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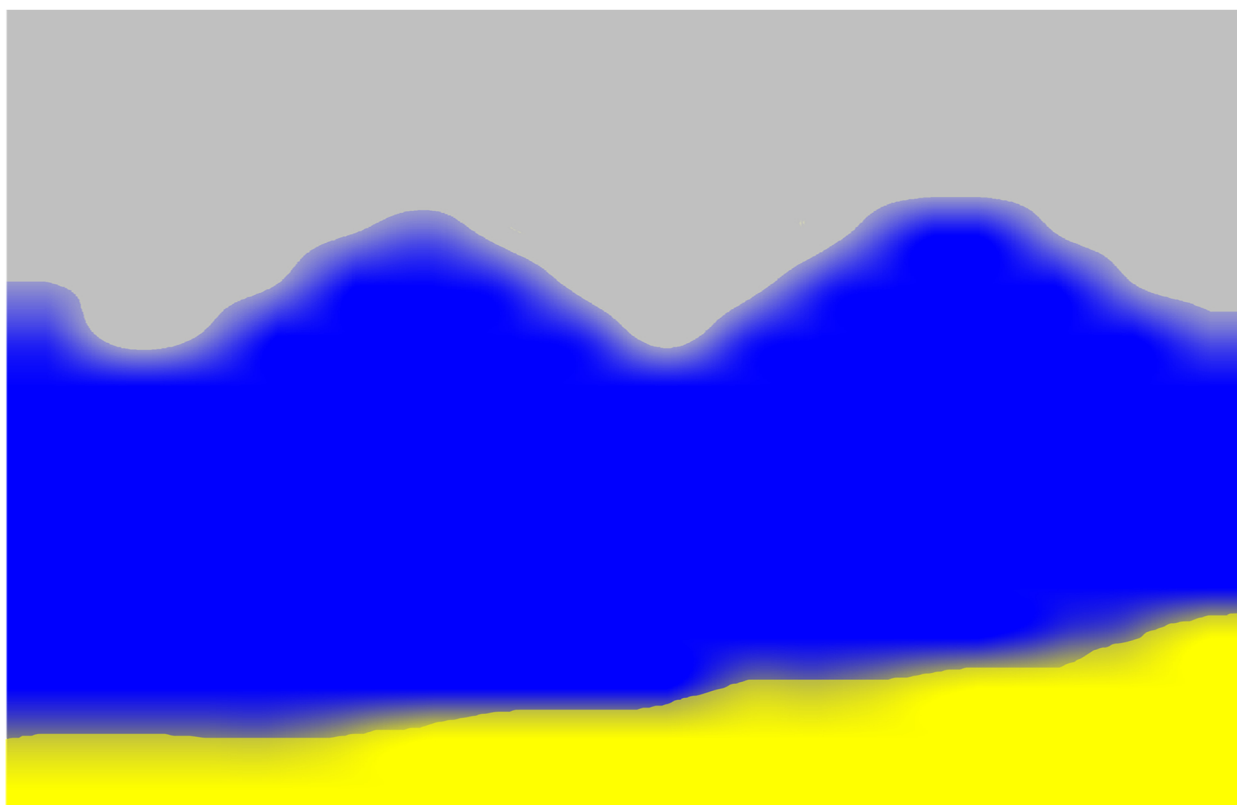
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Guide to MildSim

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Kristina Thomassen
Jens Peter Kofoed



Aalborg University
Department of Civil Engineering
Water and Soil

DCE Technical Report No. 73

Guide to MildSim

by

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Jens Peter Kofoed

October 2009

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Introduction to MildSim

The changes in the wave conditions when approaching the coast are caused by shoaling, refraction, diffraction, and wave breaking [Andersen and Frigaard, 2008]. All these effects are easiest taken into account by using a numerical program such as MILDsim which accurately computes the mentioned effects.

MILDsim is based on solving the coupled mild-slope partial differential equations (PDE). These PDEs are derived from the governing PDE for water wave mechanics and the boundary conditions for linear waves propagating in areas where the variation of the water depth is small. By integrating the PDE in the vertical direction, the dependence of the water depth is removed and the problem is reduced to a 2D problem, and thereby the two dimensional PDE only is valid when the bottom slope is small. The derivation of the PDE's are described in Brorsen [2007].

Because MILDsim is based on the mild-slope equations with corrections, the program works with models where the slope of the seabed is up to 1:1. As input in MILDsim the water depths in the analysed area are needed and the programs ENGAGE and VANDLAND are therefore described as well, as they set up the distribution of land, water, and water depths.

In this paper an expansion of Hanstholm Harbour is used as an example. The expansion includes a new breakwater north-east of the existing harbour at a water depth of 7 m. From an extreme wave analysis the significant wave height at a water depth of 20 m is found to $H_s = 7.3$ m and a corresponding peak period $T_p = 14.4$ s. MILDsim is then used to find the design wave height at the position of the new breakwaters.

1.1 Installation Guide

The program ENGAGE is downloaded to the computer just by unzipping the zip-file 'engage'. The programs SEASTATE and STOKE1 can be downloaded directly.

The programs VANDLAND and MILDsim is installed on the computer by clicking the icon 'SetupVandlandMildSim2008.exe' and following the Vandland-Mildsim setup wizard.

When the programs are installed it is a good idea to rearrange the folders as described in Section 1.2.

The cd contains a zip-file 'Hals Havn' which is an example where the installed programs has been used. Notice that this example is not the example of Hanstholm Harbour described in this paper. The example is included because it might be a help to getting to

know the programs and as the model is fairly simple the computational time is rather short.

1.2 Structure of the Folders

When using the mentioned programs, a specific structure of the folders is recommended because of the steps described in this guide. The structure of the folders and the calculation flow is shown in Figure 1.1. The arrows indicate the calculation flow and the input and output needed. The ordinary lines show the folder structure together with the necessary files in the different folders. Note that the folders “db” contain important program files, and the programs will not be able to function without them.

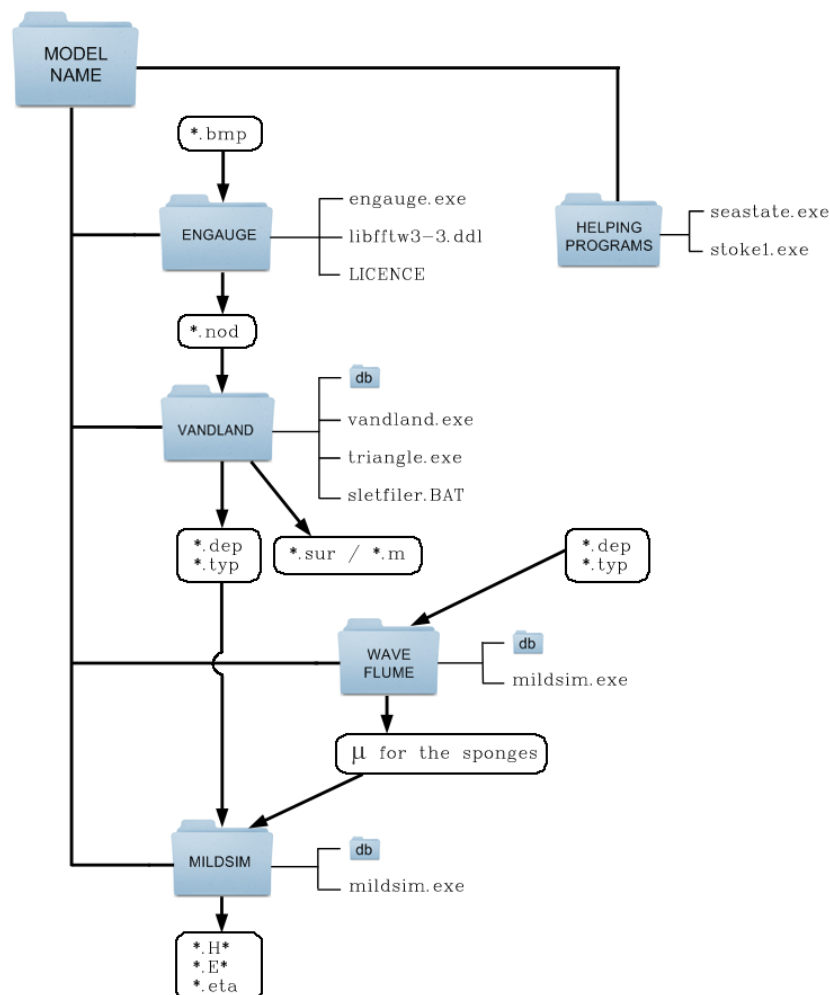


Figure 1.1 The structure of the folders and the calculation flow when using the programs Engauge, Vandland, and MildSim.

The *.bmp file should be saved in the folder ENGAUGE. From ENGAUGE the *.nod file is produced and should be saved in the folder VANDLAND. VANDLAND produces the files

*.dep and *.typ which should be saved in the folder MILDSIM. The files *.H*, *.E*, and *.eta produced by MILDSIM can be used to analyse the wave conditions at the wanted position in the model. The description of the different files are given during the guide for the different steps.

1.3 Preliminary Choices

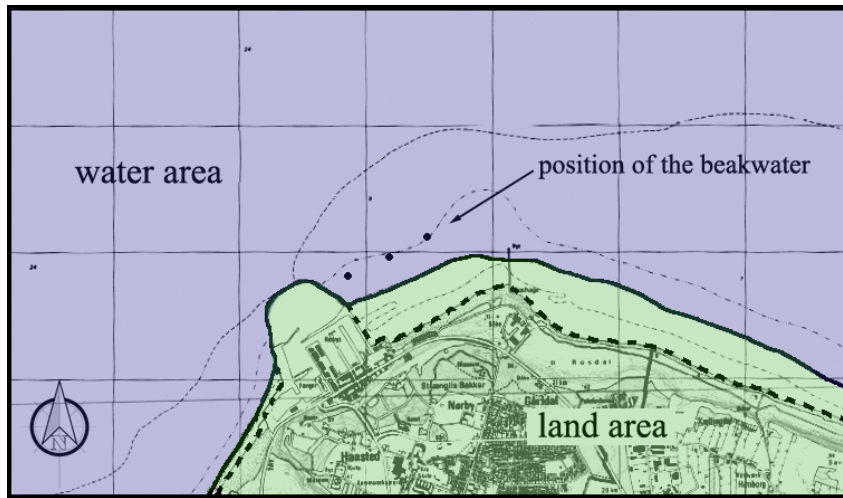
When the model is made in VANDLAND it has to be large enough to show the influence of the water depth and small enough in order to save computational time. As the significant wave height found by the extreme wave analysis is positioned at a water depth of 20 m the model must contain this position and water depth. For the model of Hanstholm a minimum water depth of 5 m is chosen. This is done because the design wave height that should be found is at a depth of 7 m where the breakwaters are going to be located.

By choosing this water depth as the minimum depth in the model, the boxes described in Section 3.1 can be made rather large and thereby the whole set up of the model will be eased. Because of this it is a good idea to consider how low the lowest water depth in the model needs to be, and make it as high as possible without influencing the results.

The sponge-layers which gives full absorption as described in Section 3.7 absorb nearly 100% of the incident wave energy and this will have an effect on the waves near the borders of the model. This effect will grow in the direction of the wave propagation which means that the model should be made wide enough, so that these border effects have no influence on the positions in the model where the data should be extracted. In the final plot of the simulation shown in Figure 4.13 it is possible to see the border effects.

The created borders in the model should correspond to the wanted direction of the generation-line described in Section 3.7. The program is able to generate waves forming an angle with the actual generation-line. When the waves are generated as regular waves or 2D irregular waves this angle can be up to around 45° . Are the waves generated as 3D irregular waves they are spread in an angle of 45° and the angle with the generation-line can only be up to 20° . The width of the model is important here as well, as the area, from where the data should be extracted in the model, should be covered by the wave propagation.

The chosen model size for Hanstholm Harbour is shown in Figure 1.2. The dotted lines in the water shows the contour lines of the seabed. The bold dotted line indicates the coastline.



Engauge

In the program ENGAUGE the node-coordinate file needed as input to the program VANDLAND is set up. The procedure is as follows:

1. A map of the area that should be analysed is saved as e.g. a bmp-file. Before saving the image, a coordinate system which indicates the scale of the map should be drawn.
2. The file is imported to ENGAUGE via **Import** in the menu **File**.
3. The coordinate system is defined by three points: Origo, the end of the x-axis and the y-axis, respectively, as it can be seen in Figure 2.1. The points are set up by **Axis Point** in the menu **Digitize**.

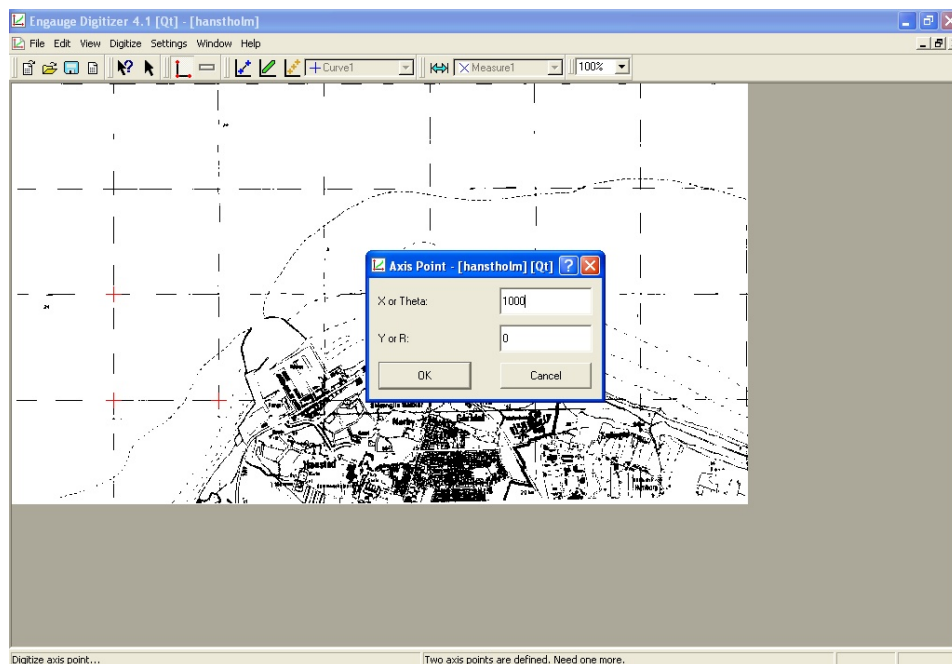


Figure 2.1 Defining the coordinate system in Engauge.

4. The next step is to define the water depths in the map by drawing curves that follows the contour lines. This should be done by discretising points on one contour line at the time. Choose **Settings - Curves - Rename** where the default-name **Curve 1** can be changed to another name that indicates the water depth e.g. h=5 m as shown in Figure 2.2.

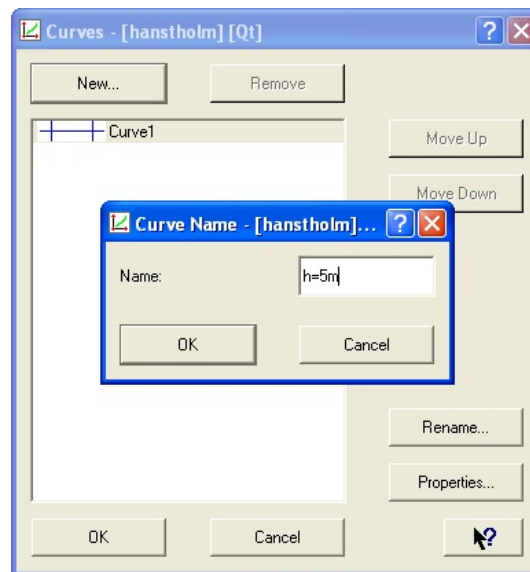


Figure 2.2 Defining the name of the curves in Engauge.

Afterwards, choose **Properties** and choose **Connect as** to **contour** if the water depths that should be defined lie on a contour line as shown in Figure 2.3. If the water depths are only given in a single point on the map choose **Connect as** to **Single Valued Function** instead.

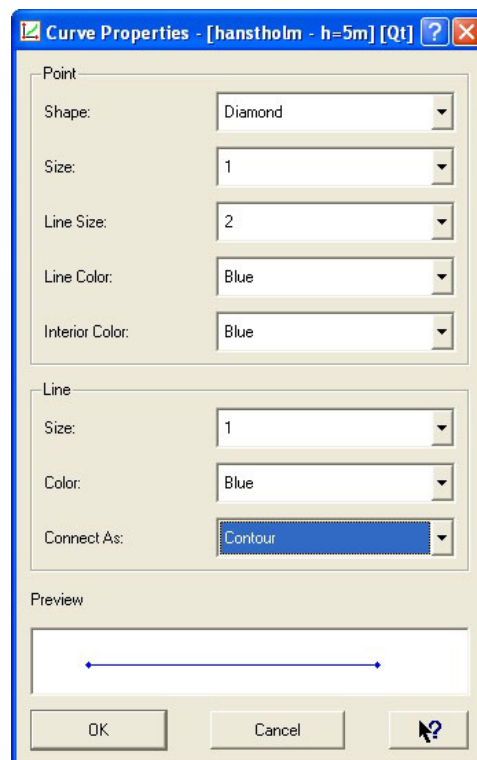


Figure 2.3 Properties of the contour lines in Engauge.

- Choose **Curve Point** in the menu line and be sure to mark the correct name of the contour line before starting to plot as shown in Figure 2.4. It is important to save each time a contour line is made correctly, because the only two ways of correcting an error is either to close down the program and start it again, or by changing the height directly in the node-coordinate file.

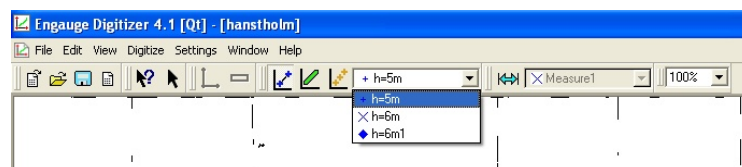


Figure 2.4 Plotting the curves in Engauge.

- When all the contour lines are discretised, it should be chosen how the values should be saved. This is done by choosing **Settings - Export Setup**, where the following should be chosen: **Points Selection = Raw X's and Y's**, **Layout = One curve on each line**, **Delimiters = Tabs**, and **Header = Simple** as shown in Figure 2.5. It is only necessary to chose these for the first curve, as ENGAGE automatically chooses the same settings for the rest of the curves.

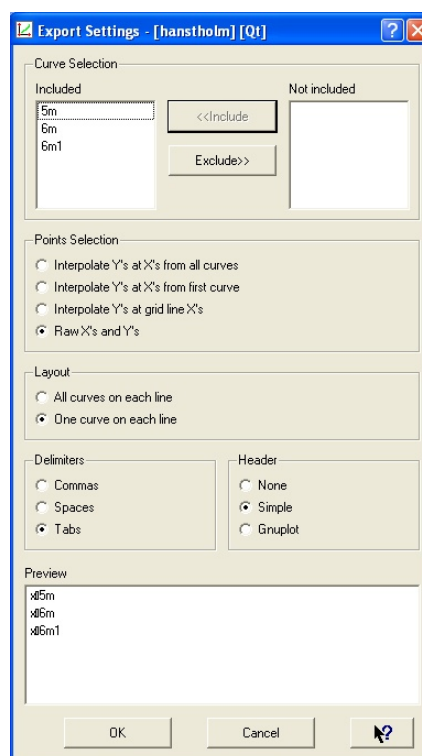
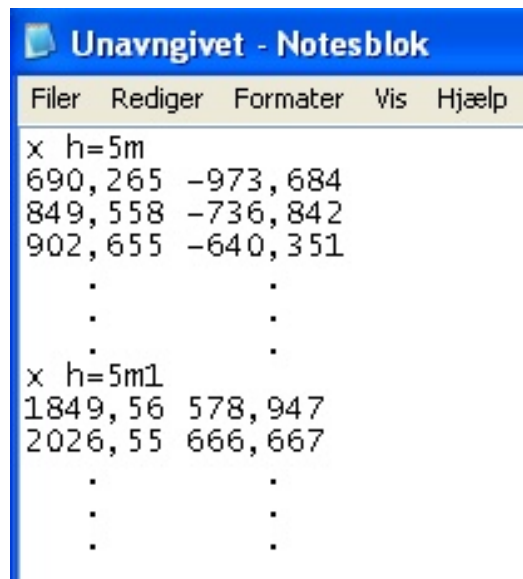


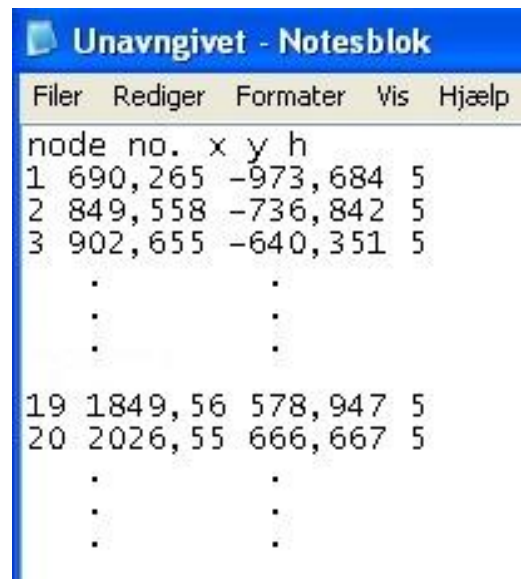
Figure 2.5 Settings for saving the values in Engauge.

The values are saved in a text-file (.csv) via **File - Export**.

When opening the text-file in Notebook it will look as shown in Figure 2.6.



Filer	Rediger	Formater	Vis	Hjælp
x	h=5m			
690,265	-973,684			
849,558	-736,842			
902,655	-640,351			
.	.			
.	.			
.	.			
x	h=5m1			
1849,56	578,947			
2026,55	666,667			
.	.			
.	.			
.	.			

Figure 2.6 Water depths text file.


Filer	Rediger	Formater	Vis	Hjælp
node no.	x	y	h	
1	690,265	-973,684	5	
2	849,558	-736,842	5	
3	902,655	-640,351	5	
.	.	.	.	
.	.	.	.	
.	.	.	.	
19	1849,56	578,947	5	
20	2026,55	666,667	5	
.	.	.	.	
.	.	.	.	
.	.	.	.	

Figure 2.7 Node file for use in Vandland.

These values should be imported to e.g. Microsoft Excel, where the setup of the node-file can be made. The setup should end up with a result as shown in Figure 2.7 where the first column defines the node number, second and third column is the x- and y-coordinates for the node, respectively, and the fourth column is the water depth at the node.

When this is done, the set up should be imported to Notebook and the file should be saved as *.nod in the folder VANDLAND.

Vandland

In the program VANDLAND the model used by MILDSIM is set up. The model consists of a number of boxes, and the size of these boxes are determined from the minimum wave length in the model as described later. VANDLAND produces text-files which contain the water depth and the type (land or water) of each box.

3.1 Selection of box size

Two requirements should be fulfilled when choosing the size of the boxes. Firstly, the boxes should have a size so that the geometry of the harbour can be described fairly well. Secondly, a rule of thumb is for MILDSIM to be able to calculate the waves with the necessary accuracy there should be 6-8 boxes per wave length. This means that the box sizes should be chosen from the minimum wave length in the model as seen in Equation (3.1).

$$dx \approx \frac{L_{\min}}{7} \quad (3.1)$$

Where:

dx Box size [m]

L_{\min} Minimum wave length [m]

To find the minimum wave length, the programs SEASTATE and STOKES1 can be used.

The program SEASTATE is used if the only data available is wind data. From this program a significant wave height and a peak period are determined. The program is based on the SPM-method revised by Hurdle and Stive [1989]. From Figure 3.1 it can be seen that the program can use both hindcast with know duration and fetch limited hindcast.

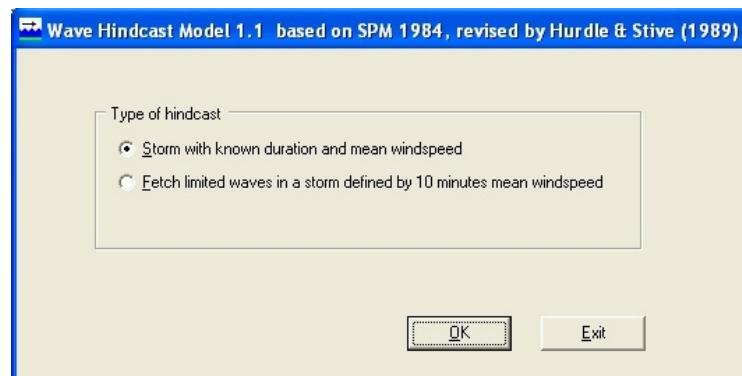


Figure 3.1 Selection of the calculation methods in the program Seastate.

When choosing **Storm with known duration and mean wind speed** the input data are the fetch, the water depth, the storm duration, and the mean wind speed. When pressing **Calculate** the program calculates the significant waveheight, H_{m0} , the peakperiod, T_p , and the effective fetch as shown in Figure 3.2 by using the equations given in Brorsen [2006b].

Sea state in a storm with known duration and mean windspeed	
Input data	Results
Fetch (km) 080.0	Wave height, H_{m0} (m) 1.21
Water depth (m) 020.0	Peak period, T_p (s) 3.6
Duration of storm (minutes) 0060	The sea state is duration limited.
Mean windspeed (m/s) 20.0	Effective fetch (km) 6.73
<input type="button" value="Calculate"/> <input type="button" value="Print"/> <input type="button" value="Exit"/>	

Figure 3.2 Input and output when choosing hindcast with known duration in the program Seastate.

When choosing **Fetch limited waves in a storm defined by 10 minutes mean wind speed** instead the input data are the fetch, the water depth, and the 10 minutes mean wind speed. When pressing **Calculate** the program calculates the significant waveheight, H_{m0} , the peakperiod, T_p , the necessary duration, and the mean wind speed as shown in Figure 3.3 by using the equations given in Brorsen [2006b].

Fetch limited sea state in a storm defined by U_10min	
Input data	Results
Fetch (km) 080.0	Wave height, H_{m0} (m) 3.08
Water depth (m) 020.0	Peak period, T_p (s) 7.4
10 min mean windspeed, U_{10} (m/s) 20.0	Necessary duration (hh:mm) 5:35
	Mean windspeed (m/s) 16.9
<input type="button" value="Calculate"/> <input type="button" value="Print"/> <input type="button" value="Exit"/>	

Figure 3.3 Input and output when choosing fetch limited hindcast in the program Seastate.

SEASTATE only takes the correction of the duration into account. If the given wind data should be corrected for elevation, local effects, or stability, it has to be done before defining the wind speed in the program. A general description of the SPM-method with the different corrections can be found in Liu and Frigaard [2001], Brorsen [2006b], and Hurdle and Stive [1989].

Instead, if the data available are measured wave heights, the significant wave height can be found from an extreme wave height analysis [Liu and Frigaard, 2001, p. 40-64].

The peak period can be found from Equation (3.2) [Liu and Frigaard, 2001, p. 60].

$$\sqrt{\frac{130 \cdot H_s}{g}} \leq T_p \leq \sqrt{\frac{280 \cdot H_s}{g}} \quad (3.2)$$

Where:

- H_s Significant wave height [m]
- g Gravitational acceleration [m/s^2]
- T_p Peak period [s]

As the significant wave height for the example of Hanstholm Harbour is found to 7.3 m, the peak period is chosen conservative as the highest T_p , 14.4 s.

$$\sqrt{\frac{130 \cdot 7.3\text{m}}{9.82 \frac{\text{m}}{\text{s}^2}}} \leq T_p \leq \sqrt{\frac{280 \cdot 7.3\text{m}}{9.82 \frac{\text{m}}{\text{s}^2}}} \quad (3.3)$$

$$9.83\text{s} \leq T_p \leq 14.43\text{s}$$

The program STOKES1 can then be used to find the minimum wave length as the input is the wave period, the significant wave height, and the minimum water depth in the model. The wave period that should be used, is the one corresponding to the highest generated wave frequency. If the peak frequency of the wave spectrum, f_p , is known, the highest frequency, that is normally generated, will be around $2f_p$ as it is shown in Figure 3.4.

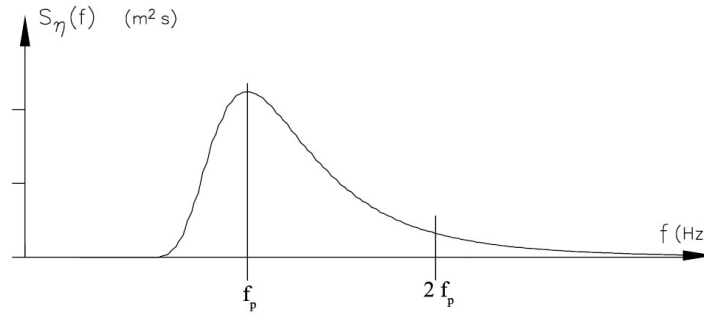


Figure 3.4 Variance spectrum.

This means that the wave period T_{min} that should be used in STOKES1 is found from Equation (3.4).

$$\begin{aligned} f_p &= \frac{1}{T_p} \\ 2f_p &= \frac{1}{T_{min}} \Leftrightarrow \\ 2 \frac{1}{T_p} &= \frac{1}{T_{min}} \Leftrightarrow \\ T_{min} &= 0.5 T_p \\ T_{min} &= 0.5 \cdot 14.4\text{s} = 7.2\text{s} \end{aligned} \quad (3.4)$$

The program uses linear wave theory which means, that the wave length is calculated by an iterative process by the dispersion relation given in Equation (3.5) [Andersen and Frigaard, 2008, p. 28]. The input can be seen in Figure 3.5, remember to push **Beregn** everytime the input is changed.

$$L_{min} = \frac{g T_{min}^2}{2\pi} \tanh\left(\frac{2\pi h}{L_{min}}\right) \quad (3.5)$$

Figure 3.5 Input and output in Stokes 1. order calculation program.

As the minimum wave length is found to $L_{min} = 47.15$ m, the maximum box size is found to $dx \approx 6.7$ m by using Equation (3.1). The chosen box size in the model is $dx = 5$ m.

3.2 Edit general data

The first thing to be done when starting VANDLAND is to choose the menu **Edit general data**. In the first tab **Input Files** shown in Figure 3.6 the model should be given a name in **Job ID**. In 'Node file' the node-file made via the program ENGAUGE should be written. The file in **Border file** is a file the program makes itself, it is just necessary to write the wanted name of the file.

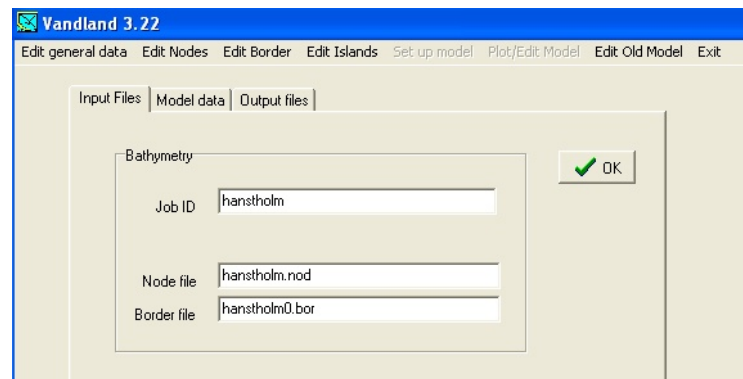


Figure 3.6 Input files in Vandland.

In Figure 3.7 the inputs in the tab **Model Data** can be seen. In **Placement of the SW-corner of the model in node (x,y)-system** the south west corner of the model should be given in relation to the coordinate system used by the program ENGAUGE. When entering the menu **Edit Nodes** a blue box will mark the model area. If it does not surround the whole area, the placement of the south west corner can be changed by going back to the menu **Model Data**.

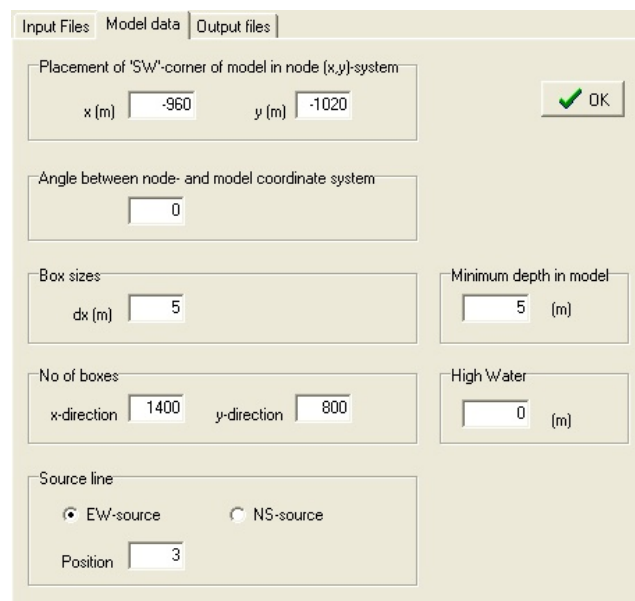


Figure 3.7 Model data in Vandland.

If the node-coordinate system made in ENGAUGE and the model coordinate system are not the same, an angle between the two can be written in **Angle between node- and model coordinate system**. This could be used if the direction, from where the waves are generated, is much different than the directions of the node-coordinate system.

The box sizes is written in **Boxsizes** and the minimum water depth in the model is written in **Minimum depth in model**. **No of boxes** are the number of boxes that the model should

consist of in the x- and y-direction, respectively, compared to the size of the map used to set up the model.

Normally, a calculation of the wave height at high water levels is needed. The correct water depth is then found by defining the magnitude of the high water level in **High Water**. This way, the program only needs to load the depth from the node file one time. Note that it is thereby possible to have several depth-files corresponding to the same type-file.

When the type-file is made in VANDLAND, the program itself makes a layer of sponges and a point where the waves are generated from. In **Source line** it can be chosen in which direction the waves should be generated. VANDLAND always marks the outermost boxes in the model as land boxes and automatically marks the box next to this land box as a sponge box.

The **Source line** from where the waves are generated in the model is not automatically marked by VANDLAND. The row of boxes that should function as generation line should be defined here.

In Figure 3.8 the output files from VANDLAND can be seen. In **Files to MildSim** the names of the depth and the type files should be written. These two files are for later use in the program MILD SIM. In **Plot files** a name of a file that can be used to plot the depth data in another program should be written. Here it is possible to choose between a surfer or a MATLAB file.

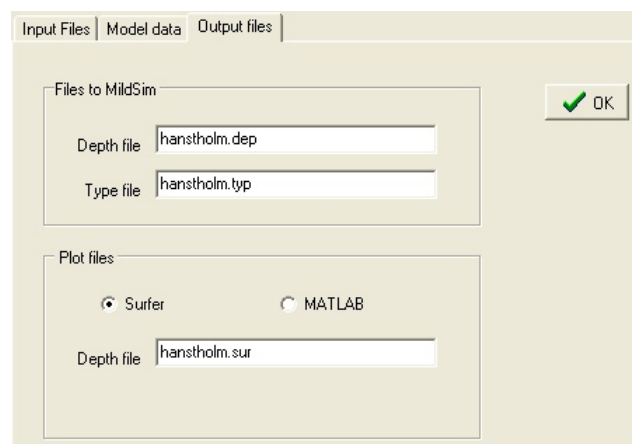
The image shows a software dialog box with three tabs at the top: 'Input Files', 'Model data', and 'Output files'. The 'Output files' tab is selected. Inside the dialog, there are two main sections. The first section, titled 'Files to MildSim', contains two text input fields: 'Depth file' with the text 'hanstholm.dep' and 'Type file' with the text 'hanstholm.typ'. To the right of these fields is an 'OK' button with a green checkmark icon. The second section, titled 'Plot files', contains two radio buttons: 'Surfer' (which is selected) and 'MATLAB'. Below the radio buttons is a text input field for 'Depth file' with the text 'hanstholm.sur'.

Figure 3.8 Output files from Vandland.

3.3 Edit Nodes

In the menu **Edit Nodes** the node-file generated in ENGAUGE is imported automatically as it can be seen in Figure 3.9. Be aware that some of the nodes might be in a different place than where they were placed in ENGAUGE. The nodes can be removed by pressing **Remove node** and marking the node that should be removed. Another node can be placed in the correct position by pressing **Add node**, the water depth at the new node can be set at the same time. The changes are saved by pressing OK. The intersection between the red

lines shows the south west corner of the xy-coordinate system set in **Model Data** and the blue box indicates the size of the model.

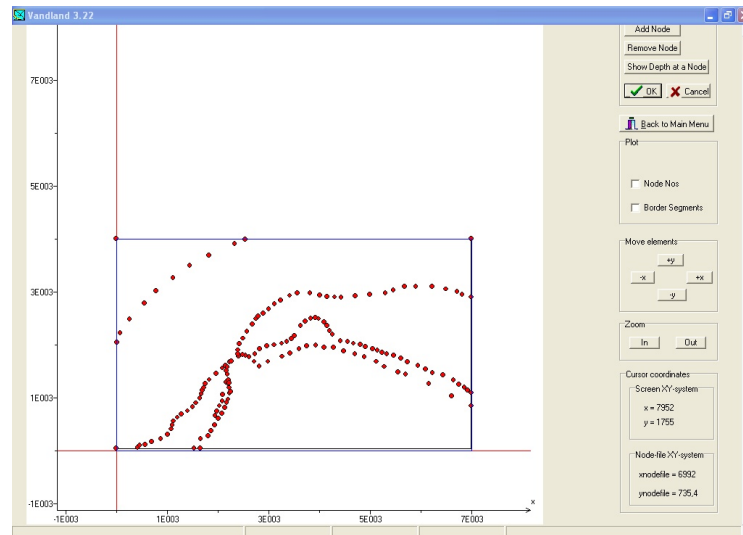


Figure 3.9 Edit nodes in Vandland.

3.4 Edit Border

In the menu **Edit Borders** the border around the water in the model should be defined. This is done by adding segments between the nodes, the marked land (also islands and detached breakwaters), the minimum water depth, and the sides where the model only consists of water as shown in Figure 3.10.

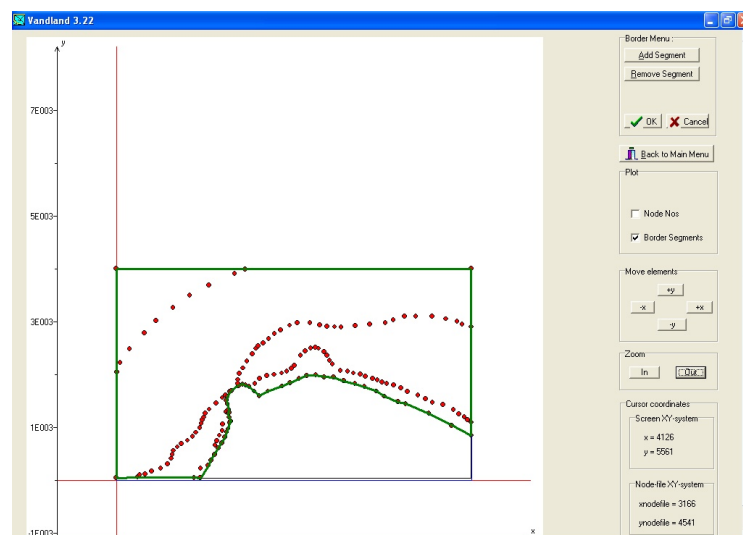


Figure 3.10 Edit borders in Vandland.

3.5 Edit Islands

If the model contains islands or detached breakwaters, one island node should be placed inside the borders of the island or the detached breakwater.

3.6 Set up model

When the nodes and borders are set and OK is pressed in **Edit general Data - Output files** the model is set up by pressing the menu **Set up model**. The program uses the given node and border file and creates triangles between the nodes. When the program calculates the water depths, it examines if the middle of each box are placed within one of these triangles. If this is the case, the water depth in the middle of the box is calculated by bilinear interpolation of the water depths of the three nodes in the elements. If the center of the box is placed outside the triangle, the box is assumed to be on land and is marked as a land box. Because of this, it is important to make sure that the whole water area is covered with nodes. In Figure 3.11 the principle for the definition method is shown.

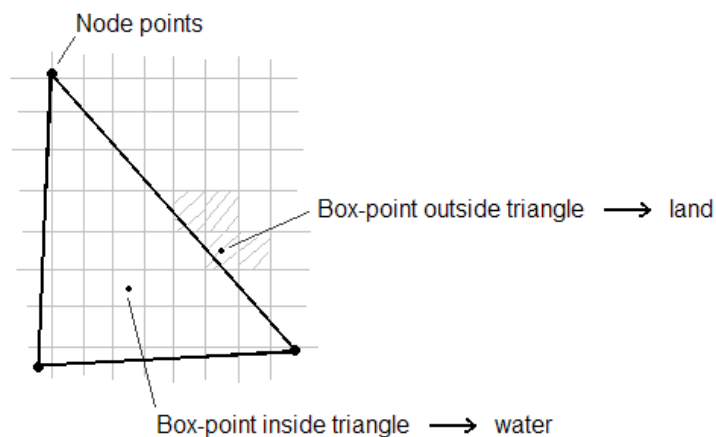


Figure 3.11 The principle of defining the box type in Vandland.

When the depth- (*.dep) and type-files (*.typ) are generated, it is possible to press **Plot Elements** as shown in Figure 3.12 and the plot shown in Figure 3.13 will appear. Here the model with the triangles between the nodes are visible.

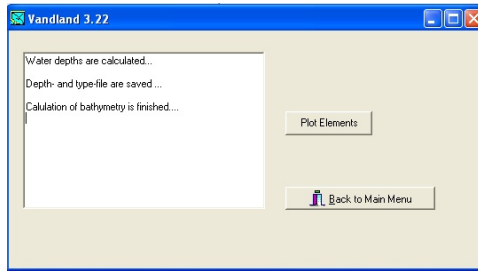


Figure 3.12 Set up model in Vandland.

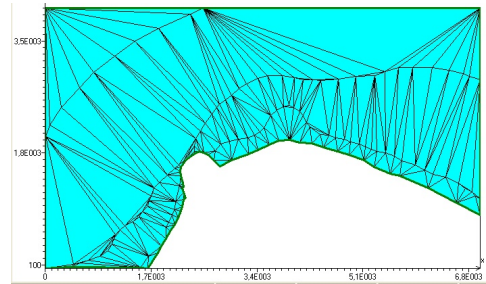


Figure 3.13 Plotted elements in Vandland.

If the node-file is not defined, the error message **I/O error 6** appears. Is no name for the border file, the depth file, or the type file defined, the errors shown in Figure 3.14 and Figure 3.15 will appear, one after the other, and the program closes.

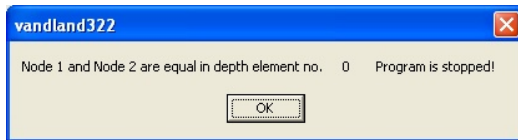


Figure 3.14 Error when the node file is not entered as an input file in Vandland.



Figure 3.15 Error when the border, depth, or type file is not entered as an input/output file in Vandland.

If the node file contains commas instead of dots, or a misplaced letter the error **Invalid numeric input** will occur, when trying to set up the model.

3.7 Plot/Edit Model

The depth- and the type-file are both text-files, and can be edited directly. Another way to edit the files is to use the menu **Plot/edit Model**, where the model is plotted from the depth- and the type-files as it is shown in Figure 3.16. The depth or type is changed by choosing either **Box Type** or **Water depth** in **Edit Model**, entering the box type or water depth, and click at the box in the model where either of these should be changed.

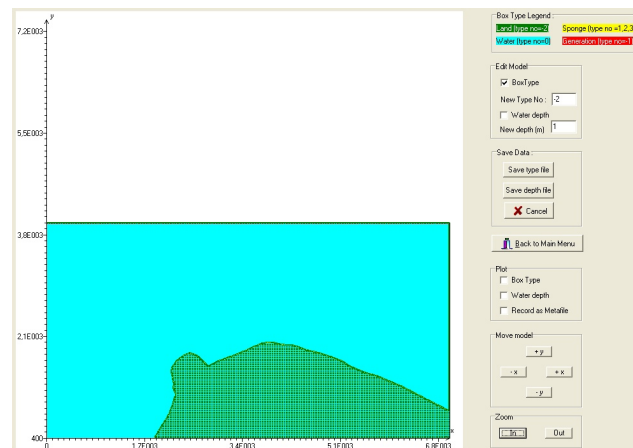


Figure 3.16 Edit model in Vandaland.

In **Box Type Legend** the four kinds of box-types that can be edited in the model are shown. Land is given as green boxes by the number -2 . Water is given as blue boxes by the number 0 . The generation-line is given as red boxes by the number -1 . Sponges are given as yellow boxes with the numbers $1, 2, 3, \dots$

The generation-line is the line from where MILD SIM should generate the waves. The water depth in the boxes of the generation-line must be constant. The line should be fairly long compared to the area of the model that should be analysed to avoid boundary effects as mentioned in Section 1.3.

A single sponge-layer should be placed along all the borders to get the correct reflection coefficients also inbetween the generation line and the border land boxes. These sponge-layers will pull the energy out of the wave by multiplying the surface elevation by a factor, $\mu < 1$ after each time step. The value of μ is found by calibration in a numeric wave flume as it will be explained in Chapter 5.

The sponge layers placed at the boundary between the water and the single layer of land boxes, should in theory be fully absorbing, as in reality all outgoing wave energy passes through an open bound. In a numerical model the lowest possible reflection is around 1-3% and in a physical model a reflection under 5-10% is rarely obtained. The way of finding the value for fully absorption is described in Chapter 5.

Vertical breakwaters should be modelled as fully reflective, which can be done either by setting the μ -coefficient for the sponges to 1 or not make a sponge-layer at all in front of the vertical breakwater. The second option is possible because MILD SIM automatically assumes full reflection when the waves in the model hits land-boxes directly. For rubble mound breakwaters or sloping breakwaters, the reflection will be something in between full absorption and full reflection.

Equal μ -coefficients on different water depths will result in different reflection coefficients. This means that it is a good idea to name the sponges in a way that indicates both the border and the water depth in the model. For instance a sponge could be named 110; 1 for fully absorption and 10 for a water depth of 10 m.

Because a μ -coefficient gives different reflection when used on different water depths, there should be a new sponge type for every change in water depth. This will lead to an unreasonable amount of different boxes, and in the model it is chosen only to have a new sponge type for each whole metre i.e. 5 m, 6 m, 7 m etc. By looking at the water depth in the individual boxes it is evaluated which unit the box should belong to.

The name of each box and the water depth of each box is shown when marked in **Plot**. In Figure 3.17 a zoom of the model where the boxes with names and water depths can be seen. When marking **Record as Metafile** a plot of the model is made and saved in the folder.

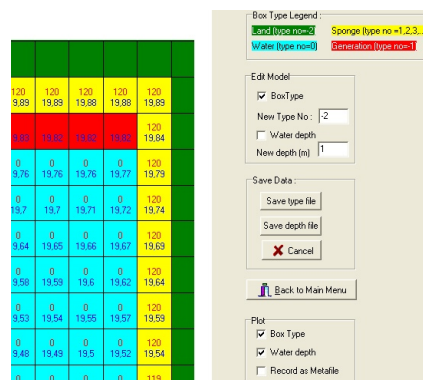


Figure 3.17 The names of and water depths in the boxes in Vandland.

Be aware, that if the type and depth file is changed and **set up model** is pressed again, the program will overwrite the files with new files consisting only of land and water boxes and the generation line and sponge layers has to be made all over again. It is therefore always a good idea to have a backup folder where the files are saved every time the correct files are achieved.

3.8 Plot Old Model

When the program is closed, the model made previously can be edited by using the menu **Plot Old Model**, and the program will then open the old *.typ and *.dep file. If several different models are run, e.g. with a generation of waves from north and west, respectively, be aware that the files VANDLAND suggest to open are the ones for the model run the last time, and not the ones saved in the folder VANDLAND.

If the opening of the depth- and type-file are cancelled an error **I/O error 6** will occur, press OK, close the window, and start over by pressing **Plot Old Model**.

The generated depth-and type-file should be saved in the folder MILDSIM.

The depth-file can be used to make a contour plot of the model in e.g. MATLAB as shown in Figure 3.18.

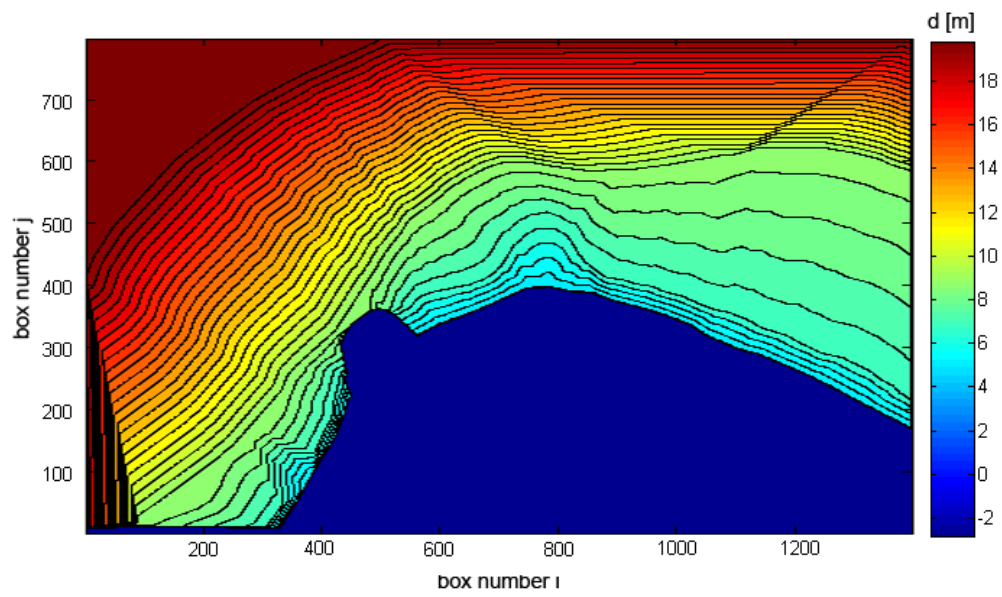


Figure 3.18 Bottom contour at Hanstholm Harbour.

MildSim

When MILDsim is started click on the tab **model data** and the different entries for input data will appear. The entries are described in the following. Throughout the description of the procedure, the model where the waves are generated from north is used as an example.

4.1 Bathymetry

Name of model: Type in a name for the model e.g. hanstholm.

DEPTH-file and **TYPE-file:** The names of the two files created by VANDLAND are typed in. In this case it is the files hanstholm.dep and hanstholm.typ.

Placement of 'SW'-corner of model area: If the model calculated with MILDsim should have another coordinate system than the one used in VANDLAND, the new position is typed in. Otherwise, the position is set as $X(m) = 0$ and $Y(m) = 0$.

Box size: It is important to choose $dx = dy$ and use the same size as used in VANDLAND. Here the chosen box size is set as $dx(m) = dy(m) = 5$.

No. of boxes: It is important to choose the same number of boxes as used in VANDLAND because the numbers used are basis for the type and depth- files. The numbers are therefore set as $X-dir = 1400$ and $Y-dir = 800$.

Figure 4.1 Plot of the bathymetry used in the model.

4.2 Runtime Data

Time step: The time step should be chosen as large as possible while fulfilling the criterion for the Courant number $C_r < 0.7$. The Courant number is given in Equation (4.1).

$$C_r = c \cdot \frac{dt}{dx} \quad (4.1)$$

Where:

- c Lowest phase velocity of the waves, found as $c = \frac{L_{min}}{T}$ [m/s]
- L_{min} Shortest wave length. In the model it is 47.15 m
- T Period of the wave. In the model it is 7.20 s

The largest time step is then calculated.

$$dt = C_r \cdot \frac{T}{L_{min}} \cdot dx = 0.7 \cdot \frac{7.2 \text{ s}}{47.15 \text{ m}} \cdot 5 = 0.53 \text{ s} \quad (4.2)$$

If the time step is chosen too large, the MILDsim calculations become unstable, but the program will give a warning if this is the case. The warning is shown in Figure 4.2.

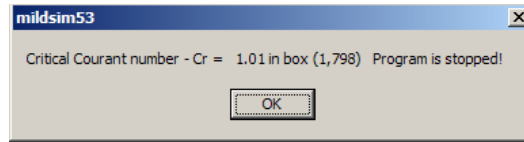


Figure 4.2 The error warning if the time step is chosen to large.

The time step, found in Equation (4.2), is used as an upper limit for the choice of step. The time step, used in the model, should be the same as the time step in the wave flume when finding the relation between μ and R_c . How to find the time step is therefore described in Section 5.2.

'Warm up' time: The time before the wanted wave heights are generated at the generation line. Use a value in the interval 0 – 20 seconds.

Time at which the wave field is saved: This step is very important! The wave field (more correctly, the surface elevation) for the whole model is saved in a file (*.E*) at that specific time. The file can subsequently be used for illustrative plots of the wave field. In order to make the plot representative it is necessary that the wave heights are stable. This means that the chosen time should be large enough for the waves to spread from the generation line to the most distant point in the model and back again. Normally it is sufficient to calculate the necessary time as Equation (4.3).

$$t_{nec} = 2 \cdot \frac{S_{dist}}{c} \quad (4.3)$$

Where:

- t_{nec} Smallest time for which the wave field is saved [s]
- S_{dist} Distance from the generation line to the most distant point in the model (along the direction of the wave spread) [m]
- c Phase velocity of the waves [m/s]

In the hanstholm model, the distance measured is 4000 m when the waves are generated from north, and the phase velocity is chosen as the smallest occurrence 6.35 m/s. The needed time is thereby given as:

$$t_{nec} = 2 \cdot \frac{4000 \text{ m}}{6.35 \text{ m/s}} = 1260 \text{ s}$$

When the surface elevation is saved, the calculation of the wave height, more correctly the variance of the elevation in each box, starts. The significant wave heights are found from a variance spectrum and calculated by Equation (4.4). [Liu and Frigaard, 2001]

$$H_{m0} = 4 \cdot s_{\eta} = 4 \cdot \sqrt{m_0} \quad (4.4)$$

Where:

- s_{η} Standard deviation of the surface elevation in each box.
- m_0 Total variance

In MILD SIM the variance is calculated in each box and the standard deviation is found as the square root of the total variance (the area under the graph in the variance spectrum).

No. of peak periods in the estimate of significant wave field: The duration of the simulation must be defined here. In order to obtain a reliable estimate of the variance, this must be calculated during a rather long time. Normally, $100 \times T_p$ is sufficient for 2D irregular waves, but if a directional spectrum is to be found, $400 - 500 \times T_p$ is necessary. When the given number of peak periods are calculated the significant wave heights are saved in the file *.H*.

The numbers of periods are based on experience and are probably a bit conservative. If the correct needed time is to be found, the model should be tested with varying time until the variance (hence the wave height) in the boxes becomes reasonable constant.

The different input for the runtime data are shown in Figure 4.3.

The screenshot shows a software window titled 'Form-4' with several tabs: 'Bathymetry', 'Runtime data', 'Wave field', 'Calibration of waves', 'Sponge layer data', and 'Gauge positions'. The 'Runtime data' tab is selected. Inside the tab, there are four input fields with their respective values: 'time step [secs]' is 0.2187, 'warm up' time [secs]' is 20, 'Time at which the wave field is saved (secs)' is 1260, and 'No. of peak periods in the estimate of significant wave field.' is 100. Below the last field, there is a small text label: 'and the calculation of the significant wave field i started.' To the right of the input fields are two buttons: 'OK' with a green checkmark and 'Cancel' with a red X.

Figure 4.3 Plot of the runtime data used in the model.

4.3 Wavefield

In this step, different wave types can be selected; regular waves, 2D irregular waves, and 3D irregular waves.

For the *regular waves*, only the wave height, the frequency and the direction have to be defined. With regular waves, the used frequency should result in a period which is half of the peak period.

When using *2D irregular waves* the following needs to be defined. In the hanstholm model these type of waves are used.

Wave height, H: Here the significant wave height of the wanted waves is defined. In the hanstholm model, the wave height is set to 7.3 m based on the extreme data analysis of the measured wave elevation near the harbour at a water depth of 20 m.

Carrier frequency: The frequency used when calculating $f(z)$, i.e. the vertical variation of the velocity potential. Normally, the frequency is chosen to be the same as the peak frequency. Be aware, that the program does not give a warning if they are chosen much different even though it might lead to large errors in the wave field.

No. of bands: The wave spectrum is always a JONSWAP-spectrum (Joint North Sea Wave Project) [Liu and Frigaard, 2001, p. 35-36]. In this step, it is defined how many bands the spectrum should be divided into, i.e. the number of different frequencies by which the waves are generated. In the model, 21 bands are used. In Figure 4.4, an illustration of the division of the bands is shown.

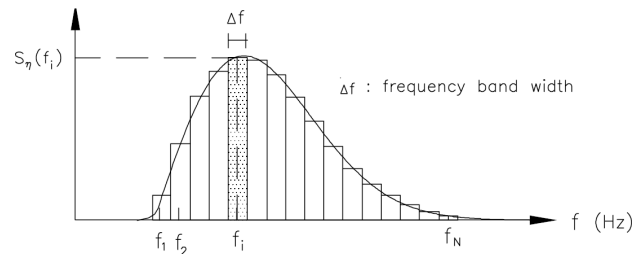


Figure 4.4 Illustration of the division into bands. [Liu and Frigaard, 2001, p. 16]

Peak frequency: The peak frequency of the spectrum f_p . In the model, the frequency is found by trial and error until the shown peak period is equal to the needed. In the model a peak frequency of 0.0714 will result in the wanted peak period of 14.01 s. The wanted peak period is based on the calculations shown in Section 3.1.

f_min and f_max: The JONSWAP spectrum is truncated so that very short and long waves are not generated. The **f_min** and **f_max** defines the truncation frequencies. Normally, choosing $f_{\min}=0.66 \times f_p$ and $f_{\max}=2 \times f_p$ is a good truncation. In Figure 4.5, the spectrum with the truncation frequency is shown.

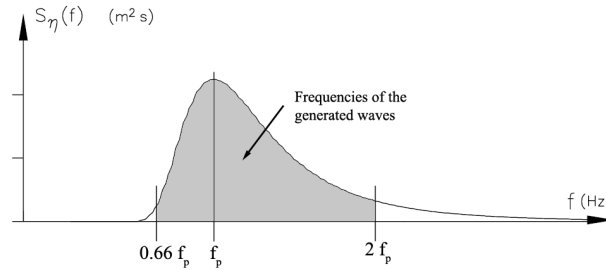


Figure 4.5 The JONSWAP spectrum with truncation frequencies.

Direction: Here it is possible to adjust the direction in which the waves are generated from the generation line. In case of regular and 2D irregular waves, the direction can be rotated within the limits $\pm 45^\circ$.

A plot of the chosen wave field for 2D irregular waves are shown in Figure 4.6.

Figure 4.6 The chosen wave field for 2D irregular waves.

When using *3D waves*, all the same parameters as for 2D irregular waves needs to be specified. Further a more specific definition of the generated waves are necessary because the waves are generated with different directions. The directions is set by defining **no. of directions=11**, **min. direction (deg)=-45**, **main direction (deg)=0**, **max. direction (deg)= 45**. This means that 11 different directions are generated in a fan of 90° as shown in Figure 4.7. Because the waves have different direction from the beginning, the limits for rotating the waves are given as $\pm(20 - 25)^\circ$. When defining the 3D waves, the **s-coefficient** needs to be specified. It is a parameter in the distribution that describes how big the spread of the direction is. When normal wind generated waves are used, a value of 5 is a good estimate. When the value of *s* is increased the spread of direction is decreased.

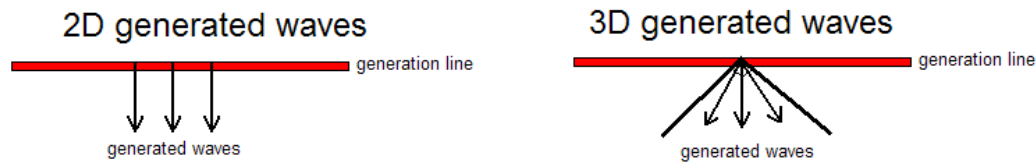


Figure 4.7 Illustration of 2D and 3D generated waves.

4.4 Calibration of Waves

Nothing should be changed in this tab as it is not used in the program. It is a survival from earlier (before 1997) where it was not possible to generate correct wave heights.

4.5 Sponge Layer Data

In this step, the connection between the used sponge box numbers and the μ coefficient is defined. The values in the table shown in Figure 4.8 defines the reflection of each type of sponge layer. Remember that equal values of μ in the sponge layers on different water depths will give a different reflection coefficient R_c . The relation between the values can only be found by an iterative procedure in a numeric wave flume. The procedure in the wave flume is described in Chapter 5.

Sponge type	Mu value (-)
120	0.51
119	0.51
118	0.52
117	0.53
116	0.53
115	0.54
114	0.55
113	0.555
112	0.575
111	0.583
110	0.601
19	0.615
18	0.635
17	0.65

Figure 4.8 Plot of the Sponge layer data used in the model.

4.6 Gauge Positions

In the table shown in Figure 4.9, it is defined at which point a time series of the surface elevation is saved. The position of the points are given by the box number in the x- and y-direction respectively, i.e. as (i,j). In VANDLAND **Edit old model** it is possible to find

the position by holding the mouse at the wanted position in the figure. Thereby the box numbers are shown in the bottom of the screen. In the model it can be difficult to find the wanted position directly because no contour lines or points are shown. The position can then be found by using **Edit Nodes** or **Edit Border**. Notice that the positions given in these two are shown in metre and not as the box number. When the gauge position has to be defined, the position should then be divided by the box size dx .

In the hanstholm model, the interest of data is where the breakwater should be placed. In total, three gauges are selected with the positions $(i,j) = (570,370)$, $(702,436)$, $(638,400)$. The positions are shown as the three dots in Figure 1.2.

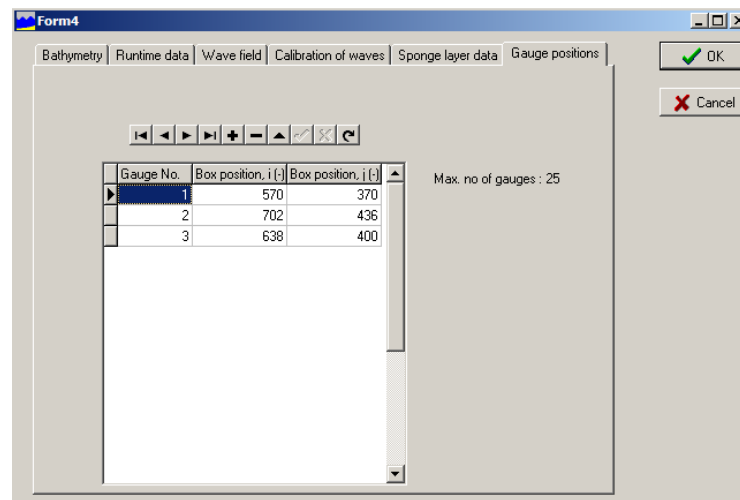


Figure 4.9 Plot of the gauge position used in the model.

If the box number typed in is outside the model, the program will give the message shown in Figure 4.10 and change the position of the box itself. The new position chosen is at the border of the model which means, that the surface elevation stored from that box will give no usable results.

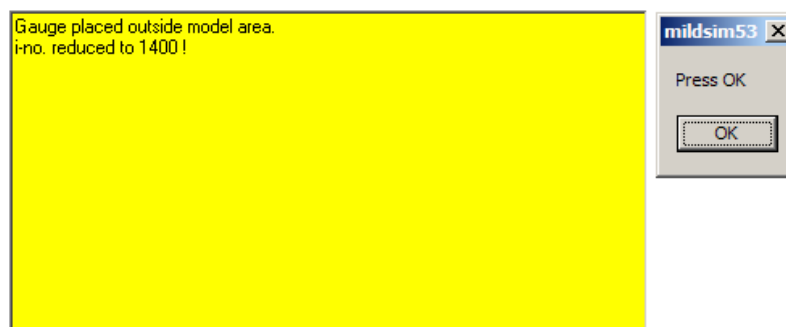


Figure 4.10 The warning message when the gauge position is chosen outside the model.

4.7 Running MildSim

When all the model data is defined press OK and the simulation is carried out by pressing **run**. When the simulation is carried out, make sure to put a checkmark in **calculate H_{m0} -field**. This means that the program saves a text file (*.H*), when **No. of peak periods in the estimate of significant wave field** is obtained. At the time specified in **Time at which the wave field is saved**, the program saves a text file (*.E*) with the surface elevation in the entire model. The files contain three columns where the first defines the y-coordinate in the model, the second column defines the x-coordinate and the third column defines either the wave height or the surface elevation. These output files can later be used for making illustrative plots of the results.

During the simulation it is possible to save the significant wave heights or the surface elevations by pressing either **Save H_{m0} -field** or **Save Eta-field**. The program will name the files *.H1, *.H2, *.H3 etc. and *.E1, *.E2, *.E3 etc. in the order the files are saved.

The elevation heights at the chosen positions of the gauges are calculated and saved in a text file (*.eta). Notice that due to the typically small time step, the elevations are only saved every second time step. For every saved time step, the time together with the elevation height in each gauge is saved in one line. The first elevation in the line is from gauge no. 1, the next is from gauge no. 2 etc. The eta-file from the hanstholm model is shown in Figure 4.11.

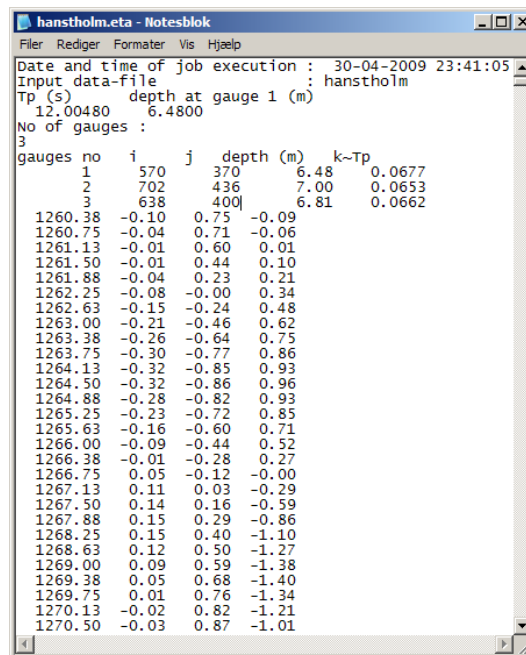


Figure 4.11 The output file *.eta from the simulation of Hanstholm Harbour.

During the simulation, it is possible to see how the wave field is developing, but notice that the calculation of the contour lines of the wave elevation and wave heights takes a long time. It is therefore a good idea to click the box **cancel plotting** and postpone the plotting until the simulation is done. When the simulation is done, the message shown in Figure 4.12 will appear. If the button **Ja** is pressed, the program will close and it is not

possible to make plots without running the simulation again. In order to make the plots, press **Nej** and the program will continue the simulation. Now the different plots can be made by removing the checkmark in **cancel plotting** and choose the wanted plot.

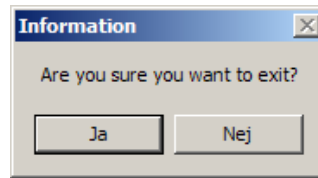


Figure 4.12 Message when the simulation is done.

The contour plot of the wave height will be as shown in Figure 4.13, and the surface elevation in the model is shown in Figure 4.14. For the plot it is possible to choose a maximum of eight contour lines.



Figure 4.13 Contour plot of the wave height.

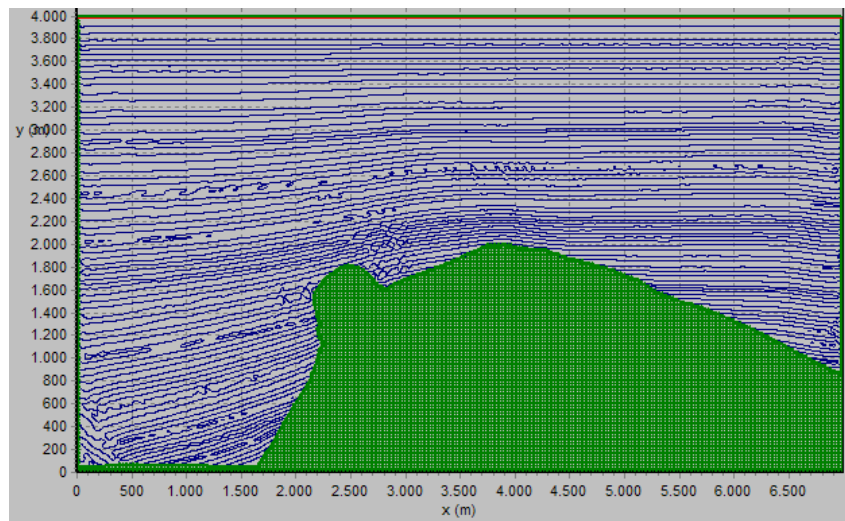


Figure 4.14 Contour plot of the surface elevation

If a more detailed plot is wanted, the output files can be used. When using the *.H*-file in MATLAB, the plot of the wave height could be as shown in Figure 4.15 plotted by means of waveheight.m. The black line indicates the position of the breakwater. In the output files the land boxes are given by a value that is significantly larger than the wave heights. This means, that if the output files are used directly MATLAB, it might not be possible to see the difference of the wave heights in the contour plot. Because of this, it can be necessary to open the text file and change the value of the land boxes to a value closer to the wave heights to get a nice plot.

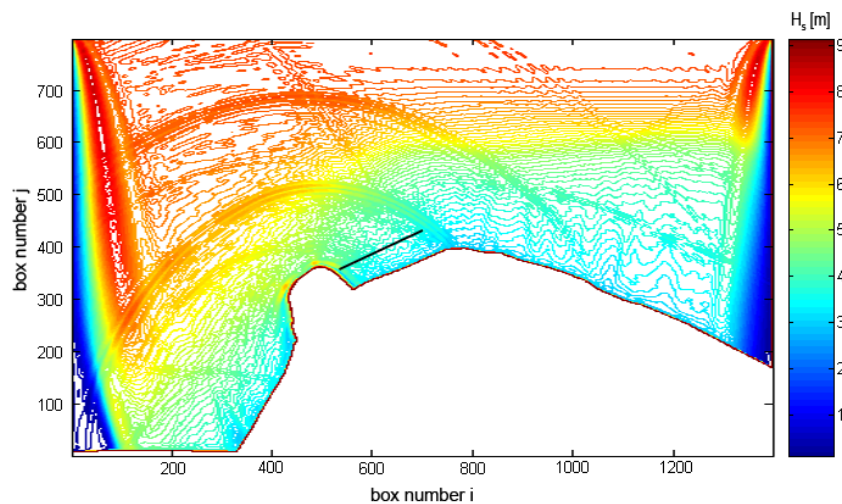


Figure 4.15 The wave height at Hanstholm Harbour. The black line indicates the position of the breakwater.

The wave height when the waves are propagating from north-west and west can be seen in Figure 4.16 and 4.17. Here it can be seen that the boundary effect is larger than for the waves propagation from north.

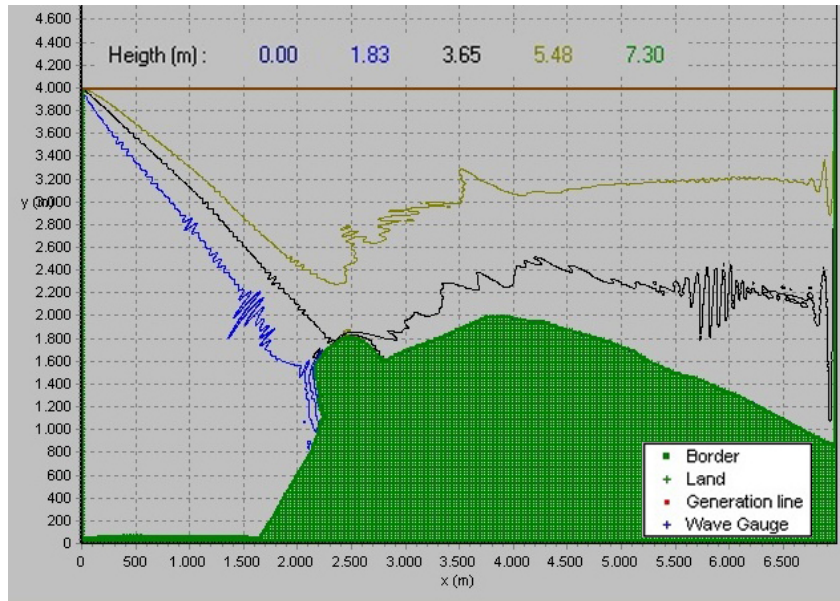


Figure 4.16 The wave height in the model when the waves approaches from north west.

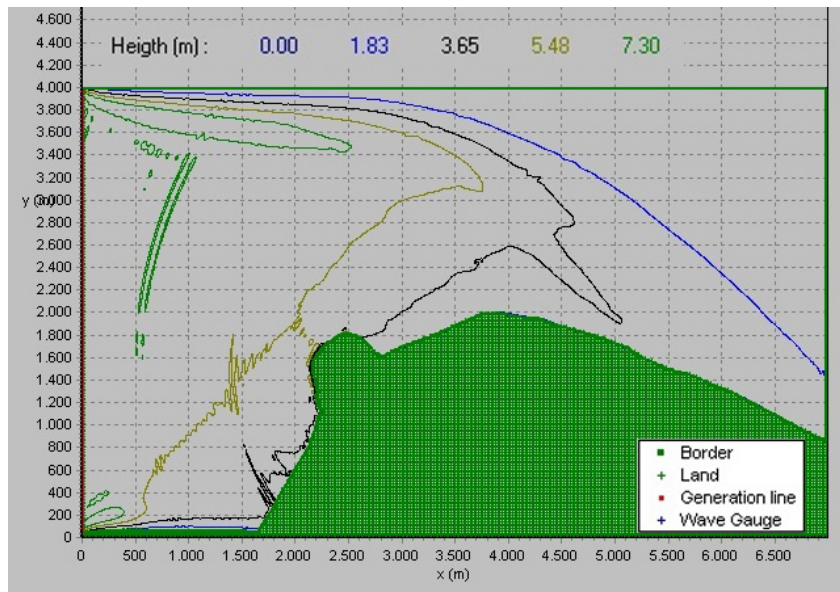


Figure 4.17 The wave height in the model when the waves approaches from west.

The accurate value of the wave height is extracted from the *.H* files for the three directions of wave propagation north, north-west, and west. In the *.H* files, the coordinates for the three chosen gauge positions are found and the wave heights are extracted. This gives the following values for the wave heights in the three wave propagation directions.

$$\begin{aligned}
 H_N &= 3.88 \text{ m} \vee 3.64 \text{ m} \vee 3.67 \text{ m} = 3.88 \text{ m} \\
 H_{NW} &= 3.86 \text{ m} \vee 3.67 \text{ m} \vee 3.71 \text{ m} = 3.86 \text{ m} \\
 H_W &= 3.84 \text{ m} \vee 3.69 \text{ m} \vee 3.54 \text{ m} = 3.84 \text{ m}
 \end{aligned}$$

The wave height that should be used in subsequent analyses is then the highest found, i.e. 3.88 m.

The peak period can be found by an FFT analysis. When the simulation in MILDsim is done and afterwards continued an FFT analysis can be made by marking the box **FFT analysis**, it is then possible to choose the box for which the analysis should be made. When the box is chosen, the program uses some time to calculate the spectrum and afterwards shows a plot of the frequency spectrum for both the JONSWAP spectrum and the measured wave heights at the chosen position. If the program is not stopped after a while a new spectrum slightly different to the first one is shown, as it can be seen in Figure 4.18. The difference between the spectra is due to the fact, that the spectra is calculated for a limited time period.

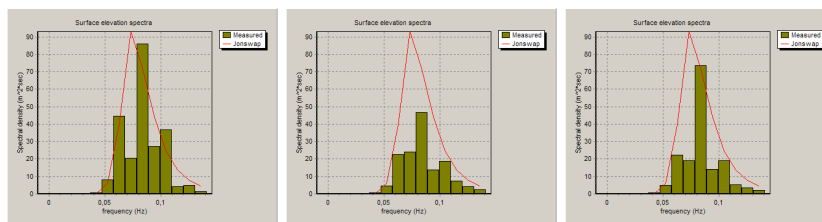


Figure 4.18 Wave spectra found by FFT analysis in MildSim.

In accordance with the JONSWAP-spectrum a more consistent frequency spectrum can be found in the following way by using the time series for the whole simulation. The output file from the gauges can be used for plotting the surface elevation as a function of time at these specific positions. When the data from the hanstholm model is used with a gauge placed at the position (570,370) with waves propagating from north, the surface elevation can be shown as in Figure 4.19.

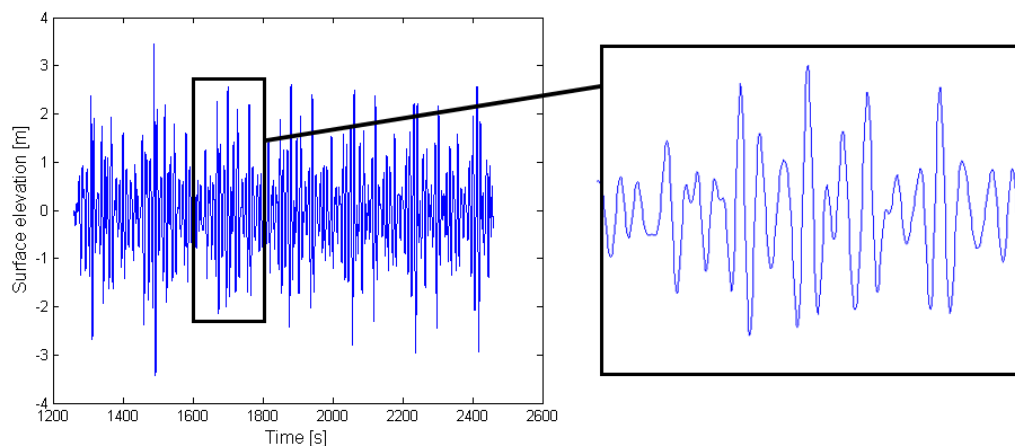


Figure 4.19 Surface elevation as a function of time at box position (570,370).

When the peak period for the waves is to be found, a time series analysis of the data from the gauges is carried out. [Liu and Frigaard, 2001]. In Figure 4.20 the wave spectrum from one of the gauge positions are shown, and it can be seen that the peak frequency is 0.07 Hz, hence the peak period is 13.9 s. The wavespectrum shown in Figure 4.20 is

not very smooth, because MILDsim only generates waves with discrete frequencies, and wave heights.

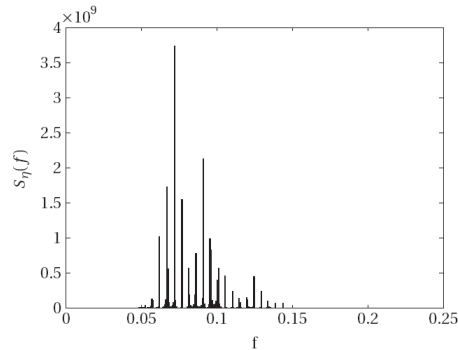


Figure 4.20 Wave spectrum in front of the breakwater, found from MildSim.

As an easier alternative the peak frequency can be read directly from the *.eta file as shown in Figure 4.21.

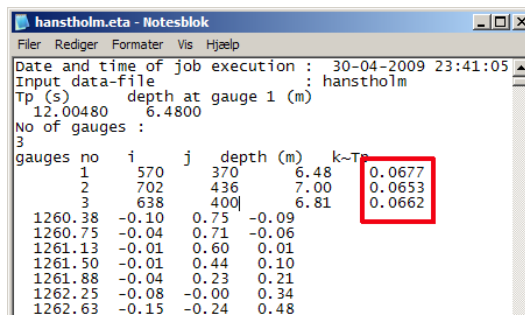


Figure 4.21 The peak frequency in the three gauge positions.

Wave Flume (MildSim)

The relation between the μ -value in the sponge layers and the reflection coefficient R_c is dependent on the water depth, the time step in the model, and the box-size. The only way to determine the μ -value is by iteration in a numerical wave flume.

The wave flume is a simple MILD SIM-model, and the steps through the model is therefore similar to the steps described in Chapter 4. The description of the individual steps are therefore not as detailed, apart from the steps that differs from the big model.

5.1 Bathymetry

Name of model: Type in a name for the flume.

DEPHT-file and **TYPE-file:** The most simple way of making the type- and depth-file is to create them directly in notebook and save them as *.dep and *.typ (e.g. set up the type and depth in Excel and copy and paste to notebook).

The geometry for the wave flume is build of boxes typically $3 \times dx$ wide and $120 \times dx$ long. The border of the flume is made of land-boxes (type-number: -2). In each end of the flume a sponge-box is placed. The type number of the sponges should be different (type-number: 1- ∞). In one "end" of the flume a generation box is placed e.g. box no. 20 (type-number: -1). A sketch of the flume is shown in Figure 5.1.

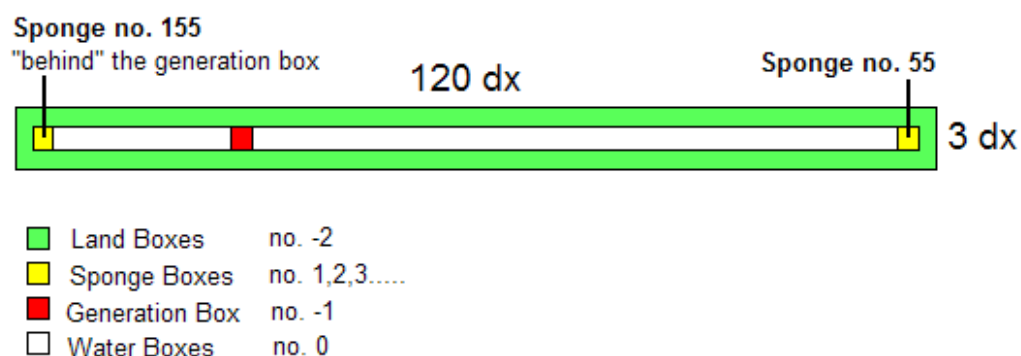
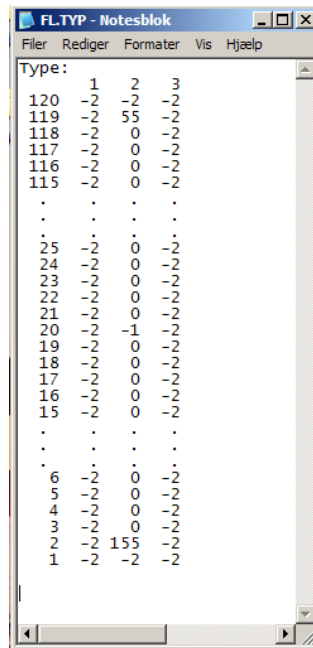


Figure 5.1 Sketch of the Wave flume model in MildSim.

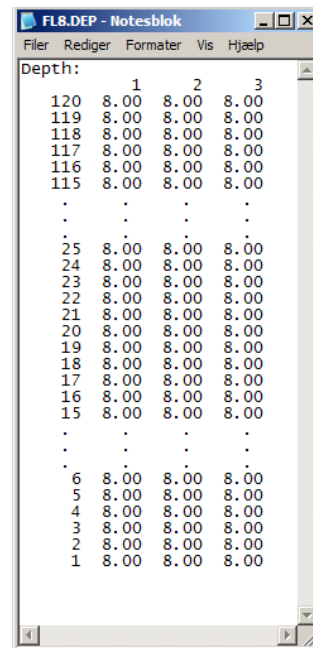
The Notebook file for the type is then created as shown in Figure 5.2.

The structure of the depth file is similar to the type file, and for a wave flume with a water depth of 8 m the depth file will be as shown in Figure 5.3.



Type:	1	2	3
120	-2	-2	-2
119	-2	55	-2
118	-2	0	-2
117	-2	0	-2
116	-2	0	-2
115	-2	0	-2
.	.	.	.
.	.	.	.
25	-2	0	-2
24	-2	0	-2
23	-2	0	-2
22	-2	0	-2
21	-2	0	-2
20	-2	-1	-2
19	-2	0	-2
18	-2	0	-2
17	-2	0	-2
16	-2	0	-2
15	-2	0	-2
.	.	.	.
.	.	.	.
6	-2	0	-2
5	-2	0	-2
4	-2	0	-2
3	-2	0	-2
2	-2	155	-2
1	-2	-2	-2

Figure 5.2 Type file for the wave flume.



Depth:	1	2	3
120	8.00	8.00	8.00
119	8.00	8.00	8.00
118	8.00	8.00	8.00
117	8.00	8.00	8.00
116	8.00	8.00	8.00
115	8.00	8.00	8.00
.	.	.	.
.	.	.	.
25	8.00	8.00	8.00
24	8.00	8.00	8.00
23	8.00	8.00	8.00
22	8.00	8.00	8.00
21	8.00	8.00	8.00
20	8.00	8.00	8.00
19	8.00	8.00	8.00
18	8.00	8.00	8.00
17	8.00	8.00	8.00
16	8.00	8.00	8.00
15	8.00	8.00	8.00
.	.	.	.
.	.	.	.
6	8.00	8.00	8.00
5	8.00	8.00	8.00
4	8.00	8.00	8.00
3	8.00	8.00	8.00
2	8.00	8.00	8.00
1	8.00	8.00	8.00

Figure 5.3 Depth file for the wave flume with a water depth of 8 m.

Placement of 'SW'-corner of model area: When the type- and depth-files for the flume is created directly, no correction of the coordinate system is necessary and the X (m) and Y (m) are set equal to zero.

Box size: In order to find μ -coefficients valid in the big model, equal box sizes needs to be used. The box sizes are therefore set as dx (m)=5 and dy (m)=5, as they are in the big model.

No. of boxes: Here the geometry of the wave flume as shown in Figure 5.1 is defined. The values should therefore be X-dir = 3 and Y-dir = 120.

5.2 Runtime Data

Time step: When the coefficients are found, it is important to use the same time step in the big model and the wave flume. When choosing the time step, it is important to consider the way the programs calculate the reflection coefficient. The calculations are based on FFT-analysis, which assumes that the signal is periodic with a period equal to the amount of data used in the analysis. If the statement in Equation (5.1) is not fulfilled, the reflection spectrum will give more than one "bar" and the reflection can not be read directly.

$$\frac{T}{dt} = 2^n \quad (5.1)$$

Where:

T Period for the wave [s] (in the flume the peak period is used).

dt Time step used in the flume model [s]

n Optional integer

In the big model, the peak period for the waves is 14 s and when n is chosen as 6 this leads to a time step of 0.2187 s. When comparing this time step with the upper limit found in Section 4.2 (0.53 s) it is seen that the limit is not exceeded.

'Warm up' time: The number should be set between 0-20 s. In the flume 20 m is chosen.

Time at which the wave field is saved: In the flume model regular waves are used which means that a stable result is obtained rather fast. Here the time is set to 1000 s. The reason for choosing this time is mainly because it is convenient that the program does not end the simulation before the reflection coefficient is found.

No. of peak periods in the estimate of significant wave field: Again, this value is not of great importance and the value used in the hanstholm model is set to 1000.

In Figure 5.4 the different inputs for the runtime are shown.

The screenshot shows a software window titled 'Form4' with several tabs: 'Bathymetry', 'Runtime data', 'Wave field', 'Calibration of waves', 'Sponge layer data', and 'Gauge positions'. The 'Runtime data' tab is active. It contains four input fields with the following values: 'time step (secs)' is 0.2187, 'warm up' time (secs)' is 20, 'Time at which the wave field is saved (secs)' is 1260, and 'No. of peak periods in the estimate of significant wave field.' is 1000. Below the last field is a note: 'and the calculation of the significant wave field i started.' To the right of the input fields are 'OK' and 'Cancel' buttons.

Figure 5.4 The runtime data in the waveflume model.

5.3 Wave Field

When running the wave flume model, the waves can be set to regular waves because the reflection should be the same no matter the type of wave. By using regular waves, a stable result is obtained fast and it is easy to read the reflection. In Figure 5.5 the input for the wave field is shown.

Wave height, H : In the wave flume the wave height should not be chosen too big because MILDSIM, even though it is a linear model, takes breaking of waves into account which would then give false results. The wave height in the flume is chosen to 0.6 m.

Wave frequency, f : The wave used in the wave flume should have the same peak period as the input wave in MILDSIM. The frequency should then be set to 0.0714 Hz which results in a period of 14.01 s.

Direction: The waves should propagate directly into the end-sponges and the angle of the direction of the waves is therefore set to 0.

Alpha-coeff. in breaker criterion: Just let this stay as 1.

Figure 5.5 The inputs in the wave field tab when running the wave flume in MildSim.

5.4 Calibration of waves

Nothing should be changed.

5.5 Sponge layer data

If the reflection of the sponges should be 100 %, the μ -coefficient could be set to 1. In any other cases the coefficient has to be found by iteration as described below.

At first the two end sponges are given the same μ -value. This value is systematically changed until the reflection of the waves are approximately 1 – 3 %. How the reflection is found is described in Section 5.7. When fully absorbing sponges are wanted, the μ -value of the sponges that gives the lowest reflection is chosen. For the flume with a water depth of 8 m, the μ -coefficient that gives the lowest reflection is found as 0.635.

If the MILD SIM model contains non-vertical structures, the reflection is neither 100% nor $\approx 0\%$ and an extra step is needed in order to find the correct μ -coefficient. Before finding the μ -coefficient, the wanted reflection needs to be known. An estimation of the reflection can be found by use of Postma's formula Equation (5.2). [Brorsen, 2006a]

$$R_c = 0.14 \left(\frac{\tan \alpha}{\sqrt{\frac{H_s}{L_p}}} \right)^{0.73} \quad (5.2)$$

Where:

- R_c Reflection coefficient [-]
- α Slope angle from horizontal [°]
- H_s Significant wave height [m]
- T_p Peak period [s]
- L_p Wave length corresponding to the peak period [m]

This could be an iterative process because the wave length and significant wave height might not be known at the position of the structure.

When the wanted reflection is found, the corresponding μ -value can be found. After finding the μ -coefficient for both the boxes that results in a reflection of 1–3%, this value is kept in the sponge behind the generation box. For the other sponge, the μ -coefficient is now changed until the wanted reflection is obtained. When changing the μ -coefficient, a relation like the one shown in Figure 5.6 can be found for the wanted reflection and the μ -coefficient can be read.

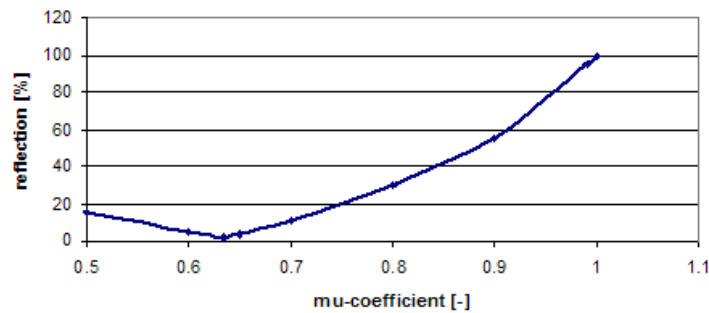


Figure 5.6 Relation between the μ -coefficient and the reflection R_c at a water depth of 8 m.

5.6 Gauge Positions

If the reflection coefficient is to be found only by use of the wave flume in MILDsim, which is based on Goda and Suzuki [1976], no gauges need to be selected in this step. The choice of gauges is made directly from the plot when running the model which is described in the following section.

If another program should be used for determining the reflection, it should be specified from which points in the flume the surface elevation is saved. The program saves the surface elevation at each second time step. If the reflection analysis is carried out with e.g. Wavelab, three gauges are needed. Alternatively the reflection can be carried out by following Goda and Suzuki [1976] and then only two gauges are needed.

In order to get the necessary information about the surface elevation, hence the reflection, a requirement needs to be set for the distance between the chosen gauges. The distance should be large enough to detect a change in the elevation but at the same time not so large that the elevation is found from another wave. The principle in the distances is shown in Figure 5.7.

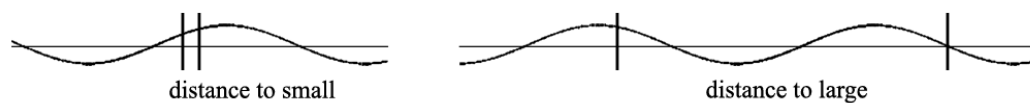


Figure 5.7 The distance between the gauges where the distance is selected to small or to large.

The limits for the distance between the boxes can be calculated by Equation (5.3). [Goda and Suzuki, 1976]

$$\begin{aligned} 0.05 \cdot L_{max} \leq \text{distance} \leq 0.45 \cdot L_{min} \\ 3.77\text{m} \leq \text{distance} \leq 21.22\text{m} \end{aligned} \quad (5.3)$$

Where:

L_{max} Maximum wave length in the big model found by the program STOKES1 to 75.37 m.

L_{min} Minimum wave length in the big model found by the program STOKES1 to 47.15 m.

Normally, a use of distances of $3 - 4 \times dx$ will give a distance within the limits given in Equation (5.3). In the model the box size is 5 m which leads to a distance of 15 m which is seen to be within the limits.

5.7 Running the Model

The wave flume is simulated by pressing **run** after which several choices can be made. It is possible to make a 2D plot of the surface elevation by pressing **2D plot**. The program now displays the flume as shown in Figure 5.8. To make the 2D plot it is necessary to mark two points in the flume between which the plot is made. The distance can be chosen arbitrary. In Figure 5.8 the two points are shown and in Figure 5.9 the appurtenant 2D plot is shown.

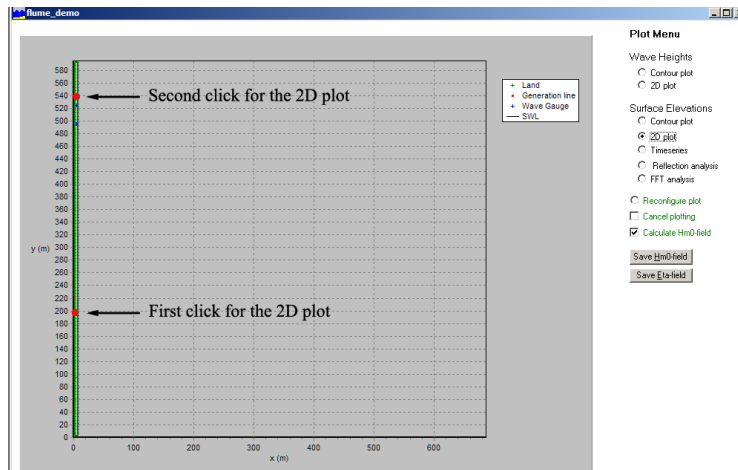


Figure 5.8 Two arbitrary points when making a 2D plot.

From Figure 5.9 it is possible to find the reflection coefficient by using Equation (5.4).

$$R_c = \frac{a_{max} - a_{min}}{a_{max} + a_{min}} = 0.024 = 2.4\% \quad (5.4)$$

Where:

a_{max} Maximum value of the amplitude, read as 0.319.

a_{min} Minimum value of the amplitude, read as 0.304.

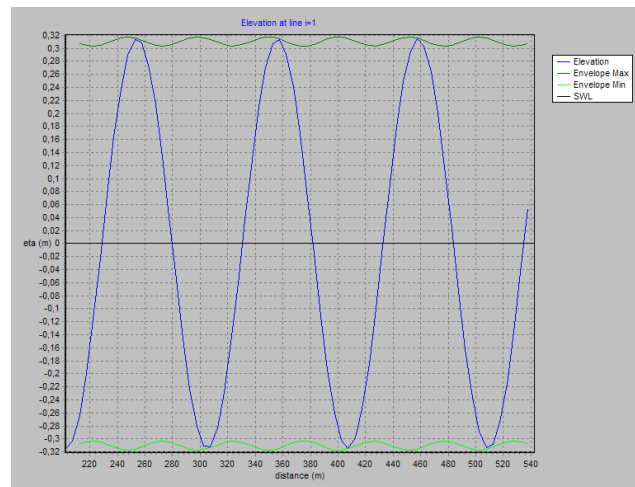


Figure 5.9 The 2D plot within the points chosen in Figure 5.8.

When reading the values a_{min} and a_{max} it is a good idea to start by pressing **cancel plotting**. Afterwards, it is possible to zoom in on the wanted area by marking a square around it.

If the time step in the model is chosen as described in Section 5.2, the reflection can be found in an easier way. When running the model, the program itself calculates the reflection spectrum by use of FFT. A plot of this spectrum can be made by choosing **Reflection analysis** during the simulation. When the time step is chosen as in Section 5.2, the plot will only contain one bar, and the reflection can be read directly. If the time step is chosen differently, the spectrum contains several bars and a direct reading is not possible.

When plotting the reflection spectrum, two boxes from where the surface elevation is used for estimation of R_c have to be selected. Here the requirement for the distance between the boxes is as described in Section 5.6 and a distance of 15 m is therefore chosen.

In the program these limits defined in Equation (5.3) are included in the way that if the distance between the two chosen boxes is either too large or too small, the messages shown in Figure 5.10 and 5.11 will appear. After **OK** is pressed, it is possible to choose a new distance.

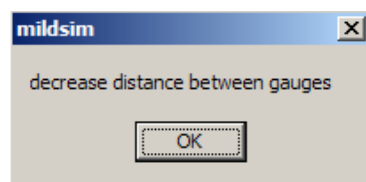


Figure 5.10 The message box when the distance is chosen to large.

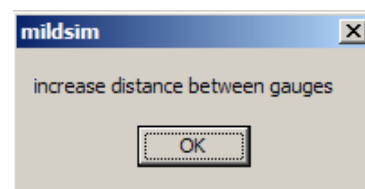


Figure 5.11 The message box when the distance is chosen to small.

After selecting the two boxes, the spectrum of reflection will be as shown in Figure 5.12. The shown plot is when the μ -value is set as 0.635 corresponding to the lowest reflection

possible.

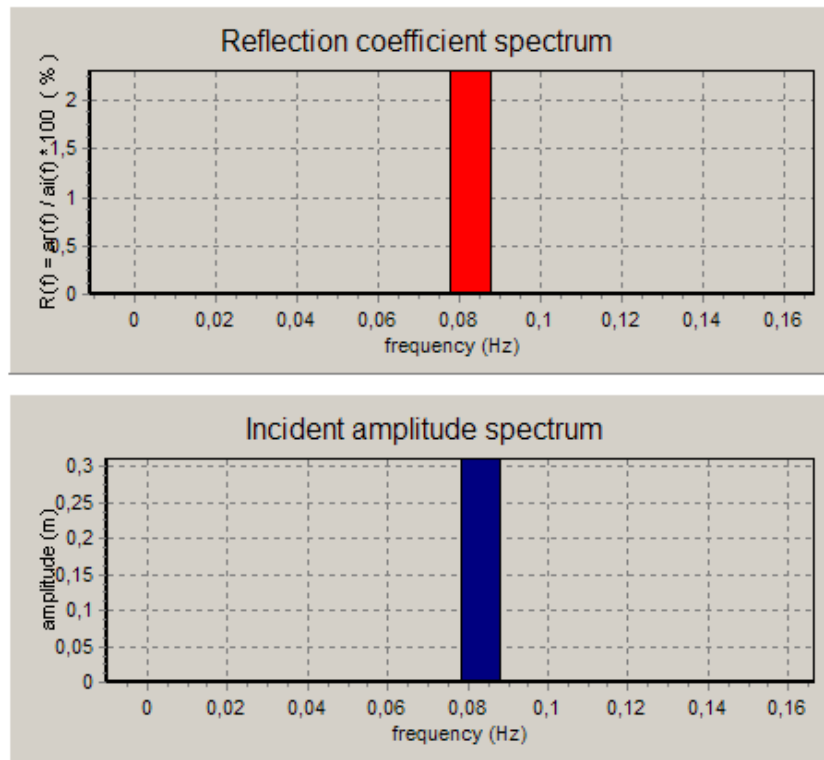


Figure 5.12 The reflection spectrum and incident amplitude spectrum of the flume with a μ -coefficient of 0.635 and a water depth of 8 m.

From Figure 5.12 it can be seen that the reflection in the flume is 2.4% which is the same as the reflection obtained by Equation (5.4).

The reflection is then found for fully absorbing sponges at 8 m. The same procedure is to be followed if there is a change in the amount of absorbing or a change in the water depth.

Bibliography

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List of CD contents

Literature

Estimation of incident and reflected waves in random wave experiments.pdf
Exercise 20.pdf
Generation and analysis of random waves.pdf
Lecture notes for the course in water wave mechanics.pdf
linear wave models.pdf
Mildsim paper 1998.pdf
On Estimation of wave heights based on wind statistics.pdf
Revision of SPM 1984 wave hindcast model to avoid inconsistencies in engineering applications.pdf

Programs

engauge.zip Zipped folder with the program engauge.exe.
Hals Havn.zip Zipped folder with an example of the use of the different programs.
Seastage.exe Program for finding the sea state conditions by hindcast from vind data.
SetupVandlandMildSim2008.exe Setup file for VANDLAND and MILD SIM.
Stoke1.exe Program for finding the wave length.
waveheight.m Matlab-program for plotting the significant wave height in the Hanstholm model.

