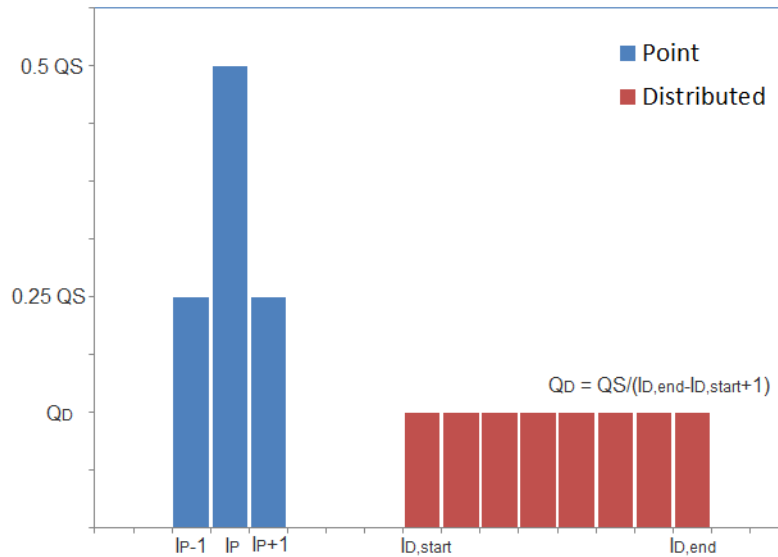

Figure 5.23   Distribution of sediment discharge from a point source and a distributed source, respectively, for the same source magnitude QS

5.12   Coastline Calculation Parameters

The coastline calculation parameters relate to the numerical solution applied in the calculation of the local transport capacity and the related coastline evolution.

5.12.1   General description

The coastline evolution calculations are based on a co-ordinate system in which the x-axis is a baseline that runs parallel to the primary coastline orientation, while the y-axis runs from the baseline in offshore direction, see Figure 5.24.
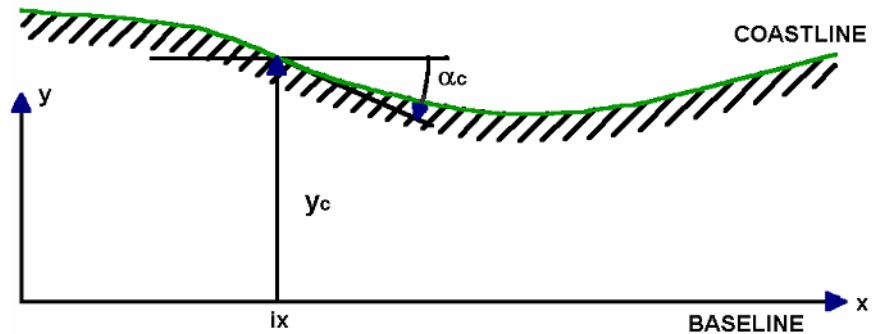
Figure 5.24   Coordinate system in coastline evolution model

The coastline is defined by the variation of y_c in the longshore (x) direction, while the cross-shore profile defines the water depth (bottom position) as a function of the cross-shore position relative to the coastline position y_c. The local variation of y_c determines the local cross-shore profile orientation α_c.

Q-α curve

For given wave properties, the total longshore transport of sediment, Q, is determined as a function of the longshore position y_c and the local coastline orientation α_c.

With known values of local wave conditions at the breaker line (I, wl, T, H_b, and α_b), the total longshore transport Q corresponding to the applied value of α_c can be determined by interpolation in the transport tables. For each calculation point X_{cal} Q is found for different values of α_c to provide a "discrete" $Q(X_{cal}, \alpha)$ relation, as shown in Figure 5.25.

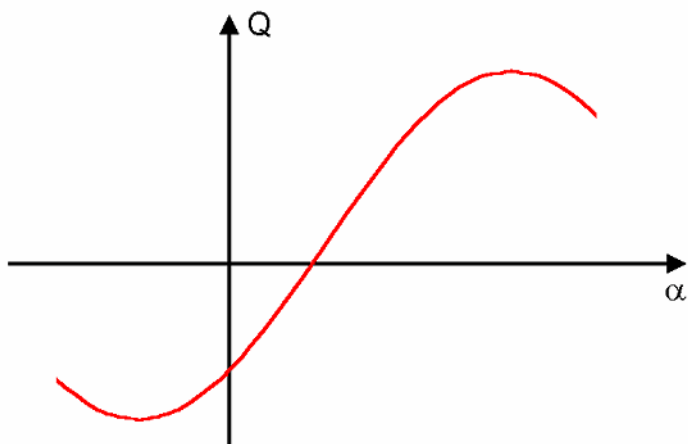The coastline evolution model calculates the Q-a curve in all grid points along the coastline.

Figure 5.25 $Q(X_{cal}, \alpha)$ for varying α

5.12.2 Calculation parameters

The coastline calculation parameters relate to the numerical solution applied in the calculation of the local transport capacity and the related coastline evolution.

Tables

Transport capacity
It is possible to modify the transport tables so that the calculation only considers the inner part of a transport profile. This is in particular of interest when a coastline is protected by short groynes that do not extend across the surf zone.

The extension is defined as the distance from the actual coastline.

Transport gradient
It is possible to stabilise the simulation result by modifying the Q-α curve. However, this has the effect that the sediment transport for incoming waves from oblique angles (>45 deg.N) will be over-estimated, see Figure 5.26.
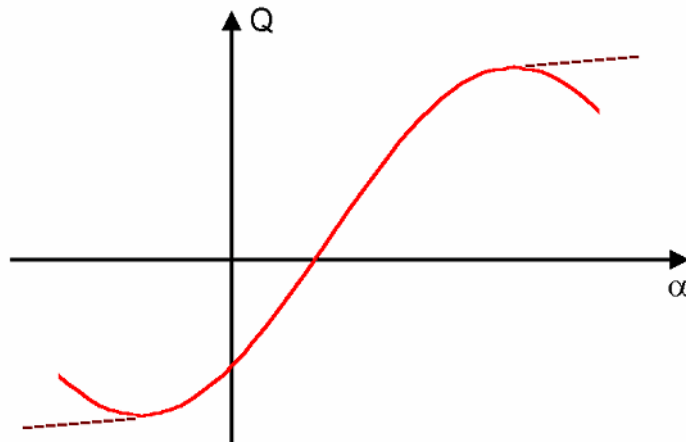
Figure 5.26   Stippled line indicates stabilised Q-alpha curve for varying α

Structures diffraction

When including a jetty or an offshore breakwater in the model the wave conditions shorewards of the structure are affected by diffraction.

The number of points behind the structure defines in how many points a Q-α curve should to be calculated to include the effect of diffraction. A larger number may increase the accuracy, but will slow down the speed of the model.

The spreading factor describes the wave concentration parameter in deep water and is used in the diffraction calculations. A large value denotes a fairly narrow wave spectrum.

Structures blocking

The active length is used in the calculation of bypass of sediment by structures.

The active length should correspond to the width of the active zone. However when several sediment transport tables are included in the simulation the active zone can differ from one cross-section to another why a common value needs to be defined.

5.13   Morphology

You have the option of including or excluding morphology in the calculations.

Excluding morphology will enable you to assess the annual drift under steady conditions, as the integrated sediment drift after one year of simulation will be

a measure of the annual sediment transport in each grid point along the coast (assuming original Q-α curve).

If you include morphology, you have to define the Update description and the Active profile for the calculations.

5.13.1 General description

The main equation in coastline evolution modelling is the continuity equation for sediment volumes expressed by:

$$\frac{\partial y_c(x)}{\partial t} = -\frac{1}{h_{act}(x)}\frac{\partial Q(x)}{\partial x} + \frac{Q_{sou}(x)}{h_{act}(x)\Delta x} \tag{5.3}$$

where $y_c(x)$ is the distance from the baseline to the coastline, t is the time, $h_{act}(x)$ is the height of the active cross-shore profile, $Q(x)$ is the longshore transport of sediment expressed in volumes, $Q_{sou}(x)$ is the source/sink term expressed in volume/Δx, x is the longshore position and Δx is the longshore discretisation step.

As sketched in Figure 5.27 the active profile height, $h_{act}(x)$, is composed of two components and it is calculated by the sum of the beach height, *hbeach*, and the local active depth, *Dactive(x)*.

$$h_{act}(x) = h_{beach} + D_{active}(x) \tag{5.4}$$

where *hbeach* is the height of the 'front beach' and *Dactive(x)* is the local active depth.
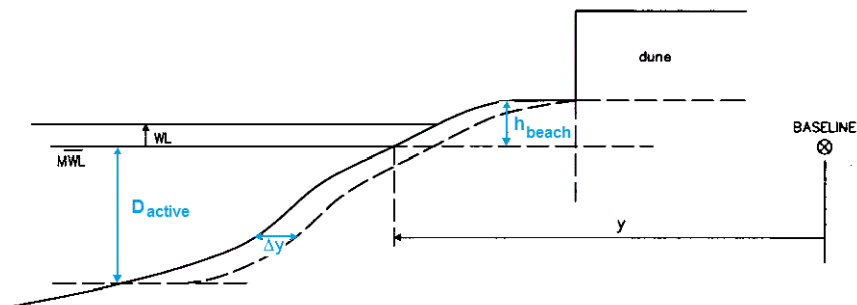

Figure 5.27   Definition of active profile height and initial movement of coastline

5.13.2 Update description

The frequency of the morphological update of the coastline in the simulation may be set in three ways:

- Update continuously
  This cause the coastline to be updated for every internal time step in the simulation

- Update by time interval
  The update frequency interval is defined by hours in between update

- Update by wave interval
  The update frequency interval is defined by the number of wave events in the wave climate between update

5.13.3 Active profile

The active profile height is the sum of the active beach height above MWL and the active depth of the profile below MWL, see Figure 5.27.

The height of active beach indicates how much of the beach above mean water level is subject to erosion and accretion.

The active depth indicates how much of the profile below mean water level is subject to erosion and accretion.

5.14 Outputs

Standard data files with computed results from the simulation can be specified here.

In the main Outputs dialogue you can add a new output file by clicking on the 'New output' button. By selecting a file in the Output list and clicking on the 'Delete output' you can remove this file. For each output file you can specify the name (title) of the file and whether the output file should be included or not. The specification of the individual output files is made subsequently. You can go to the dialogue for specification by clicking on the 'Go to...' button. Finally, you can view the results using the relevant MIKE Zero viewing/editing tool by clicking on the 'View' button during and after the simulation.

5.14.1 Output specification

For each selected output file, you must specify:

- the field type
- the output format
- the output file (name and location)
- the time step must be specified

The available output field types and output formats are closely related to the model definition.

Field type

All dependent on the Model Definition, the bathymetry description and the number of time steps, you can choose between different types of data. The types are as described in Table 5.4.

Table 5.4   List of possible output data

Field type	File type	Model Definition
Point values	dfs0	Transport in point
Z-level values	dfs1	Transport in point
Intra-wave period	dfs0	Transport in point
Intra-wave period z-level	dfs1	Transport in point
Profile output	dfs1	Littoral drift / Table generation
Drift output	dfs0	Littoral drift / Table generation
Annual drift	dfs1	Littoral drift
Q-alpha curve	dfs0	Littoral drift
Coastline evolution	dfs1	Coastline evolution

Output format

You can choose between the following types of output formats

- Point series (dfs0)
- Line series (dfs0)

The file type depends on the Field type as described in Table 5.4.

Output file

A name and location of the output file must be specified.

Time step

In general, the temporal range refers to the time step formulation specified in the Time dialogue and the number of time steps is user-defined.

In case the selected model definition is Table generation, the number of time steps in the output is fixed and equals the number of events in the generated transport table.

Point values

The time series file contains the selected Output items for each selected bathymetry point.

Z-level values

In case you have defined only one bathymetry point, you can select to output the time-averaged mean values in the vertical.

Intra-wave period

In case you have defined only one bathymetry point and simulated only one time step, you can select to output the intra-wave period values of various, internal simulation parameters.

The number of time steps in the file will automatically be equal to the number of steps per period specified in Section 5.8.5 Sediment calculation parameters *(p. 91)*.

Intra-wave period z-level

In case you have defined only one bathymetry point and simulate only 1 time step, you can select to output intra-wave period values in the vertical of various internal simulation parameters.

The number of time steps in the file will automatically be equal to the number of steps per period specified in Section 4.8.5 Sediment calculation parameters (p. 50).

Profile output

The line series file contains values for the selected Output items corresponding to all the grid points in the specified cross-shore profile. In case you have defined more than one profile in the setup, you need to specify the relevant profile number.

The number of time steps in the output file is user defined.

Drift output

The time series file contains values for the selected Output items for the specified cross-shore profile. In case you have defined more than one profile in the setup, the output data from the different cross-shore profiles will be saved within the same file.

The number of time steps in the output file is user defined.

Annual drift

This is a special version of the Profile output. The line series file contains values for the selected Output items corresponding to all the grid points in the specified cross-shore profile. In case you have defined more than one profile in the setup, you need to specify the relevant profile number.

The output file has only one time step and contains time-integrated values over the entire simulation period for the specified cross-shore profile.

Q-alpha curve

This field type is a special version of the Drift output and is only available in case you have two or more cross-shore profiles in your simulation. The output file is typically used to assess the annual Q-α curve.

The number of time steps in the output file corresponds to the number of cross-shore profiles. Each time step in the time series file contains the time-integrated values for the entire simulation period along with the coastline orientation for the individual cross-shore profile.

Coastline evolution

The line series file contains values corresponding to all the grid points in the specified coastline file.

The number of time steps in the output file is user defined.

5.14.2 Output items

All output items are optional, i.e. the user is free to select among the variables.

The available output variables are closely related to the Model Definition.

Transport in point

The flow and the transport in x-direction and y-direction correspond to the Eastern and Northern direction, respectively.

Littoral drift

The flow and the transport rates for a cross-shore profile are considered positive when the direction is towards the right side of the shore normal, see Figure 5.28.

Figure 5.28   Definition of flow and transport direction for cross-shore profile

Coastline evolution

The transport rates for a coastline are considered positive when the direction is towards the right side of the shore normal, similar to Figure 5.28. Accumulated volume is considered positive when the coastline accrete.